ENHANCED MINIMUM STAFFING PILOT PROGRAM
4/18/2023

PURPOSE

Seek authorization of an Enhanced Staffing Pilot Program designed to enhance public safety and the efficiency of the Fire Department by implementing a 4-person Engine Company response model.

BACKGROUND

In **2009**, National City retained **Citygate Associates LLC** to conduct a Standards of Response Analysis for the City. This comprehensive analysis provided several recommendations for emergency service delivery improvements, which included increasing daily staffing.
(See Appendix A - Citygate Executive Summary- Recommendation #4)

In **2022**, the City of National City retained the services of **Center for Public Safety Management LLC (CPSM)** to complete an analysis of the city's Fire Department, EMS ground transport service, and fire dispatch services. This comprehensive analysis provided several recommendations for emergency service delivery improvements, once again recommending an increase to daily staffing (See Appendix B - CPSM Executive Summary).

Using the **CPSM** study as a reference, in the year 2020 the Fire Department responded to **8,923** calls for service. This number represents an increase of **55%** since the **2009** Citygate study with no increase to fire department staffing levels.

RECOMENDATIONS

Included in the Fire department analysis, **CPSM** recommends that the city develop a plan to implement a 4-person Engine Company response model on Engine 34 and Engine 31 due to the following factors:

- Demand for service
- Population density that includes substantial current and projected vertical density structures, many involving assisted and/or senior living
- Building and other risks identified in the report such as:
    - The San Diego Port property
    - Industrial and commercial properties that include heavy rail and tractor-trailer transportation
    - Proposed industrial and commercial properties
- The resiliency issues caused by marked increases in demand for service
- Ability to assemble an Effective Firefighting/Response Force
  (See Appendix C - NIST Report on Residential Fireground Field Experiments)

IMPLEMENTATION

In an effort to adopt the recommendations of the CPSM's Fire Department analysis, staff recommends the Fire Department begin an Enhanced Staffing Pilot Program.

On April 18, 2023 (or upon Council approval):

- Addition of one (1) Full Time Equivalent (FTE) Firefighter on each of the three (3) operational shifts increasing on-duty operational staffing to fourteen (14) personnel per day.
    - These 3 additional FTE's are currently included in the FY23 Fire budget and proposed FY24 Budget.
    - Offset funding is provided through an existing SAFER Grant through March of 2024.

- The expected cost of the Enhanced Staffing Pilot Program to the Fire Department budget during the period (March 9, 2024-June 30, 2024), is expected to be in the range of $139,313.00 *(table.2)*
    - The range takes into account personnel cost not covered by the SAFER Grant and predicted use of leave (Sick leave with pay, Vacation, injury leave, etc.)

- The Fire Department will maintain management rights regarding staffing as outlined in the existing Memorandum of Understanding (MOU) between the City of National City and the National City Firefighters' Association (January 1, 2022 - December 21, 2024)

FY24/25:

- FY24/25 Fire Budget to include three (3) additional FTE Firefighters previously funded by SAFER Grant.

- The cost to the FY24/25 Fire Budget is expected to be in the range of $485,000 to $514,000 *(table. 3)*
    - This range takes into account predicted salary, salary increases and leave costs.

- These three (3) additional FTE's increase the number of General Funded Firefighters to **18**.

- Additional SAFER Grant funding is currently being explored.

SCOPE OF ENHANCED STAFFING PILOT PROGRAM

The Fire Department has three operational shifts A, B, and C. Each shift is staffed by **5** Firefighters, 3 Engineers, 4 Captains, and 1 Battalion Chief, for an on-duty operational response force of **13 personnel**.

On April 18 2023, 1 Firefighter will be added to E34 on each of the three operational shifts, A, B, and C, thereby increasing on-duty operational staffing by 1 to a total of **14 personnel**- (**6** Firefighters per operational shift)-*(table 1*)

A Shift (24-Hour) Shift)	**B Shift (24-Hour) Shift)**	**C Shift (24-Hour) Shift)**
B57 ■ 1 Battalion Chief	**B57** ■ 1 Battalion Chief	**B57** ■ 1 Battalion Chief
E34 ■ 1 Captain ■ 1 Engineer ■ 1 Firefighter ■ 1 Firefighter	**E34** ■ 1 Captain ■ 1 Engineer ■ 1 Firefighter ■ 1 Firefighter	**E34** ■ 1 Captain ■ 1 Engineer ■ 1 Firefighter ■ 1 Firefighter
T34 ■ 1 Captain ■ 1 Engineer ■ 1 Firefighter ■ 1 Firefighter	**T34** ■ 1 Captain ■ 1 Engineer ■ 1 Firefighter ■ 1 Firefighter	**T34** ■ 1 Captain ■ 1 Engineer ■ 1 Firefighter ■ 1 Firefighter
E31 ■ 1 Captain ■ 1 Engineer ■ 1 Firefighter ■	**E31** ■ 1 Captain ■ 1 Engineer ■ 1 Firefighter ■	**E31** ■ 1 Captain ■ 1 Engineer ■ 1 Firefighter ■
Squad 33 ■ 1 Captain ■ 1 Firefighter	**Squad 33** ■ 1 Captain ■ 1 Firefighter	**Squad 33** ■ 1 Captain ■ 1 Firefighter

(table 1)

FISCAL IMPACT

As presented, the Enhanced Staffing Pilot Program will result in the following ongoing costs:

FY23/24 Fire Budget (General Fund) Cost-

** Staffing costs encumbered by the city as a result of the **5** SAFER Grant funded positions expiring in March 2024*

Personnel (4-person Engine Company, Engine 34)

- Personnel cost not covered by Safer Grant – $37,020 x **3**	**$111,060.00**
- Predicted use of leave– $9,417 x **3**	**$ 28,253.00**
** Total cost to increase GF Budgeted FF positions to **18***	**$139,313.00**

(table 2)

FY24/25 Fire Budget (General Fund) Costs

Personnel (4-person Engine Company, Engine 34)

- 1- Firefighter/Paramedic – $167,452
- 1- Firefighter/Paramedic – $167,452
- 1- Firefighter/EMT – $149,773
- Predicted use of leave– $29,100

Total Cost to General Fund for **FY25 $513,777.00**

- *These three (3) additional FTE's increase the number of General Funded Firefighters to **18**.*

(*table 3*)

GOALS OF THE ENHANCED STAFFING PILOT PROGRAM

- Enhance service delivery and improve efficiency to the residents of National City
- Increase ability to complete critical tasking elements for specific incident responses
- Improve cardiac arrest survivability rates by decreasing patient down time prior to initiation of life saving interventions. (See Appendix D - NIST Report on EMS Field Experiments)
- Maintain and enhance public satisfaction with the service delivery of our Fire Department
- Increase Department resiliency (ability to handle more than one incident at a time)
- Assembling of an effective response force
- Reduce overall workload on the workforce
- Increase minimum daily staffing from 13 to 14 Firefighters
- Provide 14 National City Firefighters on first alarm responses in National City

CITYGATE ASSOCIATES, LLC
Folsom (Sacramento), CA
Management Consultants

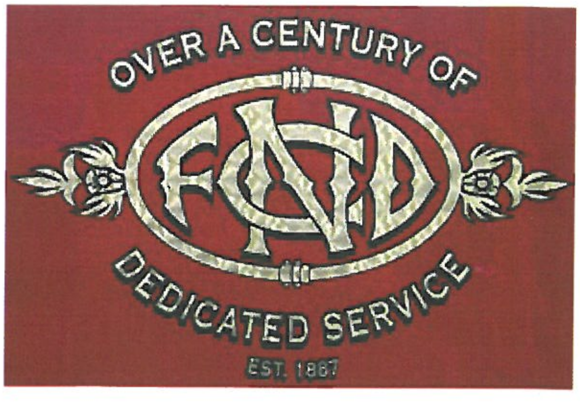
APPENDIX A

FIRE RESPONSE STUDY FOR THE

NATIONAL CITY FIRE DEPARTMENT

VOLUME 1 OF 3 – MAIN REPORT

January 23, 2009



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CITYGATE ASSOCIATES, LLC
FIRE & EMERGENCY SERVICES

EXECUTIVE SUMMARY

National City retained Citygate Associates, LLC to conduct a Standards of Response Cover Planning analysis (fire response study) for the City. This study reviews the adequacy of the existing deployment system from the current fire station locations, and based on that analysis and possible service area growth, proposes what deployment enhancements the City could consider as funds allow. This deployment report is presented in two main sections, including this Executive Summary summarizing the most important findings and recommendations and a deployment analysis section supported by maps and response statistics bound in supplemental volumes as attachments to this document.

This planning effort is part of National City's efforts to enhance its services through progressive planning as the community continues to evolve. At this point in a slow economy, it is an ideal time to take stock of fire services and place fire defense planning on the forefront before the pace of growth again becomes fast and the City finds itself behind the planning timeline to match a desire for additional services to serve growth.

POLICY CHOICES FRAMEWORK

First, the City leadership must understand there are no mandatory federal or state regulations directing the level of fire service response times and outcomes. The body of regulations on the fire service provides that *if fire services are provided at all, they must be done so with the safety of the firefighters and citizens in mind* (see regulatory discussion on page 7). Historically, the City has made significant investments in its fire services, and as a result, has good fire and EMS response coverage, which is further supported by the countywide automatic aid system, which provides for the closest appropriate unit response to all emergencies regardless of jurisdictional borders. Some of these resources are commonly dispatched by one east countywide communications center, and the remainder by the City of San Diego.

CITYGATE'S OVERALL OPINIONS ON THE STATE OF THE CITY'S FIRE SERVICES

In brief, Citygate finds that the challenge of providing fire services in the National City is similar to that found in many California communities: providing an adequate level of fire services within the context of limited fiscal resources, competing needs, growing and aging populations plus uncertainty surrounding the exact timing of future development. The Department today is handling the City's needs through local resources and the use of partnerships with its neighbors in the mutual aid system. The deployment system meets the City's current basic needs and could grow commensurate with additional development and revenue to provide increased fire services over time as the City approaches build out of its General Plan. Throughout this report, Citygate makes observations, key findings, and, where appropriate, specific action item recommendations. Overall, there are 10 key findings and 3 specific action item recommendations.

CHALLENGE – FIELD OPERATIONS DEPLOYMENT (FIRE STATIONS)

Fire department deployment, simply stated, is about the ***speed*** and ***weight*** of the attack. Speed calls for first-due, all risk intervention units (engines and ladder trucks) strategically located across a community. These units are tasked with controlling everyday average emergencies without the incident escalating to second alarm or greater size, which then unnecessarily depletes the department's resources as multiple requests for service occur. Weight is about multiple-unit response for significant emergencies like a "room and contents structure fire," a multiple-patient incident, a vehicle accident with extrication required, or a complex rescue incident. In these situations, departments must assemble enough firefighters in a reasonable period in order to control the emergency safely without it escalating to greater alarms.

In Section 2 of this study, Standards of Cover (Deployment) Analysis, Citygate's analysis of prior response statistics and use of geographic mapping tools reveals that the City has good fire station coverage for *some* of its neighborhoods. However, given the large area, hilly terrain, insufficient roadway circulation, and mix of suburban and rural population densities, the City is challenged to provide a desirable suburban level of service to the northeastern City from only the existing two fire stations. The maps provided in Volume 2 and the corresponding text explanation beginning on page 26 of Section 2 of this volume show that the City would need a combination of improvements to increase service levels above the current amount.

For effective outcomes on serious medical emergencies and to keep serious, but still-emerging fires small, best practices recommend that the first-due fire unit should arrive within **7** minutes of the 911-call receipt, 90 percent of the time. For serious fires and rescues, the balance of the multiple units needed (first alarm) should arrive within **11** minutes of the 911-call receipt, 90 percent of the time. In the City, the current fire station system provides the following unit coverage, averaged Citywide for emergency medical and fire incident types:

1st Apparatus On Scene 7:45 @ 90.6% of the time
1st Alarm On Scene <= 12:15 @ 90.3% of the time

The City is only staffed for one serious building fire at a time or one to two medical calls for service at the same time. The regional automatic response system delivers greater alarm and multiple-incident support, when needed, although with longer response times.

Citygate's deployment findings and recommendations are summarized below. For reference purposes, the findings and recommendation numbers refer to the sequential numbers as these are presented in the main body of the report.

Finding #1: The City does not have a fire deployment measure adopted by the City Council that includes the beginning time measure starting from the point of fire dispatch receiving the 911-phone call, and a goal statement tied to risks and outcome expectations. The deployment measure should have a second measurement statement to define multiple-unit response coverage for serious emergencies. Making these deployment goal changes will meet the best practice recommendations of the Center for Public Safety Excellence (formerly the Commission on Fire Accreditation International).

Finding #2: The age of the City's housing stock and the increasing numbers of younger and older populations means that there is a greater chance of more serious fires where rescues will be necessary, and if so, the current quantity of in-city firefighter staffing will be quickly overwhelmed with too many critical tasks to accomplish.

Finding #3: Given the travel distance difficulties in the northeast area of National City, coverage by a first-due unit within the desirable time of 4 minutes travel and 7 minutes from the time of 911 call is problematic. While a San Diego unit can make the 4-minute drive time, it is not always available, and due to multiple dispatch centers, it cannot make all of the needed National City areas within 7 minutes of the 911 call being processed.

Finding #4: If an additional fire company location could be funded, effective first-due unit coverage can be obtained from three (3) fire station sites, at 4 minutes travel time. This means that National City would add a 3rd fire station in the hard-to-serve northeast area.

Finding #5: Due to mutual aid, the multiple-unit first alarm coverage is good throughout National City at 8 minutes travel. However, this also depends on successful, timely, mutual aid.

Finding #6: With a City fire/EMS incident first-due unit performance of 07:00 minutes/seconds at 84.3 percent, as the mapping analysis predicted, the City does not have enough primary neighborhood fire stations in the City to deliver suburban response times to all areas. This is also seen in the first alarm response time measures.

Finding #7: The City has dispatch times close to meeting national best practices and these efforts need to continue. The City's overall turnout time measure is about 45 seconds slower than it could be.

Finding #8: The simultaneous emergency call for service rate of 18 percent for two incidents at once, while not a large problem, is a problem for the eastern City area. Even with a second company (the ladder truck) in Station 34 downtown, Station 31 east of I-805 runs 18 percent of their total calls in Station 34's area. When this occurs, the eastern City has to rely on a mutual aid company for a "3rd" simultaneous call for service and these companies are farther away in the eastern City than along the I-5 corridor.

Finding #9: The City's geography is a little too large to provide suburban outcome first alarm response time coverage from only two stations.

Finding #10: The City benefits from the closest unit "automatic aid" regional dispatch and response system. While this system cannot replace existing City stations or units, the City should continue to participate in this valuable support system for simultaneous calls for service and multiple-unit serious emergencies.

Observation: *Generally, population, not buildings, drives fire department calls for service. Additional people have accidents, medical problems, auto accidents, and cause fires. Over recent years, National City Fire has seen a call for service rate of 81 incidents per 1,000 population. The current City population is approximately 61,000 residents and the current General Plan year 2020 population forecast is for a population of approximately 76,000. At the current rate of 81 calls per 1,000 residents, in the year 2020 the annual incident count would be approximately 6,200, an increase of 25 percent over the current count of 4,928 calls per year. While this appears to be a large increase, it occurs slowly at a rate of about 2 percent per year, which gives the City time to assess its fire planning policies and, if desired, add a 3rd fire station and 4th crew per day as revenue allows.*

Recommendation #1: The City should adopt revised performance measures to direct fire station location planning and to monitor the operation of the Department. The measures should take into account a realistic company turnout time of 2 minutes and be designed to deliver outcomes that will save patients medically salvageable upon arrival; and to keep small, but serious fires from becoming greater alarm fires. Citygate recommends these measures be:

1.1 Distribution of Fire Stations: To treat medical patients and control small fires, the first-due unit should arrive within 7 minutes, 90 percent of the time from the receipt of the 911 call. This equates to 1 minute dispatch time, 2 minutes company turnout time and 4 minutes drive time spacing for single stations.

1.2 Multiple-Unit Effective Response Force for Serious Emergencies: To confine fires near the room of origin, to stop wildland fires to under 3 acres when noticed promptly and to treat up to 5 medical patients at once, a multiple-unit response of at least 14 personnel should arrive within 11 minutes from the time of 911 call receipt, 90 percent of the time. This equates to 1 minute dispatch time, 2 minutes company turnout time and 8 minutes drive time spacing for multiple units.

Recommendation #2: As fiscal resources allow, the most beneficial next improvement in fire services the City could make would be to add a fire station in the northeast City area equipped with one fire engine and a 3-person crew.

This capital improvement project can be phased over several fiscal years, from final location to land acquisition, design, bidding, and finally construction as the economy allows.

Recommendation #3: As fiscal resources allow, a follow-on step to adding the 3rd fire station would be to increase the daily staffing by one firefighter on the downtown engine at Station 34. The east side stations due to lower call for service volumes could stay long term at three personnel per day staffing.

CENTER FOR PUBLIC SAFETY MANAGEMENT, LLC

FIRE & EMS SERVICES ANALYSIS REPORT

National City, California

Final Report-August 2022

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The International City/County Management Association is a 103-year old, nonprofit professional association of local government administrators and managers, with approximately 13,000 members located in 32 countries.

Since its inception in 1914, ICMA has been dedicated to assisting local governments and their managers in providing services to its citizens in an efficient and effective manner.
ICMA advances the knowledge of local government best practices with its website (www.icma.org), publications, research, professional development, and membership. The ICMA Center for Public Safety Management (ICMA/CPSM) was launched by ICMA to provide support to local governments in the areas of police, fire, and emergency medical services.

ICMA also represents local governments at the federal level and has been involved in numerous projects with the Department of Justice and the Department of Homeland Security.

In 2014, as part of a restructuring at ICMA, the Center for Public Safety Management (CPSM) was spun out as a separate company. It is now the exclusive provider of public safety technical assistance for ICMA. CPSM provides training and research for the Association's members and represents ICMA in its dealings with the federal government and other public safety professional associations such as CALEA, PERF, IACP, IFCA, IPMA-HR, DOJ, BJA, COPS, NFPA, and others.

The Center for Public Safety Management, LLC, maintains the same team of individuals performing the same level of service as when it was a component of ICMA. CPSM's local government technical assistance experience includes workload and deployment analysis using our unique methodology and subject matter experts to examine department organizational structure and culture, identify workload and staffing needs, and align department operations with industry best practices. We have conducted 341 such studies in 42 states and provinces and 246 communities ranging in population from 8,000 (Boone, Iowa) to 800,000 (Indianapolis, Ind.).

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SECTION 1. EXECUTIVE SUMMARY

The Center for Public Safety Management LLC (CPSM) was contracted by the City of National City, CA to complete an analysis of the city's Fire Department, EMS ground transport service, and fire dispatch services.

The National City Fire Department (NCFD) is responsible for providing services from two primary divisions that include Operations (fire suppression, first response emergency medical services, emergency management, training and education, EMS oversight and logistics, fleet and facility oversight, emergency communications liaison, and technical rescue), and Community Risk Reduction (fire code enforcement, fire investigation, weed abatement, new business license inspections, public education to the extent possible, and juvenile fire setter intervention). The NCFD carries out these and other logistical and administrative functions through the Fire Chief's office and operational fire suppression officers and staff.

The service demands on the department from the community are numerous and include EMS first response; fire suppression; wild land-urban interface; technical rescue; hazardous materials; and transportation emergencies to include extensive rail and vehicle traffic, a mass transit system utilizing bus and light rail transportation, the Port of San Diego property to include marine vessels, buildings, and occupancies located within the city's municipal boundaries; and other non-emergency responses typical of urban fire departments. A significant component of this report is the completion of an All-Hazard Risk Assessment of the Community. The All-Hazard Risk Assessment of the Community contemplates many factors that cause, create, facilitate, extend, and enhance risk in and to a community. The risk assessment includes Port property and proposed new industrial businesses/processes that are contemplating build-out in National City.

The response time and staffing components discussion of this report are designed to examine the current level of service provided by the NCFD compared to national best practices. As well, these components of the report provide incident data and relevant information that can be utilized for future planning and self-review of service levels for continued improvement designed to meet community expectations and mitigate emergencies effectively and efficiently. Included also is an analysis of fire and EMS responses the NCFD provides through a regional automatic aid agreement to Paradise Hills, an area of San Diego City contiguous to National City.

Other significant components of this report are an analysis of the current deployment of resources and the performance of these resources in terms of response times and the three NCFD fire stations; current staffing levels and patterns; department resiliency (ability to handle more than one incident at a time); critical tasking elements for specific incident responses and assembling an effective response force; the private EMS ground transport system with an analysis that depicts the start-up and annualized cost of a city EMS service; and an analysis to include start-up and annualized costs of a city fire dispatch section in the National City Police 911 Center. CPSM analyzed these items and provides recommendations where applicable to improve service delivery and for future planning purposes.

A comprehensive risk assessment and review of deployable assets are critical aspects of a fire department's operation. First, these reviews will assist the NCFD in quantifying the risks that it faces. Second, the NCFD will be better equipped to determine if its current response resources are sufficiently staffed, equipped, trained, and positioned. The factors that drive the service needs are examined and then link directly to discussions regarding the assembling of an effective response force; these factors also must be considered when contemplating the response capabilities needed to adequately address the existing and future risks, and which encompass the component of critical tasking. CPSM does recommend additional staffing on both Engines 31 and 34 over a five-year period. This recommendation is based on current and projected building, transportation, and other risks inherent to the city, and as comprehensively discussed herein.

This report also contains a series of observations and planning objectives and recommendations provided by CPSM which are intended to help the NCFD deliver services more efficiently and effectively. This includes succession planning for near-term retirements, administrative capacity needed to manage day-to-day programs and processes such as workforce training and education, EMS (the greatest response workload of the department), and fleet and facilities (the infrastructure backbone of the department), and as well additional capacity in the Fire Marshal's Office, based on current and projected fire code inspection workload.

Recommendations and considerations for continuous improvement of services are presented here. CPSM recognizes there may be recommendations and considerations offered that first must be budgeted and/or bargained, or for which processes must be developed prior to implementation.

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RECOMMENDATIONS

Department Structure

1. CPSM recommends the NCFD work with the city's Human Resources Department and develop and implement a succession planning process that identifies and develops future organizational leadership and includes key components that focuses on the retention of current talent. Included in this planning should be consideration for a 40-hour Deputy Fire Chief position that will work with the Fire Chief managing the day-to-day activities and programs of the department. This position would be the likely successor to the Fire Chief on his retirement and would ensure succession of current department direction. This position can be implemented and filled through promotion (retention opportunity), which will create a vacancy to be filled at the lesser expensive Firefighter level. (See pp. 5-8.)

2. CPSM also recommends the city consider adding an administrative Battalion Chief position to assist with the day-to-day management of the department and to assume key program assignments currently assigned to shift Battalion Chiefs such as training, EMS, fleet and facilities, and health and safety. This position can be implemented through promotion (retention opportunity), which will create a vacancy to be filled at the lesser expensive Firefighter level. (See pp. 5-8.)

   Estimated cost alternatives to support these recommendations are: Deputy Chief position internal promotion, $108,000 (salary and benefits for one firefighter/EMT and $20,000 for promotions for Engineer, Captain, and Battalion Chief); Battalion Chief position through internal promotion, $103,000 (salary and benefits for one firefighter/EMT and $15,000 for promotions of Engineer and Captain).

Fleet and Facilities

3. CPSM recommends the NCFD, due to the current and expected future workload on apparatus, follow to the extent possible the current apparatus in-service and replacement schedule. (See pp. 11-16.)

4. CPSM further recommends the city continue with its planning to construct a permanent brick and mortar station in the northeast portion of the city utilizing national industry standards for fire facilities as outlined herein and designed to accommodate current and future response apparatus and personnel. (See pp. 11-16.)

ISO Rating

5. CPSM recommends the NCFD review and address, to the extent possible, deficiencies in the current ISO Public Protection Classification report (Fire Department Section) as outlined in this analysis. This includes, and given the identified building risks in the city, ensuring company personnel conduct (and document for future ISO reviews) some level of commercial, industrial, institutional, and other similar type buildings (all buildings except one- to four-family dwellings) familiarization and pre-plan information gathering; work with Sweetwater Authority to ensure the fire hydrants are inspected and flow-tested on a more regular basis; address Community Risk Reduction staffing and make adjustments to staffing to ensure current (and future) inspectable properties (2,700 total current) are receiving annualized (where required) inspections, and those not requiring annualized inspections receive timely inspections in accordance with applicable laws and standards, and as established by the Fire Marshal. Addressing the Community Risk Reduction deficiency will require additional staffing, to the extent possible with available funding, which has an estimated cost of $87,500 to $117,000 per Community Risk Reduction inspector, dependent on placement in the pay range. (See pp. 39-41.)

Risk Assessment / Resiliency

6. CPSM recommends the NCFD continue with the Squad program as designed, due to the efficiencies and effectiveness this unit has produced for the city. CPSM further recommends the NCFD monitor dual responses (Squad/Engine) and make necessary adjustments to maintain a 10-percent ratio. (See pp. 47-50.)

NCFD Staffing Model

7. CPSM recommends the NCFD, to the extent possible and if practical depending on available automatic and mutual aid resources, work with regional Fire Chiefs to increase response resources to commercial, apartment, and high-rise fire responses that align more closely with the NFPA 1710 standard. (See pp. 63-69.)

8. CPSM further recommends due to the following factors: demand for service on the NCFD; population density that includes substantial current and projected vertical density structures, many involving assisted and/or senior living; building and other risks identified in this report such as the San Diego Port property; industrial and commercial properties that include heavy rail and tractor-trailer transportation; proposed industrial and commercial properties; the resiliency issues the department faces due to demand for service; and to increase NCFD resources regarding assembling an Effective Response Force, that the city develop a one- to three-year funding plan to increase staffing on Engine 31 to four per shift (three total personnel with estimated costs of $263,000) as this is a single station response unit in a high-demand fire management zone, and in the subsequent three- to five-year period develop a funding plan to increase staffing on Engine 34 to four per shift (three total personnel with estimated costs of $263,000 to $300,000, depending on implementation year). (See pp. 63-69.)

Ambulance Service

9. The current method of ambulance service provision of using an outside contractor should be retained, and the NCFD should not assume responsibility for providing ambulance services to the city. (See pp. 83-91.)

10. The city should negotiate with AMR for significant contracting updates or consider undergoing an RFP process to seek enhanced service delivery models, either from the current, or prospective ambulance service providers. (See pp. 83-91.)

Mobile Integrated Healthcare

11. NCFD should engage in discussions with local and regional stakeholders to determine the potential benefits and impact of initiating a Mobile Integrated Healthcare / Community Paramedicine program. (See p. 91.)

Fire Emergency Communications

12. Based on the initial start-up and annualized costs CPSM estimates Fire Dispatch in-house totals, and that the annualized costs almost double the current San Diego Metro Fire Dispatch costs, CPSM strongly recommends National City continue with the current agreement with San Diego City for fire dispatch services. CPSM does recommend, however, that National City work with San Diego City to reduce the current fire dispatch agreement costs to offset the costs the NCFD incurs as the de facto fire department for Paradise Hills, which was demonstrated in the analysis. (See pp. 92-93.)

SECTION 2. AGENCY REVIEW AND CHARACTERISTICS

DEPARTMENT OVERVIEW AND ORGANIZATIONAL STRUCTURE

The National City Fire Department (NCFD) is responsible for providing emergency services from two primary divisions that include Operations (primarily fire suppression, first response emergency medical services) and Community Risk Reduction (fire code enforcement, fire prevention and plans review, new business license inspection program, weed abatement). Other programs administered through these primary divisions include the City's emergency management function, a department health and safety program, professional development programs, community education to include juvenile fire setter intervention program and CPR classes, hazardous materials and technical rescue response, and Community Emergency Response Team or CERT program. ***These represent best practices/best program practices for fire service agencies.***

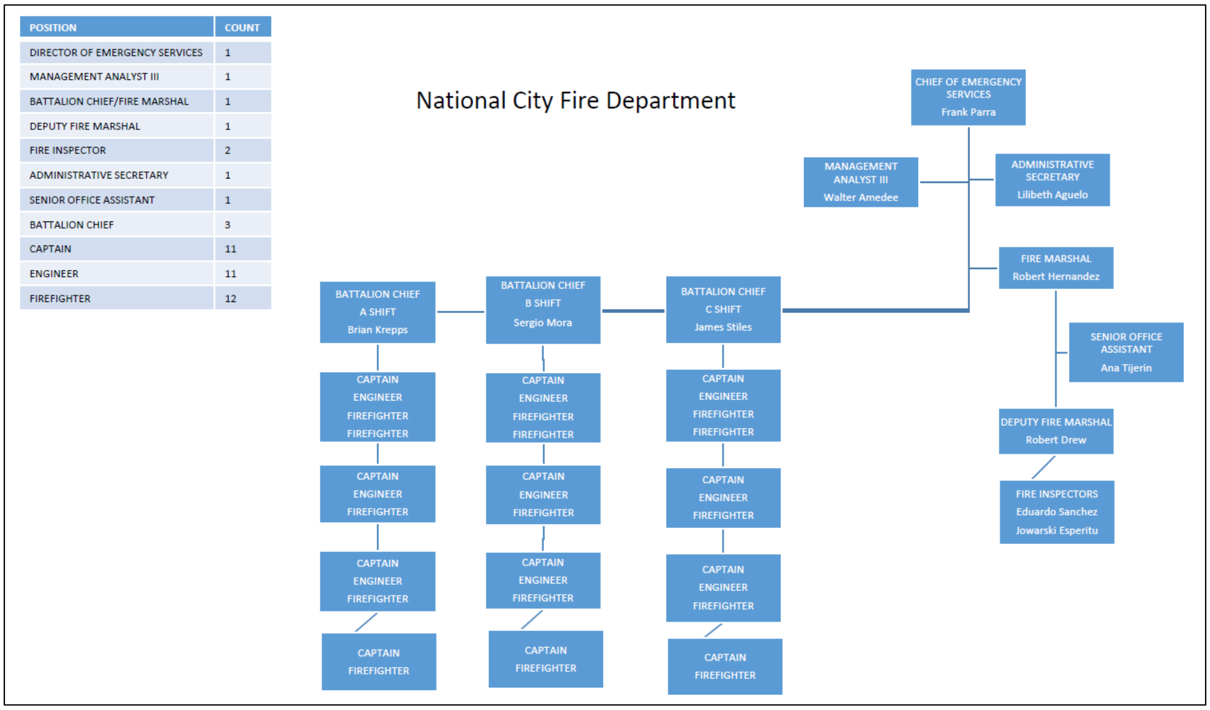
The NCFD is led by a Chief of Emergency Services/Fire Chief. This position (department head level) serves as a member of the City Manager's cabinet. The organizational structure includes senior and middle manager level positions (Fire Marshal, Deputy Fire Marshal, Battalion Chiefs), first-line supervisors (Captain level), engineers (apparatus driver-operator), firefighters, and civilian support staff. The largest contingent of personnel in the organization are company-level officers, engineers, and firefighters.

Field operations provide services from three operational shifts and work a 24-hour schedule. The operational shift schedule consists of a 24-hour shift every other day for 7 total days (4 x 24-hour shifts, with a day off in between each), followed by 4 days off and then 6 days in the next cycle. This schedule ensures compliance with 29 U.S.C 207(k) wherein firefighters working in excess of 53-hours/week must be compensated for the three additional hours worked each week or scheduled off. ***This is a national best practice.***

Emergency Medical Services (EMS) ground transportation is provided in National City by a single private ambulance service, American Medical Response (AMR). The NCFD responds to EMS incidents as a first responder agency. NCFD engine, ladder, and squad companies have appropriately trained staff (including Paramedic level) on duty on each apparatus to render pre-transport emergency care to those requiring that care.

The following figure illustrates the NCFD's chart of the organization.

FIGURE 2-1: NCFD Organizational Chart



POSITION	COUNT
DIRECTOR OF EMERGENCY SERVICES	1
MANAGEMENT ANALYST III	1
BATTALION CHIEF/FIRE MARSHAL	1
DEPUTY FIRE MARSHAL	1
FIRE INSPECTOR	2
ADMINISTRATIVE SECRETARY	1
SENIOR OFFICE ASSISTANT	1
BATTALION CHIEF	3
CAPTAIN	11
ENGINEER	11
FIREFIGHTER	12

Note: On July 25, 2022, Fire Chief Parra became the Interim Assistant City Manager. BC Sergio Mora became the Interim Fire Chief. These assignments are for the near term (three-month period) but could be longer.

In addition to normal work assignments—and due to the limited capacity of NCFD administrative positions—operational shift Battalion Chiefs perform and oversee many ancillary duties and programs necessary to maintain administrative and operational systems and components of the organization. These are illustrated in the next three figures.

FIGURE 2-2: Operations Ancillary Duties, Battalion Chief Mora

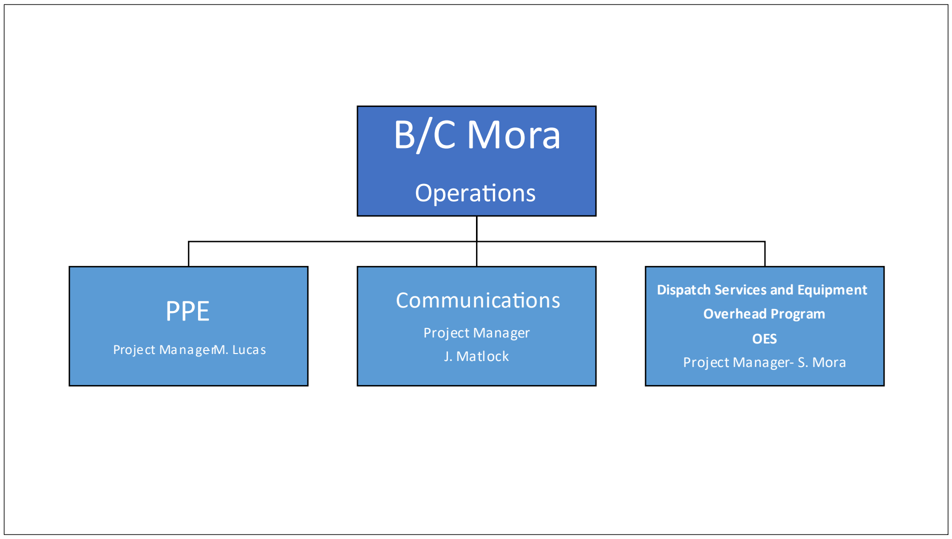


FIGURE 2-3: Training/EMS Ancillary Duties, Battalion Chief Stiles

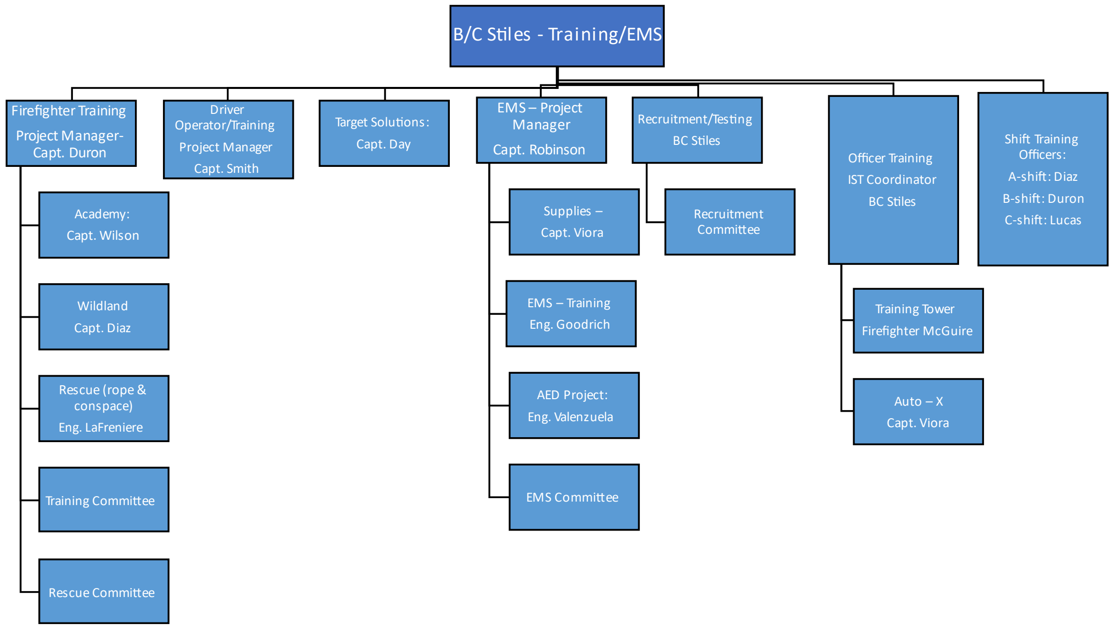
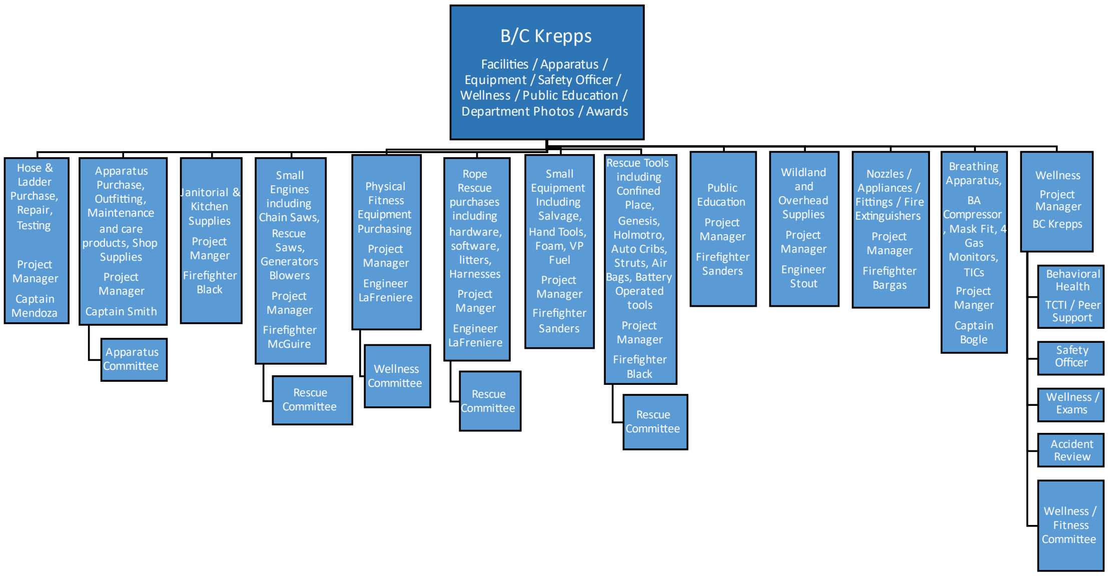


FIGURE 2-4: Support Programs Ancillary Duties, Battalion Chief Krepps



The programs, processes, and inter-workings of a fire department are many as can be seen in the above three figures. A drawback to assigning almost all of these components to shift personnel is that during their absence (either off-duty on shift rotation or out on leave) is the potential something is not getting done or will be missed. This is a real occurrence in any fire department. Traditional administrative support positions in a fire department include those assigned the training, EMS and logistics (radio and comms, supply chain management, fleet, and facility) functions. Most smaller fire departments combine one or more of these main functions together and also include the health and safety oversight function as well.

CPSM learned while on-site in March 2022, that the Fire Chief may retire in 24 to 30 months, and one Battalion Chief and the Fire Marshal (Battalion Chief Position) are also approaching retirement in the near term (18 to 36 months). This will create a gap at the senior management level as 60 percent of the top leadership may depart over a three-year period. While there likely is an informal succession plan in the department, a more formal plan should be developed to address these and other near-term retirements. Our analysis of the NCFD did not identify a clear organizational succession plan.

Succession planning in the NCFD should include a systematic approach to developing potential successors to ensure organizational leadership stability is maintained. A plan should be in place to identify, develop, and nurture potential future leaders. CPSM sees this as critical for the long-term success of the NCFD. This plan should also include a focus on current talent and the retention of this valuable staff. CPSM was told by senior management that other area fire departments pursue the hiring of NCFD staff because of the urban response and firefighting capabilities in which staff is trained in National City. This raiding of seasoned staff creates knowledge and experience gaps in an already small agency and leads to continual hiring and onboarding expenses. Together (succession planning and retention of talent) is a systems approach that should not be overlooked.

Recommendations:

- CPSM recommends the NCFD work with the city's Human Resources Department and develop and implement a succession planning process that identifies and develops future organizational leadership and includes key components that focuses on the retention of current talent. Included in this planning should be consideration for a 40-hour Deputy Fire Chief position that will work with the Fire Chief managing the day-to-day activities and programs of the department. This position would be the likely successor to the Fire Chief on his retirement and would ensure succession of current department direction. This position can be implemented and filled through promotion (retention opportunity), which will create a vacancy to be filled at the lesser expensive Firefighter level. (Recommendation No. 1.)
- CPSM also recommends the city consider adding an administrative Battalion Chief position to assist with the day-to-day management of the department and to assume key program assignments currently assigned to shift Battalion Chiefs such as training, EMS, fleet and facilities, and health and safety. This position can be implemented through promotion (retention opportunity), which will create a vacancy to be filled at the lesser expensive Firefighter level. (Recommendation No. 2.)

Estimated cost alternatives to support these recommendations are: Deputy Chief position internal promotion, $108,000 (salary and benefits for one firefighter/EMT and $20,000 for promotions for Engineer, Captain, and Battalion Chief); Battalion Chief position through internal promotion, $103,000 (salary and benefits for one firefighter/EMT and $15,000 for promotions of Engineer and Captain).

SERVICE AREA

National City is in the south bay area of San Diego County. The city boundaries encompass 9.1 total square miles of which 7.8 square miles are land area and the remainder water area. Contiguous jurisdictions include the City of San Diego city to the north and northeast, Bonita to the southeast (unincorporated San Diego County), and Chula Vista to the south (National City and Chula Vista are separated by the Sweetwater River).

The next figure illustrates the municipal boundaries of the city in which the NCFD responds. The NCFD also provides automatic/mutual aid to San Diego city and county, Bonita, and Chula Vista.

FIGURE 2-5: National City Jurisdictional Boundaries

Area within red outline is unincorporated San Diego County

A southern, noncontiguous area of National City is located within the South San Diego Bay Unit of the San Diego National Wildlife Refuge that. In this refuge are approximately 1,050 acres of salt ponds currently in active salt production by a commercial solar salt operation, which is permitted to operate within the refuge through the United States Fish and Wildlife Service (USFWS). Source: National City General Plan 2011.

The NCFD provides emergency services from three stations located in the city. Response is primarily made through two engine companies, one ladder/truck company, one quick response squad unit, one shift command vehicle, and various other operational support vehicles to include a state Office of Emergency Services Type 1 engine apparatus for wildland firefighting and deployment. In addition to in-city mitigation of fire and emergency service incidents, the NCFD provides and receives mutual/automatic aid from neighboring/contiguous jurisdictions (***a national best practice***).

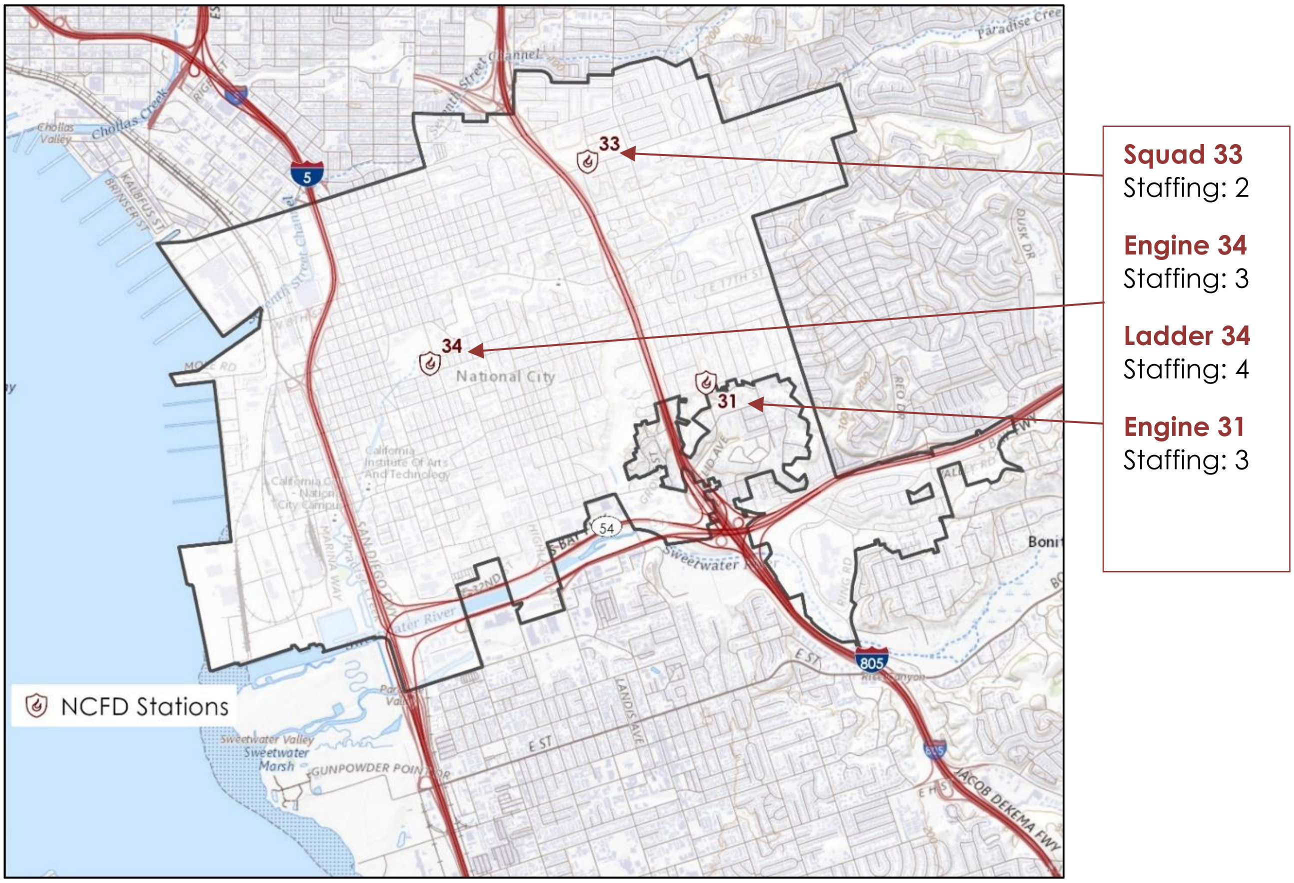
Engine and ladder company response is provided through traditional fire apparatus. The squad apparatus is a Type 6 engine (heavy-duty pick-up truck chassis with equipment body) unit that has a 120 gpm pump and 250-gallon water tank and carries a crew of two (Captain and FF). This unit also has hose for initial attack on small outside fires, fire-related hand tools, self-contained breathing apparatus for the two-person crew, and basic and advanced medical equipment for first response EMS calls for service. This unit also carries crew member structural and wildland firefighting protective clothing and other crew-related equipment.

The squad unit was placed in service as the result of a 2009 fire service consultant report that identified gaps in response service in the northeast area of the city. This busy area of the city was receiving emergency response from NCFD stations 31 and 34, as well as from mutual aid partner the City of San Diego. Several benefits have been realized by placing this unit in service:

- Quicker first due response to fire and EMS calls in the busy northeast portion of the city.
- Since this unit is not a resource type that is included in the mutual/auto aid agreements in the region, it does not leave the city, increasing its readiness to respond at all times.
- This unit provides an additional two firefighters (Captain, Firefighter) to respond to multi-unit responses such as structure fires in the city, increasing the ability for the NCFD to quickly assemble an Effective Response Force.

The following figure shows the municipal boundaries with NCFD fire station locations.

FIGURE 2-6: NCFD Fire Station Locations



Squad 33
Staffing: 2

Engine 34
Staffing: 3

Ladder 34
Staffing: 4

Engine 31
Staffing: 3

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NCFD BUDGET AND CAPITAL ASSETS

An overview of the annual NCFD appropriations from the general fund is provided in the following table; it includes the general fund budget allocations for fiscal years 2020, 2021, and 2022.

TABLE 2-1: NCFD General Fund Appropriations, Fiscal Years 2020–2022

FY 2020 Adopted (General Fund)	FY 2021 Adjusted Appropriations (General Fund)	FY 2022 Adjusted Appropriations (General Fund)
$11,424,457	$11,369,542	$11,106,737

Traditionally, and like every other career fire department in the nation, the NCFD's budget is primarily consumed by personnel costs. This includes salary, benefit and retirement costs, overtime, and worker's compensation, which are the larger line items in this budget area. The NCFD personnel services budget area consistently represents approximately 80 percent of the total budget. The next largest budget area is internal service charges (12 percent in FY 2022), which are for the operation and repair of facilities and equipment, automotive operational/repair costs and replacement, and maintenance and operations of equipment.

The NCFD does have certain revenues line items in the budget to offset overall expenditures. These include (FY 2022 proposed budget):

- Charges for community risk reduction services (plans review, fire permit fees, license and permit fees, weed abatement): $71,879.
- False alarm fines: $55,000.
- AMR (EMS ground transport provider) station rental fees: $94,200
- Charges for fire services (misc. fire services, fire protection services for certain unincorporated San Diego County areas, fire services for the Port of San Diego, fire/life safety annual fire inspection fees): $1,317,620.
- AMR Franchise Fee (EMT-D Revolving Fund): $334,124 (used for certain personnel services costs in fire operations).
- Development impact fees: $10,000.

The NCFD received a grant from the Staffing for Adequate Fire and Emergency Response (SAFER) program and has a FY 2022 expenditure of $590,185 from this grant. Lastly, the city and department are utilizing Community Development Block Grant (CDBG) funds for bond principal and interest redemption in fire operations.

Capital Assets

Facilities

Fire facilities must be designed and constructed to accommodate both current and forecast trends in fire service vehicle type and manufactured dimensions. A facility must have sufficiently-sized bay doors, circulation space between garaged vehicles, departure and return aprons of adequate length and turn geometry to ensure safe response, and floor drains and oil separators to satisfy environmental concerns. Station vehicle bay areas should also consider future tactical vehicles that may need to be added to the fleet to address forecast response challenges, even if this consideration merely incorporates civil design that ensures adequate parcel space for additional bays to be constructed in the future.

Personnel-oriented needs in fire facilities must enable performance of daily duties in support of response operations. For personnel, fire facilities must have provisions for vehicle maintenance and repair; storage areas for essential equipment and supplies; space and amenities for administrative work, training, physical fitness, laundering, meal preparation, and personal hygiene/comfort; and—where a fire department is committed to minimize "turnout time"—bunking facilities.

A fire department facility may serve as a de facto "safe haven" during local community emergencies and also serve as likely command center for large-scale, protracted, campaign emergency incidents. Therefore, design details and construction materials and methods should embrace a goal of having a facility that can perform in an uninterrupted manner despite prevailing climatic conditions and/or disruption of utilities. Programmatic details, such as the provision of an emergency generator connected to automatic transfer switching—even going as far as to provide tertiary redundancy of power supply via a "piggyback" roll-up generator with manual transfer (should the primary generator fail)—provide effective safeguards that permit the fire department to function fully during local emergencies when response activity predictably peaks.

Personnel/occupant safety is a key element of effective station design. This begins with small details such as the quality of finish on bay floors and nonslip treads on stairwell steps to decrease tripping/fall hazards, or use of hands-free plumbing fixtures and easily disinfected surfaces/countertops to promote infection control. It continues with installation of specialized equipment such as an exhaust recovery system to capture and remove cancer-causing by-products of diesel fuel exhaust emissions. A design should thoughtfully incorporate best practices for achieving a safe and hygienic work environment.

An ergonomic layout and corresponding space adjacencies in a fire station should seek to limit the travel distances between occupied crew areas to the apparatus bays. Likewise, facility design should carefully consider complementary adjacencies, such as lavatories/showers in proximity of bunk rooms, desired segregations, and break rooms or fitness areas that are remote from sleeping quarters. Furnishings, fixtures, and equipment selections should provide thoughtful consideration of the around-the-clock occupancy inherent to fire facilities. Durability is essential, given the accelerated wear and life cycle of systems and goods in facilities that are constantly occupied and operational.

Sound community fire-rescue protection requires the strategic distribution of fire station facilities to ensure that effective service area coverage is achieved, that predicted response travel times satisfy prevailing community goals and national best practices, and that the facilities are capable of supporting mission-critical personnel and vehicle-oriented requirements and needs. Additionally, depending on a fire-rescue department's scope of services, size, and complexity, other facilities may be necessary to support emergency communications, personnel training, fleet and essential equipment maintenance and repair, and supply storage and distribution.

National standards such as NFPA 1500, *Standard on Fire Department Occupational Safety, Health, and Wellness Program*, outlines standards that transfer to facilities such as infection control, personnel and equipment decontamination, cancer prevention, storage of protective clothing, and employee fitness. NFPA 1851, *Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural Firefighting and Proximity Fire Fighting*, further delineates laundering standards for protective clothing and station wear. Laundry areas in fire facilities continue to evolve and are being separated from living areas to reduce contamination. Factors such as wastewater removal and air flow need to be considered in a facility design.

The NCFD operates out of three operational facilities strategically located throughout the city. Each station houses around-the-clock crews, 365 days a year. Two stations house one crew and one piece of first response apparatus (an engine at Station 31 and a squad at Station 33), while one station houses more than one crew and two primary first response apparatus (engine and truck companies-Station 34).

Apparatus and staffing assignments are outlined in the following table.

TABLE 2-2: NCFD Facilities, with Apparatus and Staffing

Station Number	Resource Assignment	Year Constructed	# Apparatus Bays
31	Engine: 3 staff 24/7/365	1984	2
33	Squad: 2 staff 24/7/365	2019	2
34	Engine: 3 staff Truck: 4 staff Battalion Chief: 1 staff 24/7/365	2004	4

Station 33 is not a permanent brick and mortar facility. The implementation of the Squad Company, as discussed above, originated from a previous consulting study the city commissioned for the specific purpose of examining ways to service the increased demand (particularly regularly dispatched EMS and lower acuity fire responses) in the northeast area of the city and NCFD response area. Station 33 is a modular type building with an open awning that provides cover to response apparatus. The awning and building are not connected.

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FIGURE 2-7: NCFD Station 33

Fleet

The provision of an operationally ready and strategically located fleet of mission-essential fire-rescue vehicles is fundamental to the ability of a fire-rescue department to deliver reliable and efficient public safety within a community.

The NCFD currently operates a fleet of front-line fire apparatus as outlined in the following table.

TABLE 2-3: NCFD Fleet

Apparatus Type	Year In Service	Operational Assignment / Station Assigned
Type 1 Engine	2011	Front Line / 34
Type 1 Engine	2019	Front Line / 31
Type 1 Engine	2006	Reserve
Ladder-105' Quint	2015	Front Line / 34
Ladder-105' Quint	2009	Reserve
Water Tender-2000 gallons		Front Line / 34
Type 6 Squad	2017	Front Line / 33

The procurement, maintenance, and eventual replacement of response vehicles is one of the largest expenses incurred in sustaining a community's fire-rescue department. While it is the personnel of the NCFD who provide emergency services within the community, the department's fleet of response vehicles is essential to operational success. Reliable vehicles are needed to deliver responders and the equipment/materials they employ to the scene of dispatched emergencies within the city. Regular maintenance is performed by city fleet mechanics; specialized maintenance and repair of pump, aerial, and other fire apparatus are performed by a third-party fire apparatus maintenance vendor.

Replacement of fire-rescue response vehicles is a necessary, albeit expensive, element of fire department budgeting that should reflect careful planning. A well-planned and documented emergency vehicle replacement plan ensures ongoing preservation of a safe, dependable, and operationally capable response fleet. A plan must also include a schedule for future capital outlay in a manner that is affordable to the community.

NFPA 1901, *Standard for Automotive Fire Apparatus*, serves as a guide to the manufacturers that build fire apparatus and the fire departments that purchase them. The document is updated every five years using input from the public/stakeholders through a formal review process. The committee membership is made up of representatives from the fire service, manufacturers, consultants, and special interest groups. The committee monitors various issues and problems that occur with fire apparatus and attempts to develop standards that address those issues. A primary interest of the committee over the past years has been improving firefighter safety and reducing fire apparatus crashes.

The Annex Material in NFPA 1901 (2016) contains recommendations and work sheets to assist in decision-making in vehicle purchasing. With respect to recommended vehicle service life, the following excerpt is noteworthy:

> *"It is recommended that apparatus greater than 15 years old that have been properly maintained and that are still in serviceable condition be placed in reserve status and upgraded in accordance with NFPA 1912, Standard for Fire Apparatus Refurbishing (2016), to incorporate as many features as possible of the current fire apparatus standard. This will ensure that, while the apparatus might not totally comply with the current edition of the automotive fire apparatus standards, many improvements and upgrades required by the recent versions of the standards are available to the firefighters who use the apparatus."*

The impetus for these recommended service life thresholds is continual advances in occupant safety. Despite good stewardship and maintenance of emergency vehicles in sound operating condition, there are many advances in occupant safety, such as fully enclosed cabs, enhanced rollover protection and air bags, three-point restraints, antilock brakes, higher visibility, cab noise abatement/hearing protection, and a host of other improvements as reflected in each revision of NFPA 1901. These improvements provide safer response vehicles for those providing emergency services within the community, as well those "sharing the road" with these responders.

The NCFD follows the NFPA recommendations for apparatus replacement as such: 10-years front line, 5-years reserve. At the 15-year mark, the NCFD budgets in the Capital Improvement Plan (CIP) to replace the apparatus so as not to extend the service life much beyond 15 years**.** The 2006 engine apparatus is due to be replaced in the FY 23 CIP budget. Staff vehicles are replaced based on age, mileage, and consideration of recurrent maintenance costs.

Recommendations:

- CPSM recommends the NCFD, due to the current and expected future workload on apparatus, follow to the extent possible the current apparatus in-service and replacement schedule. (Recommendation No. 3.)

- CPSM further recommends the city continue with its planning to construct a permanent brick and mortar station in the northeast portion of the city utilizing national industry standards for fire facilities as outlined herein and designed to accommodate current and future response apparatus and personnel. (Recommendation No. 4.)

TRAINING PROGRAMS

Training is, without question, one of the most essential functions that a fire department should be performing on a regular basis. One could even make a credible argument that training is, in some ways, as important as emergency responses because a department that is not well trained, prepared, and operationally ready will be unable to fulfill its emergency response obligations and mission. Education and training are vital at all levels of fire service operations to ensure that all necessary functions are completed correctly, safely, and effectively. A comprehensive, diverse, and ongoing training program is critical to the fire department's level of success.

An effective fire department training program must cover all the essential elements of that department's core missions and responsibilities. The level of training or education required given a set of tasks varies with the jobs to be performed. The program must include an appropriate combination of technical/classroom training, manipulative or hands-on/practical evolutions, and training assessment to gauge the effectiveness of these efforts. Much of the training, and particularly the practical, standardized, hands-on training evolutions should be developed based upon the department's own operating procedures and operations while remaining cognizant of widely accepted practices and standards that could be used as a benchmark to judge the department's operations for any number of reasons.

The NCFD has an extensive Fire Services Manual, which serves as the standard operating guidelines for the department. Chapter 600 of this manual is dedicated to training and education of the workforce and comprehensively outlines the training regimen of the department.

Chapter 600.1 outlines the purpose of training, which is:

> *It is the policy of this department to administer a training program that will provide for the professional growth and continued development of its members. By doing so, the Department will ensure its members possess the knowledge and skills necessary to provide a professional level of service that meets the needs of the community.*

Chapter 600.2 states the policy of the department with regards to training, which is:

> *The Department seeks to provide ongoing training and encourages all members to participate in advanced training and formal education on a continual basis. Training is provided within the confines of funding, the requirements of a given assignment, staffing levels and legal mandates.*
>
> *Whenever possible, the Department will use courses certified by the California Office of the State Fire Marshal (OSFM), the California Fire Service Training and Education System (CFSTES), the U.S. Department of Homeland Security or other accredited entities.*

Chapter 623.1 further states the department's policy on individual responsibility as it links to training, and is:

> *The department shall provide a standardized Mandated Training Program to its members.*
>
> *The department shall provide standardized training references and materials made available for the use of its members in conjunction with the Mandated Training Program.*
>
> *All members shall participate in the Mandated Training Program relative to their position and classification within the department.*

Certain Occupational Safety and Health Administration (OSHA) regulations dictate that minimum training must be completed on an annual basis, covering assorted topics that include:

- A review of the respiratory protection standard, self-contained breathing apparatus (SCBA) refresher and user competency training, SCBA fit testing (29 CFR 1910.134).
- Blood Borne Pathogens Training (29 CFR 1910.1030).
- Hazardous Materials Training (29 CFR 1910.120).
- Confined Space Training (29 CFR 1910.146).
- Structural Firefighting Training (29 CFR 1910.156).

Because so much depends upon the ability of the emergency responder to effectively deal with an emergency, education and training must have a prominent position within an emergency responder's schedule of activities when on duty. Education and training programs also help to create the character of a fire service organization. Agencies that place a real emphasis on their training tend to be more proficient in carrying out day-to-day duties. The prioritization of training also fosters an image of professionalism and instills pride in the organization. Overall, the NCFD has an excellent robust and comprehensive training program and there exists a dedicated effort focused on a wide array of training activities.

The NCFD does not have a stand-alone training unit. Incumbent training is developed and implemented by and through in-house instructors. Training and education opportunities are available through community college programs, other regional fire departments, and Vector Solutions, an on-line training platform.

The department hires only fire- and EMS-certified prospective employees. Minimum hiring requirements include (per NCFD Lateral FF job announcement):

- Possession of Calf. State Fire Marshal Firefighter I certification and one year of employment with a paid municipal fire department, California State fire department, or Federal fire department.
- High School Diploma or GED.
- Possession of a valid California Class C driver's license is required at the time of appointment.
- Possession of a valid EMT Level IA certification with the County of San Diego or the State Fire Marshal, or State of California Paramedic License, or National Registry Paramedic License.

Prospective employees are also noticed through the job announcement that the ability to obtain additional certificates as required to operate in an ever-changing fire service, Technical Rescue, Hazardous Material Awareness and Operations, etc., may be required during the term of employment.

Title 8 of the California Code of Regulations (CCR) also stipulates certain training classes that are grouped dependent on whether the staff member is initial and entry level staff; emergency response staff; firefighter level staff; and certain training dependent on response functions.

The NCFD has implemented a three-year training task book for new firefighters, ***which is a national best practice.*** This task book is assigned to the Captain level, where the accountability for completing the book rests. The task book is comprehensive, task oriented, and includes written, manipulative (hands-on), and presentation scoring at the end of years one and two. Training includes manipulative, didactic, computer-based, and self-study. The assigned Captain manages the employee's progress and is responsible for ensuring the employee is prepared to perform at the firefighter level. Shift Battalion Chiefs have oversight of the program as well.

The NCFD has also implemented a task book for engine company driver operations. This Task Book is designed to provide a training format and in-house certification of the minimum skill level needed to successfully operate engine (pumper) apparatus as the driver and pump operator. This task book is a model as well and is ***a national best practice.*** To achieve certification and subsequently be released to drive and operate the engine apparatus, the firefighter must successfully complete all task and job performance requirements outlined in the task book. Tasks include driving and safe driving checks; apparatus inspection and safety checks; understanding of manufacturers' recommendations; and pump operations.

The NCFD utilizes Vector Solutions as a didactic/virtual platform for department training. Vector Solutions has a robust course catalog system for fire and EMS training (among other disciplines in need of continuing education) that can be utilized to meet all federal, state, and local public safety training mandates. Its inventory is comprised of more than 450 hours of fire department training, as well as 250 hours of accredited EMS training.[1] Training personnel (and really any officer or member so authorized) can post training and information materials online for personnel to reference. The training schedule is posted prominently on Vector Solutions and accessible to all personnel. Vector Solutions also provides the platform for managing all training records and reports. The use of this program will help to ensure that there is a reliable and accurate data base for tracking and retrieval of all department-level training and for recording and tracking the status of certifications for all personnel. The NCFD is one of more than 7,000 public agencies that uses Vector Solutions.[2]

COMMUNITY RISK REDUCTION PROGRAMS

Community risk reduction is an important undertaking of a modern-day fire department. A comprehensive fire protection system in every jurisdiction should include, at a minimum, the key functions of fire prevention, code enforcement, inspections, and public education. Preventing fires before they occur, and limiting the impact of those that do, should be priority objectives of every fire department. Fire investigation is a mission-important function of fire departments, as this function serves to determine how a fire started and why the fire behaved the way it did, providing information that plays a significant role in fire prevention efforts. Educating the public about fire safety and teaching them appropriate behaviors on how to react should they be confronted with a fire is also an important life safety responsibility of the fire department.

Fire suppression and response, although necessary to protect property, have negligible impact on preventing fire. Rather, it is public fire education, fire prevention, and built-in fire protection systems that are essential elements in protecting citizens from death and injury due to fire, smoke

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1. https://www.vectorsolutions.com
2. Ibid

inhalation, and carbon monoxide poisoning. The fire prevention mission is of utmost importance, as it is the only area of service delivery that dedicates 100 percent of its effort to the reduction of the incidence of fire.

Fire prevention is a key responsibility of every member of the fire department, and fire prevention activities should include all personnel. On-duty personnel can be assigned with the responsibility for "in-service" inspections to identify and mitigate fire hazards in buildings, to familiarize firefighters with the layout of buildings, identify risks that may be encountered during firefighting operations, and to develop pre-fire plans. On-duty personnel in many departments are also assigned responsibility for permit inspections and public fire safety education activities.

Fire prevention should be approached in a truly systematic manner, and many community stakeholders have a personal stake and/or responsibility in these endeavors. It has been estimated that a significant percentage of all the requirements found in building/construction and related codes are related in some way to fire protection and safety. Various activities such as plan reviews, permits, and inspections are often spread among different departments in the municipal government and are often not coordinated nearly as effectively as they should be. Every effort should be made to ensure these activities are managed effectively between departments.

The Fire Prevention Division in the NCFD is commanded by the Fire Marshal. In addition to the Fire Marshal, the office is staffed with a Deputy Fire Marshal and two Fire Inspectors. Together, these positions administer the fire code inspection program, fire plan reviews, weed abatement program, fire permitting, and public education mission of the department. The Fire Prevention Division works closely with the city's Community Development Department concerning matters of fire protection and relevant plan reviews, and fire code enforcement when building code issues are identified.

At the time of this analysis the City of National City and NCFD were utilizing the following fire and building codes:

- California Fire Code, 2019 edition.
- California Building Code, 2019 edition.
- California Mechanical Code.
- California Electrical Code.
- California Plumbing Code.
- Uniform Housing Code.
- California Energy Code.
- California Green Buildings Standard Code.
- California Residential Code.

In addition to state statutes and adopted fire and building codes, Chapter 400 of the NCFD Fire Services Manual outlines department policies for fire prevention, permit fees, fire investigation, public education, and associated Community Risk Reduction programs. These policies are comprehensive and are ***a best practice.***

There are 2,700 inspectable occupancies in the city. For 2019 and 2020 the fire inspection division conducted the following number of inspections:

- 2020: 599 (COVID impact affected total).
- 2019: 992.

The Fire Marshal and staff complete required annual occupancy inspections to Assembly, Institutional, and High-Hazard occupancies as required. Additionally, the Fire Marshal's Office inspects those occupancies involving a complaint, and all occupancies issued a new Business License to operate in the city. All other occupancy types are inspected once every three years to the extent possible. This type of inspection plan is typical in smaller agencies with minimal staffing. The plans review function typically conducted in-house in the Fire Marshal's Office is contracted out to a third party due to current workload, which is also common in smaller community risk reduction offices.

There are many reasons why existing buildings should be inspected for fire code compliance. The obvious purpose is to ensure that occupants of the building are living, working, or occupying a building that is safe for them to do so. Some buildings are required to have specific inspections conducted based on the type of occupancy and the use of the building such as but not limited to healthcare facilities (hospitals, nursing homes, etc.), schools, restaurants, and places of assembly. These inspections are mandated by various statutes, ordinances, and codes. Fire inspections can also identify violations and lead to follow-up inspections to ensure that violations are addressed and that the fire code is enforced.

In fire prevention, the term "enforcement" is most often associated with inspectors performing walk-throughs of entire facilities, looking for any hazards or violations of applicable codes. Educating the owner to the requirements, as well as the spirit and intent, of the code can also attain positive benefits for fire and life safety. This practice also improves community and business relationships.

Taking into consideration that fire prevention activities are important and also a community-wide responsibility, the City Council adopted a city-wide self-inspection program for certain business occupancy types. Title 15.29.020 of the city code of ordinances establishes a self-inspection program for certain occupancies B1 (business) and R1 (hotels, motels, boarding houses, congregate housing) to *maintain functions necessary for the prevention of fire and for the protection of life and property from fire and panic, the city council establishes a business fire safety self-inspection program assuring that certain "B-2" and "R-1" occupancies within the city are inspected on an annual basis for fire safety.*

Under the self-inspection program, and pursuant to Title 15.29.030 of the code, the owner or manager of the occupancy or person in highest authority in the occupancy shall within 30 days inspect each occupancy, complete the forms mentioned in subsection A of this section, correct all deficiencies, and return the same to the National City fire department. All deficiencies observed shall be reported on the forms and corrected prior to returning the forms to the National City fire department.

Public education is the area where the fire service will make the greatest impact on preventing fires and subsequently reducing the accompanying loss of life, injuries, and property damage through adjusting people's attitudes and behaviors regarding fires and fire safety. The NCFD <u>does not</u> have a comprehensive public fire education program due to the current inspection workload, and the effort it is able to commit is commendable and results in time and resources well spent. A substantial percentage of all fires, fire deaths, and injuries occur in the home, an area where code enforcement and inspection programs have little to no jurisdiction. The NCFD provides community fire extinguisher training, conducts a juvenile fire setter program, and provides community fire prevention classes when requested.

The investigation of the cause and origin of fires is also an important part of a comprehensive fire prevention system. Determining the cause of fires can help with future prevention efforts. Battalion Chiefs and Captains initiate the fire origin and cause determination process by NCFD policy 402.5. When possible, they can and should make the origin and cause determination. When needed, particularly when the on-scene officers cannot determine the origin and cause of the fire, or they believe a crime has been committed, the Fire Marshal or fire investigator responds to perform an in-depth investigation.

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SECTION 3. ALL-HAZARDS RISK ASSESSMENT OF THE COMMUNITY

COMMUNITY RISKS

Population and Community Growth

The 2020 U.S. Census determined the population of National City is 56,173. This is a 4 percent decrease from the 2010 population of 58,582. As the city land area is about 7.28-square miles, the population density based on Census population data is 8,050/square mile.[3]

In terms of fire and EMS risk, the age and socio-economic profiles of a population can have an impact on the number of requests for fire and EMS services. Evaluation of the number of seniors and children by fire management zones can provide insight into trends in service delivery and quantitate the probability of future service requests. In a 2021 National Fire Protection Association (NFPA) report on residential fires, the following key findings were identified for the period 2015–2019:[4]

- Males were more likely to be killed or injured in home fires than females and accounted for larger percentages of victims (57 percent of the deaths and 55 percent of the injuries).
- The largest number of deaths (19 percent) in a single age group was among people ages 55 to 65.
- 59 percent of the victims of fatal home fires were between the ages of 39 and 74, and three of every five (62 percent) of the non-fatally injured were between the ages of 25 and 64.
- Slightly over one-third (36 percent) of the fatalities were age 65 or older; only 17 percent of the non-fatally injured were in that age group.
- Children under the age of 15 accounted for 11 percent of the home fire fatalities and 10 percent of the injuries. Children under the age of 5 accounted for 5 percent of the deaths and 4 percent of the injuries.
- Adults of all ages had higher rates of non-fatal fire injuries than children.
- Smoking materials were the leading cause of home fire deaths overall (23 percent) with cooking ranking a close second (20 percent).
- The highest percentage of fire fatalities occurred while the person was asleep or physically disabled and not in the area of fire origin, which are key factors to vulnerable populations.

In National City the following age and socio-economic factors are considered when assessing and determining risk for fire and EMS preparedness and response:[5]

- Children under the age of five represent 5.5 percent of the population.
- Persons under the age of 18 represent 20.6 percent of the population.

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[3] U.S. Census Bureau Quick Facts, National City, California.
[4] M. Ahrens, R. Maheshwari "Home Fire Victims by Age and Gender," Quincy, MA: NFPA, 2021.
[5] https://www.census.gov/quickfacts/nationalcityCalifornia

- Persons over the age of 65 represent 13.4 percent of the population.
- Female persons represent 49.5 percent of the population.
- There are 3.33 persons per household in National City.
- The median household income in 2019 dollars is $47,119.
- Persons living in poverty make up 18.3 percent of the population.
- Black or African-American alone represents 4.8 percent of the population. The remaining percentage of population by race includes White alone at 64.6 percent, American Indian or Alaska Native alone at 0.5 percent, Asian alone at 18.5 percent, two or more races at 3.0 percent, and Hispanic or Latino at 63.5 percent.

Estimated build-out in National City is discussed in two ways in the city's 2011 General Plan. The plan first contemplates build-out based on allowable denisities, and if all open land is utilized. As this is unlikely to occur, the 2011 Genaral Plan discusses build-out assumptions by 2030 on vacant or underutilized parcels near sites that are likely to redevelop within the city considering site and other development constraints. These assumptions are:[6]

- 5,091 new dwelling units.
- 20,362 new residents.
- 2.6 million square feet of new retail/office space.
- 3.2 million square feet of new industrial space.[7]

Regardless of the build-out in the city, an increase in population, the type of housing units (multi-family, vertical density etc.) built, and the type of industry and retail space have impacts on call demand and increases building risks as outlined further in this section.

Environmental Factors

The City of National City is prone to and will continue to be exposed to certain environmental hazards that may impact the community. The most common natural hazards prevelant to the city according to the National City Emergency Operations Plan (EOP), and that create environmental risks are:

- **Earthquakes**: National City is in proximity to local faults such as the Rose Canyon Fault and that are potential risks to older structures (structural integrity and collapse causing natural gas leaks, fires, and trapping residents); potential for loss of life, injuries, and damage to property, as well as disruption to infrastructure and services. According to the San Diego County Multi-Jurisdictional Hazard Mitigation Plan, the city has had no repetitive loss from earthquake risks.
- **Dam Failure**: National City is proximity to and downstream from the Sweetwater Dam. Dam inundation to property and infrastructure in and adjacent to the Sweetwater River channels exists. The National City EOP considers the likelihood of dam failure to be low due to the construction features of the dam; however, it still poses an environmental risk. According to the San Diego County Multi-Jurisdictional Hazard Mitigation Plan, the city has had no repetitive loss from dam failure risks.
- **Floods**: According to the National City EOP, significant portions of the City are within FEMA mapped 100-year floodplains, thus posing a risk of flooding. Urban and flash flooding can

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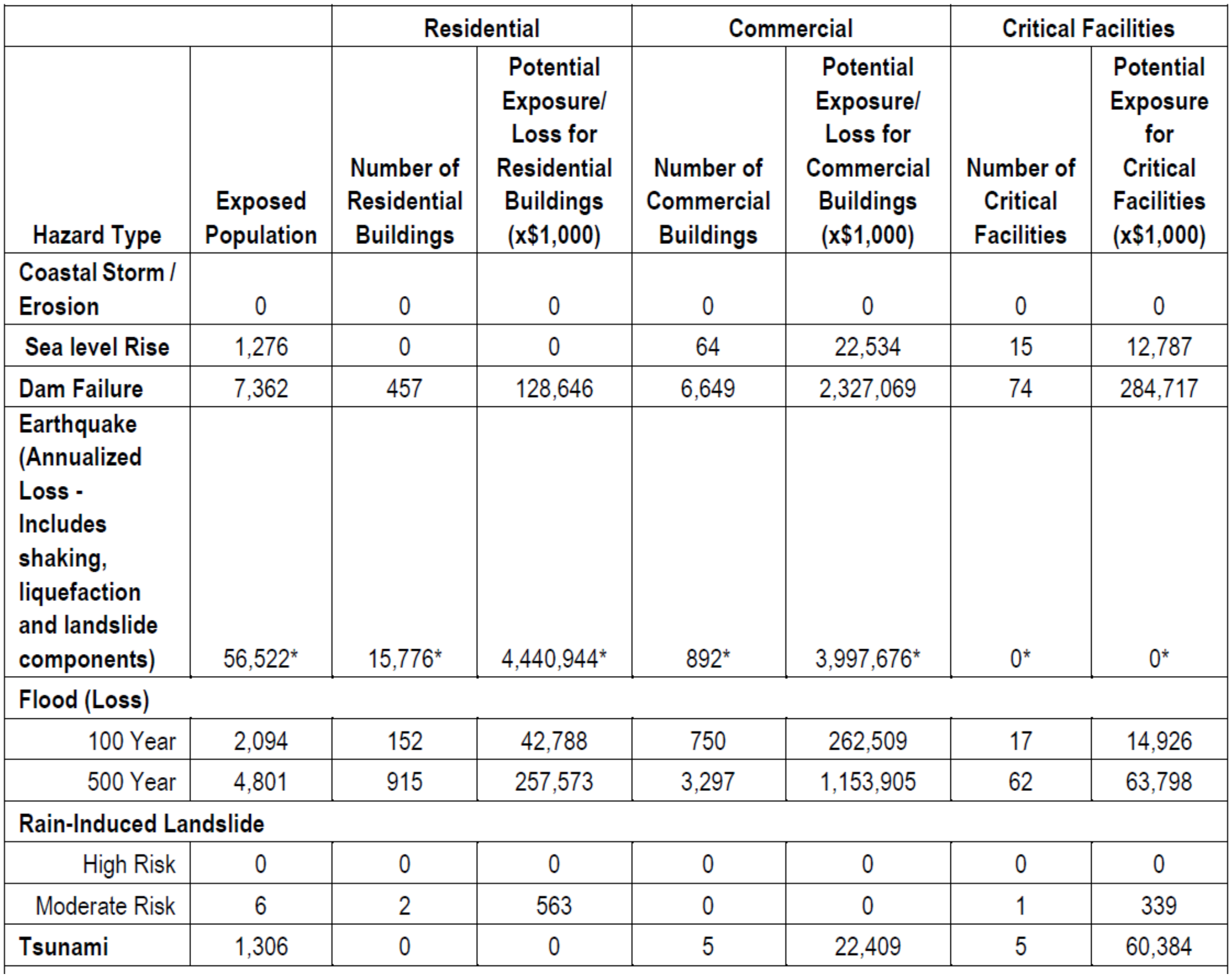
[6] National City 2011 General Plan.
[7] Ibid.

occur during heavy rain events. According to the San Diego County Multi-Jurisdictional Hazard Mitigation Plan, the city has minimal (two) repetitive losses from flood risks.

- **Tsunami**: Coastal land areas on the east and west coasts of the United States are susceptible to tsunami events that create significant coastal flooding. According to the San Diego County Multi-Jurisdictional Hazard Mitigation Plan, the city has had no repetitive loss from Tsunami risks.
- **Extreme Heat**: Increased risk of medical complications from increased temperatures.
- **Drought**: Periods of prolonged drought may limit water supply available to the region.[8] [9]

The following table describes the potential hazard-related exposure and loss from environmental risks in National City, as detailed by the San Diego County Office of Emergency Services for the San Diego County Multi-Jurisdictional Hazard Mitigation Plan.

TABLE 3-1: Environmental Risks: Potential Hazard and Loss in National City



		Residential		Commercial		Critical Facilities	
Hazard Type	**Exposed Population**	**Number of Residential Buildings**	**Potential Exposure/ Loss for Residential Buildings (x$1,000)**	**Number of Commercial Buildings**	**Potential Exposure/ Loss for Commercial Buildings (x$1,000)**	**Number of Critical Facilities**	**Potential Exposure for Critical Facilities (x$1,000)**
Coastal Storm / Erosion	0	0	0	0	0	0	0
Sea level Rise	1,276	0	0	64	22,534	15	12,787
Dam Failure	7,362	457	128,646	6,649	2,327,069	74	284,717
Earthquake (Annualized Loss - Includes shaking, liquefaction and landslide components)	56,522*	15,776*	4,440,944*	892*	3,997,676*	0*	0*
Flood (Loss)							
100 Year	2,094	152	42,788	750	262,509	17	14,926
500 Year	4,801	915	257,573	3,297	1,153,905	62	63,798
Rain-Induced Landslide							
High Risk	0	0	0	0	0	0	0
Moderate Risk	6	2	563	0	0	1	339
Tsunami	1,306	0	0	5	22,409	5	60,384

Note: *Represents best data available at time of analysis

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[8] 2020 National City Emergency Operations Plan.

[9] 2018 San Diego County Multi-Jurisdictional Hazard Mitigation Plan.

Building and Target Hazards

A community risk and vulnerability assessment will evaluate the community, and regarding buildings, it will review all buildings and the risks associated with each property segregating the property as either a high-, medium-, or low-hazard depending on factors such as the life and building content hazard, and the potential fire flow and staffing required to mitigate an emergency in the specific property. According to the NFPA *Fire Protection Handbook*, these hazards are defined as:

High-hazard occupancies: Schools, hospitals, nursing homes, explosives plants, refineries, high-rise buildings, and other high life-hazard (vulnerable population) or large fire-potential occupancies.

Medium-hazard occupancies: Apartments, offices, and mercantile and industrial occupancies not normally requiring extensive rescue by firefighting forces.

Low-hazard occupancies: One-, two-, or three-family dwellings and scattered small business and industrial occupancies.[10]

The predominant building type/building risk in National City is single-family detached dwellings (*low-hazard*). The primary construction type for residential structures is Type V-B, which does not require a fire resistance rating for any of the building elements (typically wood frame).

Multifamily, apartments, and condominiums (vertical density) represent a large percent of the city's housing stock. Typical construction is mixed and includes fire resistive, ordinary, non-fire resistive, wood frame with one-hour fire rating, and protected combustible. Some apartment and condominium complexes include a multibuilding footprint. The city has an assortment of manufactured homes as well (small percentage), which are typically made of light metal/wood construction with various exterior coverings. Of greater risk is the vertical housing that exists in the city, which not only creates much higher occupant density, but also requires greater response resources if a fire breaks out, particularly to manage the life safety component, even in cold smoke conditions.

The strip mall inventory consists of non-fire resistive, fire resistive (one-hour fire rating), and protected combustible construction (one-hour fire rating). The commercial/industrial structure building inventory is ordinary (block/brick) construction, wood frame with composite siding, and masonry non-combustible.

National City has the following building types:

- Single-family homes, 9,507 (highest total building count at 53.9 percent).[11]
- Multifamily units (apartments, condomuniums, some vertical), 7,636 units (43.3 percent).[12]
- Manufactured homes, 416.[13]
- Professional business, single and multi-story.
- Commercial and industrial buildings.

National City has at least 167 commercial buildings of which 56 have ISO fire flows of 2000 gpm or higher and 13 that have fire flows of 3,500 gpm or higher.
Source: 2009 National City Standard of Cover-Citygate Assoc. LLC

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[10] Cote, Grant, Hall & Solomon, eds., *Fire Protection Handbook* (Quincy, MA: National Fire Protection Association, 2008), 12.

[11] Census Reporter, National City, Calif.

[12] Ibid.

[13] Ibid.

- Strip malls.
- Assisted living/long-term care buildings/homes (multiple facilities and homes in the city).
- Public education structures (elementary, junior, and high school buildings).
- Public government buildings.
- High-rise buildings.

The next figure illustrates the existing land use map for the city, which indicates the type of building risk and its general location, along with two aerial views of the landscape that illustrate further the building types and risk.[14]

FIGURE 3-1: National City Existing Land Use Map

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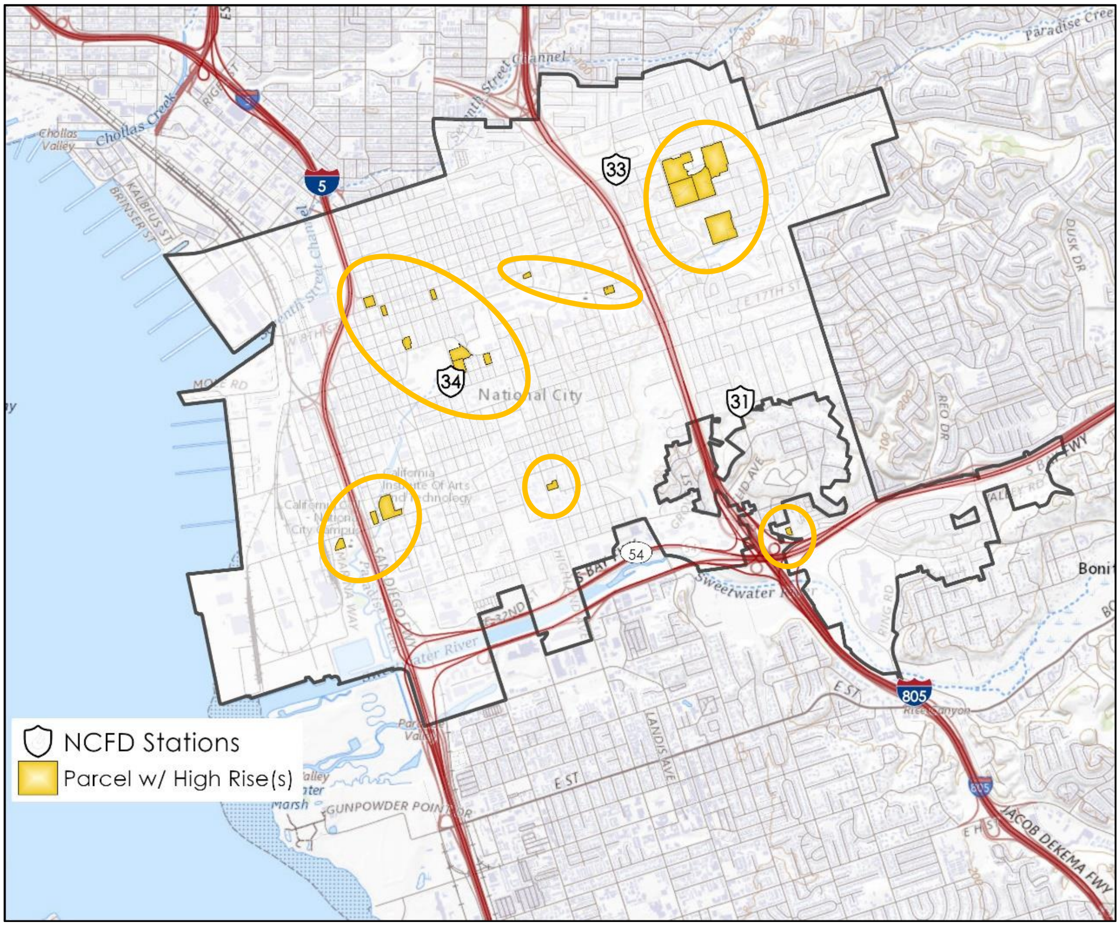
[14] National City 2011 General Plan.

In terms of identifying target hazards, consideration must be given to the activities that take place (public assembly, life safety vulnerability, manufacturing, processing, etc.), the number and types of occupants (elderly, youth, handicapped etc.), and other specific aspects related to the construction of the structure. National City has more than 2,700 occupancies that the NCFD considers target hazards such as:

- High-rise target hazards (life safety) of which there are mixed occupancy types and include housing units.
- Hospital/medical center target hazard (Paradise Valley Hospital).
- Educational/school/public assembly target hazard (life safety).
- Mercantile/business/industrial (life safety, hazardous storage and or processes).
- Long-term and assisted care target hazards (life safety, vulnerable population).
- Government business target hazards (life safety, continuity of operations).
- Private business target hazards (life safety).

The following figure illustrates the location of high-rise building risks in the city.

FIGURE 3-2: High-Rise Building Risk Locations



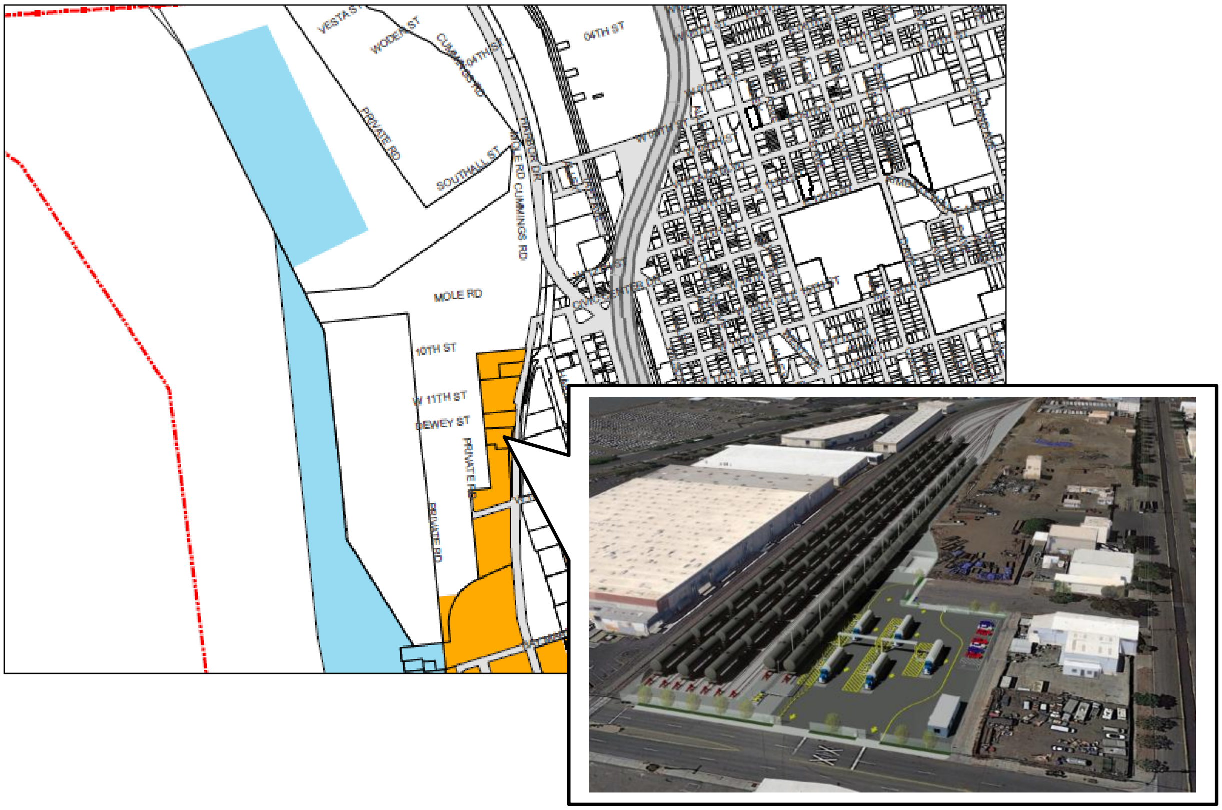
The city has a mix of low- and medium-risk structures that make up the majority of the target hazard risk. High-hazard/high rise building risks are noted in this section as well.

Building risks, associated population, and other factors as discussed include assisted/long-term care facilities, residential structures housing a vulnerable population, hospital/medical center, residential structures more than three stories in height, public assembly structures when occupied, and those mercantile occupancies that have hazardous materials used in processes or that are stored in large quantities.

Future growth calls for vertical density (multifamily/unit) structures to include a 22-story building. The building risk outside of single-family dwellings, particularly those of multi-unit and multi-story residential buildings pose additional firefighting risk in terms of life safety, ability to reach the seat of the fire quickly, and assembling an Effective Response Force needed to mitigate an emergency in structures such as these. Even small fires in these structures create cold smoke issues for multiple units, all requiring some level of mitigation for life safety and smoke removal, or even occupant removal from and by the fire department.

The city also has a potential future risk that is worth noting here. USD Clean Fuels and Plastic Express (USDCF/PEX) are working with the city to locate a biofuels transloading site on the current Pacific Steel property site in the city. This site is situated west of the I-5 corridor in the industrial section of the city and east of the Port of San Diego property (see the next figure). This site will include transloading of biofuels onto rail tank cars and tractor trailer tank trucks. The project is designed with many safety features and will meet state building and fire prevention codes. Fuel transloading, hazardous materials, and transportation risks (rail, rail at-grade crossings, road transportation) discussed herein will be present with this facility.

FIGURE 3-3: USDCF/PEX Biofuels Transloading Project Location

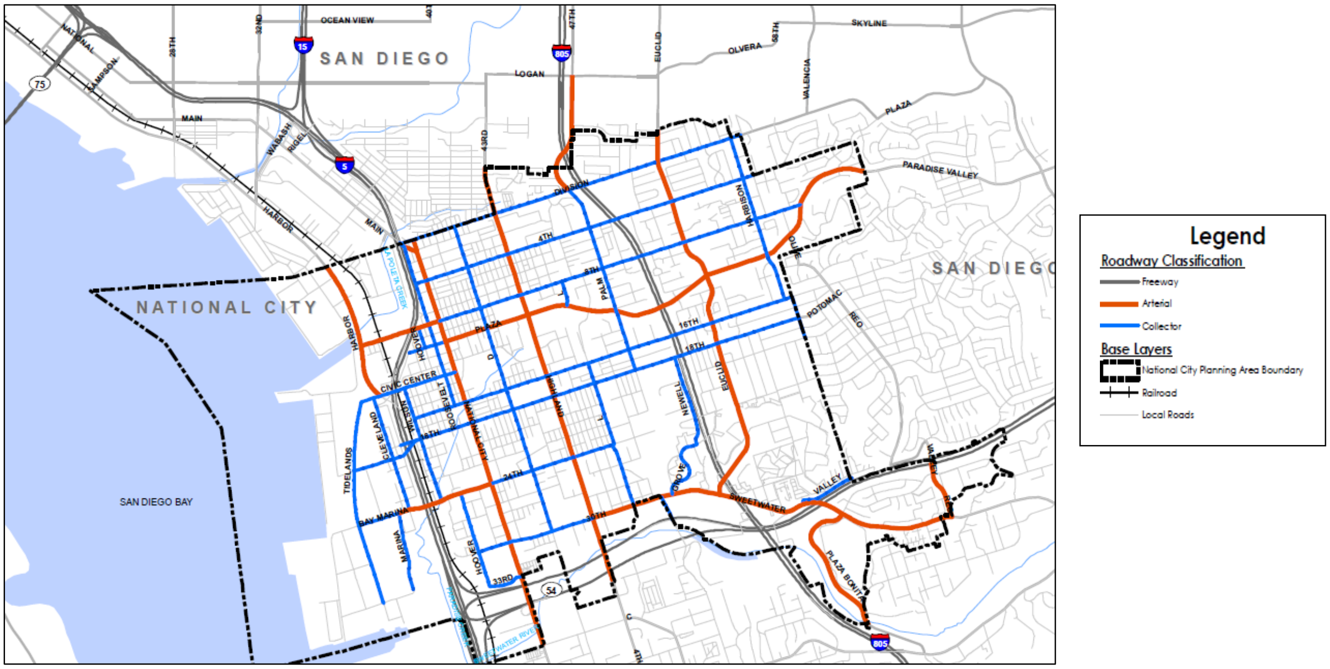


Transportation Factors

The road network in National City is typical of cities in the region. In National City this includes freeways, which are high-speed, high capacity, and of limited access; arterial streets, which carry high volumes of traffic and are typically four lanes with synchronized signals; collector streets, which provide connection to arterial roads and local street networks as well as residential and commercial land uses; and local streets, which provide a direct road network to property and move traffic through neighborhoods and business communities. [15]

At the time of the 2011 General Plan, the city had 110 miles of paved roads, with 15 arterial and 30 collector roads. National City has also designated certain truck routes (primary and alternate) designed to route trucks to and from their likely business destinations and to major freeways. The following figure illustrates the National City transportation road network.

FIGURE 3-4: National City Road Network



The San Diego Metropolitan Transit System (MTS) operates fixed bus routes in the city. There are ten bus routes with 205 individual bus stops. The city also has an MTS trolley line (Blue Line) that runs from San Diego City to the U.S.-Mexico Border. There are two stops in National City. According to the March 2021 *Transportation Elements Draft Report*, National City residents rely more on public transportation such as the MTS bus and trolley systems than other commuters in San Diego County. Bus and trolley accidents during populated rides pose a mass casualty response risk if multiple riders are injured.

Active railroad lines other than the trolley system are also present in the city. The primary active rail lines are the Burlington Northern Santa Fe (BNSF) and the San Diego and Imperial Valley Railway (SDIV). These rail lines operate on and share track right-of-way with the MTS trolley system. SDIV trains are operated primarily at night along the main line when the trolley service is not operating. This includes to and from the port and to and from other destinations. The primary

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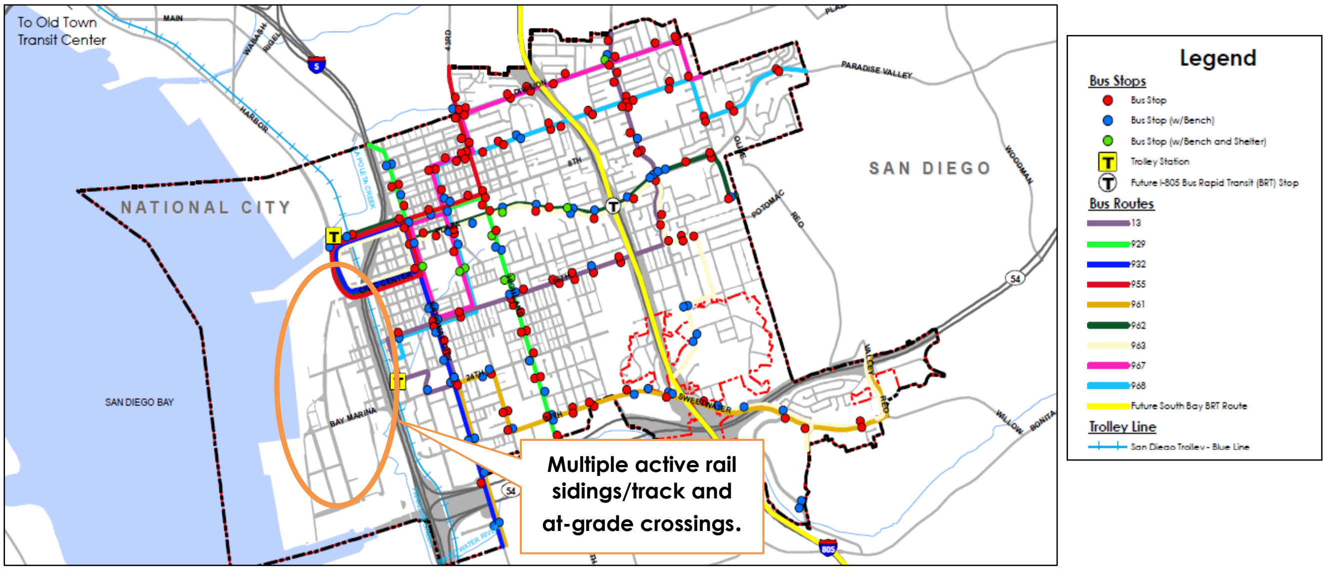
15. National City 2011 General Plan.

commodities hauled by the SDIV are petroleum products, agricultural products, and wood pulp. Other commodities transported in and through National City are automobiles and containers originating through the Port of San Diego. While not all these commodities may be considered hazardous materials, fires involving these commodities can produce smoke and other products of combustion risks that may be hazardous to health. Hazardous materials themselves present hazards to health risks if being transported and involved in a rail accident. At-grade crossings exist in the city and pose transportation accident risks.

The next figure illustrates the National City mass transit system.

FIGURE 3-5: National City Mass Transit System



Multiple active rail sidings/track and at-grade crossings.

The road and transportation network described herein poses risks for vehicular accidents, some at medium to greater than medium speeds, as well as vehicular-versus-pedestrian risks. There are additional transportation risks since tractor-trailer and other commercial vehicles traverse the roadways of National City to deliver mixed commodities to business locations. Fires involving these products can produce smoke and other products of combustion risks that may be hazardous to health.

Port of San Diego

The Port of San Diego (Port) occupies approximately 7 percent of the city's land area. There are significant risks on the Port property, which include:

- Significant rail traffic on Port property and significant rail traffic not directly on Port property but that serves commercial business on Port property and travels through the city. This rail has multiple at-grade crossings which pose a traffic risk, and rail cars that transport combustibles and other hazards the NCFD will respond to and mitigate.
- The Port property in National City has large footprint buildings that are several thousand square feet in size, and although considered single story have the ceiling height of multistory structures. These buildings have processes and storage that are combustible and hazardous. Larger footprint buildings pose additional building risks to the NCFD in terms of mass storage of commodities and hazardous/combustible materials utilized in work processes, and

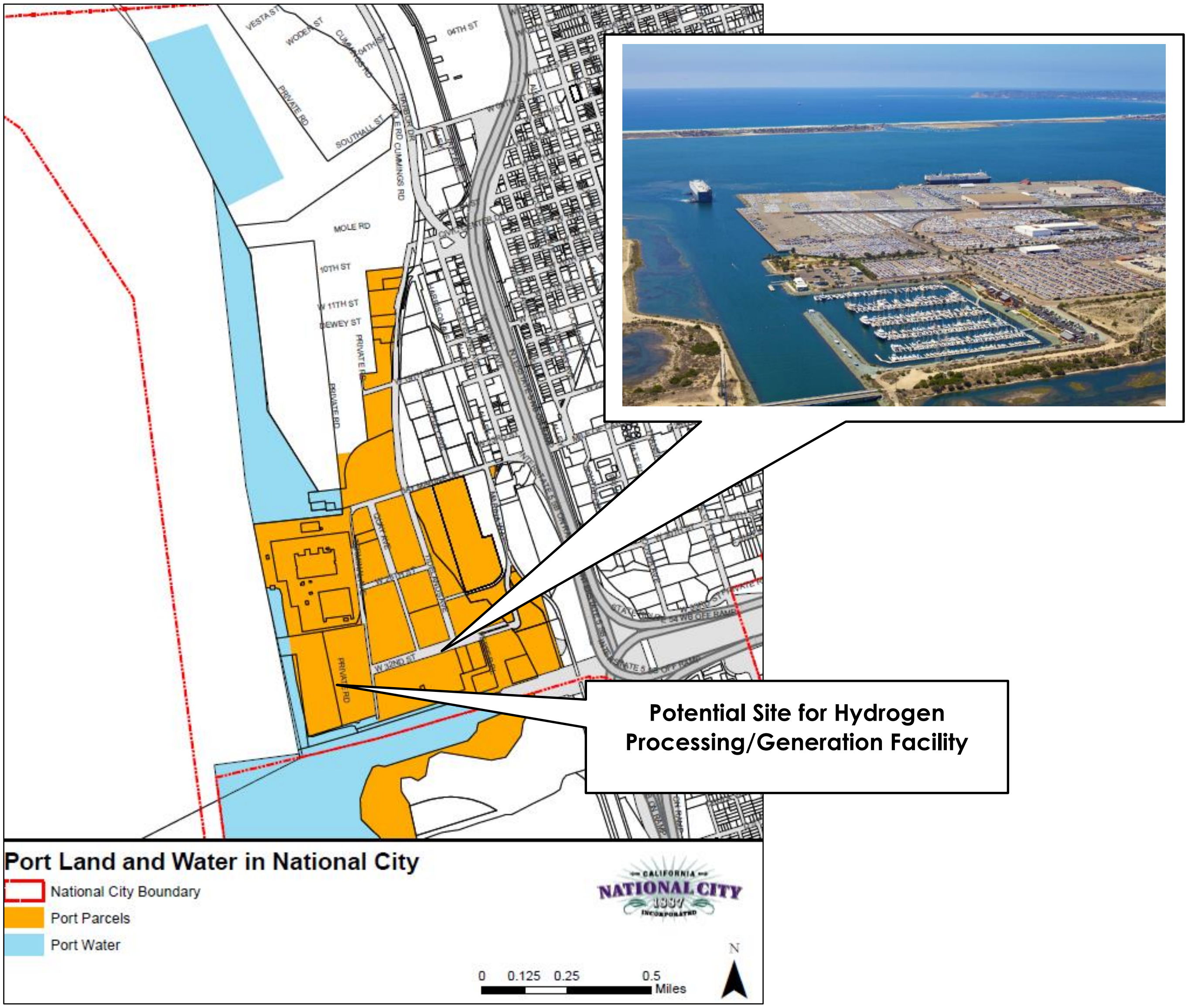
considerable waterflow requirements based on the size of the building footprint, commodities stored, and mercantile processes being conducted.

These buildings are typically built of fire resistive structural members and are sprinklered, but contain internally combustible accessories, materials, storage, processes, and internal structures. While the life-safety hazard normally will not require extensive rescue by firefighting forces (in terms of the number of people on premises at one time to be rescued), the scope and complications of the larger footprint to be covered by initial attack lines and in a search and rescue undertaking raise these types of structures to a high-hazard building risk.

- The Port property has other commercial and mercantile properties, although not large footprint buildings, which pose building and property risk due to the on-site storage (lumber, petroleum products, vehicles, hazardous materials) as well as business processes and storage in the interior of property buildings that are combustible and hazardous. Not all of these buildings have fire protection systems. These buildings are of medium to high risk based on building/property content. These occupancies also support heavy vehicles that move product to and from these properties, posing traffic and hazard risks. Included on Port property is a small retail/restaurant area with significant private vessel docking and boat marina slips.
- Proposed additions to Port property include:
  - Hydrogen Processing Plant south of the Pasha property. If this project is realized, this will be the largest hydrogen processing plant in the nation, according to NCFD staff. Transport of this product will be by marine, rail, and over-the-road vehicles. This facility will be of high/special risk hazard, and all transportation modes will be of high/special risk as well.
  - Hotel(s), restaurants, RV Park. Each of these brings certain building and life-safety risks. Hotels are of a higher risk as they include vertical density. Restaurants are assembly classifications, which raise the life-safety risk when occupied. RV parks, although seemingly a low or no risk hazard, actually are, in that RVs are combustible and when on fire burn rather rapidly because of the interior combustibles. There is also the hazard of on-board fuel (gasoline or diesel fuels, and pressurized gas for cooking). One additional risk is proximity from RV to RV, which creates exposure hazards (when one RV is on fire it typically spreads to another exposed RV).

The next figure illustrates the Port property within National City boundaries.

FIGURE 3-6: Port of San Diego in National City



Potential Site for Hydrogen Processing/Generation Facility

Fire and Fire-Related Risk

An indication of the community's fire risk is the type and number of fire-related incidents the fire department responds to. CPSM conducted a data analysis for this project that analyzed NCFD incident responses and workload.

The following table details the call types and call type totals for these types of fire-related risks for 2019 and 2020.

TABLE 3-2: Fire Call Types, 2019 and 2020

Call Type	2019		2020	
	Total Calls	Calls per Day	Total Calls	Calls per Day
False alarm	318	0.9	216	0.6
Good intent	56	0.2	81	0.2
Hazard	48	0.1	33	0.1
Outside fire	125	0.3	162	0.4
Public service	121	0.3	139	0.4
Structure fire	31	0.1	29	0.1
Fire Total	**699**	**1.9**	**660**	**1.8**

EMS Risk

As with fire risks, an indication of the community's pre-hospital emergency medical risk is the type and number of EMS calls to which the fire department responds. The following table outlines the call types and call type totals for these types of EMS risks.

TABLE 3-3: EMS Call Types, 2019 and 2020

Call Type	2019		2020	
	Total Calls	Calls per Day	Total Calls	Calls per Day
Breathing difficulty	722	2.0	674	1.8
Cardiac and stroke	779	2.1	740	2.0
Fall and injury	999	2.7	952	2.6
Illness and other	1,344	3.7	1,303	3.6
MVA	407	1.1	349	1.0
Overdose and psychiatric	151	0.4	171	0.5
Seizure and unconsciousness	738	2.0	620	1.7
EMS Total	**5,140**	**14.1**	**4,809**	**13.1**

National City utilizes a private EMS service for EMS transport, which is discussed in a seperate section in this report. Here though, we show the EMS transport demand by the private EMS service, which links to the overall EMS risk factor in National City. The next two tables descibe the EMS ground transport demand in the city for 2019 and 2020.

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TABLE 3-4: AMR Calls by Call Type, 2019 and 2020

Call Type	Number of Calls		Calls per Day	
	2019	2020	2019	2020
Breathing difficulty	815	758	2.2	2.1
Cardiac and stroke	881	864	2.4	2.4
Fall and injury	1,296	1,229	3.6	3.4
Illness and other	2,453	2,421	6.7	6.6
MVA	677	589	1.9	1.6
Overdose and psychiatric	266	286	0.7	0.8
Seizure and unconsciousness	867	726	2.4	2.0
EMS Total	**7,255**	**6,873**	**19.9**	**18.8**
Fire & FD assist	73	72	0.2	0.2
Total	**7,328**	**6,945**	**20.1**	**19.0**

TABLE 3-5: Transport Calls by Call Type by AMR EMS Service for 2019

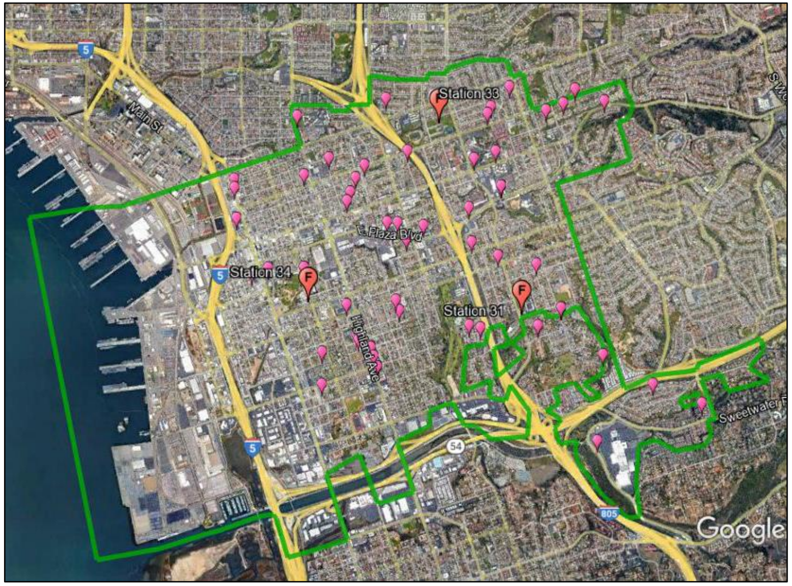
Call Type	Number of Calls			Conversion Rate, Calls to Transports
	Non-transport	Transport	Total	
Breathing difficulty	167	648	815	79.5
Cardiac and stroke	183	698	881	79.2
Fall and injury	458	838	1,296	64.7
Illness and other	846	1,607	2,453	65.5
MVA	422	255	677	37.7
Overdose and psychiatric	116	150	266	56.4
Seizure and unconsciousness	232	635	867	73.2
EMS Transport Total	**2,424**	**4,831**	**7,255**	**66.6**

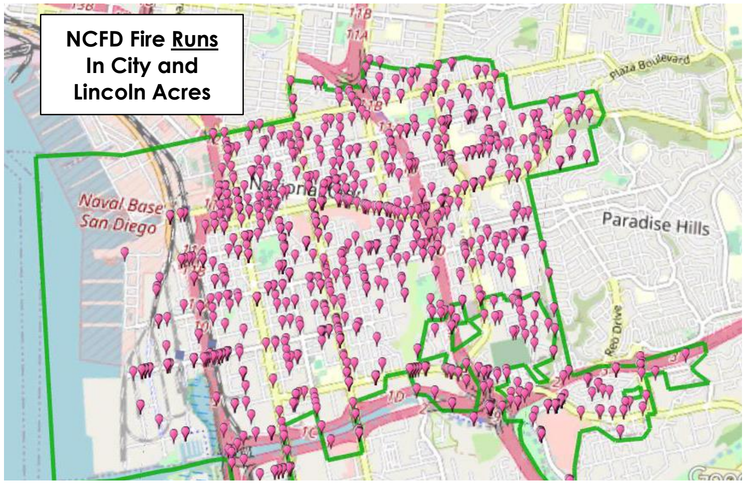
FIRE AND EMS INCIDENT DEMAND

Analyzing where the fire and EMS incidents occur, and the demand density of fire and EMS incidents, helps to determine adequate fire management zone resource assignment and deployment.

The following figures illustrate fire and EMS demand in the NCFD fire management zone. These include fire incidents (structural and outside fires); other types of fire-related incidents such as good intent and public service calls, which are calls for service such as smoke scares (no fire), wires down, lock outs, water leaks, etc.; false alarms (typically fire alarms); and EMS incident demand that includes all EMS incidents, breathing difficulty and cardiac related, and motor vehicle accidents. All demand maps are the aggregate of 2019 and 2020 responses. Demand maps labeled with "Runs" show demand of multiple NCFD unit response.

FIGURE 3-7: NCFD In-City Fire Incident Demand (Structure and Outside Fires)

Structure Fires	Outside Fires
	



NCFD Fire **Runs**
In City and
Lincoln Acres

FIGURE 3-8: NCFD In-City False (Fire) Alarms, Good Intent, Hazard, Public Service Call Demand

False Alarms	Good Intent, Hazard, Public Service Calls
	

NCFD Fire Runs In City and Lincoln Acres

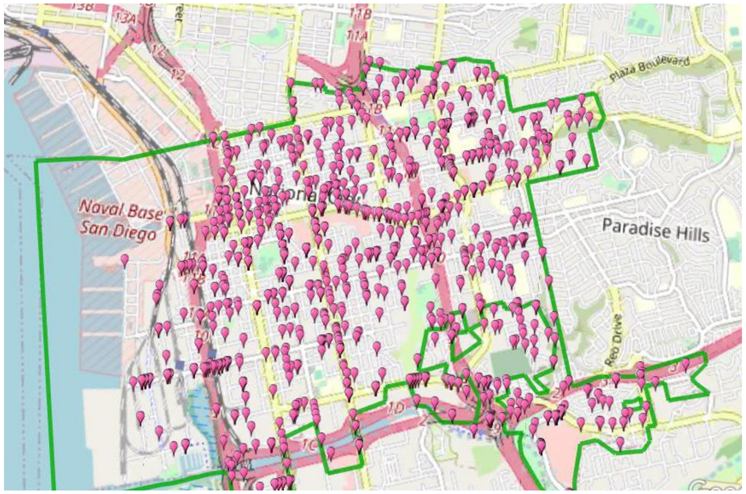
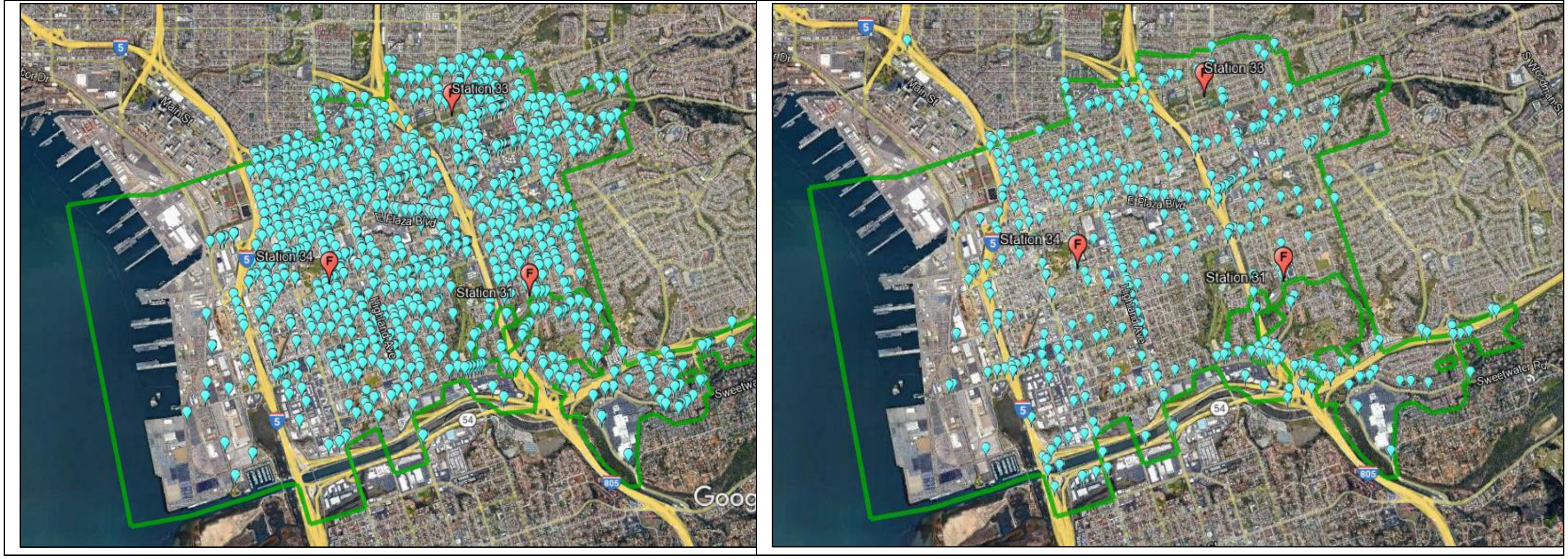
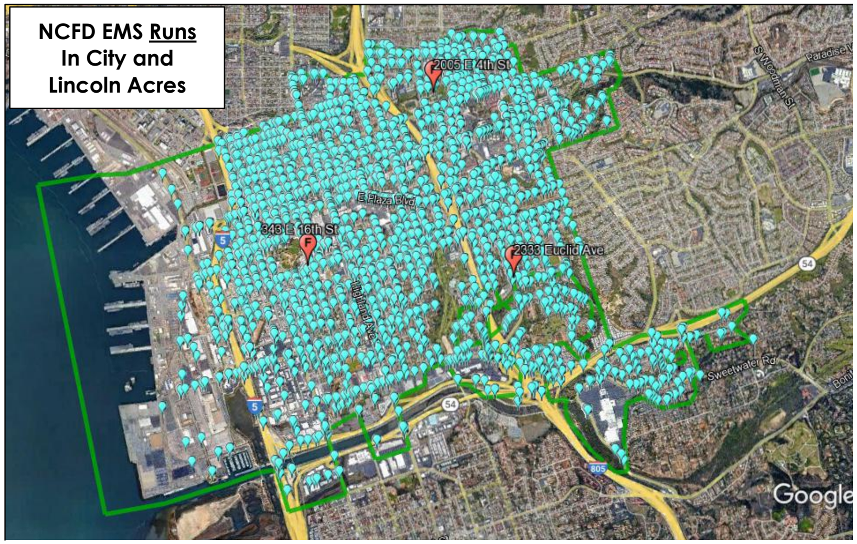


FIGURE 3-9: NCFD In-City EMS High Acuity Demand (Breathing Difficulty, Cardiac and Stroke and MVA)



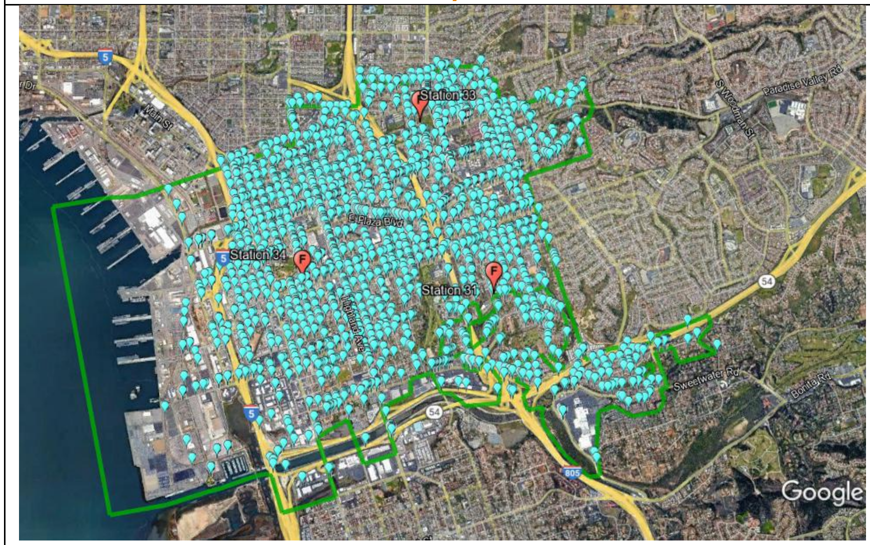
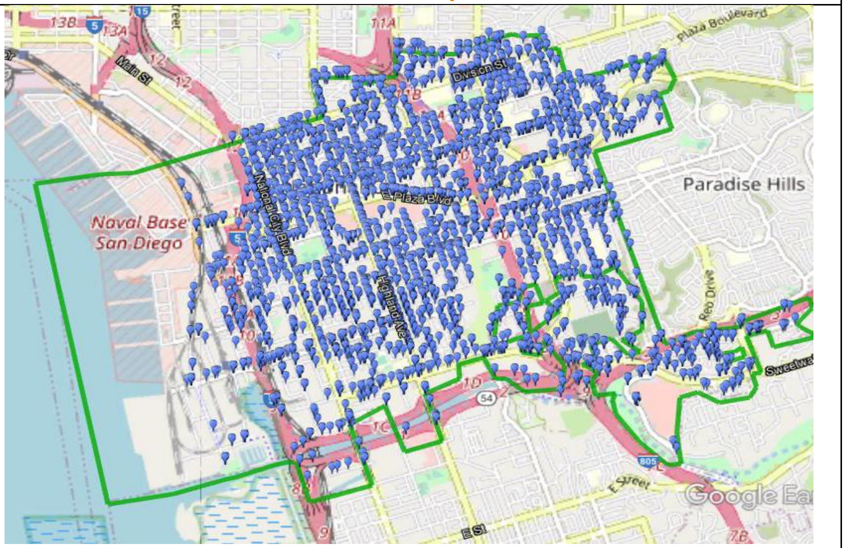
Breathing Difficulty, Cardiac and Stroke

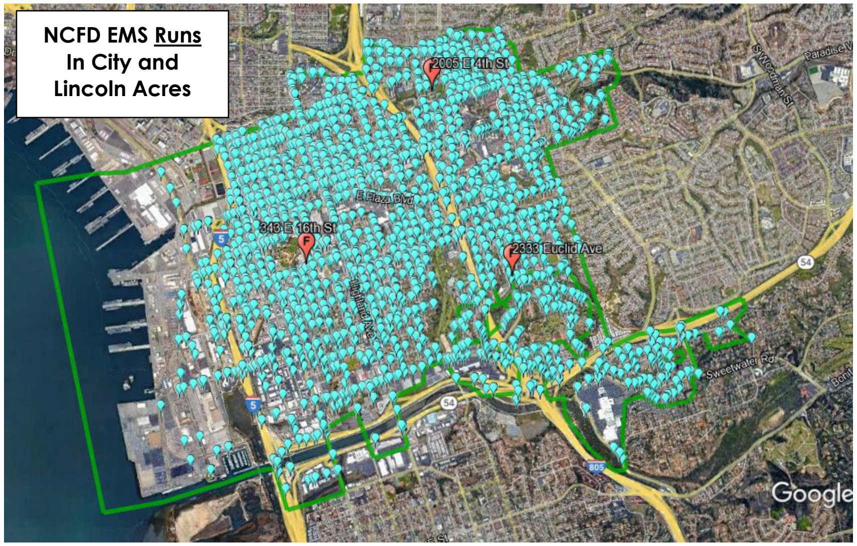
Motor Vehicle Accident



NCFD EMS Runs In City and Lincoln Acres

FIGURE 3-10: NCFD In-City EMS Demand and AMR Ground Transport Demand

NCFD Low-Acuity EMS Demand	AMR Ground Transport Demand
	



ISO RATING

The ISO is a national, not-for-profit organization that collects and evaluates information from communities across the United States regarding their capabilities to combat building fires. ISO conducts field evaluations in an effort to rate communities and their relative ability to provide fire protection and mitigate fire risk. This evaluation allows ISO to determine and publish the Public Protection Classification (PPC). The data collected from a community is analyzed and applied to ISO's Fire Suppression Rating Schedule (FSRS) from which a Public Protection Classification (PPC) grade is assigned to a community (1 to 10).

A Class 1 (highest classification/lowest numerical score) represents an exemplary community fire suppression program that includes all of the components outlined below. A Class 10 indicates that the community's fire suppression program does not meet ISO's minimum criteria. It is important to understand the PPC is not just a fire department classification, but a compilation of community services that include the fire department, the emergency communications center, and the community's potable water supply system operator.[16]

The lower score indicates a more favorable rating which potentially translates into lower insurance premiums for the business owner and homeowner. This lower classification makes the community more attractive from an insurance risk perspective. How the PPC for each community affects business and homeowners can be complicated because each insurance underwriter is free to utilize the information as they deem appropriate. Overall, many factors feed into the compilation of an insurance premium, not just the PPC.

A community's PPC grade depends on:

- **Needed Fire Flows** (building locations used to determine the theoretical amount of water necessary for fire suppression purposes).
- **Emergency Communications** (10 percent of the evaluation).
- **Fire Department** (50 percent of the evaluation).
- **Water Supply** (40 percent of the evaluation).

The City of National City has an ISO rating of ***Class 02, the second-highest rating achievable***. This rating became effective in March 2019. The final rating included the following credit by category:

- **Emergency Communications**: 9.14 earned credit points/10.00 credit points available.
- **Fire Department**: 40.90 earned credit points/50.00 credit points available.
- **Water Supply**: 36.85 earned credit points/40.00 credit points available.
- **Community Risk Reduction** (Fire Prevention/Inspection, Public Education, and Fire Investigation activities): 3.31 earned credit points/5.50 credit points available.

Overall, the community PPC rating yielded 88.14 earned credit points out of 105.50 credit points available. There was a 2.06 point diversion reduction assessed as well, which is automatically calculated based on the relative difference between the fire department and water supply scores. **80.00 points or more qualify a community for a rating of 2. National City is on the higher end of this classification.**

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[16] NCFD ISO PPC report; March 2019.

The following figures illustrate the dispersion of PPC ratings across the United States and in California.

FIGURE 3-11: PPC Ratings in the United States[17]

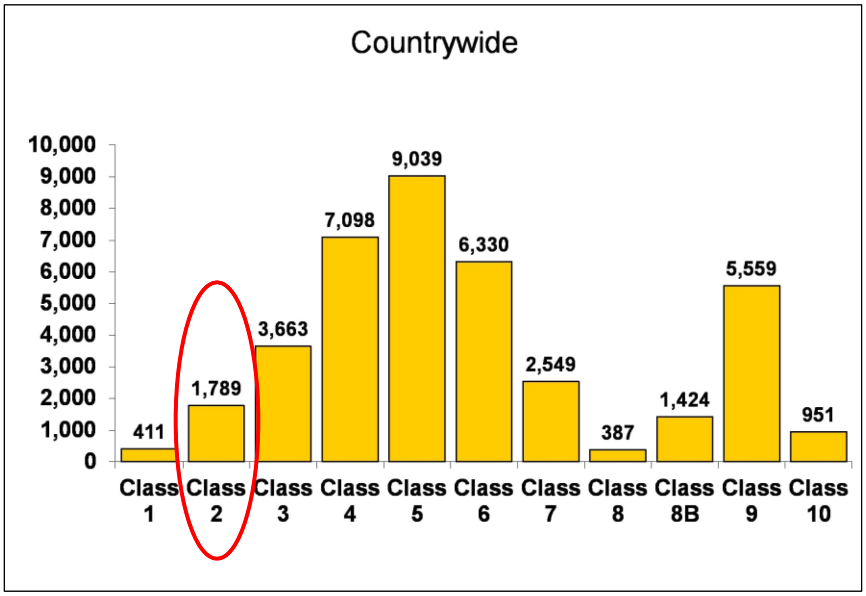
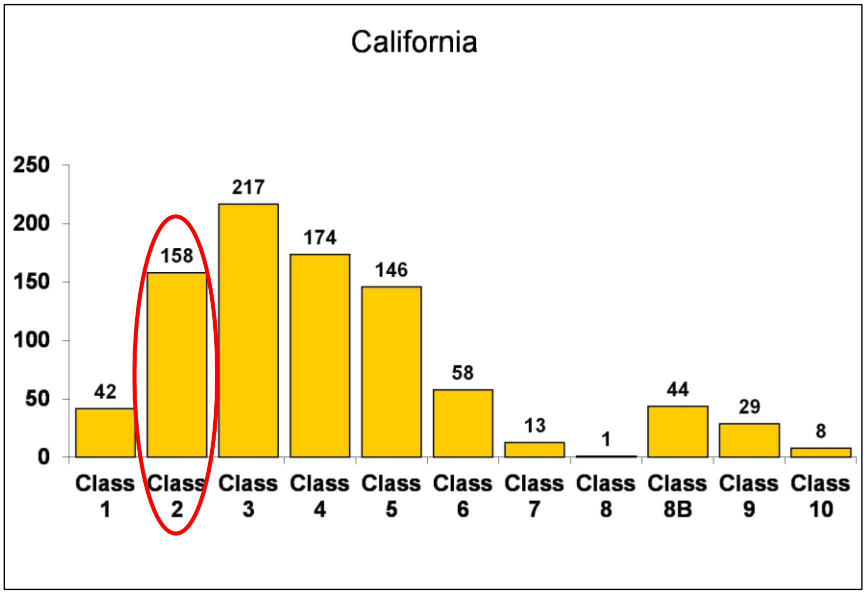


FIGURE 3-12: PPC Ratings in California[18]



Areas of scoring that should be reviewed further internally by the city and the NCFD, and which can have the most impact on individual areas evaluated and scored and that subsequently affect total section scoring include:

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[17] https://www.isomitigation.com/ppc/program-works/facts-and-figures-about-ppc-codes-around-the-country/

[18] Ibid.

- Training: #581(H) Pre-Fire Planning Inspections (0.35/12 credits)
    - For maximum credit, pre-fire planning inspections of each commercial, industrial, institutional, and other similar type building (all buildings except one- to four-family dwellings) should be made annually by company members. Pre-fire planning inspections are company level walk-throughs of commercial, industrial, institutional, hotels/motels, and larger footprint buildings to become familiar with floor plans, hose connections, means of egress, concentrations of population, hazardous materials storage, and the like. Typically fire departments have templates they fill in while conducting these pre-fire plan inspections that include pertinent owner/occupant information, sketched floor plans, hydrant locations, fire department connections, elevator locations, hazardous storage, or process locations in the building etc. Another purpose of a pre-fire plan is its use when an actual incident is occurring at the target hazard site or building. In this case the incident commander has at his/her disposal vital information that he/she can reference when making incident decisions. A record of inspections is important as well to gain appropriate credits.
- Water Supply: #630, #631 Credit for Inspection and Flow Testing (1.60/7.00 credits).
    - This item contemplates fire hydrant inspection and testing frequency in the city, and the completeness of the inspections, to include documentation. This score indicates the hydrants have not been inspected or flow tested on a regular basis.
- Communty Risk Reduction: #1025 Credit for Fire Prevention Code Adoption and Enforcement.
    - Evaluation of Fire Prevention Staffing (3.23/8.0 credits).
- Communty Risk Reduction: #1044 Credit for Fire Investigation Programs (7.40/20.0 credits).

Recommendation:

- CPSM recommends the NCFD review and address, to the extent possible, deficiencies in the current ISO Public Protection Classification report (Fire Department Section) as outlined in this analysis. This includes, and given the identified building risks in the city, ensuring company personnel conduct (and document for future ISO reviews) some level of commercial, industrial, institutional, and other similar type buildings (all buildings except one- to four-family dwellings) familiarization and pre-plan information gathering; work with Sweetwater Authority to ensure the fire hydrants are inspected and flow-tested on a more regular basis; address Community Risk Reduction staffing and make adjustments to staffing to ensure current (and future) inspectable properties (2,700 total current) are receiving annualized (where required) inspections, and those not requiring annualized inspections receive timely inspections in accordance with applicable laws and standards, and as established by the Fire Marshal. Addressing the Community Risk Reduction deficiency will require additional staffing, to the extent possible with available funding, which has an estimated cost of $87,500 to $117,000 per Community Risk Reduction inspector, dependent on placement in the pay range. (Recommendation No. 5.)

COMMUNITY LOSS AND SAVE INFORMATION

Fire loss is an estimation of the total loss from a fire to the structure and contents in terms of replacement. Fire loss includes contents damaged by fire, smoke, water, and overhaul. Fire loss does not include indirect loss, such as business interruption.

In a 2021 report published by the National Fire Protection Association on trends and patterns of U.S. fire losses, it was determined that home fires still cause the majority of all civilian fire deaths, civilian injuries, and property loss due to fire. Key findings from this report include:[19]

- Public fire departments responded to 1,338,500 fires in 2020, a 7.5-percent increase from the previous year.
- 490,500 fires occurred in structures (37 percent). Of these fires, 379,500 occurred is residential structures and 86,000 occurred in apartments or multifamily structures.
- 2,230 civilian fire deaths occurred in residential fires, and 350 deaths occurred in apartments or multifamily structures.
- Home fires were responsible for 11,500 civilian injuries.
- An estimated $21.9 billion in direct property damage occurred as a result of fire in 2020 (includes fires in the California Wildland Urban Interface and a large loss naval ship fire in California).

The next table describes National City fire loss in terms of dollars for the years indicated.

TABLE 3-6: Content and Property Loss, Structure and Outside Fires, 2016–2020

2016	2017	2018	2019	2020
$870,370	$963,900	$440,050	$1,406,300[20]	$522,760

AUTOMATIC-MUTUAL AID

The NCFD primarily receives and provides fire services automatic aid with:

- San Diego City Fire Department.
- Bonita-Sunnyside Fire Protection District.
- Chula Vista City Fire Department.

The primary purpose of automatic aid is the response of primary units to multi-company response incidents regardless of jurisdiction, where another jurisdiction may be closer by location, and to supplement an intial alarm assignment, particularly to multi-unit responses, to ensure an Effective Reponse Force is assmbled to mitigate the incident.

The next table illustrates the response metrics for certain fire structural fire responses in the metro San Diego region. The NCFD staffs two engines, one truck, and one quick response squad. By the metrics in the next table, it can be seen that the NCFD relies heavily on automatic aid from surrounding fire departments.

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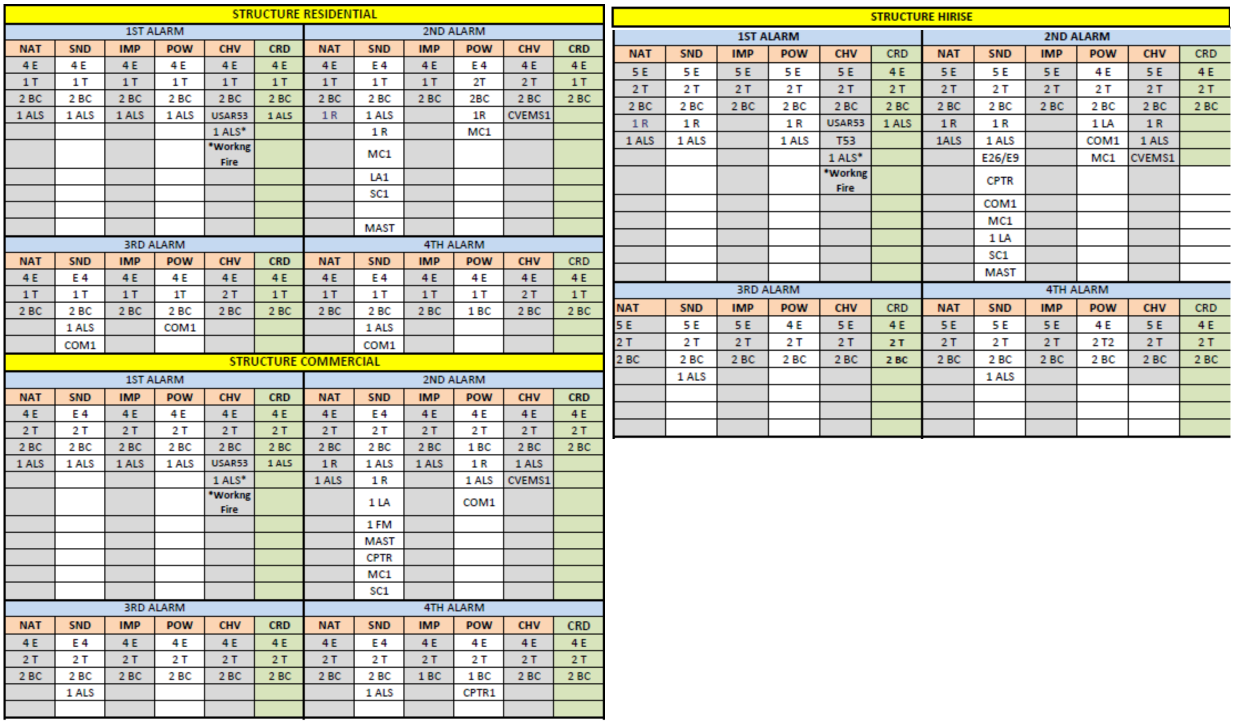
[19] Fire Loss in the United States During 2020, National Fire Protection Association.

[20] Includes fire loss of $1,077,500 in category 14b. Fires in Other Vehicles (planes, trains, ships, construction, or farm vehicles, etc.).

TABLE 3-7: San Diego Metro Zone Response Plan Matrix



STRUCTURE RESIDENTIAL

1ST ALARM						2ND ALARM					
NAT	SND	IMP	POW	CHV	CRD	NAT	SND	IMP	POW	CHV	CRD
4 E	4 E	4 E	4 E	4 E	4 E	4 E	E 4	4 E	E 4	4 E	4 E
1 T	1 T	1 T	1 T	1 T	1 T	1 T	1 T	1 T	2T	2 T	1 T
2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2BC	2 BC	2 BC
1 ALS	1 ALS	1 ALS	1 ALS	USAR53	1 ALS	1 R	1 ALS		1R	CVEMS1	
				1 ALS*			1 R		MC1		
				*Workng Fire			MC1				
							LA1				
							SC1				
							MAST				

3RD ALARM						4TH ALARM					
NAT	SND	IMP	POW	CHV	CRD	NAT	SND	IMP	POW	CHV	CRD
4 E	E 4	4 E	4 E	4 E	4 E	4 E	E 4	4 E	4 E	4 E	4 E
1 T	1 T	1 T	1T	2 T	1 T	1 T	1 T	1 T	1 T	2 T	1 T
2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	1 BC	2 BC	2 BC
	1 ALS		COM1				1 ALS				
	COM1						COM1				

STRUCTURE COMMERCIAL

1ST ALARM						2ND ALARM					
NAT	SND	IMP	POW	CHV	CRD	NAT	SND	IMP	POW	CHV	CRD
4 E	E 4	4 E	4 E	4 E	4 E	4 E	E 4	4 E	4 E	4 E	4 E
2 T	2 T	2 T	2 T	2 T	2 T	2 T	2 T	2 T	2 T	2 T	2 T
2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	1 BC	2 BC	2 BC
1 ALS	1 ALS	1 ALS	1 ALS	USAR53	1 ALS	1 R	1 ALS	1 ALS	1 R	1 ALS	
				1 ALS*		1 ALS	1 R		1 ALS	CVEMS1	
				*Workng Fire			1 LA		COM1		
							1 FM				
							MAST				
							CPTR				
							MC1				
							SC1				

3RD ALARM						4TH ALARM					
NAT	SND	IMP	POW	CHV	CRD	NAT	SND	IMP	POW	CHV	CRD
4 E	E 4	4 E	4 E	4 E	4 E	4 E	E 4	4 E	4 E	4 E	4 E
2 T	2 T	2 T	2 T	2 T	2 T	2 T	2 T	2 T	2 T	2 T	2 T
2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	1 BC	1 BC	2 BC	2 BC
	1 ALS						1 ALS		CPTR1		

STRUCTURE HIRISE

1ST ALARM						2ND ALARM					
NAT	SND	IMP	POW	CHV	CRD	NAT	SND	IMP	POW	CHV	CRD
5 E	5 E	5 E	5 E	5 E	4 E	5 E	5 E	5 E	4 E	5 E	4 E
2 T	2 T	2 T	2 T	2 T	2 T	2 T	2 T	2 T	2 T	2 T	2 T
2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC
1 R	1 R		1 R	USAR53	1 ALS	1 R	1 R		1 LA	1 R	
1 ALS	1 ALS		1 ALS	T53		1ALS	1 ALS		COM1	1 ALS	
				1 ALS*			E26/E9		MC1	CVEMS1	
				*Workng Fire			CPTR				
							COM1				
							MC1				
							1 LA				
							SC1				
							MAST				

3RD ALARM						4TH ALARM					
NAT	SND	IMP	POW	CHV	CRD	NAT	SND	IMP	POW	CHV	CRD
5 E	5 E	5 E	4 E	5 E	4 E	5 E	5 E	5 E	4 E	5 E	4 E
2 T	2 T	2 T	2 T	2 T	2 T	2 T	2 T	2 T	2 T2	2 T	2 T
2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC	2 BC
	1 ALS						1 ALS				

The next table depicts the aid NCFD received from neighboring departments where the unit actually arrived on scene in National City.

TABLE 3-8: Aid Received Actual Arrivals by Agency, First Due Area, 2019 and 2020

Agency	2019			2020		
	First Due Area		Total	First Due Area		Total
	31	34		31	34	
Bonita FD	75	0	**75**	61	1	**62**
Coronado FD	0	1	**1**	0	0	**0**
Chula Vista FD	95	131	**226**	121	159	**280**
Lemon Grove FD	0	0	**0**	0	1	**1**
San Diego FD	326	207	**533**	372	257	**629**
Total	**496**	**339**	**835**	**554**	**418**	**972**

The next three tables detail the responses that National City provided to areas outside of the municipal boundaries in 2019 and 2020.

TABLE 3-9: Aid Given Workload, Actual Arrival by NCFD, 2019 and 2020

District	2019			2020		
	Calls	Runs	Hours	Calls	Runs	Hours
San Diego City	1,323	1,495	494.5	1,328	1,525	541.6
Chula Vista	699	864	225.1	653	813	224.8
San Diego County	101	105	56.8	77	83	45.1
Imperial Beach	21	21	4.5	21	25	5.8
Coronado	7	9	4.4	10	13	5.6
Lemon Grove	3	3	0.5			
Fresno County *				1	3	752.9
Total	**2,154**	**2,497**	**785.7**	**2,090**	**2,462**	**1,575.7**

One area of particular interest is Lincoln Acres. While not officially part of National City, it is an unincorporated area of San Diego County that is entirely enclosed within National City's boundaries, and to which the NCFD provides initial response. Lincoln Acres has been included in all prior workload tables for NCFD. The next table calls out specifically the NCFD workload in Lincoln Acres.

TABLE 3-10: Calls and Workload in Lincoln Acres by Call Type, 2019 and 2020

Call Type	2019			2020		
	Calls	Hours	Runs	Calls	Hours	Runs
Breathing difficulty	16	20.7	34	16	23.7	35
Cardiac and stroke	19	30.7	46	21	27.7	48
Fall and injury	16	23.9	35	15	24.4	34
Illness and other	23	31.4	54	31	42.6	67
MVA	23	30.4	74	31	30.4	93
OD	2	2.0	4	6	6.6	13
Seizure and UNC	14	19.7	29	15	23.2	31
EMS Total	**113**	**158.8**	**276**	**135**	**178.6**	**321**
False alarm	5	1.8	9	5	7.0	15
Good intent	3	2.6	5	6	5.1	24
Hazard	1	0.1	1	4	2.3	10
Outside fire	5	5.6	20	7	12.5	20
Public service	5	1.6	6	3	0.9	3
Structure fire	4	42.0	36	0	0.0	0
Fire Total	**23**	**53.8**	**77**	**25**	**27.7**	**72**
Canceled	28	23.7	77	41	34.9	100
Total	**164**	**236.2**	**430**	**201**	**241.2**	**493**

Another area of particular interest is Paradise Hills, an urban neighborhood in the southeast portion of the City of San Diego, and to which the NCFD provides automatic aid on a regular basis. The next table shows the workload of the NCFD into Paradise Hills.

TABLE 3-11: Calls and Workload in Paradise Hills by Call Type. 2019 and 2020

Call Type	2019			2020		
	Calls	Hours	Runs	Calls	Hours	Runs
Breathing difficulty	95	31.3	95	110	45.1	111
Cardiac and stroke	116	46.2	116	107	48.2	108
Fall and injury	91	31.6	94	99	36.2	102
Illness and other	120	47.6	128	127	48.2	128
MVA	17	8.3	20	23	7.5	28
OD	7	2.2	7	14	5.9	14
Seizure and UNC	93	39.9	94	73	28.8	73
EMS Total	**539**	**207.3**	**554**	**553**	**219.9**	**564**
False alarm	19	7.1	19	21	5.9	26
Good intent	2	0.4	2	7	1.4	7
Hazard	3	1.7	6	4	19.3	9
Outside fire	6	3.2	6	6	2.6	9
Public service	9	2.6	9	7	2.8	7
Structure fire	12	7.5	18	13	6.8	20
Fire Total	**51**	**22.5**	**60**	**58**	**38.8**	**78**
Canceled	73	12.3	99	93	19.1	129
Total	**663**	**242.0**	**713**	**704**	**277.9**	**771**

Key takeaways from the auto/mutual aid response data tells us:

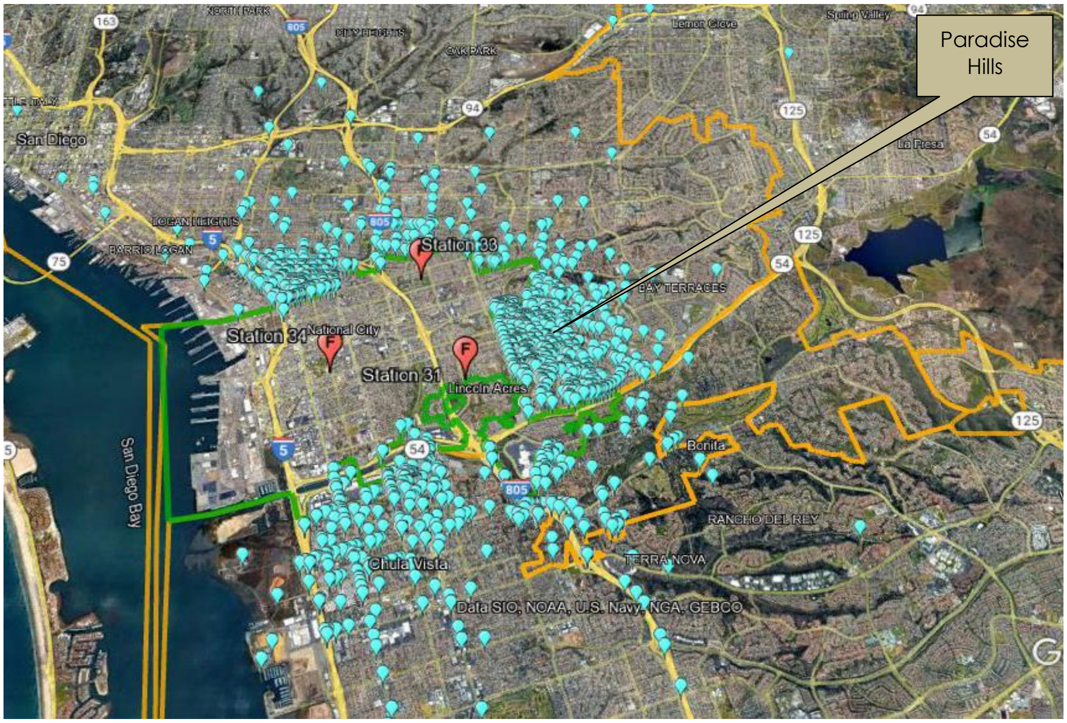
- The NCFD receives the largest number of auto/mutual aid responses from the City of San Diego, and provides the greatest amount of response aid to San Digo by a greater than a 2 to 1 ratio. ***The NCFD serves as the de facto fire department for Paradise Hills in San Diego.***
- The NCFD also provides response aid to Chula Vista at a greater than 2 to 1 ratio.

The importance of auto/mutual aid cannot be stressed enough, particularly for small fire departments that have the population density, building, and hazard risks such as that in National City, and which do not have the ability to assemble an Effective Response Force with on-duty equipment and staffing. However, where the NCFD is the de facto fire department for San Diego City for the Paradise Hills district, this goes beyond the concept of automatic/mutual aid.

The next figure shows the demand areas for auto/mutual aid provided by the NCFD as described in the tables above.

FIGURE 3-13: NCFD Structure and Outside Fire Auto/Mutual Aid Demand Map (Out of City)

FIGURE 3-14: NCFD EMS Auto/Mutual Aid Demand Map (Out of City)



RESILIENCY

Resiliency as defined by the Center for Public Safety Excellence (CPSE) in the Fire and Emergency Service Self-Assessment Manual (FESSAM), Ninth Edition, is: "An organization's ability to quickly recover from an incident or events, or to adjust easily to changing needs or requirements." Greater resiliency can be achieved by constant review and analysis of the response system and focuses on three key components:

- Resistance: The ability to deploy only resources necessary to control an incident and bring it to termination safely and effectively.
- Absorption: The ability of the agency to quickly add or duplicate resources necessary to maintain service levels during heavy call volume or incidents of high resource demand.
- Restoration: The agency's ability to quickly return to a state of normalcy.

Resistance is controlled by the NCFD through staffing and response protocol, and with NCFD resources dependent on the level of staffing and units available at the time of the alarm.

Absorption is accomplished through availability to respond by NCFD units and through regional auto aid resources. This is aided through the computer-aided dispatch at the regional fire dispatch center.

Restoration is managed by NCFD unit availability as simultaneous calls occur, the availability of regional auto aid resources, recall of staff to staff fire units during campaign events when warranted, and backfilling NCFD stations when needed through the computer-aided dispatch at the regional fire dispatch center.

The following tables and figure analyze NCFD resiliency. In this analysis, CPSM included all 9,298 calls that occurred <u>inside</u> and <u>outside</u> National City in the data analysis study period. We did this because NCFD is part of a regional auto/mutual aid system, so responses outside of the city impact resiliency of the department to respond to calls inside of the city.

TABLE 3-12: Call Workload by NCFD Units, 2019 and 2020

Station	**Unit**	**Unit Type**	**2019**		**2020**	
			Hours	**Runs**	**Hours**	**Runs**
31	NCE31	Engine	915.3	3,031 8.3/day	916.6	2,989 8.2/day
	NCE231	Engine	0.6	3		
	Total		**915.9**	**3,034**	**916.6**	**2,989**
33	NCSQ33	Squad	742.2	2,201 6.0/day	696.3	2,098 5.7/day
34	B57	Battalion	145.2	462	182.8	460
	NCE34	Engine	1,011.5	3,495 9.6/day	1,711.0	3,152 8.6/day
	NCE234	Engine	10.8	1	113.3	368
	NCT34	Truck	280.0	1,046 2.9/day	275.9	935 2.6/day
	Total		**1,447.5**	**5,004**	**2,282.9**	**4,915**
Total			**3,105.6**	**10,239**	**3,895.8**	**10,002**

FIGURE 3-15: Calls by Hour of Day

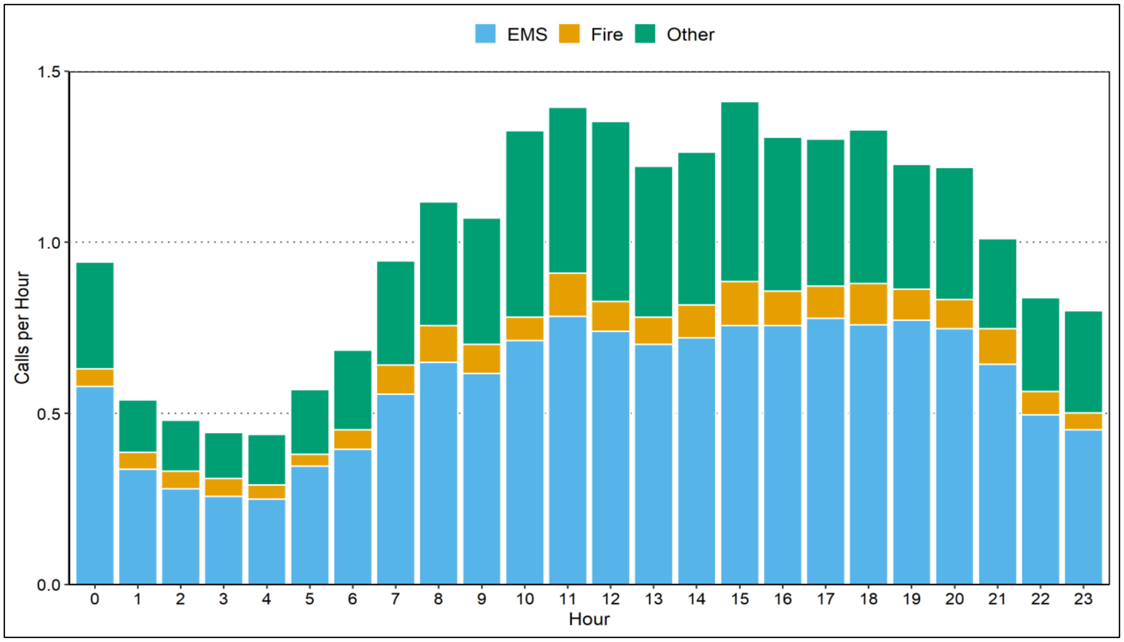


TABLE 3-13: Trend of Frequency of Overlapping Calls

Station	Scenario	Number of Calls	Percent of All Calls	Total Hours
31	No overlapped call	2,862	87.1	995.8
	Overlapped with one call	380	11.6	65.9
	Overlapped with two calls	41	1.2	4.8
	Overlapped with three calls	3	0.1	0.5
34	No overlapped call	3,289	85.3	1,048.1
	Overlapped with one call	505	13.1	87.6
	Overlapped with two calls	55	1.4	7.6
	Overlapped with three calls	7	0.2	0.6
	Overlapped with four calls	2	0.1	0.0
Outside	No overlapped call	1,968	91.4	631.1
	Overlapped with one call	173	8.0	34.3
	Overlapped with two calls	13	0.6	1.3

TABLE 3-14: Station Availability to Respond to Calls

Station	Calls in Area	First Due Responded	First Due Arrived	First Due First	Percent Responded	Percent Arrived	Percent First
31	3,063	1,430	1,347	1,270	46.7	44.0	41.5
34	3,508	2,700	2,639	2,588	77.0	75.2	73.8
Total	6,571	4,130	3,986	3,858	62.9	60.7	58.7

TABLE 3-15: Trend of Frequency Distribution of the Number of Calls

Calls in an Hour	Frequency	Percentage
0	3,297	37.6
1	2,938	33.5
2	1,641	18.7
3	582	6.6
4	217	2.5
5	62	0.7
6+	23	0.3
Total	**8,760**	**100.0**

Regarding the NCFD's resiliency to respond to calls, analysis of these tables and figure tells us:

- The peak call time is consistently between 10:00 a.m. and 8:00 p.m.
- E34 has the highest workload in terms of runs for 2019 and 2020 followed closely by E31.
- Overall, in 2019, all four first response units aggregately averaged 27 runs per day. In 2020, all four first response units averaged 25 runs per day.
- 13 percent of the time the E31 fire management zone has an overlapped call. The greatest percentage of the time the zone is overlapped with one call.
- 15 percent of the time the E34 fire management zone has an overlapped call. The greatest percentage of the time the zone is overlapped with one call.
  - 9 percent of the time when a NCFD unit is on an auto/mutual aid run, their district is overlapped with a call. The greatest percentage of the time the zone is overlapped with one call.
  - Aggregately, 28 percent of the time the E31 and E34 fire management zones have an overlapped call. The greatest percentage of the time the zones are overlapped with one call.
- 62 percent of the time one to six-plus calls occur in an hour. The greatest percent of the time (33.5 percent) one call occurs in an hour and the second gretaest percent of the time (18.7 percent) two calls occur in an hour.
- E31 as a single apparatus station and due to the demand in this fire management zone arrived on scene in its first due district only 41.5 percent of the time. The E34 fire management zone was markedly better (73.8 percent). This is because two units (E34, T34) are available to respond out of this station.

The NCFD does have resilliency issues as detailed above. Specifically the workload of the engine companies, aggregate percent of the time each fire management zone has an overlapped call, ability to arrive first in their specific fire management zone due to being out of position due to a previous call or on another call, and that over 50 percent of the day one or two calls occur in an hour that are either single appratus or multiple appratus responses.

One resiliency element the NCFD has built in is the implementation of Squad 33. This unit primarily responds to EMS and lower acuity fire calls for service, which account for a sizable percentage of calls to which the NCFD responds in the city. In 2019, Squad 33 responded to 2,201 runs (21 percent of the NCFD total) and in 2020 this unit responded to 2,098 runs (21 percent of the NCFD total). The greatest percentage of runs Squad 33 made were EMS in each year. Squad 33 did respond to fire incidents as well, when available, as added staffing to assist in the assembling of an Effective Response Force.

Deploying a unit such as this for specific calls and to augment the assembling of an Effective Response Force for building fires when the unit is available, ***is a best practice*.**

When implementing this type of unit, which is designed to reduce workload on engine and ladder companies, it is important to measure its efficiency as a single responding company. CPSM analyzed this in the following table. The NCFD Squad program is extremely efficient! In 2019 the Squad arrived with an Engine (dual response) only 8 percent of the time. In 2020 the dual response/arrival occurred on 10 percent of the calls the Squad responded to.

The next table describes the workload for Squad 33 in 2019 and 2020.

TABLE 3-16: Squad 33 Workload in 2019 and 2020

Run Type	2019			2020		
	Dispatched	Arrived	Arrived with Engine	Dispatched	Arrived	Arrived with Engine
Breathing difficulty	273	269	0	278	273	3
Cardiac and stroke	285	279	31	293	283	41
Fall and injury	412	406	2	380	367	6
Illness and other	433	420	10	386	362	8
MVA	86	73	25	66	59	26
OD	47	41	0	55	52	1
Seizure and UNC	237	232	5	215	213	9
EMS Total	**1,773**	**1,720**	**73**	**1,673**	**1,609**	**94**
False alarm	76	66	29	65	56	27
Good intent	12	10	2	20	16	9
Hazard	13	10	5	10	8	4
Outside fire	29	27	18	28	21	11
Public service	37	34	3	33	27	10
Structure fire	23	22	20	23	20	20
Fire Total	**190**	**169**	**77**	**179**	**148**	**81**
Canceled	229	111	9	237	90	12
Aid given	9	5	1	9	2	0
Total	**2,201**	**2,005**	**160**	**2,098**	**1,849**	**187**

Recommendation:

- CPSM recommends the NCFD continue with the Squad program as designed, due to the efficiencies and effectiveness this unit has produced for the city. CPSM further recommends the NCFD monitor dual responses (Squad/Engine) and make any necessary adjustments to maintain a 10 percent ratio. (Recommendation No. 6.)

RISK CATEGORIZATION

A comprehensive risk assessment is a critical aspect of creating standards of cover and can assist the NCFD in quantifying the risks that it faces. Once those risks are known, the department is better equipped to determine if the current response resources are sufficiently staffed, equipped, trained, and positioned.

In this component, the factors that drive the service needs are examined and then link directly to discussions regarding the assembling of an effective response force (ERF) and when contemplating the response capabilities needed to adequately address the existing risks, which encompasses the component of critical tasking.

The risks that the department faces can be natural or manufactured and may be affected by the changing demographics of the community served. With the information available from the CPSM data analysis, the NCFD, the city, and public research, CPSM and the NCFD can begin an analysis of the city's risks and can begin working towards recommendations and strategies to mitigate and minimize their effects. This section contains an analysis of the various risks considered within the NCFD's service area.

Risk is often categorized in three ways: consequence of the event on the community, the probability the event will occur in the community, and the impact on the fire department. The following three tables look at the probability of the event occurring (Table 3-16) which ranges from unlikely to frequent; consequence to the community (Table 3-17), which is categorized as ranging from insignificant to catastrophic; and the impact to the organization (Table 3-18), which ranges from insignificant to catastrophic.

TABLE 3-17: Event Probability

Probability	Chance of Occurrence	Description	Risk Score
Unlikely	2%-25%	Event may occur only in exceptional circumstances.	**2**
Possible	26%-50%	Event could occur at some time and/or no recorded incidents. Little opportunity, reason, or means to occur.	**4**
Probable	51%-75%	Event should occur at some time and/or few, infrequent, random recorded incidents, or little anecdotal evidence. Some opportunity, reason, or means to occur; may occur.	**6**
Highly Probable	76%-90%	Event will probably occur and/or regular recorded incidents and strong anecdotal evidence. Considerable opportunity, means, reason to occur.	**8**
Frequent	90%-100%	Event is expected to occur. High level of recorded incidents and/or very strong anecdotal evidence.	**10**

TABLE 3-18: Consequence to Community Matrix

Impact	Consequence Categories	Description	Risk Score
Insignificant	Life Safety	▪ 1 or 2 people affected, minor injuries, minor property damage, and no environmental impact.	**2**
Minor	Life Safety Economic and Infrastructure Environmental	▪ Small number of people affected, no fatalities, and small number of minor injuries with first aid treatment. Minor displacement of people for <6 hours and minor personal support required. ▪ Minor localized disruption to community services or infrastructure for <6 hours. Minor impact on environment with no lasting effects.	**4**
Moderate	Life Safety Economic and Infrastructure Environmental	▪ Limited number of people affected (11 to 25), no fatalities, but some hospitalization and medical treatment required. Localized displacement of small number of people for 6 to 24 hours. Personal support satisfied through local arrangements. Localized damage is rectified by routine arrangements. ▪ Normal community functioning with some inconvenience. Some impact on environment with short-term effects or small impact on environment with long-term effects.	**6**
Significant	Life Safety Economic and Infrastructure Environmental	▪ Significant number of people (>25) in affected area impacted with multiple fatalities, multiple serious or extensive injuries, and significant hospitalization. ▪ Large number of people displaced for 6 to 24 hours or possibly beyond. External resources required for personal support. Significant damage that requires external resources. Community only partially functioning, some services unavailable. Significant impact on environment with medium- to long-term effects.	**8**
Catastrophic	Life Safety Economic and Infrastructure Environmental	▪ Very large number of people in affected area(s) impacted with significant numbers of fatalities, large number of people requiring hospitalization; serious injuries with long-term effects. General and wide-spread displacement for prolonged duration; extensive personal support required. Extensive damage to properties in affected area requiring major demolition. ▪ Serious damage to infrastructure. Significant disruption to, or loss of, key services for prolonged period. ▪ Community unable to function without significant support. ▪ Significant long-term impact on environment and/or permanent damage.	**10**

TABLE 3-19: Impact on NCFD

Impact	**Impact Categories**	**Description**	**Risk Score**
Insignificant	Personnel and Resources	One apparatus out of service for period not to exceed one hour.	**2**
Minor	Personnel and Resources	More than one but not more than two apparatus out of service for a period not to exceed one hour.	**4**
Moderate	Personnel and Resources	More than 50 percent of available resources committed to incident for over 30 minutes.	**6**
Significant	Personnel and Resources	More than 75 percent of available resources committed to an incident for over 30 minutes.	**8**
Catastrophic	Personnel, Resources, and Facilities	More than 90 percent of available resources committed to incident for more than two hours or event which limits the ability of resources to respond.	**10**

This section also contains an analysis of the various risks considered in the city. In this analysis, information presented and reviewed in this section (All-Hazards Risk Assessment of the Community) have been considered. Risk is categorized as Low, Moderate, High, or Special.

Prior risk analysis has only attempted to evaluate two factors of risk: probability and consequence. Contemporary risk analysis considers the impact of each risk to the organization, thus creating a three-axis approach to evaluating risk as depicted in the following figure. A contemporary risk analysis now includes probability, consequences to the community, and impact on the organization, in this case the NCFD.

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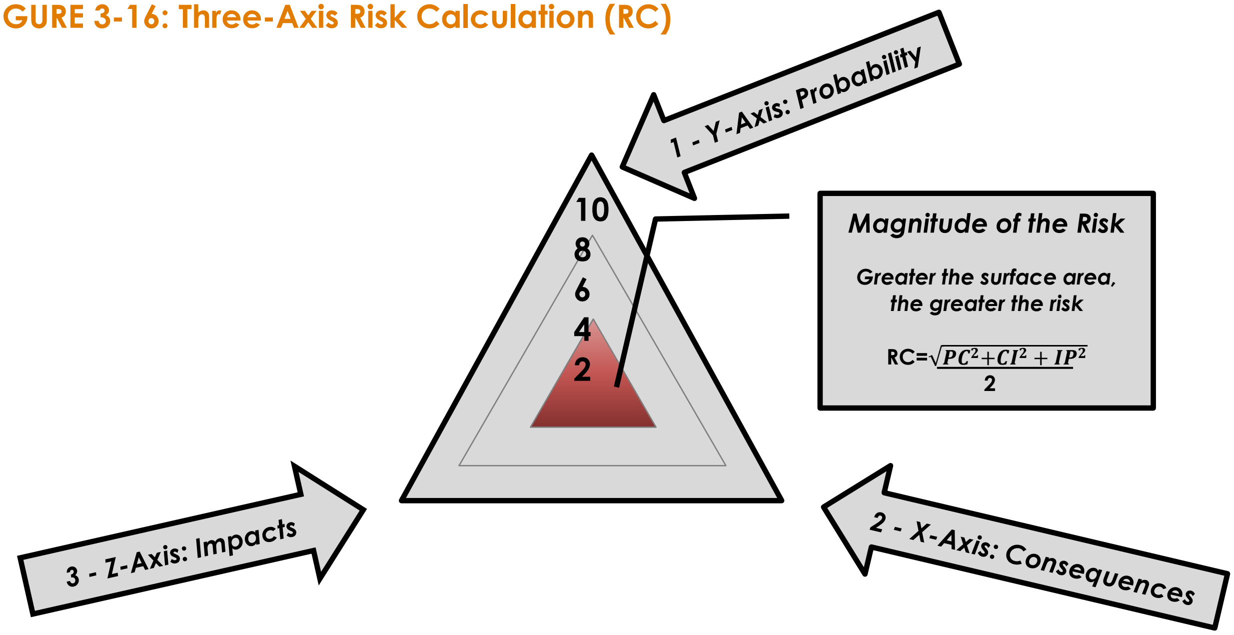
FIGURE 3-16: Three-Axis Risk Calculation (RC)



The following factors/hazards were identified and considered:

- **Demographic factors** such as age, socio-economic, vulnerability.
- **Natural hazards** such as flooding, wind events, wildland fires.
- **Manufactured hazards** such as rail lines, roads and intersections, target hazards.
- **Structural/building risks**.
- **Fire and EMS incident numbers and density**.

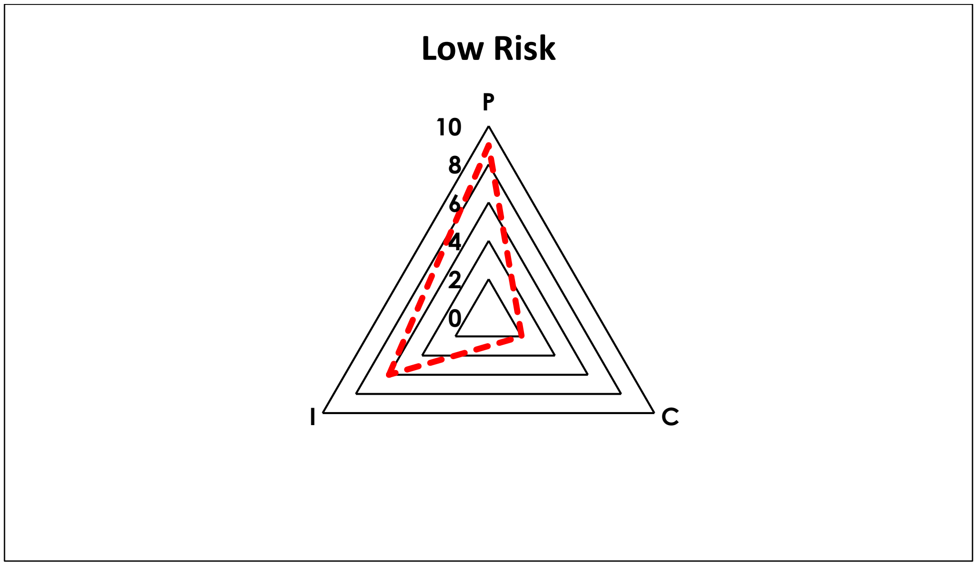
The assessment of each factor and hazard as listed below took into consideration the likelihood of the event, the impact on the city itself, and the impact on NCFD's ability to deliver emergency services, which includes NCFD resiliency and automatic aid capabilities as well. The list is not all inclusive but includes categories most common or that may present to the city and the NCFD.

§ § §

Low Risk

- Automatic fire/false alarms.
- Low acuity-BLS EMS Incidents.
- Low-risk environmental event.
- Motor vehicle accident (MVA).
- Good intent/hazard/public service fire incidents with no life-safety exposure.
- Outside fires such as grass, rubbish, dumpster, vehicle with no structural/life-safety exposure.

FIGURE 3-17: Low Risk



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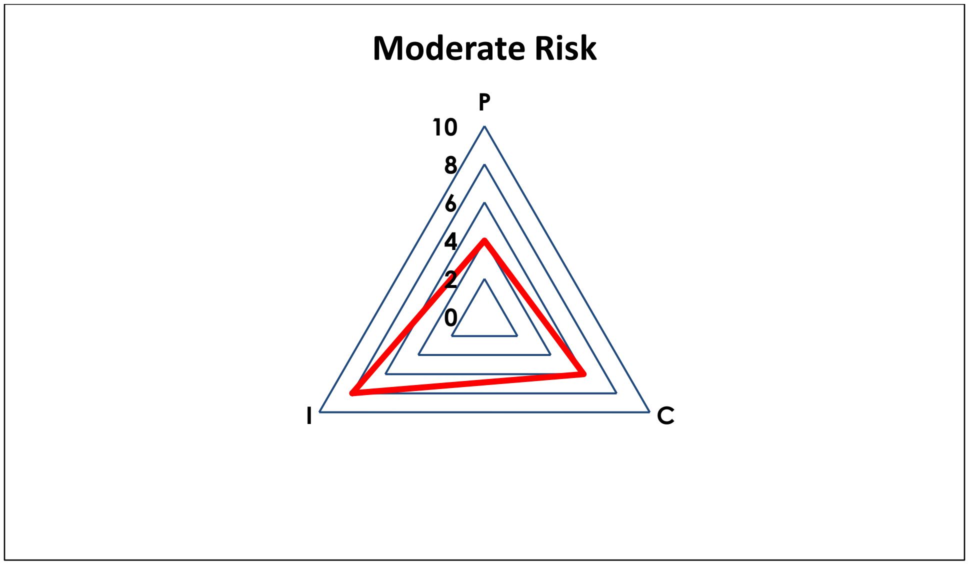
Moderate Risk

- Fire incident in a single-family dwelling where fire and smoke or smoke is visible, indicating a working fire.
- Suspicious substance investigation involving multiple fire companies and law enforcement agencies.
- ALS EMS incident.
- MVA with entrapment of passengers.
- Grass/brush fire with structural endangerment/exposure.
- Low-angle rescue involving ropes and rope rescue equipment and resources.
- Surface water rescue.
- Good intent/hazard/public service fire incidents with life-safety exposure.
- Rail event with no release of product or fire, and no threat to life safety.

FIGURE 3-18: Moderate Risk



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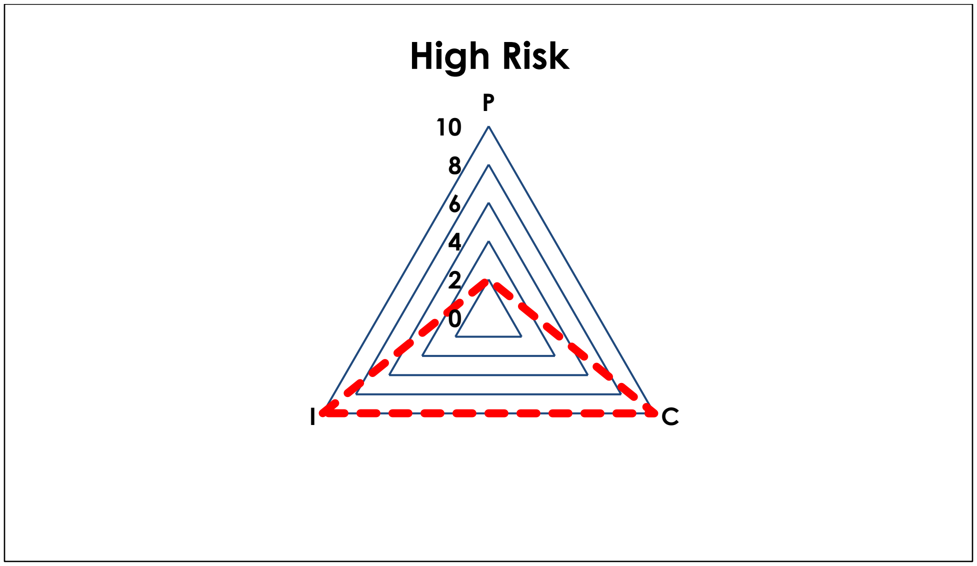
High Risk

- Working fire in a target hazard.
- Cardiac arrest.
- Mass casualty incident of more than 10 patients but fewer than 25 patients.
- Confined space rescue.
- Structural collapse involving life-safety exposure.
- High-angle rescue involving ropes and rope rescue equipment.
- Trench rescue.
- Suspicious substance incident with multiple injuries.
- Industrial leak of hazardous materials that causes exposure to persons or threatens life safety.
- Weather event that creates widespread flooding, heavy winds, building damage, and/or life-safety exposure.

FIGURE 3-19: High Risk



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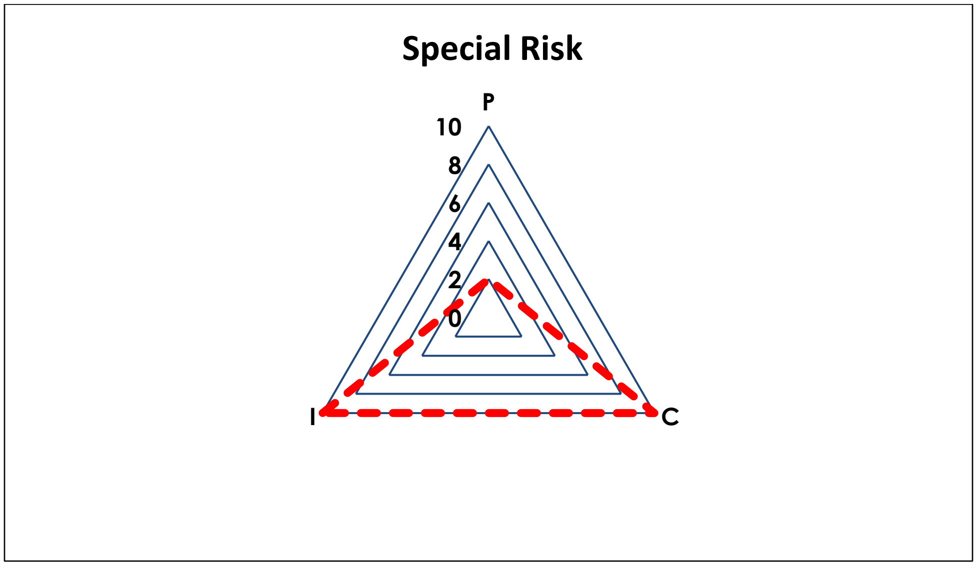
Special Risk

- Working fire in a structure of more than three floors.
- Fire at an industrial building or complex with hazardous materials.
- Fire in an occupied targeted hazard with special life-safety risks such as age, medical condition, or other identified vulnerabilities.
- Mass casualty incident of more than 25 patients.
- Rail or transportation incident that causes life-safety exposure or threatens life safety through the release of hazardous smoke or materials and evacuation of residential and business occupancies.
- Explosion in a building that causes exposure to persons or threatens life safety or outside of a building that creates exposure to occupied buildings or threatens life safety.
- Massive river/estuary flooding, fire in a correctional or medical institution, high-impact environmental event, pandemic.
- Mass gathering with threat fire and threat to life safety or other civil unrest, weapons of mass destruction release.

FIGURE 3-20: Special Risk



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SECTION 4. STAFFING, DEPLOYMENT, AND PERFORMANCE

When exploring staffing and deployment of fire departments it makes the most sense to design an operational strategy around the actual circumstances that exist in the community and the fire and risk problems that are identified. The strategic and tactical challenges presented by the widely varied hazards that a fire department protects against are identified and planned for through a community risk analysis as described in this report. It is ultimately the responsibility of elected officials working closely with a local government's senior management and Fire Chief to staff and deploy a fire department to the extent possible with available financing to manage the community risk through well-defined operational service goals.

The staffing of fire and EMS companies is a never-ending focus of attention among fire service and governmental leadership. While NFPA 1710 and OSHA provide guidelines (and to some extent the law, specifically OSHA in OSHA states) as to the level of staffing and response of personnel, the adoption of these documents varies from state to state and department to department. NFPA 1710 addresses the recommended staffing in terms of specific types of occupancies and building risks. The needed staffing to conduct the critical tasks for each specific occupancy and risk are defined as an *Effective Response Force* (ERF). The ERF for each of these occupancies is detailed in NFPA 1710 (2020 edition), section 5.2.4, Deployment, and further discussed in this section.

CPSM has researched and compiled eleven staffing and deployment topics we consider to be among the leading industry standards the fire service follows and utilizes when making decisions about staffing and deployment of fire resources. These are:

All-Hazard Risk Assessment of the Community: A fire department collects and organizes risk evaluation information about community risk (population and demographics; environmental; transportation; fire and EMS call demand and call types) and individual property types. The all-hazard community risk and community assessment is used to evaluate the community. With regard to individual property types, the assessment is used to measure all property and the risk associated with that property and then segregate the property as either a high-, medium-, or low-hazard risk depending on factors such as the life and building content hazard, the potential fire flow, and the staffing and apparatus types required to mitigate an emergency in the specific property. Factors such as fire protection systems are considered in each building evaluation. Included in this assessment should be both a structural and nonstructural (weather, wildland-urban interface, transportation routes, rail, mass-transit, etc.) analysis. All factors are then analyzed and the probability of an event occurring, the impact on the fire department, and the consequences on the community are measured and scored.

Population, Demographics, and Socio-economic Factors of a Community: Population and population density is a primary driver of calls for local government service, particularly public safety. The risk from fire is not the same for everyone, with studies telling us age, gender, race, socio-economic factors, and what region in the country one might live in contribute to the risk of death from fire. Studies also tell us these same factors affect demand for EMS, such as the increased use of hospital emergency departments by uninsured or underinsured patients, who rely on emergency services for their primary and emergency care and utilize pre-hospital EMS transport systems as their entry point.

Call Demand: Demand is made up of the types of calls to which fire and EMS units are responding and the location of the calls. This drives workload and station staffing and apparatus considerations. Higher population centers with increased demand and building risk require greater resources.

Workload of Units: This factor involves the types of calls to which units are responding and the workload of each unit in the deployment model. This defines what resources are needed and where; it links to demand and station location, or in a dynamic deployed system, the area(s) in which to post units, and the resiliency of the fire department to respond to multiple calls for service at once or calls for service that require multiple units to respond due to the higher risk.

Travel Times from Fire Stations: Analyzes the ability to cover the fire management zone/response district in a reasonable and acceptable travel time when measured against national benchmarks such as NFPA 1710, 1720, and the ISO-FSRS engine and ladder company grading parameters. This metric links to demand, risk assessment, unit workload, and resiliency.

NFPA Standards, ISO, OSHA, State OSHA requirements (and other national benchmarking).

EMS Demand: Community demand; demand on available units and crews; hospital off-load wait times; demand on non-EMS transport units responding to calls for service (fire/police units); availability of crews in departments that utilize cross-trained EMS staff to perform fire suppression.

Critical Tasking: On-scene capabilities to control and mitigate emergencies is determined by staffing and deployment of certain resources for low-, medium-, and high-risk responses. Critical tasking is the individual or team level task that is required to be performed by on-scene personnel based on the type of incident the firefighting and EMS force is responding to. Critical tasks are to the greatest extent performed simultaneously for a more effective operation aimed at increased firefighter and the public's safety. Those risks/incidents that require more critical tasks to be performed simultaneously drive a larger response force. An example of simultaneous critical tasking is a search and rescue crew and a ventilation crew operating while a crew or crews are advancing attack lines.

Effective Response Force: The ability of the jurisdiction to assemble the necessary personnel on the scene to perform the critical tasks necessary in rapid sequence to mitigate the emergency. The speed, efficiency, and safety of on-scene operations are dependent upon the number of firefighters performing the tasks. If fewer firefighters are available to complete critical on-scene tasks, those tasks will require more time to complete and impact overall operations and the safety of firefighters and the public, and in some cases intensify the spread of fire or the inability to mitigate the non-fire emergency.

Innovations in Staffing and Deployable Apparatus: This is the fire department's ability and willingness to develop and deploy innovative apparatus (combining two apparatus functions into one to maximize available staffing, as an example). Deploying quick response vehicles (light vehicles equipped with medical equipment and some light fire suppression capabilities) on those lower acuity calls (typically the largest percentage of calls) that do not require heavy fire apparatus.

Community Expectations: The gathering of input and feedback from the community, then measuring, understanding, and developing goals and objectives to meet community expectations.

Ability to Fund: The community's understanding of, and its ability and willingness to fund fire and EMS services, while considering how budgetary revenues are divided up to meet all community's expectations.

NFPA 1710 AND TWO-IN/TWO-OUT

National Fire Protection Association (NFPA) standards are consensus standards; they are not mandates nor are they the law. Many cites and countries strive to achieve these standards to the extent possible without causing an adverse fiscal impact to the community and use these standards as benchmarks and service delivery goals.

NFPA 1710 outlines organization and deployment of operations by career, and primarily career fire and rescue organizations.[21] It serves as a benchmark to measure staffing and deployment of resources to certain structures and emergencies.

According to NFPA 1710, fire departments should base their capabilities on a formal all-hazards community risk assessment, as discussed earlier in this report, and taking into consideration:[22]

- Life hazard to the population protected.
- Provisions for safe and effective firefighting performance conditions for the firefighters.
- Potential property loss.
- Nature, configuration, hazards, and internal protection of the properties involved.
- Types of fireground tactics and evolutions employed as standard procedure, type of apparatus used, and results expected to be obtained at the fire scene.

According to NFPA 1710, if a community follows this standard, engine and ladder companies shall be staffed with a minimum of four on-duty members.[23] Additional staffing parameters in this standard for engine and ladder companies is based on geographical isolation and tactical hazards, and increases each to five or six as a minimum.[24] This staffing configuration is designed to ensure a fire department can efficiently assemble an effective response force for each risk the department may encounter and complete the critical tasking necessary on building fires and other emergency incidents simultaneously to the extent possible. ***NFPA 1710 permits fire departments to use established automatic aid and mutual aid agreements to comply with the assembling of on-scene personnel to complete critical tasks as outlined in the standard.***

Another consideration, and one that links to critical tasking and assembling an effective response force, is that of two-in/two-out regulations. Essentially, prior to starting any fire attack in an immediately dangerous to life and health (IDLH) environment [with no confirmed rescue in progress], the initial two-person entry team shall ensure that there are sufficient resources on-scene to establish a two-person initial rapid intervention team (IRIT) located outside of the building.

This critical tasking model has its genesis with the Occupational Safety and Health Administration, specifically 29 CFR 1910.134(g)(4). The California State Plan also applies to state and local government employers. Federal OSHA covers the issues not covered by the California State Plan.[25] The federal rule (29 CFR 1910.134(g)(4)) applies to the NCFD.

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[21] NFPA 1710 is a nationally recognized standard, but it has not been adopted as a mandatory regulation by the federal government or the State of California. It is a valuable resource for establishing and measuring performance objectives for the City of National City but should not be the only determining factor when making local decisions about the city's fire services.

[22] NFPA 1710, 5.2.1.1, 5.2.2.2

[23] NFPA 1710, 5.2.3.1.1; 5.2.3.2.1

[24] NFPA 1710, 5.2.3.1.2, 5.2.3.1.2.1.,5.2.3.2.2.,5.3.2.3.2.2.1

[25] California State Plan | Occupational Safety and Health Administration (osha.gov)

CFR 1910.134: Procedures for interior structural firefighting. The employer shall ensure that:

(i) At least two employees enter the IDLH atmosphere and remain in visual or voice contact with one another at all times;

(ii) At least two employees are located outside the IDLH atmosphere; and

(iii) All employees engaged in interior structural firefighting use SCBAs.[26]

According to the standard, one of the two individuals located outside the IDLH atmosphere may be assigned to an additional role, such as incident commander in charge of the emergency or safety officer, so long as this individual is able to perform assistance or rescue activities without jeopardizing the safety or health of any firefighter working at the incident.

NFPA 1500, *Standard on Fire Department Occupational Health, Safety, and Wellness*, 2021 Edition, has similar language as CFR 1910.134(g)(4) to address the issue of two-in/two-out, stating *the initial stages of the incident where only one crew is operating in the hazardous area of a working structural fire, a minimum of four individuals shall be required consisting of two members working as a crew in the hazardous area and two standby members present outside this hazard area available for assistance or rescue at emergency operations where entry into the danger area is required.*[27]

NFPA 1500 also speaks to the utilization of the two-out personnel in the context of the health and safety of the firefighters working at the incident. *The assignment of any personnel including the incident commander, the safety officer, or operations of fire apparatus, shall not be permitted as standby personnel if by abandoning their critical task(s) to assist, or if necessary, perform rescue, this clearly jeopardizes the safety and health of any firefighter working at the incident.*[28]

In order to meet CFR 1910.134(g)(4), and NFPA 1500, the NCFD must utilize two personnel to commit to interior fire attack while two firefighters remain out of the hazardous area or immediately dangerous to life and health (IDLH) area to form the Initial Rapid Intervention Team (IRIT), while attack lines are charged, and a continuous water supply is established.

However, NFPA 1500 allows for fewer than four personnel under specific circumstances. It states: *Initial attack operations shall be organized to ensure that if on arrival at the emergency scene, initial attack personnel find an imminent life-threatening situation where immediate action could prevent the loss of life or serious injury, such action shall be permitted with fewer than four personnel*.[29]

CFR 1910.134(g)(4) also states that nothing in section (g) is meant to preclude firefighters from performing emergency rescue activities before an entire team has assembled.[30]

It is also important to note that the OSHA standard (and NFPA 1710) specifically references "interior firefighting." Firefighting activities that are performed from the exterior of the building are not regulated by this portion of the OSHA standard. However, in the end, the ability to assemble adequate personnel, along with appropriate apparatus, on the scene of a structure fire, is critical to operational success and firefighter safety.

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26. CFR 1910.134 (g) 4
27. NFPA 1500, 2021, 8.8.2.
28. NFPA 1500, 2021, 8.8.2.5.
29. NFPA 1500, 2021 8.8.2.10.
30. CFR 190.134, (g).

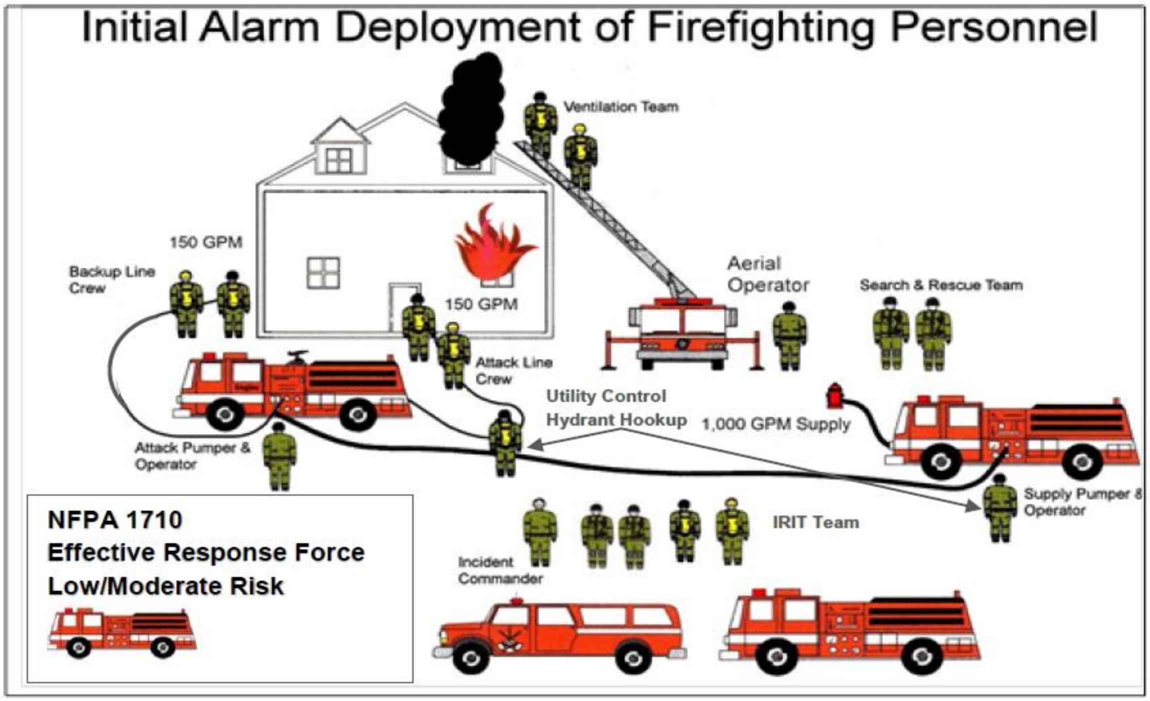
EFFECTIVE RESPONSE FORCE AND CRITICAL TASKING

Critical tasks are those activities that must be conducted on time and preferably simultaneously by responders at emergency incidents to control the situation and minimize/stop loss (property and life-safety). Critical tasking for fire operations is the minimum number of personnel needed to perform the tasks needed to effectively control and mitigate a fire or other emergency. To be effective, critical tasking must assign enough personnel so that all identified functions can be performed simultaneously. However, it is important to note that initial response personnel may manage secondary support functions once they have completed their primary assignment. Thus, while an incident may end up requiring a greater commitment of resources or a specialized response, a properly executed critical tasking assignment will provide adequate resources to immediately begin bringing the incident under control.

The specific number of people required to perform all the critical tasks associated with an identified risk or incident type is referred to as an Effective Response Force (ERF). The goal is to deliver an ERF within a prescribed period. NFPA 1710 provides the benchmarks for effective response forces.

The next figure illustrates an ERF for a single family dwelling as outlined in NFPA 1710 (which is 16 personnel, 17 if the aerial device is in operation).

FIGURE 4-1: Effective Response Force for Single-Family Dwelling Fire



NCFD Staffing Model

The NCFD has three operational shifts, A, B, and C. Each of the shifts is staffed with five firefighters, three engineers, four captains (company officer), and one Battalion Chief (shift commander), for an on-duty operational response force of 13 personnel.

The following table details the positions for each shift.

TABLE 4-1: NCFD Shift Matrix

A Shift (24-Hour Shift)	B Shift (24-Hour Shift)	C Shift (24-Hour Shift)
E31 ■ 1 Captain ■ 1 Engineer ■ 1 Firefighter	**E31** ■ 1 Captain ■ 1 Engineer ■ 1 Firefighter	**E31** ■ 1 Captain ■ 1 Engineer ■ 1 Firefighter
E34 ■ 1 Captain ■ 1 Engineer ■ 1 Firefighter	**E34** ■ 1 Captain ■ 1 Engineer ■ 1 Firefighter	**E34** ■ 1 Captain ■ 1 Engineer ■ 1 Firefighter
L34 ■ 1 Captain ■ 1 Engineer ■ 2 Firefighters	**L34** ■ 1 Captain ■ 1 Engineer ■ 2 Firefighters	**L34** ■ 1 Captain ■ 1 Engineer ■ 2 Firefighters
Squad 33 ■ 1 Captain ■ 1 Firefighter	**Squad 33** ■ 1 Captain ■ 1 Firefighter	**Squad 33** ■ 1 Captain ■ 1 Firefighter
■ **BC:** 1 Battalion Chief	■ **BC:** 1 Battalion Chief	■ **BC:** 1 Battalion Chief

The following discussion and tables will outline how critical tasking and assembling an effective response force is first measured in NFPA 1710, and how the NCFD is benchmarked against this standard for the building types existing in National City. This discussion will cover single-family dwelling buildings, open-air strip mall buildings, and apartment buildings as outlined in the NFPA standard. As discussed above, for certain responses the NCFD relies on automatic aid to assemble an Effective Response Force. NCFD tables are built using the first alarm assignment in accordance with the San Diego Metro Zone Response Plan Matrix.

Single-Family Dwelling: NFPA 1710, 5.2.4.1

The initial full alarm assignment (ERF) to a structural fire in a typical 2,000 square-foot, two-story, single-family dwelling without a basement and with no exposures must provide for a minimum of 16 members (17 if an aerial device is used). The following table outlines the critical task matrix.

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TABLE 4-2: Effective Response Force for Single-Family Dwelling Fire

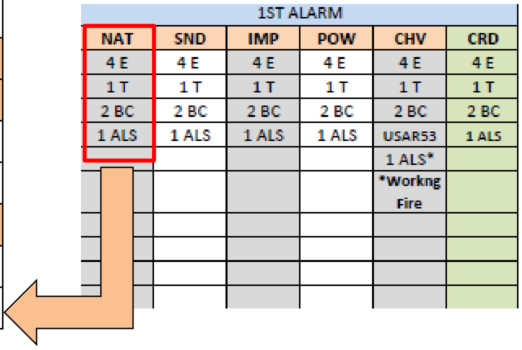
Critical Tasks	Personnel
Incident Command	1
Continuous Water Supply	1
Fire Attack via Two Handlines	4
Hydrant Hook Up – Forcible Entry – Utilities	2
Primary Search and Rescue	2
Ground Ladders and Ventilation	2
Aerial Operator if Aerial is Used	1
Establishment of IRIC (Initial Rapid Intervention Crew)	4
Total Effective Response Force	16 (17 If aerial is used)

The following table outlines how the NCFD assembles staffing and deployable resources as measured against NFPA 1710 benchmarking for an effective response force for a single-family dwelling fire. NCFD units are highlighted.

TABLE 4-3: NCFD Effective Response Force for Single-Family Dwelling Fire

Apparatus	Personnel
NCFD Battalion Chief	1
Auto Aid Battalion Chief	1
NCFD Engine	3
NCFD Engine	3
Auto Aid Engine	4
Auto Aid Engine	4
NCFD Ladder	4
1-ALS unit	2
Total NCFD ERF	**22**

San Diego Metro Zone Response Plan Matrix
Residential Structure Fire



1ST ALARM					
NAT	SND	IMP	POW	CHV	CRD
4 E	4 E	4 E	4 E	4 E	4 E
1 T	1 T	1 T	1 T	1 T	1 T
2 BC	2 BC	2 BC	2 BC	2 BC	2 BC
1 ALS	1 ALS	1 ALS	1 ALS	USAR53	1 ALS
				1 ALS*	
				*Workng Fire	

As a single responding agency, NCFD does not meet the minimum benchmarks of NFPA 1710 for an Effective Response Force for single-family dwelling fires. With regional automatic aid, the NCFD does meet this benchmark. ***NFPA 1710 permits fire departments to use established automatic aid and mutual aid agreements to comply with section 5.2 of this standard.***[31]

Open-Air Strip Mall/Commercial, NFPA 5.2.4.2

The initial full alarm assignment (ERF) to a structural fire in a typical open-air strip center/commercial structure ranging from 13,000 square feet to 196,000 square feet in size must provide for a minimum of 27 members (28 if an aerial device is used). The following table outlines the critical tasking matrix for this type of fire. This can also be typed as a commercial building fire response.

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[31] NFPA 1710. 5.2.1.3

TABLE 4-4: Effective Response Force for Open-Air Strip Mall/Commercial Fire

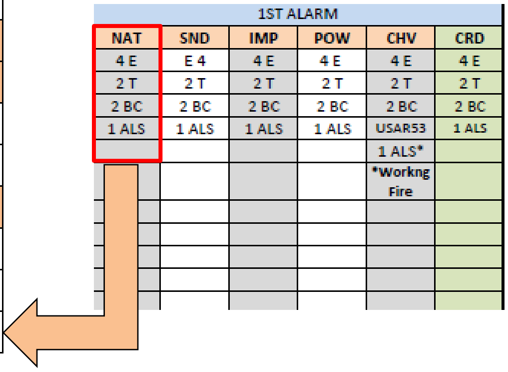
Critical Tasks	Personnel
Incident Command	2
Continuous Water Supply	2
Fire Attack via Two Handlines	6
Hydrant Hook Up – Forcible Entry - Utilities	3
Primary Search and Rescue	4
Ground Ladders and Ventilation	4
Aerial Operator if Aerial is Used	1
Establishment of IRIC (Initial Rapid Intervention Crew)	4
Medical Care Team	2
Total Effective Response Force	**27** **(28 If aerial is used)**

The following table outlines how the NCFD assembles staffing and deployable resources as measured against NFPA 1710 benchmarking for an effective response force for an open-air strip mall and commercial building fire. NCFD units are highlighted.

TABLE 4-5: NCFD Effective Response Force for Open-Air Strip Mall/Commercial Fire

Apparatus	Personnel
NCFD Battalion Chief	1
Auto Aid Battalion Chief	1
NCFD Engine	3
NCFD Engine	3
Auto Aid Engine	4
Auto Aid Engine	4
NCFD Ladder	4
Auto Aid Ladder	4
1 ALS unit	2
Total NCFD ERF	**26**

San Diego Metro Zone Response Plan Matrix
Commercial Structure Fire



1ST ALARM					
NAT	SND	IMP	POW	CHV	CRD
4 E	E 4	4 E	4 E	4 E	4 E
2 T	2 T	2 T	2 T	2 T	2 T
2 BC	2 BC	2 BC	2 BC	2 BC	2 BC
1 ALS	1 ALS	1 ALS	1 ALS	USAR53	1 ALS
				1 ALS*	
				*Workng Fire	

As a single responding agency, NCFD does not meet the minimum benchmarks of NFPA 1710 for an Effective Response Force for an open-air strip mall fire. With regional automatic aid, the NCFD does not meet the benchmark (minus 2 FFs). ***NFPA 1710 permits fire departments to use established automatic and mutual aid agreements to comply with section 5.2 of this standard.***[32]

Apartment Building, NFPA 5.2.4.3

The initial full alarm assignment (ERF) to a structural fire in a typical 1,200 square-foot apartment within a three-story, garden-style apartment building must provide for a minimum of 27 members (28 if an aerial device is used). The following table outlines the critical tasking matrix for this type

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32. NFPA 1710. 5.2.1.3

of building fire. The NCFD has no specific response matrix for apartment buildings, so we utilized the NFPA commercial fire ERF matrix has it has similar staffing.

TABLE 4-6: Effective Response Force for Apartment Building Fire

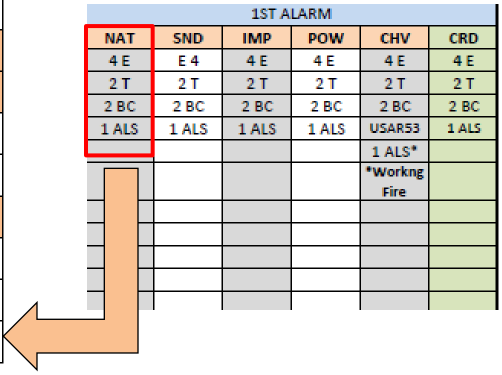
Critical Tasks	Personnel
Incident Command	2
Continuous Water Supply	2
Fire Attack via Two Handlines	6
Hydrant Hook Up – Forcible Entry – Utilities	3
Primary Search and Rescue	4
Ground Ladders and Ventilation	4
Aerial Operator if Aerial is Used	1
Establishment of IRIC (Initial Rapid Intervention Crew	4
Medical Care Team	2
Total Effective Response Force	**27** **(28 If aerial is used)**

The following table outlines how the NCFD assembles staffing and deployable resources as measured against NFPA 1710 benchmarking for an effective response force for an apartment building or other multi-unit housing type building fire. NCFD units are highlighted.

TABLE 4-7: NCFD Effective Response Force for Apartment Building Fire

Apparatus	Personnel
NCFD Battalion Chief	1
Auto Aid Battalion Chief	1
NCFD Engine	3
NCFD Engine	3
Auto Aid Engine	4
Auto Aid Engine	4
NCFD Ladder	4
Auto Aid Ladder	4
1 ALS unit	2
Total NCFD ERF	**23-26**

San Diego Metro Zone Response Plan Matrix
Apartment-Commercial Structure Fire



1ST ALARM					
NAT	SND	IMP	POW	CHV	CRD
4 E	E 4	4 E	4 E	4 E	4 E
2 T	2 T	2 T	2 T	2 T	2 T
2 BC	2 BC	2 BC	2 BC	2 BC	2 BC
1 ALS	1 ALS	1 ALS	1 ALS	USAR53	1 ALS
				1 ALS*	
				*Workng Fire	

As a single responding agency, NCFD does not meet the minimum benchmarks of NFPA 1710 for an Effective Response Force for an apartment building fire. With regional automatic aid, the NCFD does not meet the benchmark (minus 2 FFs). ***NFPA 1710 permits fire departments to use established automatic aid and mutual aid agreements to comply with section 5.2 of this standard.***[33]

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[33] NFPA 1710. 5.2.1.3

High-Rise, NFPA 1710 5.2.4.4

The initial full alarm assignment to a fire in a building where the highest floor is greater than 75 feet above the lowest level of fire department vehicle access must provide for a minimum of 42 members (43 if the building is equipped with a fire pump).

TABLE 4-8: Structure Fire – High Rise

Critical Tasks	Personnel
Incident Command	2
Continuous Water Supply	1 FF for continuous water; if fire pump exists, 1 additional FF required.
Fire Attack via Two Handlines	4
One Handline above the Fire Floor	2
Establishment of IRIC (Initial Rapid Intervention Crew)	4
Primary Search and Rescue Teams	4
Entry Level Officer with Aide near entry point of Fire Floor	2
Entry Level Officer with Aide near the entry point above the Fire Floor	2
Two Evacuation Teams	4
Elevator Operations	1
Safety Officer	1
FF Two Floors below Fire to Coordinate Staging	1
Rehabilitation Management	2
Officer and FFs to Manage Vertical Ventilation	4
Lobby Operations	1
Transportation of Equipment below Fire Floor	2
Officer to Manage Base Operations	1
Two ALS Medical Care Teams	4
Total Effective Response Force	**42** (43 If building is equipped with pump)

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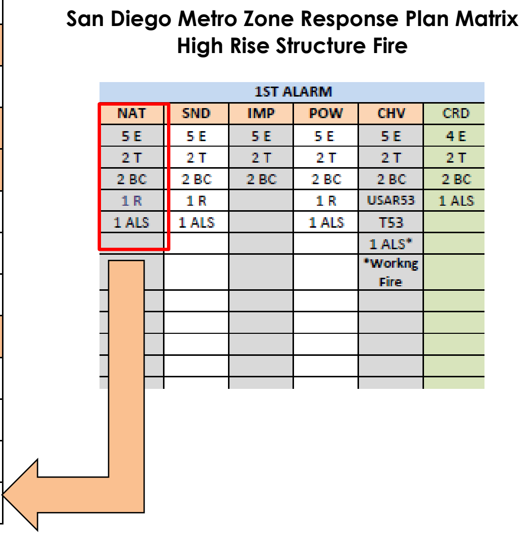
TABLE 4-9: NCFD Effective Response Force for High-Rise Fire

Apparatus	Personnel
NCFD Battalion Chief	1
Auto Aid Battalion Chief	1
NCFD Engine	3
NCFD Engine	3
Auto Aid Engine	4
Auto Aid Engine	4
Auto Aid Engine	4
NCFD Ladder	4
Auto Aid Ladder	4
1 Rescue	4
1 ALS unit	2
Total NCFD ERF	**34**



San Diego Metro Zone Response Plan Matrix
High Rise Structure Fire

1ST ALARM					
NAT	SND	IMP	POW	CHV	CRD
5 E	5 E	5 E	5 E	5 E	4 E
2 T	2 T	2 T	2 T	2 T	2 T
2 BC	2 BC	2 BC	2 BC	2 BC	2 BC
1 R	1 R		1 R	USAR53	1 ALS
1 ALS	1 ALS		1 ALS	T53	
				1 ALS*	
				*Workng Fire	

As a single responding agency, NCFD does not meet the minimum benchmarks of NFPA 1710 for an Effective Response Force for a high-rise fire. With regional automatic aid, the NCFD does not meet this benchmark. ***NFPA 1710 permits fire departments to use established automatic aid and mutual aid agreements to comply with section 5.2 of this standard.***[34]

Recommendations:

- CPSM recommends the NCFD, to the extent possible and if practical depending on available automatic and mutual aid resources, work with regional Fire Chiefs to increase response resources to commercial, apartment, and high-rise fire responses that align more closely with the NFPA 1710 standard. (Recommendation No. 7.)
- CPSM further recommends due to the following factors: demand for service on the NCFD; population density that includes substantial current and projected vertical density structures, many involving assisted and/or senior living; building and other risks identified in this report such as the San Diego Port property; industrial and commercial properties that include heavy rail and tractor-trailer transportation; proposed industrial and commercial properties; the resiliency issues the department faces due to demand for service; and to increase NCFD resources regarding assembling an Effective Response Force, that the city develop a one- to three-year funding plan to increase staffing on Engine 31 to four per shift (three total personnel with estimated salary costs of $263,000) as this is a single station response unit in a high-demand fire management zone, and in the subsequent three- to five-year period develop a funding plan to increase staffing on Engine 34 to four per shift (three total personnel with estimated costs of $263,000 to $300,000, depending on implementation year). (Recommendation No. 8.)

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[34] NFPA 1710. 5.2.1.3

NCFD RESPONSE TIMES

Response times are typically utilized as a primary measurement for evaluating fire and EMS services. Response times are used as a benchmark to determine how well a fire department is currently performing, to help identify response trends, and to predict future operational needs and station placement. Achieving the quickest and safest response times possible should be a fundamental goal of every fire department.

Fire incident response time criterion is linked to the concept of "flashover." This is the state at which super-heated gasses from a fire are released rapidly, causing the fire to burn freely, and become so volatile that the fire reaches an explosive state (simultaneous ignition of all the combustible materials in a room). In this situation, usually after an extended period (often eight to twelve minutes after ignition but at times as quickly as five to seven minutes), and a combination of the right conditions (fuel and oxygen), the fire expands rapidly and is much more difficult to contain. When the fire does reach this extremely hazardous state, initial firefighting forces are often overwhelmed, larger and more destructive fire occurs, the fire escapes the room and possibly even the building of origin, and significantly more resources are required to affect fire control and extinguishment.

Flashover occurs more quickly and more frequently today and is caused at least in part by the introduction of significant quantities of plastic and foam-based products into homes and businesses (e.g., furnishings, mattresses, bedding, plumbing and electrical components, home and business electronics, decorative materials, insulation, and structural components). These materials ignite and burn quickly and produce extreme heat and toxic smoke.

The next figure illustrates the time progression of a fire from inception (event initiation) through flashover. The time-versus-products of combustion curve shows activation times and effectiveness of residential sprinklers (approximately one minute), commercial sprinklers (four minutes), flashover (eight to ten minutes), and firefighters applying first water to the fire after notification, dispatch, response, and set up (ten minutes).

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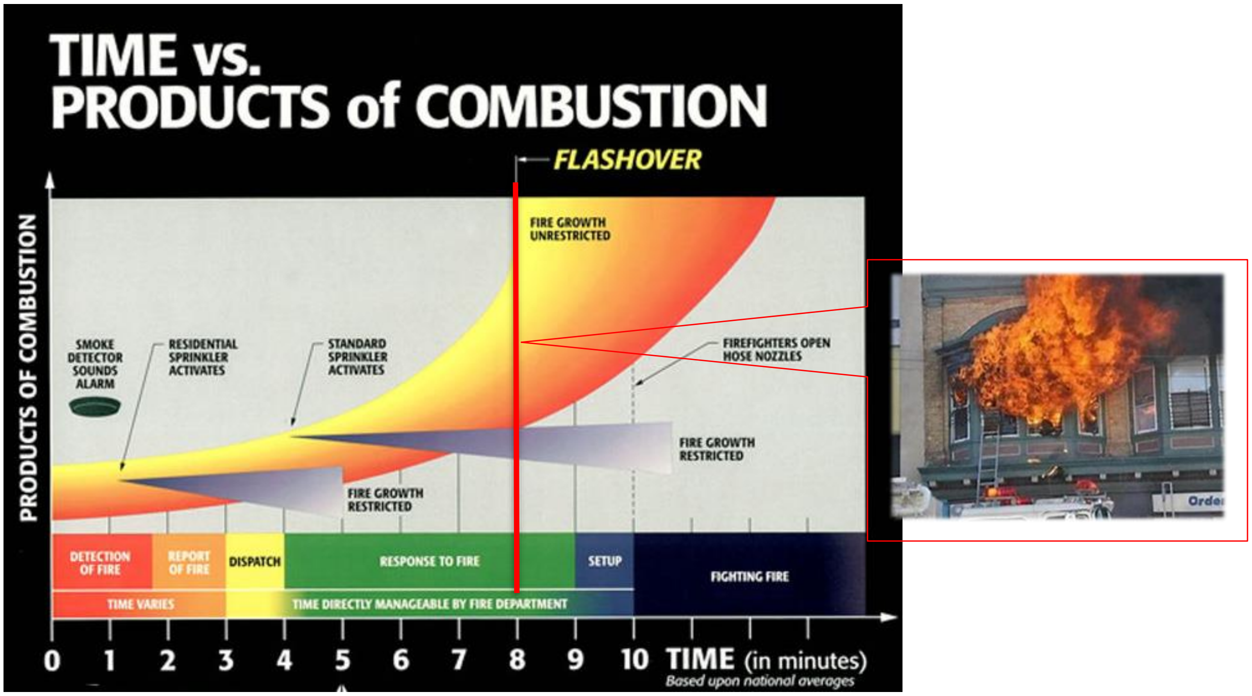
FIGURE 4-2: Fire Growth from Inception to Flashover[35]



EMS response times are measured differently than fire service response times. Where the fire service uses NFPA 1710 as a response time benchmarking document, the focus for EMS is and should be directed to the evidence-based research relationship between clinical outcomes and response times. Much of the current research suggests response times have reduced impact on clinical outcomes outside of a small segment of call types. These include cerebrovascular accidents (stroke); injury or illness compromising the respiratory system; injury or illness compromising the cardiovascular system to include S-T segment elevation emergencies, high-acuity medical and pediatric emergencies; cardiac and respiratory arrest; and certain high-risk obstetrical emergencies to name a few. Each requires rapid response times, rapid on-scene treatment and packaging for transport, and rapid transport to the hospital.

The next figure illustrates the chance of survival from the onset of cardiac arrest, largely due to ventricular fibrillation in terms of minutes without emergency defibrillation delivered by the public or emergency responders. The chance of survival has not changed over time since this graphic was first published by the American Heart Association in 2000.

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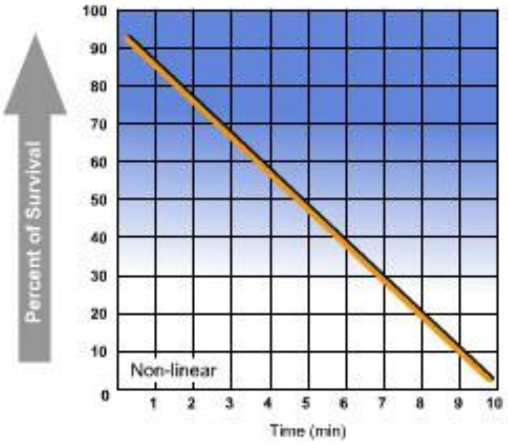
[35] Source: https://www.slideserve.com/tavon/the-international-society-of-fire-service-instructors

FIGURE 4-3: Cardiac Arrest Survival Probability by Minute



"Survival rates after VF cardiac arrest decrease approximately 7% to 10% with every minute that defibrillation is delayed." p I-61

Guidelines 2000 for Cardiovascular Resuscitation and Emergency Cardiovascular Care.Circulation. 2000;102 (suppl I)8. August 22, 2000

A crucial factor in the whole response time question is what we term "**detection time**." This is the time it takes to detect a fire or a medical situation and notify 911 to initiate the response. In many instances, particularly at night or when automatic detection systems (fire sprinklers and smoke detectors) are not present or inoperable, the fire detection process can be extended. The same holds true for EMS incidents. Many medical emergencies are often thought to be something minor by the patient, treated with home remedies, and the true emergency goes undetected until signs and symptoms are more severe. When the fire-EMS department responds, they often find these patients in acute states. Fires that go undetected and are allowed to expand in size become more destructive, are difficult to extinguish, and require more resources for longer periods of time.

For the purpose of this analysis, ***response time*** is a product of three components: ***dispatch time***, ***turnout time***, and ***travel time***.

For this study, and unless otherwise indicated, response times and travel times measure the first arriving unit only. The primary focus of this section is the dispatch and response time of the first arriving units for calls responded to with lights and sirens.

Dispatch time is the difference between the time a call is received and the earliest time an agency is dispatched. Dispatch time includes call processing time, which is the time required to determine the nature of the emergency and the types of resources to dispatch. The NFPA 1710 standard for this component of response times is the event is processed and dispatched in:

- ≤ 64 seconds 90 percent of the time.
- ≤ 106 seconds 95 percent of the time.
- Special call types
    - ≤ 90 seconds 90 percent of the time.
    - ≤ 120 seconds 99 percent of the time.

The next component of response time is **turnout time**, an aspect of response which is controlled by the responding fire department. NFPA 1710 states that turnout time shall be:

- ≤ 80 seconds (1.33 minutes) for fire and special operations 90 percent of the time.
- ≤ 60 seconds (1.0 minute) for EMS responses.

The last component of response time is **travel time,** an aspect of response time that is affected by factors such as station location, road conditions, weather, and traffic control systems. NFPA 1710 states that travel time for the first arriving fire suppression unit to a fire incident shall be:

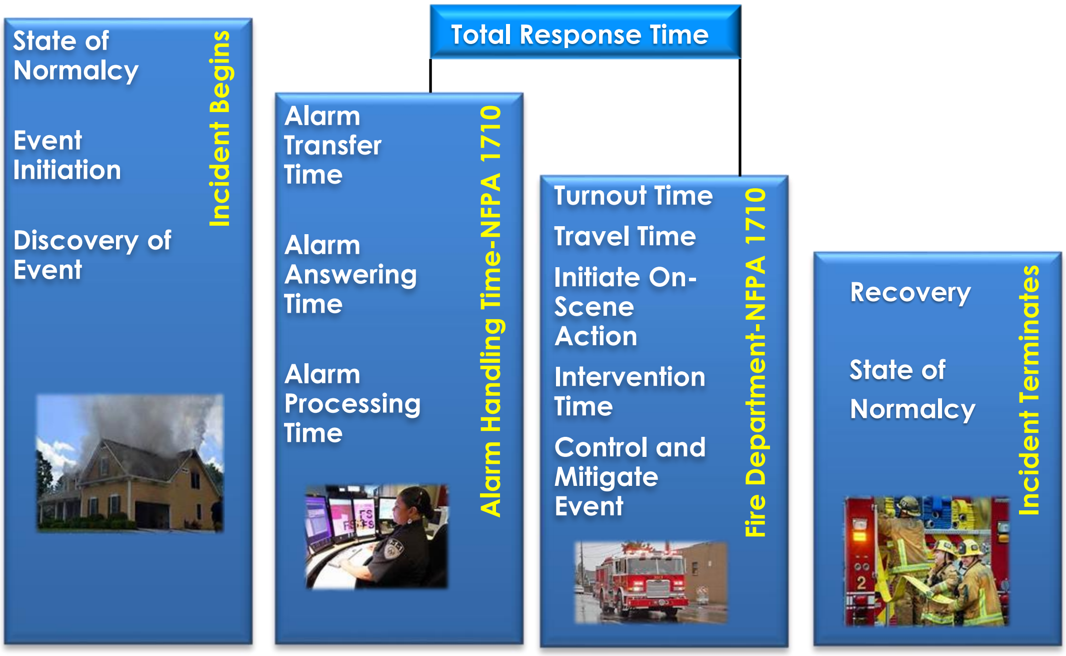
- ≤ 240 seconds for the first arriving engine company to a fire suppression incident 90 percent of the time.
- ≤ 360 seconds for the second company 90 percent of the time.
- ≤ 480 seconds to assemble the initial first alarm assignment on scene 90 percent of the time for low/medium hazards, and 610 seconds for high-rise fire incidents 90 percent of the time.

For EMS incidents the standard NFPA 1710 standard establishes a travel time of:

- ≤ 240 seconds for the first arriving engine company with automatic external defibrillator (AED) or higher level capability.
- ≤ 480 seconds or less travel time of an Advanced Life Support (ALS) unit at an EMS incident where the service is provided by the fire department provided a first responder with an AED or basic life support unit arrived in 240 seconds or less travel time.

The following figure provides an overview of the fire department incident cascade of events and further describes the total cascade of events and their relationship to the total response time of a fire incident.

FIGURE 4-4: Incident Cascade of Events



Travel time is key to understanding how fire and EMS station location influences a community's aggregate response time performance. Travel time can be mapped when existing and proposed station locations are known. The location of responding units is one key factor in response time; reducing response times, which is typically a key performance measure in determining the efficiency of department operations, often depends on this factor. The goal of placement of a single fire station or creating a network of responding fire stations in a single community is to optimize coverage with short travel distances, when possible, while giving special attention to natural and manmade barriers, and response routes that can create response-time problems.[36] This goal is generally budget-driven and based on demand intensity of fire and EMS incidents, travel times, and identified risks.

As already discussed, the NCFD responds fire suppression units (engines/ladder/squad) from three stations and receives automatic aid from surrounding jurisdictions. This section expands on the earlier discussion on travel times and depicts how travel times of 240, 360, and 480 seconds look when mapped from the current fire station locations. Illustrating response time is important when considering the location from which assets should be deployed. When historic demand is coupled with risk analysis, a more informed decision can be made.

The following figures use GIS mapping to illustrate travel time bleeds using the existing street network from the current NCFD stations. CPSM also mapped the travel time projections from primary auto aid stations that may respond into National City.

The GIS data for streets includes speed limits for each street segment and allows for "U-turns" for dead-end streets and intersections, as well as other travel obstacles.

It is important to understand that measuring and analyzing response times and response time coverage are measurements of performance. When we discussed community risk above, we identified that the NCFD like most other fire departments in the nation is an all-hazards response agency. While different regions of the country respond to different environmental risks, the remaining hazards that fire departments confront remain the same. Linking response data to community risks lays the foundation for future fire department planning in terms of fire station location, the need for additional fire stations, and staffing levels whether supplied by the fire department or a combination of a city's fire department and automatic aid. Managing fire department response capabilities to the identified community's risk focuses on three components which are:

- Having a full understanding of the total risk in the community and how each risk impacts the fire department in terms of resiliency, what the consequences are to the community and fire department should a specific risk or combination of two or more occur and preparing for and understanding the probability that the risk may occur.
- Linking risk to the deployment of resources to effectively manage every incident. This includes assembling an Effective Response Force for the response risk in measurable times benchmarked against NFPA standards, deploying the appropriate apparatus (engines, ladders, heavy rescues, ambulances), and having a trained response force trained to combat a specific risk.
- Understanding that each element of response times plays a role in the management of community risk. Low response times of the initial arriving engine and low time to assemble an Effective Response Time on fire and other incidents is associated with positive outcomes.

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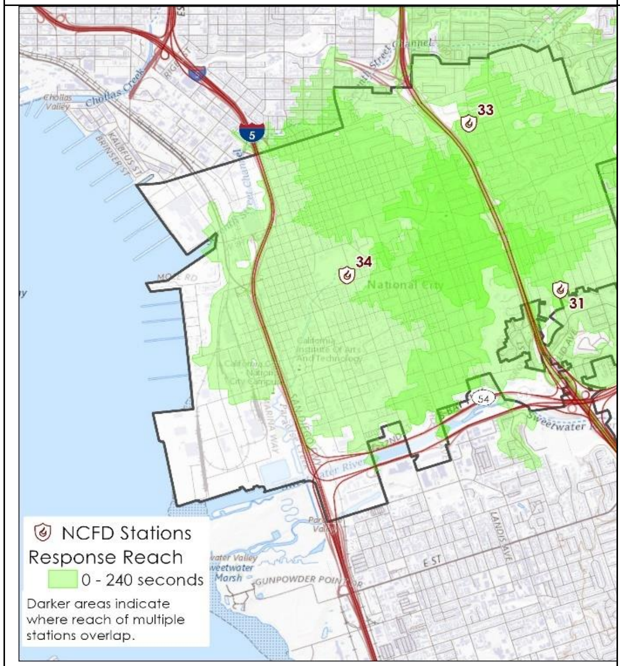
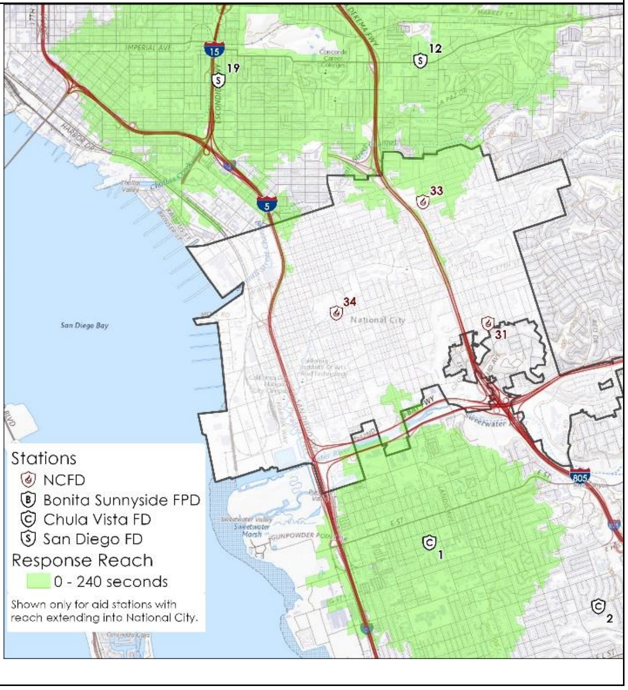
[36] NFPA 1710, *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Departments*, 2020 Edition.

The following figure looks at the travel time projection at 240 seconds from NCFD stations and the primary auto aid stations that respond into National City. From the NCFD stations, all but the western edges of the city are covered as benchmarked against the NFPA standard. These areas are largely industrial. In the central and central east potions of the city there is good overlap by NCFD stations, which supports resiliency. Auto/mutual aid stations do not have an impact other than the northeast portion of the city.

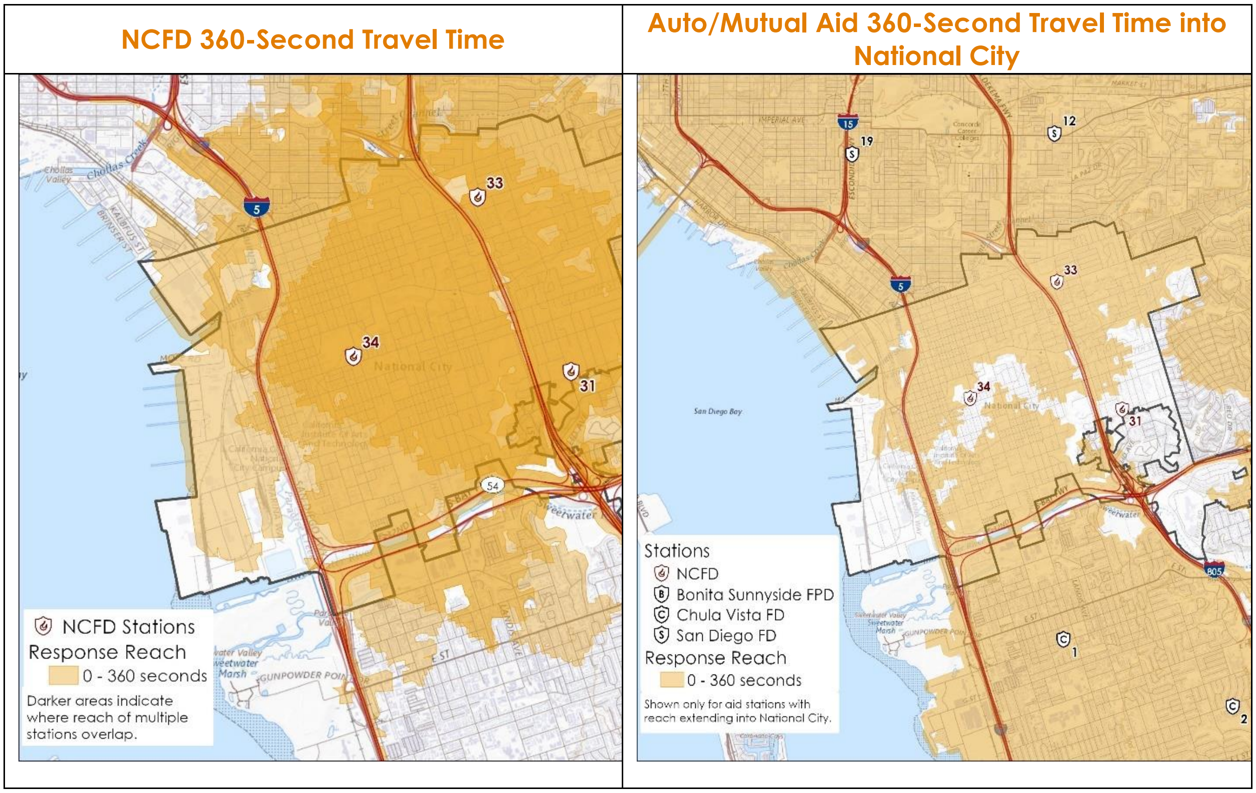
FIGURE 4-5: 240-Second Travel Time Maps

NCFD 240-Second Travel Time	**Auto/Mutual Aid 240-Second Travel Time into National City**
	

The next figure shows travel time projections at 360 seconds, which in the NFPA 1710 standard is the time benchmark for the second fire company to arrive on the scene in less than or equal to 360 seconds 90 percent of the time. This standard links to the two-in/two-out regulation from OSHA and NFPA 1500 standards, as well as the initial critical tasking and the early assembly of an Effective Response Force for the incident. This figure compares the 360-second response from the NCFD stations and as well from the primary auto aid stations that respond into National City.

From the NCFD stations, nearly 100 percent of the city is covered as benchmarked against the NFPA standard. Station 33 is included here as Squad 33 counts as a second arriving fire unit per the standard. Auto/mutual aid stations have a positive impact in meeting this benchmark in a substantial share of the north and south areas of the city.

FIGURE 4-6: 360-Second Travel Time Maps



NCFD 360-Second Travel Time

Auto/Mutual Aid 360-Second Travel Time into National City

The next figure looks at the travel time bleeds of 480 seconds, which in the NFPA 1710 standard is the time benchmark for the assembly of the initial first alarm assignment on scene in 480 seconds or less 90 percent of the time for low/medium hazards. This standard links to the incident critical tasking and the assembly of an Effective Response Force for the incident. This figure shows the 480 seconds response bleed from the NCFD stations and the primary auto aid stations that respond into National City.

These maps show us that together, NCFD and auto/mutual aid stations cover the city nearly 100 percent, with small gaps in the northeast and northwest corners. As the city is covered at 480 seconds, at the 610 second mark for high-rise incidents, the city is covered as well under the response standard (number of companies) the regional response plan designates for National City.

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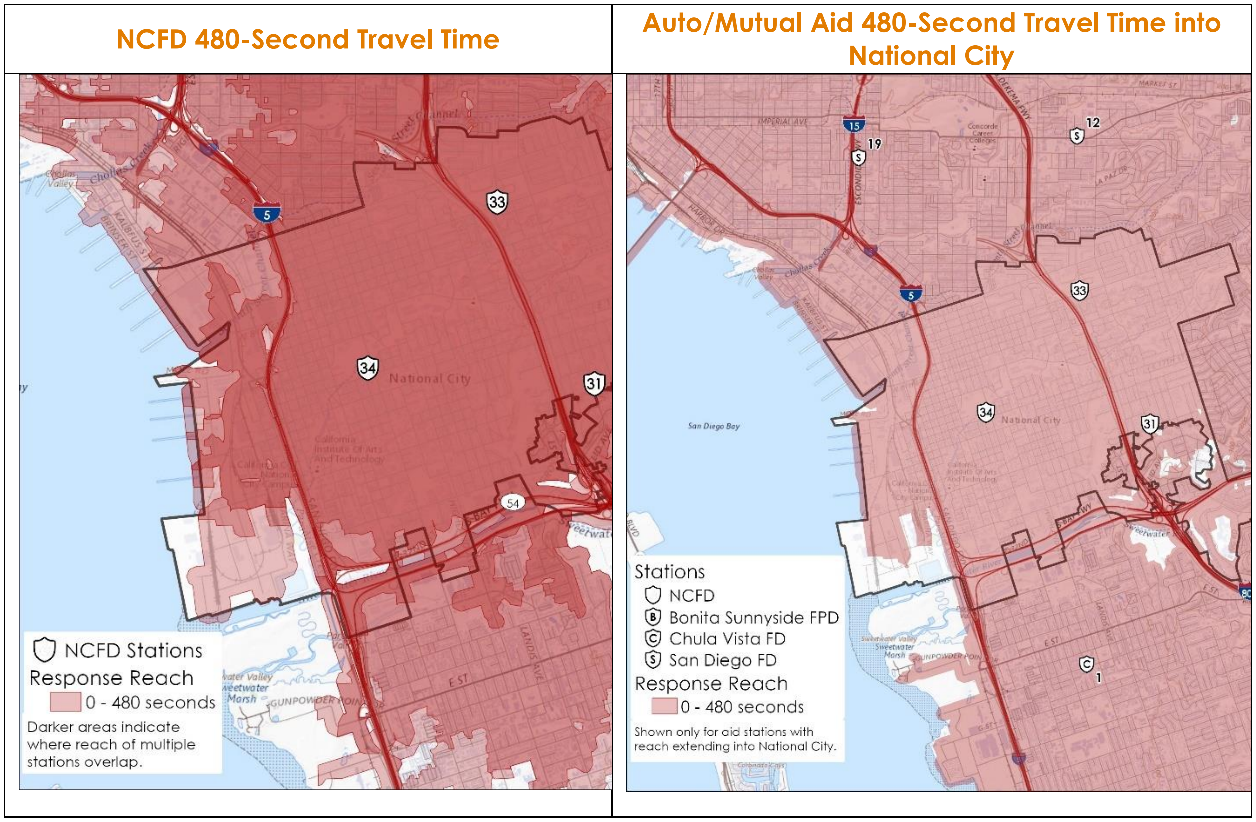
FIGURE 4-7: 480-Second Travel Time Maps



NCFD 480-Second Travel Time

Auto/Mutual Aid 480-Second Travel Time into National City

The next two tables depict the NCFD's turnout, travel, and total response times for 2019 and 2020 as an average and at the 90th percentile as benchmarked against the NFPA 1710 standard.

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TABLE 4-9: Average Response Time of First Arriving Unit, by Call Type, 2019 and 2020

Call Type	2019					2020				
	Minutes				Calls	Minutes				Calls
	Dispatch	Turnout	Travel	Total		Dispatch	Turnout	Travel	Total	
False alarm	1.7	1.2	3.5	6.4	300	1.8	1.1	3.9	6.8	203
Good intent	2.3	1.1	5.3	8.7	51	2.0	1.1	4.4	7.6	75
Hazard	1.7	1.2	4.0	6.9	47	1.7	1.0	3.4	6.1	33
Outside fire	1.7	1.3	3.6	6.5	123	1.8	1.2	4.1	7.0	160
Public service	2.3	1.1	4.1	7.5	112	2.0	1.1	4.3	7.3	126
Structure fire	2.2	1.0	2.6	5.8	30	1.7	0.9	3.3	5.8	29
Fire Total	**1.9**	**1.2**	**3.7**	**6.8**	**663**	**1.8**	**1.1**	**4.0**	**7.0**	**626**
EMS Total	**2.0**	**1.0**	**3.3**	**6.4**	**4,991**	**2.1**	**1.1**	**3.7**	**6.8**	**4,738**
Total	**2.0**	**1.1**	**3.4**	**6.5**	**5,654**	**2.1**	**1.1**	**3.7**	**6.9**	**5,364**

TABLE 4-10: 90th Percentile Response Time of First Arriving Unit, by Call Type, 2019 and 2020

Call Type	2019					2020				
	Dispatch	Turnout	Travel	Total	Calls	Dispatch	Turnout	Travel	Total	Calls
False alarm	2.7	2.1	5.5	8.7	300	2.9	2.0	6.1	9.4	203
Good intent	4.7	1.7	10.6	13.8	51	3.6	2.0	6.4	11.0	75
Hazard	2.7	2.0	5.8	10.8	47	3.0	1.5	5.0	8.4	33
Outside fire	2.5	2.0	5.6	9.3	123	3.0	2.1	6.2	9.4	160
Public service	3.5	2.0	6.6	10.8	112	3.9	2.0	7.3	10.8	126
Structure fire	3.3	1.7	4.4	7.7	30	2.4	1.8	5.1	8.2	29
Fire Total	**3.2**	**2.0**	**6.1**	**9.7**	**663**	**3.1**	**2.0**	**6.2**	**9.4**	**626**
EMS Total	**3.5**	**1.8**	**5.2**	**8.6**	**4,991**	**3.6**	**2.0**	**5.5**	**9.3**	**4,738**
Total	**3.5**	**1.8**	**5.3**	**8.7**	**5,654**	**3.5**	**2.0**	**5.6**	**9.3**	**5,364**

The call demands the NCFD experiences have an effect on response travel times when compared to each station's ability to cover its fire management zone in 240 seconds as illustrated in Figure 4-5 above. Companies are at times out of position for the next call and often cross districts for first due responses. This is noted when reviewing the 90th percentile travel times in the table above and discussed in the resiliency section above. Turnout times at the 90th percentile should be reviewed by NCFD leadership to determine if there are any physical issues contributing to the overage in this response time element. This is an element the fire department has the greatest control over.

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SECTION 5. EMS ANALYSIS

NATIONAL CITY EMS PROVIDER BACKGROUND

Emergency medical services (EMS) in National City are provided through a partnership between the National City Fire Department (NCFD) and a contracted ambulance provider, American Medical Response (AMR).

The NCFD provides Advanced Life Support (ALS) medical first response for high-acuity medical responses (Priority 1 and Priority 2), as presumptively determined through an Emergency Medical Dispatch (EMD) call-taking process through San Diego Metro Dispatch. NCFD does not typically respond to low-acuity medical calls (Priority 3 and Priority 4); those responses are managed by an AMR ambulance response only.

Evidence of the effectiveness of this response configuration is demonstrated in the response volume differences between NCFD and AMR.

In 2019, NCFD responded to 5,140 EMS calls (58 percent of all NCFD calls), an average of 14.1 calls per day. Comparatively, AMR responded to 7,328 EMS response in National City, an average of 20.1 calls per day.

This response configuration is an optimal use of ALS first response resources by not committing these resources to low-acuity calls in which an ALS first response would likely not be necessary to affect the patient's outcome. Rather, ALS first response is preserved for the responses in which the arrival of additional ALS resources may have an impact on patient outcomes.

NATIONAL CITY EMS WORKLOAD

The workload of NCFD's units is measured in two ways: runs and deployed time. The deployed time of a run is measured from the time a unit is dispatched through the time the unit is cleared. Because multiple units respond to some calls, there are more runs (10,239) than calls (8,846) and the average deployed time per run varies from the average duration per call.

Deployed time, also referred to as deployed hours, is the total deployment time of NCFD units deployed on all runs. The CPSM data analysis shows that the total deployed time for NCFD's 5,596 EMS responses was 1,824.5 hours, an average of 0.326 hours per EMS response, or an average of 19.6 minutes per response.

Another method for measuring workload is *Unit Hour Utilization* (UHU). UHU is a measure of activity, essentially measuring the amount of on-duty time that an EMS response unit is dispatched on a call.

A *Unit Hour* is defined as one unit, fully staffed, equipped and available for a response. For example, one unit on-duty, 24 hours per pay, 365 days per year equates to 8,760 unit hours (1 x 24 x 365). A UHU is derived by dividing the number of *responses* by the total number of *unit hours*.

NCFD staffs three primary EMS response units from three response stations, NCE31, NCSQ33, and NCE34. These three response units responded to 81.6 percent of EMS requests in National City in 2019, with the remaining EMS requests being handled by secondary EMS response units of NCE231, B57, and NCT34.

Using the Unit Hours of NCFD's three primary EMS response units, we derive a Unit Hour staffing of 26,280 hours (3 x 8,760). Dividing the number of responses into the number of Unit Hours, we derive a *response* UHU of 0.213. This essentially means that an NCFD unit is on an EMS response 21.3 percent of the time they are on-duty.

A limitation of the UHU calculation is that it generally presumes that an EMS response will last one hour. However, as referenced earlier, an NCFD unit is typically committed on an EMS call for only an average of 19.6 minutes. Therefore, we can also use a ***time*** analysis to more clearly indicate the percentage of ***time*** that NCFD units are committed on EMS responses.

As referenced, the CPSM data analysis reveals that in 2019, the total time that NCFD units were committed on EMS calls was 1,824.5 hours. Using the 26,280 annual staffed Unit Hours for the three primary EMS response units, we can calculate the percentage of time that NCFD's primary EMS response units were committed on EMS responses as 0.069, or 6.9 percent of their on-duty time. In other words. NCFD's primary EMS first response units maintain an available percentage of 93.1 percent.

EMS response volume is generally not evenly distributed by time of day. Typically, EMS volume peaks during times when people are engaging in activity as opposed to when they are sleeping. Figure 7-6 in the data analysis displays NCFD's average deployed minutes by time of day. Average deployed time peaked between noon and 1:00 p.m., averaging 28.4 minutes. During this time, NCFD typically has three primary EMS first response units on duty (3 unit hours), meaning that even at peak times, only 15.8 percent of on duty time is committed on responses (28.4 minutes ÷ 90 minutes (3 Unit Hours)).

From an EMS response perspective, this represents a very high degree of response capability, because of a very desirable system design in which first response units maintain a high level of availability, while ambulance resources may be committed on much longer task times due to ambulance transport and hospital destination times.

EMS Reliability

A detailed response time analysis for NCFD was completed by CPSM. To review, we separate response time into its identifiable components.

To derive the total response times for NCFD, and as discussed in an earlier section, we analyze three specific time segments:

- **Dispatch time** is the difference between the time a call is received and the earliest time an agency is dispatched. Dispatch time includes call processing time, which is the time required to determine the nature of the emergency and the types of resources to dispatch.
- **Turnout time** is the difference between the earliest dispatch time and the earliest time an agency's unit is en route to a call's location.
- **Travel time** is the difference between the earliest en route time and the earliest arrival time. Response time is the total time elapsed between receiving a call to arriving on scene.

CPSM uses two response time measures to evaluate EMS response times, *average* and *fractile*. The average time represents the response time internal at which half of the responses are LESS than that interval, and half are LONGER than that interval. It is a level of <u>performance</u>, but not necessarily a level of <u>reliability</u>.

The 90th percentile measure is a measure of reliability. A 90th percentile analysis determines the response interval in which 90 percent of the EMS response times fall under that interval. In other words, the response time interval in which only 10 percent of the EMS response time was longer than that 90th percent interval.

For NCFD's EMS responses, the *average and 90th percentile* times for each segment are described in the following tables for 2019.

TABLE 5-1: NCFD Average EMS Response Times

EMS Response Segment	Dispatch	Turnout	Travel	Total
Average, Minutes	2.0	1.0	3.3	6.4

TABLE 5-2: NCFD 90th Percentile EMS Response Times

EMS Response Segment	Dispatch	Turnout	Travel	Total
90th Percentile, Minutes	3.5	1.8	5.2	8.6

The following tables depict the *average* dispatch, turnout, travel, and total response times for all calls to which AMR responded within the National City fire district in 2019.

TABLE 5-3: AMR Average EMS Response Times

AMR Response Segment	Dispatch	Turnout	Travel	Total
Average, Minutes	0.9	0.8	6.4	8.0

TABLE 5-4: AMR 90th Percentile EMS Response Times

AMR Response Segment	Dispatch	Turnout	Travel	Total
90th Percentile, Minutes	2.4	1.8	10.9	13.2

Both the average and fractile response times for AMR are consistent with national standards, and compliant with contractual requirements.

Because of the dual-tier EMS response configuration for Priority 1 and Priority 2 EMS responses, that is, those in which both a NCFD and AMR unit respond, on average an NCFD unit will arrive on scene in 6.4 minutes with an AMR ambulance arriving in 8.0 minutes, or a 1.6-minute time difference. At the 90th percentile level, the time difference is 4.6 minutes.

CPSM was provided 37 monthly AMR response time compliance reports from January 2018 through December 2020. An analysis of these reports revealed that nearly every monthly report showed that AMR was response time compliant with the requirements in their service agreement with National City; in some months AMR achieved a 99 percent compliance rate.

This data analysis depicts a highly functional and reliable EMS response system.

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CONSIDERATION FOR NCFD GROUND AMBULANCE OPERATIONS

As part of our analysis, CPSM has been asked to evaluate the feasibility for NCFD to engage in ground ambulance transport services.

CPSM has been engaged in a multi-year study in San Diego County, which includes a detailed financial analysis for ambulance operations in two County Service Areas (CSAs) within the county. This project has provided us a unique insight into revenues generated from ambulance operations.

For this part of the report, we will begin with potential revenue generation from ground ambulance services provided by NCFD.

Payer Mix

Payer mix refers to the sources of revenue from ground ambulance services. The payer mix impacts the ability for revenue generation since payer sources reimburse ambulance services in vastly different ways. For example, collection percentages from self-pay patients are generally only 2 to 3 percent, while collection rates from commercial insurers is generally much higher. Medicare and Medi-Cal generally pay fixed amounts, but generally less than the cost of providing the service.

Based on our experience with other San Diego County CSAs, National City would likely experience a payer mix shown in the 2022 column of the following table.

TABLE 5-5: National City Projected EMS Payer Mix

Payer	2019	2020	2021	National City
Medicare	14.7%	16.7%	16.5%	15.2%
Medicare MCO	26.9%	30.7%	28.8%	25.5%
Medi-Cal	2.7%	4.3%	4.0%	3.7%
Medi-Cal MCO	17.0%	22.0%	22.6%	22.6%
Dual Eligible	N/A	2.1%	2.2%	2.2%
Commercial	12.0%	16.1%	17.7%	15.3%
Self-Pay	10.9%	6.3%	6.0%	14.1%
Other	15.7%	1.8%	2.1%	1.5%
Total	**99.9%**	**100.0%**	**100.0%**	**100.0%**

Recent trends in employment have led to a shift from commercially insured patients to self-pay, due to people leaving employment with health insurance benefits to start business on their own, or even becoming unemployed. Since reimbursement from self-pay patients tends to be significantly less than commercially insured patients, EMS systems across the country have experienced a reduction in revenue for services provided.

Potential National City Ground Transport Revenues

Revenue from ambulance service is generally based on four factors; transport volume, service mix (ALS/BLS, emergency/non-emergency), ambulance rate schedule, and payer mix (which impacts collection amounts).

For our analysis, we used the prevailing ambulance rate schedule that is consistent with surrounding communities in San Diego County.

TABLE 5-6: Projected Transport Fee Schedule

Ambulance Fee Schedule	HCPCS Code	Fee
ALS Base Emergency	A0427	$2,356.37
ALS Level 2 Emergency	A0433	$2,626.09
Mileage Urban	A0425	$45.27
Oxygen	A0422	$148.52
BLS Base Emergency	A0429	$1,173.37
BLS Base (Non-Emergency)	A0428	$1,058.73
Treat No Transport	A0998	$175.75

Using this fee schedule, we estimate that the Average Patient Charge (APC) for an NCFD-based ambulance service would be $2,816.88, with a net (collected) reimbursement of $567.60 (a 20.15 percent gross collection rate).

Using these predictions, we can estimate the revenue generated by an ambulance service run by NCFD over the next three years as follows:

TABLE 5-7: NCFD 3-Year Estimated EMS Transport Revenues

Year 1		**Average Patient Charge**	**Gross Fees**	**Collection %**	**Average Collected**	**Net Collections**
Responses	7,137					
Transports	4,782	$2,816.88	$13,469,729	20.2%	$567.60	$2,714,150
Non-Transports	2,355	$175.75	$413,928	5.0%	$8.79	$20,696
Total			**$13,883,657**			**$2,734,847**
Year 2		**Average Patient Charge**	**Gross Fees**	**Collection %**	**Average Collected**	**Net Collections**
Responses	7,351					
Transports	4,925	$2,901.39	$14,290,035	20.1%	$583.18	$2,872,297
Non-Transports	2,426	$181.02	$439,136	5.0%	$9.05	$21,957
Total			**$14,729,171**			**$2,894,254**
Year 3		**Average Patient Charge**	**Gross Fees**	**Collection %**	**Average Collected**	**Net Collections**
Responses	7,572					
Transports	5,073	$2,988.43	$15,160,298	19.7%	$588.72	$2,986,579
Non-Transports	2,499	$186.45	$465,880	5.0%	$9.32	$23,294
Total			**$15,626,178**			**$3,009,873**

Ambulance service billing is complex, and it is recommended that NCFD use the services of an outside ambulance billing agency for ambulance billing. Generally, contracted billing services charge fees based on the actual revenue collected. These fees are typically 4.5 percent of net collections. Billing expenses are included later in this analysis.

Potential National City Ground Transport Expenses

To provide services comparable to what is currently provided by AMR, NCFD would need to staff three ambulances, 24/7. Based on response volume and overall task times, this would yield a Unit Hour Utilization of 0.300.

TABLE 5-8: NCFD 24/7 Ambulance Needs

	Responses	Transports	Non-Transports	Transport Ratio	Transport Task Time	Non-Transport Task Time	Average Task Time	Total Time on Task	Unit Hour Utilization	Unit Hours Needed	Ambulances Needed
2022	7,137	4,782	2,355	0.670	1.5	0.617	1.21	7,553	0.300	25,178	2.9
2023	7,351	4,925	2,426	0.670	1.5	0.617	1.21	7,780	0.300	25,933	3.0
2024	7,572	5,073	2,499	0.670	1.5	0.617	1.21	8,013	0.300	26,711	3.0

For the projected expenses for running an NCFD-based ambulance system, we presume NCFD would use sworn personnel to staff the ambulances, giving the system additional flexibilities for cross-staffing and cross-functioning personnel that could be deployed for a fire or medical response. We also presume an EMT/Paramedic staffing configuration, since currently, a second paramedic, if needed for ALS patient care, would be typically provided by an engine co-responding on the medical call.

NCFD could use non-sworn, dual-role personnel for ambulance service provision. This would reduce some of the personnel expenses; however, it would also limit the ability of personnel assigned to ambulance duties to fulfill other duties that may be valuable for the city.

For this analysis, we used the pay rates, salary schedule, and shift patterns as outlined in the July 2020 – December 2021 Memorandum of Understanding between National City and the Fire Fighters Association.

Based on these presumptions, and using the current and future pay rates for each position, including the wage differences based on hours worked per week, the staffing configuration and costs for three years is shown in the tables that follow.

TABLE 5-9: NCFD EMS Staffing Cost: Year 1

Ambulance Personnel	Rate	#	Reg. Hours	Regular Wages	Overtime Rate	FLSA Pay (1)	Training Hours (2)	Overtime Wages	Total Wages	Benefit %	Total Expense
A-Shift Ambulance 1 EMT (240 Shift)	$21.63	1.00	2756	$59,611	$32.44	156	10	$5,386	$64,997	45.0%	$94,246
B-Shift Ambulance 1 EMT (240 Shift)	$21.63	1.00	2756	$59,611	$32.44	156	10	$5,386	$64,997	45.0%	$94,246
C-Shift Ambulance 1 EMT (240 Shift)	$21.63	1.00	2756	$59,611	$32.44	156	10	$5,386	$64,997	45.0%	$94,246
A-Shift Ambulance 2 EMT (240 Shift)	$21.63	1.00	2756	$59,611	$32.44	156	10	$5,386	$64,997	45.0%	$94,246
B-Shift Ambulance 2 EMT (240 Shift)	$21.63	1.00	2756	$59,611	$32.44	156	10	$5,386	$64,997	45.0%	$94,246
C-Shift Ambulance 2 EMT (240 Shift)	$21.63	1.00	2756	$59,611	$32.44	156	10	$5,386	$64,997	45.0%	$94,246
A-Shift Ambulance 3 EMT (240 Shift)	$21.63	1.00	2756	$59,611	$32.44	156	10	$5,386	$64,997	45.0%	$94,246
B-Shift Ambulance 3 EMT (240 Shift)	$21.63	1.00	2756	$59,611	$32.44	156	10	$5,386	$64,997	45.0%	$94,246
C-Shift Ambulance 3 EMT (240 Shift)	$21.63	1.00	2756	$59,611	$32.44	156	10	$5,386	$64,997	45.0%	$94,246
A-Shift Ambulance 1 Paramedic (240 Shift)	$24.51	1.00	2756	$67,540	$36.76	156	20	$6,470	$74,010	45.0%	$107,314
B-Shift Ambulance 1 Paramedic (240 Shift)	$24.51	1.00	2756	$67,540	$36.76	156	20	$6,470	$74,010	45.0%	$107,314
C-Shift Ambulance 1 Paramedic (240 Shift)	$24.51	1.00	2756	$67,540	$36.76	156	20	$6,470	$74,010	45.0%	$107,314
A-Shift Ambulance 2 Paramedic (240 Shift)	$24.51	1.00	2756	$67,540	$36.76	156	20	$6,470	$74,010	45.0%	$107,314
B-Shift Ambulance 2 Paramedic (240 Shift)	$24.51	1.00	2756	$67,540	$36.76	156	20	$6,470	$74,010	45.0%	$107,314
C-Shift Ambulance 2 Paramedic (240 Shift)	$24.51	1.00	2756	$67,540	$36.76	156	20	$6,470	$74,010	45.0%	$107,314
A-Shift Ambulance 3 Paramedic (240 Shift)	$24.51	1.00	2756	$67,540	$36.76	156	20	$6,470	$74,010	45.0%	$107,314
B-Shift Ambulance 3 Paramedic (240 Shift)	$24.51	1.00	2756	$67,540	$36.76	156	20	$6,470	$74,010	45.0%	$107,314
C-Shift Ambulance 3 Paramedic (240 Shift)	$24.51	1.00	2756	$67,540	$36.76	156	20	$6,470	$74,010	45.0%	$107,314
Floater Paramedic (240 Shift)	$24.51	1.00	2756	$67,540	$36.76	156	20	$6,470	$74,010	45.0%	$107,314
Ambulance Supv./Coordinator/Captain	$40.35	1.00	2080	$83,935	$60.53	104	20	$7,506	$91,441	45.0%	$132,589
Year 1 Total Personnel Expense											**$ 2,053,941**

TABLE 5-10: NCFD EMS Staffing Cost: Year 2

Ambulance Personnel	Rate	#	Reg. Hours	Regular Wages	Overtime Rate	FLSA Pay (1)	Training Hours (2)	Overtime Wages	Total Wages	Benefit %	Total Expense
A-Shift Ambulance 1 EMT (240 Shift)	$22.71	1.00	2756	$62,576	$34.06	156	10	$5,654	$68,230	45.0%	$98,934
B-Shift Ambulance 1 EMT (240 Shift)	$22.71	1.00	2756	$62,576	$34.06	156	10	$5,654	$68,230	45.0%	$98,934
C-Shift Ambulance 1 EMT (240 Shift)	$22.71	1.00	2756	$62,576	$34.06	156	10	$5,654	$68,230	45.0%	$98,934
A-Shift Ambulance 2 EMT (240 Shift)	$22.71	1.00	2756	$62,576	$34.06	156	10	$5,654	$68,230	45.0%	$98,934
B-Shift Ambulance 2 EMT (240 Shift)	$22.71	1.00	2756	$62,576	$34.06	156	10	$5,654	$68,230	45.0%	$98,934
C-Shift Ambulance 2 EMT (240 Shift)	$22.71	1.00	2756	$62,576	$34.06	156	10	$5,654	$68,230	45.0%	$98,934
A-Shift Ambulance 3 EMT (240 Shift)	$22.71	1.00	2756	$62,576	$34.06	156	10	$5,654	$68,230	45.0%	$98,934
B-Shift Ambulance 3 EMT (240 Shift)	$22.71	1.00	2756	$62,576	$34.06	156	10	$5,654	$68,230	45.0%	$98,934
C-Shift Ambulance 3 EMT (240 Shift)	$22.71	2.00	2756	$62,576	$34.06	156	10	$5,654	$68,230	45.0%	$98,934
A-Shift Ambulance 1 Paramedic (240 Shift)	$25.73	1.00	2756	$70,899	$38.59	156	20	$6,792	$77,691	45.0%	$112,652
B-Shift Ambulance 1 Paramedic (240 Shift)	$25.73	1.00	2756	$70,899	$38.59	156	20	$6,792	$77,691	45.0%	$112,652
C-Shift Ambulance 1 Paramedic (240 Shift)	$25.73	1.00	2756	$70,899	$38.59	156	20	$6,792	$77,691	45.0%	$112,652
A-Shift Ambulance 2 Paramedic (240 Shift)	$25.73	1.00	2756	$70,899	$38.59	156	20	$6,792	$77,691	45.0%	$112,652
B-Shift Ambulance 2 Paramedic (240 Shift)	$25.73	1.00	2756	$70,899	$38.59	156	20	$6,792	$77,691	45.0%	$112,652
C-Shift Ambulance 2 Paramedic (240 Shift)	$25.73	1.00	2756	$70,899	$38.59	156	20	$6,792	$77,691	45.0%	$112,652
A-Shift Ambulance 3 Paramedic (240 Shift)	$25.73	1.00	2756	$70,899	$38.59	156	20	$6,792	$77,691	45.0%	$112,652
B-Shift Ambulance 3 Paramedic (240 Shift)	$25.73	1.00	2756	$70,899	$38.59	156	20	$6,792	$77,691	45.0%	$112,652
C-Shift Ambulance 3 Paramedic (240 Shift)	$25.73	1.00	2756	$70,899	$38.59	156	20	$6,792	$77,691	45.0%	$112,652
Floater Paramedic (240 Shift)	$25.73	1.00	2756	$70,899	$38.59	156	20	$6,792	$77,691	45.0%	$112,652
Ambulance Supv./Coordinator/Captain	$42.39	1.00	2080	$88,169	$63.58	104	20	$7,884	$96,053	45.0%	$139,278
Year 2 Total Personnel Expense											**$ 2,156,201**

TABLE 5-11: NCFD EMS Staffing Cost: Year 3

Ambulance Personnel	Rate	#	Reg. Hours	Regular Wages	Overtime Rate	FLSA Pay (1)	Training Hours (2)	Overtime Wages	Total Wages	Benefit %	Total Expense
A-Shift Ambulance 1 EMT (240 Shift)	$23.84	1.00	2756	$65,710	$35.76	156	10	$5,937	$71,646	45.0%	$103,887
B-Shift Ambulance 1 EMT (240 Shift)	$23.84	1.00	2756	$65,710	$35.76	156	10	$5,937	$71,646	45.0%	$103,887
C-Shift Ambulance 1 EMT (240 Shift)	$23.84	1.00	2756	$65,710	$35.76	156	10	$5,937	$71,646	45.0%	$103,887
A-Shift Ambulance 2 EMT (240 Shift)	$23.84	1.00	2756	$65,710	$35.76	156	10	$5,937	$71,646	45.0%	$103,887
B-Shift Ambulance 2 EMT (240 Shift)	$23.84	1.00	2756	$65,710	$35.76	156	10	$5,937	$71,646	45.0%	$103,887
C-Shift Ambulance 2 EMT (240 Shift)	$23.84	1.00	2756	$65,710	$35.76	156	10	$5,937	$71,646	45.0%	$103,887
A-Shift Ambulance 3 EMT (240 Shift)	$23.84	1.00	2756	$65,710	$35.76	156	10	$5,937	$71,646	45.0%	$103,887
B-Shift Ambulance 3 EMT (240 Shift)	$23.84	1.00	2756	$65,710	$35.76	156	10	$5,937	$71,646	45.0%	$103,887
C-Shift Ambulance 3 EMT (240 Shift)	$23.84	1.00	2756	$65,710	$35.76	156	11	$5,973	$71,682	45.0%	$103,939
A-Shift Ambulance 1 Paramedic (240 Shift)	$27.01	1.00	2756	$74,449	$40.52	156	20	$7,132	$81,581	45.0%	$118,292
B-Shift Ambulance 1 Paramedic (240 Shift)	$27.01	1.00	2756	$74,449	$40.52	156	20	$7,132	$81,581	45.0%	$118,292
C-Shift Ambulance 1 Paramedic (240 Shift)	$27.01	1.00	2756	$74,449	$40.52	156	20	$7,132	$81,581	45.0%	$118,292
A-Shift Ambulance 2 Paramedic (240 Shift)	$27.01	1.00	2756	$74,449	$40.52	156	20	$7,132	$81,581	45.0%	$118,292
B-Shift Ambulance 2 Paramedic (240 Shift)	$27.01	1.00	2756	$74,449	$40.52	156	20	$7,132	$81,581	45.0%	$118,292
C-Shift Ambulance 2 Paramedic (240 Shift)	$27.01	1.00	2756	$74,449	$40.52	156	20	$7,132	$81,581	45.0%	$118,292
A-Shift Ambulance 3 Paramedic (240 Shift)	$27.01	1.00	2756	$74,449	$40.52	156	20	$7,132	$81,581	45.0%	$118,292
B-Shift Ambulance 3 Paramedic (240 Shift)	$27.01	1.00	2756	$74,449	$40.52	156	20	$7,132	$81,581	45.0%	$118,292
C-Shift Ambulance 3 Paramedic (240 Shift)	$27.01	1.00	2756	$74,449	$40.52	156	21	$7,172	$81,621	45.0%	$118,351
Floater Paramedic (240 Shift)	$27.01	1.00	2756	$74,449	$40.52	156	22	$7,213	$81,662	45.0%	$118,410
Ambulance Supv./Coordinator/Captain	$44.49	1.00	2080	$92,546	$66.74	104	21	$8,343	$100,889	45.0%	$146,289
Year 3 Total Personnel Expense											**$2,264,422**

Capital Costs

In addition to the personnel costs, NCFD would need to make capital purchases for the provision of ambulance services. For the purposes of this analysis, we will use annual depreciation estimates based on the predicted useful life of the capital equipment, but it should be noted that the initial costs are listed in the Capital Outlay column of the following table.

TABLE 5-12: NCFD EMS Capital Outlay and Capital Annualized Costs

	Capital Expense	Number Needed	Capital Outlay	Useful Life (Years)	Annual Expense
Ambulance	$350,000	4	$1,400,000	5	$280,000
Cardiac Monitor	$45,000	5	$225,000	7	$32,143
Auto-Load/Stretcher	$35,000	5	$175,000	7	$25,000
Radios	$3,500	12	$42,000	4	$10,500
Mobile Computers	$1,750	5	$8,750	2	$4,375
Total	-	-	**$1,850,750**	-	**$352,018**

Annual Operating Expenses

In addition to personnel and capital expenses, NCFD will have other expenses related to providing ambulance services. These include vehicle expenses such as fuel, maintenance, and tires, but also include additional medical supplies for the additional service level of ambulance provision. These are summarized below for Year 1 and escalated by a factor of 7 percent for subsequent years in our analysis.

TABLE 5-13: NCFD EMS Annualized Operating Costs

Annual Responses	7,137				
Annual Transports	4,782				
Category	**Annual Miles**	**Miles Per Gallon**	**Gallons**	**Price**	**Total**
Fuel	49,959	5	9,992	$5.20	$51,957
	Annual Miles	**Cost per Mile**			**Total**
Maintenance/Tires	49,959	$0.41			$20,483
	Per Response	**Responses**			**Total**
Medical Supplies	$21.00	7,137			$149,877
Equipment Maintenance	$3.50	7,137			$24,980
Total Operations Expense					$247,297

Financial Rollup – NCFD Operated Ambulance Service

Combining the potential revenue and expenses for a NCFD operated ambulance service, the net operating margin for services is summarized in the following table.

TABLE 5-14: NCFD EMS Net Operating Margin

Expense	Year 1	Year 2	Year 3
Personnel	$1,949,373	$2,046,431	$2,149,157
Vehicles/Equipment	$352,018	$369,619	$388,100
Operations	$247,297	$264,608	$283,130
Billing Fees	$130,241	$135,444	$135,444
Total	**$2,678,929**	**$2,816,102**	**$2,955,831**
Revenue	**$2,734,847**	**$2,894,254**	**$3,009,873**
Net From Operations	**$63,091**	**$83,355**	**$54,042**

Note that *operationally*, there is slight retained earnings each year, however, this amount decreases over time, as personnel and operational expenses increase at a faster rate than revenues.

However, AMR currently pays fees to the city for ambulance operations in the city. These fees consist of a $320,000 annual franchise fee, and $80,000 annually for renting space in fire station to house ambulances. It is likely that if NCFD assumed ambulance service provision, the fees would no longer be paid to the City. Adding the loss of $400,000 annually, the total financial impact to the city can be illustrated below.

TABLE 5-15: NCFD EMS Financial Impact

Expense	Year 1	Year 2	Year 3
Personnel	$1,949,373	$2,046,431	$2,149,157
Vehicles/Equipment	$352,018	$369,619	$388,100
Operations	$247,297	$264,608	$283,130
Billing Fees	$123,068	$130,241	$135,444
Total	**$2,671,756**	**$2,810,899**	**$2,955,831**
Revenue	$2,734,847	$2,894,254	$3,009,873
Net From Operations	**$63,091**	**$83,355**	**$54,042**
Loss of AMR Fees	**$ (400,000)**	**$ (400,000)**	**$ (400,000)**
Net to the City	**$ (336,909)**	**$ (316,645)**	**$ (345,958)**

Overall, there will be significant net financial losses to the city if NCFD assumes responsibility for providing ambulance service.

Based on the fact that AMR is providing services that are consistent with the contractual requirements, and the contract is contributing a net financial benefit to the city, it is our recommendation that the current method of ambulance service provision of using an outside contractor be retained, and that NCFD not assume responsibility for providing ambulance services to the city.

Recommendation:

- The current method of ambulance service provision of using an outside contractor should be retained, and the NCFD should not assume responsibility for providing ambulance services to the city. (Recommendation No. 9.)

AMR AMBULANCE SERVICE CONTRACT

AMR is currently operating under a contract with National City that was initially established in 2006. There have been significant changes in National City, as well as with ambulance service delivery over the past 15 years. Additionally, ambulance service providers within the southern San Diego region have changed and there may be other options for contracted ambulance service providers for National City.

Therefore, the city should negotiate with AMR for significant contracting updates or consider options for procuring enhanced service delivery models, either from the current or prospective ambulance service providers.

Recommendation:

- The city should negotiate with AMR for significant contracting updates or consider undergoing an RFP process to seek enhanced service delivery models, either from the current, or prospective ambulance service providers. (Recommendation No. 10.)

MOBILE INTEGRATED HEALTHCARE/COMMUNITY PARAMEDICINE

One of the fastest growing value-added service enhancements in EMS is the development of Mobile Integrated Healthcare / Community Paramedicine (MIH/CP) programs. MIH/CP is comprised of a suite of potential services that EMS could provide to fill gaps in the local healthcare delivery system. In essence, MIH/CP is intended to better manage the increasing EMS call volume and better align the types of care being provided with the needs of the patient. To be effective, MIH/CP is commonly accomplished in a collaborative approach with healthcare and social service agencies within the community.

We believe that there are opportunities for NCFD to use existing service capacity to collaborate with local stakeholders to implement an MIH/CP program to help manage the navigation of patients to treatment options more efficiently.

Recommendation:

- NCFD should engage in discussions with local and regional stakeholders to determine the potential benefits and impact of initiating a Mobile Integrated Healthcare / Community Paramedicine program. (Recommendation No. 11.)

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SECTION 6. FIRE EMERGENCY COMMUNICATIONS SYSTEM

CPSM was asked to review the current fire dispatching system and costs and provide a recommendation on brining this function in-house. The police department currently provides law enforcement dispatch services to the National City Police Department.

The NCFD currently has an agreement with San Diego City for the receiving of fire and medical related emergency calls as a secondary Public Safety Answering Point (PSAP), processing the call, and then dispatching the appropriate response assets as defined in the San Diego metro call algorithms. Key components of this the agreement include:

- Triaging medical calls to ensure the most appropriate resource is dispatched.
- Dispatching the closest available unit via Automatic Vehicle Location (AVL).
- Fire Station Alerting via CAD to station interface utilizing agency self-managed alerting system.
- Mobile Data Computer (MDC) or other mobile platform services such as mapping, live-routing, and loading agency self-managed building pre-plans.
- Records Management System (RMS) services for a CAD-to-Fire RMS interface.

Compensation to San Diego City for the dispatch service is subject to change each fiscal year of the contract and has a base “cost per call” dispatch fee for service. Dispatch fees are based on the adopted 911-Center budget for personnel services and prior year actuals for non-personnel expenditures (agency per-call volume).

National City currently has a five-year agreement with San Diego City for 911 Fire and EMS Dispatch services that became effective July 1, 2019. The agreement has a five-year extension clause. Year-to-year cost increases are based on any increase in call volume, with a five percent increase (plus or minus) service as the base fee escalator. Should NCFD’s call volume increase more than five percent, an increase in non-personnel expenditures will increase equal to the percent increase in call volume rounded to the nearest tenth. A five percent escalator applies if the call volume does not increase to a sum equaling five percent. The base agreement cost in 2019 was $361,050. The current fire dispatch agreement cost is $442,000.

CPSM visited the National City Police 911 Center and spoke with the Support Services Manager (SSM) who manages the center. In our conversation with the SSM, CPSM was informed that to bring fire dispatching into the National City 911 Center, the following would have to be added:

- Two 911 Center workstations.
  - Workstation with chair, radio, computer, computer monitors, and ancillary console equipment and interfaces, with a cost of $25,000 to $30,000 per workstation depending on availability of current city radio and computer equipment. Total estimated cost: $50,000 to$60,000. Annualized software support per console would be $500 to $1,000.
- The current CAD system would have to be upgraded with a fire module solution to include all GIS, AVL, RMS Fire Station Alerting, On-screen Tablet Incident Command with GIS and Pre-Plan function, and other interfaces NCFD has with San Diego City. Currently the National City 911 Center only has the module and licensing for a law enforcement module.

  - Cost for this is dependent on features and if the current CAD system can perform all the functions the NCFD currently utilizes through San Diego City. Quote from current vendor would be needed to establish start-up and annualized fire CAD solution costs.
- A priority medical dispatch solution would have to be purchased and added to the CAD to continue the efficiency of a prioritized medical dispatch the NCFD is currently operating under.
  - For four radio positions the initial start-up fee is estimated to be $85,000 to $95,000 and includes licensing for four positions, training software, case review software, on-site training, and ancillary components included in the system.
  - Annualized-licensing fees are estimated to be $21,000 to $25,000.
- Two dispatchers per shift (1 call taker, 1 radio position) would have to be added (total of eight personnel).
  - The current starting hourly rate for 911 dispatcher in National City is $27.74/hour. At 2,080 hours/year, the annualized salary is $57,699 (+40% benefits=$80,779). The cost of eight personnel is estimated to be $646,228.
  - The Priority Medical Dispatch solution typically requires a dedicated Quality Assurance staff member. Annualized salary for this position is estimated to be $88,857 (dispatcher salary + 40% benefits +10% for QA supervisory work).

Overall, to implement fire dispatch in the NCPD 911 Center, CPSM estimates it would cost:

- Startup fees, licensing, hardware: $135,000 to $155,000 + current CAD vendor quote to start up a fire CAD system software solution that can perform all functions the NCFD currently utilizes through San Diego City.
- Annualized licensing fees and salaries (no overtime included): $756,585 to $761,085.

During the on-site visit CPSM conducted in March 2022, CPSM visited the San Diego Metro Fire Dispatch Center and spoke the Center's senior staff, and also observed Center operations to include call-taking and dispatching. The center was adequately staffed (average of nine personnel on duty around the clock, including a uniform fire officer who serves as an operational liaison) and was performing all operations without incident. Based on our observations and discussion with NCFD and San Diego dispatch center staff, we view the San Diego center as a high-performing fire and EMS dispatch system.

Recommendation:

- Based on the estimated start-up and annualized costs, the annualized costs for fire dispatching through the National City Police 911 Center would be almost double the cost of the contract with San Diego Metro Fire Dispatch. CPSM strongly recommends that National City continue with the current agreement with San Diego City for fire dispatch services. CPSM does recommend, however, that National City work with San Diego City to reduce the current fire dispatch agreement costs to offset the costs the NCFD incurs as the de facto fire department for Paradise Hills, a situation that was demonstrated in the analysis. (Recommendation No. 12.)

SECTION 7. NCFD DATA ANALYSIS

This data analysis was prepared as a key component of the study of the National City Fire Department (NCFD), which provides fire protection service to the City of National City and surrounding communities. This analysis examines all calls for service between January 1, 2019, and December 31, 2020, as recorded in the regional computer-aided dispatch (CAD) system, with National Fire Incident Reporting System (NFIRS) data obtained from multiple sources. The analysis results are primarily presented for 2019; the results for 2020 are compared with those for the prior year in Attachment I.

This analysis is made up of five parts. The first part focuses on call types and dispatches. The second part explores the time spent and the workload of individual units. The third part presents an analysis of the busiest hours in the year studied. The fourth part provides a response time analysis of the studied agency's units. The fifth and final part analyzes the total fire loss.

The NCFD is a multi-service fire department, primarily serving an area of approximately 9.1 square miles and 63,000 residents. It provides fire, rescue, and paramedic first responder emergency medical services (EMS) to the National City Fire District including the City of National City, Lower Sweetwater Fire Protection District, the Port of San Diego, and surrounding communities. The department operates out of three fire stations and utilizes two frontline engines, one fire truck, one squad unit, and one command unit (battalion chief).

In 2019, the NCFD responded to 8,846 calls, of which 58 percent were EMS calls. The total combined workload (deployed time) for NCFD units was 3,105.6 hours. The average response time was 6.5 minutes. The 90th percentile response time was 8.7 minutes.

In 2020, the NCFD responded to 8,481 calls, of which 57 percent were EMS calls. The total combined workload (deployed time) for NCFD units was 3,895.8 hours. The average response time was 6.9 minutes. The 90th percentile response time was 9.3 minutes.

METHODOLOGY

In this report, CPSM analyzes calls and runs. A call is an emergency service request or incident. A run is a dispatch of a unit (i.e., a unit responding to a call). Thus, a call may include multiple runs.

We linked the CAD and NFIRS data sets. Then, we classified the calls in a series of steps. We first used the NFIRS incident type to identify canceled calls, motor vehicle accidents (MVA), and fire category call types. Calls identified by NFIRS as EMS calls along with any calls that lacked a matching NFIRS record were categorized using the CAD system's incident descriptions. We describe the method in Attachment VII.

The analysis focuses on calls that involved a responding NCFD unit. We examine aid received by other fire departments within National City in Table 7-1 and provide greater detail in Attachment IV. We analyze American Medical Response's (AMR) EMS calls within National City in a separate section.

We received records for a total of 23,415 calls in 2019 and 2020. We removed 3,150 calls that had no responding units. These calls were canceled, and their cancel reasons are summarized in Attachment VIII. We also removed 2,022 calls in National City where only AMR responded. In addition, we removed 21 calls outside National City that did not record a responding NCFD unit. Finally, we excluded one incident to which the NCFD's administrative unit was the sole responder; however, the workload of administrative units is documented in Attachment II. The remaining 18,221 calls included in this analysis are summarized in Table 7-1.

The main analysis in the following sections focuses on the 8,846 calls in 2019 where NCFD responded inside and outside of its fire district (see the highlighted rows in Table 7-1). All calls outside NCFD's fire district are identified as aid given. The detailed call types for aid given calls are presented in Attachment III. During the two years, NCFD received aid from other fire departments for incidents that occurred inside National City. This included 1,069 calls together with NCFD and 894 calls without a responding NCFD unit. Attachment IV provides further detail for aid received calls.

TABLE 7-1: Studied Calls by Location, Responding Agency, and Year

Location	Responding Agency	2019	2020	Total
Inside NCFD District	NCFD only	6,193	5,821	12,014
	NCFD and FD agencies	499	570	1,069
	NCFD Total	**6,692**	**6,391**	**13,083**
	Other FD agencies only	452	442	894
	Total	**7,144**	**6,833**	**13,977**
Outside NCFD District	**NCFD Total**	**2,154**	**2,090**	**4,244**
Total		**9,298**	**8,923**	**18,221**

Observations:

- Of all calls involving NCFD, 76 and 75 percent were inside the National City fire district in 2019 and 2020, respectively.
- Of all calls within the National City fire district, outside agencies responded independently to 6 percent of calls in both years.

AGGREGATE CALL TOTALS AND RUNS

In 2019, NCFD responded to 8,846 calls, of which, 6,692 occurred inside and 2,154 occurred outside the National City fire district, respectively. During the year, there were 31 structure fire calls and 125 outside fire calls within the National City fire district.

Calls by Type

Table 7-2 shows the number of calls that NCFD responded to by call type, average calls per day, and the percentage of calls that fall into each call type category. Figures 7-1 and 7-2 show the percentage of calls that fall into each EMS (Figure 7-1) and fire (Figure 7-2) type category.

TABLE 7-2: Calls by Type

Call Type	Total Calls	Calls per Day	Call Percentage
Breathing difficulty	722	2.0	8.2
Cardiac and stroke	779	2.1	8.8
Fall and injury	999	2.7	11.3
Illness and other	1,344	3.7	15.2
MVA	407	1.1	4.6
Overdose and psychiatric	151	0.4	1.7
Seizure and unconsciousness	738	2.0	8.3
EMS Total	**5,140**	**14.1**	**58.1**
False alarm	318	0.9	3.6
Good intent	56	0.2	0.6
Hazard	48	0.1	0.5
Outside fire	125	0.3	1.4
Public service	121	0.3	1.4
Structure fire	31	0.1	0.4
Fire Total	**699**	**1.9**	**7.9**
Canceled	853	2.3	9.6
Aid given	2,154	5.9	24.3
Total	**8,846**	**24.2**	**100.0**

FIGURE 7-1: EMS Calls by Type

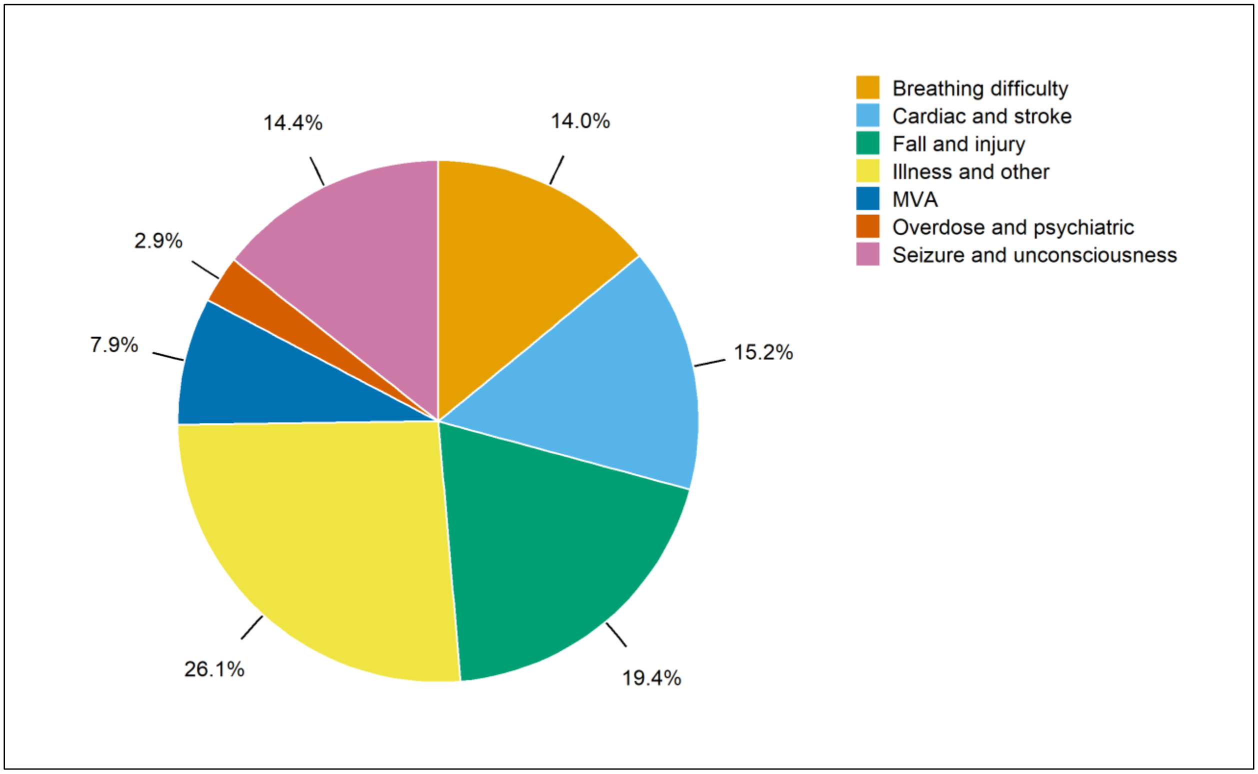
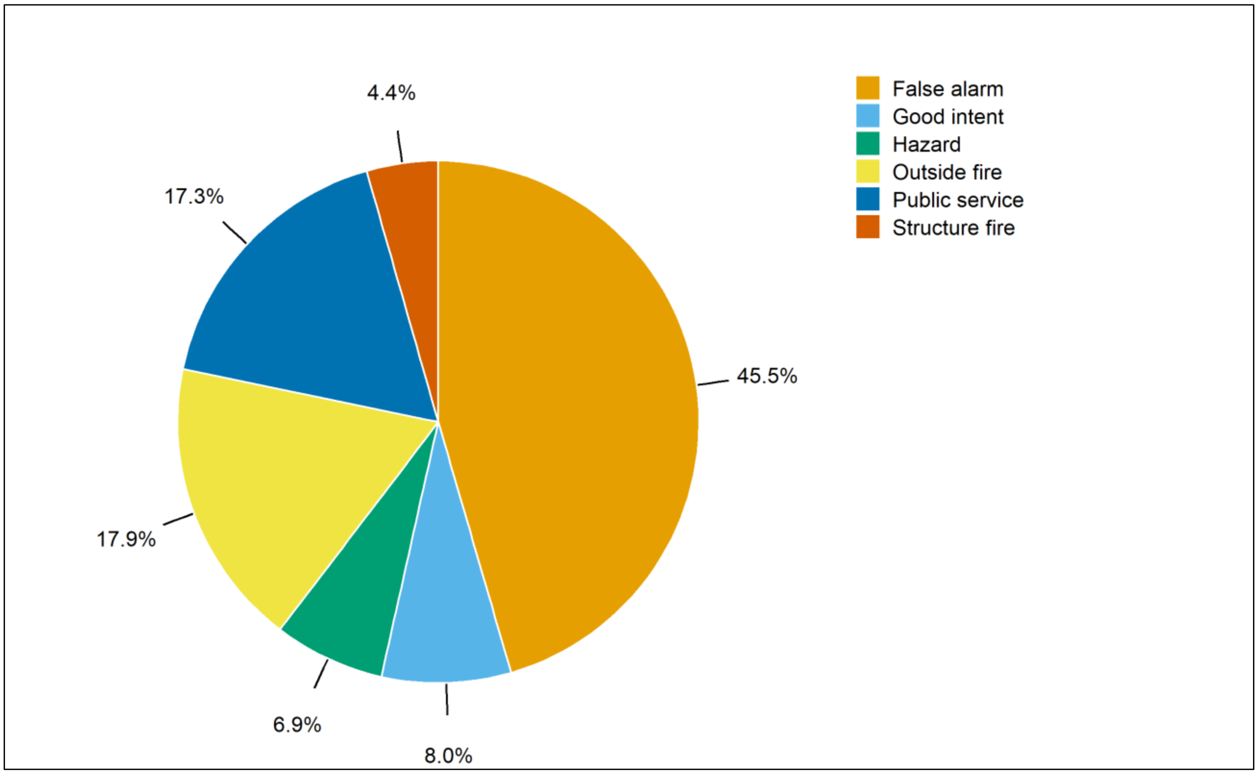


FIGURE 7-2: Fire Calls by Type



Observations:

- In 2019, NCFD responded to an average of 24.2 calls per day, including 2.3 canceled (10 percent) and 5.9 (24 percent) mutual aid calls per day.
- EMS calls for the year totaled 5,140 (58 percent of all calls), an average of 14.1 calls per day.
    - Illness and other calls were the largest category of EMS calls at 15 percent of total calls (26 percent of EMS calls).
    - Motor vehicle accidents (MVA) made up 5 percent of total calls (8 percent of EMS calls).
    - Cardiac and stroke calls made up 9 percent of total calls (15 percent of EMS calls).
- Fire calls for the year totaled 699 (8 percent of all calls), or an average of 1.9 calls per day.
    - False alarm calls made up 4 percent of total calls (45 percent of fire calls).
    - Structure and outside fire calls combined made up 2 percent of total calls (22 percent of fire calls), or an average of 0.4 calls per day, or one call every 2.3 days.

Calls by Type and Duration

The following table shows the duration of calls by type using four duration categories: less than 30 minutes, 30 minutes to one hour, one to two hours, and two or more hours.

TABLE 7-3: Calls by Type and Duration

Call Type	Less than 30 Minutes	30 Minutes to One Hour	One to Two Hours	Two or More Hours	Total
Breathing difficulty	633	84	5	0	722
Cardiac and stroke	662	81	34	2	779
Fall and injury	876	102	20	1	999
Illness and other	1,212	117	14	1	1,344
MVA	359	39	9	0	407
OD	136	13	2	0	151
Seizure and UNC	642	84	12	0	738
EMS Total	**4,520**	**520**	**96**	**4**	**5,140**
False alarm	289	25	4	0	318
Good intent	52	3	1	0	56
Hazard	34	12	2	0	48
Outside fire	84	29	10	2	125
Public service	95	18	5	3	121
Structure fire	18	5	4	4	31
Fire Total	**572**	**92**	**26**	**9**	**699**
Canceled	837	11	5	0	853
Aid given	1,883	210	44	17	2,154
Total	**7,812**	**833**	**171**	**30**	**8,846**

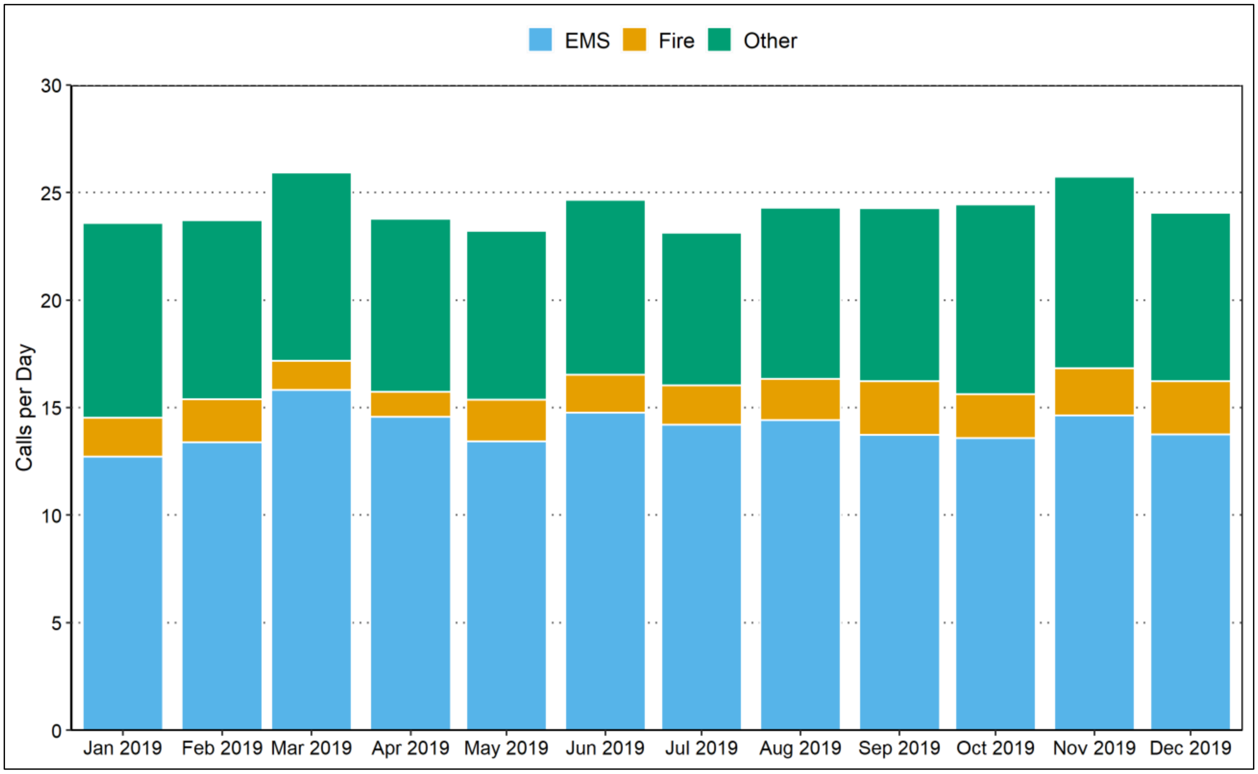
Observations:

- A total of 5,040 EMS calls (98.1 percent) lasted less than one hour, 96 EMS calls (1.9 percent) lasted one to two hours, and 4 EMS calls (0.1 percent) lasted two or more hours.
- A total of 664 fire calls (95.0 percent) lasted less than one hour, 26 fire calls (3.7 percent) lasted one to two hours, and 9 fire calls (1.3 percent) lasted two or more hours.
- A total of 113 outside fire calls (90.4 percent) lasted less than one hour, 10 outside fire calls (8.0 percent) lasted one to two hours, and two outside fire calls (1.6 percent) lasted two or more hours.
- A total of 23 structure fire calls (74.2 percent) lasted less than one hour, four structure fire calls (12.9 percent) lasted one to two hours, and four structure fire calls (12.9 percent) lasted two or more hours.

Average Calls by Month and Hour of Day

Figure 7-3 shows the monthly variation in the average daily number of calls handled by NCFD in 2019. Similarly, Figure 7-4 illustrates the average number of calls received each hour of the day.

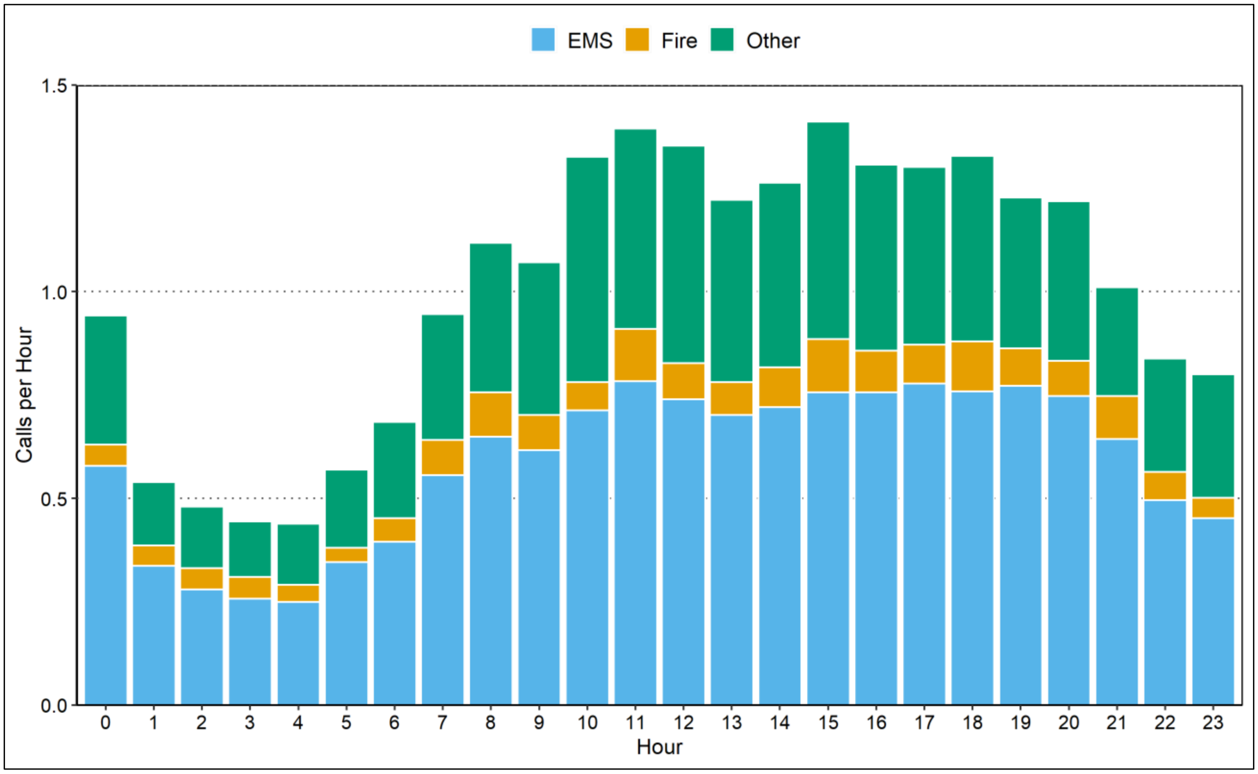
FIGURE 7-3: Calls per Day by Month



Observations:

- EMS calls per day ranged from 12.7 in January 2019 to 15.8 in March 2019.
- Fire calls per day ranged from 1.2 in April 2019 to 2.5 in September 2019.
- Other calls per day ranged from 7.1 in July 2019 to 9.1 in January 2019.
- Total calls per day ranged from 23.1 in July 2019 to 25.9 in March 2019.

FIGURE 7-4: Average Calls by Hour of Day



Observations:

- Average EMS calls per hour ranged from 0.25 between 4:00 a.m. and 5:00 a.m. to 0.78 between 11:00 a.m. and noon.
- Average fire calls per hour ranged from 0.04 between 5:00 a.m. and 6:00 a.m. to 0.13 between 3:00 p.m. and 4:00 p.m.
- Average other calls per hour ranged from 0.13 between 3:00 a.m. and 4:00 a.m. to 0.55 between 10:00 a.m. and 11:00 a.m.
- Average total calls per hour ranged from 0.44 between 4:00 a.m. and 5:00 a.m. to 1.41 between 3:00 p.m. and 4:00 p.m.

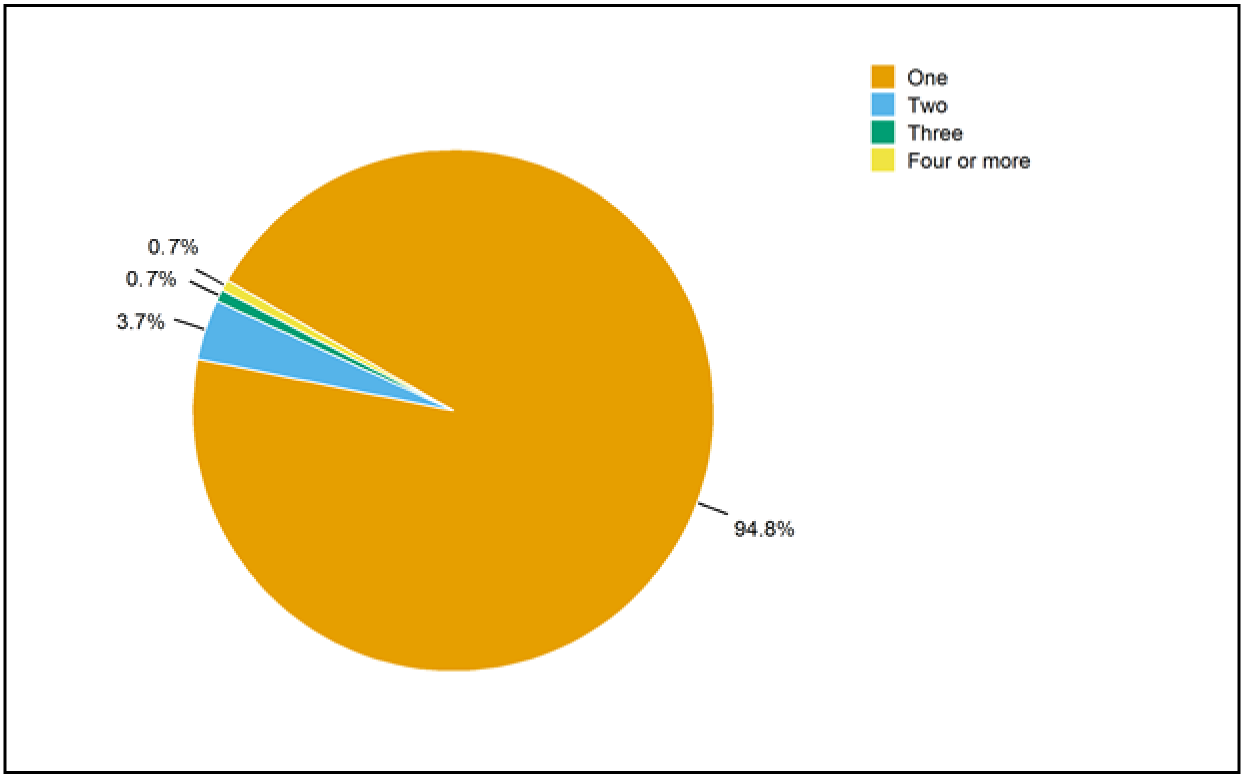
Units Arriving at Calls

In this section, we limit ourselves to calls where a unit from NCFD arrived. For this reason, there are fewer calls in Table 7-4 than in Table 7-2. For 2019, Table 7-4, along with Figure 7-5, detail the number of calls with one, two, three, and four or more NCFD units arriving at a call, broken down by call type.

TABLE 7-4: Calls by Call Type and Number of Arriving NCFD Units

Call Type	Number of Units				Total Calls
	One	Two	Three	Four or More	
Breathing difficulty	715	0	1	0	716
Cardiac and stroke	743	31	0	0	774
Fall and injury	975	3	0	0	978
Illness and other	1,298	22	1	1	1,322
MVA	319	61	12	1	393
Overdose and psychiatric	138	0	0	0	138
Seizure and unconsciousness	728	6	0	0	734
EMS Total	**4,916**	**123**	**14**	**2**	**5,055**
False alarm	233	63	4	5	305
Good intent	49	4	1	0	54
Hazard	41	2	3	2	48
Outside fire	92	14	9	9	124
Public service	111	6	1	2	120
Structure fire	6	5	2	18	31
Fire Total	**532**	**94**	**20**	**36**	**682**
Canceled	400	20	1	1	422
Aid given	1,513	53	23	14	1,603
Total	**7,361**	**290**	**58**	**53**	**7,762**
Percentage	**94.8**	**3.7**	**0.7**	**0.7**	**100.0**

FIGURE 7-5: Calls by Number of Arriving NCFD Units



Observations:

Overall

- On average, 1.1 units arrived at all calls; for 94.8 percent of calls, only one unit arrived.
- Overall, four or more units arrived at 0.7 percent of calls.

EMS

- On average, 1.0 units arrived per EMS call.
- For EMS calls, one unit arrived 97.3 percent of the time, two units arrived 2.4 percent of the time, three units arrived 0.3 percent of the time, and four units arrived less than 0.1 percent of the time.

Fire

- On average, 1.4 units arrived per fire call.
- For fire calls, one unit arrived 78.0 percent of the time, two units arrived 13.8 percent of the time, three units arrived 2.9 percent of the time, and four or more units arrived 5.3 percent of the time.
- For outside fire calls, three or more units arrived 14.5 percent of the time.
- For structure fire calls, three or more units arrived 64.5 percent of the time.

WORKLOAD: RUNS AND TOTAL TIME SPENT

The workload of NCFD's units is measured in two ways: runs and deployed time. The deployed time of a run is measured from the time a unit is dispatched through the time the unit is cleared. Because multiple units respond to some calls, there are more runs (10,239) than calls (8,846) and the average deployed time per run varies from the average duration per call.

Runs and Deployed Time – NCFD Units

Deployed time, also referred to as deployed hours, is the total deployment time of NCFD units deployed on all runs. Table 7-5 shows the total deployed time, both overall and broken down by type of run, for all non-administrative NCFD units in 2019. Table 7-6 and Figure 7-6 present the average deployed minutes by hour of day.

TABLE 7-5: Annual Runs and Deployed Time by Run Type

Run Type	Deployed Minutes per Run	Total Annual Hours	Percent of Total Hours	Deployed Minutes per Day	Total Annual Runs	Avg. Runs per Day
Breathing difficulty	20.0	251.2	8.1	41.3	753	2.1
Cardiac and stroke	22.2	315.3	10.2	51.8	851	2.3
Fall and injury	20.1	349.7	11.3	57.5	1,046	2.9
Illness and other	17.9	433.4	14.0	71.2	1,451	4.0
MVA	17.2	160.3	5.2	26.4	558	1.5
OD	18.4	47.5	1.5	7.8	155	0.4
Seizure and UNC	20.5	267.1	8.6	43.9	782	2.1
EMS Total	**19.6**	**1,824.5**	**58.8**	**299.9**	**5,596**	**15.3**
False alarm	13.5	103.1	3.3	16.9	459	1.3
Good intent	15.8	17.9	0.6	2.9	68	0.2
Hazard	17.5	22.5	0.7	3.7	77	0.2
Outside fire	25.1	89.3	2.9	14.7	213	0.6
Public service	23.0	57.5	1.9	9.4	150	0.4
Structure fire	41.1	81.5	2.6	13.4	119	0.3
Fire Total	**20.5**	**371.8**	**12.0**	**61.1**	**1,086**	**3.0**
Canceled	7.0	123.6	4.0	20.3	1,060	2.9
Aid given	18.9	785.7	25.3	129.2	2,497	6.8
Other Total	**15.3**	**909.3**	**29.3**	**149.5**	**3,557**	**9.7**
Total	**18.2**	**3,105.6**	**100.0**	**510.5**	**10,239**	**28.1**

Note: OD=Overdose and psychiatric; UNC=Unconsciousness.

Observations:

Overall

- The total deployed time for 2019 was 3,105.6 hours. The daily average was 8.5 hours for all NCFD units combined.
- There were 10,239 runs, including 1,060 runs dispatched for canceled calls and 2,497 runs dispatched for aid given calls. The daily average was 28.1 runs.

EMS

- EMS runs accounted for 59 percent of the total workload.
- The average deployed time for EMS runs was 19.6 minutes. The deployed time for all EMS runs averaged 5.0 hours per day.

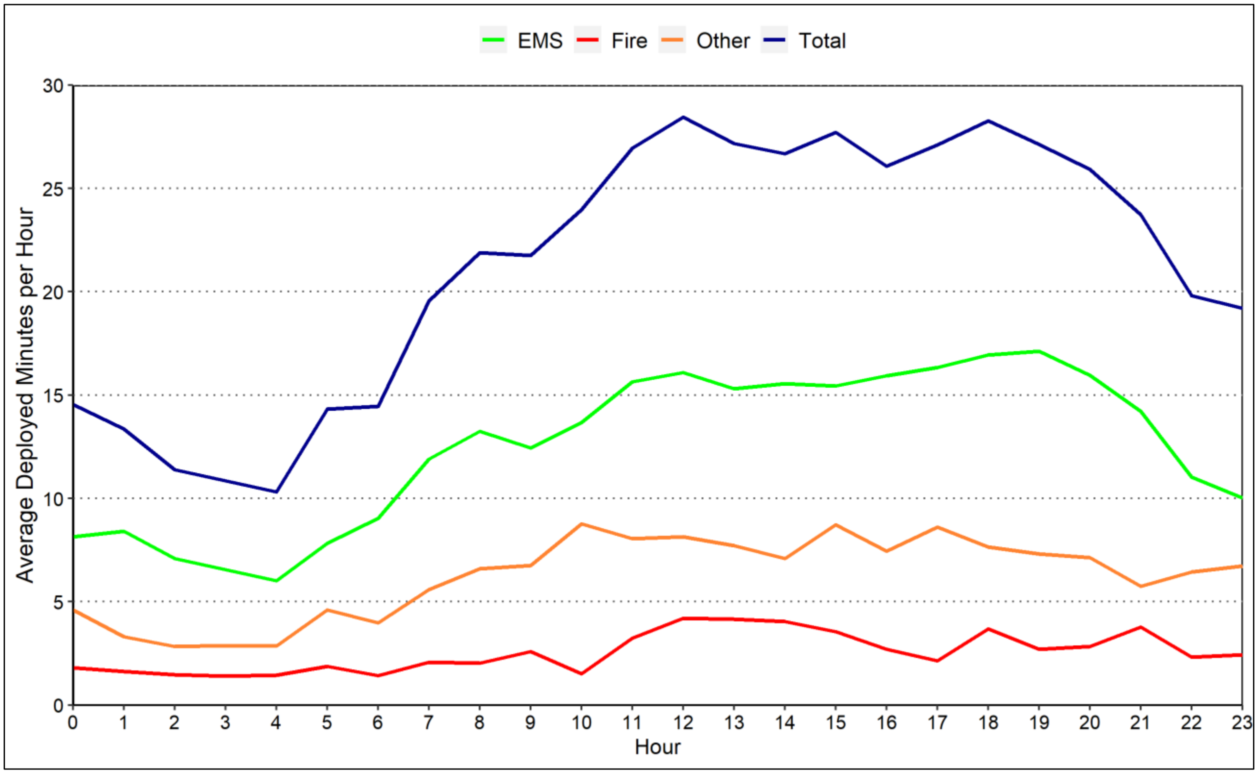
Fire

- Fire runs accounted for 12 percent of the total workload.
- The average deployed time for fire runs was 20.5 minutes. The deployed time for all fire runs averaged 1.0 minutes per day.
- There were 332 runs for structure and outside fire calls combined, with a total workload of 170.8 hours. This accounted for 5 percent of the total workload.
- The average deployed time for outside fire runs was 25.1 minutes per run, and the average deployed time for structure fire runs was 41.1 minutes per run.

TABLE 7-6: Deployed Minutes by Hour of Day

Hour	EMS	Fire	Other	Total
0	8.1	1.8	4.6	14.5
1	8.4	1.6	3.3	13.4
2	7.1	1.5	2.8	11.4
3	6.6	1.4	2.9	10.8
4	6.0	1.4	2.9	10.3
5	7.8	1.9	4.6	14.3
6	9.0	1.4	4.0	14.4
7	11.9	2.1	5.6	19.6
8	13.2	2.0	6.6	21.9
9	12.4	2.6	6.8	21.8
10	13.7	1.5	8.8	24.0
11	15.6	3.2	8.1	26.9
12	16.1	4.2	8.2	28.4
13	15.3	4.2	7.7	27.2
14	15.6	4.1	7.1	26.7
15	15.4	3.6	8.7	27.7
16	15.9	2.7	7.4	26.1
17	16.3	2.2	8.6	27.1
18	16.9	3.7	7.7	28.3
19	17.1	2.7	7.3	27.1
20	16.0	2.8	7.1	25.9
21	14.2	3.8	5.8	23.7
22	11.0	2.3	6.4	19.8
23	10.0	2.4	6.7	19.2
Daily Avg.	**299.9**	**61.1**	**149.5**	**510.5**

FIGURE 7-6: Average Deployed Minutes by Hour of Day



Observations:

- Hourly deployed time was highest during the day from 11:00 a.m. to 9:00 p.m., averaging more than 26 minutes per hour.
- Average deployed time peaked between noon and 1:00 p.m., averaging 28.4 minutes.
- Average deployed time was lowest between 4:00 a.m. and 5:00 a.m., averaging 10.3 minutes.

Workload by Unit

Table 7-7 provides a summary of each NCFD unit's workload for the year. Tables 7-8 and 7-9 provide a more detailed view of workload, showing each unit's runs broken out by run type (Table 7-8) and its daily average deployed time by run type (Table 7-9).

TABLE 7-7: Workload by Unit

Station	Unit	Unit Type	Deployed Minutes per Run	Total Hours	Total Pct.	Deployed Minutes per Day	Total Runs	Runs per Day
31	NCE31	Engine	18.1	915.3	29.5	150.5	3,031	8.3
	NCE231	Engine	12.3	0.6	0.0	0.1	3	0.0
	Total		**18.1**	**915.9**	**29.5**	**150.6**	**3,034**	**8.3**
33	NCSQ33	Squad	**20.2**	**742.2**	**23.9**	**122.0**	**2,201**	**6.0**
34	B57	Battalion	18.9	145.2	4.7	23.9	462	1.3
	NCE34	Engine	17.4	1,011.5	32.6	166.3	3,495	9.6
	NCE234	Engine	648.0	10.8	0.3	1.8	1	0.0
	NCT34	Truck	16.1	280.0	9.0	46.0	1,046	2.9
	Total		**17.4**	**1,447.5**	**46.6**	**237.9**	**5,004**	**13.7**
Total			**18.2**	**3,105.6**	**100.0**	**510.5**	**10,239**	**28.1**

TABLE 7-8: Total Runs by Run Type and Unit

Station	Unit	EMS	False Alarm	Good Intent	Hazard	Outside Fire	Public Service	Structure Fire	Cancel	Aid Given	Total
31	NCE31	1,279	101	27	21	68	31	26	279	1,199	3,031
	NCE231	2	0	0	0	0	0	0	1	0	3
	Total	**1,281**	**101**	**27**	**21**	**68**	**31**	**26**	**280**	**1,199**	**3,034**
33	NCSQ33	**1,773**	**76**	**12**	**13**	**29**	**37**	**23**	**229**	**9**	**2,201**
34	B57	33	12	3	6	28	5	22	17	336	462
	NCE34	2,008	181	22	29	65	60	22	428	680	3,495
	NCE234	0	0	0	0	0	0	0	0	1	1
	NCT34	501	89	4	8	23	17	26	106	272	1,046
	Total	**2,542**	**282**	**29**	**43**	**116**	**82**	**70**	**551**	**1,289**	**5,004**
Total		**5,596**	**459**	**68**	**77**	**213**	**150**	**119**	**1,060**	**2,497**	**10,239**

Note: See Table 7-7 for unit type.

TABLE 7-9: Deployed Minutes per Day by Run Type and Unit

Station	Unit	EMS	False Alarm	Good Intent	Hazard	Outside Fire	Public Service	Structure Fire	Cancel	Aid Given	Total
31	NCE31	66.1	3.3	1.1	1.0	4.8	1.3	2.9	4.7	65.1	150.5
	NCE231	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
	Total	**66.2**	**3.3**	**1.1**	**1.0**	**4.8**	**1.3**	**2.9**	**4.7**	**65.1**	**150.6**
33	NCSQ33	**107.0**	**2.6**	**0.3**	**0.7**	**1.8**	**1.7**	**2.3**	**5.4**	**0.2**	**122.0**
34	B57	1.4	0.3	0.2	0.2	1.5	0.9	2.0	0.3	17.1	23.9
	NCE34	104.1	7.7	1.1	1.4	5.0	4.3	2.9	8.1	31.7	166.3
	NCE234	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	1.8
	NCT34	21.2	3.0	0.3	0.4	1.5	1.3	3.3	1.8	13.3	46.0
	Total	**126.7**	**11.0**	**1.5**	**2.0**	**8.1**	**6.4**	**8.2**	**10.2**	**63.9**	**237.9**
Total		**299.9**	**16.9**	**2.9**	**3.7**	**14.7**	**9.4**	**13.4**	**20.3**	**129.2**	**510.5**

Note: See Table 7-7 for unit type.

Observations:

- Station 34 made the most runs (5,004 or an average of 13.7 runs per day) and had the highest total annual deployed time (1,447.5 or an average of 4.0 hours per day).
  - EMS calls accounted for 51 percent of runs and 53 percent of total deployed time.
  - Outside and structure fire calls accounted for 4 percent of runs and 7 percent of total deployed time.
- Station 31 made the second-most runs (3,034 or an average of 8.3 runs per day) and had the second-highest total annual deployed time (915.9 or an average of 2.5 hours per day).
  - EMS calls accounted for 42 percent of runs and 44 percent of total deployed time.
  - Outside and structure fire calls accounted for 3 percent of runs and 5 percent of total deployed time.
- Unit NCE34 made the most runs (3,495 or an average of 9.6 runs per day) and had the highest total annual deployed time (1,011.5 or an average of 2.8 hours per day).
  - EMS calls accounted for 57 percent of runs and 63 percent of total deployed time.
  - Outside and structure fire calls accounted for 2 percent of runs and 5 percent of total deployed time.
- Unit NCE31 made the second most runs (3,031 or an average of 8.3 runs per day) and had the second-highest total annual deployed time (915.3 or an average of 2.5 hours per day).
  - EMS calls accounted for 42 percent of runs and 44 percent of total deployed time.
  - Outside and structure fire calls accounted for 3 percent of runs and 5 percent of total deployed time.

Workload by Fire District

Table 7-10 breaks down the agency's workload by fire district. Table 7-11 provides further detail for the workload associated with structure and outside fire calls. Table 7-11 includes the aid given runs to outside and structure fires outside the National City fire district.

TABLE 7-10: Annual Workload by Fire District

District	Calls	Pct. Annual Calls	Runs	Runs Per Day	Deployed Minutes Per Run	Annual Hours	Pct. Annual Work	Deployed Minutes Per Day
National City	6,692	75.7	7,742	21.2	18.0	2,319.9	74.7	381.3
San Diego City	1,323	15.0	1,495	4.1	19.8	494.5	15.9	81.3
Chula Vista	699	7.9	864	2.4	15.6	225.1	7.2	37.0
San Diego County	101	1.1	105	0.3	32.4	56.8	1.8	9.3
Imperial Beach	21	0.2	21	0.1	13.0	4.5	0.1	0.7
Coronado	7	0.1	9	0.0	29.0	4.4	0.1	0.7
Lemon Grove	3	0.0	3	0.0	9.3	0.5	0.0	0.1
Total	**8,846**	**100.0**	**10,239**	**28.1**	**18.2**	**3,105.6**	**100.0**	**510.5**

TABLE 7-11: Structure and Outside Fire Runs by Fire District

District	Structure Fire Runs	Structure Fires Deployed Min. per Run	Outside Fire Runs	Outside Fires Deployed Min. per Run	Hours for Structure and Outside Fires	Pct. of Structure and Outside Fire Workload
National City	119	41.1	213	25.1	170.8	51.3
San Diego	122	22.9	44	62.1	92.2	27.7
Chula Vista	75	34.3	36	22.0	56.1	16.8
Imperial Beach	12	17.6	0	NA	3.5	1.0
San Diego County	3	53.9	3	78.6	6.6	2.0
Coronado	2	119.0	0	NA	4.0	1.2
Total	**333**	**32.7**	**296**	**30.8**	**333.2**	**100.0**

Note: All runs outside the National City fire district were mutual aid. The runs within National City match the number of runs described in Table 7-5.

Observations:

National City Fire

- There were 6,692 calls or 76 percent of the total calls.
- There were 7,742 runs or 21.2 runs per day.
- Total deployed time for the year was 2,319.9 hours or 75 percent of the total annual workload. The daily average was 381.3 minutes for all units combined.

San Diego Fire

- There were 1,323 calls or 15 percent of the total calls.
- There were 1,495 runs or 4.1 runs per day.
- Total deployed time for the year was 494.5 hours or 16 percent of the total annual workload. The daily average was 81.3 minutes for all units combined.

Chula Vista Fire

- There were 699 calls or 8 percent of the total calls.
- There were 864 runs or 2.4 runs per day.
- Total deployed time for the year was 225.1 hours or seven percent of the total annual workload. The daily average was 37.0 minutes for all units combined.

Other

- There were 132 calls or one percent of the total calls.
- There were 138 runs or 0.4 runs per day.
- Total deployed time for the year was 66.2 hours or two percent of the total annual workload. The daily average was 10.9 minutes for all units combined.

ANALYSIS OF BUSIEST HOURS

In this analysis, we included all 9,298 calls that occurred inside and outside National City's fire district in 2019. For these calls, there is significant variability in the number of calls from hour to hour. One special concern relates to the resources available for hours with the heaviest workload. We tabulated the data for each of the 8,760 hours in the year. Table 7-12 shows the number of hours in the year in which there were zero to six and more calls during the hour. Table 7-13 shows the ten one-hour intervals which had the most calls during the year. Table 7-14 examines the number of times a call overlapped with another call in each station area in 2019.

TABLE 7-12: Frequency Distribution of the Number of Calls by Year

Calls in an Hour	Frequency	Percentage
0	3,297	37.6
1	2,938	33.5
2	1,641	18.7
3	582	6.6
4	217	2.5
5	62	0.7
6+	23	0.3
Total	**8,760**	**100.0**

TABLE 7-13: Top Ten Hours with the Most Calls Received

Hour	Number of Calls	Number of Runs	Total Deployed Hours
5/14/2019, midnight to 1:00 a.m.	10	10	3.1
3/5/2019, midnight to 1:00 a.m.	9	12	2.2
11/28/2019, 11:00 a.m. to noon	8	19	2.8
7/20/2019, 2:00 p.m. to 3:00 p.m.	8	13	4.9
6/3/2019, midnight to 1:00 a.m.	8	11	1.7
10/31/2019, 11:00 a.m. to noon	8	10	1.0
11/15/2019, 2:00 p.m. to 3:00 p.m.	7	7	2.0
4/12/2019, 2:00 p.m. to 3:00 p.m.	6	10	2.4
1/8/2019, 3:00 p.m. to 4:00 p.m.	6	9	2.6
12/28/2019, 3:00 p.m. to 4:00 p.m.	6	9	2.4

Note: Total deployed hours is a measure of the total time spent responding to calls received in the hour. The deployed time from these calls may extend into the next hour or hours. The number of runs and deployed hours includes all units from the studied agencies. Here we considered units from all responding agencies

TABLE 7-14: Frequency of Overlapping Calls

Station	Scenario	Number of Calls	Percent of All Calls	Total Hours
31	No overlapped call	2,862	87.1	995.8
	Overlapped with one call	380	11.6	65.9
	Overlapped with two calls	41	1.2	4.8
	Overlapped with three calls	3	0.1	0.5
34	No overlapped call	3,289	85.3	1,048.1
	Overlapped with one call	505	13.1	87.6
	Overlapped with two calls	55	1.4	7.6
	Overlapped with three calls	7	0.2	0.6
	Overlapped with four calls	2	0.1	0.0
Outside	No overlapped call	1,968	91.4	631.1
	Overlapped with one call	173	8.0	34.3
	Overlapped with two calls	13	0.6	1.3

Table 7-15 examines each NCFD station's availability to respond to calls within its first due area. At the same time, it focuses on calls where at least one unit (NCFD or another FD agency) eventually arrived and ignores calls where no unit arrived. While there were 7,144 calls within National City's fire district (See Table 7-1, the fifth row of the "Total" column), there were 573 calls without an arriving unit.

TABLE 7-15: NCFD Station Availability to Respond to Calls

Station	Calls in Area	First Due Responded	First Due Arrived	First Due First	Percent Responded	Percent Arrived	Percent First
31	3,063	1,430	1,347	1,270	46.7	44.0	41.5
34	3,508	2,700	2,639	2,588	77.0	75.2	73.8
Total	**6,571**	**4,130**	**3,986**	**3,858**	**62.9**	**60.7**	**58.7**

Note: For each station, we count the number of calls occurring within its first due area. Then, we count the number of calls to where at least one unit arrived. Next, we focus on units from the first due station to see if any of its units responded, arrived, or arrived first.

Observations:

- During 23 hours (0.3 percent of all hours), six or more calls occurred; in other words, the department responded to six or more calls in an hour roughly once every 16 days.
  - The highest number of calls to occur in an hour was 10, which happened once.
- The hour with the most calls was from midnight to 1:00 a.m. on May 14, 2019. The hour's 10 calls involved 10 individual dispatches resulting in 3.1 hours of deployed time. These 10 calls included three cardiac and stroke calls, two illness and other calls, two MVA calls, one breathing difficulty call, one fall and injury call, and one seizure and unconsciousness call.

RESPONSE TIME

In this part of the analysis, we present response time statistics for different call types. We separate response time into its identifiable components. *Dispatch time* is the difference between the time a call is received and the time a unit is dispatched. Dispatch time includes call processing time, which is the time required to determine the nature of the emergency and the types of resources to dispatch. *Turnout time* is the difference between dispatch time and the time a unit is en route to a call's location. *Travel time* is the difference between the time en route and arrival on scene. *Response time* is the total time elapsed between receiving a call to arriving on scene.

In this analysis, we included all calls within the National City fire district to which at least one non-administrative NCFD unit arrived. Units from non-NCFD agencies were also included. Also, calls with a total response time exceeding 30 minutes were excluded. In addition, non-emergency calls were excluded. Finally, we focused on units that had complete time stamps, that is, units with all components recorded, so that we could calculate each segment of response time.

Based on the methodology above, for 8,846 calls in 2019, we excluded 2,154 aid given calls (outside National City), 853 canceled calls, one non-emergency call, 43 calls where no units recorded a valid on-scene time, 85 calls with a total response time exceeding 30 minutes, and 56 calls where one or more segments of the first arriving unit's response time could not be calculated due to missing or faulty data. As a result, in this section, a total of 5,654 calls are included in the analysis. Using the same method, we obtained 5,364 calls for the same analysis for 2020. 2020's response time analysis is compared with that of 2019 in Attachment I.

Response Time by Type of Call

Table 7-16 breaks down the average dispatch, turnout, travel, and total response times by call type for all 2019 calls in the National City fire district, and Table 7-17 does the same for 90th percentile response times. A 90th percentile means that 90 percent of calls had response times at or below that number. For example, Table 7-17 shows an overall 90th percentile response time of 8.7 minutes, which means that 90 percent of the time, a call had a response time of no more than 8.7 minutes. Figures 7-7 and 7-8 illustrate the same information.

TABLE 7-16: Average Response Time of First Arriving Unit, by Call Type

Call Type	Time in Minutes				Number of Calls
	Dispatch	Turnout	Travel	Total	
Breathing difficulty	1.8	1.1	3.2	6.1	703
Cardiac and stroke	2.1	1.0	3.1	6.2	762
Fall and injury	2.1	1.0	3.5	6.7	979
Illness and other	2.2	1.0	3.3	6.6	1,300
MVA	1.2	1.1	3.7	6.0	377
Overdose and psychiatric	2.3	1.1	4.2	7.5	145
Seizure and unconsciousness	2.0	1.0	3.2	6.2	725
EMS Total	**2.0**	**1.0**	**3.3**	**6.4**	**4,991**
False alarm	1.7	1.2	3.5	6.4	300
Good intent	2.3	1.1	5.3	8.7	51
Hazard	1.7	1.2	4.0	6.9	47
Outside fire	1.7	1.3	3.6	6.5	123
Public service	2.3	1.1	4.1	7.5	112
Structure fire	2.2	1.0	2.6	5.8	30
Fire Total	**1.9**	**1.2**	**3.7**	**6.8**	**663**
Total	**2.0**	**1.1**	**3.4**	**6.5**	**5,654**

FIGURE 7-7: Average Response Time of First Arriving Unit, by Call Type – EMS

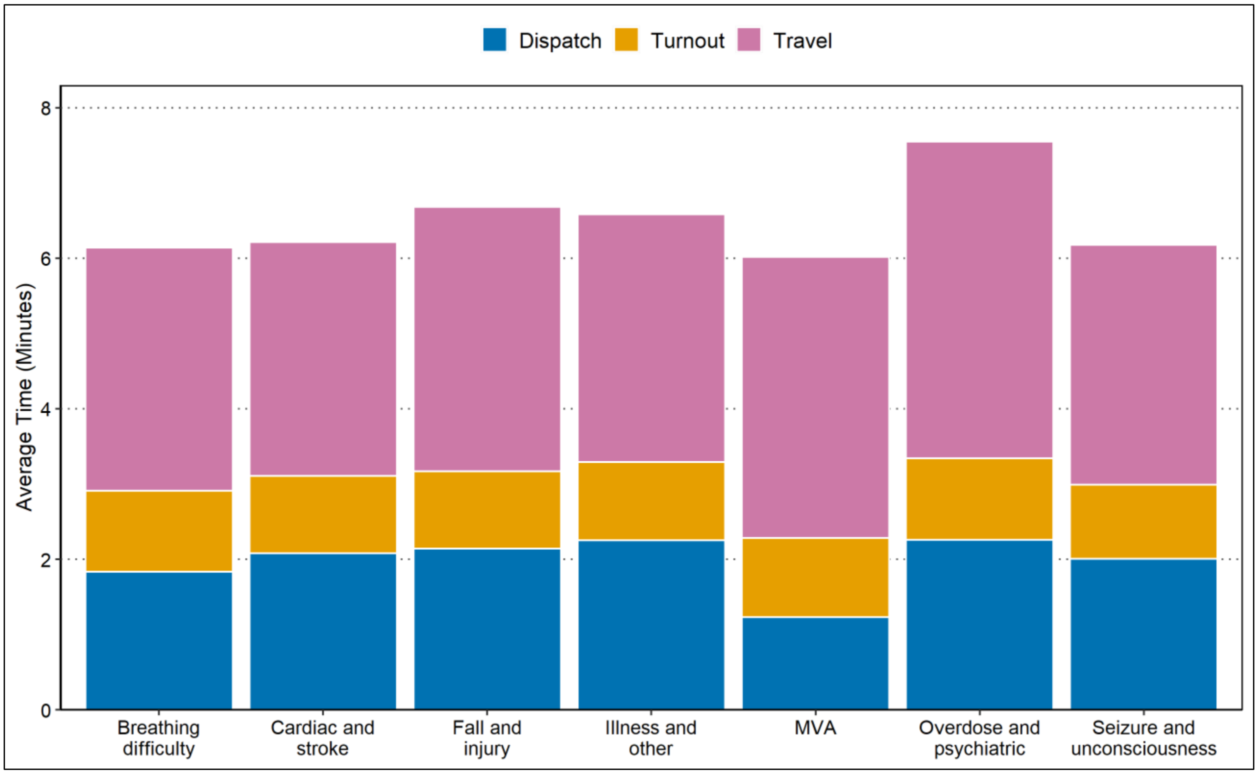


FIGURE 7-8: Average Response Time of First Arriving Unit, by Call Type – Fire

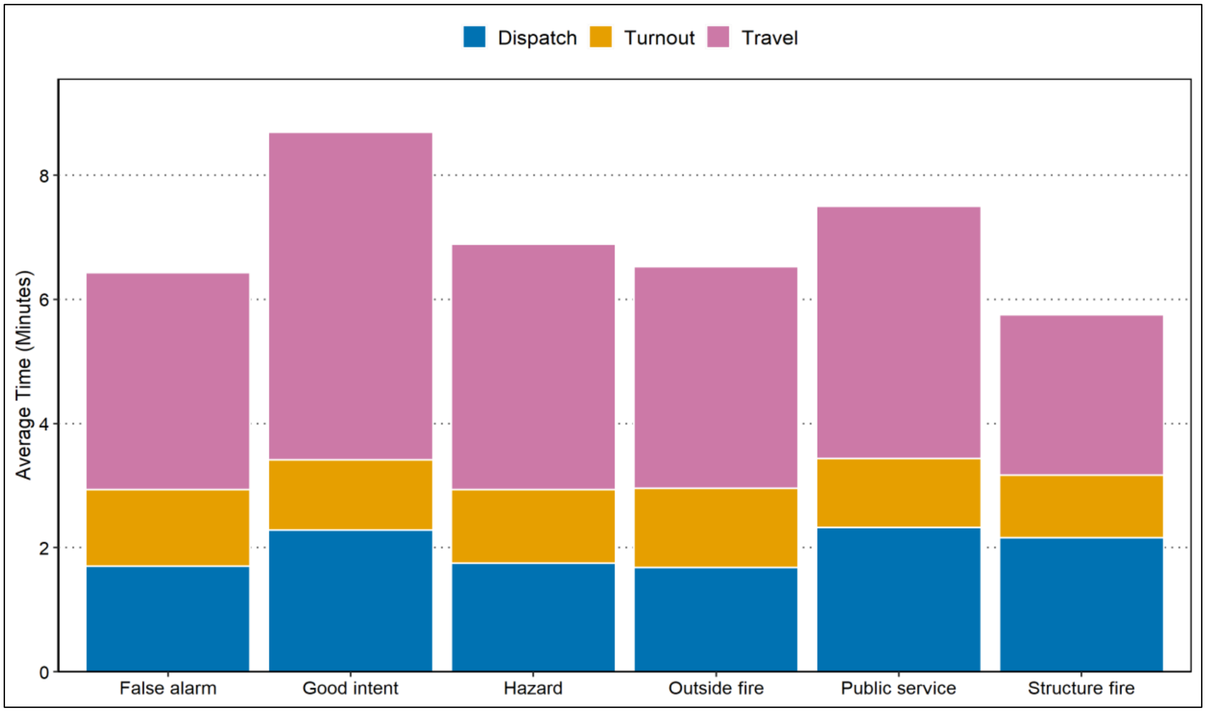


TABLE 7-17: 90th Percentile Response Time of Average Response Time of First Arriving Unit, by Call Type

Call Type	Time in Minutes				Number of Calls
	Dispatch	Turnout	Travel	Total	
Breathing difficulty	3.1	1.9	4.8	8.0	703
Cardiac and stroke	3.4	1.8	4.8	8.3	762
Fall and injury	3.6	1.8	5.4	8.8	979
Illness and other	3.8	1.8	5.1	8.9	1,300
MVA	2.1	1.8	5.9	8.5	377
Overdose and psychiatric	3.9	1.8	6.8	10.4	145
Seizure and unconsciousness	3.5	1.7	4.8	8.2	725
EMS Total	**3.5**	**1.8**	**5.2**	**8.6**	**4,991**
False alarm	2.7	2.1	5.5	8.7	300
Good intent	4.7	1.7	10.6	13.8	51
Hazard	2.7	2.0	5.8	10.8	47
Outside fire	2.5	2.0	5.6	9.3	123
Public service	3.5	2.0	6.6	10.8	112
Structure fire	3.3	1.7	4.4	7.7	30
Fire Total	**3.2**	**2.0**	**6.1**	**9.7**	**663**
Total	**3.5**	**1.8**	**5.3**	**8.7**	**5,654**

Observations:

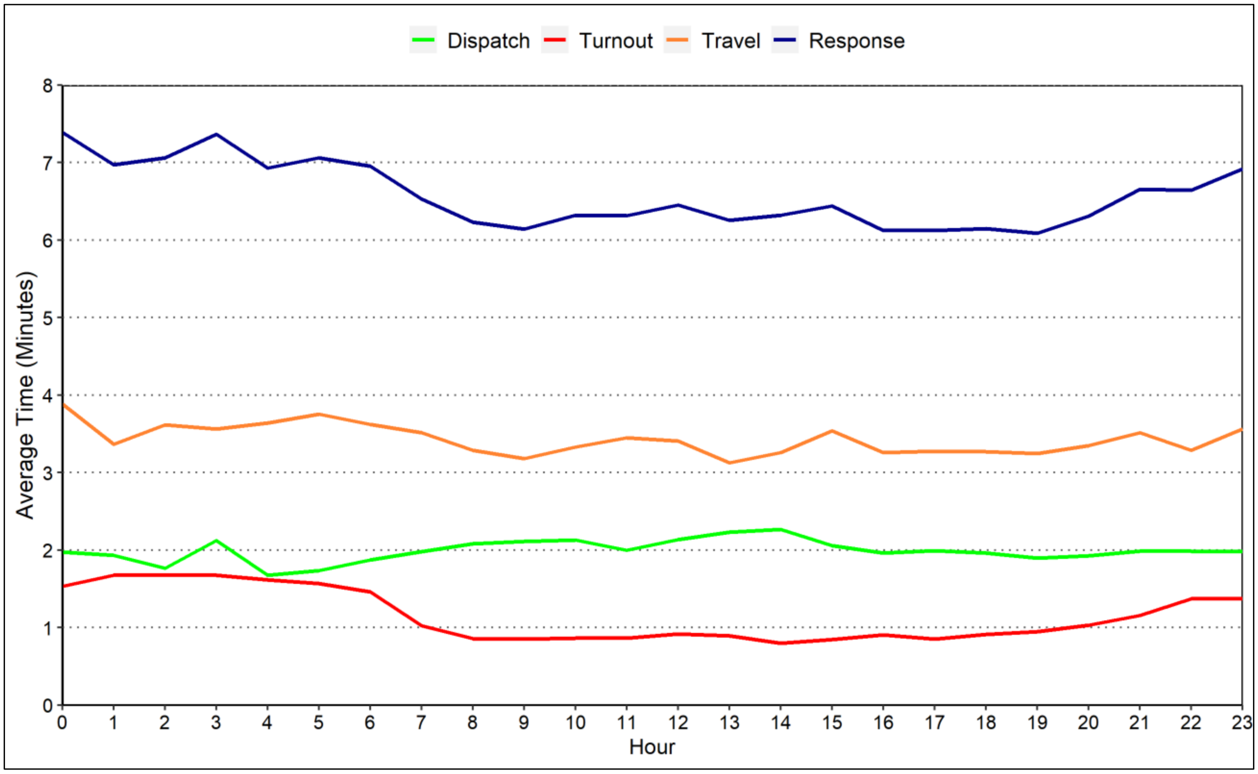
- The average dispatch time was 2.0 minutes.
- The average turnout time was 1.1 minutes.
- The average travel time was 3.4 minutes.
- The average total response time was 6.5 minutes.
- The average response time was 6.4 minutes for EMS calls and 6.8 minutes for fire calls.
- The average response time was 6.5 minutes for outside fires and 5.8 minutes for structure fires.
- The 90th percentile dispatch time was 3.5 minutes.
- The 90th percentile turnout time was 1.8 minutes.
- The 90th percentile travel time was 5.3 minutes.
- The 90th percentile total response time was 8.7 minutes.
- The 90th percentile response time was 8.6 minutes for EMS calls and 9.7 minutes for fire calls.
- The 90th percentile response time was 9.3 minutes for outside fires and 7.7 minutes for structure fires.

Table 7-18 shows the average response time by the time of day. The table also shows 90th percentile response times. Figure 7-9 shows the average response time by the time of day.

TABLE 7-18: Average and 90th Percentile Response Time of First Arriving Unit, by Hour of Day

Hour	Dispatch	Turnout	Travel	Response Time	90th Percentile Response Time	Number of Calls
0	2.0	1.5	3.9	7.4	9.6	152
1	1.9	1.7	3.4	7.0	9.2	138
2	1.8	1.7	3.6	7.1	9.0	120
3	2.1	1.7	3.6	7.4	9.4	111
4	1.7	1.6	3.6	6.9	8.6	105
5	1.7	1.6	3.8	7.1	8.6	139
6	1.9	1.5	3.6	7.0	9.1	164
7	2.0	1.0	3.5	6.5	8.8	226
8	2.1	0.9	3.3	6.2	8.6	272
9	2.1	0.9	3.2	6.1	8.4	246
10	2.1	0.9	3.3	6.3	8.2	280
11	2.0	0.9	3.4	6.3	8.8	324
12	2.1	0.9	3.4	6.5	8.8	298
13	2.2	0.9	3.1	6.3	8.4	281
14	2.3	0.8	3.3	6.3	8.8	290
15	2.1	0.8	3.5	6.4	9.2	314
6	2.0	0.9	3.3	6.1	8.4	309
17	2.0	0.9	3.3	6.1	8.2	312
18	2.0	0.9	3.3	6.1	8.3	316
19	1.9	0.9	3.2	6.1	8.3	307
20	1.9	1.0	3.3	6.3	8.3	297
21	2.0	1.2	3.5	6.7	8.8	270
22	2.0	1.4	3.3	6.6	8.8	203
23	2.0	1.4	3.6	6.9	9.1	180
Total	**2.0**	**1.1**	**3.4**	**6.5**	**8.7**	**5,654**

FIGURE 7-9: Average Response Time of First Arriving Unit, by Hour of Day



Observations:

- Average dispatch time was between 1.7 minutes (4:00 a.m. to 5:00 a.m.) and 2.3 minutes (2:00 p.m. to 3:00 p.m.).
- Average turnout time was between 0.8 minutes (2:00 p.m. to 3:00 p.m.) and 1.7 minutes (2:00 a.m. to 3:00 a.m.).
- Average travel time was between 3.1 minutes (1:00 p.m. to 2:00 p.m.) and 3.9 minutes (midnight to 1:00 a.m.).
- Average response time was between 6.1 minutes (7:00 p.m. to 8:00 p.m.) and 7.4 minutes (midnight to 1:00 a.m.).
- The 90th percentile response time was between 8.2 minutes (10:00 a.m. to 11:00 a.m.) and 9.6 minutes (midnight to 1:00 a.m.).

Response Time Distribution

Here, we present a more detailed look at how response times to calls are distributed. The cumulative distribution of total response time for the first arriving unit to EMS calls is shown in Figure 7-10 and Table 7-19. Figure 7-10 shows response times for the first arriving unit to EMS calls as a frequency distribution in whole-minute increments, and Figure 7-11 shows the same for the first arriving unit to outside and structure fire calls.

The cumulative percentages here are read in the same way as a percentile. In Figure 7-10, the 90th percentile of 8.6 minutes means that 90 percent of EMS calls had a response time of 8.6 minutes or less. In Table 7-19, the cumulative percentage of 84.7, for example, means that 84.7 percent of EMS calls had a response time under 8 minutes.

FIGURE 7-10: Cumulative Distribution of Response Time – First Arriving Unit – EMS

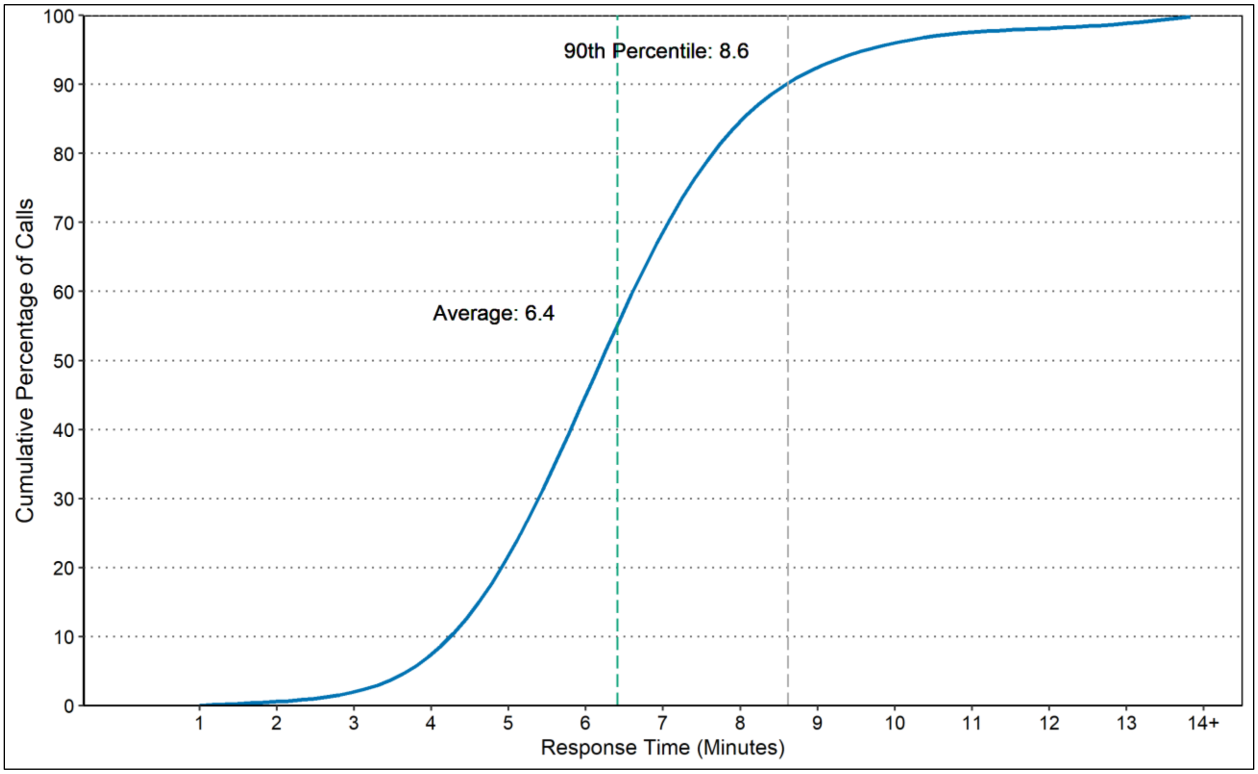


FIGURE 7-11: Cumulative Distribution of Response Timer – First Arriving Unit – Outside and Structure Fires

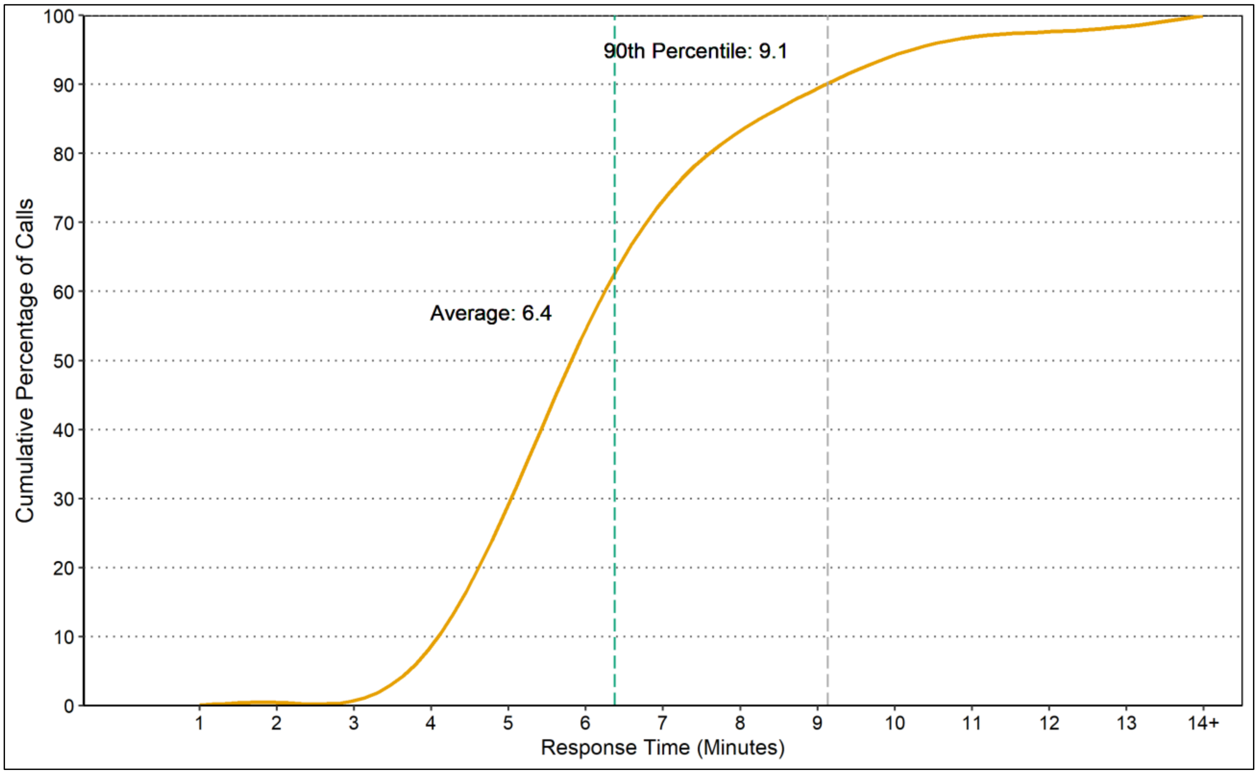


TABLE 7-19: Cumulative Distribution of Response Time – First Arriving Unit – EMS

Response Time (Minute)	Frequency	Cumulative Percentage
1	2	0.0
2	24	0.5
3	79	2.1
4	260	7.3
5	709	21.5
6	1,177	45.1
7	1,183	68.8
8	794	84.7
9	386	92.4
10	177	96.0
11	80	97.6
12	31	98.2
13	26	98.7
14+	63	100.0

TABLE 7-20: Cumulative Distribution of Response Time – First Arriving Unit – Outside and Structure Fires

Response Time (Minute)	Frequency	Cumulative Percentage
1	0	0.0
2	1	0.7
3	1	1.3
4	9	7.2
5	33	28.8
6	42	56.2
7	25	72.5
8	17	83.7
9	8	88.9
10	9	94.8
11	3	96.7
12	1	97.4
13	2	98.7
14+	2	100.0

Observations:

- For 85 percent of EMS calls, the response time of the first arriving unit was less than 8 minutes.
- For 84 percent of outside and structure fire calls, the response time of the first arriving unit was less than 8 minutes.

FIRE LOSS

Table 7-21 presents the number of outside and structure fires, broken out by levels of fire loss. Table 7-22 shows the amount of property and content loss for outside and structure fires inside the NCFD fire district in 2019.

TABLE 7-21: Total Fire Loss Above and Below $25,000

Call Type	No Loss	Under $25,000	$25,000 plus	Total
Outside fire	108	16	1	125
Structure fire	16	11	4	31
Total	**124**	**27**	**5**	**156**

TABLE 7-22: Content and Property Loss – Structure and Outside Fires

Call Type	Property Loss		Content Loss	
	Loss Value	Number of Calls	Loss Value	Number of Calls
Outside fire	$1,092,100	15	$3,200	5
Structure fire	$287,200	13	$39,700	13
Total	**$1,379,300**	**28**	**$42,900**	**18**

Note: The table includes only fire calls with a recorded loss greater than 0.

Observations:

- 108 outside fires and 16 structure fires had no recorded loss.
- 1 outside fire and 4 structure fires recorded losses above $25,000.
- Structure fires:
  - The highest total loss for a structure fire was $155,000.
  - The average total loss for structure fires with loss was $21,793.
  - 13 structure fires recorded a content loss totaling $39,700.
  - Out of 31 structure fires, 13 recorded a property loss totaling $287,200.
- Outside fires:
  - The highest total loss for an outside fire was $1,000,000.
  - The average total loss for outside fires with loss was $64,429.
  - 5 outside fires recorded content losses totaling $3,200.
  - Out of 125 outside fires, 15 recorded property losses totaling $1,092,100.

ATTACHMENT I: 2019 & 2020 COMPARISON

In this analysis, we compare portions of the previous analysis with similar records for 2020. We compare calls by type, unit workload, agency's availability, and response times.

Calls Volume by Year

Table 7-23 shows the number of calls for both 2019 and 2020. Figure 7-12 shows the monthly variation in the number of calls per day for both years. Similarly, Figure 7-13 illustrates the average number of calls per hour for both years.

TABLE 7-23: Calls by Type and Year

Call Type	2019		2020	
	Total Calls	Calls per Day	Total Calls	Calls per Day
Breathing difficulty	722	2.0	674	1.8
Cardiac and stroke	779	2.1	740	2.0
Fall and injury	999	2.7	952	2.6
Illness and other	1,344	3.7	1,303	3.6
MVA	407	1.1	349	1.0
Overdose and psychiatric	151	0.4	171	0.5
Seizure and unconsciousness	738	2.0	620	1.7
EMS total	**5,140**	**14.1**	**4,809**	**13.1**
False alarm	318	0.9	216	0.6
Good intent	56	0.2	81	0.2
Hazard	48	0.1	33	0.1
Outside fire	125	0.3	162	0.4
Public service	121	0.3	139	0.4
Structure fire	31	0.1	29	0.1
Fire total	**699**	**1.9**	**660**	**1.8**
Canceled	853	2.3	922	2.5
Aid given	2,154	5.9	2,090	5.7
Total	**8,846**	**24.2**	**8,481**	**23.2**

FIGURE 7-12: Average Calls by Month and Year

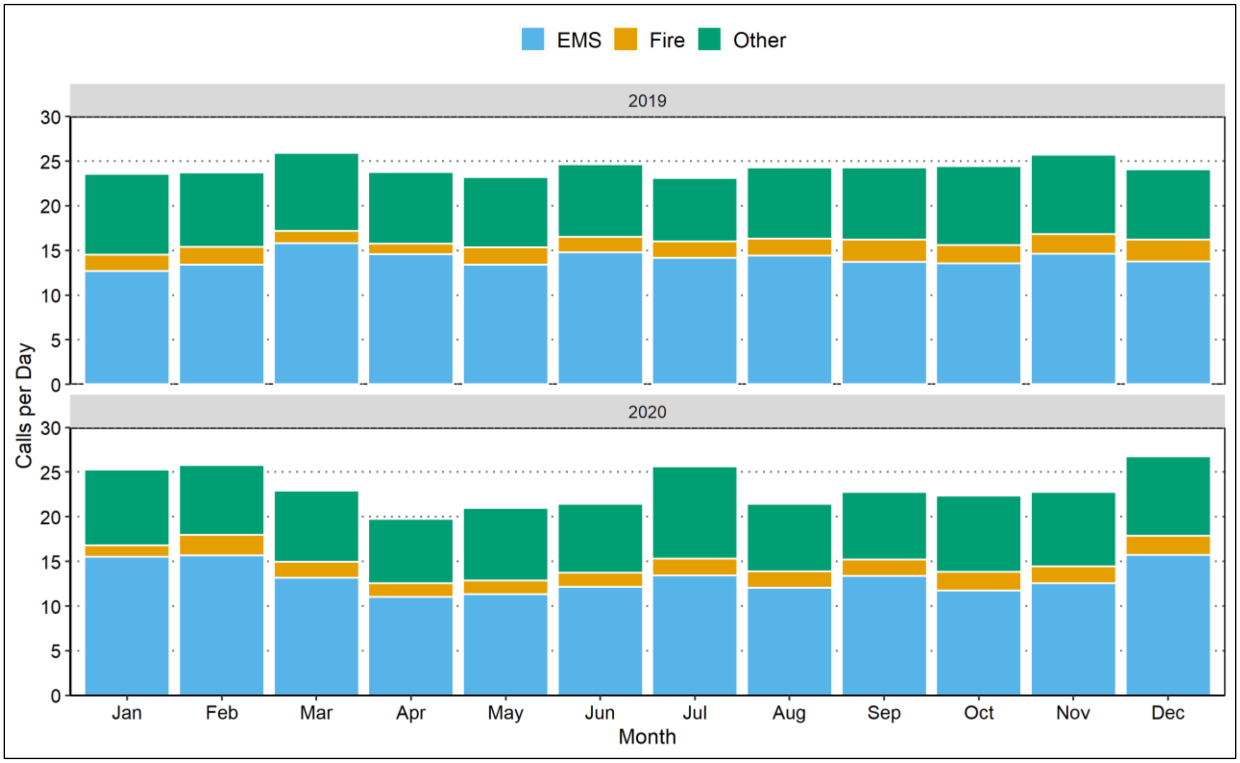
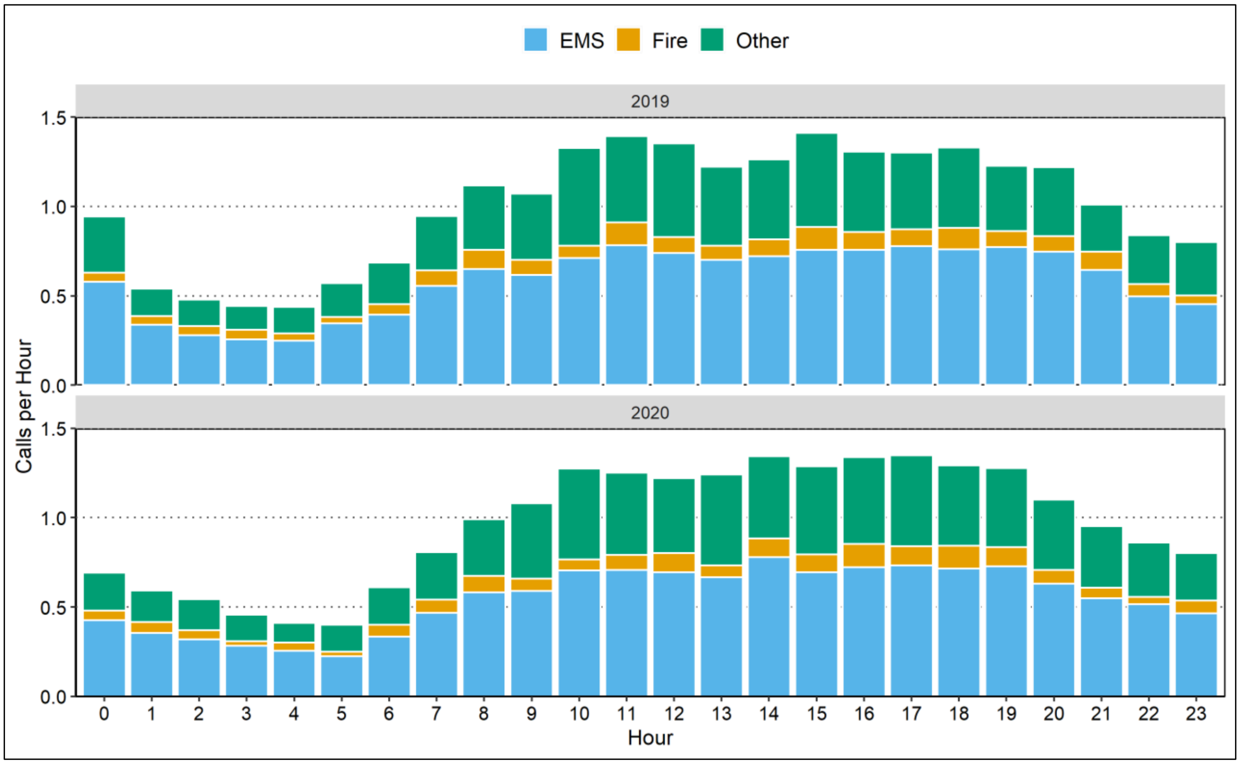


FIGURE 7-13: Average Calls by Hour of Day and Year



Workload by Year

Table 7-24 compares the call volume, annual runs, and workload by fire district in 2019 and 2020. Table 7-25 compares the annual runs and workload by NCFD station and unit during the two years. Figure 7-14 compares the average deployed minutes by the hour of the day in 2019 and 2020. Note that in Figure 7-14, the workload created by incident FMSC202350 was not included. Unit NCE34 responded to this incident with a duration time of 752.9 hours (19 percent of the annual workload). This is an outlier but has a significant influence on the workload in 2020.

TABLE 7-24: Annual Workload by District and Year

District	2019			2020		
	Calls	Runs	Hours	Calls	Runs	Hours
National City	6,692	7,742	2,319.9	6,391	7,540	2,320.1
San Diego	1,323	1,495	494.5	1,328	1,525	541.6
Chula Vista	699	864	225.1	653	813	224.8
San Diego County	101	105	56.8	77	83	45.1
Imperial Beach	21	21	4.5	21	25	5.8
Coronado	7	9	4.4	10	13	5.6
Lemon Grove	3	3	0.5			
Fresno County *				1	3	752.9
Total	**8,846**	**10,239**	**3,105.6**	**8,481**	**10,002**	**3,895.8**

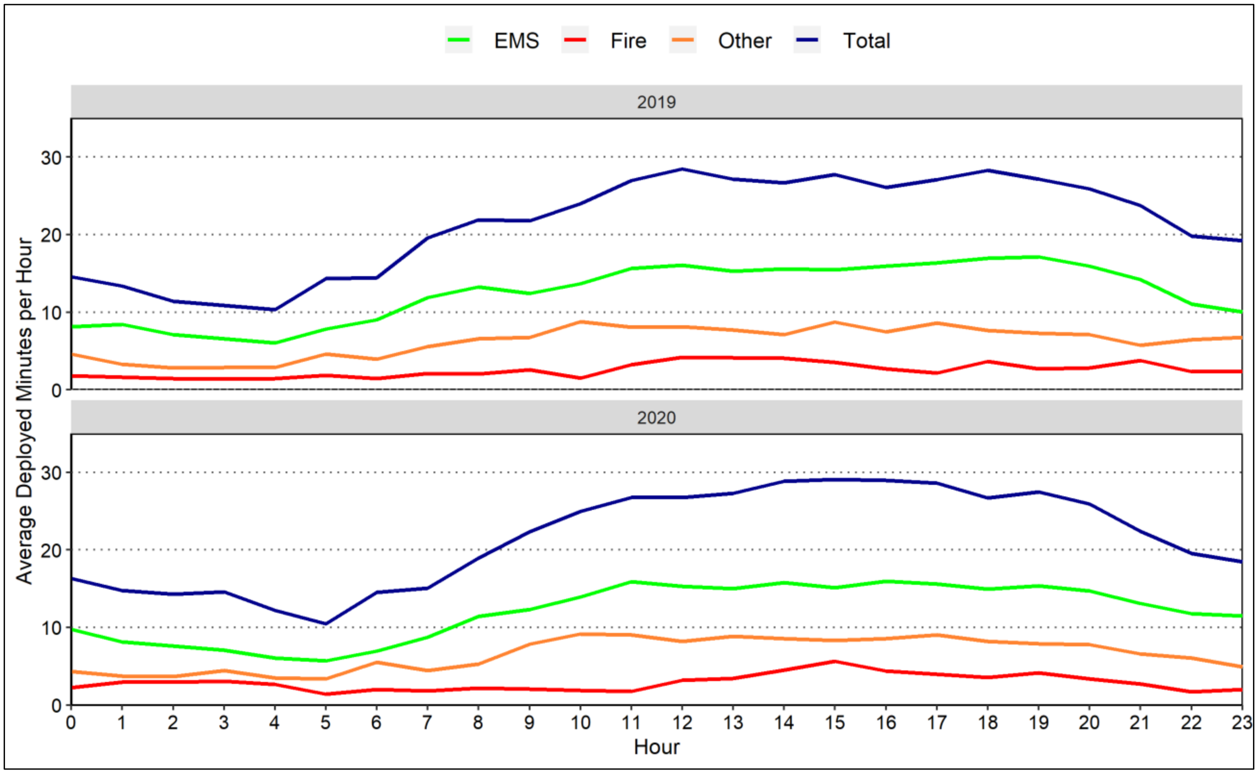
Note: *2020 included responses to one wildfire (Creek Fire) recorded as incident number FMSC202350. Unit NCE34 responded to this call from September 6, 2020, to October 7, 2020.

TABLE 7-25: Annual Workload by Station, Unit, and Year

Station	Unit	Unit Type	2019		2020	
			Hours	Runs	Hours	Runs
31	NCE31	Engine	915.3	3,031	916.6	2,989
	NCE231	Engine	0.6	3		
	Total		**915.9**	**3,034**	**916.6**	**2,989**
33	NCSQ33	Squad	**742.2**	**2,201**	**696.3**	**2,098**
34	B57	Battalion	145.2	462	182.8	460
	NCE34*	Engine	1,011.5	3,495	1,711.0	3,152
	NCE234	Engine	10.8	1	113.3	368
	NCT34	Truck	280.0	1,046	275.9	935
	Total		**1,447.5**	**5,004**	**2,282.9**	**4,915**
Total			**3,105.6**	**10,239**	**3,895.8**	**10,002**

Note: *NCE34 includes 753 hours associated with one wildfire (Creek Fire) in 2020.

FIGURE 7-14: Average Deployed Minutes by Hour of Day in 2019 and 2020



Agency's Availability by Year

Table 7-26 compares each NCFD station's response availability to calls that occurred in its first due area in both years. We focused on calls where a unit eventually arrived and ignores calls where no unit arrived.

TABLE 7-26: NCFD Station Availability to Respond to Calls by Year

Station	2019				2020			
	Calls in Area	Percent Responded	Percent Arrived	Percent First	Calls in Area	Percent Responded	Percent Arrived	Percent First
31	3,137	45.6	42.9	30.1	2,880	46.4	42.7	30.8
34	3,658	73.8	72.1	54.5	3,584	73.7	71.6	53.7
Total	**6,795**	**60.8**	**58.7**	**43.2**	**6,464**	**61.6**	**58.7**	**43.5**

Note: For each station, we count the number of calls occurring within its first due area. Then, we count the number of calls to where at least one unit arrived. Next, we focus on units from the first due station to see if any of its units responded, arrived, or arrived first.

Response Time by Year

Tables **7-**27 and **7-**28 compare the average and 90th percentile response times by call type in 2019 and 2020.

TABLE 7-27: Average Response Time of First Arriving Unit, by Call Type and Year

Call Type	2019					2020				
	Time in Minutes				Calls	Time in Minutes				Calls
	Dispatch	Turnout	Travel	Total		Dispatch	Turnout	Travel	Total	
False alarm	1.7	1.2	3.5	6.4	300	1.8	1.1	3.9	6.8	203
Good intent	2.3	1.1	5.3	8.7	51	2.0	1.1	4.4	7.6	75
Hazard	1.7	1.2	4.0	6.9	47	1.7	1.0	3.4	6.1	33
Outside fire	1.7	1.3	3.6	6.5	123	1.8	1.2	4.1	7.0	160
Public service	2.3	1.1	4.1	7.5	112	2.0	1.1	4.3	7.3	126
Structure fire	2.2	1.0	2.6	5.8	30	1.7	0.9	3.3	5.8	29
Fire Total	**1.9**	**1.2**	**3.7**	**6.8**	**663**	**1.8**	**1.1**	**4.0**	**7.0**	**626**
EMS Total	**2.0**	**1.0**	**3.3**	**6.4**	**4,991**	**2.1**	**1.1**	**3.7**	**6.8**	**4,738**
Total	**2.0**	**1.1**	**3.4**	**6.5**	**5,654**	**2.1**	**1.1**	**3.7**	**6.9**	**5,364**

TABLE 7-28: 90th Percentile Response Time of First Arriving Unit, by Call Type and Year

Call Type	2019					2020				
	Time in Minutes				Calls	Time in Minutes				Calls
	Dispatch	Turnout	Travel	Total		Dispatch	Turnout	Travel	Total	
False alarm	2.7	2.1	5.5	8.7	300	2.9	2.0	6.1	9.4	203
Good intent	4.7	1.7	10.6	13.8	51	3.6	2.0	6.4	11.0	75
Hazard	2.7	2.0	5.8	10.8	47	3.0	1.5	5.0	8.4	33
Outside fire	2.5	2.0	5.6	9.3	123	3.0	2.1	6.2	9.4	160
Public service	3.5	2.0	6.6	10.8	112	3.9	2.0	7.3	10.8	126
Structure fire	3.3	1.7	4.4	7.7	30	2.4	1.8	5.1	8.2	29
Fire Total	**3.2**	**2.0**	**6.1**	**9.7**	**663**	**3.1**	**2.0**	**6.2**	**9.4**	**626**
EMS Total	**3.5**	**1.8**	**5.2**	**8.6**	**4,991**	**3.6**	**2.0**	**5.5**	**9.3**	**4,738**
Total	**3.5**	**1.8**	**5.3**	**8.7**	**5,654**	**3.5**	**2.0**	**5.6**	**9.3**	**5,364**

ATTACHMENT II: ADDITIONAL PERSONNEL

Table 7-29 illustrates the workload of NCFD's administrative units in 2019 and 2020, respectively.

TABLE 7-29: Workload of Administrative Units by Year

Unit ID	Unit Type	2019		2020	
		Annual Hours	Annual Runs	Annual Hours	Annual Runs
5701	Fire Chief	6.9	2	0.0	0
5703	Battalion Chief	0.0	0	0.3	2
5705	Fire Marshal	10.5	10	10.3	6
5706	Deputy Fire Marshal	9.7	6	12.4	9

ATTACHMENT III: CALLS OUTSIDE NATIONAL CITY FIRE DISTRICT

From 2019 to 2020, NCFD responded to 4,244 aid-given calls outside of its fire district (see Table 7-23). Table 7-30 details these calls by call type and year. Of these, 241 were structure fire calls and 153 were outside fire calls. Figures 7-15 and 7-16 show the percentage of calls that fall into each EMS (Figure 7-15) and fire (Figure 7-16) type category by year.

TABLE 7-30: Calls Outside NCFD District by Call Type and Year

Call Type	**2019**			**2020**		
	Total Calls	**Calls per Day**	**Pct. Calls**	**Total Calls**	**Calls per Day**	**Pct. Calls**
Breathing difficulty	173	0.5	8.0	176	0.5	8.4
Cardiac and stroke	209	0.6	9.7	192	0.5	9.2
Fall and injury	204	0.6	9.5	181	0.5	8.7
Illness and other	347	1.0	16.1	303	0.8	14.5
MVA	128	0.4	5.9	128	0.3	6.1
OD	26	0.1	1.2	36	0.1	1.7
Seizure and UNC	178	0.5	8.3	143	0.4	6.8
EMS Total	**1,265**	**3.5**	**58.7**	**1,159**	**3.2**	**55.5**
False alarm	80	0.2	3.7	81	0.2	3.9
Good intent	16	0.0	0.7	25	0.1	1.2
Hazard	25	0.1	1.2	35	0.1	1.7
Outside fire	67	0.2	3.1	86	0.2	4.1
Public service	31	0.1	1.4	37	0.1	1.8
Structure fire	135	0.4	6.3	106	0.3	5.1
Fire Total	**354**	**1.0**	**16.4**	**370**	**1.0**	**17.7**
Canceled	535	1.5	24.8	561	1.5	26.8
Total	**2,154**	**5.9**	**100.0**	**2,090**	**5.7**	**100.0**

Note: OD=Overdose and psychiatric; UNC=unconsciousness.

FIGURE 7-15: EMS Calls by Type and Year, Outside National City

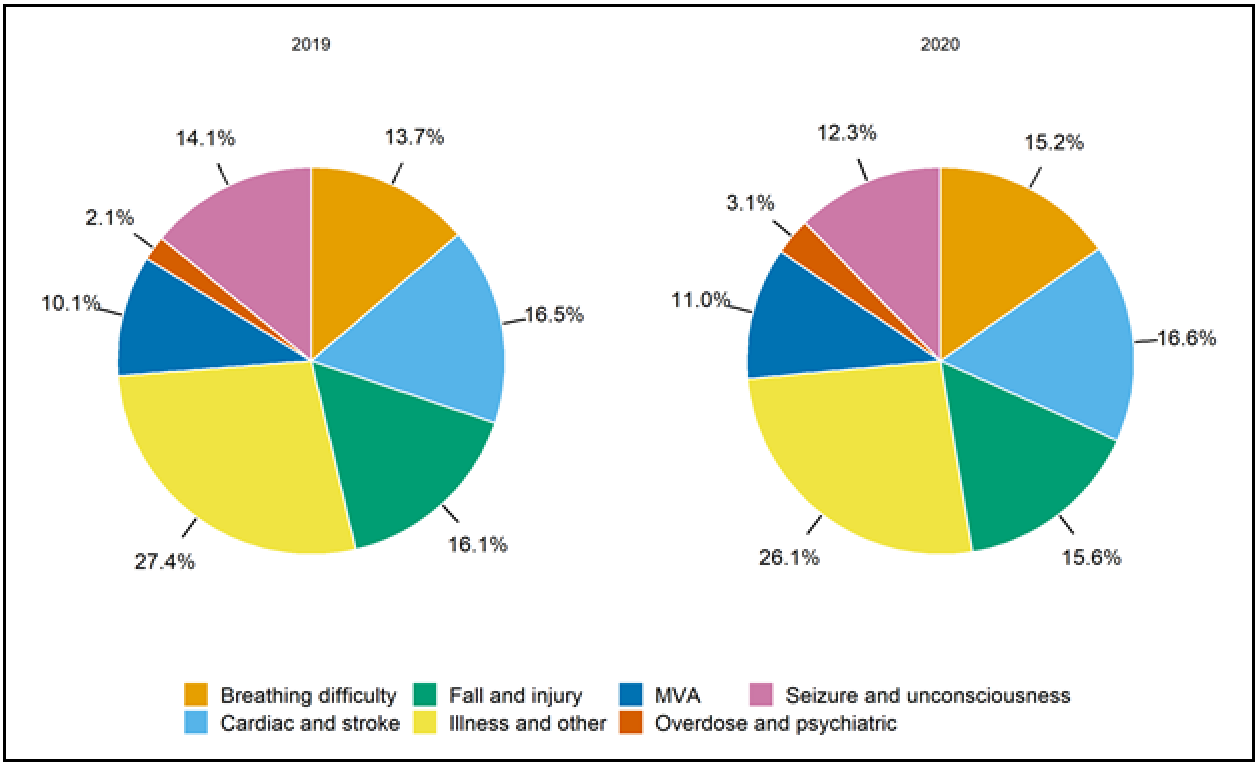
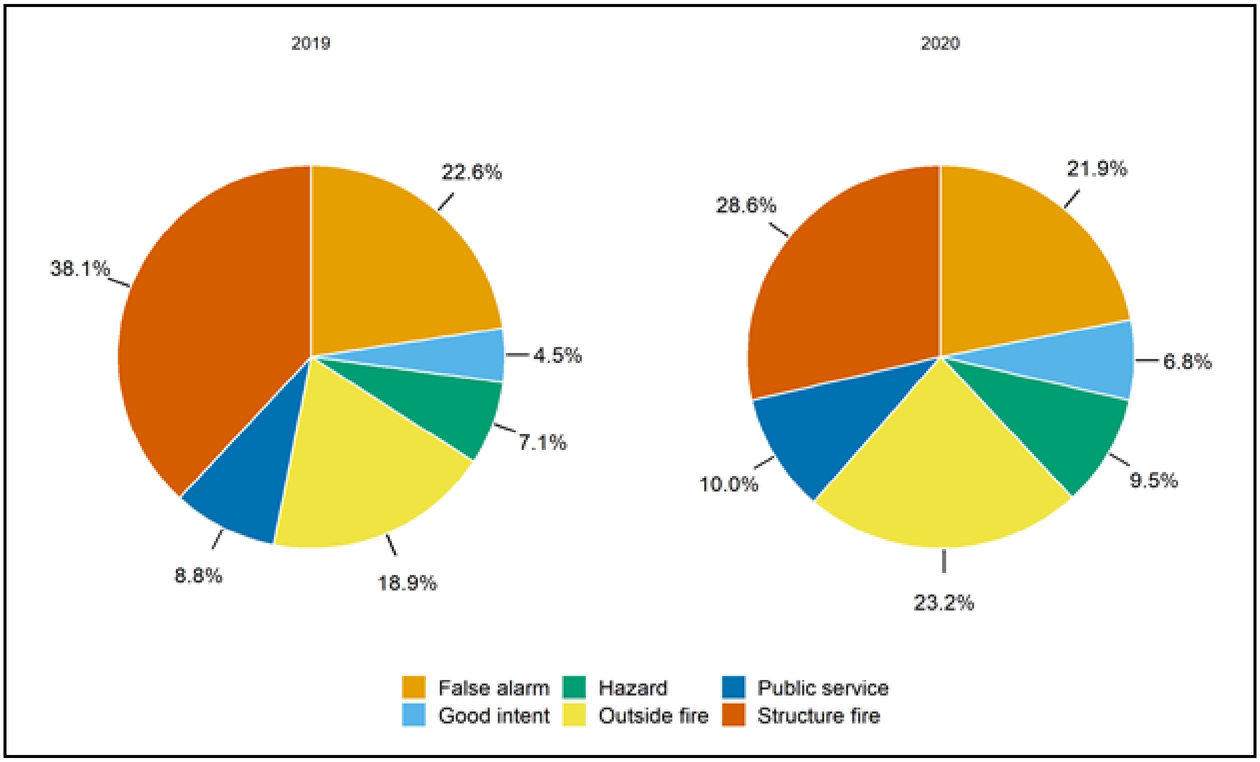


FIGURE 7-16: Fire Calls by Type and Year, Outside National City



ATTACHMENT IV: AID RECEIVED WORKLOAD

This section focuses on aid received within National City's fire district from other fire agencies. From 2019 to 2020, there were 1,963 calls in National City where aid was received from other agencies. Of these, 1,069 calls involved a joint response with NCFD and 894 calls involved a response by other agencies alone (See Table 7-1).

Aid Received Calls by Type

Table 7-31 shows the number of calls to which other FD agencies responded, broken out by call type and year. The table also presents the annual runs and work hours for each type of call.

TABLE 7-31: Aid Received Workload by Type and Year, Inside National City

Call Type	Total Annual Calls		Total Annual Runs		Total Annual Hours	
	2019	2020	2019	2020	2019	2020
Breathing difficulty	62	66	65	72	30.1	40.7
Cardiac and stroke	75	86	85	94	43.9	41.4
Fall and injury	100	114	106	119	38.5	47.2
Illness and other	131	140	144	179	52.7	80.7
MVA	193	177	295	270	75.1	68.7
OD	19	22	22	24	8.6	12.4
Seizure and UNC	69	71	70	75	30.4	42.0
EMS Total	**649**	**676**	**787**	**833**	**279.1**	**333.1**
False alarm	67	52	104	94	15.1	15.2
Good intent	21	48	22	77	5.9	12.5
Hazard	13	18	32	46	9.9	6.2
Outside fire	36	57	94	127	23.5	45.6
Public service	25	31	32	54	12.1	8.8
Structure fire	24	25	106	135	31.7	48.8
Fire Total	**186**	**231**	**390**	**533**	**98.2**	**137.1**
Canceled	116	105	153	146	35.2	29.2
Total	**951**	**1,012**	**1,330**	**1,512**	**412.4**	**499.4**

Note: OD=Overdose and psychiatric; UNC=Unconsciousness.

Runs and Arrivals by Aid Agency

Tables 7-32 and 7-33 compare the number of aid-received runs and arrivals by different agencies in 2019 and 2020.

TABLE 7-32: Aid Received Runs by Agency, First Due Area, and Year

Agency	**2019**			**2020**		
	First Due Area		**Total**	**First Due Area**		**Total**
	31	**34**		**31**	**34**	
Bonita FD	104	0	**104**	94	1	**95**
Coronado FD	0	4	**4**	1	1	**2**
Chula Vista FD	136	196	**332**	182	240	**422**
Escondido FD	1	0	**1**	0	0	**0**
Federal FD	0	1	**1**	1	0	**1**
Lemon Grove FD	0	0	**0**	0	1	**1**
San Diego FD	522	364	**886**	569	421	**990**
San Miguel FD	1	1	**2**	1	0	**1**
Total	**764**	**566**	**1,330**	**848**	**664**	**1,512**

TABLE 7-33: Aid Received Arrivals by Agency, First Due Area, and Year

Agency	**2019**			**2020**		
	First Due Area		**Total**	**First Due Area**		**Total**
	31	**34**		**31**	**34**	
Bonita FD	75	0	**75**	61	1	**62**
Coronado FD	0	1	**1**	0	0	**0**
Chula Vista FD	95	131	**226**	121	159	**280**
Lemon Grove FD	0	0	**0**	0	1	**1**
San Diego FD	326	207	**533**	372	257	**629**
Total	**496**	**339**	**835**	**554**	**418**	**972**

ATTACHMENT V: LINCOLN ACRES

One area of particular interest is Lincoln Acres. While not officially part of National City, it is an unincorporated area that is entirely enclosed within National City's boundaries. Up until this point, calls within Lincoln Acres were included as part of the National City Fire District. For this section, we used each call's recorded latitude and longitude to locate the calls within Lincoln Acres.

Table 7-34 compares the volume of calls and the workload for this area for both years, broken down by call type. While Table 7-1 distinguishes calls without a responding NCFD unit, all calls within Lincoln Acres involved a responding NCFD unit. To better understand the workload within Lincoln Acres, we included runs and associated work for all fire agencies responding to calls within the area. Table 7-35 shows the average and 90 percentile response time to calls that occurred in this area. Due to the small sample size, we used all calls in two years in the analysis of response time. Table 7-36 examines the average and 90th response times of the first arriving units by the time of day (in four-hour intervals).

TABLE 7-34: Calls and Workload in Lincoln Acres by Call Type and Year

Call Type	2019			2020		
	Calls	Hours	Runs	Calls	Hours	Runs
Breathing difficulty	16	20.7	34	16	23.7	35
Cardiac and stroke	19	30.7	46	21	27.7	48
Fall and injury	16	23.9	35	15	24.4	34
Illness and other	23	31.4	54	31	42.6	67
MVA	23	30.4	74	31	30.4	93
OD	2	2.0	4	6	6.6	13
Seizure and UNC	14	19.7	29	15	23.2	31
EMS Total	**113**	**158.8**	**276**	**135**	**178.6**	**321**
False alarm	5	1.8	9	5	7.0	15
Good intent	3	2.6	5	6	5.1	24
Hazard	1	0.1	1	4	2.3	10
Outside fire	5	5.6	20	7	12.5	20
Public service	5	1.6	6	3	0.9	3
Structure fire	4	42.0	36	0	0.0	0
Fire Total	**23**	**53.8**	**77**	**25**	**27.7**	**72**
Canceled	28	23.7	77	41	34.9	100
Total	**164**	**236.2**	**430**	**201**	**241.2**	**493**

Note: OD=Overdose and psychiatric; UNC=Unconsciousness.

TABLE 7-35: Response Time in Lincoln Acres, by Call Type

Call Type	Average Response Time (Minutes)				90 Percentile Response Time (Minutes)				Call Count
	Dispatch	Turnout	Travel	Total	Dispatch	Turnout	Travel	Total	
False alarm	2.7	0.7	3.3	6.8	12.3	1.7	7.2	12.6	8
Good intent	2.3	0.8	4.9	8.0	7.0	1.6	10.6	13.2	7
Hazard	2.5	1.1	4.2	7.7	7.8	1.5	5.6	9.1	5
Outside fire	1.7	1.0	3.9	6.6	2.7	1.8	6.6	8.7	12
Public service	3.2	1.1	4.5	8.8	10.8	2.0	7.9	15.5	7
Structure fire	3.6	0.6	1.6	5.8	7.4	1.2	2.0	9.3	3
Fire Total	**2.5**	**0.9**	**3.9**	**7.3**	**7.0**	**1.7**	**6.6**	**11.5**	**42**
EMS Total	**2.0**	**1.0**	**3.9**	**7.0**	**3.4**	**1.8**	**6.2**	**9.6**	**240**
Total	**2.1**	**1.0**	**3.9**	**7.0**	**3.5**	**1.8**	**6.3**	**9.8**	**282**

TABLE 7-36: Response Time in Lincoln Acres, by Time of Day

Time	Average, Minutes				90 Percentile, Minutes				Call Count
	Dispatch	Turnout	Travel	Total	Dispatch	Turnout	Travel	Total	
00:00 - 03:59	2.1	1.6	3.5	7.2	4.3	2.3	5.4	9.8	28
04:00 - 07:59	1.8	1.3	4.5	7.6	2.9	2.2	8.5	12.4	26
08:00 - 11:59	1.8	0.8	4.0	6.6	3.0	1.4	6.2	9.0	60
12:00 - 15:59	2.3	0.7	3.9	6.9	3.0	1.4	6.2	8.9	50
16:00 - 19:59	2.1	0.8	4.2	7.1	3.4	1.4	6.8	9.2	61
20:00 - 23:59	2.2	1.2	3.6	7.1	5.0	1.9	6.2	10.3	57
Total	**2.1**	**1.0**	**3.9**	**7.0**	**3.5**	**1.8**	**6.3**	**9.8**	**282**

ATTACHMENT VI: PARADISE HILLS

Another area of particular interest is Paradise Hills. Paradise Hills is a neighborhood within San Diego that is located close to National City. Calls into Paradise Hills are part of aid given calls measured in Table 7-10. As in the previous section, we used each call's recorded latitude and longitude to locate calls within Paradise Hills. We compare the volume of calls and the workload for this area over two years. Table 7-37 presents the comparison, broken down by call type. Aid given workload only included calls, workload, and runs associated with NCFD units.

TABLE 7-37: Calls and Workload in Lincoln Acres by Call Type and Year

Call Type	2019			2020		
	Calls	Hours	Runs	Calls	Hours	Runs
Breathing difficulty	95	31.3	95	110	45.1	111
Cardiac and stroke	116	46.2	116	107	48.2	108
Fall and injury	91	31.6	94	99	36.2	102
Illness and other	120	47.6	128	127	48.2	128
MVA	17	8.3	20	23	7.5	28
OD	7	2.2	7	14	5.9	14
Seizure and UNC	93	39.9	94	73	28.8	73
EMS Total	**539**	**207.3**	**554**	**553**	**219.9**	**564**
False alarm	19	7.1	19	21	5.9	26
Good intent	2	0.4	2	7	1.4	7
Hazard	3	1.7	6	4	19.3	9
Outside fire	6	3.2	6	6	2.6	9
Public service	9	2.6	9	7	2.8	7
Structure fire	12	7.5	18	13	6.8	20
Fire total	**51**	**22.5**	**60**	**58**	**38.8**	**78**
Canceled	73	12.3	99	93	19.1	129
Total	**663**	**242.0**	**713**	**704**	**277.9**	**771**

Note: OD=Overdose and psychiatric; UNC=Unconsciousness.

Observations:

- In 2019, there were 663 aid-given calls to Paradise Hills. This was 50 percent of aid-given calls (1,323) to San Diego.
- In 2019, there were 713 aid-given runs to Paradise Hills. This was 48 percent of aid-given runs (1,495) to San Diego
- In 2019, there were 242.0 aid-given work hours associated with calls in Paradise Hills. This was 49 percent (494.5) of aid-given work associated with calls in San Diego.
- In 2020, call volume increased by 6 percent from 663 to 704.
- In 2020, total runs increased by 8 percent from 713 to 771.
- In 2020, the workload increased by 15 percent from 242.0 to 277.9.

ATTACHMENT VII: CALL TYPE IDENTIFICATION

When available, NFIRS data serves as our primary source for assigning call categories. In this work, for an MVA or fire call that had a matched NFIRS record, we used the NFIRS incident type to assign a call category. Otherwise, we used the CAD incident type and problem description to assign a call category. All EMS calls were categorized by the CAD incident type and problem description. Tables 7-38 and 7-39 specify the call categories identified by available NFIRS and CAD information, respectively.

TABLE 7-38: Call Type by NFIRS Incident Type Code

Call Type	Incident Type Code	Frequency	
		2019	2020
Canceled	611	1,357	1,421
	621	1	0
	622	38	64
False Alarm	700	296	217
	710	2	1
	713	1	0
	715	1	1
	730	3	0
	733	3	1
	735	3	4
	736	4	2
	740	1	0
	743	2	0
	744	3	2
	745	4	11
	746	1	10
Good Intent	600	40	39
	631	0	2
	641	0	2
	650	6	4
	651	8	29
	652	2	1
	653	3	3
	661	0	2
	671	5	10
	672	1	0

Call Type	Incident Type Code	Frequency	
		2019	2020
Hazard	223	1	0
	400	4	7
	410	1	1
	411	3	1
	412	6	12
	413	2	0
	420	0	1
	421	2	1
	423	0	1
	424	2	1
	440	7	4
	441	3	2
	442	1	1
	443	1	0
	444	7	1
	445	5	2
	460	1	1
	461	1	1
	480	4	7
	481	0	1
MVA	322	464	392
	323	7	5
	324	2	9
	352	1	1
Outside Fire	100	6	8
	130	29	38
	131	0	1
	140	26	46
	150	101	126
	151	5	3
	161	0	1

Call Type	Incident Type Code	Frequency	
		2019	2020
Public Service	500	14	22
	510	13	9
	511	20	10
	512	1	1
	520	7	7
	521	2	1
	522	5	5
	531	11	24
	540	1	1
	541	0	1
	542	2	1
	550	7	6
	551	6	8
	552	4	9
	553	6	9
	554	25	13
	561	7	23
	571	0	1
	812	1	0
	813	1	0
	900	3	3
	911	0	1
Structure Fire	111	51	59
	113	22	15
Total		**2,686**	**2,730**

TABLE 7-39: Call Type by CAD Problem Description

Call Type	Problem	Frequency	
		2019	2020
Breathing Difficulty	Breathing Problems	909	856
	Choking	30	30
Cardiac and Stroke	Cardiac / Respiratory Arrest	131	175
	Chest Pain	563	512
	Heart Problems	119	116
	Stroke	213	169
Fall and Injury	Assault/Rape	210	214
	Drowning/Diving Accident	1	3
	Electrocution	3	1
	Falls / Back Inj	868	812
	Stabbing/Gunshot	39	42
	Traumatic Injuries Spec	26	19
	Traumatic Injuries, Spec	115	108
False Alarm	Carbon Monoxide Alarm	3	3
	Ringing Alarm	53	27
	Ringing Alarm Coronado	2	0
	Ringing Alarm Highrise	18	13
	Vegetation 1st Alarm	18	17
Good Intent	Noxious Odor	0	1
	Odor of Chemical	0	2
	Odor of Smoke	1	1
	Smoke Check	21	43
Hazard	Nat Gas Leak Broken/Blowing	5	11
	Natural Gas Leak/Odor-Inside	3	3
	Natural Gas Odor - Outside	2	2
	Electrical Short	2	1
	Extinguished Fire	1	4
	Fuel Spill	1	2
	HazMat	1	0
	HazMat Single Engine	0	2
	Illegal Burn	12	2
	Wires down	2	1

Call Type	Problem	Frequency	
		2019	2020
Illness and Other	Confined Space/Trench Rescue	1	0
	Abdominal Pain/Problems	60	63
	Advised Incident*	7	0
	Allergy/Hives/Med Rx/Stng	41	43
	Animal Bites/ Attacks	13	11
	Back Pain	33	19
	Burns / Explosion*	3	4
	C O / Inhalation/ Haz Mat*	2	2
	CV Medical Aid	2	2
	Diabetic Problems	147	141
	Elevator Rescue	11	11
	Eye Problems / Injuries	2	1
	Headache	42	32
	Heat / Cold Exposure	3	6
	Hemorrhage / Lacerations	236	219
	Illegal Burn*	3	0
	Industrial Rescue	0	1
	Lift Assist*	7	2
	Medical Aid	16	13
	Medical Alert Alarm	43	38
	Miscellaneous Rescue	0	1
	NC Medical Aid	0	1
	Open Space Rescue	1	1
	Poison Control	0	1
	Preg/Birth/Miscarriage	30	25
	Sick Person	806	763
	Special Service*	10	5
	Suspected COVID19	0	63
	Traffic Accident*	90	70
	Traffic Accident FWY*	5	3
	Unknown Problem*	152	129
	Vehicle Fire Freeway*	1	0
	Vehicle Rescue	11	13
	Vehicle vs. Pedestrian*	4	3
	Water Rescue	0	2
MVA	Traffic Accident	120	122
	Traffic Accident FWY	30	26
	Vehicle vs Structure	3	5
	Vehicle vs. Pedestrian	1	1

Note: *NRIFS incident type code is 321.

Call Type	**Problem**	**Frequency**	
		2019	**2020**
Outside Fire	Boat Fire 1st Alm	0	1
	Fence*	1	0
	Pole Fire	0	1
	Rubbish Fire	8	8
	Tree*	0	1
	Vegetation Initial Attack	10	13
	Vehicle Fire	5	4
	Vehicle Fire Freeway	5	7
Overdose and Psychiatric	OD/Ingestion/Poisonings	112	122
	Psych / Suicide Attempt	78	100
Public Service	Advised Incident	1	2
	AID - ENGINE	0	1
	Assist PD	1	1
	Assist PD - Ladder Bldg	0	1
	Investigate	1	0
	Knocked Off Hydrant	3	4
	Lift Assist	2	0
	Lock in/out	3	9
	Move Up	7	6
	SNAKE REMOVAL	1	0
	Special Service	4	8
	Strike Team Type 1	1	3
	Strike Team Type 3	1	1
	Water Removal/Flooding CV/NC	2	0
	yGT General Transport	1	0
Seizure and UNC	Convulsions / Seizures	330	258
	Unc/Fainting	634	549
Structure Fire	Oven Fire	1	1
	Structure Fire - Comm / Apt	38	29
	Structure Highrise/Hospital	1	0
	Structure Residential	53	31
Total		**6,612**	**6,193**

Note: *Level 2 fires; UNC = Unconsciousness.

ATTACHMENT VIII: REMOVED CANCELED CALLS

TABLE 7-40: Removed Calls by Cancel Reason and Year

Cancel Reason	Frequency	
	2019	2020
Duplicate Call	754	793
Call complete / Available	425	485
CAD test	263	220
False Alarm	81	46
Caller refused ambulance	11	11
Patient not ready	8	9
Stand back cancellation	8	2
Canceled by PD/CHP on scene	2	6
Canceled/Turned	1	3
Change in level of service	0	2
Delayed in traffic	2	0
Private transport arranged	1	1
Wrong location	1	1
Level 4 triage	0	1
Canceled by first responder	1	0
NA	6	6
Total	**1,564**	**1,586**

SECTION 8. AMR DATA ANALYSIS

This data analysis was prepared as a key component of the study of the American Medical Response (AMR) ambulance service in the National City fire district. This analysis examines all calls for service between January 1, 2019, and January 1, 2021, as recorded in the regional computer-aided dispatch (CAD) system, and AMR's EMS incident Reporting System.

This analysis is made up of five parts. The first part focuses on call types and dispatches. The second part explores the time spent and the workload of individual units. The third part presents an analysis of the busiest hours in the year studied. The fourth part provides a response time analysis of the studied agency's units. The fifth and final part is an analysis of unit transports. The analysis results are primarily presented for the 2019 calendar year. The results for 2020 are compared with those for the prior year in Attachment I.

As the primary emergency medical service (EMS) provider within the National City fire district, AMR works closely with the National City Fire Department (NCFD) to provide both advanced life support (ALS) and basic life support (BLS) services. In 2019, AMR responded to 7,328 calls. The total workload was 7,335.9 hours. The average response time to EMS calls was 8.0 minutes, and the 90th percentile response time was 13.2 minutes. In 2020, the AMR responded to 6,945 calls. The total workload was 6,561.9 hours. The average response time to EMS calls was 8.3 minutes, and the 90th percentile response time was 13.5 minutes.

METHODOLOGY

In this report, CPSM analyzes calls and runs. A call is an emergency service request or incident. A run is a dispatch of a unit (i.e., a unit responding to a call). Thus, a call may include multiple runs.

This analysis studied AMR's 9-1-1 EMS response. We received data from both the regional CAD system and the AMR's EMS incident Reporting System. We first matched the two sets of data based on the available information of call time and location. The AMR data lacked information of incident type and unit transport times. Therefore the analysis was primarily conducted based on the CAD data that included the description of call nature and transport time stamps of AMR units. The method to categorize calls based on the call nature description is detailed in Attachment II. With the AMR data, we used the call received time for the analysis of AMR unit's response time to calls and used the available unit time stamps to fill the missing unit time stamps in the CAD data.

Working independently or jointly with fire departments, AMR responded to 14,273 total calls in the National City fire district in 2019 and 2020. The following table summarizes these calls by responding agency and year. The main analysis in the following sections focuses on the 7,328 calls in 2019. The results for 2020 are presented along with the corresponding 2019 results in Attachment I for comparison.

TABLE 8-1: Studied Calls Responding Agency and Year

Responding Agency	2019	2020	Total
AMR only	1,036	986	2,022
AMR and FD agencies	6,292	5,959	12,251
Total	**7,328**	**6,945**	**14,273**

Observations:

- Of all calls where AMR responded within the National City fire district, AMR responded jointly with FD agencies to 86 percent of calls in both years.

AGGREGATE CALL TOTALS AND RUNS

In 2019, AMR responded to 7,328 calls in the National City fire district. Of these calls, 99 percent were 9-1-1 EMS calls and one percent were the service calls for assisting fire or PD agencies.

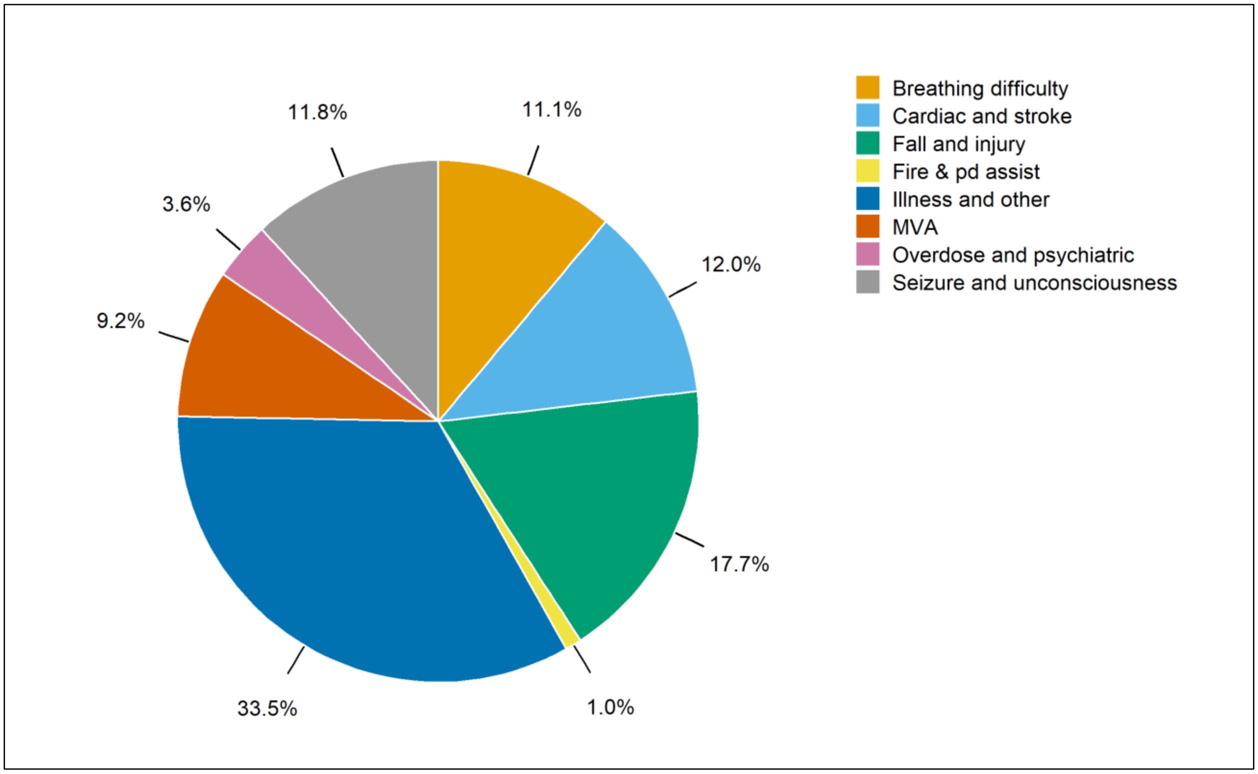
Calls by Type

Th following table and figure show the number of calls by call type, average calls per day, and the percentage of calls that fall into each call type category for the 12 months studied.

TABLE 8-2: Call Types

Call Type	Number of Calls	Calls per Day	Call Percentage
Breathing difficulty	815	2.2	11.1
Cardiac and stroke	881	2.4	12.0
Fall and injury	1,296	3.6	17.7
Illness and other	2,453	6.7	33.5
MVA	677	1.9	9.2
Overdose and psychiatric	266	0.7	3.6
Seizure and unconsciousness	867	2.4	11.8
EMS Total	**7,255**	**19.9**	**99.0**
Fire & PD assist	73	0.2	1.0
Total	**7,328**	**20.1**	**100.0**

FIGURE 8-1: Calls by Type



Note: Other includes Canceled and Fire & FD assist calls.

Observations:

- In 2019, AMR responded to an average of 20.1 calls per day.
- EMS calls for the year totaled 7,255 (99 percent of all calls), an average of 19.9 calls per day.
  - Illness and other calls were the largest category of EMS calls at 34 percent of total calls (34 percent of EMS calls) or an average of 6.7 calls per day.
  - Cardiac and stroke calls made up 12 percent of total calls (12 percent of EMS calls) or an average of 2.4 calls per day.
  - Motor vehicle accidents made up 9 percent of total calls (9 percent of EMS calls) or an average of 1.9 calls per day.

Calls by Type and Duration

The following table shows the duration of calls by type using four duration categories: less than 30 minutes, 30 minutes to one hour, one to two hours, and two or more hours.

TABLE 8-3: Calls by Type and Duration

Call Type	Less than 30 Minutes	30 Minutes to One Hour	One to Two Hours	Two or More Hours	Total
Breathing difficulty	103	202	477	33	815
Cardiac and stroke	118	207	533	23	881
Fall and injury	315	248	683	50	1,296
Illness and other	651	509	1,189	104	2,453
MVA	374	86	201	16	677
Overdose and psychiatric	81	63	113	9	266
Seizure and unconsciousness	161	174	493	39	867
EMS Total	**1,803**	**1,489**	**3,689**	**274**	**7,255**
Fire & FD assist	58	1	13	1	73
Total	**1,861**	**1,490**	**3,702**	**275**	**7,328**

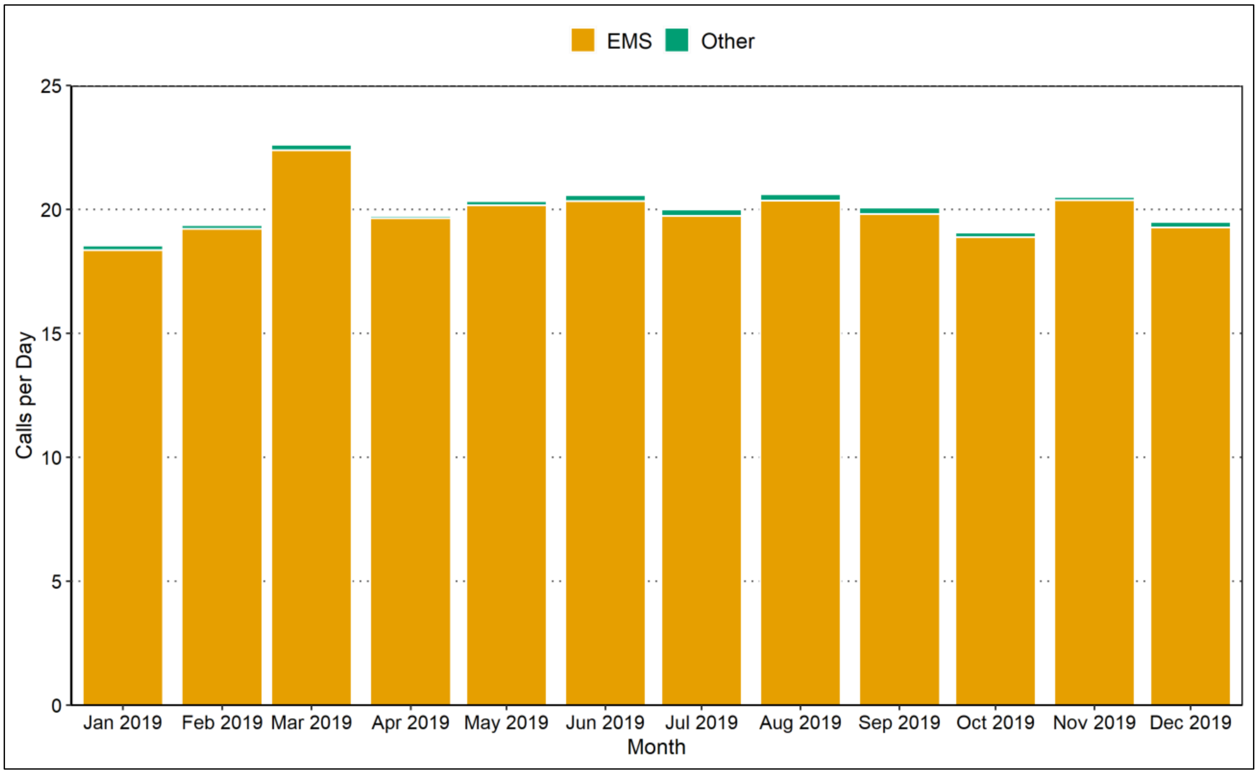
Observations:

- On average, there were 10.9 EMS calls per day that lasted more than one hour.
- A total of 3,292 EMS calls (45 percent) lasted less than one hour, 3,689 EMS calls (51 percent) lasted one to two hours, and 274 EMS calls (4 percent) lasted two or more hours.
- A total of 325 cardiac and stroke calls (37 percent) lasted less than one hour, 533 cardiac and stroke calls (60 percent) lasted one to two hours, and 23 cardiac and stroke calls (3 percent) lasted two or more hours.
- A total of 460 motor vehicle accidents (68 percent) lasted less than one hour, 201 motor vehicle accidents (30 percent) lasted one to two hours, and 16 motor vehicle accidents (2 percent) lasted two or more hours.

Average Calls by Month and Hour of Day

Figure 8-2 shows the monthly variation in the average daily number of calls handled by AMR in 2019. Similarly, Figure 8-3 illustrates the average number of calls received each hour of the day over the year.

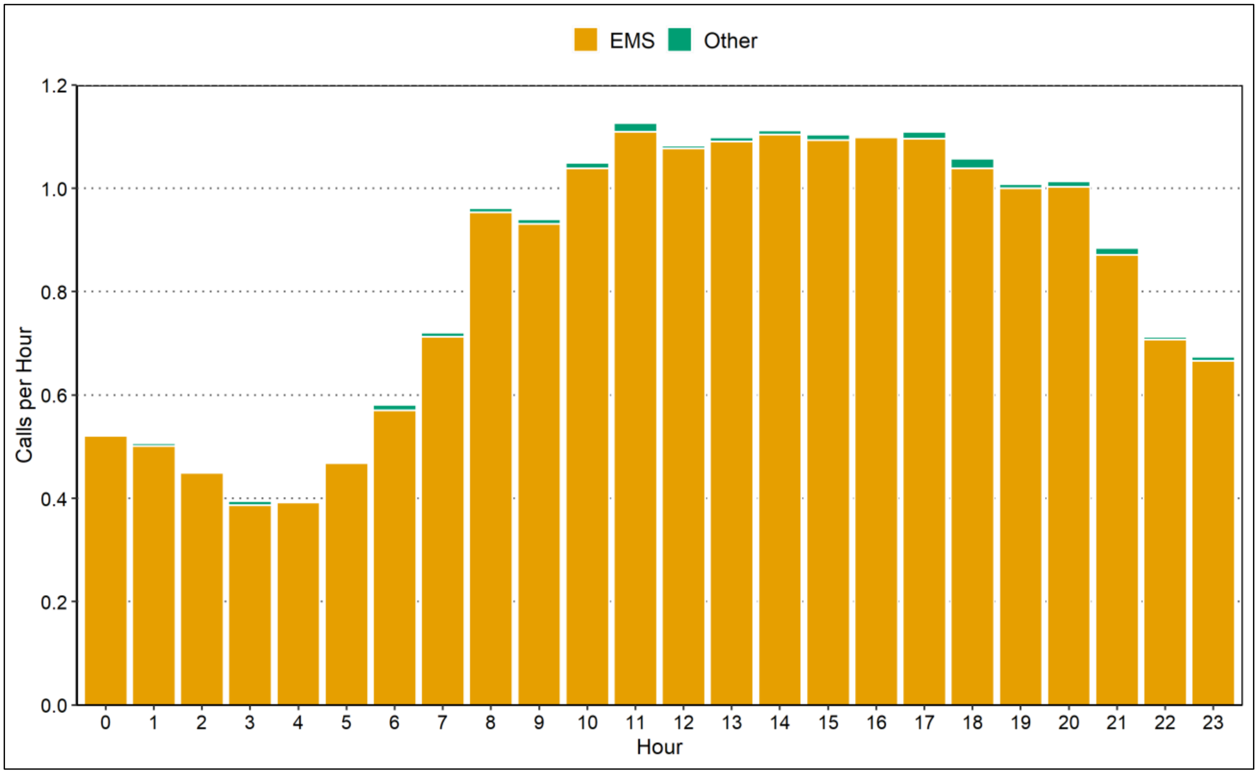
FIGURE 8-2: Average Calls by Month



Observations:

- Average calls per day overall ranged from 18.5 in January 2019 to 22.6 in March 2019.

FIGURE 8-3: Calls by Hour of Day



Observations:

- Average calls per hour overall ranged from 0.4 between 3:00 a.m. and 5:00 a.m. to 1.1 between 11:00 a.m. and noon.

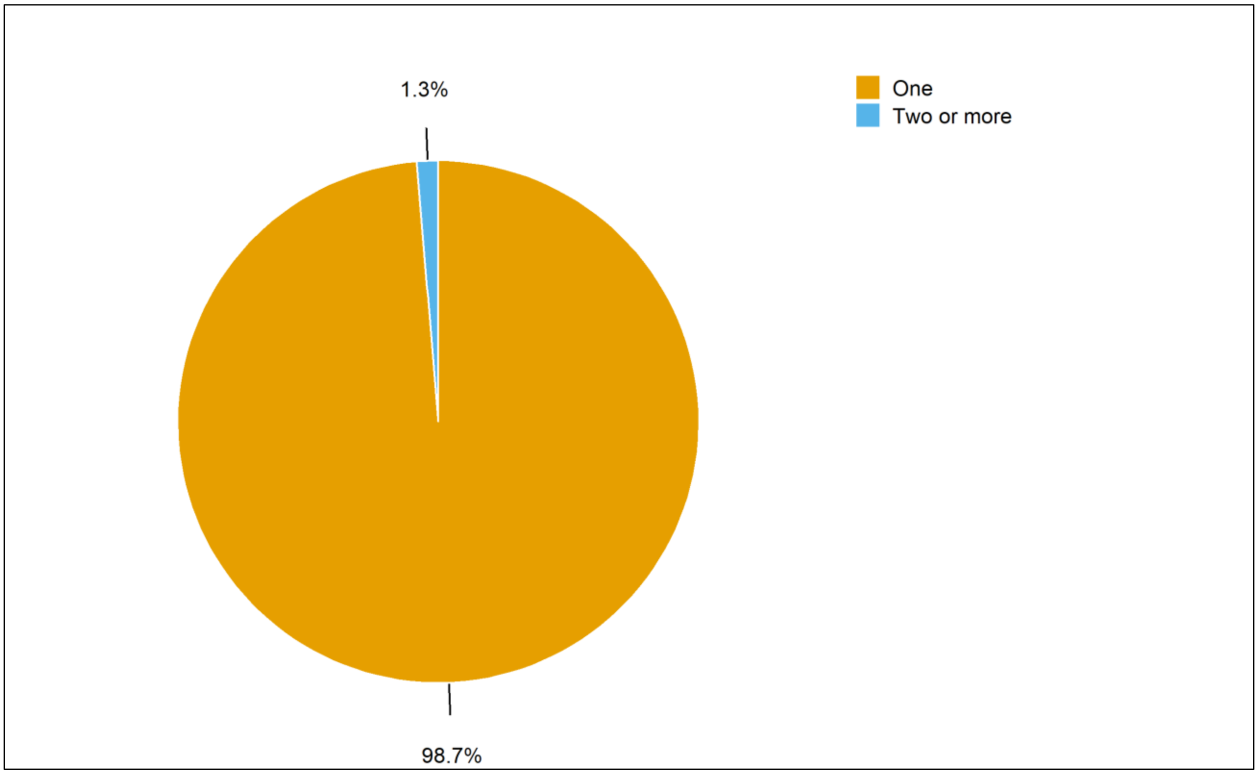
Arriving Units

Table 8-4, along with Figure 8-4, detail the number of calls with one and two or more units arriving to a call, broken down by call type. In this analysis, we limit ourselves to calls where a unit from AMR arrives. For this reason, there are fewer calls in Table 8-4 than in Table 8-2.

TABLE 8-4: Calls by Call Type and Number of Units Arriving

Call Type	Number of Units		Total Calls
	One	Two	
Breathing difficulty	780	7	787
Cardiac and stroke	848	4	852
Fall and injury	1,221	11	1,232
Illness and other	2,129	18	2,147
MVA	480	36	516
Overdose and psychiatric	227	4	231
Seizure and unconsciousness	818	7	825
EMS Total	**6,503**	**87**	**6,590**
Fire & FD assist	30	1	31
Total	**6,533**	**88**	**6,621**
Percentage	**98.7**	**1.3**	**100.0**

FIGURE 8-4: Calls by Number of Units Arriving



Observations:

- On average, 1.0 units arrived at all calls
- For 99 percent of calls, one unit arrived.
- For 1 percent of calls, two or three units arrived.

WORKLOAD: RUNS AND TOTAL TIME SPENT

The workload of each AMR units is measured in two ways: runs and deployed time. The deployed time of a run is measured from the time a unit is dispatched through the time the unit is cleared. Because multiple units respond to some calls, there are more runs than calls and the average deployed time per run varies from the total duration of calls.

Runs and Deployed Time – All Units

Deployed time is the total deployment time of all units deployed on all runs. Table 8-5 shows the total deployed time, both overall and broken down by type of run, for all units in 2019.
Table 8-6 and Figure 8-5 present the average deployed minutes by hour of day.

TABLE 8-5: Annual Runs and Deployed Time by Run Type

Call Type	Deployed Minutes per Run	Annual Hours	Percent of Total Hours	Deployed Minutes per Day	Annual Runs	Runs per Day
Breathing difficulty	61.3	916.6	12.5	150.7	897	2.5
Cardiac and stroke	60.4	995.3	13.6	163.6	988	2.7
Fall and injury	54.7	1,342.3	18.3	220.7	1,472	4.0
Illness and other	50.8	2,395.0	32.6	393.7	2,826	7.7
MVA	35.8	480.6	6.6	79.0	805	2.2
Overdose and psychiatric	47.1	244.7	3.3	40.2	312	0.9
Seizure and unconsciousness	58.2	936.2	12.8	153.9	966	2.6
EMS Total	**53.1**	**7,310.7**	**99.7**	**1,201.8**	**8,266**	**22.6**
Fire & FD assist	18.9	25.1	0.3	4.1	80	0.2
Total	**52.7**	**7,335.9**	**100.0**	**1,205.9**	**8,346**	**22.9**

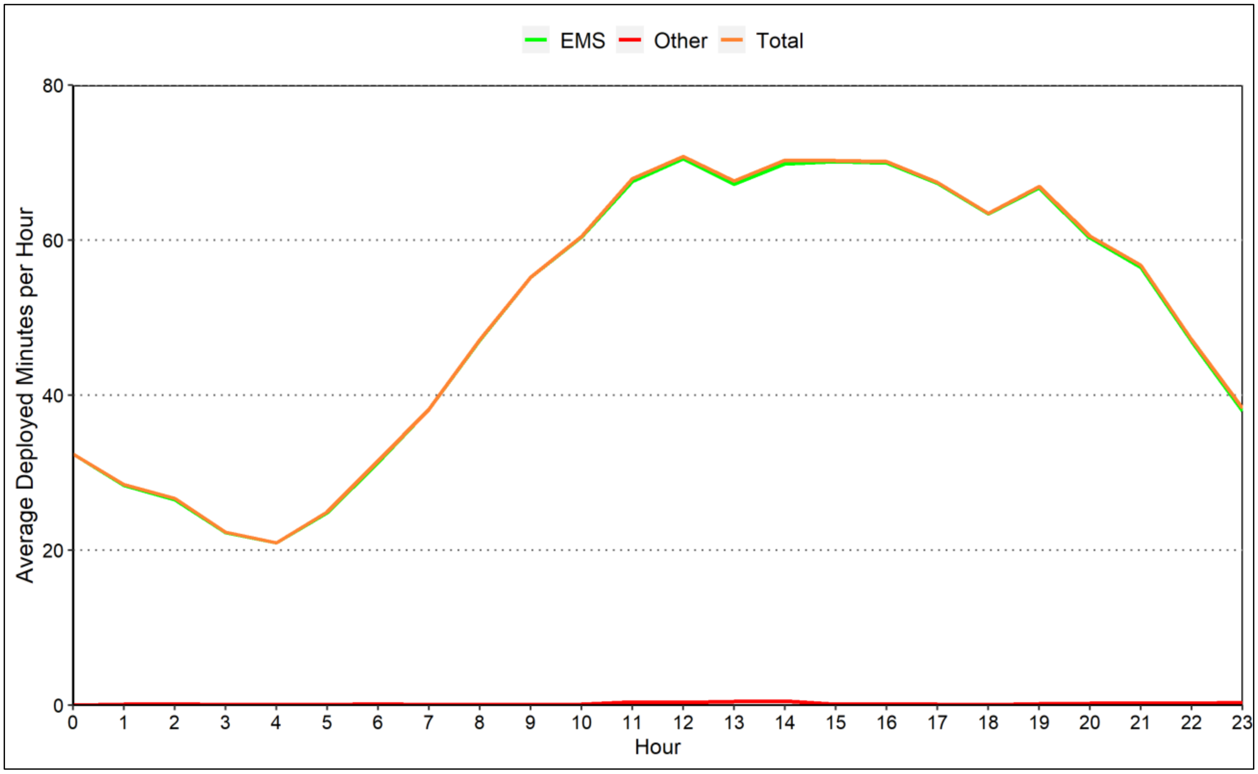
Observations:

- The total deployed time for the year was 7,335.9 hours. The daily average was 20.1 hours for all units combined.
- There were 8,346 runs. The daily average was 22.9 runs.
- The average deployed time for EMS runs was 53.1 minutes per run. The deployed time for all EMS runs averaged 20.0 hours per day.

TABLE 8-6: Average Deployed Minutes by Hour of Day

Hour	EMS	Fire & FD Assist	Total
0	32.4	0.0	32.4
1	28.4	0.1	28.5
2	26.5	0.2	26.7
3	22.3	0.0	22.3
4	20.9	0.0	21.0
5	24.8	0.1	24.9
6	31.4	0.2	31.5
7	38.2	0.0	38.2
8	47.1	0.0	47.1
9	55.2	0.0	55.2
10	60.4	0.1	60.4
11	67.5	0.4	67.9
12	70.5	0.3	70.8
13	67.2	0.5	67.7
14	69.8	0.5	70.3
15	70.1	0.1	70.2
16	69.9	0.2	70.1
17	67.3	0.1	67.4
18	63.4	0.1	63.5
19	66.7	0.2	66.9
20	60.3	0.2	60.5
21	56.5	0.3	56.8
22	46.9	0.2	47.2
23	38.0	0.3	38.3
Daily Avg.	**1,201.8**	**4.1**	**1,205.9**

FIGURE 8-5: Average Deployed Minutes by Hour of Day



Observations:

- Hourly deployed time was highest during the day from 9:00 a.m. to 9:00 p.m., averaging more than 65 minutes.
- Average deployed time peaked between noon and 1:00 p.m., averaging 70.8 minutes.
- Average deployed time was lowest between 4:00 a.m. and 5:00 a.m., averaging 21.0 minutes.

Workload by Unit

Tables 8-7 summarizes the overall workload of AMR's ambulances in 2019. Tables 8-8 and 8-9 provide a more detailed view of workload, showing each ambulance's runs broken out by run type (Table 8-8) and the resulting daily average deployed time broken out by run type (Table 8-9). Here, we grouped the ambulances by SA and SD types. SA ambulances primarily responded to general 9-1-1 medic calls and SD ambulances primarily responded to BLS calls. Additionally, we grouped together all SD ambulances that had less than seven total runs.

TABLE 8-1: Call Workload by Unit

Type	Unit	Deployed Minutes per Run	Total Hours	Total Pct.	Deployed Minutes per Day	Total Runs	Runs per Day
SA	AM254	24.1	11.6	0.2	1.9	29	0.1
	AM255	13.0	7.8	0.1	1.3	36	0.1
	AM256	82.4	30.2	0.4	5.0	22	0.1
	AM257	26.3	40.4	0.6	6.6	92	0.3
	AM401	57.6	98.9	1.3	16.3	103	0.3
	AM402	51.4	14.6	0.2	2.4	17	0.0
	AM411	53.0	210.4	2.9	34.6	238	0.7
	AM412	52.0	246.4	3.4	40.5	284	0.8
	AM413	38.7	87.0	1.2	14.3	135	0.4
	AM414	44.3	280.5	3.8	46.1	380	1.0
	AM415	48.3	286.4	3.9	47.1	356	1.0
	AM416	49.2	557.9	7.6	91.7	680	1.9
	AM417	54.1	2,218.3	30.2	364.7	2,460	6.7
	AM418	55.9	2,012.5	27.4	330.8	2,160	5.9
	AM419	49.3	109.3	1.5	18.0	133	0.4
	AM420	49.9	185.6	2.5	30.5	223	0.6
	AM492	45.6	49.4	0.7	8.1	65	0.2
	AM493	58.0	238.0	3.2	39.1	246	0.7
	AM494	82.0	5.5	0.1	0.9	4	0.0
	AM495	53.4	188.8	2.6	31.0	212	0.6
	AM496	56.8	225.5	3.1	37.1	238	0.7
	AM980	55.9	42.8	0.6	7.0	46	0.1
	AM985	55.9	24.2	0.3	4.0	26	0.1
	Total	**52.6**	**7,172.0**	**97.8**	**1,179.0**	**8,185**	**22.4**
SD	AM202	60.8	7.1	0.1	1.2	7	0.0
	AM205	81.2	10.8	0.1	1.8	8	0.0
	AM231	57.7	7.7	0.1	1.3	8	0.0
	AM239	37.2	4.3	0.1	0.7	7	0.0
	Other*	61.3	133.9	1.8	22.0	131	0.4
	Total	**61.1**	**163.9**	**2.2**	**26.9**	**161**	**0.4**
Total		**52.7**	**7,335.9**	**100.0**	**1,205.9**	**8,346**	**22.9**

Note: *"Other" is the group of SD ambulances that made less than seven total runs.

TABLE 8-8: Annual Runs by Run Type and Unit

Type	Unit	Breathing Difficulty	Cardiac and Stroke	Fall and Injury	Illness and Other	MVA	OD	Seizure and UNC	Fire & FD assist	Total
SA	AM254	2	4	3	11	4	2	3	0	29
	AM255	2	11	3	9	5	2	4	0	36
	AM256	2	4	3	9	2	1	1	0	22
	AM257	11	7	16	36	8	2	11	1	92
	AM401	0	2	1	12	1	0	1	0	17
	AM402	21	37	45	71	30	11	23	0	238
	AM411	22	27	51	90	39	9	41	5	284
	AM412	11	17	27	42	20	3	14	1	135
	AM413	36	52	65	124	44	12	47	0	380
	AM414	43	41	69	99	42	10	47	5	356
	AM415	76	79	118	213	65	21	102	6	680
	AM416	268	300	425	877	211	102	250	27	2,460
	AM417	267	259	387	687	214	74	250	22	2,160
	AM418	22	10	23	42	13	6	16	1	133
	AM419	28	25	35	75	20	9	28	3	223
	AM420	6	6	16	21	3	3	9	1	65
	AM492	15	33	47	76	28	7	39	1	246
	AM493	0	2	2	0	0	0	0	0	4
	AM494	21	22	41	69	20	7	29	3	212
	AM495	24	23	48	80	22	3	36	2	238
	AM496	4	9	14	11	4	0	4	0	46
	AM980	3	2	6	5	5	2	2	1	26
	AM985	2	10	10	68	1	8	3	1	103
	Total	**886**	**982**	**1,455**	**2,727**	**801**	**294**	**960**	**80**	**8,185**
SD	AM202	0	0	0	7	0	0	0	0	7
	AM205	0	0	1	7	0	0	0	0	8
	AM231	0	0	1	6	0	1	0	0	8
	AM239	2	0	1	2	1	1	0	0	7
	Other	9	6	14	77	3	16	6	0	131
	Total	**11**	**6**	**17**	**99**	**4**	**18**	**6**	**0**	**161**
Total		**897**	**988**	**1,472**	**2,826**	**805**	**312**	**966**	**80**	**8,346**

Note: OD=Overdose and psychiatric; UNC=Unconsciousness; "Other" is the group of SD ambulances that made less than seven total runs.

TABLE 8-9: Average Deployed Minutes by Run Type and Unit

Type	Unit	Breathing Difficulty	Cardiac and Stroke	Fall and Injury	Illness and Other	MVA	OD	Seizure and UNC	Fire & FD assist	Total
SA	AM254	0.1	0.2	0.2	0.5	0.4	0.0	0.4	0.0	1.9
	AM255	0.2	0.8	0.0	0.2	0.0	0.0	0.0	0.0	1.3
	AM256	0.6	1.5	0.5	1.9	0.2	0.3	0.0	0.0	5.0
	AM257	1.3	0.1	1.1	2.2	0.8	0.2	1.0	0.0	6.6
	AM401	0.0	0.1	0.0	2.2	0.0	0.0	0.0	0.0	2.4
	AM402	3.6	6.3	6.5	8.6	3.6	1.9	4.1	0.0	34.6
	AM411	3.9	4.7	8.3	12.0	4.2	1.0	6.0	0.4	40.5
	AM412	1.1	2.3	3.3	3.8	1.4	0.2	2.1	0.0	14.3
	AM413	4.9	8.4	8.4	13.6	3.5	1.3	6.0	0.0	46.1
	AM414	6.6	7.3	10.2	11.8	4.5	0.8	5.9	0.0	47.1
	AM415	12.4	11.8	17.0	27.6	4.6	2.8	15.5	0.1	91.7
	AM416	46.3	50.1	66.7	123.5	21.9	12.6	41.8	1.7	364.7
	AM417	47.9	47.1	61.5	98.1	20.9	10.7	43.5	1.2	330.8
	AM418	4.7	1.4	2.4	4.8	0.9	1.0	2.9	0.0	18.0
	AM419	4.2	2.6	5.1	10.5	1.9	0.9	5.2	0.1	30.5
	AM420	0.9	0.6	2.0	3.2	0.1	0.3	1.0	0.0	8.1
	AM492	2.9	6.1	6.6	11.8	4.1	1.3	6.2	0.2	39.1
	AM493	0.0	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.9
	AM494	2.8	4.0	5.6	10.5	2.1	0.8	5.1	0.2	31.0
	AM495	4.4	4.7	7.8	11.7	2.2	0.4	5.8	0.0	37.1
	AM496	0.5	1.3	2.4	1.6	0.5	0.0	0.8	0.0	7.0
	AM980	0.5	0.5	0.9	0.9	0.9	0.2	0.2	0.0	4.0
	AM985	0.3	1.2	0.7	12.5	0.3	1.1	0.1	0.1	16.3
	Total	**150.1**	**163.4**	**217.8**	**373.6**	**78.9**	**37.7**	**153.5**	**4.1**	**1,179.0**
SD	AM202	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	1.2
	AM205	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	1.8
	AM231	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	1.3
	AM239	0.1	0.0	0.1	0.3	0.1	0.2	0.0	0.0	0.7
	Other	0.5	0.2	2.8	15.7	0.0	2.3	0.4	0.0	22.0
	Total	**0.6**	**0.2**	**2.9**	**20.1**	**0.1**	**2.6**	**0.4**	**0.0**	**26.9**
Total		**150.7**	**163.6**	**220.7**	**393.7**	**79.0**	**40.2**	**153.9**	**4.1**	**1,205.9**

Note: OD=Overdose and psychiatric; UNC=Unconsciousness; "Other" is the group of SD ambulances that made less than seven total runs.

Observations:

- SA ambulances made 8,185 runs (22.4 runs per day) and had 7,172.0 hours of annual deployed time (19.6 hours per day).
- SD ambulances made 161 runs (0.4 runs per day) and had 163.9 hours of annual deployed time (26.9 minutes per day).
- Ambulance AM417 made the most runs (2,460, or an average of 6.7 runs per day) and had the highest total annual deployed time (2,218.3 hours or an average of 6.1 hours per day).
- Ambulance AM418 made the second most runs (2,160, or an average of 5.9 runs per day) and had the second highest total annual deployed time (2,012.5 hours or an average of 5.5 hours per day).

Workload by District

The following table breaks down AMR's annual workload by the service district of each NCFD fire station.

TABLE 8-10: Annual Workload by NCFD Station Service District

NCFD Station	Calls	Pct. Annual Calls	Runs	Runs Per Day	Deployed Minutes Per Run	Annual Hours	Pct. Annual Work	Deployed Minutes Per Day
31	3,350	45.7	3,785	10.4	55.1	3,477.3	47.4	571.6
34	3,978	54.3	4,561	12.5	50.8	3,858.5	52.6	634.3
Total	**7,328**	**100.0**	**8,346**	**22.9**	**52.7**	**7,335.9**	**100.0**	**1205.9**

Observations:

NCFD Station 31

- There were 3,350 calls, or 46 percent of the total calls.
- There were 3,785 runs. The daily average was 10.4 runs.
- Total deployed time for the year was 3,477.3 hours or 47 percent of the total annual workload. The daily average was 9.5 hours for all units combined.

NCFD Station 34

- There were 3,978 calls, or 54 percent of the total calls.
- There were 4,561 runs. The daily average was 12.5 runs.
- Total deployed time for the year was 3,858.5 hours or 53 percent of the total annual workload. The daily average was 10.6 hours for all units combined.

ANALYSIS OF BUSIEST HOURS

There is significant variability in the number of calls from hour to hour. One special concern relates to the resources available for hours with the heaviest workload. We tabulated the data for each of the 8,760 hours in the year. Table 8-11 shows the number of hours in the year in which there were zero to five or more calls during the hour. Table 8-12 shows the 10 one-hour intervals which had the most calls that AMR responded during the year. Table 8-13 examines the number of times a call overlapped with another call within the National City fire district.

TABLE 8-11: Frequency Distribution of the Number of Calls

Calls in an Hour	Frequency	Percentage
0	3,928	44.8
1	3,025	34.5
2	1,266	14.5
3	419	4.8
4	101	1.2
5+	21	0.2
Total	**8,760**	**100.0**

TABLE 8-12: Top 10 Hours with the Most Calls Received

Hour	Number of Calls	Number of Runs	Total Deployed Hours
11/15/2019, 2:00 p.m. to 3:00 p.m.	6	12	8.1
8/27/2019, 10:00 a.m. to 11:00 a.m.	6	7	9.0
6/21/2019, 5:00 p.m. to 6:00 p.m.	6	7	5.5
4/12/2019, 2:00 p.m. to 3:00 p.m.	6	6	6.7
3/10/2019, 4:00 p.m. to 5:00 p.m.	6	6	4.2
3/20/2019, 8:00 p.m. to 9:00 p.m.	5	7	9.4
4/23/2019, 5:00 p.m. to 6:00 p.m.	5	7	5.9
10/22/2019, 3:00 p.m. to 4:00 p.m.	5	6	12.0
5/28/2019, 5:00 p.m. to 6:00 p.m.	5	6	6.7
7/18/2019, 11:00 p.m. to midnight	5	6	5.9

Note: Total deployed hours is a measure of the total time spent responding to calls received in the hour. The deployed time from these calls may extend into the next hour or hours. The number of runs and deployed hours includes all AMR units.

TABLE 8-13: Frequency of Overlapping Calls

Scenario	Number of Calls	Percent of All Calls	Total Hours
No overlapped call	3,064	41.8	2,977.7
Overlapped with one call	2,540	34.7	1,274.6
Overlapped with two calls	1,177	16.1	390.3
Overlapped with three calls	393	5.4	98.8
Overlapped with four calls	123	1.7	22.7
Overlapped with five calls	24	0.3	4.3
Overlapped with six calls	5	0.1	1.3
Overlapped with seven calls	2	0.0	0.2

Observations:

- During 21 hours (0.2 percent of all hours), five or more calls occurred; in other words, AMR responded to five or more calls in an hour roughly once every 17 days.
    - The highest number of calls to occur in an hour was six, which happened five times.

RESPONSE TIME

In this part of the analysis, we present response time statistics for different call types. We separate response time into its identifiable components. *Dispatch time* is the difference between the time when AMR received a call and the earliest time an ambulance is dispatched. Dispatch time includes call processing time, which is the time required to determine the nature of the emergency and the types of resources to dispatch. *Turnout time* is the difference between the earliest dispatch time and the earliest time an ambulance is en route to a call's location. *Travel time* is the difference between the earliest en route time and the earliest arrival time. *Response time* is the total time elapsed between receiving a call to arriving on scene.

In this analysis, with all calls that were responded by AMR within the National City fire district, we excluded the fire & PD assist calls. In addition, calls with a total response time of more than 30 minutes were excluded. Finally, we focused on units that had complete time stamps, that is, units with all components recorded, so that we could calculate each segment of response time.

Based on the methodology above, we excluded 73 fire & PD calls, four non-emergency calls, 659 calls where no units recorded a valid on-scene time, 30 calls where the first arriving unit's response time was greater than 30 minutes, and 14 calls where one or more segments of the first arriving unit's response time could not be calculated due to missing or faulty data. As a result, the analysis in this section included 6,548 calls for 2019. Using the same method, we obtained 6,214 calls for the same analysis for 2020. 2020's response time analysis is compared with that of 2019 in Attachment I.

Response Time by Type of Call

Table 8-14 breaks down the average dispatch, turnout, travel, and total response times by call type for all calls that AMR responded within the National City fire district, and Table 8-15 does the same for 90th percentile response times. A 90th percentile response time means that 90 percent of calls had response times at or below that number. For example, Table 8-15 shows a 90th percentile response time of 13.2 minutes, which means that 90 percent of the time, a call had a response time of no more than 13.2 minutes. Figure 8-6 illustrates the components of the average response time.

TABLE 8-14: Average Response Time of First Arriving Unit, by Call Type

Call Type	Time in Minutes				Number of Calls
	Dispatch	Turnout	Travel	Total	
Breathing difficulty	0.7	0.8	5.9	7.4	786
Cardiac and stroke	0.8	0.8	6.2	7.7	851
Fall and injury	0.9	0.7	6.4	8.0	1,227
Illness and other	1.0	0.8	6.7	8.6	2,125
MVA	1.0	0.8	6.2	8.0	508
Overdose and psychiatric	1.0	0.9	6.7	8.6	225
Seizure and unconsciousness	0.8	0.8	6.1	7.7	826
Total	**0.9**	**0.8**	**6.4**	**8.0**	**6,548**

FIGURE 8-6: Average Response Time of First Arriving Unit, by Call Type

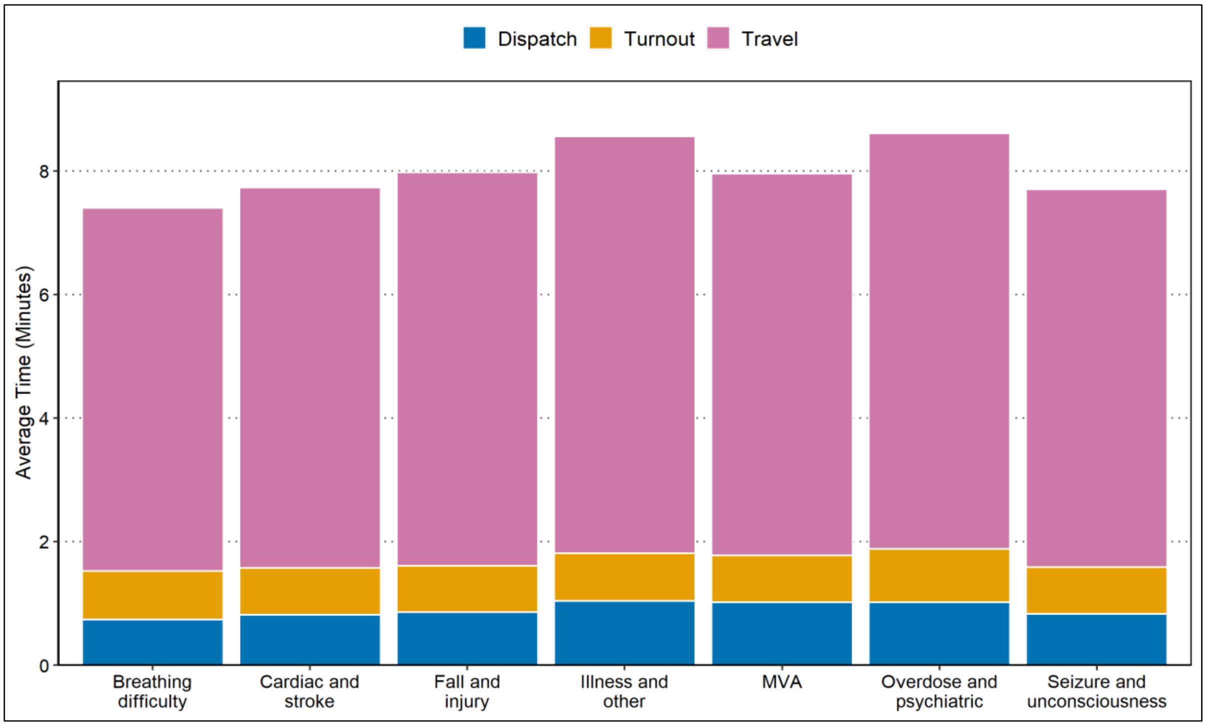


TABLE 8-15: 90th Percentile Response Time of First Arriving Unit, by Call Type

Call Type	Time in Minutes				Number of Calls
	Dispatch	Turnout	Travel	Total	
Breathing difficulty	1.6	1.8	10.1	11.6	786
Cardiac and stroke	2.0	1.8	10.7	12.6	851
Fall and injury	2.1	1.8	10.8	12.8	1,227
Illness and other	3.1	1.8	11.6	14.9	2,125
MVA	2.4	1.7	10.9	12.8	508
Overdose and psychiatric	3.1	2.0	11.7	14.2	225
Seizure and unconsciousness	2.0	1.7	10.4	12.2	826
Total	**2.4**	**1.8**	**10.9**	**13.2**	**6,548**

Observations:

- The average dispatch time was 0.9 minutes.
- The average turnout time was 0.8 minutes.
- The average travel time was 6.4 minutes.
- The average total response time was 8.0 minutes.
- The 90th percentile dispatch time was 2.4 minutes.
- The 90th percentile turnout time was 1.8 minutes.
- The 90th percentile travel time was 10.9 minutes.
- The 90th percentile total response time was 13.2 minutes.

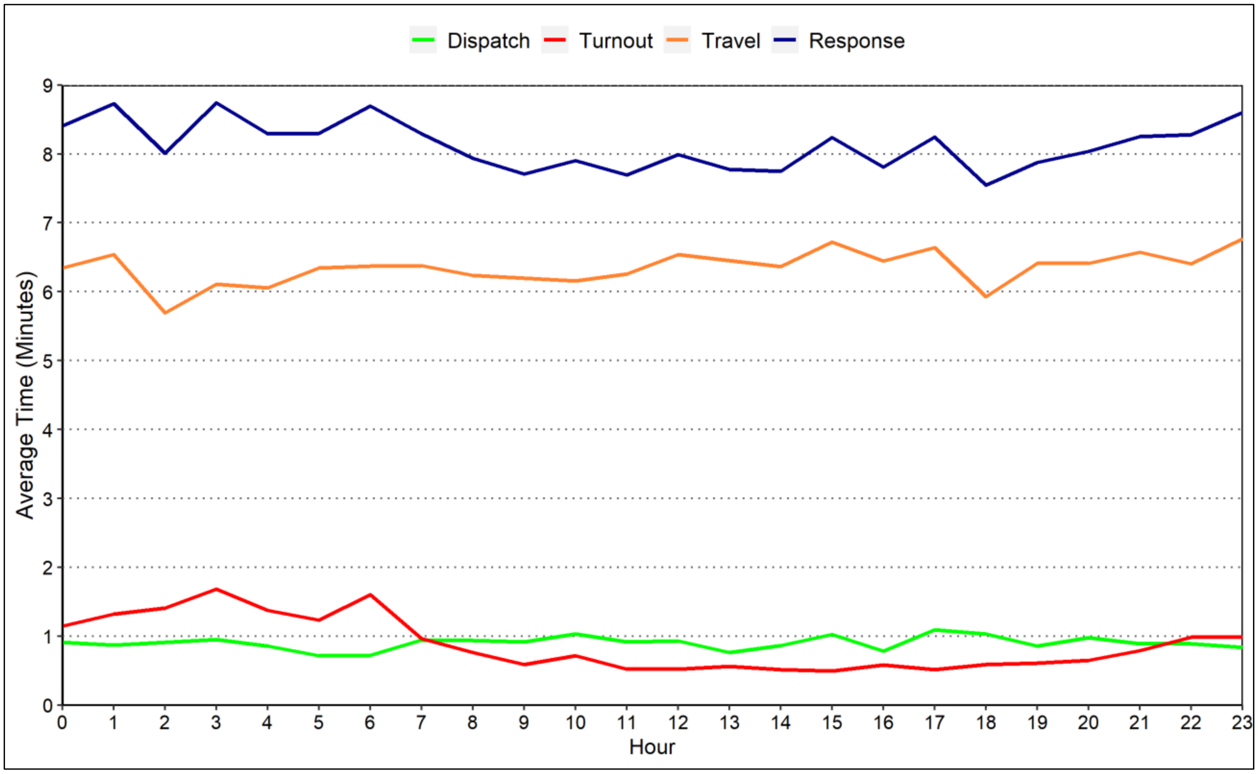
Response Time by Hour

The components of average response time by the time of day are shown in Table 8-16. The table also shows the 90th percentile response time. Figure 8-7 shows the same information.

TABLE 8-16: Average and 90th Percentile Response Time of First Arriving Unit, by Time of Day

Hour	**Time in Minutes**				**90th Percentile Response Time**	**Number of Calls**
	Dispatch	**Turnout**	**Travel**	**Response Time**		
0	0.9	1.1	6.3	8.4	13.5	168
1	0.9	1.3	6.5	8.7	14.3	160
2	0.9	1.4	5.7	8.0	13.3	153
3	1.0	1.7	6.1	8.7	13.4	130
4	0.9	1.4	6.1	8.3	13.5	130
5	0.7	1.2	6.3	8.3	12.6	155
6	0.7	1.6	6.4	8.7	14.3	188
7	0.9	1.0	6.4	8.3	13.6	232
8	0.9	0.8	6.2	7.9	13.5	312
9	0.9	0.6	6.2	7.7	12.1	303
10	1.0	0.7	6.2	7.9	13.2	350
11	0.9	0.5	6.3	7.7	12.3	369
12	0.9	0.5	6.5	8.0	13.3	357
13	0.8	0.6	6.5	7.8	12.8	363
14	0.9	0.5	6.4	7.7	12.5	367
15	1.0	0.5	6.7	8.2	12.4	363
16	0.8	0.6	6.4	7.8	12.5	358
17	1.1	0.5	6.6	8.2	14.1	354
18	1.0	0.6	5.9	7.6	12.4	338
19	0.9	0.6	6.4	7.9	13.0	344
20	1.0	0.6	6.4	8.0	12.8	323
21	0.9	0.8	6.6	8.3	13.6	291
22	0.9	1.0	6.4	8.3	13.5	223
23	**0.8**	**1.0**	**6.8**	**8.6**	**13.3**	**217**
Total	**0.9**	**0.8**	**6.4**	**8.0**	**13.2**	**6,548**

FIGURE 8-7: Average Response Time of First Arriving Unit, by Hour of Day



Observations:

- Average dispatch time was between 0.7 minutes (5:00 a.m. to 6:00 a.m.) and 1.1 minutes (5:00 p.m. to 6:00 p.m.).
- Average turnout time was between 0.5 minutes (3:00 p.m. to 4:00 p.m.) and 1.7 minutes (3:00 a.m. to 4:00 a.m.).
- Average travel time was between 5.7 minutes (2:00 a.m. to 3:00 a.m.) and 6.8 minutes (11:00 p.m. to midnight).
- Average response time was between 7.6 minutes (6:00 p.m. to 7:00 p.m.) and 8.7 minutes (3:00 a.m. to 4:00 a.m.).
- The 90th percentile response time was between 12.1 minutes (9:00 a.m. to 10:00 a.m.) and 14.3 minutes (1:00 a.m. to 2:00 a.m.).

Response Time Distribution

Here, we present a more detailed look at how response times to calls are distributed. The cumulative distribution of total response time for the first arriving unit is shown in Figure 8-8 and Table 8-17. Figure 8-8 shows response times for the first arriving unit as a frequency distribution in whole-minute increments.

The cumulative percentages here are read in the same way as a percentile. In Figure 8-8, the 90th percentile of 13.2 minutes means that 90 percent of calls had a response time of 13.2 minutes or less. In Table 8-17, the cumulative percentage of 61.8 means that 61.8 percent of calls had a response time under 8 minutes.

FIGURE 8-8: Cumulative Distribution of Response Time – First Arriving Unit

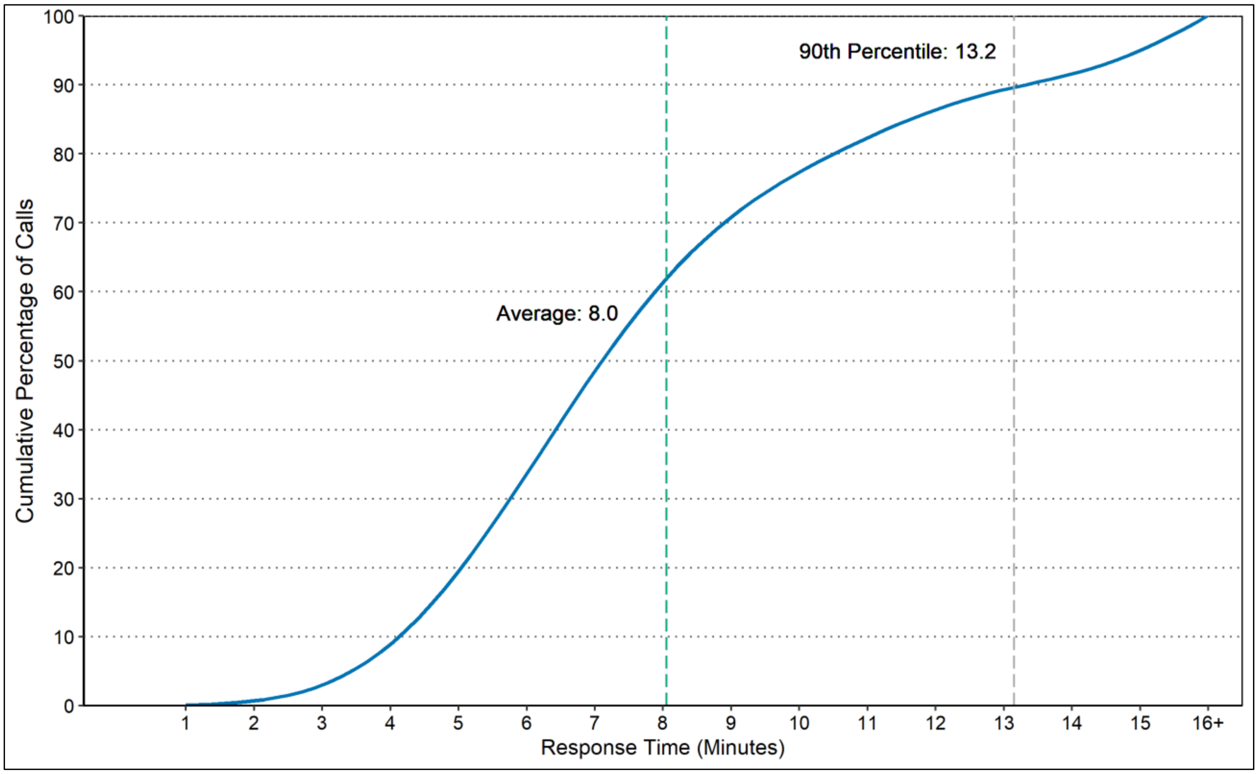


TABLE 8-17: Cumulative Distribution of Response Time – First Arriving Unit

Response Time (minute)	Frequency	Cumulative Percentage
1	13	0.2
2	33	0.7
3	150	3.0
4	360	8.5
5	721	19.5
6	918	33.5
7	990	48.6
8	863	61.8
9	586	70.8
10	430	77.3
11	315	82.1
12	272	86.3
13	221	89.7
14	152	92.0
15	118	93.8
16+	406	100.0

Observations:

- For 62 percent of calls, the response time of the first arriving unit was less than 8 minutes.

TRANSPORT CALL ANALYSIS

In this section, we present an analysis for unit activity that involved transporting patients, the variations by hour of day, and the average time for each stage of transport service. We identified transport calls by requiring that at least one responding unit had recorded both a "beginning to transport" time and an "arriving at the hospital" time. Based on these criteria, we note that eight non-EMS (fire & FD assist) calls that resulted in transports are included in this analysis.

Transport Calls by Type

Table 8-18 shows the number of calls by call type broken out by transport and non-transport calls.

TABLE 8-18: Transport Calls by Call Type

Call Type	Number of Calls			Conversion Rate
	Non-transport	Transport	Total	
Breathing difficulty	167	648	815	79.5
Cardiac and stroke	183	698	881	79.2
Fall and injury	458	838	1,296	64.7
Illness and other	846	1,607	2,453	65.5
MVA	422	255	677	37.7
Overdose and psychiatric	116	150	266	56.4
Seizure and unconsciousness	232	635	867	73.2
EMS Total	**2,424**	**4,831**	**7,255**	**66.6**
Fire & FD assist	65	8	73	11.0
Total	**2,489**	**4,839**	**7,328**	**66.0**

Observations:

- 67 percent of EMS calls involved transporting one or more patients
- On average, 13 EMS calls per day involved transporting one or more patients.

Average Transport Calls per Hour

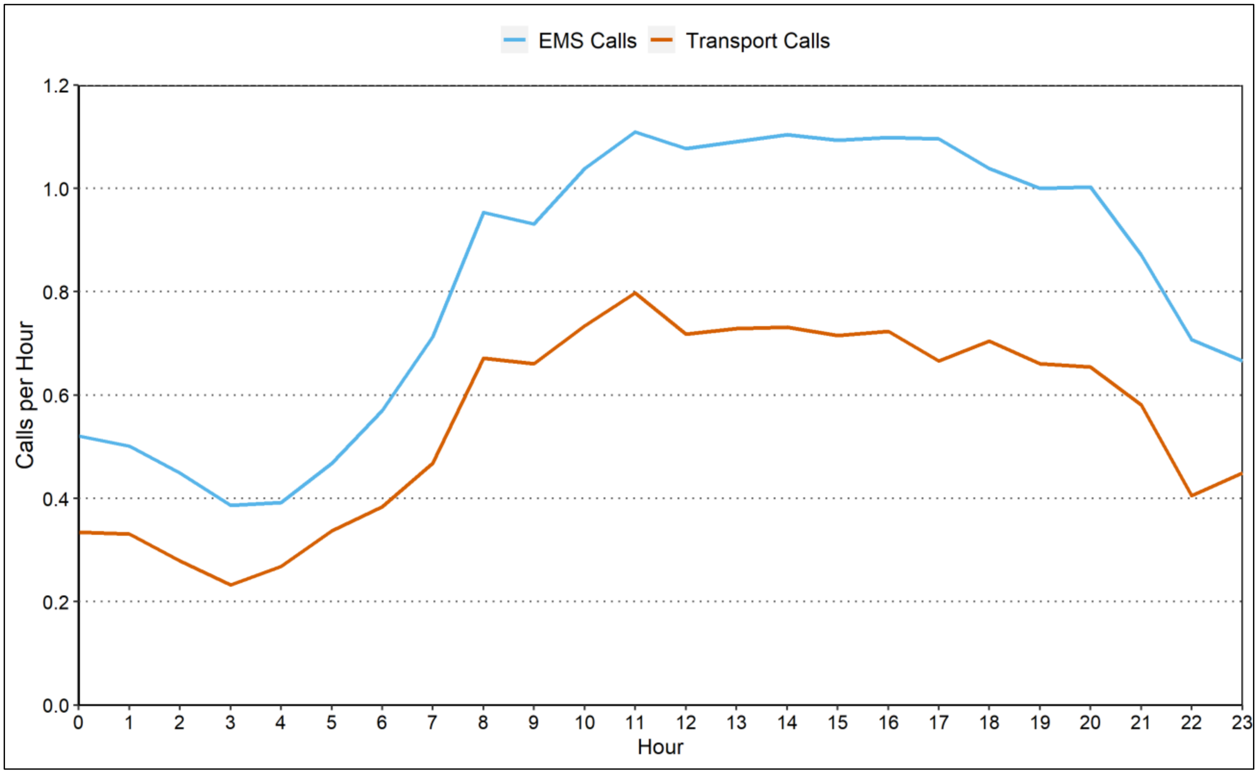
Table 8-19 and Figure 8-9 show the average number of EMS calls received each hour of the day during 2019. In the table the conversion rate measures the percent of EMS calls in which one or more patients was transported.

TABLE 8-19: EMS Transport Calls per Hour, by Time of Day

Hour	EMS Calls	Transport	EMS Calls per Day	Transports per Day	Conversion Rate
0	190	122	0.5	0.3	64.2
1	183	121	0.5	0.3	66.1
2	164	102	0.4	0.3	62.2
3	141	85	0.4	0.2	60.3
4	143	98	0.4	0.3	68.5
5	171	123	0.5	0.3	71.9
6	208	140	0.6	0.4	67.3
7	260	171	0.7	0.5	65.8
8	348	245	1.0	0.7	70.4
9	340	241	0.9	0.7	70.9
10	379	268	1.0	0.7	70.7
11	405	291	1.1	0.8	71.9
12	393	262	1.1	0.7	66.7
13	398	266	1.1	0.7	66.8
14	403	267	1.1	0.7	66.3
15	399	261	1.1	0.7	65.4
16	401	264	1.1	0.7	65.8
17	400	243	1.1	0.7	60.8
18	379	257	1.0	0.7	67.8
19	365	241	1.0	0.7	66.0
20	366	239	1.0	0.7	65.3
21	318	212	0.9	0.6	66.7
22	258	148	0.7	0.4	57.4
23	243	164	0.7	0.4	67.5
Total	**7,255**	**4,831**	**19.9**	**13.2**	**66.6**

Note: The conversion rate is measured by dividing the number of EMS transports by the number of EMS calls. For example, between midnight and 1:00 a.m., there were 122 EMS transports out of 190 EMS calls. This gives a conversion rate of 122 / 190 = 0.642, or 64.2 percent.

FIGURE 8-9: Average Transport Calls by Hour of Day



Observations:

- Hourly EMS calls per day were highest during the day from 8:00 a.m. to 9:00 p.m., averaging between 0.9 and 1.1 calls per day.
- Average hourly EMS calls per day peaked between 11:00 a.m. and noon, averaging 1.1 calls per day.
- Average hourly EMS calls per day was lowest between 3:00 a.m. and 4:00 a.m., averaging 0.4 calls per day.
- Hourly transport calls per day were highest during the day from 8:00 a.m. to 8:00 p.m., averaging between 0.7 calls per day and 0.8 calls per day.
- Average hourly transport calls per day peaked between 11:00 a.m. and noon, averaging 0.8 calls per day.
- Average hourly transport calls per day was lowest between 3:00 a.m. and 4:00 a.m., averaging 0.2 calls per day.
- Average hourly transport conversion rates per day peaked between 5:00 a.m. and 6:00 a.m., averaging 72 percent per day.
- Average hourly transport conversion rates per day was lowest between 10:00 p.m. and 11:00 p.m., averaging 57 percent per day.

Calls by Type and Duration

The following table shows the average duration of transport and non-transport EMS calls by call type.

TABLE 8-20: Transport Call Duration by Call Type

Call Type	Non-transport		Transport	
	Average Duration	Number of Calls	Average Duration	Number of Calls
Breathing difficulty	34.4	167	75.2	648
Cardiac and stroke	33.6	183	76.2	698
Fall and injury	29.0	458	79.2	838
Illness and other	23.2	846	76.3	1,607
MVA	16.2	422	78.6	255
Overdose and psychiatric	28.3	116	74.7	150
Seizure and unconsciousness	31.1	232	76.8	635
EMS Total	**25.6**	**2,424**	**76.8**	**4,831**
Fire & FD assist	12.0	65	82.2	8
Total	**25.3**	**2,489**	**76.8**	**4,839**

Note: Duration of a call is defined as the longest deployed time of any of the units responding to the same call.

Observations:

- The average duration was 25.6 minutes for non-transport EMS calls.
- The average duration was 76.8 minutes for EMS calls where one or more patients were transported to a hospital.

Transport Time Components

Table 8-21 gives the average deployed time for an ambulance on a transport call, along with three major components of the deployed time: on-scene time, travel to hospital time, and at-hospital time.

The on-scene time is the interval from the unit arriving on-scene time through the time the unit departs the scene for the hospital. Travel to hospital time is the interval from the time the unit departs the scene to travel to the hospital through the time the unit arrives at the hospital. At-hospital time is the time it takes for patient turnover at the hospital.

This table analyzes times by run. Normally, the number of runs will exceed the number of calls as a call may have multiple runs. In addition, average times may differ slightly from similar averages measured per call.

TABLE 8-21: Time Component Analysis for Ambulance Transport Runs by Call Type

Call Type	Average Minutes Spent per Run				Number of Runs
	On Scene	Traveling to Hospital	At Hospital	Deployed	
Breathing difficulty	16.0	13.4	39.0	74.9	649
Cardiac and stroke	16.0	13.7	38.7	75.3	698
Fall and injury	17.9	15.3	38.1	78.5	842
Illness and other	16.5	13.8	37.9	75.8	1,612
MVA	13.8	16.1	39.4	76.6	279
Overdose and psychiatric	15.8	11.2	39.4	73.4	151
Seizure and unconsciousness	15.9	13.2	40.4	76.5	637
EMS Total	**16.4**	**14.0**	**38.6**	**76.1**	**4,868**
Fire & Other Total	17.0	16.8	42.8	82.0	8
Total	**16.4**	**14.0**	**38.7**	**76.1**	**4,876**

Note: Average unit deployed time per run is lower than average call duration for some call types because call duration is based on the longest deployed time of any of the units responding to the same call, which may include an engine or ladder. Total deployed time is greater than the combination of on-scene, transport, and hospital wait times as it includes turnout, initial travel, and hospital return times.

Observations:

- The average time spent on-scene for a transport EMS call was 16.4 minutes.
- The average travel time from the scene of the EMS call to the hospital was 14.0 minutes.
- The average deployed time spent on transport EMS calls was 76.1 minutes.
- The average deployed time at the hospital was 38.6 minutes, which accounts for approximately 51 percent of the average total deployed time for a transport EMS call.

ATTACHMENT I: 2019 & 2020 COMPARISON

In this analysis, we compare portions of the previous analysis with similar records for 2020. We compare calls by type, unit workload, response time, and transport workload over the two years.

Call Volume by Year

Table 8-22 shows the number of calls by call type for both 2019 and 2020. Figure 8-10 shows the monthly variation in the average daily number of calls in two years. Similarly, Figure 8-11 illustrates the average number of calls received each hour of the day in two years.

TABLE 8-22: Calls by Call Type and Year

Call Type	Number of Calls		Calls per Day	
	2019	2020	2019	2020
Breathing difficulty	815	758	2.2	2.1
Cardiac and stroke	881	864	2.4	2.4
Fall and injury	1,296	1,229	3.6	3.4
Illness and other	2,453	2,421	6.7	6.6
MVA	677	589	1.9	1.6
Overdose and psychiatric	266	286	0.7	0.8
Seizure and unconsciousness	867	726	2.4	2.0
EMS Total	**7,255**	**6,873**	**19.9**	**18.8**
Fire & FD assist	73	72	0.2	0.2
Total	**7,328**	**6,945**	**20.1**	**19.0**

Observations:

- The call volume decreased five percent, from 7,328 in 2019 to 6,945 in 2020.

FIGURE 8-10: Calls per Day by Month and Year

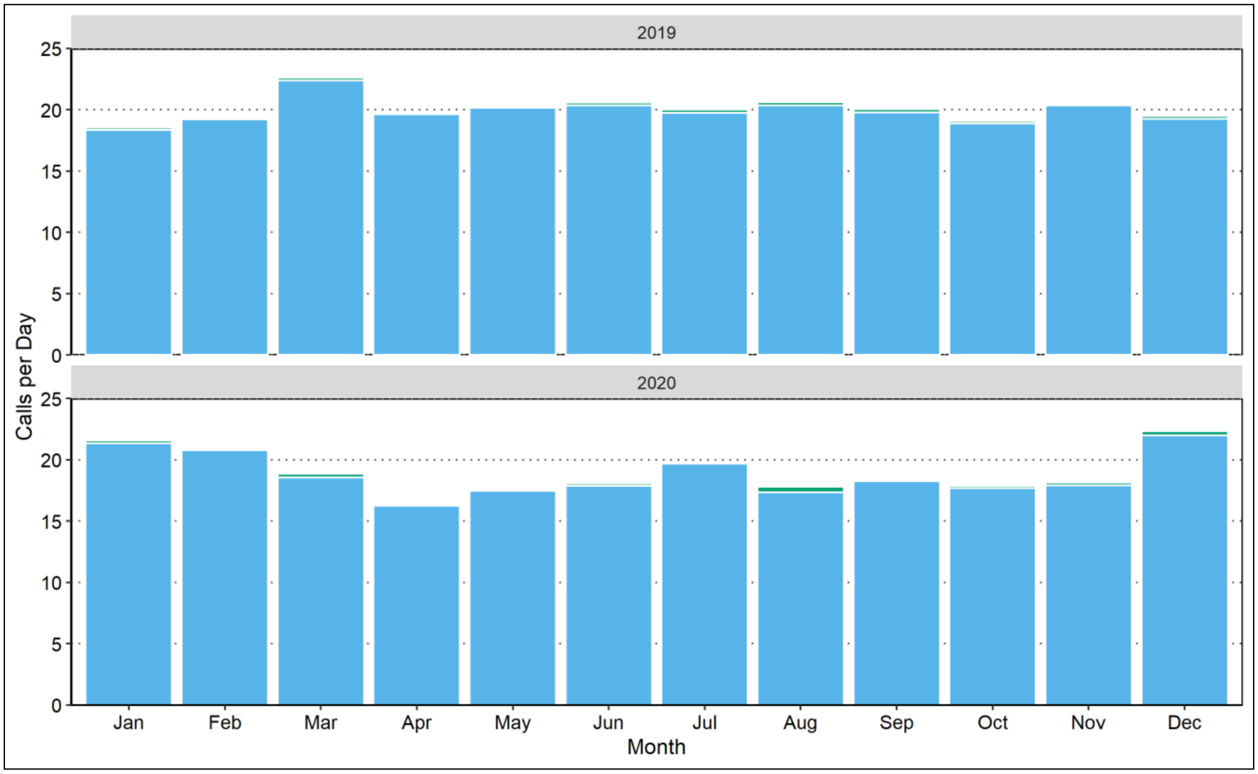
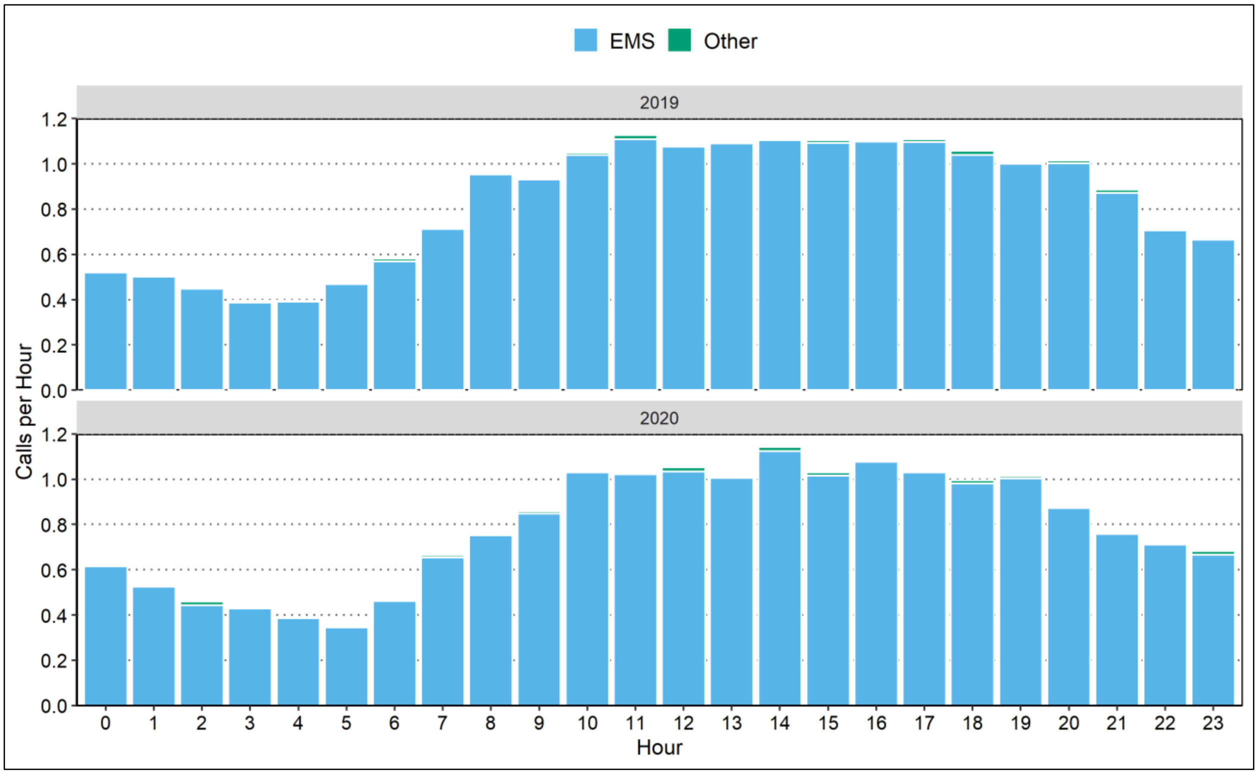


FIGURE 8-11: Calls per Hour by Time of Day and Year



Workload by Year

Table 8-23 compares the runs and workload for AMR units in 2019 and 2020. In the table, all SD type units are grouped. Figure 8-12 compares the average deployed minutes by the hour of the day in 2019 and 2020.

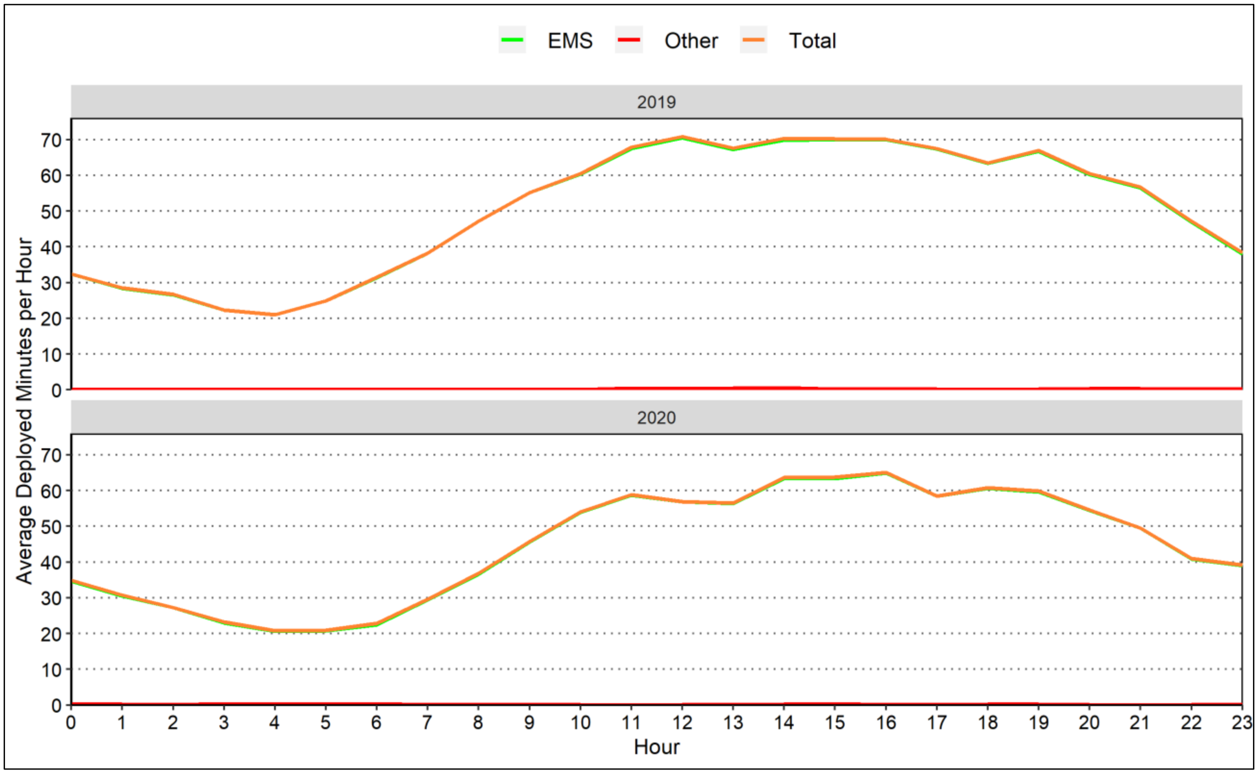
TABLE 8-23: Workload by Unit and Year

Type	Unit	Total Runs		Runs per Day		Total Hours		Deployed Minutes per Day	
		2019	2020	2019	2020	2019	2020	2019	2020
SA	AM254	29	49	0.1	0.1	11.6	26.4	1.9	4.3
	AM255	36	35	0.1	0.1	7.8	14.8	1.3	2.4
	AM256	22	19	0.1	0.1	30.2	28.5	5.0	4.7
	AM257	92	113	0.3	0.3	40.4	66.4	6.6	10.9
	AM401	103	78	0.3	0.2	98.9	84.5	16.3	13.8
	AM402	17	16	0.0	0.0	14.6	15.4	2.4	2.5
	AM411	238	189	0.7	0.5	210.4	171.6	34.6	28.1
	AM412	284	232	0.8	0.6	246.4	182.2	40.5	29.9
	AM413	135	187	0.4	0.5	87.0	117.3	14.3	19.2
	AM414	380	396	1.0	1.1	280.5	301.0	46.1	49.3
	AM415	356	326	1.0	0.9	286.4	266.3	47.1	43.7
	AM416	680	641	1.9	1.8	557.9	514.0	91.7	84.3
	AM417	2,460	2,352	6.7	6.4	2,218.3	1,983.9	364.7	325.2
	AM418	2,160	2,097	5.9	5.7	2,012.5	1,713.1	330.8	280.8
	AM419	133	280	0.4	0.8	109.3	221.1	18.0	36.3
	AM420	223	267	0.6	0.7	185.6	191.1	30.5	31.3
	AM492	65	56	0.2	0.2	49.4	38.7	8.1	6.3
	AM493	246	166	0.7	0.5	238.0	141.7	39.1	23.2
	AM494	4	16	0.0	0.0	5.5	10.9	0.9	1.8
	AM495	212	99	0.6	0.3	188.8	87.1	31.0	14.3
	AM496	238	175	0.7	0.5	225.5	164.6	37.1	27.0
	AM980	46	14	0.1	0.0	42.8	10.1	7.0	1.7
	AM985	26	0	0.1	0.0	24.2	0.0	4.0	0.0
	Total	**8,185**	**7,803**	**22.4**	**21.3**	**7,172.0**	**6,350.7**	**1,179.0**	**1,018.8**
SD	**Total**	**161**	**208**	**0.4**	**0.6**	**163.9**	**211.2**	**26.9**	**34.6**
Total		**8,346**	**8,011**	**22.9**	**21.9**	**7,335.9**	**6,561.9**	**1,205.9**	**1,075.7**

Observations:

- The total runs decreased 4 percent from 8,346 in 2019 to 8,011 in 2020.
- The total work hours decreased 11 percent from 7,335.9 hours in 2019 to 6,561.9 hours in 2020.

FIGURE 8-12: Average Deployed Minutes by Hour of Day in 2019 and 2020



Response Time Comparison by Year

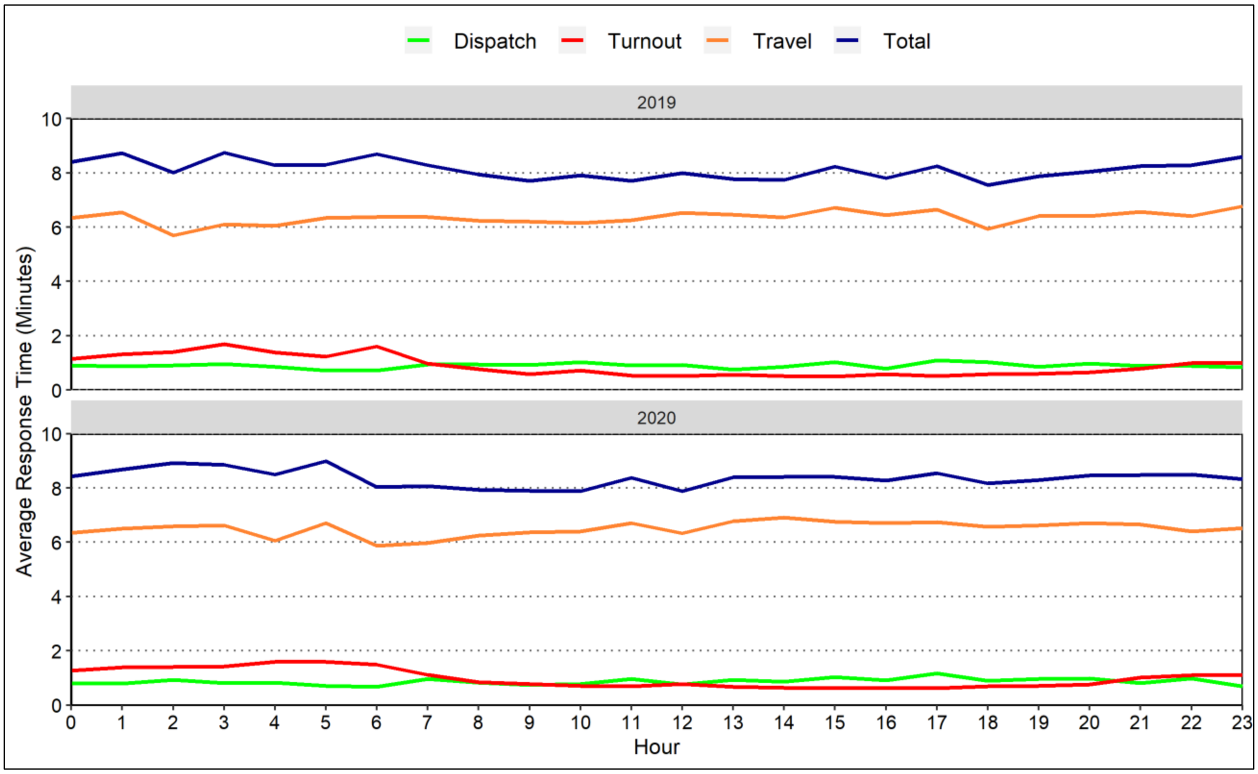
Tables 8-24 compares the average and 90th percentile response times broken out by call type and year. Figure 8-13 compares 2019's and 2020's average response time by hour of day.

TABLE 8-24: Average Response Time of First Arriving Unit by Call Type and Year

Call Type	2019			2020		
	Average	90th Percentile	Calls	Average	90th Percentile	Calls
Breathing difficulty	7.4	11.6	786	7.8	12.6	727
Cardiac and stroke	7.7	12.6	851	7.8	13.1	825
Fall and injury	8.0	12.8	1,227	8.2	13.1	1,131
Illness and other	8.6	14.9	2,125	8.9	14.8	2,145
MVA	8.0	12.8	508	8.1	13.1	454
OD	8.6	14.2	225	9.1	14.8	257
Seizure and UNC	7.7	12.2	826	7.8	12.3	675
Total	**8.0**	**13.2**	**6,548**	**8.3**	**13.5**	**6,214**

Note: OD= Overdose and psychiatric; UNC=Unconsciousness.

FIGURE 8-13: Average Response Time of First Arriving Unit, by Hour of Day and Year



Observations:

- The response times in two years did not change significantly.

TRANSPORT COMPARISON BY YEAR

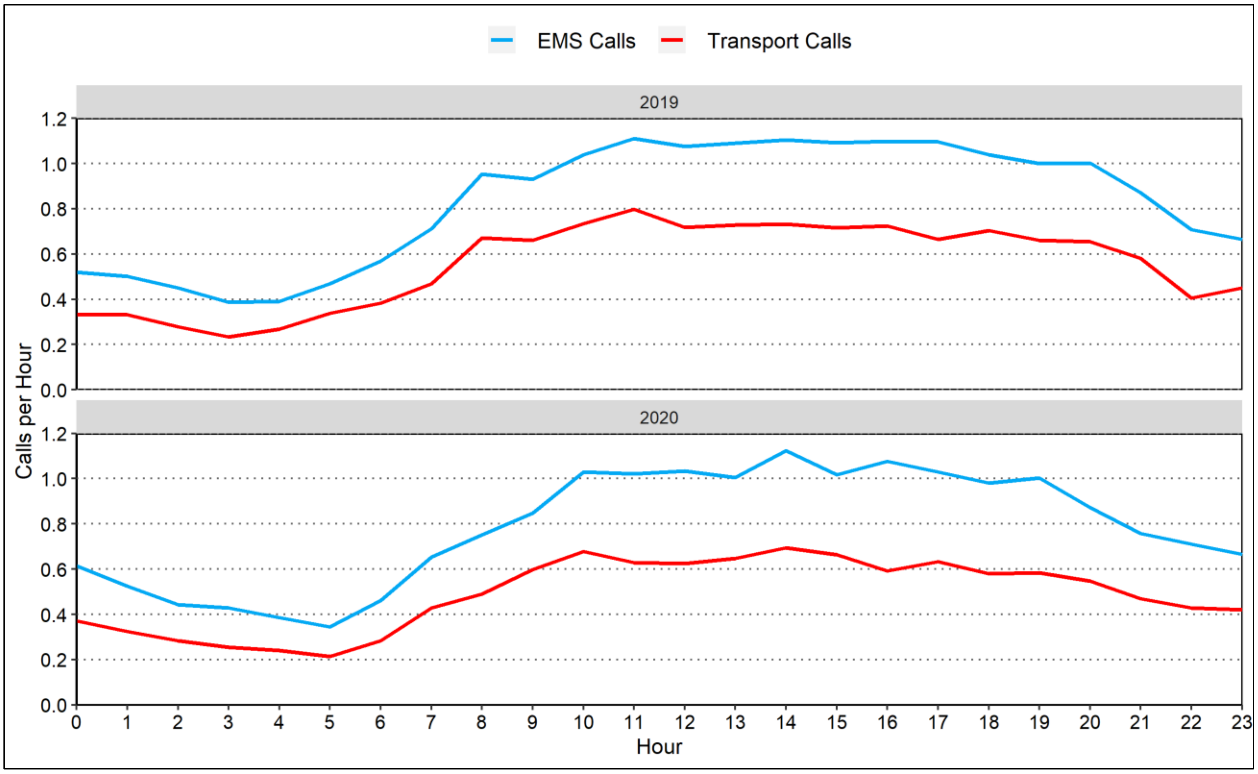
Table 8-25 compares the transport calls and workload in 2019 and 2020. Figure 8-14 compares the average number of EMS and transport EMS calls received each hour of the day over the two-year period.

TABLE 8-25: Transport Calls and Workload by Call Type and Year

Call Type	2019			2020		
	Calls	Runs	Average Call Duration (Minutes)	Calls	Runs	Average Call Duration (Minutes)
Breathing difficulty	648	649	75.2	569	569	72.2
Cardiac and stroke	698	698	76.2	625	626	71.7
Fall and injury	838	842	79.2	701	704	73.8
Illness and other	1,607	1,612	76.3	1,516	1,522	75.8
MVA	255	279	78.6	206	232	74.4
OD	150	151	74.7	166	167	72.4
Seizure and UNC	635	637	76.8	493	493	72.1
EMS Total	**4,831**	**4,868**	**76.8**	**4,276**	**4,313**	**73.8**
Fire & FD assist	**8**	**8**	**82.2**	**4**	**6**	**66.2**
Total	**4,839**	**4,876**	**76.8**	**4,280**	**4,317**	**73.7**

Note: OD= Overdose and psychiatric; UNC=Unconsciousness

FIGURE 8-14: Average Transport Calls by Hour and Year



ATTACHMENT II: CALL TYPE IDENTIFICATION

TABLE 8-26: Call Type by CAD Problem Description

Call Type	Problem	Frequency	
		2019	2020
Breathing Difficulty	Breathing Problems	781	723
	Choking	34	35
Cardiac and Stroke	Cardiac / Respiratory Arrest	110	142
	Chest Pain	485	465
	Heart Problems	112	114
	Stroke	174	143
Fire & PD Assist	Burns / Explosion	7	4
	.Nat Gas Leak Broken/Blowing	0	1
	.Natural Gas Odor - Outside	0	1
	AID - MEDIC	1	0
	Assist PD	3	2
	Carbon Monoxide Alarm	12	6
	Electrical Short	1	1
	Extinguished Fire	1	0
	Fuel Spill	4	4
	HazMat	1	0
	HazMat 1st Alarm	0	1
	HazMat Single Engine	3	2
	Illegal Burn	2	0
	Investigate	1	0
	Knocked Off Hydrant	1	0
	Lift Assist	1	0
	Lock in/out	3	2
	Odor of Chemical	0	1
	Oven Fire	1	0
	Ringing Alarm Highrise	0	1
	Rubbish Fire	1	2
	Safe Surrender	0	1
	SNAKE REMOVAL	1	0
	Special Service	2	1
	Structure Collapse	1	2
	Structure Fire - Comm / Apt	8	21
	Structure Highrise/Hospital	0	1
	Structure Residential	10	11
	Vegetation Initial Attack	1	2
	Vehicle Fire	4	1
	Vehicle Fire Freeway	2	4
	Wires down	1	0

Call Type	Problem	Frequency	
		2019	2020
Fall and Injury	Assault/Rape	227	238
	Drowning/Diving Accident	1	1
	Electrocution	4	1
	Falls / Back Inj	855	787
	Stabbing/Gunshot	34	36
	Traumatic Injuries, Spec	175	166
Illness and Other	Abdominal Pain/Problems	209	222
	Allergy/Hives/Med Rx/Stng	43	48
	Animal Bites/ Attacks	14	13
	Back Pain	75	67
	C O / Inhalation/ Haz Mat*	3	4
	Diabetic Problems	151	139
	Elevator Rescue	12	9
	Eye Problems / Injuries	3	8
	Headache	61	43
	Heat / Cold Exposure	6	6
	Hemorrhage / Lacerations	227	237
	Industrial Rescue	0	1
	Lift Assist*	1	1
	Medical Aid	7	4
	Medical Alert Alarm	95	76
	Miscellaneous Rescue	0	1
	NC Medical Aid	53	51
	Poison Control	2	1
	Preg/Birth/Miscarriage	29	29
	Sick Person	1,246	1,158
	Special Service*	0	3
	Suspected COVID19	0	108
	Unknown Problem*	189	162
	Vehicle vs. Pedestrian*	5	7
	Vehicle Rescue	22	22
	Water Rescue 3	0	1
MVA	Traffic Accident	589	529
	Traffic Accident FWY	74	50
	Vehicle vs Structure	13	9
	Vehicle vs. Pedestrian	1	1
Overdose and Psychiatric	OD/Ingestion/Poisonings	123	113
	Psych / Suicide Attempt	143	173
Seizure and UNC	Convulsions / Seizures	285	227
	Unc/Fainting	582	499
Total		**7,328**	**6,945**

Note: *NRIFS incident type code is 321; UNC = Unconsciousness.

- END -

APPENDIX C

Report on Residential
Fireground Field Experiments

NIST Technical Note 1661

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Report on Residential Fireground Field Experiments

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Abstract

Service expectations placed on the fire service, including Emergency Medical Services (EMS), response to natural disasters, hazardous materials incidents, and acts of terrorism, have steadily increased. However, local decision-makers are challenged to balance these community service expectations with finite resources without a solid technical foundation for evaluating the impact of staffing and deployment decisions on the safety of the public and firefighters.

For the first time, this study investigates the effect of varying crew size, first apparatus arrival time, and response time on firefighter safety, overall task completion, and interior residential tenability using realistic residential fires. This study is also unique because of the array of stakeholders and the caliber of technical experts involved. Additionally, the structure used in the field experiments included customized instrumentation; all related industry standards were followed; and robust research methods were used. The results and conclusions will directly inform the NPFA 1710 Technical Committee, who is responsible for developing consensus industry deployment standards.

This report presents the results of more than 60 laboratory and residential fireground experiments designed to quantify the effects of various fire department deployment configurations on the most common type of fire — a low hazard residential structure fire. For the fireground experiments, a 2,000 sq ft (186 m^2), two-story residential structure was designed and built at the Montgomery County Public Safety Training Academy in Rockville, MD. Fire crews from Montgomery County, MD and Fairfax County, VA were deployed in response to live fires within this facility. In addition to systematically controlling for the arrival times of the first and subsequent fire apparatus, crew size was varied to consider two-, three-, four-, and five-person staffing. Each deployment performed a series of 22 tasks that were timed, while the thermal and toxic environment inside the structure was measured. Additional experiments with larger fuel loads as well as fire modeling produced additional insight. Report results quantify the effectiveness of crew size, first-due engine arrival time, and apparatus arrival stagger on the duration and time to completion of the key 22 fireground tasks and the effect on occupant and firefighter safety.

Executive Summary

Both the increasing demands on the fire service - such as the growing number of Emergency Medical Services (EMS) responses, challenges from natural disasters, hazardous materials incidents, and acts of terrorism — and previous research point to the need for scientifically based studies of the effect of different crew sizes and firefighter arrival times on the effectiveness of the fire service to protect lives and property. To meet this need, a research partnership of the Commission on Fire Accreditation International (CFAI), International Association of Fire Chiefs (IAFC), International Association of Firefighters (IAFF), National Institute of Standards and Technology (NIST), and Worcester Polytechnic Institute (WPI) was formed to conduct a multiphase study of the deployment of resources as it affects firefighter and occupant safety. Starting in FY 2005, funding was provided through the Department of Homeland Security (DHS) / Federal Emergency Management Agency (FEMA) Grant Program Directorate for Assistance to Firefighters Grant Program — Fire Prevention and Safety Grants. In addition to the low-hazard residential fireground experiments described in this report, the multiple phases of the overall research effort include development of a conceptual model for community risk assessment and deployment of resources, implementation of a generalizable department incident survey, and delivery of a software tool to quantify the effects of deployment decisions on resultant firefighter and civilian injuries and on property losses.

The first phase of the project was an extensive survey of more than 400 career and combination (both career and volunteer) fire departments in the United States with the objective of optimizing a fire service leader's capability to deploy resources to prevent or mitigate adverse events that occur in risk- and hazard-filled environments. The results of this survey are not documented in this report, which is limited to the experimental phase of the project. The survey results will constitute significant input into the development of a future software tool to quantify the effects of community risks and associated deployment decisions on resultant firefighter and civilian injuries and property losses.

The following research questions guided the experimental design of the low-hazard residential fireground experiments documented in this report:

1. How do crew size and stagger affect overall start-to-completion response timing?

2. How do crew size and stagger affect the timings of task initiation, task duration, and task completion for each of the 22 critical fireground tasks?

3. How does crew size affect elapsed times to achieve three critical events that are known to change fire behavior or tenability within the structure:
   a. Entry into structure?
   b. Water on fire?
   c. Ventilation through windows (three upstairs and one back downstairs window and the burn room window).

4. How does the elapsed time to achieve the national standard of assembling 15 firefighters at the scene vary between crew sizes of four and five?

In order to address the primary research questions, the research was divided into four distinct, yet interconnected parts:

- Part 1 — Laboratory experiments to design appropriate fuel load

- Part 2 — Experiments to measure the time for various crew sizes and apparatus stagger (interval between arrival of various apparatus) to accomplish key tasks in rescuing occupants, extinguishing a fire, and protecting property

- Part 3 — Additional experiments with enhanced fuel load that prohibited firefighter entry into the burn prop – a building constructed for the fire experiments

- Part 4 — Fire modeling to correlate time-to-task completion by crew size and stagger to the increase in toxicity of the atmosphere in the burn prop for a range of fire growth rates.

The experiments were conducted in a burn prop designed to simulate a low-hazard[1] fire in a residential structure described as typical in NFPA 1710® *Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*. NFPA 1710 is the consensus standard for career firefighter deployment, including requirements for fire department arrival time, staffing levels, and fireground responsibilities.

Limitations of the study include firefighters' advance knowledge of the burn prop, invariable number of apparatus, and lack of experiments in elevated outdoor temperatures or at night. Further, the applicability of the conclusions from this report to commercial structure fires, high-rise fires, outside fires, terrorism/natural disaster response, HAZMAT or other technical responses has not been assessed and should not be extrapolated from this report.

Primary Findings

Of the 22 fireground tasks measured during the experiments, results indicated that the following factors had the most significant impact on the success of fire fighting operations. All differential outcomes described below are statistically significant at the 95 % confidence level or better.

Overall Scene Time:

The four-person crews operating on a low-hazard structure fire completed all the tasks on the fireground (on average) seven minutes faster — nearly 30 % — than the two-person crews. The four-person crews completed the same number of fireground tasks (on average) 5.1 minutes faster — nearly 25 % — than the three-person crews. On the low-hazard residential structure fire, adding a fifth person to the crews did not decrease overall fireground task times. However, it should be noted that the

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[1] A low-hazard occupancy is defined in the NFPA Handbook as a one-, two-, or three-family dwelling and some small businesses. Medium hazards occupancies include apartments, offices, mercantile and industrial occupancies not normally requiring extensive rescue or firefighting forces. High-hazard occupancies include schools, hospitals, nursing homes, explosive plants, refineries, high-rise buildings, and other highlife hazard or large fire potential occupancies.

benefit of five-person crews has been documented in other evaluations to be significant for medium- and high-hazard structures, particularly in urban settings, and is recognized in industry standards.[2]

Time to Water on Fire:

There was a 10% difference in the "water on fire" time between the two- and three-person crews. There was an additional 6% difference in the "water on fire" time between the three- and four-person crews. (i.e., four-person crews put water on the fire 16% faster than two person crews). There was an additional 6% difference in the "water on fire" time between the four- and five-person crews (i.e. five-person crews put water on the fire 22% faster than two-person crews).

Ground Ladders and Ventilation:

The four-person crews operating on a low-hazard structure fire completed laddering and ventilation (for life safety and rescue) 30 % faster than the two-person crews and 25 % faster than the three-person crews.

Primary Search:

The three-person crews started and completed a primary search and rescue 25 % faster than the two-person crews. The four- and five-person crews started and completed a primary search 6 % faster than the three-person crews and 30 % faster than the two-person crew. A 10 % difference was equivalent to just over one minute.

Hose Stretch Time:

In comparing four-and five-person crews to two-and three-person crews collectively, the time difference to stretch a line was 76 seconds. In conducting more specific analysis comparing all crew sizes to the two-person crews the differences are more distinct. Two-person crews took 57 seconds longer than three-person crews to stretch a line. Two-person crews took 87 seconds longer than four-person crews to complete the same tasks. Finally, the most notable comparison was between two-person crews and five-person crews — more than 2 minutes (122 seconds) difference in task completion time.

Industry Standard Achieved:

As defined by NFPA 1710, the "industry standard achieved" time started from the first engine arrival at the hydrant and ended when 15 firefighters were assembled on scene.[3] An effective response force was assembled by the five-person crews three minutes faster than the four-person crews. Based on the study protocols, modeled after a typical fire department apparatus deployment strategy, the total number of firefighters on scene in the two- and three-person crew scenarios never equaled 15 and therefore the two- and three-person crews were unable to assemble enough personnel to meet this standard.

Occupant Rescue:

Three different "standard" fires were simulated using the Fire Dynamics Simulator (FDS) model. Characterized in the *Handbook of the Society of Fire Protection Engineers* as slow-, medium-, and fast-growth rate[4], the fires grew exponentially with time. The rescue scenario was based on a non-ambulatory occupant in an upstairs bedroom with the bedroom door open.

Independent of fire size, there was a significant difference between the toxicity, expressed as fractional effective dose (FED), for occupants at the time of rescue depending on arrival times for all crew sizes. Occupants rescued by early-arriving crews had less exposure to combustion products than occupants rescued by late-arriving crews. The fire modeling showed clearly that two-person crews cannot complete essential fireground tasks in time to rescue occupants without subjecting them to an increasingly toxic atmosphere. For a slow-growth rate fire with two-person crews, the FED was approaching the level at which sensitive populations, such as children and the elderly are threatened. For a medium-growth rate fire with two-person crews, the FED was far above that threshold and approached the level affecting the general population. For a fast-growth rate fire with two-person crews, the FED was well above the median level at which 50 % of the general population would be incapacitated. Larger crews responding to slow-growth rate fires can rescue most occupants prior to incapacitation along with early-arriving larger crews responding to medium-growth rate fires. The result for late-arriving (two minutes later than early-arriving) larger crews may result in a threat to sensitive populations for medium-growth rate fires. Statistical averages should not, however, mask the fact that there is no FED level so low that every occupant in every situation is safe.

Conclusion:

More than 60 full-scale fire experiments were conducted to determine the impact of crew size, first-due engine arrival time, and subsequent apparatus arrival times on firefighter safety and effectiveness at a low-hazard residential structure fire. This report quantifies the effects of changes to staffing and arrival times for residential firefighting operations. While resource deployment is addressed in the context of a single structure type and risk level, it is recognized that public policy decisions regarding the cost-benefit of specific deployment decisions are a function of many other factors including geography, local risks and hazards, available resources, as well as community expectations. This report does not specifically address these other factors.

The results of these field experiments contribute significant knowledge to the fire service industry. First, the results provide a quantitative basis for the effectiveness of four-person crews for low-hazard response in *NFPA 1710*. The results also provide valid measures of total effective response force assembly on scene for fireground operations, as well as the expected performance time-to-critical-task measures for low-hazard structure fires. Additionally, the results provide tenability measures associated with a range of modeled fires.

Future research should extend the findings of this report in order to quantify the effects of crew size and apparatus arrival times for moderate- and high-hazard events, such as fires in high-rise buildings, commercial properties, certain factories, or warehouse facilities, responses to large-scale non-fire incidents, or technical rescue operations.

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[2] NFPA Standard 1710 - A.5.2.4.2.1 …Other occupancies and structures in the community that present greater hazards should be addressed by additional fire fighter functions and additional responding personnel on the initial full alarm assignment.

[3] NFPA 1710 Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments. Section 5.2.1 – Fire Suppression Capability and Section 5.2.2 Staffing.

[4] As defined in the handbook, a fast fire grows exponentially to 1.0 MW in 150 seconds. A medium fire grows exponentially to 1 MW in 300 seconds. A slow fire grows exponentially to 1 MW in 600 seconds. A 1 MW fire can be thought-of as a typical upholstered chair burning at its peak. A large sofa might be 2 to 3 MWs.

Background

The fire service in the United States has a deservedly proud tradition of service to community and country dating back hundreds of years. As technology advances and the scope of service grows (e.g., more EMS obligations and growing response to natural disasters, hazardous materials incidents, and acts of terrorism), the fire service remains committed to a core mission of protecting lives and property from the effects of fire.

Firefighting is a dangerous business with substantial financial implications. In 2007, U.S. municipal fire departments responded to an estimated 1,557,500 fires. These fires killed 3,430 civilians (non-firefighters) and contributed to 17,675 reported civilian fire injuries. Direct property damage was estimated at $14.6 billion dollars (Karter, 2008). In spite of the vigorous nationwide efforts to promote firefighter safety, the number of firefighter deaths has consistently remained tragically high. In both 2007 and 2008, the U.S. Fire Administration reported 118 firefighter fatalities (USFA 2008).

Although not all firefighter deaths occur on the fireground — accidents in vehicles and training fatalities add to the numbers — every statistical analysis of the fire problem in the United States identifies residential structure fires as a key component in firefighter and civilian deaths, as well as direct property loss. Consequently, community planners and decision-makers need tools for optimally aligning resources with the service commitments needed for adequate protection of citizens.

Problem

Despite the magnitude of the fire problem in the United States, there are no scientifically based tools available to community and fire service leaders to assess the effects of prevention, fixed sprinkler systems, fire fighting equipment, or deployment and staffing decisions. Presently, community and fire service leaders have a qualitative understanding of the effect of certain resource allocation decisions. For example, a decision to double the number of firehouses, apparatus, and firefighters would likely result in a decrease in community fire losses, while cutting the number of firehouses, apparatus, and firefighters would likely yield an increase in the community fire losses, both human and property. However, decision-makers lack a sound basis for quantifying the total impact of enhanced fire resources on the number of firefighter and civilian lives saved and injuries prevented.

Studies on adequate deployment of resources are needed to enable fire departments, cities, counties, and fire districts to design an acceptable level of resource deployment based upon community risks and service provision commitment. These studies will assist with strategic planning and municipal and state budget processes. Additionally, as resource studies refine data collection methods and measures, both subsequent research and improvements to resource deployment models will have a sound scientific basis.

Review of Literature

Research to date has documented a consistent relationship between resources deployed and firefighter and civilian safety. Studies documenting engine and ladder crew performance in diverse simulated environments as well as actual responses show a basic relationship between apparatus staffing levels and a range of important performance variables and outcome measurements such as mean on-scene time, time-to-task completion, incidence of injury among fire service personnel, and costs incurred as a result of on-scene injuries (Cushman 1981, McManis 1984, Morrison 1990, Ontario 1991, Phoenix 1991, Roberts 1993).

Reports by fire service officials and consulting associates reviewing fire suppression and emergency response by fire crews in U.S. cities were the first publications to describe the relationship between adequate staffing levels and response time, time to completion of various fireground tasks, overall effectiveness of fire suppression, and estimated value of property loss for a wide range of real and simulated environments. In 1980, the Columbus Fire Division's report on firefighter effectiveness showed that for a predetermined number of personnel initially deployed to the scene of a fire, the proportion of incidents in which property loss exceeded $5,000 and horizontal fire spread of more than 25 sq ft (2.3 $m^{2)}$ was significantly greater for crews whose numbers fell below the set thresholds of 15 total fireground personnel at residential fires and 23 at large-risk fires (Backoff 1980). The following year, repeated live experiments at a one-family residential site using modern apparatus and equipment demonstrated that larger units performed tasks and accomplished knockdown more quickly, ultimately resulting in a lower percentage of loss attributable to factors controlled by the fire department. The authors of this article highlighted that the fire company is the fire department's basic working unit and further emphasized the importance of establishing accurate and up-to-date performance measurements to help collect data and develop conclusive strategies to improve staffing and equipment utilization (Gerard 1981).

Subsequent reports from the United States Fire Administration (USFA) and several consulting firms continued to provide evidence for the effects of staffing on fire crews' ability to complete tasks involved in fire suppression efficiently and effectively. Citing a series of tests conducted in 1977 by the Dallas Fire Department that measured the time it took three-, four-, and five-person teams to advance a line and put water on a simulated fire at the rear of the third floor of an old school, officials from the USFA underscored that time-to-task completion and final level of physical exhaustion for crews markedly improved not after any one threshold, but with the addition of each new team member. This report went on to outline the manner in which simulated tests exemplify a clear-cut means to record and analyze the resources initially deployed and finally utilized at fire scenes (NFA 1981). A later publication detailing more Dallas Fire Department simulations — ninety-one runs each for a private residential fire, high-rise office fire, and apartment house fire — showed again that increased staffing levels greatly enhanced the coordination and effectiveness of crews' fire suppression efforts during a finite time span (McManis Associates 1984). Numerous studies of local departments have supported this conclusion using a diverse collection of data, including a report by the National Fire Academy (NFA) on fire department staffing in smaller communities, which showed that a company crew staffed with four firefighters could perform rescue of potential victims approximately 80 % faster than a crew staffed with three firefighters (Morrison 1990).

During the same time period that the impact of staffing levels on fire operations was gaining attention, investigators began to question whether staffing levels could also be associated with the risk of firefighter injuries and the cost incurred as a result of such injuries at the fire scene. Initial results from the Columbus Fire Division showed that "firefighter injuries occurred more often when the total number of personnel on the fireground was less than 15 at residential fires and 23 at large-risk fires" (Backoff 1980), and mounting evidence has indicated that staffing levels are a fundamental health and safety issue for firefighters in addition to being a key determinant of immediate response capacity. One early analysis by the Seattle Fire Department for that city's Executive Board reviewed the average severity of injuries suffered by three-, four-, and five-person engine companies, with the finding that "the rate of firefighter injuries expressed as total hours of disability per hours of fireground exposure were 54 % greater for engine companies staffed with 3 personnel when compared to those staffed with 4 firefighters, while companies staffed with 5 personnel had an injury rate that was only one-third that associated with four-person companies" (Cushman 1981). A joint report from the International Association of Fire Fighters (IAFF) and Johns Hopkins University concluded, after a comprehensive analysis of the minimum staffing levels and firefighter injury rates in U.S. cities with populations of 150,000 or more, that jurisdictions operating with crews of less than four firefighters had injury rates nearly twice the percentage of jurisdictions operating with crews of four-person crews or more (IAFF, JHU 1991).

More recent studies have continued to support the finding that staffing per piece of apparatus integrally affects the efficacy and safety of fire department personnel during emergency response and fire suppression. Two studies in particular demonstrate the consistency of these conclusions and the increasing level of detail and accuracy present in the most recent literature, by looking closely at the discrete tasks that could be safely and effectively performed by three- and four-person fire companies. After testing drills comprised of a series of common fireground tasks at several fire simulation sites, investigators from the Austin Fire Department assessed the physiological impact and injury rates among the variably staffed fire crews. In these simulations, an increase from a three- to four-person crew resulted in marked improvements in time-to-task completion or efficiency for the two-story residential fire drill, aerial ladder evolution, and high-rise fire drill, leading the researchers to conclude that loss of life and property increases when a sufficient number of personnel are not available to conduct the required tasks efficiently, independent of firefighter experience, preparation, or training. Reviews of injury reports by the Austin Fire Department furthermore revealed that the injury rate for three-person companies in the four years preceding the study was nearly one-and-a-half that of crews staffed with four or more personnel (Roberts 1993). In a sequence of similar tests, the Office of the Fire Marshal of Ontario, Canada likewise found that three-person fire companies were unable to safely perform deployment of backup protection lines, interior suppression or rescue operations, ventilation operations that required access to the roof of the involved structure, use of large hand-held hose lines, or establish a water supply from a static source without additional assistance and within the time limits of the study. Following these data, Fire Marshal officials noted that three-person crews were also at increased risk for exhaustion due to insufficient relief at fire scenes and made recommendations for the minimum staffing levels per apparatus necessary for suppression and rescue related tasks (Office of the Fire Marshal of Ontario 1993).

The most comprehensive contemporary studies on the implications of fire crew staffing now include much more accurate performance measures for tasks at the fireground, in addition to the basic metric of response time. They include environmental measures of performance, such as total water supply, which expand the potential for assessing the cost-effectiveness of staffing not only in terms of fireground personnel injury rates but also comparative resource expenditure required for fire suppression. Several examples from the early 1990s show investigators and independent fire departments beginning to gather the kind of specific, comprehensive data on staffing and fireground tasks such as those suggested and outlined in concurrent local government publications that dealt with management of fire services (Coleman 1988). A report by the Phoenix Fire Department laid out clear protocols for responding to structure fires and response evaluation in terms of staffing, objectives, task breakdowns, and times in addition to outlining the responsibilities of responding fire department members and the order in which they should be accomplished for a full-scale simulation activity (Phoenix 1991). One attempt to devise a prediction model for the effectiveness of manual fire suppression similarly reached beyond response time benchmarks to describe fire operations and the step-by-step actions of firefighters at incident scenes by delineating the time-to-task breakdowns for size-up, water supply, equipment selection, entry, locating the fire, and advancing hose lines, while also comparing the predicted time-to-task values with the actual times and total resources (Menker 1994). Two separate studies of local fire department performance, one from Taoyuan County in Taiwan and another from the London Fire Brigade, have drawn ties between fire crews' staffing levels and total water demand as the consequence of both response time and fire severity. Field data from Taoyuan County for cases of fire in commercial, business, hospital, and educational properties showed that the type of land use as well as response time had a significant impact on the water volume necessary for fire suppression, with the notable quantitative finding that the water supply required on-scene doubled when the fire department response increased by ten minutes (Chang 2005).

Response time as a predictor of residential fire outcomes has received less study than the effect of crew size. A Rand Institute study demonstrated a relationship between the distance the responding companies traveled and the physical property damage. This study showed that the fire severity increased with response distance, and therefore the magnitude of loss increased proportionally (Rand 1978). Using records from 307 fires in nonresidential buildings over a three-year period, investigators in the United Kingdom correspondingly found response time to have a significant impact on final fire area, which in turn was proportional to total water demand (Sardqvist 2000).

Recent government and professional literature continues to demonstrate the need for more data that would quantify in depth and illustrate the required tasks, event sequences, and necessary response times for effective fire suppression in order to determine with accuracy the full effects of either a reduction or increase in fire company staffing (Karter 2008). A report prepared for National Institute of Standards and Technology (NIST) stressed the ongoing need to elucidate the relationship between staffing and personnel injury rates, stating that “a scientific study on the relationship between the number of firefighters per engine and the incidence of injuries would resolve a long-standing question concerning staffing and safety” (TriData 2005). While not addressing staffing levels as a central focus, an annual review of fire department calls and false alarms by the National Fire Protection Association (NFPA) exemplified the need to capture not only the number of personnel per apparatus for effective fire suppression but also to clarify the demands on individual fire departments with resolution at the station level (NFPA 2008).

In light of the existing literature, there remain unanswered questions about the relationships between fire service resource deployment levels and associated risks. For the first time this study investigates the effect of varying crew size, first apparatus arrival time, and response time on firefighter safety, overall task completion and interior residential tenability using realistic residential fires. This study is also unique because of the array of stakeholders and the caliber of technical advisors involved. Additionally, the structure used in the field experiments included customized instrumentation for the experiments; all related industry standards were followed; robust research methods were used; and the results and conclusions will directly inform the *NFPA 1710* Technical Committee, as well as public officials and fire chiefs.[5]

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[5] NFPA is a registered trademark of the National Fire Protection Association, Quincy, Massachusetts. NFPA 1710 defines minimum requirements relating to the organization and deployment of fire suppression operations, emergency medical operations, and special operations to the public by substantially all career fire departments. The requirements address functions and objectives of fire department emergency service delivery, response capabilities, and resources. The purpose of this standard is to specify the minimum criteria addressing the effectiveness and efficiency of the career public fire suppression operations, emergency medical service, and special operations delivery in protecting the citizens of the jurisdiction and the occupational safety and health of fire department employees. At the time of the experiments, the 2004 edition of NFPA 1710 was the current edition.

Purpose and Scope of the Study

This project systematically studies deployment of fire fighting resources and the subsequent effect on both firefighter safety and the ability to protect civilians and their property. It is intended to enable fire departments and city/county managers to make sound decisions regarding optimal resource allocation to meet service commitments using the results of scientifically based research. Specifically, the residential fireground experiments provide quantitative data on the effect of crew size, first-due engine arrival time, and subsequent apparatus stagger on time-to-task for critical steps in response and fire fighting.

The first phase of the multiphase project was an extensive survey of more than 400 career and combination fire departments in the United States with the objective of optimizing a fire service leader's capability to deploy resources to prevent or mitigate adverse events that occur in risk- and hazard-filled environments. The results of this survey are not documented in this report, which is limited to the experimental phase of the project, but they will constitute significant input into future applications of the data presented in this document.

This report describes the second phase of the project, divided into four parts:

- Part 1 — Laboratory experiments to design the appropriate fuel packages to be used in the burn facility specially constructed for the research project
- Part 2 — Field tests for critical time-to-task completion of key tasks in fire suppression
- Part 3 — Field tests with real furniture (room and contents experiments)
- Part 4 — Fire modeling to apply data gathered to slow-, medium-, and fast-growth rate fires

The scope of this study is limited to understanding the relative influence of deployment variables on low-hazard, residential structure fires, similar in magnitude to the hazards described in NFPA® 1710, *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*. The standard uses as a typical residential structure a 2,000 sq ft (186 m^2) two-story, single-family dwelling with no basement and no exposures (nearby buildings or hazards such as stacked flammable material).

The limitations of the study, such as firefighters' advance knowledge of the facility constructed for this experiment, invariable number of apparatus, and lack of experiments in extreme temperatures or at night, will be discussed in the Limitations section of this report. It should be noted that the applicability of the conclusions from this report to commercial structure fires, high-rise fires, outside fires, and response to hazardous material incidents, acts of terrorism, and natural disasters or other technical responses has not been assessed and should not be extrapolated from this report.

A Brief Overview of the Fireground Operations

Regardless of the size of a structure on fire, firefighting crews identify four priorities: life safety of occupants and firefighters, confinement of the fire, property conservation, and reduction of adverse environmental impact. Interdependent and coordinated activities of all fire fighting personnel are required to meet the priority objectives.

NFPA 1710 specifies that the number of on-duty fire suppression personnel must be sufficient to carry out the necessary fire fighting operations given the expected fire fighting conditions. During each fireground experiment, the following were dispatched to the test fire building:

- three engine companies
- one truck company
- a command vehicle with a battalion chief and a command aide

Staffing numbers for the engine and truck crews and response times were varied for the purposes of the tests. Additional personnel available to ensure safety will be described later in this report.

The following narrative account describes the general sequence of activities in part 2 of the experiments (time-to-task), when the fuel load permitted firefighter entry:

> The first arriving engine company conducts a size-up or initial life safety assessment of the building to include signs of occupants in the home, construction features, and location of the original fire and any extension to other parts of the structure. This crew lays a supply line from a hydrant close to the building for a continuous water supply.
>
> The truck company usually arrives in close proximity to the first engine company. The truck company is responsible for gaining access or forcing entry into the building so that the engine company can advance the first hose line into the building to locate and extinguish the fire. Usually, they assist the engine company in finding the fire. The NFPA and OSHA 2 In/2 Out[6] crew is also assembled prior to anyone entering an atmosphere that is immediately dangerous to life or health (IDLH). This important safety requirement will have a large impact on availability of firefighters to enter the building when small crews are deployed.
>
> Once a door is opened, the engine crew advances a hose line (attack line) toward the location of the fire. At the same time, members from the truck crew accompany the engine crew and assist in ventilating the building to provide a more tenable atmosphere for occupants and firefighters. Ventilation also helps by improving visibility in an otherwise "pitch black" environment, but it must be coordinated with the attack line crew to ensure it helps control the fire and does not contribute to fire growth. The truck crew performs a systematic rapid search of the entire structure starting in the area where occupants would be in the most danger. The most dangerous area is proximate to the fire and the areas directly above the fire.
>
> Depending upon the travel distance, the battalion chief and command aide will have arrived on the scene and have taken command of the incident and established a command post. The role of the incident commander is to develop the action plan to mitigate the incident and see that those actions are carried out in a safe, efficient, and effective manner. The command aide is responsible for situational assessment and communications, including communications with crew officers to ensure personnel accountability.
>
> Depending on response time or station location, the second (engine 2) and possibly the third engine company (engine 3) arrive. The second arriving engine (engine 2) connects to the fire hydrant where the first engine (engine 1) laid their supply line. Engine 2 pumps water from the hydrant through the supply line to the first engine for fire fighting operations. According to *NFPA 1710*, water should be flowing from the supply line to the attack engine prior to the attack crew's entry into the structure.
>
> The crew from the second engine advances a second hand line as a backup line to protect firefighters operating on the inside and to prevent fire from spreading to other parts of the structure.
>
> The third engine crew is responsible for establishing a Rapid Intervention Team (RIT), a rescue team staged at or near the command post or as designated by the Incident Commander (in the front of the building) with all necessary equipment needed to locate and/or rescue firefighters that become trapped or incapacitated. The RIT plans entry/exit portals and removes hazards, if found, to assist interior crews.
>
> As the fire fighting, search and rescue, and ventilation operations are continuing, two members of the truck company are tasked with placing ground ladders to windows and the roof to provide a means of egress for occupants or firefighters. The truck crew is responsible for controlling interior utilities such as gas and electric after their ventilation, search, and rescue duties are completed.
>
> Once the fire is located and extinguished and occupants are

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[6] The "2 In/2 Out" policy is part of paragraph (g)(4) of OSHAs revised respiratory protection standard, 29 CFR 1910.134. This paragraph applies to private sector workers engaged in interior structural fire fighting and to Federal employees covered under Section 19 of the Occupational Safety and Health Act. States that have chosen to operate OSHA-approved occupational safety and health state plans are required to extend their jurisdiction to include employees of their state and local governments. These states are required to adopt a standard at least as effective as the Federal standard within six months.

OSHAs interpretation on requirements for the number of workers required to be present when conducting operations in atmospheres that are immediately dangerous to life and health (IDLH) covers the number of persons who must be on the scene before fire fighting personnel may initiate an attack on a structural fire. An interior structural fire (an advanced fire that has spread inside of the building where high temperatures, "heat" and dense smoke are normally occurring) would present an IDLH atmosphere and therefore, require the use of respirators. In those cases, at least two standby persons, in addition to the minimum of two persons inside needed to fight the fire, must be present before fire fighters may enter the building.
Letter to Thomas N. Cooper, Purdue University, from Paula O. White, Director of Federal-State Operations, U.S. Department of Labor, Occupational Safety & Health Administration, November 1, 1995.

removed, the incident commander reassesses the situation and provides direction to conduct a very thorough secondary search of the building to verify that the fire has not extended into void spaces and that it is fully extinguished. (In a nonexperimental fire situation, salvageable property would be covered or removed to minimize damage.)

Throughout the entire incident, each crew officer is responsible for the safety and accountability of his or her personnel along with air management. The location and wellness of crews is tracked by the command aide through a system of personal accountability checks conducted at 20-minute intervals.

Following extinguishment of the fire, an onsite review is conducted to identify actions for improvement. Crews are monitored, hydrated and rested before returning to work in the fire building.

The Relation of Time-to-Task Completion and Risk

Delayed response, particularly in conjunction with the deployment of inadequate resources, reduces the likelihood of controlling the fire in time to prevent major damage and possible loss of life and increases the danger to firefighters.

Figure 1 illustrates a hypothetical sequence of events for response to a structure fire. During fire growth, the temperature of a typical compartment fire can rise to over 1,000° F (538° C). When a fire in part of a compartment reaches flashover, the rapid transition between the growth and the fully developed fire stage, flame breaks out almost at once over the surface of all objects in the compartment, with results for occupants, even firefighters in full gear, that are frequently deadly.

Successful containment and control of a fire require the coordination of many separate tasks. Fire suppression must be coordinated with rescue operations, forcible entry, and utilities control. Ventilation typically occurs only after an attack line is in place and crews are ready to move in and attack the fire. The incident commander needs up-to- the-minute knowledge of crew activities and the status of task assignments which could result in a decision to change from an offensive to a defensive strategy.

Standards of Response Cover

Developing a standard of response cover — the policies and procedures that determine the distribution, concentration, and reliability of fixed and mobile resources for response to fire (as well as other kinds of technical response) — related to service commitments to the community is a complex task. Fire and rescue departments must evaluate existing (or proposed) resources against identified risk levels in the community and against the tasks necessary to conduct safe, efficient and effective fire suppression at structures identified in these various risk levels. Leaders must also evaluate geographic distribution and depth or concentration of resources deployed based on time parameters.

Recognition and reporting of a fire sets off a chain of events before firefighters arrive at the scene: call receipt and processing, dispatch of resources, donning protective gear, and travel to the scene. *NFPA 1710* defines the overall time from dispatch to scene arrival as the *total response time*. The standard divides total

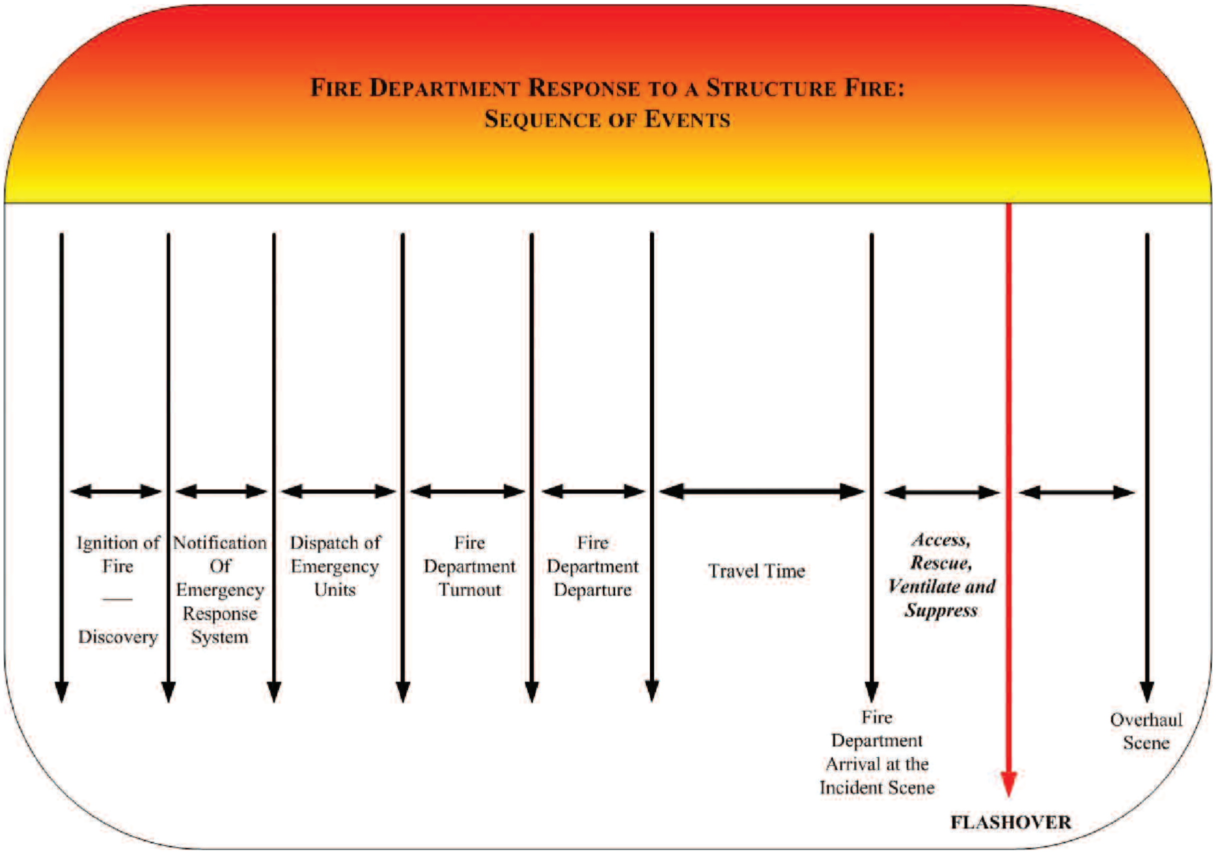

Figure 1: Hypothetical Timeline of Fire Department Response to Structure Fire

response time into a number of discrete segments, of which travel time — the time interval from the beginning of travel to the scene to the arrival at the scene — is particularly important for this study.

Arrival of a firefighting response force must be immediately followed by organization of the resources into a logical, properly phased sequence of tasks, some of which need to be performed simultaneously. Knowing the time it takes to accomplish each task with the allotted number of personnel and equipment is critical. Ideally crews should arrive and intervene in sufficient time to prevent flashover or spread beyond the room of origin.

Decision-making about staffing levels and geographic distribution of resources must consider those times when there will be simultaneous events requiring resource deployment. There should be sufficient redundancy or overlap in the system to allow for simultaneous calls and high volume of near simultaneous responses without compromising the safety of the public or firefighters.

Policy makers have long lacked studies that quantify changes in fireground performance based on apparatus staffing levels and on-scene arrival time intervals. These experiments were designed to observe the impact of apparatus staffing levels and apparatus arrival times on the time it takes to execute essential fireground tasks and on the tenability inside the burn prop for a full initial alarm assignment response. It is expected that the results of this study will be used to evaluate the related performance objectives in *NFPA 1710*.

Part 1: Planning for the Field Experiments

Laboratory Experiments

The purpose of the first segment, the laboratory experiments, was to characterize the burning behavior of the wood pallets as a function of:

- number of pallets and the subsequent peak heat release rate (HRR)
- compartment effects on burning of wood pallets
- effect of window ventilation on the fire
- effect on fire growth rate of the loading configuration of excelsior (slender wood shavings typically used as packing material)

Characterization of the fuel package was critical in order to ensure that the field experiments would not result in a flashover condition, one of the primary safety considerations in complying with the protocols in *NFPA 1403: Standard on Live fire Training Evolutions*.[7] Appendix A of this report contains the methods and full results for the laboratory experiments, which are summarized below. Figure 2 shows a test burn of pallets in the laboratory.

Figure 2: Test Burn of Pallets in Laboratory

Results of Laboratory Experiments

The objective of the laboratory experiments was to quantify the spread of heat and smoke throughout the planned burn prop in order to ensure that the fuel package would result in a fire large enough to generate heat and smoke consistent with a residential structure fire, yet not so large as to transition to flashover. The full results of the laboratory experiments and modeling are shown in Appendix A and Appendix B. To summarize briefly, a four-pallet configuration, which produced a peak of approximately 2 MW, was determined to be the largest fuel load the room could support without the threat of transitioning to flashover. The compartment produced a negligible effect on the heat release rate of the fire compared to open burning conditions. The presence of an open window in the burn room reduced the production of carbon monoxide and carbon dioxide gases, primarily through enhanced oxygen availability and dilution, respectively. The location and quantity of excelsior had a significant impact on the growth rate of fire. More excelsior located nearer the bottom of the pallets resulted in a more rapid achievement of peak burning.

The results of the fuel load experiments to inform the building and experimental design indicated development of untenable conditions in the field experiments between 5 min and 15 min, depending upon several factors: fire growth rate, ventilation conditions, the total leakage of heat into the building and through leakage paths, and manual fire suppression. This time frame allowed for differentiation of the effectiveness of various fire

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[7] NFPA 1403 contains the minimum requirements for training all fire suppression peronnel engaged in firefighting operations under live fire conditions.

department response characteristics.

In part 2, fire experiments were conducted in a residential-scale burn prop at the Montgomery County Public Safety Training Academy in Rockville, MD.

Field Site

Montgomery County (MD) Fire and Rescue Department provided an open space to construct a temporary burn prop, with ready access to water and electrical utilities, at the Montgomery County Fire and Rescue Training Facility in Rockville, MD.

The burn prop was constructed as a two-story duplex with a common stairwell and movable walls between the sections to allow for multiple experiments daily. Symmetrically dividing the structure about the short axis allowed one side of the test structure to cool and dry out after a fire test with suppression. The burn prop contained two mirror-image, two-story units each totaling 2,000 ft^2 (186 m^2), without basement or nearby exposures — each therefore a typical model of a low-hazard single-family residence identified in *NFPA 1710*. An exterior view of the burn prop is shown in Figure 3. For each experiment there was a confirmed fire in the living room in the first floor rear of one unit of the structure.

Figure 3: Exterior View of Burn Prop

Details and dimension are shown in the floor plan in Figure 4.

The black lines in Figure 4 indicate load-bearing reinforced concrete walls and red lines indicate the gypsum over steel stud partition walls. The ceiling height was 94 in (2.4 m) throughout the entire structure except in the burn compartments, where additional hardening was installed to protect against repeated exposure to fire during the experiments. This additional fire proofing slightly reduced the ceiling height. Complete details about the building construction are included in Appendix C.

Noncombustible furniture (angle iron and gypsum board construction) was fashioned to represent obstacles of realistic size and location for firefighters navigating the interior of the structure. The dimensions were typical of residential furnishings. Figure 5 shows an example of the noncombustible furniture used in the time-to-task experiments.

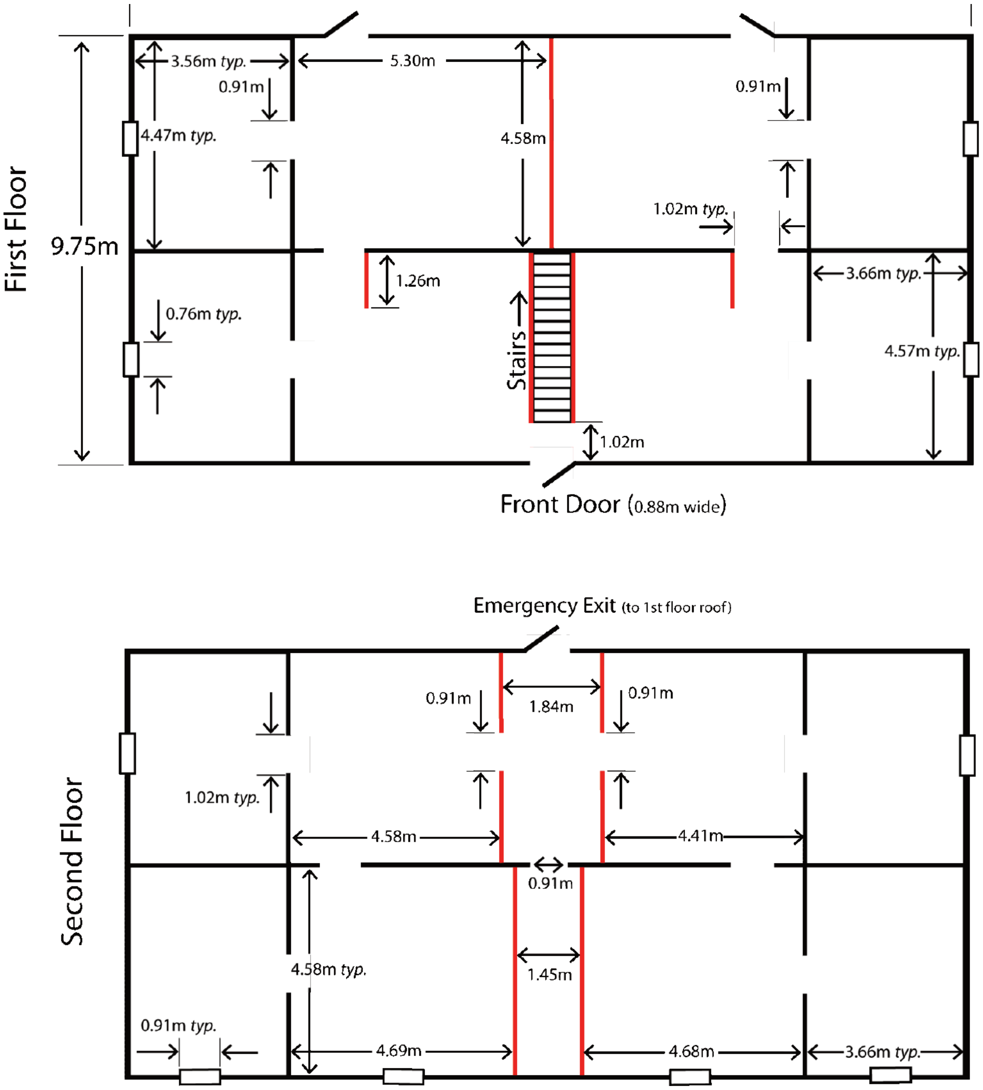

Figure 4: Dimensions of the Burn Prop Floor Plan

Overview of Field Experiments

In order to evaluate the performance representative of a *NFPA 1710*-compliant fire department, the field experiments consisted of two parts (the second and third parts of the four described in this report). In the first of the two parts of the field experiments, firefighter participants from Montgomery County (MD) and Fairfax County (VA) Fire Departments simulated an initial alarm assignment response to a structure described in *NFPA 1710* as a low-hazard residential structure to which firefighters respond on a regular basis. The staffing level of fire apparatus was varied incrementally from two to five personnel per piece. The interval between apparatus on-scene arrival times was varied at either 60 s or 120 s. Trained timing staff were used to record the start and completion times of 22 tasks deemed essential for mitigation of a residential fire incident by the study's technical experts. The pallet and excelsior configuration chosen from the laboratory experiments repeatedly produced a consistent and realistic quantity of heat and smoke, similar to what firefighters encounter at a residential structure fire.

Although the fire source used in part 2 of the field experiments created a realistic amount of heat and smoke, the requirements of *NFPA 1403* prevented use of a fire source which could potentially reach flashover within the structure. Therefore, part 3 of the fire experiments was conducted in order to change the fuel package to be representative of realistic fuel loading that could be found in a living room in a residential structure (sleeper-sofa, upholstered chairs, end tables, etc). The intent of this part of the study was to determine how the times of firefighter interactions, averaged with respect to the staffing and arrival intervals, impacted the interior tenability conditions. Fire fighting tactics were performed in a manner which complied with *NFPA 1403*; ventilation was performed with proper personal protective equipment (PPE) and hand tools from the exterior of the burn prop. Suppression was performed with an interior remote suppression device operated from the exterior of the burn prop.

Instrumentation

Instrumentation to measure gas temperature, gas concentrations, heat flux, visual obscuration, video, and time during the experiments was installed throughout the burn prop. The data were recorded at 1-second intervals on a computer-based data acquisition system. Figure 6 presents a schematic plan view of the instrumentation. All instruments were wired to a centralized data collection room attached as a separate space on the west side of the building, which is described later in this report ensuring physical separation for the data collection personnel from the effects of the fire, while minimizing the wire and tube lengths to the data logging equipment. See Appendix C for additional details about the instrumentation.

Figure 5: Noncombustible Furniture Used in the Time-to-Task Experiments

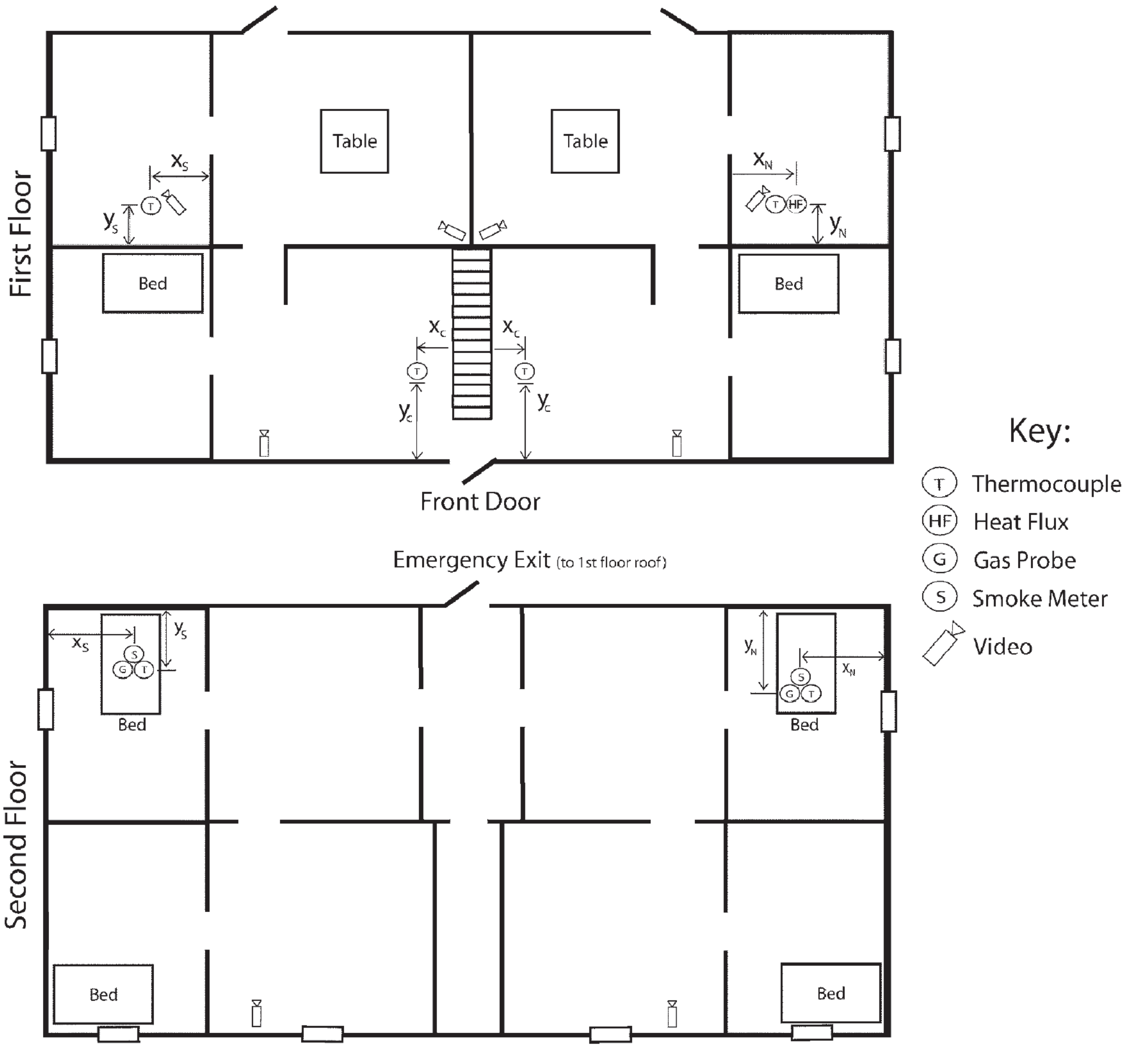

Figure 6: Instrumentation and Furniture Prop Layout

Figure 7: Fireground Safety Officer

Safety Protocols

Firefighter safety was always a primary concern in conducting the research. Participants were drawn from two departments — Fairfax County, VA and Montgomery County, MD — that regularly conduct NFPA 1403 compliant live fire training for their staff and recruits.

A safety officer was assigned to the experiments by the Montgomery County Fire and Rescue Department to assure compliance with *NFPA 1403*. The safety officer (Figure 7) participated in all orientation activities, daily briefings, and firefighter gear checks and was always actively involved in overseeing all experiments. The safety officer had full authority to terminate any operation if any safety violation was observed. In addition to the safety officer, a rapid intervention team (RIT), assigned from dedicated crews not in the actual experiment, was in place for each experiment, and a staffed ambulance was on standby at the site. Radio communication was always available during the experiments should a "mayday" emergency arise.

Experiments were stopped for any action considered to be a protocol breach or safety concern. For example, all ladders — 24 ft (7.3 m) or 28 ft (8.5 m) — were to be raised by two firefighters. As crew sizes were reduced, some firefighters attempted to place ladders single-handedly in an effort to complete the task more quickly. This procedure, while vividly illustrating how firefighters try to do more with less in the field, is unsafe and could potentially result in strain or impact injuries.

Additional safety features were built in to the field structure. A deluge sprinkler system oriented to the known location of the fuel package could be remotely activated for rapid fire suppression. All first floor rooms had direct access to the exterior of the building through either doors or windows. The second story had an emergency exit to the roof of the attached instrumentation room.

A closely related concern to ensure firefighter safety and readiness to repeat experiments with equivalent performance was adequate rehabilitation (see Figure 8). At the beginning and end of each day, crews completed a health and safety check. The importance of staying well-hydrated before and during experiments was especially emphasized.

Figure 8: Crew Rehabilitation

Time-to-Task Experiments

On-Scene Fire Department Tasks

The on-scene fire department task part of the study focused on the tasks firefighters perform after they arrive on the scene of a low-hazard residential structure fire. A number of nationally recognized fire service experts were consulted during the development of the on-scene fire department tasks in order to ensure a broad applicability and appropriateness of the task distribution.[8] The experiments compared crew performance and workload for a typical fire fighting scenario using two-, three-, four-, and five-person crews. 24 total experiments were conducted to assess the time it took various crew sizes to complete the same tasks on technically similar fires in the same structure. In addition to crew sizes, the experiments assessed the effects of stagger between the arriving companies. Close stagger was defined as a 1-minute time difference in the arrival of each responding company. Far stagger was defined as a 2-minute time difference in the arrival of each responding company. One-minute and two-minute arrival stagger times were determined from analysis of deployment data from more than 300 U.S. fire departments responding to a survey of fire department operations conducted by the International Association of Fire Chiefs (IAFC) and the International Association of Fire Fighters (IAFF). Considering both crew size and company stagger there were eight experiments conducted in triplicate totaling twenty-four tests, as shown in the full replicate block in Table 1. A full replicate was completed in a randomized order (determined by randomization software) before a test configuration was repeated.

Crew Size	Apparatus Stagger
2 Person	Close Stagger (One minute)
3 Person	Close Stagger (One minute)
4 Person	Close Stagger (One minute)
5 Person	Close Stagger (One minute)
2 Person	Far Stagger (Two minutes)
3 Person	Far Stagger (Two minutes)
4 Person	Far Stagger (Two minutes)
5 Person	Far Stagger (Two minutes)

Table 1: Primary Variables for Time-to-Task Experiments

Crew Size

For each experiment, three engines, a ladder-truck and a battalion chief and an aide were dispatched to the scene of the residential structure fire. The crew sizes studied included two-, three-, four-, and five-person crews assigned to each engine and truck dispatched. Resultant on-scene staffing totals for each experiment follow: (FF = firefighter)

- Two Person crews = 8 FFs + Chief and Aide = 10 total on-scene
- Three Person crews = 12 FFs + Chief and Aide= 14 total on-scene
- Four Person crews = 16 FFs + Chief and Aide = 18 total on-scene
- Five Person crews = 20 FFs + Chief and Aide = 22 total on-scene[9]

Department Participation

The experiments were conducted in Montgomery County, MD at the Montgomery County Fire Rescue Training Academy during the months of January and February 2009. All experiments took place in daylight between 0800 hours and 1500 hours. Experiments were postponed for heavy rain, ice, or snow and rescheduled for a later date following other scheduled experiments.

Montgomery County (MD) and Fairfax County (VA) firefighters participated in the field experiments. Each day both departments committed three engines, a ladder truck and associated crews, as well as a battalion chief to the experiments. The two battalion chiefs, alternated between the roles of battalion chief and aide. Firefighters and officers were identified by participating departments and oriented to the experiments. Each experiment included engine crews, truck crews and command officers from each participating department. Participants varied with regard to age and experience. Crews that normally operated together as a company were kept intact for the experiments to assure typical operation for the crew during the scenarios. However, in all experiments crews were used from both departments, including engine crews, truck crews, and officers.

This allocation of resources made it possible to conduct back-to-back experiments by rotating firefighters between field work and rehabilitation areas.

Crew Orientation

All study participants were required to attend an orientation prior to the beginning of the experiments (see Figure 9, page 25). The orientations were used to explain experiment procedures, task flows, division of labor between crews, and milestone events in the scenario.

Daily orientations were conducted for all shifts to assure every participant attended. Orientations included a description of the overall study objectives as well as the actual experiments in which they would be involved. Per the requirements of *NFPA 1403*, full disclosure regarding the structure, the fire, and the tasks to be completed were provided. Crews were also oriented to the fireground props, instrumentation used for data collection, and the specific scenarios to be conducted. Every crew member was provided a walkthrough of the structure during the orientation and each day prior to the start of the experiments.

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[8] Technical experts included Dennis Compton, Russell Sanders, William "Shorty" Bryson, Vincent Dunn, David Rohr, Richard Bowers, Michael Clemens, James Walsh, Larry Jenkins and Doug Hinkle. More information about the experts is presented in the Acknowledgments later in this report.

[9] Note that the on-scene totals account for only the personnel assigned to "work" the fire. Additional personnel were provided for an RIT team, a staffed ambulance on site, and a safety officer specific to the experiments. The additional personnel are not included in thee staffing described above.

Tasks

Twenty-two fireground tasks were completed in each experiment. Meticulous procedures gathered data to measure key areas of focus, such as individual task start times, task completion times, and overall scenario performance times. Each task was assigned a standardized start and end marker, such as crossing the threshold to enter the building with a hose line or touching a ladder to raise it to a second story window. The 22 tasks, with the events for measuring start and stop times, are shown in Table 2 (page26). Figures 10 — 19 illustrate firefighter activity in a number of the tasks to complete experiments or prepare for the next experiment.

For reasons of both safety and cost efficiency, two tasks — forcible entry of the front door and ventilation of the windows on the first and second stories — required special procedures.

The study could not accommodate replacing the doors and windows daily for the fire suppression experiments. Before the start of experiments with the full sequence of tasks, these two tasks were measured in a realistic manner using training props constructed at the site of the fireground experiments. As with the overall experiments, these two tasks were repeated in triplicate and the times averaged. The average time to complete the tasks was then used in the larger scale experiment. As firefighters came to the point of breaching the door or windows, the timers would hold them for the time designated by the earlier experiments and then give them the approval to open the door or windows. The start and end times were then recorded just as other tasks were.

Figure 9: Crew Orientation and Walkthrough

Figure 10: Ground Ladders

Figure 11: Ventilation

Figure 12: Ground Level Window Breakage Prop

Figure 13: Second Story Window Breakage Prop

Figure 14: Door Forcible Entry Prop

Figure 15: Crew Preparation and Cue Cards

Table 2: Tasks and Measurement Parameters

Tasks	Measurement Parameters
1. Stop at Hydrant, Wrap Hose	START - Engine stopped at hydrant STOP - Firefighter back on engine and wheels rolling
2. Position Engine 1	START - Wheels rolling from hydrant STOP - Wheels stopped at structure
3. Conduct Size-up (360-degree lap), transmit report, establish command	START - Officer off engine STOP - Completes radio transmission of report
4. Engage Pump	START - Driver off engine STOP - Driver throttles up pump
5. Position Attack Line (Forward Lay)	START - Firefighter touches hose to pull it from engine STOP - Flake, charge and bleed complete (hose at front door prepared to advance)
6. Establish 2 In/2 Out	Company officer announces – "2 In/2 Out established" (4 persons assembled on scene OR at the call of the Battalion Chief/Company Officer)
7. Supply Attack Engine	START - Firefighter touches hydrant to attach line STOP - Water supply to attack engine
8. Establish RIT **9. Gain/Force Entry**	Time that Company Officer announces RIT is established START - Action started (HOLD time= 10 seconds)
10. Advance Attack Line	STOP - Door opened for entry START – Firefighter touches hose STOP – Water on fire
11. Advance Backup Line (stop time at front door)	START - Firefighter touches hose to pull from engine bed STOP - Backup line charged to nozzle
12. Advance Backup Line/Protect Stairwell	START - Firefighter crosses threshold STOP - Position line for attack at stairwell
13. Conduct Primary Search	START - Firefighters enter front door STOP - Firefighters transmit "search complete"
14. Ground Ladders in Place	START - Firefighter touches ladder to pull it from truck STOP - 4 Ladders thrown: 3 ladders on the 2nd-story windows and 1 to the roof
15. Horizontal Ventilation (Ground)	START- Firefighter at 1st window to begin ventilation (HOLD for 8 seconds) STOP - Hold time complete - window open
16. Horizontal Ventilation (2nd Story)	START - Firefighter grabs ladder for climb. (Firefighter must leg lock for ventilation. HOLD time at each window is 10 seconds) STOP - All 2nd-story windows open - descend ladder - feet on ground.
17. Control Utilities (Interior)	START - Radio transmission to control utilities STOP - When firefighter completes the task at the prop
18. Control Utilities (Exterior)	START - Radio transmission to control utilities STOP - When firefighter completes the task at the prop
19. Conduct Secondary Search	START - Firefighters enter front door STOP - Firefighters transmit "secondary search complete"
20. Check for Fire Extension (walls)	START- Firefighters pick up check-for-extension prop STOP- Completion of 4 sets total (1 set = 4 in and 4 out) This task may be done by more than one person.
21. Check for Fire Extension (ceilings)	START - Firefighters pick up check-for-extension prop STOP - Completion of 4 sets total (1 set = 3 up and 5 down) This task may be done by more than one person.
22. Mechanical Ventilation	START - Firefighters touch fans to remove from truck STOP - Fans in place at front door and started

Data Collection: Standardized Control Measures

Several control measures were used to collect data, including crew cue cards, radio communications, task timers, and video recording. Performance was timed for each task in each scenario including selected milestone tasks such as door breach, water-on-fire, and individual window ventilation. Data were collected for crew performance on each task, and individual firefighter performance was not considered.

Task Flow Charts and Crew Cue Cards

Task procedures were standardized for each experiment/scenario. Technical experts worked with study investigators to break down crew tasks into individual tasks based on crew size. Task flow charts were created and then customized for the various crew sizes. The carefully designed task flow ensured that the same overall workload was maintained in each experiment, but was redistributed based on the number of personnel available for the work. See Appendix D for additional details.

All tasks were included in each scenario and cue cards were developed for each individual participant in each scenario. For example, a four-person crew would have a cue card for each person on the crew including the officer, the driver, and the two firefighters. Cards were color coded by crew size to assure proper use in each scenario.

Figure 16: Connecting to the Hydrant

Figure 17: Crews Responding

Figure 18: Ceiling Breach/Molitor Machine

Figure 19: Incident Command

Figure 20: Task Timers

Figure 21: Video Recording for Quality Control

Radio communications

Interoperability of radio equipment used by both participating departments made it possible to use regular duty radios for communication during the experiments. Company officers were instructed to use radios as they would in an actual incident. Montgomery County Fire and Rescue Communications recorded all radio interaction as a means of data backup. Once all data quality control measure were complete, the records were then overwritten as a routine procedure.

Task Timers

Ten observers/timers, trained in the use of a standard stop watch with split-time feature, recorded time-to-task data for each field experiment. To assure understanding of the observed tasks, firefighters were used as timers, each assigned specific tasks to observe and to record the start and end times.

To enhance accuracy and consistency in recording times, the data recording sheets used several different colors for the tasks (see Appendix D). Each timer was assigned tasks that were coded in the same color as on the recording sheet. All timers wore high-visibility safety gear on the fireground (see Figure 20).

Video records

In addition to the timers, video documentation provided a backup for timed tasks and for quality control (see Figure 21). No less than six cameras were used to record fireground activity from varied vantage points. Observer/timer data were compared to video records as part of the quality control process.

Crew Assignment

Crews from each department that regularly operated together were assigned to work as either engine or truck companies in each scenario. Both Fairfax County and Montgomery County crews participated in each experiment.

Crews assigned to each responding company position in one scenario were assigned to another responding company position in subsequent scenarios, with the objective of minimizing learning from one experiment to another. For example, crews in the role of engine 1 in a morning scenario might be assigned to the engine 3 position in the afternoon, thus eliminating learning from exact repetition of a task as a factor in time to completion. Additionally, participating crews from both Montgomery County and Fairfax County were from three different shifts, further reducing opportunities for participant repetition in any one position.

Response Time Assumptions

Response time assumptions were made based on time objectives set forth in the *NFPA 1710*. Time stagger allocations were set by the project technical advisors in order to assess the impact of arriving unit time separation on task start and completion times, as well as the overall scene time.

Below are the values assigned to the various time segments in the overall response time. The total of the response time segments may also be referred to as the total reflex time.

1. Fire ignition = time zero
2. 60 s for recognition (detection of fire) and call to 9-1-1
3. 60 s for call processing/dispatch
4. 60 s for turnout[10]
5. Close Stagger = 240 s travel time FIRST engine with 60 s ladder-truck lag and 90 s lag for each subsequent engine
    a. Truck arrives at 300 s from notification
    b. Second engine at 330 s from notification
    c. Third engine at 420 seconds from notification
6. Far Stagger = 240 s travel time FIRST engine with 120 s ladder-truck lag and 150 s lag for each subsequent engine
    a. Truck arrives at 360 s from notification
    b. Second engine arrives at 390 s from notification
    c. Third engine arrives at 540 s from notification.

The design of this part of the experiments allowed firefighter entry into the burn building. The next part of the experiments required a modified methodology.

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[10] After the experiments were complete, the NFPA 1710 technical committee released a new edition of the standard that prescribes 80 seconds for turnout time.

Part 3: Room and Contents Fires

As previously discussed, *NFPA 1403* prohibits firefighters in a training exercise from entering a structure with sufficient fuel load to result in room flashover. But the value of the data from the time-to-task experiments lies not just in the duration and time-of-completion statistics for tasks, but also in measuring the tenability of the atmosphere for occupants urgently needing firefighter assistance. Therefore Part 3 of the experiments (room and contents fires) used a larger fuel load to focus on the seven of the 22 tasks that cause a change in the fire behavior through ventilation or active suppression:

The Tornado Remote Controlled Monitor is Produced by Task Force Tips, Valparaiso, Indiana, USA. Permission to publish courtesy of Task Force Tips

Figure 22: Remotely Controlled Fire Suppression Nozzle for Room and Contents Fires

1. Forced entry of the front door
2. Water on fire
3. Second floor window #1 ventilated (burn room window)
4. Second floor window #2 ventilated (front window, near corner)
5. Second floor window #3 ventilated (front window, near front door)
6. First floor window #1 ventilated (window beside the fire room)
7. First floor window #2 ventilated (self-ventilated at flashover)

Because the fuel load was sufficient for flashover, all firefighter activity was conducted outside the building. Tasks that in Part 3 required entry into the building, such as search or interior utility control, were factored into this part by delaying the next task for the average duration of the task from Part 2. Firefighters in full gear opened the door with a gloved hand or opened windows from the ground with a tool such as a pike pole or angle iron, again at the time specified by the averages from Part 2. Averages were derived from the three iterations of each scenario. The different number of iterations in Part 3 will be explained later in this report.

Because firefighters could not enter the building, a nozzle controlled from the instrumentation room was installed. The nozzle was placed in the room directly outside the burn room and oriented toward the burn room near the doorway in order to best emulate the nozzle location of live firefighter suppression (see Figure 22). The nozzle was encased with mineral wool and heavy-duty aluminum foil (bottom picture in Figure 22) to protect the electronics and wiring from the intense radiation energy emitted by the fire. Blocks were used to anchor the nozzle against the lateral forces exerted by the momentum of the water supply. The activation time for suppression was determined by the data from the time-to-task test results.

A 15° spray pattern was directed toward the seat of the fire and swept horizontally from side to side. While the remotely controlled hose line knocked down the majority of the fire, it was not as effective as a live firefighter with a better view into the room of origin. Therefore, after the fire was diminished, a supplemental stream was applied through the burn room window in order to control the fire (see Figure 23). All personnel on the hose line were in full turnout gear and self-contained breathing apparatus during the exterior application of water.

Fuel Packages for the Room and Contents Fires

In order to maximize the repeatability of the fire development, nominally identical rooms of furniture of identical manufacturer, style, and age were used for each test. A plan-view schematic of the furniture is shown in Figure 24 and pictures of the burn room prior to testing are shown in Figure 25. Key dimensions, mass, and materials for combustible furnishings are detailed in Appendix C.

Figure 23: Supplemental Suppression Applied for Room and Contents Tests

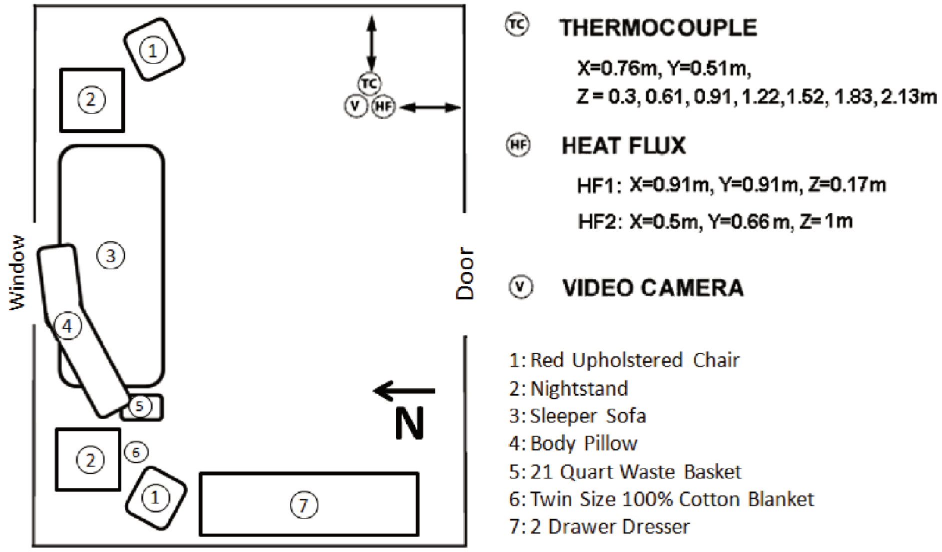


Figure 24: Configuration of Furnishings in Burn Room (Room and Contents Fires)

Figure 25: Pictures of the Room and Contents Furnishings

The ignition source consisted of a cardboard book of 20 matches that was ignited by an electrically heated wire, often referred to as an electric match. The electric match was placed near the bottom of a 21 qt (19.9 L) polypropylene waste container. The height of the waste container was 15.5 in (394 mm) with interior dimensions at the top opening of 14.5 in (368 mm) by 11.3 in (287 mm). Approximately 0.7 lbs (0.3 kg) of dry newspaper was added to the waste container. The majority of the newspaper was folded flat, and placed on edge along the sides of the waste container. Four sheets of newspaper, 22 in (559 mm) by 25 in (635 mm) were crumpled into "balls" approximately 3.9 in (100 mm) diameter and placed on top of the electric match in the center of the waste container.

Experimental Matrix for Room and Contents Fires

Sufficient amounts of furniture for 16 rooms were available for the room and contents fires, so eight experiment scenerios were conducted — each with a replicate. Because the time to untenable conditions was a primary variable of interest in the room and contents fires, the arrival time of the first due engine was a paramount consideration. Because the effects of the subsequent apparatus stagger were explored in the time-to-task tests, the stagger was fixed at the "close arrival" time. Additionally, a baseline measurement was required to compare the effectiveness of response to the absence of a fire department response. Therefore, a five-person, later arrival combination was eliminated in favor of a no-response scenario (with replicate). Table 3 summarizes the 16 tests conducted.

The first due engine arrival times were determined using the following assumptions: ignition of the fire occurs at time zero. Smoke detector activation and a call to 9-1-1 occurs at 60 seconds after the fire starts. Call intake and processing requires an additional 90 seconds. The firefighters take 60 seconds to complete their turnout at the station and begin travel to the scene. Thus travel time begins 3.5 minutes into experiment. The two levels of arrival time are then determined by two different travel times: early arrival assumes a three-minute travel time, while later arrival assumes a five-minute travel time. For all scenarios in the room and contents experiments, the close stagger (60 seconds) between subsequent apparatus times was used.

Crew Size	First Due Arrival Time
2-Person	Early Arrival of First Engine (6.5 min) – close stagger
3-Person	Early Arrival of First Engine (6.5 min) – close stagger
4-Person	Early Arrival of First Engine (6.5 min) – close stagger
5-Person	Early Arrival of First Engine (6.5 min) – close stagger
2-Person	Later Arrival of First Engine (8.5 min) – close stagger
3-Person	Later Arrival of First Engine (8.5 min) – close stagger
4-Person	Later Arrival of First Engine (8.5 min) – close stagger
No Response (Baseline)	N/A

Table 3: Experimental Matrix for Room and Contents Tests (Each Conducted in Replicate)

Procedure for Minimizing the Effect of Variance in Fire Growth Rate

Fires involving furnishings have inherent variance in burning behaviors. Factors such as humidity and minor variations in materials (particularly worn furnishings that may have different foam compression or fabric wear patterns), can result in uncertainty of 20 % or more, despite significant efforts to enhance repeatability. The early growth period of fire development is often associated with the greatest variance, since minor factors (as discussed above) can influence the thermal environment more easily when the fire is small. Therefore, the room and contents fires were normalized to the 212 °F (100 °C) temperature near the ceiling in the burn room in order to minimize the variance of the room and contents fires. The time at which the burn room reached this temperature (usually in approximately 180 seconds) rather than the actual ignition time, was designated as the "zero time."

Figure 26 shows the time-temperature curves before and after normalizing at 100°C. This approach was implemented during the experiments by watching the time temperature data in real-time from the instrumentation room and announcing the "zero-time" over the fireground radio system. The normalization procedure did not negatively affect tenability measurements in the target room because when the fire is small, products of combustion do not reach the room because of lack of momentum. Therefore, adjusting all room and contents tests to the same upper layer temperature was an appropriate way to minimize variance.

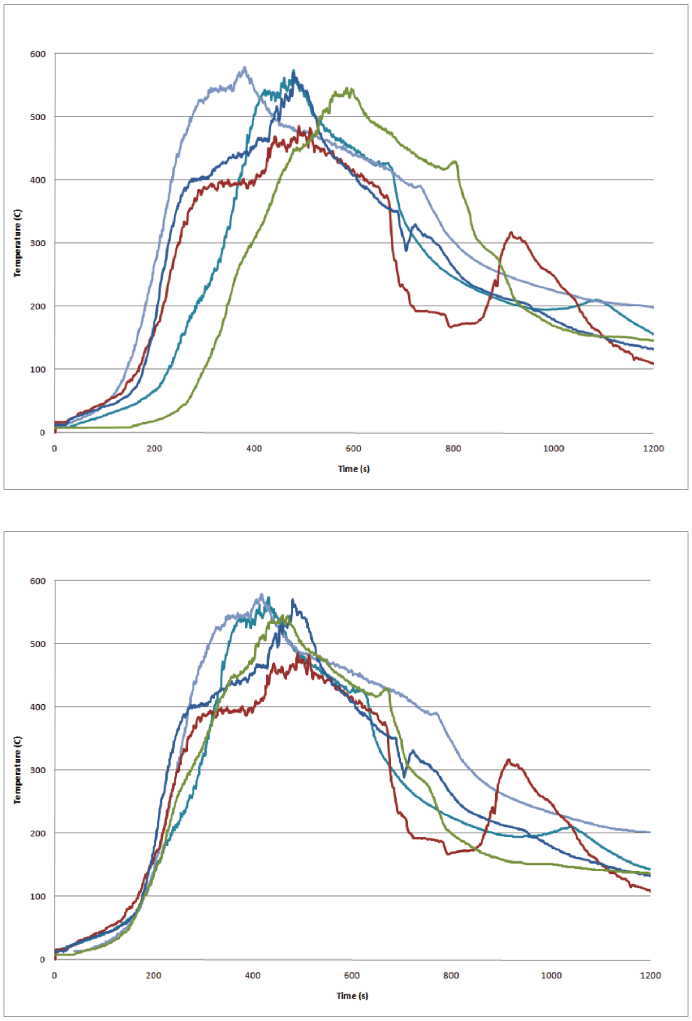


Figure 26: Direct Comparison of Temperatures, Before (Top) and After Adjustment (Bottom)

Milestone Times for Critical Tasks

As stated earlier, firefighters could not enter the burn building during the room and contents experiments because of the danger for potential flashover in an experimental scenario. Therefore, prescribed tasks were performed at specified times based on data from part 2. In this section we report on significant data gathered from instrumentation and describe an additional part of the experiments designed to extend our understanding of the effect of crew size and stagger on the tenability of the atmosphere in a burning structure.

Table 4 (page 32) identifies significant tasks selected as key milestones because of the way they affect fire behavior and atmospheric tenability inside the structure.

Milestone Tasks	2-Person Close Stagger
	Time from ignition (min : s)
Breached Door	8:44
Water On Fire	9:56
Upper Fire Window	13:01
Ground Non-fire Window	14:51
Upper Corner Window	17:55
Upper Front Door Window	19:55
Ground Fire Window	4:30

Milestone Tasks	3-Person Close Stagger
	Time from ignition (min : s)
Breached Door	7:48
Water On Fire	8:54
Upper Fire Window	11:26
Ground Non-fire Window	13:31
Upper Corner Window	15:54
Upper Front Door Window	17:58
Ground Fire Window	4:30

Milestone Tasks	4-Person Close Stagger
	Time from ignition (min : s)
Breached Door	7:46
Water On Fire	8:41
Upper Fire Window	9:23
Ground Non-fire Window	10:32
Upper Corner Window	11:46
Upper Front Door Window	13:45
Ground Fire Window	4:30

Milestone Tasks	5-Person Close Stagger
	Time from ignition (min : s)
Breached Door	7:35
Water On Fire	8:03
Upper Fire Window	10:11
Ground Non-fire Window	10:54
Upper Corner Window	12:31
Upper Front Door Window	12:47
Ground Fire Window	04:30

Table 4: Tasks That Affect Fire Behavior and Atmospheric Tenability

Analysis of Experimental Results

This section describes the analytic approaches used to address the research objectives of the study. First the statistical methods used to analyze the fireground time-to-task observations are presented. Then the time-to-task data and the room and contents data were combined to assess crew performance in relation to tenability within the structure.

Time-to-Task Analysis

Time-to-task data were compiled into a database and assessed for outliers and missing entries. Because all time-to-task experiments were conducted in triplicate, missing data were apparent and were reviewed via video and radio tapes. Missing data attributable to timer error were replaced by a time observed in the video. Where video and/or radio documentation was not adequate, missing data were recoded to the mean of the task times from the other two experiments.

Data Queries

The statistical methods used to analyze the time-to-task data were driven by a principal goal of this research project — to assess the effect of crew size, first-due engine arrival time, and subsequent apparatus stagger on time-to-task for critical steps in response and fire fighting. This research goal motivated the development of four specific research questions (see Figure 27) that in turn pointed to specific statistical analyses for generating inference and insight.

Time-to-Task Research Questions

1) How do crew size and stagger (i.e., timing of between first engine and subsequent apparatuses) affect overall (i.e., start to completion) response timing?

    a. To what extent do variations in crew size affect overall response timing?

    b. To what extent do variations in both crew size and stagger affect overall response timing?

2) How do crew size and stagger affect the timings of task initiation, task duration, and task completion for each of the tasks comprising the suite of 22 tasks?

    a. To what extent do variations in crew size affect timings across the suite of tasks?

    b. To what extent do variations in both crew size and stagger affect response timings across the suite of tasks?

3) How does crew size affect elapsed times to achieve three critical events known to change fire behavior or atmospheric tenability for occupants?

    a. Entry into structure

    b. Water on fire

    c. Ventilation of each window (three upstairs and one downstairs window and the burn room window)

4) How does the elapsed time to achieve the national standard of assembling 15 firefighters at the scene (measured using "at hydrant" as the start time) vary by crew sizes of 4 and 5?

Figure 27: Research Questions for Time-to-Task Experiments

Statistical Methods – Time-to-Task

The analysis of the time-to-task data involved a sequence of multiple linear regressions using Ordinary Least Squares to generate and test the effects of staffing and stagger on timings. The regressions were of the form:

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_k x_{ik} + \varepsilon_i$$

where the x_{ik} reflect factors such as stagger and crew size, and the y represents our dependent/outcome variable.

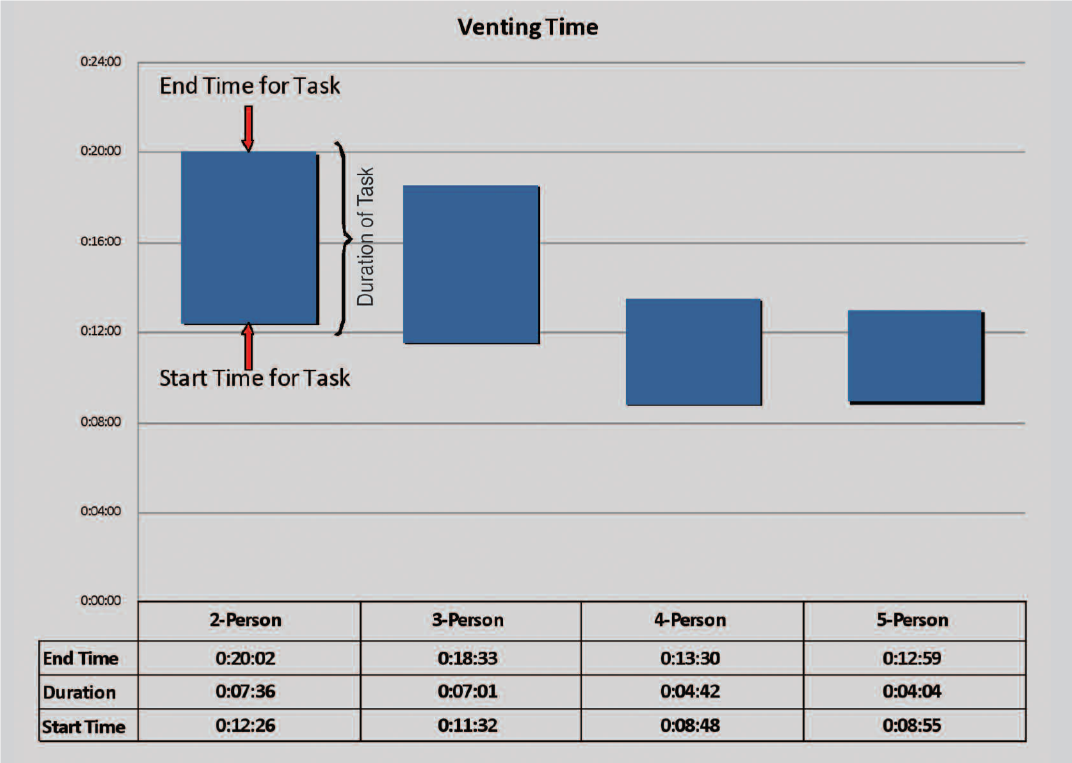
Time-related outcomes (i.e., the dependent variables in the regression equations) could include task duration, elapsed time to start the task, and elapsed time until task completion, all measured in seconds. Table 5 (page 34) lists the time-related outcomes used to test the effect of crew size and stagger for the tasks in the field experiments.

The effects of crew size and stagger were explored using indicator variables in the regression analyses. The coefficient for a given indicator (for example, crew size of four relative to a crew size of two) indicated the number of seconds the larger crew size added or reduce the timing outcome of a task. Crew sizes were collapsed in some regressions to test whether the timings of "larger" crew sizes of four and five were significantly different than "smaller" crew sizes of two and three. Interaction terms were not assessed in these regression analyses because of the small number of experiments available for analysis.

Standard t-tests examined statistical significance (i.e., to see if the hypothesis of "no impact" could be rejected) to estimate the impact of several specific configurations:

- crew sizes of three versus two
- crew sizes of four versus three
- crew sizes of five versus four
- (occasionally) five versus two, and four versus two
- larger (four & five combined) versus smaller (two & three combined) and
- stagger

The specific tests for each task (regression analysis) are shown in the Appendix E. The actual coefficients of each regression and their corresponding standard errors are presented in Appendix F. To infer impact, significant tests were conducted at the 0.05 significance level. Only statistically significant contrasts of crew size and/or stagger are included in this section of the report. Graphic expositions of relevant time/task related findings are then presented as well. Where stagger was statistically significant, the effects are graphed separately. Where stagger was not statistically significant, the data for crew size were combined.



	2-Person	3-Person	4-Person	5-Person
End Time	0:20:02	0:18:33	0:13:30	0:12:59
Duration	0:07:36	0:07:01	0:04:42	0:04:04
Start Time	0:12:26	0:11:32	0:08:48	0:08:55

Figure 28: Example Time-to-Task Graph

Regression analyses

Appendix F presents the regression results for each task and relevant outcome, along with their corresponding standard errors. The results of conducting significance tests at the 0.05 level of significance are shown in Appendix E. Rather than detailing each of the lengthy lists of coefficients found to be significant, only the answers to the primary research questions are presented for each task.

Measurement Uncertainty

The measurements of length, temperature, mass, moisture content, smoke obscuration, and stopwatch timing taken in these experiments have unique components of uncertainty that must be evaluated in order to determine the fidelity of the data. Appendix G summarizes the uncertainty of key measurements taken during the experiments. Importantly, the magnitudes of uncertainties associated with these measurements have no impact on the statistical inferences presented in this report.

How to Interpret Time-to-Task Graphs

Figure 28 presents a sample time-to-task analysis, in this case results for venting time. Each crew size has a column graphic showing the start time and completion time for the task. Visually, columns starting lower on the graph depict deployment configurations that resulted in earlier start times. The height of the column graphic is a visualization of the duration of the task, taller columns indicating longer times to task completion. Time data are also shown in a table below the graph. Where stagger was statistically significant, the effects are graphed separately. Where stagger was *not* statistically significant, as in the illustration, the data for crew size were combined.

	Time-to-Task Outcome Measures		
Task:	*Elapsed Time Until Start**	*Elapsed Time for Task Completion**	*Duration**
Conduct size-up	X	X	X
Position attack line	X		X
Establish 2 in - 2 out		X	
Establish RIT		X	
Gain forced entry	X		
Advance line	X		
Advance line		X	
Advance backup line to door	X	X	
Advance backup line to stairwell	X		
Advance backup line 2		X	
Conduct primary search 1	X		
Ground ladders in place		X	X
Horizontal ventilation, second story, window 3	X	X	
Horizontal ventilation, second story, window 2	X	X	
Horizontal ventilation, second story, window 1	X	X	
Horizontal ventilation, first story, window 2	X	X	
Control utilities interior	X		
Control utilities exterior	X		
Conduct secondary search	X		
Check for fire extension walls	X		
Check for fire extension ceiling	X		

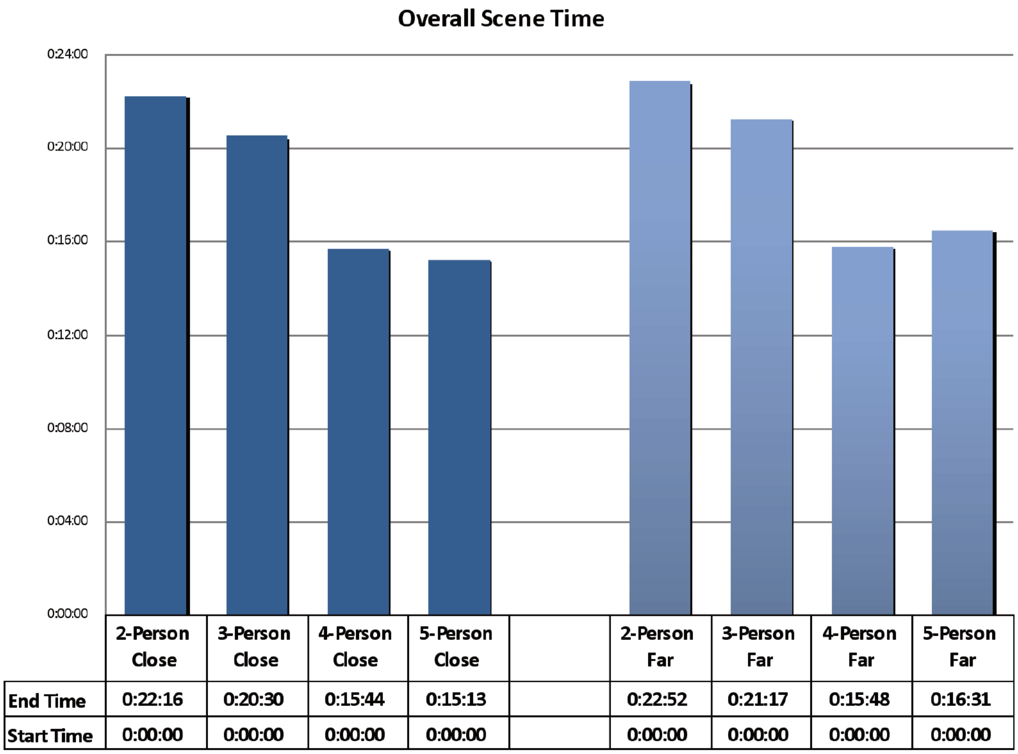
* The columns of this table show the dependent variables, and the rows indicate the Tasks; an 'X' in a cell indicates that a separate regression analysis was conducted for a given dependent variable.

Table 5: Dependent Variables Used in a Regression Analysis of the Effect of Crew Size and Stagger on Time-to-Task Outcomes

Time-to-Task Graphs

Overall Scene Time (Time to Complete All 22 Tasks)

The four-person crews operating on a low-hazard structure fire completed the same number of tasks on the fireground (on average) 7 minutes faster than the two-person crews (see Figure 29). The four-person crews completed the same number of fireground tasks (on average) 5.1 minutes faster than the three-person crew. The four-person crews were able to complete necessary fireground tasks on a low-hazard residential structure fire nearly 30 % faster than the two-person crews and nearly 25 % faster than the three-person crews. Although on the low-hazard residential structure fire, adding a fifth person to the crews did not show any additional decrease in fireground task times, the benefits of a five-person vs. a four-person crew are significant in other measurements, particularly the "water-on-fire" time. Additionally, the greater need for five-person crews for medium- and high-hazard structures, particularly in urban settings, has been documented in other studies (Backoff et al., 1980; Cushman, 1982; McManis Associates et al., 1984) and five-person crews are required for areas that contain medium and high-hazard structures in fire protection consensus standards.[11]



	2-Person Close	3-Person Close	4-Person Close	5-Person Close		2-Person Far	3-Person Far	4-Person Far	5-Person Far
End Time	0:22:16	0:20:30	0:15:44	0:15:13		0:22:52	0:21:17	0:15:48	0:16:31
Start Time	0:00:00	0:00:00	0:00:00	0:00:00		0:00:00	0:00:00	0:00:00	0:00:00

Figure 29: Overall Scene Time

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[11] NFPA 1710, Section 5.2.3.1.2 and Section 5.2.3.2.2: In jurisdictions with tactical hazards, high-hazard occupancies, high incident frequencies, geographical restrictions, or other pertinent factors as identified by the AHJ, these companies shall be staffed with a minimum of five or six on duty members.

Overall Scene Time and Crew Sizes

The graphs in Figure 30 show average times for each task by crew size.

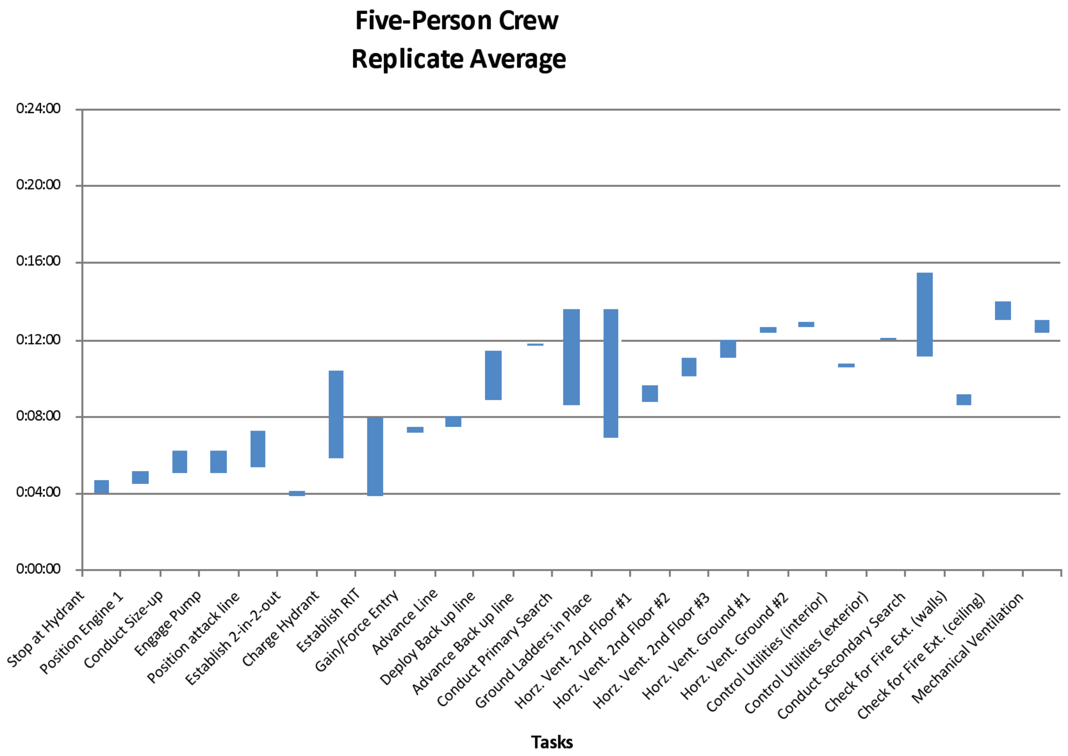


Figure 30 a: Overall Scene Time-FIve Person Crew

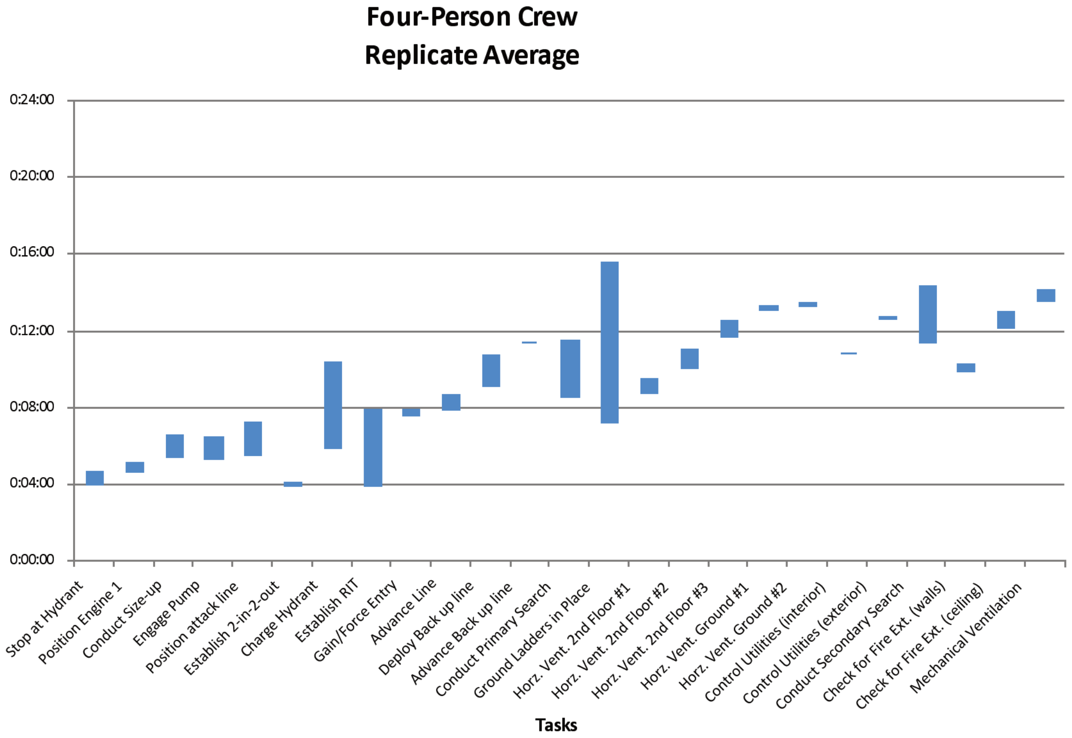


Figure 30 b: Overall Scene Time-Four Person Crew

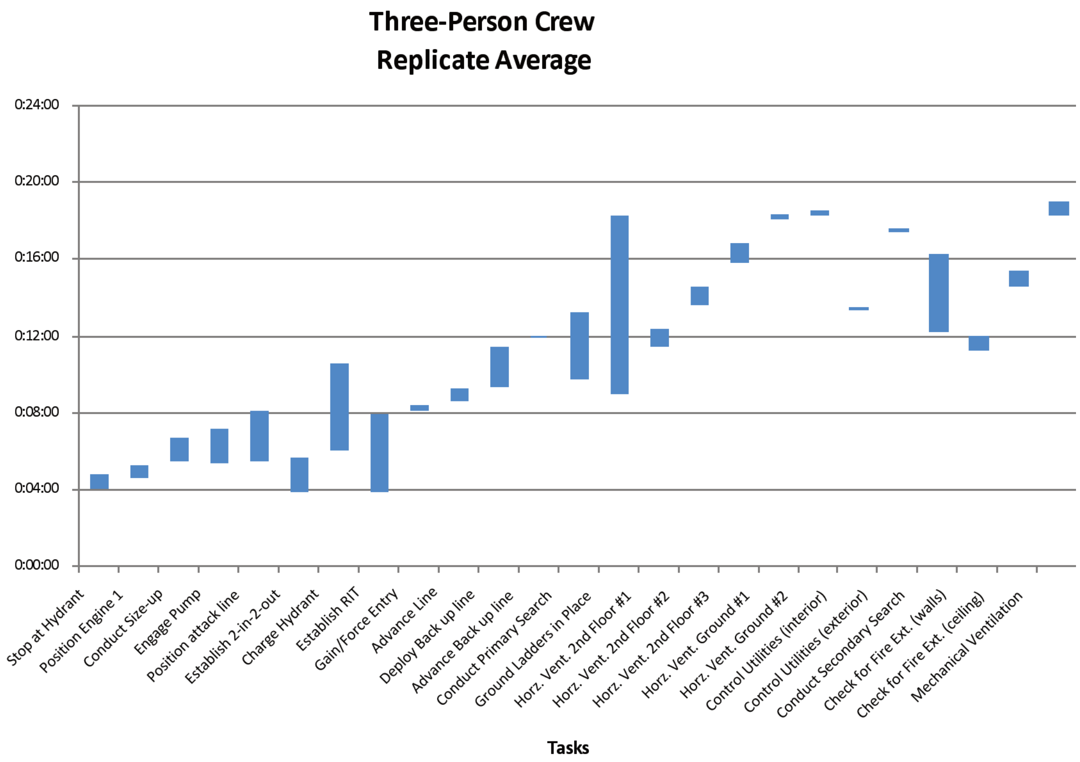


Figure 30 c: Overall Scene Time-Three Person Crew

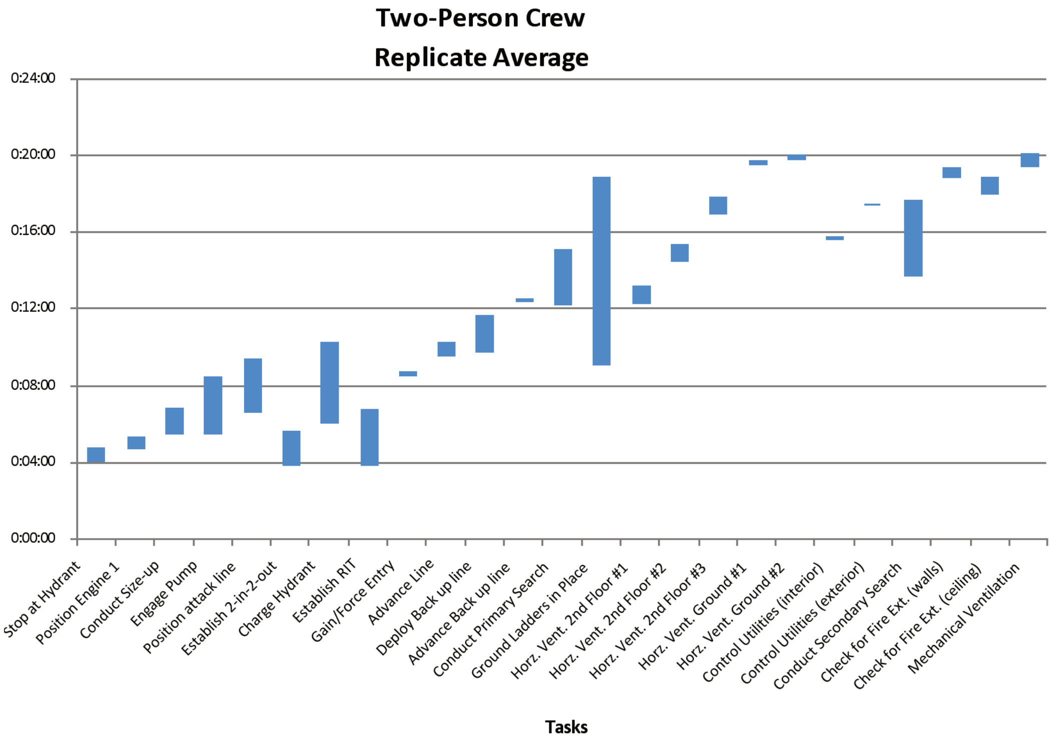
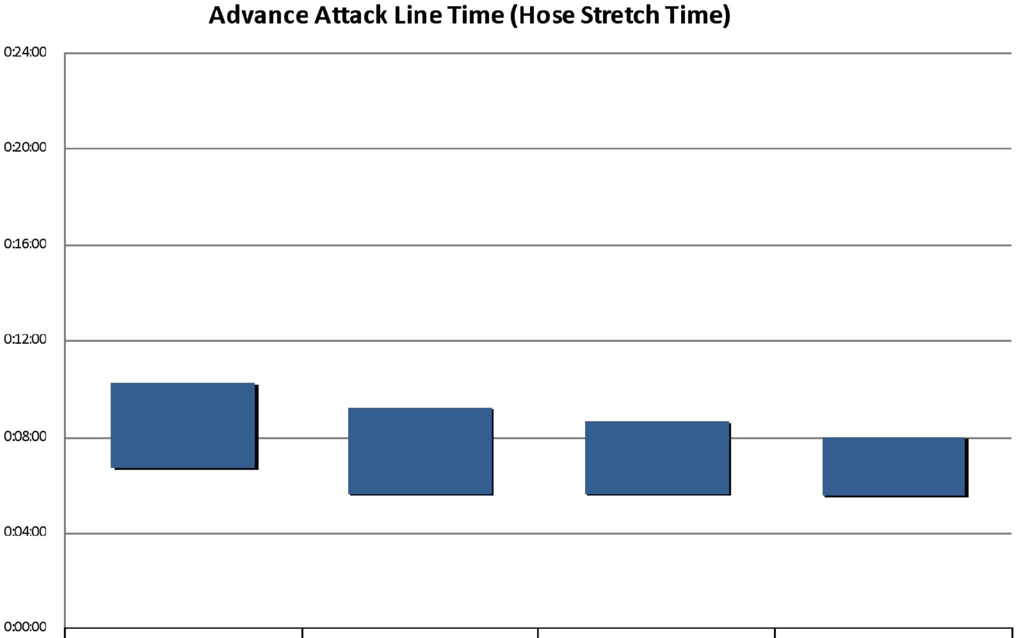


Figure 30 d: Overall Scene Time-Two Person Crew

Advance Attack Line Time (Hose Stretch Time)

Figure 31 measures the interval from the start of the task "Position Attack Line" to the end of the task "Advance Attack Line." In comparing four- and five-person crews to two and three-person crews collectively, the time difference for this measure was statistically significant at 76 seconds (1 minute 16 seconds). In conducting more specific analysis comparing all crew sizes to a two-person crew the differences are more distinct. A two-person crew took 57 seconds longer than a three-person crew to stretch a line. A two-person crew took 87 seconds longer than a four-person crew to complete the same task. Finally, the most notable comparison was between a two-person crew and a five-person crew, with a 122-second difference in task completion time.[12, 13]



	2-Person	3-Person	4-Person	5-Person
End Time	0:10:16	0:09:15	0:08:41	0:08:01
Duration	0:03:34	0:03:36	0:03:02	0:02:29
Start Time	0:06:43	0:05:39	0:05:39	0:05:33

Figure 31: Advance Line Time (Hose Stretch Time) by Crew Size

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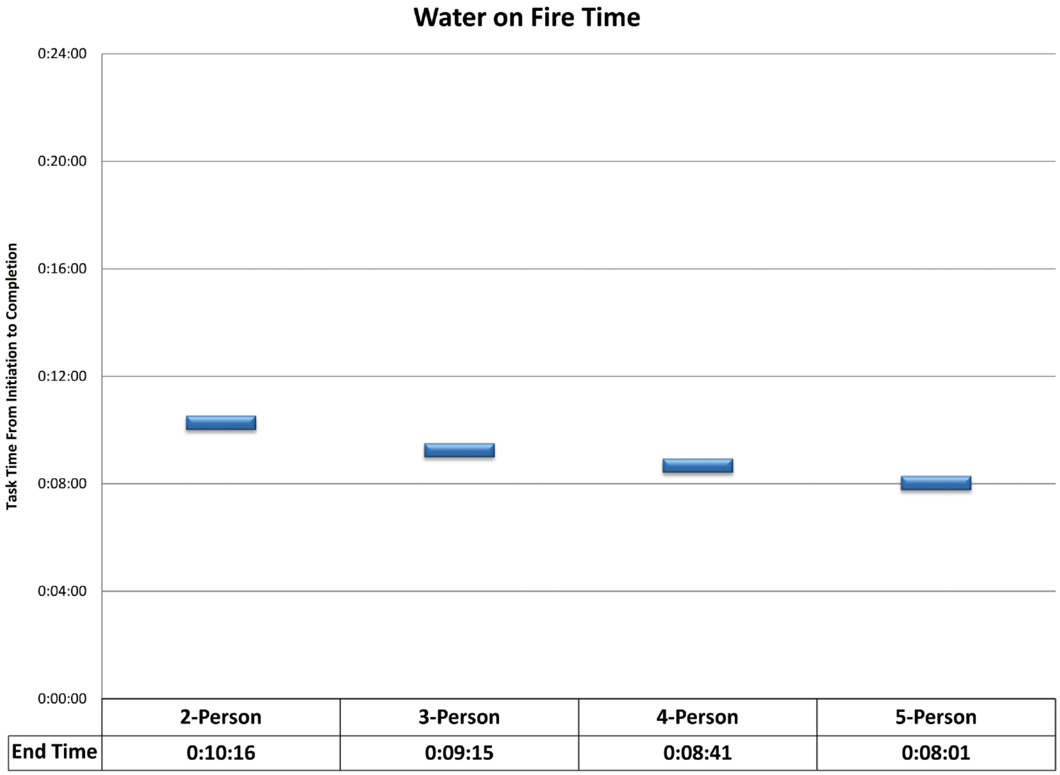
12 Apparatus stagger was not statistically significant, so the data for crew size were combined.

13 Where subtracting the start time from the end time yields a result that differs from the duration noted in the chart by one second, it is the result of rounding fractional seconds to the nearest whole second.

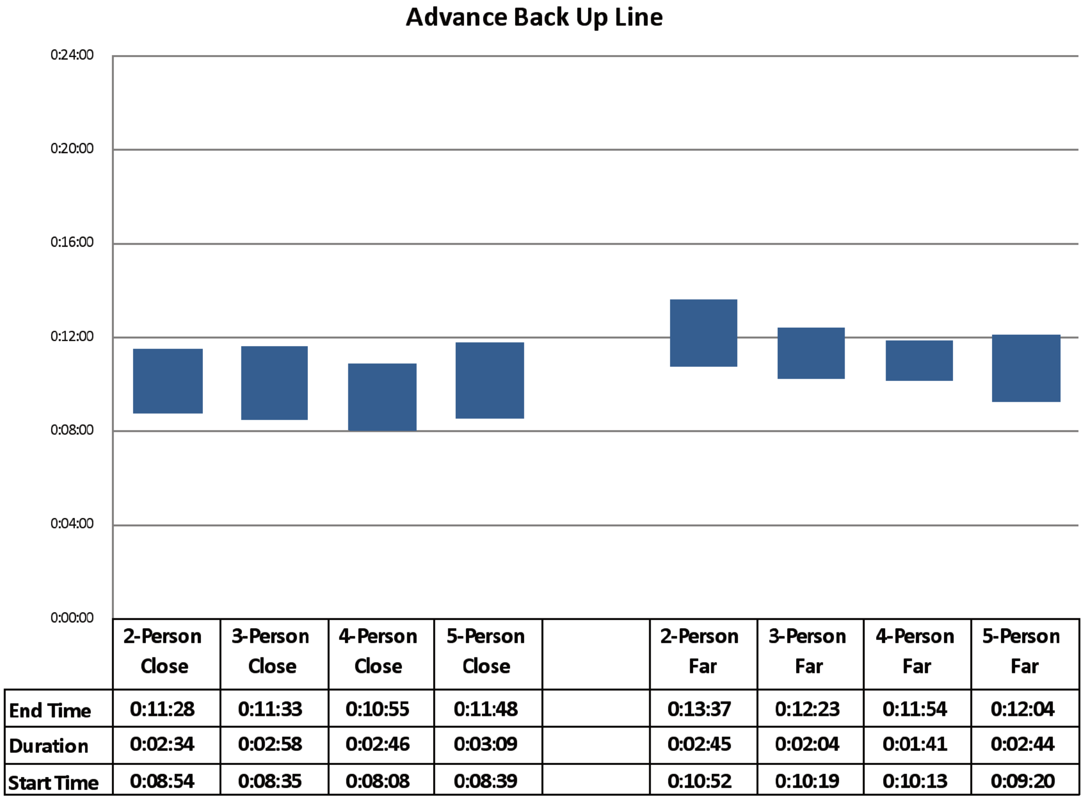


	2-Person	3-Person	4-Person	5-Person
End Time	0:10:16	0:09:15	0:08:41	0:08:01

Figure 32: Water on Fire Time by Crew Size and Stagger

Time to Water on Fire

There was a 10% difference in the “water on fire” time between the two- and three-person crews. There was an additional 6% difference in the "water on fire" time between the three- and four-person crews. (i.e., four-person crews put water on the fire 16% faster than two person crews). There was an additional 6% difference in the “water on fire” time between the four- and five-person crews (i.e. five-person crews put water on the fire 22% faster than two-person crews).



	2-Person Close	3-Person Close	4-Person Close	5-Person Close		2-Person Far	3-Person Far	4-Person Far	5-Person Far
End Time	0:11:28	0:11:33	0:10:55	0:11:48		0:13:37	0:12:23	0:11:54	0:12:04
Duration	0:02:34	0:02:58	0:02:46	0:03:09		0:02:45	0:02:04	0:01:41	0:02:44
Start Time	0:08:54	0:08:35	0:08:08	0:08:39		0:10:52	0:10:19	0:10:13	0:09:20

Figure 33: Times to Advance Backup Line by Crew Size and Stagger

Advancing a Backup Line

Advancing a backup line to the door and stairwell was started 16 % faster and completed 9 % for replicates with shorter staggers between company arrivals. Advancing a backup line is typically a task completed by the third arriving engine on a full alarm assignment and is critical to the safety of firefighters already in the building on the initial attack line. For this task, stagger of arrival was statistically significant and is an important consideration for overall station location and full alarm response capability. The differences can be seen in Figure 33, which shows the time from the start for the task “Deploy Backup Line” to the end of the task “Advance Backup Line.”

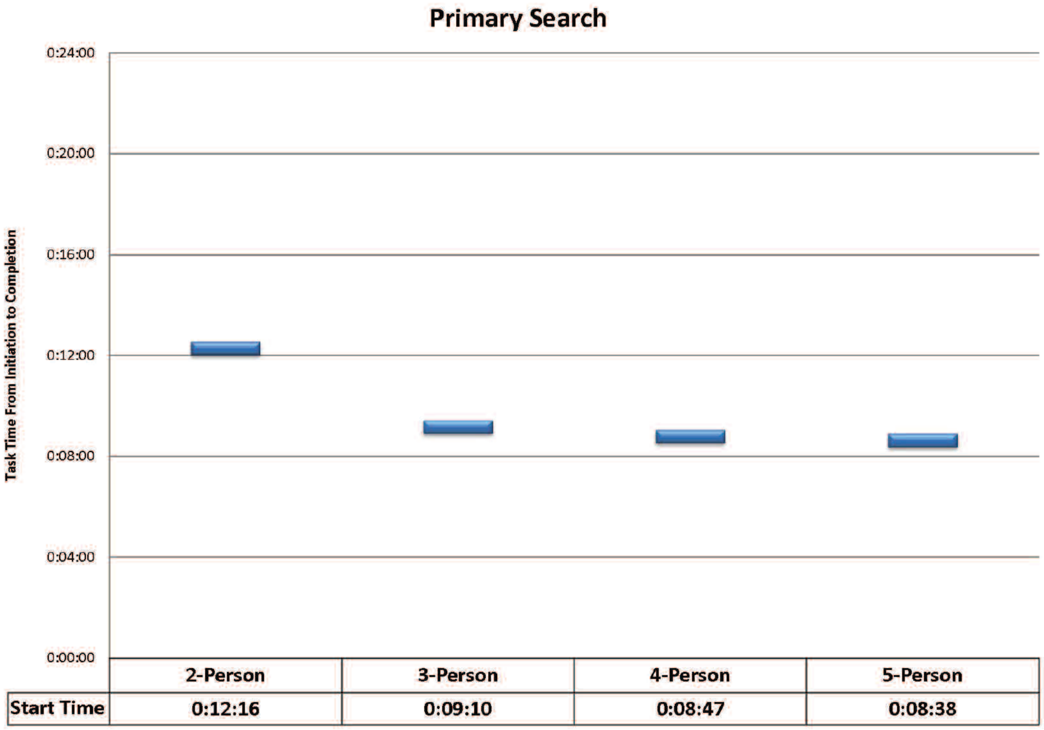


Figure 34: Times to Conduct Primary Search by Crew Size

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14 Stagger was not significant, so data from close and far were combined to increase statistical power.

Primary Search

Figure 34 summarizes the times that crews took to start the primary search. On the low-hazard, two-story single-family dwelling 2,000 sq ft (186 m^2) , the three-person crew started a primary search/rescue more than 25 % faster than the two-person crew. In the same structure, the four- and five-person crews started a primary search 6 % faster than the three-person crews and 30 % faster than the two-person crew. Note that there is no end time included in this figure. Primary search end times were reliant upon radio communication by firefighters inside the structure. On occasion this communication did not occur or was delayed. Therefore data reliability was insufficient for analysis of task duration and end time.[14]

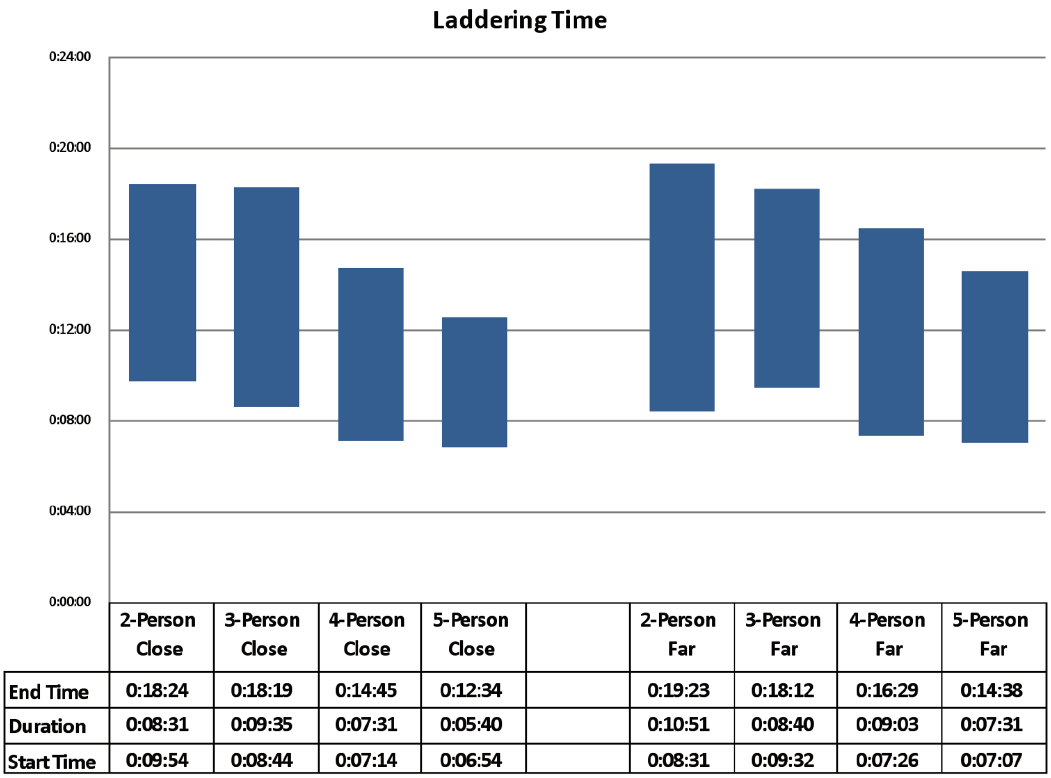
Laddering and Venting Time

A four-person crew operating on a low-hazard structure fire completed laddering and ventilation (for life safety and rescue) 30 % faster than a two-person crew and 25 % faster than a three-person crew.

Ground laddering time started with the removal of the first ladder from the truck and stopped at end time of the last ladder put in place. A total of four ladders were raised on each experiment.

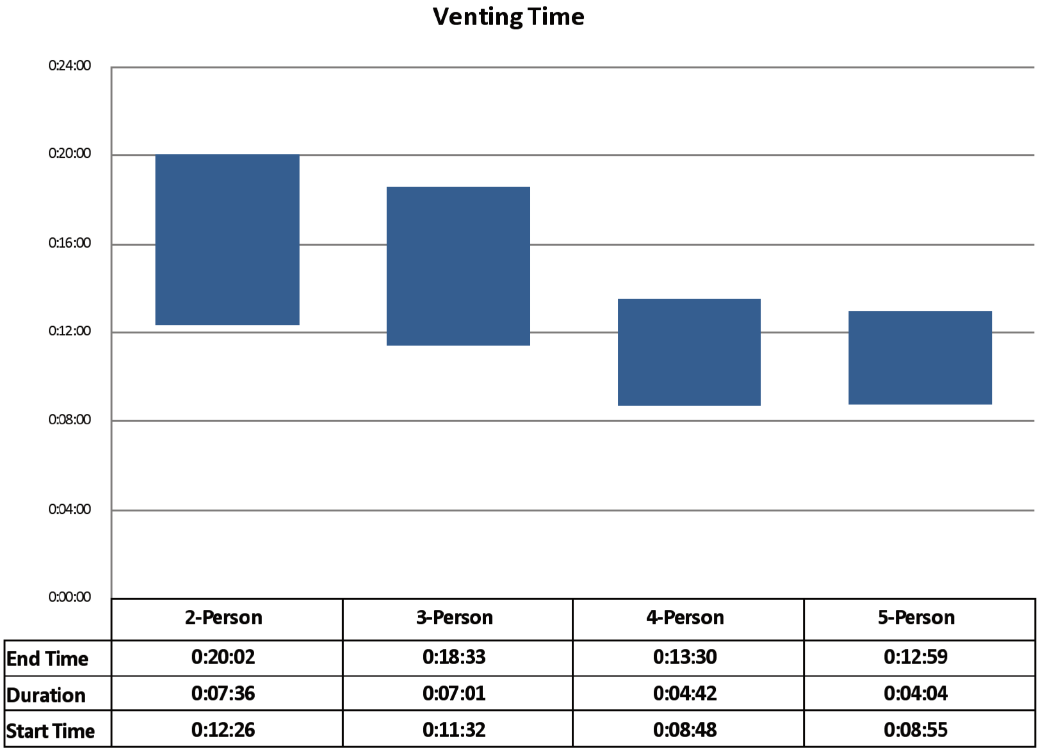
Truck operations ventilation time is the time from the start time of ventilation of the first window until the last window ventilation was complete.

The differences in start times and duration of the tasks can be seen in Figure 35 and Figure 36.



	2-Person Close	3-Person Close	4-Person Close	5-Person Close		2-Person Far	3-Person Far	4-Person Far	5-Person Far
End Time	0:18:24	0:18:19	0:14:45	0:12:34		0:19:23	0:18:12	0:16:29	0:14:38
Duration	0:08:31	0:09:35	0:07:31	0:05:40		0:10:51	0:08:40	0:09:03	0:07:31
Start Time	0:09:54	0:08:44	0:07:14	0:06:54		0:08:31	0:09:32	0:07:26	0:07:07

Figure 35: Laddering Time by Crew Size



	2-Person	3-Person	4-Person	5-Person
End Time	0:20:02	0:18:33	0:13:30	0:12:59
Duration	0:07:36	0:07:01	0:04:42	0:04:04
Start Time	0:12:26	0:11:32	0:08:48	0:08:55

Figure 36: Ventilation Times by Crew Size[15]

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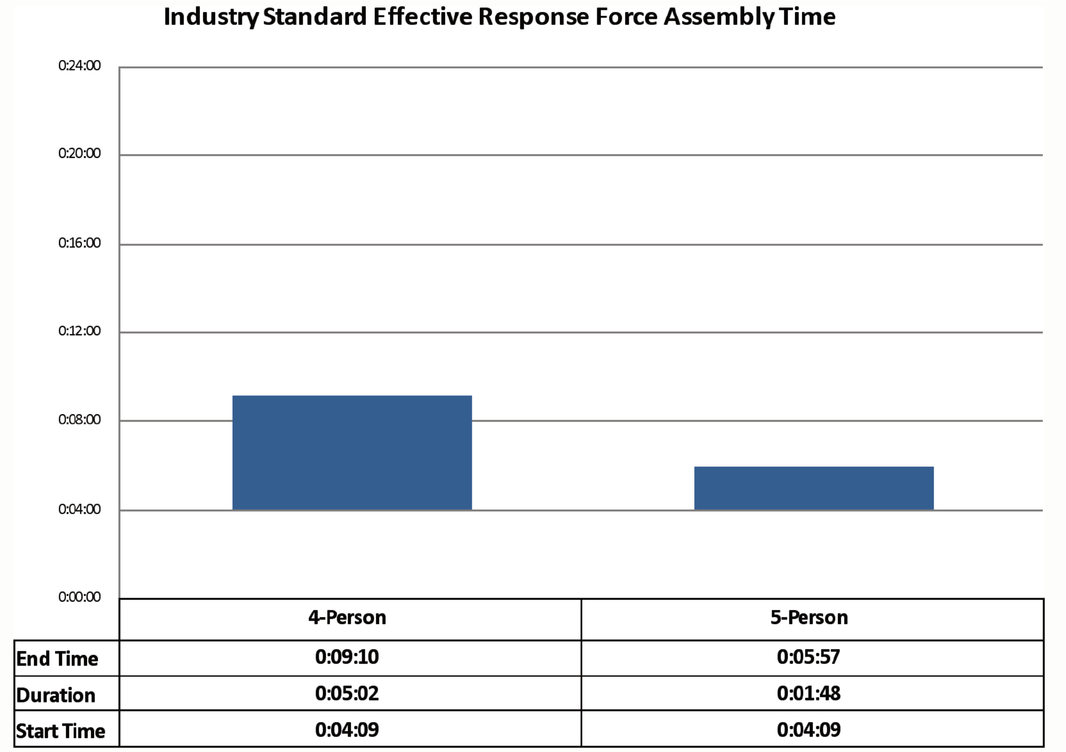
[15] Stagger was not statistically significant, so the data for crew size were combined.

Industry Standard Effective Response Force Assembly Time

NFPA 1710 requires that a fire department have the capability to deploy an initial full-alarm assignment to a scene within eight-minutes (480 seconds). The number of people required falls between 15 and 17, depending on whether an aerial apparatus is used, and/or if two engines are being used to provide a continuous water supply. In these experiments, the measurement for an effective response force assembly time started from the first engine arrival at the hydrant and ended when 15 firefighters were assembled on scene. Figure 37 reveals the differences in assembly times between the four and five-person crews. An effective response force was assembled by the five-person crews a full three minutes faster than the four-person crews. It is important to note that (by definition), the two-and three-person crews were unable to meet this standard at any time during the experiments.[16]



	4-Person	5-Person
End Time	0:09:10	0:05:57
Duration	0:05:02	0:01:48
Start Time	0:04:09	0:04:09

Figure 37: Industry Standard Effective Response Force Assembly Time

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[16] Stagger was not statistically significant, so the data for far and near stagger were combined.

Part 4: Fire Modeling

In the room and contents experiments conducted in Part 3 of the study, instrumentation measured oxygen, carbon dioxide, and carbon monoxide concentrations. Data were grouped by the type of experiment conducted with respect to crew size and first due engine arrival time. As previously shown in the experimental matrix, each group contained two replicate tests. In each group of data the results of the replicates were averaged to simplify the data for further comparison. Figure 38 and Figure 39 show the typical concentration curves for the experiments.

These two graphs show the ranges representative of those found in the experiments. Charts of gas curves for the remainder of the experiments — for both the burn room and the target room — can be found in Appendix H.

Fire Modeling Methods

A primary goal of fire department response is to prevent civilian injuries and deaths. Because the significant majority of fire deaths in the United States occur in residences, a rapid fire service response provides the last line-of-defense against civilian fire deaths. Further, because the fire service is less likely to rescue occupants intimate with the fire (i.e., inside the room of origin where conditions deteriorate rapidly), tenability measurements were taken in a remote bedroom on the second floor of the residential burn structure. The gas and temperature measurements were taken at the 5 ft (1.5 m) height above the floor, 3 ft (0.9 m) from the west wall in order to simulate a nonambulatory occupant (e.g, someone asleep, under the influence of alcohol or drugs, or otherwise mobility impaired).

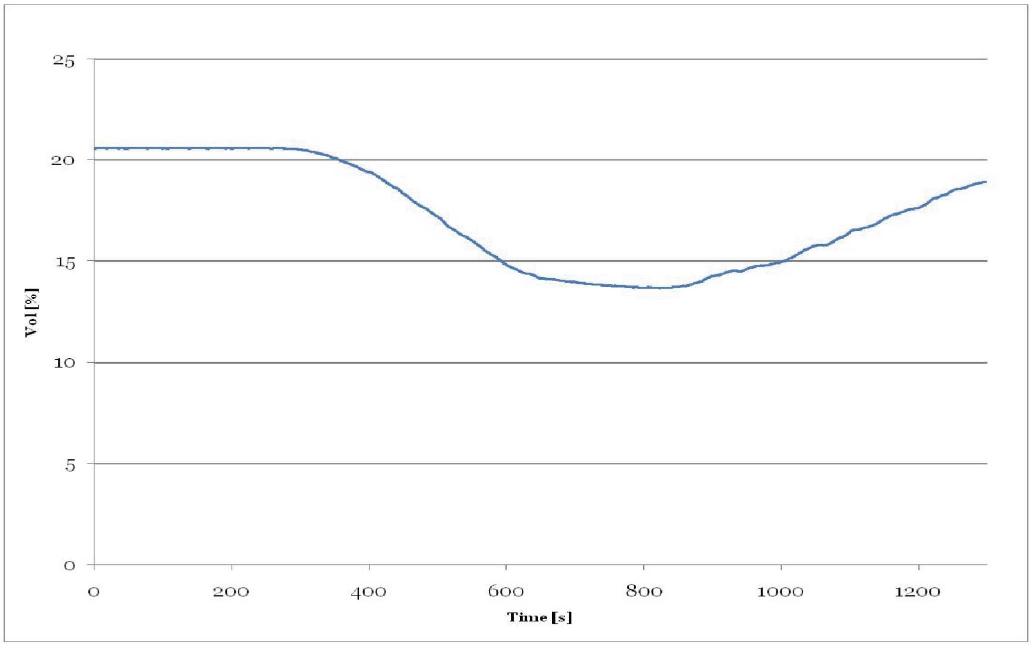

Figure 38: Representative Oxygen Concentration

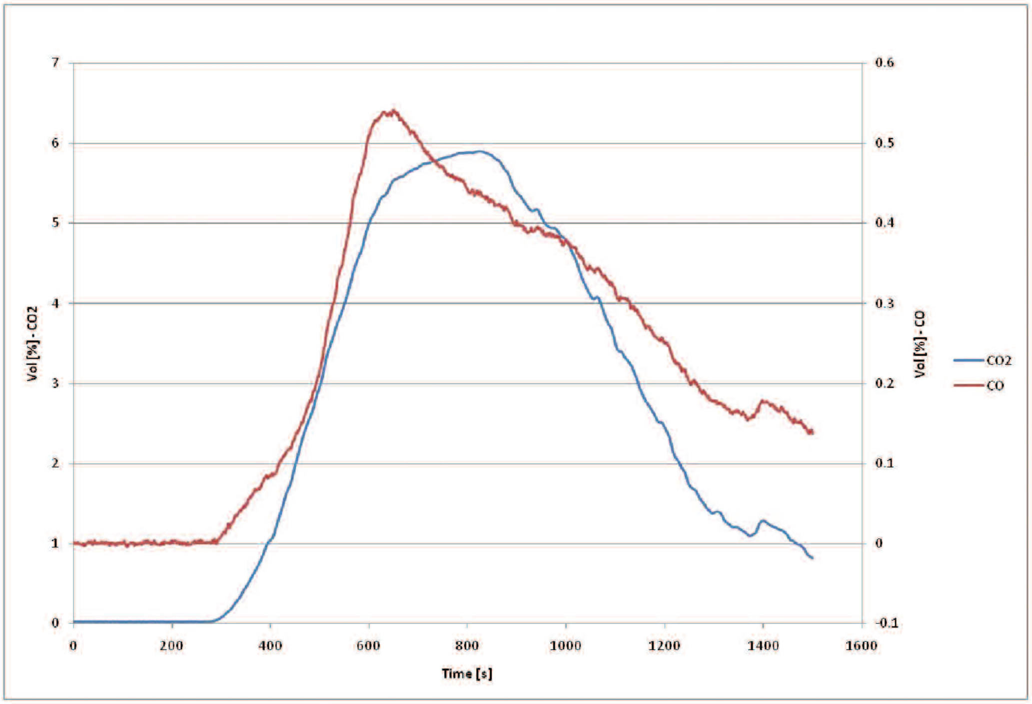

Figure 39: Representative Carbon Monoxide and Carbon Dioxide Concentrations

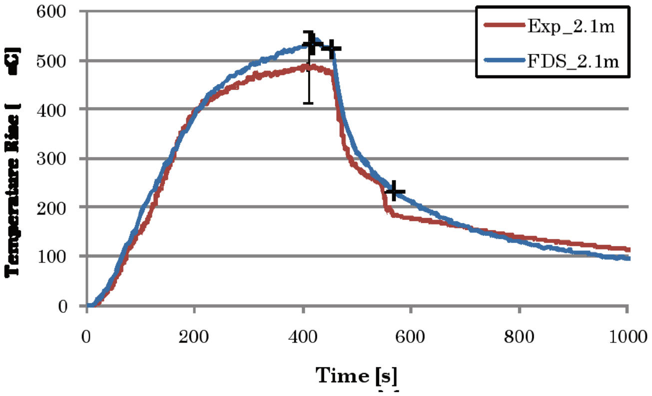

Figure 40: Measured vs. Predicted Temperature at the 2.1 m (6.9 ft) Thermocouple Location in the Burn Compartment

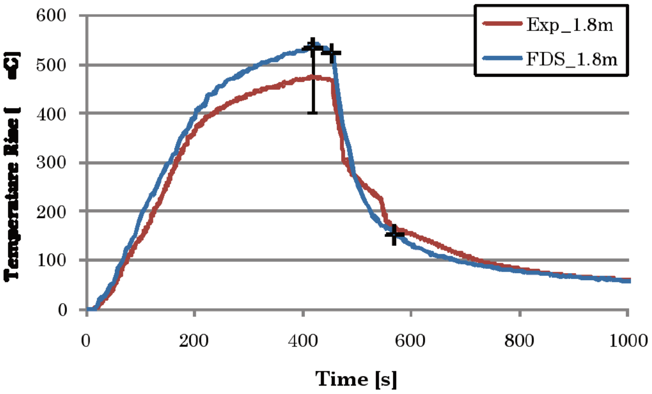

Figure 41: Measured vs. Predicted Temperature at the 1.8 m (5.9 ft) Thermocouple Location in the Burn Compartment

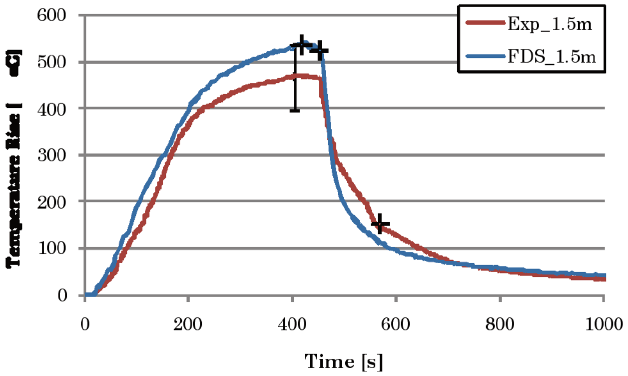

Figure 42: Measured vs. Predicted Temperature at the 1.5 m (4.9 ft) Thermocouple Location in the Burn Compartment

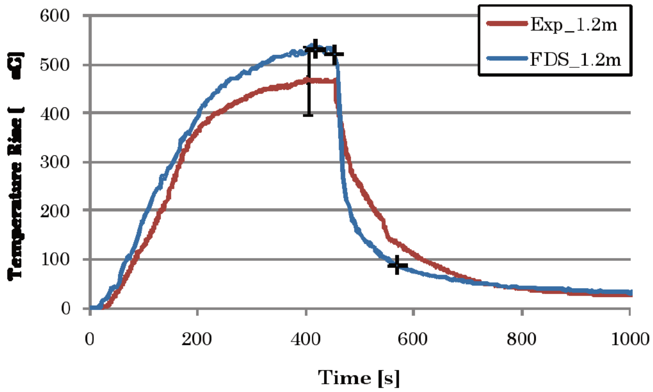

Figure 43: Measured vs. Predicted Temperature at the 1.2 m (3.9 ft) Thermocouple Location in the Burn Compartment

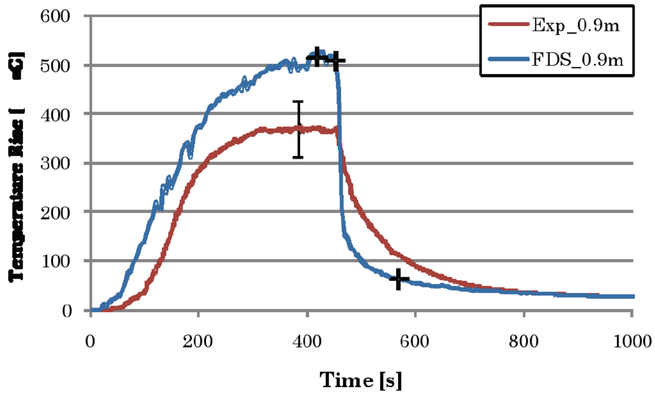

Figure 44: Measured vs. Predicted Temperature at the 0.9 m (2.9 ft) Thermocouple Location in the Burn Compartment

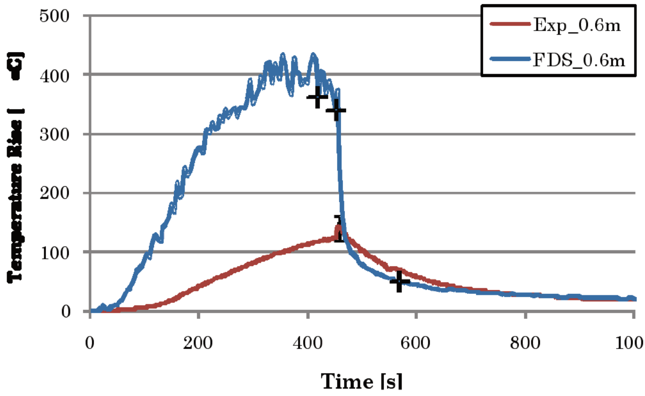

Figure 45: Measured vs. Predicted Temperature at the 0.6 m (1.9 ft) Thermocouple Location in the Burn Compartment

Computational fire models used the average suppression timings obtained from the time-to-task experiments under specific deployment configurations as inputs to the model. This quantitative approach eliminated the experimental variance of the fire. The resulting "computational" fire is repeatable, and therefore, any differences in occupant exposure to toxic gases will be due to the intervention times associated with a specific deployment configuration rather than the random variation that naturally occurs from fire to fire.

Fire simulations were completed using the NIST Fire Dynamics Simulator (FDS). FDS is a computational fluid dynamics model of fire-driven fluid flow. The first version of the FDS was released in 2000. FDS has been extensively verified and validated (USNRC 2007). Since the initial release, numerous improvements have been made and new features added. This study used FDS version 5.4.2 (Sub-version #4957), which was released on October 19, 2009. In order to calibrate the model, simulations were performed to replicate the experimental results observed in the room-and-contents fires. Once the ability of the model to replicate experimental results was established, the different fire growth rates and deployment configurations were simulated to characterize the effectiveness of different responses relative to different fire growth rates.

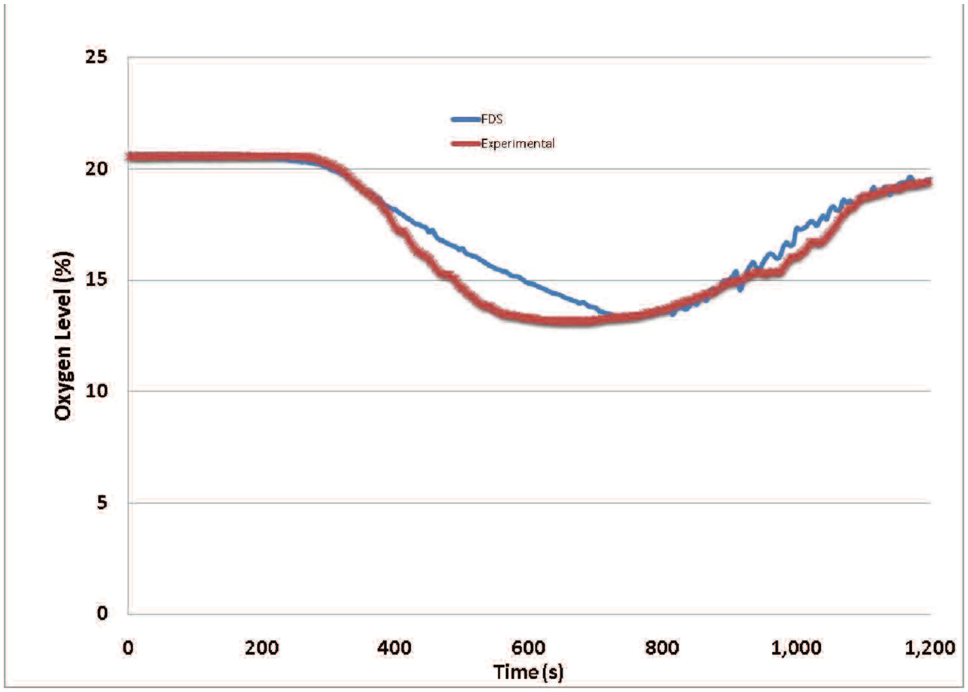

Figure 46: Measured Versus Predicted Oxygen Levels in the Upstairs Bedroom at 5 ft (1.5 m)

The occupant exposure to toxic gases was assumed to occur until the occupant is rescued by the truck crew (start time of primary search plus one minute). Table 6 shows the "rescue time" for the various crew sizes that correspond to the test matrix for the room and contents experiments.

Part 4 of the experiments used fire modeling to correlate response times to atmospheric tenability in a burning structure. In order to calibrate the computer fire model, simulations were performed to replicate the experimental results observed in the room-and-contents fires. Model inputs include building geometry and material properties, ventilation paths (doors, windows, leakage paths), and heat release rate of the fuel package. While the building geometry is easily measured and material properties (such as the thermal properties of drywall and concrete) are readily estimated, the heat release rate was not directly measured during the experiments. The heat release rate of the fuel package is the primary determinant of the production rate of heat, smoke, and gas species (e.g., carbon dioxide, carbon monoxide).

Figures 40 through 45 compare the experimental and simulated burn room temperatures using the burn room thermocouple tree. The tree contained thermocouples located at 0.6 m (1.9 ft), 0.9 m (2.9 ft), 1.2 m (3.9 ft), 1.5 m (4.9 ft), 1.8 m (5.9 ft), and 2.1 m (6.9 ft) above the floor. For additional information about the instrumentation type location, see Appendix C. The results for thermocouples located in the hot gas layer show excellent agreement. The temperature at the lower two thermocouples show an overprediction of the hot gas layer depth in the computer simulation. A small difference in the location of the interface height (the steep temperature gradient between the relatively cool lower gas layer and the hot upper gas layer), can result in significant predicted temperature differences with relatively little effect on the bulk heat and mass transport accuracy. This explanation is supported by the agreement of the temperatures in the remote bedroom.

Figure 46 compares the experimental and predicted oxygen concentration levels in the upstairs bedroom (measured at 5 ft (1.5 m) above the floor, centered above the bed). Figures 47 through 52 compare the experimental and simulated temperatures in the upstairs (target room) bedroom. As expected, the temperatures are moderated by mixing (cool ambient air mixes with hot combustion gases during transport between the burn room and the target room) and by thermal losses to the (cooler) surfaces between the two rooms.

Once the model inputs were determined to agree with the experimental results, the input heat release rate was changed to represent three fire growth rates representative of a range of fire hazard development – slow, medium, and fast, which are described in greater detail in the following sections.

Time to Untenable Conditions: Research Questions

In the real world, fires grow at many different rates – from very slow, smoldering fires all the way to ultra-fast, liquid fuel or spray fires. In order to extend the applicability of the findings of this report beyond the one fire growth rate observed in part 3 of this report (residential room and contents fires), computer fire modeling was used to quantify the effectiveness of fire department operations in response to an idealized range of fire growth rates (characterized as slow, medium, and fast). Based on the research questions shown in Figure 53, fire modeling methods were then selected to maximize the applicability of the times to task results.

1) How do performance times relate to fire growth as projected by standard fire time/temperature curves?

2) How do these performance times vary by crew size, first due arrival time, and stagger?

3) How do crew size, stagger, and arrival time affect occupant tenability within the structure?

Figure 53: Research Questions for Time to Untenable Conditions

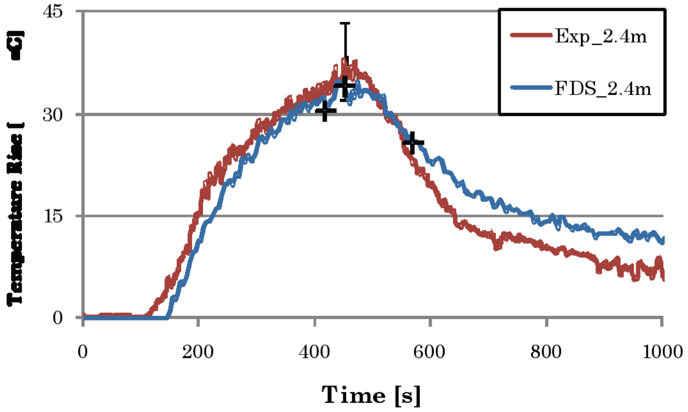

Figure 47: Measured vs. Predicted Temperature at the 2.4 m (7.8 ft) Thermocouple Location in the Bedroom

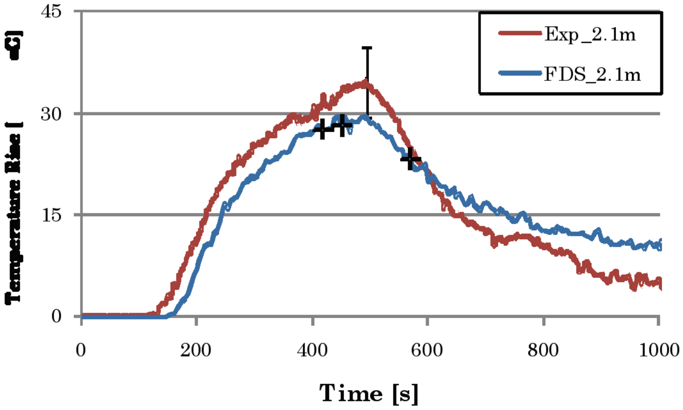

Figure 48: Measured vs. Predicted Temperature at the 2.1 m (6.8 ft) Thermocouple Location in the Bedroom

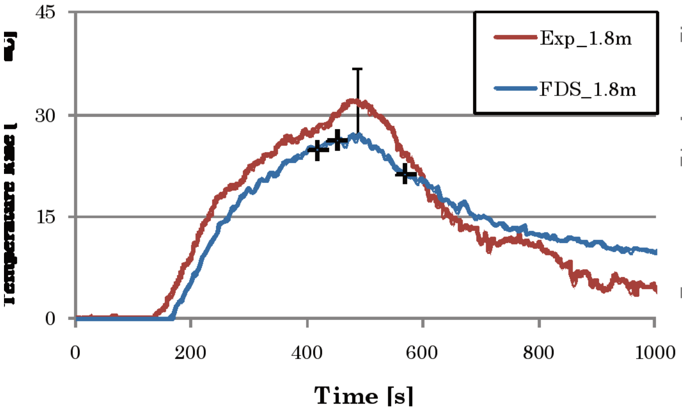

Figure 49: Measured vs. Predicted Temperature at the 1.8 m (5.9 ft) Thermocouple Location in the Bedroom

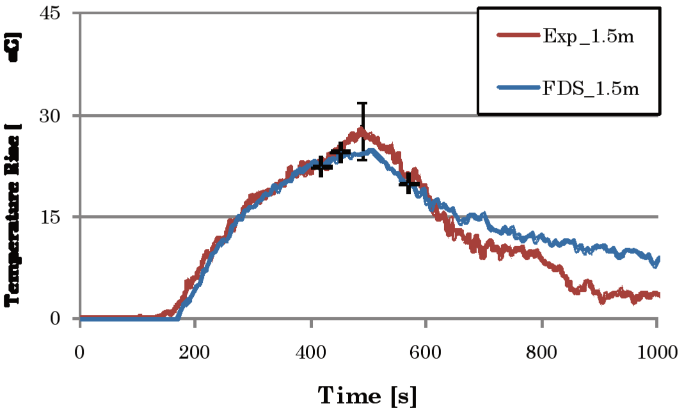

Figure 50: Measured vs. Predicted Temperature at the 1.5 m (4.9 ft) Thermocouple Location in the Bedroom

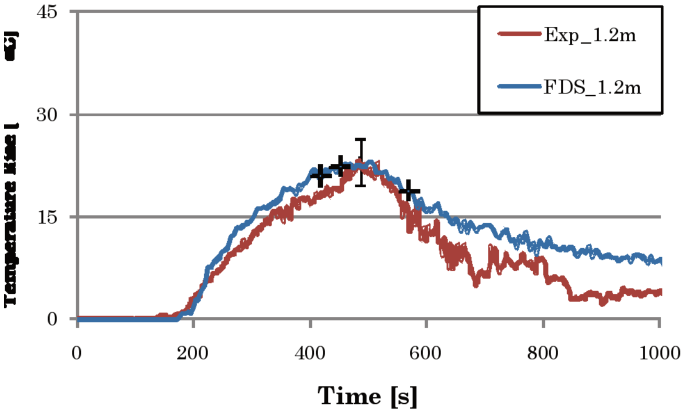

Figure 51: Measured vs. Predicted Temperature at the 1.2 m (3.9 ft) Thermocouple Location in the Bedroom

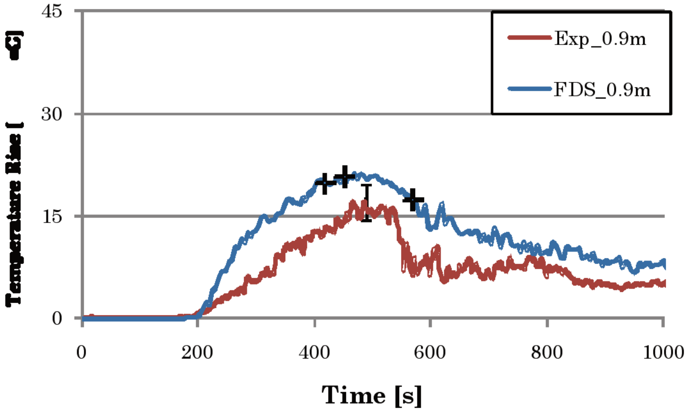

Figure 52: Measured vs. Predicted Temperature at the 0.9 m (2.9 ft) Thermocouple Location in the Bedroom

Fire Growth Rates

Three fire growth rates were used in the computer fire modeling to assess the effectiveness of different fire department deployment configurations in response to fires that were similar to, faster growing, and slower growing than the fires observed in the room-and-contents fires. The slow, medium, and fast fire growth rates are defined by the Society of Fire Protection Engineers according to the time at which they reach 1 megawatt (MW). A typical upholstered chair burning at its peak would produce a 1-MW fire, while a large sofa at its burning peak would produce roughly a 2-MW fire.

The growth rate of fires is often approximated by simple correlation of heat release rate to the square of time. If a fire is not suppressed before full-room involvement, the probability of spread beyond the room of origin increases dramatically if there is nearby fuel load to support fire spread. If a nearby fuel load is available, the 12 ft (3.7 m) by 16 ft (4.9 m) compartment used in the fire experiments would become fully involved at approximately 2 MW. Table 7 shows the time in seconds at which 1-MW and 2-MW (fully involved) fires in this compartment would be reached in the absence of suppression.

Fire Growth Rate	Time in Seconds Reach 1 MW	Time in Seconds to Reach to 2 MW
Slow	600	848
Medium	300	424
Fast	150	212

Table 7: Time to Reach 1 MW and 2 MW by Fire Growth Rate In the Absence of Suppression

A fire department rescue operation is a race between the deteriorating interior conditions inside the structure and the rescue and suppression activities of the fire department. Each fire growth rate was used as a baseline heat release rate for the simulation. Intervention times (window and door opening times and suppression time) from the time-to-task tests were systematically input into the model to evaluate the effects on interior tenability conditions. The interior tenability conditions were calculated in a remote upstairs bedroom (above the room of fire origin on the first floor) in order to maximize the opportunity for differentiation among different crew configurations.

Fractional Effective Dose (FED)

In order to convert instantaneous measurements of local gas conditions, the fractional effective dose (FED) formulation published by the International Standards Organization (ISO) in document 13571 *Life-threatening Components of Fire – Guidelines for the Estimation of Time Available for Escape Using Fire Data* (ISO 2007) were used. FED is a probabilistic estimate of the effects of toxic gases on humans exposed to fire effluent. The formulation used in the simulations accounts for carbon monoxide (CO), carbon dioxide (CO_2), and oxygen (O_2) depletion. Other gases, including hydrogen cyanide (HCN) and hydrogen chloride (HCl), were not accounted for in this analysis and may alter FED for an actual occupant.

$$FED = \sum_{i=1}^{n} \frac{C_i}{(C_t)_i} \Delta t \qquad \text{Eq.1}$$

Where C_i is the concentration of the ith gas and $(C_t)_i$ is the toxic concentration of ith gas and Δt is the time increment.

There are three FED thresholds generally representative of different exposure sensitivities of the general population. An FED value of 0.3 indicates the potential for certain sensitive populations to become incapacitated as a result of exposure to toxic combustion products. Sensitive populations may include elderly, young, or individuals with compromised immune systems. Incapacitation is the point at which occupants can no longer effect their own escape. An FED value of 1.0 represents the median incapacitating exposure. In other words, 50 % of the general population will be incapacitated at that exposure level. Finally, an FED value of 3.0 represents the value where occupants who are particularly tolerant of combustion gas exposure (extremely fit persons, for example) are likely to become incapacitated.

These thresholds are statistical probabilities, not exact measurements. There is variability in the way individuals respond to toxic atmospheric conditions. FED values above 2.0 are often fatal doses for so-called typical occupants. There is no threshold so low that it can be said to be safe for every exposed occupant.[17]

Deployment Configuration (All times with close stagger adjusted for early and late arrival of first due engine)	Rescue Time for Deployment Configuration (Min : Sec)
2-Person Early	12:47
3-Person Early	9:03
4-Person Early	9:10
5-Person Early	8:57
2-Person Late	14:47
3-Person Late	11:03
4-Person Late	11:10

Table 6: Rescue Time for Different Deployment Configurations

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[17] See the following sections of ISO Document 13571:
5.2 Given the scope of this Technical Specification, FED and/or FEC values of 1,0 are associated, by definition, with sublethal effects that would render occupants of average susceptibility incapable of effecting their own escape. The variability of human responses to toxicological insults is best represented by a distribution that takes into account varying susceptibility to the insult. Some people are more sensitive than the average, while others may be more resistant (see Annex A.1.5). The traditional approach in toxicology is to employ a safety factor to take into consideration the variability among humans, serving to protect the more susceptible subpopulations.
5.2.1 As an example, within the context of reasonable fire scenarios FED and/or FEC threshold criteria of 0,3 could be used for most general occupancies in order to provide for escape by the more sensitive subpopulations. However, the user of this Technical Specification has the flexibility to choose other FED and/or FEC threshold criteria as may be appropriate for chosen fire safety objectives. More conservative FED and/or FEC threshold criteria may be employed for those occupancies that are intended for use by especially susceptible subpopulations. By whatever rationale FED and FEC threshold criteria are chosen, a single value for both FED and FEC must be used in a given calculation of the time available for escape.

Results from Modeling Methods

Table 8 shows the FED for slow-, medium-, and fast-growth rate fires correlated to rescue times based on crew size and arrival time in the study. As with the room-and-contents fire in part 3, results in Table 8 included only the close-stagger rescue time data. The effect of far-stagger rescue times on occupant tenability should be investigated in future studies. Values above 0.3 are shown in yellow, and those above the median incapacitating exposure of 1.0 are shown in red.

Figure 54 shows that with slow-growth fires in the experimental residential structure, all crew configurations could achieve rescue time before FED reached incapacitating levels. Figure 55 illustrates the greater danger of medium-growth fires, where the FED at rescue time for two-person crews is well above the 0.3 level, and almost to that level for the other crews.

Figure 56 (page 49) vividly illustrates the extreme danger of fast-growth fires. By the time a two-person crew is able to facilitate a rescue, the FED has far exceeded the median 1.0 level. For other crew sizes, the FED has exceeded 0.3, which is a threshold level for vulnerable populations.

Crew Configuration	Rescue Time	Fire Growth Rates		
		Slow	Medium	Fast
2 Early	12:47	.12	.72	1.49
2 Late	14:47	.35	1.37	2.56
3 Early	9:03	.01	.11	.40
3 Late	11:03	.04	.36	.84
4 Early	9:10	.01	.11	.42
4 Late	11:10	.05	.38	.91
5 Early	8:57	.01	.10	.38

KEY	White	89% or more of population may be capable of effecting their own escape if they are able.
	Yellow	Potential for certain sensitive populations (such as children and the elderly) to become incapacitated.
	Red	More than 50% of the population would be incapable of effecting their own escape.

Table 8: FED as a Function of Deployment Configuration and Fire Growth Rate

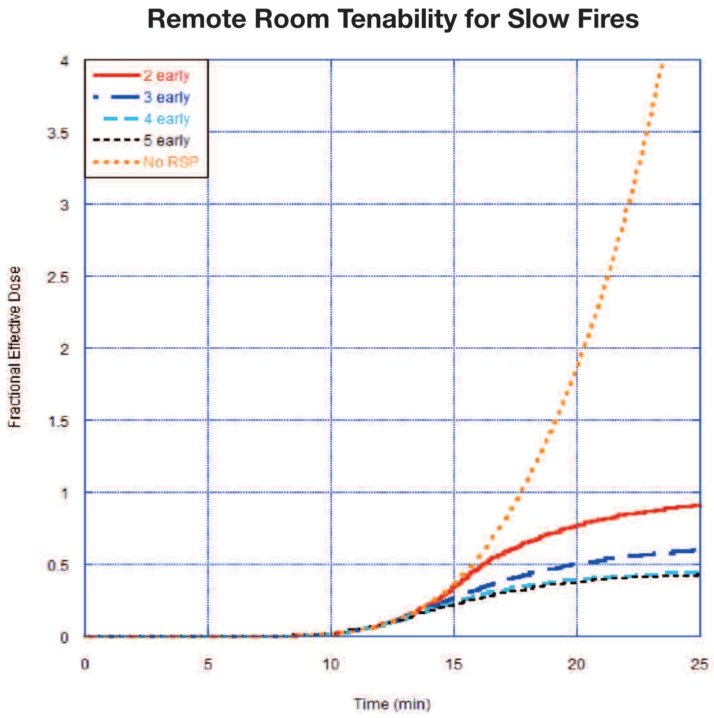
Remote Room Tenability for Slow Fires

Figure 54: FED Curves for Early Arrival for All Crew Sizes at Slow-Growth Fires

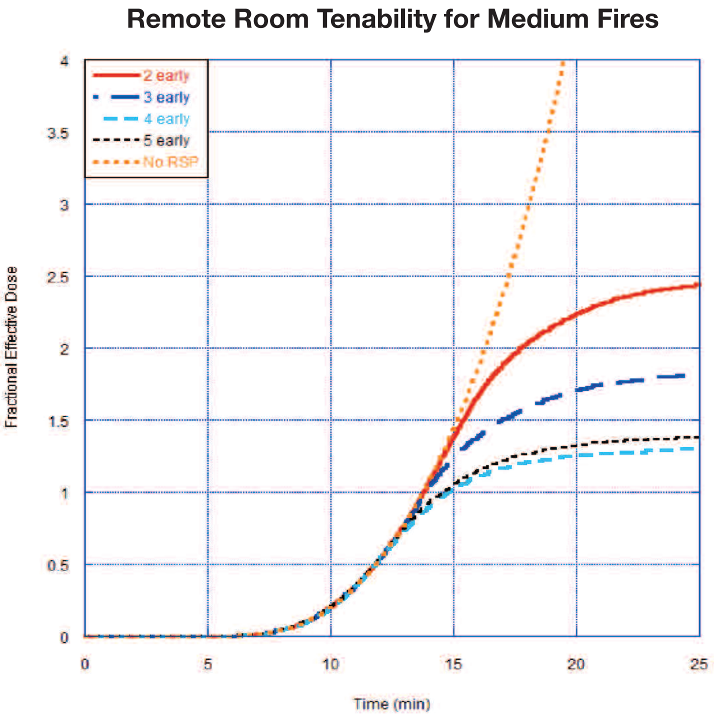
Remote Room Tenability for Medium Fires

Figure 55: Average FED Curves for Early Arrival for All Crew Sizes at Medium-Growth Fires

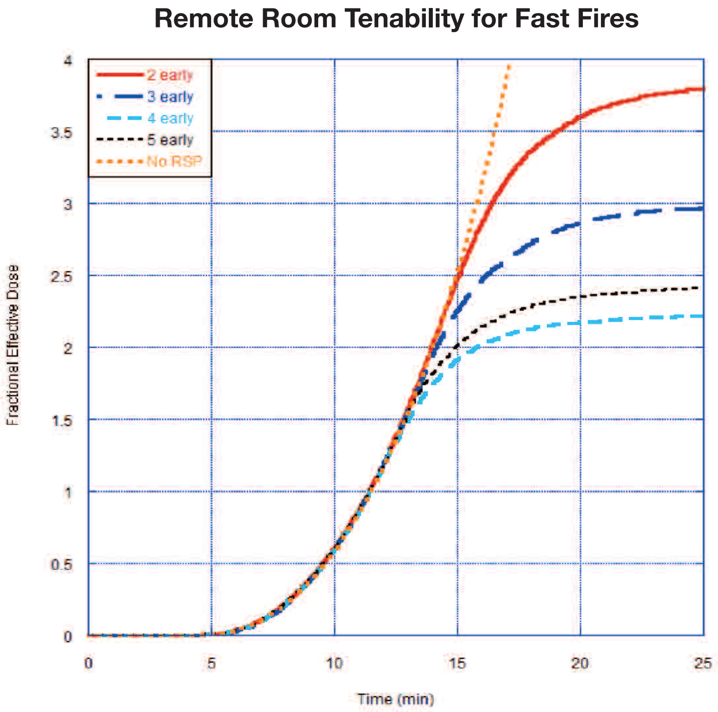

Figure 56: Average FED Curves for Early Arrival for All Crew Sizes at Fast-Growth Fires

Interior Firefighting Conditions and Deployment Configuration

The available time to control a fire can be quite small. Risks to firefighters are lower for smaller fires than larger fires because smaller fires are easier to suppress and produce less heat and fewer toxic gases. Therefore, firefighter deployment configurations that can attack fires earlier in the fire development process present lower risk to firefighters. The longer the duration of the fire development process without intervention, the greater the increase in risk for occupants and responding firefighters. Therefore, time is critical.

Stopping the escalation of the event involves firefighter intervention via critical tasks performed on the fireground. Critical tasks, as described previously, include those tasks that directly affect the spread of fire as well as the associated structural tenability.

There are windows of opportunity to complete critical tasks. A fire in a structure with a typical residential fuel load at six minutes post-ignition is very different from the same fire at eight minutes or at ten minutes post-ignition. Some tasks that are deemed "important" (e.g., scene size-up) for a fire in early stages of growth become critical if intervention tasks are delayed. Time can take away opportunities. If too much time passes, then the window of opportunity to affect successful outcomes (e.g., rescue victim or stop fire spread) closes.

For a typical structure fire event involving a fire department response, there is an incident commander on the scene who determines both the strategy and tactics that will be employed to stop the spread of the fire, rescue occupants, ventilate the structure, and ultimately extinguish the fire. Incident commanders must deal with the fire in the present and make intelligent command decisions based on the circumstances at hand upon arrival. Additionally, arrival time and crew size are factors that contribute to the incident commander's decisions and affect the capability of the firefighters to accomplish necessary tasks on scene in a safe, efficient, and effective manner.

Table 9 illustrates vividly the more dangerous conditions small crews face because of the extra time it takes to begin and complete critical tasks (particularly fire suppression). In the two minutes more it took for the two-person crew (early arrival) than the five-person crew (early arrival) to get water on the fire, a slow growth rate fire would have increased from 1.1 MW to 1.5 MW. This growth would have been even more extreme for a medium-or fast-growth rate fire. The difference is even more substantial for the two-person crew with late arrival as the fire almost doubled in size in the time difference between this crew and the five-person crew.

Based on fire modeling for the low hazard structure studied with a typical residential fuel load, it is likely that medium- and fast-growth rate fires will move beyond the room of origin prior to the arrival of firefighters for all crew sizes. Note that results in Table 8 included only the close-stagger rescue time data. The effect of far-stagger rescue times on occupant tenability should be investigated in future studies. Therefore, the risk level of the event upon arrival will be higher for all crews which must be considered by the incident commander when assigning firefighters to on-scene tasks.

Deployment Configuration	Time to Water on Fire (Min : Sec)	Fire Size at Time of Suppression for Slow-Growth Fires
2-Person, Late Arrival	14:26	2.1 MW
2-Person, Early Arrival	12:26	1.5 MW
3-Person, Late Arrival	13:24	1.8 MW
3-Person, Early Arrival	11:24	1.3 MW
4-Person, Late Arrival	13:11	1.7 MW
4-Person, Early Arrival	11:11	1.3 MW
5-Person, Late Arrival	12:33	1.6 MW
5-Person, Early Arrival	10:33	1.1 MW

Table 9: Fire Size at Time of Fire Suppression

Physiological Effects of Crew Size on Firefighters

Reports on firefighter fatalities consistently document overexertion/overstrain as the leading cause of line-of-duty fatalities. There is strong epidemiological evidence that heavy physical exertion can trigger sudden cardiac events (Mittleman et al. 1993; Albert et al. 2000). Therefore, information about the effect of crew size on physiological strain is very valuable.

During the planning of the fireground experiments, investigators at Skidmore College recognized the opportunity to conduct an independent study on the relationship between firefighter deployment configurations and firefighter heart rates. With the approval of the Institutional Review Board of Skidmore College, they were able to leverage the resources of the field experiments to conduct a separate analysis of the cardiac strain on fire fighters on the fireground.

For details, consult the complete report (Smith 2009). Two important conclusions from the report reinforce the importance of crew size:

- Average heart rates were higher for members of small crews, particularly two-person crews.
- Danger is increased for small crews because the stress of fire fighting keeps heart rates elevated beyond the maximum heart rate for the duration of a fire response, and so the higher heart rates were maintained for sustained time intervals.

Study Limitations

The scope of this study is limited to understanding the relative influence of deployment variables to low-hazard, residential structure fires, similar in magnitude to the hazards described in *NFPA 1710*. The applicability of the conclusions from this report to commercial structure fires, high-rise fires, outside fires, terrorism/natural disaster response, HAZMAT or other technical responses has not been assessed and should not be extrapolated from this report.

Every attempt was made to ensure the highest possible degree of realism in the experiments while complying with the requirements of *NFPA 1403*, but the dynamic environment on the fireground cannot be fully reproduced in a controlled experiment. For example, *NFPA 1403* required a daily walkthrough of the burn prop (including identifying the location of the fire) before ignition of a fire that would produce an Immediately Dangerous to Life and Health (IDLH) atmosphere, a precaution not available to responders dispatched to a live fire.

The number of responding apparatus for each fireground response was held constant (three engines and one truck, plus the battalion chief and aide) for all crew size configurations. The effect of deploying either more or fewer apparatus to the scene was not evaluated.

The fire crews who participated in the experiments typically operate using three-person and four-person staffing. Therefore, the effectiveness of the two-person and five-person operations may have been influenced by a lack of experience in operating at those staffing levels. Standardizing assigned tasks on the fireground was intended to minimize the impact of this factor, which has an unknown influence on the results.

The design of the experiments controlled for variance in performance of the incident commander. In other words, a more-or less-effective incident commander may have a significant influence on the outcome of a residential structure fire.

Although efforts were made to minimize the effect of learning across experiments, some participants took part in more than one experiment, and others did not.

The weather conditions for the experiments were moderate to cold. Frozen equipment such as hydrants and pumps was not a factor. However, the effect of very hot weather conditions on firefighter performance was not measured.

All experiments were conducted during the daylight hours. Nighttime operations could pose additional challenges.

Fire spread beyond the room of origin was not considered in the room and contents tests or in the fire modeling. Therefore, the size of the fire and the risk to the firefighter may be somewhat underestimated for fast-growing fires or slower-response configurations.

There is more than one effective way to perform many of the required tasks on the fireground. Attempts to generalize the results from these experiments to individual departments must take into account tactics and equipment that vary from those used in the experiments.

Conclusions

More than 60 laboratory and full-scale fire experiments were conducted to determine the impact of crew size, first-due engine arrival time, and subsequent apparatus arrival times on firefighter safety and effectiveness at a low-hazard residential structure fire. This report quantifies the effects of changes to staffing and arrival times for low-hazard residential firefighting operations. While resource deployment is addressed in the context of a single structure type and risk level, it is recognized that public policy decisions regarding the cost-benefit of specific deployment decisions are a function of many factors including geography, available resources, community expectations, as well as all local hazards and risks. Though this report contributes significant knowledge to community and fire service leaders in regard to effective resource deployment for fire suppression, other factors contributing to policy decisions are not addressed.

The objective of the experiments was to determine the relative effects of crew size, first-due engine arrival time, and stagger time for subsequent apparatus on the effectiveness of the firefighting crews relative to intervention times and the likelihood of occupant rescue using a parametric design. Therefore, the experimental results for each of these factors are discussed below.

Of the 22 fireground tasks measured during the experiments, the following were determined to have especially significant impact on the success of fire fighting operations. Their differential outcomes based on variation of crew size and/or apparatus arrival times are statistically significant at the 95 % confidence level or better.

Overall Scene Time:

The four-person crews operating on a low-hazard structure fire completed all the tasks on the fireground (on average) seven minutes faster — nearly 30 % — than the two-person crews. The four-person crews completed the same number of fireground tasks (on average) 5.1 minutes faster — nearly 25 % — than the three-person crew. For the low-hazard residential structure fire, adding a fifth person to the crews did not decrease overall fireground task times. However, it should be noted that the benefit of five-person crews has been documented in other evaluations to be significant for medium- and high-hazard structures, particularly in urban settings, and should be addressed according to industry standards.[18]

Time to Water on Fire:

There was a nearly 10 % difference in the "water on fire time" between the two and three-person crews and an additional 6 % difference in the "water on fire time" between the three- and four-person crews (i.e., 16 % difference between the four and two-person crews). There was an additional 6 % difference in the "water on fire'" time between the four- and five-person crews (i.e., 22 % difference between the five and two-person crews).

Ground Ladders and Ventilation:

The four-person crew operating on a low-hazard structure fire can complete laddering and ventilation (for life safety and rescue) 30 % faster than the two-person crew and 25 % faster than the three-person crew.

Primary Search:

The three-person crew started and completed a primary search and rescue 25 % faster than the two-person crew. In the same structure, the four- and five-person crews started and completed a primary search 6 % faster than the three-person crews and 30 % faster than the two-person crew. A 10 % difference was equivalent to just over one minute.

Hose Stretch Time:

In comparing four-and five-person crews to two-and three-person crews collectively, the time difference to stretch a line was 76 seconds. In conducting more specific analysis comparing all crew sizes to a two-person crew the differences are more distinct. A two-person crew took 57 seconds longer than a three-person crew to stretch a line. A two-person crew took 87 seconds longer than a four-person crew to complete the same tasks. Finally, the most notable comparison was between a two-person crew and a five-person crew — more than 2 minutes (122 seconds) difference in task completion time.

Industry Standard Achieved:

The "industry standard achieved" time started from the first engine arrival at the hydrant and ended when 15 firefighters were assembled on scene.[19] An effective response force was assembled by the five-person crews three minutes faster than the four-person crews. According to study deployment protocal, the two- and three-person crews were unable to assemble enough personnel to meet this standard.

Occupant Rescue:

Three different "standard" fires (slow-, medium-, and fast-growth rate) were simulated using the Fire Dynamics Simulator (FDS) model. The fires grew exponentially with time. The fire modeling simulations demonstrated that two-person, late arriving crews can face a fire that is twice the intensity of the fire faced by five-person, early arriving crews. The rescue scenario was based on a nonambulatory occupant in an upstairs bedroom with the bedroom door open.

Independent of fire size, there was a significant difference between the toxicity, expressed as fractional effective dose (FED), for occupants at the time of rescue depending on arrival times for all crew sizes. Occupants rescued by crews starting tasks two minutes earlier had lesser exposure to combustion products.

The fire modeling showed clearly that two-person crews cannot complete essential fireground tasks in time to rescue occupants without subjecting either firefighters or occupants to an increasingly hazardous atmosphere. Even for a slow-growth rate fire, the FED was approaching the level at which sensitive populations, such as children and the elderly are threatened. For a medium-growth rate fire with two-person crews, the FED was far above that threshold and approached the level affecting the median sensitivity in general population. For a fast-growth rate fire, the FED was well above the median level at which 50 % of the general population would be incapacitated. Larger crews responding to slow-growth rate fires can rescue most occupants prior to incapacitation along with early-arriving larger crews responding to medium-growth rate fires. The result for late-arriving (two minutes later than early-arriving) larger crews may result in a threat to sensitive populations for medium-growth rate fires." The new sentence is consistent with our previous description for two-person crews where we identify a threat to sensitive populations.. Statistical averages should not, however, mask the fact that there is no FED level so low that every occupant in every situation is safe.

---

[18] NFPA Standard 1710 - A.5.2.4.2.1 …Other occupancies and structures in the community that present greater hazards should be addressed by additional fire fighter functions and additional responding personnel on the initial full alarm assignment.

[19] NFPA 1710 Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments. Section 5.2.1 – Fire Suppression Capability and Section 5.2.2 Staffing.

Summary:

The results of these field experiments contribute significant knowledge to the fire service industry. First, the results establish a technical basis for the effectiveness of company crew size and arrival time in *NFPA 1710*. The results also provide valid measures of total effective response force assembly on scene for fireground operations, as well as the expected performance of time-to-critical-task measures for a low-hazard structure fires. Additionally, the results provide tenability measures associated with the occupant exposure rates to the range of fires considered by the fire model.

Future Research

In order to realize a significant reduction in firefighter line-of-duty death (LODD) and injury, fire service leaders must focus directly on resource allocation and the deployment of resources, both contributing factors to LODD and injury. Future research should use similar methods to evaluate firefighter resource deployment to fires in medium- and high-hazard structures, including multiple-family residences and commercial properties. Additionally, resource deployment to multiple-casualty disasters or terrorism events should be studied to provide insight into levels of risks specific to individual communities and to recommend resource deployment proportionate to such risk. Future studies should continue to investigate the effects of resource deployment on the safety of both firefighters and the civilian population to better inform public policy.

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A project of this magnitude extends significantly beyond the capabilities and expertise of the report authors. The following individuals were instrumental in the success of the experiments:

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APPENDIX A: Laboratory Experiments

The fire suppression and resource deployment experiments consisted of four distinct parts: laboratory experiments, time-to-task experiments, room and contents experiments and fire modeling. The purpose of the laboratory experiments was to assure a fire in the field experiments that would consistently meet *NFPA 1403* requirements for live fire training exercises. The laboratory experiments enabled investigators to characterize the burning behavior of the wood pallets as a function of:

- number of pallets and the subsequent peak heat release rate
- compartment effects on burning of wood pallets
- effect of window ventilation on the fire
- effect on fire growth rate of the loading configuration of excelsior (slender wood shavings typically used as packing material)

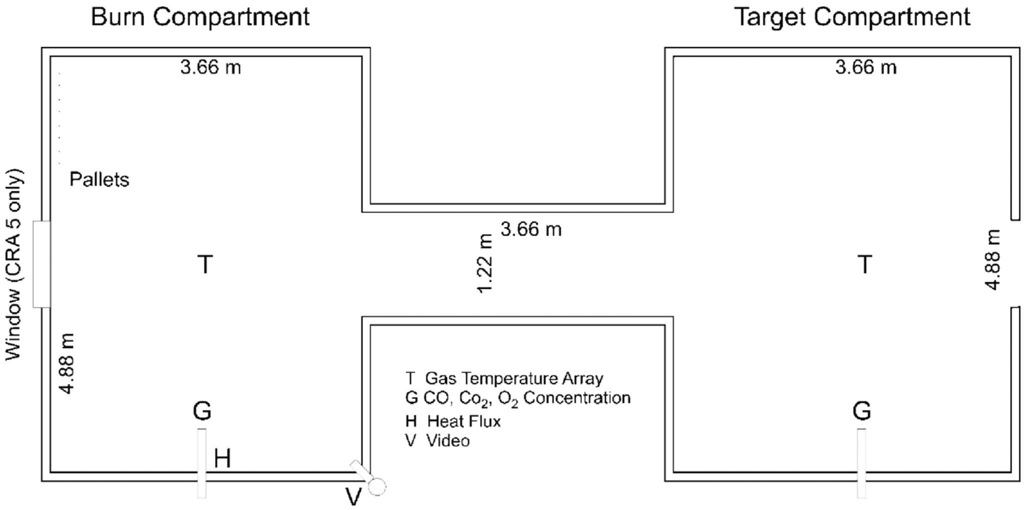


Figure A-1. Compartment Configuration and Instrumentation for Pallet Tests

Design and Construction

Figure A-1 shows the experimental configuration for the compartment pallet burns. Two identically sized compartments (3.66 m x 4.88 m x 2.44 m) were connected by a hallway (4 m x 1 m x 2.4 m). At each end of the hallway, a single door connected the hallway to each of the compartments. In the burn compartment, a single window (3 m x 2 m) was covered with noncombustible board that was opened for some experiments and closed for others. At the end of test, it was opened to extinguish the remaining burning material and to remove any debris prior to the next test. In the second compartment, a single doorway connected the compartment to the rest of the test laboratory. It was kept open throughout the tests allowing the exhaust to flow into the main collection hood for measurement of heat release rate.

The structure was constructed of two layer of gypsum wallboard over steel studs. The floor of the structure was lined with two layers of gypsum wallboard directly over the concrete floor of the test facility. In the burn compartment, an additional lining of cement board was placed over the gypsum walls and ceiling surfaces near the fire source to minimize fire damage to the structure after multiple fire experiments. A doorway 0.91 m wide by 1.92 m tall connected the burn compartment to the hallway and an opening 1 m by 2 m connected the hallway to the target compartment. Ceiling height was 2.41 m throughout the structure, except for the slight variation in the burn room.

Fuel Source

The fuel source for all of the tests was recycled hardwood pallets constructed of several lengths of hardwood boards nominally 83 mm wide by 12.7 mm thick. Lengths of the individual boards ranged from nominally 1 m to 1.3 m. The finished size of a single pallet was approximately 1 m by 1.3 m by 0.11 m. **Figure A-2** shows the fuel source for one of the tests including six stacked pallets and excelsior ignition source. For an ignition source, excelsior was placed within the pallets, with the amount and location depending on the ignition scenario. Figure A-3 shows the pallets prior to a slow and a fast ignition scenario fire. Table A-1 details the total mass of pallets and excelsior for each of the free burn and compartment tests.

Experimental Conditions

The experiments were conducted in two series. In the first series, heat release measurements were made under free burn conditions beneath a 6 m by 6 m hood used to collect combustion gases and provide the heat release rate (HRR) measurement. A second series of tests was conducted with the fire in a compartmented structure to assess environmental conditions within the structure during the fires and determine the effect of the compartment enclosure on the fire growth. Table A-1 presents a summary of the tests conducted.

Figure A-2. Pallets and Excelsior Ignition Source Used as a Fuel Source

Table A-1. Tests Conducted and Ambient Conditions at Beginning of Each Test

Test	Test Type	Number of Pallets	Ignition Scenario	Total Pallet Mass (kg)	Excelsior Mass (kg)
PAL 1	Free burn	4	Fast	79.3	8.1
PAL 2	Free burn	6	Fast	118.8	15.1
PAL 3	Free burn	8	Fast	146.7	16.2
PAL 4	Free burn	4	Slow	51.0	1.65
PAL 5	Free burn	6	Slow	160.3	0.85
CRA 1	Compartment	6	Slow	114.0	0.83
CRA 2	Compartment	4	Slow	69.7	
CRA 3	Compartment	4	Fast	71.1	0.8
CRA 4	Compartment	4	Slow	73.9	0.83
CRA 5	Compartment	4	Slow	73.8	0.85

Notes: PAL stands for "pallet" and CRA ("Community Risk Assessment") is the designator for the configuration of pallets burned in the compartment. Efforts were made to use the same amount of excelsior mass for CRA 2 (~0.8 kg), but the value was not measured.

Figure A-3. Fuel and Excelsior Source for Slow (top) and Fast (bottom) Ignition Scenarios

Measurements Conducted

Heat release rate (HRR) was measured in all tests. HRR measurements were conducted under the 3 m by 3 m calorimeter at the NIST Large Fire Research Laboratory. The HRR measurement was based on the oxygen consumption calorimetry principle first proposed by Thornton (Thornton 1917) and developed further by Huggett (Huggett 1980) and Parker (Parker 1984). This method assumes that a known amount of heat is released for each gram of oxygen consumed by a fire. The measurement of exhaust flow velocity and gas volume fractions (O_2, CO_2 and CO) were used to determine the HRR based on the formulation derived by Parker (Parker 1984) and Janssens (Janssens 1981). The combined expanded relative uncertainty of the HRR measurements was estimated at ± 14 %, based on a propagation of uncertainty analysis (Bryant 2004).

For the compartment fire tests, gas temperature measurements were made in the burn compartment and in the target compartment connected by a hallway to the burn compartment using 24 gauge bare-bead chromel-alumel (type K) thermocouples positioned in vertical array. Thermocouples were located at the center of each compartment at locations 0.03 m, 0.30 m, 0.61 m, 0.91 m, 1.22 m, 1.52 m, 1.83 m, and 2.13 m from the ceiling. The expanded uncertainty associated with a type K thermocouple is approximately ± 4.4° C. (Omega 2004)

Gas species were continuously monitored in the burn compartment at a level 0.91 m from the ceiling at a location centered on the side wall of the compartment, 0.91 m from the wall. Oxygen was measured using paramagnetic analyzers. Carbon monoxide and carbon dioxide were measured using non-dispersive infrared (NDIR) analyzers. All analyzers were calibrated with nitrogen and a known concentration of gas prior to each test for a zero and span concentration calibration. The expanded relative uncertainty of each of the span gas molar fractions is estimated to be ± 1 %.

Total heat flux was measured on the side wall of the enclosure at a location centered on the side wall, 0.61 m from the ceiling level. The heat flux gauges were 6.4 mm diameter Schmidt-Boelter type, water cooled gauges with embedded type-K thermocouples (see Figure A-4). The manufacturer reports a ± 3 % expanded uncertainty in the response calibration (the slope in $kW/m^2/mV$). Calibrations at the NIST facility have varied within an additional ± 3 % of manufacturer's calibration. For this study, an uncertainty of ± 6 % is estimated.

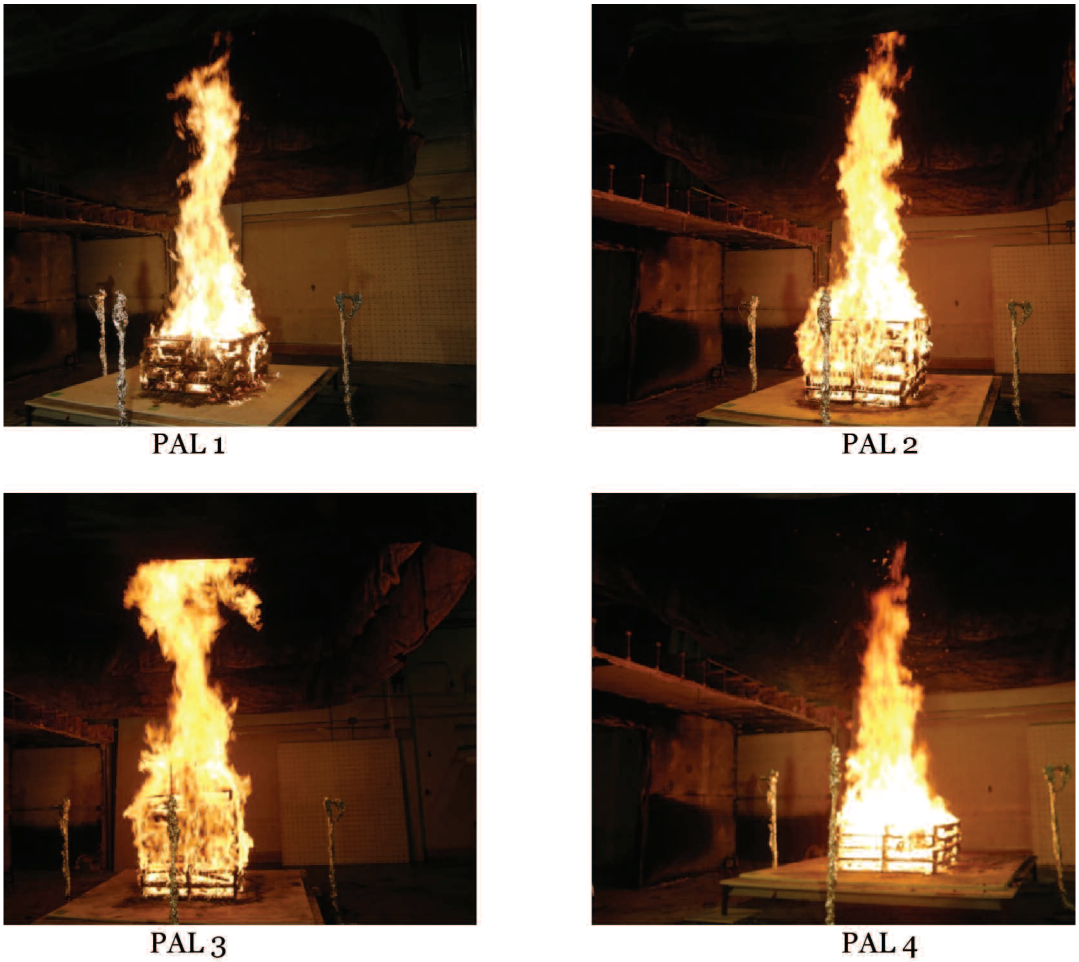
Figure A-4: Heat Flux Gauge with Radiation Shielding

Test	Test Type	Number of Pallets	Ignition Scenario	Peak HRR (kW)	Time to Peak HRR (s)
PAL 1	Free burn	4	Fast	2144	205
PAL 2	Free burn	6	Fast	2961	320
PAL 3	Free burn	8	Fast	3551	301
PAL 4	Free burn	4	Slow	1889	385
PAL 5	Free burn	6	Slow	2410	986
CRA 1	Compartment	6	Slow	1705	1102
CRA 2	Compartment	4	Slow	1583	649
CRA 3	Compartment	4	Fast	1959	159
CRA 4	Compartment	4	Slow	1620	775
CRA 5	Compartment	4	Slow	1390	927

Table A-2. Peak Heat Release Rate During Several Pallet Tests in Free-burn and in a Compartment

Results

Table A-2 shows the peak HRR and time to peak HRR for the free burn tests and for the compartment tests. Figure A-5 includes images from the free burn experiments near the time of peak HRR for each of the experiments. Figure A-6 illustrates the progression of the fire from the exit doorway looking down the hallway to the burn compartment for one of the tests. Figure A-7 to Figure A-10 present graphs of the heat release rate for all of the tests. Figure A-11 through Figure A-15 shows the gas temperature, major gas species concentrations, and heat flux in the burn compartment and target compartment in the five compartment tests.


PAL 1

PAL 2

PAL 3

PAL 4

Figure A-5. Free-Burn Experiments Near Time of Peak Burning

Figure A-6. Example Fire Progression from Test CRA 1

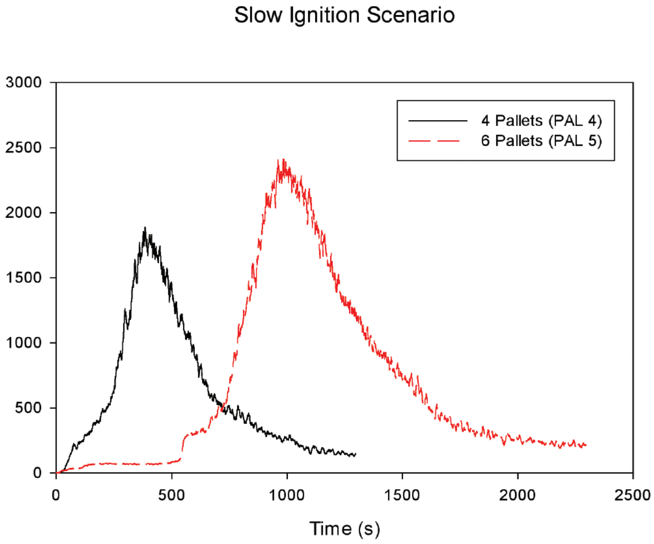


Figure A-7. HRR, Slow Ignition, Free Burn Scenario

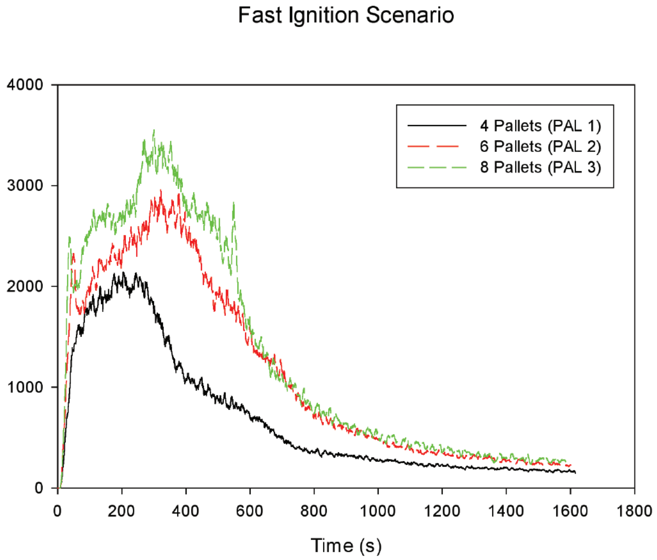


Figure A-8. HRR, Fast Igntion, Free Burn Scenario

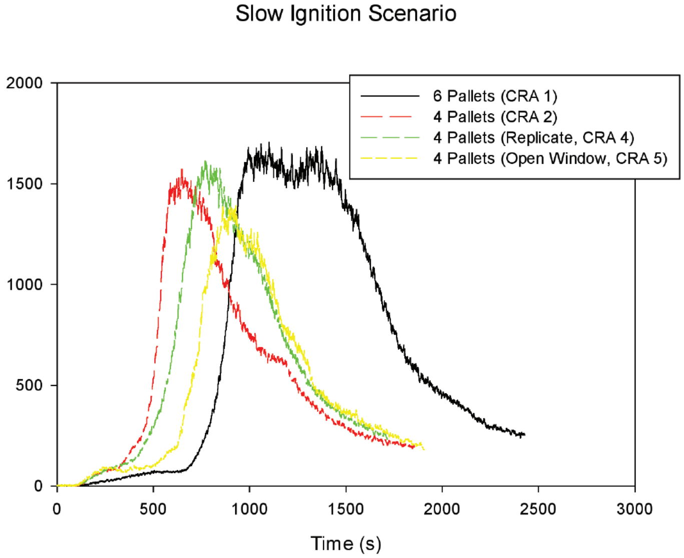


Figure A-9. HRR, Slow Ignition, Compartment Test

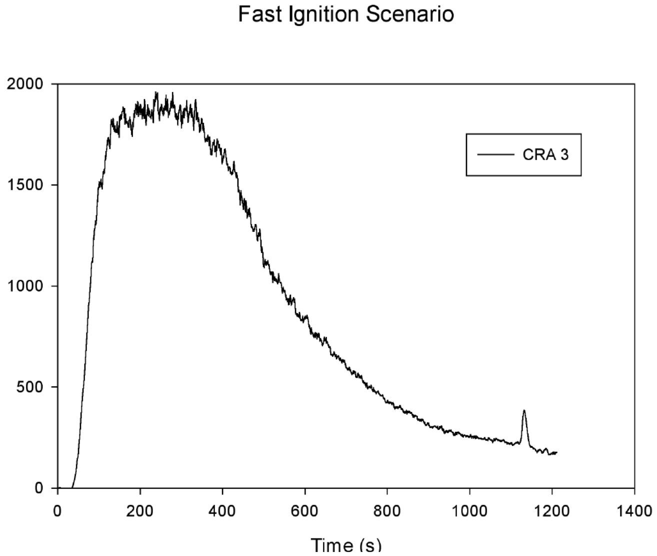
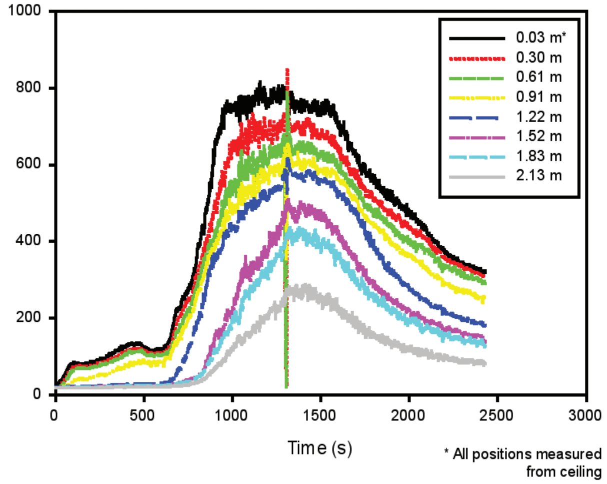
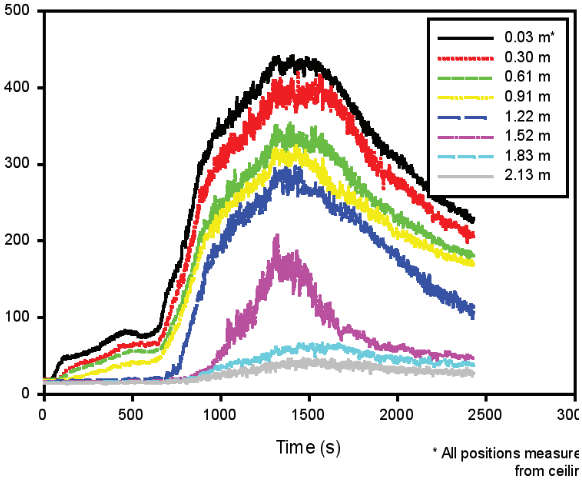


Figure A-10. HRR, Fast Ignition, Compartment Test

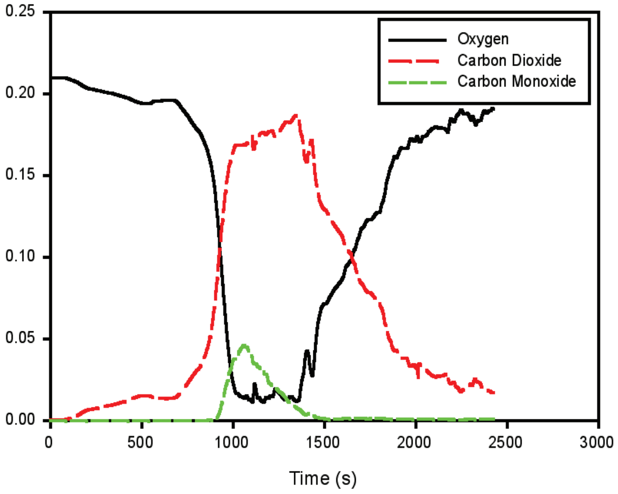
6 Pallets, Slow Ignition Scenario, Burn Room



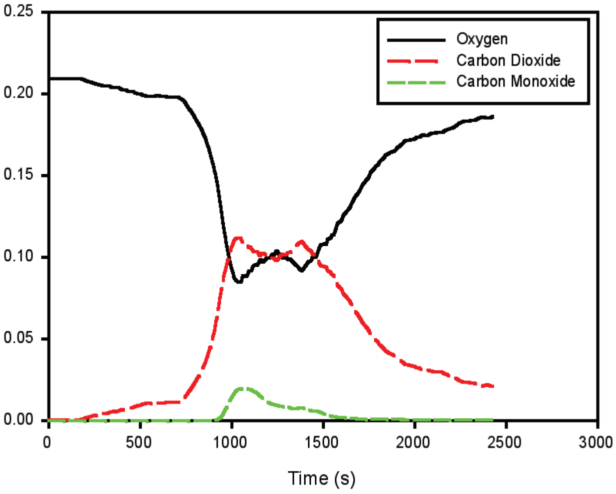
6 Pallets, Slow Ignition Scenario, Target Room



6 Pallets, Slow Ignition Scenario, Burn Room



6 Pallets, Slow Ignition Scenario, Target Room



6 Pallets, Slow Ignition Scenario, Burn Room

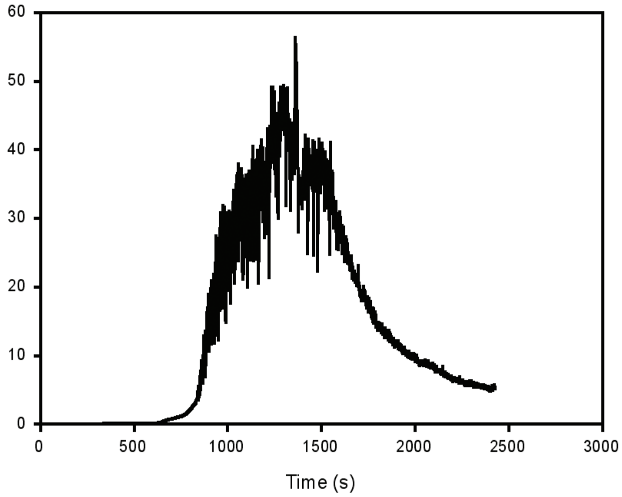


Figure A-11. Temperature, Gas Concentration, and Heat Flux During Test CRA 1, 6 Pallets, Slow Ignition Scenario

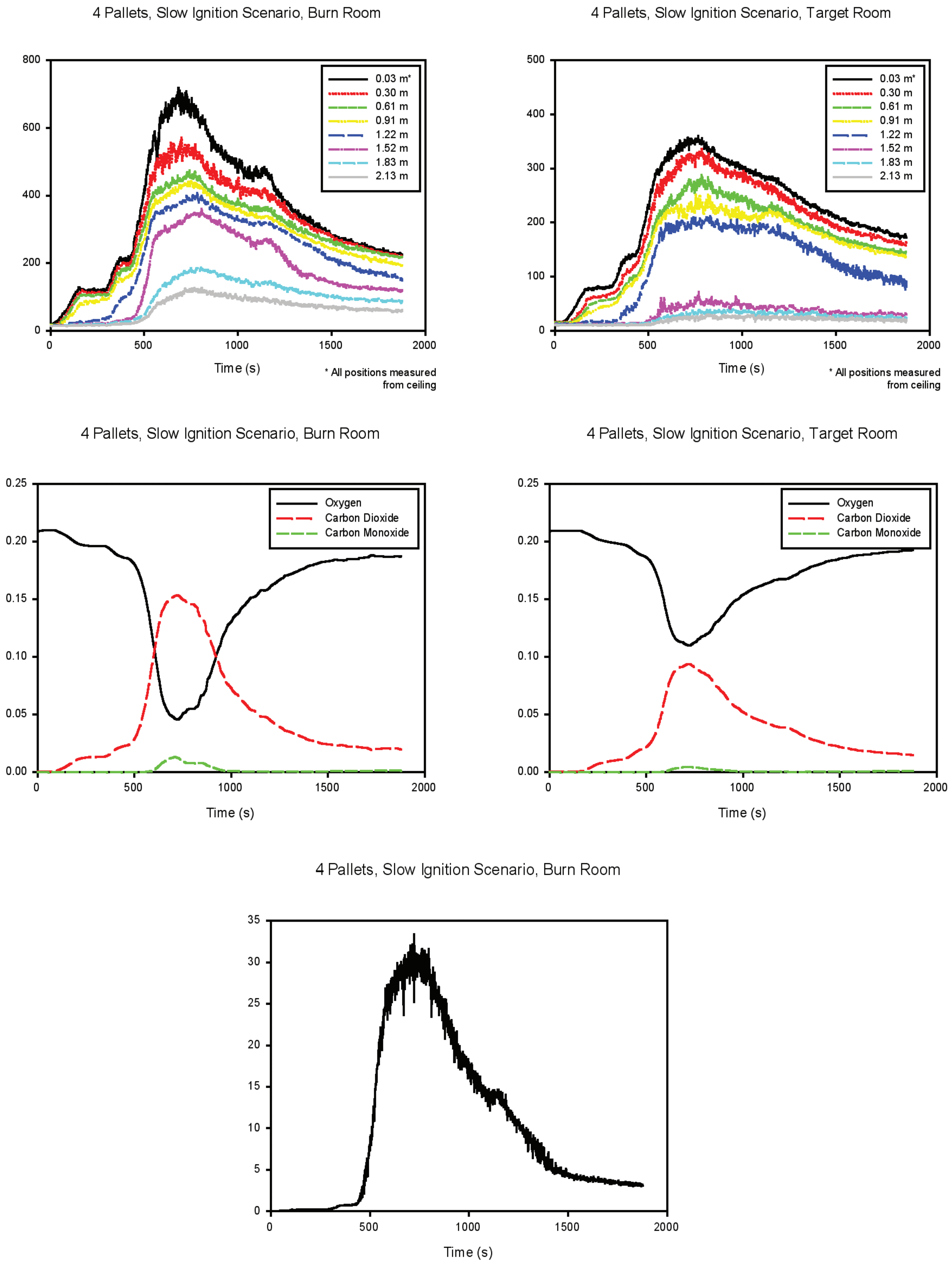
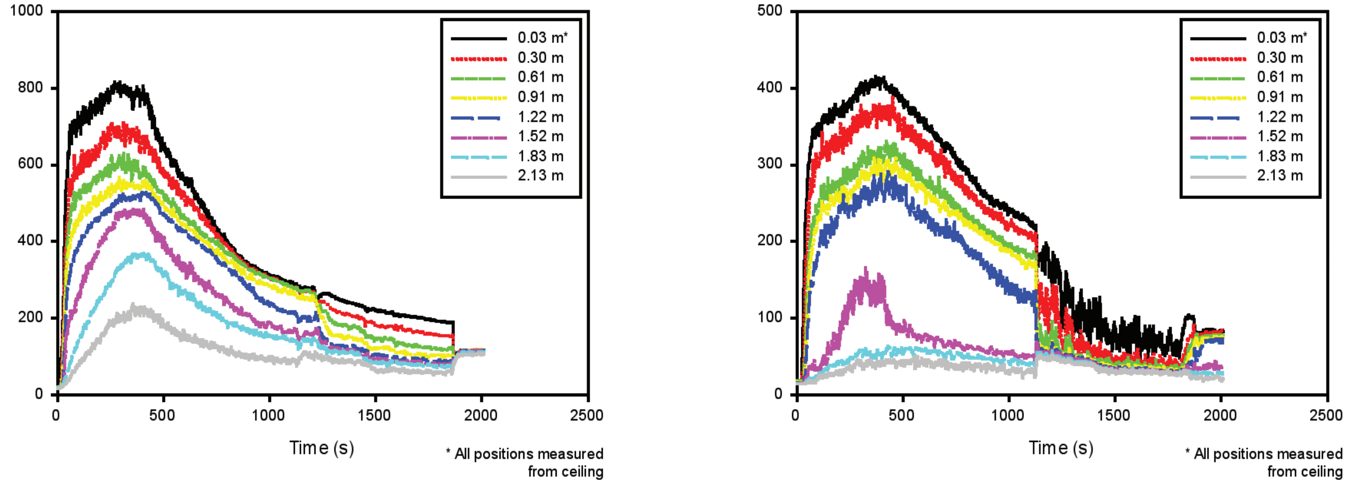
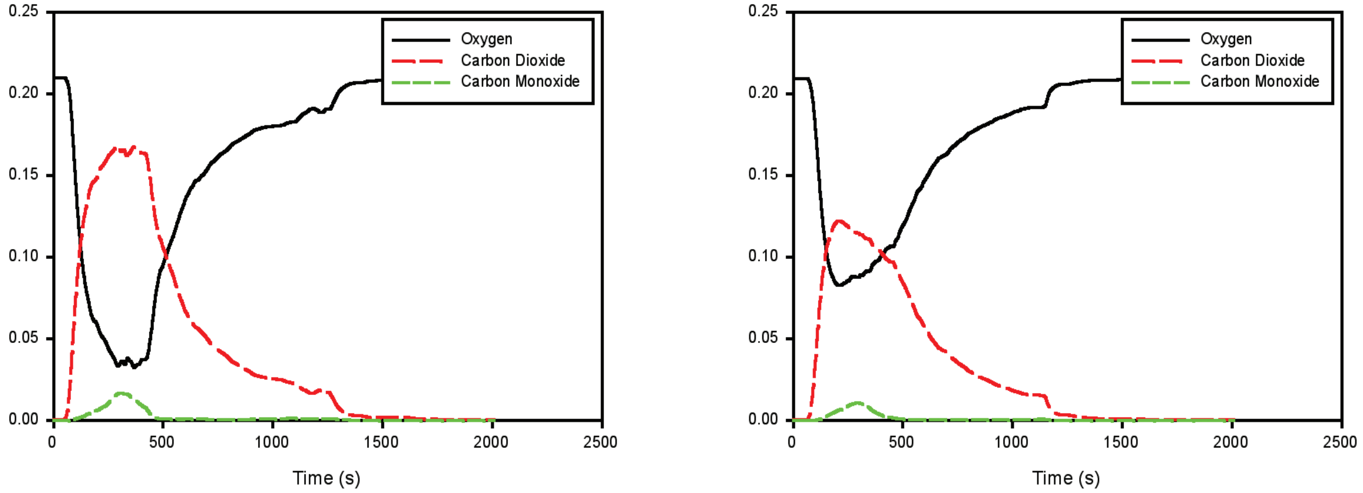


Figure A-12. Temperature, Gas Concentration, and Heat Flux During Test CRA 2, 4 Pallets, Slow Ignition Scenario



4 Pallets, Fast Ignition Scenario, Burn Room

4 Pallets, Fast Ignition Scenario, Target Room



4 Pallets, Fast Ignition Scenario, Burn Room

4 Pallets, Fast Ignition Scenario, Target Room

4 Pallets, Fast Ignition Scenario, Burn Room

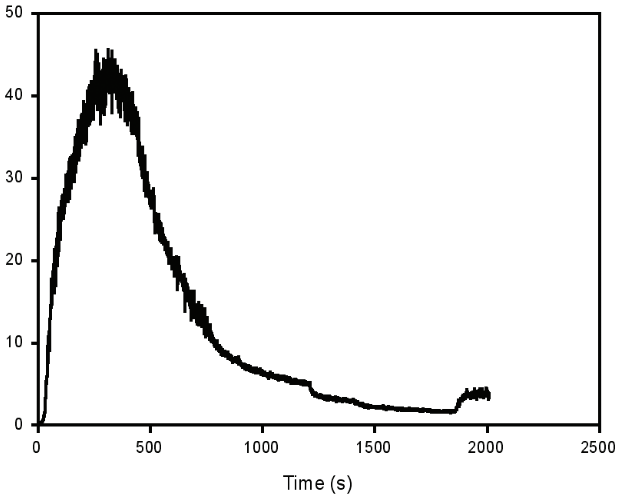
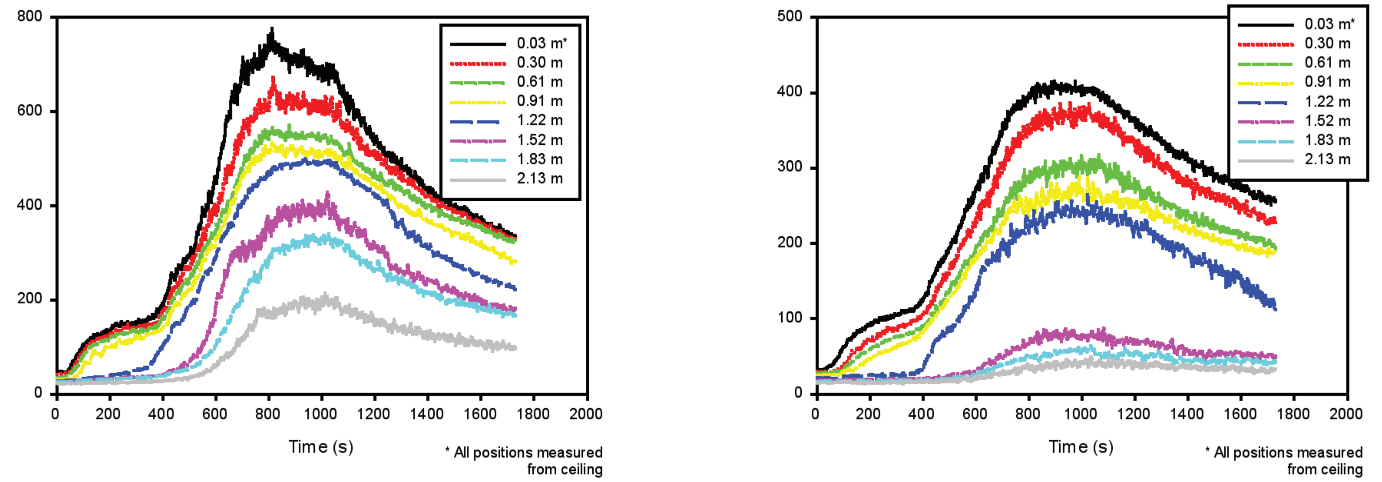


Figure A-13. Temperature, Gas Concentration, and Heat Flux During Test CRA 3, 4 Pallets, Fast Ignition Scenario

4 Pallets, Slow Ignition Scenario, Burn Room
(Replicate)

4 Pallets, Slow Ignition Scenario, Target Room
(Replicate)

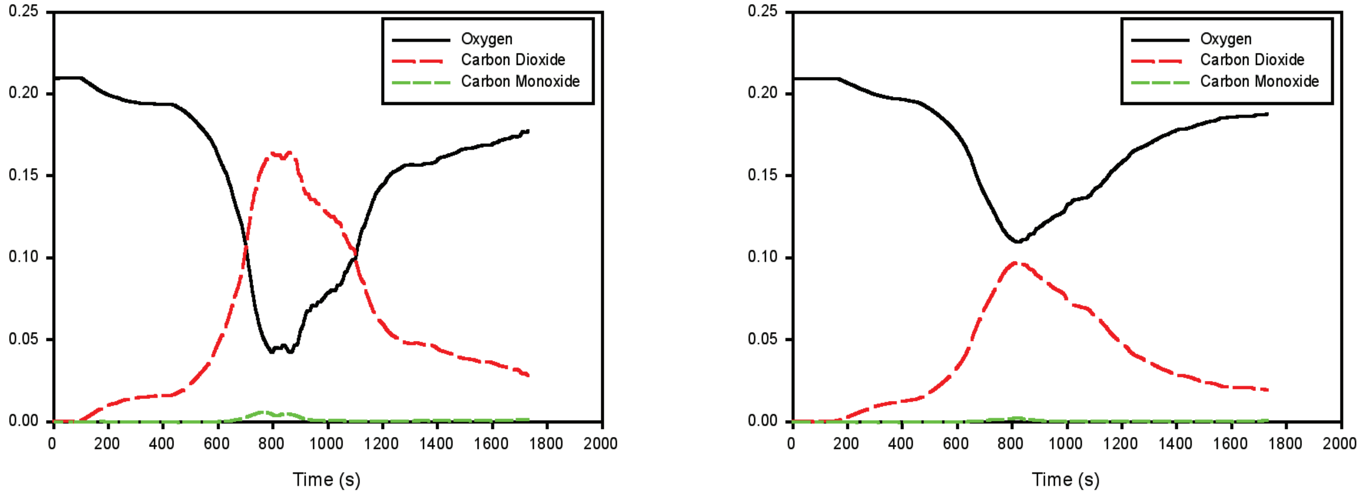


* All positions measured from ceiling

* All positions measured from ceiling

4 Pallets, Slow Ignition Scenario, Burn Room
(Replicate)

4 Pallets, Slow Ignition Scenario, Target Room
(Replicate)



4 Pallets, Slow Ignition Scenario, Burn Room
(Replicate)

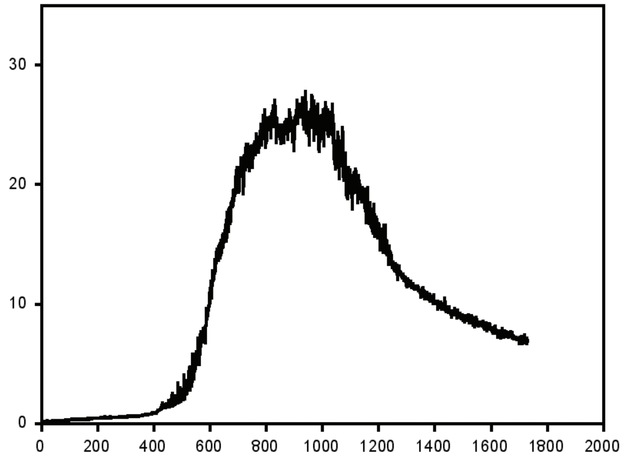


Figure A-14. Temperature, Gas Concentration, and Heat Flux During Test CRA 4, 4 Pallets, Slow Ignition Scenario (Replicate)

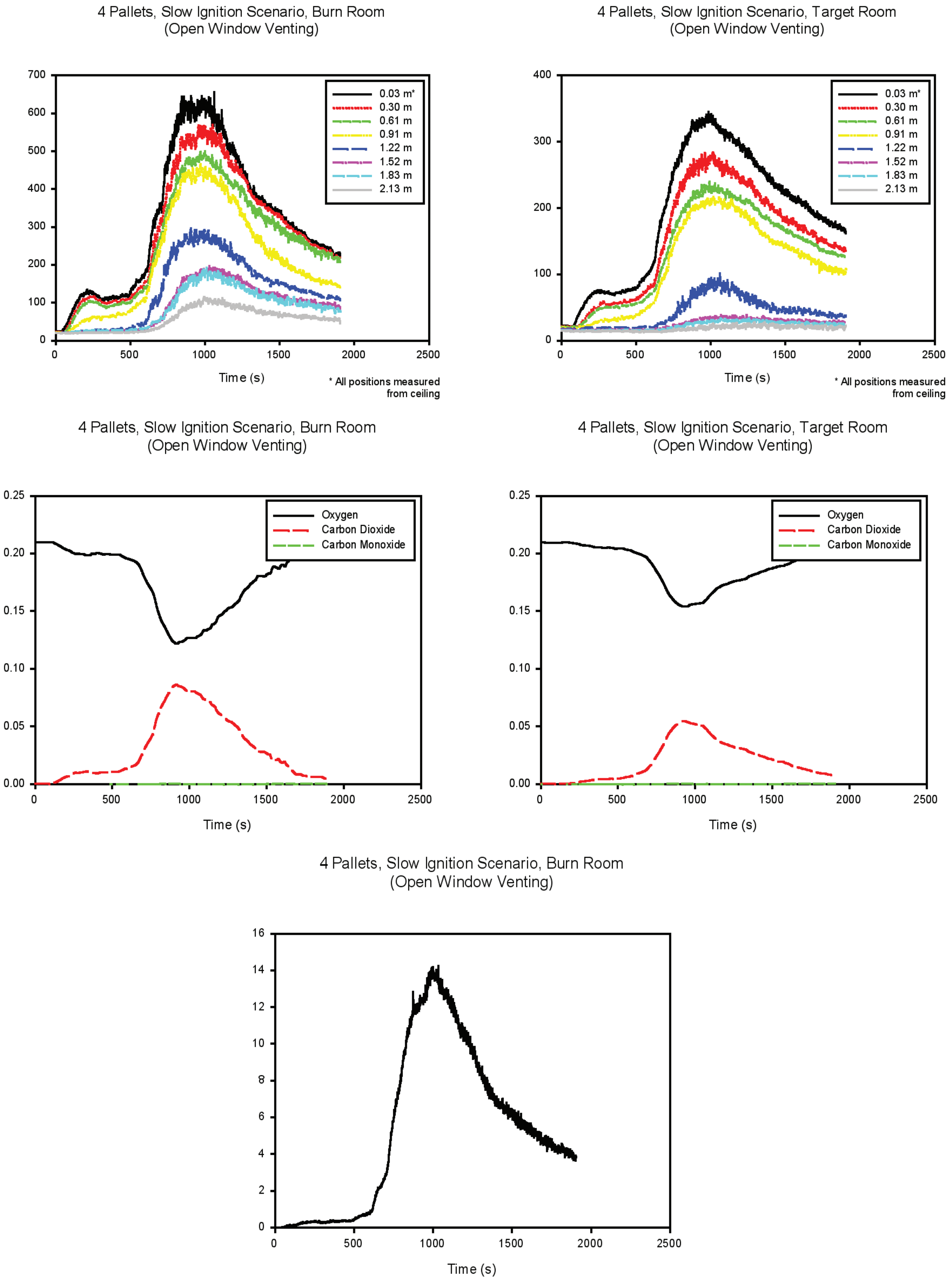
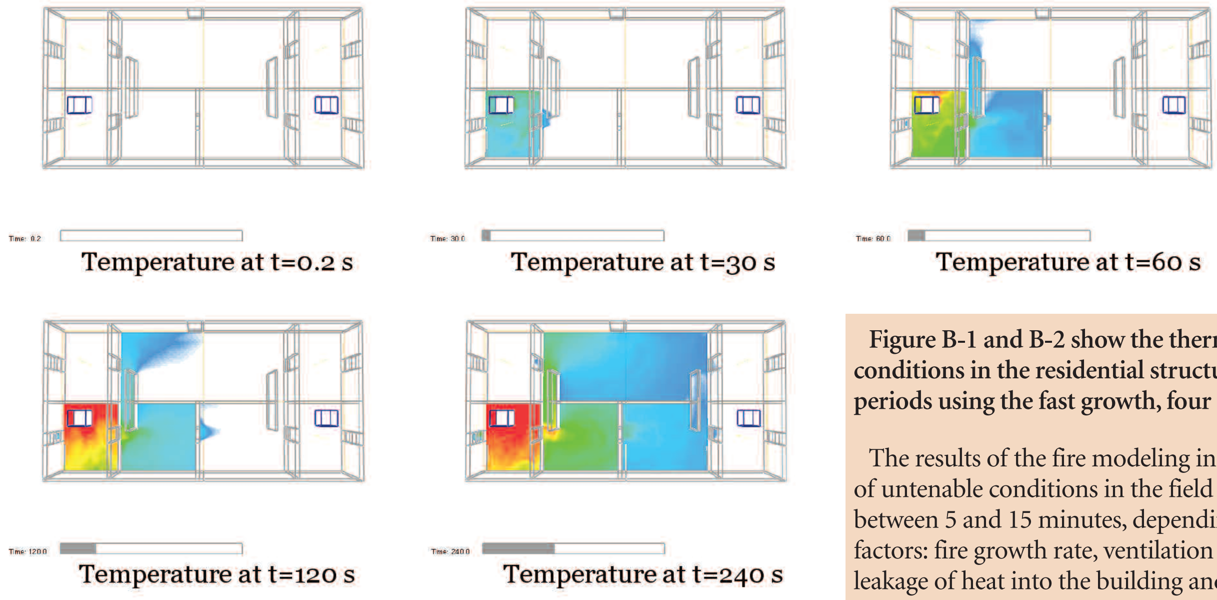


Figure A-15. Temperature, Gas Concentration, and Heat Flux During Test CRA 5, 4 Pallets, Slow Ignition Scenario (Open Window Venting)

APPENDIX B: Designing Fuel Packages for Field Experiments

Based upon the results of the laboratory experiments, the project team determined that four pallets would provide both a realistic fire scenario, as well as a repeatable and well-characterized fuel source. Varying the placement and quantity of excelsior provided significant variance in the rate of fire growth. Prior to finalization of the fuel package and construction specifications, modeling was used to ensure that the combination of fuel and residential geometry would result in untenable conditions throughout the structure without subjecting the firefighters to unsafe testing conditions. Therefore, CFAST (the consolidated fire and smoke transport model (Jones 2000)) and FDS (fire dynamics simulator model (McGrattan 2006)) were used to predict the temperatures and toxic species within the structure as a function of the experimentally determined heat release rates. The results summarized below confirmed that the building geometry and fuel package produced adequate variation in tenability conditions in the residential structure and ensured that the room of origin would not reach flashover conditions (a key provision of *NFPA 1403*). Meeting these conditions provided the foundation for experiments to meet the two primary objectives of fire department response: preservation of life and property.



Temperature at t=0.2 s

Temperature at t=30 s

Temperature at t=60 s

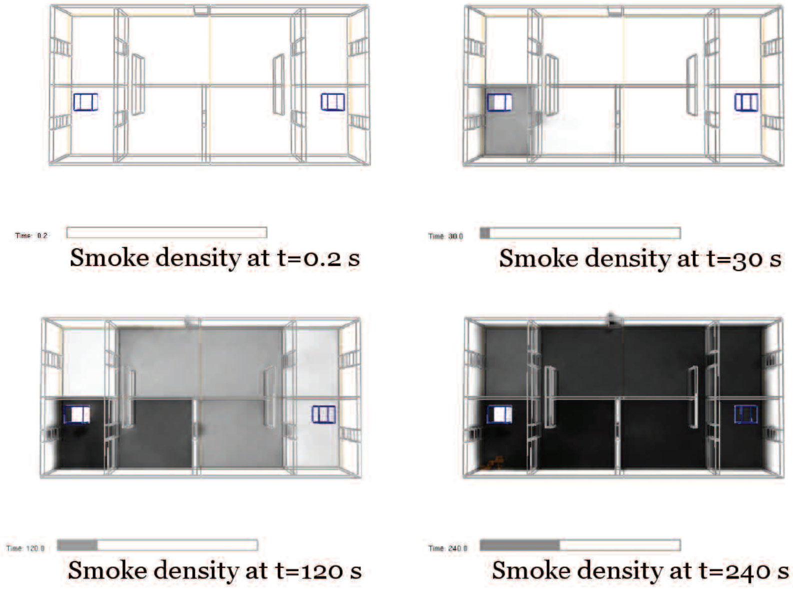
Temperature at t=120 s

Temperature at t=240 s

Figure B-1: Time-dependent temperature contours in field structure with fast growth fire

Figure B-1 and B-2 show the thermal and smoke conditions in the residential structure at different time periods using the fast growth, four pallet fuel package.

The results of the fire modeling indicated development of untenable conditions in the field experiments between 5 and 15 minutes, depending upon several factors: fire growth rate, ventilation conditions, the total leakage of heat into the building and through leakage paths, and firefighter intervention. This time frame allowed for differentiation of the effectiveness of various fire department deployment models.



Smoke density at t=0.2 s

Smoke density at t=30 s

Smoke density at t=60 s

Smoke density at t=120 s

Smoke density at t=240 s

Figure B-2: Time-dependent smoke density contours in field structure with fast growth fire

APPENDIX C: Temporary Burn Prop Construction and Instrumentation

Through the generosity of the Montgomery County (MD), an open space was provided to construct a temporary burn prop at the Montgomery County Fire and Rescue Training Facility in Rockville, MD. The area had ready access to water and electrical utilities. A licensed general contractor was retained, including a structural engineer for the design of critical ceiling members, and the burn prop was constructed over a several month period in late 2008.

The burn prop consisted of two 2,000 ft.^{2} (186 m^2) floors totaling 4,000 ft.^{2} (372 m^2). An exterior view of two sides of the burn prop is shown in Figure C-1.

Additional partitions were installed by NIST staff to create a floor plan representative of a two-story, 186 m^2 (2,000 ft.^{2}) single family residence. Note that the structure does not have a basement and includes no exposures. The overall dimensions are consistent with the general specifications of a typical low hazard residential structure that many fire departments respond to on a regular basis, as described in *NFPA 1710*.

Further details about typical single family home designs are not provided in the standard. Therefore, a floor plan representative of a typical single family home was created by the project team. Details and floor plan dimensions are shown in Figure C-2.

Figure C-1: View of two sides of the burn prop

The black lines indicate load-bearing reinforced concrete walls and red lines indicate the gypsum over steel stud partition walls. The ceiling height, not shown in Figure C-2, is 94 in. (2.4 m) throughout the entire structure except in the burn compartments, where the ceiling height is 93 in. (2.4 m). The purpose of the partition walls was to symmetrically divide the structure about the short axis in order to allow one side of the test structure to cool down and dry-out after a fire test with suppression while conducting experiments on the other side.

The concrete walls original to the burn prop were 8 in. (204 mm) thick steel reinforced poured concrete and the floors on the first level and second levels were 4 in. (102 mm) thick poured concrete. The support structure for the second floor and the roof consisted of corrugated metal pan welded to open web steel joists. The dimensions of the joists are shown in Figure C-3. The ceiling was constructed from ½ in. (13 mm) thick cement board fastened to the bottom chord of the steel joists. Partition walls were constructed from 5/8 in. (17 mm) thick gypsum panels attached to 20 gauge steel studs fastened to steel track, spaced 16 in. (407 mm) on center.

Additional construction was implemented in the burn compartments to address thermal loading and hose stream impingement concerns. Spray-on fireproofing was applied to the steel joists prior to fastening the ceiling, as shown in Figure C-4. The ceilings were constructed with three layers of ½ in. (13 mm) cement board, as opposed to one layer construction in the rest of the building. Each layer was fastened in a different direction so that seams of adjacent layers ran orthogonally. The difference in ceiling heights previously

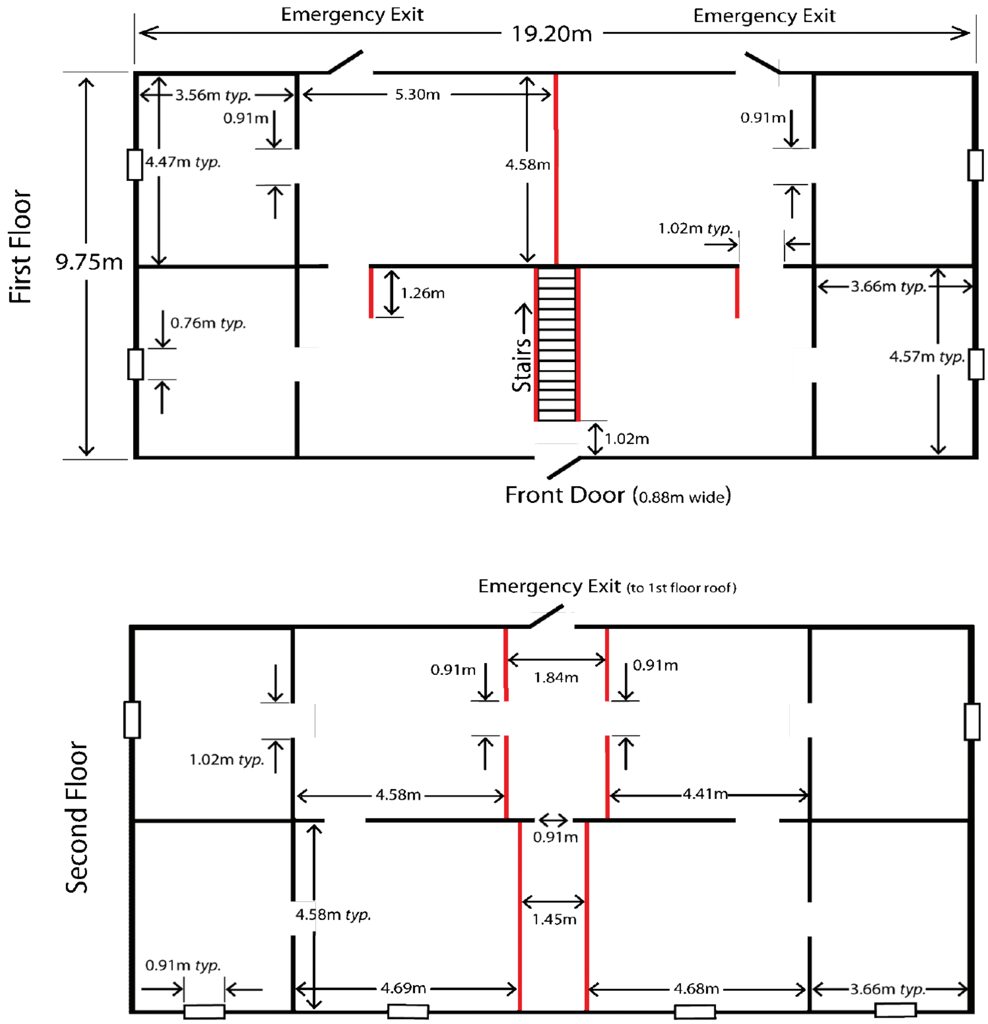


Figure C-2: Dimensions of the Burn Prop Floor Plan

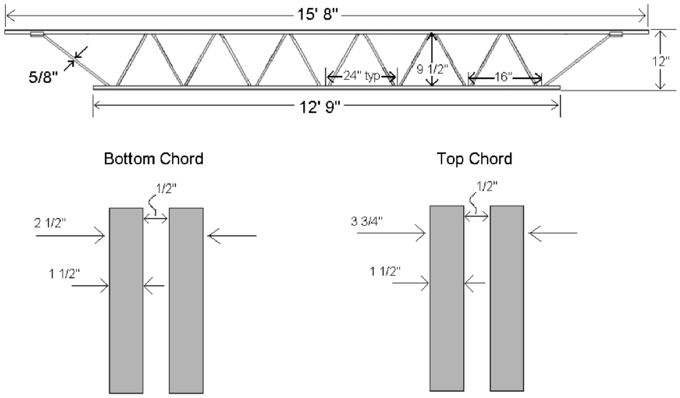


Figure C-3: Structural Steel Dimensions

mentioned is the result of the two additional sheets of cement board. The burn compartment walls were constructed from a single layer of ½ in. (13 mm) cement board over a single layer of 5/8 in. (16 mm) gypsum board, attached to 7/8 in. (22 mm) offset metal furring strips. Particular care was taken so that all ceiling and partition wall seams were filled with chemically-setting type joint compound to prevent leakage into the interstitial space between the ceiling and the floor above. After construction of the ceiling was complete, a dry-standpipe deluge system was installed with one head in each burn room to provide emergency suppression. During an experiment, a 2.5 in. (104 mm) ball valve fitting was attached and charged from a nearby hydrant. Figure C-5 was taken during the process of replacing "worn out" ceiling panels and shows the additional construction implemented in the burn room as well as the deluge sprinkler head.

Windows and exterior doors were constructed to be non-combustible. Windows were fabricated from 0.25 in. (10 mm) thick steel plate and the exterior doors were of prefabricated hollow-core steel design. The windows on the first floor were 30 in. (0.76 m) width x 36 in. (0.91 m) height and 36 in. (0.91 m) width x 40 in. (1.02 m) height on the second floor. Exterior doors were 35.8 in. (0.88 m) width x 80.5 in. (2.03 m) height. There were no doors attached to the doorways inside the structure. Figure C-6 shows the construction of the burn prop windows as well as the NFPA 1403-compliant latch mechanism. Figure C-7 is a picture of the interior of the burn prop taken just outside the burn compartment, showing the construction of the ceiling, interior doorway construction, gypsum wing wall and the joint compound used to seal seams in the ceiling and walls.

Instrumentation

After construction, the instrumentation to measure the propagation of products of combustion was installed throughout the burn prop. The instrumentation plan was designed to measure gas temperature, gas concentrations, heat flux, visual obscuration, video, and time during the experiments. The data were recorded at intervals of 1 s on a computer based data acquisition system. A schematic plan view of the instrumentation arrangement is shown in Figure C-8.

Table C-1 gives the locations of all of the instruments. Measurements taken prior to the compartment fire experiments were length, wood moisture content, fuel mass and weather conditions (relative humidity, temperature, wind speed and direction). Gas temperatures were measured with two different constructs of type K (Chromel-Alumel) thermocouples. All thermocouples outside the burn compartments were fabricated from 30 gauge glass-wrapped thermocouple wire. Vertical arrays of three thermocouples were placed near the front door on the north side and south sides of the stairwell on the first floor. On the second floor, vertical arrays of eight thermocouples were placed near the center of each target room. Inside the burn compartments, seven 3.2 mm (0.125 in.) exposed junction thermocouples and 0.76 m (30 in.) SUPER OMEGACLAD XL® sheathed thermocouple probes were arranged in a floor-to-ceiling array. Figure C-9 shows the vertical array in the burn

Figure C-4: Fireproofing added to structural steel

Figure C-5: Additional construction of burn room walls and ceiling and deluge sprinkler head.

Figure C-6: Window & Latch Construction

Figure C-7: Interior View of Burn Prop

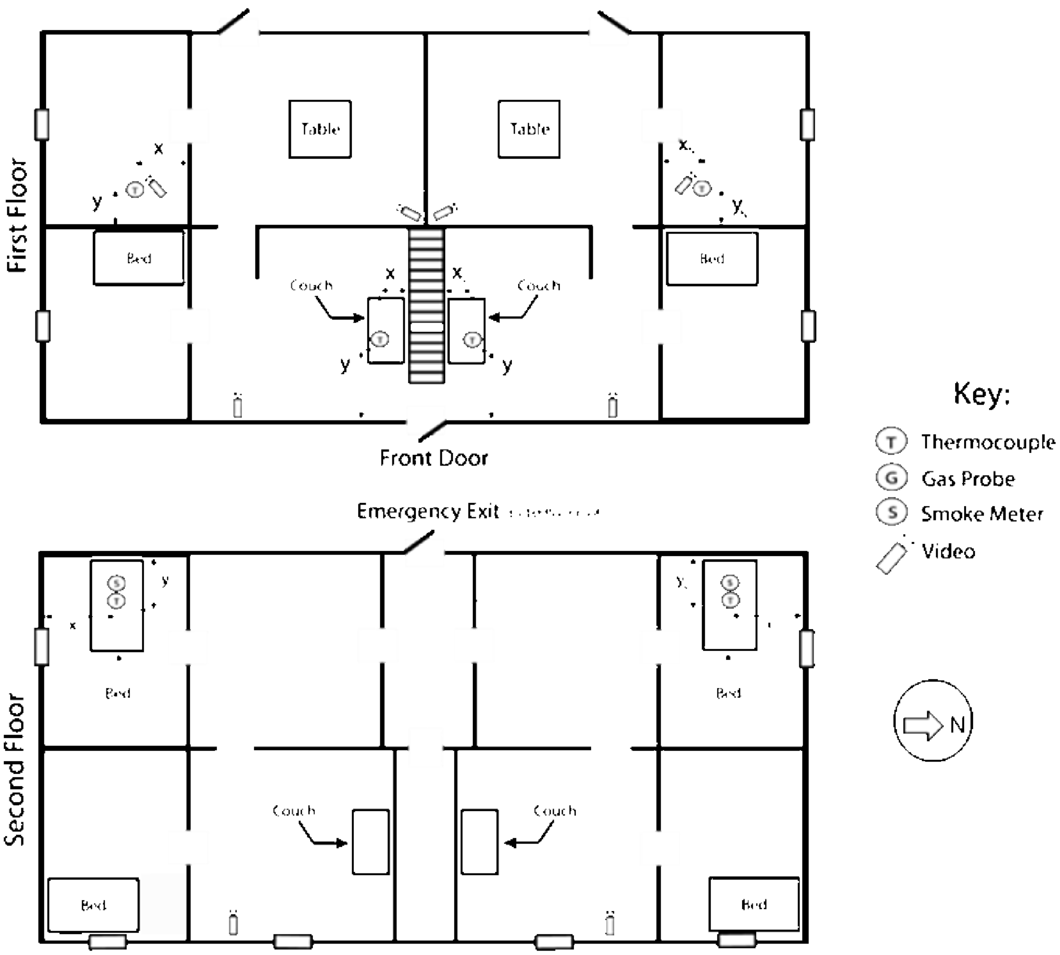


Figure C-8: Instrumentation & Furniture Prop Layout

compartment. Type K thermocouple probes were chosen because of their ability to withstand high temperature, moisture and physical abuse resulting from physical contact with hose streams and firefighters. To protect the extension wire and connectors from the effects of heat and water, through-holes were drilled in the burn compartment walls and the sheaths were passed through from the adjacent compartment. To prevent leakage through the holes, all void spaces were tightly packed with mineral wool. Inside the burn compartment the end of each probe was passed through an angle iron stand, and fastened to the floor and ceiling to provide additional protection from physical contact with firefighters and to ensure that the measurement location remained fixed throughout the experiments. In consideration of the risk associated with heating the open web steel joists, additional thermocouples were placed above each burn compartment to monitor the temperature of the interstitial space.

Table C-1: Detailed locations of instruments within respective rooms

Floor	Instrument	X_S [m]	Y_S [m]	Z_S [m]	X_N [m]	Y_N [m]	Z_N [m]	X_C [m]	Y_C [m]	Z_C [m]
1	**Thermocouple**	0.76	0.51	0.3, 0.61, 0.91, 1.22, 1.52, 1.83, 2.13	0.76	0.51	0.3, 0.61, 0.91, 1.22, 1.52, 1.83, 2.13	Find	Find	0.91, 1.52, 2.41
	HF Gauge 1		N/A		0.91	0.91	0.17			
	HF Gauge 2				0.5	0.66	1			
2	**Thermocouple**	1.83	0.91	0.3, 0.61, 0.91, 1.22, 1.52, 1.83, 2.13, 2.41	1.83	0.91	0.3, 0.61, 0.91, 1.22, 1.52, 1.83, 2.13, 2.41		N/A	
	Smoke Meter	1.7	0.49	1.52	1.64	0.43	1.5			
	Gas Probe	1.83	0.91	1.7	1.83	0.91	1.52			

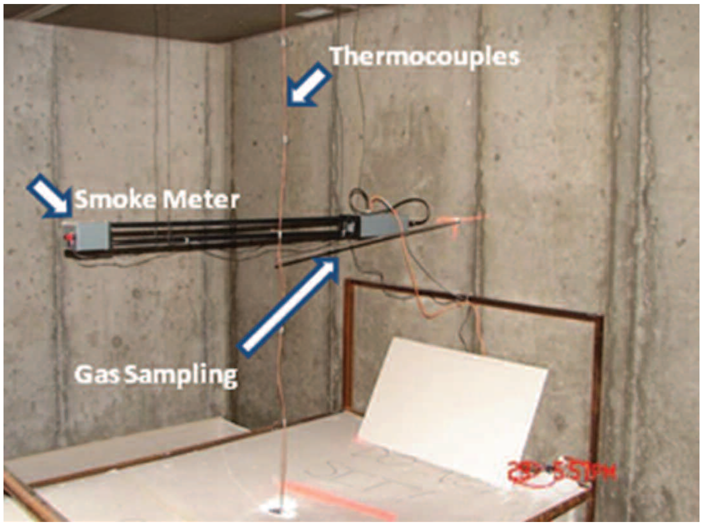


Figure C-9: Burn Room Thermocouple Array Figure C-10: Target Room Instrument Cluster

Gas concentrations were sampled at the same location in each target room. Both gas probes were plumbed to the same analyzer and isolated using a switch valve; gas was only sampled at one location during any given test. The gas sampling points were located in the center of the West wall (C Side) of both rooms, 1.5 m (5 ft.) above the floor. The sampling tubes were connected to a diaphragm pump which pulled the gas samples through stainless steel probes into a sample conditioning system designed to eliminate moisture in the gas sample. The dry gas sample was then piped to the gas analyzer setup. In all of the experiments, oxygen was measured using a paramagnetic analyzer and carbon monoxide and carbon dioxide were measured using a non-dispersive infrared (NDIR) analyzer. One floor-to-ceiling thermocouple array was also co-located with each sample port inlet.

Schmidt-Boelter heat flux gauges were placed in the North burn room. One gauge was located 1.0 m (3.3 ft.) above the floor and was oriented towards the fire origin (waste basket). This heat flux gauge was placed to characterize the radiative heat flux at the face piece level that would be experienced by a firefighter inside the room. A second flux gauge was placed on the floor in order to characterize the radiative heat flux from the upper layer and to make an estimate of how close the room was to flashing over with respect to time from ignition (using the common criteria of flashover occurring at ~20kW/m^2 at the floor level). The heat flux gauges were co-located with the thermocouple probe array.

Figure C-11: Non-combustible “Prop” Table

All length measurements were made using a steel measuring tape. Wood moisture content measurements were taken using a non-insulated-pin type wood moisture meter. Fuel mass was measured prior to each experiment using a platform-style heavy duty industrial scale. Mass was not measured after each experiment because of the absorption of fire suppression water. Publicly accessible Davis Vantage Pro2 weather instrumentation (available via http://www.wunderground.com) located approximately two miles from the experimentation site was used to collect weather data in five minute intervals for the each day that the experiments were conducted. Figure C-10 is a photograph of the West wall of the North target room, showing the thermocouple array, the smoke obscuration meter, and a gas sampling probe used during the phase two experiments. The layout is identical to that in the South target room.

Non-combustible “prop” furniture was fabricated from angle iron stock and gypsum wallboard. The purpose of the furniture was twofold. The furniture was placed inside the burn prop to simulate realistic obstacles which obscure the search paths and hose stream advancement. The second use for the furniture was so that measurement instrumentation could be strategically placed within the frame of the furniture. This served to protect instrumentation from physical damage as a result of contact with firefighters and their tools. Figure C-11 shows an example of a table placed outside the burn room.

All instruments were wired to a centralized data collection room, shown in Figure C-12, which was attached as a separate space on one side of the building. This ensured physical separation for the data collection personnel from the effects of the fire, while minimizing the wire and tube lengths to the data logging equipment. Note that the roof of the instrument room was designed to serve as an additional means of escape for personnel from the second floor of the burn prop through a metal door. A railing was installed in order to minimize the fall risk in the event that the emergency exit was required.

Outside

Inside

Figure C-12: Instrumentation Room

Table C-2: Dimensions and Mass of Furniture for Room and Contents Tests

Furniture	Width [m]	Depth [m]	Height [m]	Mass [kg]	Material
Couch	1.8	0.8	0.9	58.1	See D-3
Dresser	1.8	0.5	0.6	72.3	Laminated Particle Board
Nightstand	0.5	0.6	0.61	22.7	Laminated Particle Board
Chair	0.5	0.7	0.6	9.2	Wood, Fabric, and Polyurethane Foam
	Back cushion = 0.1m, Bottom cushion = 0.07m				
Blanket	1.8	-	2.4	1.3	100 % Cotton
Body Pillow	0.5	-	1.4	1.3	100 % cotton cover, polyester fill
Trash Can	0.4	0.3	0.4	1.3	Polypropylene
Towel	0.8	-	1.4	0.4	100 % Cotton
Wallboard	1.2	0.003	2.4	9.0	MDF

Table C-3: Materials in Couch

Body:	Resinated dyed fiber (unknown material) 3 %
	PU foam pad 46%
	Waste fiber batting (unknown material) 26 %
	Polyester fiber batting 25 %
Cushions:	PU foam pad 86 %
	Polyester fiber batting 14 %

APPENDIX D: Data Collection and Company Protocols for Time-to-Task Tests

Time-to-Task Data Collection Chart

Date ______________ Start Time __________ End Time (all task complete) __________

Timer Name ____

Task	Start Time	Completion Time	Duration
Stop at Hydrant-- Wrap Hose			
Position Engine 1			
Conduct Size-up - 360° lap - Transmit report - establish command			
Engage Pump			
Position attack line (stop time – at front door)			
Establish 2-in-2-out			
Charge Hydrant – supply attack Engine			
Establish RIT			
Gain/Force Entry			
Advance Line (stop time –water on fire)			
Deploy Back up line (stop time at front door)			
Advance Back up line/protect stairwell (start time at front door – Stop at stairwell)			
Conduct Primary Search			
Ground Ladders in Place			
Horizontal Ventilation (ground)			
Horizontal Ventilation (2nd story)			
Control Utilities (interior)			
Control Utilities (exterior)			
Conduct Secondary Search			
Check for Fire Extension (walls)			
Check for Fire Extension (ceiling)			
Mechanical Ventilation			

Company Protocols: Crew Size of 2

(10 total personnel on scene)

PLUS 4 RIC – 1403 = total 14 needed

Tasks/Company	Engine 1/2	Truck 1/2	Engine 2/2	Battalion Chief/ Aide	Engine 3/2
Arrive on Scene				- Arrives - Assumes Command - Evaluates Resources - Establishes Command post - Evaluates exposure problems - Directs hose positioning - Coordinates Units - Transmits Progress reports - Changes strategy - Orders, records, and transmits results of primary and secondary searches - Declares fire under control	
- Arrive/ stop at hydrant					
- Position engine	Driver	-Arrive - 360º lap			
————————					
- Layout report					
- On-scene report					
- Conduct size-up – 360º lap – incident action plan – offensive – detail incident (situation report)	Officer -				
- Transmit size-up to responding units					
- Transfer command to chief					
Establish Supply line			-Dry Lay – 2nd engine takes hydrant		
- Hydrant-Drop line (wrap)	Driver/O				
- Position engine	Driver/O	Position Truck	- Charged hydrant		
- Pump engaged	Driver/O				
- 4" straight lay			– Supply attack engine		
- ----------------					
- Supply attack engine			Driver		
Position attack line	Officer – (Not interior—just front door)				
- Flake					
- Charge					
- Bleed					
- ----------------					
- Advance	Officer	Officer			
Establish - 2 in – 2 out					
(Initial RIT)		O/D			
Establish RIT					
(Dedicated)		O/D (performs all RIT duties)			

Tasks/Company	Engine 1/2	Truck 1/2	Engine 2/2	Battalion Chief/ Aide	Engine 3/2
Gain/ Force Entry		O/D			
Advance Line - scan search fire room - suppression	Officer (if officer commits then he must pass command)		Officer		
Deploy Back-up Line and protect stairwell					O/D
Complete Primary Search (in combo with Fire Attack) Search Fire Floor Search other Floors					O/D
Ventilation (vent for fire or vent for life) - Horizontal - Ventilation		Driver/Officer			
Ground Laddering – 2nd story windows, front and side, for firefighter means of egress and for vertical ventilation – 24'/28' and roof ladder in case of vertical vent.		Driver /Officer			
Control Utilities (Interior and exterior)					Driver/Officer
Conduct Secondary Search	Officer		Officer		
- Search Fire Floors					
- Search other Floors					
Check for Fire Extension					
Open ceiling walls near fire on fire floor	Officer		Officer		
Check floor above for fire extension					O/D
- wall breech					
- ceiling breech					
Mechanical Ventilation		Driver/Officer			

Company Protocols: Crew Size of 3

(14 total personnel on scene)

PLUS 4 RIC – 1403 = total 18 needed

Tasks/Company	Engine 1/3	Truck 1/3	Engine 2/3	Battalion Chief/ Aide	Engine 3/2
Arrive on Scene		-Arrive		- Arrives - Assumes Command - Evaluates Resources - Establishes Command post - Evaluates exposure problems - Directs hose positioning - Coordinates Units - Transmits Progress reports - Changes strategy - Orders, records, and transmits results of primary and secondary searches - Declares fire under control	
- Arrive/ stop at hydrant	Driver	- 360 degree lap			
- Position engine					
________________					
- Layout report					
- On-scene report					
- Conduct size-up – 360° lap – incident action plan – offensive – detail incident (situation report)	Officer -				
- Transmit size-up to responding units					
- Transfer command to chief					
Establish Supply line	Driver	Position Truck	Dry Lay – 2nd engine takes hydrant		
- Hydrant-Drop line (wrap)	Driver				
- Position engine	Driver		Charged hydrant –		
- Pump engaged			Supply attack engine		
- 4” straight lay					
- ----------------					
- Supply attack engine			Driver		
Position attack line	D/RB				
- Flake					
- Charge					
- Bleed					
- Advance					
Establish - 2 in – 2 out		O/RB			
(Initial RIT)					
Establish RIT			O/RB— advance by foot to get to point of entry – performs all RIT duties		
(Dedicated)					

Tasks/Company	Engine 1/3	Truck 1/3	Engine 2/3	Battalion Chief/ Aide	Engine 3/3
Gain/ Force Entry		O/RB			
Advance Line - scan search fire room - suppression	O/RB (if officer commits then he must pass command)				
Deploy Back-up Line and protect stairwell					O/RB
Complete Primary Search (in combo with Fire Attack) Search Fire Floor Search other Floors		O/ RB -			
Ventilation (vent for fire or vent for life) - Horizontal - Ventilation		Driver			Driver
Ground Laddering – 2nd story windows, front and side, for firefighter means of egress and for vertical ventilation – 24'/28' and roof ladder in case of vertical vent.		Driver			Driver
Control Utilities (Interior and exterior)		Driver (exterior) O/RB (Interior)			Driver (exterior)
Conduct Secondary Search - Search Fire Floors - Search other Floors					O/RB
Check for Fire Extension Open ceiling walls near fire on fire floor Check floor above for fire extension - wall breech - ceiling breech	O/RB	O/RB			
Mechanical Ventilation		Driver			Driver

Company Protocols: Crew Size of 4

Total on scene = 18

PLUS 4 RIC – 1403 = total 22 needed

Tasks/Company	Engine 1/4	Truck 1/4	Engine 2/4	Battalion Chief/ Aide	Engine 3/4
Arrive on Scene	Driver	-Arrive		- Arrives - Assumes Command - Evaluates Resources - Establishes Command post - Evaluates exposure problems - Directs hose positioning - Coordinates Units - Transmits Progress reports - Changes strategy - Orders, records, and transmits results of primary and secondary searches - Declares fire under control	
- Arrive/ stop at hydrant		- 360 degree lap			
- Position engine					
- Layout report					
- On-scene report					
- Conduct size-up – 360º lap – incident action plan – offensive – detail incident (situation report)	Officer -				
- Transmit size-up to responding units					
- Transfer command to chief					
Establish Supply line	Driver	Position Truck	-Dry Lay – 2nd engine takes hydrant		
- Hydrant-Drop line (wrap)	Driver				
- Position engine	Driver		Charged hydrant – Supply attack engine		
- Pump engaged					
- 4" straight lay			Driver		
- ----------------					
- Supply attack engine (1 3/4")					
Position attack line	RB/Nozzle				
- Flake	LB/Flake				
- Charge					
- Bleed	Both advance line for fire attack				
- Advance					
Establish - 2 in – 2 out		D/LB			
(Initial RIT)					
Establish RIT			O/LB/RB— advance by foot to point of entry – performs all RIT duties		
(Dedicated)					

Tasks/Company	Engine 1/4	Truck 1/4		Battalion Chief/ Aide	Engine 3/4
Gain/ Force Entry		O/RB			
Advance Line - scan search fire room - suppression	RB/LB Officer – not on line (if officer commits then he must pass command)				
Deploy Back-up Line and protect stairwell					O/RB
Complete Primary Search (in combo with Fire Attack) Search Fire Floor Search other Floors		Officer and RB -			
Ventilation - Horizontal - Ventilation		Driver and LB			
Ground Laddering – 2nd story windows, front and side, for firefighter means of egress and for vertical ventilation – 24’/28’ and roof ladder in case of vertical vent.		Driver /LB			
Control Utilities (Interior and exterior) Conduct Secondary Search - Search Fire Floors - Search other Floors		Driver/LB (control exterior) O/RB (control interior)			D/LB
Check for Fire Extension Open ceiling walls near fire on fire floor Check floor above for fire extension - wall breech - ceiling breech	O/RB	O/RB			
Mechanical Ventilation		D/LB			

Company Protocols: Crew Size of 5

D/O/LB/RB/CB Total on scene = 22

PLUS 4 RIC – 1403 = total 26 needed

Tasks/Company	Engine 1/5	Truck 1/5	Engine 2/5	Battalion Chief/ Aide	Engine 3/4
Arrive on Scene	Driver	-Arrive - 360 degree Size up.		- Arrives - Assumes Command - Evaluates Resources - Establishes Command post - Evaluates exposure problems - Directs hose positioning - Coordinates Units - Transmits Progress reports - Changes strategy - Orders, records, and transmits results of primary and secondary searches - Declares fire under control	
- Arrive/ stop at hydrant					
- Position engine					
- Layout report	Officer -				
- On-scene report					
- Locate Fire					
- Conduct size-up – 360° lap – incident action plan – offensive – detail incident (situation report)					
- Transmit size-up to responding units					
- Transfer command to chief					
Establish Supply line	Driver	Position Truck	-Dry Lay – 2nd engine takes hydrant		
- Hydrant-Drop line (wrap)	Driver				
- Position engine	Driver				
- Pump engaged			Charged hydrant – Supply attack engine		
- 4” straight lay					
- ----------------					
- Supply attack engine (1 3/4”)			Driver		
Position attack line	RB/Nozzle LB/Flake CB/ Control --------------- Advance line for fire attack ---------------- The Officer responsibility is to supervise hose stretch /monitor safety and continually survey the scene				
- Flake					
- Charge					
- Bleed					
- Advance					
Establish - 2 in – 2 out		D/LB			
(Initial RIT)					

Tasks/Company	Engine 1/5	Truck 1/5	Engine 2/5	Battalion Chief/ Aide	Engine 3/5
Establish RIT (Dedicated)			O/LB/RB—advance by foot to get to point of entry – performs all RIT duties		
Gain/ Force Entry		O/RB/CB			
Advance Line - scan search fire room - suppression	RB/LB/CB Officer – not on line (if officer commits then he must pass command)				
Insures first line flowing water— Deploy Back-up Line and protect stairwell (1 ¾”)					O/RB/CB
Complete Primary Search (in combo with Fire Attack) Search Fire Floor – Search other floors-		Officer and RB/CB			
Ventilation (vent for fire or vent for life) - Horizontal - Vertical		Driver and LB			
Ground Laddering – 2nd story windows, front and side, for firefighter means of egress and for vertical ventilation – 24’/28’ and roof ladder in case of vertical vent.		Driver /LB			
Control Utilities after search, force entry, venting and fire extinguished (Interior and exterior)		Driver/LB (control exterior) O/RB/CB (control interior)			
Conduct Secondary Search -Fire Floor -Primary and secondary search of entire floor above		D/LB			D/LB O/RB/CB
Check for Fire Extension Open ceiling walls near fire on fire floor Check floor above for fire extension wall breech ceiling breech-	O/RB				O/RB/CB
Mechanical Ventilation					

Appendix E: Statistical Analysis of Time to Task Test Data

Identifying Statistically Significant Differences in Crew Size and Stagger on a Number of Task Timings Using Regression Analyses of Times (Start, End and Duration) on Crew Size and Stagger

	Crew Size			Stagger	Crew Size	Stagger
Task-Based Measure of Time	3 vs. 2	4 vs. 3	5 vs. 4		5/4 vs. 3/2	
Total time	X *	X			X	
Conduct size up (start)			X		X	
Conduct size up (end)					X	
Conduct size up (duration)						
Position attack line (start)	X				X	
Position attack line (duration)		X			X	
Establish 2 in 2 out (end)		X		X	X	X
Establish RIT (end)	na	na	na	na	na	na
Gain forced entry (start)		X			X	
Advance line (start)	X	X			X	
Advance line (end)	X		X		X	
Deploy backup line (start)					X	X
Deploy backup line (end)				X		X
Advance backup line (start)				X		X
Advance backup line (end)				X		X
Conduct primary search (start)	X	X			X	
Ground ladders in place (end)		X	x	X	X	o
Ground ladders in place (duration)			X	X	X	X
Horizontal ventilation Story 2 window 3 (Start)		X			X	
Horizontal ventilation Story 2 window 3 (End)		X			X	
Horizontal ventilation Story 2 window 2 (Start)		X			X	
Horizontal ventilation Story 2 window 2 (End)		X			X	
Horizontal ventilation Story 2 window 1 (Start)		X			X	
Horizontal ventilation Story 2 window 1 (End)		X			X	
Horizontal ventilation Story 1 window 2 (Start)	o	X			X	
Horizontal ventilation Story 1 window 2 (End)		X			X	
Control utilities (interior) (Start)	X	X			X	
Conduct Secondary Search (Start)	X				X	
Check for Fire Ext (walls) (Start)	X	X			X	
Check for Fire Ext (ceiling) (Start)		X				
Stretch time**	X		o		X	

* An **'X'** denotes statistical significance at the 0.05 level; a **'o'** denotes significance at the 0.10 level.

Appendix F: All Regression Coefficients

Regression Models of Time to Task (in Seconds) as a Function of Crew Size and Stagger (Standard Errors are in Parentheses underneath coefficients)

	Coefficients					
Measure of Task Time	**Time measured**	**Crew size of 3**	**Crew size of 4**	**Crew size of 5**	**Close Stagger**	**Constant**
Total time		-100.5	**-408.33**	**-402.17**	**-40.83**	**1374.42**
		(50.29)	(50.29)	(50.29)	(35.56)	(39.77)
Conduct size up	Start	**2.5**	**-5.167**	**-18.17**	**-1.25**	**335**
		(5.97)	(5.97)	(5.97)	(4.22)	(4.72)
Conduct size up	Complete	**-5.167**	**-13.17**	**-38.33**	**-12**	**416**
		(13.60)	(13.60)	(13.60)	(9.62)	(10.75)
Conduct size up	Duration	**-7.667**	**-8**	**-20.17**	**-10.75**	**81.04**
		(12.10)	(12.10)	(12.10)	(8.56)	(9.57)
Position attack line	Start	**-63.5**	**-63.5**	**-69.67**	**-11.17**	**408.1**
		(14.09)	(14.09)	(14.09)	(9.96)	(11.14)
Position attack line	Duration	**-16**	**-63.67**	**-61.67**	**5.167**	**160.6**
		(13.79)	(13.79)	(13.79)	(9.75)	(10.90)
Establish 2in - 2 out	Complete	**-6.7E-15**	**-90**	**-90**	**-30**	**355**
		(9.73)	(9.73)	(9.73)	(6.88)	(7.69)
Establish RIT	Complete	**70**	**70**	**70**	**-60**	**435**
		0.00	0.00	0.00	0.00	0.00
Gain forced entry	Start	**-23.5**	**-54**	**-80.83**	**-20.83**	**528.6**
		(19.66)	(19.66)	(19.66)	(13.90)	(15.54)
Advance line	Start	**-54**	**-97.83**	**-123.5**	**-17.5**	**586.3**
		(18.83)	(18.83)	(18.83)	(13.31)	(14.88)
Advance line	Complete	**-61**	**-95.5**	**-134.7**	**-19.08**	**625.5**
		(20.35)	(20.35)	(20.35)	(14.39)	(16.08)
Deploy backup line	Start	**-26**	**-42.67**	**-53.5**	**-96.75**	**641.5**
		(17.11)	(17.11)	(17.11)	(12.10)	(13.53)
Deploy backup line	Complete	**-15.83**	**-56.17**	**-17.5**	**-53.75**	**728.9**
		(33.49)	(33.49)	(33.49)	(23.68)	(26.48)
Advance backup line	Start	**-33**	**-66.83**	**-34.83**	**-63**	**779.7**
		(29.65)	(29.65)	(29.65)	(20.97)	(23.44)
advancebackupline2	Complete	**-34.5**	**-68.17**	**-36.17**	**-63.75**	**784.4**
		(29.73)	(29.73)	(29.73)	(21.02)	(23.50)
conductprimarysearch1	Start	**-147**	**-215.8**	**-211.5**	**0.1667**	**736.1**
		(25.08)	(25.08)	(25.08)	(17.74)	(19.83)
Ground ladders in place	Complete	**-38**	**-196.5**	**-317.8**	**-69.83**	**1168**
		(48.38)	(48.38)	(48.38)	(34.21)	(38.24)
Ground ladders in place	Duration	**-33.83**	**-83.67**	**-185.7**	**-72.08**	**617**
		(48.12)	(48.12)	(48.12)	(34.03)	(38.04)
Horizontal ventilation, second story, window 3	Start	**-53.67**	**-217.8**	**-211**	**-26.59**	**759.1**
		(30.75)	(30.75)	(30.75)	(21.75)	(24.31)
Horizontal ventilation, second story, window 3	Complete	**-64.83**	**-316**	**-353**	**-33.58**	**1088**
		(49.74)	(49.74)	(49.74)	(35.17)	(39.32)
Horizontal ventilation, second story, window 2	Start	**-51.67**	**-265.8**	**-261.2**	**-18.83**	**885.1**
		(37.20)	(37.20)	(37.20)	(26.30)	(29.41)

All Regression Coefficients (CONTINUED)

Regression Models of Time to Task (in Seconds) as a Function of Crew Size and Stagger (Standard Errors are in Parentheses underneath coefficients)

Horizontal ventilation, second story, window 2	Complete	**-53.5**	**-259.8**	**-262.3**	**-13.33**	**931.3**
		(39.97)	(39.97)	(39.97)	(28.26)	(31.60)
Horizontal ventilation, second story, window 1	Start	**-70**	**-316.3**	**-348.8**	**-31.08**	**1038**
		(48.37)	(48.37)	(48.37)	(34.20)	(38.24)
Horizontal ventilation, second story, window 1	Complete	**-51.83**	**-219**	**-214.8**	**-24**	**805.7**
		(33.71)	(33.71)	(33.71)	(23.83)	(26.65)
Horizontal ventilation, first story, window 2	Start	**-87.17**	**-386.3**	**-428.5**	**-44.67**	**1200**
		(45.13)	(45.13)	(45.13)	(31.91)	(35.68)
Horizontal ventilation, first story, window 2	Complete	**-88.5**	**-391.5**	**-423.3**	**-44.17**	**1224**
		(47.02)	(47.02)	(47.02)	(33.25)	(37.17)
Control utilities interior	Start	**-136.5**	**-287.8**	**-300**	**-6.333**	**946.3**
		(45.57)	(45.57)	(45.57)	(32.22)	(36.02)
Control utilities exterior	Start	**6.667**	**-281.8**	**-312.8**	**-38.17**	**1063**
		(70.21)	(70.21)	(70.21)	(49.65)	(55.51)
Conduct secondary search	Start	**-92.5**	**-143**	**-152.7**	**-28.25**	**846**
		(38.97)	(38.97)	(38.97)	(27.56)	(30.81)
Check for fire extension walls	Start	**-453.8**	**-535.3**	**-608.7**	**-38.25**	**1155**
		(38.28)	(38.28)	(38.28)	(27.07)	(30.26)
Check for fire extension ceiling	Start	**-206.3**	**-349.7**	**-292.7**	**-2.833**	**1086**
		(48.29)	(48.29)	(48.29)	(34.14)	(38.17)

Regression Models of Time to Task (in Seconds) as a Function of Combined Crew Size and Stagger (Standard Errors appear in Parentheses)

		Coefficients		
Measure of Task Time*	Time measured	Crew size of 4/5 vs. 3/2	Close Stagger	Constant
Total time		**-355**	**-40.83**	**1324.00**
		(37.23)	(37.23)	(32.24)
Conduct size up	Start	**-12.92**	**-1.25**	**336.2**
		(4.50)	(4.50)	(3.90)
Conduct size up	Complete	**-23.17**	**-12**	**413.4**
		(9.97)	(9.97)	(8.64)
Conduct size up	Duration	**-10.25**	**-10.75**	**77.21**
		(8.44)	(8.44)	(7.31)
Position attack line	Start	**-34.83**	**-11.17**	**376.3**
		(13.66)	(13.66)	(11.83)
Position attack line	Duration	**-54.67**	**5.167**	**152.6**
		(9.60)	(9.60)	(8.31)
Establish 2in - 2 out	Complete	**-90**	**-30**	**355**
		(6.55)	(6.55)	(5.67)
Establish RIT	Complete	**35**	**-60**	**470**
		(10.80)	(10.80)	(9.35)
Gain forced entry	Start	**-55.67**	**-20.83**	**516.8**
		(14.32)	(14.32)	(12.40)
Advance line	Start	**-83.67**	**-17.5**	**559.3**
		(15.67)	(15.67)	(13.57)
Advance line	Complete	**-84.58**	**-19.08**	**595**
		(17.67)	(17.67)	(15.31)
Deploy backup line	Start	**-35.08**	**-96.75**	**628.5**
		(12.30)	(12.30)	(10.65)
Deploy backup line	Complete	**-28.92**	**-53.75**	**721**
		(23.43)	(23.43)	(20.29)
Advance backup line	Start	**-34.33**	**-63**	**763.2**
		(21.17)	(21.17)	(18.33)
advancebackupline2	Complete	**-34.92**	**-63.75**	**767.1**
		(21.27)	(21.27)	(18.42)
conductprimarysearch1	Start	**-140.2**	**0.1667**	**662.6**
		(28.28)	(28.28)	(24.49)
Ground ladders in place	Complete	**-238.2**	**-69.83**	**1149**
		(37.99)	(37.99)	(32.90)
Ground ladders in place	Duration	**-117.7**	**-72.08**	**600.1**
		(36.37)	(36.37)	(31.49)
Horizontal ventilation, second story, window 3	Start	**-187.6**	**-26.59**	**732.3**
		(22.31)	(22.31)	(19.32)
Horizontal ventilation, second story, window 3	Complete	**-302.1**	**-33.58**	**1056**
		(35.38)	(35.38)	(30.64)

Regression Models of Time to Task (in Seconds) as a Function of Combined Crew Size and Stagger (CONTINUED) (Standard Errors appear in Parentheses)

Horizontal ventilation, second story, window 2	Start	**-237.7** (26.27)	**-18.83** (26.27)	**859.3** (22.75)
Horizontal ventilation, second story, window 2	Complete	**-234.3** (28.12)	**-13.33** (28.12)	**904.6** (24.36)
Horizontal ventilation, second story, window 1	Start	**-297.6** (34.64)	**-31.08** (34.64)	**1003** (30.00)
Horizontal ventilation, second story, window 1	Complete	**-191** (24.05)	**-24** (24.05)	**779.8** (20.83)
Horizontal ventilation, first story, window 2	Start	**-363.8** (33.83)	**-44.67** (33.83)	**1156** (29.30)
Horizontal ventilation, first story, window 2	Complete	**-363.2** (34.80)	**-44.17** (34.80)	**1180** (30.14)
Control utilities interior	Start	**-225.7** (37.23)	**-6.333** (37.23)	**878.1** (32.25)
Control utilities exterior	Start	**-300.7** (47.48)	**-38.17** (47.48)	**1066** (41.12)
Conduct secondary search	Start	**-101.6** (29.88)	**-28.25** (29.88)	**799.7** (25.88)
Check for fire extension walls	Start	**-345.1** (75.46)	**-38.25** (75.46)	**927.9** (65.35)
Check for fire extension ceiling	Start	**-218** (46.32)	**-2.833** (46.32)	**983.1** (40.12)
Stretch time = advance line minus position engine	Duration	**-75.7** (16.68)	**-17.2** (16.68)	**273.3** (14.44)

*** Standard errors are in parentheses below coefficient value**

		Crew size of 3	Crew size of 4	Crew size of 5	Close Stagger	Constant
Stretch time = advance line minus position engine	Duration	**-57.3** (19.39)	**-86.7** (19.39)	**-122.0** (19.39)	**-17.2** (13.71)	**301.9** (15.33)

APPENDIX G: Measurement Uncertainty

The measurements of length, temperature, mass, moisture content, smoke obscuration, and time taken in these experiments have unique components of uncertainty that must be evaluated in order to determine the fidelity of the data. These components of uncertainty can be grouped into two categories: Type A and Type B. Type A uncertainties are those evaluated by statistical methods, such as calculating the standard deviation of the mean of a set of measurements. Type B uncertainties are based on scientific judgment using all available and relevant information. Using relevant information, the upper and lower limits of the expected value are estimated so that the probability that the measurement falls within these limits is essentially 100 %. After all the component uncertainties of a measurement have been identified and evaluated it is necessary to use them to compute the combined standard uncertainty using the law of propagation of uncertainty (the "root sum of squares"). Although this expresses the uncertainty of a given measurement, it is more useful in a fire model validation exercise to define an interval for which the measurement will fall within a certain level of statistical confidence. This is known as the expanded uncertainty. The current international practice is to multiply the combined standard uncertainty by a factor of two (k=2), giving a confidence of 95 %.

Length measurements of room dimensions, openings and instrument locations were taken using a steel measuring tape with a resolution of 0.02 in (0.5 mm). However, measurement error due to uneven and unlevel surfaces results in an estimated uncertainty of ± 0.5 % for length measurements taken on the scale of room dimensions. The estimated total expanded uncertainty for length measurements is ± 1.0 %.

The standard uncertainty of the thermocouple wire itself is 1.1°C or 0.4 % of the measured value, whichever is greater (Omega 2004). The estimated total expanded uncertainty associated with type K thermocouples is approximately ± 15 %. Previous work done at NIST has shown that the uncertainty of the environment surrounding thermocouples in a full-scale fire experiment has a significantly greater uncertainty (Blevins 1999) than the uncertainty inherent with thermocouple design. Furthermore, while a vertical thermocouple array gives a good approximation of the temperature gradient with respect to height, temperatures cannot be expected to be uniform across a plane at any height because of the dynamic environment in a compartment fire. Inaccuracies of thermocouple measurements in a fire environment can be caused by:

- Radiative heating or cooling of the thermocouple bead
- Soot deposition on the thermocouple bead which change its mass, emissivity, and thermal conductivity
- Heat conduction along thermocouple wires
- Flow velocity over the thermocouple bead

To reduce these effects, particularly radiative heating and cooling, thermocouples with smaller diameter beads were chosen. This is particularly important for thermocouples below the interface because the radiative transfer between the surrounding room surfaces will be significantly less uniform than if the thermocouple were in the hot gas layer. It is suggested in [Pitts] that it may be possible to correct for radiative transfer given enough sufficient knowledge about thermocouple properties and the environment. However, measurements of local velocity and the radiative environment were not taken. Additionally, the probes were located away from the burn compartment walls in order to avoid the effects of walls and corners.

The gas measurement instruments and sampling system used in this series of experiments have been demonstrated to have an expanded (k = 2) relative uncertainty of ± 1 % when compared with span gas volume fractions (Matheson). Given the limited set of sampling points in these experiments, an estimated uncertainty of ± 10 % is being applied to the results.

The potential for soot deposition on the face of the water-cooled total heat flux gauges contributes significant uncertainty to the heat flux measurements. Calibration of heat flux gauges was completed at lower fluxes and then extrapolated to higher values and this resulted in a higher uncertainty in the flux measurement. Combining all of component uncertainties for total heat flux resulted in a total expanded uncertainty of -24 % to +13 % for the flux measurements.

Prior to experimentation, ten of the wooden pallets used in the fuel packages were randomly selected for measurement. Two measurements were taken, moisture content and mass. Moisture content was measured using a pin-type moisture meter with a moisture measurement range of 6 % to 40% and an accuracy of <0.5 % of the measured value between 6 % and 12 % moisture content. Mass measurements were made with an industrial bench scale having a range of 0kg to 100 kg, a resolution of 0.1 kg and an uncertainty of ± 0.1 kg.

All timing staff were equipped with the same model of digital stopwatch with a resolution of 0.01 seconds and an uncertainty of ± 3 seconds per 24 hours; the uncertainty of the timing mechanism in the stopwatches is small enough over the duration of an experiment that it can be neglected. There are three components of uncertainty when using people to time fire fighting tasks. First, timers may have a bias depending on whether they record the time in anticipation of, or reaction to an event. A second component exists because multiple timers were used to record all tasks. The third component is the mode of the stimulus to which the staff is reacting: audible (firefighters announcing task updates over the radio) or visual (timing staff sees a task start or stop).

Milestone events in these experiments were recorded both audibly and visually. A test series described in the *NIST Recommended Practice Guide for Stopwatch and Timer Calibrations* found the reaction times for the two modes of stimulus to be approximately the same, so this component can be neglected. Because of the lack of knowledge regarding the mean bias of the timers, a rectangular distribution was assumed and the worst case reaction time bias of 120 ms was used, giving a standard deviation of 69 ms. The standard deviation of the reaction time was assumed to be the worst case of 230 ms. The estimated total expanded uncertainty of task times measured in these experiments is 240 ms.

An additional component of uncertainty exists for the time measurement of the application of water on the fire. In order to measure this time, timing staff were required to listen for radio confirmation that suppressing water had been applied by the interior attack crew. This process required a member of the interior crew to find and manipulate their microphone, wait for the radio to access a repeater, and transmit the message. Because of the lack of knowledge about the distributions of time it takes for each part of this process, all parts are lumped into a single estimate of uncertainty and a rectangular distribution is assumed. This is most reasonably estimated to be 2.5 seconds with a standard deviation of ±2.89 seconds and an expanded uncertainty of ± 5.78 seconds.

Weather measurement uncertainty was referenced to the published user's manual for the instrumentation used. The weather instrumentation has calibration certificates that are traceable to NIST standards. A summary of experimental measurement uncertainty is given in Table G-1.

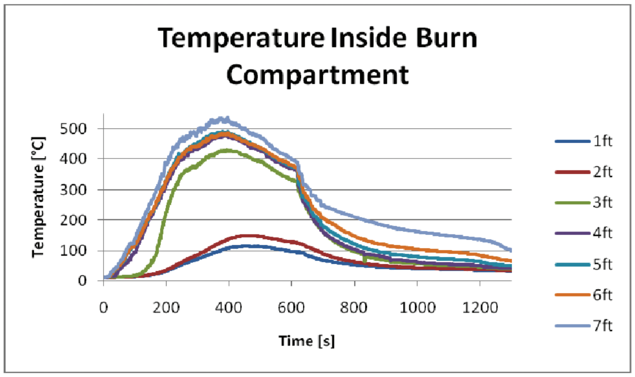
Table G-1: Summary of Measurement Uncertainty

Measurement	Component Standard Uncertainty	Combined Standard Uncertainty	Total Expanded Uncertainty
Length Measurements			
Instrumentation Locations	± 1 %	± 3 %	± 6 %
Building Dimensions	± 1 %		
Repeatability[1]	± 2 %		
Random[1]	± 2 %		
Gas Temperature – Lower Layer			
Calibration	± 1 %	± 8 %	± 15 %
Radiative Cooling	- 5 % to + 0 %		
Radiative Heating	0 % to + 5 %		
Repeatability [1]	± 5 %		
Random [1]	± 3 %		
Wood Moisture Content			
	± 0.5 %	± 0.5 %	± 1%
Wood Pallet Mass			
	± 0.2%	± 0.1%	± 0.1%
Weather			
Relative Humidity	± 3%		
Barometric Pressure	± 0.03" Hg		
Wind Speed	± 5%		
Wind Direction	± 5%		
Outside Temperature	±0.5°C		
Time			
Timer Bias	± 0.069s	± 2.90s	
Reaction Time	± 0.230s		± 5.80 s
Radio Operation	± 2.890s		
Notes: 1. Random and repeatability evaluated as Type A, other components as Type B.			

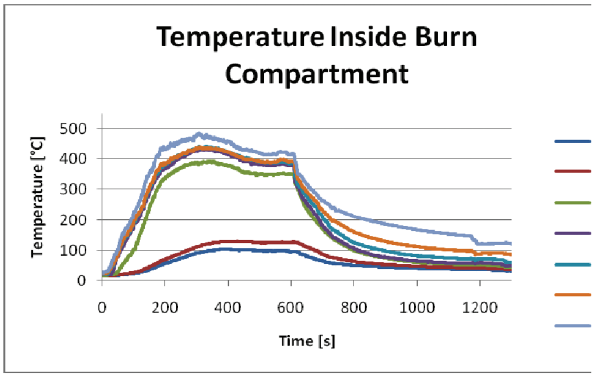
APPENDIX H: Charts of Gas and Temperature Data

Examples of Gas and Temperature Data for Time-to-Task Tests

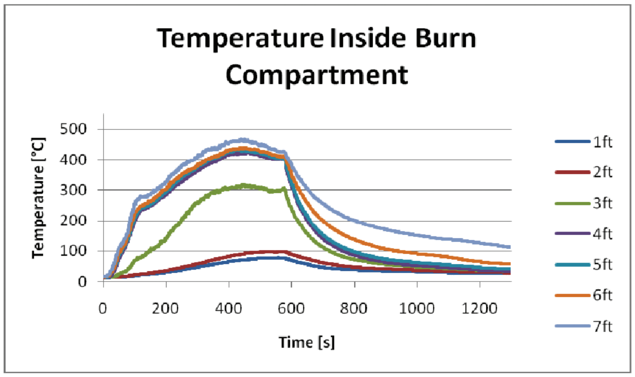
Burn Room Data



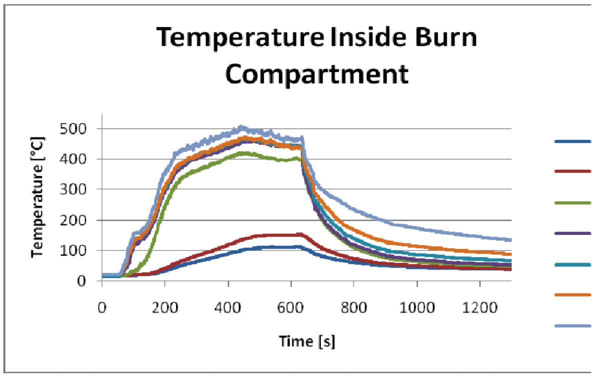
2 Person, Close Stagger



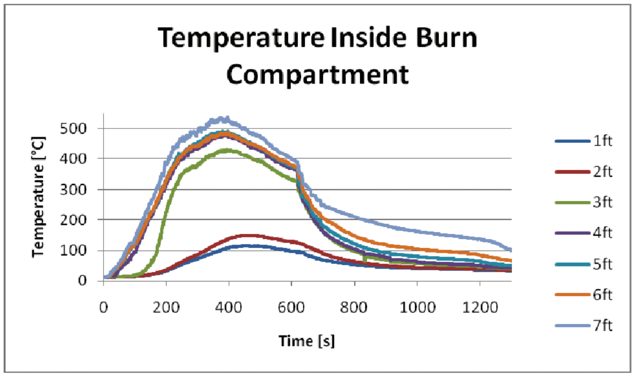
2 Person, Far Stagger



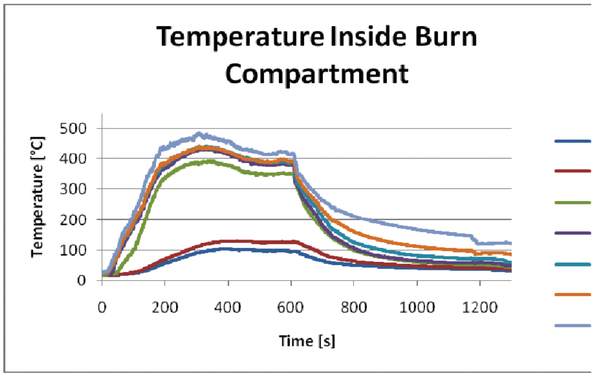
3 Person, Close Stagger



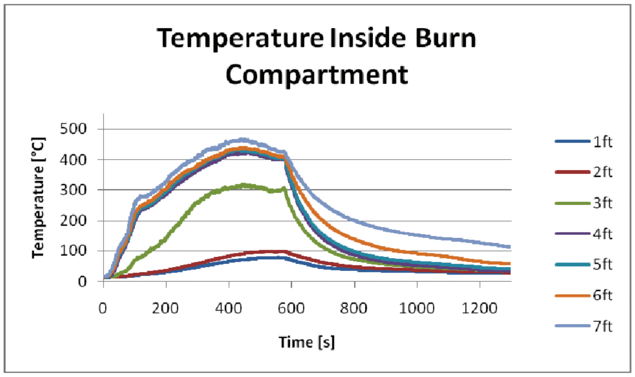
3 Person, Far Stagger



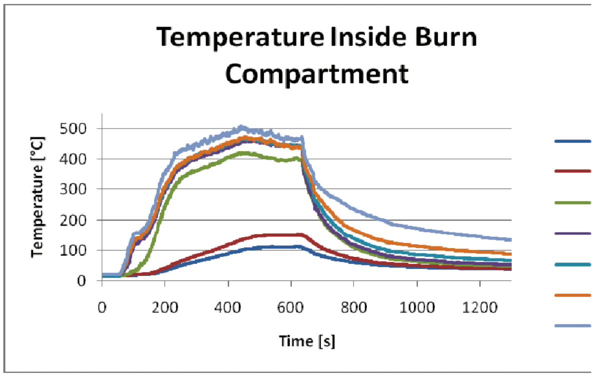
2 Person, Close Stagger



2 Person, Far Stagger

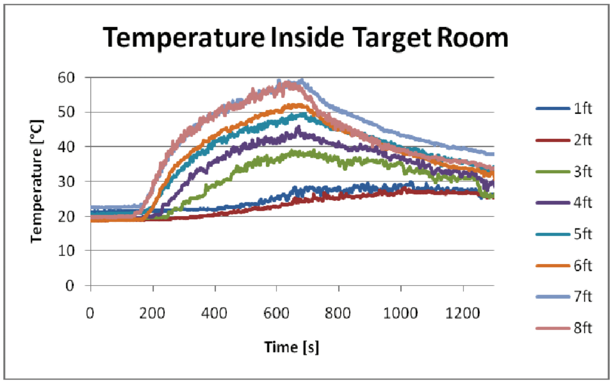


3 Person, Close Stagger

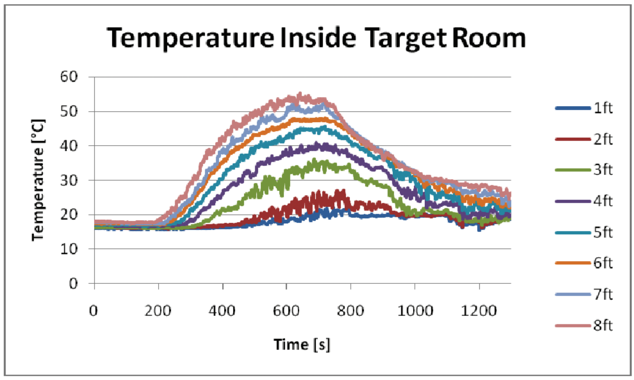


3 Person, Far Stagger

Target Room Data

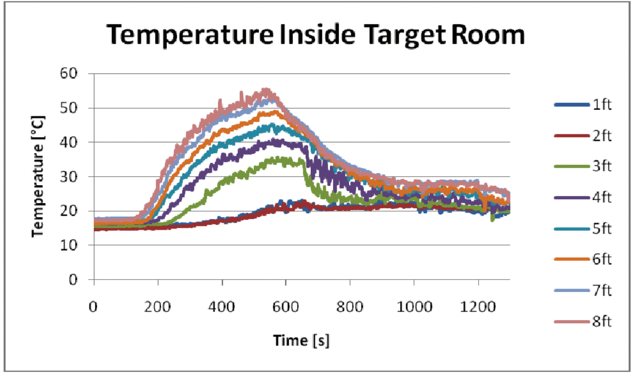


2 Person, Close Stagger

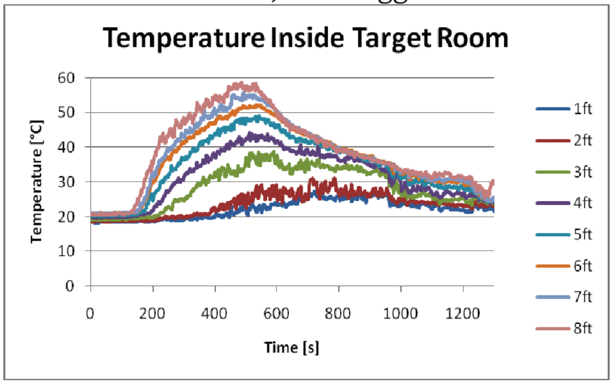


2

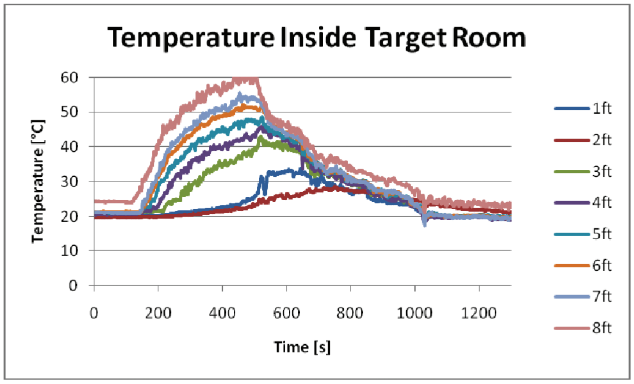
Person, Far Stagger

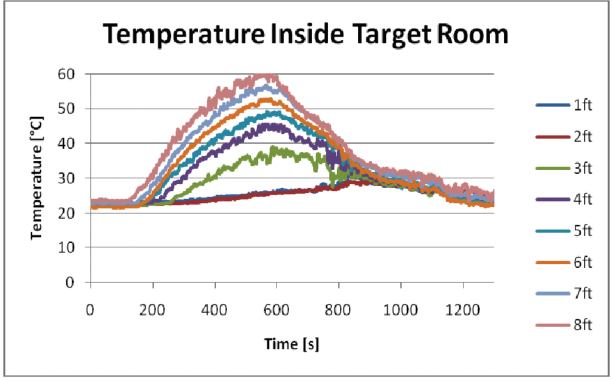


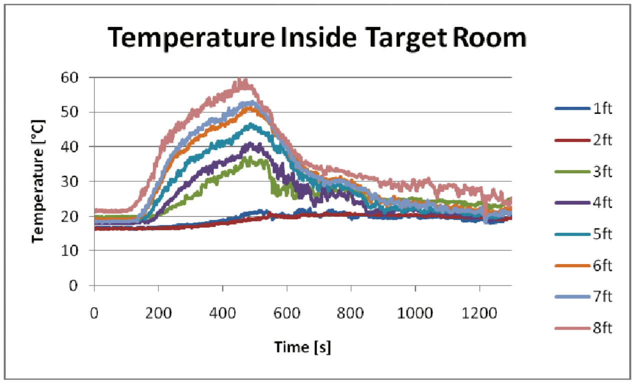
3 Person, Close Stagger



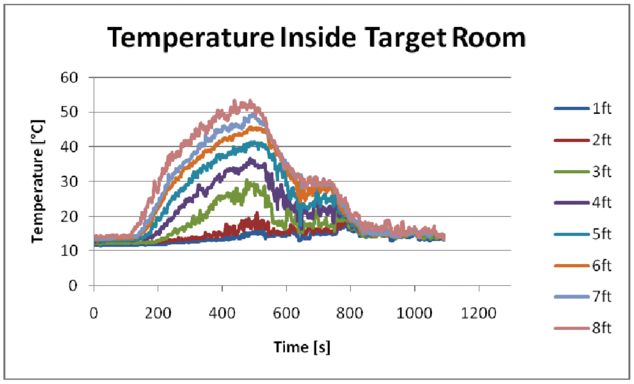
3 Person, Far Stagger





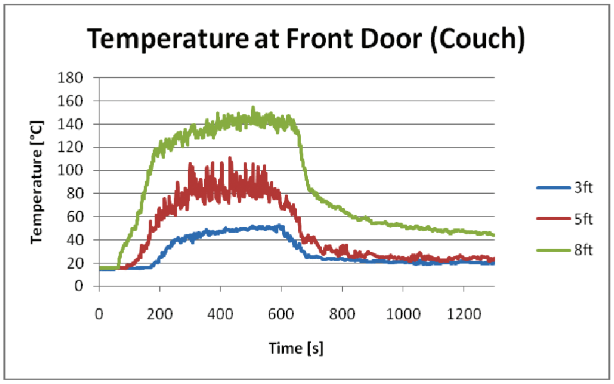


5 Person, Close Stagger

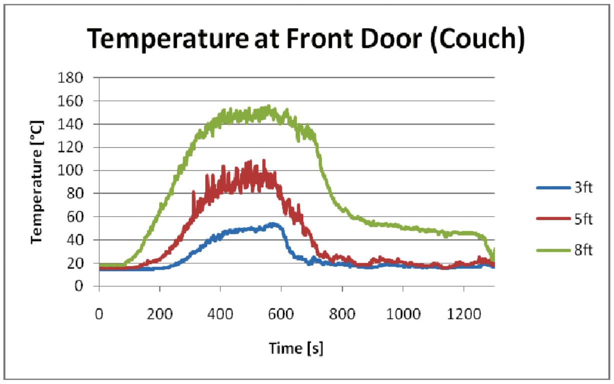


5 Person, Far Stagger

Temperature Near Front Door (Couch)



2 Person, Close Stagger



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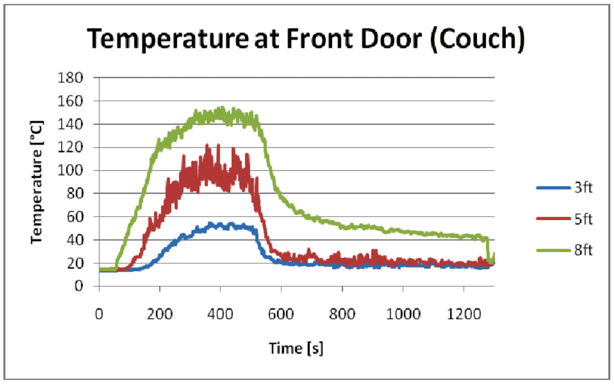

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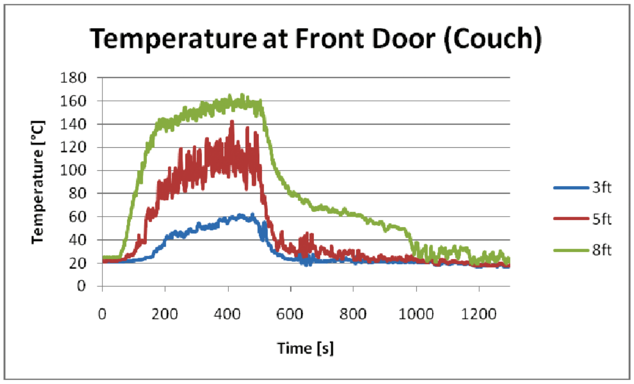

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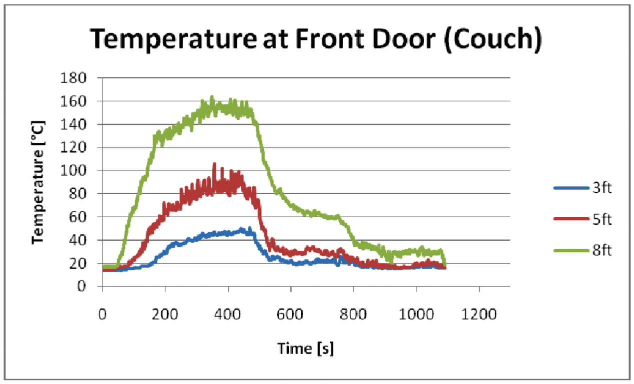

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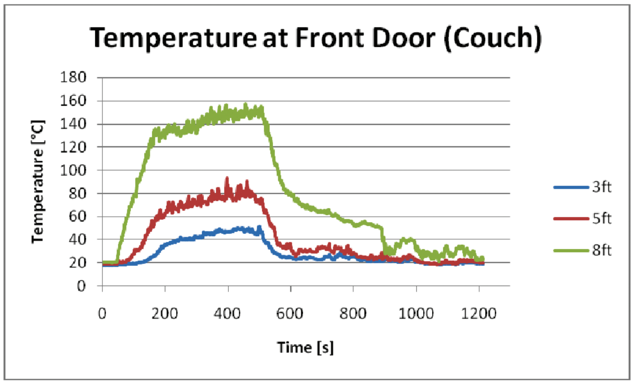

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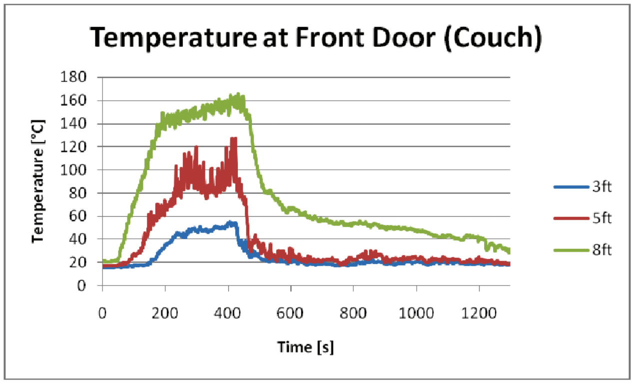

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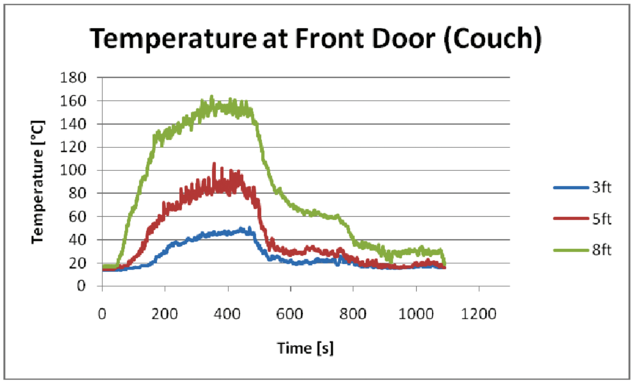

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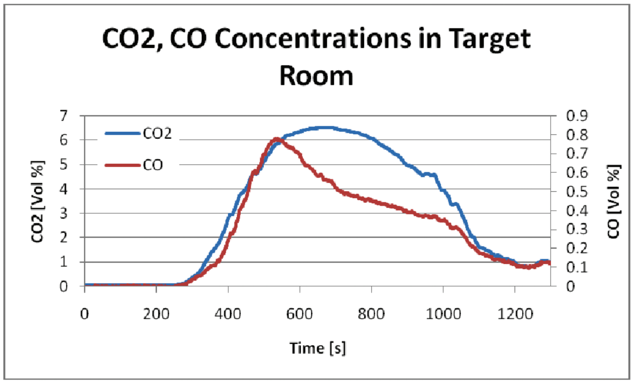
Gas and Temperature Data for Room and Contents Tests

Examples of Gas Data in Target Room



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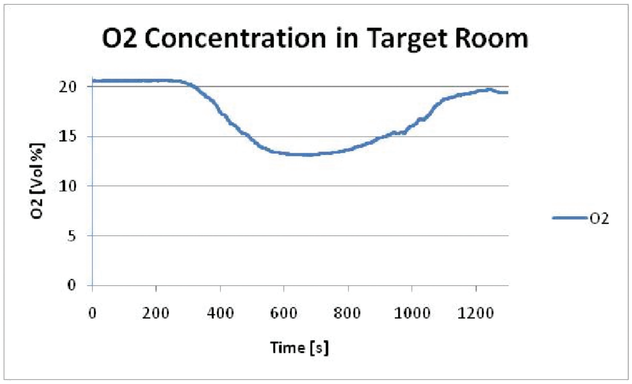

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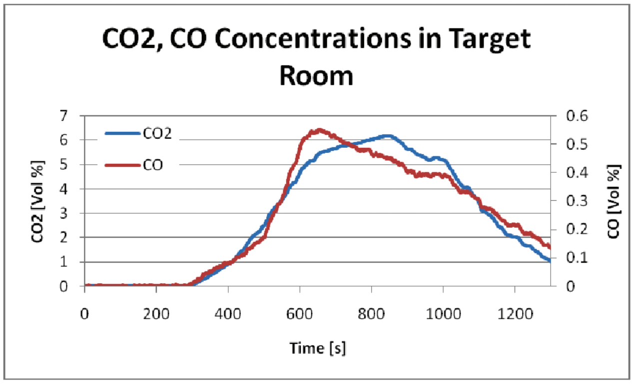

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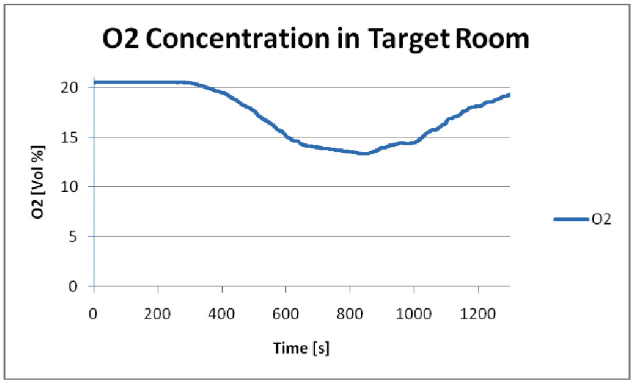

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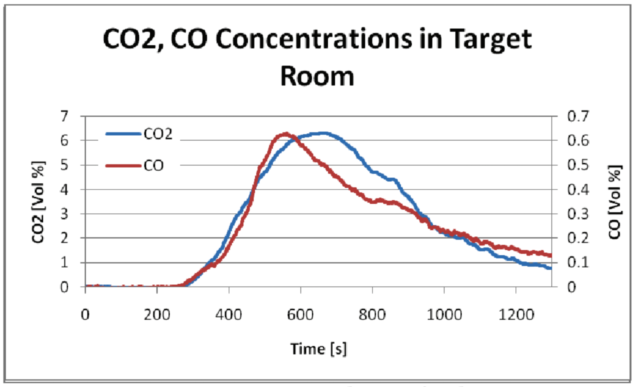

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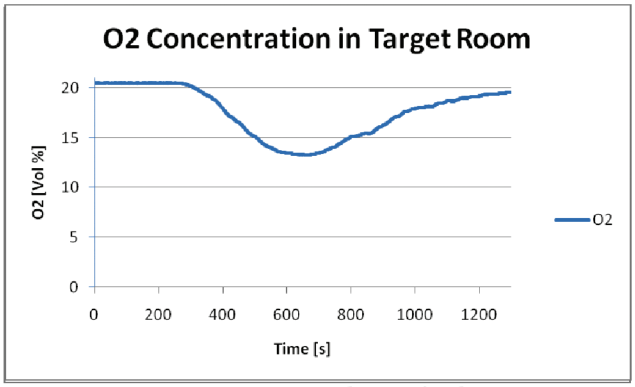

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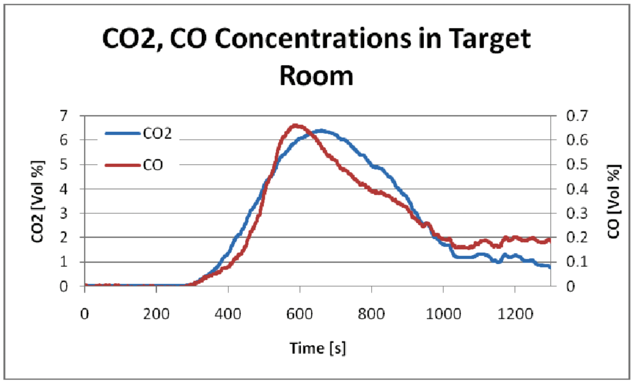
Gas and Temperature Data for Room and Contents Tests

Examples of Gas Data in Target Room



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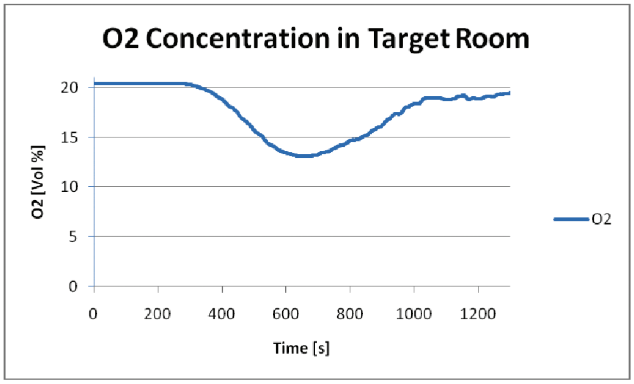

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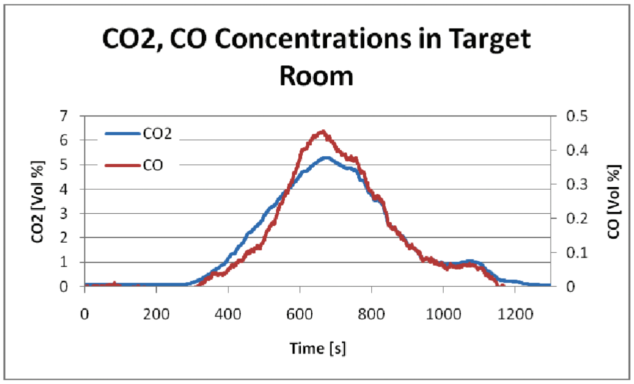

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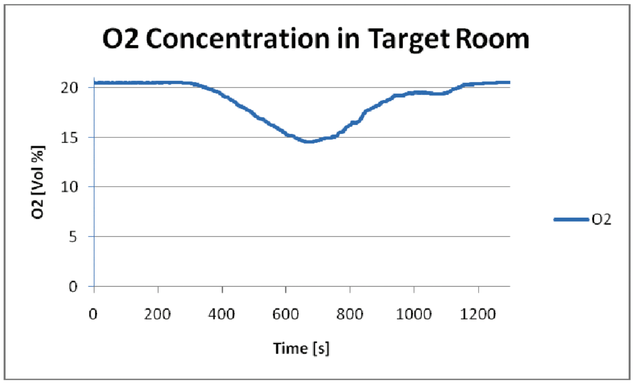

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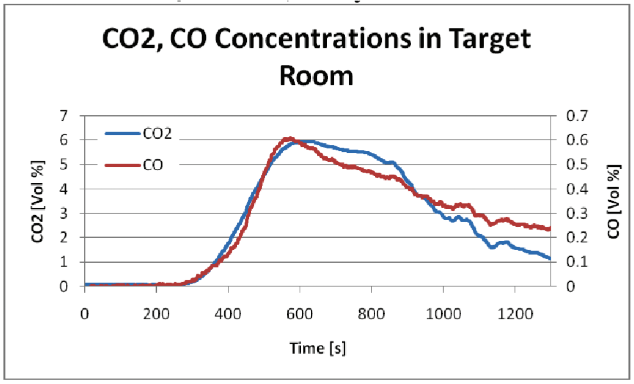

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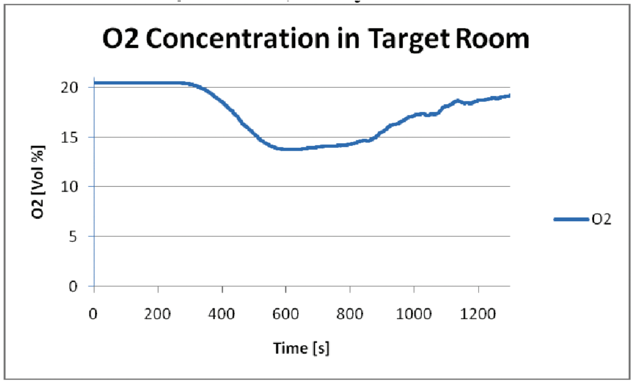

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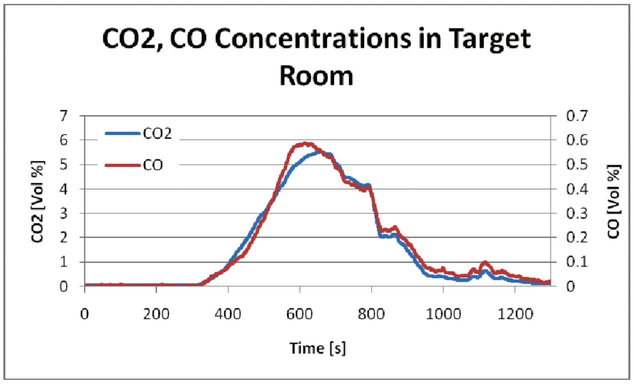

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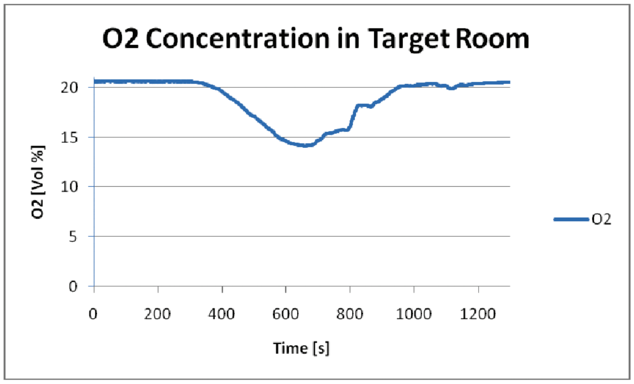

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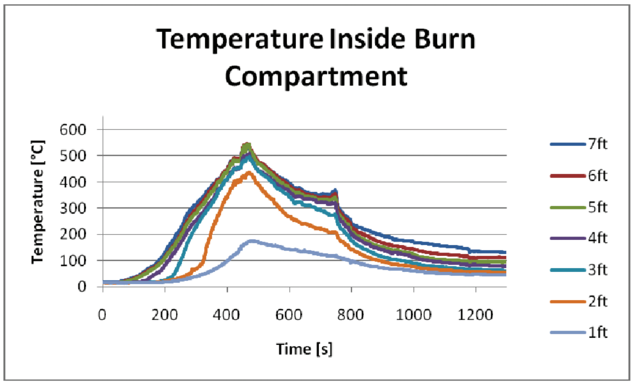
Temperatures in Burn Room



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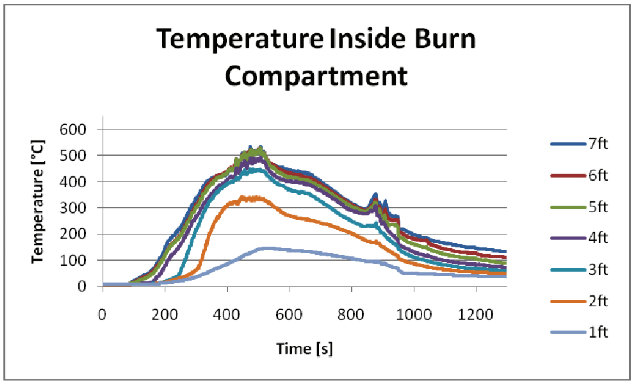

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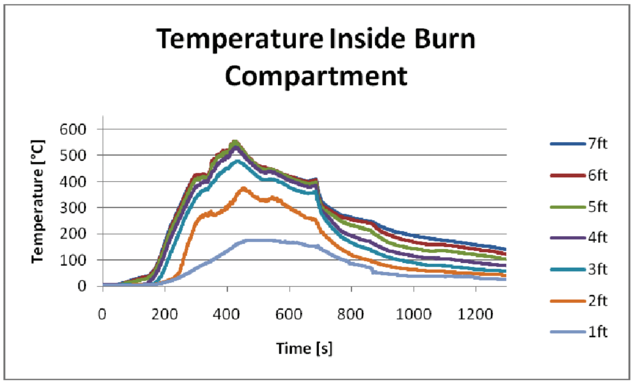

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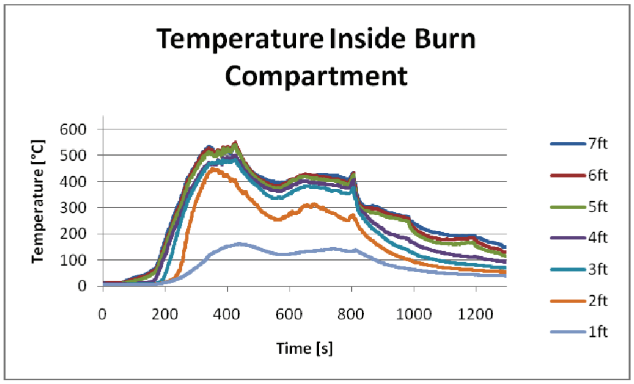

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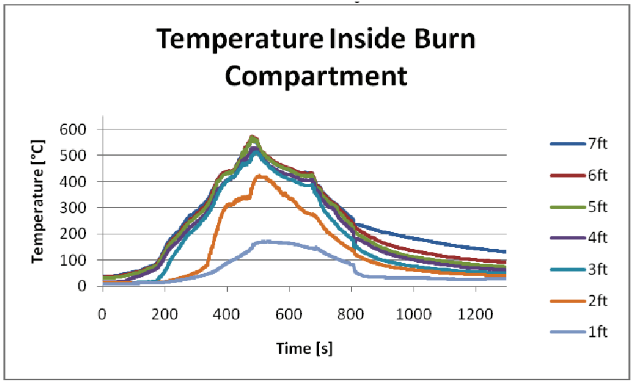

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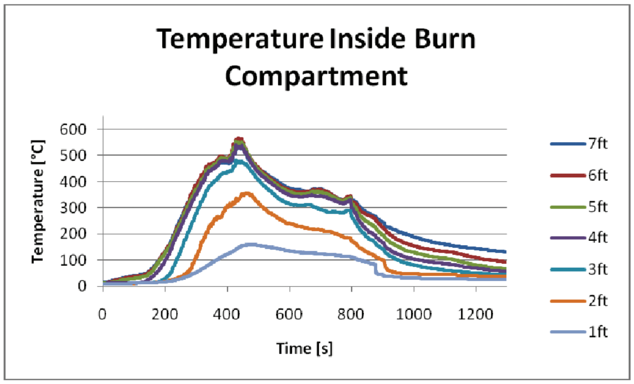

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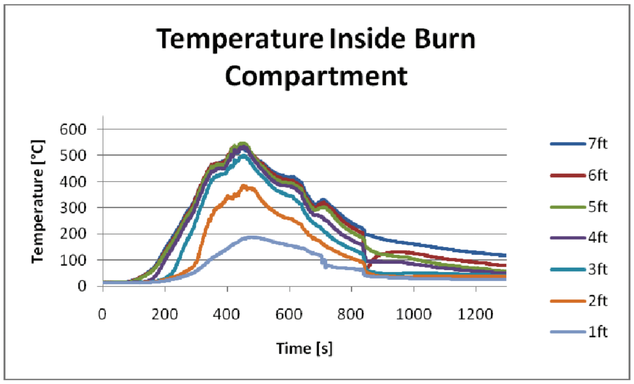

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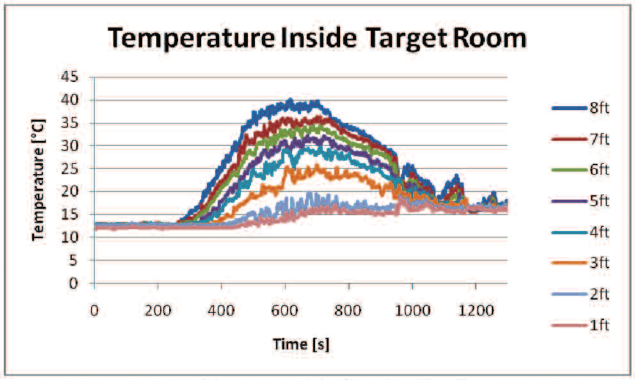

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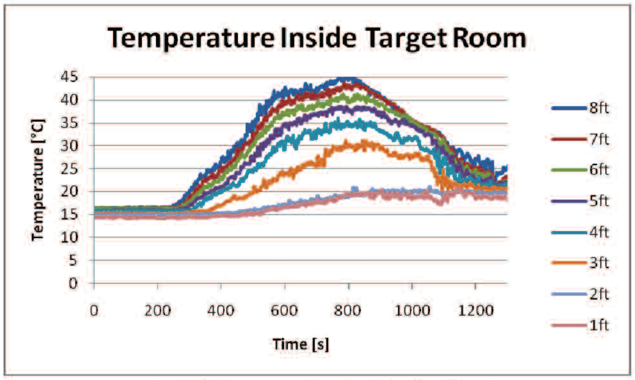

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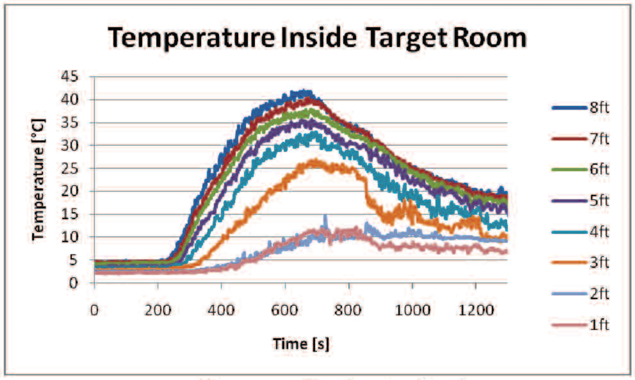

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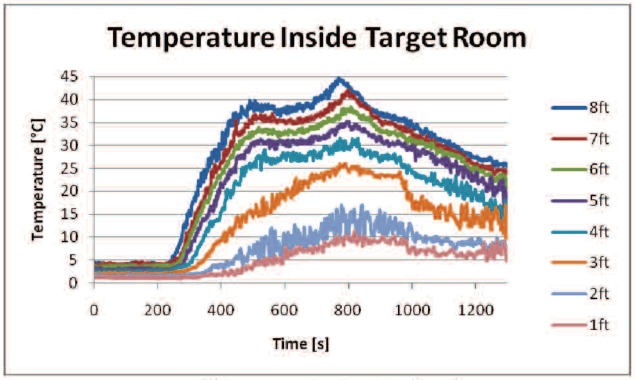

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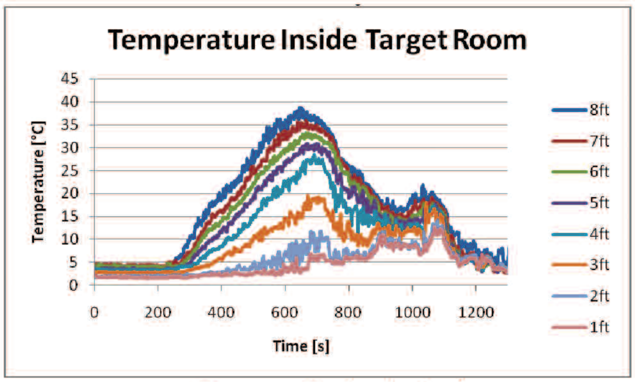

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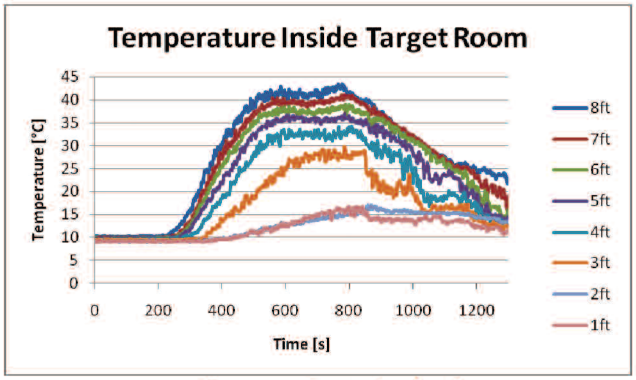

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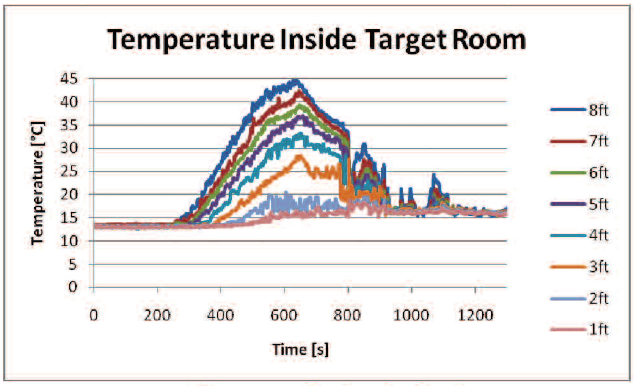

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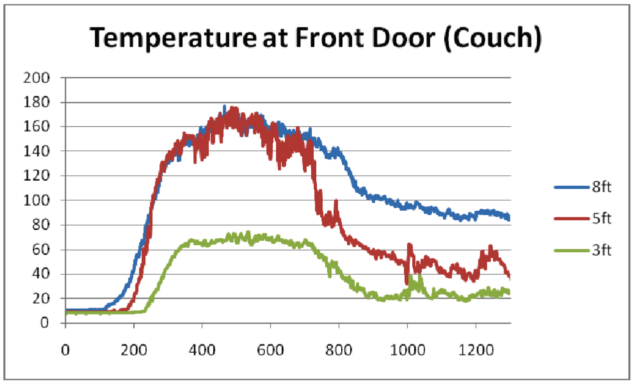
Temperatures Near Front Door (Couch)



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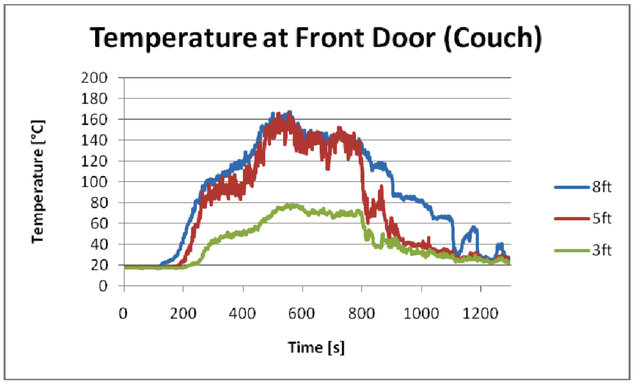

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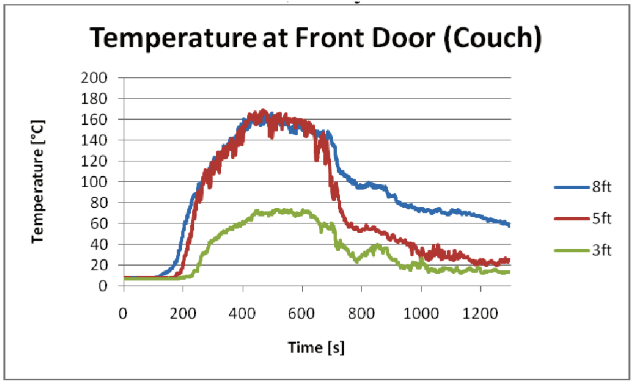

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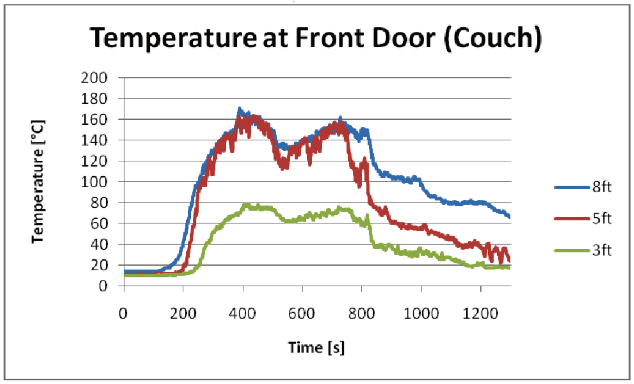

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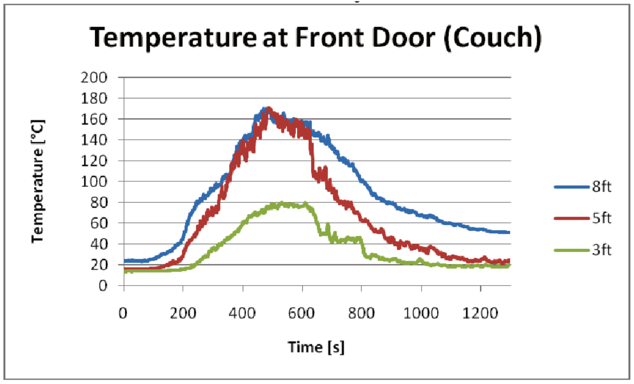

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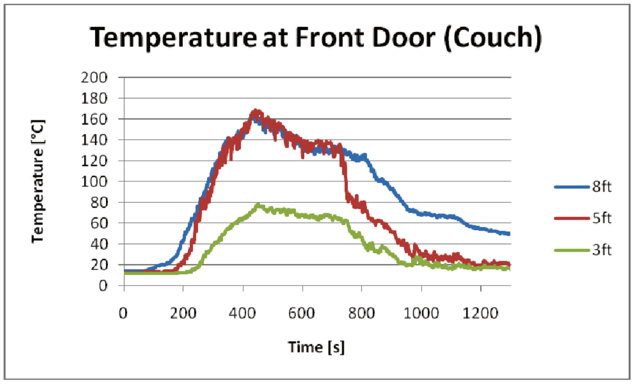

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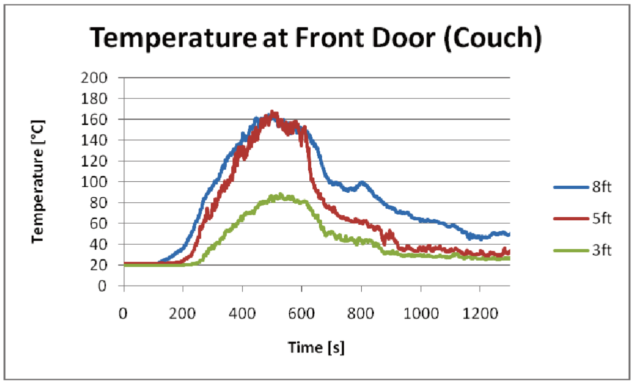

5-Person, Early Arrival

NOTES:

APPENDIX D

FIRE FIGHTER
SAFETY AND
DEPLOYMENT
STUDY

Report on
EMS Field Experiments

Lori Moore-Merrell
Rob Santos
Doug Wissoker
Ron Benedict
Nicole Taylor
Randy Goldstein
Greg Mears
Jane Brice
Jason D. Averill
Kathy Notarianni

NIST
National Institute of
Standards and Technology
U.S. Department of Commerce

September 2010

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FIRE FIGHTER SAFETY AND DEPLOYMENT STUDY

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Fire and Rescue, Department
Chief Richard Bowers

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Abstract

The fire service has become the first line medical responder for all types of medical emergencies in the majority of the United States. Fire departments typically deliver first-on-scene, out-of-hospital care services, regardless of whether or not they provide transport. The design of fire department-based Emergency Medical Services (EMS) systems varies across communities. Some departments deploy only Basic Life Support (BLS) units and personnel, some deploy a mix of BLS and Advanced Life Support (ALS) units and personnel, and a few departments operate solely at an ALS level. Additionally, the number of total personnel dispatched on an EMS call also differs. This number is dependent on factors such as the type of system resources, the nature of the EMS incident, and the number of simultaneous and concurrent incidents.

For the first time, this study investigates the effects of varying crew configurations for first responders, the apparatus assignment of ALS personnel, and the number of ALS personnel on scene on the task completion times for ALS level incidents. This study is also unique because of the array of stakeholders and the caliber of technical experts involved. Throughout the experiments, all industry standards and safety protocols were followed and robust research methods were used. The results and conclusions will directly inform the NFPA 1710[1] and NFPA 1720 Technical Committees, who are responsible for developing industry operational and deployment standards.

This report presents the results of more than 102 field experiments designed to quantify the effects of various fire department-based EMS deployment configurations for three different scenarios—-1) patient access and removal from the incident scene, 2) a victim of systemic trauma due to a long distance fall and 3) a patient with chest pain leading to a cardiac arrest. In addition to systematically controlling for arrival times of units, first responder crew size was varied to consider two-, three-, and four-person staffing. ALS personnel configuration for both the first responder unit and ambulance transport unit were also varied for purposes of the experiments. In each deployment, personnel performed a series of defined tasks consistent with the scenario being evaluated. Report results quantify the effectiveness of crew size, ALS configuration, and the number of ALS personnel on the start, duration, and completion time of all tasks delineated in the three scenarios. Conclusions are drawn from statistically significant results.

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Executive Summary

Increasing demands on the fire service, including the rising number of EMS responses, point to the need for scientifically-based studies on the effect of first responder crew size, Advanced Life Support configuration, and the number of Advanced Life Support (ALS) personnel on scene on the safety of responders, as well as the operational efficiency and effectiveness of fire departments responding to emergency medical incidents. To address this need, a research partnership of the Commission on Fire Accreditation International (CFAI), International Association of Fire Chiefs (IAFC), International Association of Fire Fighters (IAFF), National Institute of Standards and Technology (NIST), and Worcester Polytechnic Institute (WPI) was formed to conduct a multiphase study of firefighter safety and the deployment of resources. A portion of that study, as reported here, includes an assessment of time-to-tasks for EMS incidents.

Beginning in FY 2005, funding was provided through the Department of Homeland Security (DHS)/ Federal Emergency Management Agency (FEMA) Grant Program Directorate for Assistance to Firefighters Grant Program-Fire Prevention and Safety Grants. In addition to the EMS field experiments described in this report, the multiple phases of the overall research effort include development of a conceptual model for community risk assessment and deployment of resources, implementation of a generalizable department incident survey, and delivery of a software tool to quantify the effects of deployment decisions on resultant firefighter and civilian injuries and on property losses.

The first phase of the project was an extensive survey of more than 400 career and combination (both career and volunteer) fire departments in the United States with the objective of optimizing a fire service leader's capability to deploy resources to prevent or mitigate adverse events that occur in risk- and hazard-filled environments. The results of this survey are not documented in this report, which is limited to the EMS experimental phase. The survey results will constitute significant input into the development of a future software tool to quantify the effects of community risks and associated deployment decisions on resultant firefighter and civilian illnesses and injuries.

The National Fire Protection Association estimates that 10,380 EMS workers were exposed to infectious diseases in 2008 (Karter, 2009). Another study noted that almost 10 % of Emergency Medical Technicians (EMTs) and Paramedics miss work at any given time due to job-related illness or injury (Studnek et al, 2007). Another study noted that injury rates for EMS workers are higher than rates reported by the Department of Labor (DOL) for any other industry in 2000 (Maguire et al, 2005) and another study noted that EMS providers have a high risk for occupational injury, with approximately 25 % of workers reporting at least one work-related injury in the previous six months. Many of these injuries were the result of falls or lifting patients (Heick, 2009). Funding and additional research are critical to further defining the high risks to firefighters during EMS responses and developing interventions to mitigate this serious problem.

In order to address the primary research questions using realistic scenarios, the research was divided into three distinct, yet interconnected parts.

- Part 1 — Time-to-task experiments related to gaining access to a patient and removing the patient from the incident scene.
- Part 2 — Time-to-task experiments related to the care of a victim with multi-system trauma.
- Part 3 — Time-to-task experiments related to the care of a victim with chest pain and witnessed cardiac arrest.

These parts included the most basic elements of an overall EMS response, which are — access the patient, conduct patient assessment, deliver on scene patient care, package the patient, and remove the patient from the scene to a transport-capable vehicle.

Scope

The EMS portion of the Firefighter Safety and Deployment of Resources Study was designed solely to assess the personnel number and configuration aspect of an EMS incident for responder safety, effectiveness, and efficiency. This study does not address the efficacy of any patient care intervention. This study does however quantify first responder crew size, i.e., the number and placement of ALS trained personnel resources on the time-to-task measures for EMS interventions. Upon recommendation of technical experts, the investigators selected trauma and cardiac scenarios to be used in the experiments as these events are resource intensive and will likely reveal relevant differences in regard to the research questions. The applicability of the conclusions from this report to a large-scale hazardous or multiple-casualty event has not been assessed and should not be extrapolated from this report.

EMS protocols pertaining to the treatment and transport of patients vary by departments. For the purpose of this study, apparatus arrival times and on scene tasks were standardized by technical experts. Individual performance times were recorded for each task. Response data from more than 300 United States Fire Departments show that when dispatched simultaneously, a first responder arrives prior to an ambulance in approximately 80 % of EMS responses, (IAFC/IAFF, 2005). Therefore, arrival times of the first responder engine and the ambulance were staggered. Additionally, in real-world situations, as in this study, many of the tasks can be performed simultaneously based on the number and training level of responding personnel. Attempts to generalize the results from these experiments to individual departments must take into account response and patient care protocols and equipment that may vary from those used in the experiments.

Primary Findings

The objective of the experiments was to determine how first responder crew size, ALS provider placement, and the number of ALS providers is associated with the effectiveness of EMS providers. EMS crew effectiveness was measured by task intervention times in three scenarios including patient access and removal, trauma, and cardiac arrest. The results were evaluated from the perspective of firefighter and paramedic safety and scene efficiency rather than as a series of distinct tasks. More than 100 full-scale EMS experiments were conducted for this study.

Hundreds of firefighters and paramedics are injured annually on EMS responses. Most injuries occur during tasks that require *lifting or abnormal movement* by rescuers. Such tasks include lifting heavy objects (including human bodies both conscious and unconscious), manipulating injured body parts and carrying heavy equipment. Several tasks included in the experiments fall into this category, including splinting extremities, spinal immobilization (back boarding) and patient packaging. Similar to the lifting or heavy workload tasks, larger crews were able to complete the labor intensive tasks using multiple crew members on a single task to assure safe procedures were used reducing the likelihood of injury or exposure.

A number of tasks are also *labor intensive*. These tasks can be completed more efficiently when handled by multiple responders. Several tasks in the experiments are in this category. These include checking vital signs, splinting extremities, intubation with spinal restriction, establishing I.V. access, spinal immobilization, and patient packaging. During the experiments larger crews completed these tasks more efficiently by distributing the work load among more people thereby reducing the likelihood of injury.

Finally, there are opportunities on an EMS scene to reduce scene time by completing tasks simultaneously rather than sequentially thus increasing operational efficiency. For the experiments, crews were required to complete all tasks in each scenario regardless of their crew size or configuration. Therefore, patterns in task start times and overall scene times reveal operational efficiencies. When enough hands are available at the scene to complete tasks simultaneously, this leads to overall time reductions relative to smaller crews that are forced to complete tasks sequentially.

Patient Access and Removal

With regard to accessing the patient, crews with three or four first responders reached the patient around half a minute faster than smaller crews with two first responders. With regard to completing patient removal, larger first responder crews in conjunction with a two-person ambulance were more time efficient. The removal tasks require heavy lifting and are labor intensive. The tasks also involve descending stairs while carrying a patient, carrying all equipment down stairs, and getting patient and equipment out multiple doors, onto a stretcher and into an ambulance.

The patient removal results show substantial differences associated with crew size. Crews with three- or four-person first responders complete removal between 1.2 – 1.5 minutes faster than smaller crews with two first responders. All crews with first responders complete removal substantially faster (by 2.6 - 4.1 minutes) than the ambulance-only crew.

These results suggest that time efficiency in access and removal can be achieved by deploying three- or four-person crews on the first responding engine (relative to a first responder crew of two). To the extent that each second counts in an EMS response, these staffing features deserve consideration. Though these results establish a technical basis for the effectiveness of first responder crews and specific ALS crew configurations, other factors contributing to policy decisions are not addressed.

Trauma

Overall, field experiments reveal that four-person first responder crews completed a trauma response faster than smaller crews. Towards the latter part of the task response sequence, four-person crews start tasks significantly sooner than smaller crews of two or three persons.

Additionally, crews with one ALS provider on the engine and one on the ambulance completed all tasks faster and started later tasks sooner than crews with two ALS providers on the ambulance. This suggests that getting ALS personnel to the site sooner matters.

A review of the patterns of significant results for task start times reinforced these findings and suggests that (in general) small non-significant reductions in task timings accrue through the task sequence to produce significantly shorter start times for the last third of the trauma tasks.

Finally, when assessing crews for their ability to increase on-scene operational efficiency by completing tasks simultaneously, crews with an ALS provider on the engine and one ALS provider on the ambulance completed all required tasks 2.3 minutes (2 minutes 15 seconds) faster than crews with a BLS engine and two ALS providers on the ambulance. Additionally, first responders with four-person first responder crews completed all required tasks 1.7 minutes (1 minute 45 seconds) faster than three-person crews and 3.4 minutes (3 minutes and 25 seconds) faster than two-person crews.

Cardiac

The overall results for cardiac echo those of trauma. Regardless of ALS configuration, crews responding with four first responders completed all cardiac tasks (from at-patient to packaging) more quickly than smaller first responder crew sizes. Moreover, in the critical period following cardiac arrest, crews responding with four first responders also completed all tasks more quickly than smaller crew sizes. As noted in the trauma scenario, crew size matters in the cardiac response.

Considering ALS placement, crews responding with one ALS provider on both the engine and ambulance completed all scene tasks (from at-patient to packaging) more quickly than a crew with a BLS engine and two ALS providers on the ambulance. This suggests that ALS placement can make a difference in response efficiency. One curious finding was that crews responding with a BLS engine and an ambulance with two ALS providers completed the tasks that follow cardiac arrest 50 seconds *sooner* than crews with an ALS provider on both the engine and ambulance. As noted, this counter-intuitive difference in the results may be attributable to the delay of the patient arrest time based on the arrival of the 12-Lead ECG monitor with the two-person ALS Ambulance crew. The 12-Lead ECG task *end time* was the arrest *start time*. In this scenario, there were instantaneously two ALS providers present at the arrest rather than the one ALS provider placing the 12-Lead ECG device in the ALS engine /ALS Ambulance crew.

A review of the patterns of significant findings across task start times showed mixed results. An ALS on an engine showed an advantage (sooner task starting times) over an ALS on an ambulance for a few tasks located earlier in the cardiac response sequence (specifically, ALS Vitals 12-Lead through IV access). A first responder with four-person crew also showed shorter start times for a few early tasks in the cardiac response sequence (initial airway, breathing and circulation (ABCs), and the ALS Vitals 12-Lead and expose chest sequence). More importantly, a sequential time advantage appears for the last three tasks of the sequence (analyze shock #2 through package patient).

Finally, when assessing crews for their ability to increase on-scene operational efficiency by completing tasks simultaneously, crews with an ALS provider on the engine and one ALS provider on the ambulance completed all required tasks 45 seconds faster than crews with a BLS engine and two ALS providers on the ambulance. Regardless of ALS configuration, crews responding with four first responders completed all cardiac tasks from the 'at patient time' to completion of packaging 70 seconds faster than first responder crews with three persons, and 2 minutes and 40 seconds faster than first responder crews with two persons. Additionally, *after the patient arrested*, an assessment of time to complete remaining tasks revealed that first responders with four-person crews completed all required tasks 50 seconds faster than three-person crews and 1.4 minutes (1 minute 25 seconds) faster than two-person crews.

Summary

While resource deployment is addressed in the context of three basic scenarios, it is recognized that public policy decisions regarding the cost-benefit of specific deployment decisions are a function of many factors including geography, resource availability, community expectations as well as population demographics that drive EMS call volume. While this report contributes significant knowledge to community and fire service leaders in regard to effective resource deployment for local EMS systems, other factors contributing to policy decisions are not addressed. The results, however, do establish a technical basis for the effectiveness of first responder crews and ALS configuration with at least one ALS level provider on first responder crews. The results also provide valid measures of total crew size efficiency in completing on-scene tasks some of which involve heavy lifting and tasks that require multiple responders to complete.

These experimental findings suggest that ALS provider placement and crew size can have an impact on some task start times in trauma and cardiac scenarios, especially in the latter tasks leading to patient packaging. To the extent that creating time efficiency is important for patient outcomes, including an ALS trained provider on an engine and using engine crew sizes of four are worth considering. The same holds for responder safety – for access and removal and other tasks in the response sequence, the availability of additional hands can serve to reduce the risks of lifting injuries or injuries that result from fatigue (e.g., avoid having small crews repeatedly having to ascend and descend stairs).

Background

In recent years, the provision of emergency medical services has progressed from an amenity to a citizen-required service. Today more than 90 % of career and combination fire departments deliver emergency medical care services, making fire departments the largest group of providers of prehospital EMS in North America. Fire department operations are geared to rapid response, whether it is for EMS, resuce, or fire suppression. In many jurisdictions, EMS responses equate to over 75 % of a fire departments call volume. EMS deployment decisions are therefore a critical driving factor for any department considering both short and long term resource deployment decisions.

The National Fire Protection Association estimates that 10,380 EMS workers were exposed to infectious diseases in 2008 (Karter, 2009). Another study noted that almost 10 % of EMTs and Paramedics miss work at any given time due to job-related illness or injury (Studnek et al, 2007). Another study noted that injury rates for EMS workers are higher than rates reported by the Department of Labor (DOL) for any other industry in 2000 (Maguire et al, 2005) and another study noted that EMS providers have a high risk for occupational injury, with approximately 25 % of workers reporting at least one work-related injury in the previous 6 months. Many of these injuries were the result of falls or lifting patients (Heick, 2009). Funding and additional research are critical to further quantifying the high risks to firefighters during EMS responses and developing interventions to mitigate this serious problem.

Much discussion and past research has focused on ambulance transport services, largely ignoring the impact of critical interventions that can be provided prior to ambulance transport unit arrival. Ambulances are important for the transport of patients needing more definitive medical care (Pratt, 2007). However, based on the number and the geographic distribution of apparatus stationed for “all hazards” response, a more rapid response is typically provided by fire department baseline units carrying medical supplies and EMS trained personnel (IAFC/IAFF, 2005). As fire departments continue to enhance their roles in EMS, it becomes important to examine how different deployment configurations and initiation of specific medical interventions may change the long-term outcome for the patient. Consequently, community planners and decision-makers need tools to optimally align resources with their service commitment for adequate emergency medical care for citizens.

Problem

Despite the role played by the fire service in the provision of emergency medical services, there are no scientifically based tools available to community and fire service leaders to assess the effects of EMS crew size and deployment on firefighter safety. More and more individuals, including the indigent, the working uninsured, and the underinsured, rely on prehospital medical care, which continuously increases the need for EMS resources in fire departments. The continued lack of comprehensive community health services and comprehensive health care reform means addressing this issue is a critical step in the evolution of the fire service and public safety.

Presently, community and fire service leaders have a qualitative understanding of the effect of certain resource allocations. For example, an increase in the number of fire houses, medically equipped apparatus, and EMS trained personnel would lead to a decrease in the time citizens spend waiting for EMS resources to arrive. Consequently a decrease in the number of fire houses, medically equipped apparatus, and EMS trained personnel would likely lead to an increase in the time before critical medical interventions can be provided. However, decision-makers lack a sound basis for quantifying the overall impact of enhanced emergency medical resources and the number of EMS-trained personnel on the timely provision of life-saving procedures.

Studies on adequate deployment of resources are needed to enable fire departments, cities, counties, and fire districts to design an acceptable level of resource deployment based upon community risks and service provision commitment. These studies will assist with strategic planning and municipal and state budget processes. Additionally, as resource studies refine data collection methods and measures, both subsequent research and improvements to resource deployment models will have a sound scientific basis.

Literature Review

Within the past four decades, the range and structure of services provided by firefighters have broadened and changed dynamically as an ever-increasing amount of department resources are used to respond to emergency medical calls. Expanded activities and increased expectations bring advantages, as well as challenges for both communities and fire departments in terms of providing optimal protection during emergency situations, while quantitatively assessing objective systems performance.

Studies documenting engine and ladder response times and crew performance in diverse live and simulated fire hazard environments, show a relationship between apparatus staffing levels and a range of important performance variables and outcome measurements such as response time, time-to-task completion, fire growth status at the time of attack, and occupant toxicity levels (Averill et al, 2010). Recent analyses of EMS crew staffing configuration have suggested that both the number of personnel dispatched per unit and the level of emergency medical certification of that crew may influence similar standards of measurement in the realm of medical response by multi-role firefighters. (Brown et al, 1996)

The rapid evolution of emergency service delivery and the growth of fire-based EMS systems correspond with an increase in literature that has detailed both the need for careful outcomes evaluation and continued innovation in terms of establishing performance variables that accurately assess the effectiveness of prehospital care provided by emergency medical technicians (EMTs). Investigators from government, professional organizations, and academia have described the progress made in the field of prehospital care and the challenges that EMT's and multi-role firefighters face in an expanding body of literature (Moore, 2002).

Publications to date have continually reached towards ascertaining the performance measures, operational protocols, and dispatch configurations that optimize outcomes across diverse communities. Many of the currently established EMS benchmarks and obstacles identified in recent literature hold particular importance for multi-role firefighters. Far-reaching studies of EMS response have demonstrated how response time, scene time, transport time, crew size, equipment, and the level of crew staffing and certification levels have influenced patient survival (Cummins et al, 1991). While studies have continued to demonstrate the impact of these factors with increasingly sophisticated methods, the need to improve understanding of EMS delivery persists. Existing standards of care need to be reevaluated so current systems can adjust and progress in response to ongoing research findings.

Historically, total response time has been measured from the time a responding unit leaves a fire station until the time the unit arrives at the incident. However, anecdotal evidence suggests that total response time should include the time to locate and access the patient (time to patient side). Previous studies have shown a substantial time difference between the time the first responder arrives on-scene and the time of patient access. One study noted that the patient access time interval represented 24 % of the total EMS response time interval among calls originating less than three floors above or three floors below ground and 32 % of those located three or more stories above ground. (Morrison et al, 2005)

Early literature on out-of-hospital cardiac arrest (OHCA) sought to uncover the effects of patient characteristics and location of initial collapse on survival to hospital discharge, with researchers then beginning to quantify the importance of response time. A paper by researchers from the EMS Division of King County, Washington and University of Washington Departments of Medicine and Biostatistics found significantly higher survival rates for patients who arrested outside the home, noting that of those 781 patients, most were more frequently younger, male, and more likely to be witnessed at the time of collapse and had received bystander cardiopulmonary resuscitation (CPR). (Litwin et al, 1987)

A growing number of defibrillation effectiveness studies began to demonstrate that response time, EMT training and practice, and population density influenced the effectiveness of this type of EMS delivery. (Olson, 1989; Kellerman, 1992; Hallstrom, 2004; DeMaio, 2005) For an urban environment exceeding three million, at least one study noted that over a period of one year, survival rates were lower in urban environments than those reported for smaller cities, but reaffirmed that the single factor most likely contributing to poor overall survival was a relatively long interval between collapse and defibrillation. In their conclusions, the authors recommended the use of standardized terms and methodology and stressed that "detailed analysis of each component of the emergency medical services systems will aid in making improvements to maximize survival of out-of-hospital cardiac arrest." (Becker, 1991)

Researchers studying patient outcomes following traumatic brain injury (TBI) were employing the specific anatomic, physiologic, and age characteristics of patients to formulate methods that would evaluate the effectiveness of trauma care. The "Trauma and Injury Severity Scores" (TRISS) method was one such system that generated scores for patients based upon systolic blood pressure, capillary refill, respiratory rate, and respiratory expansion. These scores provided a means of accurate analysis for EMS performance for cases of TBI, just as situational characteristics for OHCA, such as location of collapse, collapsing rhythm, and time to initial call were being used to gauge the effectiveness of emergency medical interventions for patients in distinct crisis scenarios. For instance, the correlation between age and predicted mortality for patients with comparable Trauma and Injury Severity Scores in an early study of the TRISS method suggested that a significantly narrower margin of effectiveness exists for seriously injured patients age 55 years or older. (Boyd, 1987)

Fire departments have long grappled with the most appropriate dispatch and notification configurations for EMS systems in different communities. Analyses have focused on comparisons of "one-tier" versus "two-tier" notification systems. "One-tier" systems require ALS units to respond to and transport all calls. In

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[2] "Multi-role" is a term given to firefighters cross-trained in a number of related emergency services fields, such as EMS, hazardous materials response, and technical rescue.

a "two-tier" system, ALS units are allowed to delegate varying degrees of responsibility for response and transport to BLS units. Two studies appearing in the *Annals of Emergency Medicine* in the same year examined the response capacity and performance measures for a broad sample of urban EMS systems with regard to dispatching protocols and notification systems. (Sweeney, 1998; Chu, 1998) Reviewing previously published studies on 39 emergency medical services programs from 29 different locations from 1967 to 1988, researchers focusing specifically on cardiac arrest and resuscitation outcomes noted survival rates to be higher for two-tiered systems where both a paramedic and either an EMT or EMT-D were dispatched to calls, as compared to survival rates for one-tier systems where dispatches were exclusive for an EMT, EMT-D, or paramedic. This analysis also showed rates of survival to hospital discharge to be slightly higher for patients with a collapse rhythm of ventricular fibrillation, which suggested that the earlier CPR initiation possible in two-tier configurations was a primary means to the higher survival rates in these systems (Eisenberg et al., 1990).

In an article that plotted responses to an EMS system configuration survey against Code 3 ("lights and sirens") response times to emergency calls, investigators identified three different types of "two-tier" configurations. In the first two-tier system, ALS units responded to all calls but once on-scene could turn a patient over to a BLS unit for transport. In the second two-tier model, ALS units did not respond to all calls and BLS units could be sent for noncritical calls. In the final two-tier configuration, a non-transport ALS unit was dispatched with a transporting BLS unit with ALS personnel joining BLS personnel for transport on all ALS calls. After reviewing survey responses from EMS systems in 25 mid-sized cities with populations of 400,000 to 900,000, researchers suggested that a two-tier response system that permitted dispatch of BLS units for noncritical calls would allow a given number of ALS units to serve a much larger population while still maintaining rapid Code 3 response times (Braun et al, 1990).

The emergence of the "chain of survival" concept in the prehospital treatment of cardiac arrest merged the effectiveness of specific EMS interventions for individual patient characteristics and the level of qualification of staffing on emergency apparatus as standards of measurement within a system-wide scheme of performance evaluation. In a statement explaining the chain of survival and detailing its components, researchers argued that time to recognition of OHCA, EMS system activation, initiation of CPR, defibrillation, intubation, and intravenous administration of medications were successive, distinct factors that directly influenced outcomes of sudden cardiac arrest and should therefore be used inclusively as measurements of overall performance for EMS systems. The authors presented a thorough review of past literature and noted that while a small number of urban EMS systems approached the then-current practical limit for survivability from sudden cardiac arrest, most EMS systems in the U.S. and other countries had defects in their chain, as demonstrated by a near universal preponderance of poor resuscitation rates. This paper was notable for describing the research supporting each "link" in the chain or performance measurement of EMS system effectiveness and recommending specific actions to improve each area, thereby strengthening the chain of survival. Moreover, researchers suggested that communities implementing two-tier, double response systems might show optimal improvements in survival rates, as reports on EMT-D systems showed small response times but restricted intervention methods while ALS-only systems recorded longer response times with more advanced treatment options (Cummins et al, 1991).

Time-to-task measurements that have more recently been formulated into the "chain of survival" model for sudden cardiac arrest have been widely accepted as measurements of fire crews' performance. The continuous patient care and vigilant monitoring of vitals advocated in most EMS models are duties that multi-role firefighters are distinctly well-equipped to perform, especially in emergency situations requiring both fire suppression and emergency medical response. Critical thinking, strategic teamwork, and ongoing, immediate priority assessments during emergency situations are all skills taught and regularly instilled by training and routine evaluation for multi-role firefighters.

In light of the existing literature, there remain unanswered questions about the relationship between resource deployment levels, in terms of first responder crew size and EMS training levels, and the associated task performance during EMS incidents. For the first time, this study investigates the effects of varying crew configurations for first responders, the apparatus assignment of ALS personnel, and the number of ALS personnel on scene on the task completion for ALS level incidents. This study is also unique because of the array of stakeholders and technical advisors involved. All industry standards and safety protocols were followed, and robust research methods were used. The results and conclusions will directly inform the NFPA 1710 Technical Committee, who is responsible for developing industry standards associated with the deployment of fire suppression operations, emergency medical operations, and special operations to the public by career fire departments.

Purpose and Scope of the Study

This project systematically studies deployment of fire department-based EMS resources and the subsequent effect on the ability to provide an efficient and effective response. It will enable fire departments and city/county managers to make sound decisions regarding optimal resource allocation to meet service commitments using the results of scientifically based research. Specifically, the EMS field experiments provide quantitative data on the effects on varying crew size configurations, ALS personnel placement, and the number of ALS personnel available on ALS level incidents.

The first phase of the multiphase project was an extensive survey of more than 400 career and combination fire departments in the United States with the objective of optimizing a fire service leader's capability to deploy resources to prevent or mitigate adverse events that occur in risk- and hazard-filled environments. The results of this survey are not documented in this report, which is limited to the experimental phase of the project, but they will constitute significant input into future applications of the data presented in this document.

In order to address the primary research questions using realistic scenarios, the research was divided into three distinct, yet interconnected parts.

- Part 1- Time-to-task experiments related to gaining access to a patient and removing the patient from the incident scene.
- Part 2- Time-to-task experiments related to the care of a victim with multi-system trauma.
- Part 3- Time-to-task experiments related to the care of a victim with chest pain and witnessed cardiac arrest.

These parts included the most basic elements of an overall EMS response and included time for personnel to access the patient, conduct patient assessment, deliver on-scene patient care, package the patient, and remove the patient from the scene to a transport-capable vehicle.

The EMS portion of the Firefighter Safety and Deployment of Resources Study was designed to assess the labor aspect of an EMS incident necessary to ensure safe, effective, and efficient operations. While studies have shown a relationship between response time and efficiency of patient care intervention, this project has no direct measures. This study does however quantify the effects of first responder crew size and ALS trained personnel resources on time-to-task for EMS interventions. The applicability of the conclusions from this report to a large-scale hazardous or multiple-casualty event has not been assessed and should not be extrapolated from this report.

EMS protocols pertaining to the treatment and transport of patients vary by departments. For the purpose of this study, tasks were standardized by technical experts and individual times were recorded for each task. In real-world situations, as in this study, many of these can be performed simultaneously based on the number and training level of responding personnel. Attempts to generalize the results from these experiments to individual departments must take into account protocols and equipment that vary from those used in the experiments.

A Brief Overview of the EMS Response

Considering the setting and the circumstances of emergency medical care delivery, the prehospital 9-1-1 emergency care patient should be considered a distinct type of patient in the continuum of health care. These patients not only have medical needs, but they may also need simultaneous physical rescue, protection from the elements and the creation of a safe physical environment, as well as management of non-medical surrounding sociologic concerns (Pratt et al., 2007). Interdependent and coordinated activities of all personnel are required to meet the priority objectives.

NFPA 1710: *Standard on Fire Department Operations, Emergency Medical Operations, and Special Operations to the public by Career Fire Departments* specifies that the number of on-duty EMS providers must be sufficient relative to the level of EMS provided by the fire department, and be based on the minimum levels needed to provide patient care and member safety.[3] NFPA Standard 1710 also recommends that personnel deployed to ALS emergency responses include a minimum of two members trained at the emergency medical technician-basic level and two members trained at the emergency medical technician-paramedic level, arriving at the scene within the established time frame of two hundred and forty seconds (four minutes) or less for BLS units and four hundred and eighty seconds (eight minutes) or less for ALS units provided that a first-responder with Automated External Defibrillator (AED) or BLS unit arrived in two hundred forty seconds (four minutes) or less travel time, or at the minimum levels established by the authority having jurisdiction.[4]

During each EMS experiment, a first responder unit and an ambulance transport unit was dispatched to the scene. Crew size for the first responder unit and ALS configuration for both the first responder unit and ambulance transport unit were varied for purposes of the experiments. There were three specific scenarios to which personnel responded.

- Patient access and removal from incident site
- Systemic trauma/fall victim
- Chest pain/cardiac arrest

Important time intervals typically not measured by EMS systems are “time to patient access” and the “time to patient removal” intervals. These intervals include the time it takes personnel with equipment to locate and access the patient and the time it takes personnel to remove the patient and equipment from the incident scene to the ambulance for transport. These intervals are critically important to calculating overall scene time, particularly in scenarios where the patient is not immediately accessible (high-rise buildings, commercial complexes, schools, etc.).

The Star of Life

The elements comprising an EMS incident are symbolized by the Star of Life.[5] The six branches of the star are symbols of the six main tasks executed by rescuers throughout an emergency medical event.

Figure 1: The Star of Life

The six branches of the star include the elements listed below.

- Detection: Citizens must first recognize that an emergency exists and know how to contact the emergency response system in their community. This can be done using several different methods such as dialing 9-1-1, dialing a seven digit local emergency number, using amateur radios, or call boxes.

- Reporting: Upon accessing a call center, callers are asked for specific information so that the proper resources can be sent. In an ideal system, certified Emergency Medical Dispatchers (EMDs) ask a pre-defined set of questions. In this phase, dispatchers also become a link between the scene and the responding units and can provide additional information as it becomes available.

- Response: This branch identifies the response of emergency crews to the scene. The response may include an engine with firefighters trained as EMT’s followed by an ambulance carrying additional firefighter/EMT’s or it may be a fire engine first responder crew followed by an ambulance carrying single role EMS personnel.

- On scene care: Definitive care is provided on the scene by the emergency response personnel. Standing orders and radio or cellular contact with an emergency physician has broadened the range of on scene care that can be provided by EMS responders. A long algorithm of procedures and drugs may be used before the patient is removed from the scene.

- Care in Transit: Emergency personnel transport the patient to the closest appropriate medical care facility for definitive care. During transport, patient care/treatment is continued.

- Transfer to Definitive care: Emergency crews transfer the patient to the appropriate specialized care facility. Transfer includes providing a detailed written report of the patient assessment and care provided on-scene and in-transit.

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[3] NFPA 1710, Section 5.3.3.2.1: On duty EMS units shall be staffed with the minimum personnel necessary for emergency medical care relative to the level of EMS provided by the fire department.

[4] NFPA 1710, Section 5.3.3.3.4: Personnel deployed to ALS emergency responses shall include a minimum of two members trained at the emergency medical technician-paramedic level and two members trained at the emergency medical technician-basic level arriving on scene within the established travel time.

[5] Designed by Leo R. Schwartz, Chief of the EMS Branch, National Highway Traffic Safety Administration (NHTSA) in 1977.

EMS Response to Time Critical Events

In a statement explaining the chain of survival and detailing its components, researchers argued that time to recognition of OHCA, EMS system activation, initiation of CPR, defibrillation, intubation, and intravenous administration of medications were successive, distinct factors that directly influenced outcomes of sudden cardiac arrest and should therefore be used inclusively as measurements of overall performance for EMS systems. This paper was notable for describing the research supporting each "link" in the chain or performance measurement of EMS system effectiveness and recommending specific actions to improve each area, thereby strengthening the chain of survival (Cummins et al., 1991).

A typical EMS event, regardless of the nature of the incident, follows a basic script. The first arriving unit performs a scene size-up and initial life safety assessment. The crew then gathers the appropriate equipment from the unit based upon patient injury, illness and location, and accesses and treats the patient.

In an analysis of data from more than 300 U.S. Fire Departments, first responder units arrived prior to ambulances in approximately 80 % of responses (IAFC/IAFF 2005). This response capability is likely attributed to the strategic locations of fire stations housing the engines and the fact that engines are often more densely located than ambulance transport units. In some cases, as is the case with motor vehicles accidents with entrapment and some structural collapse incidents, initial responding personnel may need to perform patient treatment and stabilization while performing patient rescue. For these types of incidents, it is necessary to have additional personnel on scene to assist with patient care and removal from the incident scene.

However, even without these major impediments, additional crew members assist with patient care and movement. In the experiments, crew members were used to assist with patient treatment, packaging, removing the patient from the incident location to the ambulance transport unit, repositioning the ambulance transport unit, and other tasks that streamlined the on-scene activity.

The Relation of Time-to-Task Completion and Risk

Delayed response, combined with inadequate personnel resources exacerbates the likelihood of negative patient outcomes. While rapid response is critical to patient survival, the personnel who respond must also be highly competent in patient assessment and stabilizing treatment delivery.

Figure 2 illustrates a hypothetical sequence of events for response to a cardiac arrest (heart attack). A rapid response to an EMS incident is effective only if the personnel arriving on the scene can initiate appropriate emergency medical interventions. This requires adequate numbers of personnel, as well as appropriate equipment and prior training. Early advanced cardiac life support (ACLS) provided by paramedics at the scene is another critical link in the management of cardiac arrest. According to industry standards EMS systems should have sufficient staffing to provide a minimum of two rescuers trained in ACLS to respond to the emergency. However, because of the difficulties in treating cardiac arrest in the field, additional responders should be present (AHA, 2005).

The delivery of prehospital care is complex requiring both interpersonal and clinical skills. Firefighter/Paramedics must be able to communicate with patients, bystanders, on scene safety personnel, and hospital personnel. A lack of cooperation in any of these interactions could have a detrimental effect on the patient.

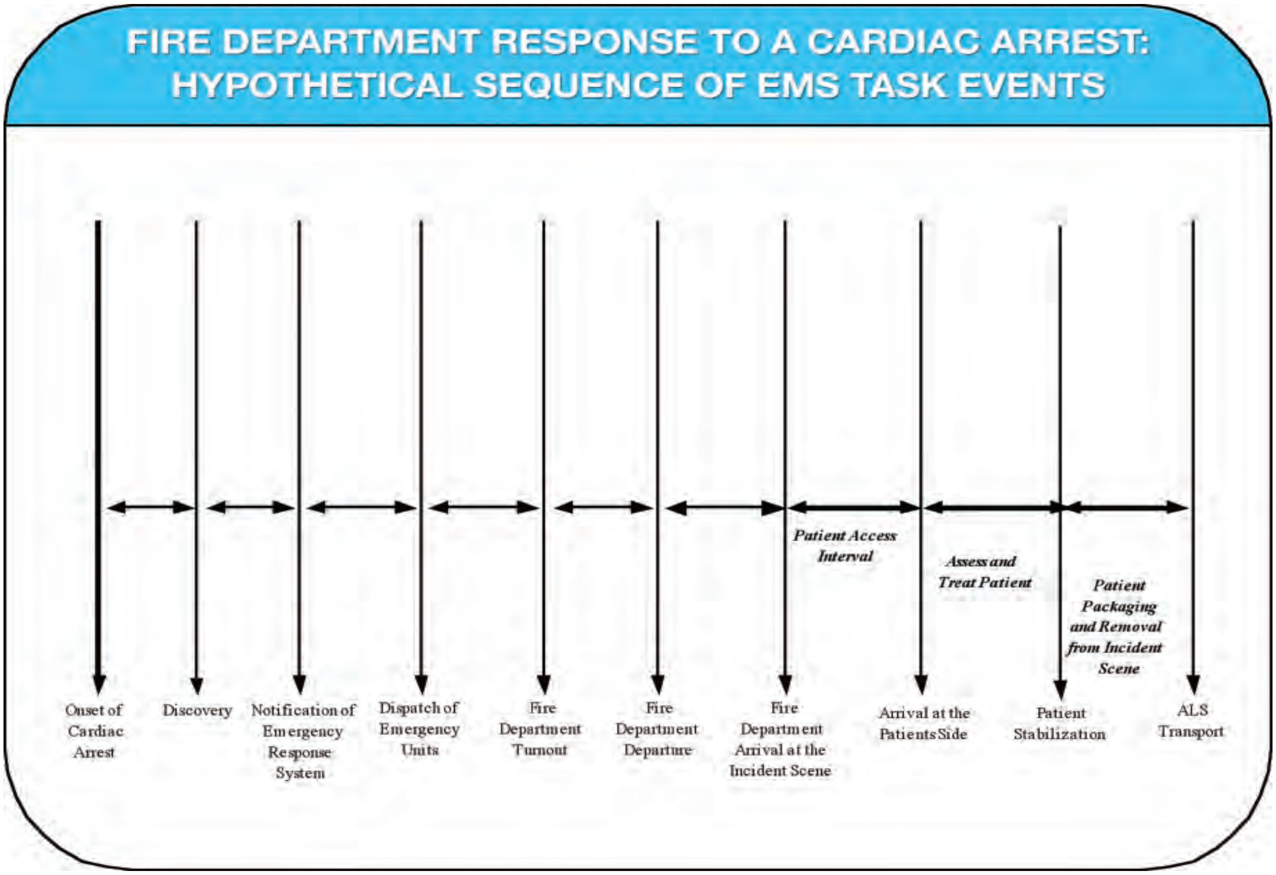

Figure 2: Hypothetical Timeline of a Fire Department Response to an EMS Incident

Standards of Response Cover

Developing a standard of response cover (SORC) related to service commitments to the community is a complex task. A SORC includes the policies and procedures that determine the distribution, concentration, and reliability of fixed and mobile resources for response to emergency medical incidents (CFAI, 2009). Fire departments that provide EMS must evaluate existing (or proposed) resources against identified risk levels in the community and against the tasks necessary to provide safe, efficient and effective emergency medical services. EMS risks that must be considered include population demographics such as socioeconomic status, age, ethnicity and health insurance status, as well as population density, community type (urban, suburban, or rural), access to healthcare, and traffic patterns and congestion. In addition to community risks, leaders must also evaluate geographic distribution and depth or concentration of resources deployed based on time parameters established by community expectation, state or local statute or industry standards.

Recognition and reporting of an emergency medical incident begins a chain of events that occur before firefighters arrive at the scene. These events include call receipt and processing, dispatch of resources, donning protective gear, and travel to the scene. NFPA 1710 defines the overall time from dispatch to the scene arrival as total response time. The standard divides total response time into a number of discrete segments, shown in Figure 2.

Arrival of emergency crews on scene is then followed by a sequence of tasks. Depending on the availability of resources available, tasks may be completed simultaneously or sequentially. Knowing the time it takes to accomplish each task with an allotted number of personnel and equipment can be useful in planning resource deployment. Ideally crews should arrive and intervene in sufficient time to prevent patient brain death, excessive blood loss, and minimize pain and suffering with the goal and expectation of transporting and delivering a viable patient to an appropriate medical facility.

Decision-making regarding staffing levels and geographic distribution of resources must also consider times when there are simultaneous events requiring multiple resource deployment into multiple areas of the jurisdiction. There should be sufficient redundancy or overlap in the system to allow for simultaneous incidents and high volume of near-simultaneous responses without compromising the safety of the patient, the public, or firefighters.

Policy makers have long lacked studies that quantify changes in EMS scene performance based on crew sizes and configuration. These experiments were designed to observe the impact of first responder crew size and ALS configuration on the time it takes to execute essential EMS tasks. It is expected that the results of this study will be used to inform the threshold performance objectives to the NFPA 1710 and 1720 Technical Committees.

Experiment Planning and Methodology

The EMS field experiments consisted of three distinct parts:

- Part 1- Time-to-task experiments related to gaining access to a patient and removing the patient from the incident scene.
- Part 2- Time-to-task experiments related to the care of a victim with multi-system trauma.
- Part 3- Time-to-task experiments related to the care of a victim with chest pain and witnessed cardiac arrest.

Following is a detailed description of the overall methods used throughout the experiments. Specific information pertaining to each part is presented separately.

The following research questions guided the experimental design of the EMS field experiments documented in this report:

- 1. What is the effect of first responder crew size on EMS task times?
- 2. What is the effect of ALS personnel placement on EMS task times?
- 3. What is the effect of the number of ALS trained personnel on EMS task times?

Department Participation

The experiments were conducted in Montgomery County, MD at the Montgomery County Public Safety Training Academy and in Fairfax County, VA at the EMS Simulation Center. Experiments took place during the months of April and May 2009. All experiments took place in daylight between 0800 hours and 1500 hours.

Montgomery County (MD) and Fairfax County (VA) firefighters and paramedics participated in the field experiments. Each day, both departments committed one ALS engine, one ALS ambulance and the associated crews. Firefighters and paramedics were identified and oriented to the experiments. Participants varied with regard to age and experience. The allocation of resources made it possible to conduct back-to-back experiments by rotating firefighters between field work and rehabilitation areas.

Crew Orientation

Daily orientations were conducted. Orientations included a description of the overall study objectives, as well as the actual experiments in which they would be involved. Crews were also oriented to the site layouts and specific scenarios to be conducted.

Cue Cards

Task procedures were standardized for each experiment/scenario. Technical experts worked with the study investigators to break down crew tasks based on crew size. Task flow charts were then created and customized for the various crew sizes. The carefully designed task flow ensured that the same overall workload was maintained in each experiment, but was redistributed based on the number of personnel available for work.

All tasks were included in each scenario and cue cards were developed for each individual participant in each scenario. For example, a four-person first responder crew would have a cue card for each person on the crew including the driver, officer, and two firefighter/EMTs or paramedics. Cards were color coded by crew size to ensure proper use in each scenario.

Tasks

Tasks were completed specific to each scenario (patient access and removal from incident scene, trauma, and cardiac). Meticulous procedures gathered data to measure key areas of focus such as individual start times, task completion times, and overall scenario performance times. Each task in each scenario was assigned a standardized start and end marker, such as retrieving the key from the Knox Box[6] or patient secured with straps to stretcher/cot. All tasks, with the events for measuring start and stop times, are shown in Table 3 through Table 5.

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[6] A Knox Box, known officially as the KNOX-BOX Rapid Entry System is a small, wall-mounted safe that holds building keys for firefighters and EMTs to retrieve in emergencies. Local fire companies can hold master keys to all such boxes in their response area, so that they can quickly enter a building without having to force entry or find individual keys held in deposit at the station.

On-Scene EMS Tasks

The on-scene tasks focused on the activities firefighters perform after they arrive on the scene of an emergency medical incident. A number of nationally recognized EMS experts were consulted during the development of the on scene EMS tasks in order to ensure a broad applicability and appropriateness of task distribution.[7] The experiments compared crew performance and workload for typical medical response scenarios using two-, three-, and four-person first responder crews, along with a two-person ambulance crew. In total, 102 experiments were conducted to assess the time it took various crew configurations to complete the overall tasks in Parts 1, 2, and 3. In addition to first responder crew sizes, the experiments assessed the time necessary to access the patient, conduct a patient assessment, deliver on scene patient care, package the patient, and remove the patient from the incident scene to the ambulance. Two scenarios were selected as the basis of Parts 2 and 3. The scenarios included a patient with systemic trauma and a patient with chest pains leading to cardiac arrest.

The experiments also assessed the placement and number of responding ALS-trained personnel. There were 15 crew configurations considered during the experiments. These included the first responder crew being varied from two-, three-, and four-person crews. Additionally, the first responder crew configuration was varied to include either an all BLS crew or a combination crew containing one firefighter trained at the ALS level. The ambulance crew was held constant at two-persons. However, the ambulance crew configuration was varied to include two BLS crew members, one BLS and one ALS crew member, or two ALS crew members. Table 1 shows the crew configurations used throughout the experiments.

During the experiment crews dispatched to various scenarios included a first responder crew and ambulance transport unit or a single ambulance transport unit. For those experiments where both an engine company and an ambulance were dispatched, a three-minute stagger time was imposed for each of those trials. The three minute stagger time was determined from an analysis of deployment data from more than 300 fire departments responding to a survey of fire department operations conducted by the IAFC and the IAFF (2005). Each experiment containing a specific crew configuration was conducted in triplicate and completed in a randomized order (determined by randomization software) before a test configuration was repeated.

First Responder Engine Company	Ambulance Transport Unit	ALS Personnel On-Scene	Total Personnel On-Scene
N/A	2 BLS	0	2
N/A	2 ALS	2	2
N/A	1 BLS/1 ALS	1	2
2 BLS	2 ALS	2	4
3 BLS	2 ALS	2	5
4 BLS	2 ALS	2	6
1 BLS/1 ALS	1 BLS/1 ALS	2	4
2 BLS/1 ALS	1 BLS/1 ALS	2	5
3 BLS/1 ALS	1 BLS/1 ALS	2	6
2 BLS	1 BLS/1 ALS	1	4
3 BLS	1 BLS/1 ALS	1	5
4 BLS	1 BLS/1 ALS	1	6
1 BLS/1 ALS	2 BLS	1	4
2 BLS/1 ALS	2 BLS	1	5
3 BLS/1 ALS	2 BLS	1	6

Table 1: Crew Configurations for Time-to-Task Experiments

Radio Communication

Interoperability of radio equipment used by both participating departments made it possible to use regular duty radios for communication during the experiments. Company officers were instructed to use radios as they would in an actual incident. Montgomery County Fire and Rescue Communications recorded all radio interaction as a means of data backup. Once all data quality control measures were complete, the records were then overwritten as a routine procedure.

Task Timers

Ten observers/timers, trained in the use of identical standard stop watches with split-time feature, recorded time-to-task data for each field experiment. To assure understanding on the observed tasks, firefighters were used as timers, each assigned to specific tasks to observe and record the start and end times.

To enhance accuracy and consistency during recording times, the data recording sheets used several different colors for the tasks (see Appendix A). Each timer was assigned tasks that were coded in the same color as the recording sheet. All timers wore high-visibility safety gear on the incident scene.

Video records

In addition to the timers, video documentation provided a backup for timed tasks and for quality control. Cameras were used to record EMS scene activity from varied vantage points. Observer/timer data were compared to video records as part of the quality control process.

Crew Assignment

Crews from each department that regularly operated together were assigned to work as either a first responder crew or ambulance transport crew in each scenario. Both Fairfax County and Montgomery County crews participated in the experiment.

Crews assigned to each responding company position in one scenario were assigned to another responding company position in subsequent scenarios, with the objective of minimizing learning from one experiment to another. For example, crews in the role of first responder in the morning scenario might be assigned to the ambulance transport crew in the afternoon, thus eliminating learning the exact repetition of a task as a factor in time to completion. Additionally, participating crews from both Montgomery County and Fairfax County were from three different shifts, further reducing opportunities for participant repetition in any one position.

Props

Crews were assigned specific equipment lists to bring for this scenario. All equipment used was actual working equipment from the units assigned to the scenario. Specific items included in all scenarios were an airway bag, medical bag, oxygen cylinder, ECG monitor defibrillator, cot, and clipboard. Items specific to a particular scenario will be listed in that section of the report, including manikins and a live individual acting as a patient.

---

[7] Technical experts included Greg Mears, Michael McAdams, and Philip Pommerening. More information about the experts is presented in the Acknowledgements later in this report.

Safety Protocols

Participant safety was a primary concern in conducting the experiments. All participants and experiments complied with guidelines and recommendations as outlined in NFPA 450: *Guide for Emergency Medical Services and Systems*, NFPA 1500: *Standard on Fire Department Occupational Safety and Health Program*, and NFPA 1999: *Standard on Protective Clothing for Emergency Medical Operations*.

Figure 3: Safety Officer

A safety officer from the Montgomery County Fire and Rescue Department was assigned to oversee all experiments.

The safety officer ensured all protocols concerning participant safety, under both real and experimental conditions were followed. This included wearing the correct personal protective equipment, vehicle maneuvering, and overall scene safety. The safety officer participated in all orientation activities and daily briefings. The safety officer had full authority to terminate any operation if any safety violation was observed. Radio communication was always available.

A closely related concern to firefighter safety and readiness to repeat experiments with equivalent performance was adequate rehabilitation. Each "team" of participants had ample time between experiments to rest and rehydrate.

Response Time Assumptions

Response time assumptions were made based on time objectives set forth in NFPA 1710. Time stagger allocations were set by project technical advisors in order to assess the impact of arriving unit time separation on task start and completion times, as well as overall scene time. Table 2 shows the values assigned to the various segments in overall response time.

Event Occurrence = time zero

60 seconds for recognition and call to 9-1-1

90 seconds for call processing and dispatch

60 seconds for responder turnout

Travel time = first responder engine = 420 seconds post event

Ambulance = 600 seconds post event

Table 2: Response Time Assumptions

Figure 4: Ascending Stairs to Access Patient

Figure 5: Carrying Patient Using Stair Chair

Figure 6: Trauma Patient Assessment

Figure 7: Trauma Patient Spinal Immobilization

Figure 8: Trauma Patient Packaging

Figure 9: Loading Patient on to Stretcher for Transport

Figure 10: Cardiac Patient Assessment

Figure 11: Cardiac Patient Intubation

Figure 12: Cardiac Patient I.V. & Medication Admin.

Figure 13: Moving Patient for Transport

Part 1: Patient Access and Removal from Incident Scene

Historically, total response time has been measured from the time a responding unit leaves a fire station until the time the unit arrives at the incident location. However, some studies suggest that total response time should include the additional time to locate and access the patient. Previous studies have shown a substantial time difference between the time the first responder arrives on scene and the time of patient access. One study noted that the patient access time interval represented 24 % of the total EMS response time interval among calls originating less than three floors above or three floors below ground and 32 % of those located three or more stories above ground (Morrison et al., 2005).

This study quantifies the time interval from arrival at the incident address until the crew begins the patient assessment, known as "at patient arrival time." The experiment assumed the patient was on the 3rd floor of a garden style apartment complex with stair access. This is representative of a typical structure to which firefighters respond in many residential neighborhoods. Patient assessment and treatment were not performed during the patient access and removal experiment. The primary purpose of this part of the experiment was to ascertain patient access and removal times. This part of the experiment was conducted separately from the patient care scenarios in an effort to establish distinctive timelines for patient access and removal separate from the patient care scenarios where on scene time can vary widely based on patient illness or injury.

Incident Scene

Garden Apartment Complex Scenario:

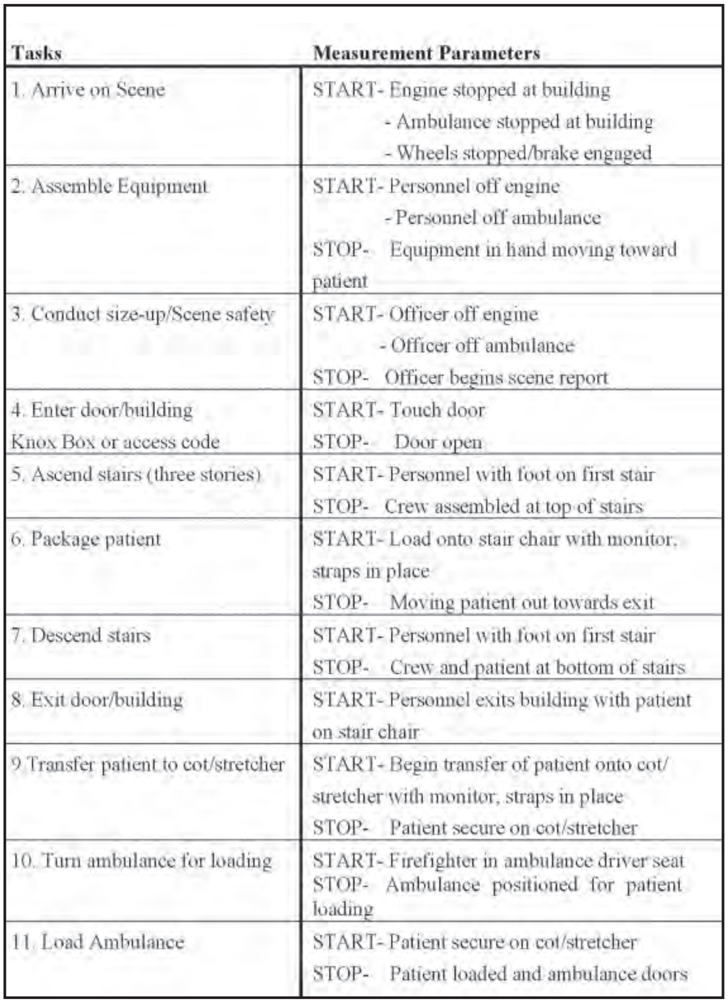
Firefighters from Fairfax County (VA) and Montgomery County (MD) simulated an initial EMS response for a patient with difficulty breathing in a garden style apartment building, represented by Simulation Lab #1 on the grounds of the Montgomery County Safety Training Academy in Rockville, MD. Simulation Lab #1 is a seven-story building, consisting of concrete scissor stairwells leading to the top floor of the building. The front of the building was equipped with a Knox Box, which firefighters accessed before entering the building. This task was typical of security access at any apartment complex.

Apparatus and crews were staged approximately 500 ft (150 m) from the Montgomery County Simulation Lab #1. Apparatus responded to the incident location, personnel dismounted and assembled equipment. Equipment included a defibrillator, airway bag, oxygen, and drug bag. Additionally, ambulance crews were required to bring the stair chair for patient packaging and removal. A crew member obtained an access key from the Knox Box and gained entry. Once crews entered the building they proceeded with the equipment to locate the patient on the third floor stairwell landing.

Patient assessment and treatment were not performed in this part of the experiments. In each experiment, the patient was packaged onto a stair chair, and then the patient and equipment were carried down three flights of stairs and out of the building. The patient was then transferred to a stretcher and loaded into the ambulance for transport.

Tasks

Tasks for the garden apartment scenario for patient access and removal are delineated in Table 3.



Tasks	Measurement Parameters
1. Arrive on Scene	START- Engine stopped at building - Ambulance stopped at building - Wheels stopped/brake engaged
2. Assemble Equipment	START- Personnel off engine - Personnel off ambulance STOP- Equipment in hand moving toward patient
3. Conduct size-up/Scene safety	START- Officer off engine - Officer off ambulance STOP- Officer begins scene report
4. Enter door/building Knox Box or access code	START- Touch door STOP- Door open
5. Ascend stairs (three stories)	START- Personnel with foot on first stair STOP- Crew assembled at top of stairs
6. Package patient	START- Load onto stair chair with monitor, straps in place STOP- Moving patient out towards exit
7. Descend stairs	START- Personnel with foot on first stair STOP- Crew and patient at bottom of stairs
8. Exit door/building	START- Personnel exits building with patient on stair chair
9 Transfer patient to cot/stretcher	START- Begin transfer of patient onto cot/ stretcher with monitor, straps in place STOP- Patient secure on cot/stretcher
10. Turn ambulance for loading	START- Firefighter in ambulance driver seat STOP- Ambulance positioned for patient loading
11. Load Ambulance	START- Patient secure on cot/stretcher STOP- Patient loaded and ambulance doors

Table 3: Time-to-Task Measures for Garden Apartment Scenario/Patient Access and Removal

Part 2: Trauma Patient

The trauma scenario involved time-to-task experiments focusing on a labor intensive traumatic scenario. In the experiment, a patient had fallen from a 25 ft (7.5 m) ladder at a construction site. This part of the experiment quantified the time intervals for different crew sizes and configurations responding to this event.

Incident Scene

The gymnasium at the Montgomery County (MD) Public Safety Training Academy was used for the trauma experiments. A classroom at the facility was also used for crew orientation and staging. Prior to the start of the experiments, participants were provided with the scenario background. Specifically, the call originated from a construction site that was only accessible by foot.

When cued, crews entered the gym and walked approximately 40 ft (12 m), carrying an airway bag (including suction), oxygen, spinal mobilization equipment, a trauma bag, and a radio and clip board. The "patient" was a 150 lb (68 kg) training manikin "voiced" when prompted by one of the timers. The patient could answer basic questions until the point in the sequence where the patient lost consciousness. During the scenario, when it became clear that the patient needed to be transported, a backboard was brought into the scene by the ambulance crew. After packaging the patient onto a backboard, the patient and equipment were carried out of the construction site to a waiting stretcher approximately 40 ft (12 m) away.

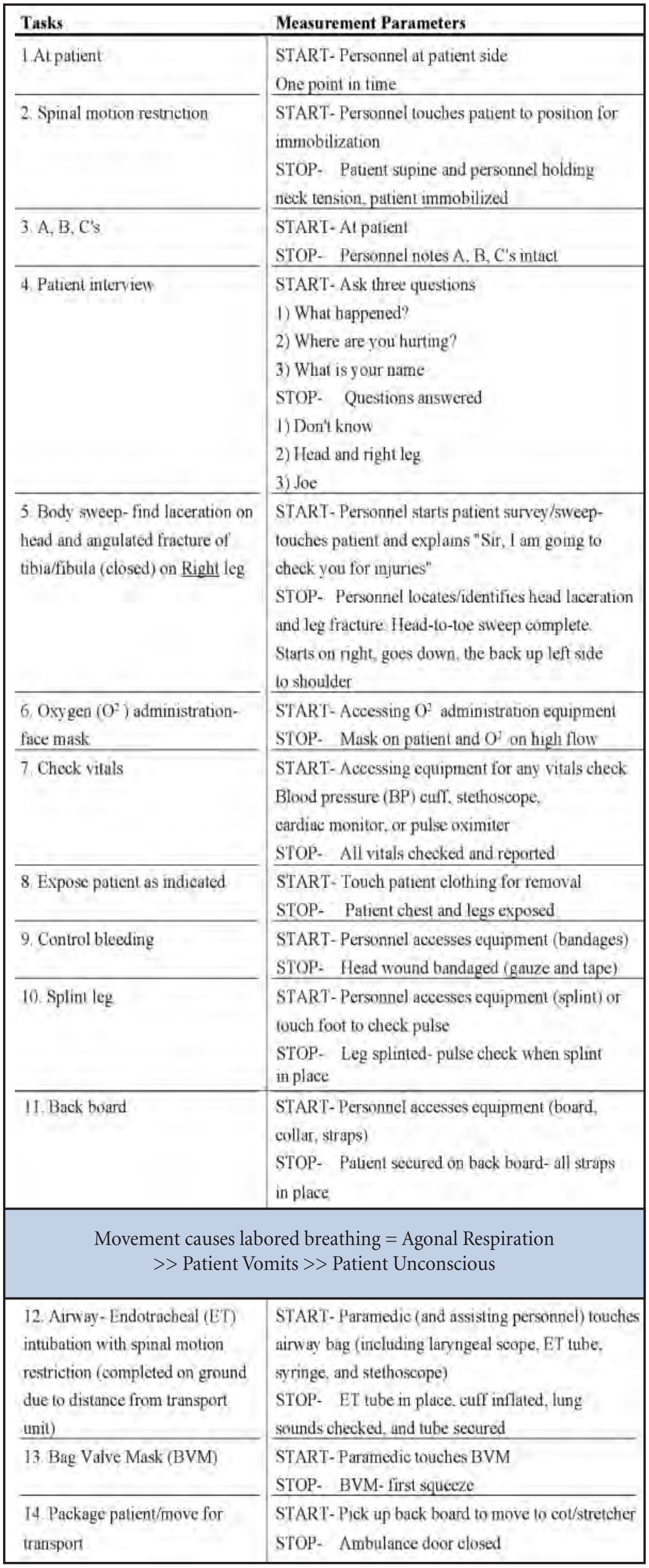
Tasks

The on-scene tasks focused on the activities firefighters regularly perform after they arrive on the scene of a patient with a traumatic injury. The experiments compared time-to-task performance based on varying crew sizes and ALS configurations.

Forty-five trauma experiments were conducted to assess the time it took various crew sizes and ALS configurations to complete the assigned tasks. Time between arrival of the first responding unit and ambulance transport unit was held constant at three minutes.

The following narrative describes the general sequence of activities in Part 2 of the experiments.

> The first responding unit arrived, conducted a size-up and initial life safety assessment of the area, and gathered the appropriate equipment. The crew, with equipment, then proceeded into the construction site and located the patient. The patient was lying supine on the ground. The responders introduced themselves, obtained patient consent to examine and treat, and immediately initiated cervical spinal immobilization precautions and the patient interview. Other crew members then followed Airway, Breathing, and Circulation (A, B, C's) protocols. During the patient assessment, it was revealed the patient had a head laceration and an angulated fracture of the tibia/fibula (closed) on the right leg. Patient information was recorded on a standardized form created for the experiments and can be seen in Appendix B.
>
> During the scenario, when the backboard straps were secure, the patient went into respiratory arrest. Crews then rechecked vital signs which revealed the patient had stopped breathing. The crew immediately began respiratory arrest protocol including administering a patent patient airway using an endotracheal tube. Intubation was performed using strict spinal immobilization restriction. With the airway established, the patient was then ventilated using a bag-valve-mask and patient packaging was completed. Crews then carried the patient and all equipment out of the construction site to the waiting stretcher.



Tasks	Measurement Parameters
1. At patient	START- Personnel at patient side One point in time
2. Spinal motion restriction	START- Personnel touches patient to position for immobilization STOP- Patient supine and personnel holding neck tension, patient immobilized
3. A, B, C's	START- At patient STOP- Personnel notes A, B, C's intact
4. Patient interview	START- Ask three questions 1) What happened? 2) Where are you hurting? 3) What is your name STOP- Questions answered 1) Don't know 2) Head and right leg 3) Joe
5. Body sweep- find laceration on head and angulated fracture of tibia/fibula (closed) on Right leg	START- Personnel starts patient survey/sweep- touches patient and explains "Sir, I am going to check you for injuries" STOP- Personnel locates/identifies head laceration and leg fracture. Head-to-toe sweep complete. Starts on right, goes down, the back up left side to shoulder
6. Oxygen (O^2) administration- face mask	START- Accessing O^2 administration equipment STOP- Mask on patient and O^2 on high flow
7. Check vitals	START- Accessing equipment for any vitals check Blood pressure (BP) cuff, stethoscope, cardiac monitor, or pulse oximiter STOP- All vitals checked and reported
8. Expose patient as indicated	START- Touch patient clothing for removal STOP- Patient chest and legs exposed
9. Control bleeding	START- Personnel accesses equipment (bandages) STOP- Head wound bandaged (gauze and tape)
10. Splint leg	START- Personnel accesses equipment (splint) or touch foot to check pulse STOP- Leg splinted- pulse check when splint in place
11. Back board	START- Personnel accesses equipment (board, collar, straps) STOP- Patient secured on back board- all straps in place
Movement causes labored breathing = Agonal Respiration >> Patient Vomits >> Patient Unconscious	
12. Airway- Endotracheal (ET) intubation with spinal motion restriction (completed on ground due to distance from transport unit)	START- Paramedic (and assisting personnel) touches airway bag (including laryngeal scope, ET tube, syringe, and stethoscope) STOP- ET tube in place, cuff inflated, lung sounds checked, and tube secured
13. Bag Valve Mask (BVM)	START- Paramedic touches BVM STOP- BVM- first squeeze
14. Package patient/move for transport	START- Pick up back board to move to cot/stretcher STOP- Ambulance door closed

Table 4: Time-to-Task Measures for Trauma Scenerio

Fourteen tasks were completed in the trauma experiments. Meticulous procedures gathered data to measure key areas of focus, such as individual task start times, task completion times, and overall scenario performance times. Each task was assigned a standardized start and end marker, such as accessing oxygen equipment (start) until the mask was on the patient and oxygen was flowing (stop). The 14 tasks can be seen in Table 4.

Part 3: Cardiac Patient

The cardiac scenario involved time-to-task experiments focusing on a labor-intensive medical event, i.e., a patient that experiences a myocardial infarction leading to cardiac arrest. This part of the experiment quantified the time intervals for different crew sizes and ALS configurations responding to the event.

Incident Scene

The cardiac experiments were conducted in a laboratory at the Fairfax County Fire and Rescue Department EMS Simulation Center. The Simulation Center houses classrooms, laboratories, and offices for training of EMT's and paramedics. Assorted furniture was staged in the laboratory to duplicate a "home" setting. When cued, crews entered the room and proceeded approximately 10 ft (3 m) to the patient. The patient was represented by SimMan® by Laerdal. SimMan® is an adult-sized manikin that can produce vital signs including, a pulse, heartbeat, lung sounds, blood pressure and other signs noted in real humans. SimMan® also had vocal capabilities such as speaking or crying (Laerdal, 2010). SimMan® was operated remotely from a control booth adjacent to the laboratory.

Prior to the start of the experiments, participants were provided with the scenario background. Specifically, the call originated from a private residence and the caller complained of chest pain. Responders entered the room carrying an airway bag, oxygen, drug bag, and defibrillator. The defibrillator was either an AED and/or a 12-Lead ECG model defibrillator dependent upon the arrival of ALS trained personnel. During the scenario, the patient went into cardiac arrest on cue and crews reacted by changing their path of patient care for chest pain to a more time-critical path of treatment for a pulseless, apneic patient. When crews had completed on-scene patient care tasks, the patient was packaged onto a backboard and stretcher. The patient and all equipment were removed from the room to conclude the experiment.

Tasks

As noted previously, the on-scene tasks focused on the activities firefighters perform after they arrive on the scene of a patient with a cardiac emergency. The experiments compared crew performance for a typical cardiac scenario using a combination of varying crew sizes and configurations.

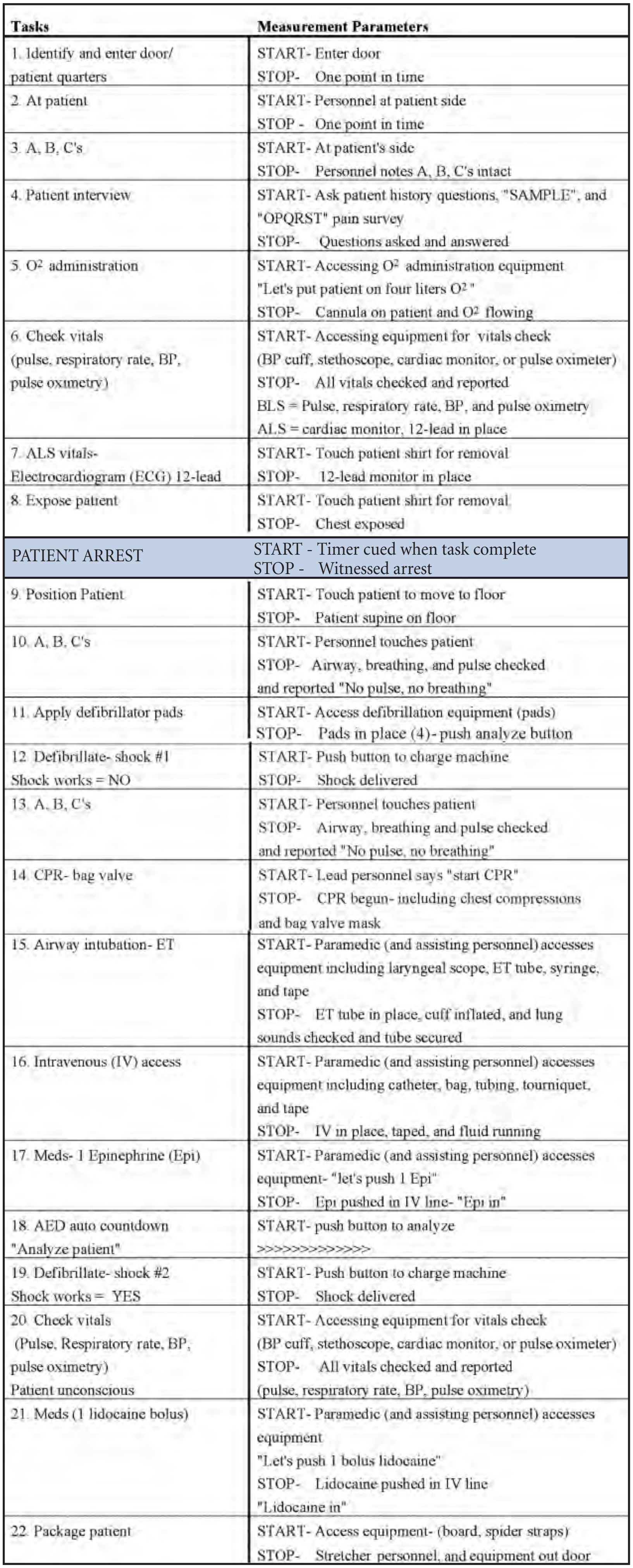
Forty-five cardiac experiments were conducted to assess the time it took various crew sizes and configurations to complete the assigned tasks. Time between arrival of the first responding unit and ambulance transport unit was held constant at three minutes.

The following narrative describes the general sequence of activities in Part 3 of the experiments.

> The first responding unit arrived, conducted a size-up and initial life safety assessment of the building and gathered the appropriate equipment. The crew, with equipment, then proceeded to the front door of the patient residence, knocked, and entered. After confirming the scene was safe, patient assessment was begun.
>
> The responders introduced themselves, obtained the patient's consent to examine and treat and then proceeded to conduct the patient interview. The patient interview was standardized to include SAMPLE and OPQRST protocols. Patient information was recorded on a standardized form created for the experiments and can be seen in Appendix C.
>
> During the scenario, on cue, the patient went into cardiac arrest. Upon patient arrest, the crew rechecked the patient's vital signs which revealed the patient had stopped breathing and had no pulse.
>
> The crew then followed protocol and moved the patient to the floor where they could immediately begin CPR and prepare to administer defibrillation. Study protocol then followed Advanced Cardiac Life Support guidelines for patient care (AHA, 2005).

Twenty-two tasks were completed in the cardiac experiments. Meticulous procedures gathered data to measure key areas of focus, such as individual task start times, task completion times, and overall scenario performance times. Each task was assigned a standardized start and end marker, such as accessing oxygen tank equipment (start) until the mask was on patient and oxygen was flowing (stop). The 22 tasks can be seen in Table 5.

Table 5: Time-to-Task Measures for Cardiac Scenerio



Tasks	Measurement Parameters
1. Identify and enter door/ patient quarters	START- Enter door STOP- One point in time
2. At patient	START- Personnel at patient side STOP - One point in time
3. A, B, C's	START- At patient's side STOP- Personnel notes A, B, C's intact
4. Patient interview	START- Ask patient history questions, "SAMPLE", and "OPQRST" pain survey STOP- Questions asked and answered
5. O² administration	START- Accessing O² administration equipment "Let's put patient on four liters O²" STOP- Cannula on patient and O² flowing
6. Check vitals (pulse, respiratory rate, BP, pulse oximetry)	START- Accessing equipment for vitals check (BP cuff, stethoscope, cardiac monitor, or pulse oximeter) STOP- All vitals checked and reported BLS = Pulse, respiratory rate, BP, and pulse oximetry ALS = cardiac monitor, 12-lead in place
7. ALS vitals- Electrocardiogram (ECG) 12-lead	START- Touch patient shirt for removal STOP- 12-lead monitor in place
8. Expose patient	START- Touch patient shirt for removal STOP- Chest exposed
PATIENT ARREST	START - Timer cued when task complete STOP - Witnessed arrest
9. Position Patient	START- Touch patient to move to floor STOP- Patient supine on floor
10. A, B, C's	START- Personnel touches patient STOP- Airway, breathing, and pulse checked and reported "No pulse, no breathing"
11. Apply defibrillator pads	START- Access defibrillation equipment (pads) STOP- Pads in place (4)- push analyze button
12. Defibrillate- shock #1 Shock works = NO	START- Push button to charge machine STOP- Shock delivered
13. A, B, C's	START- Personnel touches patient STOP- Airway, breathing and pulse checked and reported "No pulse, no breathing"
14. CPR- bag valve	START- Lead personnel says "start CPR" STOP- CPR begun- including chest compressions and bag valve mask
15. Airway intubation- ET	START- Paramedic (and assisting personnel) accesses equipment including laryngeal scope, ET tube, syringe, and tape STOP- ET tube in place, cuff inflated, and lung sounds checked and tube secured
16. Intravenous (IV) access	START- Paramedic (and assisting personnel) accesses equipment including catheter, bag, tubing, tourniquet, and tape STOP- IV in place, taped, and fluid running
17. Meds- 1 Epinephrine (Epi)	START- Paramedic (and assisting personnel) accesses equipment- "let's push 1 Epi" STOP- Epi pushed in IV line- "Epi in"
18. AED auto countdown "Analyze patient"	START- push button to analyze >>>>>>>>>>>>>
19. Defibrillate- shock #2 Shock works = YES	START- Push button to charge machine STOP- Shock delivered
20. Check vitals (Pulse, Respiratory rate, BP, pulse oximetry) Patient unconscious	START- Accessing equipment for vitals check (BP cuff, stethoscope, cardiac monitor, or pulse oximeter) STOP- All vitals checked and reported (pulse, respiratory rate, BP, pulse oximetry)
21. Meds (1 lidocaine bolus)	START- Paramedic (and assisting personnel) accesses equipment "Let's push 1 bolus lidocaine" STOP- Lidocaine pushed in IV line "Lidocaine in"
22. Package patient	START- Access equipment- (board, spider straps) STOP- Stretcher personnel, and equipment out door

Analysis of Experimental Results

This section describes the analytic approaches used to address the research objectives of the study. The statistical methods used to analyze the EMS time-to-task observations are presented. Then the time-to-task results are reported for EMS responses in three scenarios:

- access and removal of patient;
- a trauma event; and
- a cardiac event.

Time-to-Task Analysis

Time-to-task data were compiled into a database and assessed for outliers and missing entries. As is common in a repeated experiment with many pieces of data to be entered, occasionally data elements were not collected. Missing data occurred in less than 1 % of timing observations. Such instances were reviewed via video and/or radio tapes. Missing data attributable to timer error were replaced by the time observed in the video. Where video and/or radio documentation proved inadequate, missing data were imputed with the mean of the observed corresponding task times from the other two experiments. The extremely low occurrence of missing data and associated imputation should have a negligible impact on the statistical findings in the analyses.

Data Queries

The statistical methods used to analyze the time-to-task data were driven by the principal goals of this research project —- to assess the effect of crew size, ALS placement on the responding crews, and the number of ALS trained personnel in the crew configuration on time-to-task for critical steps in each EMS scenario. The research goal motivated the development of four specific research questions (see Figure 14) that in turn pointed to specific statistical analyses to generate inference and insight.

TIME-TO-TASK RESEARCH QUESTIONS

For Response Access & Removal:

1. What are the effects of first responder crew size regardless of ALS placement with respect to:

    a. reaching a patient?
    b. removing a patient after packaging?

For Cardiac and Trauma Scenarios (task timings measured between *arrival at patient* to the *completion of patient packaging*):

1. What is the effect of crew size on EMS task times?

2. What is the effect of ALS personnel placement on EMS task times?

3. What is the effect of the number of ALS trained personnel on EMS task times?

Figure 14: Research Questions for Time-to-Task Experiments

Statistical Methods

The analysis of the time-to-task data involved a sequence of ordinary least squares regression models. The models relate the *experimental outcomes* (i.e., various measures of time — start time, completion time, or duration of the task) to *key dimensions* for each scenario as follows:

For Access and Removal:

- first responder crew size (regardless of ALS placement), and
- ambulance-only versus ambulance with first responder engine with varying crew sizes.

For Trauma and Cardiac scenarios:

- presence of an engine at the scene,
- crew size on the first responder engine, and
- placement and number of ALS personnel (on the engine, on the ambulance, or both).

To account for these dimensions in the analyses, indicator variables representing each key dimension were employed. For example, for the trauma and cardiac scenarios there were indicators for the number of first responders on the engine, three indicators of the assignment of ALS personnel to the ambulance or engine, and indicators for the "no engine" scenarios.

Using these indicators, sets of regression equations were developed for the analysis of each scenario. Indicators corresponding to the three scenarios and multiple dimensions listed above were included. For example, when an engine was sent, the number of first responders (two, three, or four) assigned to the engine were varied, as well as the placement of ALS personnel (one ALS on the engine only; one on the ambulance only; two on the ambulance; and one ALS each on the ambulance and engine). When no engine was sent, zero, one, or two ALS personnel were placed on the ambulance.

The regression equations took the form:

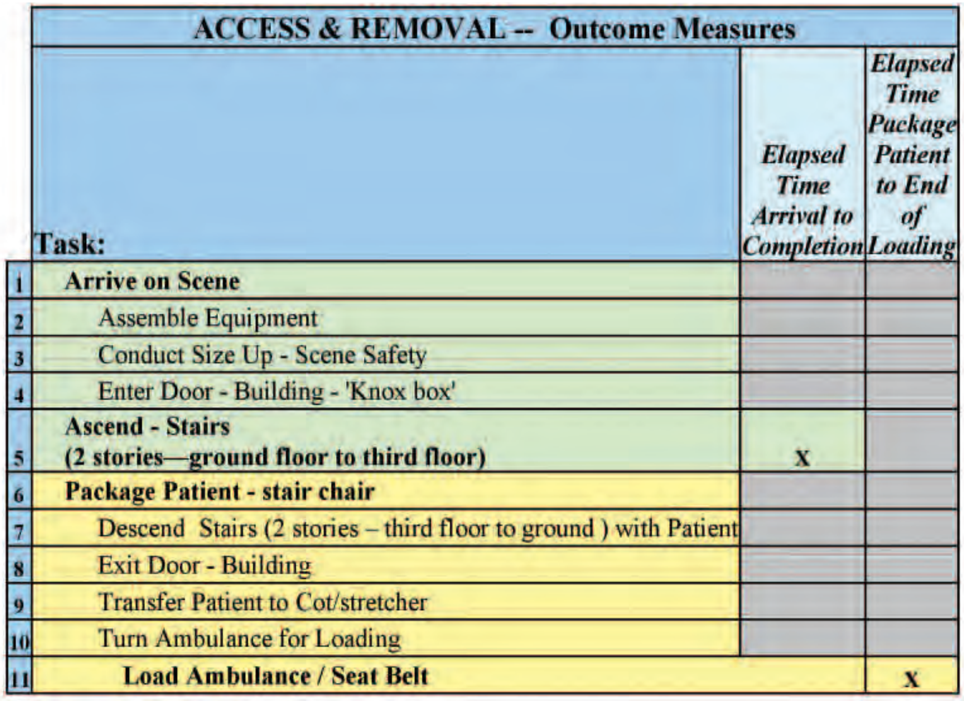
$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_k x_{ik} + \varepsilon_i$$

Where the x_k represented the test conditions such as presence of an engine or placement of ALS personnel, and the dependent variable y represents the observed outcome (e.g., task duration).

The model coefficients from the completed regressions provided direct estimates of the change in time associated with the number of first responders (e.g., four versus two, three versus two), as well as the change in time associated with alternative assignments of ALS personnel. These estimates are generally the same as those obtained by comparing the difference in means across groups. However, for a small number of outcomes, the estimates differ from those obtained using difference in means by appropriately accounting for data that are missing in particular scenarios.

Table 6 to Table 8 present the list of time-related outcomes that were used to explore effects on outcomes for patient access/removal, as well as for cardiac and trauma scenarios, respectively. Not all tasks were subjected to testing for this report. Only substantively critical milestones in the task sequence were considered. For instance, the *assembly of equipment* and *conduct* *of size*-up were **not** assessed for the Access and Removal scenario. Instead, the elapsed time from arrival on scene to reaching the patient (as denoted by completing the ascent of stairs) was determined to be of primary importance. Similarly, the elapsed time between packaging patient and the completion of loading the ambulance was assessed rather than individual timings of any task in the sequence between these two major milestones. Similar judicious choices of critical milestones were made in the assessments of trauma and cardiac, and these are depicted in the outcome measures tables.

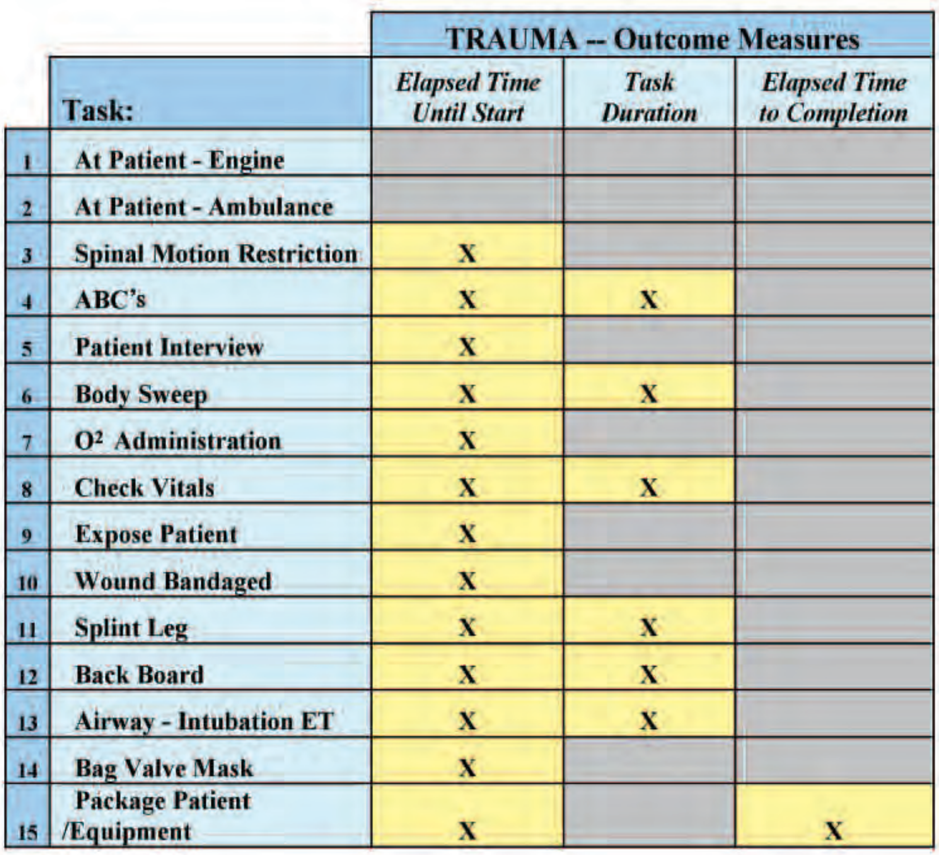
Although several of the analytic questions of interest can be obtained directly from the model, others require a linear combination of the coefficients. The statistical software (Stata) calculates both the desired combination of coefficients and the measure of statistical significance via t-test.



ACCESS & REMOVAL -- Outcome Measures

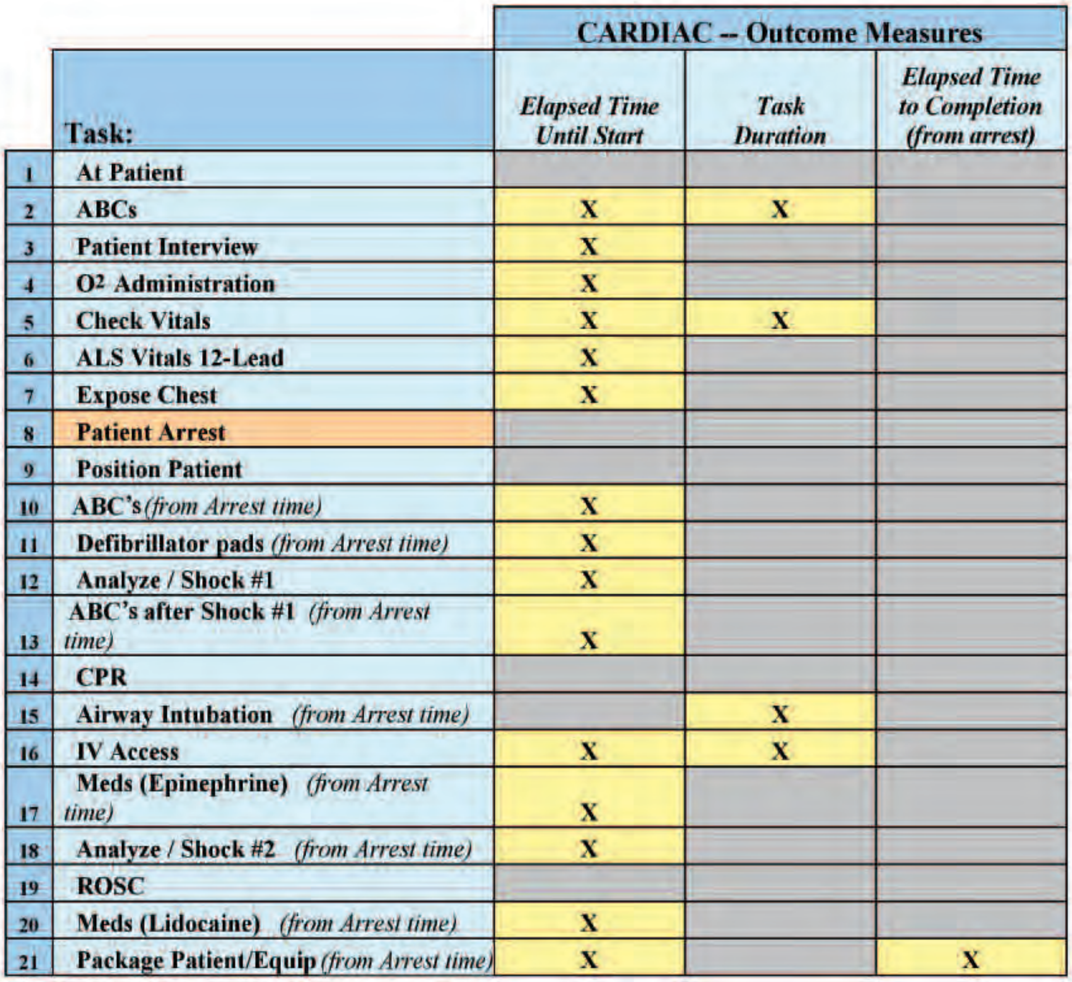
	Task:	***Elapsed Time Arrival to Completion***	***Elapsed Time Package Patient to End of Loading***
1	**Arrive on Scene**		
2	Assemble Equipment		
3	Conduct Size Up - Scene Safety		
4	Enter Door - Building - 'Knox box'		
5	**Ascend - Stairs (2 stories—ground floor to third floor)**	x	
6	**Package Patient - stair chair**		
7	Descend Stairs (2 stories – third floor to ground) with Patient		
8	Exit Door - Building		
9	Transfer Patient to Cot/stretcher		
10	Turn Ambulance for Loading		
11	**Load Ambulance / Seat Belt**		x

Table 6: Outcome Measures for Access and Removal Scenario by Task



		TRAUMA -- Outcome Measures		
	Task:	*Elapsed Time Until Start*	*Task Duration*	*Elapsed Time to Completion*
1	At Patient - Engine			
2	At Patient - Ambulance			
3	Spinal Motion Restriction	X		
4	ABC's	X	X	
5	Patient Interview	X		
6	Body Sweep	X	X	
7	O^2 Administration	X		
8	Check Vitals	X	X	
9	Expose Patient	X		
10	Wound Bandaged	X		
11	Splint Leg	X	X	
12	Back Board	X	X	
13	Airway - Intubation ET	X	X	
14	Bag Valve Mask	X		
15	Package Patient /Equipment	X		X

Table 7: Outcome Measures for Trauma Scenario by Task



		CARDIAC -- Outcome Measures		
	Task:	*Elapsed Time Until Start*	*Task Duration*	*Elapsed Time to Completion (from arrest)*
1	At Patient			
2	ABCs	X	X	
3	Patient Interview	X		
4	O^2 Administration	X		
5	Check Vitals	X	X	
6	ALS Vitals 12-Lead	X		
7	Expose Chest	X		
8	Patient Arrest			
9	Position Patient			
10	ABC's *(from Arrest time)*	X		
11	Defibrillator pads *(from Arrest time)*	X		
12	Analyze / Shock #1	X		
13	ABC's after Shock #1 *(from Arrest time)*	X		
14	CPR			
15	Airway Intubation *(from Arrest time)*		X	
16	IV Access	X	X	
17	Meds (Epinephrine) *(from Arrest time)*	X		
18	Analyze / Shock #2 *(from Arrest time)*	X		
19	ROSC			
20	Meds (Lidocaine) *(from Arrest time)*	X		
21	Package Patient/Equip *(from Arrest time)*	X		X

Table 8: Outcome Measures for Cardiac Scenario by Task

The objective of the experiments was to determine the relative effects of first responder crew size, ALS provider placement and the number of ALS providers on the effectiveness of the EMS crews relative to key milestones among the task intervention times for each of the three scenarios. The experimental results are discussed below.

Of the various EMS tasks measured during the experiments, those described in the remainder of this section were determined to have significant differences based on the crew configurations studied. Their differential outcomes based on variation of first responder crew size, ALS crew configuration, and the number of ALS level providers on scene, are statistically significant at the 95 % confidence level or better. Times reported in seconds are rounded to the nearest five seconds. As a final technical note, we did not adjust significance levels to take into account the large number of tests being conducted. The observed number of significant results far exceeds what would be expected simply by chance.

Measurement Uncertainty

The measurement of tasks using stopwatch timing has unique components of uncertainly that must be evaluated in order to determine the fidelity of the data. All timers were equipped with the same model of digital stopwatch with a resolution of 0.01s and an uncertainty of ± 3s per 24 hr. The uncertainty of the timing mechanism in the stopwatches is small enough over the duration of an experiment that it can be neglected.

There are three components of uncertainty when using people to time the EMS tasks. First, timers may have a bias depending on whether they record the time in anticipation of, or in reaction to an event. Second, multiple timers were used to record all tasks. Third, the mode of the stimulus to which the timer is reacting—audible or visual.

Milestone events in the EMS experiments were recorded both audibly and visually. A test series described in the *NIST Recommended Practice Guide for Stopwatch and Timer Calibrations* noted that reaction times for the two modes of stimulus to be approximately the same, so this component can be neglected. Based on the assumptions made in the Residential Fireground Experiments (Averill et al., 2010), bias estimated for timer reaction time was determined to be 230 ms as a worst case scenario.

Considering the above, the total estimated combined standard uncertainty is ± 3.23 s. The magnitude of uncertainty associated with these measurements has no impact on the statistical inferences presented in this report.

How to Interpret the Time-to-Task Graphs

Figure 15 presents a sample of a time-to-task results graph. Each crew size/configuration has a bar graphic showing the start time and completion time for the task. Visually, bars start from the left and extend horizontally across the graph based on time expended by various EMS crew configurations. The length of the bar graphic is a visualization of the duration of the task. Longer bars indicate longer duration times. Actual time data are also shown on each bar.

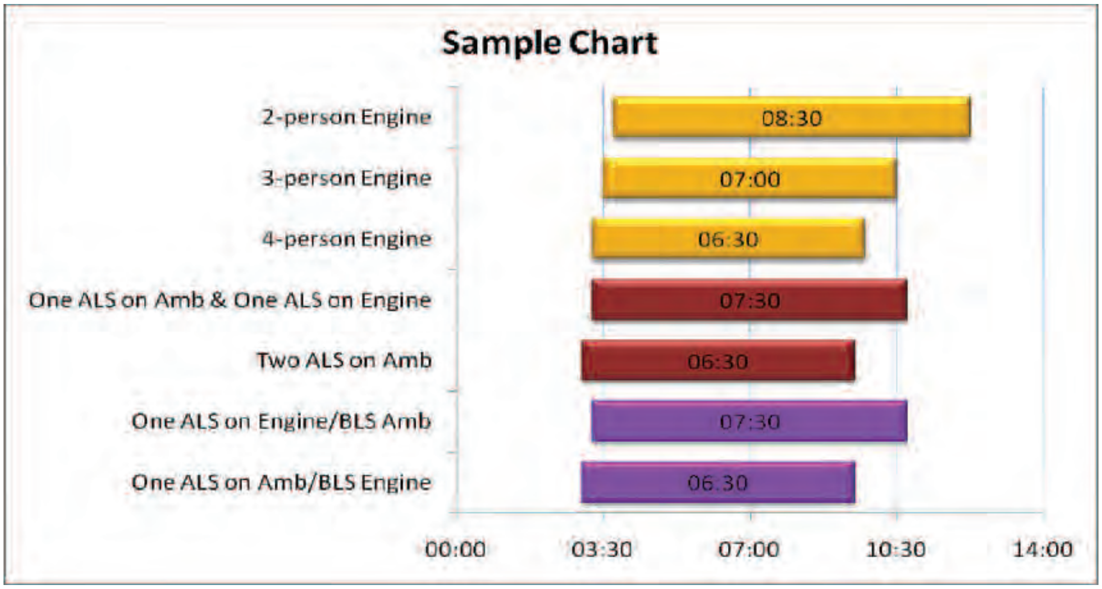


Figure 15: Sample Time-to-Task Graph

Time-to-Task Graphs

Part 1- Patient Access and Removal

Overall Scene Time (Time to complete all EMS tasks for Patient Access and Removal)

Access

The crews can differ in the time required to reach the patient (*access*) and in the time needed for patient *removal*. To address these tasks, sets of simulations were conducted by varying crew size on the first responding engine. Ambulance crews were held constant at two persons. As noted previously, the arrival times were staggered between the engine and the ambulance. When an ambulance was sent without a first responder engine, for measurement consistency, it was assumed to arrive at the scene *at the same time* as would an engine (i.e., there is no systematic, built-in delay).

The results for *patient access* show that two-person first responder crews take longer to reach a patient than configurations with larger crew sizes. Two-person crews finished the patient access tasks approximately *half a minute* later than larger first responder crews. Moreover, the ambulance crew alone finished with a time between that of the two-person and the larger first responder crews. The *ambulance alone* result is likely attributed to the removal of the staggered arrival time when first responder crews were not sent. (See Appendix E for the timings by staffing configuration, difference of means and associated t-tests.)

Patient Removal

The patient removal results show substantial differences associated with crew size. Crews with two-person first responder crews completed patient removal between (1.2 – 1.5) minutes slower than larger crews, depending on crew size. This is largely the result of work load in carrying equipment, supplies and the patient with fewer crew members. All crews with first responders completed removal substantially faster (by 2.6 min. - 4.1 min.) relative to the ambulance-only crew. Again, this is largely the result of the difficulty of carrying and loading the patient, as well as the equipment and supplies with only a two-person crew, given that one person must remain with the patient at all times. (See Appendix E)

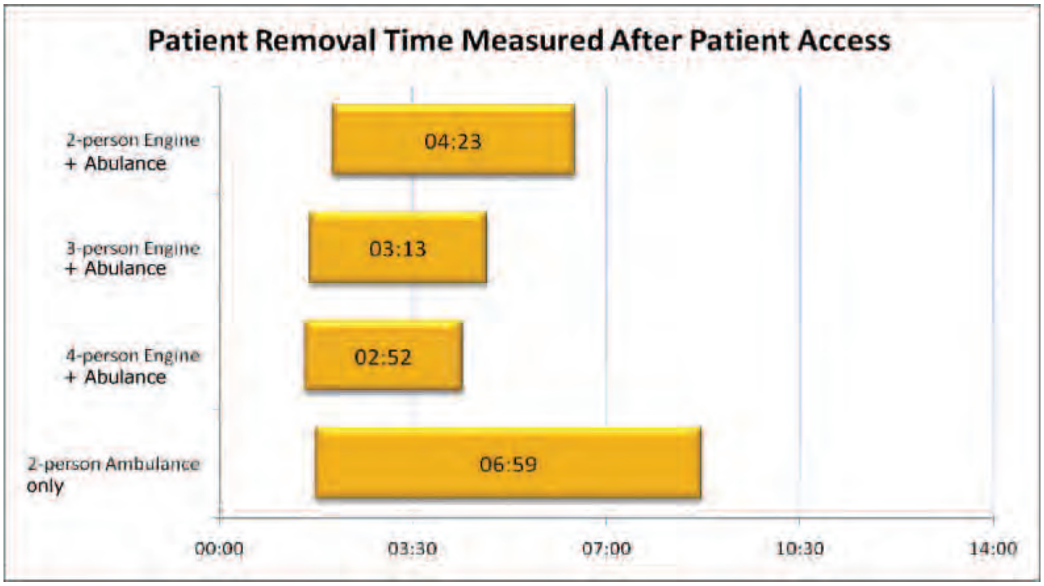


Figure 16: Patient Removal Time

Part 2- Multi-System Trauma

Overall Scene Time (Time to complete all EMS tasks for Trauma Patient)

As previously noted, for the trauma scenario part of the experiments, there was an assumed three minute stagger in arrival between the first responder crew and the ambulance crew.

Crews responding with one ALS provider on the engine and on the ambulance completed all trauma tasks 2.3 minutes (2 minutes and 16 seconds) faster than crews with a BLS engine and an ALS ambulance with two ALS level providers.

Crews responding with four-person first responder crews, regardless of ALS configuration, completed all trauma tasks 1.7 minutes (1 minute and 50 seconds) faster than first responder crews with three persons, and 3.4 minutes (3 minutes and 25 seconds) faster than first responder crews with two persons. This suggests that for trauma scenarios, the more hands available, the easier it is to implement the full portfolio of tasks to be completed.

The statistical tests that correspond to these findings appear in Appendix F. Appendix H shows the original regression coefficient estimates upon which the tests in Appendix F were constructed.

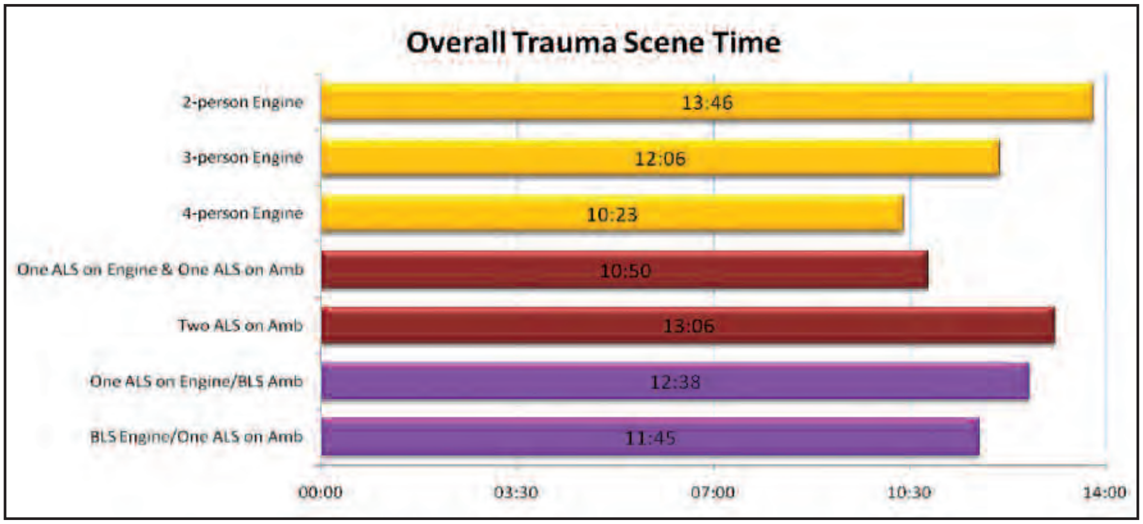


Figure 17: Overall Trauma Scene Time

Individual Task Times

Oxygen Administration

First responders with four-person crews were able to begin oxygen administration to the patient nearly a full minute (55 seconds) sooner than the three-person crew.

Vital Sign Assessment

First responders with four-person crews were able to begin checking the patient's vital signs nearly one minute (55 seconds) sooner than a two-person crew. They also completed the check about 80 seconds faster than the two-person crew. First responders with four-person crews were able to begin checking the patient's vital signs 30 seconds sooner than a three-person crew. To the extent that checking vitals is a critical task in a trauma response sequence, the reduction of half a minute to a minute of time could be seen as an important improvement.

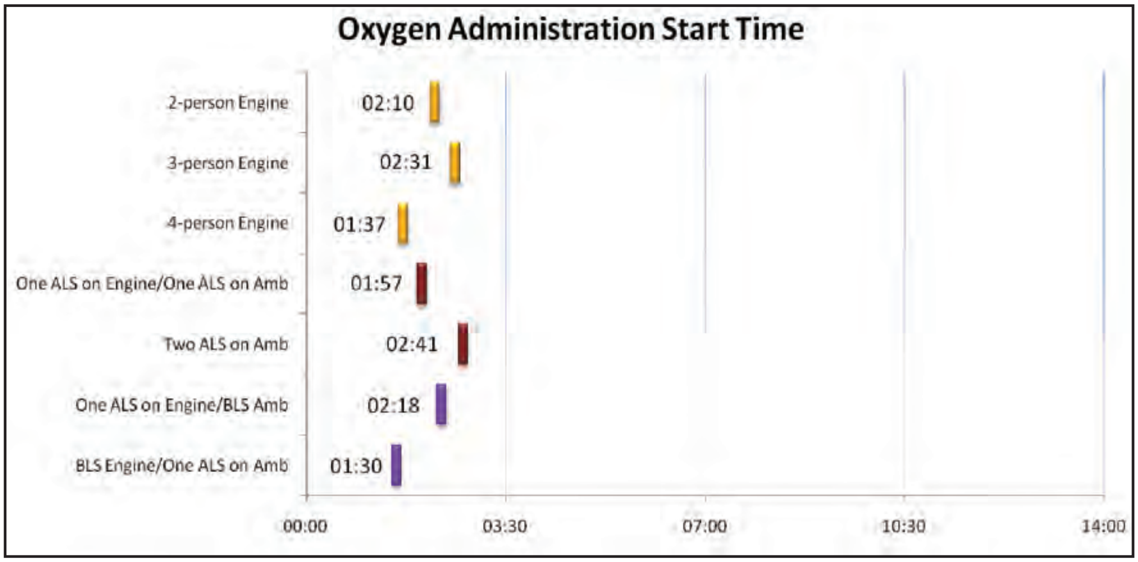


Figure 18: Oxygen Administration Start Time

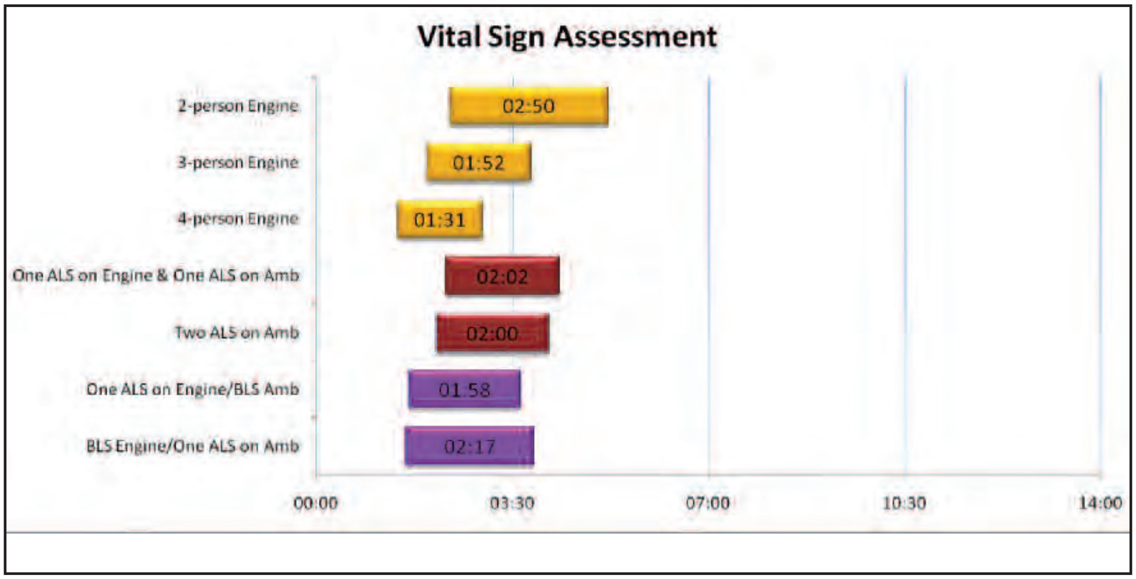


Figure 19: Vital Sign Assessment Start and Duration

Wound Bandaging

First responders with three-person crews were able to begin bandaging the patient's wounds a minute and 40 seconds sooner than first responders with two-person crews. The value of a four-person crew witnessed in the earlier tasks (e.g., checking vitals) did not manifest for this task.

Splint Leg

First responders with four-person crews were able to begin splinting the patient's leg approximately a minute faster than either the two- or three-person crews. A small advantage of a four-person crew re-emerges at this next step (i.e., following bandaging) in the response task sequence.

Crew configurations with one ALS provider on the first responding engine and one on the ambulance were able to begin splinting the patient's leg 40 seconds sooner than crews with two ALS providers on the ambulance.

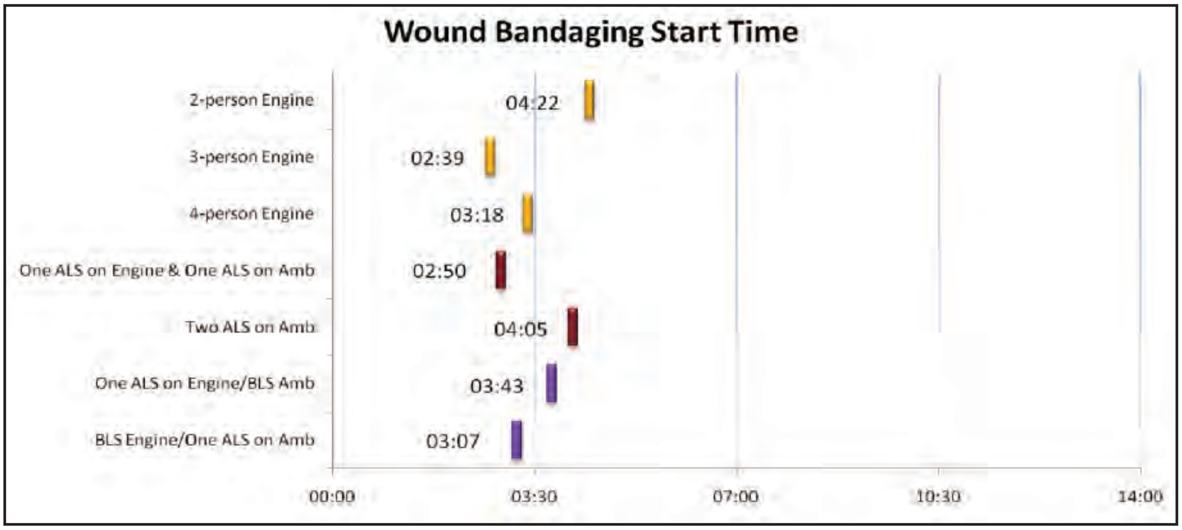


Figure 20: Wound Bandaging Start Time

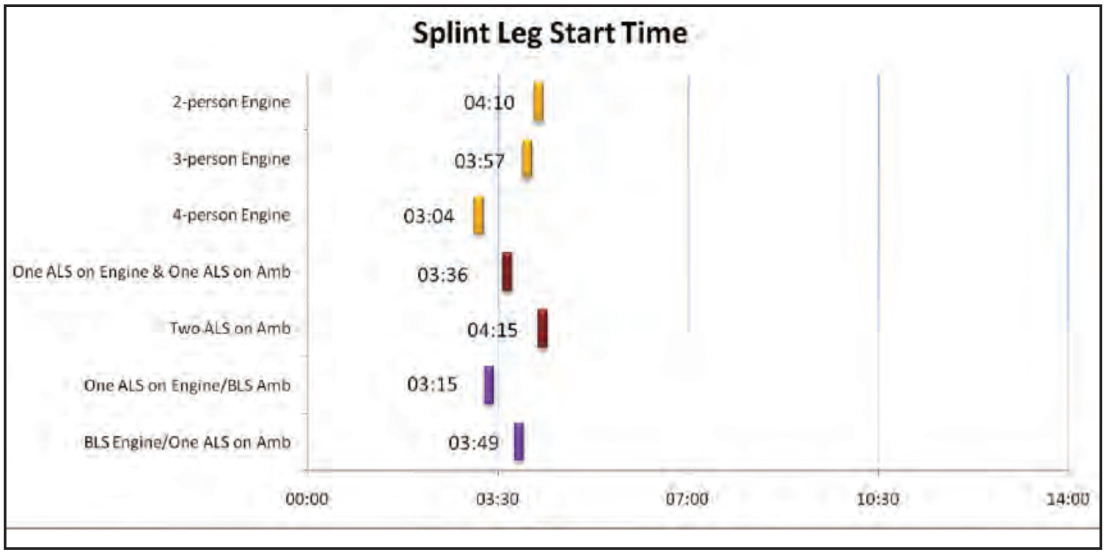


Figure 21: Splint Leg Start Time

Spinal Immobilization/ Back board

First responders with four-person crews were able to conduct spinal immobilization/back-boarding of the patient two minutes faster than either two- or three-person crews. No differences were observed based on placement or number of the ALS personnel.

Airway — Endotracheal Intubation

First responders with four-person crews were able to begin securing the patient's airway using endotracheal intubation two and one-half minutes (2 minutes and 35 seconds) sooner than the two-person crews and two minutes sooner than the three-person crews.

Crew configurations with one ALS provider on the first responding engine and one on the ambulance were able to begin securing the airway using endotracheal intubation one minute and 25 seconds sooner than crews with two ALS providers on the ambulance.

Additional personnel marginally speed up the intubation procedure. A second ALS person and having more than two persons on the engine each reduce the time of the intubation by half a minute.

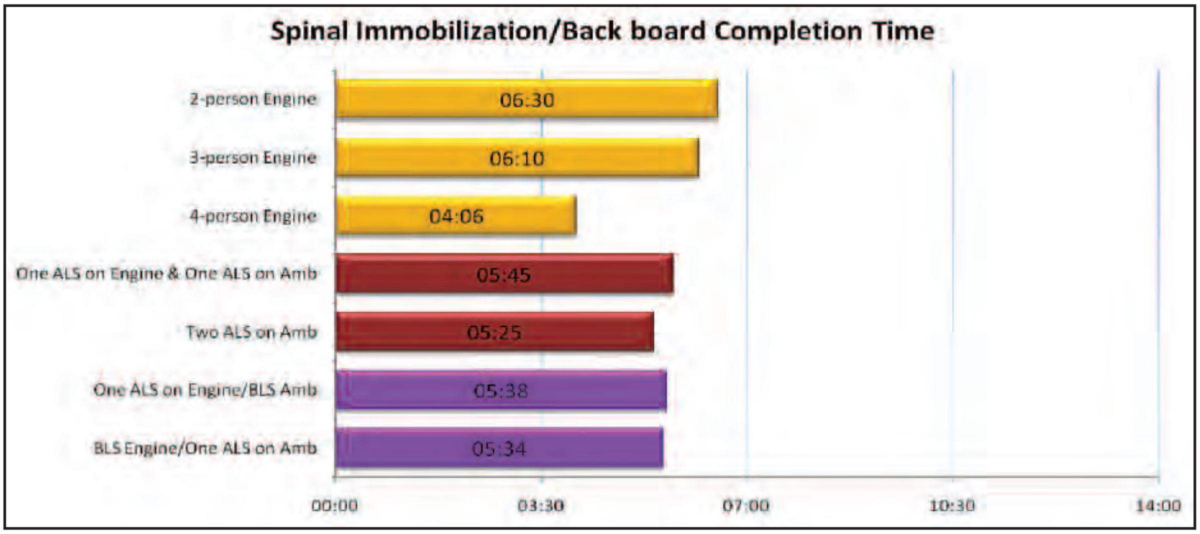


Figure 22: Spinal Immobilization Time Airway – Endotracheal Intubation

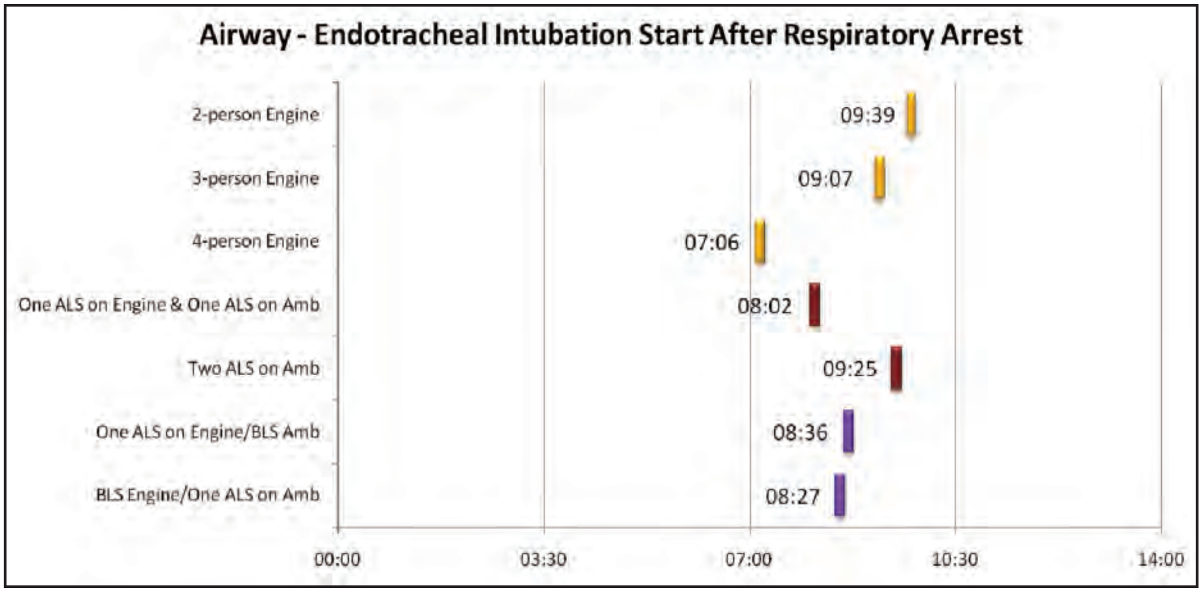


Figure 23: Airway – Intubation Start Time

Bag Valve Mask

First responders with four-person crews were able to begin bag valve mask ventilation after intubation two minutes and 35 seconds sooner than the two–person crews and nearly two minutes (110 seconds) sooner than the three-person crews.

Crew configurations with one ALS provider on the first responding engine and one on the ambulance were able to begin bag valve mask ventilation after intubation one and one-half minutes (one minute and 29 seconds) sooner than crews with two ALS providers on the ambulance.

Patient Packaging

Additional first responders reduce the times until the start and completion of packaging. First responders with four-person crews were able to begin patient packaging 3.1 minutes (three minutes and 5 seconds) sooner and complete all packaging activities moving toward transport nearly 3.4 minutes (three minutes and 25 seconds) sooner than the two-person crews. In addition, the four-person crews were able to begin patient packaging 1.6 minutes (one minute 35 seconds) sooner and complete all packaging activities moving toward transport 1.7 minutes (one minute 40 seconds) sooner than the three–person crews.

Crew configurations with one ALS provider on the first responding engine and one on the ambulance were able to begin patient packaging 2.1 minutes (two minutes and 5 seconds) sooner and complete all packaging activities moving toward transport 2.3 minutes (two minutes and 15 seconds) sooner than crews with both ALS personnel arriving on the ambulance. No differences were associated with placement of a single ALS

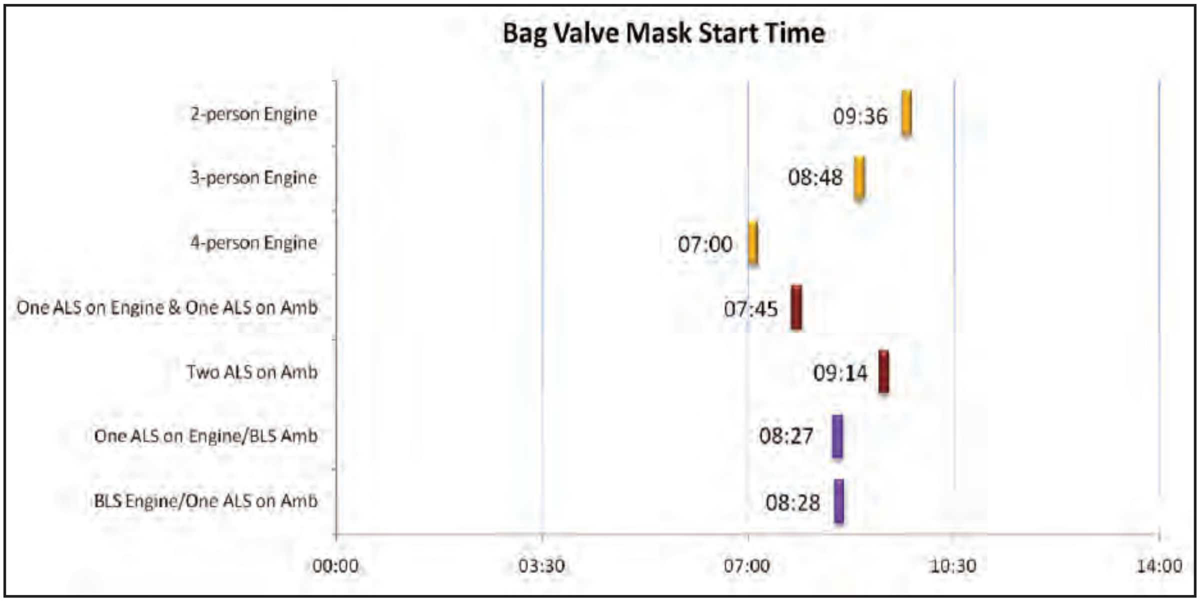


Figure 24: Bag Valve Mask Start Time

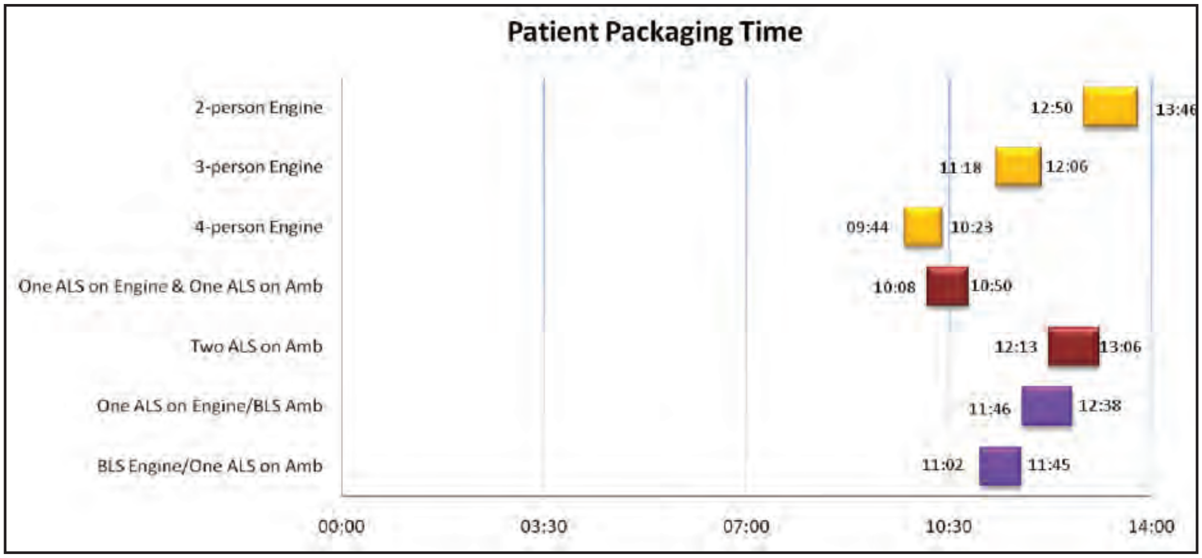


Figure 25: Patient Packaging Start and End Times

provider or with the availability of a second ALS provider.

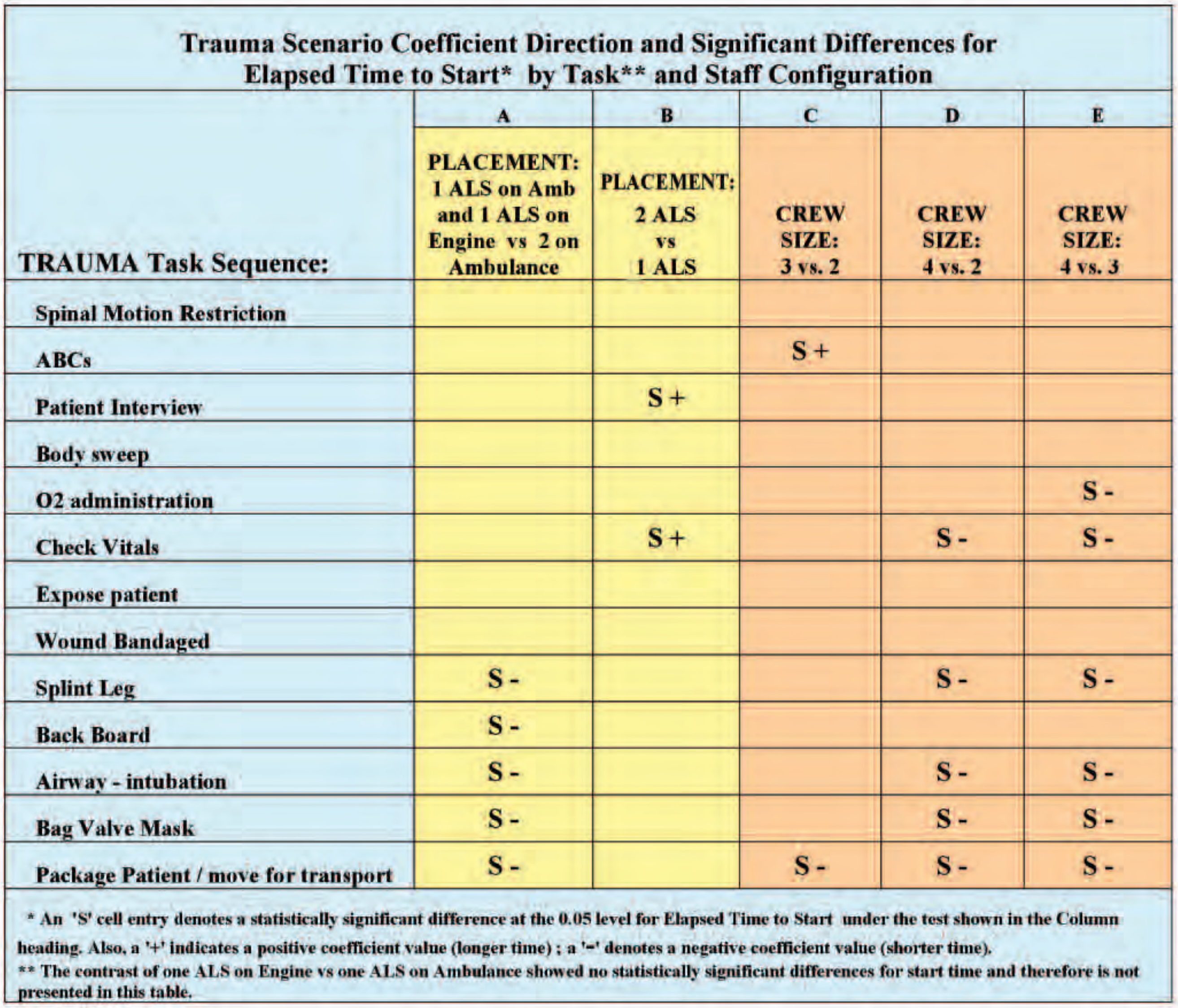
Patterns in the Trauma Scenario

The preceding presentation focuses on the specific tasks that comprise the overall trauma response sequence. Examination of the collection of findings across tasks, reveals patterns that provide insight into how crew configurations affect trauma response. To examine this, the occurrences of significant differences of elapsed time to start by task were tabulated. Table 9 presents the task sequence and statistically significant differences when comparing ALS placement (Columns A and B) and contrasting crew sizes (Columns C – E) for the outcome "elapsed time to the start of a task." Column A shows a clear advantage to placing one ALS on the engine (with one on an ambulance that arrives three minutes later) versus two ALS on a later arriving ambulance. The time advantage manifests in the last third of the task sequence, beginning with splinting the leg. One explanation for this would be that that having an ALS on the engine creates small increments of time that cumulate and finally manifest (at a statistically significant level) beginning with splinting the leg and carrying forward to all subsequent tasks. Another factor may be that certain tasks may be performed concurrently rather than sequentially when enough hands are available at the scene and this leads to overall time reductions relative to smaller crews that are forced to complete some set of tasks sequentially.

No clear pattern emerges for starting time significant differences when contrasting the addition of a second ALS person (Column B). The same appears to be true for comparing the crew sizes of three versus two (see Column C).

On the other hand, distinct patterns are seen in Columns D and E of Table 9 which depict the comparison of four versus two and four versus three crew sizes, respectively. Although there is some evidence of real time savings (as far as elapsed time to start a task) for the middle third of tasks in the sequence (for example between O^2 administration and splint leg), a consistent pattern favoring a crew size of four is seen beginning with airway intubation and continuing through patient packaging.

Taken as a whole, Table 9 suggests that while a crew size of four may not consistently produce time savings in the start of tasks initially in the trauma task sequence, there are clear advantages as work progresses, beginning with airway intubation through patient packaging. The same can be seen (beginning earlier with leg splinting) when comparing the start times for one ALS on the engine and one on the ambulance versus two ALS on the ambulance. No such pattern emerges for the single ALS provider regardless of placement on the engine versus the ambulance.



Trauma Scenario Coefficient Direction and Significant Differences for Elapsed Time to Start* by Task and Staff Configuration**

	A	B	C	D	E
TRAUMA Task Sequence:	**PLACEMENT: 1 ALS on Amb and 1 ALS on Engine vs 2 on Ambulance**	**PLACEMENT: 2 ALS vs 1 ALS**	**CREW SIZE: 3 vs. 2**	**CREW SIZE: 4 vs. 2**	**CREW SIZE: 4 vs. 3**
Spinal Motion Restriction					
ABCs			S +		
Patient Interview		S +			
Body sweep					
O2 administration					S -
Check Vitals		S +		S -	S -
Expose patient					
Wound Bandaged					
Splint Leg	S -			S -	S -
Back Board	S -				
Airway - intubation	S -			S -	S -
Bag Valve Mask	S -			S -	S -
Package Patient / move for transport	S -		S -	S -	S -

* An 'S' cell entry denotes a statistically significant difference at the 0.05 level for Elapsed Time to Start under the test shown in the Column heading. Also, a '+' indicates a positive coefficient value (longer time) ; a '-' denotes a negative coefficient value (shorter time).

** The contrast of one ALS on Engine vs one ALS on Ambulance showed no statistically significant differences for start time and therefore is not presented in this table.

Table 9: Trauma Scenario Coefficient Direction and Significant Differences

Part 3- Chest Pain and Witnessed Cardiac Arrest

Overall Scene Time

Crews responding with four first responders, regardless of ALS configuration, completed all cardiac tasks from the "at patient time" 70 seconds faster than first responder crews with three persons, and two minutes and 40 seconds faster than first responder crews with two persons.

Additionally, crews responding with one ALS provider on both the engine and ambulance completed all scene tasks from the "at patient time" 45 seconds sooner than crews with two ALS providers on the ambulance and a BLS engine.

Crews responding with an ALS Engine and a BLS Ambulance completed tasks from "at patient time" two minutes 36 second sooner than crews with a BLS Engine and one ALS provider on the Ambulance.

These results echo the trauma findings.

Due to the nature of the cardiac scenario, where crews began the experiment with a chest pain patient who then went into cardiac arrest (no pulse and no respirations), it was necessary to assess some tasks relative to the time the patient arrested. The arrest was cued from the end time for the 12-Lead ECG task.

Crews responding with four first responders, regardless of ALS configuration, completed cardiac tasks following the patient going into cardiac arrest 85 seconds faster than first responder crews with two persons.

Crews responding with a BLS engine and an ambulance with two ALS level providers completed all cardiac tasks following the patient arrest 50 seconds sooner than crews with an ALS provider on both the engine and ambulance. This counter-intuitive difference in the results may be attributable to the delay of the patient arrest time based on the arrival of the 12-Lead ECG monitor with the two-person ALS Ambulance crew. The 12-Lead ECG task *end time* was the arrest *start time*. In this scenario, there were instantaneously two ALS providers present at the arrest rather than the one ALS provider placing the 12-Lead ECG device in the ALS engine /ALS Ambulance crew.

The statistical tests that correspond to these findings appear in Appendix G. Appendix H shows the original regression coefficient estimates upon which the tests in Appendix G were constructed.

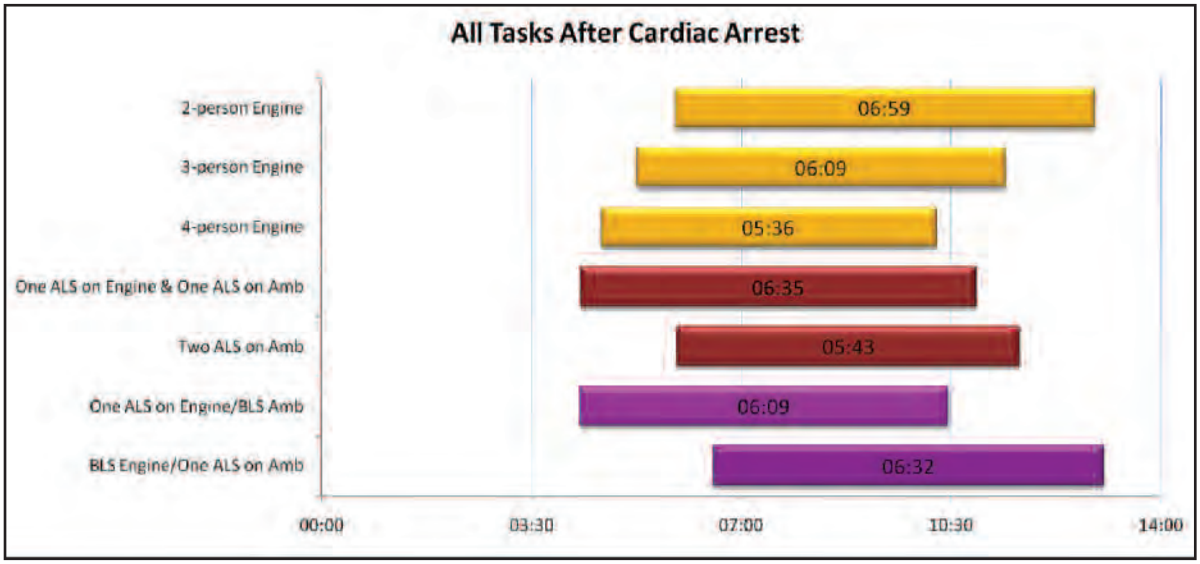


Figure 27: Total Cardiac Completion Time

Individual Task Times

12-Lead ECG Monitor

Crew configurations with one ALS provider on the first responding engine and one ALS level provider on the ambulance were able to apply the 12-lead ECG device two minutes and 20 seconds sooner than crews with both ALS providers on the ambulance.

Similarly, crew configurations with one ALS provider on the first responding engine and no medic on the ambulance also were able to apply the 12-lead ECG device two minutes and 20 seconds sooner than crews with no ALS on the first responding engine and a single ALS level provider on the ambulance.

These results may be influenced by the fact that this task can only be administered by ALS level providers. When ALS personnel are only on the ambulance, the task cannot begin until three minutes after the start of the experiment – the ambulance arrival time built into the experiments. Nonetheless, this finding is noteworthy given that national data show that ambulances typically arrive later than first responder crews.

Only a small difference in the time to begin applying the ECG device was associated with having a second ALS provider on the scene. This is not surprising, as ECG application typically requires a single ALS trained provider. Other ALS tasks later in the sequence show greater significance for having two ALS personnel on scene.

IV Access

Crew configurations with one ALS provider on the first responding engine and no medic on the ambulance were able to start the procedure for IV access two minutes and 30 seconds sooner than crews with no ALS on the first responding engine and a single ALS level provider on the ambulance. No reductions in the time to IV access were associated with a second ALS on scene. Although likely a by-product of the three-minute ambulance stagger, this finding is noteworthy because of the typical lag (behind first responders) in the arrival of an ambulance.

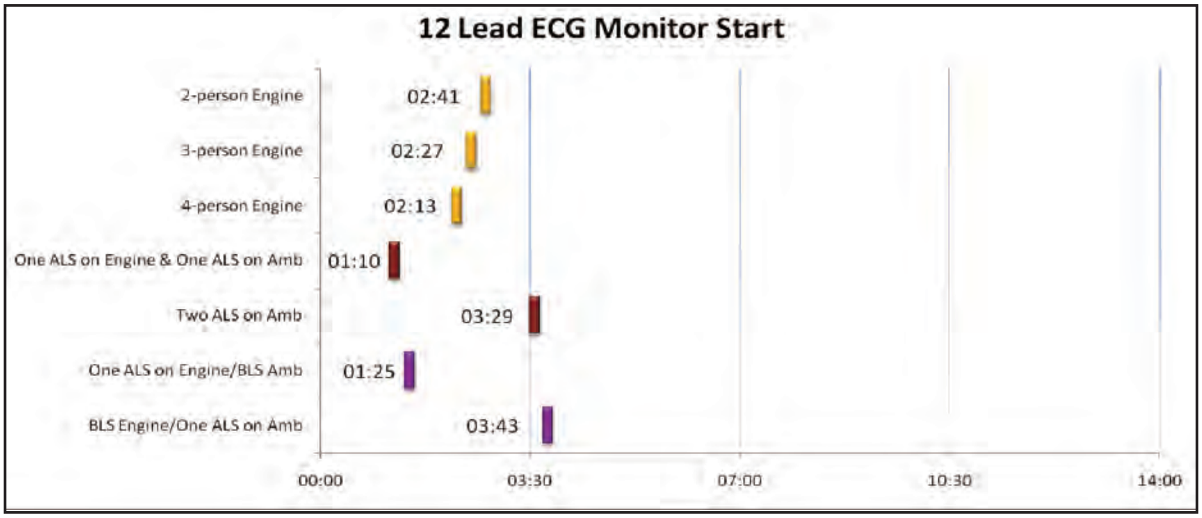


Figure 28: 12-Lead ECG Start Time

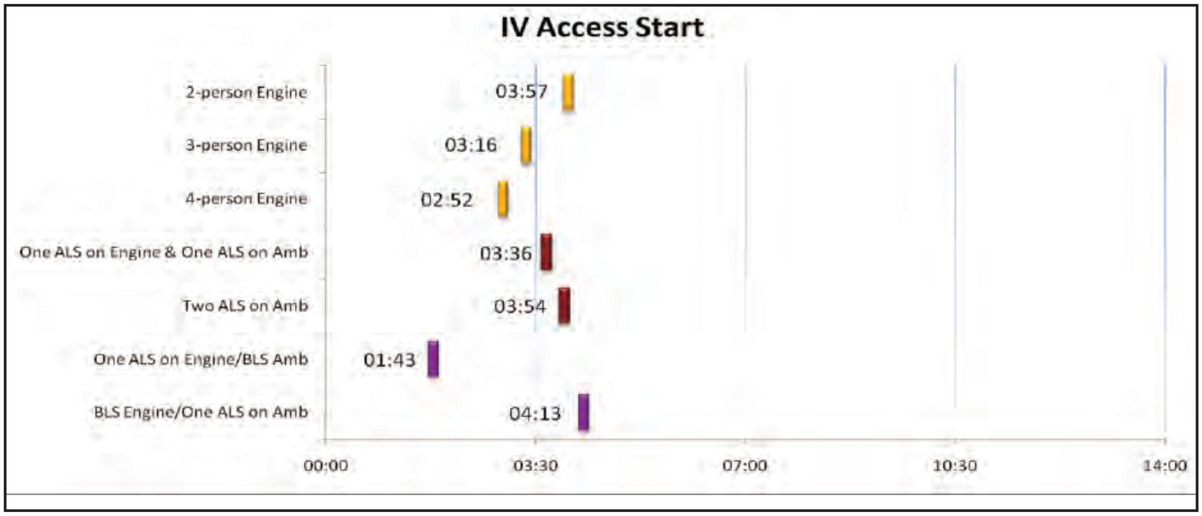


Figure 29: IV Access Start Time

Airway- Endotracheal Intubation

Crew configurations with two ALS level providers were able to begin to secure the patient's airway using endotracheal intubation over a minute (65 seconds) sooner than crew configurations with one ALS provider.

Patient Packaging

Measured from the time of arrest, first responders with four-person crews were able to begin patient packaging one minute sooner and complete all packaging activities moving toward transport one minute and 25 seconds sooner than the two-person crews.

First responders with three-person crews were able to complete all patient packaging activities moving toward transport 50 seconds sooner than the two-person crews, while four-person crews were able to complete all patient packaging activities moving toward transport 85 seconds sooner than the two-person crews.

Crew configurations with two ALS personnel arriving on the ambulance were able to complete all packaging activities, post arrest and move toward transport 50 seconds sooner than crews with one ALS provider on the first responding engine and one on the ambulance.

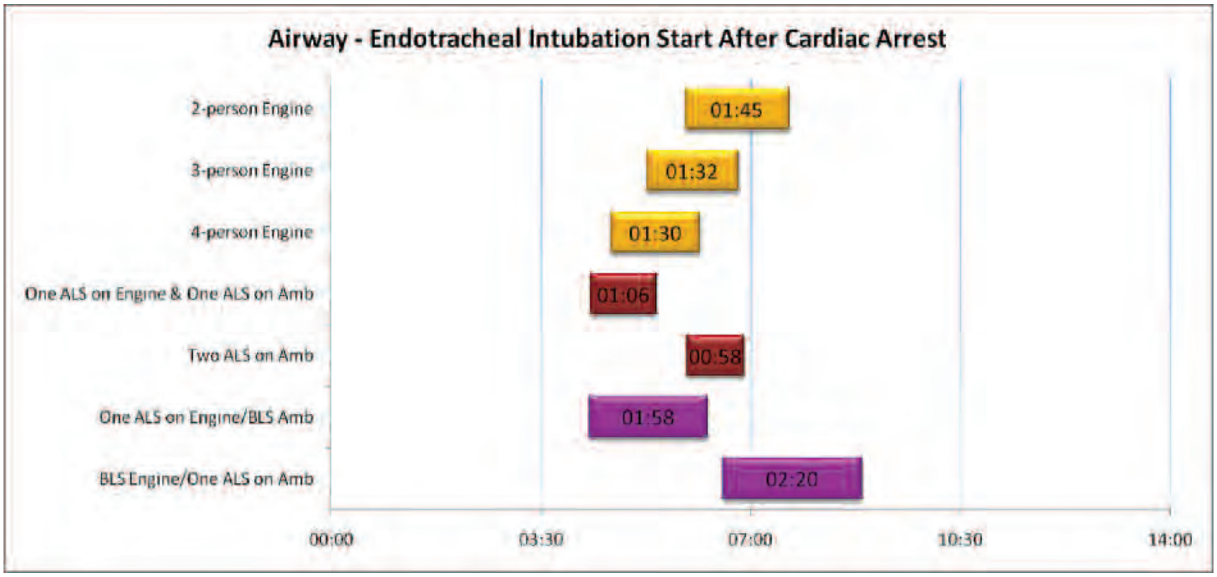


Figure 30: Airway- Intubation After Patient Arrest

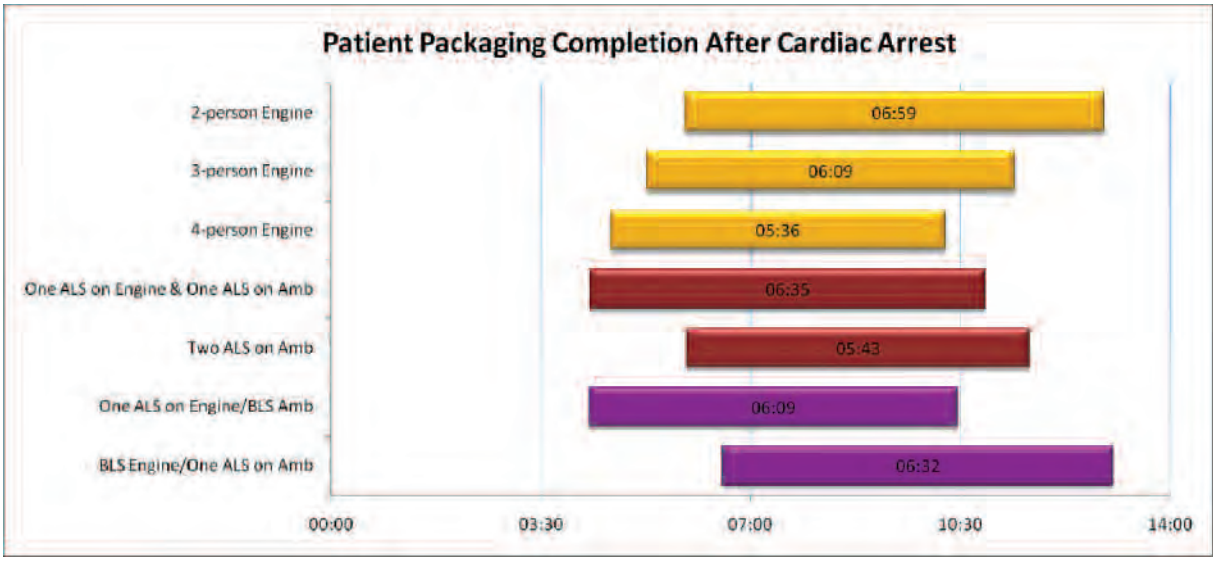


Figure 31: Patient Packaging Completion After Patient Arrest

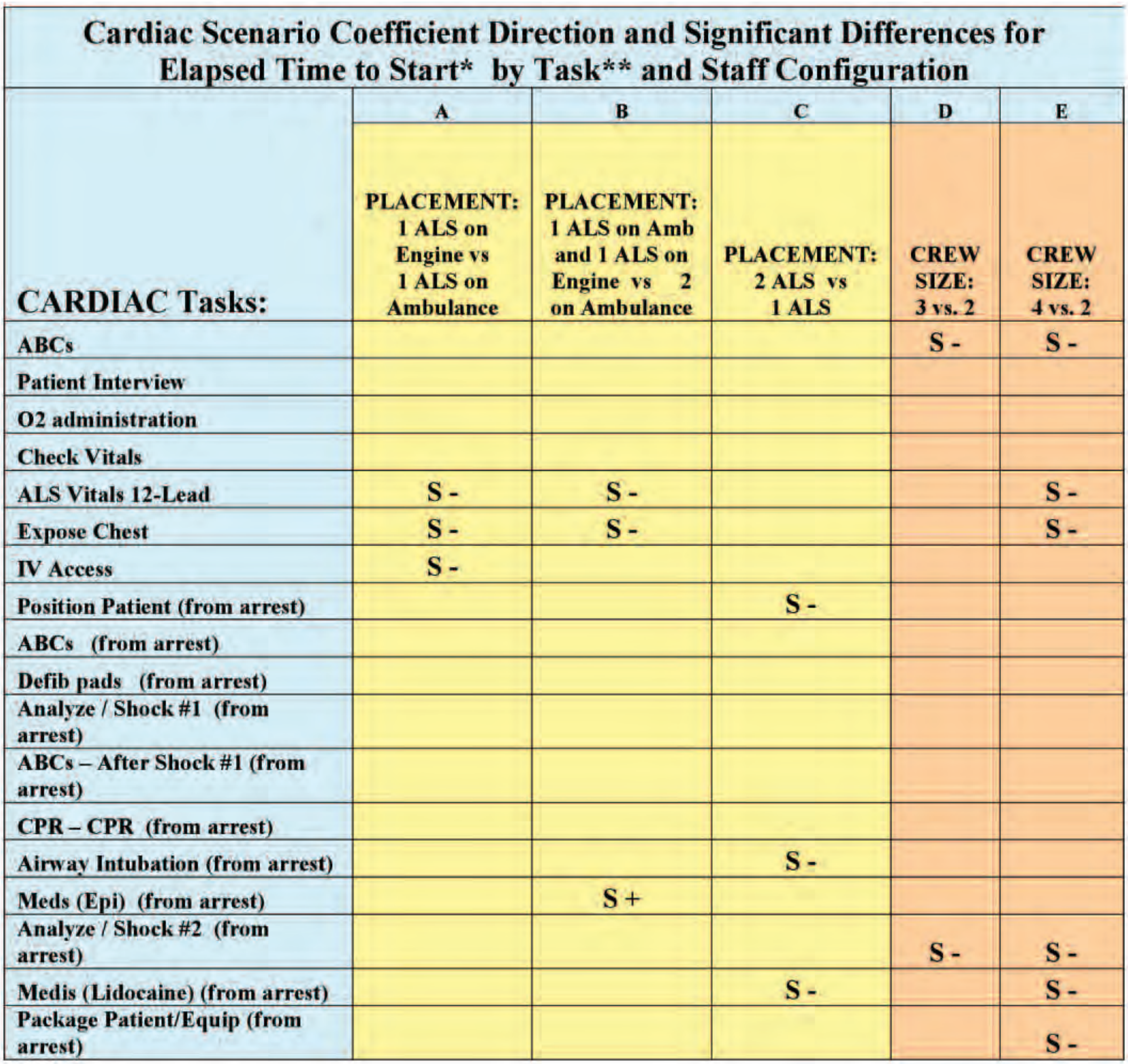
Patterns in the Cardiac Scenario

As with the trauma analysis, the preceding presentation of findings focused on specific tasks that comprise an EMS cardiac response. The significant differences of elapsed task start times were tabulated by task and appear as Table 10. The table presents the task sequence and statistically significant differences when comparing ALS placement (Columns A – C) and contrasting crew sizes (Columns D – F) for the outcome "elapsed time to the start of a task."

The results appear mixed. Column A shows that an ALS provider on an engine has advantages over an ALS provider on an ambulance for start times in earlier tasks – ALS Vitals 12-Lead through IV access. No other ALS provider placement advantages appear for the remainder of the response sequence.

Columns B and C show sporadic task-specific advantages for start times in a few tasks. For example, when comparing crews with one ALS provider on the engine and one ALS provider on the ambulance versus two ALS providers on ambulance, and when comparing crew configurations with two ALS providers (regardless of placement) to crews with one ALS provider. A Similar sporadic advantage appears when comparing first responder crew sizes of three versus a crew size two.

A pattern similar to that observed with trauma appears when comparing the start times for a first responder crew of four versus a first responder crew of two. The advantage of the four-person crew appears in a few early tasks with at least two tasks being completed sequentially, including the initial ABC's being completed with the vital sign check, and the 12-Lead ECG being completed with exposing the patient's chest task. However, comparing these first responder crew sizes, a greater sequential time advantage is revealed for the last three tasks (analyze shock #2 through package patient), as shown in the last three rows of Column E.



Cardiac Scenario Coefficient Direction and Significant Differences for Elapsed Time to Start* by Task and Staff Configuration**

	A	B	C	D	E
CARDIAC Tasks:	**PLACEMENT: 1 ALS on Engine vs 1 ALS on Ambulance**	**PLACEMENT: 1 ALS on Amb and 1 ALS on Engine vs 2 on Ambulance**	**PLACEMENT: 2 ALS vs 1 ALS**	**CREW SIZE: 3 vs. 2**	**CREW SIZE: 4 vs. 2**
ABCs				S -	S -
Patient Interview					
O2 administration					
Check Vitals					
ALS Vitals 12-Lead	S -	S -			S -
Expose Chest	S -	S -			S -
IV Access	S -				
Position Patient (from arrest)			S -		
ABCs (from arrest)					
Defib pads (from arrest)					
Analyze / Shock #1 (from arrest)					
ABCs – After Shock #1 (from arrest)					
CPR – CPR (from arrest)					
Airway Intubation (from arrest)			S -		
Meds (Epi) (from arrest)		S +			
Analyze / Shock #2 (from arrest)				S -	S -
Medis (Lidocaine) (from arrest)			S -		S -
Package Patient/Equip (from arrest)					S -

Table 10: Cardiac Scenario Coefficient Direction and Significant Differences

Conclusions

The objective of the experiments was to determine how first responder crew size, ALS provider placement, and the number of ALS providers is associated with the effectiveness of EMS providers. EMS crew effectiveness was measured by task intervention times in three scenarios including patient access and removal, trauma, and cardiac arrest. The results were evaluated from the perspective of firefighter and paramedic safety and scene efficiency rather than as a series of distinct tasks. More than 100 full-scale EMS experiments were conducted for this study.

As noted in the literature review, hundreds of firefighters and paramedics are injured annually on EMS responses. Most injuries occur during tasks that require *lifting or abnormal movement* by rescuers. Such tasks include lifting heavy objects (including human bodies both conscious and unconscious), manipulating injured body parts and carrying heavy equipment. Several tasks included in the experiments fall into this category, including splinting extremities, spinal immobilization (back boarding) and patient packaging. During the experiments larger crews completed these tasks more efficiently by distributing the workload among more people thereby reducing the likelihood of injury.

A number of tasks are also *labor intensive*. These tasks can be completed more efficiently when handled by multiple responders. Several tasks in the experiments are in this category. These include checking vital signs, splinting extremities, intubation with spinal restriction, establishing IV access spinal immobilization, and patient packaging. Similar to the lifting or heavy work load task, larger crews were able to complete labor intensive tasks using multiple crew members on a single task to assure safe procedures were used reducing the likelihood of injury or exposure.

Finally, there are opportunities on an EMS scene to reduce scene time by completing tasks simultaneously rather than concurrently thus increasing operational efficiency. Since crews were required to complete all tasks in each scenario regardless of their crew size or configuration, overall scene times reveal operational efficiencies.

Each of these perspectives is discussed below for the patient access/removal scenario, as well as both the trauma and the cardiac scenarios.

Patient Access and Removal

With regard to accessing the patient, crews with three or four first responders reached the patient around half a minute faster than smaller crews with two first responders. With regard to completing patient removal, larger first responder crews in conjunction with a two-person ambulance were more time efficient. The removal tasks require heavy lifting and are labor intensive. The tasks also involve descending stairs while carrying a patient, carrying all equipment down stairs, and getting patient and equipment out multiple doors, onto a stretcher and into an ambulance.

The patient removal results show substantial differences associated with crew size. Crews with three- or four-person first responders complete removal between (1.2 – 1.5) minutes faster than smaller crews with two first responders. All crews with first responders complete removal substantially faster (by 2.6 min. - 4.1 min.) than the ambulance-only crew.

These results suggest that time efficiency in access and removal can be achieved by deploying three-or four-person crews on the first responding engine (relative to a first responder crew of two). To the extent that each second counts in an EMS response, these staffing features deserve consideration. Though these results establish a technical basis for the effectiveness of first responder crews and specific ALS crew configurations, other factors contributing to policy decisions are not addressed.

Trauma

Overall, field experiments reveal that four-person first responder crews completed a trauma response faster than smaller crews. Towards the latter part of the task response sequence, four-person crews start tasks significantly sooner than smaller crews.

Additionally, crews with one ALS provider on the engine and one on the ambulance completed all tasks faster and started later tasks sooner than crews with two ALS providers on the ambulance. This suggests that getting ALS personnel to the site sooner matters.

A review of the patterns of significant results for task start times reinforced these findings and suggests that (in general) small non-significant reductions in task timings accrue through the task sequence to produce significantly shorter start times for the last third of the trauma tasks.

Finally, when assessing crews for their ability to increase on-scene operational efficiency by completing tasks simultaneously, crews with an ALS provider on the engine and one ALS provider on the ambulance completed all required tasks 2.3 minutes (2 minutes 15 seconds) faster than crews with a BLS engine and two ALS providers on the ambulance. Additionally, first responders with four-person first responder crews completed all required tasks 1.7 minutes (1 minute 45 seconds) faster than three-person crews and 3.4 minutes (3 minutes and 25 seconds) faster than two-person crews.

Cardiac

The overall results for cardiac echo those of trauma. Regardless of ALS configuration, crews responding with four first responders completed all cardiac tasks (from at-patient to packaging) more quickly than smaller first responder crew sizes. Moreover, in the critical period following cardiac arrest, crews responding with four first responders also completed all tasks more quickly than smaller crew sizes. As noted in the trauma scenario, crew size matters in the cardiac response.

Considering ALS placement, crews responding with one ALS provider on both the engine and ambulance completed all scene tasks (from at-patient to packaging) more quickly than a crew with a BLS engine and two ALS providers on the ambulance. This suggests that ALS placement can make a difference in response efficiency. One curious finding was that crews responding with a BLS engine and an ambulance with two ALS providers completed the tasks that follow cardiac arrest 50 seconds *sooner* than crews with an ALS provider on both the engine and ambulance. As noted, this counter-intuitive difference in the results may be attributable to the delay of the patient arrest time based on the arrival of the 12-Lead ECG monitor with the two-person ALS Ambulance crew. The 12 -Lead ECG task *end time* was the arrest *start time*. In this scenario, there were instantaneously two ALS providers present at the arrest rather than the one ALS provider placing the 12-Lead ECG device in the ALS engine /ALS Ambulance crew.

A review of the patterns of significant results across task start times showed mixed results. An ALS on an engine showed an advantage (sooner task starting times) over an ALS on an ambulance for a few tasks located earlier in the cardiac response sequence (specifically, ALS Vitals 12-Lead through IV access). A crew size of four also showed shorter start times for a few early tasks in the cardiac response sequence (initial ABC's, and the ALS Vitals 12-Lead and expose chest sequence). More importantly, a sequential time advantage appears for the last three tasks of the sequence (analyze shock #2 through package patient).

Finally, when assessing crews for their ability to increase on-scene operational efficiency by completing tasks simultaneously, crews with an ALS provider on the engine and one ALS provider on the ambulance completed all required tasks 45 seconds faster than crews with a BLS engine and two ALS providers on the ambulance. Regardless of ALS configuration, crews responding with four first responders completed all cardiac tasks from the "at patient time" to completion of packaging 70 seconds faster than first responder crews with three persons, and two minutes and 40 seconds faster than first responder crews with two persons. Additionally, *after the patient arrested*, an assessment of time to complete remaining tasks revealed that first responders with four-person crews completed all required tasks 50 seconds faster than three-person crews and 1.4 minutes (1 minute 25 seconds) faster than two-person crews.

Summary

While resource deployment is addressed in the context of three basic scenarios, it is recognized that public policy decisions regarding the cost-benefit of specific deployment decisions are a function of many factors including geography, resource availability, community expectations as well as population demographics that drive EMS call volume. While this report contributes significant knowledge to community and fire service leaders in regard to effective resource deployment for local EMS systems, other factors contributing to policy decisions are not addressed. The results however do establish a technical basis for the effectiveness of first responder crews and ALS configuration with at least one ALS level provider on first responder crews. The results also provide valid measures of total crew size efficiency in completing on-scene tasks some of which involve heavy lifting and tasks that require multiple responders to complete.

These experimental findings suggest that ALS provider placement and crew size can have an impact on some task start times in trauma and cardiac scenarios, especially in the latter tasks leading to patient packaging. To the extent that creating time efficiency is important for patient outcomes, including an ALS trained provider on an engine and using engine crew sizes of four are worth considering. The same holds for responder safety – for access and removal and other tasks in the response sequence, the availability of additional hands can serve to reduce the risks of lifting injuries or injuries that result from fatigue (e.g., avoid having small crews repeatedly having to ascend and descend stairs). Cost considerations for EMS response and crew configurations were not considered in this study.

Study Limitations

The scope of this study is limited to understanding the relative influence of deployment variables on labor-intensive emergency medical incidents, specifically multi-system trauma and cardiac arrest events. It should be noted that the applicability of the conclusions from this report to a large scale hazardous or multiple-casualty event have not been assessed and should not be extrapolated from this report.

The crews involved in this study typically operate using three- to four-person engine crews, and two-person ambulance crews. However, other departments across the United States vary in crew sizes, some using two- to five-person first responder engine crews and three-person ambulance crews.

Every attempt was made to ensure the highest possible degree of realism in the experiments including the use of multiple crews from multiple shifts in the participant departments. However, as the trauma and cardiac experiments were repeated a minimum of 45 times, for crews involved in more than one experiment, a learning curve on the part of the participants may have been established.

All experiments were conducted indoors, during daylight hours. Treating patients outside among varying weather conditions or at night, when visibility is lower, could pose additional obstacles. Additionally, the actual effect of ALS interventions on patient outcome is beyond the scope of this study. Patient outcomes were not quantified or estimated.

The design of the experiments limited the patient care scenarios to a systemic trauma event and a medical cardiac event. Other patient illnesses and injuries including diabetes, seizures, gunshot wounds, stabbings, and motor vehicle accidents were not considered.

EMS protocols pertaining to the treatment and transport of patients vary by departments. For the purpose of this study, tasks were standardized by technical experts and individual times were recorded for each task. In real-world situations, as in this study, many of these can be performed simultaneously based on the number and training level of responding personnel. Attempts to generalize the results from these experiments to individual departments must take into account protocols and equipment that vary from those used in the experiments.

Finally, data from U.S. fire departments were used to set response and arrival time assumptions. For departments with different deployment capability for both first responder crews and ambulances, the results may vary.

Future Research

In order to realize a significant reduction in firefighter and paramedic line-of-duty injury, fire service leaders must focus directly on resource allocation and the deployment of resources, a known contributing factor to LOD injury. Future research should use similar methods to evaluate firefighter/paramedic deployment to other medical emergencies as well as combination scenes where both fire suppression and EMS resources are needed. Additionally, resource deployment to multiple-casualty disasters or terrorism events should be studied to provide insight into levels of risks specific to individual communities and to recommend resource deployment proportionate to such risk. Future studies should continue to investigate the effects of resource deployment on the safety of firefighters, paramedics and the civilian population to better inform public policy. Finally, the ability to relate response and task timing to patient outcomes and survival rates should be quantified.

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A project of this magnitude extends well beyond the capabilities and expertise of the authors of this report. The following individuals were instrumental to the success of the EMS experiments.

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Glossary

12-Lead Electrocardiogram (ECG) — A representation of the heart's electrical activity recorded from 10 electrodes placed in standard positions on the body's surface.

Advanced Cardiac Life Support (ACLS) — A set of clinical interventions for the urgent treatment of cardiac arrest and other life threatening medical emergencies, as well as the knowledge and skills to use those interventions.

Advanced Life Support (ALS) — Emergency medical treatment beyond basic life support that provides for advanced airway management including intubation, advanced cardiac monitoring, defibrillation, establishment and maintenance of intravenous access, and drug therapy.

Ambulance Transport Unit — Provides transport for patients from the incident scene to a health care facility.

Automated External Defibrillator (AED) — A portable electronic device that automatically diagnoses potentially life-threatening cardiac arrhythmias of ventricular fibrillation, and is able to treat them through defibrillation, the application of electrical therapy which stops the arrhythmias, allowing the heart to reestablish an effective rhythm.

Basic Life Support (BLS) — A specific level of prehospital medical care provided by trained responders, focused on rapidly evaluating a patient's condition; maintaining a patient's airway, breathing, and circulation; controlling external bleeding; preventing shock; and preventing further injury or disability by immobilizing potential spinal or other bone fractures.

Cardiac Arrest — Sudden cessation of heartbeat and heart functions, resulting in the loss of effective circulation.

Cardiopulmonary Resuscitation (CPR) — Procedure designed to support and maintain breathing and circulation for a person who has stopped breathing (respiratory arrest) or whose heart has stopped (cardiac arrest).

Chain of Survival — The four components of EMS response to out-of-hospital cardiac arrest that are thought to effect the most optimal patient outcome. The four components include early recognition and EMS access, early CPR, rapid defibrillation, and advanced life support.

Combination Fire Department — Fire department consisting of both paid (career) and volunteer personnel.

Crew configurations — Specific ways of staffing or organizing members of the work force.

Definitive Medical Care — Medical treatment or services beyond emergency medical care, initiated upon inpatient admission to a hospital or health care facility.

Emergency Medical Services (EMS) — The treatment of patients using first aid, cardiopulmonary resuscitation, basic life support, advanced life support, and other medical procedures prior to arrival at a hospital or other health care facility.

EMS Protocols — Written medical instructions authorized by an EMS medical director to be used by personnel in the field without the necessity of on-line or real-time consultation with a physician or nurse.

Emergency Medical Technician (EMT) — A member of the emergency medical services team who provides out-of-hospital emergency care, trained to any level of emergency medical services.

Emergency Medical Technician- Basic (EMT-B) — A member of the emergency medical services team who provides out-of-hospital emergency care, trained in the delivery of Basic Life Support services.

Emergency Medical Technician- Defibrillator (EMT-D) — A member of the emergency medical services team with special training in the use of cardiac defibrillating equipment. (Defibrillation training is now part of Basic Emergency Medical training.)

Emergency Medical Technician- Paramedic (EMT-P) — A member of the emergency medical services team who provides out-of-hospital emergency care, trained in the delivery of Advanced Life Support services.

Endotrachael Tube (ET) — Flexible plastic catheter placed into the trachea to protect the airway and provide a means of mechanical ventilation.

First Responder — Functional provision of initial assessment (i.e., airway, breathing, and circulatory systems) and basic first-aid intervention, including CPR and automatic external defibrillator capability.

First Responder Unit — The first arriving unit at an emergency medical incident, whether it be a fire suppression vehicle or ambulance.

Intervention — Act designed to alter or hinder an action or development.

Intravenous (IV) — An injection administered into a vein.

Intubation — Insertion of a tube through the mouth or nose and into a patient's lungs to help them breathe.

Knox Box Rapid Entry System — Small, wall-mounted safe that holds building keys for firefighters and EMTs to retrieve in emergencies.

Mayocardial Infarction — Heart attack.

Measurement uncertainty — Parameter, associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measure.

National Fire Protection Association (NFPA) — A nonprofit organization, established in 1896, with the mission to reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating consensus codes and standards, research, training and education.

NFPA 450— Guide for emergency medical services and systems.

NFPA 1500 — Standard on fire department occupational safety and health program.

NFPA 1710 — Standard for the organization and deployment of fire suppression operations, emergency medical operations, and special operations to the public by career fire departments.

NFPA 1720 — Standard for the organization and deployment of fire suppression operations, emergency medical operations, and special operations to the public by volunteer fire departments.

NFPA 1999 — Standard on protective clothing for emergency medical operations.

One-Tier EMS System — EMS system in which all units are advanced life support.

Operational Effectiveness — Capable of producing a particular desired effect in “real world” circumstances.

Operational Efficiency — The effect or results achieved in relation to the effort expended.

Ordinary Least Squares (OLS) — In statistics and econometrics, OLS or linear least squares is a method for estimating the unknown parameters in a linear regression model.

Out-of-hospital — Care for the sick or injured in settings other than hospitals or hospital-affiliated outpatient medical or surgical facilities, typically beginning with a call to 9-1-1.

Patient Packaging — Securing a patient to a mobile contrivance (e.g., stretcher or stair chair) for moving to the transport unit.

Pulse Oximeter — Medical device that measures the oxygen saturation of a patient’s blood.

Regression analysis — Includes any techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. More specifically, regression analysis helps us understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held.

Standard of Response Cover (SORC) — Policies and procedures that determine distribution, concentration, and reliability of fixed and mobile resources for an emergency response system.

Standard t-test — Measures whether there is any statistical difference in the mean of two groups.

Statistical significance — A number that expresses the probability that the result of a given experiment or study could have occurred purely by chance. This number can be a margin of error or it can be a confidence level.

System resources — Personnel, vehicles, and equipment used in providing EMS.

Systemic trauma — Injury or shock affecting the body generally.

Transport — Conveyance of the sick or injured in an ambulance or emergency vehicle to a hospital setting.

Trauma and Injury Severity Scores (TRISS) — A system developed in the 1980’s to improve the prediction of patient outcomes through the use of physiological and anatomical criteria.

Two-Tier EMS System — EMS system that uses first responder or BLS units that typically arrive and begin treatment prior to the arrival of a transport unit.

Acronyms

- **A, B, C's —** Airway, Breathing, and Circulation
- **ACLS —** Advanced Cardiac Life Support
- **AED —** Automated External Defibrillator
- **AHA —** American Heart Association
- **ALS —** Advanced Life Support
- **BLS —** Basic Life Support
- **CFAI —** Commission on Fire Accreditation International
- **CPR —** Cardiopulmonary resuscitation
- **DHS —** Department of Homeland Security
- **DOL —** Department of Labor
- **ECG —** Electrocardiogram
- **EMS —** Emergency Medical Services
- **EMT —** Emergency Medical Technician
- **EMT-B —** Emergency Medical Technician- Basic
- **EMT-D —** Emergency Medical Technician- Defibrillator
- **EMT-P —** Emergency Medical Technician- Paramedic
- **FEMA —** Federal Emergency Management Agency
- **IAFC —** International Association of Fire Chiefs
- **IAFF —** International Association of Fire Fighters
- **LOD —** Line-of-Duty
- **NFPA —** National Fire Protection Association
- **NIST —** National Institute of Standards and Technology
- **OHCA —** Out-of-hospital cardiac arrest
- **OPQRST —** Onset, Provokes, Quality, Radiates, Severity, Time
- **SAMPLE —** Signs and Symptoms, Allergies, Previous history, Medications, Last oral intake, Events leading up to
- **SORC —** Standard of Response Cover
- **TBI —** Traumatic brain injury
- **TRISS —** Trauma and Injury Severity Scores
- **WPI —** Worcester Polytechnic Institute

Appendix A: Time to Task Measures

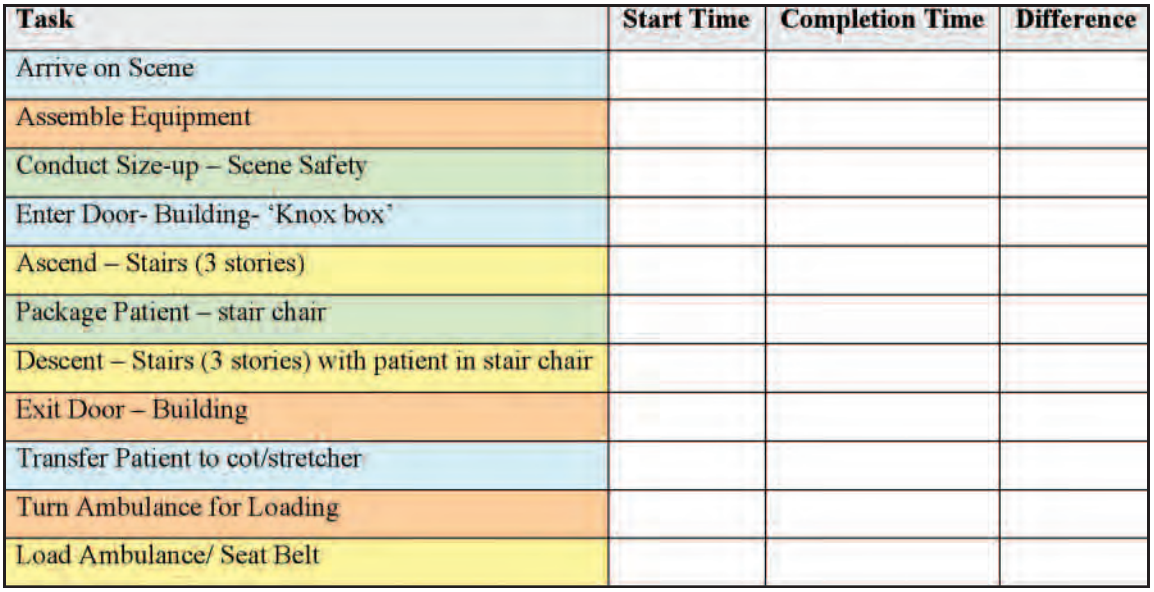
Time-to-Task Data Collection Chart -EMS

(Overall Response- Patient Access and Removal)

Date ___________ Start Time____________ End Time (all tasks complete) ___________

Crew Used: ☐ Montgomery County ☐ Fairfax County

Timer Name____



Task	Start Time	Completion Time	Difference
Arrive on Scene			
Assemble Equipment			
Conduct Size-up – Scene Safety			
Enter Door- Building- 'Knox box'			
Ascend – Stairs (3 stories)			
Package Patient – stair chair			
Descent – Stairs (3 stories) with patient in stair chair			
Exit Door – Building			
Transfer Patient to cot/stretcher			
Turn Ambulance for Loading			
Load Ambulance/ Seat Belt			

Time-to-Task Data Collection Chart -EMS

(Trauma — BLS — ALS on scene)

Date ___________ Start Time____________ End Time (all tasks complete) ___________

Timer Name____

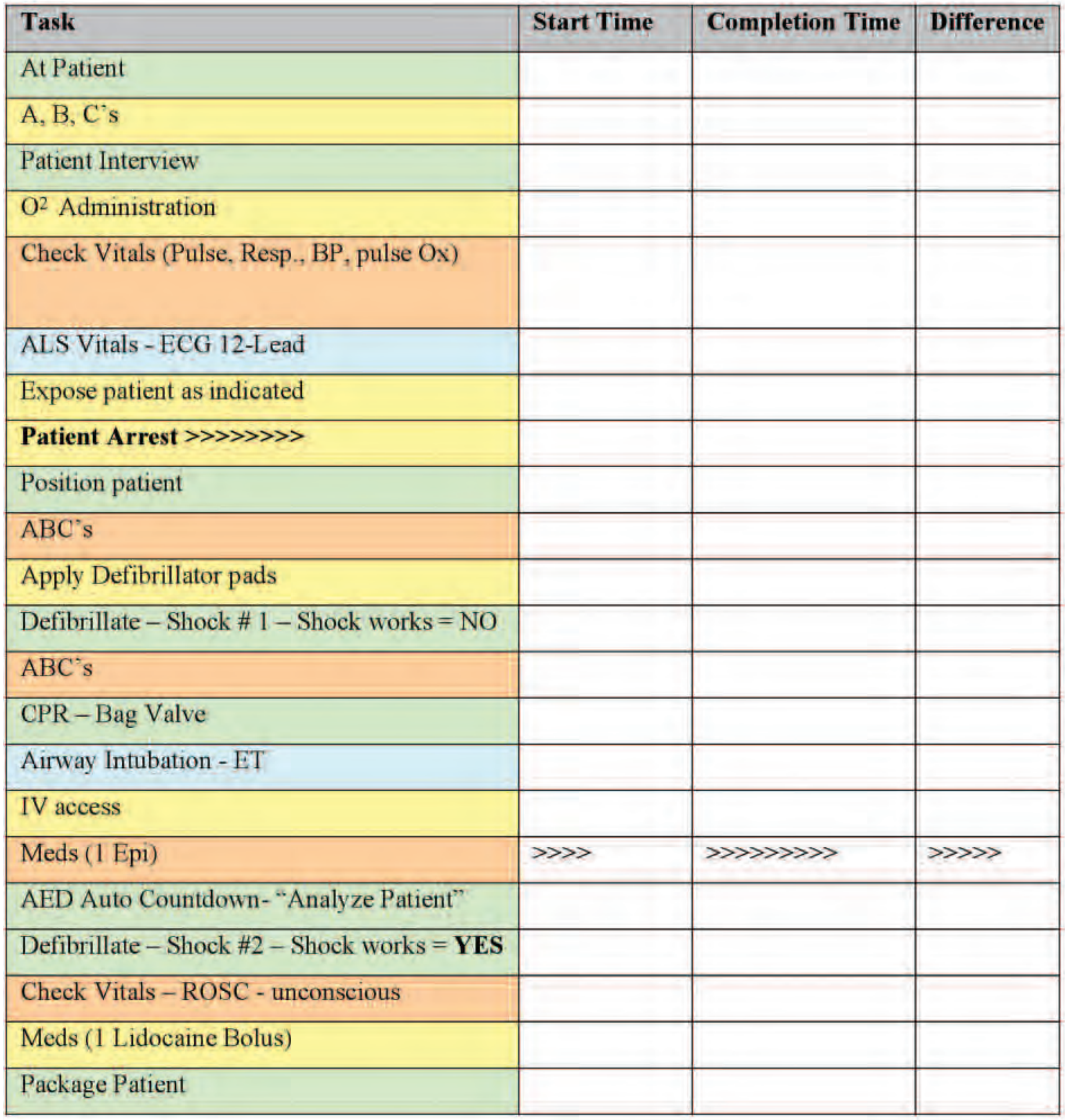
Task	Start Time	Completion Time	Difference
At Patient			
Spinal motion restriction			
A, B, C's			
Patient Interview			
Body sweep – find laceration on head and angulated fracture of tib/fib (closed) on Right leg			
O² Administration – face mask			
Check Vitals (Pulse, Resp., BP, Pulse Ox)			
Expose patient as indicated			
Control Bleeding			
Splint leg			
Back Board			
Movement causes labored breathing – Agonal Respiration ➔ Patient vomits (projectile)			
Airway – Intubation ET with spinal motion restriction – on ground due to distance from transport unit			
Bag Valve Mask			
Package patient / move for transport			

Time-to-Task Data Collection Chart -EMS

(Medical — Cardiac)

Date ____________ Start Time_____________ End Time (all tasks complete) ____________

Timer Name____



Task	Start Time	Completion Time	Difference
At Patient			
A, B, C's			
Patient Interview			
O^2 Administration			
Check Vitals (Pulse, Resp., BP, pulse Ox)			
ALS Vitals - ECG 12-Lead			
Expose patient as indicated			
Patient Arrest >>>>>>>>			
Position patient			
ABC's			
Apply Defibrillator pads			
Defibrillate – Shock # 1 – Shock works = NO			
ABC's			
CPR – Bag Valve			
Airway Intubation - ET			
IV access			
Meds (1 Epi)	>>>>	>>>>>>>>>	>>>>>
AED Auto Countdown- "Analyze Patient"			
Defibrillate – Shock #2 – Shock works = **YES**			
Check Vitals – ROSC - unconscious			
Meds (1 Lidocaine Bolus)			
Package Patient			

Appendix B: Trauma Patient Assessment and Interview Form

Name:____ Age: ________ Male / Female

Chief Complaint: ____

Mechanism of Injury: ____

Primary Survey:

Airway status: open / occluded

Breathing: normal / labored-abnormal / none

Circulation: normal / shocky / none

Mental Status: alert / voice / pain / unresponsive

Body Sweep Findings? ______________________

Secondary / Focused Survey Findings:

Head

Face

Neck

Chest

Back

L Arm

R Arm

Abdomen

L Leg

R Leg

Vital Signs:

BP ______ Pulse: ______ Resp:______ PulseOx: ______

BP ______ Pulse: ______ Resp:______ PulseOx: ______

Treatment:

☐ oxygen ☐ C-spine ☐ Splinting ☐ Bandaging

Appendix C: Medical Patient Interview Form

Name:____ Age: ________ Male / Female

Chief Complaint: ____

Mechanism of Injury: ____

"SAMPLE" history	**"OPQRST" pain survey**
Signs & Symptoms	**Onset?** What were you doing?
Allergies	**Provokes?** What makes it better or worse?
Medications	**Quality?** "What does it feel like?
Previous Medical History	**Radiation?** "Does it go anywhere?"
Last Oral Intake	**Severity?** 1-10 scale
Events Leading Up to?	**Time?** When did it begin?

Vital Signs:

BP ______ Pulse: ______ Resp: _____ PulseOx: _____

Treatment:

☐ oxygen ☐ ECG ☐ 12-lead ☐ IV

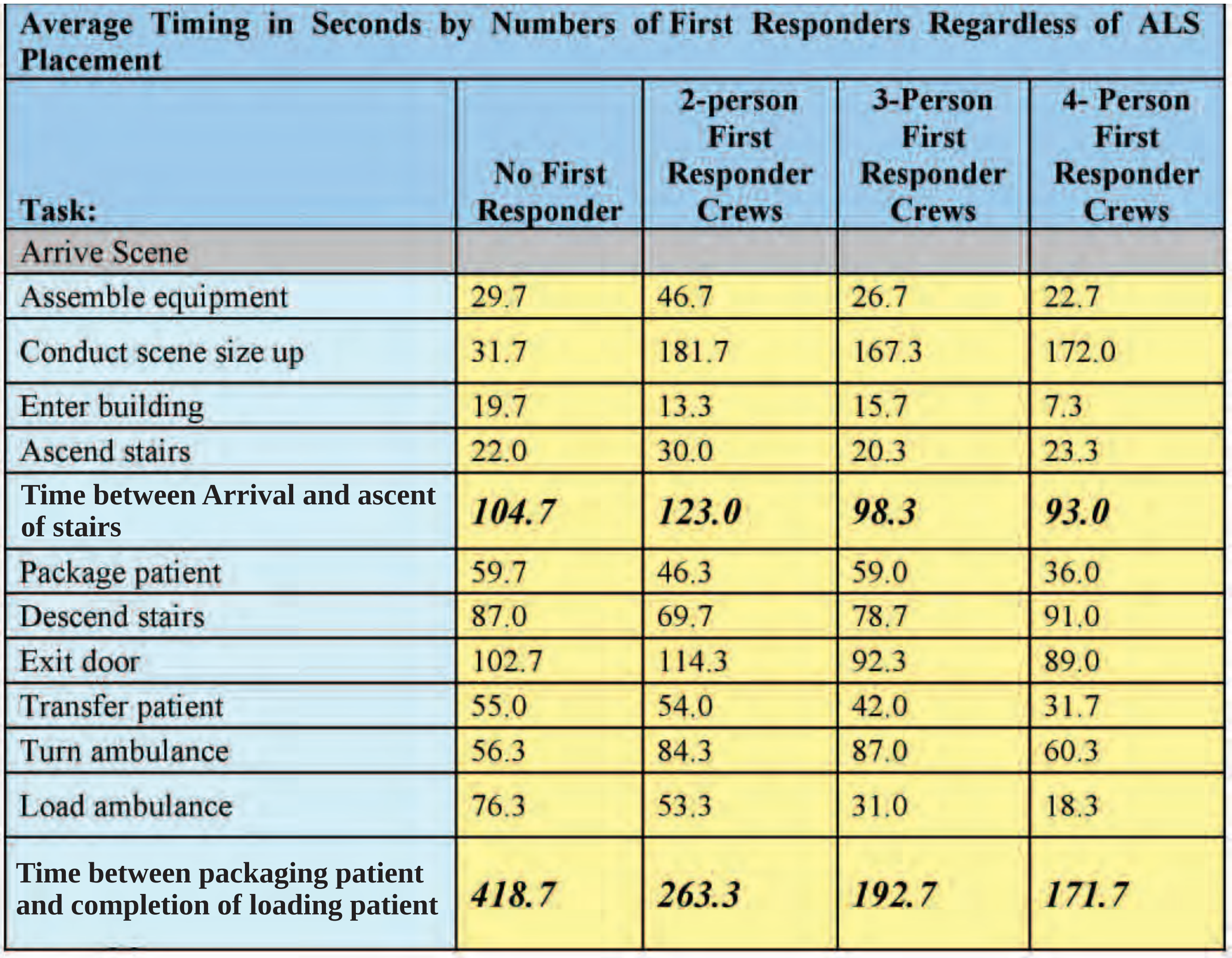
☐ medications? ____

Appendix D: Medical Patient Assessment/Interview Form

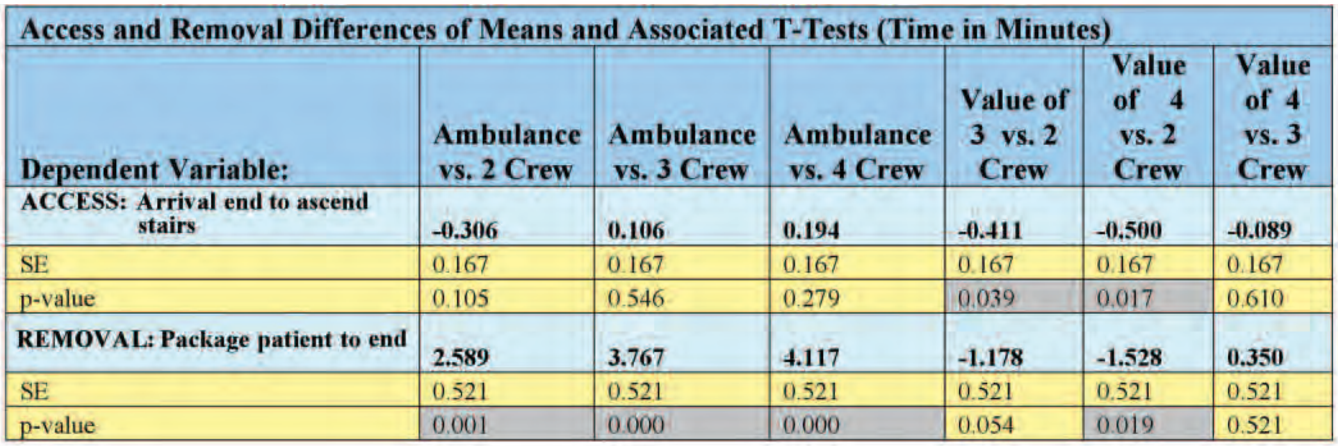
“SAMPLE HISTORY”	**Signs & Symptoms** “What is bothering you this morning?	Pain under my breastbone.
	Allergies “Are you allergic to any medications?”	None
	Medications “Do you take any medications?”	Aspirin and Cardizem.
	Previous History “Do you have any medical problems? Has this ever happened to you before?”	I was diagnosed with high blood pressure two years ago. No, I have never felt pain like this before.
	Last Oral Intake “Have you been eating normally?”	Yes. Had a full breakfast this morning.
	Events Leading Up to? “What happened prior to you developing this pain?”	Nothing, I was feeling fine before this.

PAIN SURVEY	**PAIN SURVEY Onset?** “What were you doing when pain began?”	I was sitting on the couch watching television.
	Provokes? “Have you done anything that makes the pain better?”	No, it is a steady pain and I can’t get in a comfortable position.
	Radiates? “Do you feel the pain anywhere besides your chest?”	Yes, I feel it in my spine also.
	Severity? “On a scale of 1 to 10, with ten worst pain you can imagine, how severe is your pain now?”	It is a 6.
	Time? “When did your chest pain begin?”	About 30 minutes ago.

Appendix E: Statistical Analysis of Time to Task Data Patient Access and Removal

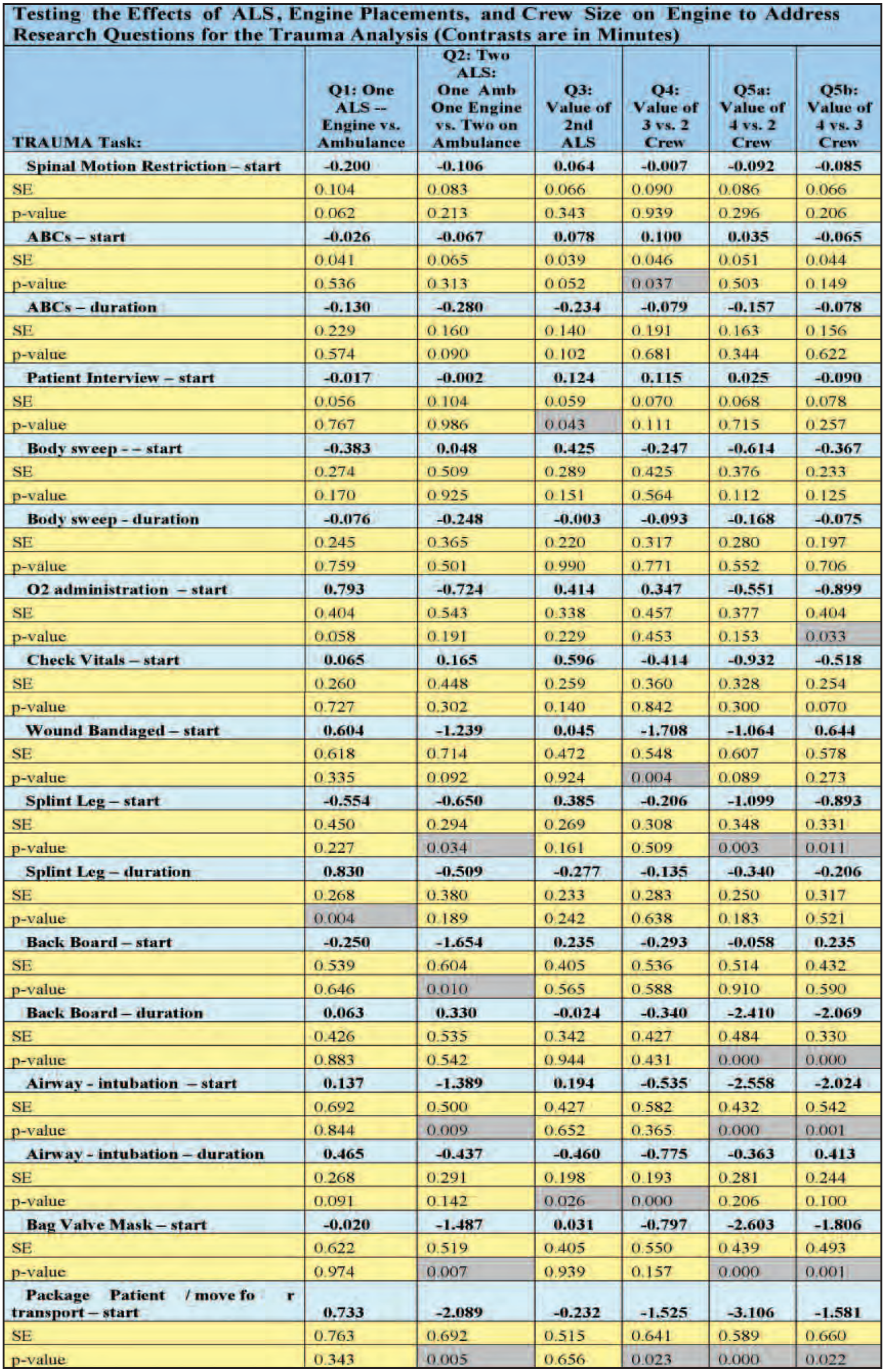


Average Timing in Seconds by Numbers of First Responders Regardless of ALS Placement				
Task:	**No First Responder**	**2-person First Responder Crews**	**3-Person First Responder Crews**	**4- Person First Responder Crews**
Arrive Scene				
Assemble equipment	29.7	46.7	26.7	22.7
Conduct scene size up	31.7	181.7	167.3	172.0
Enter building	19.7	13.3	15.7	7.3
Ascend stairs	22.0	30.0	20.3	23.3
Time between Arrival and ascent of stairs	***104.7***	***123.0***	***98.3***	***93.0***
Package patient	59.7	46.3	59.0	36.0
Descend stairs	87.0	69.7	78.7	91.0
Exit door	102.7	114.3	92.3	89.0
Transfer patient	55.0	54.0	42.0	31.7
Turn ambulance	56.3	84.3	87.0	60.3
Load ambulance	76.3	53.3	31.0	18.3
Time between packaging patient and completion of loading patient	***418.7***	***263.3***	***192.7***	***171.7***



Access and Removal Differences of Means and Associated T-Tests (Time in Minutes)						
Dependent Variable:	**Ambulance vs. 2 Crew**	**Ambulance vs. 3 Crew**	**Ambulance vs. 4 Crew**	**Value of 3 vs. 2 Crew**	**Value of 4 vs. 2 Crew**	**Value of 4 vs. 3 Crew**
ACCESS: Arrival end to ascend stairs	**-0.306**	**0.106**	**0.194**	**-0.411**	**-0.500**	**-0.089**
SE	0.167	0.167	0.167	0.167	0.167	0.167
p-value	0.105	0.546	0.279	0.039	0.017	0.610
REMOVAL: Package patient to end	**2.589**	**3.767**	**4.117**	**-1.178**	**-1.528**	**0.350**
SE	0.521	0.521	0.521	0.521	0.521	0.521
p-value	0.001	0.000	0.000	0.054	0.019	0.521

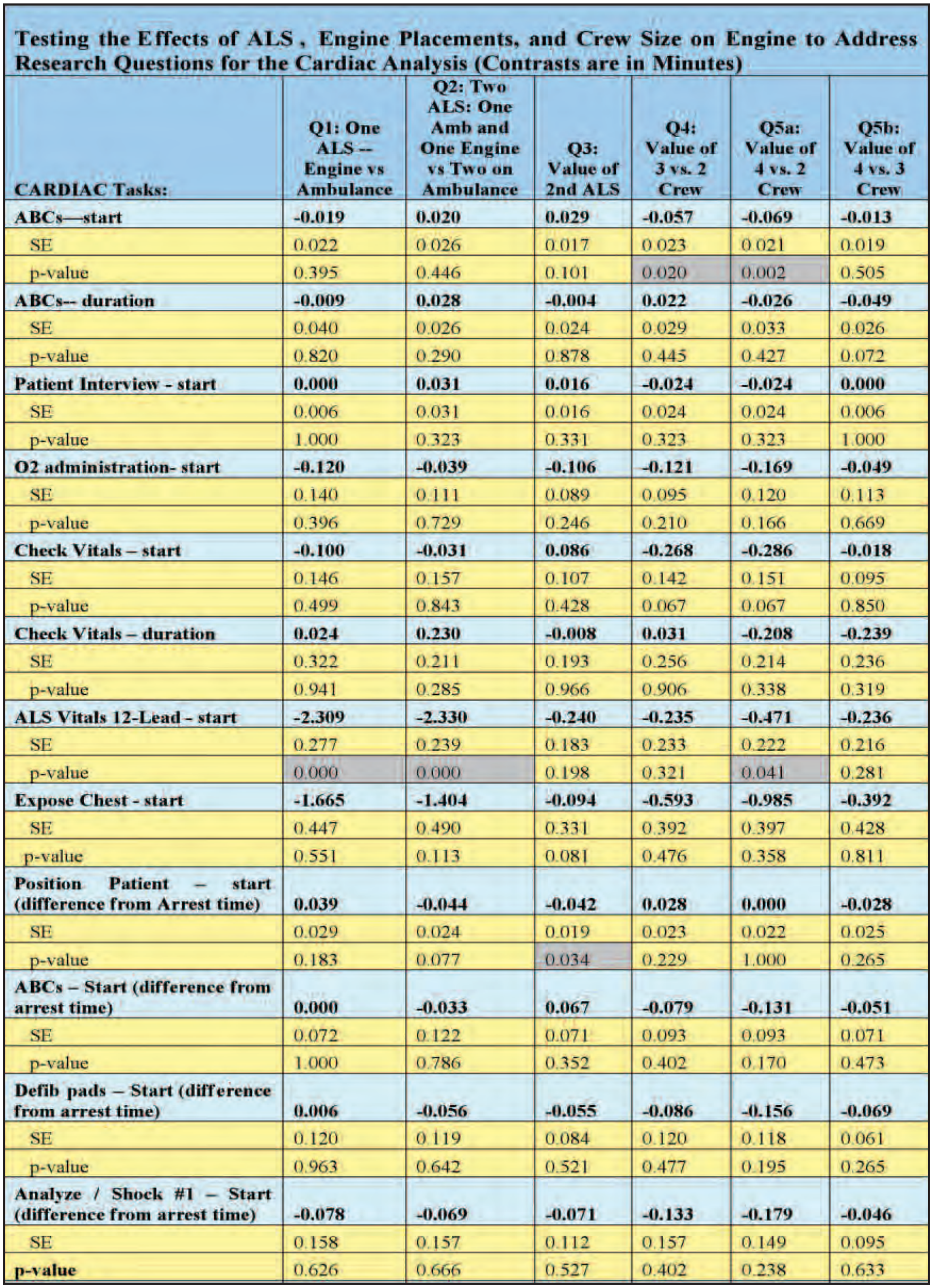
Appendix F: Statistical Analysis of Time to Task Data Patient Systemic Trauma Patient



Testing the Effects of ALS, Engine Placements, and Crew Size on Engine to Address Research Questions for the Trauma Analysis (Contrasts are in Minutes)

TRAUMA Task:	**Q1: One ALS -- Engine vs. Ambulance**	**Q2: Two ALS: One Amb One Engine vs. Two on Ambulance**	**Q3: Value of 2nd ALS**	**Q4: Value of 3 vs. 2 Crew**	**Q5a: Value of 4 vs. 2 Crew**	**Q5b: Value of 4 vs. 3 Crew**
Spinal Motion Restriction – start	**-0.200**	**-0.106**	**0.064**	**-0.007**	**-0.092**	**-0.085**
SE	0.104	0.083	0.066	0.090	0.086	0.066
p-value	0.062	0.213	0.343	0.939	0.296	0.206
ABCs – start	**-0.026**	**-0.067**	**0.078**	**0.100**	**0.035**	**-0.065**
SE	0.041	0.065	0.039	0.046	0.051	0.044
p-value	0.536	0.313	0.052	0.037	0.503	0.149
ABCs – duration	**-0.130**	**-0.280**	**-0.234**	**-0.079**	**-0.157**	**-0.078**
SE	0.229	0.160	0.140	0.191	0.163	0.156
p-value	0.574	0.090	0.102	0.681	0.344	0.622
Patient Interview – start	**-0.017**	**-0.002**	**0.124**	**0.115**	**0.025**	**-0.090**
SE	0.056	0.104	0.059	0.070	0.068	0.078
p-value	0.767	0.986	0.043	0.111	0.715	0.257
Body sweep - – start	**-0.383**	**0.048**	**0.425**	**-0.247**	**-0.614**	**-0.367**
SE	0.274	0.509	0.289	0.425	0.376	0.233
p-value	0.170	0.925	0.151	0.564	0.112	0.125
Body sweep - duration	**-0.076**	**-0.248**	**-0.003**	**-0.093**	**-0.168**	**-0.075**
SE	0.245	0.365	0.220	0.317	0.280	0.197
p-value	0.759	0.501	0.990	0.771	0.552	0.706
O2 administration – start	**0.793**	**-0.724**	**0.414**	**0.347**	**-0.551**	**-0.899**
SE	0.404	0.543	0.338	0.457	0.377	0.404
p-value	0.058	0.191	0.229	0.453	0.153	0.033
Check Vitals – start	**0.065**	**0.165**	**0.596**	**-0.414**	**-0.932**	**-0.518**
SE	0.260	0.448	0.259	0.360	0.328	0.254
p-value	0.727	0.302	0.140	0.842	0.300	0.070
Wound Bandaged – start	**0.604**	**-1.239**	**0.045**	**-1.708**	**-1.064**	**0.644**
SE	0.618	0.714	0.472	0.548	0.607	0.578
p-value	0.335	0.092	0.924	0.004	0.089	0.273
Splint Leg – start	**-0.554**	**-0.650**	**0.385**	**-0.206**	**-1.099**	**-0.893**
SE	0.450	0.294	0.269	0.308	0.348	0.331
p-value	0.227	0.034	0.161	0.509	0.003	0.011
Splint Leg – duration	**0.830**	**-0.509**	**-0.277**	**-0.135**	**-0.340**	**-0.206**
SE	0.268	0.380	0.233	0.283	0.250	0.317
p-value	0.004	0.189	0.242	0.638	0.183	0.521
Back Board – start	**-0.250**	**-1.654**	**0.235**	**-0.293**	**-0.058**	**0.235**
SE	0.539	0.604	0.405	0.536	0.514	0.432
p-value	0.646	0.010	0.565	0.588	0.910	0.590
Back Board – duration	**0.063**	**0.330**	**-0.024**	**-0.340**	**-2.410**	**-2.069**
SE	0.426	0.535	0.342	0.427	0.484	0.330
p-value	0.883	0.542	0.944	0.431	0.000	0.000
Airway - intubation – start	**0.137**	**-1.389**	**0.194**	**-0.535**	**-2.558**	**-2.024**
SE	0.692	0.500	0.427	0.582	0.432	0.542
p-value	0.844	0.009	0.652	0.365	0.000	0.001
Airway - intubation – duration	**0.465**	**-0.437**	**-0.460**	**-0.775**	**-0.363**	**0.413**
SE	0.268	0.291	0.198	0.193	0.281	0.244
p-value	0.091	0.142	0.026	0.000	0.206	0.100
Bag Valve Mask – start	**-0.020**	**-1.487**	**0.031**	**-0.797**	**-2.603**	**-1.806**
SE	0.622	0.519	0.405	0.550	0.439	0.493
p-value	0.974	0.007	0.939	0.157	0.000	0.001
Package Patient / move fo r transport – start	**0.733**	**-2.089**	**-0.232**	**-1.525**	**-3.106**	**-1.581**
SE	0.763	0.692	0.515	0.641	0.589	0.660
p-value	0.343	0.005	0.656	0.023	0.000	0.022

Appendix G: Statistical Analysis of Time to Task Data Cardiac Arrest Patient

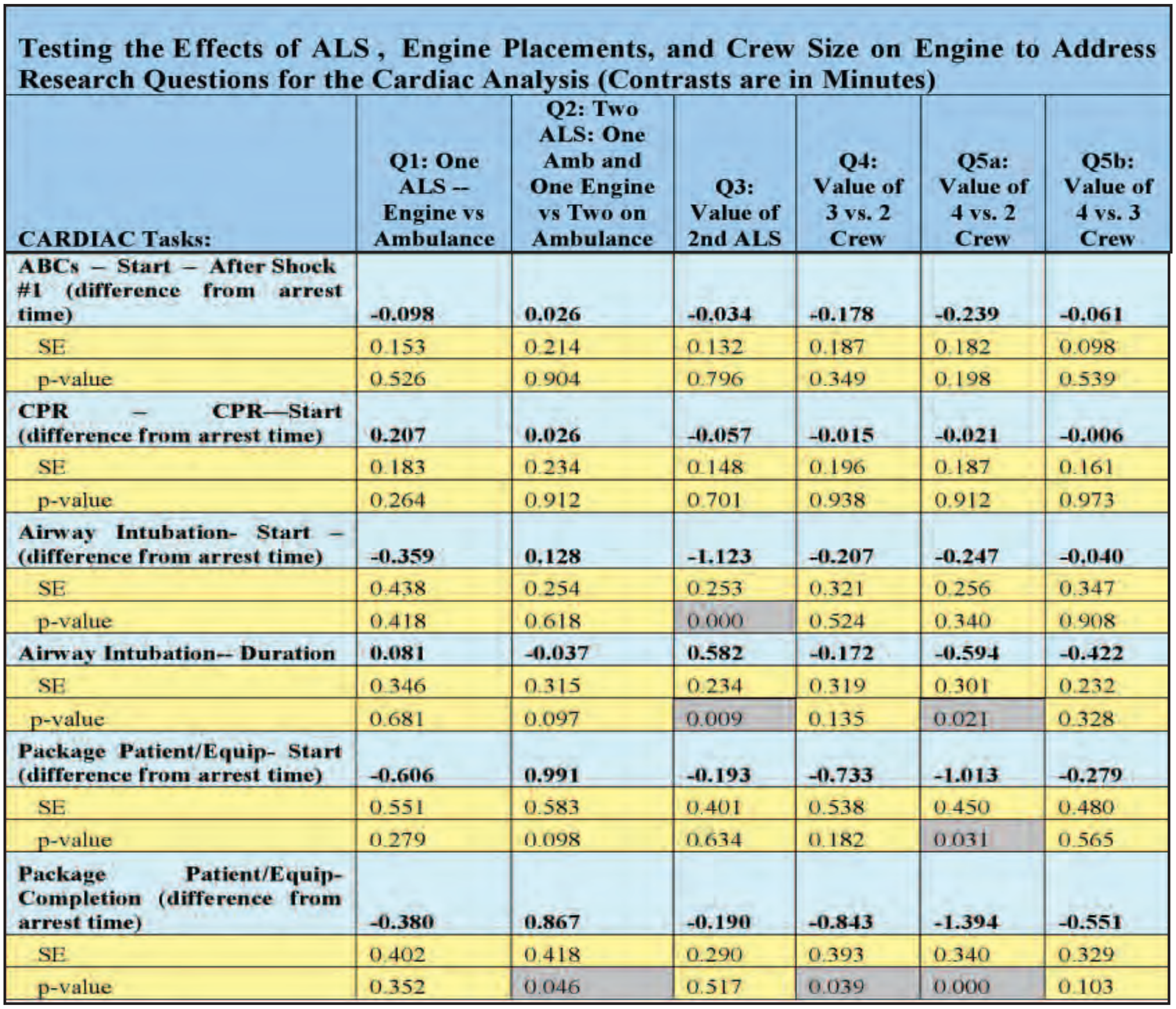


Testing the Effects of ALS , Engine Placements, and Crew Size on Engine to Address Research Questions for the Cardiac Analysis (Contrasts are in Minutes)

CARDIAC Tasks:	Q1: One ALS -- Engine vs Ambulance	Q2: Two ALS: One Amb and One Engine vs Two on Ambulance	Q3: Value of 2nd ALS	Q4: Value of 3 vs. 2 Crew	Q5a: Value of 4 vs. 2 Crew	Q5b: Value of 4 vs. 3 Crew
ABCs—start	**-0.019**	**0.020**	**0.029**	**-0.057**	**-0.069**	**-0.013**
SE	0.022	0.026	0.017	0.023	0.021	0.019
p-value	0.395	0.446	0.101	0.020	0.002	0.505
ABCs-- duration	**-0.009**	**0.028**	**-0.004**	**0.022**	**-0.026**	**-0.049**
SE	0.040	0.026	0.024	0.029	0.033	0.026
p-value	0.820	0.290	0.878	0.445	0.427	0.072
Patient Interview - start	**0.000**	**0.031**	**0.016**	**-0.024**	**-0.024**	**0.000**
SE	0.006	0.031	0.016	0.024	0.024	0.006
p-value	1.000	0.323	0.331	0.323	0.323	1.000
O2 administration- start	**-0.120**	**-0.039**	**-0.106**	**-0.121**	**-0.169**	**-0.049**
SE	0.140	0.111	0.089	0.095	0.120	0.113
p-value	0.396	0.729	0.246	0.210	0.166	0.669
Check Vitals – start	**-0.100**	**-0.031**	**0.086**	**-0.268**	**-0.286**	**-0.018**
SE	0.146	0.157	0.107	0.142	0.151	0.095
p-value	0.499	0.843	0.428	0.067	0.067	0.850
Check Vitals – duration	**0.024**	**0.230**	**-0.008**	**0.031**	**-0.208**	**-0.239**
SE	0.322	0.211	0.193	0.256	0.214	0.236
p-value	0.941	0.285	0.966	0.906	0.338	0.319
ALS Vitals 12-Lead - start	**-2.309**	**-2.330**	**-0.240**	**-0.235**	**-0.471**	**-0.236**
SE	0.277	0.239	0.183	0.233	0.222	0.216
p-value	0.000	0.000	0.198	0.321	0.041	0.281
Expose Chest - start	**-1.665**	**-1.404**	**-0.094**	**-0.593**	**-0.985**	**-0.392**
SE	0.447	0.490	0.331	0.392	0.397	0.428
p-value	0.551	0.113	0.081	0.476	0.358	0.811
Position Patient – start (difference from Arrest time)	**0.039**	**-0.044**	**-0.042**	**0.028**	**0.000**	**-0.028**
SE	0.029	0.024	0.019	0.023	0.022	0.025
p-value	0.183	0.077	0.034	0.229	1.000	0.265
ABCs – Start (difference from arrest time)	**0.000**	**-0.033**	**0.067**	**-0.079**	**-0.131**	**-0.051**
SE	0.072	0.122	0.071	0.093	0.093	0.071
p-value	1.000	0.786	0.352	0.402	0.170	0.473
Defib pads – Start (difference from arrest time)	**0.006**	**-0.056**	**-0.055**	**-0.086**	**-0.156**	**-0.069**
SE	0.120	0.119	0.084	0.120	0.118	0.061
p-value	0.963	0.642	0.521	0.477	0.195	0.265
Analyze / Shock #1 – Start (difference from arrest time)	**-0.078**	**-0.069**	**-0.071**	**-0.133**	**-0.179**	**-0.046**
SE	0.158	0.157	0.112	0.157	0.149	0.095
p-value	0.626	0.666	0.527	0.402	0.238	0.633

Appendix G: Statistical Analysis of Time to Task Data Cardiac Arrest Patient

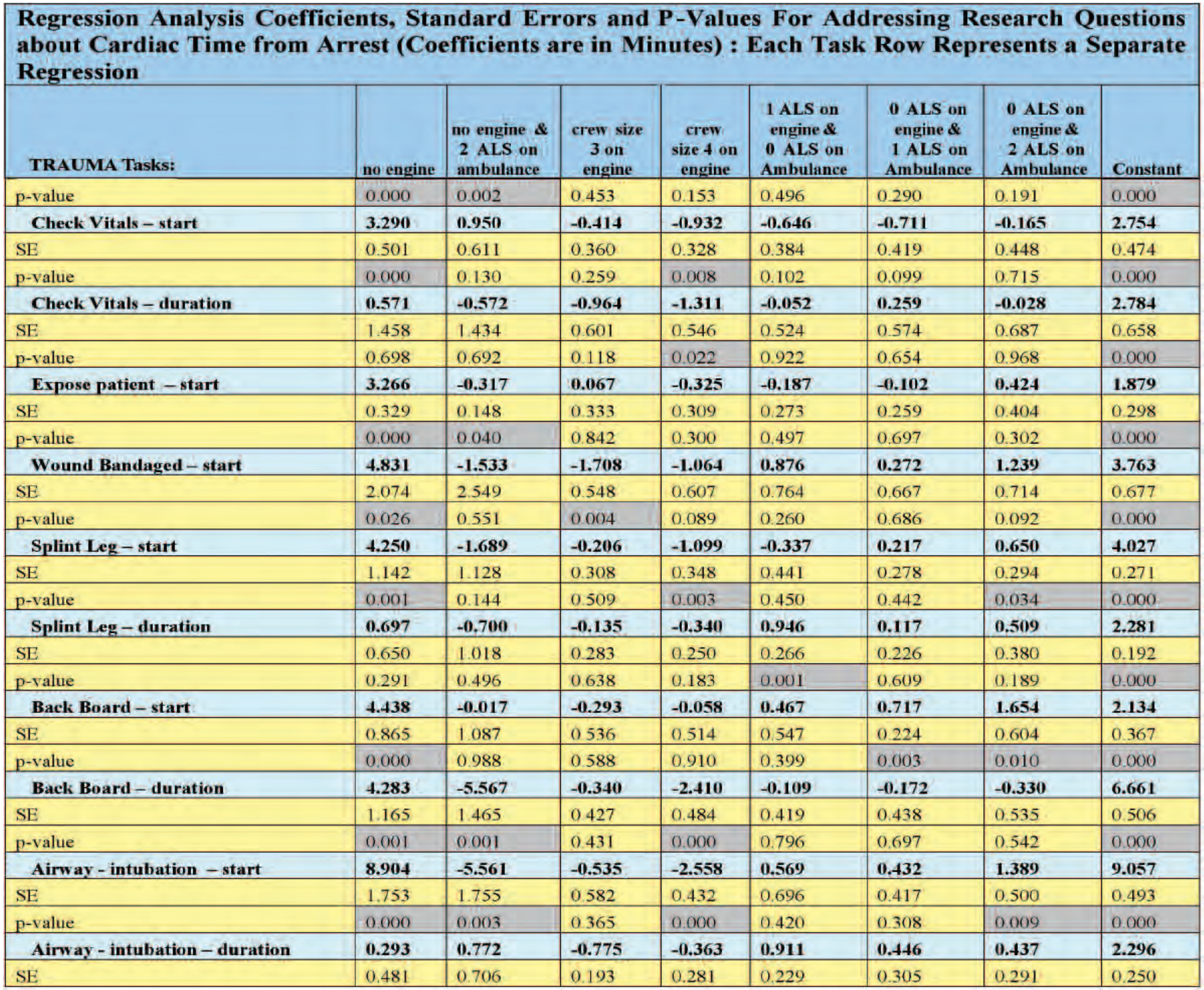
Continued



Testing the Effects of ALS , Engine Placements, and Crew Size on Engine to Address Research Questions for the Cardiac Analysis (Contrasts are in Minutes)

CARDIAC Tasks:	Q1: One ALS -- Engine vs Ambulance	Q2: Two ALS: One Amb and One Engine vs Two on Ambulance	Q3: Value of 2nd ALS	Q4: Value of 3 vs. 2 Crew	Q5a: Value of 4 vs. 2 Crew	Q5b: Value of 4 vs. 3 Crew
ABCs – Start – After Shock #1 (difference from arrest time)	**-0.098**	**0.026**	**-0.034**	**-0.178**	**-0.239**	**-0.061**
SE	0.153	0.214	0.132	0.187	0.182	0.098
p-value	0.526	0.904	0.796	0.349	0.198	0.539
CPR – CPR—Start (difference from arrest time)	**0.207**	**0.026**	**-0.057**	**-0.015**	**-0.021**	**-0.006**
SE	0.183	0.234	0.148	0.196	0.187	0.161
p-value	0.264	0.912	0.701	0.938	0.912	0.973
Airway Intubation- Start – (difference from arrest time)	**-0.359**	**0.128**	**-1.123**	**-0.207**	**-0.247**	**-0.040**
SE	0.438	0.254	0.253	0.321	0.256	0.347
p-value	0.418	0.618	0.000	0.524	0.340	0.908
Airway Intubation-- Duration	**0.081**	**-0.037**	**0.582**	**-0.172**	**-0.594**	**-0.422**
SE	0.346	0.315	0.234	0.319	0.301	0.232
p-value	0.681	0.097	0.009	0.135	0.021	0.328
Package Patient/Equip- Start (difference from arrest time)	**-0.606**	**0.991**	**-0.193**	**-0.733**	**-1.013**	**-0.279**
SE	0.551	0.583	0.401	0.538	0.450	0.480
p-value	0.279	0.098	0.634	0.182	0.031	0.565
Package Patient/Equip- Completion (difference from arrest time)	**-0.380**	**0.867**	**-0.190**	**-0.843**	**-1.394**	**-0.551**
SE	0.402	0.418	0.290	0.393	0.340	0.329
p-value	0.352	0.046	0.517	0.039	0.000	0.103

Appendix H: All Regression Coefficients Continued



Regression Analysis Coefficients, Standard Errors and P-Values For Addressing Research Questions about Cardiac Time from Arrest (Coefficients are in Minutes) : Each Task Row Represents a Separate Regression

TRAUMA Tasks:	no engine	no engine & 2 ALS on ambulance	crew size 3 on engine	crew size 4 on engine	1 ALS on engine & 0 ALS on Ambulance	0 ALS on engine & 1 ALS on Ambulance	0 ALS on engine & 2 ALS on Ambulance	Constant
p-value	0.000	0.002	0.453	0.153	0.496	0.290	0.191	0.000
Check Vitals – start	**3.290**	**0.950**	**-0.414**	**-0.932**	**-0.646**	**-0.711**	**-0.165**	**2.754**
SE	0.501	0.611	0.360	0.328	0.384	0.419	0.448	0.474
p-value	0.000	0.130	0.259	0.008	0.102	0.099	0.715	0.000
Check Vitals – duration	**0.571**	**-0.572**	**-0.964**	**-1.311**	**-0.052**	**0.259**	**-0.028**	**2.784**
SE	1.458	1.434	0.601	0.546	0.524	0.574	0.687	0.658
p-value	0.698	0.692	0.118	0.022	0.922	0.654	0.968	0.000
Expose patient – start	**3.266**	**-0.317**	**0.067**	**-0.325**	**-0.187**	**-0.102**	**0.424**	**1.879**
SE	0.329	0.148	0.333	0.309	0.273	0.259	0.404	0.298
p-value	0.000	0.040	0.842	0.300	0.497	0.697	0.302	0.000
Wound Bandaged – start	**4.831**	**-1.533**	**-1.708**	**-1.064**	**0.876**	**0.272**	**1.239**	**3.763**
SE	2.074	2.549	0.548	0.607	0.764	0.667	0.714	0.677
p-value	0.026	0.551	0.004	0.089	0.260	0.686	0.092	0.000
Splint Leg – start	**4.250**	**-1.689**	**-0.206**	**-1.099**	**-0.337**	**0.217**	**0.650**	**4.027**
SE	1.142	1.128	0.308	0.348	0.441	0.278	0.294	0.271
p-value	0.001	0.144	0.509	0.003	0.450	0.442	0.034	0.000
Splint Leg – duration	**0.697**	**-0.700**	**-0.135**	**-0.340**	**0.946**	**0.117**	**0.509**	**2.281**
SE	0.650	1.018	0.283	0.250	0.266	0.226	0.380	0.192
p-value	0.291	0.496	0.638	0.183	0.001	0.609	0.189	0.000
Back Board – start	**4.438**	**-0.017**	**-0.293**	**-0.058**	**0.467**	**0.717**	**1.654**	**2.134**
SE	0.865	1.087	0.536	0.514	0.547	0.224	0.604	0.367
p-value	0.000	0.988	0.588	0.910	0.399	0.003	0.010	0.000
Back Board – duration	**4.283**	**-5.567**	**-0.340**	**-2.410**	**-0.109**	**-0.172**	**-0.330**	**6.661**
SE	1.165	1.465	0.427	0.484	0.419	0.438	0.535	0.506
p-value	0.001	0.001	0.431	0.000	0.796	0.697	0.542	0.000
Airway - intubation – start	**8.904**	**-5.561**	**-0.535**	**-2.558**	**0.569**	**0.432**	**1.389**	**9.057**
SE	1.753	1.755	0.582	0.432	0.696	0.417	0.500	0.493
p-value	0.000	0.003	0.365	0.000	0.420	0.308	0.009	0.000
Airway - intubation – duration	**0.293**	**0.772**	**-0.775**	**-0.363**	**0.911**	**0.446**	**0.437**	**2.296**
SE	0.481	0.706	0.193	0.281	0.229	0.305	0.291	0.250

Appendix H: All Regression Coefficients Continued

Regression Analysis Coefficients, Standard Errors and P-Values For Addressing Research Questions about Cardiac Time from Arrest (Coefficients are in Minutes) : Each Task Row Represents a Separate Regression

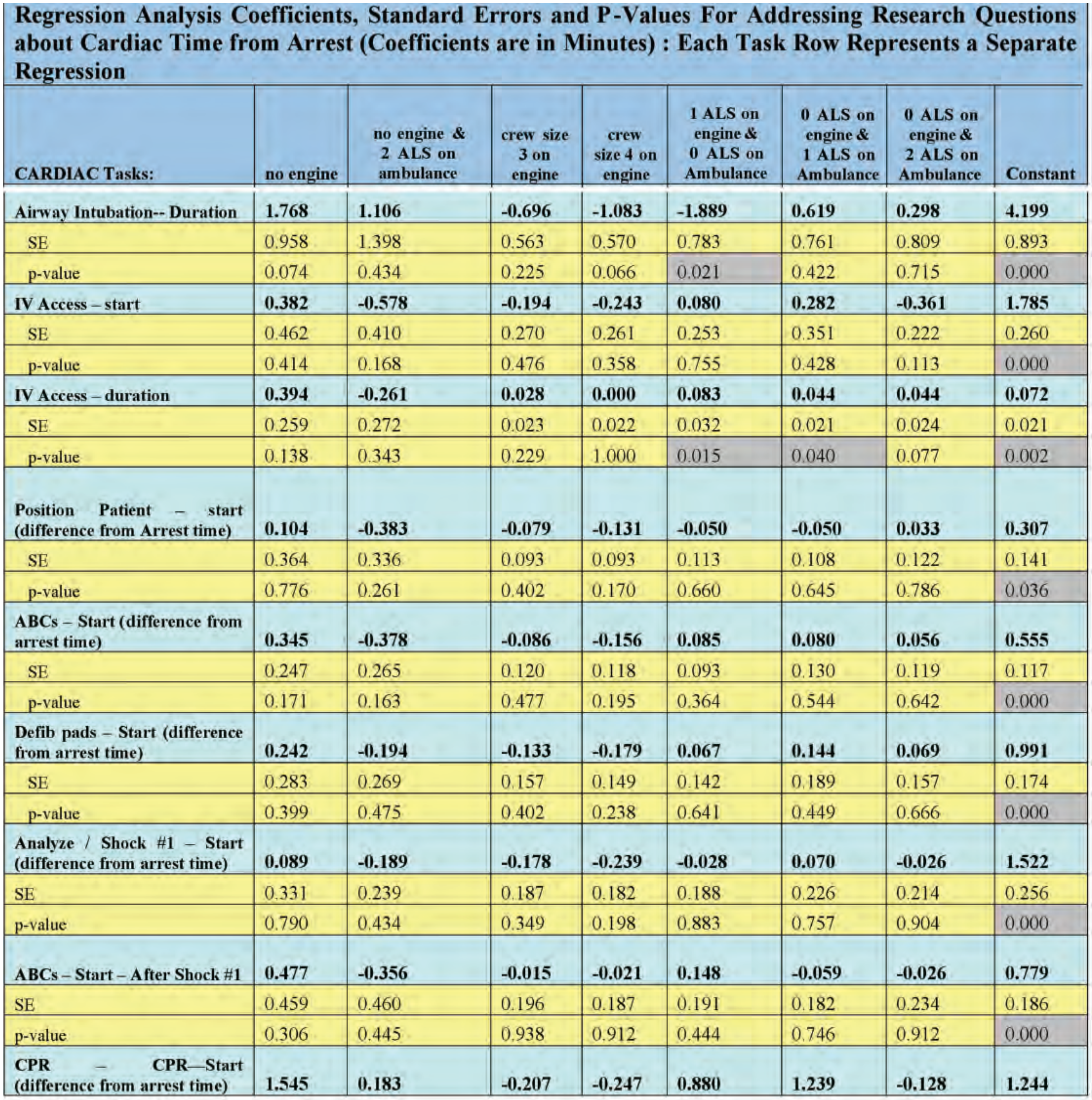
TRAUMA Tasks:	no engine	no engine & 2 ALS on ambulance	crew size 3 on engine	crew size 4 on engine	1 ALS on engine & 0 ALS on Ambulance	0 ALS on engine & 1 ALS on Ambulance	0 ALS on engine & 2 ALS on Ambulance	Constant
p-value	0.546	0.282	0.000	0.206	0.000	0.153	0.142	0.000
Bag Valve Mask – start	**8.867**	**-5.556**	**-0.797**	**-2.603**	**0.702**	**0.722**	**1.487**	**8.878**
SE	1.830	1.812	0.550	0.439	0.643	0.444	0.519	0.499
p-value	0.000	0.004	0.157	0.000	0.283	0.113	0.007	0.000
Package Patient / move for transport – start	**10.330**	**-5.544**	**-1.525**	**-3.106**	**1.643**	**0.909**	**2.089**	**11.670**
SE	2.542	2.644	0.641	0.589	0.738	0.546	0.692	0.611
p-value	0.000	0.044	0.023	0.000	0.033	0.105	0.005	0.000
Package Patient / move for transport – completion	**11.030**	**-5.039**	**-1.672**	**-3.390**	**1.806**	**0.915**	**2.267**	**12.520**
SE	2.612	2.760	0.657	0.597	0.773	0.565	0.704	0.617
p-value	0.000	0.077	0.016	0.000	0.025	0.115	0.003	0.000

Appendix H: All Regression Coefficients

Regression Analysis Coefficients, Standard Errors and P-Values For Addressing Research Questions about Cardiac Time from Arrest (Coefficients are in Minutes) : Each Task Row Represents a Separate Regression

CARDIAC Tasks:	no engine	no engine & 2 ALS on ambulance	crew size 3 on engine	crew size 4 on engine	1 ALS on engine & 0 ALS on Ambulance	0 ALS on engine & 1 ALS on Ambulance	0 ALS on engine & 2 ALS on Ambulance	Constant
ABCs—start	**3.017**	**-0.017**	**-0.057**	**-0.069**	**-0.048**	**-0.030**	**-0.020**	**0.316**
SE	0.047	0.041	0.023	0.021	0.027	0.025	0.026	0.028
p-value	0.000	0.687	0.020	0.002	0.084	0.249	0.446	0.000
ABCs-- duration	**0.012**	**-0.044**	**0.022**	**-0.026**	**-0.015**	**-0.006**	**-0.028**	**0.172**
SE	0.046	0.051	0.029	0.033	0.041	0.033	0.026	0.035
p-value	0.805	0.391	0.445	0.427	0.722	0.869	0.290	0.000
Patient Interview - start	**2.953**	**0.000**	**-0.024**	**-0.024**	**-0.031**	**-0.031**	**-0.031**	**0.047**
SE	0.046	0.000	0.024	0.024	0.031	0.031	0.031	0.046
p-value	0.000	0.358	0.323	0.323	0.323	0.323	0.323	0.311
O2 administration- start	**3.207**	**0.044**	**-0.121**	**-0.169**	**0.065**	**0.185**	**0.039**	**0.815**
SE	0.283	0.452	0.095	0.120	0.132	0.123	0.111	0.094
p-value	0.000	0.922	0.210	0.166	0.625	0.141	0.729	0.000
Check Vitals – start	**2.728**	**-0.050**	**-0.268**	**-0.286**	**-0.120**	**-0.020**	**0.031**	**1.005**
SE	0.133	0.052	0.142	0.151	0.130	0.141	0.157	0.128
p-value	0.000	0.340	0.067	0.067	0.360	0.886	0.843	0.000
Check Vitals – duration	**0.335**	**-0.689**	**0.031**	**-0.208**	**-0.094**	**-0.119**	**-0.230**	**1.948**
SE	0.410	0.399	0.256	0.214	0.229	0.300	0.211	0.218
p-value	0.419	0.094	0.906	0.338	0.683	0.695	0.285	0.000
ALS Vitals 12-Lead - start	**2.789**	**0.678**	**-0.235**	**-0.471**	**0.250**	**2.559**	**2.330**	**1.394**
SE	0.437	0.472	0.233	0.222	0.346	0.240	0.239	0.255
p-value	0.000	0.160	0.321	0.041	0.474	0.000	0.000	0.000
Expose Chest - start	2.772	-0.433	-0.593	-0.985	-0.037	1.628	1.404	2.267
SE	0.583	0.479	0.392	0.397	0.496	0.501	0.490	0.470

Appendix H: All Regression Coefficients Continued



Regression Analysis Coefficients, Standard Errors and P-Values For Addressing Research Questions about Cardiac Time from Arrest (Coefficients are in Minutes) : Each Task Row Represents a Separate Regression

CARDIAC Tasks:	no engine	no engine & 2 ALS on ambulance	crew size 3 on engine	crew size 4 on engine	1 ALS on engine & 0 ALS on Ambulance	0 ALS on engine & 1 ALS on Ambulance	0 ALS on engine & 2 ALS on Ambulance	Constant
Airway Intubation-- Duration	**1.768**	**1.106**	**-0.696**	**-1.083**	**-1.889**	**0.619**	**0.298**	**4.199**
SE	0.958	1.398	0.563	0.570	0.783	0.761	0.809	0.893
p-value	0.074	0.434	0.225	0.066	0.021	0.422	0.715	0.000
IV Access – start	**0.382**	**-0.578**	**-0.194**	**-0.243**	**0.080**	**0.282**	**-0.361**	**1.785**
SE	0.462	0.410	0.270	0.261	0.253	0.351	0.222	0.260
p-value	0.414	0.168	0.476	0.358	0.755	0.428	0.113	0.000
IV Access – duration	**0.394**	**-0.261**	**0.028**	**0.000**	**0.083**	**0.044**	**0.044**	**0.072**
SE	0.259	0.272	0.023	0.022	0.032	0.021	0.024	0.021
p-value	0.138	0.343	0.229	1.000	0.015	0.040	0.077	0.002
Position Patient – start (difference from Arrest time)	**0.104**	**-0.383**	**-0.079**	**-0.131**	**-0.050**	**-0.050**	**0.033**	**0.307**
SE	0.364	0.336	0.093	0.093	0.113	0.108	0.122	0.141
p-value	0.776	0.261	0.402	0.170	0.660	0.645	0.786	0.036
ABCs – Start (difference from arrest time)	**0.345**	**-0.378**	**-0.086**	**-0.156**	**0.085**	**0.080**	**0.056**	**0.555**
SE	0.247	0.265	0.120	0.118	0.093	0.130	0.119	0.117
p-value	0.171	0.163	0.477	0.195	0.364	0.544	0.642	0.000
Defib pads – Start (difference from arrest time)	**0.242**	**-0.194**	**-0.133**	**-0.179**	**0.067**	**0.144**	**0.069**	**0.991**
SE	0.283	0.269	0.157	0.149	0.142	0.189	0.157	0.174
p-value	0.399	0.475	0.402	0.238	0.641	0.449	0.666	0.000
Analyze / Shock #1 – Start (difference from arrest time)	**0.089**	**-0.189**	**-0.178**	**-0.239**	**-0.028**	**0.070**	**-0.026**	**1.522**
SE	0.331	0.239	0.187	0.182	0.188	0.226	0.214	0.256
p-value	0.790	0.434	0.349	0.198	0.883	0.757	0.904	0.000
ABCs – Start – After Shock #1	**0.477**	**-0.356**	**-0.015**	**-0.021**	**0.148**	**-0.059**	**-0.026**	**0.779**
SE	0.459	0.460	0.196	0.187	0.191	0.182	0.234	0.186
p-value	0.306	0.445	0.938	0.912	0.444	0.746	0.912	0.000
CPR – CPR—Start (difference from arrest time)	**1.545**	**0.183**	**-0.207**	**-0.247**	**0.880**	**1.239**	**-0.128**	**1.244**

Appendix H: All Regression Coefficients Continued

Regression Analysis Coefficients, Standard Errors and P-Values For Addressing Research Questions about Cardiac Time from Arrest (Coefficients are in Minutes) : Each Task Row Represents a Separate Regression

CARDIAC Tasks:	no engine	no engine & 2 ALS on ambulance	crew size 3 on engine	crew size 4 on engine	1 ALS on engine & 0 ALS on Ambulance	0 ALS on engine & 1 ALS on Ambulance	0 ALS on engine & 2 ALS on Ambulance	Constant
SE	0.588	1.163	0.321	0.256	0.313	0.374	0.254	0.236
p-value	0.013	0.876	0.524	0.340	0.008	0.002	0.618	0.000
Airway Intubation- Start and duration – (difference from arrest time)	**-0.244**	**-0.078**	**-0.172**	**-0.594**	**-0.522**	**-0.604**	**0.037**	**2.800**
SE	0.417	0.453	0.319	0.301	0.322	0.286	0.315	0.260
p-value	0.562	0.865	0.593	0.057	0.114	0.043	0.907	0.000
Meds (Epi)- Start (difference from arrest time)	**0.632**	**-0.542**	**-0.228**	**-0.508**	**-0.504**	**-0.394**	**-1.022**	**2.751**
SE	0.957	1.262	0.339	0.303	0.365	0.390	0.408	0.430
p-value	0.513	0.671	0.506	0.103	0.177	0.318	0.017	0.000
Analyze / Shock #2 -- Start time	**-0.070**	**-0.300**	**-0.442**	**-0.479**	**-0.009**	**-0.137**	**-0.133**	**4.003**
SE	0.394	0.237	0.216	0.208	0.245	0.255	0.250	0.315
p-value	0.860	0.214	0.049	0.027	0.970	0.594	0.597	0.000
Medis (Lidocaine) - Start (difference from arrest time)	**2.054**	**-2.278**	**-0.440**	**-0.721**	**0.293**	**0.424**	**-0.596**	**4.763**
SE	0.424	0.404	0.287	0.297	0.296	0.359	0.350	0.258
p-value	0.000	0.000	0.135	0.021	0.329	0.246	0.097	0.000
Package Patient/Equip- Start	**1.444**	**0.328**	**-0.733**	**-1.013**	**-0.606**	**0.000**	**-0.991**	**5.795**
SE	0.673	1.375	0.538	0.450	0.554	0.530	0.583	0.480
p-value	0.039	0.813	0.182	0.031	0.282	1.000	0.098	0.000
Package Patient/Equip- Completion	**2.173**	**-0.072**	**-0.843**	**-1.394**	**-0.433**	**-0.054**	**-0.867**	**7.327**
SE	0.610	1.248	0.393	0.340	0.365	0.458	0.418	0.402
p-value	0.001	0.954	0.039	0.000	0.244	0.907	0.046	0.000

NOTES:

APPENDIX E

I A F F

Safe Fire Fighter Staffing

– Critical Considerations –

International Association
of Fire Fighters

Safe Fire Fighter Staffing

Critical Considerations

Second Edition

Department of Research and Labor Issues
International Association of Fire Fighters, AFL-CIO, CLC

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Introduction

This manual identifies those benchmarks by which safe and effective minimum fire suppression services should be assessed. It provides both citizens and municipal officials with the facts they must consider in making informed decisions regarding the appropriate level of service for their communities. Fire fighter staffing directly affects delivery of fire protection service and is therefore essential to any discussion or debate involving service levels.

It is generally accepted that a municipality has the right to determine the overall level of fire protection it wants. However, regardless of the level of fire protection chosen by the citizens, neither they nor their elected representatives have the right to jeopardize the safety of the employees providing those services.

Citizens pay for protection of life and property through their tax dollars, and they assume that their elected and appointed officials will make informed decisions regarding that protection. Too often, that decision making process has been based solely on budgetary expedience. However, irrespective of the resources provided, citizens continue to believe that fire fighters are prepared to provide an aggressive interior assault on fires, successfully accomplishing victim rescue, fire control, and property conservation. They do not expect fire fighters to take defensive actions, i.e., to simply surround a fire and drown it, because to do so would be to concede preventable loss of both life and property. However, when staffing levels are reduced, misguided economics and community expectations collide, with politicians insisting that potential budgetary savings will not affect the level of service.

Unless citizens understand the relationship between staffing levels and their own life safety and the protection of their property, it is not realistic for fire fighters to expect them to insist on appropriate service levels, including minimum staffing. Elected officials and managers cannot be expected to make appropriate decisions concerning the level of service without an education in **effective** firefighting and an understanding of the impact their policy decisions have on the citizens they represent. Therefore, it is essential to make clear to the community that reduced staffing equates to reduced service levels, and that if they expect a continued aggressive attack on fires, they must provide the department with at least the minimum resources required to meet the community's expectations. To do less forces fire fighters to accept a level of risk to their own health and safety that the community at large finds unacceptable for itself.

Historically, the standard for fire suppression in North America has mandated an **offensive** attack in situations involving structural fire. Study after study has demonstrated that if the force available to initiate an interior fire attack is less than fifteen personnel, the goals of victim rescue, fire control, and property conservation are seriously compromised. These studies state that when fireground staffing is reduced below the level necessary for aggressive tactics, the inevitable result is that fire fighters must resort to **defensive** rather than offensive operations or risk their own safety.

Firefighting has always been labor intensive and remains so. Although new technology has improved firefighting equipment and protective gear, it is fire fighters who still perform the critical tasks necessary to contain and extinguish fires. When staffing falls below minimum acceptable levels, so does service, and the goals and expectations set by the community are essentially abandoned.

A number of court decisions and arbitration awards have recognized that while firefighting is one of the most dangerous occupations in North America, fire fighters should be provided the safest possible working environment. Thus, staffing affects not only the public safety but also the safety of fire fighters and as such is a condition of employment. Although firefighting is by its nature dangerous, that does not justify employers increasing that inherent level of risk by reducing safe minimum staffing under the guise of financial difficulty.

This position has been recognized by many organizations such as the International Association of Fire Fighters, Metropolitan Fire Chiefs' Division of the International Association of Fire Chiefs and the U.S. Fire Administration. Even the International City Management Association has stated:

> *...too few companies or poorly manned ones, can result in property and life loss beyond community accepted norms. Also, the cost of a firefighter death or disabling injury may far exceed the expense of a fire company. This is not to say that there is a fixed value on a life or injury. The point is that the firefighting forces are the asset that protects the economic and tax base as well as its health and welfare. This asset is a valuable one and must be carefully provided and wisely managed.*

Chapter 1

Impact of Initial Fire Attack on Property Loss and Citizen Safety

Successful delivery of fire protection services involves two major elements – fire prevention and fire suppression. Fire prevention can be defined as those "*pre-fire activities that reduce the probability of fires occurring and help limit the loss of property and life in the fires that do occur.*"[1] Since fire prevention will never be 100 percent successful, it is necessary to buttress fire prevention goals with adequate fire suppression services. It is the objective of fire suppression to "*get to the fire as quickly as possible and to extinguish it with minimum loss to persons and property from the fire and from fire fighting activities.*"[2]

The successful attainment of the goals of both prevention and suppression require a balanced approach and commitment of resources. This balance has in recent years been tipped in the direction of fire prevention while largely ignoring fire suppression.

As the data in the following table shows, the concern with fire prevention has been substantially rewarded. According to the NFPA's Annual National Fire Experience Survey, the total number of fires, civilian deaths, and injuries has declined remarkably over the last decade. This data attests to the substantial impact that public education, smoke detectors, and development and enforcement of building codes can have on preventing fires.

However, closer examination of the same data also tells the other side of the story, which is that de-emphasis of fire suppression in recent years has led to increasing rates of civilian deaths and injuries and property loss when fires do occur.

				Rate Per 1,000 Residential Fires			
Year	**Total Residential Fires**	**Total Civilian Deaths**	**Total Civilian Injuries**	**Civilian Death**	**Civilian Injuries**	**Direct Property Damage Per Residential Fire**	**Real Property Damage Per Residential Fire [1]**
1978	730,500	6,185	21,260	8.47	29.1	$3,000.68	$4,602
1979	721,500	5,765	20,450	7.99	28.3	$3,505.20	$4,828
1980	757,500	5,446	21,100	7.19	27.9	$4,015.84	$4,874
1981	733,000	5,540	20,375	7.56	27.8	$4,446.11	$4,891
1982	676,500	4,940	21,100	7.30	31.2	$4,808.57	$4,983
1983	641,500	4,820	21,450	7.51	33.4	$5,153.55	$5,174
1984	623,000	4,240	19,275	6.81	30.9	$5,521.67	$5,314
1985	622,000	5,025	19,825	8.08	31.9	$6,067.52	$5,623
1986	581,500	4,770	19,025	8.20	32.7	$6,115.22	$5,580
1987	551,500	4,660	20,440	8.45	37.1	$6,707.16	$5,904
1988	552,500	5,065	22,600	9.17	40.9	$7,276.02	$6,150
1989	513,500	4,435	20,750	8.64	40.4	$7,785.78	$6,279
1990	467,000	4,115	20,650	8.81	44.2	$9,107.07	$6,968
1991	478,000	3,575	21,850	7.48	45.7	$11,615.06	$8,547
1992	472,000	3,705	21,600	7.85	45.8	$8,220.00	$5,859
1993	470,000	3,825	22,600	8.14	48.1	$10,304.00	$7,131
1994	451,000	3,465	20,025	7.68	44.4	$9,572.00	$6,394
1978-84	-14.7%	-31.4%	-9.3%	-19.6%	6.2%	84.0%	15.5%
1984-94	-27.6%	-18.3%	4.0%	12.8%	43.7%	73.3%	60.8%

[1] Determined by deflating the direct property damage by the CPI-U.

SOURCE: National Fire Protection Association

During the six-year period 1978-84, measures of both fire prevention and fire suppression exhibited equally impressive results. Through the efforts of fire prevention, the total number of residential fires declined 14.7%, while the total number of civilian deaths and injuries, respectively, dropped by 31.4% and 9.3%.

In those situations where fires did occur, firefighting also scored substantial gains. During the period, the rate of civilian deaths per 1,000 fires declined 19.6%, while the rate of civilian injuries and real property damage showed only modest increases.

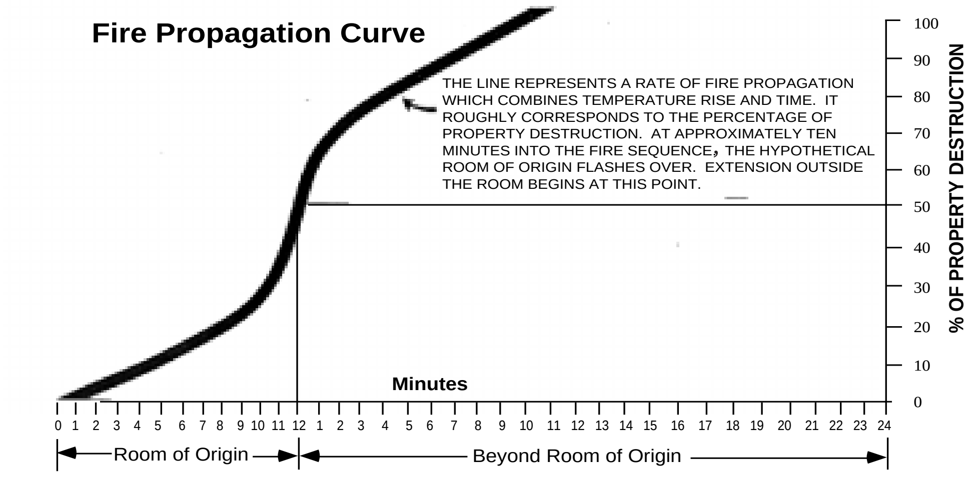
However in the last ten years, the results were substantially different. Between 1984 and 1994, the rate of civilian fire deaths per 1,000 residential fires increased 12.8%, the rate of civilian injuries increased 43.7% and real property loss rose 60.8%.

The ability of adequate fire suppression forces to greatly influence the outcome of a structural fire is undeniable and predictable. Data generated by the National Fire Protection Association provides empirical proof that rapid and aggressive interior attack can substantially reduce the human and property loss associated with structural fires. At each stage of a fire's extension beyond the room of origin, the rate of civilian deaths, injuries, and property damage grows exponentially.

	Rate Per 1,000 Fires		**Average**
Fire Extension in Residential Structures:	**Civilian Deaths**	**Civilian Injuries**	**Property Damage**
Confined to Room of Origin	**2.07**	**24.30**	**$1,505**
Confined to Floor of Origin	**18.60**	**80.44**	**$12,134**
Beyond Floor of Origin	**27.23**	**55.37**	**$21,343**

SOURCE: National Fire Protection Association

Clearly, an early aggressive and offensive initial interior attack on a working structural fire results in greatly reduced loss of life and property damage. Consequently, given that the progression of a structural fire to the point of "flashover" (the very rapid spreading of the fire due to super heating of room contents and other combustibles) generally occurs in less than 10 minutes[3], two of the most important elements in limiting fire spread are the quick arrival of sufficient numbers of personnel and equipment to attack and extinguish the fire as close to the point of its origin as possible.



THE LINE REPRESENTS A RATE OF FIRE PROPAGATION WHICH COMBINES TEMPERATURE RISE AND TIME. IT ROUGHLY CORRESPONDS TO THE PERCENTAGE OF PROPERTY DESTRUCTION. AT APPROXIMATELY TEN MINUTES INTO THE FIRE SEQUENCE, THE HYPOTHETICAL ROOM OF ORIGIN FLASHES OVER. EXTENSION OUTSIDE THE ROOM BEGINS AT THIS POINT.

SOURCE: John C. Gerard & A. Terry Jacobsen

Assuming a crew of five fire fighters is 100% effective in performing the critical tasks required for an interior fire attack, the following table shows the impact that reduced staffing has on the effectiveness of fireground operations involving a single-family residential structure.

Impact of Crew Size of First Alarm Assignment on Fire Attack in a Residential Structure

	1st Engine Company		2nd Engine Company		Truck/Ladder Company		
Crew Size:	**Charge Initial Interior Line and Advance**	**Locate & Rescue Victim**	**Charge Interior Support Line & Advance**	**Charge Exterior Line & Advance**	**Roof Ventilation**	**Search and Rescue**	**Check Exposures for Fire Extension**
5 Fire Fighters	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
4 Fire Fighters	**84.7%**	**96.1%**	**77.9%**	**72.9%**	**79.0%**	**90.3%**	**80.2%**
3 Fire Fighters	**71.3%**	**82.8%**	**0.0%**	**62.3%**	**0.0%**	**79.6%**	**0.0%**

SOURCE: "Dallas Fire Department Staffing Level Study," McManis Associates, June 1984.

The conclusions reached in the Dallas Study have recently been confirmed for small fire departments by the Westerville, Ohio Fire Department.[4] Using standard firefighting tactics, the results of the Westerville Fire Department study showed that 4 fire fighters could perform rescue of potential fire victims 80% faster than a 3 fire fighter crew.

The implications that enhanced crew size can have on rescue operations is all the more dramatic when victim survivability is considered. Data produced by the Dallas Fire Department showed that:

> *when rescue occurred between 12 and 15 1/2 minutes, the survival rate was 46.6 percent. The rate dropped to 5.5 percent when rescue occurred between 15 and 17 1/2 minutes.*

Thus, a variance of only 2 to 3 minutes in the speed with which rescue operations could be completed can increase fire victim survivability eightfold.

Consequently, the fire service in North America has for most of the twentieth century accepted the premise and the expectation that fire fighters will perform aggressive interior fire attacks when confronted with a working structural fire. This has been and still is the industry's standard of performance.

ENDNOTES

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[1] Measuring Fire Protection Productivity in Local Government, Philip S. Schaenman and Joe Swartz (Boston, MA:NFPA) 1974; p. 5.

[2] Ibid.; p. 30.

[3] "Reduced Staffing: At What Cost?," John C. Gerard and A. Terry Jacobsen, *Fire Service Today,* September 1981, pp. 15 and 17; and "Hazard I Fire Hazard Assessment Method," National Institute of Standards and Technology, U.S. Department of Commerce, June 1991.

[4] National Fire Academy, "Manning Levels for Engine and Ladder Companies in Small Fire Departments" (RR No. 14613), Richard C. Morrison.

Chapter 2

Staffing for Initial Fire Attack and Fire Fighter Safety

The purpose of this manual is to objectively relate staffing to fire fighter safety. Discussion of staffing must also address the level of effectiveness of the fire suppression services. It is expected that fire fighters will aggressively intervene to extinguish a fire. Fire fighter safety and the effectiveness of fire suppression service are closely linked. Fire fighters cannot maintain the same level of aggressive fire suppression services while receiving fewer and fewer resources.

FIRE FIGHTER SAFETY AND EFFECTIVENESS OF INITIAL FIRE ATTACK

Inappropriate reductions merely shift the burden of attempting to maintain the expected level of service to the fire fighter at the expense of his/her own safety. Consequently, fireground productivity and effectiveness are seriously compromised.

Over the last 25 years deviations from the industry's standard regarding recommended, acceptable levels of staffing per unit of response have seriously compromised fire fighter safety. In 1967, the International City Management Association (ICMA) recommended that engine companies maintain a minimum of 5 personnel, while those operating in "high value" areas require 7 personnel. The ICMA went further to state that "*ladder companies are governed by similar manpower considerations*." Citing the reason for these requirements, ICMA stated:

> *It is axiomatic that there must be enough men to put fire apparatus into effective use. Three men are needed to place a single line of 2 1/2-inch hose in service. One additional man is needed to operate a pump, plus a foreman so pumper companies require a minimum of five men.*[1]

Thus a reduction in the "industry standard" regarding the appropriate level of fire company staffing would be justified only in those circumstances where the nature and number of tasks to be accomplished at any given structural fire by fire suppression personnel were also reduced. Fire suppression has always been labor intensive and a substantial impact on productivity in the form of reductions in the number of personnel required at the company level can only be offset by major advances in technology or increased risk to the fire fighter.

Some advances have been made in technology. The industry has developed state-of-the-art apparatus, electronic communications, self-contained breathing apparatus, and personal protective gear. However, none of these advances have eliminated the critical tasks that must be performed by fire fighters at the scene of a structural fire. In fact, these advances in many ways have been offset by introduction of more hazardous materials and construction techniques.

New technologies and materials used in construction and furnishings are more combustible and toxic than those in use a quarter century ago, while advances in such areas as SCBA's and personnel protective gear have in some quarters increased the expectation that fire fighters can perform more aggressive interior fire attacks with fewer personnel.

However, just as it is logical to accept that technologies enhancing fire fighter safety also lead to increased fireground effectiveness, it is also logical to accept that diminished safety correspondingly reduces the effectiveness of fireground operations. Given that structural fire suppression is so labor intensive, reductions in firefighting personnel must inevitably lead to increased injuries unless those reductions are accompanied by viable alternative technologies or the number of critical tasks that must be performed are reduced.

The level of available technology and critical tasks that must be performed at the scene of a structural fire remain essentially unchanged. Today, however, very few jurisdictions operate units with staffing levels of more than 4 fire fighters, with many now suggesting that 2 or 3 fire fighters is an adequate and acceptable level of fire company staffing.

But, as an article in *Fire Engineering* succinctly put it:

> *A football coach who sent his team out on the field with six men and then fed the other five in piecemeal as the game progressed would be considered an idiot. Yet this is the same policy that many city officials and their hired consultants are forcing on fire chiefs–always in the guise of greater efficiency and, of course, economy.*
>
> *One man cannot be called a fire company, no matter how many men are available after he has made a sizeup and hollered for help. Neither can two or three men be considered a fire company. (These are not enough to handle a fair-sized grass fire.)*[2]

The requirement for initial arriving apparatus to be staffed with at least 4 personnel to initiate an interior fire attack is not new. It has been the fire service standard and industry practice for most of the twentieth century, as well as recognized and recommended by the National Fire Protection Association (NFPA) since at least 1962. The adherence to a minimum level of safety staffing grew out of intuition and experience and is empirically grounded in results from study after study showing the causal relationship of deficient fireground staffing and increased fire fighter injuries.

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

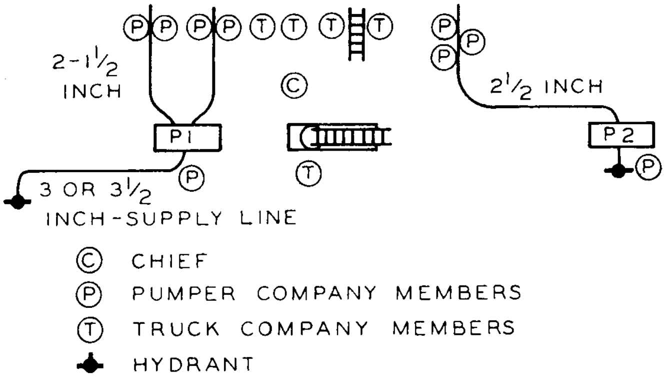
In 1966, the National Fire Protection Association issued NFPA Standard 197, *Training Standard on Initial Fire Attack.* This standard set forth the evolutions required for an initial interior attack on working structural fires. The minimum standard required sufficient number of fire fighters and equipment to deploy two attack one-and-one-half inch hose lines producing at least 150 gpm within 60 seconds of arrival, followed by a two-and-one-half inch backup line providing at least 250 gpm within 180 seconds of arrival.

While the NFPA 197 did not specify the number of fire fighters necessary to deliver this required flow, it does specify the tasks that must be performed within a given time period.

Although NFPA 197 was silent on the minimum number of fire fighters necessary to safely conduct these evolutions, the National Fire Protection Association clearly defined in its book, Fire Attack-1, the number of personnel required:

> *Standard initial fire attack for isolated buildings of average size such as one- or two-story single family dwellings consists of ability to quickly apply 1 1/2-inch attack lines plus at least one standard 250 gpm stream from 2 1/2-inch hose supplied by a pumper. The latter is required for knocking down any heavy volume of fire and for protecting exposures where necessary. Such an attack requires two pumper companies with adequate manning to run the lines and operate the nozzles and pumps, plus a truck company capable of simultaneously performing forcible entry, search and rescue, ventilation, raising of ladders, salvage operations, and operation of the various power tools carried on the truck such as electric generators and lights and smoke removal equipment. The entire operation is directed and coordinated by a chief officer.*
>
> *The desirable number of men normally required to respond with the apparatus to give this level of performance with properly manned hose streams and equipment would be approximately fifteen plus the chief. An aide who assists the chief in giving orders and in serving as radio communications specialist in contact with the alarm office, supplies the chief with one additional man.*
>
> *The operation may be performed with slightly less men (but with reduced efficiency) where weaker truck service is provided. In a standard operation, the truck operator is expected to operate the power ladder if needed for ventilation, rescue or access, and also to operate auxiliary power equipment such as generators and to provide the various tools and appliances that are likely to be required during the fire. Therefore, his basic position is with his truck just as a pump operator or 'engineer' should be provided with each pumper to give the correct volume and pressure to each hose stream. The balance of the truck crew may be divided into teams. One of these teams would normally be assigned to inside search, rescue, forcible entry and ventilation in support of the fire*

> *attack. The other would be an outside crew for raising ladders (up to 35 feet) for possible rescue as well as for topside ventilation. They would also provide truck support for hose crews assigned to the rear of the fire building. All truckmen should perform salvage operations as soon as practicable.*



> *Hose crew requirements are based upon the need for two men to properly apply each stream from 1 1/2-inch hose and three men to effectively operate a 250 gpm stream from a 2 1/2-inch hand line.*[3] (UNDERLINING ADDED)

Hence, adherence to NFPA 197 required two pumpers and a ladder truck with a total complement of at least 15 personnel. NFPA further stated that:

> *Ordinarily (except where there are major rescue operations), the greatest manpower is needed for fast application and operation of hand hose streams carried directly to the seat of the fire. Thus, adequate manpower on the initially arriving pumper companies is most essential, and large forces mobilized later cannot be accepted as a substitute for deficiencies in the manning of the first alarm response.*[4]

The NFPA further cross-referenced the initial attack criteria of NFPA 197 in the Fire Protection Handbook,[5] stating:

> *Regardless of how companies are organized, response to alarms for structural fires should include sufficient apparatus and manpower under at least one chief officer. Normally, a minimum initial response would be two pumpers, a vehicle for truck service, and 12 to 15 men and a chief.*

and

> *An initial response of this level should be able to handle the immediate tactical fire fighting and rescue requirements for structures where there are no major rescue problems, no serious internal or external exposures,*

> *and where the possible area involved in fire, heat or smoke normally will be less than 12,500 cubic feet.*

It is important to note that in the past edition of its Managing Fire Services,[6] the International City Management Association not only subscribed to the NFPA 197 Standard, but also endorsed the National Fire Protection Association's definition relating to the number of personnel required to conduct those initial interior attack operations.

In 1985, a revised Training Standard on Initial Fire Attack was adopted as NFPA 1410. This revised standard continued to maintain that:

> *The required performance for handlines shall consist of obtaining a water supply through one or two supply lines, placing one initial attack line into operation, and providing immediate backup with another line.*

and

> *The total flow of the required streams shall be a minimum of 300 gpm. The initial attack line shall provide a minimum flow of 100 gpm.*

and

> *The required flow from the back-up line shall be a minimum of 200 gpm.*

NFPA 1410 *Training Standard on Initial Attack* also linked for the first time personnel requirements necessary for interior fire attack and fire fighter safety. Appendix A-3-2.1 of NFPA 1410 states:

> *The limitation of emergency scene operations to those that can be safely conducted by the number of personnel on the scene is intended to reduce the risk of fire fighter death or injury due to understaffing. While members may be assigned and arrive at the scene of an incident in many different ways, it is strongly recommended that interior fire fighting operations not be conducted without an adequate number of qualified fire fighters operating in companies under the supervision of company officers.*
>
> *It is recommended that a minimum acceptable fire company staffing level consist of four members responding on or arriving with each engine or aerial ladder company responding to any type of fire. Companies responding in high-risk areas should have a minimum acceptable staffing of six fire fighters per ladder company and five fire fighters per engine company. These recommendations are based on experience from actual fires and in-depth fire simulations, critically and objectively evaluating fire company effectiveness. These studies indicate significant reductions in performance and safety when crews have fewer members than the above recommendations. Overall, five-member crews were found to provide a more coordinated approach for search and rescue and fire suppression tasks. (<u>See NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, A-6-2.1.</u>)*
>
> (UNDERLINING ADDED)

This language in NFPA 1410 for complying with safe minimum staffing per unit also appears in NFPA 1500 *Standard on Fire Department Occupational Safety and Health Program:*

> *The limitation of emergency scene operations to those that can be safely conducted by the number of personnel on the scene is intended to reduce the risk of fire fighter death or injury due to understaffing. While members can be assigned and arrive at the scene of an incident in many different ways, it is strongly recommended that interior fire fighting operations not be conducted without an adequate number of qualified fire fighters operating in companies under the supervision of company officers.*
>
> *It is recommended that a minimum acceptable fire company staffing level should be 4 members responding on or arriving with each engine and each ladder company responding to any type of fire. The minimum acceptable staffing level for companies responding in high-risk areas should be 5 members responding or arriving with each engine company and 6 members responding or arriving with each ladder company. These recommendations are based on experience derived from actual fires and in-depth fire simulations and are the result of critical and*

> *objective evaluation of fire company effectiveness. These studies indicate significant reductions in performance and safety where crews have fewer members than the above recommendations. Overall, 5 member crews were found to provide a more coordinated approach for search and rescue and fire suppression tasks.*
>
> *During actual emergencies, the effectiveness of companies can become critical to the safety and health of fire fighters. Potentially fatal work environments can be created very rapidly in many fire situations. The training and skills of companies can make a difference in the need for additional personnel and in reducing the exposure to safety and health risks to fire fighters where a situation exceeds their capabilities.*[7]

This direct linkage between NFPA 1410 and NFPA 1500 specifically indicates that the number of personnel required to successfully conduct an initial interior fire attack is not just a service issue but most importantly an issue of fire fighter safety.

Acknowledging this linkage, the National Fire Protection Association again endorsed a minimum initial attack staffing level. In its 1991 version of the Fire Protection Handbook, the NFPA produced its most strongly worded statements on fireground staffing to date:

> *The effectiveness of pumper companies must be measured by their ability to get required hose streams into service quickly and efficiently. NFPA 1410, Training Standard on Initial Fire Attack, should be used as a guide in measuring this ability. Seriously understaffed fire companies generally are limited to the use of small hose streams until additional help arrives. Often this action may be totally ineffective in containing even a small fire and in conducting effective rescue operations.*[8]

and

> *Critical task analysis indicates that fewer than eleven fire fighters would be most hard pressed to accomplish safe, effective, initial interior fire attack in a timely manner at a detached single-family dwelling.*[9]

The NFPA went further in its recommendations as to the number of personnel and equipment necessary to perform an interior structural fire attack by type of hazard involved as follows:

Typical Initial Attack Response Capability Assuming Interior Attack and Operations Response Capability
High-Hazard Occupancies (Schools, hospitals, nursing homes, explosive plants, refineries, high-rise buildings, and other high life hazard or large fire potential occupancies) At least 4 pumpers, 2 ladder trucks (or combination apparatus with equivalent capabilities), 2 chief officers, and other specialized apparatus as may be needed to cope with the combustible involved, not less than 24 fire fighters and 2 chief officers.
Medium-Hazard Occupancies (Apartments, offices, mercantile and industrial occupancies not normally requiring extensive rescue or fire fighting forces) At least 3 pumpers, 1 ladder truck (or combination apparatus with equivalent capabilities), 1 chief officer, and other specialized apparatus as may be needed or available; not less than 16 fire fighters and 1 chief officer.
Low-Hazard Occupancies (One, two- or three-family dwellings and scattered small businesses and industrial occupancies) At least 2 pumpers, 1 ladder truck (or combination apparatus with equivalent capabilities), 1 chief officer, and other specialized apparatus as may be needed or available, not less than 12 fire fighters and 1 chief officer.
Rural Operations (Scattered dwellings, small businesses, and farm buildings) At least 1 pumper with a large water tank (500 gal [l. 9m^3] or more), one mobile water supply apparatus (1000 gal [3.78m^3] or larger), and such other specialized apparatus as may be necessary to perform effective initial fire fighting operations; at least 12 fire fighters and 1 chief officer.
Additional Alarms At least the equivalent of that required for Rural Operations for second alarms; equipment as may be needed according to the type of emergency and capabilities of the fire department. This may involve the immediate use of mutual aid companies until local forces can be supplemented with additional off-duty personnel. In some communities, single units are "special called" when needed, without always reporting to a multiple alarm. Additional units also may be needed to fill at least some empty fire stations.

INTERNATIONAL CITY MANAGEMENT ASSOCIATION (ICMA)

In its second edition of Managing Fire Services published in 1988, the International City Management Association (ICMA) supported the minimum level for safe fireground staffing called for in NFPA 1410 and NFPA 1500:

> *Fire suppression operations have three basic functions: (1) rescue; (2) work involving the ladder, forcible entry, and ventilation; and (3) the application of water through hose lines. Rescue and ladder companies handle the first two, and engine companies the third. To raise ladders, ventilate, search, and rescue simultaneously takes quick action by at least four and often eight or more firefighters, each team under the supervision of an officer. The number of firefighters required to search and rescue should never be fewer than two and typically at least four. The number of firefighters needed to advance and operate one hose line varies from two on smaller lines to four on large hand lines.*
>
> *The standard formula for determining the volume of water needed and the number of hose lines to be advanced at a working structural fire is based*

> *on a minimum of two engine companies with at least eight firefighters. This formula calls for the discharge of three gallons of water per minute for every 100 cubic feet of involved fire area with typical fire loading. An area of 40 feet by 40 feet with 8-foot ceilings requires 384 gallons per minute. Two hose lines are needed to produce that flow, and a third line to cover the floor above. Exposure coverage and search and rescue are not yet taken into consideration, but already eight or nine hosemen are needed, plus the pump operators, plus the supervisor.*
>
> *Various controlled and statistically based experiments by some cities and universities reveal that if about sixteen trained firefighters are not operating at the scene of a working fire within the critical time period, then dollar loss and injuries are significantly increased, as are the square feet of fire spread.*
>
> *As firefighting tactics were conducted for comparative purposes, five-person fire suppression companies were judged to be 100 percent effective in their task performance, four-person companies 65 percent effective, and three-person companies 38 percent effective; six person companies are judged 20 percent faster than four person companies.*[10]

CENTAUR / FEMA STUDY

The linkage between fire fighter safety and the number of personnel on the initial fire attack has been demonstrated in study after study. In 1982, the U.S. Fire Administration conducted a survey of over 150 fire departments as to current crew size and standard response practices.[11] When asked to identify those factors that were most important in determining crew size and initial response, fire chiefs and city managers ranked crew safety at the top of the list.

Columbus, OH Fire Department Study

Ohio State University, in a 1980 study of actual fireground operations of the Columbus, Ohio Fire Department, developed data on fire fighter injuries and rate of fire spread involving 404 structural fires. The data showed that when the total number of fire fighters at the scene fell below 15 the rate of fire fighter injuries per 10 residential structural fires increased 46.7%, and the number of fires which spread beyond 25 square feet per 10 residential fires increased 24%.

	Rate Per 10 Fires	
Fireground Staffing:	**Fire Fighter Injuries**	**Number of Fires Which Spread Beyond 25 Square Feet**
I. Residential		
Less Than 15 Fire Fighters	**2.2**	**3.6**
15 or More Fire Fighters	**1.5**	**2.9**
Difference	**46.7%**	**24.1%**
II. Large Fire Risk		
Less Than 23 Fire Fighters	**5.9**	**3.4**
23 or More Fire Fighters	**3.4**	**2.9**
Difference	**73.5%**	**17.2%**

SOURCE: Ohio State University

The data associated with large risk fires such as high-rise apartments, etc., showed that staffing had an even more dramatic impact on fire fighter injuries. When fireground staffing was reduced in those types of structural fires to less than 23 personnel, the rate of fire fighter injuries per 10 structural fires increased 73.5%, while the number of fires which spread beyond 25 square feet per 10 fires increased nearly 17.2%.

Seattle, WA Fire Department Study

In 1982, the NFPA's *Fire Service Today* published the results of a study conducted by the Seattle Fire Department. Based on a series of textbook training drills and live fire drills, the Seattle Fire Department calculated model effectiveness indices of various levels of manpower as follows:

	3 Person	4 Person	5 Person	6 Person
Engine	**45%**	**59%**	**79%**	**100%**
Ladder	**N/A**	**57%**	**78%**	**100%**

These effectiveness indices related to the time required to successfully complete all the given tasks required by a particular evolution in the initial fire attack. The study concluded that:

> *These effectiveness indices relate to the time taken to accomplish an objective. A large index means a shorter time. Specifically, if a six-man engine takes 5 minutes to accomplish an objective, a three-man engine will require 5 ÷ .45 = 11.1 minutes to accomplish the same objective; a four-man engine will take 5 ÷ .59 = 8.5 minutes, and a five-man engine will take 6.33 minutes. (Seattle did not examine levels of manpower greater than six men.) The same process was used to compare ladder company evolution times.*

> *The conclusion is that doubling the manpower from three to six men more than doubles the team's effectiveness. There is a synergetic effect at work....*

While the Seattle Fire Department's main objective was to produce an appropriateness of service model, unpublished data on fire fighter injuries relating to various levels of staffing were also examined. At the time of the Seattle study, the fire department consistently operated engine and truck companies with varying levels of staffing. To test the relationship between staffing effectiveness and fire fighter injuries, Jon Cushman of the Seattle Fire Department, undertook three separate analyses over a 5-year period.

The results of each analysis yielded the same results:

> *Average time per disability increased as company strength decreased for both types of companies.*

One analysis performed by Cushman examined the Seattle Fire Department's disability report statistics. The results of this analysis indicated that the rate of fire fighter injuries expressed as total hours of disability per hours of fireground exposure were 54% greater for engine companies staffed with 3 personnel when compared to those staffed with 4 fire fighters, while companies staffed with 5 personnel had an injury rate that was only one-third that associated with 4-person companies.

Unit	Average Man-Hours Per Disability	Total Disability Hours	Total Number Disabilities	Total Man-Hours At Fire	Frequency (Column #4 Into #3)	Severity (Column #4 Into #2)
3-Man Engine	**90.607**	**2,537**	**28**	**12,660**	**.00221**	**.20**
4-Man Engine	**58.375**	**1,401**	**24**	**10,460**	**.00229**	**.13**
5-Man Engine	**49.500**	**99**	**2**	**2,125**	**.00094**	**.05**
6-Man Engine	**59.517**	**1,726**	**29**	**12,924**	**.00224**	**.13**
4-Man Ladder	**58.000**	**986**	**17**	**3,964**	**.00429**	**.25**
5-Man Ladder	**20.455**	**450**	**22**	**4,895**	**.00449**	**.09**
6-Man Ladder	**45.857**	**642**	**14**	**6,366**	**.00220**	**.10**

SOURCE: Seattle Fire Department

An even more telling statistic relates to severity rates in Cushman's subsequent analysis that also concluded that average hours per disability associated with 3-person company staffing was nearly 50% greater than those occurring when units were staffed with 4 and 5 personnel.

DALLAS , TX FIRE DEPARTMENT STUDY

The Dallas Fire Department, in 1969 and again in 1984, also conducted textbook drills and live fire tests to compare effectiveness among various levels of staffing.[12] The study concluded that deficient levels of staffing will result in an inability to cover critical tasks. As the numbers of fire fighters decrease without eliminating any of the tasks to be accomplished the Department must delay some of the required tasks or attempt to perform all the tasks unsafely with inadequate staff.

Consequently, the Dallas Fire Department concluded that in a residential fire:

> *The five-person crews demonstrated a more coordinated and effective attack on the fire and search and rescue operation,* while
>
> *The four-person crew was capable of performing satisfactorily in controlling the fire and in effecting the rescue operation.*

The study's conclusion regarding the three-person crew was that not all the required critical tasks could be accomplished within a given time span. Regarding the three-person crew, the report stated:

> *At this level there was little margin for error and any appreciable delay in arrival might place the control of the fire beyond their capability.*

This is an extremely important statement given that the Dallas Fire Department took great care to insure that improvements in the time it took to complete each critical task was not made at the expense of sound operating practices or safety. However, this would not be the situation in actual fireground operations. Fire fighters operating in understaffed environments are too often expected to perform beyond their capabilities.

The Dallas study, in addressing this issue, indicated that inadequate staffing resulted in:

- A cumulative effect created by combined delays and lost functions on the part of each crew resulting in an even greater loss of overall effectiveness;
- Increased physiological stress on fire fighters as they try to compensate for the lower staffing level; and
- Increased risk to the fire fighters when aggressive procedures are undertaken without the support necessary to complete them safely.[13]

The National Fire Academy also noted in a research project developed for its Executive Development III Program that:

> *In 1977 a test was conducted by the Dallas Fire Department, which consisted of a simulated fire involving several rooms at the rear of the third floor of an old school. This simulated fire was being done to determine how long it took a three, four, or five man team to advance its line to this area, get water on the fire, and to check each individual's physical condition afterwards. Timing began as each engine company entered the school yard.*

> *The average time of the Engine Companies is revealing. The first consisted of a three-man team and their average was 18.18 minutes. All personnel were exhausted, rubber legged, had difficulty standing up and all three were unfit for further fire fighting.*
>
> *The four-man team conducting the very same test, averaged 10.29 minutes and upon completing they were nearing exhaustion.*
>
> *Next came the five-man team which averaged 6.15 minutes, and afterwards all showed little evidence of fatigue.* [14]

The Academy's project report went on further to state:

> *The implication is that when a smaller work force, using the same heavy equipment, has to do the job that was done in the past by a larger workforce, injuries of this nature will continue to increase. Injuries to back and knees are injuries that take a long time to correct. The cost to the city and department are heavy.* [15]

U.S. FIRE ACADEMY FIRE RISK ANALYSIS

In 1984, the U.S. Fire Academy introduced the training manual Fire Risk Analysis: A System's Approach. The manual stated that suppression capability must be measured to include both initial attack operations that attempt to quickly deal with marginal situations before they get out of control, and sustained firefighting procedures that can be put into operation against major fires. In addition to the ability to apply water to the fire, the analysis emphasized that the size of the fireground workforce must be of sufficient size in order to simultaneously have the ability "to engage in search and rescue, forcible entry, ventilation, preservation of property, and additional support activities as required by the situation." The U.S. Fire Academy further stated that time is a critical factor in determining the effectiveness of the tasks with the expectation for the fire to increase until sufficient personnel are assembled to overcome it.

Thus, interior offensive tactics should be measured by the ability to place effective handlines in operation in interior positions and the attempt to gain control of the fire before it exceeds the assembled workforce's capability. This involves assigning personnel to a myriad of activities contingent upon the nature and complexity of the target hazard.

Initial attack capability must be measured in terms of a reflex action by the fire department. Upon receiving an alarm, the department must be able to respond quickly and with the necessary equipment and personnel to put a fire attack into motion without delay.

Based on the above objectives, the U.S. Fire Academy concluded that in order to safely conduct an effective interior attack required at least 15 personnel distributed as follows:

Hoselines:		
2 personnel per attack line (1- 1/2 inch lines – 100 gpm)	=	2
2 personnel per attack line (1- 3/4 inch lines – 150 gpm)	=	2
2 personnel per backup line (2 inch line – 200 gpm)	=	2
1 personnel to operate each pumper	=	2
Search and Rescue Operations:		
1 of 2 personnel team for every 2,000 sq. ft. (residential occupancies)	=	2
Support Functions:		
At least 1 fire fighter to perform forcible entry, utility control, and related support functions for each hand-line placed in operation	=	2
Ventilation:		
At least 2 personnel to perform ventilation	=	2
Command:		
At least 1 individual assigned as fireground commander	=	1
TOTAL PERSONNEL REQUIRED		15

FIRE DEPARTMENT EVALUATION SYSTEM (FIREDAP)

In December 1991, the Phoenix, AZ Fire Department developed the Fire Department Evaluation System (FIREDAP) to precisely identify the components and objectives for complying with the NFPA's 1410 *Training Standard on Initial Fire Attack*. [16] This evaluation system involved responding to and extinguishing a working fire in a single story residential structure of 2,000 square feet with no exterior exposures.

The Department concluded that to safely conduct an aggressive interior attack based on standard evolutions and the critical tasks that needed to be accomplished required 15 personnel distributed as follows:

4 personnel on each engine	=	8 personnel
4 personnel on truck	=	4 personnel
2 personnel in BC vehicle	=	2 personnel
1 personnel on utility vehicle	=	1 personnel
	TOTAL	15 personnel

It is important to note that the Phoenix study indicated that one of the primary objectives of the first arriving engine company was to "*utilize hose line for fire control and personnel protection.*"

It should be further noted in the Phoenix study's findings that the initial attack ultimately required at least 15 personnel on the scene. This is consistent with previous studies such as the Dallas, Ohio State University and Seattle studies, ICMA's Managing Fire Services, NFPA's Fire Attack-1, NFPA's Fire Protection Handbook, and NFPA's *Training Standard on Initial Attack.*

These studies not only form the basis for the “industry standard and practice” for training but also are the basis for the actual response to structural fires which will require aggressive and offensive actions including interior attack.

AUSTIN , TX FIRE DEPARTMENT STUDY

In 1993, the Austin Fire Department embarked on a study to determine whether companies staffed with 4 fire fighters were safer and more effective than the 3 person companies the Department was currently deploying. In order to compare the effectiveness, physiological impact on fire fighters and Austin Fire Department injury rates at various staffing levels, the Fire Department conducted drills consisting of a series of common fireground tasks divided into three scenarios: a simulated two-story residential fire, a simulated aerial ladder evolution, and a simulated engine company highrise fire.

These simulations revealed, once again, that regardless of the experience or how prepared fire fighters are, with an insufficient number of personnel to conduct the tasks efficiently, life and property continue to suffer inevitably. Severity and the degree of hazard increases until controlled or the fire passes the critical point. Consequently, the Austin Fire Department concluded that the effectiveness significantly improved when the company was increased from 3 to 4 personnel. The Austin Fire Department’s report stated:

> *In the two-story residential fire the efficiency or time improvement between the three person and four person crews was 73%.*
>
> *In the aerial ladder evolution the efficiency improvement between three and four person crews was 66%.*
>
> *In the engine company high-rise fire the efficiency improvement between three and four person crews was 35%.*
>
> *Averaging all scenarios the improved efficiency was 58%.*

The Austin study also examined the physiological impact of increased company level staffing had on fire fighters. Before and immediately after the completion of each scenario, medical evaluations including pulse, respiration, blood pressure, EKG strips, body temperature, and visual assessment were given to each fire fighter.

Not surprisingly, the crews consisting of 4 fire fighters recorded a notable decrease in the pulse rate (cardiovascular stress level) and respirations than did 3 person crews:

> *For three person staffs the average pulse rate per minute, post drill, was 127.28; whereas, the average pulse rate per minute for four person staff was 119.69. This is a 16% difference rate increase with the two crews having equal baseline pulse rates.*
>
> *Air consumption for each firefighter working on a four-person crew as opposed to a three person crew decreased by 53%. The dramatic decrease was determined to be a result of less exertion involved in the exercises with four-person crews.*
>
> *Visual assessment of each firefighter verified the additional exhaustion level of the three person crew members.*

In addition to the fireground simulations, the Austin Fire Department also reviewed injury reports involving 136 emergency incidents to which 1,938 fire fighters responded from 1989 to 1992. The analysis revealed:

> *Four- and five-person crews' injury rate was 5.3 per 100 firefighters;*
>
> *while*
>
> *Three-person companies experienced an injury rate of 7.77 injuries per 100 firefighters – a 46% higher rate than the larger crews.*

Upon its conclusion, the Austin staffing study had exactly confirmed the results the Dallas study conducted some ten years earlier. The Austin Fire Department had found that inadequate staffing directly caused the following problems:

- A higher risk for victims due to delays which are indirectly related to likelihood of survival;
- A loss of critical functions;
- An increased loss of overall effectiveness as a result of combined delays and loss of critical functions;
- Higher physiological stress on fire fighters as they attempt to compensate for lower crew size;
- Higher risk to fire fighter safety as aggressive procedures are conducted without the necessary support.

The Austin study concluded that increased staffing levels from 3 to 4 provided substantial benefits such as:

- A smaller number of multiple alarms;
- Lower fire damage dollar loss and higher loss/save ratio;
- Fewer injuries/deaths for civilians and fire fighters;
- Fewer Worker's Compensation for fire fighters;
- Retainment of tax base properties; and
- Lower civil liability for the City and the Fire Department.

ENFORCING AN INDUSTRY STANDARD (CLARK CO., NV FIRE DEPARTMENT)

It was this concept of ignoring "industry standards" that was the basis of a 1989 complaint filed by the Division of Occupational Safety and Health of the Nevada Department of Industrial Relations against the Clark County Fire Department. Nevada OSHA's regulations maintain that an employer shall not:

> *Require, permit or suffer any employee to go or be in any employment or place of employment which is not safe and healthful.*
>
> *Fail to furnish, provide and use safety devices and safeguards or fail to adopt and use methods and processes reasonably adequate to render such employment and place of employment safe and healthful.*
>
> *Fail or neglect to do every other thing reasonably necessary to protect the life, safety and health of such employees....*[17]

Citing that the Clark County Fire Department had prior knowledge that units staffed with 3 personnel were unsafe, N.D.O.S.H. issued a complaint that the Fire Department had willfully violated the industry standards relating to fire fighter safety. In late 1990, the N.D.O.S.H. agreed to vacate the violation when the Clark County Fire Department stipulated that it would immediately "*maintain minimum staffing levels at each fire station so that no engine or ladder truck shall be dispatched from a fire station, manned with less than four persons.*"

In addition, the stipulation entered into by the Fire Department stated that:

> *Any engine or ladder truck manned with less than four persons shall be defined to be "unsafely manned."*

The body of evidence and industry practice over the last quarter century certainly indicates that the adherence to a minimum safe fireground staffing level is professionally appropriate.

ONTARIO FIRE MARSHAL STUDY

In 1993, the Fire Marshal of Ontario (Canada) Research Project embarked on a study to thoroughly examine the tasks which 3- and 4- person crews could safely accomplish. The project determined that 3-person crews are very limited in their firefighting capabilities. It is found that until additional assistance has arrived on the scene, the following cannot be accomplished safely:

- deployment of back-up protection lines;
- conducting interior suppression or rescue operations;
- ventilation operations requiring access to the roof of the involved structure;
- the use of large (65mm) hand-held hose lines;
- the establishment of a water supply from a static source within the reasonable time limits.

In addition, the companies' 3-person crews were not of sufficient size in order to provide the necessary breaks to recover from metabolic heat and exhaustion during incidents requiring abstained fireground operations.

Four-person crews were also determined to be substantially more effective versus 3-person crews once a water supply from an external source is established. Such additional tasks which may be accomplished by a 4-person crew include:

- two person interior search and rescue with no hand-held back-up line;
- two person interior structure firefighting with no rescue component and no hand-held back-up line;
- limited roof level ventilation operations:
- laddering operations; and
- salvage operations.

Four-person crews, depending on the circumstance, may also be capable of completing the following:

- use of large (65mm) diameter hand lines;
- establishment of a water supply from a static source;
- establishment of a second point of entry and approach to the fire location in the structure; and
- preparing for a second area of search and rescue for person(s) in need of rescue.

The study further concluded that the addition of one crew member allows for increase command and pumper operations as the driver or supervisor is given a single function.

METROPOLITAN FIRE CHIEFS AND MINIMUM STAFFING

At their 1992 annual meeting, the Metropolitan Fire Chiefs Division of the IAFC not only endorsed the assembly of at least 4 fire fighters before initiating an interior attack, but went further stating:

> *In order to permit the effective operation of fire companies at the scene of a structure fire, the minimum number of personnel on both engine and ladder companies should be five members per unit.*

In support of its position and addressing the impact that inadequate fireground staffing has on fire fighter safety, the IAFC's Metro Chiefs listed the following points:

A fire company should be able to function as an independent unit at the scene of a fire in order to permit the Incident Commander to employ the proper tactics and strategies to safeguard the occupants of the building, as well as the operating force, and to protect the property of the citizens.

Whenever understaffing necessitates the combination of two companies to accomplish a specific task at the scene of a fire, which normally could be completed by one effective unit, the standard operating procedures are dramatically and adversely affected.

Proper fire fighting procedures require strategies that result in the commitment of fire companies not only to the area involved on arrival, but to the internal and external exposures as well, if the endangered citizens are to be safeguarded and the property damaged limited. Understaffing prevents the Incident Commander from achieving these essential objectives.

To justify the position taken by the Metro Fire Chiefs, there is sufficient documentation available that indicates increased injury rates to occupants and fire fighters, as well as higher property losses, are due to an inadequate firefighting force at the scene of a fire.

The Metro Chiefs recognize that current economic difficulties are affecting public safety organizations nationwide but these factors do not alter the tasks that must be accomplished at the fire scene.

The decline in the number of members per unit, as well as the reduction in the number of fire companies in cities, have already reached a dangerously low level. To accept or support further reductions is inappropriate.

Any fire chief who attempts to obtain sufficient funding to provide adequate personnel for the protection of the community he serves, even if he fails, is performing his sworn duty to the best of his ability. In doing so, he is conscientiously informing the elected officials and the citizenry of their needs according to his professional judgment and experience.

We believe that our, the Metro Fire Chiefs, position is strong enough to assist all fire chiefs in their efforts to obtain adequate staffing.

This firm position has been taken by the Metro Chiefs solely in the interest of the safety of both those we serve and our nation's fire fighter.

INCREASING FIREGROUND INJURIES

Since the NFPA 1500 *Standard on Fire Department Occupational Safety and Health Program* was promulgated, the average annual rate of fireground injuries per 1,000 fires has increased by 6.4% as the table below shows.

Rate of Fire Fighter Fireground Injuries Per 1,000 Fires

	Total	Smoke Inhalation, Eye Injuries, Burns	Wounds, Dislocations, Fractures, Heart Attack, Strains and Sprains
1981-1986	**25.22**	**8.89**	**13.54**
1987-1993	**26.83**	**7.45**	**15.59**
% Change	**6.4%**	**(16.2%)**	**15.1%**

Note: Prior to 1981, data was not classified in same manner.

SOURCE: NFPA Annual National Fire Experience Survey

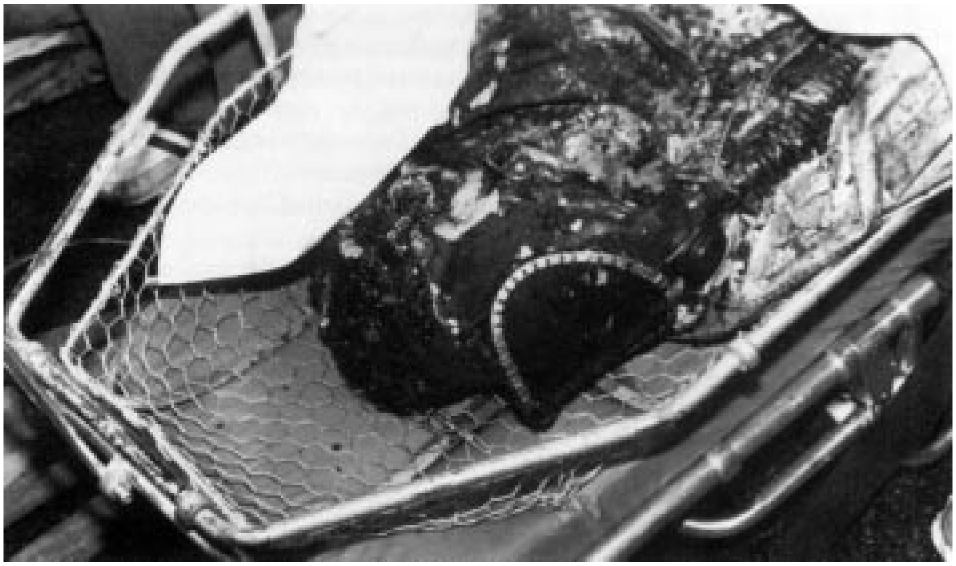
Comparing the average annual rate of fireground injuries for the six-year period prior to the promulgation of NFPA 1500 to the seven-year post NFPA 1500 period reveals that those injuries (i.e., smoke inhalation, eye injuries and burns) most closely associated with SCBA usage and personal protective equipment declined by 16.2%. On the other hand, the rate of fireground injuries for those injuries (i.e., wounds, dislocations, fractures, heart attacks, strains and sprains) associated with understaffed fireground operations increased by 15.1%.

JOHNS HOPKINS UNIVERSITY STUDY

A recent study produced by the IAFF with the cooperation of Johns Hopkins University also reflects the fact that fire fighter injuries are significantly influenced by inadequate staffing. This analysis compared the rate of injuries per 100 fire fighters and per 100 alarms for cities operating 4-person staffing versus those operating 3-person units.

The analysis showed that:

- Cities which operated fire suppression companies with less than 4 personnel had an injury rate per 100 workers that was 36.3% greater than those cities which had staffing levels of 4 or more;
- The percentage of cities having an injury rate of 10 injuries or more per 100 fire fighters was nearly double for those operating with less than 4 person crews as compared to those cities operating with minimum staffing levels of 4 or more;
- Fire fighter injury rates per 100 alarms were an average of 38% greater in cities with minimum staffing of less than 4 personnel per unit; and
- 72.5% of the cities staffing with less than 4 had an injury rate per 100 alarms of 0.5 or greater compared to only 35.3% of the cities staffing with at least 4 per fire suppression unit.



Tests for statistical significance on this data established that such differences in the injury rates associated with 3 versus 4 person staffing are not due to random chance.

PROVIDENCE , RI EXPERIENCE

The significant effect that increasing staffing from 3 to 4 can have on the rate of fire fighter injuries is apparent from a recent trial experience in Providence, Rhode Island. In order to test the hypothesis that 4 person staffing was safer than units staffed with only 3 fire fighters, the City agreed to provide 4 person minimum staffing on 6 of its 15 units and examine the results.

As the following table shows, the resulting 55.4% drop in fire fighter injuries was so dramatic that the Mayor entered into an agreement with the local union to extend the 4 fire fighter minimum staffing level to all 15 of the Providence Fire Department's fire suppression units.

COMPARISON OF INJURY RATES IN PROVIDENCE, RI
FOR 3 PERSON VERSUS 4 PERSON STAFFING

Year	Fire Suppression Incidences	Fire Fighters On-Duty	Number of Fire Fighters	# of Injuries at Emergency Scene	Emergency Scene Injuries Per 100 F/F	% Decrease in Emergency Scene Injuries Per 100 FF
1989	**3,869**	**83**	**479**	**431**	**90.0**	
1990	**3,871**	**89**	**479**	**339**	**70.8**	**21.3%**
1991	**4,143**	**98**	**479**	**192**	**40.1**	**43.4%**
				TOTAL DECLINE		**55.4%**

In 1989, minimum staffing per piece was 3 personnel. Beginning in September of 1990, 6 units were staffed with 4 personnel through overtime; beginning in October of 1991, all 15 units were staffed with 4 personnel through overtime.

U. S. FIRE ACADEMY'S FINDINGS

In conjunction with the Providence study, an applied research project was conducted as part of the U.S. Fire Academy's Executive Officer Program. This project addresses the fire fighter perspective and explores possible areas of discrepancies within the study. Through literature reviews, interviews with the Providence Fire Department Chief, the Fire Department Historian, and a member of the Department of Economic Planning and Development, and examinations of the Providence Fire Department Injury-Exposure Database, the analysis provides substantial evidence in support of the initial Providence staffing study findings:

- a 23.8% decrease in the number of reported injuries;
- a 25% decrease in the number of time loss injuries when staffing increases;
- a 71% decrease in work time lost; and
- a dramatic decrease in the frequency and severity of fire injuries when staffing increases from three- to four-person crews.

The study further concluded that this significant decline in frequency and severity of injuries was not caused by the decrease in the number of fires or incident volume, nor was the drop in fire fighter injuries caused by changes in protective clothing, new safety or operational procedures, substantive training changes, new physical fitness programs, or the implementation of new OSHA programs since these were held constant during the study period. Taking all of these factors into consideration, the analysis concluded that increased staffing from 3 to 4-person crews leads directly to significant reductions in the frequency and severity of fire fighter injuries.

INDUSTRY CONSENSUS STANDARD ON FIRE DEPARTMENT OCCUPATIONAL SAFETY & HEALTH (NFPA 1500)

In 1993, the National Fire Protection Association (NFPA) included in its Consensus Standard on Fire Department Occupational Safety and Health (NFPA 1500) a requirement addressing the minimum number of fire fighters necessary to initiate an offensive interior attack on a structural fire. This Tentative Interim Amendment (TIA) to the fire fighter safety standard states:

> *At least four members shall be assembled before initiating interior fire fighting operations at a working structural fire.*

However, while the above language was clear as to the minimum number of personnel required to safely begin interior firefighting operations, it left some confusion as to how personnel would be "assembled."

Consequently, in 1994, Mr. M.E. Hines, Director of the Texas Commission on Fire Protection, sought formal clarification from the NFPA on this issue. NFPA's formal interpretation of how the 4 fire fighters should assemble is as follows:

> *...when a company is dispatched from a fire station together as a unit (which includes both personnel responding on or arriving with apparatus), rather than from various locations, the standard recommends that the company should contain a minimum of four fire fighters.*

The National Fire Protection Association (NFPA) interpretation of the Standard goes even further to address "high risk" fires:

> *It should be noted that four fire fighters is a baseline recommended minimum for 'any type of fire.' For companies responding in 'high risk areas' a higher minimum of 5 responding or arriving with each engine company and 6 responding or arriving with each ladder company is recommended.*

FEDERAL OCCUPATIONAL SAFETY AND HEALTH ACT'S "2 IN / 2 OUT" STANDARD

The Occupational Safety and Health Act of 1970, signed into law on December 29, 1970, was designed to assure so far as possible every working man and woman in the nation safe and healthful working conditions. In administering the Act, the U.S. Department of Labor's Occupational Safety and Health Administration (OSHA) issues standards and rules for safe and healthful working conditions, tools, equipment, facilities, and processes. OSHA also conducts workplace inspections to assure the standards are followed. Under the Act, employers have the general duty of providing their workers a place of employment free from recognized hazards to safety and health, and must comply with OSHA standards.

Many of OSHA's standards are not new. Employers have operated under them for years as national consensus standards – those agreed upon by members of groups such as the American National Standards Institute and the National Fire Protection Association – or as federal standards established under other laws, such as the Public Contracts Act. Many of these standards were codified as OSHA standards upon passage of the OSHA act. Included were ANSI standards pertaining to the use of respiratory equipment.

The International Association of Fire Fighters requested officials at Federal OSHA to provide uniform interpretation and compliance information on its standards addressing self-contained breathing apparatus use and the application of these standards to fire fighters responding to hazardous materials incidents and structural fires. On May 1, 1995, Federal OSHA issued a compliance instruction to all OSHA Regional and Area Offices, Compliance Officers and State Agencies having responsibility for enforcing safety and health regulations. This compliance instruction thus not only establishes the link between fire fighter safety and fireground staffing, but also provides for universal interpretation and enforcement of these regulations.

This compliance standard known as the “2 in/2 out” rule provides federally enforced protection for all professional fire fighters, whether state, county, or municipal, in any of the states or territories where an OSHA State Plan agreement is in effect. The following 25 states/territories have State OSHA Plans:

Alaska
Arizona
California
Connecticut
Hawaii
Indiana
Iowa
Kentucky
Maryland
Michigan
Minnesota
Nevada
New Mexico
New York
North Carolina
Oregon
Puerto Rico
South Carolina
Tennessee
Utah
Vermont
Virginia
Virgin Islands
Washington
Wyoming

While there is not universal occupational health and safety coverage for all U.S. and Canadian fire fighters, these regulations must be considered the minimum acceptable standard for safe fireground staffing when self-contained breathing apparatus is required to be used. Thus, this interpretation is appropriate evidence for arbitration and grievance hearings on fire fighter safety.

In addition, Executive Order 12196 issued February 26, 1980 and implemented December 21, 1980 requires that all federal agencies comply with the same safety and health requirements as private employers. Thus, federal fire fighters are protected under Federal OSHA safety and health standards, including this interpretation.

The U.S. Environmental Protection Agency (EPA) has promulgated a standard that adopts the OSHA Hazardous Waste Operations and Emergency Response Standard (29 CFR 1910.120) to protect employees who work in the public sector where there is not an OSHA approved State program in place (40 CFR 311). Additionally, EPA and OSHA have agreed that all interpretations regarding compliance with HAZWOPER will be made by OSHA. Thus, those fire fighters in the 27 non-OSHA states and other U.S. territories (e.g., Guam, Canal Zone) making a response to emergency operations where there is a potential release of hazardous substances, as defined by this standard, are covered by the interpretation.

The substance of Federal OSHA’s “2 in/2 out” standard is as follows:

- *The HAZWOPER standard requires the use of the buddy system with standby personnel for emergency response operations involving the release of hazardous substance(s) producing IDLH conditions for employees responding. The regulation specifies a minimum of four personnel, two as a team in the buddy system and two standby backup personnel, to conduct operations in hazardous areas safely.*

- *The use of SCBA's in IDLH atmospheres for circumstances not covered by HAZWOPER is covered by the Respiratory Protection standard which requires two standby personnel to be present outside the IDLH hazard area. Failure to have two standby persons for a known, existing IDLH, e.g., an interior structural fire, would be a violation of 1910.134 (e)(3)(ii).*

- *The Fire Brigade standard covers employers whose employees perform interior attack on interior structural fires and references the Respiratory Protection standard's requirements above.*

- *The National Fire Protection Association (NFPA) recognizes that fire fighters must operate in teams of two or more when conducting interior structural firefighting operations; failure to respond with teams of two or more would be a violation of the General Duty Clause.*

- ***The Respiratory Protection standard and industry practice (as codified through the NFPA standards) require that a minimum of four fire fighters be involved in emergency operations during interior structural firefighting. Two act as a team in the hazard area, and two stand by outside the hazardous area to monitor the operation and provide assistance should a rescue be necessary.***

- *OSHA regulations and NFPA standards specifically require communication between members of the team. Fire fighters working in teams of two or more (buddy system) in hazardous areas (IDLH atmospheres) are required to maintain communications (voice, visual contact, or tethering with a signal line). Radios or other means of electronic contact shall not be substituted for direct visual contact between employees within the individual team in the danger area.*

- *One of the individuals outside of the hazard area may be assigned more than one role, such as the incident commander in charge of the emergency or operator of fire apparatus, where it does not jeopardize worker safety and health.*

Clearly, the evidence establishes the connection between staffing and fire fighter fireground injuries. So long as understaffed fire suppression units are expected to initiate and perform sustained interior attack operations involving structural fires, the rate of fireground injuries will continue to increase at alarming rates.

ENDNOTES

[1] Municipal Fire Administration, International City Managers' Association (Chicago, IL: ICMA) 1967; pp. 161-162.

[2] "Manpower – How Much Do You Need?" James F. Casey, *Fire Engineering*, October 1969; p. 112.

[3] Fire Attack-1 Command Decisions and Company Operations, Warren Y. Kimball (Boston, MA:NFPA) 1966; pp. 20-21.

[4] Ibid.; p. 44.

[5] Fire Protection Handbook, 13th Edition, National Fire Protection Association (Quincy, MA: NFPA) 1969; pp. 10-24 and 10-25.

[6] Managing Fire Services, International City Management Association (Washington, DC: ICMA) 1979; p. 80.

[7] *Standard on Fire Department Occupational Safety and Health Program,* NFPA No. 1500, National Fire Protection Association, 1992; Appendix A-6-4.1.

[8] Fire Protection Handbook, 17th Edition, National Fire Protection Association (Quincy, MA: NFPA) 1991; p. 10-41.

[9] Ibid.; p. 10-40.

[10] Managing Fire Services, 2nd Edition, International City Management Association (Washington, DC:ICMA) 1988; pp. 119-120.

[11] "Report on the Survey of Fire Suppression Crew Size Practices, " Centaur Associates conducted for FEMA, June 30, 1982; pp. 18-20.

[12] "Dallas Fire Department Staffing Level Study," McManis Associates & John T. O'Hagan & Associates, June 1984; pp. II-1 through II-7.

[13] Ibid.; p. I-2.

[14] "Fire Engines Are Becoming Expensive Taxi Cabs—Inadequate Manning," National Fire Academy, Executive Development III Program, 1981; p. 4.

[15] Ibid.; p. 2.

[16] "Fire Department Evaluation System (FIREDAP)," Phoenix, AZ Fire Department, December 1991; p. 1.

[17] State of Nevada NRS 618.385.

Chapter 3

Local Jurisdiction's Overall Fire Protection Requirements

In any community, the level of service provided by the fire department is based on factors such as community expectations, financial resources, and political decisions. Fire fighter safety and requirements for performing successful interior structural fire attacks should not be subject to political debate.

These precepts are best described in a statement by the International City Management Association (ICMA):

> *The fire control system is by far the most costly element of a fire department's operations and should be designed and operated in the most cost-effective fashion. (The value of 'cost-effectiveness' is determined by definition at each local level of government and will vary from community to community. This variation results from the process of balancing the accepted or tolerated risk against the actual risk in each community.) One three or four man company costs several hundreds of thousands of dollars per year. A fire control company not needed or poorly utilized represents a significant financial waste. <u>On the other hand, too few companies, or poorly manned ones, can result in property and life loss beyond community accepted norms. Also, the cost of a firefighter death or a disabling injury may far exceed the expense of a fire company. This is not to say that there is a fixed value on a life or injury. The point is that the firefighting forces are the asset that protects the community's economic and tax base as well as its health and welfare. This asset is a valuable one and must be carefully provided and wisely managed.</u>*
>
> *There is no single problem or solution to be found when a community's fire control system is designed, although many fire chiefs and managers are engaged in just such a search. But such an attempt merely illustrates a lack of understanding of the complexities of what constitutes an adequate fire protection delivery system.*[1] (UNDERLINING ADDED)

In its 1988 edition of <u>Managing Fire Services</u>, ICMA suggested an overall master plan for providing safe and effective fire suppression services:

> *A prudent response pattern needs quick response times as well as a sufficient number of firefighters for the immediate attack.*
>
> *Officials need to establish a maximum response time following receipt of the dispatch instructions at the station. In some urban areas, one and a half minutes are considered a desirable maximum, whereas in other urban areas the number is set at two and a half or three. Obviously, the response time policy varies according to the fire danger, the ability of the munici-*

> *pality to locate stations and staff apparatus, and traffic speed. Average urban response speed is usually about 20 miles per hour. Once fire apparatus and personnel arrive at the scene, their initial activities require several more minutes.*
>
> *Considering that the time required for flashover in structural fires with standard fuels is typically about seven minutes, the apparatus and firefighters must arrive and get operating very quickly. If it takes a resident two or three minutes to discover and report a fire and three minutes for the apparatus to be dispatched and arrive, the sizing up and initial attack need to be done in a minute or two, or the typical fire will have grown significantly in size. An unconscious person with depleted oxygen will typically suffer permanent brain damage after approximately four minutes. All of this needs to be considered within the context of multiple alarm fires and simultaneous alarms. Delayed response and understaffed response appear inevitable under those circumstances, unless planning is complete.*
>
> *<u>One task, then, in evaluating suppression ability is to determine how fast adequate firefighting forces can arrive at the scene of an incident and launch rescue operations, if needed, plus initial fire attack.</u> Once the community or the evaluation team has determined satisfactory parameters for the size of the initial attack team and response time and has measured the local situation, it can judge how satisfactory the response is. <u>Often the response time is longer than officials expected, especially if the time span is measured from the moment the alarm was received to the actual initial attack. Team size may not be satisfactory until several vehicles arrive, and this time delay must be considered as well. The efficiency of the attack team will be greatly diminished if an optimum number are not working at the scene.</u>*[2] (UNDERLINING ADDED)

Thus, if <u>successful and safe,</u> initial interior structural fire attack minimally requires at least:

- 4 fire fighters arriving with the first due engine,

and

- total fireground resources of 15 to 16 personnel staffing 2 pumpers and 1 ladder truck,

the only additional piece of the equation is response time.

RESPONSE TIME

Response time involves four elements: detection time, alarm processing time, turnout time and travel time. For the first of these elements — detection time — no reliable data or analysis exists.

However, for the two elements involving alarm processing[3] and turnout time,[4] the International Association of Fire Chiefs' Accreditation Committee recently completed an analysis.[5] The study indicated that in "staffed departments" the average time required to process the alarm was 53.76 seconds, while the average turnout time was 57.55 seconds.

On the basis of the International City Management Association statement that fire apparatus in an urban setting can average about 20 miles per hour, travel time involving distances of 1 mile is approximately 3 minutes. Therefore, the total average response time of “staffed departments” approximates 5 minutes from receipt of the alarm to arrival at the scene.

MINIMUM STAFFING AND RESPONSE TIMES REQUIRED FOR DELIVERY OF EMERGENCY MEDICAL CARE

The response times for fire suppression are also consistent with those recommended by the American Heart Association (AHA) for delivery of pre-hospital emergency medical care. The AHA’s emergency medical services maximum response time recommendation has been 4 minutes for initiation of basic life support (BLS) and 8 minutes for initiation of advanced life support (ALS).

Recently the AHA reconfirmed this recommendation by stating:

> *For cardiac arrest, the highest hospital discharge rate has been achieved in patients in whom CPR was initiated within 4 minutes of arrest and ACLS within 8 minutes. Early bystander rescue breathing or CPR intervention and fast emergency medical services (EMS) response are therefore essential in improving survival rates.*[6] (UNDERLINING ADDED)

In 1992, the National Conference on Cardiopulmonary Resuscitation and Emergency Cardiac Care, listed among its recommendations that all fire-fighting units be equipped with and trained to operate automatic external defibrillators and the following recommendation regarding minimum staffing per EMS response:

> *Early ACLS provided by paramedics at the scene is another critical link in the management of cardiac arrest. EMS systems should have sufficient*

> *staffing to provide a minimum of two rescuers trained in ACLS to respond to the emergency. However, because of the difficulties in treating cardiac arrest in the field, additional responders should be present. <u>In systems that have attained survival rates higher than 20% for patients with ventricular fibrillation, the response teams have a minimum of two ACLS providers plus a minimum of two BLS personnel at the scene. Most experts agree that four responders (at least two trained in ACLS and two trained in BLS) are the minimum required to provide ACLS to cardiac arrest victims...</u>*[7] (UNDERLINING ADDED)

TACTICAL FIRE SUPPRESSION GOALS

Given the total requirements of firefighting personnel and equipment to safely conduct an initial interior structural fire attack and provide pre-hospital emergency medical care according to the industry's standard, the only politically driven decision that is appropriately within a local community's discretion is response times. For it is through its decision regarding these response times that the local community defines the acceptable level of risk in providing the delivery of fire suppression services.

The International City Management Association (ICMA) defines just such a set of tactical fire suppression goals as the following:

> *For all structural fires, to deploy one engine company within five (5) minutes and an additional engine company, one ladder company, one paramedic unit, and one chief officer within ten (10) minutes for 90 percent of all alarms in areas with a required fire flow of 4,500 gallons per minute (GPM) or less. For all areas over 4,500 GPM, the first engine and truck (ladder) must arrive within five (5) minutes for 90 percent of all alarms. The lapsed time (reflex time) is to include fire dispatch and response time. The objective is to control the fire before flashover (sudden spread), or before the fire has extended beyond the first (original) area of involvement. (Using the standard time versus temperature curve as a base, flashover is estimated to be eight (8) minutes after ignition in standard fuels.)*
>
> *The general tactical objective is to develop an attack force that can aggressively advance two standard fire stream hand lines (or the equivalent). For major emergencies beyond the normal capability of the first alarm assignment, the objective is to deploy a programmed reserve and automatic aid fire force of six (6) engine companies, three (3) truck (ladder) companies, and three (3) chief officers within fifteen (15) minutes of a third alarm. The objective is to prevent large fires from extending to other structures.*
>
> *For all fire and emergencies (i.e., a probability of fire or explosion) in petroleum storage and production areas, to deploy, within ten (10) minutes, special light water or foam firefighting equipment and prepare for long relays and extended pumping operations. The objective is to provide engine companies with adequate petroleum firefighting equipment. For fires in water deficient areas, the objective is to deploy, within ten (10) minutes, a pumper-tanker and relay operation of adequate capacity to augment local supplies.*

> *For fires in harbor areas, to deploy within five (5) minutes for 90 percent of all marine-oriented incidents adequate marine firefighting equipment of 500 GPM.*
>
> *To maintain and deploy one engine company within five (5) minutes of notification in 90 percent of all light rescue emergencies. In addition, a paramedic unit shall be deployed within five (5) minutes 80 percent of the time. The objective is to provide emergency medical services (EMS) and rescue all trapped persons, including those who need to be extricated with forcible entry equipment.*
>
> *To deploy a truck company in addition to an engine and paramedic unit on heavy rescue incidents. The truck shall arrive within ten (10) minutes 90 percent of the time. The objective is to rescue all trapped persons regardless of the situation.*[8]

The requirement to establish tactical objectives in terms of response times and to provide sufficient personnel and equipment to successfully and safely initiate structural interior fire attacks is also required by NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program.* In this regard, the NFPA 1500 Standard, Section 2-1.2 mandates that:

> *The fire department organizational statement shall set forth the operational response criteria for the various types of emergency incidents to which the fire department is required to respond. This written criteria for each type of emergency incident shall contain and identify the following:*
>
> *(a) The types of standard firefighting functions or evolutions, such as incident management, providing a water supply, hose deployment, forcible entry, search and rescue, ladder placement, ventilation, salvage, and overhaul required to safely complete the operation; specifying a determination of functions or evolutions that need to be performed simultaneously;*
>
> *(b) The minimum number of members required to safely perform each identified fire function or evolution, based on written standard operating procedures;*
>
> *(c) The number and types of apparatus and members required for the initial response to each type of emergency incident, as well as the total complement of apparatus and members to be dispatched for each type of incident that defines the total response for all incidents up to the level of a major incident for that Jurisdiction;*
>
> *(d) A description of a typical emergency operation, including alarm time, response time, arrival sequence, initiation of basic function and evolution assignments, and standard operating procedures, as these factors relate to fire fighter safety and health.*[9] (UNDERLINING ADDED)

Section 6-4.1 of NFPA 1500 further mandates that fire departments adhere to the industry's standard of safe minimum fire fighter staffing by requiring that a fire department not force any fire fighter(s) to perform duties that are unsafe.

> *The fire department shall provide an adequate number of personnel to safely conduct emergency scene operations. Operations shall be limited to those that can be safely performed by the personnel available at the scene. No member or members shall commence or perform any firefighting function or evolution that is not within the established safety criteria of the organizational statement as specified in 2-1.2 of this standard.*[10]

These studies and the industry's standard of performance endorse the International Association of Fire Fighters' position that the minimum safe and effective fire fighter staffing per unit of response must be:

> *...at least 4 fire fighters on each engine or pumper company and at least 5 fire fighters on each ladder truck company to any type of structural fire. It must be noted that this is the minimum company staffing for safe and effective operations. Safe fire suppression operations involving high density or high risk occupancies will require additional personnel assigned to each company.*

This position is consistent with NFPA Standards 1500 and 1410. Furthermore, it is supported by the National Fire Protection Association in its Fire Protection Handbook and the International City Management Association's Managing Fire Services.

The IAFF position has been endorsed and supported by the U.S. Fire Administration and the Metropolitan Fire Chiefs Division of the International Association of Fire Chiefs.

Study after study, including the Dallas, Seattle, Ohio State, Phoenix, Providence and Westerville studies, have independently provided additional evidence supporting the IAFF's position. Appropriate unit staffing and station distribution further lead to a reasonable standard of performance for response to fires and medical emergencies that has been endorsed by fire service professionals and city administrators as follows:

- First responding unit shall arrive at the scene within 4 minutes of receipt of the alarm in 90% of the instances,

  and/or

  the initial alarm assignment, consisting of two engine companies and one ladder, shall arrive at the scene within 8 minutes of the alarm in 90% of the instances.

  The initial alarm assigned to a fire shall be comprised of sufficient personnel and equipment to control a fire in a structure up to 5,000 square feet in area and effectively remove or rescue any endangered occupants.

  and

- The initial alarm response to a medical emergency shall be sufficient to provide advanced life support for victim stabilization, including cardiac emergency, in a manner consistent with the American Heart Association and the American Medical Association recommendations.

ENDNOTES

[1] Managing Fire Services, International City Management Association (Washington, DC:ICMA) 1979, pp. 214-215.

[2] Managing Fire Services, 2nd Edition, International City Management Association, (Washington, DC:ICMA) 1988, p. 120.

[3] "Alarm processing time" is defined as the period of time that is required for the Communications Center to identify the fact that an emergency is in progress, collect the information pertinent to making the appropriate dispatch, and access the methodology used by the agency to deploy resources.

[4] "Turnout time" is defined as the period of time that is required for the on-duty emergency system and hazardous material personnel to discontinue the activities they are engaged in, properly attire themselves, and board the vehicle in readiness for response.

[5] "IAFC Accreditation Committee Surveys Fire Department, Charts Response Times," International Association of Fire Chiefs' *On Scene*, September 1, 1992; pp. 7-8.

[6] *The Journal of the American Medical Association*, October 28, 1992; p. 2184.

[7] Ibid.; p. 2291.

[8] Managing Fire Services, International City Management Association (Washington, DC:ICMA) 1979, pp. 218-219.

[9] *Standard on Fire Department Occupational Safety and Health Program*, NFPA No. 1500, National Fire Protection Association, 1992; Chapter 2, Section 2-1.2.

[10] Ibid.; Chapter 6, Section 6-4.1.

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