Aircraft Rescue Fire Fighting Working Group Response to the National Transportation Safety Board A-14-60 Recommendation

by the

Aircraft Rescue Fire Fighting Working Group A-14-60 Task Group

FINAL REPORT

May 20, 2018
EXECUTIVE SUMMARY

This paper explored the third of four recommendations directed to the Aircraft Rescue Fire Fighting Working Group (ARFFWG) as part of the National Transportation Safety Board’s (NTSB) letter, dated July 16, 2014 [1]. The letter contained specific recommendations from the accident involving a Boeing 777-200ER, Korean registration HL7742, operating as Asiana Airlines flight 214, that occurred on July 6, 2013, at San Francisco International Airport, San Francisco, California. The third recommendation (A-14-60) from the NTSB was aimed at the development of “a minimum aircraft rescue and firefighting staffing level that would allow exterior firefighting and rapid entry into an airplane to perform interior firefighting and rescue of passengers and crewmembers” [1].

In response to the NTSB’s recommendations, the ARFFWG created a Task Group that conducted an applied research project to examine theories, knowledge, methods and techniques concerning the creation of a minimum staffing level. The project consisted of a comprehensive literature review of all relevant documents and publications, as well as a research exercise which was conducted at Atlantic City International Airport (ACY). The purpose of these timed trials was to collect data sets measuring time requirements for the individual steps necessary to:

1. Gain rapid access into the airplane  
2. Perform interior firefighting  
3. Perform rescue of passengers and crewmembers.

The timed trials did not include simulated exterior firefighting, while the three steps identified above were tested. The personnel required to continue exterior firefighting during each evolution in the timed trials are factored into the results.

This paper documents the findings derived from the literature review and provides the description of all timed trials and the results of those trials. The final portion of this paper addresses critical factors that must be considered in the determination of the minimum firefighting staff required in any given scenario, as well as the conclusions and recommendations derived from this research project by the Task Group.

The following list and table summarize the primary responses of the Task Group relative to A-14-60.

- For Index A airports, increase the agent quantities and number of ARFF vehicles to align with Category 5 (NFPA and ICAO). That would require a minimum of two vehicles and
2,760 gallons of water for foam production, i.e., an increase of 1,420 gallons of water. This would improve the airports’ ability to perform exterior firefighting by providing the opportunity to re-service a vehicle with agent if a vehicle runs out of agent before an event is terminated, while at least one vehicle remains staffed to continue exterior firefighting. This would also provide water for interior firefighting and a minimum of two firefighters to attack an interior fire and make rescue.

- For all Index B, C, D and E airports, require an interior access vehicle, staffed by a minimum of one firefighter, that has sufficient reach to gain rapid entry to all aircraft with scheduled service at the airports.
- For Index B airports, in addition to dedicated drivers/operators for each ARFF vehicle, and an interior access vehicle staffed with a minimum of one firefighter, require additional staffing of two to perform initial search and rescue, and two to perform interior firefighting.
- For Index C airports, in addition to dedicated drivers/operators for each ARFF vehicle, and an interior access vehicle staffed with a minimum of one firefighter, require additional staffing of two to perform initial search and rescue, and two to perform interior firefighting.
- For Index D airports, in addition to dedicated drivers/operators for each ARFF vehicle, and an interior access vehicle staffed with a minimum of one firefighter, require additional staffing of four to perform initial search and rescue, and four to perform interior firefighting (two per aircraft aisle per task).
- For Index E airports, in addition to dedicated drivers/operators for each ARFF vehicle, and an interior access vehicle staffed with a minimum of one firefighter, require additional staffing of four to perform initial search and rescue, and four to perform interior firefighting (two per aircraft aisle per task).
- Create Index F for all airports operating multi-deck passenger aircraft or aircraft exceeding 250 feet in length to carry sufficient quantities of water. In addition to dedicated drivers/operators for each ARFF vehicle, and an interior access vehicle staffed with a minimum of one firefighter, require additional staffing of four to perform initial search and rescue, and four to perform interior firefighting (two per aircraft aisle per task).
- Require that each interior entry team is equipped with a Thermal Imaging Camera to assist in search and rescue.

Simplified Version of NFPA 403 Guidance for Water, Agent, and Number of Trucks per Index/Category

<table>
<thead>
<tr>
<th>Category</th>
<th>Index</th>
<th>Water US Gallons includes Q1, Q2 and Q3*</th>
<th>Complementary Agent</th>
<th>Minimum Number of Trucks</th>
<th>Example Aircraft</th>
<th>Aircraft Length up to, but not including (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GA-1</td>
<td>120</td>
<td>100</td>
<td>1</td>
<td>Cessna 206</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>GA-1</td>
<td>200</td>
<td>200</td>
<td>1</td>
<td>Cessna 414</td>
<td>39</td>
</tr>
<tr>
<td>3</td>
<td>GA-2</td>
<td>670</td>
<td>300</td>
<td>1</td>
<td>Beech 1900</td>
<td>59</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>1340</td>
<td>300</td>
<td>1</td>
<td>DHC-8-100</td>
<td>78</td>
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<tr>
<td>5</td>
<td>A</td>
<td>2760</td>
<td>450</td>
<td>2</td>
<td>ATR-72</td>
<td>90</td>
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<tr>
<td>6</td>
<td>B</td>
<td>3740</td>
<td>450</td>
<td>2</td>
<td>B-737-300, E145</td>
<td>126</td>
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<tr>
<td>7</td>
<td>C</td>
<td>4880</td>
<td>450</td>
<td>2</td>
<td>B757</td>
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<tr>
<td>8</td>
<td>D</td>
<td>7780</td>
<td>900</td>
<td>3</td>
<td>A300, B-767-300</td>
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<tr>
<td>9</td>
<td>E</td>
<td>9570</td>
<td>900</td>
<td>4</td>
<td>B-747-200, A-340-400</td>
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<tr>
<td>10</td>
<td></td>
<td>14260</td>
<td>900</td>
<td>4</td>
<td>A-380, B-747-8</td>
<td>295</td>
</tr>
</tbody>
</table>

*Quantity Q1. The quantity required to obtain a 1-minute control time of the fire.
*Quantity Q2. The quantity required for continued control of the fire after the first minute or for complete extinguishment of the fire or both.
*Quantity Q3. The quantity required for interior firefighting
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ACRONYMS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AES</td>
<td>Airport Emergency Service (Changi Airport)</td>
</tr>
<tr>
<td>ARAC</td>
<td>Aviation Rulemaking Advisory Committee</td>
</tr>
<tr>
<td>ARFF</td>
<td>Aircraft Rescue and Firefighting</td>
</tr>
<tr>
<td>ARFFWG</td>
<td>Aircraft Rescue and Firefighting Working Group</td>
</tr>
<tr>
<td>ARFFRWG</td>
<td>Aircraft Rescue and Firefighting Requirements Working Group</td>
</tr>
<tr>
<td>CAA</td>
<td>Civil Aviation Authority</td>
</tr>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
</tr>
<tr>
<td>FAA</td>
<td>Federal Aviation Administration</td>
</tr>
<tr>
<td>IAV</td>
<td>Interior Access Vehicle</td>
</tr>
<tr>
<td>ICAO</td>
<td>International Civil Aviation Organization</td>
</tr>
<tr>
<td>IDLH</td>
<td>Immediately Dangerous to Life and Health</td>
</tr>
<tr>
<td>NATEC</td>
<td>National Aviation Facilities Experimentation Center</td>
</tr>
<tr>
<td>NPRM</td>
<td>Notice of Proposed Rulemaking</td>
</tr>
<tr>
<td>NTSB</td>
<td>National Transportation Safety Board</td>
</tr>
<tr>
<td>OSHA</td>
<td>Occupational Safety and Health Administration</td>
</tr>
<tr>
<td>PCA</td>
<td>Practical Critical (fire) Area</td>
</tr>
<tr>
<td>RRA</td>
<td>Rapid Response Area</td>
</tr>
<tr>
<td>TCA</td>
<td>Theoretical Critical (fire) Area</td>
</tr>
</tbody>
</table>
1.0 INTRODUCTION

This paper explores the third of four recommendations directed to the Aircraft Rescue Fire Fighting Working Group (ARFFWG) and the Federal Aviation Administration (FAA) as part of the National Transportation Safety Board’s (NTSB) letter, dated July 16, 2014 [1]. The letter contained specific recommendations from the accident involving a Boeing 777-200ER, Korean registration HL7742, operating as Asiana Airlines flight 214, that occurred on July 6, 2013, at San Francisco International Airport, San Francisco, California. The NTSB’s investigation of the accident was documented in Accident Report NTSB/AAR-14/01 [2]. The third recommendation deals with the development of “a minimum aircraft rescue and firefighting staffing level that would allow exterior firefighting and rapid entry into an airplane to perform interior firefighting and rescue of passengers and crewmembers” [1].

In response to the NTSB’s recommendations, the ARFFWG created a Task Group that conducted an applied research project to examine theories, knowledge, methods and techniques concerning the creation of a minimum staffing level. The membership of the committee was comprised of subject matter experts from various ARFF industry areas, including National Fire Protection Association (NFPA) ARFF Technical Committee members, and professional and private sector organizations. It was jointly chaired by members of the Federal Aviation Administration (FAA) and the ARFFWG.

The applied research project was carried out from April 2015 through September 2017, with a membership of thirty-two individuals, including both chairs. The Task Group studied and considered various issues within the subject area of minimum staffing levels for ARFF response personnel.

2.0 BACKGROUND AND PROBLEM DEFINITION

On July 6, 2013, at approximately 1128 Pacific daylight time, a Boeing 777-200ER, Korean registration HL7742, operating as Asiana Airlines flight 214, was on approach to runway 28L when it struck a seawall at San Francisco International Airport (SFO), San Francisco, California. ARFF initial response consisted of 23 staff and seven apparatus, which the NTSB stated more than exceeded the “FAA-required minimum of three vehicles,” but the report went on to highlight no minimum staffing level set forth by the FAA [2].

There was a 98% passenger self-evacuation that occurred at this incident. ARFF personnel extricated five passengers who were unable to self-evacuate, one of whom died later. This incident had a 99% survival
rate for occupants of the aircraft. According to the NTSB Accident Report [2], the SFFD-Airport Battalion accomplished the primary objective of ARFF by engaging the fire and protecting egress paths for evacuating passengers. Firefighters also performed a successful interior fire attack and search and rescue mission. By doing so, they located five injured passengers in the rear of the aircraft. The NTSB noted (AAR-14/01, 2.8.3.3), that the extrication of those five passengers was successful because the airports staffing level allowed the opportunity for simultaneous interior fire attack, search and rescue and sustained exterior fire attack. Various objectives were successfully met by SFFD-ARFF in a timely fashion; however, the NTSB report expressed concern about the non-existence of minimum staffing levels being required by the FAA.

While the FAA’s Title 14 Code of Federal Regulations (CFR), Part 139.319 [3] defines that airports are required to have “sufficient rescue and firefighting personnel…available during all air carrier operations,” it does not address specific numbers needed to complete tasks required during an aircraft emergency. The NTSB’s trepidation was directed precisely to the possibility of an aircraft incident at a lower index airport due to “a minimum aircraft rescue and firefighting staffing level that would allow exterior firefighting and rapid entry into an airplane to perform interior firefighting and rescue of passengers and crewmembers” [2].

3.0 RESEARCH AND DISCUSSION
3.1 Literature Review

Only one document published by the FAA that specifically addressed ARFF staffing was found in the literature search. FAA AC 150/5210-8 “Aircraft Firefighting and Rescue Personnel Clothing” [4] was published on 1/13/1967 and cancelled by AC – 00-2RR “Advisory Circular Checklist” on 01/15/1980 [5]. The stated purpose of the cancelled Advisory Circular is to “provide guidance concerning the manning of aircraft fire and rescue trucks, the physical qualifications that personnel assigned to these trucks should meet and the protective clothing with which they should be equipped.” As this document is difficult to find, a copy is included in Appendix A.

Several things have changed since 1966, including how the FAA defines Airport Indexes. AC 150/5210-8 [4] provides a recommended number of firefighters and the number/type of vehicles recommended for each Airport Index. At that time, the FAA Indexes I through VIII. The method of Index determination was different from the system used today. In 1966, Indexes were determined by the number of air carrier departures and the distance of their routes. Today Indexes are determined based on the length of the largest air carrier aircraft with five or more scheduled departures at the airport. There is little need to
compare the old Index system with the current system as part of the staffing study since there is no minimum number of personnel required by the current standard. For historical purposes, the recommended staffing found in FAA AC 150/5210-8 is presented in the following table. The total agent quantities required were taken from **AC 150/5210-6** [6], which was in force at the time that AC 150/5210-8 was published.

Table 1. Staffing, Agent and Vehicle Requirements as per AC 150/5210-8 [5]

<table>
<thead>
<tr>
<th>Index</th>
<th>Apparatus</th>
<th>Minimum Trucks</th>
<th>Recommended Staffing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index I</td>
<td>No fire suppression or rescue capability</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>Index II</td>
<td>Portable fire extinguishers. This man services extinguishers and trains airport workers to operate them</td>
<td>0</td>
<td>1 Firefighter</td>
</tr>
<tr>
<td>Index III</td>
<td>One Lightweight Truck <em>(500 Lbs. Dry Chemical)</em></td>
<td>1</td>
<td>2 Firefighters</td>
</tr>
<tr>
<td>Index IV</td>
<td>One Combination Truck <em>(300 Lbs. Dry Chemical, 500 gallons water and foam)</em></td>
<td>1</td>
<td>2 Firefighters</td>
</tr>
<tr>
<td>Index V</td>
<td>One Combination Truck (see Above) One 1000 or 1500-gallon water/foam trucks One Supervisor (Chief) <strong>Minimum Water 1500 Gallons</strong> <strong>Minimum Dry Chemical 500 Lbs.</strong> <em>(NOTE: If the roof turret on a truck is operated from the roof an extra firefighter shall be assigned.)</em></td>
<td>2</td>
<td>2 Firefighters 3 Firefighters TOTAL 5 Firefighters and 1 Chief (6) +1 if applicable</td>
</tr>
<tr>
<td>Index VI</td>
<td>One lightweight or one combination truck One 1000 or 1500-gallon water/foam truck One 1000 or 1500-gallon water/foam truck One 1000 or 2000-gallon water tank truck <strong>Minimum Required Water 3000 Gallons</strong> <strong>Minimum Required Dry Chemical 500 Lbs.</strong> One Supervisor (Chief) <em>(NOTE: If the roof turret on a truck is operated from the roof an extra firefighter shall be assigned.)</em></td>
<td>4</td>
<td>2 Firefighters 3 Firefighters 3 Firefighters 2 Firefighters TOTAL 10 Firefighters and 1 Chief (11) +1, 2 if applicable</td>
</tr>
</tbody>
</table>
The recommended staffing levels recommended by the FAA are described in 150/5210-8 [5] in the following excerpt.

4. **FIREFIGHTER RECOMMENDATIONS.**

   a. Listed below, by type and equipment, is the recommended number of firefighters per tour of duty necessary to obtain the desired potential from each type of truck:

   1) **Lightweight Aircraft Fire and Rescue Truck (2 firefighters).** ...When so used, it is normally the first truck to arrive at the scene of the emergency.; and, where practicable, its extinguishing agent may be used to control or contain a fire until the arrival of the water/foam trucks. Subsequent to the arrival of these larger trucks, the men assigned to this truck function as the rescue men. Experience has demonstrated the need for rescue men to work in teams. ...
3) Water / Foam Truck (3 firefighters each). These trucks, carrying 1000 or 1500 gallons of water and 200 or 300 gallons of foam concentrate, are capable of discharging the water/foam carried at a rate from 500 to 800 GPM respectively through a single turret remotely operated from the cab and 60 GPM from each of 2 handlines. Should the turret be operated from the cab roof, an additional man is required. …

c. In addition, all airport Indexes V and above should have a supervisor (Chief)

FAA Advisory Circular 150/5210-6 – “Aircraft Fire and Rescue Facilities and Extinguishing Agents” was first published on 9/7/1966 [6]. Table I of the AC describes the same quantity of vehicles and agent carried as was described in AC 150/5210-8 and in Table 1 above.

FAA Advisory Circular 150/5210-6A [7] does not address staffing but increases some agent quantities. It also creates an Index IX. Index IX is defined in 150/5210-6A as: “Airports having 1,400 or more annual departures of aircraft between 200 and 310 feet in length and designed for seating 151 or more passengers.”

AC 150/5210-8 was still in effect at the time 6A was published. Table 2 below correlates information from the two ACs.

Table 2. Agent and Vehicle Guidance from 150/5210-6A Correlated with Staffing Guidance from 150/5210-8

<table>
<thead>
<tr>
<th>Index</th>
<th>Apparatus</th>
<th>Minimum Trucks</th>
<th>Recommended Staffing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index I</td>
<td>No fire suppression or rescue capability</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>Index II</td>
<td>Portable fire extinguishers. This man services extinguishers and trains airport workers to operate them</td>
<td>0</td>
<td>1 Firefighter</td>
</tr>
<tr>
<td>Index III</td>
<td>One light rescue truck (500 Lbs. Dry Chemical)</td>
<td>1</td>
<td>2 Firefighters</td>
</tr>
<tr>
<td>Index IV</td>
<td>One Combination Truck (300 Lbs. Dry Chemical, 500 gallons water and foam)</td>
<td>1</td>
<td>2 Firefighters</td>
</tr>
<tr>
<td>Index V</td>
<td>One Combination Truck (300 Lbs. Dry Chemical, 500 gallons&lt;br&gt;One 1000 or 1500-gallon water/foam trucks&lt;br&gt;One Supervisor (Chief))</td>
<td>2</td>
<td>2 Firefighters&lt;br&gt;3 Firefighters</td>
</tr>
<tr>
<td>Index</td>
<td>Minimum 1500 Gallons Water</td>
<td>Minimum 300 Lbs. Dry Chemical</td>
<td></td>
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<tr>
<td>--------</td>
<td>---------------------------</td>
<td>-------------------------------</td>
<td></td>
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<tr>
<td>VI</td>
<td>One light rescue (500 Lbs. Dry Chemical)</td>
<td>One 1500-gallon water/foam truck</td>
<td></td>
</tr>
<tr>
<td></td>
<td>One 1500-gallon water/foam truck</td>
<td>Minimum 3000 Gallons Water</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minimum 500 Lbs. Dry Chemical</td>
<td>One Supervisor (Chief)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>(NOTE: If the roof turret on a truck is manually operated from the cab roof, an additional firefighter is required)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL 5 Firefighters and 1 Chief (6)</td>
<td>+1 (if applicable)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Index</th>
<th>Minimum 1500 Gallons Water</th>
<th>Minimum 300 Lbs. Dry Chemical</th>
</tr>
</thead>
<tbody>
<tr>
<td>VII</td>
<td>One light rescue (500 Lbs. Dry Chemical)</td>
<td>One 2500-gallon water/foam truck</td>
</tr>
<tr>
<td></td>
<td>One 2500-gallon water/foam truck</td>
<td>Minimum 5000 gallons water</td>
</tr>
<tr>
<td></td>
<td>Minimum 500 Lbs. Dry Chemical</td>
<td>One Supervisor (Chief)</td>
</tr>
<tr>
<td></td>
<td><em>(NOTE: If the roof turret on a truck is operated from the roof an extra firefighter shall be assigned.)</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL 8 Firefighters and 1 Chief (9)</td>
<td>+1 or 2 (if applicable)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Index</th>
<th>Minimum 1500 Gallons Water</th>
<th>Minimum 300 Lbs. Dry Chemical</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIII</td>
<td>One light rescue (500 Lbs. Dry Chemical)</td>
<td>One 2500-gallon water/foam truck</td>
</tr>
<tr>
<td></td>
<td>One 2500-gallon water/foam truck</td>
<td>Minimum 7500 Gallons Water</td>
</tr>
<tr>
<td></td>
<td>One 2500-gallon water / foam truck</td>
<td>Minimum 1000 Lbs. Dry Chemical.</td>
</tr>
<tr>
<td></td>
<td>One Supervisor (Chief)</td>
<td><em>(NOTE: If the additional 500 Lbs. required is not carried on one of the 2500 Gallon ARFF vehicles, an additional light rescue with Dry Chemical will require 2 more firefighters.)</em></td>
</tr>
<tr>
<td></td>
<td>TOTAL 11 Firefighters and 1 Chief (1)</td>
<td>+1 or 2 if applicable</td>
</tr>
</tbody>
</table>
NOTE: If the roof turret on a truck is operated from the roof an extra firefighter shall be assigned.

<table>
<thead>
<tr>
<th>Index</th>
<th>Equipment Description</th>
<th>Personnel Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>IX</td>
<td>One light rescue (500 Lbs. Dry Chemical) One 2500-gallon water/foam truck</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>One 2500-gallon water/foam truck</td>
<td>2 Firefighters</td>
</tr>
<tr>
<td></td>
<td>One 2500-gallon water/foam truck</td>
<td>3 Firefighters</td>
</tr>
<tr>
<td></td>
<td>One 2500-gallon water / foam truck</td>
<td>3 Firefighters</td>
</tr>
<tr>
<td></td>
<td>One 2500-gallon water / foam truck</td>
<td>3 Firefighters</td>
</tr>
<tr>
<td></td>
<td>One Supervisor (Chief)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minimum 10,000 Gallons Water</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minimum 1000 Lbs. Dry Chemical</td>
<td></td>
</tr>
<tr>
<td></td>
<td>If the additional 500 Lbs. required is not carried on one of the 2500 Gallon ARFF vehicles, an additional light rescue with Dry Chemical will require 2 more firefighters.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NOTE: If the roof turret on a truck is operated from the roof an extra firefighter shall be assigned.</td>
<td></td>
</tr>
</tbody>
</table>

FAA Advisory Circular 150/5210-6B – Aircraft Fire and Rescue Facilities and Extinguishing Agents [8] was published on January 26, 1973. This AC includes significant changes from the previous version. This AC provides discussion on the TCA/PCA calculations developed by the ICAO Rescue Fire Fighting Panel (RFFP II) and research conducted by the FAA at National Aviation Facilities Experimental Center (NATEC) now called the William J. Hughes Technical Center. These tests are documented in FAA-RD-71-57, “Evaluation of Aircraft Ground Fire Fighting Agents and Techniques”, George Geyer [9]. The Theoretical Critical Fire Area is defined as the area adjacent to the fuselage extending outward in all directions to those points beyond which a large fuel fire would not melt an aluminum fuselage regardless of the fire exposure time. The TCA formula serves as a means for categorizing aircraft in terms of the terms of magnitude of the potential fire hazard that exists.

Based on the TCA formulas, it appears that the FAA developed a new method of determining airport Index based on the size of the aircraft being protected. They changed from the 9 Index system (I – IX) to a 5 Index system A-E. The agent quantities found in 150/5210-6B (see Table 3 below) were reduced from those published in 150/5210-6A. It was recognized at that time that Aqueous Film Forming Foam
(AFFF) was more effective than Protein based foams, so the guidance in 150/5210-6B provided quantities for each Index based on the type of foam used.

Table 3. FAA AC 150/5210-6B – Table 2 – Quantities of Fire Extinguishing Agents for Airports

<table>
<thead>
<tr>
<th>Index</th>
<th>Protein Foam</th>
<th>AFFF</th>
<th>Supplementary Agents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water for Foam Production (gal)</td>
<td>Application Rate (GPM)</td>
<td>Water for Foam Production (gal)</td>
</tr>
<tr>
<td>A</td>
<td>1,830 *</td>
<td>1,100</td>
<td>1,190</td>
</tr>
<tr>
<td>B</td>
<td>3,181</td>
<td>1,590</td>
<td>2,070</td>
</tr>
<tr>
<td>C</td>
<td>4,820</td>
<td>2,110</td>
<td>3,140</td>
</tr>
<tr>
<td>D</td>
<td>7,290</td>
<td>2,890</td>
<td>4,740</td>
</tr>
<tr>
<td>E</td>
<td>9,770</td>
<td>3,620</td>
<td>6,350</td>
</tr>
</tbody>
</table>

NOTE: * Rounded off from 1,834 gallons, as other quantities in this table were rounded to the nearest 10 gallons. For practical application, it is suggested that the quantities in Columns 2 and 4 be adjusted upward to coincide with the conventional quantities of water tanks which are normally sized in increments of 500 gallons, 1,000 gallons, etc.

DOT/FAA/TC-13-12 – “Aircraft Rescue and Firefighting Strategies and Tactical Considerations for New Large Aircraft” – Final Report – April 2013 [10] provides a wealth of information and guidance from the FAA that directly relates to the objectives of this study, specifically to determine how many personnel would be required to initiate interior firefighting on an aircraft.

Chapter 10.1 Access

Gaining safe and rapid access to the aircraft for immediate intervention of the risk or hazard is important. When away from the jet bridge, these mammoth aircraft have no convenient access points. Airline mobile air stairs or IAVs are necessary tools for gaining access with ARFF personnel and equipment.

While the timed trials conducted provided a base timeline to “get water in an aircraft”, the actual execution of an interior fire attack, particularly on a large aircraft, must take several things into consideration.
Chapter 10.8 Consideration for Interior Fire Attack

The 1.75” pre-connected line on an ARFF vehicle is a standard installation and will hopefully satisfy most of the fires facing ARFF crews. The Asiana fire was not typical, and the scale of the interior fire was well beyond the ability of a single 1.75” attack line to handle during the minimum time allowed to contribute to survivability. In simple terms, the amount of water being put on the fire must be sufficient to overtake the BTU’s of the burning contents. Small fires can be attacked with fire extinguishers or small hose lines. Big fires need larger quantities of water.

This report used guidelines for accepted hose stream practices and flow rates provided by the International Fire Service Training Association (IFSTA) “Essentials of Firefighting, 5th edition” [11] to identify recommended hose line application on multi-deck aircraft. The guidance is scalable to single deck aircraft, with single or dual passenger aisles. As per this FAA Technical Report:

On a wide-body aircraft with two aisles, the recommended hose line applies to each aisle. If the fire is beyond the “small developing fire” stage, or is located a distance from the closest access point, an appropriately sized line should be advanced simultaneously in each aisle.

The FAA ARFF Strategies and Tactics report for NLA provides an excellent description of the water requirements and hose size for various size fires. Hose line selection should be based on the flow rate required, the reach of the stream required, the size of the space involved, and the size/intensity of the fire. The table from the FAA Report [10] below provides a specific understanding of not only the flow rate, but the stages of fire those flow rates are designed to handle. The obvious tactical goal of any fire attack is to stop the fire while in the incipient stage to prevent further risk to life and property. Any delay in the initiation of fire attack is directly related to fire growth and the period that the atmosphere in the aircraft cabin remains survivable.
A continuous water supply must be provided to supply the interior fire attack, while still providing sufficient agent to continue exterior fire attack, with both efforts obviously affecting manpower needs.

The table below from the FAA NLA Report identifies quantities required for each Category of Index from ICAO, the FAA and NFPA.

<table>
<thead>
<tr>
<th>Size Inches (mm)</th>
<th>GPM (LPM)</th>
<th>Reach Maximum Feet (m)</th>
<th>When Used</th>
<th>Effective Area (Estimate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 (38)</td>
<td>40-125 (160-500)</td>
<td>25-50 (8-15)</td>
<td>Small developing fire. Anticipated to be easy stop.</td>
<td>One to three cabins on same deck.</td>
</tr>
<tr>
<td>1.75 (45)</td>
<td>40-175 (160-700)</td>
<td>25-50 (8-15)</td>
<td>Quick attack when ratio of fuel load to area is relatively light.</td>
<td></td>
</tr>
<tr>
<td>2 (50)</td>
<td>100-250 (400-1000)</td>
<td>40-70 (12-21)</td>
<td>When intensity or size of fire exceeds capability of smaller line. When larger water volume or longer stream reach are required. Requires adequate manpower and water supply.</td>
<td>One deck or more with heavy fire load.</td>
</tr>
<tr>
<td>2.5 (65)</td>
<td>125-350 (500-1400)</td>
<td>50-100 (15-30)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: GPM = Gallons per minute. LPM = Liters per minute
Table 4. Excerpt from FAA NLA Report Identifying Water Needed by Agent/Quantity Requirements
According to ICAO, the FAA and the NFPA

Table 2. Agent/Quantity Comparison

<table>
<thead>
<tr>
<th>Category</th>
<th>Index</th>
<th>ICAO</th>
<th>FAA</th>
<th>NFPA Q1 and Q2</th>
<th>NFPA Q1, Q2, and Q3</th>
<th>Example Aircraft</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GA-1</td>
<td>61</td>
<td>—</td>
<td>120</td>
<td>120</td>
<td>Cessna 206</td>
</tr>
<tr>
<td>2</td>
<td>GA-1</td>
<td>177</td>
<td>—</td>
<td>200</td>
<td>200</td>
<td>Cessna 414</td>
</tr>
<tr>
<td>3</td>
<td>GA-2</td>
<td>317</td>
<td>—</td>
<td>370</td>
<td>670</td>
<td>Beech 1900</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>634</td>
<td>100</td>
<td>740</td>
<td>1,340</td>
<td>DHC-8-100</td>
</tr>
<tr>
<td>5</td>
<td>A</td>
<td>1427</td>
<td>100</td>
<td>1,510</td>
<td>2,760</td>
<td>AT-12-72</td>
</tr>
<tr>
<td>6</td>
<td>B</td>
<td>2087</td>
<td>150</td>
<td>2,490</td>
<td>3,740</td>
<td>B-737-300; Emb-145</td>
</tr>
<tr>
<td>7</td>
<td>C</td>
<td>3197</td>
<td>3000</td>
<td>3,630</td>
<td>4,880</td>
<td>B-757</td>
</tr>
<tr>
<td>8</td>
<td>D</td>
<td>4808</td>
<td>4000</td>
<td>5,280</td>
<td>7,780</td>
<td>A300; B-767-300</td>
</tr>
<tr>
<td>9</td>
<td>E</td>
<td>6419</td>
<td>6000</td>
<td>7,070</td>
<td>9,570</td>
<td>B-747-200; A340-400</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>8533</td>
<td></td>
<td>9,260</td>
<td>14,260</td>
<td>AN-225; A380</td>
</tr>
</tbody>
</table>

Note: Q1 is the quantity of water required to obtain a 1 minute control time in the Practical Critical Area.
Q2 is the quantity of water required for continued control of the fire after the first minute, or for complete extinguishment of the fire, or for both.
Q3 is the quantity of water required for interior firefighting.

Table 3. Category 10 Aircraft-Agent/Chassis Comparison

<table>
<thead>
<tr>
<th>Reference</th>
<th>Gallons for Q1-Q2</th>
<th>Chassis</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAA</td>
<td>6000</td>
<td>3</td>
</tr>
<tr>
<td>ICAO</td>
<td>8533</td>
<td>3</td>
</tr>
<tr>
<td>NFPA</td>
<td>9260</td>
<td>4</td>
</tr>
</tbody>
</table>

Of the three references (FAA, ICAO, and NFPA), only the FAA does not calculate additional water for aircraft over 250 ft (76 m) long or over 23 ft (7 m) wide. The ICAO has increased water quantities for Category 10 aircraft over the quantities required for Category 9 aircraft by 2114 gallons (8002 liters) or 33%. Without factoring in Q3 water for interior firefighting, the NFPA has increased water quantities for Category 10 aircraft over the quantities required for Category 9 aircraft by 2190 gallons (8290 liters) or 31%.

Although there are several factors that explain the vast differences in the minimum quantities, the primary difference is that only the NFPA quantities include agent for interior firefighting. **NFPA 403** [12] uses a formula to determine agent quantities required based on the Category or Index of Airport and the size of the largest aircraft with service at the airport. The quantities are broken into three groups which are referenced in the table above.

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Quantity Q1. The quantity required to obtain a 1-minute control time in the PCA. The formula for the water required for control (Q1) in the PCA can be expressed as Q1 = PCA x R x T, where:

- PCA = practical critical area
- R = rate of application for the specific foam
- T = time of application

Quantity Q2. The quantity required for continued control of the fire after the first minute or for complete extinguishment of the fire or for both.

Quantity Q3 is based on accepted flow rates for anticipated interior aircraft firefighting operations as follows:

The method used by the NFPA committee that recommended these quantities was based on an anticipated flow rate and duration of flow necessary to fight an interior aircraft fire, based on the size of an aircraft as represented by the applicable Category or Index.

Table 5. NFPA 403 Quantities for Interior Firefighting

<table>
<thead>
<tr>
<th>Category</th>
<th>Index</th>
<th>Q3 Water (U.S. Gallons)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>GPM</td>
</tr>
<tr>
<td>1</td>
<td>GA-1</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>GA-1</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>GA-2</td>
<td>60 GPM</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>60 GPM</td>
</tr>
<tr>
<td>5</td>
<td>A</td>
<td>125 GPM</td>
</tr>
<tr>
<td>6</td>
<td>B</td>
<td>125 GPM</td>
</tr>
<tr>
<td>7</td>
<td>C</td>
<td>125 GPM</td>
</tr>
<tr>
<td>8</td>
<td>D</td>
<td>250 GPM</td>
</tr>
<tr>
<td>9</td>
<td>E</td>
<td>250 GPM</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>500 GPM</td>
</tr>
</tbody>
</table>
The Asiana aircraft accident that prompted this study was a Boeing 777-200 ER. This aircraft is 209’ 1” long. 14 CFR Part 139.315 “ARFF Index Determination” identifies aircraft, “at least” 200’ in length” to fall into Index E. The Q3 quantity assumes that 10 minutes of sustained interior firefighting at 250 GPM could either control the fire or allow time to get mutual aid companies with additional water supply to the scene.

As a basis for that discussion, it should be noted that each of these tasks requires a quantity of firefighting agent to support the activity. For example, if a fire is suspected or confirmed in any structure, including an aircraft, a firefighter should never open the door without the protection of a firefighting stream. In the tasks investigated by this committee, i.e., gaining rapid access to an aircraft, initiating interior firefighting and conducting rescue of an occupant, all require quantities of agent above the minimum requirements found in 14 CFR Part 139.317.

Although not specifically identified as a Task in NTSB Recommendation A-14-60, a discussion of agent quantities is likewise warranted. To initiate interior firefighting on an aircraft, ARFF must carry sufficient quantities of agent to satisfy that mission. Quantities of water needed to fight interior fires are not included in the FAA minimum agent requirements found in 14 CFR Part 139.317.

The only FAA regulation issued regarding ARFF at Certificated airports is 14 CFR Part 139. Advisory Circulars are simply guidance to an airport certificate holder. There has been a great deal of guidance material published by the FAA relative to agent quantities. Airports are expected to use best judgement to provide adequately trained personnel, equipment and agent quantities, based upon the needs of their airport.

This literature review provided a timeline of the changes to recommended agent quantities from September 7, 1966 until present. The quantities of agent recommended by the FAA have been reduced over the years. In 1970, FAA AC 150/5210-6A [7] required 10,000 gallons of water and 1000 lbs. of dry chemical. In 1997, FAA AC 150/5210-6B [8] reduced the quantity of water for airports using protein foam to 9,770 gallons by using the TCA/PCA formula but still recommended rounding up the quantity to match standard tank sizes (10,000 gallons). For airports using AFFF, the quantity was reduced to 6,350 gallons. The Table in both ACs 6A and 6B recommends that the 6,350 gallons be rounded up to 6,500 gallons as tanks are normally sized in increments of 500 gallons, however the quantities for Index E in Part 139.317 remains at 6,000 gallons. The recommended dry chemical quantities listed in 150/5210-6B
increased (from AC 6A) by 500 lbs. to 1500 lbs. at Index D and E airports. These same quantities were maintained in 150/5210-6C [13]. The current AC 150/5210-6D [14] does not specify minimum quantities, but rather refers to NFPA 403, Chapter 5, Table 5.3.1, which is provided in Appendix D of this report. Table 5.3.1 requires a minimum of 900 lbs. of dry chemical at Index D and E airports. Although the recommended quantities of dry chemical have increased and decreased in various versions of the FAA Advisory Circular, the regulation in 14 CFR Part 139.317 only requires 500 lbs.

None of the agent quantities recommended by the FAA have included water to be carried for fighting interior fires. The point being that, if the FAA required ARFF to initiate interior firefighting on aircraft, it would not just affect the minimum staffing, but also the minimum amount of agent to be carried, as well as the number of vehicles required.

There are various current documents that contain information related to ARFF staffing requirements regarding objectives that must be met during incidents, yet only two provide a specific number of personnel. The FAA’s Code of Federal Regulations (CFR) 14 Part 139 [3] regulation does not state a required number of ARFF personnel to be on duty at all times; however, the NFPA does publish minimum staffing figures.

Within the same NFPA standard, in Annex D, a framework is provided for an airport to research what ARFF staffing numbers are needed. It is based on a step-by-step Task and Resource Analysis model based upon each airport’s unique characteristics, fleet mix, capabilities, resources and support. The rest of the document addresses principle objectives necessary for effective rescues by specifically targeting the following factors: a) training received, b) effectiveness of equipment, and c) speed at which ARFF personnel and equipment are deployed. All are applicable in the research model provided in Annex D.

After an accident in Little Rock Arkansas in 1999, the NTSB issued Safety Recommendation A-01-65 [15] which asked the FAA to amend 14 CFR Part 139.319(j) to require a minimum ARFF staffing level to allow exterior firefighting and rapid entry into an airplane to perform interior firefighting and rescue of passengers and crewmembers. In response to the recommendation, the Aviation Rulemaking Advisory Committee (ARAC) established the ARFF Requirements Working Group in 2001 to work under ARAC’s existing Airport Certification Issues Group.

The tasks assigned to the ARAC ARFFRWG were as follows:
1. Review the existing aircraft rescue and firefighting (ARFF) requirements contained in 14 CFR Part 139, subpart D and identify ARFF requirements that should be added, modified, or deleted. This review should include the current rule and any other documents that the agency may have issued regarding Part 139, subpart D, and any ARFF standards issued by other organizations.

2. Develop a Notice of Proposed Rulemaking (NPRM) to incorporate the modifications, deletions, and additions identified in the preceding reviews. The NPRM should include the preamble and rule language along with any supporting legal analysis.

3. ARAC may be asked to recommend the disposition of any substantive comments the agency received in response to the NPRM. As part of this project, ARAC specifically was asked to address the following ARFF issues:
   a. The number of trucks and amount of agent;
   b. Vehicle response times;
   c. Personnel requirement; and
   d. Airport ARFF Index.

The committee appointed to the ARFFRWG was a balanced committee providing representation from recognized stakeholder organizations and agencies.

The FAA's Office of Airport Safety and Standards and the William J. Hughes Technical Center also provided technical support. The FAA is obligated to provide staff to ARAC committees when working on assigned tasks. This committee was to have representation from FAA Legal and an FAA Economist. The FAA was unable to assign these staff members.

ARAC ultimately refused to accept the ARFFRWG report for the following two reasons.

1. An economic analysis had not been performed as part of the study, as required. (The FAA acknowledged that this was a direct result of not assigning an FAA economist to the committee).
2. The Committee failed to reach consensus on the tasks. While there was an overwhelming majority of agreement of committee members on most subjects addressed, there were very few topics where a unanimous consensus was reached, so the ARAC and the FAA decided to refuse to accept the entire report [16].

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The Air Line Pilots Association International, Aircraft Rescue and Fire Fighting, Working Group, Aviation Cabin Safety Specialists, Inc., Independent Pilots Association, International Association of Fire Fighters, National Fire Protection Association, International Association of Fire Chiefs, and the San Jose (CA) Fire Department believed there is a need to provide a table outlining the minimum number of trained ARFF personnel for each airport. The other organizations represented on the committee saw no need for the list providing minimum staffing numbers but agreed with the staffing task analysis.

That minority opinion was expressed in the report as follows:

A minority of the ARFFRWG was of the opinion that a staffing analysis alone was sufficient because each airport is unique in size, physical layout and availability of external resources. The utilization of hard numbers may also lead to staff reductions at some airports and may cause some airports to rely on hard numbers and not properly address the task analysis. The staffing task analysis provides a means of identifying tasks and time parameters. Airports may have resources available or made available to meet their requirements.

The minimum staffing levels based on Index in Table 7 are from NFPA 403 [12]. These minimum staffing requirements were supported by most of the ARAC – ARFFRWG members when accompanied by a staffing task analysis with a qualitative analysis of a certificated airport’s ARFF services response to a worst case, aircraft accident scenario.

The qualitative analysis should be supported by a quantitative risk assessment to estimate the reduction in risk. This risk assessment should be related to the reduction in risk to passengers and aircrew from deploying additional personnel. One of the most important elements is to assess the impact of any critical paths identified by the qualitative analysis.

Table 6. Minimum Required ARFF Personnel at Airport per NFPA 403

<table>
<thead>
<tr>
<th>Airport Category</th>
<th>Index</th>
<th>ARFF Personnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GA-1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>GA-1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>GA-2</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>A</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>B</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>C</td>
<td>12 ***</td>
</tr>
<tr>
<td>8</td>
<td>D</td>
<td>15</td>
</tr>
</tbody>
</table>
Annex D of NFPA 403 describes a “Task and Resources Analysis Model”. This Annex material is not part of the requirements of the NFPA document. It is provided for informational purposes. Annex D, which provides a logical and appropriate approach to accurately determine the necessary levels of staffing required at airports, was developed by reviewing and combining several task analysis methodologies from multiple sources. The stated purpose of the NFPA 403, Annex D Task and Resource Analysis focuses on worst case scenarios at an airport. The research conducted in response to NTSB A-14-60 has a prescribed focus, specifically to “develop a minimum aircraft rescue and firefighting staffing level that would allow exterior firefighting and rapid entry into an airplane to perform interior firefighting and rescue of passengers and crewmembers.” [1]. The approach calls for a determination of the minimum number of personnel required to perform identified tasks in real time before external services are needed at the incident site. This task group followed this approach for the specific tasks necessary to satisfy the task identified in A-14-60.

Additionally, FAA CFR Part 139 [3] discusses the need for “at least one individual who has been trained and is current in basic emergency medical services” to be available during aircraft operations, with minimum training of at least 40 hours in outlined medical areas (paragraph 35 of Part 139). While several other prominent emergency medical associations, including, but not limited to, the National Association of Emergency Medical Technicians, the American Ambulance Association, the National Association of EMS Physicians, the National EMS Management Association, and the National Association of State EMS Officials have not made EMS recommendations for staffing at airports, the ARFFRWG’s Notice of Proposed Rulemaking Final Recommendation [16] to the Aviation Rulemaking Advisory Committee Airport Certification Issues Group clearly outlined no less than “two personnel trained at the emergency medical technician-paramedic level and two personnel trained at the emergency medical technician-basic level” to be on the scene during an aircraft emergency (Page 21).

The NFPA ARFF standards and the ARFFRWG reported on staffing established numbers based upon the category or Index of the airport, but the Department of Defense (DOD) and the Department of the Air Force (AF) provided minimum staffing numbers by applying different factors. The DOD’s base numbers are provided, as seen below [17], and an additional worksheet is attached to the document to assist in the
determination of the correct number of staffing needed to meet outlined objectives plus “contracting, cross-staffing, and mutual aid considerations.” (Page 27).

<table>
<thead>
<tr>
<th>ARFF Program Element</th>
<th>ARFF Personnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unannounced 1st Arriving Company</td>
<td>3</td>
</tr>
<tr>
<td>Announced Fire Arriving Company</td>
<td>3</td>
</tr>
<tr>
<td>Additional Units – should arrive at 30-minute intervals</td>
<td>-</td>
</tr>
</tbody>
</table>

The AF pamphlet [18] addresses staffing, considering different levels of operational service during air traffic control tower hours and apparatus utilized: optimum, reduced, critical and inadequate. While these requirements are not applied to civil airports, the objectives are extremely similar, and it is important to note the existence of these documents when discussing ARFF staffing.
Table 8. Fire Fighting Personnel/Agent Requirements (AF)

<table>
<thead>
<tr>
<th>Aircraft Type</th>
<th>Optimum Level of Service</th>
<th>Reduced Level of Service</th>
<th>Critical Level of Service</th>
<th>Inadequate Level of Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircraft</td>
<td>AF Vehicle Set</td>
<td>OLS - Firefighters</td>
<td>OLS - Gallons Q1=Q2=Q3</td>
<td>RLS - Firefighters</td>
</tr>
<tr>
<td>A-18, C-21, E-13, F-16, F-22, F-35, F-417, T-37/E, B-57/E, MQ-1A, T-38, AT-38, MQM-107, T-6A, UV-10, QF-4, CV-22, UH-1N, C-26A, T-1, QK-4, and C-12</td>
<td>1 14</td>
<td>2,500 - 1,340</td>
<td>13 - 8</td>
<td>1,339 - 513</td>
</tr>
<tr>
<td>C-9, C-22, C-32, C-37, C-40, C-130, E-1, E-6, T-43, MH-53, and RC-135</td>
<td>2 14</td>
<td>4,000 - 2,760</td>
<td>13 - 8</td>
<td>2,759 - 1,316</td>
</tr>
<tr>
<td>B-1, B-2, B-32, C-17, RC-46, and RC-135</td>
<td>3 14</td>
<td>5,000 - 4,380</td>
<td>13 - 8</td>
<td>4,879 - 3,027</td>
</tr>
<tr>
<td>E-7 T-47, KC-10 and VC-25</td>
<td>4 16</td>
<td>8,000 - 7,780</td>
<td>15 - 8</td>
<td>7,779 - 4,364</td>
</tr>
<tr>
<td>C-5</td>
<td>5 17</td>
<td>10,000 - 9,570</td>
<td>16 - 8</td>
<td>9,569 - 6,292</td>
</tr>
<tr>
<td>C-39</td>
<td>6 18</td>
<td>13,000 - 12,626</td>
<td>17 - 8</td>
<td>12,635 - 7,508</td>
</tr>
</tbody>
</table>

* Firefighters numbers are on a per shift basis
** Below Optimum Level of Service – Aircrew Awareness (NOTAS)
*** Below Reduced Level of Service – Mission Commander or OGS/CC approval
**** At or Below Critical Level of Service – Waiver approval as specified in paragraph 7.1

Other documents were examined regarding ARFF staffing in relation to meeting objectives required during an incident: NFPA ARFF standards, FAA Advisory Circulars, NTSB aircraft accident reports, the Civil Aviation Authority (CAA) Licensing of Aerodromes, the International Fire Service Training Association’s (IFSTA) ARFF manual, the International Civil Aviation Organization (ICAO) documents, Occupational Safety Health Administration documents related to ARFF, and the National Institute of Standards and Technology’s report on Residential Fireground Field Experiments.

Additional NFPA ARFF standards: 402 [19], 405 [20], 424 [21] and 1003 [22] discuss the organization’s defined ideal numbers for personnel to achieve specifically considered goals and needed job performance requirements that must be completed during rescue events. For instance, within NFPA 402: 10.4.4, it is suggested that a rescue team should consist of a minimum of four personnel to achieve the primary objective of “controlling and extinguishing the fire to enable safe evacuation of the aircraft” [19]. NFPA 405 outlines various tasks that need to be achieved by ARFF personnel: a) rescue, b) exposure protection, c) fire confinement, d) ventilation, e) interior attack, f) fire extinguishment, and g) overhaul and that the level of staffing needs to be considered for these tasks to be successfully performed [20]. The NFPA 424 standard considers the airport emergency plan and all perceived emergencies that could occur and would
need to be staffed accordingly: a) aircraft accidents on and off airport property, airborne and other emergencies and emergency medical care [21]. In the fourth chapter of NFPA 1003, job performance requirements for an airport firefighter are discussed, which highlight the need of these staff to be properly trained in various emergency situations: a) fire suppression, b) interior fire attack, c) interior rescue, d) gain interior access, e) locate and disentangle trapped victims, and f) implement initial triage [22].

To assist with guidance, the FAA publishes Advisory Circulars (ACs), of which there are fourteen 150-Series ACs related to ARFF [References 23 through 34]. These provide guidance to the Part 139 airports, and, in some cases, may be tied to FAA funding eligibility. None of these ACs expressly specify ARFF staffing at certificated airports, but instead provide guidance on required or recommended tasks that ARFF departments may be expected to accomplish.

There are other materials written by various other organizations that are dedicated to ARFF personnel meeting incident objectives, but not specifically staffing levels. **IFSTA’s ARFF 6th edition** [35] generically addresses manpower requirements for extinguishment and other operations for ARFF incidents, including, but not limited to, the need of personnel for triage, EMS and other vital maneuvers.

**In an examination of NTSB aircraft accident reports**, it was found that the first recommendation addressing ARFF staffing levels occurred in the report involving a McDonnell Douglas MD-82, operating as American Airlines Flight 1420, that occurred on June 1, 1999, when, during landing, the aircraft overran the end of the runway at Little Rock National Airport, in Little Rock, Arkansas [15]. Within the recommendations, the NTSB stated the following directly to the FAA:

```
Amend 14 Code of Federal Regulations 139.319(j) to require a minimum Aircraft Rescue and fire Fighting staffing level that would allow exterior firefighting and rapid entry into an airplane to perform interior firefighting and rescue of passengers and crewmembers (NTSB, A-01-65, p. 39).
```

An additional NTSB report [36] from a 2011 aviation incident, involving an experimental Gulfstream Aerospace Corporation GVI (G650), N652GD, that crashed during takeoff at Roswell International Air Center, Roswell, New Mexico, had another recommendation directed to the FAA regarding ARFF staffing:

```
Determine whether 14 Code of Federal Regulations Part 139 airports have sufficient and qualified operations personnel on duty at the airport during all scheduled air carrier operations,
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and direct airports without such staffing to implement actions to meet the personnel requirements of section 139.303 (NTSB, A-12-71, p. 5).

With the restatement of such a recommendation in the Asiana NTSB report, it is suggested that the NTSB considers that ARFF crews arriving at the scene of a burning aircraft should have sufficient staff to begin rescue efforts for passengers and crew inside the burning airplane who may be disabled or otherwise unable to escape. The A-01-65 action recommendation is classified as a closed-unacceptable action since no action was taken by the FAA.

The Civil Aviation Authority (CAA) discusses the need for ARFF staff to meet principal objectives and all firefighting apparatus being operated successfully in Licensing of Aerodromes: CAP 186 but does not delve into how many employees are needed to obtain these goals [37]. The International Civil Aviation Organization (ICAO) states the need for appropriately trained staff to be available to conduct firefighting objectives, including the operation of apparatus at maximum aptitude during any flight operations [38].

...sufficient trained personnel should be detailed and be readily available to ride the rescue and fire fighting vehicles and to operate the equipment at maximum capacity. These trained personnel should be deployed in a way that ensures that minimum response times can be achieved and that continuous agent application at the appropriate rate can be fully maintained. Consideration should also be given for personnel to use hand lines, ladders and other rescue and firefighting equipment normally associated with aircraft rescue and fire fighting operations (Paragraph 9.2.40).

While no other literature was found that addressed ARFF staffing levels specifically, there are a few documents that were reviewed from the structural fire operations standpoint that are applicable.

In OSHA’s regulations on Occupational Safety and Health Standards, Part 1910.134(g)(4) [39] the need for two or more firefighters at various locations during a fire to “render immediate assistance to those inside if needed” is stated as a procedure for interior structural firefighting. The NIST Report on Residential Fireground Field Experiments [40] addresses “deployment of resources and how it affects firefighter and occupant safety” during a fire (Page 10). While this was a multiphase research project that included assistance from various fire service and Federal government organizations, it was specific to
structural firefighting; however, the research questions encompass the key concept of essential staffing numbers to accomplish tasks during a fire. Although the last few documents examined were structural fire related, the objectives are reasonably like those encountered during an aircraft incident.

A review of the relevance of OSHA 1910.134 to ARFF services at Part 139 airports is found in Appendix B of this paper. Current FAA regulations relative to ARFF (14 CFR Part 139) do not require minimum staffing numbers and do not require interior aircraft firefighting by ARFF. These omissions are not intended to limit ARFF staffing, nor does it imply that interior rescue and firefighting at airports should not be accomplished. As interior rescue firefighting is not a task required by the regulation, OSHA 1910.134 and 14 CFR Part 139 are not relevant to each other.

Ultimately, any aircraft fire at an airport will be fought, and if the fire extends to the interior, there will eventually be interior firefighting conducted. These actions may or may not be taken by airport based ARFF. All workers in the United States (including firefighters) are protected by laws created by OSHA. In the case of OSHA 1910.134, ARFF is not exempt from the protection afforded by the OSHA Respiratory Standard. OSHA does not intend for “two in – two out” to serve as a minimum staffing requirement.

While the examined existing literature generally references the need for appropriate staffing levels and the similar objectives that must be accomplished by personnel during an aircraft incident, there is no existing literature like the NIST report that explicitly examines ARFF staffing levels. Therefore, the NIST document served as the model for the research framework of this study. Adaptations were made to variables to directly apply the research to ARFF staffing and the objectives, as well as the NFPA 403 Annex D – “Task and Resource Analysis Model”.

In 2009 the Airport Cooperative Research Board (ACRP) published a report “Risk Assessment of Proposed ARFF Standards” [41]. The purpose of the ACRP research was to determine if changes to ARFF standards would have reduced the number fatality of serious injuries that occurred during past accidents. Part of the “proposed ARFF standards” deals with staffing, making this ACRP research project applicable to this Task Group report.

Several topics were researched in the ACRP report. One of the areas explored is relative to aircraft evacuation and ARFF response times. In the ACRP report, the following data was extracted from
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DOT/FAA/AR-09-18, “Determination of Evacuation and Firefighting Times Based on an Analysis of Aircraft Accident Survivability Data” [42]. The FAA research targeted the following four areas.

1. Time to initiate an evacuation measured from the time the aircraft came to a rest to the time the evacuation started.
2. Time to complete an evacuation, measured from the time the aircraft came to rest to the time the evacuation started.
3. Time to arrival of firefighters measured from the time the aircraft stopped to the time firefighters were in a position to start firefighting activities.
4. Time for firefighters to establish control in a ground pool fire accident measured from the time of arrival of the firefighters to the time they established control of the fire.

Analysis of the data consisted of looking at 147 aircraft accidents occurring from March of 1967 through October 2000. Of these 147 accidents, 101 were considered survivable and 70 had fire a fire involvement. Of the 70 fire-related accidents, 36 were confirmed ground pooled fuel fires. Pooled fuel fires occur on the ground under an aircraft when fuel tanks or lines are ruptured, and the leak results in pooled fuel which finds an ignition point.

The analysis of the extracted data from the Cabin Safety Research Technical Group Aircraft Accident Database, produced a “Curve of Best Fit” with the following results.

1. Evacuation Initiation: 50% of evacuations are initiated within 20 seconds and 90% within 40 seconds.
2. Evacuation Completion Times: 50% of evacuations are completed within 130 seconds and 90% within 325 seconds.
3. For Time of Arrival of Firefighters: on 50% of occasions, the firefighters arrive within 4 minutes (240 seconds) and 90% of occasions within 12 minutes (720 seconds).
4. For Firefighters to Establish Control: on 50% of occasions, the firefighters establish control within 10 minutes (600 seconds) and 90% of occasions within 42 minutes (2,520 seconds).

Burn-through Times

Appropriately the ACRP research studied burn-through times of the aircraft fuselage. Specifically, that is the duration of time during which the pool fire needed to burn through to the aircraft cabin. To reach the aircraft cabin, the fire must burn through the aircraft skin, thermal-acoustical insulation and the interior sidewall and floor panel combination. The results of burn-through testing ranged from 30 to 60 seconds for aluminum skin. Aircraft fuselages constructed using thermal-acoustical insulation, comprised of fiberglass batting encased in a polyvinyl fluoride (PVF) moisture barrier, can offer an additional one to
two minutes of protection. Combinations of several new materials and combinations tested showed improved burn-through times over existing materials. A heat-treated oxidized polyacrylonitrile fiber (OPF) encased in polyimide bagging material prevented burn-through for over eight minutes.

This ACRP study compiled a great deal of data and identified average times for the critical tasks required during the initial moments of an aircraft crash. Following is a merge of those average times to understand how effective current ARFF staffing and response criteria may or may not increase survivability or minimize the time in which an aircraft occupant remains in an IDLH atmosphere.

<table>
<thead>
<tr>
<th>% Occasions</th>
<th>Evacuation Initiation Time</th>
<th>Evacuation Completed Time</th>
<th>Firefighter Arrival Time</th>
<th>Control of Pooled Fuel Fire</th>
<th>Burn-through time</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 %</td>
<td>20 seconds</td>
<td>130 seconds (2 minutes 10 seconds)</td>
<td>240 seconds (4 minutes)</td>
<td>600 seconds (10 minutes)</td>
<td>30 to 60 seconds for aluminum skin aircraft. Up to 8 minutes for some NLA</td>
</tr>
<tr>
<td>90 %</td>
<td>40 seconds</td>
<td>325 seconds (5 minutes 25 seconds)</td>
<td>720 seconds (12 minutes)</td>
<td>2,520 seconds (42 minutes)</td>
<td></td>
</tr>
</tbody>
</table>

As stated in Chapter 1 (Introduction) of the ACRP report, “ARFF is one component that contributes to survivability”. The actions of ARFF that prevent injuries or extinguish a fire or mitigate any emergency that threatens the occupants were only recorded during a worst-case scenario.

For example, most injuries occurring during evacuation using escape slides occur on the slide, or more likely at the bottom of the slide. If a firefighter is positioned at the bottom of a slide to assist evacuating passengers to their feet and direct them to a safe area of refuge, it is likely to contribute to a safer evacuation. The vast majority of aircraft emergencies occurring at airports include notification to ARFF that the aircraft is inbound with an abnormality or has declared an emergency. Upon receipt of advance notification, most ARFF Departments respond to forward hold-off positions and monitor the final sequence of the flight from the airfield. This provides an opportunity for rapid arrival at the scene, but most airports lack the ARFF staffing to put firefighters on the ground to assist at the bottom of evacuation slides.
The ACRP research identified nine accidents between 1989 and 2008 wherein aircraft occupants needed to be extricated from the aircraft by ARFF. Six of these accidents occurred in the United States.

The ACRP research indicated that there were 38 accidents where all the fatalities and serious injuries occurred during the evacuation of the aircraft. This represents 47% of the 81 “accidents of interest” in this study. Thirty-five of the 81 “accidents of interest” involved actual fire.

For an aircraft experiencing a pooled fuel fire, flame impingement on the fuselage puts all occupants immediately in harm’s way. An immediate aggressive exterior fire attack is required. If the aircraft is no longer up on its landing gear, the fire attack might be necessary from two or more attack angles. If the fuel continues to flow, the fire becomes a 3-dimensional fire, meaning it continues to feed the fire with fuel. The introduction of fuel adds to quantity of flammable liquids and disrupts the foam blanket and allows the fuel vapor trapped under the foam blanket to escape and find an ignition source. This 3-dimensional fire must be immediately controlled, or the running, burning fuel will continue to fuel the pool fire and the fire impingement that will lead to burn-through. The longer the pooled fuel fire burns, the larger the fire will become, as well as the quantity of agent and time required for extinguishment. This relates to staffing, as multiple simultaneous actions are required in the initial critical moments of an aircraft involved with a pooled fuel fire.

14 CFR Part 139 does not include a requirement to perform rescue or assist in emergency evacuation, nor does it include any requirement or demonstration of the ability to extinguish a pooled fuel fire in less time than burn-through occurs. Providing adequate staffing, equipment and agent for these duties are at the discretion of the airport.

The goal of the ACRP study was to determine if proposed ARFF standards would have reduced fatalities or injuries of past accidents. After reviewing the accident data, the research team concluded that there was insufficient data in the accident records, particularly as causes of injuries are not included in the record. The researchers did indicate that, in the case of the accident in Quincy Illinois on November 19, 1996, ten aircraft occupants died from “carbon monoxide intoxication from inhalation of smoke and soot”, and the remaining four occupants died from “inhalation of products of combustion”. The research team believes that had any of the current FAA, ICAO or NFPA standards been in place, all or most of the lives would have been saved.
The accident that occurred at Little Rock, AK on June 1, 1999 was rich with data for analysis. In that accident, the Captain and five passengers died due to traumatic injuries, and five died from smoke and soot inhalation and/or thermal injuries. Due to severe weather and poor communications between ARFF and Air Traffic Control, the response time to the accident was 16 minutes from the initial notification of ARFF. The NTSB concluded that the accident was potentially survivable for two of the occupants that were included in the fatalities.

The Little Rock, AK Aircraft Accident Report NTSB Aircraft Accident Report – Runway Overrun During Landing American Airlines 1420 MacDonnell Douglas MD-82, N215AA, Little Rock, Arkansas, June 1, 1999 [15] indicates that the four ARFF personnel that responded to the accident were not available to enter the airplane because they were involved in positioning the fire trucks and operating fire suppression equipment. Thus, an interior search of the airplane could not be conducted until off-airport firefighters arrived on scene about 0022. In footnote 220 of the NTSB Accident Investigation Report, Section 2.4.1, the Safety Board recognized that Little Rock airport is now always staffed with six ARFF personnel.

The following reference is taken directly from the NTSB Report.

2.4.1 Aircraft Rescue and Fire Fighting Staffing Levels

The Safety Board could not determine whether the passenger in seat 27E would have survived if sufficient ARFF personnel had been available to perform a rescue. However, previous accidents in which the occupants’ survival was aided by or depended on the abilities of rescue personnel to enter an airplane (see section 1.18.7.1) provide lessons learned that highlight the need for an adequate number of ARFF personnel to perform rescue operations.

The FAA’s January 1997 final report, Aircraft Rescue and Firefighting Services— Mission Response Study, indicated that evacuation of an aircraft was a primary responsibility of the air carriers and that the carriers have crew complements trained for that function. This finding concerns the Safety Board because, in the event that crewmembers are incapacitated or the conditions aboard the airplane deteriorate to the point that the crew is forced to leave, the remaining airplane occupants must rely on ARFF personnel to assist in the evacuation. In fact, the first officer and two of the four flight attendants in the Little Rock accident sustained serious injuries and were unable to assist with the evacuation.
Title 14 CFR 139.319(j) requires that “sufficient rescue and firefighting personnel are available during all air carrier operations to operate the vehicles, meet the response times, and meet the minimum agent discharge rates required by this part.” However, the regulation does not contain any specific staffing requirement for ARFF units. Thus, the regulation does not ensure that ARFF units will be staffed at a level that would allow timely entry into an airplane for rescue and firefighting activities.

Insufficient ARFF staffing levels were demonstrated in two recent events. First, on October 10, 2000, a Canadair Challenger Model 604, C-FTBZ, owned by Bombardier Inc., and being operated as a test flight, crashed into terrain and collided with an airport perimeter fence during a failed takeoff from runway 19 at the Wichita Mid-Continent Airport, Kansas. A fuel-fed fire erupted after the collision. Two ARFF fire trucks and three ARFF personnel responded within about 90 seconds and applied a mass application of firefighting agent to extinguish the exterior fire. The firefighters stated that they could hear screams for help coming from the cockpit. One of the ARFF trucks carried a “penetrating nozzle”; however, the nozzle could not be used because two trained firefighters were required to operate it, and only one was available. (Two of the three personnel were occupied in their vehicles with firefighting activities.) The pilot and flight test engineer were killed, the copilot received serious injuries and died more than 1 month later, and the airplane was destroyed.

Second, on August 8, 2000, Air Tran flight 913, a DC-9-32, N838AT, made an emergency landing in Greensboro, North Carolina, because of dense smoke in the cockpit. The airplane landed successfully, and an emergency evacuation was conducted. All occupants were able to evacuate the airplane. Four crewmembers received minor injuries from smoke inhalation in flight, 1 passenger received a minor injury during the evacuation, and 1 crewmember and 57 passengers were uninjured. As with the flight 1420 emergency response, three ARFF vehicles and four ARFF personnel responded to the Air Tran event. If the occupants aboard the Air Tran flight had not been able to evacuate, there would not have been adequate ARFF resources to enter the airplane and rescue individuals. In fact, no ARFF personnel entered the airplane until after off-airport emergency responders arrived, despite the fire progressing through the airplane.

The Safety Board concludes that ARFF units may not be staffed at a level that enables ARFF personnel, upon arrival at an accident scene, to conduct exterior firefighting activities, an interior fire suppression attack, and a rescue mission. Therefore, the Safety Board believes that the FAA should amend 14 CFR
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139.319(j) to require a minimum ARFF staffing level that would allow exterior firefighting and rapid entry into an airplane to perform interior firefighting and rescue of passengers and crewmembers.

220 The Safety Board recognizes that Little Rock airport is now staffed with six ARFF personnel at all times.

In addition to the specific review of the staffing at Little Rock, the NTSB references two other events, recent to this investigation where insufficient ARFF staffing was identified during NTSB accident investigations.

The Airport Cooperative Research Board (ACRP) also published, “How Proposed ARFF Standards Would Impact Airports” [43]. This study was conducted in response to Section 311 or H.R. 915 EH, FAA reauthorization Act of 2009 which called for more closely aligning ARFF regulations under Title 14 Code of Federal Regulation (CFR) Part 139 with voluntary consensus standards. The analyses in the report compares existing ARFF standards with those promulgated by the International Civil Aviation Organization (ICAO) and the National Fire Protection Association (NFPA). The research includes a review of eleven years of aircraft accident data covering the types of operations governed by Part 139.

One of the significant differences between Part 139 and NFPA 403 at the time that this report was written is response time. 14 CFR Part 139.319h requires an ARFF response time for the first required ARFF vehicle to the midpoint of the furthest runway in three minutes, and all required ARFF vehicles in four minutes. At the time that this report was published, NFPA 403 (2009 edition) [44] was current. In that edition Par. 9.1.3 calls for the first required ARFF vehicle to reach any point on the operational runway in two minutes. The NFPA technical committee has since changed that response requirement.

**NFPA 403 – Standard for Aircraft Rescue and Firefighting Services at Airports, 2018, Section 9.1.3 – Response Times [45]**

9.1.3.1 The response time of the first arriving ARFF vehicle to reach any point on the operational runway and begin agent application shall be within 3 minutes of the time of the alarm.

9.1.3.2 The response time of the first arriving ARFF vehicle to reach any point remaining within the on-airport portion of the rapid response area with improved surface conditions shall be within 4 minutes of the time of the alarm.

The core product of this ACRP study [43] is an evaluation of the cost to implement NFPA standards at airports. The greatest cost identified in the study is the cost of constructing additional fire stations to

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satisfy the response requirement of the 2009 edition of NFPA 403 (i.e., two minutes). The report highlights that: “The NFPA two-minute runway response requirement could more than double the number of firefighters and ARFF vehicles at the 476 Part 139 airports considered in this study.” The current NFPA response criteria is similar to the ICAO response guideline. Both ICAO and NFPA call for an increase in staffing and agent. The ACRP report estimates that the cost to increase the FAA minimum standards to ICAO standards, including the cost of vehicles and firefighters would be $884.5 million initially with recurring annual costs of $232.8 million (according to the 2009 edition of NFPA 403).

4. **RESEARCH**

A research exercise was conducted at Atlantic City International Airport to collect data sets measuring time requirements for the individual steps necessary to:

1. Gain rapid access into the airplane.
2. Perform interior firefighting.
3. Perform rescue of passengers and crewmembers.

There are multiple factors that affect the level of difficulty for these objectives. Accident location, aircraft position, condition, weather and hazards present are unique with each event and not repeatable in research. A decision was made to perform the testing on two representative aircraft types, providing opportunities to conduct repeatable time trials with different sill heights. The sill is essentially the threshold of the aircraft entry door. The sill heights are pointed out in figure 1 for test aircraft #1 and in figure 2 for test aircraft #2, a Boeing 737 and 747. The design team additionally discussed utilizing a small air carrier aircraft, such as a Bombardier CRJ or an Embraer Regional Jet; however, there were no such aircraft available at the time of the time trials conducted at ACY.
Figure 1. Test aircraft #1. Boeing 737, narrow body (single aisle) passenger aircraft with a sill height at the Left #1 door of 8’ 8”

Figure 2. Test aircraft #2. Boeing 747 SP, wide body (2 aisles) passenger aircraft with a sill height at the Right #4 door, 17’ 0”
4.1 Research Exercise Team

The ARFF Working Group Task Group 60 committee invited airport ARFF departments in the Northeast United States to participate in the time trial research event. Each airport contacted was asked to provide the following:

- Two firefighters or company level officers who are active, line personnel, capable of performing the tasks associated with rapid entry to an aircraft, initiation of interior firefighting and rescue of occupants.
- Provide their own transportation, lodging and meals for the event.
- Provide their own personal protective equipment (PPE), however self-contained breathing apparatus (SCBA) would be provided on scene.

4.2 Research Exercise Overview

Task Group 60 Research Exercise Team assembled at Atlantic City International Airport on October 11, 2016 at 0700 for a 3-day event. The ARFFWG was hosted by Atlantic City Airport ARFF on aircraft provided by the FAA Technical Center, Airport Safety Branch.

All firefighters and fire officers were trained (by their airports) to the minimum requirements of 14 CFR Part 139.319 [3] and Advisory Circular 150/5210-17 [27]. Based on the participants being “qualified” for the tasks, they were not directed by the exercise controller to follow an assigned procedure to complete each task. The teams working together conducted internal strategy briefs to plan and coordinate their actions. Exercise safety officers were assigned inside and outside the aircraft to oversee the operation and were empowered to stop the event at any time that they were concerned about the safety of participants. Whereas the participating firefighters and fire officers were from various departments, it was anticipated that different tactics would be used. An additional benefit to this research may then include recommendations for training “best practices” for the ARFF community.

Over 30 hours in video was captured from three different views of each timed event. The quantity of data was overwhelming, but a detailed review from the various angles contributed to the findings and the value of this report.
4.3 Timed Trial Objectives

The event was planned, coordinated and conducted to ensure a safe environment with substantiated documentation of findings. There were three overall objectives, as described below, for the timed exercises and correspondingly six scenarios planned for both aircraft, i.e., the B-737 and B-747:

- Initiate access to the aircraft cabin using ground ladder
- Initiate interior aircraft firefighting using ground ladder
- Initiate interior rescue operations using ground ladder
- Initiate access to the aircraft cabin using mobile stairs
- Initiate interior aircraft firefighting using mobile stairs
- Initiate interior rescue operations using mobile stairs

This timed trial event was conducted under controlled conditions with no smoke or fire present. The timed evolution included the manpower indicated for the task being tested only. Exercise controllers, safety officer(s), technicians, photo and video teams, and medical monitoring staff were on site during the time trials but did not serve as participants. The staffing required to maintain protection of the scene with turrets and handlines was not included in these time trials and will be discussed separately.
Considered a standard in the fire service, firefighters making entry into a structure (in this case, an aircraft) will always carry a tool of some type. It may be light forcible entry equipment, an air quality meter, ventilation fan or a stretcher. Each event has different needs. For the purpose of this exercise, it was important to have a single piece of equipment (for consistency) brought on board during each event. The ventilation fan was chosen by the exercise design team and used for consistency in each event.

The following objectives of the time trials were developed by the design team to satisfy the intent of NTSB recommendations.

1) **Initiate access to the aircraft cabin.**
ARFF teams shall be capable of initiating access to an aircraft cabin, using normal egress points with the capability available for forcible entry. ARFF personnel shall gain vertical access to the aircraft by use of a ground ladder or mobile stair with appropriate tools or equipment to satisfy the needs of the event. ARFF personnel gaining access to the cabin shall be equipped with full protective clothing and self-contained breathing apparatus, protected by ARFF vehicle turrets and/or handlines.

2) **Initiate interior aircraft firefighting.**
ARFF teams shall enter the aircraft with a charged handline. The interior ARFF team shall be equipped with protective clothing and self-contained breathing apparatus. The interior ARFF team shall be protected by ARFF vehicle turrets and/or additional handlines.

3) **Initiate interior rescue operations**
An interior ARFF rescue team shall enter the aircraft with rescue equipment to perform extrication of trapped or incapacitated victims. In these research scenarios, a ventilation fan was carried into the aircraft. Based on the needs of each unique event, the chosen tool could have been forcible entry tools or other equipment. The fan was used in each evolution for consistency. Victims must be removed from hazardous atmospheres inside the aircraft to the ground where proper medical examination and treatment can be initiated. The ARFF rescue team shall be equipped with tools, protective clothing and self-contained breathing apparatus. The interior ARFF team shall be protected by ARFF vehicle turrets and/or additional handlines.
4.4 Research Event Logistics

A walk through of each aircraft was conducted for all attendees. Safety briefings were conducted throughout the event.

Figure 4. Interior and exterior briefings were conducted.
Figure 5. Galloway Township Ambulance provided baseline medical screening and evaluation during rehab following each evolution.

CSRA International (CSRA) provided technicians and engineering staff to support the event. In some cases, where only one firefighter was being used to perform a timed scenario, technicians stood by to monitor safety, but were not considered ARFF staffing. Technicians also performed all the heavy work associated with placement of mannequins and equipment to minimize the fatigue of a participant in the timed trials.
Figure 6. CSRA provided logistical support.

4.5 Time Trials

The first set of trials were conducted on a B-737 and the second set of trials was conducted on a B-747. All times were recorded as participants met pre-defined benchmarks. Also recorded were observations by participants and observers that were thought to be appropriate for inclusion in the report. Appendix C contains the Excel spreadsheet in which detailed times and comments were recorded during the conduct of the evolutions.

4.5.1 Test 1 / Objective 1: Initiate Access to Aircraft Cabin

This test was designed to identify the amount of time and manpower necessary to gain access to a typical narrow body aircraft (Boeing 737) and a wide body aircraft (Boeing 747), using ladders (described in Test 1A) and air stairs (described in Test 1B) that are available to ARFF responders and then placing a ventilation fan inside the aircraft. The average times recorded for each aircraft are presented in Tables 4 and 5 below.

In the case of the B-747, a 28’ extension ladder was used to evaluate the safety of using a ground ladder to enter the aircraft. To enhance safety for this evaluation, the air stairs were left in place and the 28’ ladder was position adjacent to it. This was done to eliminate the risk of the ladder slipping as the rescuer...

Support from SRA Technicians proved additional safety personnel and performed set up and break down of equipment, manikin placement, etc.
leaned away from the ladder to operate the locking mechanism on the B-747. As seen in Figure 7, the rescuer had to reach from the ladder to the center of the door of the B-747 to begin the process of unlocking the door. The safety officers and participants agreed that this was not a safe practice. The door release is 38 inches from the beam of the ladder. Once the latch is released, this is a large heavy door which requires multiple motions to open. Each of those motions causes a weight shift on the ladder and even greater reaches. A decision was made to eliminate the ground ladder scenario from Test 1-A on the B-747, as opening the door from the ladder was too dangerous for a one-person operation.

![Test 1-A](image)

The rescuer must extend his arm sufficiently to grasp the lock handle. His palm will need to reach to a position 38” from the beam of the ladder.

Figure 7. Reaching from the ladder to the center of the B-747 is not a safe practice.

The following table provides an overview of the times recorded for each of the timed trials to get personnel on board the aircraft. Each of the timed trials referenced are discussed further in this report.

<table>
<thead>
<tr>
<th></th>
<th>Ground Ladder Evolutions (average time)</th>
<th>Air Stairs Evolutions (average time)</th>
<th>Delta time: Ground Ladder vs. Air Stairs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min:sec</td>
<td>min:sec</td>
<td>min:sec</td>
</tr>
<tr>
<td>1-Man Team</td>
<td>12:39</td>
<td>2:58</td>
<td>9:41</td>
</tr>
<tr>
<td>2-Man Team</td>
<td>7:28</td>
<td>1:49</td>
<td>5:39</td>
</tr>
<tr>
<td>3-Man Team</td>
<td>4:49</td>
<td>1:42</td>
<td>3:7</td>
</tr>
</tbody>
</table>
* Number is most likely elevated as one of the three one-man teams had no prior Ground Ladder experience

Table 11. Results from Firefighting Evolutions at ACY for Entering 747 Aircraft

<table>
<thead>
<tr>
<th></th>
<th>Ground Ladder Evolutions (average time)</th>
<th>Air Stairs Evolutions (average time)</th>
<th>Delta time: Time Reduction with Increased Staffing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Man Team</td>
<td>--</td>
<td>2:41</td>
<td>N/A</td>
</tr>
<tr>
<td>2-Man Team</td>
<td>--</td>
<td>2:14</td>
<td>(27 seconds)</td>
</tr>
<tr>
<td>3-Man Team</td>
<td>--</td>
<td>1:57</td>
<td>(17 seconds)</td>
</tr>
</tbody>
</table>

Test 1A – 1-rescuer Evolution Description (Gaining Access to B-737 utilizing a Ladder)

The timer was activated as a single rescuer, in full PPE, steps away from a pre-staged ARFF vehicle. The rescuer carried a “Little Giant” folding ladder from the ARFF unit and approached the L-1 door of the 737. The rescuer then set up the ladder and positioned it to allow the firefighter to unlock and fully open the aircraft cabin door. Once the cabin door was opened, the firefighter returned to the ARFF vehicle to retrieve a ventilation fan. The fan was carried to the aircraft and placed inside the doorway. Once the fan was inside the aircraft, the firefighter entered the cabin. Once both feet were on the sill, the time was recorded.

All doors of a B-737 except for over wing exits, are equipped with exit slides which do not automatically disarm when the door is opened from the outside. For these trials, the exit slides were not armed for any evolution. In an actual emergency involving an aircraft with this style door, additional time and effort would be required to disarm the slide from beneath the door to enable entry.
Figure 8. Test 1A – 1-rescuer using ladder to enter 737

*Test 1A – 1-rescuer Comments and Observations*

An A-frame or folding ladder like the “Little Giant” ladder used for the single rescuer evolution on the B-737 is commonly found on ARFF apparatus. These ladders are designed to fit in limited storage areas on apparatus and can be set up by one person. If set up on solid level ground, they are stable platforms and ideal for single person use. When they are set up as an A-frame as shown above, they can be climbed without the need of a second person footing (bracing) the ladder. It is never ideal to climb a ladder alone during an aircraft emergency, however, it is possible.

The initial decision-making process is based on the placement of the ladder. To open the door, the rescuer needs to be at a height, high enough to reach and operate the locking mechanism to release the door. The ladder cannot be placed in front of the door, as the door swings out when opening. As the rescuer pushes against the door to open it, he/she is required to lean away from the ladder. Without a person holding the ladder, this increases the risk of a falling and potential injury. Also, the ladder should be placed in a location where an inadvertent slide deployment from the slide inflating will not strike the ladder or the firefighter. After opening the door, the ladder will then need to be re-positioned to make entry safely. Depending upon the size, strength and overall reach of the rescuer, the ladder may need to be repositioned to completely open the door.
In a common scenario of the aircraft on a runway, the nose is pointed into the wind. If there is any wind, it will add to the amount of force required to get the aircraft door fully open and locked in the open position.

![Figure 9. Test 1A – 1-rescuer unlocks and opens aircraft door on 737](image)

After the door is locked open, only then can the rescuer step into the aircraft from the repositioned ladder. The final step in Test 1A requires the rescuer to get a piece of equipment from the apparatus and get it onboard the aircraft. For these scenarios, a ventilation fan was chosen and used for each timed trial. The ventilation fan weighs approximately 60 lbs. This is a difficult task for a single rescuer, particularly after conducting the previous steps of this evolution. The fan needs to either be lifted with both arms and pushed up the ladder or carried in one hand hanging over the side of the ladder and then lifted through the door. The preferred method to carry tools and equipment into the aircraft is to climb mobile or portable air stairs.
Conclusions Test 1A – 1-rescuer

As previously stated, no single rescuer evolutions for interior access over a ladder were attempted on the B-747. As seen in Table 4, the average of the three times to complete Test 1A with one rescuer on the B-737 was 12 minutes and 38 seconds. For several reasons, this is not an acceptable staffing level for this tactic. The most obvious reason is that a single rescuer would never be expected or allowed to enter an aircraft that was involved in a crash or fire alone without assistance. An entry team would never be less than two and would always require exterior back up.

1) Ergonomically, the rescuer is forced to reach and lift improperly both opening the door and lifting the 60 Lb. ventilation fan. Once the rescuer is injured, his role is compromised and may require the attention of caregivers.

2) This task is very physically demanding. It is necessary to wear full PPE, and PPE restricts movement, adds weight and contributes to fatigue. If there is smoke or other hazardous or toxic environments present, the rescuer would need to be breathing through the SCBA during this evolution. 12 minutes and 39 seconds of hard work will bring the rescuers 30-minute air supply down to between $\frac{1}{3}$ and $\frac{1}{2}$ remaining (at best). That rescuer is physically spent until given a time to recover.
3) The average time elapsed to complete this task with a single rescuer is too long to contribute to increasing survivability of aircraft occupants.

**Test 1A – 2-rescuer Evolution Description**

Test 1A evolutions for interior access over a ladder were not attempted on the B-747.

**Boeing 737 - Two rescuer evolution**

The timer was activated as the two rescuers stepped away from a pre-staged ARFF vehicle in full PPE, carrying a 28’ extension ladder, and performed a 2-man carry approaching the L-1 door of the 737. The rescuers then raised and positioned the ladder to the right (aft) of the L-1 door on the B-737. One rescuer climbed the ladder to open the aircraft door. The second rescuer stayed at the base of the ladder to stabilize it. Once the door was locked in the open position, the first firefighter returned to the ground, as the second firefighter, who was stabilizing the ladder, was required to return to the ARFF vehicle to retrieve the ventilation fan. The ventilation fan was carried up the ground ladder and placed into the cabin by the first firefighter. The timer was stopped when the fan and the firefighter were both in the cabin.

![2 Man Ladder Carry](image1)

![2 Man Raise](image2)

![Roll and Position](image3)

Figure 11. Test 1A – 2-rescuers initial steps for interior access to the 737

As compared to the single rescuer ladder raise, the two-rescuer ladder carry and raise is much faster, safer and efficient. A 28’ ladder that meets NFPA 1931 is rated for 750 lbs. This is to allow for more than one
person on the ladder, for example, a rescuer and a victim. A folding ladder like a “Little Giant” is typically rated for 300 lbs. When raising a straight ladder or extension ladder, both rescuers are committed if one member is on the ladder, as it needs to be footed or heeled by the second rescuer to prevent the ladder from sliding.

![Image of ladder with two rescuers]

Figure 12. Test 1A – 2-rescuers unlock and open aircraft door on 737

By utilizing the second rescuer to prevent the ladder from moving, the rescuer at the top of the ladder has greater ability to safely reach to open the door. If conditions include water or foam on the fuselage, or if the ladder is not set on hard pavement, the risk of the ladder sliding increases.
Figure 13. Test 1A – 2-rescuers final steps to access the interior of the 737

Stepping onto the aircraft from the ladder positioned alongside the door is still a dangerous maneuver. Stepping back onto the ladder from inside is even more difficult, because it is done by feel. Lifting the ventilation fan while climbing up the ladder is very difficult. Climbing a ladder requires three points of contact at all time. Either two hands and one foot or two feet and one hand must remain in contact with the aircraft or the ladder.

**Conclusions – Test 1A – 2-rescuers**

As seen in Table 4, the average time for this evolution was 7 minutes and 28 seconds. When compared to the time recorded for the same evolution (12 minutes 38 seconds) completed by a single rescuer, this is a significant improvement. A reduction of 5 minutes and 10 seconds is a 41% improvement in time, and an increase in safety is evident. The second rescuer cannot enter the airplane, however, until an additional rescuer becomes available to support the ladder. This is an improved method to gain entry, but it is far from ideal.

**Test 1A – 3-rescuer Evolution Description**

Test 1A evolutions for interior access over a ladder were not attempted on the B-747.
Boeing 737

The timer was activated as three rescuers stepped away from a pre-staged ARFF vehicle in full PPE. Two rescuers carried a 28’ extension ladder from the ARFF vehicle and performed a 2-man carry approaching the L-1 door of the 737. The third rescuer carried a ventilation fan, arriving at the aircraft at the same time as the rescuers carrying the ladder. Two rescuers then raised and positioned the ladder to the right (aft) of the L-1 door on the B-737. One rescuer climbed the ladder while a second stabilized the base of the ladder. Once in position, the rescuer at the top of the ladder opened the aircraft door. Once the door was opened, the firefighter climbed into the cabin. Once both feet were on the sill the time was recorded for gaining access to the aircraft. At this point, the second and third rescuer lifted the ventilation fan together and passed it to the rescuer inside the L-1 door. Other teams practiced using the third rescuer (who carried the fan to the airplane) to pass the fan to the rescuer on the ladder before making entry. Then the second firefighter entered the aircraft while the third rescuer secured the ladder.

Figure 14. Test 1A – 3-rescuer initial steps for interior access to the 737
Figure 15. Test 1A – 3-rescuer final steps to access the 737

Conclusions – Test 1A – 3-rescuers

Test 1A was not conducted on the B-747 for reasons of safety.

Boeing 737

As seen in Table 4, the average time for this evolution on the B-737 was 4 minutes and 49 seconds. When compared to the time recorded for the same evolution (12 minutes 38 seconds) completed by a single rescuer, this is a significant improvement. A reduction of 7 minutes and 49 seconds is a 62% improvement in time, and the increase in safety is evident. A second rescuer can immediately enter the airplane as an additional rescuer is available to support the ladder. When compared with the same evolution with two rescuers, a 2 minute 39 second reduction was observed. The obvious conclusion to this exercise is that for each additional rescuer assigned to the task, a significant reduction in time is realized.

Perhaps the greatest benefit of the 3-rescuer team is the fact that two rescuers can enter the aircraft as a team, while the third remains available to stabilize the ladder when they exit or to fetch additional equipment requested from the ARFF vehicle.
Table 12. Comparison of Elapsed Times for Access to the B-737 with Increased Number of Rescuers using Ladders Test 1-A

<table>
<thead>
<tr>
<th>Evolution</th>
<th>Elapsed Time</th>
<th>Time Reduction with additional rescuer</th>
<th>% Time Reduction with additional rescuer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-rescuer</td>
<td>12:38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-rescuers</td>
<td>7:28</td>
<td>5:10</td>
<td>41%</td>
</tr>
<tr>
<td>3-rescuers</td>
<td>4:49</td>
<td>2:39</td>
<td>35%</td>
</tr>
<tr>
<td>Total Reduction time - % of time from 1 to 3-rescuers</td>
<td>7:58</td>
<td>62%</td>
<td></td>
</tr>
</tbody>
</table>

While gaining access to the aircraft is only a single step in the management of an aircraft crash or fire, it is critical that it occurs quickly. During an actual incident, depending upon the scenario, the initial entry team will select a tool(s) to bring on board. For consistency in these timed trials, a ventilation fan was carried on board. In different scenarios, the tool of choice may be forcible entry equipment, fire extinguisher, medical equipment or air quality meters. These decisions are made by commanders at the scene or sometimes dictated by Standard Operation Procedures (SOPs).

While difficult to quantify in numbers, the overall safety of the increased manpower is a major consideration when assigning rescuers to a task. The levels of safety when comparing a rescuer operating alone at an aircraft incident on a folding ladder as compared to three rescuers on an NFPA compliant fire ladder are easy distinctions to make. Further, the level of energy expended with reduced staffing restricts the amount of time a rescuer can continue to contribute to the mission safely. This is particularly true when rescuers are working in an IDLH environment and using SCBA.

**Test 1B Description**

This test was designed to identify the amount of time and manpower necessary to gain access to a typical narrow body aircraft (Boeing 737) and a typical wide body aircraft (Boeing 747) using mobile aircraft stairs rather than ladders which were used in Test 1A. During these timed research events conducted at ACY, portable adjustable stairs were set up at the L-1 door of the B-737 and the R-4 door of the B-747. This type of stairway is well suited to these scenarios due to availability and ease of use. The test was conducted three times each with teams of one, two and three rescuers on both aircraft. Crews of 1, 2 and 3 personnel exited their vehicles fully bunkered and the timing began. They ascended the prepositioned airstair apparatus and opened the L-1 door on the B-737 and the R-4 door on the B-747 aircraft. Once opened, the rescuer stepped inside with the ventilation fan and the time was recorded. Tables 4 and 5 provide the average times for interior access using mobile stairs to the B-737 and B-747, respectively.
The stairs used for these trials were not part of a motorized stair truck (commonly referred to as air stairs). The stairs used were a portable non-motorized type often used in aircraft maintenance. The portable stairs create access to the aircraft just as well as the mobilized stairs, once in position. The set-up of these non-motorized stairs is simple if they are close by, and both the aircraft and the stairs are on pavement. During the timed trials, four men were used to position the stairs and secure them in place. Once in position, they were left in position for the duration of the timed trials. The following figure contains a photo of mobile air stairs, as well as the portable stairs used during the time trials.

![Figure 16. Two types of access stairs.](image)

The portable stairs on the left are the stairs used during the timed trials on the B-737. The mobile air stairs pictured on the right were used during a separate FAA research event, not related to this study. The photo is provided as an example only.

**Test 1B – 1-rescuer Evolution Description**

A single rescuer carried the ventilation fan from the ARFF vehicle to the top of the mobile stairs. Upon reaching the top, the fan was put down out of the swing of the door. The rescuer then unlocked and opened the aircraft door. Once the door was secured open, he picked up the fan and stepped onboard the aircraft.
Figure 17. One rescuer evolution gaining access to the 737 using mobile stairs

It is very clear that opening the aircraft door from the prepositioned stairs is a much safer and faster method of gaining entry. This was demonstrated on both the B-747 and the B-737.

Figure 18. One rescuer evolution gaining access to the 747 using air stairs
**Test 1B – 2-rescuer Evolution Description**

The test team tried two different methods utilizing two men for the time trials. In the first trial, both men carried the fan together. When they reached the top of the stairs, the first rescuer let go of the fan to unlock and open the door. Once open, the second rescuer walked onto the aircraft with the fan.

![Figure 19](image.png)

Test 1-B

“2 Man Carry” of Ventilation Fan

First Rescuer Unlocks and Opens Door. Second Rescuer Fully Opens and Locks Door Open While First Rescuer Enters

Figure 19. Two rescuers carry the fan up the mobile stairs to the 737

In another trial, the first rescuer advanced ahead of the second rescuer, ascended the stairs and unlocked and opened the door. The second rescuer carried the fan up the stairs alone and walked through the open door with the fan. The second method was found to be six seconds faster in getting the door fully open and a few seconds faster overall.
Figure 20. One rescuer opens the door and the second rescuer carries the fan and enters cabin

Figure 21. Two rescuers gain access to B-747 over air stairs
When two rescuers were available to carry the ventilation fan up the stairs together, firefighters mentioned a reduction in their fatigue. With the stairs in place, there was no need to leave a firefighter at the base of the ladder to stabilize it. Both rescuers could enter the aircraft as a team.

**Test 1B - 3-rescuer Evolution Description**

Using one rescuer to advance and open the door while two rescuers carried the fan was the fastest scenario for Test 1B, using 1, 2 or 3-rescuers on both aircraft and seemed to cause the least amount of fatigue.

![Test 1-B](image)

**Figure 22. Three rescuers complete interior access to 737 using mobile stairs**

The steps followed in Test 1B using 3 rescuers to board the B-747 began with the air stairs already in place. The first rescuer went ahead to open the B-747 door. The other two rescuers carried the ventilation fan up the stairs and straight onboard the aircraft.
Figure 23. Three rescuers access B-747, open the door and enter with tool (ventilation fan)

**Conclusions – Test 1B Evolutions**

The greatest lessons learned from Test 1B are the advantages of the air stairs over the use of ladders, as seen in the results of the time trials on the B-737 and the B-747. The improvements in time in all three scenarios, (one, two and three rescuers) were significant. The benefits to speed, safety and survivability when using boarding stairs rather than ladders during emergency operations are evident (Figure 24).
Figure 24. Benefits of stairs vs. ladders to access B-747 are obvious

Table 13. Comparison of Elapsed Times for Access to the B-737 with Increased Number of Rescuers Using Air Stairs, Carrying Ventilation Fan (Test 1B)

<table>
<thead>
<tr>
<th>Evolution</th>
<th>Elapsed Time</th>
<th>Time Reduction with additional rescuer</th>
<th>% Time Reduction with additional rescuer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-rescuer</td>
<td>43 seconds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-rescuers</td>
<td>32 seconds</td>
<td>11 seconds</td>
<td>26%</td>
</tr>
<tr>
<td>3-rescuers</td>
<td>31 seconds</td>
<td>1 second</td>
<td>negligible</td>
</tr>
<tr>
<td>Total Reduction time - % of time from 1 to 3-rescuers</td>
<td></td>
<td></td>
<td>28%</td>
</tr>
</tbody>
</table>

Table 14. Comparison of Elapsed Times for Access to the B-747 with Increased Number of Rescuers Using Air Stairs, Carrying Ventilation Fan (Test 1B)

<table>
<thead>
<tr>
<th>Evolution</th>
<th>Elapsed Time</th>
<th>Time Reduction with additional rescuer</th>
<th>% Time Reduction with additional rescuer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-rescuer</td>
<td>50 seconds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-rescuers</td>
<td>42 seconds</td>
<td>8 seconds</td>
<td>16 %</td>
</tr>
<tr>
<td>3-rescuers</td>
<td>36 seconds</td>
<td>6 seconds</td>
<td>14 %</td>
</tr>
<tr>
<td>Total Reduction time - % of time from 1 to 3-rescuers</td>
<td></td>
<td></td>
<td>28 %</td>
</tr>
</tbody>
</table>
In timed trials for both aircraft types, the reduction in time entering the aircraft was reduced by 28%, when using 3 rescuers as compared to one.

For most ARFF departments that use air stairs as part of their response to aircraft incidents, the stairs are dispatched to the scene in the same response wave as the ARFF vehicles. They travel more slowly than ARFF vehicles and stand back until ARFF vehicles are in position, at which time the driver of the stairs positions the vehicle so that it can be quickly brought to the designated door on the aircraft. This occurs while the entry crew is completing the donning of PPE and removing tools or hose lines from the apparatus.

Interior Access Vehicles (IAV) also known as mobile air stairs are further discussed in Chapter 4 DOT/FAA/TC-13/12, (April 2013), “Aircraft Rescue and Firefighting Strategies and Tactical Considerations for New Large Aircraft” [10]. As this report focused on NLA, evacuations from large aircraft, particularly evacuations from the upper deck of large aircraft were focused upon. As cited in the report, Changi Airport in Singapore has conducted two full A380 evacuations over air stairs. The details of both evacuations are taken from DOT/FAA/TC-13/12.

In terms of emergency services, Changi Airport Emergency Services (AES) conducted a needs analysis and developed plans to satisfy the ICAO regulations and guidance, as well as to satisfy Changi Airport goals for emergency preparedness for NLA.

In 2006, Changi AES procured two (2) Rosenbauer Mobile Air Stairs. Each is equipped with a firefighting package, including 264 gallons (1,000 liters) of water and a hose connection at the top of the platform for rapid access to either deck of an NLA for interior firefighting. The standard response for an incident involving an A-380 at Changi calls for a response of six ARFF Appliances, including AES 2 (Mobile Stairs).

The first A-380 evacuation on record occurred at Changi Airport. On January 10, 2010, SQ Flight 221 became disconnected prematurely from a push back tractor and the aircraft rolled off pavement and into the soft turf adjacent to Terminal 3. The aircraft was deplaned and recovered from the grass strip.

The second evacuation of an A-380 also occurred at Singapore Changi Airport. The incident on November 4, 2010 unfolded as Qantas Flight 32 left Singapore bound for Sydney. The A-380 suffered an uncontained engine failure of its Number 2 engine just six minutes into the flight. The failure and flying shrapnel sliced electrical cables and hydraulic lines in the wings. The wings forward spar was damaged, and two wing fuel tanks were ruptured. As fuel leaked out, an imbalance was created between the wings. The electrical problems meant that the pilots were unable to transfer fuel forward and the aircraft became tail heavy. The pilots struggled to maintain balance and keep the A-380 from losing lift, which would cause the aircraft to stall, while fielding fifty-four alarms of system failures or impending failures in the cockpit. The number 2 engine was on fire. The flaps were inoperable, as were the landing gear doors. The pilots were able to use gravity to lower the gear.
During landing, the brake temperature exceeded 1,650 degrees Fahrenheit (900 Celsius), causing four flat tires. The possibility of leaking fuel reaching the hot brakes was a significant threat. The pilots rolled out the plane the full length of the runway so that it would be close to ARFF vehicles to facilitate the application of foam under the aircraft. Upon landing, the crew was unable to shut down the Number 1 engine. Foam from Changi AES was used to choke out the engine.

Forty-four minutes after declaring the emergency, Qantas Flight 32 landed at Changi Airport. The events that had occurred during the previous forty-four minutes would certainly have justified the pilot to order evacuation by slides, but in spite of the combination of events, he elected to deplane the passengers over air stairs on scene provided by Changi AES.

Deplane of QF 32 Passengers
Singapore Airport Emergency Services “ES2”, capable of reaching the upper deck of the A-380. During this evacuation, a determination was made to deplane all passengers from the main deck. Had it been necessary, ES2 could have reached the upper deck just as easily. Take note of the diversity in age and physical characteristics of the sampling of passengers in the photo. An escape slide exit if not required by the situation puts some passengers at risk more than others.

Figure 25. Deplaning of QF 32 by IAV (air stairs) after catastrophic engine failure at Changi

It should be noted that all evolutions in Test 1B on both aircraft using an air stair put at least one rescuer on the aircraft in less than three minutes, except for one trial on the 747 with a one-rescuer crew (time was 3 minutes, 15 seconds). In a worst-case aircraft incident / accident where products of combustion are entering the aircraft and / or burning aviation fueling is impinging on the aircraft, three minutes is a long way into the event.

Fuselage burnthrough refers to the impingement and penetration of an exterior aviation fuel fire into the interior of an aircraft during a post-crash fire. Because of FAA testing of aircraft construction materials and insulations; they have consistently improved the survival factor in an aircraft with a post-crash fire. The challenge to increasing survivability for ARFF is to take steps to remove the occupants from an
Immediately Dangerous to Life and Health (IDLH) atmosphere in an aircraft cabin or improve the conditions in the cabin, before it is non-survivable. An FAA report, “Full Scale Test Evaluation of Fuel Fire Burnthrough Resistance Improvements” [46] reports:

“*The burnthrough resistance of aluminum skin is well known. It takes only 20-60 seconds for the skin to melt, depending on its thickness. The thermal acoustic insulation is the next impediment to burnthrough following the melting of aluminum skin. In past outdoor fuel fire burn tests on surplus fuselages, it was determined that fiberglass insulation provided another 1 - 2 minutes of protection, if it completely covered the fire area and remained in place.*”

The use of advanced composites has increased burnthrough resistance in some new model of aircraft. It is clear that exterior firefighting and rapid, simultaneous entry to the aircraft for interior firefighting and rescue is a race against the clock for the survival of those in the aircraft.

An example of an accident with large loss of life from burnthrough was in 1985 during a B-737 fire in Manchester, England. In this accident, investigators concluded that 55 people died from the fire which burned through in just 60 seconds.

4.5.2 Test 2 / Objective 2 - Initiate Interior Aircraft Firefighting

This test was designed to identify the amount of time and manpower necessary to advance a charged fire attack line into a narrow body aircraft (Boeing 737), as well as a wide body aircraft (Boeing 747). Entry over ladders (Test 2A) and air stairs (Test 2B) were evaluated. The scenarios of Test 2 were conducted three times on the 737 aircraft using teams of one, two and three rescuers all wearing full PPE and SCBA. The same scenarios were conducted three times on the 747, as well, except for the trial with one rescuer using a ladder due to safety issues previously discussed.

*Test 2A - Evolution Background (Initiate Interior Firefighting Over Ladders)*

ARFF vehicles are designed to allow operation with as few people as possible. The limited staffing provided at airports over the years has motivated the development of a great deal of automation to allow operation of the vehicle and firefighting components with as few people as possible. This includes the mechanical ability for a single firefighter to pull a pre-connected 1.5” or 1.75” attack line (fire hose) out of a storage compartment of an ARFF vehicle and fill the line with water after stretching it out without having to return to the ARFF vehicle to open a valve and increase the pump pressure.
The easiest way to carry a fire hose to a position near the entry point of the burning structure is to carry it flat and empty. Without the weight of the water and the lack of flexibility of a charged hose line, the line can be advanced with significantly less effort. If the ARFF department has adequate staffing to leave a pump operator at the truck while the firefighting team is advancing, the introduction of a handline can be accomplished more safely and easily. Once the line is in position, a pump operator can charge the line from the ARFF vehicle. The benefits of carrying a flat line (not filled with water) are even more obvious when going up stairs and ladders or going around obstacles such as aircraft seats and bulkheads.

These timed scenarios were conducted using a charged handline (when possible), as the overall objective of this research was to identify the “minimum” staffing level that would allow rapid entry into an airplane to perform interior firefighting and rescue of passengers and crewmembers. Performing these actions at an actual aircraft accident would also require exterior firefighting, which was not evaluated in these tests, but was factored into staffing recommendations.

Test 2A – Evolution Description – Initiate Interior Firefighting Over a Ladder

The timer began when crews of 1, 2 and 3 personnel stepped away from an ARFF vehicle in full personal protective equipment. They pulled a water-filled 1.75” handline (with bale tied closed) (See figure 26) from the ARFF vehicle that had been placed on the ground in an extended “S” pattern to allow for advance towards the aircraft. Each crew utilized the ladder already in place. The Little Giant folding ladder was used for the 1-person evolution on the 737, while the 28’ extension ladder was used for all other evolutions. Proper ladder ascending techniques were followed. The teams entered the aircraft doors and proceeded to the midpoint of the aircraft and the time was stopped. There was a mark in the aircraft aisle indicating the mid-point that must be reached to satisfy the objective. The safety officers determined that there would not be a test conducted using a single rescuer to advance a handline up the ladder into the B-747.

(It should be noted that the ladder was already in position and the aircraft door locked in the open position prior to these scenarios.) The times recorded to bring the 1.75” charged handline presented in this section are to be added to the times recorded for gaining access to the aircraft.
Figure 26. Nozzle control valve (bale) secured to prevent accidental discharge of agent.

**Test 2A – 1 -Rescuer Evolution (B-747)**

The single rescuer event to bring a handline onto the B-747 was found to be unrealistic. There are simply too many places for the line to get caught, and rescuers were exhausted before reaching the finish. One of the tests was stopped by the safety officers who were evaluating the timed scenarios, as they were concerned with the participant’s obvious exhaustion. The safety officers determined that there would be not be a test conducted using a single rescuer to advance a handline up the ladder into the B-747.

**Test 2A – 1-rescuer Evolution Description (Boeing 737)**

The 1.75” attack line was charged and positioned adjacent to the ARFF vehicle for each test on the 737. The rescuer(s) needed to carry the hose and reposition it so that it could be brought onto the aircraft and down the aisle to the pre-designated mid-point of the aircraft.
As detailed in Table 14, the average time required to bring the charged handline to the midpoint of the aircraft (inside) on the 737 with a single rescuer was recorded at 5 minutes and 18 seconds. When combined with the time for a single rescuer to gain access to the aircraft using a folding ladder (12 minutes and 39 seconds), the total time was 17 minutes 57 seconds.

Table 15. Results from Firefighting Evolutions at ACY for Deploying the Interior Handline on 737 Aircraft (after ladder or stairs were in place and aircraft door open)

<table>
<thead>
<tr>
<th>Number of Rescuers</th>
<th>Ground Ladder Evolutions (average time) min:sec</th>
<th>Time Reduction with additional rescuer</th>
<th>% Time reduction with additional rescuer</th>
<th>Airstair evolutions (average time) min:sec</th>
<th>Time Reduction with additional rescuer</th>
<th>% Time reduction with additional rescuer</th>
<th>Time Reduction Air stairs vs Ladder</th>
<th>% Time reduction air stairs vs ladder</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5:18</td>
<td>--</td>
<td>--</td>
<td>4:44</td>
<td>--</td>
<td>--</td>
<td>:34</td>
<td>11%</td>
</tr>
<tr>
<td>2</td>
<td>2:31</td>
<td>2:47</td>
<td>53%</td>
<td>1:26</td>
<td>3:18</td>
<td>70%</td>
<td>1:05</td>
<td>43%</td>
</tr>
<tr>
<td>3</td>
<td>1:53</td>
<td>:38</td>
<td>25%</td>
<td>1:06</td>
<td>:20</td>
<td>23%</td>
<td>:47</td>
<td>42%</td>
</tr>
</tbody>
</table>
The results shown in Table 14 are very telling. It provides a snapshot of the benefits of having the right tools and sufficient manpower to get water quickly on a fire. Controlling or extinguishing the fire in the incipient stage directly increasing the opportunities for occupant survival.

The first horizontal row of Table 14 provides the time it takes for a single firefighter to get water on a fire in an aircraft cabin, utilizing a ladder or air stairs already in place. These times (5 mins 18 sec) over a ladder and (4 minutes 44 sec) over an air stair are an indication of the difficulty of this effort. An attack line is awkward and heavy, it is not meant to be brought into an interior fire by one person.

The second horizontal row of Table 14 shows a 53% reduction in time when adding a second rescuer to bring the handline over a ladder to initiate interior firefighting. The same column shows an additional 43% reduction in time when two rescuers bring the same handline over air stairs to initiate interior firefighting.

**Test 2A –2-Rescuer Evolution Description (B-747)**

During the 2-rescuer evolution to deploy a handline on the B-747, the handline was carried flat into the aircraft and was charged after the nozzle reached the forward galley. As mentioned previously, this was not attempted with a single rescuer. It is noted that during the 2-rescuer evolution over the 28’ ladder, the additional height of the B-747 threshold contributed to a significant increase of work, time and fatigue, as compared to the B-737. In the 2-rescuer scenario, one of the rescuers is committed to the base of the ladder. The second rescuer is doing all the lifting, stepping around the ladder, and pulling the hose into the cabin.
Table 16. Results from Firefighting Evolutions at ACY for Deploying the Interior Handline on 747 Aircraft (after ladder or stairs were in place and aircraft door open)

<table>
<thead>
<tr>
<th>Men On Team</th>
<th>Ground Ladder Evolutions (average time) min:sec</th>
<th>Time Reduction with additional rescuer</th>
<th>% Time reduction with additional rescuer</th>
<th>Airstair evolutions (average time) min:sec</th>
<th>Time Reduction with additional rescuer</th>
<th>% Time reduction with additional rescuer</th>
<th>Time Reduction air stairs vs Ladder</th>
<th>% Time reduction air stairs vs ladder</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>6:14</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>2</td>
<td>3:27</td>
<td>--</td>
<td>--</td>
<td>1:42</td>
<td>4:32</td>
<td>78%</td>
<td>1:13</td>
<td>20%</td>
</tr>
<tr>
<td>3</td>
<td>1:39</td>
<td>1:48</td>
<td>52%</td>
<td>1:02</td>
<td>0:40</td>
<td>39%</td>
<td>0:37</td>
<td>37%</td>
</tr>
</tbody>
</table>

When comparing the times from the B-737 timed trials, there is less available data, as the single rescuer events using a ladder were not recorded. There were no single member evolutions conducted over ladders.
In every timed scenario as per Table 15 on the B-747, significant reductions of time and level of effort were reduced by using air stairs as compared to ladders. The availability of air stairs in the 2-rescuer scenario and 3-rescuer scenario allowed for time reductions of 20% and 37%, respectively.

As per Table 15, using a second rescuer over an air stair to bring a handline to the mid-point of the cabin on the board the B747, allowed a time reduction of 78%, as compared to a single rescuer over the air stairs. Adding a third rescuer over the air stairs gleaned an additional improvement of 39%. These are very important numbers when considering that the core function being evaluated in this timed trial is the time to get water on an interior fire mid cabin on a B-747.

![Test 2-A](image)

In a Single Man Operation, There is No One to Feed the Hose to the First Rescuer Pulling the Hose is Exhausting. The Hose Gets Caught on Any Obstacles Present

Figure 29. One rescuer pulling the hose is exhausting

**Test 2A – 2-rescuer Evolution Description**

In preparation for Test 2A, the 28’ extension ladder was pre-positioned to the rear (aft) of the L-1 door on the B-737 and the R-4 door of the B-747. For the B-737 scenarios, the 1.75” handline was charged and positioned adjacent to the ARFF vehicle. The 2-rescuer crew each picked up a portion of the fire hose and dragged it into position for entry. The same scenario on the B-747 was used to attempt different tactics which allowed the firefighters to at least get the hose on the aircraft before it was charged. The change was primarily based on safety. The additional height of the aircraft increases the level of difficulty
of pulling / lifting the charged firehose. The weight of 50’ of 1.75” fire hose without water is approximately 24 lbs. When charged (full of water) it weighs 76 lbs. The first 50’ or so being pulled up a ladder is a dead lift as the ladder is at approximately a 65-degree angle, therefore not supporting much of the weight. Using the stairs does bear some weight, but the couplings get caught on each step. The full 200’ handline weighs over 300 lbs. The rescuer is never lifting the whole 300 lbs. but dragging a handline full of water is exhausting.

By leaving the line flat, the weight of the hose is reduced by $\frac{2}{3}$. This method does require a person at the ARFF vehicle to charge the line.

![Figure 30. Two rescuers position the hose for entry](image)

The first rescuer climbed the ladder while the second secured the ladder from the ground. Once onboard the aircraft, the rescuer on the ground fed the hose up through the door as the rescuer onboard pulled it up.
As detailed in Table 14, the average time required for 2-rescuers to bring the charged handline to the midpoint of the 737 (inside) was recorded at 2 minutes and 31 seconds. When compared to the same evolution using a single rescuer, a reduction of 2 minutes and 47 seconds or 53% was realized when using 2-rescuers.

In Test 2A, the 2-rescuer evolutions deploying a handline on the B-747 were conducted with the hose flat (not full of water) at least until there was hose in the galley of the aircraft. The first rescuer put the flat hose and nozzle over his shoulder and climbed the ladder to the B-747 R-4 door. The second rescuer footed the ladder and fed hose up to the first rescuer, reducing the amount of drag on the hose. The second rescuer could not leave the foot of the ladder until the first was safely off the ladder and had successfully stepped around the ladder, which was blocking most of the door opening. Once onboard, the second rescuer could leave the ladder to charge the fire hose. Without a third member to foot the ladder, the second rescuer was unable to join the first to commence fire attack. Unless there is another person available to operate and monitor the fire pump, the second rescuer would need to move to that position.
As detailed in Table 15, the average time required for 2-rescuers to bring the charged handline to the midpoint of the 747 was recorded at 3 minutes 27 seconds.

**Test 2A - 3-rescuer Evolution Description**

In preparation for Test 2A, the 28’ extension ladder was pre-positioned to the rear (aft) of the L-1 door on the B-737 and into the R-4 door on the B-747. The 1.75” handline was charged and positioned adjacent to the ARFF vehicle. The first man of the 3-rescuer crew picked up the nozzle and headed for the access point. The second and third rescuers each picked up a portion of the remaining hose and positioned the working length in line with the ladder.
First Man of 3 Man Team Picked Up the Nozzle and Headed to the Access Point. The 2nd and 3rd Man Picked Up the Rest Of the Working Length of Hose and Positioned It by the Access Point.

Figure 33. 3-Rescuer team position the hose by the ladder

First Arriving Rescuer Drops Nozzle and Climbs Ladder, Boarding Aircraft. Once on Board, 2nd and Third Rescuers Pass Up the Nozzle and Begin Feeding Hose.

Figure 34. 3-Rescuer team deploys the interior handline over the ladder
As seen in Table 14, the average time for the 3-rescuer evolution on the 737 was 1 minute and 53 seconds. This time does not include the earlier recorded times for positioning the ladder and opening the door to the B-737 (4 minutes 49 seconds). The total time for the 3-rescuer evolution was 6 minutes 42 seconds. This indicates a reduction in time over the 2-rescuer scenario (9 minutes 59 seconds) of 3 minutes and 17 seconds or almost 33%.

As seen in Table 15, the average time for the 3-rescuer evolution on the 747 was 1 minute and 39 seconds.

**Conclusions – Test 2A Evolutions**

Conducting this scenario with a single rescuer was only attempted on the B-737. The safety team felt confident that they could keep the rescuer safe using support staff to conduct the time trials. In two of the three 1-rescuer evolutions, the ladder tipped over as the hose dragged over it. If, in fact, the single rescuer was alone, he would not be able to exit over that ladder. Using a single rescuer to set up a ladder, unlock and secure open an aircraft door and board the aircraft with a charged handline is an unrealistic expectation. In a controlled test scenario, it was demonstrated that it is possible. In practical application, though, the rescuer would be at risk from exhaustion, diminished capacity of breathing air supply, and
then engaged in interior fire attack alone. An analysis of the time alone shows that on average, it took nearly 18 minutes for the single rescuer to be at the mid-point of the aircraft fuselage with a charged line. If the response time is added (assume 3 minutes), an elapsed time of 21 minutes is an unacceptable duration to leave occupants that are unable to self-rescue in a burning aircraft. Each rescuer was asked immediately after the evolution about their level of exhaustion after completing the scenario. They were asked to score their level of exhaustion on a 1 to 10 scale, one being not tired at all, and 10 being totally exhausted (spent). The answers from the three participants were 7, 8 and 11.

As seen in Table 14, the 2-rescuer scenario deploying the handline over the ladder reduced the times significantly in the B-737 scenario. In terms of level of exhaustion, there were also improvements. Four of the six participants reported scores of 3, two scored at 5, and one at 6. Although the hose got on the aircraft more quickly, the use of the ladder caused only one rescuer to be onboard the aircraft available to fight the fire. A firefighter is taught never to climb an unsecure ground ladder without a person supporting the ladder. The second rescuer supports the ladder for the first, and assists in feeding the hose up the ladder, and can charge the line; however, without another person to support the ladder, the second rescuer cannot climb onboard. A sole firefighter should not be assigned to fight an interior aircraft fire without back-up.

In the trials for both aircraft, the time improves when using 3 rescuers as seen in Tables 9 and 10. The three-rescuer improvement is not as significant in the 737 trials as is the improvement from one to two rescuers. The level of exhaustion for the first and second rescuer does not change significantly, while the third rescuer is obviously doing the least amount of work. The key improvement here is that the second rescuer can join in the interior firefighting, creating a 2-rescuer fire attack team. The third is available to foot the ladder for their egress and operate the fire pump. This is the safest of the three scenarios, although still falls short of the intent of OSHA’s respiratory standard 29 CFR 1910.134(g)(4) [39]. This provision requires that at least two employees enter the Immediately Dangerous to Life or Health (IDLH) atmosphere and remain in visual or voice contact with each other at all times. It also requires that at least two employees be located outside the IDLH atmosphere, thus the term "two in/two out". This assures that the "two in" can monitor each other and assist with equipment failure or entrapment or other hazards, and the "two out" can monitor those in the building, initiate rescue, or call for back-up. One of the "two out" can be assigned another role, such as incident commander.

In the current version of 14 CFR Part 139, (Revised September 21, 2010 (as amended May 3, 2003, June 4, 2004; and January 16, 2013), the FAA does not require ARFF to make entry to an aircraft for rescue or
firefighting. Firefighters operating in an Immediately Dangerous to Life and Health (IDLH) atmosphere, including those entering an aircraft for rescue or interior firefighting, are protected by the OSHA regulation, but not mandated to make entry based on FAA regulations. An analysis of the OSHA 1910.134 (two in two out) respiratory standard, as it relates to ARFF, is included in Appendix B.

**Test 2B – Evolution Description - Initiate Interior Firefighting Using Air stairs**

Timing began when each crew of 1, 2 and 3 personnel in full personal protective equipment stepped away from a pre-staged ARFF vehicle. They pulled a 1.75” handline (with bail tied closed) off the ARFF vehicle and ascended the prepositioned air stair unit. The team entered the L-1 door on the 737 and the R-4 door on the 747, proceeded to the midpoint of the aircraft and the time was stopped. There was a mark in the aircraft aisle indicating the mid-point that must be reached to satisfy this objective.

It is important to point out that the stairs were already in position and the aircraft door locked in the open position prior to these scenarios. The times recorded to bring the 1.75” charged handline are to be added to the times recorded for gaining access to the aircraft by the one, two and three rescuer teams.

**Test 2B – 1-rescuer Evolution (B-737)**

In this evolution, a single rescuer began by pulling the 200’ of 1.75” fire hose to the access stairway. His first trip brought the nozzle to the stairs, his second and/or third trip dragged the remaining charged fire hose into position. The charged hose is very awkward, and the couplings got caught on each stair. In the 3 tests run on the 737, attempts were made to bring the hose up the stairs and up over the handrail. All were eventually successful, but exhausting work for the single rescuer. The hose also got caught on each seat foundation once onboard the aircraft. Without someone to guide the hose past obstructions, the task can be overwhelming.
A single rescuer carrying a handline line up the air stairs to a B-747 is unrealistic. It is physically exhausting and leaves the single rescuer alone in the aircraft cabin to fight an interior fire. It also leaves an ARFF vehicle running with the fire pump engaged unattended. This puts the rescuer at the end of the pressurized line and the ARFF vehicle at risk. Of the three attempts made for this scenario, one was not completed, as the rescuer was exhausted and ordered to stop by the safety officers. The average time for the single rescuer to get the handline to the middle of the cabin was 9 minutes 49 seconds. This time frame is not an option that contributes to increasing survivability of survivors in an aircraft cabin with an IDLH atmosphere.

Figure 36. One Rescuer pulling hose over stairs is exhausting

Test 2B – 1 Rescuer evolution (B-747)
In the 2-rescuer evolution, the first man brought the nozzle to the stairs, closely followed by the second rescuer who was pulling the remaining hose. The first rescuer (nozzleman) went up the stairs, pulling the handline outside the railing. Upon reaching the top of the stairs, the second rescuer fed the hose over the top railing while the nozzleman pulled the hose onboard. The charged hose line stayed in a large rounded arc. It cannot be folded, so only a portion of it can be “stored” inside the aircraft entryway. The rescuer working inside began to pull the hose into the aisle and had to frequently free the hose from seat foundations. Once all the hose was up on the top of the stairs, the second rescuer moved to the top to free the hose, allowing the nozzleman to advance to the midpoint of the aircraft.
Using a second rescuer, they could work together to share the load. The average reduction in time was 5 minutes 7 seconds.

Test 2B - 3-rescuer Evolution

The first rescuer (nozzleman) took the nozzle up the stairs, then turned right and began to make his way down the aisle of the aircraft cabin. The second rescuer was about 10 feet behind, carrying the next portion of hose. When he reached the door, he fed the hose to the nozzleman, preventing the hose from getting caught in the doorway or on the seat foundations. The third man fed the remaining hose to the door outside the aircraft, freeing up the second man to enter and back up the nozzleman on the handline.

In all scenarios on both aircraft, deployment of rescue personnel and hose for interior fire attack is made faster, safer and more efficient using boarding stairs. The larger aircraft provides both advantages and disadvantages to the deployment of a handline. The most obvious difference is that there is a greater climb required to reach the cabin. The length of the B-747 is greater than the length of a pre-connected handline from an ARFF vehicle. The line needs to be long enough to stretch from the ARFF vehicle, up
the stairs (or ladder), around the corner and down the aisle to a position from which the fire can be attacked. This may include turning a corner for an attack angle into a galley or lavatory. It may need to be advanced above or below decks to fight a fire in a crew rest area. Pre-planning would choose to position air-stairs at the door that provides the greatest tactical advantage. There are several factors that may dictate that a particular door is the only one accessible to gain entry. An advantage of the larger aircraft is the larger galley area. Fire hose needs to be maneuvered into position. When it is flat, it can’t be dropped in a pile and then charged. It will get caught up in the space and be full of kinks that prevent adequate flow. When the line is charged, it becomes very stiff and tends to form an arch or circle, making it difficult to move through small places upon which it can get caught. The larger galley space provides a little bit more maneuvering space.

Figure 39. 3-rescuer team deploys the handline into the B-737 aircraft
Conclusions – Test 2B

The benefits of rapid safe access to an aircraft (via stairs) is obvious in every evolution. This additional step must be added to the scenarios being timed, establishing the times at which the teams were ready to fight an interior fire on an aircraft. This is a significant milestone because it has never been part of the FAA defined ARFF mission at certificated airports. The time trials and the information gathered during this testing combine to help gain a realistic understanding of the level of effort and difficulty in launching an interior fire attack using the responders available during the initial response period at an aircraft incident with an interior fire, prior to the arrival of substantial off-airport firefighting resources.

Unless the result of an explosion, or in the case of an intentional fire fueled by accelerants, fires begin small (incipient) fire. An incipient fire is the first stage of fire and occurs when heat, oxygen and a fuel source (fire load) are combined. During the incipient phase of a fire, it is hoped that the fire goes out or is extinguished with a fire extinguisher. If the fire is not extinguished in the incipient phase, it moves to the growth stage. The low ceiling of an aircraft cabin contributes to the risk of the potential of thermal layering in an aircraft with an interior fire that has not yet been ventilated, i.e., doors opened. The risk of
a flashover is high during this growth period, and the survival of occupants is dependent upon resolving the buildup of heat and toxic gasses before a flashover occurs.

This is important to the overall objectives of this research and the time sensitive nature of interior fire attack. The first step for rapid entry into the aircraft is to get the door open. When the door to an aircraft with an interior fire opens, the interior environment changes. This is a good thing if it is followed by steps that control the buildup of heat and include a rapid, direct attack on the fire. If the fire is ventilated by opening the door and the interior fire attack is delayed, the growth stage of the fire will be accelerated due to added oxygen entering from the opened door, and opportunities for survival of occupants are reduced.

Although the amount of time necessary to complete each step in these scenarios is important, of equal concern is the level of energy remaining with the rescuers after completing the step. If, in fact, the rescuer(s) successfully open the door and get onboard, there is a great deal of additional physical work remaining to effect rescue or interior firefighting. The restrictions of the amount of breathing air remaining in the rescuer’s SCBA is another factor.

4.5.2.1 Discussion of Aircraft Interior Access Vehicles

The Federal Aviation Administration (FAA) Aircraft Rescue & Fire Fighting (ARFF) Research Program conducted a study regarding the feasibility and demand of a new concept vehicle designated an Interior Access Vehicle (IAV) for rapid access to aircraft doorways for the ARFF industry. The primary function of this new concept, i.e., IAV, was to aid firefighters in making a safe and rapid entry into an aircraft fuselage, as well as assist in the egress of passengers, while adding a firefighting capability.

This study was conducted based upon an NTSB investigation into 46 emergency aircraft investigations that occurred between 1997 and 1999 [47]. Using the FAA’s Civil Aerospace Medical Institute evacuation simulation programs, the ARFF Research Program studied how making closed exits available again by using an IAV could improve evacuation times, once emergency passenger evacuation had begun. Results showed that, during a total evacuation, an IAV could significantly impact evacuation times, especially in double aisle aircraft.

**NFPA 414 Chapter Five: Interior Access Vehicle.**

A4.1 ADDITION: Chapter 5. An Interior Access Vehicle (IAV) must meet at least the agent requirements of CFR Part 139.317(a)

A4.2 AMENDMENT: 5.1.3

The vehicle must provide access to sill heights of between 7 feet (2.3 meters) and up to at least the lower sills of the largest aircraft operating at the airport. This sill height is sufficiently low enough to allow access to the lowest sill height aircraft currently in operation (e.g. DC9) that does not have its own integral stairs.

A4.3 ADDITION: 5.4

While on a 15 degree tilt the platform and stairs must be able to be leveled as a unit to within 5 degrees of horizontal for operational use.

A4.4 AMENDMENT: 5.4.2

The vehicle must pass a 15-degree tilt test with stairs fully extended without stabilizing equipment. However, the platform is not required to be fully loaded to the design weight capacity. Side wheel chocks may be used to prevent the vehicle from sliding on the table surface, but their height is not to exceed 5% of the tire diameter.

**NOTE:** The FAA will allow side wheel chocks to prevent an IAV from sliding on a tilt table surface with a low coefficient of friction. The FAA has accomplished some IAV testing using a tilt table which allows chocking not to exceed 5% of the vehicle’s tire diameter.

This information on IAVs is provided to create an understanding that the value of having air stairs available for ARFF is not a new concept. The FAA recognizes the benefit of Interior Access Vehicles (mobile air stairs) both for gaining access to aircraft and to assist passengers in evacuation. NFPA 414 Addition A4.1-1 (see paragraph above) requires that an IAV carry at least the agent quantities described in 14 CFR Part 139.317a. Typically, this is 500 lbs. of dry chemical. By adding this requirement, presumably the vehicle could “count as” a portion of the required ARFF response. For airports, the most difficult hurdle in adding an IAV to the response fleet is the staffing required to drive another vehicle.

**4.5.2.2 Considerations for Interior Fire Attack**

While these timed trials provided actual times to evaluate different staffing scenarios, each scenario was conducted without fire. In a confirmed fire scenario, ARFF must make rapid assessment and take immediate action in order to make an effective fire attack. Timed trials cannot take every scenario into account, but rather gather information for a baseline.
Based on the infrequency of aircraft fires, an ARFF firefighter will never develop proficiency from the sheer number of aircraft fires that they have fought. Training and research is conducted, and a tremendous amount of data is gleaned from the structural fire service. The FAA has published a number of research documents that provide excellent guidance for ARFF. The FAA ARFF research program has conducted multiple aircraft fires, both interior and exterior to evaluate agents, technology and methods.

One such research document, DOT/FAA/TC-13/12, “Aircraft Rescue and Firefighting Strategies and Tactical Considerations for New Large Aircraft”, Final Report – April 2013 [10], explores interior firefighting in Chapter 10. The report provides detailed guidance on fire attack for various interior fire scenarios on NLA. This guidance is scalable to any size aircraft and is used to develop portions of the staffing recommendations in this report.

4.5.3 Test 3 / Objective 3 - Initiate Interior Rescue Operations

This test was planned to identify the amount of time and manpower necessary to initiate interior rescue operations on a narrow body aircraft (Boeing 737), as well as a wide body aircraft (Boeing 747). The number of trials conducted was limited due to safety issues. No rescue trials were conducted on the 747 using ladders due to safety issues that were previously discussed. Only 2-rescuer and 3-rescuer trials were conducted using air stairs on the 747. Timed trials were conducted for only one 1-rescuer team and one 2-rescuer team on the 737 using ladders. Each team member wore full PPE and SCBA. Making entry over a ladder (Test 3A) and air stairs (Test 3B) were evaluated.

An interior ARFF rescue team must be capable of entering the aircraft with rescue equipment to perform extrication of trapped or incapacitated victims. Victims must be removed from hazardous atmospheres inside the aircraft to the ground where proper medical examination and treatment can be initiated. The ARFF rescue team must be equipped with tools, protective clothing and self-contained breathing apparatus.

Test 3A Evolution Description

Timing began when crews of 1, 2 and 3 personnel in full personal protective equipment stepped away from a pre-staged ARFF vehicle. They entered the aircraft using the pre-established ladder on the 737 and using the air stairs on the 737 and 747. The teams entered the aircraft and began a row by row search of the aircraft to the midpoint where a mannequin (6'1" / 165 lb.) was located, seated and belted in an
aircraft seat. The search times to the midpoint of the aircraft were recorded. Each crew extricated the mannequin through the aircraft and the times for getting the mannequin to the doorway were recorded. The mannequin was taken down the established ladder or air stairs, using the proper ladder descending techniques, including one of the team members stabilizing the ladder on the 737. The time was stopped when the mannequin reached the ground. Results are documented below in Tables 16 and 17.

Table 17. Results from Firefighting Evolutions at ACY for Rescue and Removal of Victim from 737 Aircraft

<table>
<thead>
<tr>
<th></th>
<th>Ground Ladder Evolutions (average time)</th>
<th>Air Stairs Evolutions (average time)</th>
<th>Delta time: Ground Ladder vs. Air Stairs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min:sec</td>
<td>min:sec</td>
<td>min:sec</td>
</tr>
<tr>
<td>1-Man Team</td>
<td>7:19</td>
<td>7:57</td>
<td>0:38</td>
</tr>
<tr>
<td>2-Man Team</td>
<td>10:13</td>
<td>7:39</td>
<td>2:34</td>
</tr>
<tr>
<td>3-Man Team</td>
<td>8:30</td>
<td>5:21</td>
<td>3:09</td>
</tr>
</tbody>
</table>

Table 18. Results from Firefighting Evolutions at ACY for Rescue and Removal of Victim from 747 Aircraft

<table>
<thead>
<tr>
<th></th>
<th>Ground Ladder Evolutions (average time)</th>
<th>Air Stairs Evolutions (average time)</th>
<th>Delta time: Ground Ladder vs. Air Stairs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min:sec</td>
<td>min:sec</td>
<td>min:sec</td>
</tr>
<tr>
<td>1-Man Team</td>
<td>--</td>
<td>Not completed</td>
<td>N/A</td>
</tr>
<tr>
<td>2-Man Team</td>
<td>--</td>
<td>8:04</td>
<td>N/A</td>
</tr>
<tr>
<td>3-Man Team</td>
<td>--</td>
<td>7:24</td>
<td>N/A</td>
</tr>
</tbody>
</table>

A row by row, seat by seat search of a smoke-filled cabin is extraordinarily time consuming. Search teams must have a rehearsed coordinated pattern. Every seat must be checked visually when visibility exists and by feel when operating in smoke or darkness. This includes on the seat and under the seats. Figure 41 shows a portion of the main cabin of a wide body with similar configuration to our test aircraft.
The width of the aircraft and the hundreds of seats makes search and rescue and interior firefighting from one aisle impractical. Entry teams must progress up both aisles at the same time.

Figure 41. Main cabin of wide body aircraft


The cabin of a jumbo aircraft is very long. From one end of the aircraft to the other is a long crawl when dragging hose. During that time, fire fighters must remain aware of hazards. If the entry team is conducting search and rescue, Thermal Imaging Cameras (TIC) are highly recommended. Although the straight aisles are easy to follow and maintain direction and orientation, the depth of the rows of seats, particularly the center section shown in Figure 43, make a hand search very time consuming, and perhaps beyond the capability of a single Self-Contained Breathing Apparatus (SCBA) bottle. If ventilation and other efforts have not improved visibility, a TIC in each aisle will significantly reduce the time required for a full search of the aircraft. The TIC is also helpful in finding hot spots.

Due to the depth of each row of seats a search in a smoke-filled environment is very time consuming. A search should be conducted together from both aisles between members who have communications with each other and Command, with coordinated progression clearing one row at a time. More manpower can be utilized to coordinate a faster search.
The overhead storage bins are fastened directly to structural components and are designed to carry the weight of the contents, as shown in Figure 44. A hard landing, structural damage, weight shift, introduction of additional weight from water, or exposure to fire, may affect the integrity of the mounting system. Firefighters must remain aware of this possibility on any aircraft; if the mounting system fails, the loaded overhead bin would certainly cause injury if it landed on a firefighter or occupant. Fortunately, the design of the cabin builds in a relative level of protection. The seat backs will likely absorb most of the energy of a falling overhead bin. Contents may spill out, potentially striking a firefighter or occupant; the addition of the bins and the spilled contents will complicate passage in the aircraft. Firefighters in the aisle, particularly in a crawling position, would have a fair amount of protection from a falling bin. An exception is when the compartments are over the center section seating pods in some carriers’ business class and first-class cabins.

The photos below in Figure 42, also taken from TC-13-12, provide the view of a single aisle in an aircraft cabin from the firefighters’ vantage point. The photo on the right is the same view but through the viewfinder of a Thermal Imaging Camera (TIC). During an interior fire, if no TIC is available, the view would be black.

The first photo shows the view from the firefighters position crawling through the aircraft during a search. It is a tunnel view (in good visibility) with 2 or 3 seats on one side and 5 or more seats on the other side. During a fire, the entire view gets black – 0 visibility. The photo on the right is of the same cabin viewed through a Thermal Imaging Camera (TIC). This task should not be attempted on a large aircraft with only one or two rescuers.

Figure 42. Firefighter’s view of an aircraft aisle with the naked eye vs. with a TIC
In the main cabin of the B-747-SP used for the time trials, there are two seats on the bulkhead side of the aisle and four seats in the center section. In a smokey cabin, while breathing through an SCBA, each space must be cleared by touch.

**Test 3A – 1-rescuer Evolution**

The 1-rescuer scenario rescuing a passenger over the folding ladder was attempted by only one of the 1-rescuer teams, as it was agreed that, even in a controlled test, it was extremely difficult to handle it safely. Additionally, the manufacturer’s weight limit rating for the Little Giant ladder used in the evolution was 300 pounds. Using a mannequin that weighs 165 pounds only leaves 135 pounds for a firefighter in full personal protective clothing. The safety controllers for the exercise determined that it would not be safe to overload the ladder during these evolutions.
The 2-rescuer and 3-rescuer scenarios which used a 28’ ladder to access the B-737 cabin to rescue a passenger also required modifications to plans. The ladders needed to be set up to have a safe climbing angle. Per NFPA 1932, 5.1.8.2 “An angle of inclination of between 70 to 76 degrees shall be permitted, with an angle of 75 1/2 degrees being optimum” [49]. If the ladder is set in a safe climbing angle and tip of the ladder is placed in the doorway, it forms a barrier that blocks the doorway, greatly increasing the difficulty in placing the victim on the ladder. Placing the ladder in a traditional 75-degree angle by leaning it on the fuselage aft of the door opening was attempted, however the distance from the door threshold to the ladder rungs was over two feet. One participant attempted to carry a victim on his shoulder and utilize the ladder against the fuselage but was unable to place his foot far enough away from the aircraft to reach the ladder (figure 45).
The use of the 28’ ladder in its fully retracted condition resulted in an angle of inclination of approximately 28 degrees. At this low angle, the ladder takes a form more akin to a ramp than a ladder and requires awkward body positioning to use. Also, maneuvering the victim down this ramp-like ladder was demonstrated to be very difficult and dangerous to both the rescuer and the victim (figure 46). A shorter ladder would achieve a less severe climbing angle. This equation changes with the sill height of each aircraft.
The 28’ ground ladder was not used to bodily carry a victim off the Boeing 747, as the safety controllers determined it to be an unsafe action. While not a timely process, and requiring additional high-angle rescue equipment, such as ropes, webbing, carabiners, and pulleys that are not traditionally carried by airport fire departments, the use of a Stokes basket to lower the victims down the ground ladder was found to be an effective method (figure 47). This operation required at least four personnel – three inside the aircraft and one outside – to be conducted and was highly dependent on locating suitable anchoring points inside the aircraft cabin.
Test 3A – B-747

Patient loaded in a stokes basket in the galley, strapped in and lowered by rescuers on board, Guided by one on the ground who secures the ladder and controls the tag line.

Figure 47. Removal of patient using a Stokes basket

Test 3A – B-747

Once near the ground, the patient can be transferred to a stretcher.

Figure 48. Removal of patient in a Stokes basket, final stage
Test 3B Evolution Description

The timing for each evolution began when crews of 1, 2 and 3 personnel stepped away from a pre-staged ARFF vehicle in full personal protective clothing. A trial for 1-rescuer crew was not completed on the 747 for safety reasons. Each crew entered the aircraft using the pre-established airstair unit at the L-1 door for the 737 and the R-4 door for the 747. The mannequin was prepositioned seated and belted in an aircraft seat. Each crew conducted a search down the aisle of the aircraft until arriving at the victim. The victim was removed from the seat and moved to the galley entry area, then taken down the airstair at L-1 (B-737) and R-4 (B747). The time was stopped when the mannequin reached the ground. Results were previously provided in Tables 16 and 17.

![Image of rescue and removal of a victim from a B-747](image_url)

The air stairs provide a number of advantages that can affect survival. The first benefit is the ease at which rescue personnel can board the aircraft. The second is how much easier it is to remove a patient.

Based on the results in the previous tables summarizing results of the firefighting evolutions performed at ACY, it is apparent that the use of air stairs to enter the aircraft versus using a ground ladder is the primary factor in the time needed to perform the rescue and removal of victims from a 737 aircraft. Tables 18 and 19 contain the total time required for performance of the three objectives using ground ladders and air stairs on the B-737 and the B-747.
Table 19. Results from Firefighting Evolutions at ACY for **Total Time** for Entry of 737 Aircraft, Deployment of Interior Handline and Rescue and Removal of Victim

<table>
<thead>
<tr>
<th></th>
<th>Ground Ladder Evolutions (average time) min:sec</th>
<th>Air Stairs Evolutions (average time) min:sec</th>
<th>Delta time: Ground Ladder vs. Air Stairs min:sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Man Team</td>
<td>25:16</td>
<td>15:39</td>
<td>9:37</td>
</tr>
<tr>
<td>2-Man Team</td>
<td>20:12</td>
<td>14:30</td>
<td>5:42</td>
</tr>
<tr>
<td>3-Man Team</td>
<td>15:12</td>
<td>8:09</td>
<td>7:03</td>
</tr>
</tbody>
</table>

Table 20. Results from Firefighting Evolutions at ACY for **Total Time** for Entry of 747 Aircraft, Deployment of Interior Handline and Rescue and Removal of Victim

<table>
<thead>
<tr>
<th></th>
<th>Ground Ladder Evolutions (average time) min:sec</th>
<th>Air Stairs Evolutions (average time) min:sec</th>
<th>Delta time: Ground Ladder vs. Air Stairs min:sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Man Team</td>
<td>--</td>
<td>12:30*</td>
<td>N/A</td>
</tr>
<tr>
<td>2-Man Team</td>
<td>3:27**</td>
<td>15:27</td>
<td>N/A</td>
</tr>
<tr>
<td>3-Man Team</td>
<td>1:39**</td>
<td>12:59</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*Rescue trial not completed

**Time only reflects trial for deployment of handline, as no trials conducted for interior access or rescue

5. **Summary**

Extensive research was conducted by the Task Group committee to develop a response to the third of four recommendations directed to the Aircraft Rescue Fire Fighting Working Group (ARFFWG) as part of the National Transportation Safety Board’s (NTSB) letter, dated July 16, 2014 [1]. The letter contained specific recommendations from the accident involving a Boeing 777-200ER, Korean registration HL7742, operating as Asiana Airlines flight 214, that occurred on July 6, 2013, at San Francisco International Airport, San Francisco, California. The NTSB’s investigation of the accident was documented in Accident Report NTSB/AAR-14/01 [2]. The third recommendation deals with the development of “a minimum aircraft rescue and firefighting staffing level that would allow exterior firefighting and rapid entry into an airplane to perform interior firefighting and rescue of passengers and crewmembers” [1].

The Task Group conducted an exhaustive literature review, developed and conducted timed scenarios and reviewed all the video, still photos, observations and recorded data to answer the questions posed by the NTSB. The timed scenarios documented in this report draw certain conclusions regarding the minimum
staffing required to conduct the individual tasks necessary to continue exterior firefighting, and perform rapid entry, perform interior firefighting, and rescue of passengers and crewmembers.

Not to be overlooked in this NTSB task is the fact that the execution of the required steps to gain entry, perform interior firefighting and rescue are to be achieved while continuing exterior firefighting operations. This is true 100% of the time. The ARFF vehicles are positioned to fight the fire and protect exit routes, as well as rescue personnel operating under and around the aircraft. The operators of these vehicles should never leave the cab, as the protection of that ARFF vehicle will cease to exist if they do. If the agent carried by the ARFF vehicle is depleted before the scene is made safe, it should be re-serviced. Ideally this can be accomplished on site to reduce the risk of moving the ARFF vehicles unnecessarily in the area where passengers and crew may be evacuating. Either way, that vehicle operator is committed to the vehicle. This is an important consideration in the staffing discussion.

As per 14 CFR Part 139.303 Personnel:

(a) Provide sufficient and qualified personnel to comply with the requirements of the Airport Certification Manual and the requirements of this part.

The current regulation does not specify any minimum staffing, nor does it require any ability to gain rapid access to an aircraft, interior firefighting or rescue capability. The interpretation by many airports is that the regulation requires the airport to provide the number of trained and qualified personnel required to drive the number of vehicles required (based on the Index) to the mid-point of the furthest runway within the response times described in 14 CFR Part 139.319. Based on this interpretation, “sufficient and qualified staffing” becomes synonymous with minimum staffing or required staffing. Any increase in requirements by the FAA, including increased quantities of agent, number of required vehicles, types of vehicles, or tasks, such as interior access, interior firefighting or rescue, requires a defined minimum staffing number in addition to the implied minimum of one per vehicle.

Agent Quantities

Current minimum quantities of water required by 14 CFR Part 139.317 do not provide an allowance of agent for interior firefighting. There are three different recognized sources for minimum agent quantities for ARFF, i.e. the International Civil Aviation Organization (ICAO), the FAA, and the National Fire Protection Association.
**Number of ARFF Vehicles**

The amount of water carried is usually directly related to the number of chassis (ARFF vehicles) carrying the water. There are a number of considerations relative to whether the vehicles should carry larger quantities of agent, or if there should be more vehicles responding. From a tactical standpoint, it is best not to “put all of your eggs in one basket”. Adding a larger capacity vehicle to the response is never a bad idea, unless the loss of that vehicle due to mechanical or damage can be substituted with additional apparatus.

Initial actions at an aircraft incident include size up and set up. ARFF vehicles are positioned strategically around the aircraft to provide optimum field of view, fire attack positions, and access for evacuation and rescue. If only one ARFF vehicle is on the scene, that vehicle can only see one aspect of the aircraft at a time. Additional trucks not only increase agent availability but add tactical options for firefighting and rescue. 14 CFR Part 139.317 requires the following minimum number of vehicles by Index. Where an option is provided for “1 or 2” or “2 or 3”, it is because all Certificated Airports are required to carry complementary agent in addition to water and commensurate quantities of foam. Index B and C airports have options that allow them to carry the complementary agent on a separate vehicle or carry it on one of the vehicles carrying the required water and foam.

<table>
<thead>
<tr>
<th>Index</th>
<th>Gallons Required by FAA</th>
<th>Minimum # of Vehicles Required by FAA</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA-1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>GA-2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>A</td>
<td>100</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>1500</td>
<td>1 or 2</td>
</tr>
<tr>
<td>C</td>
<td>3000</td>
<td>2 or 3</td>
</tr>
<tr>
<td>D</td>
<td>4000</td>
<td>3</td>
</tr>
<tr>
<td>E</td>
<td>6000</td>
<td>3</td>
</tr>
</tbody>
</table>

### 6. TASK GROUP CONCLUSIONS

The Task Group’s responses to the NTSB recommendations are discussed below.

**Recommendation:**

(A-14-60) Develop a minimum aircraft rescue and firefighting staffing level that would allow exterior firefighting and rapid entry into an airplane to perform interior firefighting and rescue of passengers and crewmembers” [1].
Breakdown of Recommendation:

a) Develop a minimum aircraft rescue and firefighting staffing level that would allow exterior firefighting…

b) … and rapid entry into an airplane to perform interior firefighting

c) …and rescue of passengers and crewmembers.

In each of these response stages, the operative word remains “minimum”. Airports will always need to adjust staffing levels based on their unique operations. A Hazard Risk Analysis should be conducted at each airport. A full description of how to conduct a Hazard Analysis is found in AC 150/5200-31C, “Airport Emergency Plan”, Chapter 3-4(b) “Conduct a Hazard Risk Analysis” and Appendix A of that AC includes “General Procedures for Hazard Analysis”. A formal risk assessment is also called for in FAA AC 150/5200-37, “Introduction to Safety Management Systems (SMS)”, Chapter 3, “Safety Risk Management”.

The guidance from this Task Group is that, in addition to providing the minimum staffing identified by this research, a hazard risk analysis should be performed to determine any additional staffing needs at each airport to satisfy these objectives.

a. To determine the minimum staffing level required for exterior firefighting, one must first determine the quantity of agent and ARFF vehicles required for each Index. The current FAA Advisory Circular 150/5210-6D, “Aircraft Fire Extinguishing Systems” serves as guidance for reference material covering aircraft firefighting agent. In this AC Section 3, “Application”, the guidance is not mandatory and does not constitute a regulation. It also states clearly that if the AC conflicts with Title 14 CFR Part 139, Part 139 takes precedence. With that said, this Task Group agrees with and recommends compliance with current FAA AC 150/5210-6D [14]. In Chapter 1, Background, the following is stated:

1.2 Definitions – The following definitions do not include numerical quantities. These can be found in NFPA 403, Table 5.3.1 (b), as well as additional agents to be carried.

Table 5.3.1 (b) from NFPA 403 can be found in Appendix D.

The following table is provided as a simplified version of Table 5.3.1 (b), showing the FAA Indexes relative to NFPA Categories.
Table 22. Simplified Version of NFPA 403 Guidance for Water, Agent, and Number of Trucks per Index/Category

<table>
<thead>
<tr>
<th>Category</th>
<th>Index</th>
<th>Water US Gallons includes Q1, Q2 and Q3*</th>
<th>Complementary Agent</th>
<th>Minimum Number of Trucks</th>
<th>Example Aircraft</th>
<th>Aircraft Length up to, but not including (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GA-1</td>
<td>120</td>
<td>100</td>
<td>1</td>
<td>Cessna 206</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>GA-1</td>
<td>200</td>
<td>200</td>
<td>1</td>
<td>Cessna 414</td>
<td>39</td>
</tr>
<tr>
<td>3</td>
<td>GA-2</td>
<td>670</td>
<td>300</td>
<td>1</td>
<td>Beech 1900</td>
<td>59</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>1340</td>
<td>300</td>
<td>2</td>
<td>DHC-8-100</td>
<td>78</td>
</tr>
<tr>
<td>5</td>
<td>A</td>
<td>2760</td>
<td>450</td>
<td>2</td>
<td>ATR-72</td>
<td>90</td>
</tr>
<tr>
<td>6</td>
<td>B</td>
<td>3740</td>
<td>450</td>
<td>2</td>
<td>B-737-300,</td>
<td>126</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>E145</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>C</td>
<td>4880</td>
<td>450</td>
<td>3</td>
<td>B757</td>
<td>160</td>
</tr>
<tr>
<td>8</td>
<td>D</td>
<td>7780</td>
<td>900</td>
<td>3</td>
<td>A300,</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>B-767-300</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>E</td>
<td>9570</td>
<td>900</td>
<td>4</td>
<td>B-747-200</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A-340-400</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>14260</td>
<td>900</td>
<td>4</td>
<td>A-380</td>
<td>295</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>B-747-8</td>
<td></td>
</tr>
</tbody>
</table>

*Quantity Q1. The quantity required to obtain a 1-minute control time of the fire.
Quantity Q2. The quantity required for continued control of the fire after the first minute or for complete extinguishment of the fire or both.
Quantity Q3. The quantity required for interior firefighting

All of this information is provided to justify the answer to the first portion of NTSB A-14-60.

a) Develop a minimum aircraft rescue and firefighting staffing level that would allow exterior firefighting…

The minimum staffing required to allow exterior firefighting is one person committed to each vehicle. These dedicated driver operators should not leave the discharge controls while the vehicle still has agent. If the vehicle runs out of agent before the event has been terminated, they should be involved in servicing the vehicle with agent so that it can continue to fight the fire or protect the scene, while others are working on the ground or on board the aircraft. The NFPA Categories match up with Index B, C and D based on aircraft length. Indexes A and E, however, do not. 14 CFR Part 139.315, Index Determination identifies Index A to include aircraft less than 90’ in length. Based on the additional length of the aircraft (12’) between Category 4 and Category 5, both NFPA and ICAO call for an additional ARFF vehicle, and 1,420 gallons for Category 5. This includes water for interior firefighting. 139.315 identifies Index E to include aircraft at least 200’ in length. Both NFPA and ICAO identify Category 10 to include aircraft 250’ to 295 feet and increase the quantity of agent to 14,260 gallons for
airports with A380 operations. This quantity takes into consideration not only the additional length of the aircraft, but also quantities for interior firefighting.

b) ... and rapid entry into an airplane to perform interior firefighting

The key word in this portion of the NTSB recommendation (A-14-60) is “rapid”. Time is of the essence when boarding an aircraft involved in a crash or fire that has occupants aboard that are unable to self-evacuate. For aircraft that do not have boarding stairs, a rapid entry is dependent upon having air stairs or an Interior Access Vehicle (IAV) as part of the ARFF response. The recommendation of this Task Group is that all Index B, C, D and E airports be required to have an interior access vehicle that has sufficient reach to gain rapid entry to all aircraft with scheduled service at the airport. The minimum staffing for this vehicle is one person, whose initial job is to respond to the scene, position the vehicle, and, when appropriate, raise the stairs to the designated door. This person can then assume other duties, including interior fire attack or rescue.

Initial interior fire attack requires at least two firefighters on a handline per aisle. As the scene populates, additional lines should be staffed to serve as a RIT (Rapid Intervention Team) as described in OSHA 1910.134. The IAV driver / operator can join the interior firefighting team after donning full PPE / SCBA. The IAV driver / operator will not be ready to enter as fast as the initial entry team, because he/she cannot drive the IAV in full PPE.

The recommendation of this Task Group is to increase the agent quantities and number of ARFF vehicles at Index A airports to align with Category 5 (NFPA and ICAO). That would require a minimum of 2 vehicles and 2760 gallons of water for foam production at Index A airports. The minimum staffing would have to allow for the operation of 2 ARFF vehicles.

c) ... and rescue of passengers and crewmembers

As seen in the timed trials, rescue and removal of aircraft occupants are time consuming and exhausting. No fewer than two firefighters should be assigned to a single rescue. As with interior firefighting, interior search and rescue needs to be launched in each aisle. If interior fire attack and rescue are simultaneous, as was in the Asiana incident, the fire attack crew will lead.

For Index A airports, the size of the aircraft does not allow for an interior search team, nor does the size of the aircraft warrant it. An assessment can be made from the exterior, but if there are occupants trapped in the aircraft and fire is present, a minimum of two firefighters is necessary to attack the interior fire and
make rescue. This is in addition to at least one vehicle remaining staffed to commence or continue exterior firefighting.

The following table identifies recommended minimum staffing per Index to maintain exterior firefighting, while initiating interior firefighting and search and rescue of passengers and crew. The number of personnel listed in column 6 is the same as the minimum number of ARFF vehicles (column 5). This is not meant to imply that a crew of one is sufficient staffing for an ARFF vehicle. The personnel listed in columns nine and ten (in most cases) will arrive at the scene on the ARFF vehicles. This staffing is on board the ARFF vehicle(s) during the response to assist with communications, guidance around debris, and turret and HRET operations. After the initial exterior firefighting period when the fire is “controlled” or extinguished, staffing not committed to vehicle or turret operations may be deployed for interior firefighting or rescue (as indicated in columns eight, nine and ten). A minimum of one person must remain on each ARFF vehicle to continue exterior firefighting.

It is further recommended that Index F be created for the airports operating multi-deck passenger aircraft or aircraft 250’ to 295’ in length to carry sufficient quantities of water for interior firefighting. The Task Group also recommends that each interior entry team be equipped with a Thermal Imaging Camera (TIC) to assist in search and rescue.

Table 23. Recommendations for Water, Agent, Number of Vehicles and Staffing per Index / Category

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<td>Water US Gallons includes Q1, Q2 and Q3*</td>
<td>Comp. Agent</td>
<td>Minimum Number of ARFF Vehicles</td>
<td>Minimum Staffing for Exterior firefighting (turrets)</td>
<td>IAV</td>
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ARFFWG RESPONSE TO NTSB A-14-60  FINAL REPORT – May 20, 2018

*Quantity Q1. The quantity required to obtain a 1-minute control time of the fire.
Quantity Q2. The quantity required for continued control of the fire after the first minute or for complete extinguishment of the fire or both.
Quantity Q3. The quantity required for interior firefighting

7. SUPPORTING ORGANIZATIONS AND INDIVIDUALS

The ARFF Working Group is grateful for the participation and support of the following individuals and organizations who contributed their knowledge time and energy to this project.

<table>
<thead>
<tr>
<th>Role</th>
<th>Organization</th>
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<td>SRA International</td>
<td>Jonathan Torres</td>
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8. **REFERENCES**


3. Title 14 Code of Federal Regulations Part 139, Certification of Airports


15. NTSB AAR-01/02, Runway Overrun During Landing, American Airlines Flight 1420, McDonnel Douglas MD-82, N215AA, Little Rock, Arkansas, June 1, 1999


47. National Transportation Safety Board. (June 2000). NTSB/SS/00/01 Safety Study: Emergency Evacuation of Commercial Airplanes


APPENDIX A

Advisory Circular 150-5210-8

Aircraft Firefighting and Rescue Personnel Clothing
SUBJECT: AIRCRAFT FIREFIGHTING AND RESCUE PERSONNEL AND PERSONNEL CLOTHING

1. PURPOSE. This circular provides guidance concerning the meaning of aircraft fire and rescue trucks, the physical qualifications that personnel assigned to these trucks should meet, and the protective clothing with which they should be equipped.

2. REFERENCE. AC 150/5210-6, Aircraft Fire and Rescue Facilities and Extinguishing Agents, establishes a system for indexing airports and lists the extinguishing agent and equipment recommendations for the various indexes.

3. GENERAL. As the majority of aircraft fire and rescue trucks presently in service on airports have been built to individual specifications, it is not possible to recommend the exact number of firefighters that should be assigned. Accordingly, this subject is discussed in generalities taking the factors of truck design and the aeronautical operations experienced by an airport into consideration.

4. FIREFIGHTER RECOMMENDATIONS.
   a. Listed below, by type of equipment, is the recommended number of firefighters per tour of duty necessary to obtain the desired potential from each type of truck:

   (1) Light-Weight Aircraft Fire and Rescue Truck (2 Firefighters). This truck, carrying a dry chemical extinguishing agent, will provide, in a single unit, the fire suppression potential recommended for Index III airports. It may also be used as a rescue unit on Index V through Index VIII airports equipped with the 1000 or 1500-gallon water/foam truck(s). When so used, it is normally the first truck to arrive at the scene of an emergency; and, where practicable, its extinguishing agent may be used to control or contain a fire until the arrival of the water/foam trucks. Subsequent to the arrival of these larger trucks, the men assigned to this truck function as the rescue men. Experience has demonstrated the need for rescue men to work in pairs.
(2) Combination Foam and Dry Chemical Aircraft Fire and Rescue Truck (2 Firefighters). This truck, carrying both dry chemical and water/foam, will provide, in a single unit, the fire suppression potential recommended for Index IV airports used primarily by general aviation type aircraft grossing over 12,500 pounds. It may also be considered an acceptable substitute for the light-weight aircraft fire and rescue truck at Index V through Index VII airports.

(3) Water/Foam Truck (2 Firefighters Each). These trucks, carrying 1000 or 1500 gallons of water for foam and 200 or 300 gallons of foam concentrate, are capable of discharging the water/foam carried at the rate of from 500 to 800 GPM respectively through a single turret remotely controlled from within the cab and 60 GPM from each of two handlines. Should this turret be manually operated from the cab roof, an additional man is required.

(4) Water Tank Trucks (2 Firefighters Each). These trucks, carrying 1000 or 2000 gallons of water, provide an additional supply of water to the water/foam truck.

b. The total number of full-time firefighters per tour of duty recommended for airports in the eight Indexes defined in AC 150/5210-6, Aircraft Fire and Rescue Facilities and Extinguishing Agents, is indicated below:

(1) **Index I.**

   No fire suppression or rescue capability.

   **None**

(2) **Index II.**

   Portable fire extinguishers.

   This man monitors and services an airport’s fire extinguishers and trains airport employees and tenants in their use.

   1 - Firefighter

(3) **Index III.**

   One light-weight truck.

   2 - Firefighters

(4) **Index IV.**

   One combination truck.

   2 - Firefighters
(5) Index V.

One combination truck.  2 - Firefighters
One 1000-gallon water/foam truck.  3 - Firefighters
Total 5 - Firefighters

(6) Index VI.

One light-weight or one combination truck.  2 - Firefighters
One 1000-gallon water/foam truck.  3 - Firefighters
One 1000-gallon water tank truck.  2 - Firefighters
Total 10 - Firefighters

(7) Index VII.

One light-weight or one combination truck.  2 - Firefighters
One 1000-gallon water/foam truck.  3 - Firefighters
One 1500-gallon water/foam truck.  3 - Firefighters
One 2000-gallon water tank truck.  2 - Firefighters
Total 10 - Firefighters

(8) Index VIII.

One light-weight or one combination truck.  2 - Firefighters
One 1500-gallon water/foam truck.  3 - Firefighters
One 1500-gallon water/foam truck.  3 - Firefighters
One 2000-gallon water tank truck.  2 - Firefighters
One 2000-gallon water tank truck.  2 - Firefighters
Total 12 - Firefighters

c. In addition to the number of full-time firefighters shown above, airports falling in Index V and above should provide a minimum of one supervisor (chief).

d. The use of volunteer firefighters may be necessary at many airports. It is recommended that the following guidelines be employed in the use of volunteer firefighters:
(1) These personnel are well organized, trained, and provided with suitable transportation so they may become an integral part of an effective firefighting "team".

(2) When volunteers are to be substituted for full-time firefighters, two volunteers will be considered the equivalent of each full-time firefighter they replace.

(3) At airports in Indexes V through VIII, not less than 50 percent of the total number of personnel assigned should be full-time firefighters, and the remainder may be volunteers in the ratio described in 4d(2).

(4) A suitable audible alarm is provided to alert the volunteers. Controls to actuate this alarm should be installed in the control tower, the fire station, or fixed stations strategically located on the airport.

5. PHYSICAL REQUIREMENTS.
   a. Firefighter duties require arduous physical exertion under rigorous and unusual conditions. The firefighters will be subjected to extreme physical danger and to irregular and protracted hours of work. Care should be exercised to assure that firefighters do not have physical defects which would cause the firefighter to be a hazard to himself or to others or which would prevent proficient performance of his duties. Accordingly, a firefighter should be subjected to a thorough medical examination prior to employment, biennial physical examinations until the age of 40, and annual examinations thereafter. In the absence of suitable city or state physical standards, those contained in the Federal Civil Service Qualification Standards (Firefighting and Fire Prevention Series, GS-081, paragraph B, General; Crash; Crash-Structural) should be used as a guide.

   b. While volunteers need not be subjected to such strict physical requirements, these requirements should be used as a guide in their selection.

6. PROTECTIVE CLOTHING. Firefighters should be provided with a complete set of protective clothing. A complete set normally includes:
   a. Bunker Suit. This suit should include heat insulative interliners for coat and trousers to afford full arm, body, and leg protection; the outer garments should be treated for water repellency and flame resistance.

   b. Gloves. These gloves should be woolen and of sufficient length to provide wrist protection. Soft, pliable leather shields to fit over these gloves should be supplied to provide additional protection to the wearer.
APPENDIX B

RELEVANCE OF OSHA 1910.134 TO PART 139

OSHA 1910.134 - 2 in 2 out

NTSB recommendation A-14-60 issued subsequent to the crash of Asiana Airlines B-777ER on July 6, 2013 states:

“Develop a minimum aircraft rescue and firefighting staffing level that would allow exterior firefighting and rapid entry into an airplane to perform interior firefighting of passengers and crewmembers.”

To develop a minimum staffing level for a mission that includes interior firefighting, the OSHA Respiratory Standard 1910.134 must be a consideration. It should also be clear that there is a great deal more information in OSHA 1910.134 than the words “two in – two out”. OSHA is often asked to provide clarifications on interpretations as they relate to specific cases. These interpretations are all published on the OSHA website. A sampling is provided in this Appendix, highlighting points relevant to interior aircraft firefighting as it relates to staffing.

The first point often raised in a discussion of the relevance of “two in – two out”, the argument that an aircraft is not a structure. Those making the point believe that because the word structure or interior structure is included, the federal law is designed for structural firefighters.

For the purpose of this discussion, the definition of a structure is taken from OSHA 1910.155(c)(15). "Enclosed structure" means a structure with a roof or ceiling and at least two walls which may present fire hazards to employees, such as accumulations of smoke, toxic gases and heat, similar to those found in buildings. An aircraft meets the OSHA definition for an enclosed structure. Currently, 14 CFR Part 139 does not require ARFF to conduct interior firefighting, therefore, the portion of the OSHA 1910.134 respiratory protection standard known as “two in – two out” is not currently relevant to the requirements of 14 CFR Part 139. All other portions of OSHA 1910.134 are applicable to ARFF, and the “two in - two out” provision is applicable to ARFF if they perform interior firefighting, even though interior firefighting it is not specifically required by the FAA.

Another point commonly made is that OSHA 1910.134 is an OSHA requirement. There are 25 states that consider themselves non-OSHA states. Those states have chosen to develop their own laws to protect workers from hazards associated with their occupations. They can choose to provide their own enforcement, as well. What needs to be pointed out is that federal law requires these states to provide a
comparable standard within six months of the enactment of an OSHA standard, which is approved by OSHA. The state standard must be “at least as effective” as the federal standard.

Therefore, the protection for workers provided by OSHA standards, including OSHA 1910.134, provide workers with at least the amount of protection offered by the federal standard, whether it is implemented by the state and approved by OSHA, or implemented and enforced by OSHA themselves. The following clarification of this point (below) is from the Federal Register [59 FR 16334, April 6, 1994].

**VII. State Plan States**
The 25 States and territories with their own OSHA approved occupational safety and health plans must develop a comparable standard applicable to both the private and public (state and local government employees) sectors within six months of the publication date of a permanent final Federal rule or show OSHA why there is no need for action, e.g., because an existing state standard covering this area is already "at least as effective as" the new Federal standard. These States and territories are Alaska, Arizona, California, Connecticut (plan covers only State and local government employees), Hawaii, Indiana, Iowa, Kentucky, Maryland, Michigan, Minnesota, Nevada, New Mexico, New York (plan covers only State and local government employees), North Carolina, Puerto Rico, South Carolina, Oregon, Tennessee, Utah, Vermont, Virginia, Virgin Islands, Washington and Wyoming.

After the effective date of the Federal final rule, until such time as a State standard is promulgated, Federal OSHA will provide interim enforcement assistance, as appropriate, in these States. [59 FR 16334, April 6, 1994]

**OSHA 1910-34 Interpretations**
The following letters of interpretation are published on the OSHA website. Key points made in these examples have been highlighted. All interpretations of 1910.134 published by OSHA can be found on the following web site.


**November 13, 1998**

*Mark Schultz, GFD*

*Senior Fire Inspector*

*Gallatin Fire Department*
Dear Mr. Schultz:

This is in response to your letter of April 30, addressed to Mr. John B. Miles asking for interpretations of the new Respiratory Protection Standard, 29 CFR 1910.134. You had specific questions regarding the Occupational Safety and Health Administration's (OSHA's) two in/two out requirement. We apologize for the long delay of this response. As you may be aware, Federal OSHA does not have jurisdiction over employees of State and local governments, including firefighters. However, the State of Tennessee does cover public sector employees under its OSHA-approved occupational safety and health State plan. Tennessee has adopted a standard identical to the Federal respiratory protection standard. While the State may interpret its standard differently from Federal OSHA, the interpretations must be at least as effective as the Federal interpretations. You may wish to contact the Tennessee Department of Labor concerning its enforcement of the respiratory protection standard. The address is:

Michael E. Magill, Commissioner
Tennessee Department of Labor
710 James Robertson Parkway
Nashville, Tennessee 37243-5078

Telephone: (615) 741-2582

We are providing Commissioner Magill with a copy of this letter.

You had several questions asking if the two in/two out rule for interior structural fire fighting was a one for one policy, specifically if four people were in did that mean that four people had to stand by, if eleven people were inside, did that mean eleven people had to be on stand by and so on. No, the two in/two out rule may not be interpreted as four in/four out, eight in/eight out. There must always be at least two firefighters stationed outside during interior structural firefighting, prepared to enter if necessary to rescue the firefighters inside. However, the incident commander has the flexibility to determine whether more than two outside firefighters are necessary when more than two firefighters go inside. In a situation where the burning structure is very large, additional outside firefighters may be warranted to ensure effective assistance and rescue. For example, where the firefighting involves entry from different locations or levels, two outside fire fighters may have to be stationed at each point of entry.
You also asked whether standby personnel had to wait for additional standby personnel before entering to attempt a rescue of fire fighters in a structural fire. No. There is an explicit exemption in the Respiratory Protection Standard that if life is in jeopardy, the two-in/two out requirement is waived. The incident commander and the firefighters at the scene must decide whether the risks posed by entering an interior structural fire prior to the assembly of at least four firefighters is outweighed by the need to rescue victims who are at risk of death or serious physical harm. There is no violation of the standard under rescue circumstances.

Please note that on August 3, 1998, OSHA published Questions and Answers on the Respiratory Protection Standard. This 79-page document contains guidance on respiratory protection. There are many questions in this document on respiratory protection and firefighting issues and may help you develop a thorough respiratory protection program. In addition, OSHA has recently published the Compliance Directive, CPL 2-0.120, an inspection procedure document for the OSHA field offices, and the Small Entity Compliance Guide to assist small employers in complying with the respiratory standard. All these documents can be found on the Internet at the OSHA Home Page at http://www.osha.gov.

Should you require any additional information on this matter, please, feel free to contact our Office of Health Compliance Assistance at (202) 693-2190.

Sincerely,

Richard E. Fairfax
Acting Director
Directorate of Compliance Programs

December 15, 1998

The Honorable Jeff Bingaman
United States Senator
105 West Third St, Suite 409
Roswell, NM 88201
Dear Senator Bingaman:

This is in response to your letter dated August 4, addressed to Mr. Craig Obey, Director of the Occupational Safety and Health Administration's (OSHA's) Office of Intra-Governmental Affairs, concerning our "two-in/two-out" policy. In particular, you have asked if this requirement can be waived for smaller communities. Please accept my apology for the delay in response.

The "two-in/two-out" policy is part of paragraph (g)(4) of OSHA's 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. The extension of this standard to volunteer fire fighters is a matter decided by each State and is often dependent on whether volunteers are considered "employees" under State law.

The respiratory protection standard requires that workers engaged in fighting interior structural fires work in a buddy system; at least two workers must enter the building together, so that they can monitor each other's whereabouts as well as the work environment. There must also be at least two standby personnel outside the fire area prepared to rescue the inside firefighters should the need arise. One of these outside firefighters must actively monitor the status of the inside fighters but the second outside firefighter may perform a variety of other duties, such as pump operations, incident commander or outside hose line operation. There are no provisions in the standard to waive the requirements for either the "two-inside firefighters" or the "two-outside firefighters", although the circumstances under which this provision applies are more limited than generally understood.

The standard does not require the "two-in/two-out" provision if the fire is still in the incipient stage and it does not prohibit firefighters from fighting the fire from outside before sufficient personnel have arrived. It also does not prohibit firefighters from entering a burning structure to perform rescue operations when there is a reasonable belief that victims may be inside. It is only when firefighters are engaged in the interior attack of an interior structural firefighting that the "two-in/two-out" requirement applies. It is the incident commander's responsibility to judge whether a fire is an interior structural fire and how it will be attacked.

The New Mexico Environment Department operates its own occupational safety and health program under a plan approved and closely monitored by federal OSHA. Their program is primarily responsible
for enforcement of the OSHA Respiratory Protection Standard in New Mexico. The State of New Mexico has adopted a revised Respiratory Protection standard which is identical to the Federal standard. New Mexico also has a separate public sector firefighter standard which addresses a number of issues but also incorporates the provisions of the revised Respiratory Protection standard - including the "two-in/two-out" provision. However, New Mexico's public sector standard does not apply to volunteers. While OSHA believes that the protections afforded by the Respiratory Protection standard are reasonable and that volunteers should not face unnecessary risks, it is up to the State to decide whether to extend its enforcement jurisdiction to volunteer firefighters. If you have further questions on New Mexico's enforcement policies, you may contact:

Peter Maggiore, Secretary
New Mexico Environment Department
1190 St. Francis Drive
Santa Fe, NM 87502
(505) 827-2850

Thank you for your interest in occupational safety and health.

Sincerely,

Charles N. Jeffress
Assistant Secretary

cc: Washington, DC Office

March 12, 1999

The Honorable Rodney P. Frelinghuysen
Member, United States
House of Representatives
1 Morris Street
Morristown, NJ 07960

Dear Congressman Frelinghuysen:

This is in response to your letter dated December 11, 1998, which was sent to Craig Obey in the Office of Intra-Governmental Affairs (OIGA) of the Occupational Safety and Health Administration (OSHA). Your
letter forwarded a telefax you had received from Mr. Joel Weingarten, an Assemblyman in Livingston, New Jersey. Mr. Weingarten expressed concern with the "new" OSHA regulation that requires firefighters to follow a "two-in/two-out policy" and a newspaper article that concluded that now all fire departments would need six firefighters on duty at all times.

Mr. Weingarten is referring to paragraph (g)(4) of the revised Respiratory Protection standard, 29 CFR 1910.134, which was published in the Federal Register on January 8, 1998. The "two-in, two-out" requirement adopted by this standard is and has been standard practice in the firefighting community for many years, and reflects only the number of firefighters who must be on the scene prior to initiating the interior attack on an interior structural fire. "Two-in, two-out" is strongly supported by an analysis of information from the International Association of Fire Fighters (IAFF), the National Fire Protection Association (NFPA), and existing OSHA standards and interpretations. OSHA's respiratory protection standard codifies recommended practice. It does not require fire departments to hire additional firefighters; it does not require four-person fire companies; it does not require four persons on a fire truck. Most fire departments have more than four firefighters and can assemble the numbers required on the scene by waiting for others to arrive. During this time the fire may be attacked from the outside, sizing-up operations may occur, and emergency rescue necessary to save lives may take place. Additional staff can be assembled by such means as calling for a second fire company at the scene, calling in additional firefighters who are on standby, and calling on other nearby fire departments when necessary.

It is anticipated that small fire departments may rely on "mutual aid" agreements with neighboring jurisdictions to supply additional firefighters to assist with interior structural firefighting, if that is necessary to ensure compliance with "two-in, two-out." The intent of the "two-in, two-out" rule is a worker safety practice requirement, not a staffing requirement.

This OSHA standard - and all other Federal OSHA standards - only apply to public and municipal workers such as firefighters in States which operate their own occupational safety and health program under an OSHA-approved State Plan. Any State with an approved State plan must have standards which are "at least as effective as" the Federal standards and must extend their coverage to State and local government employees. Although New Jersey does not currently have an OSHA-approved State Plan, the State is seeking approval for such a program limited in scope to public employees only. OSHA's FY 2000 budget as proposed by President Clinton includes $1,735,000 in 50% grant funding for such a program. In the meantime, on its own initiative, the New Jersey Department of Labor is providing protection to State and local workers, which would presumably include firefighters, under State law. (Since OSHA has no jurisdiction over this group of workers, any State is free to undertake its own program with or without
an OSHA-approved State Plan.) You may want to contact the New Jersey Department of Labor at the following address for more specific information on their current requirements for firefighters:

Len Katz, Assistant Commissioner
New Jersey Department of Labor
Labor Standards and Safety Enforcement
CN 054
Trenton, New Jersey 08652-0054

We hope this has been responsive to your concerns and those of your constituent. If you have any further questions, please feel free to call OSHA's Office of Health Compliance Assistance at (202) 693-2190.

Sincerely,

Charles N. Jeffress
Assistant Secretary

February 29, 2012

Captain Max Anthouard
City of Ypsilanti Fire Department
525 West Michigan Avenue
Ypsilanti, Michigan 48197

Dear Captain Anthouard:

Thank you for your September 17, 2010, letter to the Occupational Safety and Health Administration's (OSHA's) Directorate of Enforcement Programs. We apologize for the delay in our reply. This letter constitutes OSHA's interpretation only of the requirements discussed and may not be applicable to any scenario or questions not delineated within your original correspondence. You had a specific question regarding our "two-in/two-out" policy. Our response to your paraphrased question is provided below.

**Question:** Paragraph (g)(4) of OSHA's Respiratory Protection Standard, 29 Code of Federal Regulations 1910.134, notes one of the two individuals located outside the Immediately Dangerous to Life or Health (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. What other task can the second individual perform?

Response: The safety of firefighters engaged in interior structural firefighting is the major focus of paragraph (g)(4). As stated in your letter, this provision requires that at least two employees enter the IDLH atmosphere and remain in visual or voice contact with each other at all times. It also requires that at least two employees be located outside the IDLH atmosphere. As you are aware, this assures that the "two in" can monitor each other and assist with equipment failure or entrapment or other hazards, and the "two out" can monitor those in the building, initiate rescue, or call for assistance.

One of these outside firefighters must actively monitor the status of the inside firefighters and may not be assigned additional duties. The second outside firefighter may perform a variety of other duties, but those other duties are not allowed to interfere with the member's ability to provide assistance or rescue to the firefighters working at the incident; any assignment of additional duties must be weighed against the potential for interference with this requirement. OSHA's rationale is explained in detail in the preamble to the Respiratory Protection Standard, Federal Register 63:1245-1248 (Jan. 8, 1998), located on OSHA's website at http://www.osha.gov.

OSHA emphasizes that the requirement for standby personnel does not preclude the incident commander from relying on his/her professional judgment to make assignments during a fire emergency. Although the standard requires at least two standby persons during the attack on an interior fire, there are obviously situations where more than two persons will be required both inside and outside the interior structure, a decision ultimately to be made by the incident commander.

OSHA's requirement in no way is intended to establish staffing requirements with regard to, for example, the number of persons on a fire truck or the size of a fire company. Rather, the "two-in/two-out" provision specifies only the number of firefighters who must be present before the interior attack on an interior structural fire is initiated. All that is intended is that an interior attack should not be undertaken until sufficient personal are assembled to allow for "two-in/two-out" requirement.

As you may be aware, Federal OSHA does not have jurisdiction over employees of State and local governments, including firefighters. However, the State of Michigan does cover public sector employees under its OSHA-approved occupational safety and health state plan. Michigan has adopted a standard identical to the Federal respiratory protection standard. While the State may interpret its standard differently from Federal OSHA, the interpretations must be at least as effective as the Federal
interpretations. You may wish to contact the Michigan Occupational Safety & Health Administration concerning its enforcement of the respiratory protection standard. The address is:

Douglas J. Kalinowski, CIH, Director  
Department of Licensing and Regulatory Affairs  
Michigan Occupational Safety and Health Administration  
7150 Harris Drive  
P.O. Box 30643  
Lansing, Michigan 48909-8143  
Telephone: (517) 322-1817

We are providing Director Kalinowski with a copy of this letter.

Thank you for your interest in occupational safety and health. We hope you find this information helpful. OSHA requirements are set by statute, standards, and regulations. Our interpretations letters explain the requirements, and how they apply to particular circumstances, but they cannot create additional employer obligations. This letter constitutes OSHA's interpretation of the requirements discussed. Note that our enforcement guidance may be affected by changes to OSHA rules. Also, from time to time we update our guidance in response to new information. To keep apprised of such developments, you can consult OSHA's website at http://www.osha.gov. If you have any further questions, please feel free to contact the Office of General industry enforcement at (202) 693-1850.

Sincerely,

Thomas Galassi, Director  
Directorate of Enforcement Programs

cc: MIOSHA

Summary

- The respiratory protection standard requires that workers engaged in fighting interior structural fires work in a buddy system; at least two workers must enter the building together, so that they can monitor each other's whereabouts, as well as the work environment.
- The two in/two out rule may not be interpreted as four in/four out, eight in/eight out. There must always be at least two firefighters stationed outside during interior structural firefighting,
prepared to enter if necessary to rescue the firefighters inside. However, the incident commander has the flexibility to determine whether more than two outside firefighters are necessary when more than two firefighters go inside.

- There is an explicit exemption in the Respiratory Protection Standard that, if life is in jeopardy, the two-in/two out requirement is waived. The incident commander and the firefighters at the scene must decide whether the risks posed by entering an interior structural fire prior to the assembly of at least four firefighters is outweighed by the need to rescue victims who are at risk of death or serious physical harm. There is no violation of the standard under rescue circumstances.

- The standard does not require the "two-in/two-out" provision if the fire is still in the incipient stage, and it does not prohibit firefighters from fighting the fire from outside before sufficient personnel have arrived. It also does not prohibit firefighters from entering a burning structure to perform rescue operations when there is a reasonable belief that victims may be inside

- It is anticipated that small fire departments may rely on "mutual aid" agreements with neighboring jurisdictions to supply additional firefighters to assist with interior structural firefighting, if that is necessary to ensure compliance with "two-in, two-out." The intent of the "two-in, two-out" rule is a worker safety practice requirement, not a staffing requirement.

Conclusion

All career firefighters are to be afforded the protection of the contents of the OSHA Respiratory Standard, 1910.134, either directly or through a standard established by a state. The state standard must be “at least as effective” as the federal standard.

With or without an FAA requirement for interior firefighting, if a fire department engages in interior aircraft firefighting, they are entitled the protection of OSHA 1910.134 including the “two in two out” provision.

“Two in two out” is not a minimum staffing requirement. It is a worker safety practice that, in this application, is intended to protect firefighters.

The standard does not limit the ability of firefighters to enter a burning aircraft without “two in two out” in place while the fire is in the incipient stage or to rescue victims who are at risk of death or serious harm.

Mutual aid can be used to help satisfy the “two in two out” provision during interior aircraft firefighting.
APPENDIX C

TIME TRIALS RESEARCH RESULTS
<table>
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<tr>
<th>NTSB ARFF Staffing Research</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>737</strong></td>
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<tr>
<td><strong>GROUND LADDER EVOLUTIONS</strong></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Event</th>
<th>1 - 1 person team</th>
<th>2 - 2 person team</th>
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</thead>
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<tr>
<td>Ladder raised</td>
<td>1.20</td>
<td>1.06</td>
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<tr>
<td>Door to aircraft fully open</td>
<td>2.00</td>
<td>1.48</td>
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<tr>
<td>Both feet of 1st FF in aircraft</td>
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<td>3.47</td>
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<tr>
<td>Fan in aircraft</td>
<td>2.32</td>
<td>3.42</td>
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<td>n/a</td>
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<tr>
<td>Comments</td>
<td>Able to do own work, exhausted, prior LG experience</td>
<td>No prior LG use</td>
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<tr>
<td>Deploy interior handline with ground ladder</td>
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</tr>
<tr>
<td>Nozzle at base of ladder</td>
<td>0.29</td>
<td>0.20</td>
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<tr>
<td>Nozzle passes into aircraft doorway</td>
<td>0.46</td>
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<tr>
<td>Nozzle crosses finish line inside aircraft</td>
<td>1.20</td>
<td>2.49</td>
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<tr>
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</tr>
<tr>
<td>Rescue &amp; remove victim with ground ladder</td>
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</tr>
<tr>
<td>1st FF reaches victim</td>
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<tr>
<td>Begin moving victim</td>
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<tr>
<td>Victim to doorway</td>
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</tr>
<tr>
<td>Victim on ground</td>
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<td><strong>AIR STAIRS EVOLUTIONS</strong></td>
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<th>Event</th>
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<td>Team to top of airstair</td>
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<td>Door to aircraft fully open</td>
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<td>Both feet of 1st FF in aircraft</td>
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<td>0.40</td>
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<td>Fan in aircraft</td>
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<td>0.34</td>
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<td>Fan running</td>
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<tr>
<td>Deploy interior handline with air stair</td>
<td></td>
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<tr>
<td>Nozzle at base of airstair</td>
<td>0.15</td>
<td>0.20</td>
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<td>Nozzle breaks plane of aircraft doorway</td>
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<tr>
<td>Nozzle crosses finish line inside aircraft</td>
<td>3.23</td>
<td>3.03</td>
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<tr>
<td>Comments</td>
<td>Return outside one time for more hose</td>
<td>Return outside two times for more hose</td>
</tr>
<tr>
<td>Rescue &amp; remove victim with air stair</td>
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<td></td>
</tr>
<tr>
<td>1st FF reaches victim</td>
<td>0.36</td>
<td>1.11</td>
</tr>
<tr>
<td>Begin moving victim</td>
<td>0.41</td>
<td>1.29</td>
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<td>Victim to doorway</td>
<td>1.29</td>
<td>4.06</td>
</tr>
<tr>
<td>Victim on ground</td>
<td>1.45</td>
<td>5.24</td>
</tr>
<tr>
<td>Comments</td>
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<td></td>
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**Total Times:**

- **1 - 1 person team:**
  - Total: 12:40

- **2 - 2 person team:**
  - Total: 7:57
APPENDIX D

NFPA 403, Chapter 5, Table 5.3.1, Extinguishing Agents

Table 5.3.1 (from NFPA 403) below is taken directly from NFPA 403. The area of the table that is bordered with a red broken line is not applicable. This portion of the table provides quantities of agent when fluoroprotein, FFP or Protein foams are used. FAA certificated airports are required to use AFFF as their primary agent. These quantities represent a significant increase over current FAA minimum quantities. The primary reason is that FAA does not include water for interior firefighting in the minimum quantities describes in 14 C FR Part 139.317.
Table 5.3.1(a) Extinguishing Agents, Discharge and Response Capability in U.S. Customary Units

<table>
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<tr>
<th>Airport Category</th>
<th>Response Phases</th>
<th>AFFF Required Water (U.S. gal)</th>
<th>Discharge Capability (gpm)</th>
<th>Fluorine-Free Synthetic Foam, Protein Foam, or FFP Required Water (U.S. gal)</th>
<th>Discharge Capability (gpm)</th>
<th>Protein Foam Required Water (U.S. gal)</th>
<th>Discharge Capability (gpm)</th>
<th>Complementary Agents (^a)</th>
<th>Quantity (lb)</th>
<th>Discharge (lb/sec)</th>
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<td>1</td>
<td>Q1(^b)</td>
<td>180(^b)</td>
<td>120</td>
<td>160</td>
<td>160</td>
<td>180</td>
<td>180</td>
<td></td>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Q2(^e)</td>
<td></td>
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<td></td>
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<td></td>
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<td>Q3(^e)</td>
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<td>120</td>
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</tr>
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<td>2</td>
<td>Q1(^b)</td>
<td>180(^b)</td>
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<td>213</td>
<td>236</td>
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<td>0</td>
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<td>5</td>
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<td>Q3(^e)</td>
<td>249(^e)</td>
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</table>

\(^a\)The minimum quantity is based on ISO qualified potassium bicarbonate. Powder can be substituted by a listed agent exceeding the performance of potassium bicarbonate.

\(^b\)Quantity of water for foam production for initial control of the pool fire.

\(^c\)Quantity of water for foam production to continue control or fully extinguish the pool fire.

\(^d\)Water available for interior fire fighting.

\(^e\)The 240-second requirement begins after arrival of the first ARFF apparatus.

\(^f\)For multiple passenger deck aircraft within this category, the Q5 discharge capability should be increased to 375 gpm (1439 L/min) and required water increased to 3750 gal (14,195 L).