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Aircraft Rescue and Fire Fighting Capabilities: Are Today's Standards Protecting Passenger's Futures?

Kaetlyn Blocker
Embry-Riddle Aeronautical University, blockerk@my.erau.edu

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Aircraft Rescue and Fire Fighting Capabilities:
Are Today's Standards Protecting Passenger's Futures?

Graduate Capstone Project

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By
Kaetlyn Blocker

Prescott, Arizona
Embry-Riddle Aeronautical University
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Abstract

Few studies have been conducted that have truly considered the relevance and inadequacies of applicable aircraft rescue and firefighting (ARFF) regulations. Fewer still have studied and explored accident cases that directly exemplify the deficiencies and inconsistencies of various regulatory standards and requirements. This study seeks to expose and explain those inadequacies by utilizing a historical, case-study type research method to examine accident cases during which time the governing regulations played a significant role in the ARFF operations. The findings discovered as a result of this multi-case analysis provide evidence that the current regulations governing United States ARFF operations are both outdated and inadequate. Results indicated that major regulatory issues primarily involve incomplete or inaccurate documentation, inadequate training, minimum staffing, and minimum equipment. Cross-case analysis suggests that the accident victims would be most at risk at airports that are not as fully equipped and staffed as those examined in this study. Continued research on this topic must be pursued in order to recommend specific changes to modernize ARFF regulations.

Chapter 1. Overview

Introduction

This paper explores various case studies involving Aircraft Rescue and Firefighting (ARFF) operations at Part 139 certified airports and how the capabilities of such operations play a role in modern-day aviation accidents. Airports and ARFF operations in the United States are regulated according to the U.S. Code of Federal Regulations (CFR) by the Federal Aviation Administration (FAA). These regulations are sometimes supplemented by the National Fire Protection Association (NFPA) standards. In other parts of the world, countries have different governing standards, however, for comparison, the International Civil Aviation Organization (ICAO) Standards and Recommended Procedures (SARPs) are also included in this report for comparison purposes. Many regulations governing the US ARFF operations today are both unsuitable and outdated, yet they are still affecting airports and have the potential of impacting rescue operation success and occupant safety. This research takes a safety perspective and aims at exploring the current U.S law pertaining to firefighting and rescue operations at airports, examining instances where actual inadequacies impacted accident outcomes and developing recommendations to correct any shortcomings and prevent future tragedy. As technology and capabilities rapidly evolve, the regulations which govern and protect the industry and its people age, and the need for regulatory renovation and modernization increases. It is suspected by this researcher that the current regulations, which date 11 years or more, leave too much availability for interpretation and discretion. Several significant studies that led to the creation and development of this study are included and discussed in Chapter 2. These studies and reports include those by the Office of Inspector General, the Aircraft Rescue and Fire Fighting Working Group, and the Coalition for Airport and Airplane Passenger Safety. The findings discovered in each of these reports date back over a 20-year range, and each demonstrates the need for continuing reassessment.

Background

The Federal Aviation Administration Reauthorization Act of 2009 included Section 311 of H.R. 915, which specifically called for more closely aligning aircraft rescue and firefighting (ARFF) regulations that are contained under Title 14 Code of Federal Regulations (CFR) Part 139, to voluntary standards (National Academies of Sciences, Engineering, and Medicine, 2011). Such organizations that circulate voluntary ARFF standards include the International Civil Aviation Organization (ICAO) and the National Fire Protection Association (NFPA).

Prior to this, in 2004, an ARFF Requirements working group studied these and other airport certification issues and produced a report to an Aviation Rulemaking Advisory Committee (ARAC) (National Academies of Sciences, Engineering, and Medicine, 2011). This study made no specific proposal to change the regulations in Part 139 to incorporate voluntary ARFF standards. Since 2009, the ARFF standards and regulations have not been revisited. Neither the FAA Modernization and Reform Act of 2012 nor the Reauthorization Act 2018 have accomplished any proposed changes on ARFF regulatory capabilities.

Need for Research and Problem Statement

The FAA Reauthorization Act of 2018 was signed into law on October 5, 2018, in Congress. The act reauthorizes aviation programs for the following five years, from Fiscal Year 2019 to Fiscal Year 2023 (Department of Transportation, 2019). As we now enter 2020, it has effectively been 11 years since regulatory issues, regarding ARFF response standards, have been appropriately addressed in governmental research reports. It is likely that at least another three years will pass until another Reauthorization Act will occur, further extending the time since the last consideration. Over the last 11 years, little research has sought to bring up the issues that are affecting ARFF operations, and the studies that have done so have been ineffective in producing results that lead to a change in regulations. New research needs to be conducted to examine how the current regulations are affecting modern ARFF operations and to determine precisely what needs to be improved.

Significance of the Study

Few studies have truly examined the regulatory inadequacies in U.S. ARFF regulations, and fewer still have been conducted in recent times addressing modern accidents. After 11+ years of stagnation, it is time for a reassessment of ARFF related regulations. Although past studies have been extensive in scope, providing a large sample of accident cases as well as a thorough assessment of the results, the information gathered then has now become outdated for this current time. This study contributes a new and modernized perspective by utilizing a case study approach to examine more recent and prominent aviation accidents while also aiming to provide an opportunity to reopen discussions on this critical safety topic. This research hopes to raise awareness of the safety issues surrounding outdated regulations while also promoting the continuation of future research on the topics discussed in this study.

Definition of Terms

Advisory Circular- A non-regulatory document which provides guidance and information on various topics and are published by the Federal Aviation Administration. (Federal Aviation Administration, 2020a).

Air carrier operation- "means the takeoff or landing of an air carrier aircraft and includes the period of time from 15 minutes before until 15 minutes after the takeoff or landing" (14 C.F.R. § 139.5, 2004).

Agent substitution- Aerodrome categories 1 and 2 may substitute 100 percent of the water with complementary agent. For the purposes of agent substitution, 1.0 kilogram of complementary agent shall be equivalent to 1.0 liter of water for Level A foam production. Substitution ratios should always be checked (Annex 14, Aerodromes, 2016).

AEP- Airport Emergency Plan- A plan to address "essential emergency related, and deliberate actions planned to ensure the safety of and emergency services for the airport populace and the community in which the airport is located" (Federal Aviation Administration, 2009).

Alert 3 Notification- One of three alerts of the Aircraft Alert Classification System. Alert 3 (III) is an alert which signals "an aircraft incident/accident has occurred on or in the vicinity of the airport. All designated emergency response units [should] proceed to the scene in accordance with established plans and procedures" (Minnesota Airport Technical Assistance Program, n.d.).

ARAC- Aviation Rule Making Committee- Established "to provide advice 10 and recommendations to the FAA Administrator on the FAA's rulemaking activities with respect 11 to aviation-related issues" (Aircraft Rescue and Fire Fighting Requirements Working Group, 2004).

Aqueous Film-Forming Foam Concentrate (AFFF)- A “highly effective foam intended for fighting high-hazard flammable liquid fires” and are “typically formed by combining hydrocarbon foaming agents with fluorinated surfactants. When mixed with water, the resulting solution achieves the interfacial tension characteristics needed to produce an aqueous film that spreads across the surface of a hydrocarbon fuel to extinguish the flame and to form a vapor barrier between the fuel and atmospheric oxygen to prevent re-ignition” (Interstate Technology Regulatory Council, 2018).

Categorical Aggregation- One strategic method to reach new meanings in case study research which involves seeking a collection of themes from data and combining those themes to discover relevant meanings about cases (Stake, 1995).

Class I Airport- An airport certificated to serve scheduled operations of large air carrier aircraft that can also serve unscheduled passenger operations of large air carrier aircraft and/or scheduled operations of small air carrier aircraft (14 C.F.R. § 139.5, 2004).

Class II Airport- an airport certificated to serve scheduled operations of small air carrier aircraft and the unscheduled passenger operations of large air carrier aircraft. A Class II airport cannot serve scheduled large air carrier aircraft (14 C.F.R. § 139.5, 2004).

Class III Airport- an airport certificated to serve scheduled operations of small air carrier aircraft. A Class III airport cannot serve scheduled or unscheduled large air carrier aircraft (14 C.F.R. § 139.5, 2004).

Class VI Airport- an airport certificated to serve unscheduled passenger operations of large air carrier aircraft. A Class IV airport cannot serve scheduled large or small air carrier aircraft (14 C.F.R. § 139.5, 2004).

Complementary Agent (NFPA)- Refers to an extinguishing agent that has the compatibility to perform fire-suppression functions in support of a primary extinguishing agent and where extinguishment might not be achieving using only the primary agent (National Fire Protection Association, 2017).

Direct Interpretation- One strategic method to reach new meanings in case study research which involves examining and presenting individual aspects of specific cases (Stake, 1995).

FAA Reauthorization Act- “[The] bi-partisan, five-year authorization of the FAA represents the first significant multi-year reauthorization since the FAA Modernization and Reform Act of 2012. (P.L. 112-95) and the first five-year reauthorization since 1982” (Federal Aviation Administration, 2019a). The bill “extended the FAA’s funding and authorities through Fiscal Year 2023” and it included significant legislative changes related to increasing overall aviation safety (Federal Aviation Administration, 2019a).

Flight cycle- The cycle which includes “engine start-up and increase to full or partial power (as required during a normal flight), one landing gear retraction and extension, and a complete shutdown” (National Transportation Safety Board, 1997).

Film-Forming Fluoroprotein Foam Concentrate (FFFP)- A protein-foam concentrate that uses fluorinated surfactants to produce a fluid aqueous film for suppressing hydrocarbon fuel vapors (National Fire Protection Association, 2017).

Fluorine-Free Synthetic Foam- Foam concentrate based on a mixture of hydrocarbon surface active agents that are fluorine free (National Fire Protection Association, 2017).

Fluoroprotein Foam Concentrate (FP)- A protein-based foam concentrate, with added fluorochemical surfactants, that forms a foam showing a measurable degree of compatibility with dry chemical extinguishing agents and an increase in tolerance to contamination by fuel. 3.3.1.5 Protein Foam (P) (National Fire Protection Association, 2017).

Halogenated Agent- A type of gaseous clean firefighting agent sometimes carried and used on ARFF vehicles (Federal Aviation Administration, 2011).

Joint-Use Airport- An airport owned by the Department of Defense, at which both military and civilian aircraft make shared use on the airfield (Federal Aviation Administration, 2019b).

Optimum visibility and surface conditions- "Daytime, good visibility, no precipitation with normal response route free of surface contamination, e.g. water, ice or snow" (Annex 14, Aerodromes, 2016).

Pressure-fed fuel fires- "Fires associated with fuel discharged under very high pressure from a ruptured fuel tank" (Annex 14, Aerodromes, 2016).

Protein Foam (P)- A protein-based foam concentrate consisting primarily of products from a protein hydrolysate, plus stabilizing additives and inhibitors to protect against freezing, to prevent corrosion of equipment and containers, to resist bacterial decomposition, to control viscosity, and to otherwise ensure readiness for use under emergency conditions. Protein foam is stabilized with metal salts to make a fire-resistant foam blanket (National Fire Protection Association, 2017).

Potassium-based dry chemical- A type of firefighting agent sometimes carried and used on ARFF vehicles also known as Purple K Powder (Federal Aviation Administration, 2011).

RRA- Rapid Response Area- "A rectangle that includes the runway and the surrounding area extending to a width of 500 feet (150 meters) outward from each side of the runway centerline and to a length of 1,650 feet (500 meters) beyond each runway end, but not beyond the airport property line (NFPA 403, 2018).

Response time- “The time between the initial call to the rescue and firefighting service, and the time when the first responding vehicle(s) is (are) in position to apply foam at a rate of at least 50 per cent of the discharge rate specified in Table 9-2 [Table 4]” (Annex 14, Aerodromes, 2016).

SARPs- Standards and Recommended Practices- Technical specifications adopted by ICAO found in the 19 Annexes to the Chicago Convention. A Standard is defined as “Any specification for physical characteristics, configuration, materiel, performance, personnel or procedure, the uniform application of which is recognized as necessary for the safety or regularity of international air navigation and to which Contracting States will conform in accordance with the Convention; in the event of impossibility of compliance, notification to the Council is compulsory under Article 38” (International Civil Aviation Organization, 2003). A Recommended Practice is defined as, “Any specification for physical characteristics, configuration, materiel, performance, personnel or procedure, the uniform application of which is recognized as desirable in the interest of safety, regularity or efficiency of international air navigation, and to which Contracting States will endeavor to conform in accordance with the Convention” (International Civil Aviation Organization, 2003).

List of Abbreviations

AEP- Airport Emergency Plan
AFB-FD- Air Force Base-Fire Department
AFFF- Aqueous Film-Forming Foam Concentrate
ARAC- Aviation Rule Making Committee
ARFF- Aircraft Rescue and Fire Fighting
ARFFWG- Aircraft Rescue and Fire Fighting Working Group
ASO- Airfield Safety Officer
CAAPS- Coalition for Airport and Airplane Passenger Safety
CFR- Code of Federal Regulations
DOD- Department of Defense
FAA- Federal Aviation Administration
FFFP- Film-Forming Fluoroprotein Foam Concentrate
FO- First Officer
FP- Fluoroprotein Foam Concentrate
HPRV- High-performance research vehicle
HRET- High-reach extendable turret
ICAO- International Civil Aviation Organization
IP- Instructor Pilot
KBED- Laurence G. Hanscom Field Airport
KSFO- San Francisco International Airport
LOI- Letters of Investigation
NFPA- National Fire Protection Association
NTSB- National Transportation Safety Board
OSHA- Occupational Safety and Health Administration
Protein Foam (P)-
PF- Pilot Flying
PM- Pilot Monitoring
PPE- Personal Protective Equipment
RFFS- Rescue and Fire Fighting Service
RRA- Rapid Response Area
SARPs- Standards and Recommended Practices
SFFD- San Francisco Fire Department
SFFD-AB- San Francisco Fire Department- Airport Bureau
SME- Subject Matter Expert

Chapter 2. Literature Review

Introduction

The review of literature contained in this research addresses several significant topics relating to the current and past ARFF regulations, alternative standards, as well as past potential impacts of changing the standards and regulations, all of which provide contributing viewpoints regarding the issues surrounding aircraft rescue and firefighting challenges. These challenges impact both the financial successes of Part 139 certificated airports and the safety of all passengers, pilots, crew, as well as all those in the vicinity of airports, which may be impacted. The literature is organized in both a thematic and chronological way respective to topic themes and the publishing year.

Insufficient Oversight

While some literature discussed in this review focuses specifically on the inadequacies of the ARFF related regulations and standards, other literature considers not the laws in writing, but the oversight of such law. The Office of Inspector General (2016) Audit Report Memorandum considers a specific accident case, Asiana 214, in which it audits the FAA's oversight and enforcement relating to the regulations in place governing the ARFF operations which responded to the accident at San Francisco International Airport.

The memorandum states that since 2004 (until release of the report on May 31, 2016) the FAA had "provided approximately $750 million in Airport Improvement Program funds to airports nationwide for ARFF buildings, facilities, vehicles, and equipment" (Office of Inspector General, 2016). The FAA, as mentioned in the report, is responsible for ensuring the regulatory compliance of more than 500 airports in the United States, and specifically requires airport operators to "develop plans and procedures to respond to aircraft incidents and accidents, fires, and hazardous materials incidents" and requires "all rescue and firefighting personnel to be trained prior to their first duties and to receive recurrent training every 12 consecutive calendar months" (Office of Inspector General, 2016).

The memorandum found that the FAA had not been ensuring airports compliance with ARFF standards and regulatory requirements and that in four regions visited, the FAA inspectors were not consistently reviewing compliance with vehicle readiness and certification manuals (Office of Inspector General, 2016). The report also discovered that the FAA's oversight was fragile, in part, due to the insufficient guidance and tools available to inspectors. At the time, the FAA was utilizing an Airport Certification/Safety Inspection Checklist to assess and document finishing, however, according to the memorandum, the checklist was much too broad to assess the specific details of each operation (Office of Inspector General, 2016). Additionally, inspectors were not required to document their determinations, nor were they required to maintain such documentation.

The memorandum discovered that in over 900 administrative enforcement actions between 2010 and 2014, only 73 Letters of Investigation (LOI) were issued (Office of Inspector General, 2016). According to the report, FAA policy, Order 2150.3B, states that inspectors should issue an LOI when a potential violation of federal regulations is discovered (Office of Inspector General, 2016). It was also found by this memorandum that the FAA had not been reporting the ARFF enforcement data as required by FAA policy and stated that the FAA does not enter enforcement data into the Enforcement Information System (EIS) because the Inspectors use another program which is not linked to the EIS. The report continued that the agency plans on connecting to the EIS within the next few years, however, because of the lack of reporting, the FAA's ability to evaluate enforcement actions effectively has been hindered.

While accidents are rare, the potential for such accidents and the resulting injury and fatality requires constant vigilance. The report concluded the FAA needed to improve the management processes, ensure adequate oversight and enforcement, and guarantee the effective implementation of the regulatory policies and guidance for ARFF operations (Office of Inspector General, 2016).

Reducing Fatalities and Serious Injuries

In 2011 a research study conducted by the National Academies of Sciences, Engineering, and Medicine explored and assessed contributing factors that may affect proposed ARFF standards. In addition to the National Academies of Sciences, Engineering, and Medicine, the Airport Cooperative Research Program and the Transportation Research Board also contributed to the study. The study assessed past accidents in an effort to determine whether changes to the current ARFF standards could have improved the outcomes of such accidents. The study assessed 81 accidents occurring in 17 different countries between 1989 and 2008. The research concluded that while the number of accidents assessed was vast, the research team determined that the information from the accident reports was “not conducive for determining reductions in fatalities and serious injuries based on changing the ARFF standards, i.e., the data was not to the level of detail required to make a conclusive determination that a change in standards would have reduced fatalities and/or serious injuries” (National Academies of Sciences, Engineering, and Medicine, 2011). However, the report goes on to suggest that despite this conclusion the team’s collective judgment was that a change in the standards would not have reduced the serious injuries or fatalities in any accident reviewed in this study, except for one single accident (National Academies of Sciences, Engineering, and Medicine, 2011). The report concluded with one last statement asserting that there was “no conclusive evidence in the accident reports to indicate that accident fatalities or serious injuries would be reduced by replacing the current Part 139 ARFF standards with those found in ICAO Annex 14 or NFPA 403 and its associated documents” however it did also admit that “at best, only subjective judgments could be made and even if the subjectivity were considered to be acceptable from a research perspective, there would be a question about consistency” (National Academies of Sciences, Engineering, and Medicine, 2011).

Assessing the number of lives that may or may not be affected is a daunting task, especially when considering that the accidents included in the study were all subjected to different standards pertaining to the date and location that the accident occurred. While this report concluded that the team believed a change in standards would not have affected the survivability of the occupants in all but one accident, the report also admitted that specific challenges arose relating to the data collection that could have significantly affected the results of this study. The report stated that the team was unable to determine the cause of many injuries and fatalities, for example, whether an occupant that died succumbed to smoke inhalation and thermal burns or suffered a trauma brought on by force. Additionally, the timing of such injuries and fatalities were also unclear. This resulted in the team being unable to consistently determine how and when the injury or fatality could have been prevented. Ultimately, this revelation significantly “hinders the ability to make a direct link to how many lives would be saved if changes were made to current ARFF standards” (National Academies of Sciences, Engineering, and Medicine, 2011).

Staffing Levels and Index Requirements

In 2014 the National Transportation Safety Board~~’s~~ issued a letter outlining recommendations to the Aircraft Rescue and Firefighting Working Group (ARFFWG) and the

Federal Aviation Administration in response to the Asiana Airlines Flight 214 accident that occurred at San Francisco International Airport. The ARFFWG responded to the third NTSB recommendation which suggests 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" (Aircraft Rescue and Fire Fighting Working Group A-14-60 Task Group, 2018). This response involved conducting a research project that extended from April 2015 to September 2017 during which the group "[examined] theories, knowledge, methods, and techniques concerning the creation of a minimum staffing level" (Aircraft Rescue and Fire Fighting Working Group A-14-60 Task Group, 2018).

The ARFFWG conducted, as a significant component of the project, timed scenarios to draw conclusions about the required staffing in order to continue exterior firefighting effectively, perform rapid entry, perform interior firefighting and to rescue passengers and crewmembers (Aircraft Rescue and Fire Fighting Working Group A-14-60 Task Group, 2018). One such conclusion made by the ARFFWG is that the exterior firefighting should continue while all the other actions are being performed and thus the operator of the ARFF vehicle should "never leave the cab, as the protection of that ARFF vehicle will cease to exist if they do," and should the agent be exhausted, a reservicing vehicle should be called forth so that the ARFF vehicles do not need to be removed from the scene (Aircraft Rescue and Fire Fighting Working Group A-14-60 Task Group, 2018). The ARFFWG (2018) also implies that this must be taken into consideration when setting a minimum staffing level, however "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 ARFFWG (2018) concluded that based on the interpretation made by many airports, “sufficient and qualified staffing” is essentially synonymous with *minimum* or *required staffing*, as most airports provide only the personnel that are needed to drive the required vehicles (based on airport Index) to the midpoint of the furthest runway within the regulatory response times.

One of the key takeaways from the research project conducted by the ARFFWG is the need for a hazard risk assessment. The ARFFWG (2018) purports that a hazard risk analysis should be conducted at each airport with the intent to discover the need for any additional staffing above the “minimum level,” as suggested by the NTSB.

The ARFFWG further recommends that all Index B, C, D, and E airports be required to have an interior access vehicle (IAV) to enable rapid entry into aircraft and that the agent quantities and number of ARFF vehicles be increased for Index A airports to align with the NFPA and ICAO Category 5 (Aircraft Rescue and Fire Fighting Working Group A-14-60 Task Group, 2018). Furthermore, the ARFFWG recommends the creation of an Index F category to account for airports being served by multi-deck passenger aircraft that are between 250 feet and 295 feet (Aircraft Rescue and Fire Fighting Working Group A-14-60 Task Group, 2018).

Improving Regulations and Standards

In 1999, concerns regarding aircraft rescue and firefighting capabilities were assessed and appraised in depth by the Coalition for Airport and Airplane Passenger Safety. The standards and regulations governing ARFF operations at the time were different from those in place today; however, we still find many similarities between the findings of the CAAPS report and some of those discussed in modern research. The Coalition for Airport and Airplane Passenger Safety report (1999), entitled *Surviving the Crash: The Need to Improve Lifesaving Measures at Our Nation’s Airports* stated that, at the time, the current ARFF regulations left airport authorities a significant amount of room for interpretation and discretion, thus allowing airports to choose to maximize profits which, in some cases resulted in the justification of cutting ARFF departmental budgets. This statement implies an incredible reduction in public safety and asserts that such funding cuts had the FAA's tacit approval because the administration had "not seen the need to maintain its standards in response to changes in aircraft and airport design and the increasingly complex demands placed on fire and rescue workers" (Coalition for Airport and Airplane Passenger Safety, 1999). At a time when aviation was rapidly evolving, and accidents were occurring at nearly double the most recent 2018 figure (Bureau of Transportation Statistics, n.d.), the Coalition for Airport and Airplane Passenger Safety was keen to look for any possible contributing factors that may affect passenger survivability. The report did mention that despite the FAA's implementation of the Commercial Aviation Safety Team (CAST) program, which aimed at reducing accident rate by 80% over the next ten years by implementing preventative measures, "the agency is not doing what it could do to mitigate the aftermath of accidents" and that no matter the effectiveness of any preventative program, aviation accidents will continue to occur (Coalition for Airport and Airplane Passenger Safety, 1999). The concluding recommendation of the Coalition for Airport and Airplane Passenger Safety (1999) report included amending 14 CFR 139 so that ARFF personnel have the mission of "initiating exterior and interior aircraft fire suppression and extricating trapped victims." Other specific recommendations contained in the Coalition for Airport and Airplane Passenger Safety (1999) report include: amending 14 CFR 139 to adopt the NFPA 403 response time standard; amending 14 CFR 139.319(j)(5) to adopt 29 CFR 1910.134 (OSHA Regulation) and to incorporate NFPA 414, 1976 and 1981 for staffing and vehicle standards; amending 14 CFR 139.317 by adopting NFPA 403 and 414 for fire extinguishing agents; amending 14 CFR 139 so that it "assigns ARFF personnel responsibility for airport structural fires and medical emergencies, and so that it incorporates accepted safety, training, and equipment practices for structural fires and medical emergencies occurring on airport premises" (CAAPS, 1999); amending 14 CFR 139 to adopt 29 CFR 1910.120 (OSHA Regulation), and NFPA 471 and 472 for HAZMAT response, safety procedures, and operations; and amending 14 CFR 139 so that "ARFF personnel are participants in planning for terrorist incidents and are adequately trained and equipped to manage the consequences of a terrorism attack, including those involving weapons of mass destruction" (Coalition for Airport and Airplane Passenger Safety, 1999).

Though this report was published nearly 21 years ago, the concerns regarding ARFF related regulations remain today. While some regulations have since been updated, the CAAPS declaration that "the FAA must update its regulations to keep pace with the impact of ever-expanding air traffic and the critical safety needs at our nation's airports," still holds true today (Coalition for Airport and Airplane Passenger Safety, 1999).

Standards and Regulations

United States Code of Federal Regulations (CFRs)

The United States Code of Federal Regulations (CFR) is an collection of rules published in the Federal Register by executive departments of the United States Federal Government (GovInfo, n.d.). Within Title 14 (Aeronautics and Space) of the CFR resides Chapter 1, Subchapter G, Part 139: Certification of Airports.

Part 139 Airports. 14 CFR Part 139 applies explicitly to the certification and operation of airports within the United States, the District of Columbia, or any territory or possession of the United States given that the airport is serving (1) scheduled air carriers operating aircraft configured for more than nine passenger seats and (2) unscheduled air carriers operating aircraft configured for at least 31 passenger seats (14 C.F.R. § 139, 2004).

The Code of Federal Regulations classifies Part 139 airports by both class and index. Table 1 depicts the current 2020 assessment of the airport's index and class quantities. Each airport index is determined based on both the aircraft length and the average daily departures. According to the FAA, "If there are five or more average daily departures of air carrier aircraft in a single Index group serving that airport, the longest Index group with an average of five or more daily departures is the Index required for the airport" (Federal Aviation Administration, 2011).

Table 1. *Part 139 Airport's Class and Index Quantities (Federal Aviation Administration, 2020b).*

Airport Class			Airport Index	
Inactive	11		A	238
Large Hub	29		B	145
			C	86
Class I	412		D	22
Class II	15		E	25
Class III	19		315(e)	6
Class IV	76		Not listed	0
TOTAL Part 139 Airports	**522**		**TOTAL Part 139 Airports**	**522**

Aircraft Rescue and Fire Fighting Indices and Required Equipment. Some large airports operating under Part 139 have a wide variety of aircraft serving their community. Due to this, the regulations further divide airports into five indices of aircraft rescue and firefighting capabilities (ARFF). Indices A through E determines ARFF capabilities based on aircraft length. For airports with five or more average daily departures, the longest aircraft determines the required index for the airport, airports with fewer than five daily departures of the longest aircraft will be designated with the next lower index group (14 C.F.R. § 139.315, 2004). According to 14 C.F.R. § 139.315 (2004), subpart d, the minimum designation for ARFF capabilities is Index A; however, subpart (e) states that Class III airports may still comply with this regulation by substituting a comparatively safe alternative to Index A if approved by the Administrator. Alternative compliance is further specified in subpart (e), (1-4).

Each index included in 14 C.F.R. § 139.315 corresponds to a specific minimum required equipment and agent, as defined in 14 C.F.R. § 139.317. These requirements, detailed in Table 2, represent each airport's capabilities to respond to aircraft-related emergencies and the effectiveness and success in doing so.

Table 2. *14 CFR § 139.315 and 139.317*

ARFF Index	Aircraft Length (feet)	Requirements
A	Less than 90	One vehicle carrying at least: 1. 500 pounds of sodium-based dry chemical, halon 1211, or clean agent OR 2. 450 pounds of potassium-based dry chemical and water with a commensurate quantity of AFFF to total 100 gallons for simultaneous dry chemical and AFFF application
B	At least 90 but less than 126	Either of the following: 1.One vehicle carrying at least 500 pounds of sodium-based dry chemical, halon 1211, or clean agent and 1,500 gallons of water and the commensurate quantity of AFFF for foam production. OR 2. Two vehicles, one vehicle carrying the extinguishing agents as specified for Index A and another vehicle carrying an amount of water and the commensurate quantity of AFFF so the total quantity of water for foam production carried by both vehicles is at least 1,500 gallons.
C	At least 126 but less than 159	Either of the following: 1. Three vehicles, one vehicle carrying the extinguishing agents as specified for Index A and two vehicles carrying an amount of water and commensurate quantity of AFFF so the total quantity of water for foam production carried by all three vehicles is at least 3,000 gallons. OR 2. Two vehicles, one carrying the extinguishing agents as specified for Index B and one vehicle carrying water and the commensurate quantity of AFFF so the total quantity of water for foam production carried by both vehicles is at least 3,000 gallons.
D	At least 159 but less than 200	Three vehicles – 1. One vehicle carrying the extinguishing agents as specified for Index A AND 2. Two vehicles carrying an amount of water and the commensurate quantity of AFFF so the total quantity of water for foam production carried by all three vehicles is at least 4,000 gallons.
E	At least 200	Three vehicles – 1. One vehicle carrying the extinguishing agents as specified for Index A AND 2. Two vehicles carrying an amount of water and the commensurate quantity of AFFF so the total quantity of water for foam production carried by all three vehicles is at least 6,000 gallons.

Aircraft Rescue and Fire Fighting Response Requirements. 14 C.F.R. § 139.319 of the Code of Federal Regulations defines the operational requirements of aircraft rescue and firefighting. § 139.319 subpart (h) specifies the response requirements for all ARFF operations under part 139 certified airports. Subpart (h) states that with the equipment and trained personnel required under this part, each certificate holder must respond to all emergencies during air carrier operation periods and demonstrated compliance with the response requirements when requested by the administrator (14 C.F.R. § 139.319, 2004). The response criteria that must be consistently demonstratable for this section specifies that at minimum, one required ARFF vehicle must reach the midpoint of the farthest runway serving air carriers within 3 minutes from the time of the alarm at its assigned post and begin applying the extinguishing agent (14 C.F.R. § 139.319, 2004). Additionally, all other required vehicles must reach the midpoint of the farthest runway within 4 minutes from the time of the alarm at their assigned post and begin applying the extinguishing agent (14 C.F.R. § 139.319, 2004).

International Civil Aviation Organization Standards and Recommended Practices

The International Civil Aviation Organization was initially established in 1944 at the Convention on International Civil Aviation, otherwise known as the Chicago Convention, with the intent to promote the development of both safe and efficient civil aviation (International Civil Aviation Organization, n.d. b) Today, ICAO is a United Nation’s agency comprised of 193 member states, that work together to develop and agree upon Standards and Recommended Practices (SARPs) and policies that support common international civil aviation goals (International Civil Aviation Organization, n.d. a). The SARPs are contained in nineteen annexes that support ICAO’s task of coordinating and regulating international air travel.

Annex 14. Annex 14 to the Convention on International Civil Aviation specifies the international standards and recommended practices for Aerodrome Design and Operations. This annex specifies, amongst other standards, ICAO's interpretation of minimum firefighting equipment and services.

ICAO Rescue and Fire Fighting Recommended Levels of Protection. Chapters 9.2.3-9.2.7 specify the levels of protection of rescue and firefighting capabilities at aerodromes. Chapter 9.2.3 mandates that the level of rescue and firefighting protection at an aerodrome shall correspond to the aerodrome's category. However, where the number of highest category aircraft movements (takeoff or landing) normally using the aerodrome is less than 700 in the busiest consecutive three months, the level of protection provided shall be not less than one category below the determined (Annex 14, Aerodromes, 2016). Recommendation 9.2.4 states that the level of protection provided at an aerodrome for rescue and firefighting should be equivalent to the aerodrome category determined using the principles in 9.2.5 and 9.2.6 (Annex 14, Aerodromes, 2016). Chapter 9.2.5 mandates that the aerodrome category shall be determined from Table 3 and be based on the longest and widest aircraft typically using the aerodrome (Annex 14, Aerodromes, 2016). In determining the aircraft categorization, first, evaluate the overall length and second, the fuselage width. Chapter 9.2.6 directs, if after selecting the appropriate category, that aircraft's fuselage width is greater than the maximum in Table 3, then the category for that aircraft shall be one category higher (Annex 14, Aerodromes, 2016). Chapter 9.2.7 mandates that during periods of expected reduced activity, the level of protection shall not be less than that needed for the highest category aircraft planned to use the aerodrome during that time (Annex 14, Aerodromes, 2016).

Table 3. *International Civil Aviation Organization Annex 14 Aerodrome Categories for Rescue and Fire Fighting*

Aerodrome Category	Aeroplane Overall Length	Maximum Fuselage Width
1	0 meters up to but not including 9 meters	2 meters
2	9 meters up to but not including 12 meters	2 meters
3	12 meters up to but not including 18 meters	3 meters
4	18 meters up to but not including 24 meters	4 meters
5	24 meters up to but not including 28 meters	4 meters
6	28 meters up to but not including 39 meters	5 meters
7	39 meters up to but not including 49 meters	5 meters
8	49 meters up to but not including 61 meters	7 meters
9	61 meters up to but not including 76 meters	7 meters
10	76 meters up to but not including 90 meters	8 meters

ICAO Extinguishing Agents. Chapter 9.2.8-.25 of Annex 14 specifies the directives and recommendations pertaining to extinguishing agents used by rescue and firefighting services (Annex 14, Aerodromes, 2016). Chapter 9.2.8 of Annex 14, Aerodromes (2016) specifies the ICAO recommendations, which suggest that both *principal* and *complementally agents* provided at an aerodrome. 9.2.9 suggests that the *principal extinguishing agent* be one of the following:

1. a foam meeting the minimum performance level A; or
2. a foam meeting the minimum performance level B; or
3. a foam meeting the minimum performance level C; or
4. a combination of these agents;

However, the *principal extinguishing agent* for aerodromes in categories 1 to 3 should preferably meet a performance level B or C foam. Recommendation 9.2.10 advises that the *complementary extinguishing agent* should be a dry chemical powder suitable for hydrocarbon fires (dry chemical powders should be used with careful consideration to ensure compatibility with foam) (Annex 14, Aerodromes, 2016). Alternatively, complementary agents may be used if they have equivalent capabilities. Chapter 9.2.11 mandates that the quantity of water for foam production and the number of complementary agents required to be provided on rescue and firefighting vehicles shall be determined by (1.) the aerodrome category determined in chapters 9.2.3-9.2.6 *(level of protection to be provided)*, and (2.) that which is included in Table 4 (Annex 14, Aerodromes, 2016). The one exception to this rule applies to *agent substitution*, which stipulates that for aerodrome categories 1 and 2, 100 percent of the water may be substituted with a complementary agent. Recommendation 9.2.12 suggests that at aerodromes, where larger than average aircraft are operating in a given category, water quantities should be recalculated, and water quantities and discharge rates should be increased accordingly (Annex 14, Aerodromes, 2016). Chapter 9.2.13 states that from January 1, 2015, the recommendations of 9.2.12 shall be mandated. 9.2.14 states that the quantity of foam concentrates shall be in proportion to the quantity of water and the selected foam concentrate (Annex 14, Aerodromes, 2016). Recommendation 9.2.15 suggests that the foam concentration provided on rescue and firefighting vehicles be able to produce at least two loads of foam (Annex 14, Aerodromes, 2016). Recommendation 9.2.16 suggests supplementary water supplies be provided at the scene of the aircraft accident for expeditious replenishment (Annex 14, Aerodromes, 2016). Recommendation 9.2.17 suggests that, for aerodromes providing a combination of different performance level foams, calculations be performed to determine the total amount of water needed for foam production (for each type of foam) and that these quantities be documented for each vehicle and applied to the overall requirement (Annex 14, Aerodromes, 2016). Chapter 9.2.18 mandates that the discharge rate of foam solution shall not be less than that shown in Table 4 and chapter 9.2.19 mandates that all complementary agents shall comply with the appropriate specifications of the International Organization for Standardization (ISO) (Annex 14, Aerodromes, 2016). The remainder of the Extinguishing Agents Chapters (9.2.20-9.2.25) contains ICAO recommendations. Recommendation 9.2.20 suggests the discharge rate of complementary agents be no less than that in Table 4 (Annex 14, Aerodromes, 2016). Recommendation 9.2.21 suggests that dry chemical powders be substituted only with an agent that possesses equivalent or better firefighting capabilities (for all fire types) (Annex 14, Aerodromes, 2016). Recommendation 9.2.22 suggests that a foam concentrate reserve supply (equivalent to 200 percent of the quantities identified in Table 4), be maintained on the aerodrome for replenishment (Annex 14, Aerodromes, 2016). Recommendation 9.2.23 suggests a reserve supply of complementary agent (equivalent to 100 percent of the quantity identified in Table 4), be maintained on the aerodrome for replenishment (propellant gas should be included) (Annex 14, Aerodromes, 2016). Recommendation 9.2.24 suggests category 1 and 2 aerodromes that have replaced water with complementary agents should hold a complementary agent reserve supply of 200 percent (Annex 14, Aerodromes, 2016). Recommendation 9.2.25 suggests that where a significant delay of replenishment supplies is anticipated, the amount of reserve supply in 9.2.22, 9.2.23, and 9.2.24 should be increased as determined by a risk assessment (Annex 14, Aerodromes, 2016).

Table 4. *ICAO Annex 14 Table 9-2 Minimum amounts of usable extinguishing agents*

	Performance Level A Foam		**Performance Level B Foam**		**Performance Level C Foam**		**Complementary Agents**	
Aerodrome Category	Water (L)	Discharge rate foam solution/minute (L)	Water (L)	Discharge rate foam solution/minute (L)	Water (L)	Discharge rate foam solution/minute (L)	Dry chemical powders (kg)	Discharge Rate (kg/second)
1	350	350	230	230	160	160	45	2.25
2	1,000	800	670	550	460	360	90	2.25
3	1,800	1,300	1200	900	820	630	135	2.25
4	3,600	2,600	2,400	1,800	1,700	1,100	135	2.25
5	8,100	4,500	5,400	3,000	3,900	2,200	180	2.25
6	11,800	6,000	7,900	4,000	5,800	2,900	225	2.25
7	18,200	7,900	12,100	5,300	8,800	3,800	225	2.25
8	27,300	10,800	18,200	7,200	12,800	5,100	450	4.5
9	36,400	13,500	24,300	9,000	17,100	6,300	450	4.5
10	48,200	16,600	32,300	11,200	22,800	7,900	450	4.5

ICAO Rescue Equipment and Response Time. Chapter 9.2.26 of Annex 14 (2016) recommends that rescue equipment corresponding to the appropriate level of aircraft operations should be provided on the rescue and firefighting vehicle(s). Chapter 9.2.27 of Annex 14 (2016) mandates that the operational objective of an emergency response shall be to accomplish a response time under three minutes to any point of the operating runway while in optimum visibility and surface conditions. ICAO also specifies two recommendations concerning the response time of emergency rescue and firefighting services. 9.2.28 recommends that the operational objective be no more than two minutes to any point of each operating runway in optimum visibility and surface conditions (Annex 14, Aerodromes, 2016). 9.2.29 suggests that the response time should also not be more than three minutes to any other part of the movement area, in optimum visibility and surface conditions (Annex 14, Aerodromes, 2016). Annex 14 (2016) defines *optimum visibility and surface conditions* as “daytime, good visibility, no precipitation with normal response route free of contamination, e.g., water, ice, or snow.” Annex 14 (2016) also defines *response time* as “the time between the initial call to the rescue and firefighting service, and the time when the first responding vehicles(s) is (are) in position to apply foam at a rate of at least 50 percent of the discharge specified in Table 9-2” (See Table 4). Recommendation 9.2.30 of Annex 14 (2016) suggests providing suitable guidance, equipment, and/or rescue and firefighting procedures when attempting to meet the operational objective in less than optimum visibility conditions. Chapter 9.2.31 mandates that any rescue and firefighting vehicle, other than the first to respond, that is required to deliver extinguishing agent shall ensure continuous agent application and shall arrive at the emergency location in under four minutes from the initial call, however, recommendation 9.2.32 of Annex 14 suggests keeping the response time three minutes and under from the initial call (Annex 14, Aerodromes, 2016). Lastly, recommendation 9.2.33 advises on establishing a preventative maintenance system for rescue and firefighting vehicles to ensure their effectiveness and compliance with response time standards throughout the life of the vehicle (Annex 14, Aerodromes, 2016).

ICAO Emergency Access Roads. Chapter 9.2.34-.36 of Annex 14 (2016) provides three recommendations pertaining to emergency access roads. Recommendation 9.2.34 indicates that emergency access roads should be provided to facilitate minimum response time, and special care should be taken in the establishment of access to approach areas (up to 1,000 meters from the threshold) or at a minimum within the airport boundary (Annex 14, Aerodromes, 2016). Efficient access to outside areas should be considered when a fence line is concerned. Recommendation 9.2.35 specifies that access roads should be capable of supporting the heaviest vehicle, be useable in all weather conditions, maintain sufficient overhead clearance, and should be maintained to prevent erosion within 90 meters of a runway (Annex 14, Aerodromes, 2016).

Recommendation 9.2.36 suggests that when the surface of an emergency access road is indistinguishable or obscured by snow, edge markers should be installed to be visible every 10 meters (Annex 14, Aerodromes, 2016).

ICAO Fire Station. Chapter 9.2.37-.38 of Annex 14 contains recommendations for aerodrome fire stations. Recommendation 9.2.37 advises that all rescue and firefighting vehicles be stored in a fire station and that satellite stations be provided when the minimum response time cannot be achieved from the main station (Annex 14, Aerodromes, 2016). Recommendation 9.2.38 suggests that the fire station should be located on aerodrome property so that the rescue and firefighting personnel can maneuver the vehicles on a clear and direct route to the runway requiring the minimum number of turns possible (Annex 14, Aerodromes, 2016).

ICAO Communication and Alerting Systems. Chapter 9.2.39-.40 of Annex 14 contains two *recommendations* pertaining to communication and alerting systems between onsite aerodrome fire stations and the respective control tower. The recommendation of 9.2.39 suggests ensuring a discrete communication system linking a fire station (and any other fire stations on the aerodrome) with the control tower and the rescue and firefighting vehicles (Annex 14, Aerodromes, 2016). The recommendation of 9.2.40 advises installing an alerting system for rescue and firefighting personnel, which should be operable from a station (Annex 14, Aerodromes, 2016). This system should be installed in all stations on the aerodrome and the control tower.

ICAO Number of Rescue and Firefighting Vehicles. Chapter 9.2.41 of Annex 14 describes the *recommended* minimum number of rescue and fire fighting vehicles at an aerodrome (Annex 14, Aerodromes, 2016). ICAO recommends that aerodromes categorized 1-5 at minimum have one vehicle. Aerodromes categorized 6 and 7 at a minimum shall have two vehicles, and aerodromes categorized 8-10 shall have at minimum three vehicles (Annex 14, Aerodromes, 2016). These recommendations are also reflected in Table 5.

Table 5. *International Civil Aviation Organization Annex 14 Number of Rescue and Fire Fighting Vehicles*

Aerodrome Category	Rescue and Firefighting Vehicles
1	1
2	1
3	1
4	1
5	1
6	2
7	2
8	3
9	3
10	3

ICAO Personnel. Chapter 9.2.42 of Annex 14 (2016) mandates that all rescue and firefighting personnel shall be adequately trained in performing their duties efficiently and shall participate in live-fire drills corresponding to the types of vehicles, equipment, and aircraft in use at the aerodrome (this includes *pressure-fed fuel fires*). Chapter 9.2.43 regulates that the rescue and firefighting training program must include specific training in human performance and team coordination (Annex 14, Aerodromes, 2016). Recommendation 9.2.44 suggests that sufficiently trained and competent personnel be designated to ride rescue and firefight vehicles and operate the equipment at maximum capacity (Annex 14, Aerodromes, 2016). This recommendation also states that personnel should be deployed to ensure minimum response time and that the fire agent can be administered at an appropriate rate. Consideration of personnel using hand lines, ladders, and other equipment should be given. Recommendation 9.2.45 suggests that a task resource analysis be considered in determining the minimum number of personnel required for rescue and firefighting operations and that the level of staffing be documented in the Aerodrome Manual (Annex 14, Aerodromes, 2016). The final chapter of personnel, 9.2.46, states that all responding rescue and firefighting personnel shall be provided with personal protective equipment (PPE), enabling them to perform their duties effectively (Annex 14, Aerodromes, 2016).

NFPA Standards

The National Fire Protection Association (NFPA) is a nonprofit organization that was first established in 1896 (National Fire Protection Association, n.d.). The association is “devoted to eliminating death, injury property, and economic loss due to fire, electrical and related hazards (National Fire Protection Association, n.d.). The NFPA provides both informative and knowledgeable topics in the form of 300 consensus codes and standards, which include topics relating to aircraft rescue and firefighting operations. Some NFPA standards that relate to airports, aircraft, or ARFF operations include 402, 403, 405, 407, 408, 409, 410, 412 414, 415, 424, 1003. For the purposes of this research, NFPA 403 will be reviewed. Specific chapters of NFPA 403 that pertain to this topic include chapters 4, 5, 6. and 9.

NFPA 403 Chapter 4 (2018 edition). Chapter 4 of the National Fire Protection Association Code 403 discusses the Organization of ARFF Services. Chapter 4.1 of NFPA 403 (2018) discusses the administrative responsibilities and states that the airport management should be responsible for the provisions of the ARFF services. Additionally, mutual aid should be prearranged between on-airport services and any off-airport firefighting services serving the airport (NFPA 403, 2018).

Chapter 4.2 discusses the emergency preparedness of ARFF operations. According to chapter 4.2, airports should develop a risk management plan for fire emergency scene strategy and should also prepare and maintain an airport and community emergency plan to assign duties and responsibilities to cope with a significant aircraft emergency and other potential emergencies that may require ARFF services (NFPA 403, 2018). These plans should be tested in a tabletop training method every one year and a full-scale exercise at a minimum every three years. Airport management and resource agencies should participate in the tabletop training in which their duties and responsibilities are exercised, as depicted in the emergency plan (NFPA 403, 2018). Chapter 4.3 discusses the airport categorization for ARFF services. Chapter 4.3.1 states that the authority having jurisdiction should determine the level of protection, which is based on the largest aircraft scheduled into the airport (NFPA 403, 2018). Airports are to be categorized for ARFF services according to the dimension outlined in Table 6. Chapter 4.3.2 states that the airport category should be based on the overall length of the aircraft or the width of the aircraft's fuselage (NFPA 403, 2018). Chapter 4.3.3 mandates that if, after selecting the appropriate category corresponding to the aircraft's overall length, the aircraft's fuselage width is greater than the maximum width outlined in Table 6, then the category should be the next higher (NFPA 403, 2018).

Table 6. *NFPA Airport Category (by overall length and fuselage width)*

	Overall Length of Aircraft (up to but not including)		Maximum Exterior Width (up to but not including)	
Airport Category (U.S.)	feet	meters	feet	meters
1	30	9	6.6	2
2	39	12	6.6	2
3	59	18	9.8	3
4	78	24	13.0	4
5	90	28	13.0	4
6	126	39	16.4	5
7	160	49	16.4	5
8	200	61	23.0	7
9	250	76	23.0	7
10	295	90	25.0	8

NFPA 403, Chapter 5. Chapter 5 of the National Fire Protection Association Code 403 mandates the use of extinguishing agents by ARFF services. Chapter 5.1 discusses the use of primary agents. 5.1.1 states that in fighting aircraft fires involving hydrocarbon fuels, one or more of the following primary agents should be used: a.) aqueous film-forming foams (AFFF), b.) fluoroprotein foam (FP) or film-forming fluoroprotein foam (FFFP), c.) protein foam (P), or d.) fluorine-free synthetic foam (NFPA 403, 2018). Chapter 5.1.2.1 dictates that any primary agent which issued at the minimum quantities and the minimum discharge rates shall also meet the applicable fire extinguishment and burnback performance requirements (NFPA 403, 2018). Chapter 5.2 of NFPA Code 403 (2018) discusses the complementary agents. All ARFF vehicles that respond to an alarm should carry at least one of the two listed complementary agents: a.) potassium-based dry chemical, or b.) halogenated agent.

The quantity of extinguishing agents is discussed in Chapter 5.3 and is outlined in Table 7. Chapter 5.3.1 states that the minimum quantity of water for foam production is based on the

NFPA airport category table and is outlined here in Table 7 (NFPA 403, 2018). Chapter 5.3.2 mandates, “sufficient foam concentrate should be provided on each vehicle to proportion, at the prescribed percentage of foam concentrate to water, into double the quantity of water specified in Table 7 at the maximum tolerance specified in NFPA 412” (NFPA 403, 2018). Chapter 5.3.3 discusses the airport’s needs regarding extinguishing agents. Each airport should conduct and document a needs assessment in order to determine a minimum of 100 percent water resupply capability within critical ARFF access areas (NFPA 403, 2018). Airports should also ensure that the local arrangements can fulfill that capability.

Chapter 5.4 of NFPA Code 403 discusses the chemical compatibility of agents. It is essential to ensure that the primary foam agents and the complementary agents used are chemically compatible, especially when the agents are used simultaneously or consecutively (NFPA 403, 2018). Chapter 5.5 mandates the agents used for combustible metal fires. Extinguishing agents used for these fires should be provided in portable extinguishers rated for Class D fires (NFPA 403, 2018). At least one of these extinguishers of 20 pounds should be carried aboard each vehicle. Agent discharge capabilities are discussed in Chapter 5.6 of the NFPA Code 403. The discharge capability of the agents should be no less than the rates specified in Table 7. These rates should only be met using the ARFF vehicle turrets, except for Category 1 and Category 2 airports, where handline nozzles may be used (NFPA 403, 2018).

Table 7. *NFPA Extinguishing Agents, Discharge, and Response Capabilities (simplified)*

	AFFF		FFFP		Protein Foam		Complementary Agents	
Airport Category	Required Water (gal)	Discharge Capability (gpm)	Required Water (gal)	Discharge Capability (gpm)	Required Water (gal)	Discharge Capability (gpm)	Quantity (lb)	Discharge (lb/sec)
1	120	120	160	160	180	180	100	5
2	200	157	270	213	300	236	200	5
3	670	285	810	392	870	438	300	5
4	1,340	468	1,620	646	1,730	715	300	5
5	2,760	863	3,340	1,194	3,580	1,331	450	5
6	3,740	1,245	4,700	1,725	5,090	1,920	450	5
7	4,880	1,585	6,270	2,192	6,830	2,437	450	5
8	7,780	2,095	9,810	2,901	10,620	3,222	900	10
9	9,570	2,619	12,290	3,626	13,380	4,030	900	10
10	14,260	3,195	17,830	4,424	19,250	4,915	900	10

NFPA 403, Chapter 6. Chapter 6 of the National Fire Protection Association Code 403 discusses the Aircraft Rescue and Fire Fighting Vehicle standards. The NFPA standards for the minimum number of ARFF vehicles are contained in chapter 6.1.1 of Code 403 and are outlined here in Table 8 (NFPA 403, 2018). Table 8, like the ICAO Table 5, does contain some differences. According to chapter 6.1.3, "consideration shall be given to the provision of an additional vehicle or vehicles in order that minimum requirements are maintained during periods when a vehicle is out of service." Chapter 6.1.4 states that all ARFF vehicles that produce foam are to be tested annually in accordance with NFPA 412 and chapter 6.1.5 states that the equipment which delivers the complementary extinguishing agent shall also be tested annually.

Table 8. *National Fire Protection Association (NFPA) Minimum Number of ARFF Vehicles*

Airport Category	Number of Vehicles
1	1
2	1
3	1
4	1
5	2
6	2
7	2
8	3
9	4
10	4

NFPA 403, Chapter 9. Chapter 9 of the National Fire Protection Association Code 403 dictates the standards for airport fire station location and response capability. Chapters 9.1.1 and 9.1.2 state that ARFF vehicles should be stationed at one or more strategic location around the airport to meet the response criteria, and that emergency equipment should be immediately and directly accessible and should be capable of reaching all points of the rapid response areas (RRA) in the required time. Because of these requirements, Chapter 9.1.2 also dictates that the location of the fire station based on the airport should be strategically positioned to minimize response time.

Chapter 9.1.3 of NFPA Code 403 states the standards for response time. Chapter 9.1.3.1-.3 specifically mandates the response times for the first responding ARFF vehicles. 9.1.3.1 states that the response time of the first ARFF vehicle to arrive at any point of the operational runway and to begin applying a fire agent should be accomplished within 3 minutes of the time of the alarm. 9.1.3.2 states that the response time of the first ARFF vehicle to arrive at any point remaining within the on-airport portion of the RRA, with improved surface conditions, should be accomplished within 4 minutes from the time of the alarm. 9.1.3.3 states that the response time of the first ARFF vehicle to arrive at any passenger boarding areas, with improved surface conditions, shall be within 4 minutes from the time of the alarm. Chapter 9.1.3.4 states that the response times mandated in chapters 9.1.3.1-.3 shall be considered to be performed in optimum visibility and surface conditions. While the previous 9.1 chapters specify responses to the runway or the RRA, chapter 9.1.4 specifies that ARFF services should develop and implement a plan for responding to accidents and incidents involving aircraft carrying passengers that are within the aircraft movement area but beyond or outside the runway and the RRA.

Chapter 3: Research Methodology

Introduction and Research Technique

To provide a thorough analysis of the aircraft rescue and firefighting capabilities at United States airports and the associated regulations governing the emergency response, this researcher determined that a qualitative research approach is most appropriate. Qualitative research, at its core, examines the way people make sense out of their own experiences (Cropley, 2019). Qualitative research comes in a variety of different forms, but the forms determined most suitable for this study involve historical and case study research.

Historical Research.

Considering the extensive quantities of several governing body's regulations and the variety of historical events where aircraft rescue and firefighting challenges have played a significant part in the overall success of the rescue, a historical research technique was determined to be the best to represent this study. Historical research is defined as going beyond simple data gathering in order to "analyze and develop theoretical and holistic conclusions about historical events and periods… [and] includes a critical examination of sources, interpretation of data, and analysis that focuses on the narrative, interpretation, and use of valid and reliable evidence that supports the study conclusions" (Lundy, 2012).

Case Study Research.

Historical research can take a variety of different forms, specific to the research being conducted and the availability of data and resources to the researcher (Lundy, 2012). For the purposes of this study, the type of historical research technique chosen is case study research. Case study research is described as "[shedding] light on a phenomenon through an in-depth examination of a single case exemplar of a phenomenon" (Lundy, 2012). Case studies can take a variety of different forms, including an individual person, an event, a group, or an even an institution and rely on a relatively small sub-sample of research subjects to produce an in-depth source of qualitative information (Lundy, 2012).

Research Perspective

For the research being performed in this study, this researcher acknowledges that parties involved or affected by aircraft rescue and firefighting (including the regulations and capabilities) may all have different perspectives and opinions on the matter. To accommodate the various bits of knowledge and ideas, all of which may have some truth, this study takes an interpretivism perspective. Interpretivism, according to Hurworth (2011), is a research paradigm that is “based on a philosophical framework that promotes plural perspectives in evaluations relying on qualitative approaches.” Essentially, interpretivism takes the stance that reality is filled with multiple meanings, interpretations, and emotions, and as such, the goal is to “provide an understanding of direct lived experience” (Hurworth, 2011). The interpretivism paradigm is typically categorized as subjective, with open dialog and rich content (Hurworth, 2011). The interpretivism paradigm allows this study to consider various perspectives expressed in the literature examined in Chapter 2 and consider those perspectives both independently and collectively with the perspectives of this researcher.

Research Cases (Units of Analysis)

Miles and Huberman (1994) define a case as “a phenomenon of some sort occurring in a bounded context.” In this study, the individual cases under review effectively represent the *unit of analyses.* These units, or cases, become the basis for which the findings and results will be built upon. The individual cases used in this study focus on two specific aviation accidents in recent American history where aircraft rescue and firefighting capabilities and regulations have played a significant role in the success or failure of the rescue. Each of these cases will be thoroughly examined in *Chapter 4. Case Analysis*. The analysis of the cases primarily focuses on analyzing and evaluating the challenges and issues that arose during the ARFF operations as they were being conducted and the relation of such challenges to the governing regulations. The goal of the case analysis is to discover if any instance arose where the regulations fell short of contributing sufficient oversight to the ARFF operations or sufficient protection to the occupants of the aircraft.

Sources of Data

Data sources for this study will primarily be qualitative in nature and will be gathered through analyzing and reviewing various documentation, including archival and historical records of the accidents studied and various research involving the governing standards and regulations. Regulatory and standardization data is primarily provided through three organizations discussed in the literature review: The Federal Aviation Administration, the International Civil Aviation Organization, and the National Fire Protection Association. Other sources of documentation are primarily centered around the cases analyzed. Such documents and historical records include accident records, supplemental reports from the National Transportation Safety Board (NTSB), and airport documentation, including emergency planning and ARFF documents.

Data Collection and Analysis

Before data analysis can take place, date collection must first ensue. This study primarily utilizes document review for its data collection method as document review was determined to be the most expedient and comprehensive method available to the research. The documents under review include regulatory documents, research documents, and historical records. These records provide a wealth of factual knowledge that allow for the collection of rich qualitative data most suitable for this case study.

Merriam and Tisdell (2016) define data analysis as “the process of making sense out of the data…[involving] consolidating, reducing, and interpreting what people have said and what the researcher has seen and read- it is the process of making meaning.” This study’s data analysis procedures chiefly consist of examining, organizing, and categorizing documents containing both qualitative and quantitative data while exploiting *categorical aggregation* and *direct interpretation* in order to discover emerging themes that will ultimately address this researcher’s initial propositions. Categorical aggregation and direct interpretation are two techniques first originating from Robert Stake (1995), which involve seeking out an assortment of themes from the data to produce relevant and new meanings about the cases being examined. Additionally, this research utilizes a cross-case analysis approach to examine similarities and common themes among the two cases in order to discover if there are any instances where governing regulations were deficient in both scenarios.

Research Propositions

The literature review in Chapter 2 has indicated how, over time, the need for regulatory changes periodically arises. We have reached a point where the ARFF related regulations established in the past have not been updated or improved for nearly 11 years, and the fast-paced industry that is aviation has quickly outgrown them. As aviation technology and capabilities rapidly evolve, the regulations which govern and protect the industry and its people must also do so. The regulations that are currently governing ARFF operations at airports within the United States are not only outdated but also, in some instances, irrelevant. Many of the regulations leave too much open to interpretation and enable the escape from sufficient oversight, creating voids that are often only noticed once an accident occurs. The standards governing ARFF operations need to be renovated significantly to keep up with modern times in order to protect both crew and passengers alike.

Research Design

The design of this study involves a cross-case analysis approach in which two accident cases are first to be analyzed separately in individual case studies. After the initial analysis, the cases were examined together to identify any trends or commonalities between the two. The conceptual framework which guided and inspired the strategy for this study is further explained below and represented in Figure 1.

Conceptual Framework

The conceptual framework this research is centered around follows that which is depicted in Figure 1. The framework, designed by COSMOS Corporation, is referenced by Robert Yin (1994) in *Case Study Research Design and Methods,* as a conceptual framework for conducting a multiple case study research project. This framework is ideal for this type of historical case study as it can be molded to incorporate each aviation accident while allowing for the reporting and analysis of each individually and finally the cross-analysis between the two cases.

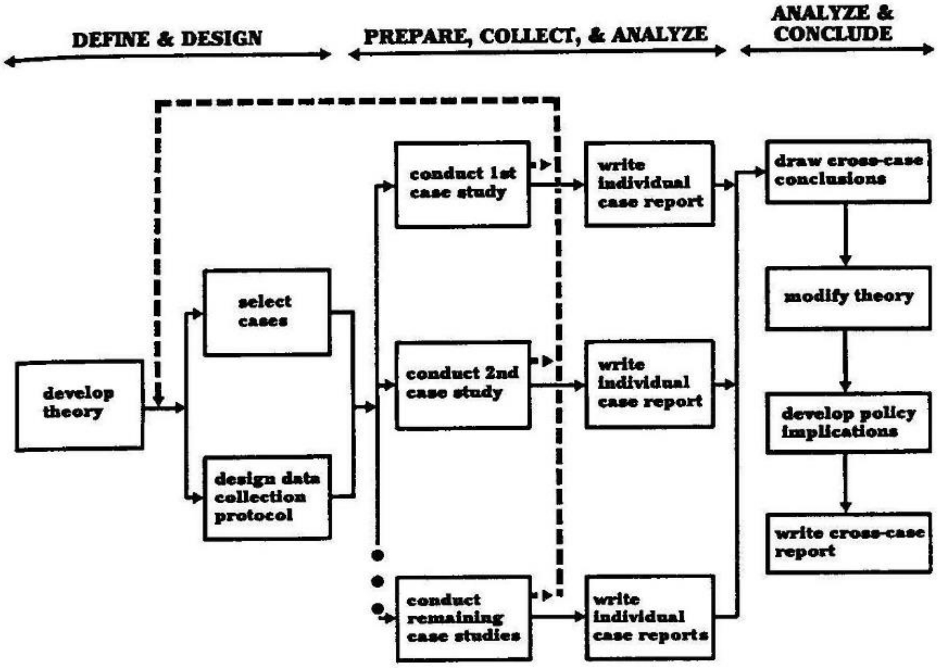


Figure 1. Case study method conceptual framework. From *Case Study Research: Design and Methods*. pp. 49. by Yin, R. K., 1994. Thousand Oaks, CA: Sage.

Research Binding/Limitations

Research binding is the process of determining what a research study will not be after determining precisely what it will include (Baxter and Jack, 2008). Prior case study researchers and pioneers, Yin (2003) and Stake (1995) have suggested reigning in your study and placing boundaries on the cases being studied in order to prevent too broad of a research topic. In order to ensure this study remains within scope, the cases chosen were done so by binding the available options to context, time, and location. For example, binding by context first narrowed accident cases by eliminating all accident cases where ARFF operations did not play a significant role. Next, the remaining available cases were then bound with location and time constraints eliminating all cases which occurred outside of the United States and those that were greater than ten years old.

Chapter 4: Case Analysis

Gulfstream Accident, Bedford Massachusetts, May 31, 2014

History of the Accident

On May 31, 2014, a Gulfstream G-IV aircraft operated by Arizin Ventures, LLC, attempted a takeoff from Laurence G. Hanscom Field (KBED) in Bedford, Massachusetts, destined for Atlantic City International Airport (KACY) in Atlantic City, New Jersey. The pilots of N121JM rejected the takeoff, and the aircraft overran the end of runway 11, during which time the aircraft passed beyond the paved overrun area, across the grass-covered area where it collided with the airport's approach light system and a localizer antenna. The aircraft then continued to rip through the airport perimeter fence and finally came to rest in a ravine just beyond. All souls aboard the aircraft, which included two pilots, one flight attendant, and four passengers, perished in the accident. The G-IV aircraft was destroyed on impact, and soon after, a post-crash fire erupted.

Figure 2. *N121JM Runway over run showing distance from ALS/localizer to perimeter fence (From NTSB (2014)* Aircraft Accident Report No. AAR-15-03)

Figure 3. *N121JM Runway over run, Aerial image (From NTSB (2014)* Aircraft Accident Report No. AAR-15-03)

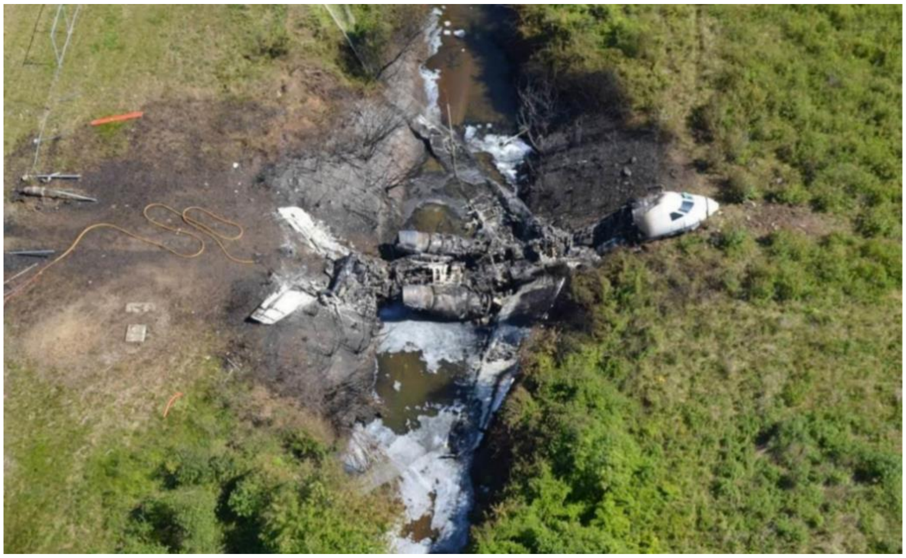


Figure 4. *N121JM wreckage in ravine (From NTSB (2014)* Aircraft Accident Report No. AAR-15-03).

The Airport

KBED is located about 1.5 miles southwest of Bedford, Massachusetts, and is owned and operated by Massachusetts Port Authority (Massport). The airport is certified under 14 *CFR* 139 and has Index B aircraft rescue and firefighting capabilities. The airport is a joint-use airport located adjacent to the Hanscom Air Force Base (AFB). The Hanscom AFB Fire Department was under a contract at the time of the accident to provide aircraft rescue and firefighting services. According to the National Transportation Safety Board (NTSB, 2014), the contract between Massport and the Department of Defense (DoD) stated that the ARFF services provided by Hanscom AFB-FD "shall at all times meet the standards prescribed by [14 *CFR*] Part 139 and FAA certification alerts and advisories, as applicable to BED as an Index B airport."

Prior to the accident, KBED underwent its annual airport certification inspection on March 25 to 27, 2014. The certification inspector was provided with a copy of the March 20, 2014 memorandum which stated that Hanscom AFB-FD met the "requirements for all ARFF in accordance with DoD I[nstruction] 6055.06, Fire & Emergency Services Program" and documentation was provided to "substantiate ARFF training and vehicle response capability." This documentation included an ARFF operations checklist, vehicle reports, and a personnel training summary. Additionally, this memorandum stated that between the time of January 1, 2014, and March 21, 2014, the Hanscom AFB-FD responded to two ARFF emergencies during which the average response time of "less than 3 minutes and 100% compliance with DoD requirements" was achieved (National Transportation Safety Board).

The Aircraft

The aircraft involved in the accident was a Gulfstream Aerospace Corporation G-IV that was manufactured on January 27, 2000, with the registration number N121JM (National Transportation Safety Board, 2014). According to the National Transportation Safety Board (2014), the accident aircraft, equipped with two Rolls Royce Tay 611-8 engines, had approximately 4,945 total hours and about 2,745 flight cycles.

The Gust Lock System

An important component that was installed on the G-IV aircraft, which played a significant role in the accident sequence was the gust lock system. The gust lock system protects the aircraft from gusting wind conditions while parked by restricting the throttles and locking the flight control surfaces, which include the ailerons, elevators, and rudders (National Transportation Safety Board, 2014). Essentially, the gust lock system is a mechanical system with an actuating lever located in the cockpit. When the lock is in the ON position, the lever is facing upright in the cockpit, as shown in Figure 4. When the pilot disengages the gust lock, the actuating lever is pushed forward toward the instrument panel and down, releasing the gust lock hooks and unlocking the flight control surfaces. In order to move the handle out of either position, a spring latch operated by the actuating lever must be first unlocked (National Transportation Safety Board, 2014).

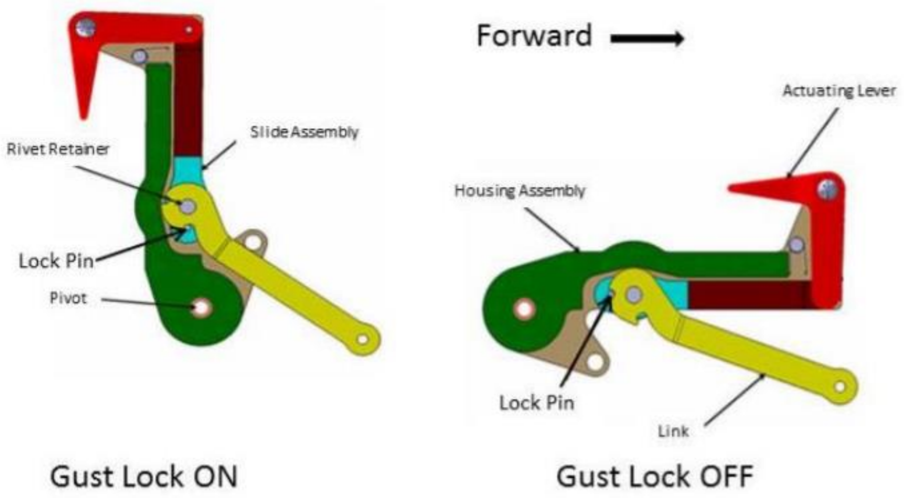


Figure 5. *N121JM Gust Lock lever (From NTSB (2014)* Aircraft Accident Report No. AAR-15-03).

Aircraft Seats and Emergency Exits

The Gulfstream G-IV was configured to seat two pilots and one cockpit observer. Additionally, there were eight passenger seats and two, triple-passenger settees. The aircraft had six exits in total: Four emergency exits were positioned over the wings, one main entry door was located on the left side of the aircraft aft of the cockpit, and one baggage compartment door was located aft of the left-wing (National Transportation Safety Board, 2014).

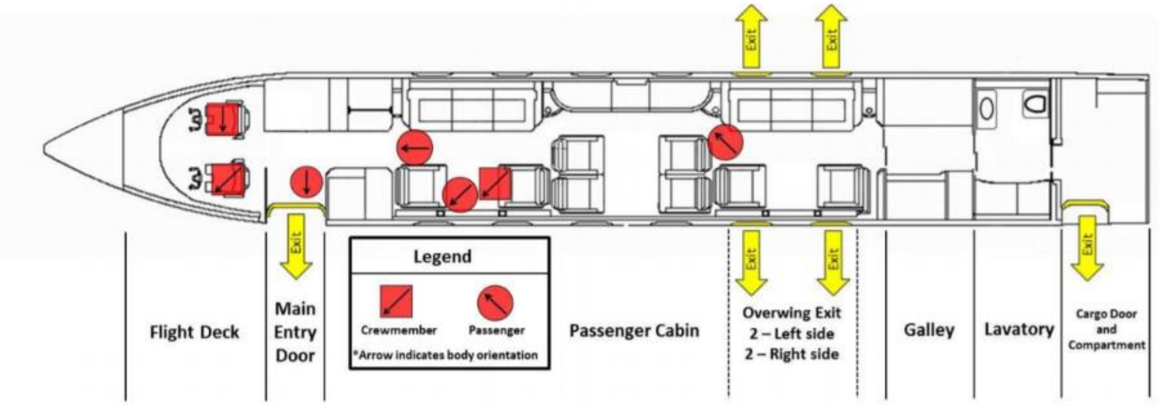


Figure 6. *Diagram of N121JM seating configuration and occupant location/orientation (From NTSB (2014)* Aircraft Accident Report No. AAR-15-03).

Hanscom AFB-FD ARFF Response Vehicles

Because Laurence G. Hanscom Field Airport was a joint-use airport in which the Air Force Base provided ARFF services, an agreement needed to be reached between the Department of Defense and the Federal Aviation Administration regarding the procedures and provisions of ARFF operations. A memorandum discussing such procedures and provisions dated April 3, 2012, stated the military would provide ARFF coverage given that the civil operator “takes credit for that coverage to meet their part 139 ARFF requirements” (Department of Defense, 2012). Additionally, the memorandum stated, “the FAA determined that DoD ARFF standards are equivalent to or exceed Part 139 requirements. The DoD will provide the civil airport operator (certificate holder) a package of standard documents that validate the DOD meets its ARFF standards" (Department of Defense, 2012).

The Hanscom AFB-FD Chief stated, in the National Transportation Safety Board accident report (2014), that seven Hanscom AFB-FD vehicles responded to the accident. The responding vehicles included Crash 9 and Crash 10, Engine 4 and Engine 6, Rescue 3, Tanker 7, and a foam trailer. Of these vehicles, Crash 9 and Crash 10, and Engine 4 and Engine 6, were firefighting vehicles which carried water, dry chemical, and foam. The remaining three vehicles included Rescue 3, a light-duty vehicle, Tanker 7, and a foam trailer that carried water and foam to refill tanks and vehicles.

The Department of Defense (2012) memorandum contained an appendix which detailed the specifics of the ARFF vehicles provided at the time of the accident, however, because the report states "the report may list all assigned ARFF vehicles or only those required to satisfy Part 139 requirements," only the specifics of ARFF vehicles Crash 9, Crash 10, Tanker 7, and the foam trailer are included (Department of Defense, 2012).

ARFF Vehicle Specifics

According to the Department of Defense (2012) memorandum, Crash 9, which was Hanscom AFB-FD's largest firefighting vehicle, was a 2006 Pierce P-23 and was capable of holding 3,300 gallons of water, 500 gallons of AFFF, and 500 pounds of potassium-based dry chemical with the maximum primary turret discharge rate of 1,200 gallons per min (gpm). Crash 10 was a 1985 Oshkosh P-19 and was capable of holding 1,000 gallons of water, 130 gallons of AFFF, and 500 gallons of potassium-based dry chemical with the maximum primary turret discharge rate of 1,000 gallons per min (gpm). (Department of Defense, 2012). Tanker 7 was 1994 International capable of holding 5,000 gallons of water with a primary turret discharge rate of 750 gallons per min (gpm) (Department of Defense, 2012). The memorandum also included some information regarding the foam trailer involved in ARFF operations, which was made in 1993 and had a 1,000 gallons AFFF capacity; however, the manufacturer and model were unlisted (Department of Defense, 2012). Specifications regarding the remaining ARFF vehicles, Engine 4, Engine 6, and Rescue 3, were not included.

Figure 7. *(Left) Variation of Crash 9*

Figure 8. *(Right) Variations of Crash 10*

Figure 9. *(Left) Variation of Engine 4*

Figure 10. *(Right) Variation of Engine 6*

Figure 11. *(Left) Variation of Tanker 7*

Figure 12. *(Right) Variation of Rescue 3*

Emergency Response

According to the National Transportation Safety Board accident report, certain challenges presented between the time of the Alert 3 notification and the time that the scene was finally secured. The initial alarm was sounded at 21:40:23 (EDT), and soon after, Rescue 3 was first to leave the station. At 21:42:56 (EDT), Crash 10, Crash 9, Engine 4, and Engine 6 departed the station, and about 5 minutes later, Crash 9 and Crash 10 had reached the airport side of the ravine together and began fighting the fire. The report stated that at this time, the aircraft was engulfed in flames on both sides of the ravine (National Transportation Safety Board, 2014).

These firefighting activities continued for approximately 25 minutes until about 22:07 EDT when Crash 9 ran out of foam and shut down. About 3 minutes later, (about 30 minutes after the Alert 3 notification) Crash 10 reported running out of water "again" (National Transportation Safety Board, 2014). A critical point to be noted here is that because the crew of Engine 4 and Engine 6 failed to drop a resupply hose at the fire hydrant (about 1,200 feet away from the accident site) on their way to the crash site, a delay of about 14 minutes ensued during which time crews had to return to the hydrant to connect the hose. The report (National Transportation Safety Board, 2014) did conclude, however, that while the delay was critical and it absolutely could have been avoided, in this case, it did not affect the occupant's survivability due to the instantaneous nature of the eruption of a post-crash fire. At 22:24, EDT Crash 9 was resupplied with water and foam, and firefighting operations resumed.

The second challenge test for the ARFF crew arose shortly thereafter. According to the National Transportation Safety Board (NTSB, 2014), confusion began to ensure about how to reach the nose of the aircraft, which lay on the non-airport side of the ravine, in order to place personnel and equipment. It took approximately 48 minutes from the time of the initial alarm for crews to decide to attempt to reach the nose of the aircraft. At 22:44 EDT, Engine 6 indicated they would attempt to reach the aircraft via the Hartwell gate, however, according to the report, the Hartwell gate is the main entrance to the Hanscom Air Force Base, and this gate does not allow access to the east side of the ravine (National Transportation Safety Board, 2014).
Another critical mistake discovered was that the Airport Emergency Plan of KBED provided a grid map of the airport; however, this map did not depict the correct gate that should have been used. Given that the FAA AC (Advisory Circular) 150/5200-31, stated that the grid map should identify locations and terrain features on and around the airport which may be significant to emergency operations and that all ARFF vehicles should carry a copy of this grid map for reference, this issue could have easily been avoided. Had the AEP grid map shown Perimeter Gate 26, ARFF crews would have been able to easily identify the correct gate through which to make a quick attempt to gain access to the correct side of the ravine. The National Transportation Safety Board report (NTSB, 2014) again concluded that had this issue been avoided it still is unlikely to have changed the survivability for the occupants of the aircraft due to the nature of the post-crash fire, however, these critical missteps could very well be more significant and detrimental given a different scenario.

The third issue that ensued began as mutual aid firefighters from Lincoln Fire Department (LFD) arrived on scene and attempted to gain access to the aircraft at the main entry door, which was about 1 hour and 47 minutes after the Alert 3 notification. The LFD firefighters were unable to open the door and requested assistance from Hanscom ABF-FD, who arrived on the east bank of the ravine at 23:41 EDT. About four minutes later, Engine 4 was at the nose of the aircraft attempting to gain access. Entry was finally accomplished at 23:51 EDT, which was 2 hours and 10 minutes after the initial Alert 3 notification. Again, the NTSB concluded that while the actions of the LFD did not affect the survivability of the occupants, their inability to access the aircraft was in direct conflict with the FAA AC 150/2510-17C, which states when mutual aid agreements among municipal fire departments exist, all parties should have familiarization training with aircraft. The fact remains that, while these mistakes may not have changed the outcome of this accident, had any of these challenges presented in a different scenario, a single mistake could have been detrimental.

Probable Cause

The National Transportation Safety Board determined the probable cause of the accident to be the flight crew’s failure to perform the pre-takeoff flight control check resulting in their attempt to take off with the gust lock system engaged, and the delayed takeoff rejection once the crew became aware of the issue (National Transportation Safety Board, 2014).

Case Discussion

While the NTSB conclusions and probable cause are an extremely important aspect of this accident, this research focuses specifically on the ARFF capabilities and response operations at KBED. As mentioned above, the applicable airport index and associated ARFF requirements, as regulated by 14 *CFR* § 139.315 and 139.317, for KBED was determined to be Index B. This index applies to airports accommodating aircraft of at least 90 feet but less than 126 feet. The regulation states that Index B airports must have either, one vehicle carrying at least 500 pounds of sodium-based dry chemical, halon 1211, or clean agent and 1,500 gallons of water and the commensurate quantity of AFFF for foam production, or, two vehicles with one vehicle carrying the extinguishing agents as specified for Index A and another vehicle carrying an amount of water and the commensurate quantity of AFFF. Hence, the total quantity of water for foam production carried by both vehicles is at least 1,500 gallons.

Given that more than 90 feet but less than 126 feet are roughly equivalent to more than 28 meters but less than 39 meters, the comparable ICAO aerodrome category would likely be Category 6. The ICAO requirement for Category 6 aircraft is a minimum of 2 firefighting vehicles. Similarly, the comparable NFPA airport category would be Category 6, which would also require a minimum of 2 vehicles.

Considering that KBED had in total seven responding ARFF vehicles, two of which, Crash 9 and Crash 10, far exceeded the regulatory requirements of 14 *CFR* § 139.315 and 139.317, the airport was seemingly over provided for and well protected. Yet, despite the various mistakes that were made and despite the National Transportation Safety Board’s assurance that these mistakes did not affect survivability, this extraordinarily well equipped joint-use airport was particularly unsuccessful in its attempts to rescue the accident victims. The question to be asked here is why. Why is it that this airport, which had so far exceeded its regulatory obligations, failed to reach and successfully extinguish the post-crash fire in a timely manner, failed to connect a resupply line, failed to breach the aircraft quick enough to rescue any survivors, and failed to access the non-airport side of the crash?

While it may seem the issue here is the ARFF crew's performance, the NTSB has vehemently stated several times that, had those mistakes not been made, the actions resulting in significate delays during the ARFF operations that day would have likely had no change in effect on the survivability of the accident victims. The issue here is not a performance; it is that had the scenario been different and had the airport only been equipped what was regulatorily required of an Index B airport, the outcome would have only been worse. If the scenario had changed just slightly, for instance, a greater delay in the outbreak of the post-crash fire allowing for an increased time period for ARFF crews to respond and rescue the victims, would it have ended as safely if in that same scenario only the minimum response was available?

The uniqueness of this case should not preclude it from analysis. Even though the regulatory requirements likely had no direct impact on the survivability of the accident, it should not be concluded that there are no flaws in the regulations themselves. In this case, had the airport only equipped what was required, the regulations would have likely still failed to protect the survivors just the same.

Figure 13. *Aerial image of N121JM impact, ARFF routes to accident scene (From NTSB (2014)* Aircraft Accident Report No. AAR-15-03).

Asiana Airlines Accident, San Francisco, California, July 6, 2013

History of the Accident

A more prominent accident that occurred just the year prior to the Gulfstream accident in Bedford, Massachusetts, was that of Asiana Airlines Flight 214. On July 6, 2013, Flight 214, a Boeing 777-200ER, which was operating under 14 CFR Part 129, departed Incheon International Airport in Seoul, South Korea, destined for San Francisco International Airport (KSFO) (National Transportation Safety Board, 2013b). According to the National Transportation Safety Board (2013a) accident report, the Boeing 777 was on the final approach to runway 28L at KSFO when at about 200 feet, the flight crew noticed that the airspeed was low. The flight crew allowed the aircraft to continue. It did not initiate a go-around maneuver until the aircraft was well below 100 feet, and because the aircraft at this point did not have the necessary performance to successfully execute the maneuver, the main landing gear and the aft fuselage collided with the seawall (National Transportation Safety Board 2013b). At this point, the tail portion broke off at the aft pressure bulkhead, and the aircraft continued to slide along the runway, became partially airborne, spun 330 degrees, and then impacted the ground a final time (National Transportation Safety Board, 2013b). The aircraft was destroyed in the accident by impact forces. When, after it came to a rest, a fire broke out within the separated right engine and spread to the fuselage (National Transportation Safety Board, 2013b). According to the National Transportation Safety Board (2013a) accident report, there were 291 passengers aboard the aircraft, three of which were fatally injured, as well as 12 cabin crew members, and four flight crew members.

The Airport

KSFO, located about 13 miles south of downtown San Francisco, is managed by both the City and County of San Francisco and is served by four paved runways: two parallel runways oriented east/west and two parallel runways oriented north/south (National Transportation Safety Board, 2013a). The airport was certified as a 14 CFR Part 139 airport with Index E firefighting capabilities (National Transportation Safety Board, 2013a). According to the accident report (National Transportation Safety Board, 2013a), at the time of the accident, KSFO had three San Francisco Fire Department-Airport Bureau (SFFD-AB) fire stations on airport property, all were solely dedicated to providing aircraft rescue and firefighting services continuously, and were staffed with a minimum of 23 firefighters and paramedic personnel. It is important to note here that at the time of the accident, 14 CFR Part 139 did not address a minimum ARFF staffing requirement (National Transportation Safety Board, 2013a). Since the regulations have not been changed or updated since then, Part 139 continues to not address a minimum staffing requirement.

The Aircraft

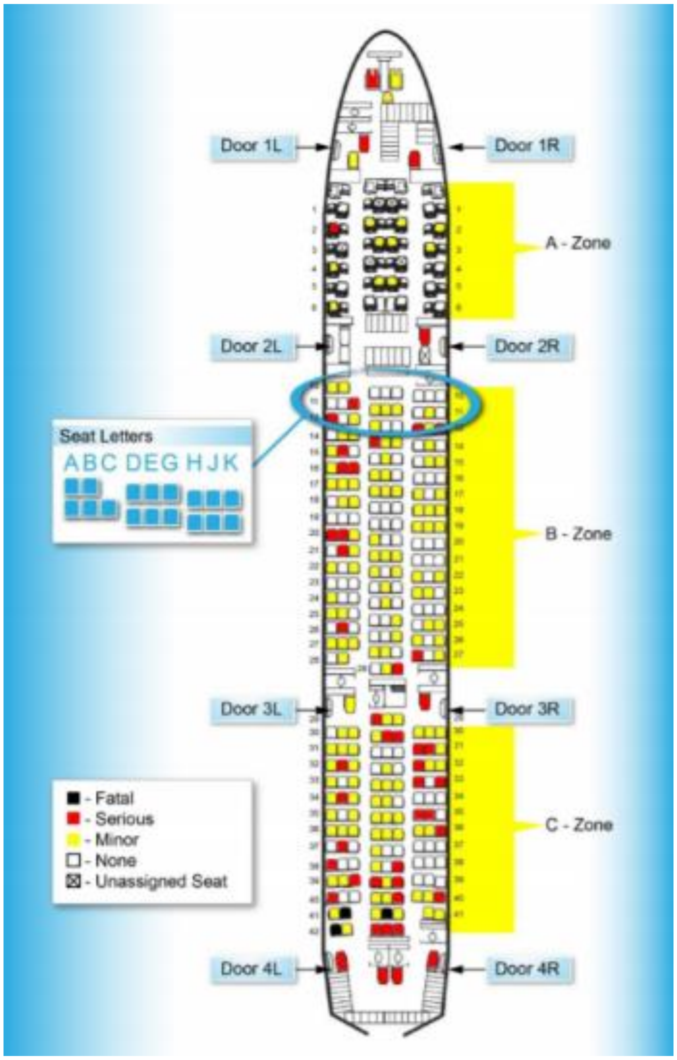
The aircraft involved in the accident was a Boeing 777-200ER that was manufactured complete on February 6, 2006, with the registration number HL7742 (National Transportation Safety Board, 2013a). According to the National Transportation Safety Board (2013a) accident report, the accident aircraft was equipped with two Pratt and Whitney PW4090 turbofan engines and had accumulated about 37,120 total hours and 5,388 total cycles. The most recent scheduled maintenance had occurred on June 28, 2013, just eight days prior to the accident, when the aircraft had accumulated 36,992 total hours.

Aircraft Seats

The Boeing 777-200ER was configured to hold 295 passenger seats, two crew seats and two observer seats in the flight deck, and 13 retractable jump seats for flight attendants (National Transportation Safety Board, 2013a). The primary flight crew consisted of a trainee captain and an instructor pilot (IP) while the relief flight crew consisted of a second captain and a first officer (FO). The trainee captain was occupying the left seat and was considered the pilot flying (PF) for the takeoff and landing sequences, while the instructor pilot was occupying the right seat as the pilot monitoring (PM), which is indicated in Figure 14. According to the accident report, the relief captain and the first officer occupied seats in the cabin for takeoff and during the initial part of the flight until about 4 hours and 15 minutes had elapsed during which time they moved forward to relieve the primary crew for the following 5 hours and 15 minutes. This allowed the primary crew time to rest in the cabin until they resumed the remainder of the flight for the landing sequence. At some point, the relief first officer returned to the flight deck to occupy the center observer jumpseat for the approach and landing sequence into KSFO.

The 12 cabin crew members were stationed at L1A (cabin manager), L1B, R1, L1A, L1B, R2A (R2B was unoccupied), L3, R3, L4, R4, and M4A and M4B (two aft-facing jumpseats located in the aft galley). Of the 295 configured seats, there were 291 passengers aboard. According to the accident report, all the passenger seats were assigned with the exception of 5 seats located in the A-Zone section (business class). There does appear to be a discrepancy; however, between the accident report and the diagram, Figure 13, provided by the NTSB. The report indicated that there were 21 passengers occupying seats in the A-Zone section; however, it is possible this discrepancy is accounting for the two relief pilots even though one was seated in the observer jumpseat.

One last important aspect to note is that the NTSB discovered that some passengers were known to have changed seats during the course of the flight. One specific passenger, 41B, was known to have been sitting in seat 41D during the landing sequence (National Transportation Safety Board, 2013a).



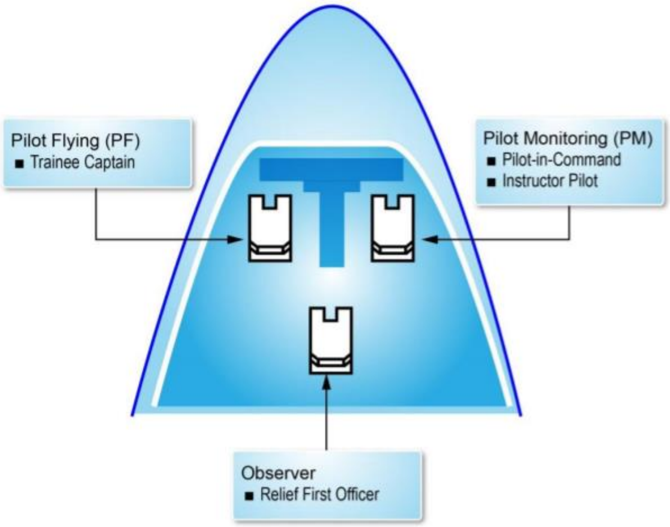


Figure 14. *(Left) Flight 214 cabin configuration, injury classification and seat assignments. Source NTSB*

Figure 15. *(Right) Flight deck seat configuration. Source NTSB*

Evacuation Process

The Boeing 777-200ER was equipped with eight doors serving as emergency exits (1-4 Left, and 1-4 Right). Each door was equipped with an observation window and an automatically inflating evacuation slide. The accident report stated that doors 1 left and 2 left were both initially operational and used in the evacuation process, though the slide pertaining to door 1 left was later punctured by rescue personnel (National Transportation Safety Board 13a). This was confirmed by airport video footage that was reviewed by investigators, which showed evacuations beginning out of door one left and 2 left about 1minute and 33 seconds after the aircraft came to a stop (National Transportation Safety Board 13a). This confirmed that doors 1 left and 2 left were operational for at least part of the evacuation sequence.

Flight attendants, R1 and R2A, that were seated adjacent to door 1 right and door 2 right reported to investigators that on the second impact the slides pertaining to door 1 right and door 2 right, were dislodged and became inflated inside the cabin pinning them into their respective seats (National Transportation Safety Board, 2013a). This was confirmed by investigators who discovered that door one right was open; however, the slide was found deployed and deflated inside the aircraft. Door 2 Right, however, was closed and exhibited fire damage but also had a slide deployed and deflated inside the aircraft. As a result, neither doors were operational in the evacuation process.

Flight attendant L3, who was stationed at door 3 left, indicated that she attempted to open door 3 left after regaining consciousness, however it was jammed, and she could not do so. The accident report stated that door 3 left remained closed for the entire duration of the evacuation process, but it was later opened from the inside by an emergency responder. Video footage shows the slide falling to the ground but not inflating. Flight attendant L3 reported seeing light emitting from the direction of door three right, and this was further confirmed to investigators by Passenger 30K, who reported that he quickly opened door three right; however, the slide had only partially deployed and was not inflated. The flight attendant stationed at door 3 Right was severely injured and subsequently unable to assist in directing evacuation as she was carried out by other passengers.

Door 4 Left was found to be detached from the aircraft lying some distance away, however the slide was found to be lying inside the aircraft. The National Transportation Safety Board (2013a) accident report indicated that the slides aspirators had ingested towels and blankets preventing its inflation, which was consistent with the slide attempting inflation during the impact sequence. Lastly, door 4 right was found to be in the open position, however the slide's girt was torn at the bar rendering the slide useless. In summary, the accident report concluded that the evacuation process was accomplished by only 5 of the 12 flight attendants utilizing only 3 of the 8 doors (1L, 2L, and 3R) (National Transportation Safety Board, 2013a).

Figure 16. *Right side of Flight 214 from the 3 o'clock position depicting doors 1R, 2R, 3R, 4R. Source, NTSB*

Image 17. *Left side of Flight 214 from the 9 o'clock position depicting doors 1L, 2L, 3L, 4L.*

Source NTSB

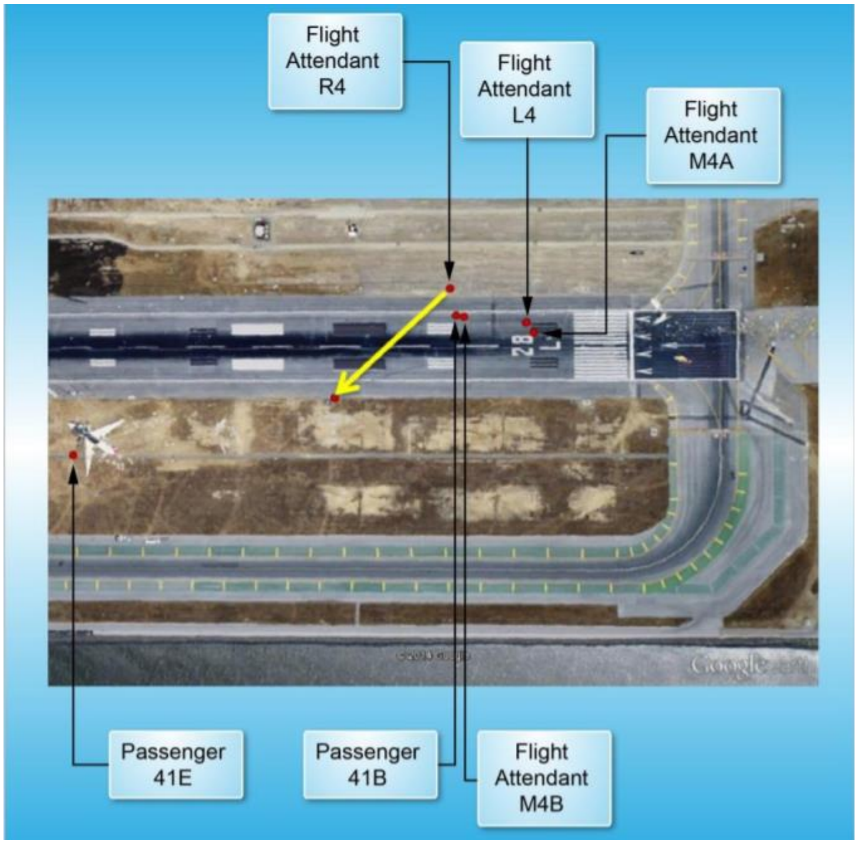


Image 18. *Aerial image of Flight 214 accident scene and ejected passengers. Source NTSB*

KSFO ARFF Response Vehicles

Because KSFO was certified with Index E capabilities, the airport would have been required to have at minimum 3 ARFF vehicles. 14 CFR 139.317 (table 2.) requires Index E airports to have at minimum one vehicle carrying either (a) 500 lbs of sodium-based dry chemical, halon 1211, or clean agent or (b) 450 lbs of potassium-based dry chemical and water with an equal quantity of aqueous film-forming foam (AFFF) to total 100 gallons for simultaneous dry chemical and AFFF application. The other two vehicles must carry an amount of water and the commensurate quantity of AFFF such that the total quantity of water for foam production carried by all three vehicles is at least 6,000 gallons.

According to the National Transportation Safety Board (2013a), SFFD-AB far exceeded this regulatory requirement with seven vehicles in total: four ARFF vehicles, Rescue 9, Rescue 10, and Rescue 11, and three structural firefighting vehicles; Rescue 44, Engine 33, and Engine 56. In addition to the seven vehicles, SFFD also maintained three reserve ARFF vehicles; Rescue 34, Rescue 37, and Rescue 49. There were also two SFFD medical vehicles, rescue 91 and Rescue 93, each was staffed with a driver/emergent medical technician and a paramedic (National Transportation Safety Board, 2013a).

ARFF Vehicle Specifics

Three of the SFFD ARFF vehicles were Oshkosh Striker 4500’s (Figures 18 and 19), each with the capacity of 4,500 gallons of water, 630 gallons of foam, 460 pounds of dry chemical, and 500 pounds of Halotron, and each striker is staffed with two firefighters (National Transportation Safety Board, 2013a). Rescue 9 and Rescue 10 were both equipped with 65-ft high-reach extendable turrets (HRET) with piercing nozzles (Figure 21). The fourth ARFF vehicle (Figure 20), Rescue 88, was an Oshkosh T3000, which had the capacity of 3,000 gallons of water, 420 gallons of foam, and 460 pounds of dry chemical, and it was staffed with two firefighters and one lieutenant.

Figure 19. *Oshkosh Striker 4500 (Rescue 11) Exhibit Photos. Source, Oshkosh Corporation*

Figure 20. *Oshkosh Striker 4500 (Rescue 9) Exhibit Photos. Equipped with the high-reach extendable turret (HRET) and piercing nozzle. Source, Oshkosh Corporation.*

Figure 21. *Oshkosh T3000 variant, Exhibit Photos. Source, Oshkosh Corporation*

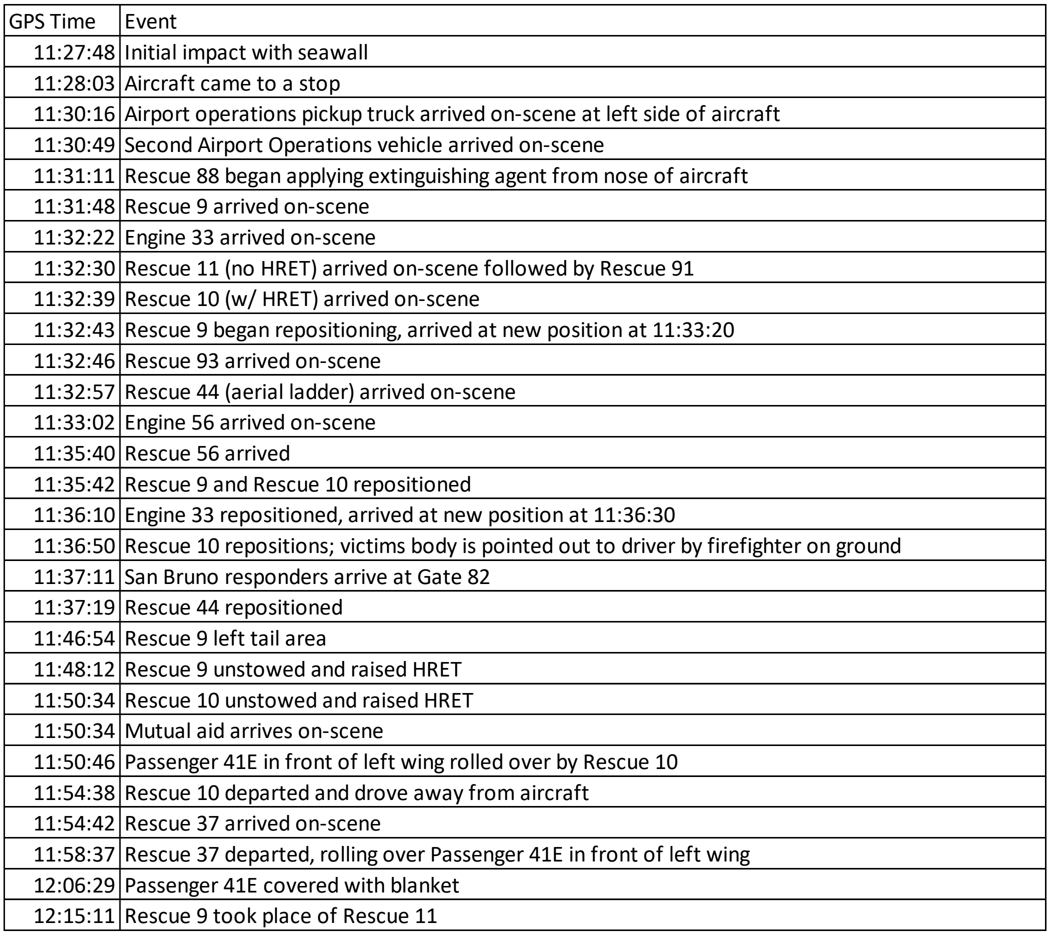
Figure 22.

Exhibit T- High Reach Extendable Turret with Skin-Penetrating Nozzle. The HPRV with HRET in a Down-in-front attack mode. Source, Department of Transportation, Federal Aviation Administration, Office of Aviation Research and Development.

Emergency Response

According to the accident report, the Alert 3 notification sounded about 10 seconds after the initial impact at about 11:28:00 Pacific Daylight Time. The first vehicle to arrive on scene was an airport operations truck driven by an airfield security officer (ASO) shortly after. The first ARFF vehicle to arrive on scene was Rescue 88 and did so about 3 minutes and 11 seconds after the alarm. About 37 seconds later, Rescue 9 arrived on scene, and about 1 minute and 14 seconds after Rescue 9's arrival, SFFD had seven firefighting vehicles positioned around the aircraft (about 5 minutes and 2 seconds after the initial Alert 3 notification). A complete timeline outlining the emergency response of the ARFF vehicles is included in Figure 22.

Figure 23. *Asiana 214 Accident, ARFF Response Timeline*



GPS Time	Event
11:27:48	Initial impact with seawall
11:28:03	Aircraft came to a stop
11:30:16	Airport operations pickup truck arrived on-scene at left side of aircraft
11:30:49	Second Airport Operations vehicle arrived on-scene
11:31:11	Rescue 88 began applying extinguishing agent from nose of aircraft
11:31:48	Rescue 9 arrived on-scene
11:32:22	Engine 33 arrived on-scene
11:32:30	Rescue 11 (no HRET) arrived on-scene followed by Rescue 91
11:32:39	Rescue 10 (w/ HRET) arrived on-scene
11:32:43	Rescue 9 began repositioning, arrived at new position at 11:33:20
11:32:46	Rescue 93 arrived on-scene
11:32:57	Rescue 44 (aerial ladder) arrived on-scene
11:33:02	Engine 56 arrived on-scene
11:35:40	Rescue 56 arrived
11:35:42	Rescue 9 and Rescue 10 repositioned
11:36:10	Engine 33 repositioned, arrived at new position at 11:36:30
11:36:50	Rescue 10 repositions; victims body is pointed out to driver by firefighter on ground
11:37:11	San Bruno responders arrive at Gate 82
11:37:19	Rescue 44 repositioned
11:46:54	Rescue 9 left tail area
11:48:12	Rescue 9 unstowed and raised HRET
11:50:34	Rescue 10 unstowed and raised HRET
11:50:34	Mutual aid arrives on-scene
11:50:46	Passenger 41E in front of left wing rolled over by Rescue 10
11:54:38	Rescue 10 departed and drove away from aircraft
11:54:42	Rescue 37 arrived on-scene
11:58:37	Rescue 37 departed, rolling over Passenger 41E in front of left wing
12:06:29	Passenger 41E covered with blanket
12:15:11	Rescue 9 took place of Rescue 11

Issues involving Emergency Response

Occupant ARFF Rollover

One of the most prominent and well-known issues surrounding Asiana 214 and the ARFF operations was the actions involving passenger 41E. Passenger 41E was one of three that were fatally injured in the accident. The NTSB concluded that two of the three fatally injured passengers, 41B and 41E, were likely unrestrained for the landing sequence and were subsequently ejected from the aircraft during the impact sequence. The third fatality, 42A, was determined to likely have been restrained; however, she succumbed to her injuries when she was struck by door 4 left when it separated.

After passenger 41E was ejected, she was found lying in a recumbent (fetal) position near the front of the left-wing. The issues surrounding 41E pertained explicitly to the ARFF response when the passenger was discovered. According to the accident report, of the four responders who first initially saw the passenger lying outside the aircraft, two had the necessary medical training that would have qualified them to triage her. The first on the scene to have seen the passenger was the airfield security officer, who indicated that he noticed no apparent injuries or no blood around the body. The second was a firefighter who indicated that he noticed the body on the ground but thought that she appeared to be deceased. This firefighter did not check her vital signs but told a nearby lieutenant. This lieutenant told investigators that she "immediately categorized it as a casualty" (National Transportation Safety Board, 2013a). The fourth person to have seen the body was another firefighter who took care to avoid the passenger while repositioning her vehicle. According to the accident report, at some time around the firefighters being in the vicinity of the passenger and noticing her, "there was a period of between 30 and 45 seconds when the passenger's location had been identified and… she had been covered by foam or rolled over by a vehicle” (National Transportation Safety Board, 2013a). The issues discovered here by the NTSB are that at least two firefighters had the time and opportunity to verify their initial assessments and yet they chose not to do so. As a result, when Rescue 10 was approaching the aircraft discharging foam, Passenger 41E was concealed by foam and was subsequently rolled over by Rescue 10. Later Rescue 37, which was dispensing agent ran out of the water and departed the scene to replenish. During the sweeping turn made to exit the area, Rescue 37 also rolled over Passenger 41E. After this point, the body was once again noticeable and was covered with a blanket.

Crew Training (HRET)

Another significant issue recognized in hindsight to Asiana Flight 214 was the problems involving the use of the high-reach extendable turret’s (HRET), which were equipped on the two most sophisticated ARFF vehicles, Crash 9 and Crash 10. The National Transportation Safety Board determined that, while the vast majority of firefighting operations were successful and greatly improved passenger survivability, ARFF operations could have been improved in that the HRET-equipped vehicles were not effectively used in the initial response. This is reflected in the timeline (Figure 22), which displays numerous situations where ARFF vehicles repositioned. The accident report explained that in several situations, the repositioning of the ARFF vehicles was neither effective nor safe. Crash 9 specifically was maneuvered into an area where there were still passengers evacuating, increasing the risk of a strike or rollover occurrence. Both vehicles were at one point positioned in locations that could not effectively fight the growing fire to protect evacuation routes. Additionally, it was whole 20 minutes after each vehicle arrived on the scene before either used the HRET to penetrate the fuselage and dispense agent inside.

The National Transportation Safety Board concluded that the issues arising during the firefighting operations were due to “improper decision-making and vehicle positioning on the part of the ARFF crewmembers” and the failure of command personnel “to properly reposition them such that they could be most effectively used” (National Transportation Safety Board, 2013a). Additionally, the crew lacked guidance relating to the proper use of HRET equipment, which ultimately led to the spread of the fire on the interior cabin (National Transportation Safety Board, 2013a). The issue of a lack of guidance and training continues to be an issue today. There has not been a change in the outdated regulations to improve this issue, and the recommendation pertaining to this matter remains classified as open. The response from the FAA in regard to recommendation A-14-049 states in part, “We understand the importance of mutual aid training and qualification, but also must operate under part 139, which does not specifically mandate ARFF qualification training for mutual aid responders. Although we concur with the intent of this recommendation, we also believe that this must be a voluntary program for ARFF training of mutual aid officers. We will work with the ARFF Working Group to assist in developing voluntary training guidance for mutual aid officers who might be placed in command at aircraft accidents or incidents” (National Transportation Safety Board, n.d.).

Staffing

The staffing issues recognized in this accident are not new to the aviation world. Challenges involving staffing were also addressed after the 1999 Little Rock, Arkansas accident. In 2009 this issue was finally addressed, however unsuccessfully, by the ARAC committee, which ultimately determined that a consensus could not be reached. As a result, the FAA then sponsored the Airport Cooperative Research Program (ARAC), which endeavored on a research project to produce “Risk Assessment of Proposed ARFF Standards” (2011), which is discussed in this research paper in the Literature Review. The ACRP concluded that any change in ARFF standards would have likely not reduced fatalities or serious injuries in any of the reviewed accidents. The NTSB eventually concluded the initial safety recommendation A-01-65 with the categorization of "Closed-Unacceptable Action" (National Transportation Safety Board, 2013a). Fortunately, for the great majority of the passengers aboard Flight 214, staffing was not a direct issue affecting survivability because SFFD-AB's equipment level far exceeded the regulatory requirement. While this issue did not directly affect the accident, the potential to affect other accidents still remain. However, the NTSB does note that "passengers involved in an aviation accident at a smaller airport may not be afforded the same level of emergency response that the passengers of flight 214 had" (National Transportation Safety Board, 2013a). The NTSB continues to state, "although the FAA did not amend 14 CFR 139.319(j) in response to Safety Recommendation A-01-65, this accident again demonstrates that the need remains for ARFF staffing levels to be sufficient to allow for interior firefighting and rescue" (National Transportation Safety Board, 2013a).

The NTSB, in response to this issue becoming evident in yet another accident, issued another recommendation, A-14-060 which stated: "To the Aircraft Rescue and Firefighting Working Group: 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" (National Transportation Safety Board, 2013a). The ARFFWG, in response, conducted a thorough research project, which the relevant results and conclusions of such a project are discussed in the literature review of this research. It is important to note, however, that while the NTSB classified the recommendation as "Acceptable Response-Closed," some of the recommendations made by the ARFFWG have still not been acted upon and the current ARFF regulations have not been changed to reflect such recommendations.

Probable Cause

The probable cause determined by the NTSB was “the flight crew’s mismanagement of the airplane’s descent during the visual approach, the pilot flying’s unintended deactivation of automatic airspeed control, the flight crew’s inadequate monitoring of airspeed, and the flight crew’s delayed execution of a go-around after they became aware that the airplane was below acceptable glide path and airspeed tolerances” (National Transportation Safety Board, 2013a).

Chapter 5: Results and Discussion

Through the dual case analysis conducted in this research, a variety of findings have been revealed. One aspect that this research aimed to accomplish was to demonstrate that there is a significant need for a regulatory reassessment of ARFF standards and the two prominent aviation accidents examined in this study assisted this researcher in the research propositions. As such, several outdated and irrelevant aspects of ARFF related regulations that affect the safety of America’s flying public have been identified.

Main Results

The main result discovered in this study, based on both simplified and extensive summaries described throughout, was not merely that the current regulations are outdated, although that is an important takeaway. In the cases of the two accidents examined, had the impacts occurred at less prepared airfields, or airfield that were meeting the bare minimum of equipment capabilities, the outcome would have likely significantly impacted the occupant's survivability. Obviously, in the case of the Gulfstream accident, the occupant survivability was as bad as it could be. However, in a situation where an accident might occur in a very similar scenario, the current regulatory requirements would certainly not have protected the occupants any more than the over-equipped fire department protecting KBED. Similarly, it was discovered that the same findings could be applied to the Asiana Flight 214 accident. Had the flight attempted landing at a smaller airfield requiring less equipment, the results could have been even more detrimental to occupant survivability. The ARFF regulations, as they currently are, leave open too much room for interpretation, specifically regarding those who leave small airports servicing small transport category aircraft unprotected. While large airports are more capable of handling the intensity of such disasters, smaller airports with less ARFF capabilities are vulnerable to an unplanned large aircraft accident.

Discussion

The examination of the two accident cases revealed common themes existing between them. In both the Gulfstream and the Asiana accidents, the airfields were exceptionally equipped for an air disaster. Both airfields far surpassed their respective minimum required equipment levels, and both airfields maintained necessary documentation, which included some inaccurate or outdated information. Both aircraft involved impacted at far ends of the runway and sustained fatalities'; however, both scenes were reached in a timely manner.

Additionally, both accidents' reports effectively concluded that the response of the ARFF crew did not negatively affect the survivability of those fatally injured. While the cases examined in this research are 6 and 7 years old, respectively, the findings of the cases are still very applicable today. The reason for this is mainly due to two aspects; a.) ARFF related regulations have not been updated since 2009, thus the same regulations applicable then are still governing today's ARFF operations, and b). the related recommendations made by the NTSB resulted in no significant changes to ARFF related regulations. It is imperative that going forward, aviation researchers continue to address this topic and the issues discussed in this study as they evolve. The findings of this research are by no means a conclusive end to the problem. This issue will be recurring every time technology surpasses regulatory reach, and as such, it is an issue that needs to be periodically reviewed.

Limitations

Several limitations constrained this research project, which ultimately affected its scope and comprehensiveness. The first limitation of the project is most obviously the time constraint.

Unfortunately, as grand as this research has the potential to be, for the purposes of this project, a time constraint of approximately three months was imposed. The time frame of three months reduced the size of the research project by constraining the number of accident cases studied. Also, this constraint eliminated the ability to conduct a project that would require a review from the Internal Review Board (IRB). The second limitation, which also significantly constrained the scope of this project, was the available resources. While this project was conducted for the partial fulfillment of a degree, the available resources for the project were limited. This limitation was further imposed by challenges that met the researcher during the middle of the three-month period, which involved a temporary closure of the university and social distancing constraints.

Recommendations

The most apparent recommendation after the conclusion of this case study is to call for the modernization of ARFF regulations. However, in order for this to be done effectively, this researcher would first suggest taking a route similar to what has been done in the past. First, further research on the subject, and any proposed changes would need to be researched more extensively. However, to avoid issues that have occurred in prior research endeavors, a group would need to be assembled that would be entirely separate from already established agencies. It is essential that the perspectives and opinions of those who are considered to be experts in the subject are included in such an endeavor. This is important in order to ensure the representation of the ARFF community in the United States accurately. Thus, members of the research collective should include subject matter experts (SMEs) who are not only highly knowledgeable in the regulations but are also highly experienced in both ARFF operations and accident survivability. A team such as this could investigate and present unbiased and impartial findings on how effective or ineffective the current regulations are and what changes should entail.

Future Research

While the limitations discussed in this chapter did, to some degree, limit the scope and the corresponding results of this study, they do not trivialize or understate the significance of the findings discovered through these case studies. Nevertheless, the need for future research is essential. In several instances, the NTSB’s conclusions and recommendations mirrored the corresponding literature discussed in Chapter 2. It was found that while the research often agrees with the recommendations made by the NTSB, changed were slow to be made. The result often ends with the NTSB adjusting the status of a recommendation while there is no corresponding change to the regulations. If a proposed change in regulation is to be brought up again, proponents would need to be readily equipped with the results of a research project that is far more expansive in scope than this one. A study involving a modern focus of accident cases would be ideal, and the researchers need to prepare to do so with a wide variety of resources available. Though such a research project is somewhat unlikely in the near future, the need for it remains.

Conclusion

The ARFF regulations, as they currently exist, have not been updated sine 2009. The regulations are not only outdated and irrelevant but also leave our airports, aircraft crew, and passengers unnecessarily vulnerable to post-accident factors. This is further amplified in situations where significant mistakes are made. The regulatory requirements governing the airport's ARFF capabilities leave more to chance than necessary when airports are voluntarily choosing to provide what they determine necessary. Many airports today are choosing to provide beyond what is required in the Code of Federal Regulations by staffing additional crew and securing additional equipment. However, for the airports that are not doing so, the regulations are failing. Unfortunately, the failure may not be apparent and are often unaddressed until a high-profile accident occurs at an underprepared airfield. As a nation, we need to update our ARFF regulations and prepare out airports for the worst. For it is then when our failures will be most amplified.

References

Aircraft Rescue and Fire Fighting Requirements Working Group. (2004). *Notice of Proposed Rulemaking Final Recommendation to ARAC Airport Certification Issues Group: 14 CFR Part 139 Subpart D.* Retrieved from https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/APCrfrT1-03222001.pdf

Aircraft Rescue and Fire Fighting Working Group A-14-60 Task Group. (2018). *Aircraft Rescue and Fire Fighting Working Group Response to the National Transportation Safety Board A-14-60 Recommendation.* Retrieved from https://arffwg.org/wp-content/uploads/2019/05/NTSB-A-14-60-ARFFWG-Final-Version-September-2018.pdf

Airport Certification: Aircraft rescue and firefighting: Index determination, 14 C.F.R. § 139.315 (2004).

Airport Certification: Aircraft rescue and firefighting: Operational requirements, 14 C.F.R. § 139.319 (2004).

Airport Certification: Definitions, 14 C.F.R. § 139.5 (2004).

Annex 14, Aerodromes. (2016). Volume I, 7th ed.

Baxter, P. E., & Jack, S. M. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The Qualitative Report*, 13(4), 544-559. Retrieved from http://www.nova.edu/ssss/QR/QR13-4/baxter.pdf

Bureau of Transportation Statistics. (n.d.). *U.S. General Aviation Safety Data.* Retrieved from https://www.bts.gov/content/us-general-aviationa-safety-data

Coalition for Airport and Airplane Passenger Safety. (1999). *Surviving the Crash: The Need to Improve Lifesaving Measures at Our Nation's Airports.* Retrieved from http://www.disastersrus.org/emtools/aircrash/iaffrpt.pdf

Cropley, A. J. (2019). *Qualitative research methods: A practice-oriented introduction for students of psychology and education.* (2nd edition). Riga, Latvia: Zinātne. doi:10.13140/RG.2.1.3095.6888

Department of Defense. (2012). *Memorandum for DoD/FAA Agreement on Inspection of DoD Firefighters at Joint Use Airfields.* Retrieved from https://dms.ntsb.gov/pubdms/search/document.cfm?docID=424804&docketID=57175&mkey=89324

Department of Transportation. (2019). I*mplementation of the FAA Reauthorization Act of 2018.* Retrieved fromhttps://www.transportation.gov/testimony/implementation-faa-reauthorization-act-2018

Federal Aviation Administration. (2009). Advisory Circular 150/5200-31C, *Airport Emergency Plan*. Retrieved from https://www.faa.gov/documentLibrary/media/150_5200_31c_chg1.pdf

Federal Aviation Administration. (2011). Advisory Circular 150/5220-10E, *Guide Specification for Aircraft Rescue and Fire Fighting (ARFF) Vehicles.* Retrieved from https://www.faa.gov/documentLibrary/media/Advisory_Circular/ 150_5220_10e.pdf

Federal Aviation Administration. (2019a). FAA Reauthorization. United States Department of Transportation. Retrieved from https://www.faa.gov/about/reauthorization/

Federal Aviation Administration. (2019b). *Joint Civilian/Military (Joint-Use) Airports.* Retrieved from https://www.faa.gov/airports/planning_capacity/joint_use_airports/

Federal Aviation Administration. (2020a). *Aeronautical Information Manual: Official Guide to Basic Flight Information and ATC Procedures.* Washington, D.C.: U.S. Department of Transportation.

Federal Aviation Administration. (2020b). Part 139 Airport Certification Status List (ACSL). Retrieved from https://www.faa.gov/airports/airport_safety/part139_cert/

GovInfo. (n.d.). Code of Federal Regulations: About the Code of Federal Regulations. Retrieved from https://www.govinfo.gov/app/collection/cfr

Hurworth, R. (2011) Interpretivism. In S. Mathison, *Encyclopedia of Evaluation.* Thousand Oaks, CA: Sage Publications, Inc. doi:https://dx.doi.org/10.4135/9781412950558

International Civil Aviation Organization. (2003). *Appendix: SARPs "Notification of Differences" Procedures and PANS Status.* Retrieved from https://www.icao.int/Meetings/AMC/MA/Eleventh%20Air%20Navigation%20Conference%20(ANConf11)/anconf11_wp142_app_en.pdf

International Civil Aviation Organization. (n.d. a). *About ICAO.* Retrieved from https://www.icao.int/about-icao/Pages/default.aspx

International Civil Aviation Organization. (n.d. b). *History.* Retrieved from https://www.icao.int/secretariat/TechnicalCooperation/Pages/history.aspx

Interstate Technology Regulatory Council. (2018). Aqueous Film-Forming Foam (AFFF). Retrieved from https://pfas-1.itrcweb.org/wp-content/uploads/2019/03/pfas-fact-sheet-afff-10-3-18.pdf

Lundy, K. S. (2012). Historical Research. In L.M. Given, *The SAGE Encyclopedia of Qualitative Research Methods*. Thousand Oaks, CA: SAGE Publication, Inc. doi:https://dx.doi.org/10.4135/9781412963909

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative Research: A Guide to Design and Implementation* (4th ed.). San Francisco, CA: Jossey-Bass.

Miles, M. B., & Huberman, A. M. (1994). Qualitative data analysis: An expanded source book (2nd ed.). Thousand Oaks, CA: Sage.

Minnesota Airport Technical Assistance Program (AirTAP). (n.d.). *Emergency Guidebook for General Aviation Airports: A Guidebook for Municipal Airport Managers.* Minneapolis, MN: University of Minnesota. Retrieved from http://www.airtap.umn.edu/publications/factsheets/documents/emergency_guidebook.pd

National Academies of Sciences, Engineering, and Medicine. (2011). Risk Assessment of Proposed ARFF Standards. Washington, DC: The National Academies Press. https://doi.org/10.17226/21942.

National Fire Protection Association (2017). *Public Input Document.* Retrieved from https://www.nfpa.org/assets/files/AboutTheCodes/412/412_AIR_AAA_A2019_PIResponses.pdf

National Fire Protection Association 403: Standard for Aircraft Rescue and Fire-Fighting Services at Airports, 2018 Edition. In *NFPA Codes & Standards.* Retrieved from https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=403

National Fire Protection Association (n.d.). *About NFPA.* Retrieved from https://www.nfpa.org/About-NFPA

National Transportation Safety Board. (1997). *Safety Recommendation.* Retrieved from https://www.ntsb.gov/safety/safety-recs/RecLetters/A97_37.pdf

National Transportation Safety Board (2013a). Aircraft Accident Report: *Descent Below Visual Glidepath and Impact With Seawall* (Report No. AAR-14/01). Retrieved from https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR1401.pdf

National Transportation Safety Board (2013b). *Board Meeting: Crash of Asiana Flight 214 Accident Report Summary*. Retrieved from https://www.ntsb.gov/news/events/pages/2014_Asiana_BMG-abstract.aspx

National Transportation Safety Board. (2014). Aircraft Accident Report: *Runway Overrun During Rejected Takeoff* (Report No. AAR-15-03). Retrieved from https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR1503.pdf

National Transportation Safety Board (n.d.) *Safety Recommendation A-14-049.* Retrieved from https://www.ntsb.gov/investigations/_layouts/ntsb.recsearch/Recommendation.aspx?Rec=A-14-049

Office of Inspector General. (2016). *FAA Lacks Sufficient Oversight of the Aircraft Rescue and Fire Fighting Program.* (Report No. AV-2016-067). Retrieved from https://www.oig.dot.gov/sites/default/files/FAA%20Aircraft%20Rescue%20and%20Fire%20Fighting%20Program%20Final%20Report%5E5-31-16.pdf

Stake, R. (1995). The art of case study research. Thousand Oaks, CA: Sage Publications

Yin, R. K. (1994). Case Study Research: Design and Methods (2nd ed.). Thousand Oaks, CA: Sage.

Yin, R. K. (2003). Case Study Research: Design and Methods (3rd ed.). Thousand Oaks, CA: Sage.