ANALYSIS OF THE EFFECTIVENESS OF F-15E RISK MANAGEMENT DURING PEACETIME OPERATIONS

THESIS

Elliot B. Vasquez, Major, USAF

AFIT-ENV-MS-15-J-060

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT-ENV-MS-15-J-060

ANALYSIS OF THE EFFECTIVENESS OF F-15E RISK MANAGEMENT DURING PEACETIME OPERATIONS

THESIS

Presented to the Faculty

Department of Systems Engineering and Management

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Systems Engineering

Elliot B. Vasquez, BS

Major, USAF

June 2015

AFIT-ENV-MS-15-J-060

TITLE

ANALYSIS OF THE EFFECTIVENESS OF F-15E RISK MANAGEMENT DURING PEACETIME OPERATIONS

Elliot B. Vasquez, BS
Major, USAF

Committee Membership:

Lt Col B. Langhals
Chair

Dr. J. Elshaw
Member

Lt Col J. Freels, PhD
Member

AFIT-ENV-MS-15-J-060

Abstract

Human factors are causal or contributory in 80% of Class A mishaps in the Air Force. Risk management tools are used throughout the service in every aircraft to help mitigate the risk of those human factors occurring. The F-15E Strike Eagle community was selected for analysis on the effectiveness of its risk management program but the data was comprised on Class A mishaps from Accident Investigation Boards since 2000 between the F-15 (all models), F-16 (all models), and F-22. Cases were selected if there were human factors root causes or contributory. A fault tree analysis coupled with the Department of Defense's Human Factors Analysis and Classification System guidelines were used to determine the underlying factors which lead to a degradation in the aircrew's ability to avoid catastrophes resulting in the loss of aircraft or life. These results were compared with existing risk management programs in the form of unit worksheet assessments. This study found all risk management programs within the F-15E community to be effective but inadequate for addressing all the risk factors and a new assessment tool was developed to properly manage risk to aircrew. Finally, the F-15E training program was found to be contributory to managing risk to aircrew through its proficiency and currency annual program and requirements.

AFIT-ENV-MS-15-J-060

This thesis is dedicated to all those affected by the loss of aircrew during training and combat operatio

Acknowledgments

Thank you to Lt Col Langhals for his helpful feedback, Capt Kyle “Raw” Sellner for his draft RM worksheet to build from, and the 494th Fighter Squadron for the opportunity and freedom to solve this on my own.

Elliot B. Vasquez

Table of Contents

List of Figures

List of Tables

ANALYSIS OF THE EFFECTIVENESS OF F-15E RISK MANAGEMENT DURING PEACETIME OPERATIONS

I. Introduction

General Issue

In April 2000 the Air Force published Air Force Instruction (AFI) 90-901 which directed all personnel to begin implementing risk management procedures titled Operational Risk Management (ORM). Just recently in February 2012, the Air Force updated this document to redefine the ORM process, eliminating the term ORM and simplifying it to just Risk Management (RM). There are now five steps to the RM process:

1. Identify the Hazards
2. Assess the Hazards
3. Develop Controls and Make Decisions
4. Implement Controls
5. Supervise and Evaluate

One of the goals of the directive was an attempt to reduce the number of Class A mishaps that resulted in the loss of personnel or significant damage to property. Since its inclusion, the Air Force has seen a measurable decline in the number of peacetime aviation related mishaps (see Figure 1). Anyone who has ever been connected to losses from a training accident understands there is inherent risk flying fighter aircraft. Losing an aircraft and the lives of its aircrew are just too high a cost for the Air Force to bear during peacetime operations. Unfortunately, according to the DoD, 80% of flying mishaps are caused by human errors, not from technical causes.

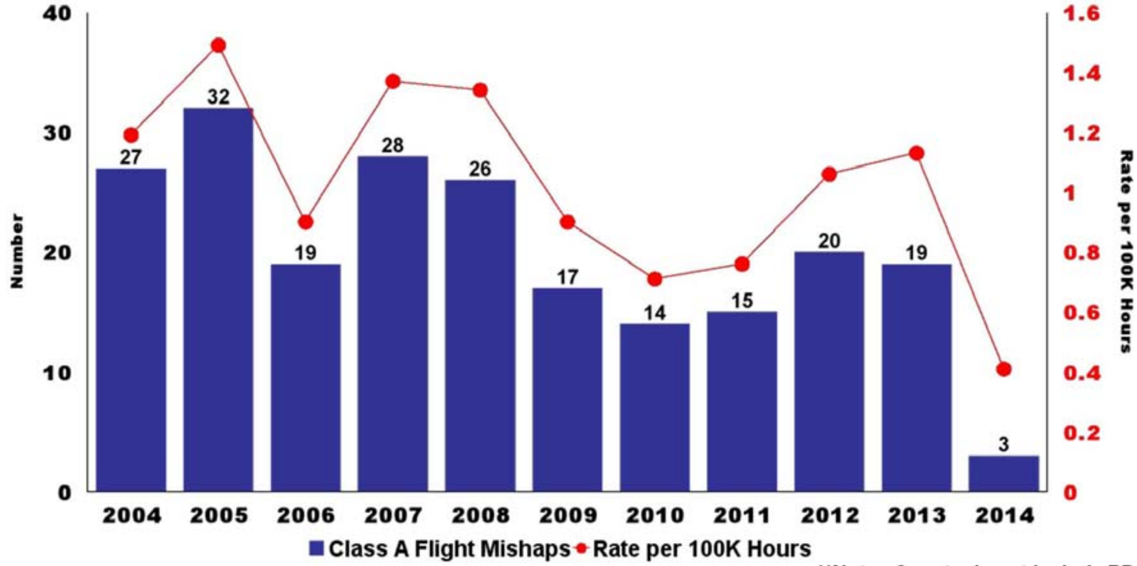


Figure 1: Class A Aviation Flight Mishaps FY14 (thru 04 May)[1]

In 2002, the Secretary of Defense Robert Gates set a goal for each of the services to reduce its number of Class A mishaps by 75%[2] over the next six years. In 2006, Secretary of Defense Donald Rumsfeld extended this goal to 2012[3]. A "Class A" mishap is defined as an accident that results in fatality or total permanent disability, loss of an aircraft, or property damage of $2 million or more. FY2010 saw the lowest flying mishap number in Air Force history: 14, 5 of which were fighter/attack aircraft. In 2011, that target number was 10. There were 15 mishaps that occurred, up from the previous year with 10 of those from fighter/attack aircraft. In 2012, the target number was 8. Unfortunately, 20 mishaps occurred across the Air Force. To be fair, the ten year average has been decreasing with each passing year but that's mainly due to the higher number of mishaps at that time. Since the goal was first stated the Air Force has only been able to meet it 30% of the time. During FY2013 19 class A mishaps occurred across the Air Force. In FY2014 there were only 7 Class A mishaps.

These annual reports also list the specific types of human errors that were responsible for the mishaps. The list includes channelized attention, cognitive task oversaturation, checklist error, complacency, overconfidence, task misprioritization, and cross-monitoring performance, to name a few.

Problem Statement

The fighter community still experiences a significant number of mishaps, mostly due to human factors. Nearly all of the causes are preventable. Risk management does not eliminate risk but it does manage it. The risk management program needs to be evaluated to determine if the current measures are effective against these causes.

In FY13 (the latest published list), the top causal human factors categories resulting in Class A mishaps across all Air Force aircraft were the following:

- Performance-Based Errors: knowing what to do but performing the actions incorrectly
- Mental Awareness: alertness, active engagement in the situation, non-complacent
- Sensory Misperception: creating a false perception due to sensory inputs, incorrectly identifying the situation or environment
- Policy and Process Issues
- Judgment & Decision Making Errors: correctly identifying the situation or environment but performing the incorrect actions in response
- Teamwork/Crew coordination
- State of Mind: distraction, fatigue, training level, experience level

- Inadequate Supervision

The risk management program needs to target these contributors, as well as historical trends, in order to manage current risks to flying, where possible.

In the F-15E Strike Eagle community, each flight lead is directed by the Air Force Instruction (AFI) 11-202 Volume 3 to perform a risk assessment prior to each training mission. In the United States Air Forces Europe (USAFE), the guidance can be found in the AFI11-202V3 USAFE supplement, General Flight Rules. The form is USAFE IMT 32, 20050515 Version 1; however, the other F-15E bases use nearly identical forms for their RM assessment, but they are not standardized between the operational/flight training units across three bases. At Mountain Home Air Force Base, Idaho both the F-15E units use unit created assessments. At Seymour Johnson Air Force Base, North Carolina the risk management sheets are part of a Flight Crew Information File (FCIF) for the entire Wing. An FCIF is a type of directive file that all aircrew are required to read and adhere. These checklists are specifically directed at identifying risks from the aircrew. Even though this is a requirement for each flight, no consistent changes are implemented based on the assessment results. Furthermore, the checklists are vague, do not account for most health risks, do not identify specific risky aircrew in the formation, and, worse of all, make no recommendations if a “risky” score is calculated. The checklist should include strategies to manage risk in problem areas.

Risk management checklists may not be the only contributor towards improper risk management. Each aircrew member is required to log training events after each flight. These are tracked to ensure each aircrew member receives their monthly/annual training requirements. Some of these include Night Vision Google (NVG) events, low altitude flying, and air to air combat maneuvering. The training events need to not only satisfy tactical objectives but also risk concerns, given the causes of most fighter aircraft Class A mishaps. In other words, the risks associated with each tactical training event need to be managed in some manner by the training program.

Research Objectives/Questions/Hypotheses

The goal of this thesis is to answer the following questions:

- Is the F-15E's RM program effective at reducing the risk of Class A mishaps resulting in the loss of personnel or property during peacetime operations?
- Are fighter flight training requirements addressing the human factors risks aircrew face?

The hypothesis is that the F-15E RM program is ineffective for isolating operational risks because it does not address all the factors that have been known to result in Class A mishaps based on the existing worksheets in use within the fighter squadrons. Furthermore, the flight requirements do not properly consider the human factors risks in its program because it only discusses specific maneuvers and training profiles.

Research Focus

This research focused on evaluating the F-15E training requirements in the context of risk management. Because the primary threats to aircrew safety are caused by human factors I focused on training requirements that manage those risks. This involved comparing the Air Force Instruction (AFI) manuals to the human factor causes. Furthermore, the effectiveness of the RM checklist in monitoring risks within flying formations was evaluated.

Assumptions/Limitations

One of the main limitations of this research is that only training data from the F-15E community was utilized. Since 2000, of all the other fighter/attack aircraft the F-15E has the lowest number of mishaps resulting in the loss of personnel or aircraft. This may make it challenging to find a correlation between the data. Additionally, the F-15E is the only Air Force platform that has two crew members of all the fighter/attack aircraft. Arguably, this may be one of the reasons it has such lower numbers than the other aircraft communities. With two aircrew members in the same aircraft there is a redundancy factor which increases their safety. However, it is possible to expand the criteria to the F-15 community at large (F-15C/E) or fighter aircraft in total but special care about the differences between aircraft in order to not skew the data and results. Lastly, the analysis only used Class A mishap data. Class A data was chosen because it is the most costly of the mishaps in terms of loss of aircraft/engines lives. These types of mishaps also require a formal investigation into their cause whereas the other classes do not so the data has been more carefully developed. The other classes are defined by their dollar amounts with class B below $2M and so forth down to class E.

One of the main assumptions of this thesis is that the results from the evaluation of the F-15E community can be applied to all fighter/attack aircraft. In today's Air Force there is a greater emphasis on flying missions integrated with dissimilar aircraft. Publications and training manuals have been rewritten to include common brevity terms and tactics. Additionally, all aircrew face the same human factor risks while flying, independent of the technological capabilities of their specific aircraft. The training requirements will differ between the different aircraft but they will be similar because they are all derived from the same source directives.

In every case, there are external influences that will affect the data. With respect to this thesis, these factors are the ones that could affect all military flying and aviation training. These factors include government shutdown, budget changes such as sequestration, maintenance, weather, and aging equipment.

II. Literature Review

Chapter Overview

This section extensively discusses the Department of Defense (DoD) regulations establishing the risk management program, roles and responsibilities and helpful definitions. Air Force specific guidance relating to risk management is also discussed and defined. Lastly, aircrew training requirements and unit training responsibilities are outlined in this section.

DoD Guidance and Air Force Regulations

In 1998, the DoD issued Instruction Number 6055.1: DoD Safety and Occupational Health (SOH) Program to refocus on safety concerns across the military. It formally establishes the requirement that each service develop a risk management program in conjunction with aviation safety, ground safety, traffic safety, occupational safety, and occupational health[4].

Every safety-conscience organization defines risk differently. DoD Instruction Number 6055.1 is the basis for all USAF risk associated definitions. The following are the list of terms pertinent to this study[5]:

Risk Management: the Department of Defense's principal structured risk reduction process to assist leaders in identifying and controlling safety and health hazards and making informed decisions.

Risk Assessment Code (RAC): an expression of the risk associated with a hazard that combines the hazard severity and accident probability into a single Arabic numeral.

Risk: chance of adverse outcome or bad circumstance; such as illness, injury, or loss. Risk level is expressed in terms or hazard probability and severity.

Hazard Severity: an assessment of the expected consequence, defined by degree of injury or occupational illness that could occur from exposure to a hazard.

Accident Probability: an assessment of the likelihood that, given exposure to a hazard, an accident will result.

The ultimate goal directed by DoD Instruction Number 6055.1 is to have zero safety accidents[6]. The DoD expects the different services to accomplish this using risk management tools[7]. Some of these risk management tools include assessment worksheets, probability/severity/impact matrices, and recurring training requirements. According to the document, the heads of each service department are responsible for establishing a risk management program that satisfies their unique challenges[8]. In the USAF, this document is the Air Force Policy Directive (AFPD) 90-8: Environment, Safety & Occupational Health Management and Risk Management.

The AFPD 90-8 formally establishes the Air Force's Risk Management (RM) program providing policy guidance and requirements for all service personnel to utilize. It further expounds on the program by listing its principles and processes that facilitate a safe, risk conscious environment that accomplishes the mission. The RM principles are as follows:

1. Accept no unnecessary risk: the most logical choices for accomplishing a mission are those that meet all mission requirements while exposing personnel and resources to the lowest acceptable risk.

2. Make risk decisions at the appropriate level: the appropriate level for risk decisions is the one that could allocate the resources to reduce the risk or eliminate the hazard and implement controls.

3. Integrate RM operations into operations, activities, and planning at all levels: to effectively apply risk management, commanders, leaders and personnel must dedicate time and resources to integrate RM principles into planning, operational processes and day-to-day activities.

4. Apply the process cyclically and continuously: RM is a continuous process applied across the full spectrum of military training and operations, base operations functions, and day-to-day activities/events both on- and off-duty.[9]

These four principles are integrated into the five RM process steps:

1. Identify the hazards.

2. Assess the hazards.

3. Develop controls and make decisions.

4. Implement controls.

5. Supervise and evaluate.[10]

Figure 2: 5-Step Risk Management process[11]

AFPD 90-8 also defines some additional terms pertinent to this study of risk management. Together with the terms from DoD Instruction Number 6055.1 these complete our risk management definitions.

Hazard – any active or latent condition that can cause mission degradation; injury, illness, or death to personnel; or loss or, or damage to, equipment or property.

Impact – any change to the environment, whether adverse or beneficial, wholly or partially resulting from organizational activities. Activities can have tangible impacts on the environment either directly or indirectly.[12]

By outlining the RM principles and steps the Air Force's goal is to develop a culture of risk aware personnel empowered to manage risk at their appropriate level both on- and off-duty. The AFPD 90-8 merely introduces the governing guidance on how to accomplish this goal but also includes directions on environmental safety, etc. For more detailed explanations on risk management implementation there are two more Air Force Instructions (AFIs) that we must review.

AFI 90-802: Risk Management focuses solely on how all Air Force organizational levels and personnel are supposed to incorporate the programs' principles. Furthermore, the document outlines more detailed explanations on the program, specifically introducing RM tenets and goals.

The RM tenets are as follows:

1. Risk is inherent in all missions, operations and activities, both on- and off-duty.
2. Risk can be effectively mitigated if understood and appropriate action is taken.

3. All personnel are responsible for utilizing RM concepts, tools and techniques.

4. The RM process outlined herein applies to risk-related decisions when such decisions are not governed via separately established requirements/guidelines (i.e. statutes, regulations, or DoD/AF policy/guidance that address personal health and safety or environmental matters and dictate particular decisions or outcomes within these requirements/guidelines).[13]

The RM goals are as follows:

1. Enhance mission effectiveness at all levels, while preserving assets and safeguarding health and warfare.

2. Create an Air Force cultural mindset in which every leader, Airman, and employee is trained and motivated to manage risk in all on- and off-duty activities.

3. Integrate RM into mission and activity planning processes, ensuring decisions are based upon risk assessments of the operation/activity.

4. Identify opportunities to increase AF warfighting effectiveness in all environments, and ensure success at minimal cost of resources. The RM Process shall be institutionalized and be an inherent part of all military operations to address safety, occupational and environmental health risks.[14]

It is important to note that the document also states that RM does not remove risk altogether or support a "Zero Defect" mindset.[15] The Air Force clearly understands that risk is part of every decision and every decision carries with it some level of risk. Additionally, it also states commanders are responsible for ensuring all personnel are trained to implement RM principles and tools.

The Air Force directs all military and civilian personnel to complete RM training through the Advanced Distributed Learning Service (ADLS) computer based training website. The training module is called the Air Force Risk Management Fundamentals Course. Completing the module is a one-time requirement for all personnel and each MAJCOM has the authority to require more frequent or additional training. For most

MAJCOMs the risk management program is managed through the safety office. In the F-15E community the requirements are to complete the ADLS module and receive annual refresher training once every year through the unit Safety Officer.

AFI 90-802: Risk Management covers most of the RM tools described in the ADLS module. In addition to restating the goals and principles of RM found in AFPD 90-8 and DoD Instruction 6055.1 the document introduces two levels of risk management: deliberate and real-time.

Deliberate RM is an in-depth, pre-planning strategy for managing risk. It involves the 5-step RM process steps and is selected for complex, short and long term timelines, and high visibility projects or activities. Real-time RM is a limited-time or no-time strategy for managing risks. It usually applies to the “execution” phase of tactical employment as well as emergency situations or off-duty activities.[16] Because of the dynamic nature of the execution phase of operations the Air Force has developed a mnemonic to assist with Real-time RM: ABCD.

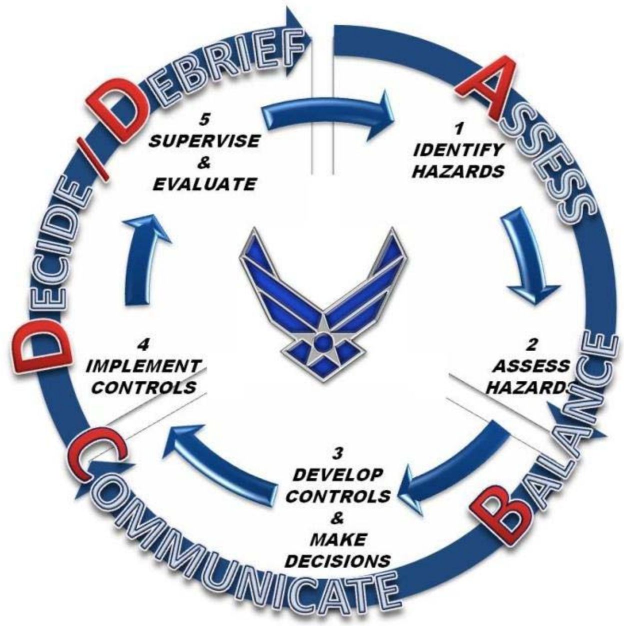


Figure 3: ABCD model superimposed on the 5-Step process[17]

Assess the Situation: Using one's available situational awareness an individual must use this to identify a perception of what is happening, integration of information and goals, and projection into the future

Balance Control: Consider all available resources/controls to eliminate or mitigate potential risks

Communicate: Establish communication with leadership or within the team to discuss options to eliminate or mitigate risk hazards; a loss of situational awareness may be identified by an inability to effectively communicate

Decide & Debrief: Select and implement a near immediate course of action[18]

The ABCD model is continuously utilized during flying operations. This model is implemented routinely during flight given the dynamic environment of F-15E training.

Aircrew flight training requirements

In USAFE, AFI 11-202 Volume 3 (USAFE Supplement) directs all MDSs to conduct a risk assessment when flying in Europe.[19] As stated earlier, the F-15E version of this form is the USAFE BASE IMT 32, 20050515, but is very similar to other checklists in operation. I will assess the effectiveness of this form in the next section and also highlight any differences from the other forms from other bases.

The Ready Aircrew Program (RAP) tasking memorandum (RTM) outlines the requirements each aircrew must accomplish in order to meet combat mission ready (CMR) status. CMR status identifies an individual as fit and trained to deploy to perform their primary duty Air Force specialty code (DAFSC), or job. The RTM is updated annually or as required and aligns with other directives including Component-Numbered Air Force (C-NAF) expectations and Designed Operational Capability (DOC) statements.[20] It becomes filed as an official document at the end of AFI 11-2F-15E Volume 1 once it is published and applies to the entire combat Air Force (CAF). The RTM defines the minimum number of required annual sorties, simulator missions, and air and ground training events for each aircrew. It does *not* specifically discuss ways to reduce risk. It is implied through the RTM that if an aircrew meets all the annual requirements for a particular training event then that individual is at an acceptable risk level for successfully completing that task, in other words, they are proficient. However, the requirements are tabulated annually. They do not assess the individual’s preparation on any given day. For example, each CMR F-15E aircrew is required to complete 3 DCA (Defensive Counter-Air) night sorties per year. If an individual completes them all in a single week in January the individual is considered proficient for the year. Common sense would dictate that if the individual did not fly another sortie of this type until April of the same year they may not be as proficient as they were in January. There is another parameter that is measured in order to account for this discrepancy: currency.

AFI 11-202 Volume 1 defines different requirements to meet qualification levels, such as CMR, BMC (Basic Mission Capable), or MQT (Mission qualification training) and the different proficiency expectations for each.[21] Furthermore, this AFI identifies further instruction in another F-15E-specific publication, AFI 11-2F-15E Volume 1.

AFI 11-2F-15E Volume 1 thoroughly describes the requirements for maintaining and regaining currency for each of the training events outlined in the RTM. Of note, there are different currency durations between experienced and inexperienced aircrew—delineated by the number of flight hours of the individual—and day and night events.[22] It's implied that remaining current in these events reduces the risk to an acceptable level for performing the task without significant incident.

It is clear the Air Force takes both risk management and combat capability seriously. There are numerous publications and directives that dictate the details establishing the guidelines for aircrew qualifications and maintaining them in accordance with annual training requirements. Indeed, they are the basis for unit training plans and tactical focus. With respect to risk management, the Air Force has also laid the groundwork for proper implementation. However, unlike the training program, the risk management program expects each MDS to produce its own assessment program as long as it incorporates the risk management models. Although USAFE BASE IMT 32, 20050515 satisfies this basic criterion, it falls short on capturing all the data associated with Class A mishap human factors causes.

Outside the DoD in the United States the Federal Aviation Administration (FAA) dictates how aviation agencies will conduct risk assessments. The FAA System Safety Handbook is the source document for these procedures. The FAA principles of risk management closely mirror the DoD and Air Force instructions discussed above with slight changes in definitions and management cycles.[23]

Conclusion

This investigation supports the hypothesis that the flight training program does not properly address human factors. The RAP Tasking Message combined with the requirements in AFI 11-2-F-15E Volume 1regarding proficiency and currency do account for risk, though not explicitly. One of the best ways it does this is through the supervision requirements for each of the upgrade sorties or currency requalification.

According to AFPD 90-8, the first step in the Risk Management process is to identify the hazards. Without a thorough completion of this step the following tasks in the cycle will also be incomplete. In the next chapter the ro qot causes of class A mishaps and their underlying factors are compared to the risk management programs at the unit levels, specifically their worksheets, to validate the hypothesis in chapter 1.

III. Methodology

Chapter Overview

This chapter discusses the different tools available to identify the root causes of class A mishaps and how to use them. There is a detailed explanation on the Fault Tree Analysis tool as the appropriate choice for this investigation.

Analysis Tools

This research will assist in determining which underlying reasons affect the probability of a debilitating human factor occurrence. There are many different methods and tools available to identify faults and root causes within a system. The failure mode and effects analysis (FMEA) is an inductive, bottom-up analysis method aimed at analyzing the effects of a single component of function failures on equipment or subsystems.[24] The FMEA is not an appropriate choice for this study because the Class A results are already know: loss of life/aircraft. The failure in one of the human factors components leads to a Class A mishap (worse case), within the confines of our study. Additionally, an FMEA is not able to analyze how multiple failure components (i.e. different human factors) affect the outcome.

A reliability block diagram (RBD) is a diagrammatic method for showing how component reliability contributes to the success of failure of a complex system. RBD is also known as a dependence diagram (DD).[25, 26] When we compare our results between different aircraft we could use an RBD to identify redundant systems and their effect on the outcome. The most obvious differences between the four aircraft frames considered are the number of engines and the number of aircrew members. Having two engines or two aircrew or both decreases the likelihood of an overall system failure due to the redundancy components. However, human factors are more complicated for this type of analysis. For example, a failure of a pilot due to channelized attention combined with task saturation will not always result in a mishap. Numerous internal and external factors can affect the outcome of the failure of this type. For instance, an experienced wingman (other pilot/aircrew part of the flight formation) may be able refocus the disabled pilot through effective communication. Also, on that particular flight the disabled pilot may have developed symptoms of illness and is unable to perform at their best for that reason potentially resulting in a mishap. When you consider these issues an RBD would be too complicated to be useful.

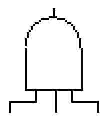
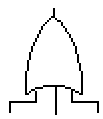
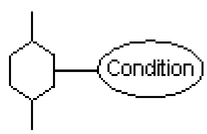
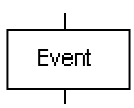
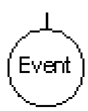
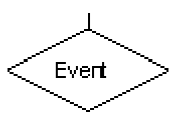
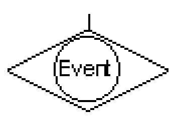
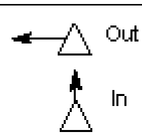
Root cause analysis (RCA) is a method of problem solving used for identifying the root causes of faults or problems.[27] RCA is utilized by Accident Investigation Boards (AIBs) and Safety Investigation Boards (SIBs) alike. The premise is the analysis determines a cause which, if removed, would not result in an undesired effect. The case studies applied to this analysis used RCA to determine which human factors were found causal in the mishaps. An RCA may be used to discover these factors but a significant disadvantage of this approach is its effectiveness. The quality of RCA is dependent on the accuracy of the input data. Also, users tend to select and interpret data to support their predispositions. Lastly, it lacks a scale to measure the severity and impact of each cause. That being said it could be used to analyze my hypothesis as well.

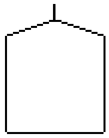
A Why-because analysis (WBA) is a method for accident analysis.[28] The result from a WBA analysis is a why-because graph (WBG) which details the casual factors leading to an accident. It is an objective look at identifying root causes of accidents. WBA is not an appropriate choice for this analysis because human factors is incredibly subjective. The subjective nature of this type of analysis is an important quality for further expansion of this research which is discussed later.

Fault Tree Analysis (FTA) is a deductive, top-down method aimed at analyzing the effectiveness of initiating faults and events on a complex system. Similarly to the RCA, the FTA is also used to identify root causes. This analytical tool is appropriate to this study because it permits the investigation to filter down to whichever level one selects. It requires a thorough understanding of the system being studied to account for all the factors affecting the fault. FTA is best suited for safety engineering and reliability engineering to understand how a system can fail or how to reduce the risk of failure. The difficulty with an FTA in this case is that human factors are very subjective but identifying underlying factors that affect the likelihood of those events occurring will overcome this obstacle. This information will be compared to the risk management worksheet USAFE BASE IMT 32, 200505015, with highlights from the other worksheets, and identified how it can be improved.

An FTA is illustrated using a diagram with specific symbols, called *events*, *transfer lines*, and *gates*, to describe the causal factors for the fault. Table 1 shows the symbols and their meanings. Figure 4 illustrates a basic example of its process.

Table 1: Fault tree analysis symbols and meanings[29]

Symbol	Name	Meaning
	And gate	Event above happens only if all events below happen.
	Or gate	Event above happens if one or more of events below are met.
	Inhibit gate	Event above happens if event below happens and conditions described in oval happen.
	Combination gate	Event that results from combination of events passing through gate below it.
	Basic event	Event that does not have any contributory events.
	Undeveloped basic event	Event that does have contributory events, but which are not shown.
	Remote basic event	Event that does have contributory events, but which are shown in another diagram.
	Transferred event	A link to another diagram or to another part of the same diagram.

	Switch	Used to include or exclude other parts of the diagram which may or may not apply in specific situations.

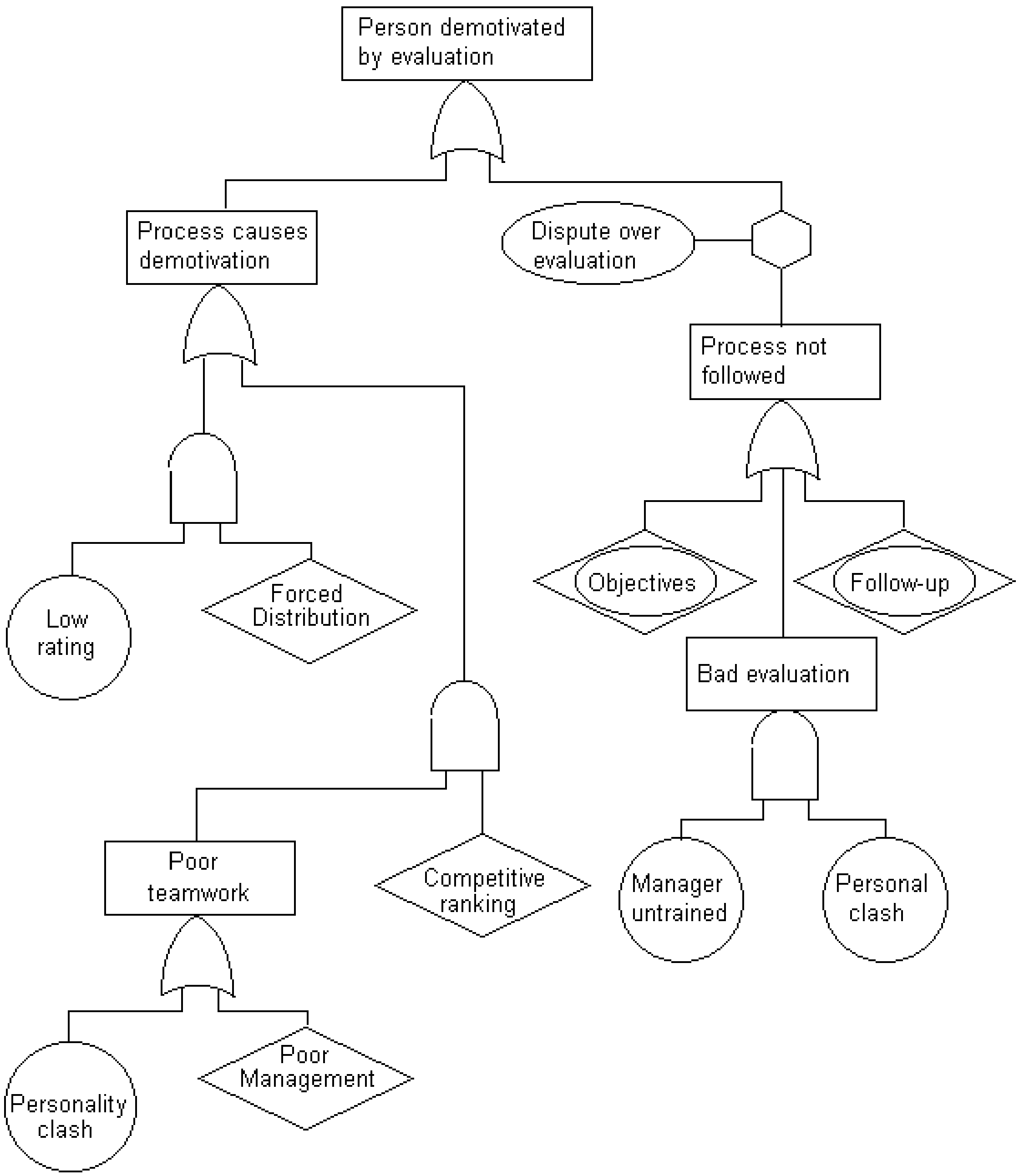


Figure 4: Fault tree analysis subjective example[30]

In the next section the data from the Class A mishaps will be listed along with the human factors causes or contributors. The FTA tool shows the underlying causes behind these human factors. Using this information the F-15E risk management worksheets are compared to each other and then evaluated on their effectiveness to determine whether changes need to be implemented.

IV. Analysis and Results

Chapter Overview

As previously discussed a fault tree analysis was used to determine the causes of F-15E Class A mishaps as they relate to human factors. Since human factors have been shown to contribute to 80% of Class A mishaps the focus has been tailored to understand how to minimize risk of their occurrence or eliminate it altogether.

Case Studies

After a Class A mishap there are two investigations that are started, a safety investigation board (SIB) and an accident investigation board (AIB). The SIB results are privileged information released only to aircrew for safety reasons to avoid future incidents of the same type. This information is protected from prosecution. The AIB results are a legal finding releasable for public record. The two board results almost always coincide. For security purposes this investigation only used AIB results.

According to DoD Human Factors Analysis and Classification System (HFACS) 7.0, all human factors can be classified into two general categories: Mishap-level factors and Person-Level factors. This analysis focuses solely on the latter category because the mishap-level factors are beyond the control of the aircrew, mostly concerned with maintenance and the mechanical workings of the aircraft. Person-Level factors are further subcategorized into three lower levels shown in figure 5 below.

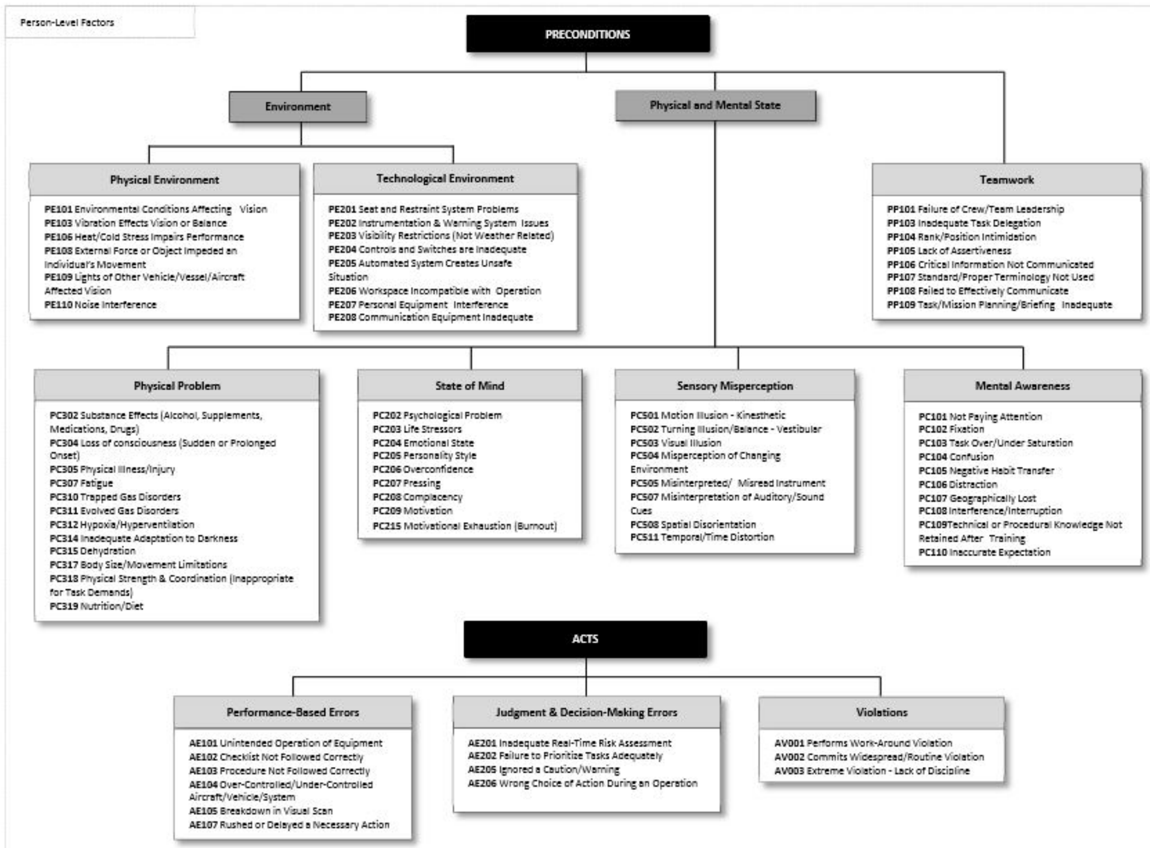


Figure 5: Person-Level Factors[31]

There are 10 categories of contributing factors to mishaps: Physical environment, technological environment, teamwork, physical/medical problem, state of mind, sensory misperception, mental awareness, performance-based errors, judgment & decision-making errors, and violations. All these categories have been contributing factors to Class A mishaps over the past five years across all Air Force aircraft. The root causes according to Accident Investigation Boards have been spatial disorientation, environmental and procedural factors[32], misperception of the operational conditions, erroneous expectation for a night event, inexperience by the crew[33], channelized attention, an improper crosscheck[34], not in compliance with restrictions, and low altitude bird strikes[35]. Unfortunately (and fortunately), there have only been 4 F-15E cases since FY2000 that resulted in Class A mishaps due to human factors. For this reason the data was expanded to include all F-15 model Class A mishaps since FY2000 as well. With this expansion the count is 15 cases total. All fighter aircraft since FY2000—which encompasses F-15, F-16, and F-22 data—was included in the data pool in order to gather significant data. There are 62 recorded Class A mishaps that fit this criteria since FY2000. The main assumption is that despite the different fighter aircraft and training all aircrew are affected by the same human factors. For example, task saturation can happen to any aircrew regardless of the platform in which he or she flies. The frequency of this human factor example occurring can vary between aircraft but that isn't relevant to this study. Furthermore, the data pool was constricted to these aircraft because they are still being flown today. Table 2 displays this data for all the cases in which human factors were the root cause or found casual to a mishap. Appendix B shows an example of an AIB report used to gather the data in the analysis.

Table 2: AIB findings for Class A Mishaps since FY2000[36]

Aircraft	*Date*	*Root Cause*	*Causal Factors*
F-16C (2)	17 Nov 99	Loss of situational awareness, cross-check breakdown	Night, Lights out
F-16CJ	19 Mar 00	Channelized attention	Strong winds
F-15E	31 May 00	Experience level	
F-16C	16 Jun 00	Checklist compliance, crew resource management	
F-15C	03 Aug 00	Pilot error	
F-16C (2)	08 Aug 00	Channelized attention, loss of situational awareness, complacency	
F-16C	28 Aug 00	Pilot error, flight discipline	Channelized attention
F-16CJ (2)	13 Nov 00	Pilot error	
F-16CG	16 Nov 00		Loss of situational awareness
F-15C (2)	26 Mar 01		Low altitude, fog
F-16CG	12 Jun 01	Spatial disorientation	Channelized attention, night
F-16CJ	06 Jul 01	G-force induced Loss of Consciousness (G-LOC)	
F-16B	17 Jul 01	Channelized attention	Loss of situational awareness
F-16C	10 Jan 02	Pilot error	Spatial disorientation
F-16CJ	20 Mar 02	Inadequate cross check	Night, weather
F-15C	21 Aug 02	Pilot error	
F-15C	03 Sep 02	Pilot error	
F-16C	09 Sep 02	Loss of situational awareness, task saturation	Night, low illumination, weather, spatial disorientation
F-16CG (2)	25 Oct 02	Pilot error	Loss of situation awareness, task misprioritization, channelized attention, expectancy
F-16C	13 Nov 02	Loss of situational awareness, channelized attention	Visual illusions
F-16CG (2)	18 Dec 02	Task misprioritization, channelized attention	Night
F-15C (2)	17 Mar 03	Pilot error	
F-16CG	12 Jun 03	Inadequate cross check	Checklist error, task misprioritization
F-16CG	09 Sep 03	Loss of situational awareness	
F-16C	14 Sep 03	Pilot error	
F-16B	25 Sep 03	Loss of situational awareness	Channelized attention, lack of proficiency/experience, task misprioritization, complacency
F-16CJ (2)	09 Mar 04	Task misprioritization, channelized attention	Fini flight, aircraft configuration
F-15E	06 May 04	Bird strike	Low altitude
F-16C (2)	17 May 04	Loss of situational awareness	Task misprioritization
F-16C	19 May 04	G-LOC, spatial disorientation	

F-15C (2)	04 Oct 04	Task misprioritization, channelized attention	Loss of situational awareness, unplanned aircraft congestion
F-16D	18 Mar 05	Checklist error	Pilot discipline
F-16	05 Apr 06	G-LOC	Extended break from flying, fatigue from multiple flights, upgrade sortie
F-16CJ	14 Sep 06	Visual illusions, misperception, task misprioritization, inattention	
F-16CG	27 Nov 06	Channelized attention	Combat
F-16D	12 Mar 07		Low altitude
F-15C/F-16C	11 Jun 07	Channelized attention	Loss of situational awareness
F-16CG	15 Jun 07	Spatial disorientation, inadequate cross check	Night, weather, low altitude
F-16CG	18 Sep 07		Severe weather including thunderstorms and icing, spatial disorientation, upgrade sortie
F-16C	15 Jan 08	Spatial disorientation	Inadequate cross check, night, weather
F-15C (2)	20 Feb 08	Pilot error	Surge operations
F-16C	14 Mar 08	G-LOC	
F-16D	02 Apr 08	Procedural error	Inexperience, proficiency, task misprioritization, channelized attention, fatigue, task oversaturation
F-15D	30 Jul 08		Low altitude
F-15C	13 Nov 08	Pilot error	
F-22A	25 Mar 09	Loss of situational awareness	
F-16CM	22 Jun 09	Inadequate cross check	Inexperience, channelized attention, expectancy, night, low illumination
F-15E	18 Jul 09		Expectancy, inexperience, channelized attention, inadequate cross check, night
F-16CM (2)	15 Oct 09	Procedural error	Channelized attention
F-22A	16 Nov 10	Channelized attention	Spatial disorientation
F-16C	28 Jun 11	G-LOC	Aircraft configuration, upgrade sortie
F-16CM	29 Jul 11	Breakdown in visual scan	Task misprioritization, channelized attention
F-15E	28 Mar 12	Visual illusion	Night, inadequate cross check
F-22A	31 May 12	Pilot error	Task misprioritization, distraction, misperception, decision making error
F-22A	15 Nov 12		Weather
F-16C	27 Dec 12	Checklist error, complacency, Procedural error	Lack of discipline, spatial disorientation, channelized attention, misperception

F-16CM	28 Jan 13	Spatial disorientation	Night, weather, breakdown in visual scan
F-16C	03 Apr 13	Night, weather	
F-15C	28 May 13		Emergency procedure proficiency, expectancy
F-16D	26 Jun 13	Decision-making error	Bird strike, channelized attention, breakdown in visual scan
F-16C (2)	01 Aug 13	Misperception, channelized attention, task misprioritization	Overconfidence, inadequate crew rest, fatigue, lack of discipline

Results of Case studies review

A compiled list of the factors is shown below. These coincide with the DoD HFACS 7.0 list of person-level factors.

- Channelized attention/Inadequate cross-check
- Loss of situational awareness
- Task misprioritization/task saturation
- Pilot error/decision-making errors/breakdown in visual scan/expectancy
- Night operations/low illumination/lights out
- Spatial disorientation/visual illusions/misperception
- Weather/thunderstorms/icing/strong winds
- Low altitude
- Flight discipline/lack of discipline/complacency/overconfidence/inattention
- G-LOC
- Crew rest/fatigue/surge operations
- Upgrade sortie
- Inexperience/break from flying
- Plan changes
- Aircraft configuration
- Fini flight
- Bird strikes
- Checklist discipline/crew resource management

Channelized attention and loss of situational awareness are by far the human factors most often identified as the root cause or supporting causes of a Class A mishap. Aircrew are trained to reduce the likelihood of the effects of these human factors by performing an adequate cross check of aircraft sensors in order to avoid fixation and to help build situational awareness. Complacency can lead to a breakdown in visual scan, expectancy, decision-making errors including a lack of checklist/flight discipline, and pilot execution errors. Complacency can be overcome by mental fortitude to remain engaged in aircraft/mission activities, proper training, physical fitness, effective crew resource management and proper cross check to increase situational awareness.[37]

Task misprioritization is another human factor that has contributed to many Class A mishaps. Some of the reasons this may occur are related to the aircrew's experience level, inadequate mission planning, and aircrew lack of proficiency. Task saturation causes performance to decrease and errors to increase, made worse with an increase in stress. It leads to channelized attention or even complete shutdown of performance in extreme cases. It can be overcome with a proper cross check, checklist discipline, and effective crew resource management, similar to combating complacency.

All fighter aircrew are required to attend and graduate from centrifuge training prior to attending their formal training course for their particular airframe. At this training aircrew are taught how to properly perform an Anti-G force Straining Maneuver (AGSM). Additionally, they are instructed on the physiological factors affecting one's ability to perform the maneuver. The factors that degrade G-LOC protection are fatigue, muscular endurance, not smoking, and proper hydration/nutrition.[38]

Training requirements also introduce increased risk. Low altitude operations are potentially dangerous due to the decrease in reaction time available prior to hitting the ground. Flying low to the ground also increases the probability of a bird strike. Increases in flying operations in the form of surges, multiple flights within the same day, duty day length, experience level, and minimum crew rest. Also, stressors from upgrade flights, extended breaks from flying, late planning changes, and overconfidence from fini flights—the last flight of an aircrew member prior to permanent change of station or separation/retirement—need to be addressed as well.

The remaining factors are mainly environmental: night operations, low illumination (<2.2 millilux), lights out (external aircraft lighting during off for training), and weather. Air Force regulations dictate the weather requirements for takeoff, landing, and training operations. Each pilot has their own weather category indicating the minimum cloud ceiling and visibility for takeoffs and landings. Also, each aircraft has its own safety restrictions based on winds and configurations. Environmental factors can also increase the probability of spatial disorientation and visual illusions. These can be overcome with proper training, focused briefing, and proper cross check.

When we fit all these factors into the FTA we get an extensive diagram that highlights underlying conditions that degrade human components. These include stressors, weather at legal minimums or close to it, experience level, mission complexity, late changes, sleep issues, ops tempo, and proficiency/currency levels, to name a few. See Figure 6 for the complete breakdown.

The FTA was developed using the person-level factors as a road map. The first step towards constructing the FTA is to begin with the fault, in this case the Class A mishap. The next step is to create contributory branches from this fault. Based on the person-level factors diagram there are three main branches that contribute to this fault: unfavorable environment, inappropriate actions, and degraded physical and mental state (individual issues). Teamwork is mentioned as a person-level factor but this is captured elsewhere under one of the other categories. The three branches are related to the three phases of the aircrew's interaction with their environment: perception, decision, and execution factors.

The unfavorable environment encompasses external influences. The external influences, although not controlled by aircrew, do affect the potential for a debilitating human factor to occur, namely the environment which influences the aircrew's perception. These are weather, light conditions, and the aircraft readiness itself. The aircraft readiness is labeled "technical issues" and is beyond the scope of human factors. They were ignored for the sake of this analysis which is why they were designated by a diamond—event that does have contributory events, but which are not shown. The weather hazards to aircrew include thunderstorms, icing, strong winds, temperature, and birds (as related to seasonal migrations and historic patterns). When these hazards increase in their impact factor or frequency it increases the risk of a Class A mishap occurring. They were indicated by circles because they are basic events. Visual illusions and bird activity were designated by diamonds because there is more depth to each of these categories but not needed for this level of analysis. With respect to the night operations the illumination level can play a factor in spatial disorientation. External aircraft lighting is controlled by the aircrew. If the training calls for reduced lighting or lights out (no external lighting) there are associated risk factors with these conditions. These are basic events designated by circles.

The internal environment is the aircrew's physical and mental abilities. These can affect the decision making ability of the aircrew. When human factors are present they can lead to the degradation of the aircrew's physical and mental state. The physical problems that can be present if aircrew is able to fly, not on DNIF (duty not including flying) status, are a G-LOC or physical fatigue. The FTA shows the factors that contribute to these two physical conditions as it relates to flying in fighter aircraft. Diamonds are used for both poor fitness and nutrition because the depth of these issues is not required to illustrate their impact. Excessive stress, circadian rhythm issues, and lack of sleep are basic events that contribute to physical fatigue. Illness is a diamond because not all illnesses degrade the physical ability for aircrew to perform their flying duties. Their inclusion implies that the illness is either being treated by flight doctor safe-for-flying prescription medications or is not deemed serious enough to completely degrade the aircrew's ability to perform their flying duties. The latter is completely subjective and not always correct. Lastly, the high ops tempo is a diamond because there are affected by many other influences outside the human factors scope. Some of these high ops tempo factors related to fatigue include the length each aircrew is working daily (related to crew rest), weekly (related to the fighter scheduling timeline), and monthly (related to required aircrew proficiency).

Distraction causes a degraded mental state for aircrew. The elements of distraction include task saturation/channelized attention, complacency, and mental stress. These all result in a loss of situational awareness, designated by an oval. The hexagon was used to show that distraction would occur if the rest of the branches below it also occurred. Mental stress was selected as a basic event for simplification. The existence of stress is enough to affect an individual's risk, regardless of where is stems from. Assessing the amount of stress is necessary for managing individual risk.

Task saturation and channelized attention are the top two human factors that are root causes or contributory to Class A mishaps and their understanding is crucial to managing their likelihood. As such, aircrew face four dimensions that contribute to this likelihood: lack of experience, poor crew resource management (CRM), upgrade sorties, and lack of proficiency. Lack of experience is a compound dimension and thus designated with a diamond. The fighter community makes this distinction by the number of flight hours attained unique to each airframe. This demarcation is beyond the scope of this study but it’s enough to understand there is one stated and restrictions are placed upon each category. Similarly, poor CRM, or teamwork, is beyond the scope as well but is related to experience level. It is difficult to predict how well a team will work together and thus those details are left out of this investigation. The FTA reveals that it plays a part and should be considered. Upgrade sorties and lack of proficiency are basic events defined by the flight syllabi and AFI11-2F-15E Volume 1, thus represented as circles.

Complacency is a result of a breakdown in visual scan, lack of discipline, and inadequate crosscheck. Both visual scan and crosscheck are basic events. A lack of discipline is not as basic and thus represented by a diamond.

Lastly, the third branch is based on the aircrew’s actions or behaviors, the execution portion of interaction with the environment. These are subdivided by misperception and insufficient training. Misperception stems from a lack of experience, discussed above, and ignored warnings. Ignored warnings are a result of overconfidence, a basic event, and a distracted state of mind, discussed in another branch. These both contribute to inappropriate checklist use.

The other branch of inappropriate action is because of insufficient training. Insufficient training, in turn, is a result of lack of knowledge, proficiency, and inadequate mission planning, all of which contribute to a loss of situational awareness. Lack of knowledge can be caused by many factors not considered for this study so it is designated by a diamond. Inadequate mission planning is a result of low altitude operations, unfamiliar aircraft configurations, lack of coordination, late changes, and mission complexity resulting in task misprioritization. All of these are basic events except for mission complexity which is composed of mission events, number of aircraft involved, training airspace required, etc. The FTA analysis was able to reveal this deeper level of causal factors that must be addressed.

Comparison

The USAFE BASE IMT 32, 20050515, V1 form assesses flight risk by 12 categories (see Appendix A-1). They are weather, experience level, mission complexity, training level, flight planning/mission preparation, estimated duty day/night (at last engine shutdown), pilot/aircrew rest, schedule, lookback/proficiency, schedule notification, ops tempo: sorties within the last 7 days, and step timing—the time aircrew receive their brief from the operational supervisor about aircraft status, current weather conditions, and mission execution notes.

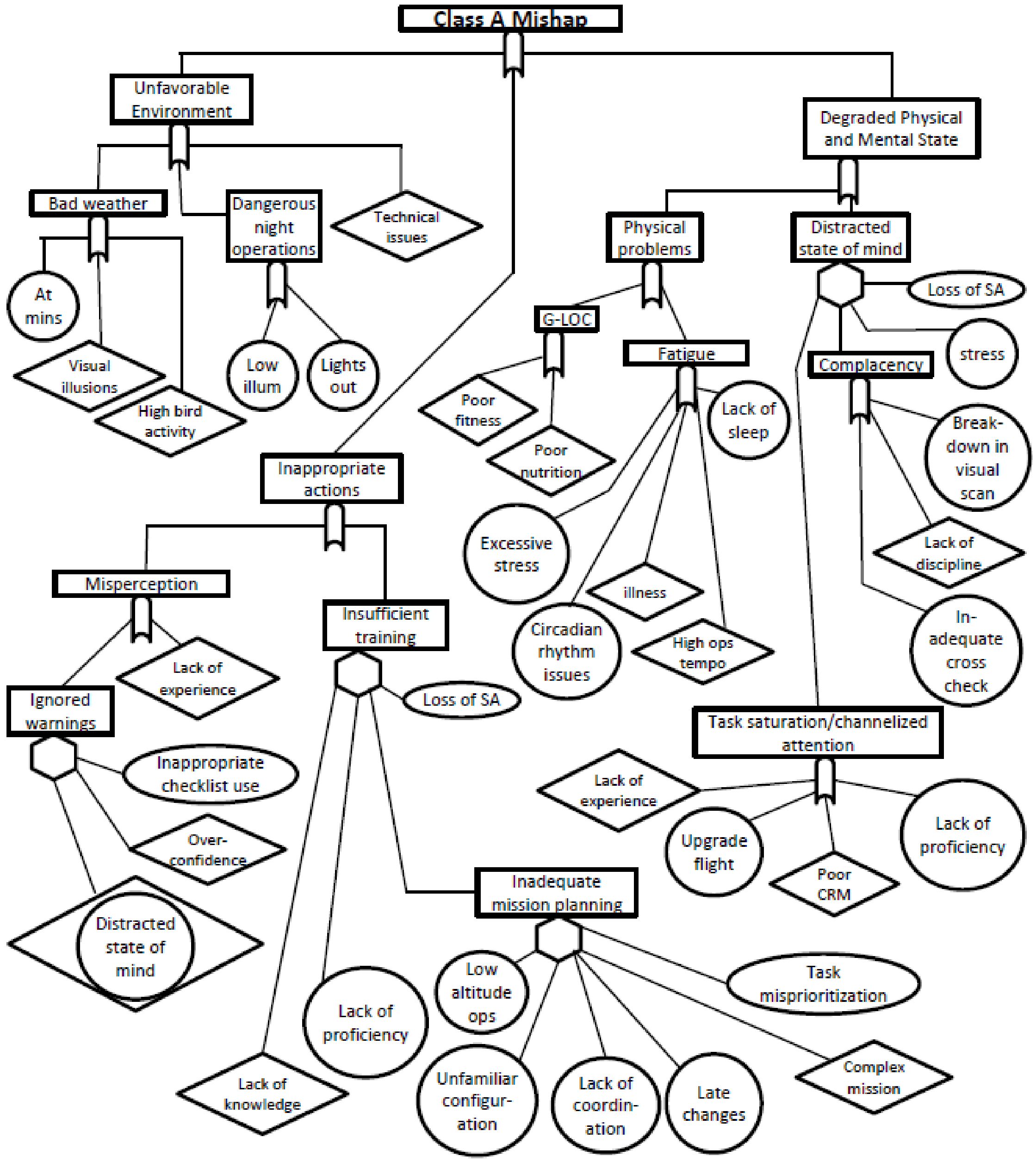


Figure 6: Fault tree analysis of Class A mishaps

The form used at Seymour Johnson Air Force Base (Appendix A-3/4) takes the risk assessment a step further by assessing the factors by each individual aircraft within the formation (rather than just the overall flight). Additionally, it expands the weather category to include not just takeoff conditions but also training airspace weather conditions, bird conditions, and runway conditions. It also elaborates on the different types of training missions including aircraft configurations and assigns point totals based on their complexity. The Mountain Home Air Force Base (Appendix A-2) squadrons use a form nearly identical to the USAFE one.

Comparing these forms to the results of the FTA yields many deficiencies (see Table 3). Although appropriate for single seat aircraft it's important to assess each individual's risk score, rather just combine them into one score. In this way supervisors can better determine how to manage risk individuals. Assessing an individual's personal stress level and physical readiness is severely lacking in the existing worksheets. Accounting for the effects of the ops tempo is included but not assessed over time adequately. The forms definitely address aircrew training proficiency and currency quite effectively but add a new category called "schedule notification" which has no bearing on risk, unless it's after the normal mission planning timeline has begun.

Table 3: Comparison of fighter unit risk management worksheets

WORKSHEET	***PROS***	***CONS***
USAFE BASE IMT 32	Accounts for different weather categories, some circadian rhythm change mitigation	Erroneous schedule notification field/step timing, does not break out for individual aircrew, does not account for environment factors
SJ AFB OPS/FTU	Different scores for different aircraft within the formation, accounts for environment factors, breaks out different mission sets	Does not break out for individual aircrew, no stress indicators or fit for duty factors, erroneous schedule notification, does not allow for the effects of mission changes
391ST OPS	Attempts to identify risky individuals, closely standardized to USAFE some circadian rhythm change mitigation	Erroneous schedule notification field/step timing, does not account for environment factors

The table was created by comparing the existing forms to the results of the FTA.

Proposed solution

Figure 7 is a new worksheet that accounts for all these factors and assigns a risk score to both each individual aircrew member and the flight as a whole. The form is broken up into three categories: human, environmental, and mission factors. The human factors have their own individual risk score to identify higher risk individuals. This new form incorporates stress levels, circadian rhythm factors, sleep levels, ops tempo, proficiency/currency level, and duty day (including non-flying events). In the environmental factors section the takeoff weather, landing fuel, bird condition, temperature condition (FITS), illumination for night flying, and winds. Furthermore, the runway condition and airspace weather is included as well. These are accessed per aircraft because the pilot weather category can vary within the same formation; it's the same with the aircraft configuration in the mission factors section.

The mission factors section addresses the different types of training missions available to the F-15E. It includes inputs for reducing external lighting or external lights out during night operations as well. In the planning subcategory the form permits risk assessments for late changes to the plan assessed by the operations supervisor described in AFI 11-218.

Scores are tabulated down the sheet to give the flight an overall risk score. The human factors section tabulates individual scores in this way as well but the flight is given the highest score in each category for its overall risk score. This score is given a rating and may require further approval for the sortie to continue as planned. There are ways to reduce risk within the aircrew of a particular aircraft or even changing the mission profile. These mitigations tactics are available to the flight leads and operational supervisors based on the assessments within the flight.

F-15E RISK MANAGEMENT WORKSHEET (TRAINING)						
CALLSIGN:		DATE:		TIME (L):	LAKENHEATH VERSION	HIGHEST RATING WITHIN FLIGHT
0	1	2	3	4	Individual: 1A, 1B, 2A, 2B, 3A, 3B, 4A, 4B	
Human Factors						
Fatigue						
Usual sleep	1 hr < Usual sleep	2 hrs < Usual sleep	multiple sleep interruptions	poor sleep over past 72 hrs		
Stress (Physical, Emotional, and Mental factors)						
Low (0)	Moderate (1): Manageable	High (2): Affects daily tasks	Extreme (3): Affects personal life	Persistent: Affects psnl/prof life		
Show time (local)						
0700 - 1059	1100 - 1459	1500 - 1959 / 0430 - 0659	2000 - 2259	2300 - 0429		
Ops Tempo within past 7 days						
1-4 sorties	>4 sorties	<1 or >6 sorties	2 dbl turns this wk	3+ dbl turns this wk		
Duty day at last engine shutdown						
1st event	2nd event	double turn	duty day limit	waiver req		
Experience						
Inst/SQ Sup	Experienced	Inexperienced	MQT/Flt doc	FAM/Incentive		
RAP as of this sortie (flying only)						
CMR/CMR rate	BMC / MQ	Probation	Non-CMR	Non-BMC		
Currency						
Current	Non-current	Upgrade/check	X-ride	XX-ride or greater		
Crew rest						
>12 hrs	Min 12 hrs					
Schedule during work week (not just flying)						
no switching	day flying swaps	day to night	night to day	multiple switches		
Individual ORM				INDIVIDUAL TOTALS:		
Low threat: ≤ 5 pts	Medium threat: 6-11 pts	High threat: ≥ 12 pts				
Environmental Factors					Formation	
Weather	Alt req: Landing fuel <10K lbs		Alt req: Landing fuel ≥10K lbs			
> 2000/3 / FITS normal	>15kts x-wind	500'/1 above PWC / >20kts x-wind / FITS caution / Birds Moderate / Hi Illum	200'/.5 above PWC / >25kts x-wind / FITS danger / Birds Severe / Low Illum	PWC mins / wind limits / FITS extreme		
Runway						
Dry/Dry or Dry/Wet	Wet/Wet	Wet, standing	CAT 3 waiver	Icy		
Airspace						
NSTR	waiverable for winds/icing in area	thunderstorms in area	>30kts land/ >20kts water			
Mission Factors						
Ordnance						
None / chaff / flare	SUU/hot gun	Inert hvywt	lives			
Type		Reduced light	Lights out			
Inst / AHC / BFM / LAO 1v1 / 2v2 ACT / BSA >5K'AGL	ACM / CAS / SCAR / MAS / BSA <5K'AGL / OCF / 2vX ACT	4vX ACT / Low fly / FCF 2vX ACT-N / BSAN >5K'AGL / off station sortie / fini	4vX ACT-N / BSAN <5K'AGL / Night low fly CAS-N / LFE day	LFE night / FLAG		
Planning		Major planning changes - Top 3 inputs				
Detailed	Abbreviated	since rally	since brief time	at step / takeoff		
Green (≤ 15 pts) Flt lead initials		Yellow (16-22 pts) Top 3 initials		Red (≥ 23 pts) Sq CC/DO initials	GRAND TOTAL:	

CAO: 23 Mar 15

Figure 7: F-15E Risk Assessment worksheet

Summary

The risk management forms from the operational and fundamental training units are inadequate to address all the factors from the FTA analysis. A complete overhaul was necessary to mitigate these possible factors in flight operations. The key points left out concerned an individual's personal fit to fly readiness. Each aircrew needs to conduct an honest assessment of their abilities and manage the risks associated with those limitations. There are certainly times when accepting that risk is an acceptable action but it must be weighed against other risk factors as well. The question of whether the benefits outweigh the risks must always be addressed.

Investigative Questions Answered

Across the CAF the F-15E risk management programs are inadequate in addressing all the human factors that have led to Class A mishaps across the Air Force but they have been effective in managing some risk. This was shown by the hazards identified as the root causes of a case studies investigation, performing a fault tree analysis to determine their underlying factors, and comparing them to existing risk assessment worksheets. The F-15E community has experienced the fewest number of Class A mishaps from human factors than the other F-15 models, F-16, and F-22. Some of this may be due to its system redundancy or its risk management program or both. Although effective it needs to be improved with the intention of proliferating these improvements across all fighter aircraft communities.

Fighter flight training requirements do provide some risk management for these human factors albeit indirectly. The requirements achieve this through the requirements for proficiency and maintaining current in certain flight tasks and profiles. If aircrews lose their proficiency or currency there are regulations in place to regain it safely with proper supervision or additional training. It is assumed that risk is at an acceptable level when these conditions are met.

V. Conclusions and Recommendations

Chapter Overview

This section outlines the ramifications of the investigation as well as recommendations for implementation and future studies to develop the risk management program within F-15E units and beyond.

Conclusions of Research

This investigation has revealed that the F-15E community has an inadequate deliberate level risk management program. The risk assessment worksheets currently in use across the CAF do not properly account for the underlying factors causal or contributory in human factors related Class A mishaps since FY2000. The data only encompassed fighters still active in the Air Force but since human factors affect all aircrew these findings could be extrapolated to other airframes. The focus of the study was the F-15E programs but the findings suggest the risk management program inadequacies are more widespread. Using the results of the fault tree analysis the pertinent factors were identified and included in the construction of a new risk management worksheet appropriate for its management.

The F-15E training program, directed by MAJCOM, includes some risk management but its underlying assumptions have not been investigated. This study merely revealed the presence of some mitigation.

Significance of Research

This investigation is significant because it reveals shortcomings within the F-15E risk management program. With the help of this new worksheet units are better equipped to assess their flight risk. Aircrew are still responsible for completing using the real-time risk management tool: ABCD to manage their risk in a dynamic environment. The goal is always to identify hazards that may result in, at worse, a Class A mishap.

Constructing a program that identifies the hazards is the first step to an effective program. There are still more opportunities to refine the program and make it stronger.

Recommendations for Action

Based on this study the new worksheet should be implemented immediately within the CAF. Not only would this be an effective way to manage risk but also standardize the programs across all units. Additionally, with minor modifications, this program can be implemented quickly within the F-15C units. Further study would allow it be implemented across all fighter units as well. Since human factors is common to all aircrew the differences between the worksheet versions would be restricted to mission sets, configurations, and MDS-specific requirements. The intent would be to standardize the Air Force risk management program across all fixed-wing aircraft. Rotary wing aircraft will have their own unique challenges. However, for all its successes this current worksheet based program has its shortcomings and requires further development to strengthen its effectiveness.

The worksheet will be maintained and updated at the Air Force Safety Center. This organization will be responsible for future changes. The Human Factors Division already exists under its control so access to more data would be easily accessible.

Recommendations for Future Research

The main way in which to develop this study would be to include trend data. Each individual aircrew will have their own baseline. Because these baselines will differ a program which identifies individual deviations from their baseline may be indicators of increased risk or underlying factors not normally found. In this way individual strengths and weaknesses can be categorized by mission sets when compared to an averaged baseline within the unit or across all active aircrew in the MDS community.

Finally, closing the loop on the risk management flight assessment would help to evaluate the program itself. If aircrew were given the opportunity to assess the *actual* risk the flight experienced it would help to refine the program and the baselines of the individuals involved. This is best done through an electronic assessment that records and analyzes the data at regular intervals.

Summary

By using the fault tree analysis tool to study Class A mishaps for the F-15 (all models), F-16, and F-22 since FY2000 (screened for human factors) a comprehensive list of root causes and contributory factors was determined and compared against the programs designed to combat those risks. In the F-15E community the programs in place were proved to be inadequate for managing those risks in accordance with Air Force defined risk management tools. The deliberate risk management tool was not adequately followed to identify existing hazards to aircrew and was in dire need of an overhaul. This study identified those hazards and proposed a new program to manage those risks. From this point the F-15E community can begin to implement the program with the plan to reconfigure it to other similar F-15 models and other fighters.

Appendix A

1. USAFE BASE IMT 32, 20050515, V1

DESIGNED ONLY FOR USE AT RAF LAKENHEATH, ENGLAND

C. FLIGHT LEAD RISK ASSESSMENT	
ITEM	POINTS
WEATHER	
0 pt - Better than 2000'/3nm 1 pt - Within 500'/1nm of highest weather category in flight 2 pt - Within 300'/.5nm of highest weather category in flight	
EXPERIENCE LEVEL	
0 pt - Experienced 1 pt - Inexperienced 2 pt - IQT or MQT	
MISSION COMPLEXITY	
0 pt - Instrument / AHC/ BFM / 1v1 Intercept / 2v2 ACT 1 pt - ACM / BSA Day / SAT Day / OCF / 2vX DACT 2 pt - 4vX DACT / BSA Night / SATN / FCF / Fini / Live / Heavyweights	
TRAINING LEVEL	
0 pt - CT / All current and qualified 1 pt - Upgrade / Non-current / Off Station LAO 2 pt - X ride rehack / Unqualified	
FLIGHT PLANNING/MISSION PREPARATION	
0 pt - Detailed 1 pt - Adequate 2 pt - Minimal	
ESTIMATED DUTY DAY/NIGHT *(At last engine shutdown)*	
0 pt - 8 hours / 6 hours 1 pt - 8 to 10 hours / 6 to 8 hours 2 pt - 10 to 12 hours / 8 to 10 hours	
PILOT/AIRCREW REST	
0 pt - > 12 hours since last duty day 1 pt - 12 hours minimum pilot rest 2 pt - Over last 3 days: > 36 hours duty or return from CONUS / Any TDY	
SCHEDULE	
0 pt - Days or nights all week with no switching 1 pt - Switched from one to the other with at least one day in-between 2 pt - Switched from night to day with no break in-between	
LOOKBACK/PROFICIENCY	
0 pt - Meets 1 month lookback requirements 1 pt - Not 1 month, but meets 3 months lookback requirements 2 pt - On probation	
SCHEDULE NOTIFICATION	
0 pt - At least 12 hours prior warning 1 pt - 4 to 12 hours prior warning 2 pt - < 4 hours prior warning	
OPS TEMPO: SORTIES WITHIN THE LAST 7 DAYS	
2 pt - 1 or less or > than 7	
STEP TIMING	
0 pt - Step on time 1 pt - Step late... *(Note: To be filled out by Ops Sup for each flight)*	
TOTAL POINTS	0

☑ GREEN *(0 - 6 Points)*	☐ YELLOW *(7 - 13 Points)*	☐ RED *(14 - 25 Points)*
FLIGHT LEAD APPROVAL INITIALS	TOP3 APPROVAL INITIALS	SQ CC/DO APPROVAL INITIALS

USAFE BASE IMT 32, 20050515, V1 *(REVERSE)* **FOR OFFICIAL USE ONLY** *(When Filled In)*

2. 391st Fighter Squadron, Mountain Home Air Force Base, ID RM sheet

Step time:

Bold Tiger ORM Worksheet

Flight Lead:	Call Sign:	Date:

Mission Overview: (mission type, airspace, threat emitters, range, deconflictions made)

	BASE FORCAST CEILING 0 -- BETTER THAN 3000'/3M 1 -- WITHIN 500'/1NM OF HIGHEST WEATHER CATEGORY IN FORMATION 2 -- WITHIN 300'/0.5 NM OF HIGHEST WEATHER CATEGORY IN FORMATION	**WHO:**
	EXPERIENCE LEVEL 0 -- EXPERIENCED 1 -- INEXPERIENCED 2 -- MQT	**WHO:**
	SORTIE TYPE 0 -- INST, AHC, BFM,1 V 1 INT, 2 V 2 INT 1 -- ACM, BSA, SAT, 2 V 2 (D)ACT, OCF 2 -- 4 V X (D)ACT, FCF, FINI, LIVE, HEAVYWEIGHT, XC 3 -- CWT, FLAG	
	SORTIE TIME 0 -- DAY 1 -- NIGHT	
	TRAINING LEVEL 0 -- CT/CURRENT IN ALL TASKS 1 -- UPGRADE/NON-CURRENT 2 -- X-SORTIE/UNQUALIFIED	**WHO:**
	LOOKBACK 0 -- MEETS 1 MONTH LOOKBACK 1 -- MEETS 3 MONTH BUT NOT ONE MONTH LOOKBACK 2 -- ON PROBATION 3 -- ON REGRESSION	**WHO:**
	FLIGHT PLANNING 1 -- DETAILED 2 -- ADEQUATE 3 -- MINIMAL	
	DUTY DAY/NIGHT (HOURS AT ENGINE SHUTDOWN) 0 -- <8/<6 1 -- 8 TO 10/6 TO 8 2 -- 10 TO 12/8 TO 10	**WHO:**
	CREW REST (HOURS) 0 -- >13 1 -- 12 TO 13 2 -- DURING LAST 3 DAYS;>36 HOURS OF DUTY OR RETURN FROM DEPLOYED LOCATION	**WHO:**
	SCHEDULING 0 -- DAYS OR NIGHTS ALL WEEK (NO SWITCHING) 1 -- SWITCHED FROM DAYS TO NIGHTS (OR VICE VERSA) WITH ONE DAY IN-BETWEEN 2 -- SWITCHED FROM NIGHT TO DAY WITH NO DAY IN-BETWEEN	**WHO:**
	SCHEDULING NOTIFICATION 0 -- >12 HOURS WARNING 1 -- 4 TO 12 HOURS WARNING 2 -- <4 HOURS WARNING	**WHO:**
	OPS TEMPO (SORTIES WITHIN LAST 7 DAYS) 2 -- <1 OR >7	**WHO:**
	TOTAL	

	Green (0-6) Flight Lead Initials		Yellow (7-13) Top 3 Initials		Red (≥14) Sq CC/DO Initials

\ALL ORM GO HERE FOR YOP 3\New ORM Sheet.xls — Current As of 24 Jul 06

3. Seymour Johnson Air Force Base, NC Ops RM sheet

4 OG OPS (335th/336th)
OPERATIONAL RISK MANAGEMENT CALCULATOR

To be completed at flight rally. Top-3/DO/CC approval must be given BEFORE brief.

Flight Callsign______________ Flight Lead________________ Flt Plan________

Note: *Points are cumulative.*

	#1	#2	#3	#4
FLIGHT CONDITIONS				
Wx < 1500' / 3 Miles (1 pt) / Wx w/in 200' / 0.5 Miles of PWC (2 pts)				
T-storms in working area (1 pt)				
Wet Runway (1 pt)				
Icing in working area (1 pt)				
Bird Condition Moderate (1 pt)				
Night (1 pt)				
MISSION PROFILE (0 pts for AHC/Instrument sorties)				
BFM, BSA (assumes low-fly/TF/Range Ops) (1 pt)				
CAS / Maritime Ops / SCAR / CSAR (1 pt)				
AF Form 8 Checkride (1 pt)				
X/C or Off-Station, Unfamiliar Airfield (1 pt)				
Orientation/Fam Sortie, Flt Doc in jet, FINI Flight (1 pt)				
Mountain Low Level (1 pt)				
Off-Station Coordination/Integration (Telecon, VTC) (1 pt)				
OCF (1 pt), FCF (2 pts)				
ACM, OCA-AI/AO, DCA, (2 pts)				
Heavyweight: Inert (1 pt), Live (2 pts)				
Dry Strafe (1 pt), Live Strafe (2 pts)				
4vX, CWT, LFE (≥10 Aircraft) (3 pts)				
HUMAN FACTORS & EXPERIENCE LEVEL				
Upgrade, Either / Both Aircrew Non-Current in planned events (1 pt)				
Both Aircrew in jet Inexperienced (1 pt)				
MQT Crew Solo (1 pt)				
PIC out of jet > 2 weeks (2 pts)				
Hot Pit (1 pt), Double Turn (2 pts), 3 sortie surge (3 pts)				
Lookback: Not 1 month, but meets 3 month (1 pt), not 3 month (2 pts)				
Scheduling Notification: 4-12 hours prior notice (1 pt), <4 hours (2 pts)				
Estimated Duty Day/Night (at last engine shutdown) 8-10 hrs/6-8 hrs (1 pt); 10-12 hrs/8-10 hrs (2 pts)				
"X" Ride (2 pt), "XX" Ride (3 pts)				
GRAND TOTAL				

Grand Totals are per Jet (i.e. each jet may have different point total/Risk Assessment)

Top 3 approval required for Medium

DO/CC approval required for High

CATEGORY	LOW	MEDIUM	HIGH
Grand Total	0-6	7-13	14+
Top 3 approval (initials)			
DO/CC approval (initials)			

4. Seymour Johnson Air Force Base, NC FTU RM sheet

4 OG FTU (333rd/334th)
OPERATIONAL RISK MANAGEMENT CALCULATOR

To be completed at flight rally. Top-3/DO/CC approval must be approved BEFORE brief.

Flight Callsign______________ Flight Lead________________ Flt Plan________

Note: *Points are cumulative.*

	#1	#2	#3	#4
FLIGHT CONDITIONS				
Wx < 1500' / 3 Miles (1 pt) / Wx w/in 200' / 0.5 Miles of PWC (2 pts)				
T-storms in working area (1 pt)				
Wet Runway (1 pt)				
Icing in working area (1 pt)				
Bird Condition Moderate (1 pt)				
Night (1 pt)				
MISSION PROFILE (0 pts for TR/AHC/Instrument sorties)				
BFM, BSA (assumes LASDT/low-fly/TF/Range Ops) (1 pt)				
DT/CAS (1 pt)				
AF Form 8 Checkride (1 pt)				
Pilot RCP upgrade (1 pt)				
X/C or Off-Station, Unfamiliar Airfield (1 pt)				
Orientation/Fam Sortie, Flt Doc in jet, FINI Flight (1 pt)				
Mountain Low Level (1 pt)				
Off-Station Coordination/Integration (Telecon, VTC) (1 pt)				
OCF (1 pt), FCF (2 pts)				
ACM, ETR, SAT, DCA, (2 pts)				
Heavyweight: Inert (1 pt), Live (2 pts). Strafe: Dry (1 pt), Live (2 pts)				
4vX, LFE (≥10 Aircraft) (3 pts)				
HUMAN FACTORS & EXPERIENCE LEVEL				
Upgrade, Either / Both Aircrew Non-Current in planned events (1 pt)				
FTU Crew Solo (2 pts)				
PIC out of jet > 2 weeks (2 pts)				
Hot Pit (1 pt), Double Turn (2 pts), 3 sortie surge (3 pts)				
Lookback: Not 1 month, but meets 3 month (1 pt), not 3 month (2 pts)				
Scheduling Notification: 4-12 hours prior notice (1 pt), <4 hours (2 pts)				
Day-of Schedule Change to put IP in RCP for Wx (2 pts)				
Estimated Duty Day/Night (at last engine shutdown) 8-10 hrs/6-8 hrs (1 pt); 10-12 hrs/8-10 hrs (2 pts)				
"X" Ride (2 pt), "XX" Ride (3 pts)				
GRAND TOTAL				

Grand Totals are per Jet (i.e. each jet may have different point total/Risk Assessment)

Top 3 approval required for Medium

DO/CC approval required for High

CATEGORY	**LOW**	**MEDIUM**	**HIGH**
Grand Total	0-6	7-13	14+
Top 3 approval (initials)			
DO/CC approval (initials)			

Appendix B

EXECUTIVE SUMMARY

AIRCRAFT ACCIDENT INVESTIGATION

F-15E, S/N 88-1682

Seymour Johnson AFB, NC

31 May 2000

On 31 May 00, at 1130 local time (1530 Zulu), an F-15E, S/N 88-1682, was damaged following an aborted takeoff at Seymour Johnson AFB, NC. The F-15E, assigned to the 336th Fighter Squadron, 4th Fighter Wing, Seymour Johnson AFB, NC was part of a surface attack training mission. The crew ground egressed the aircraft and were not injured. The aircraft suffered fire/heat damage to the main landing gear and damage to the engines due to fire retardant ingestion. No other damage or injuries occurred.

There is clear and convincing evidence that the cause of the hot brakes was the mishap pilot's decision to abort the takeoff near rotation speed, due to his lack of experience. During a formation takeoff, the mishap pilot determined that the mishap aircraft was not going to rotate and take off when he could not match the lead aircraft pitch attitude. The mishap pilot initiated an abort of the takeoff and taxied clear of the runway and into the designated hot brake area. Shortly after arriving at the aircraft, fire-fighting personnel noted smoke and flames from the main landing gear area, extinguished the fire and directed the mishap crew to shutdown and egress the aircraft.

Analysis of the aircraft discovered no anomalies that would have prevented this aircraft from flying. Due to variations in aircraft performance and pilot technique, it is possible the lead aircraft could have begun to rotate before the wingman's jet was able to rotate. There is no clear evidence to show the wingman's aircraft had reached nose wheel lift off speed prior to aborting.

The most significant portion of the cost associated with this mishap was the exposure of the engines to foam (AFFF) fire retardant.

Under 10 U.S.C. 2254(d), any opinion of the accident investigators as to the cause of, or the factors contributing to, the accident set forth in the accident investigation report may not be considered as evidence in any civil or criminal proceeding arising from an aircraft accident, nor may such information be considered an admission of liability by the United States or by any person referred to in those conclusions or statements.

All remaining reports can be found on the USAF AIB Reports website:

http://usaf.aib.law.af.mil/

Bibliography

[1] – USAF Aviation Safety: FY13 in Review, HQ AFSEC/SEH, Human Factors Division
[2] – Robert Gates, "Memorandum for Secretaries of the Military Departments," dtd May 30,2007.
[3] – Donald Rumsfeld, "Memorandum for Secretaries of the Military Departments," dtd May 19, 2003.
[4] – DoD Instruction Number 6055.1 section 2.3
[5] – DoD Instruction Number 6055.1 section E2.1.24, E2.1.25, E2.1.27
[6] – DoD Instruction Number 6055.1 section 4.1
[7] – DoD Instruction Number 6055.1 section E3.2
[8] – DoD Instruction Number 6055.1 section 5.2.1, 5.2.2
[9] – Air Force Policy Directive 90-8 Chapter 2, section 2.1.1-2.1.4
[10] – Air Force Policy Directive 90-8 Chapter 2, section 2.1.5
[11] – Air Force Instruction 90-802, section 8
[12] – Air Force Policy Directive 90-8 Chapter 2, Attachment 1: Glossary of References and Supporting Information
[13] – Air Force Instruction 90-802, section 1.2.1-1.2.4
[14] – Air Force Instruction 90-802, section 2.1-2.4
[15] – Air Force Instruction 90-802, section 3.2.2
[16] – Air Force Instruction 90-802, section 7
[17] – Air Force Instruction 90-802, section 9
[18] – Air Force Instruction 90-802, section 9
[19] – Air Force Instruction 11-202V3_USAFESUP, section 5.12.1.2
[20] – F-15E RTM, Aviation Schedule 2015 (AS-15), section 1, 2b
[21] – Air Force Instruction 11-202V1, section 3
[22] – Air Force Instruction 11-2F-15E Vol 1, Table 4.1
[23] – FAA System Safety Handbook, Chapter 15
[24] – Long, Allen, *Beauty & the Beast – Use and Abuse of Fault Tree as a Tool* (PDF), fault-tree.net, retrieved 16 January 2010
[25] – Modarres, Mohammad; Mark Kaminskiy; Vasiliy Krivtsov (1999). "4". *Reliability Engineering and Risk Analysis* (pdf). Ney York, NY: Marcel Decker, Inc. p. 198. ISBN 0-8247-2000-8. Retrieved 2010-03-16.
[26] – "6.4 Reliability Modeling and Prediction". *Electronic Reliability Design Handbook* (pdf). B. U.S. Department of Defense. 1998. MIL–HDBK–338B. Retrieved 2010-03-16.
[27] – Wilson, Paul F.; Dell, Larry D.; Anderson, Gaylord F. (1993). *Root Cause Analysis: A Tool for Total Quality Management*. Milwaukee, Wisconsin: ASQ Quality Press. pp. 8–17. ISBN 0-87389-163-5.
[28] – Ladkin, Peter; Loer, Karsten (April 1998). *Analysing Aviation Accidents Using WB-Analysis - an Application of Multimodal Reasoning* (PDF). Spring Symposion. AAAI.
[29] – "Fault Tree Analysis: How to understand it", Syque: The psychology of quality and more; http://www.syque.com/quality_tools/toolbook/FTA/example.htm
[30] – "Fault Tree Analysis: Examples", Syque: The psychology of quality and more; http://www.syque.com/quality_tools/toolbook/FTA/example.htm

[31] – Department of Defense Human Factors Analysis and Classification System Version 7.0, http://www.uscg.mil/safety/docs/pdf/DoD_HFACS7.0.pdf, p.22
[32] – Executive Summary, Aircraft Accident Investigation, 28 Mar 2012, http://usaf.aib.law.af.mil/
[33] – Executive Summary, Aircraft Accident Investigation, 31 May 2000, http://usaf.aib.law.af.mil/
[34] – Executive Summary, Aircraft Accident Investigation, 18 Jul 2009, http://usaf.aib.law.af.mil/
[35] – Executive Summary, Aircraft Accident Investigation, 06 May 2004, http://usaf.aib.law.af.mil/
[36] – Air Force Legal Operations Agency: Claims and Tort Litigation, http://usaf.aib.law.af.mil/
[37] – Jensen, R.S. (1995). Pilot Judgment and Crew Resource Management. Avebury Aviation.
[38] – Fundamentals of Aerospace Medicine (4 Ed.)– April 16, 2008 by Jeffrey R. Davis MD MS, Robert Johnson MD MPH MBA, Jan Stepanek MD MPH, Jennifer A. Fogarty PhD

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 074-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From – To)*
18-06-2015	Master's Thesis	Jun 2013 - Jun 2015

4. TITLE AND SUBTITLE	
Analysis of the Effectiveness of F-15E Risk Management during Peacetime Operations	**5a. CONTRACT NUMBER**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	**5d. PROJECT NUMBER** N/A
Vasquez, Elliot B, Maj, USAF	**5e. TASK NUMBER**
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)	**8. PERFORMING ORGANIZATION REPORT NUMBER**
Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/EN) 2950 Hobson Way, Building 640 WPAFB OH 45433-8865	AFIT-ENV-MS-15-J-060
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSOR/MONITOR'S ACRONYM(S)**
"Intentionally left blank"	**11. SPONSOR/MONITOR'S REPORT NUMBER(S)**

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution Statement A. Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Human factors are causal or contributory in 80% of Class A mishaps in the Air Force. Risk management tools are used throughout the service in every aircraft to help mitigate the risk of those human factors occurring. The F-15E Strike Eagle community was selected for analysis on the effectiveness of its risk management program but the data was comprised on Class A mishaps from Accident Investigation Boards since 2000 between the F-15 (all models), F-16 (all models), and F-22. Cases were selected if there were human factors root causes or contributory. A fault tree analysis coupled with the Department of Defense's Human Factors Analysis and Classification System guidelines were used to determine the underlying factors which lead to a degradation in the aircrew's ability to avoid catastrophes resulting in the loss of aircraft or life. These results were compared with existing risk management programs in the form of unit worksheet assessments. This study found all risk management programs within the F-15E community to be effective but inadequate for addressing the risk factors and a new assessment tool was developed to properly manage risk to aircrew. Finally, the F-15E training program was found to be contributory to managing risk to aircrew through its proficiency and currency annual program and requirements.

15. SUBJECT TERMS
F-15E, risk management, fault tree analysis, Class A mishaps

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Langhals, Brent T, Lt Col, USAF
					19b. TELEPHONE NUMBER *(Include area code)*
U	U	U	UU	63	(937) 255-6565, x 7402 (brent.langhals@afit.edu)