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An analysis of decision making strategies used by P-3 pilots in hazardous situations

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THESIS

AN ANALYSIS OF DECISION MAKING STRATEGIES USED BY P-3 PILOTS IN HAZARDOUS SITUATIONS

by

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March 2000

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Effective decision making in aeronautical environments, which often involves high elements of risk, is critical to mission success. Unfortunately, no proven methodology exists to train pilots to make successful decisions. Cockpit decision making has relied on traditional analytical models and methodologies that underestimate the role of pilot experience, expertise and judgment. Naturalistic Decision Making models (NDM) contend that decision makers facing real-world decisions use experience and judgment to make timely decisions without analyzing a multitude of alternatives.

This thesis analyzes 438 P-3 aviation hazard reports (hazreps) to ascertain which cognitive strategies from either the analytical or naturalistic methodology are more appropriate for handling malfunction situations. The author presents a hybrid model of decision making by P-3 pilots based on the results of the analysis and strategies from both methodologies.

This thesis recommends that decision making training be treated as a core activity of pilots not only in flight school, but after qualification is complete. Training pilots to become experts will improve situational awareness and reduce the number of unfavorable outcomes in hazardous situations.

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AN ANALYSIS OF DECSION MAKING STRATEGIES USED BY P-3 PILOTS IN HAZARDOUS SITUATIONS

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ABSTRACT

Effective decision making in aeronautical environments, which often involves high elements of risk, is critical to mission success. Unfortunately, no proven methodology exists to train pilots to make successful decisions. Cockpit decision making has relied on traditional analytical models and methodologies that underestimate the role of pilot experience, expertise and judgment. Naturalistic Decision Making models (NDM) contend that decision makers facing real-world decisions use experience and judgment to make timely decisions without analyzing a multitude of alternatives.

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I. INTRODUCTION

A. BACKGROUND

Aviation is a rich domain for studying decision making. Pilots frequently face situations in which the consequence of an incorrect decision may be the loss of life or expensive equipment. These decisions often are made in situations that present ambiguous information, impose severe time constraints and contain exceedingly high levels of risk. Given the costs and high levels of risk, it stands to reason that the military would have conducted thorough studies of cockpit decision making and developed a rigorous approach to training decision makers. However, this is not the case. In fact, pilot decision making skills often are considered a result of such nebulous concepts as "professionalism," "good headwork" or merely the "right stuff." In the absence of empirical knowledge regarding the best way to train decision making skills, standard analytical models of decision making simply have been assumed to be the most appropriate methods (Stokes, Kemper, & Kite, 1997). For example, Besco et al. (1994) asserted:

> Decision making in the cockpit follows traditional views of decision making...in which the decision maker is: 1) presented with a situation that requires a decision; 2) the nature of the situation is assessed by the decision maker; who 3) determines the availability of alternative outcomes to respond to the situation; and 4) after evaluating the risks and benefits of each alternative; 5) selects an alternative in response to the needs of the situation. (Besco, Maurino, Potter, Strauch, Stone & Wiener, 1994, p. 43)

Although the analytical method of decision making is clearly valid under some conditions, it does not take into account the experience, judgment and expertise of the pilot. The field of Naturalistic Decision Making contends that decision makers faced with real-world decisions use experience and judgment to make timely decisions in actual settings without analyzing a multitude of alternatives; indeed, they frequently consider only a single, workable course of action.

While decision training is incorporated into the Navy's Aircrew Coordination Training course, it is based solely on the analytical methodology. To the author's knowledge, it does not recognize many of the cognitive strategies used in Naturalistic Decision Making that could benefit pilots faced with ambiguous, unstructured situations.

B. OBJECTIVES

This thesis examines decision making in P-3 flight stations involving situations that meet the criteria for submission of a Naval Aviation Safety Program hazard report. The thesis objectives are to: (1) ascertain what types of decisions are made in different situations; (2) determine which decision making methodology, Analytical or Naturalistic, is most appropriate for a given situation; and, (3) identify the leading cause for unfavorable outcomes for those hazreps resulting in an unfavorable conclusion. Accomplishing these objectives will provide the requirements necessary to better train and equip decision makers in an aeronautical environment.

C. THESIS OVERVIEW

Chapter II discusses the process of human decision making and the need for gaining situational awareness. It reviews the literature to present both Analytical and Naturalistic Decision Making perspectives and the strengths and weaknesses of each. Several models of decision making, situation assessment and cognitive appraisal are presented as background material.

Chapter III outlines the methodology used for analyzing the hazard reports for this study. A brief history of the Naval Aviation Safety Program is presented to give the reader insight into the submission procedures and content of a hazrep. The author's expert credentials are reviewed to lend credibility to the analysis. The categorization schemes of the hazrep are identified and explained.

Chapter IV presents the results of the analysis and discusses the applicability and relevance of the situations encountered to the two decision making methodologies. Explanations for both favorable and unfavorable outcomes are given and discussed. Finally, a hybrid model of decision making is presented.

Chapter V summarizes the findings and proposes recommendations based on the results. The recommendations are intended to both increase situational awareness among pilots and reduce the occurrence of erroneous indications from faulty aircraft systems.

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II. HUMAN DECISION MAKING

A. INTRODUCTION

Decision making is a process that includes not only the decision and its subsequent action, but also the initial cues indicating that a decision must be made and assessments of the environment. After stimuli have occurred, the decision maker must accurately assess the surroundings and develop situational awareness to make an effective decision. This chapter discusses the processes involved in assessing a situation and the use of different cognitive strategies to make a decision. A representative sampling of models is presented as background material for their subsequent synthesis into an aeronautical decision making model.

The literature on decision making indicates that there are two distinct methods of decision making: analytical and intuitive. Analytical methods are based on a structured, logical analysis of the situation, while intuitive decisions are based on pattern recognition and experience. Intuitive decision making is commonly referred to as Naturalistic Decision Making (NDM), which has its roots in research on how decisions are made in actual, non-laboratory settings by experienced people. It asserts that people make decisions based on recognizing a situation as similar to situations stored in memory and applying responses that worked well to these situations in the past (Klein, 1986). Analytical decision making relies on reasoning, precise information and timely calculations (Wright, 1974) while NDM relies on experience and judgment.

B. OODA LOOP

When discussing decision making in any context, it is often helpful to model the decision making process. The figure below illustrates the OODA loop as modeled by Colonel John R. Boyd in *A Discourse on Winning and Losing,* which is discussed in Naval Doctrine Publication Six, *Naval Command and Control* (1995). While normally thought of as being applicable to a conflict between parties, this model can be used to describe the way in which decision makers gather information to reduce uncertainty, gain situational awareness and make decisions regarding a course of action in any situation. The OODA loop is an iterative process, in which the decision maker is constantly engaged in collecting information, making evaluations and decisions, and observing the consequences of these decisions. The acronym stands for observe, orient, decide and act, which describes the sequence of events performed by a decision maker. A simple scenario involving a minor aircraft malfunction is used to help illustrate the process.

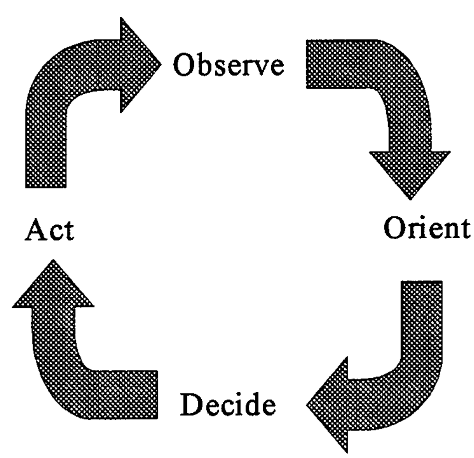

Figure 2-1 OODA Loop (adapted from Naval Command and Control)

1. **Observe**

The first step, to observe, involves gathering information on the situation from sources within, or external to, the decision maker's situation environment. This observation may occur as a result of a stimulus alerting the decision maker that an action is required. For example, the initial data may be a flashing oil pressure indicator light or a rise of oil pressure noted from a gauge.

2. **Orient**

The second step, to orient, is achieved by gathering more data on the situation and converting it to useable information, knowledge and understanding. The nature of the malfunction, seriousness of the indications, timeliness of the actions required, and procedures required are vital pieces of information the decision maker needs to assess the situation and form a mental image.

3. **Decide**

The third step in the OODA loop is making a decision, which is choosing a course of action that is either a response to the observations or a plan for future events. For example, a Plane Commander decides to abort the mission and divert to an alternate airfield after analyzing the situation and performing the applicable procedures for a rise in oil pressure.

4. **Act**

Taking action is the fourth step, and its execution is monitored by the decision maker and the pertinent crew members. In the case of an aircraft experiencing a malfunction, this monitoring involves both internal cues and external observations of the environment (in the example above, diverting to an alternate airfield would include communicating with FAA, ATC, airport personnel, etc.). A feedback loop exists to ensure the action taken is appropriate, so that adjustments can be made to alter the decision, as more information is gathered. The OODA loop is a cyclical process that requires feedback to function effectively.

It is important to understand that many of these OODA loops occur simultaneously. While a Plane Commander is gathering information and observing the situation, the Tactical Coordinator also is assessing the impact of the malfunction and the impact that the resulting decision will have on the mission. At the same time, the copilot and flight engineers are gathering information with the intention of either making their own decision or providing input to the Plane Commander. An action initiated by any of these crew members may affect the observations of the Plane Commander and therefore alter his OODA loop accordingly.

C. SITUATIONAL AWARENESS

As can be seen in the OODA loop, it is necessary to observe and orient prior to deciding on a course of action. During this phase the decision maker conceptualizes the environment, or attempts to gain situational awareness. Situational awareness is formally defined as:

> ...the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future (Endsley, 1988, p. 36).

Endsley states that decision makers often have an internal representation or a mental model comparable to the situation with which they are dealing. This mental model is compared to the current situation and projections are made (based on the degree of match) to predict events as they should occur in the future. This is the basis for two of the situational awareness models discussed in this chapter. A more specific definition of situational awareness, borrowed from a U.S. Navy Aircrew Coordination Training (ACT) Course, is: "the extent to which a pilot's perception of his environment mirrors reality." (Patrol Squadron THIRTY ACT Course, 1991)

Assessing and correctly understanding the situation frequently poses the major portion of any decision making task related to a malfunction or emergency condition in an aircraft. In almost any situation, effective decision making depends largely on having a good understanding of the situation and one's surroundings. Too often, situation assessment is not given due diligence, and situational awareness is either never developed or lost. In fact, many human errors attributed to poor decision making can be traced to errors in correctly assessing the situation and, as a result, taking inappropriate action based on this initial erroneous situation assessment. An example of incorrectly assessing a situation is an aircrew who secures a perfectly good engine as a result of an erroneous turbine inlet temperature indication, believing an overly high temperature condition exists. While securing the engine would have been the correct procedure if an actual overly high temperature existed, in this case it is unnecessarily shut down and places the crew in a potentially hazardous situation.

The following discussions explain the underlying processes and mechanisms in developing situational awareness and the relationship between this assessment of the environment and the decision making process.

1. Cognitive Hierarchy

Numerous Service Publications (e.g. NDP 6, *Naval Command and Control,* Marine Corps Doctrine Publication 6, *Command and Control)* refer to a model of the Cognitive Hierarchy to characterize how a decision maker deciphers information to achieve full understanding of a situation. Figure 2-2 (adapted from NDP 6, *Naval Command and Control*) illustrates the four steps in generating this understanding, or situational awareness, and can be viewed as the process used during the first two steps of the OODA loop, observe and orient.

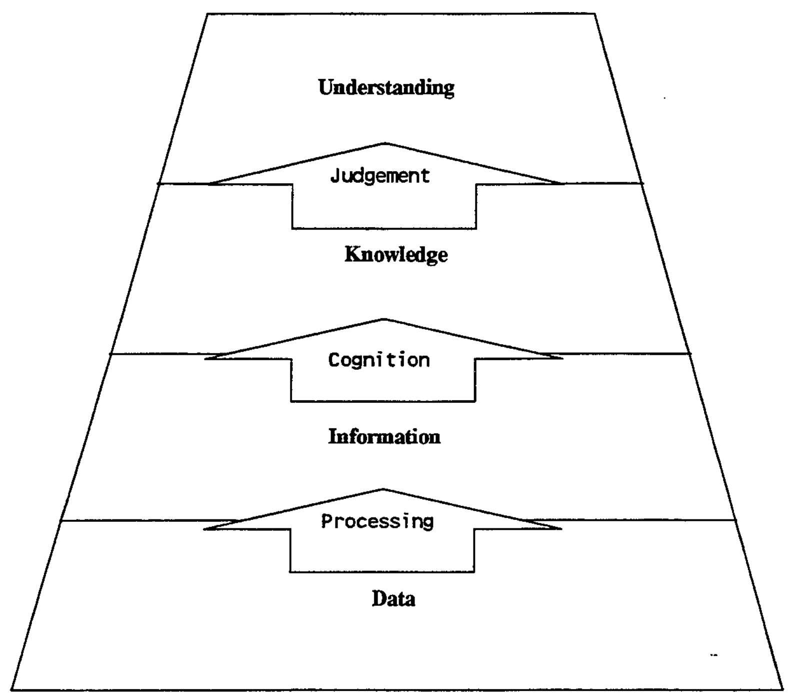

Figure 2-2 Cognitive Hierarchy (adapted from *Naval Command and Control*)

Data is meaningless to a decision maker without processing. For instance, electronic signals generated by a tachometer generator on the reduction gear box are simply not useable until they are processed and transformed into a recognizable and meaningful format or display. Once this processing occurs, the data, now integrated in the form of information, is placed in its situational context (RPM readout on a flight station gauge). Using cognition and learned aspects of the implications of RPM and propellers, the decision maker can integrate various pieces of information to build an informed picture of the situation. Perhaps an audible pitch change accompanies what appears to be an RPM over speed condition on the gauge. This analyzing and fusing of various pieces of information serves to both validate the information as factual and build a clearer picture of the situation. Finally, judgment is applied by the pilot to transform the knowledge into understanding. Intuition, experience, expertise and training are all relevant to judgment and understanding. The consequences of allowing an over speed condition to exist on an operating engine and the ramifications of acting on the condition are now clear to the decision maker as understanding emerges from knowledge.

While it is certainly desirable to achieve full understanding or perfect situational awareness of a situation before making a decision, it is obvious that many decisions must be made in an environment of ambiguous, erroneous, missing, or conflicting information. To make matters worse, many decisions must be made in an environment constrained by time-pressure and considerable amounts of stress. As uncertainty, ambiguity and stress increase, the pilot must find other methods to synthesize the available cues into an accurate understanding. Experience may be the key to understanding and grasping the situation faster and more reliably.

2. Cue Recognition

It has been hypothesized that experienced pilots differ from inexperienced pilots in the ability to retrieve domain-specific knowledge representations from long-term memory (Stokes, Belger & Zhang, 1990). Thus, when confronted with situations that could endanger the safety or efficiency of the flight, experienced pilots may more readily recognize cues relevant to the problem. They compare these cues, through a process referred to as "pattern matching," with situational schemas stored in long-term memory. Only if they are unable to match cues to their mental maps do pilots drop into an alternative strategy using real-time computational and inferential processes of working memory (Stokes, Kemper, & Kite, 1997). Inherent in working memory is a "thinking balloon" of cognitive appraisal that may expand in size and detract from working memory's capacity as time-pressure, stress and uncertainty increase. Figure 2-3, adapted from *PC Based Instrument Flight Simulation* (Sadlowe, 1991), illustrates the process of pattern matching in long-term memory versus the analytical processing done in working memory. Most of a person's active processing of information must occur in working memory. New information must be combined with existing knowledge and a composite picture of the situation developed for understanding to occur (refer to Cognitive Hierarchy). Projection of future events and subsequent decisions regarding appropriate courses of action must occur in working memory as well. For inexperienced decision makers, or those dealing with unique situations, working memory may constitute the

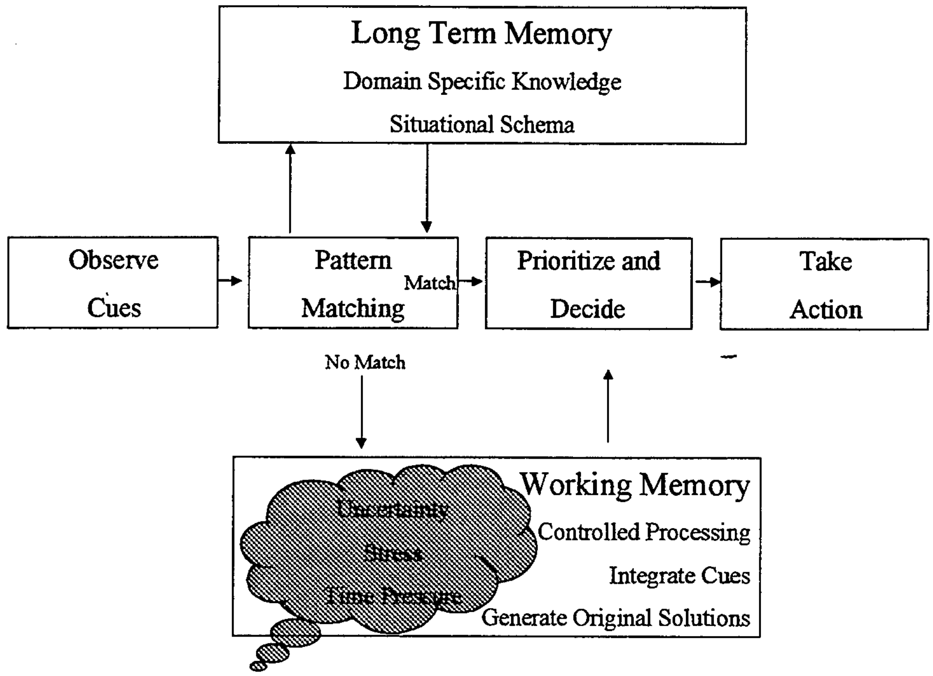

Figure 2-3 Pattern Matching Model (adapted from *PC Based Instrument Flight Simulation*)

main bottleneck for situational awareness. Within this model, experienced pilots exhibit more effective and efficient decision making as they can more readily identify significant cues and gain situational awareness than can the pilot who must integrate cues and generate an original solution.

3. Noble: Situation Assessment

Noble's model of situation assessment is similar to the Cue Recognition model above. Information on previous experiences is stored in the decision maker's memory in order to form an interpretation of the current situation (Noble, 1989). The process of performing situation assessment unfolds as follows (Figure 2-4): first, concrete information about the situation is combined with environmental, or "context" information.

Then, this current situation assessment is compared with knowledge retrieved from the decision maker's long-term memory to form a tentative interpretation (representation) of the situation. This representation includes certain expectations concerning future concrete and contextual information. These expectations are tested by this additional information from numerous sources. To the extent that the expectations do not match this information, the representation is refined or rejected in favor of a new representation that is tested, retained, refined or rejected in turn. Thus, people sometimes assess and decide by observing how the current situation is similar to previously observed situations and implementing actions that worked in these previous situations.

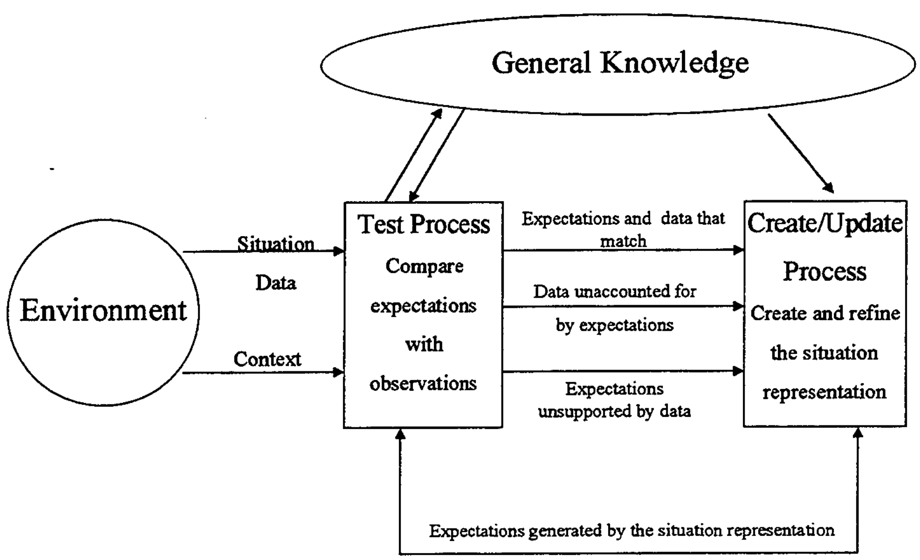

Figure 2-4 Noble's Situation Assessment Model (1993)

D. ANALYTICAL DECISION MAKING

1. Background

Analytical decision making can provide excellent results and is well suited for problems that have an accurate information base with clearly defined goals. It is soundly based in logic and is specifically designed to eliminate biases and intangible or qualitative factors that are difficult (if not impossible) to measure. The process can be reduced to algorithms and programmed in a computer. These processes can be easily taught and are independent of the knowledge and experience of the decision maker. This implies that a junior, inexperienced decision maker will reach the same answer as an expert if they have the same data and use the same process. Analytical decision methods also tend to give the decision maker a clear, defined rationale to justify and document their decisions, especially when rationalizing an optimal solution with clear goals.

Analytical decision making may be best used for predeployment and preflight preparation planning rather than "heat of the moment" or emergency scenarios. Administrative and logistical planning scenarios may also lend themselves to analytical methods to best optimize resources.

The classical model of analytical decision making holds that it is a rational and systematic process of analysis based on the concurrent comparison of multiple options. Bernoulli's Maximization of Expected Value is designed to choose the best option given ordinal or better information. For each option the product sum is computed across outcomes and the option with the largest product sum (i.e., the highest expected value) is selected (Sommer, 1954). It usually requires some type of computational aid, demands a well structured problem and often takes extensive time for application. Preflight planning for a transoceanic evolution is an ideal opportunity to employ an expected value methodology, as it requires selection of an optimal flight path given a multitude of resources and constraints (fuel, weather, field availability, winds aloft, etc.).

Using this methodology is highly time consuming in both the computational aspects and the option generation process. For the procedure to perform to its best capability, an exhaustive option production process must first be conducted to ensure completeness and optimization among competing alternatives. It takes a while to identify, analyze, and compare all the various alternatives available. As a result, no matter how quickly the computations can be performed, there will always be a certain minimum amount of time associated with a decision reached by this method.

The analytical model also requires a high level of certainty and accuracy of information. It assumes that the information is available and reliable or, if it is not available, that the decision maker will have the ability to obtain it. This may impact the amount of time required to make the decision as it will certainly take time to gather more information. If information is missing, altered, or inaccurate, the resulting quality of the decision will suffer.

Experience, perspective and judgment are not requisites of the analytical model and are not taken into consideration when computing the optimal solution. The analytical model is process-based and arrives at the correct solution as long as the right information is used in problem formulation. This model's failure to consider expertise of the decision maker results in the prediction that near-novice pilots using analytic decision making methods can operate under the same conditions as their high-time seasoned peers. The veteran's years of experience in the flight station add no particular insight to picking the optimal flight path with regard to winds aloft or weather avoidance.

The appeal of the analytical process is clearly the highly defined, clear cut, orderly process that it offers. Decisions made with this method have ample documentation to justify and rationalize the final solution. Decision makers have at their disposal a history of information that can be scrutinized and investigated to ensure the proper decision was indeed made.

In general, analytical decision making is more appropriate under the following conditions:

-Time is not a factor.

-A choice among clearly defined options exists.

-Complete and reliable information is available.

-Decision makers lack experience.

-Decisions must be justified.

2. Disadvantages

The biggest disadvantages of using analytical decision making in an aeronautical environment are the requirements for: (1) sufficient time to gather, analyze and choose a decision, and (2) accurate information as an input to the process. It is often time consuming to compile and analyze the vast amounts of data required for the analytic decision making process. Often, the information required to make the decision is lacking, misleading or wrong. Many situations encountered in an aircraft are unique to the particular event, so the information required for the option generation phase is completely unknown. Further, to improve the certainty of the optimal solution, decision maker's must gather even more information, which can increase the time factor considerably. One study also suggests that analytical decisions are shown to be less successful than other methods when made under time-pressure and stress (Wright, 1974). Since the analytical strategy can be reduced to algorithms and decision criteria, the use of analytical decision making in a tactical scenario may also give the enemy an advantage, if they were to process the same information and predict the decision maker's actions.

E. NATURALISTIC DECISION MAKING

1. Background

The naturalistic decision making (NDM) model is derived from the study of how experienced people actually make decisions in real-world situations or in "naturalistic" scenarios. A short definition of NDM is: "the way people use their experience to make decisions in field settings." (Zsambok, 1997, p. 4). The naturalistic decision making movement's center-of-gravity is based on the evidence that evolved from research on fire ground commanders (Klein, Calderwood, Clinton-Cirocco, 1986). Klein et al.'s body of research essentially states that experts use their experience to adopt a successful course of action without applying rigorous analytical strategies or deliberating over more than one option prior to making a decision. Various studies of how Naval command and control officers and infantry soldiers decide have generated the same conclusions: "under operational conditions, decision makers rarely use analytical methods, and non-analytical methods can be identified that are flexible, efficient and effective." (Klein & Klinger, 1991). Naturalistic decision making strategies are not suitable in every situation and the conditions where they are most applicable include dynamic and continually changing conditions, real time reactions to these changes, ill defined tasks, time pressure, significant personal consequences for mistakes, and experienced decision makers (Klein, 1993).

Using this intuitive process, experienced decision makers assess the situation and try to recognize familiar patterns. The first solution, although not necessarily optimal, is generally workable and evaluated to be "good enough". Mental simulation, rather than decision analysis, expected value, or multi-attribute utility functions, is used to evaluate the options. The primary methods used by decision makers employing this naturalistic strategy are pattern matching and mental simulation. Pattern matching involves a comparison of the current situation with previously experienced situations. In complex situations, mental simulation involves applying the response that the decision maker has decided to use to see how the results would "play out" if a specific response is taken.

The most significant advantages of using intuition for decision making are speed, creativity, tolerance of uncertainty and the ability to visualize the problem and its solution. In many malfunction-oriented aeronautical decisions, time is the critical factor. Intuitive decisions tend to be much faster as they rely on selection of a "satisficing" course of action (i.e., not necessarily optimal, but good enough) based on experience, rather than the generation and comparison of a multitude of possible solutions until the optimal one is chosen.

2. Klein's Recognition-Primed Decision Model (RPD)

Klein's model holds that experts, who are pressed for time, while facing a task loaded with uncertainty, first assess whether the situation strikes them as familiar or unique. This process is referred to as "recognition-primed" because recognizing the situation as similar to some situation previously experienced is key to how the accompanying response is generated and the ensuing action is carried out. Typical situations lead to typical (procedural) actions, while novel, or unique, situations pose new challenges, which cannot be solved simply by applying the same routine. To recognize the situation and guide the selection of proper action, the decision maker identifies critical cues that may explain the situation and causal factors that explain what is occurring and what may occur in the future. Experts use prior knowledge and experience to recognize and classify a situation. Rather than comparing in detail the pros and cons of the different outcomes, they quickly imagine (via mental simulation) how one course of action may play out and then either choose to adopt it, if it satisfies the situation, or adapt the response. Experts take the first workable solution they can find, and while it may not be optimal, it is often quite good.

When the situation is not recognized as familiar or typical, the experienced decision maker can still act. They can modify a course of action, retrieved from memory, that worked in a similar situation to accommodate the current situation.

Klein emphasizes that RPD is not a universal model of decision making. It is a model that is more suitable for situations that are: (1) characterized by high levels of uncertainty, and (2) likely to be encountered under time pressure by people with high levels of expertise. It is less likely to be applicable if these conditions are not met, if the decisions are naturally presented as choices, and if the decision maker feels a need to optimize the decision (Lipshitz, 1993).

3. Montgomery's Search for Dominance Structure

Montgomery is interested in how decisions are actually made when several alternatives are available. His answer is simply that a decision maker will search for a dominant alternative (Montgomery, 1989). An alternative is said to be dominant if it is at least as attractive as its competitors on all relevant attributes, and exceeds each of them on at least one attribute. Essentially, Montgomery thinks of decision making as the process of finding a good argument for acting in a certain way, first by a quick selection of a promising alternative and then by testing or ensuring the dominance of this alternative. He feels this is compatible with the limited capacity of human information processing, by focusing on a limited number of alternatives and accentuating the differences between them. Also, the availability of a dominant alternative helps decision makers to persist in its implementation and to rationalize and justify their choice. A drawback of this persistence in implementation may be the distortion of reality to maintain dominance of an alternative that is actually dominated by a better choice when the environment changes (Montgomery, 1993).

4. Rasmussen's Decision Processes

Rasmussen is interested in the decision making processes of human operators of complex systems. He has distinguished between three types of behavior that are controlled by qualitatively different cognitive mechanisms: skill-based behavior, rule-based behavior, and knowledge-based behavior (Rasmussen, 1983).

Skill-based behavior includes expert sensory-motor performance, which runs smoothly and efficiently without conscious attention. Skill-based behavior is controlled by a dynamic mental model that depicts the decision maker's movements and environment in real time, thereby enabling him to adjust rapidly to feedback. An example of this type of behavior is the pilot who subconsciously applies slight back pressure to the yoke to prevent a loss in altitude as a minor nose down pitch occurs in the aircraft. This correction is automatic and taxes neither long term nor working memory.

Rule-based behavior is controlled by rules and procedures that can be stated explicitly by the decision maker. This is a learned behavior and can become skill-based if practiced and repeated often enough. Information at this level is easily processed and indicates that a situation exists that requires invoking a known rule or specific action. Noble's situation assessment and Klein's RPD depict rule-based behavior in the early stages of situation recognition (Lipshitz, 1993). Pulling the emergency shut down handle for an indication of an engine fire is exhibiting rule-based behavior.

Knowledge-based behavior requires a deeper understanding of the situation before any action may be taken. An explicit consideration of options and objectives may be accomplished to preclude inappropriate behavior for a misunderstood environment. Unique situations, or environments with uncertainty and/or ambiguity are cases where knowledge-based behavior is most likely encountered. In the case of the engine fire above, rule-based behavior may move up a level to knowledge-based if the fire is accompanied by a simultaneous malfunction on another operating engine. An analysis of alternatives and ramifications of action would be conducted prior to automatically invoking a procedure.

5. NDM Use

Ambiguous, unstructured environments may be the best domains in which Naturalistic Decision Making is useful. Any situation requiring a rapid, almost subconscious decision may also be best suited for an intuitive process rather than a lengthy analytical one. Generally, intuitive decision making is better in conditions where:

-Time is critical.

-Decision makers are knowledgeable and experienced.

-There is a high degree of uncertainty.

-There is ambiguous or changing information.

-Innovative or creative thought is required.

The essential factor in NDM is experience. Experience is the critical element that allows for the situation assessment (which leads to situational awareness) that is at the heart of naturalistic decision making. Experience allows the decision maker to recognize a situation as typical, or if not typical, provide enough information from a similar situation to turn knowledge into understanding. If sufficient experience exists then valuable time is saved by not having to integrate cues and derive an original solution.

6. Disadvantages

There are drawbacks to using NDM for important aeronautical decisions. Intuitive decisions are based upon the decision maker's personal experiences and are subject to individual biases, prejudices, level of experience, and ego. The decision will be based on memories that may be inaccurate, incomplete or influenced by personal preferences. The situations where intuitive thinking is thought to be most applicable, under high stress and time critical, may tend to inhibit the intuitive process. Naturalistic decisions may not be trusted by seniors, peers or subordinates, as there is little or no documentation to back them up. Finally, inexperienced decision makers are not able to make good intuitive decisions, as they have little, or no, experience to draw from.

F. SUMMARY

From Bernoulli's Expected Value computation to today's NDM movement, decision theorists have produced a multitude of hypotheses on how and why decisions are actually made. Each strategy has roots in some common logic, but each is unique in its attempt to explain the reasoning and cognitive strategies of the decision maker for a particular set of circumstances or situation. Whether an analytical or naturalistic strategy is used, all decision makers use a process that requires a stimulus, developing situational awareness, choosing a decisive course of action and implementing this action. Situational awareness is the most critical aspect of any decision, as the lack of it (or an incorrect situation assessment) may result in an inappropriate response to a misdiagnosed malfunction.

It is important to realize that while cognitive strategies from the analytical and naturalistic methodologies may appear to be mutually exclusive, they can be used in a complimentary fashion during a single decision situation. To incorporate an analytical optimization into a decision process, after an intuitive situational assessment has been performed, is a practical method to deal with a unique situation that is not time critical. For example, the crew that now has time to conduct an optimal alternate airfield search after conducting a precautionary engine shut down for an unknown vibration is combining the two methodologies. The experienced crew decides the vibration warrants securing the engine, but now has the time to afford a deliberate and calculated choice of alternative landing sites. For any situation it is important to consider both models and what combination of the two will work best.

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III. METHODOLOGY

This study analyzes P-3 hazard reports (hazreps) to identify different types of decisions and decision making strategies used in an aeronautical environment. The following sections explain the purpose of a hazrep, the format and information contained within, and the analysis performed.

A. HAZARD REPORTS

1. Background

Unfortunately, naval aviation mishaps are an inevitable result of operations involving flying. The Navy continues to strive for a reduced aviation mishap rate through numerous safety programs. The Naval Aviation Safety Program is such a program; it is designed to reduce aircraft accidents through careful investigation, documentation and analysis of hazards. The goal of the program is to identify and eliminate hazards before they contribute to aviation mishaps. A hazard is defined as "a potential cause of damage or injury to aircraft or personnel" (OPNAVINST 3750.6Q, 1989, p.44). The Navy's mishap rate of 50 mishaps per 100,000 flight hours in the 1950's has dropped significantly to 0.7 per 100,000 flight hours in FY 1999 due mainly to this ongoing identification and reporting of hazards (Naval Safety Center statistics, 2000).

The most efficient and direct detection of hazards often is accomplished by an individual or command with first hand knowledge of the circumstances surrounding a hazardous situation. All command safety programs have methods in place to identify hazards, such as reviews of operating procedures, safety surveys, analysis of equipment failures and inflight incident reporting. Material/equipment failure, human error, physiological episodes, near mid-air collisions and bird strikes are examples of the multitude of inflight incidents where hazards can be identified and reported.

The Aviation Safety Officer (ASO) is a designated naval aviator or naval flight officer who is a graduate of the Aviation Safety School. The ASO is a participating pilot or naval flight officer in the squadron and possesses additional training as a specialist in the Naval Aviation Safety Program. For the purposes of investigating and reporting hazards, the ASO is the primary functionary in the process and authors the hazrep after receiving appropriate input from squadron members. It is the responsibility of the ASO (in conjunction with the Commanding Officer) to ensure that hazreps are submitted not only in the correct format but with full and forthright information surrounding the hazardous situation.

2. Format

Once a hazard is identified, submission procedures found in OPNAVINST 3750.6Q are followed to publish a hazrep, which is addressed to all pertinent commands, details the circumstances under which the hazard was identified and proposes actions to eliminate its future occurrence. To ensure the widest dissemination, the message is addressed to offices of the Chief of Naval Operations, Naval Safety Center and all activities that fly P-3's. The ASO assigns risk assessment codes to the hazard, indicating the probability of future occurrence and potential impact of the hazard if it does occur.

The body of the message summarizes the circumstances surrounding the hazard and its specific identification along with a listing of pertinent aircraft, equipment and weather data. The body of the hazrep attempts to explain the what, where, why and how of the hazard and provide enough details for others to fully comprehend the severity and repercussions if the hazard were to occur in the future. It discusses the crew's detailed analyses in order to give the reader insight into the pilot's decision making and thought processes. The corrective action section may propose a solution to eliminate the hazard (if one is readily apparent) without regard to cost or feasibility. Although a corrective action to eliminate the hazard may not always be readily identified, the hazrep still can be used as a valuable learning tool for pilots presented with similar situations in the future. Commanding Officer's comments conclude the message and provide a potential forum for further discussion of the severity of the hazard and the crew's performance in handling the situation. Figure 3-1 shows a sample format of a general use hazrep.

As mentioned above, the body of the message contains the relevant facts surrounding the identified hazard and the situation. The information presented to the crew from internal and external sources, the decisions made by the pilot and the actions performed are all outlined in the evidence and analysis section. This process mirrors the OODA loop discussed in the previous chapter: the pilot observes the environment, orients the information into some useable schema, decides on a course of action and then executes this course of action after the decision is made.

3. Concerns About Quality and Content

The quality of hazreps depends on the quality of the investigation into attendant circumstances. The success of the hazrep program relies on the submission of complete, open and forthright information and opinions in hazreps. The exercise of command influence to edit, modify, or in any way censor the content of reports is contrary to the spirit of the program and is prohibited by OPNAVINST 3750.6Q. Unfortunately, some Commanding Officers may believe that truly confessing all the bad with the good may harm the squadron's reputation or jeopardize future career opportunities; therefore some hazreps suffer from a lack of completeness.

Another area of concern is that hazreps are not considered privileged information. Privileged information assures confidentiality of the information given; such safety information cannot be used as evidence for other investigations regarding legal matters, misconduct, blame, etc. The authority for granting an assurance of confidentiality is strictly limited to the investigation and reporting of mishaps, and not hazards. The instruction states that extreme care must be taken to prevent giving the impression that the use of the hazrep is for safety purposes only, as is the case with mishap investigations. This lack of confidentiality may prevent some crews from giving open and forthright information from fear of repercussions.

B. EXPERT ANALYSIS

Due to the inherent ambiguity and incompleteness surrounding some of the content in the body of the hazrep and the Commanding Officer's comments, and due to the lack of formal investigation that accompanies the situation, the research method requires that an expert on the subject conduct the analysis. Such expertise is required to decipher the nuances familiar to the P-3 community, fill in unwritten gaps when questions arise and provide an estimate of the severity of a particular malfunction. The ability to extract what

Message Originator

PATRON XXXXXX//10//

Addressees

CNO WASHINGTON DC//N889E//
CMC WASHINGTON DC//A/SD//
COMNAVSAFECEN NORFOLK VA//00/10/11/054//
ALL ORION ACTIVITIES

Header & subject line

UNCLAS FOUO//N0370//

SUBJ/THIS IS A GENERAL USE AVIATION HAZARD REPORT, Originator, Serial Number, Date, P-3, Bureau number, REPORT SYMBOL 3750-19.//

Reference

REF/A/DOC/OPNAVINST 3750.6Q/-//
Other references as applicable

Summary

RMKS/1. THIS REPORT CONTAINS A (Routine or Severe) HAZARD TO NAVAL AVIATION. ENDORSMENT (Is or Not) REQUIRED. SUMMARY: Describe circumstances in brief statement of Who did What or What component failed When.

Message Body

2. DATA

A. AIRCRAFT (1) Model, (2) Bureau number, (3) Modex and side number, (4) Reporting Custodian
B. EQUIPMENT Nomenclature of aircraft parts or other parts involved (1) Model, (2) Make, (3) Part number, (4) Equipment code, (5) Configuration, (6) Work nit code, (7) etc.
C. ENVIRONMENT List (1) Date, (2) Local time, (3) Local time zone, (4) Day or Night, (5) Location, (6) Altitude, (7) Weather, (8) Other background information

3. CIRCUMSTANCES

A. EVIDENCE AND ANALYSIS. Fully and clearly describe the hazard in terms of who did what or what component failed.
B. CONCLUSIONS. Explain how hazard could result in damage and/or injury.

4. CORRECTIVE ACTION. Describe corrective action taken to eliminate the hazard, or corrective action needed to eliminate the hazard. Or, if it is beyond the capability of the originator to formulate recommended corrective, so state.

5. REMARKS. Content is at the discretion of the originator. Maintenance actions required to repair failed component or other postflight examination results can go here.

6. POINT OF CONTACT. Name, rank, phone number for inquires.

7. COMMANDING OFFICER COMMENTS. Commanding Officer's endorsement of the report

Figure 3-1 Hazrep Format (adapted from OPNAVINST 3750.6Q)

may appear to be inconsequential information may provide valuable insights to the resultant decision.

Based on previous experience, flight hours and schooling the author qualifies as an expert for the purposes of this study. With over 3500 flight hours in the P-3, he has personally witnessed many of the hazards identified in the 438 hazreps used in this analysis. As a former Fleet Replacement Squadron (FRS) instructor, NATOPS instructor pilot and instructor-under-training (IUT) instructor pilot, he is extremely well versed in the decision making processes of pilots and of the common errors associated with task overload, loss of situational awareness and poor airmanship. He was instrumental in developing the Aircrew Coordination Training (ACT) course for the P-3 FRS and taught the training track through several iterations. He is also a graduate of the Naval Aviation Safety Officer course and has served in billets as Aviation Safety Officer (ASO) and Safety Department Head. As such, he has authored well over a hundred hazreps (and reviewed hundreds more) in his career.

C. CONTENT ANALYSIS

The hazrep was divided into several different levels based on type, class and category as shown in Table 3-1. The analysis was based primarily on the content of the evidence and analysis paragraph, with supplemental and corroborating evidence from the CO comments and environmental data sections. While the table shows the different categories, Figure 3-2 illustrates the process used to extract the data into useable

Type	Class	Category
Airframe Electrical Engine Instrument NMAC Other Press Prop	Knowledge	Ambiguous Indications Compound factors Multiple malfunctions Unique; no NATOPS guidance Unusual malfunction
	Rule	Ambiguous Indications (single COA) Compound factors (procedural) Multiple malfunctions (procedural) Simple procedural Unique; no NATOPS guidance Unusual malfunction
	Skill	Improper procedures Situational awareness Survival

Table 3-1 Hazrep Type, Class and Category

information for the decision making analysis. As can be seen, after the type, class and categories are established, each hazrep is subjected to analysis based on the use of judgment, the outcome, and an explanation for the outcome.

1. Type

Classification by type is accomplished by selecting the aircraft system that is most responsible for the submission of the hazrep. Table 3-2 shows the eight different classifications by type and the subsystems within each type. This classification by equipment type is necessary to aid in the identification of specific systems that may have a greater propensity toward failure, thus pinpointing an area for concentrating engineering solutions to prevent future hazards. This also may shed some light on the type of system

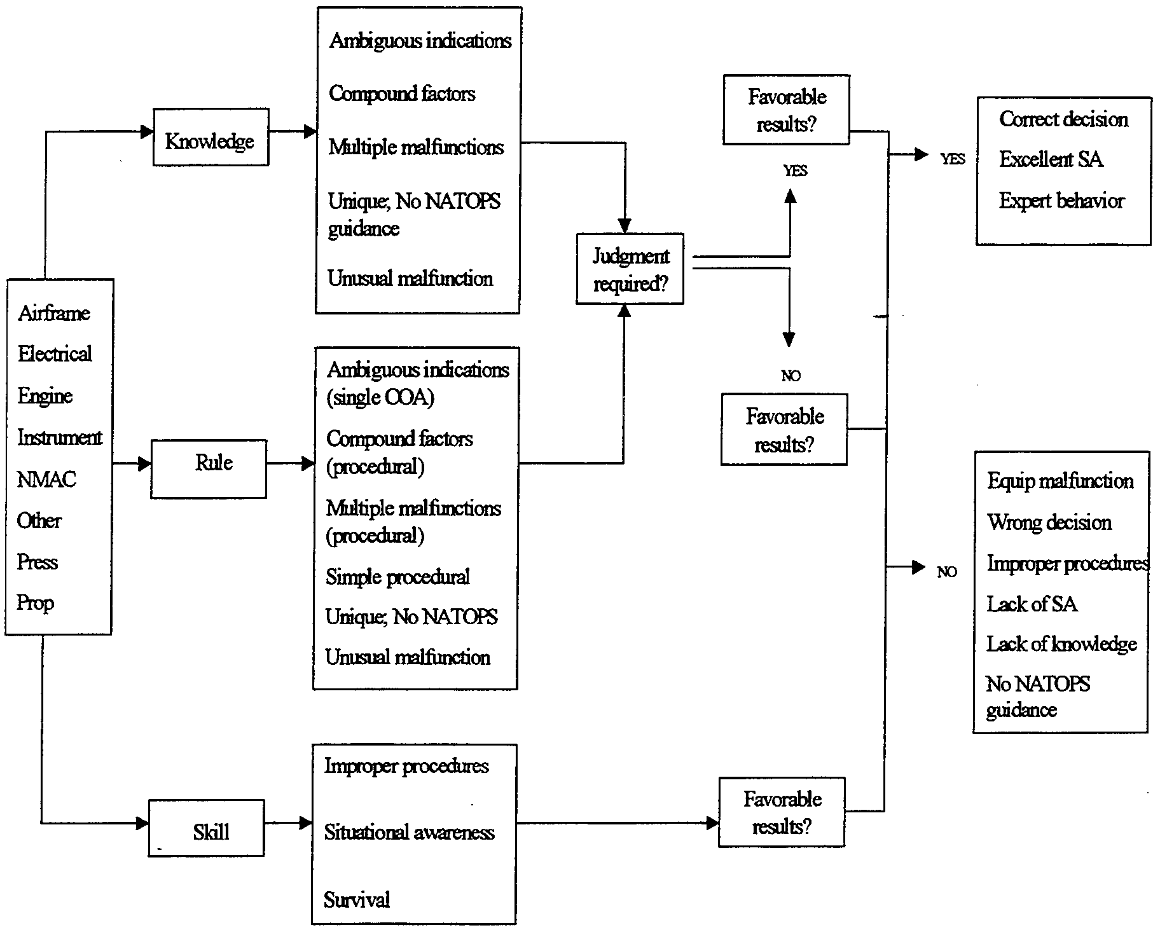

Figure 3-2 Methodology Model

malfunctions that are more prone to a specific kind of decision making, or systems that are more susceptible to errors due to their complexity, ambiguity, or lack of current guidance.

Classification by type is a relatively straight forward process and is usually easily discernible from the subject line or opening statement of the summary section. Where multiple components from different systems are involved in the scenario (e.g. chips light and propeller malfunction), the system that is most responsible for the subsequent decisions and/or procedures is cited as the type. While numerous systems may be evident in a single hazrep, one of them is usually the cause for the majority of decision making behavior. For example, a prop overspeed occurring on the return transit after an oil leak caused a mission abort, would be classified as engine, since the decision to act on the leak already has occurred.

Type	Malfunctions pertaining to:	
Airframe	Hydraulic system Flight controls Windshield Landing gear	Brakes Flaps Antennas (external) Vibrations (not engine or e-handle) Fuel tanks
Electrical	Generators Circuit breakers	Fire of Unknown Origin (FOUO) Shock
Engine	Turbines Fire warnings E-handles Bleed air Flameouts Fuel Gear boxes	Oil pressure & quantity Loss of power Vibrations Chips lights Start/Restart Power levers
Instrument	Navigation Attitude source	Gauges
Near mid-air-collisions (NMAC)	Other aircraft UAVs	Vehicles
Other	Bird strikes Basic skill errors	Weather
Pressurization	Engine driver compressors (EDC) Pressurization controller Air multiplier Refrigeration unit turbines	Outflow valve Physiological episodes Auxiliary power unit (APU)
Propeller	Off speed conditions Pitchlock Decouple Feather pump Prop leaks RPM flux	Fails to feather Fails to unfeather Negative torque sensing system (NTS) Beta & NTS inop lights Prop deice Prop pump lights

Table 3-2 Classification by Type

2. Class

Sorting the hazreps by class is a bit more difficult than separation by type. This process requires grouping the hazreps based on their environment, using the characteristics of decision processes identified by Rasmussen (1983): knowledge-based, rule-based or skill-based behavior. "Behavior" in this analysis may be appended with "environment," as the classification is based on the circumstances presented to the decision maker as well as the resulting behavior. However, this is a fine distinction as it is almost certain that a knowledge-based environment requires knowledge-based behavior, since the situation requires a deeper understanding and explicit consideration of options and objectives.

The following definitions apply to each of the classes:

Knowledge-based - requires a thorough understanding of the situation before any action may be taken; multiple alternatives may be available depending on situation assessment and judgment of the decision maker.

Rule-based - rules and procedures can be stated explicitly by the decision maker; specific action is required for given cues and indications.

Skill-based - evidence of expert sensory-motor performance without conscious attention (automatic stimulus-response reactions); skill errors.

Note that the skill-based environment is broadened from merely subconscious sensory-motor actions to one that includes immediate "survival" reactions (near mid-air collision avoidance) and skill-based errors. These survival reactions are automatic stimulus-response reactions that are so well learned that they appear to be automatic.

Skill-based errors include those hazards that are a direct result of improper procedures being performed (or proper procedures *not* being performed) and should not have occurred. An example of this situation is a three engine landing for an oil leak that is caused by an improperly seated oil cap. The skill-based error occurs during preflight when the cap is improperly replaced and this is not noticed.

The following sections develop these definitions of knowledge-based, rule-based and skill-based classes further as the categories within each are defined. The most difficult part of the classification is discriminating between knowledge-based and rule-based when the situations become more complex. The main distinction is based on whether there is a single course of action and whether the decision maker has to use experience and extensive judgment in the decision making process.

3. Categories within the Classes

a) Knowledge-based Categories

Table 3-3 shows the five categories within the knowledge-based class and the accompanying classifying criteria. The categories are: ambiguous indications, compound factors, multiple malfunctions, unique situations with no NATOPS guidance and unusual malfunctions. The hazreps fitting these categories are those involving ambiguous data or cues, multiple course of action scenarios where the pilot must make a judgment or choose among many alternatives, and unique, or unusual, situations that cannot be solved with a simple application of NATOPS procedures.

b) Rule-based Categories

Table 3-4 shows the six categories within the rule-based class and their accompanying classifying criteria. The categories are essentially the same as the knowledge-based categories with the addition of simple procedural.

The distinction between the knowledge-based and rule-based categories with the same names lies in the situation. If the situation is one that can be handled with a strict set of rules or procedures, then it is rule-based, even in the event of compound or multiple malfunctions. If the resulting action is the same regardless of the number of malfunctions or complexity of the situation, then it remains rule-based. For example, a fire warning that is not evidenced by an aircraft system warning but is seen visually by a crew member who notices a torch emitting from the turbine (ambiguous indications) is classified as rule-based, since the procedure is to secure the engine. On the other hand, a fire warning from the aircraft system that continues after the engine is secured, but is not accompanied by visual or other indications, is classified as knowledge-based, since the decision to release subsequent fire extinguishing agents is left to the pilot's discretion.

Knowledge Categories	Scenarios involving:	Sample summary/CO comments
Ambiguous indications	Indications of malfunction/failure without accompanying system warnings (e.g. suspected oil leak with quantity indicating normal)	Elected to secure based on unknown fluid… Could not determine type of fluid…
	System warnings of malfunction/failure with no accompanying indications (e.g. multiple fire warnings with no fire present)	No sign of fire existed, but warning persisted… No evidence of leak except on quantity gauge…
	Suspect system shows signs of failure, but then operates normally (e.g. near flame out followed by normal operation)	Flt station indications were normal, despite… Unable to determine cause…
Compound factors	Elements that add complexity to the decision (e.g. weather, heavy aircraft, deteriorating situation, IMC, darkness)	Elected to land overweight due to deteriorating conditions…
	High workload (e.g. air traffic density, comm.. problems)	Crew altered checklist, due to night environment…
	Detachment operations (e.g. no expert support available)	PPC had case of get-home-it is…
	Multiple divert options (e.g. destination IMC vs. no support at alternate)	Suspecting bad weather at dest, crew diverted to alternate…
	Procedures ineffective on malfunction (e.g. unable to secure power to malfunctioning equipment)	Decision contained numerous options… Multiple decisions had to be made…
Multiple malfunctions	Malfunctions or emergencies that cannot be handled by strict set of procedures (e.g. chips lt #1 & prop leak #4)	Encountered second, unrelated malfunction… Good discussion involving multiple options…
	Malfunctions where sequence of handling is up to PPC discretion (e.g. fire warning while another engine loitered)	This scenario had numerous alternatives… Sound decision making in multi-malf. scenario…
	Second malfunction causes loss of separate system due to actions taken on first malfunction (e.g. loss of press due to starboard EDC failure after #2 engine previously secured)	SA necessary when encountering multi-malf… Crew did not notice affects the procedures had on the pressurization…. PPC elected to handle prop malf first…
Unique; No NATOPS guidance	Malfunctions not addressed in NATOPS that require judgment to decide on course of action (e.g. all fuel quantity gauges show erratic indications vice one)	Unique situation, good troubleshooting… Excellent SA in situation not covered by the book... This one is not specifically covered in NATOPS...
	New systems (e.g. GPS antenna testing)	
Unusual malfunctions	Seldom seen, out of the ordinary malfunctions (e.g. yaw oscillations in rudder without the autopilot engaged)	Good troubleshooting this unusual malfunction... Prior knowledge was helpful in diagnosing this unusual malfunction…

Table 3-3 Categories in Knowledge-Based Class

Rule Categories	Scenarios involving:	Sample summary/CO comments
Ambiguous indications	Indications of malfunction/failure without accompanying system warnings, but procedures are prescribed (e.g. FOUO where crew is unable to locate source of fumes; abort mission)	Situation was confusing, but procedures straight forward...
	Expected indications after component failure not seen, but procedures still performed (No Gen 3 off light with loss of Bus B; perform Gen Off procedures)	Malfunction not readily discernible...
	No system warnings of obvious malfunction (e.g. flame from engine with no fire warning; secure engine for fire)	
Compound factors	Elements that add complexity to the event, but do not alter the prescribed procedures (e.g. malfunction on runway during simulated engine out landing)	Crew acted quickly and correctly...
	Original malfunction deteriorates, procedures still performed (e.g. engine with chips light experiences turbine failure)	Good reaction in busy environment...
Multiple malfunctions	Multiple malfunctions that can be handled procedurally (e.g. #4 Gen off light with #2 decouple)	Handled multi-malfunctions with ease....
	Multiple malfunctions that require no sequencing of actions (e.g. abort for prop leak and discover oil leak enroute dest.)	This is why we train and study the book...
Simple procedural	Straight forward malfunction with clear, unambiguous procedures (e.g. flap asymmetry light, unsafe gear, engine fire, prop overspeed, chips light, RGB failure)	Textbook handling of common malfunction...
Unique; No NATOPS guidance	Malfunctions not addressed in NATOPS that do not require judgment (e.g. frozen flap brake; no flap landing)	
	New systems (e.g. test equipment arcing; perform FOUO)	
Unusual malfunctions	Seldom seen, out of the ordinary malfunctions, but actions are obvious (e.g. RGB accessory section failure; secure eng.)	

Table 3-4 Categories in Rule-Based Class

c) Skill-based Categories

Table 3-5 shows the three categories within the skill-based class and their accompanying classifying criteria. The categories are: improper procedures, situational awareness and automatic stimulus-response. The improper procedures and situational awareness categories relate to errors made that are a direct cause of the hazard. The resulting malfunction would not have occurred if the person or persons responsible for the error had properly performed the procedures. These were special case categories created to examine how skill based behaviors affect decision making and record how often they are responsible for hazards.

Skill Categories	Scenarios involving:	Sample CO comments
Improper procedures	Actions of the pilot or crew cause a malfunction to occur (e.g. high angle of attack on climbout in a heavy aircraft with high power settings causes fire warning)	Never should have occurred...
	Oversight or preflight errors cause malfunction (e.g. oil cap improperly replaced after servicing, brakes not set)	Complacency and improper procedures caused...
	Normal inflight procedures performed incorrectly (e.g. improper fuel crossfeed results in fuel starvation and flameout of engine, altimeter conversion)	Chain of events should have been broken...
Situational awareness	Unaware of surroundings (e.g. improper malfunction set up in training scenario, missed comms, gauge reading error)	SA could have Prevented...
	Unaware of implications on system (e.g. failure to Affects of loss of mag heading to inertials)	Should have queried ATC better...
Auto stimulus-response	Immediate evasive action (e.g. NMAC without time to judge Closure or distance, vehicle on runway)	Pilot's quick reaction...
		Excellent reflexes...

Table 3-5 Categories in Skill-Based Class

4. Judgment

The question as to whether the situation requires judgment on the part of the pilot is slightly subjective. If the pilot uses discretion in the application and/or timing of procedures or is presented a choice of actions, then judgment is considered to have been used. If the pilot has a decision regarding a best case/worst case scenario, then judgment is considered to have been used. An example of this is the scenario in which an unknown fluid leak appears on the engine nacelle. If there are no indications on the flight station gauges to confirm the leak, the pilot may reason that the worst case is a fuel leak that presents the possibility of fire, while the best case is either condensation or an insignificant amount of oil. It is then up to the pilot's discretion regarding what course of action to take -- secure the engine and abort, continue engine operation and abort, or continue engine operation and the mission. Judgment is not limited solely to the knowledge category, as some rule-based scenarios require the use of judgment when deciding on aborting the mission, possible alternate airfields or the sequencing of procedures.

5. Favorable Outcome

A hazrep with a favorable outcome is one in which the correct decisions are made for a given scenario *and* the actions taken are correct for the malfunction. The second half of this rule is in place for two reasons. First, to prevent equipment malfunctions from going undocumented and second, to note the improper performance of procedures after correctly diagnosing the situation. For instance, a three engine landing for a fire warning is the correct decision for this malfunction. However, if the fire warning is due to a faulty fire warning element, then an unnecessary three engine landing has been performed. The crew made the right decision based on the information presented, but this is not a favorable outcome. Similarly, the pilot that elects to secure an engine for an unknown fluid leak (assuming worst case scenario) may have made the correct decision if the fluid was indeed a fuel leak, but not if it turns out to be a slight oil leak that is within limits.

These unfavorable outcomes are not a reflection on the pilot, but rather on the aircraft detection and warning systems. The unfavorable outcome for the crew that correctly diagnoses the situation but performs the wrong procedures is obvious and needs no further explanation.

6. Explanations for Outcomes

The author's best attempt is made to assign an explanation to those hazreps where an unfavorable outcome exists, judgment has been used, or a favorable outcome is achieved and the cause is readily apparent. For the majority of hazreps in which a favorable outcome exists (especially those in the simple procedural rule-based category) there is no assignment of correct decision, as this is implied by the lack of an unfavorable assignment. Table 3-6 lists the explanations used and the definitions adhered to for their assignment to a hazrep.

D. SAMPLE HAZREP ANALYSES

Appendix A presents an analysis of three hazreps based on the rules and criteria outlined in this chapter. Actual sample "EVIDENCE AND ANALYSIS," "REMARKS" and "CO COMMENTS" paragraphs are quoted for the reader.

Favorable outcome explanations	Behavior exhibited / Substantiating criteria
Correct decision	Action is appropriate for the situation; Decision does not involve expertise or great thought, but an incorrect choice is also available; lucky choice made
Excellent SA	Pilot has outstanding grasp and knowledge of the situation; Easily sorts through ambiguous cues to find ground truth; Reality and pilot's perception are nearly identical
Expert behavior	Prior knowledge of similar situation used; judgment used to sort through conflicting data; past experiences used to assimilate situation; troubleshooting used that is beyond textbook; creative solutions used on unusual or unique malfunctions
Unfavorable outcome explanations	**Behavior exhibited / Substantiating criteria**
Equipment malfunction	System indicators do not corroborate actual malfunction or indicate false alarm/erroneous data
Wrong decision	Pilot makes incorrect choice based on cues; bad luck
Improper procedures	Wrong choice of procedures for situation; correct procedures chosen, but performed incorrectly or out of Order
Lack of SA	Pilot does not grasp situation; reality and perception differ; correct decision made for wrong situation; tunnel vision exhibited; pilot's dominant alternative masks correct one; ramifications of actions not considered
Lack of knowledge	Insufficient knowledge to decipher cues; ramifications of actions unknown; lack of systems knowledge to properly troubleshoot situation
No NATOPS guidance	Malfunction not covered in NATOPS; no guidance Available

Table 3-6 Explanations for Outcome

IV. RESULTS AND DISCUSSION

A total of 438 hazreps covering years 1996-1999 were reviewed and analyzed (see Appendix B for complete list of hazreps). This chapter presents the results of the analysis and develops a model to illustrate the decision making process of P-3 pilots as revealed in this study. The chapter's first section presents the results of categorizing the decision events according to the class of rule-based, knowledge-based or skill-based behaviors, and the second section presents the results of analysis of the hazreps in terms of the major contributing factors for both favorable and unfavorable outcomes. The results are quite extensive and an enormous amount of information is presented (Appendix C contains full summary table). However, a majority of the results contained in the accompanying tables may be of more use for future studies and P-3 specific evaluations. Therefore, to maintain the focus on decision making, two major goals of this chapter are presented:

-Identify those situations that are best served using an Analytical decision making strategy and those where a Naturalistic decision making strategy is more applicable;

-Identify and explain the major cause of unfavorable outcomes in each of the rule-based, knowledge-based and skill-based classes.

Accomplishing these goals will provide a basis for identifying requirements to better train and equip decision makers in an aviation environment.

A. CLASS OF DECISION BEHAVIOR

The hazreps were categorized according to the class of decision behavior (using the characteristics of decision processes identified by Rasmussen: knowledge-based, rule-based or skill-based behavior), type of aircraft system that was most responsible for the submission of the hazrep and the category that most accurately describes the situation encountered in the hazrep. Table 4-1 presents the percent of hazreps for each category based on the type of decision making behavior/environment.

1. Rule-based Decisions

Rule-based overall. The greatest number (78%) of hazreps were categorized as involving rule-based behaviors. This high percentage was expected and is attributable to a sound Safety/NATOPS program and years of observation and experience. The intent of the hazrep is to reduce future hazards by identifying them and finding and incorporating into the NATOPS publications a subsequent "cure" to prevent their recurrence. One of the ways the Safety/NATOPS program accomplishes this task is by providing rules, procedures and checklists for a crew to follow in the event of a malfunction. The NATOPS program is under constant review; changes to the flight manual are submitted continuously and a conference held annually to review these submissions for additions to the manual. The NATOPS manual has grown considerably over the years as new hazards are identified (and procedures modified to best handle a situation) and is often referred to as a manual that is "written in blood": unfortunately, the blood of previous aviators that had the misfortune of not having a checklist or procedure to guide them. Ideally, the rule-based category would contain 100% of the hazreps and all malfunctions would have a corresponding procedure or textbook solution.

The rule-based class was divided into two subclasses, based on whether or not judgment was applied when deciding on a course of action. These are: rule-based simple and rule-based judgment. The judgment subclass contains those hazreps where pilot discretion was used prior to deciding on a course of action. However, the prescribed

Class		%	Type	%	Category	%
Rule 78%	Simple	90	Airframe	21	Ambiguous indications (single COA)	5
			Electrical	11	Compound factors (procedural)	2
			Engine	39	Multiple malfunctions (procedural)	4
			Instrument	0	Simple procedural	85
			NMAC	0	Unique; no NATOPS guidance	2
			Other	2	Unusual malfunction	2
			Press	3		
			Prop	24		
	Judgment	10	Airframe	18	Ambiguous indications (single COA)	6
			Electrical	18	Compound factors (procedural)	9
			Engine	24	Multiple malfunctions (procedural)	0
			Instrument	0	Simple procedural	85
			NMAC	0	Unique; no NATOPS guidance	0
			Other	3	Unusual malfunction	0
			Press	3		
			Prop	34		
Knowledge 18%			Airframe	10	Ambiguous indications	33
			Electrical	19	Compound factors	38
			Engine	36	Multiple malfunctions	13
			Instrument	6	Unique; no NATOPS guidance	6
			NMAC	9	Unusual malfunction	10
			Other	2		
			Press	5		
			Prop	13		
Skill 4%			Airframe	0	Improper procedures	56
			Electrical	0	Situational awareness	22
			Engine	33	Survival	22
			Instrument	6		
			NMAC	28		
			Other	16		
			Press	11		
			Prop	6		

Table 4-1 Results by Class of Decision Behavior, Type of Aircraft System and Category Describing the Situation

course of action was still relatively straightforward and had a clear procedure identified to handle the malfunction, thus it remained in the overall rule-based class.

Rule-based simple. Ninety percent of hazreps contained in the rule-based class were in the "simple" subclass (this group encompasses 70% of the total sample). The majority of tasks in the aviation domain are procedural in nature. Many years and numerous resources have gone into developing checklists and procedures for situations that have occurred or can be expected to occur. Since these checklists prescribe the appropriate courses of action for specified situations, in many instances, the task of the decision maker is not to generate and evaluate a course of action, but rather to accurately assess the situation and pick the appropriate procedure. As mentioned previously, ideally all situations encountered would fall into this "simple" rule-based class and aeronautical decision making would be reduced to merely picking the correct checklist or procedure to apply for any given situation.

Rule-based with judgment. Ten percent of the rule-based class fall in the rule-based with judgment subclass (8% of the total sample). This number is considerably smaller than the rule-based simple category and indicates that some rule-based decisions do require discretion or judgment, even though a procedure exists to handle the malfunction. Troubleshooting unknown vibrations or deciding on the timing of procedures in a complex scenario are examples of the types of hazreps contained in this subclass.

a) Cognitive Decision Strategy Used

Although the pilots in the rule-based situations do not have to generate and evaluate several courses of action before making a decision to act, they still utilize an analytical strategy during their decision making process. They are required to choose the proper checklist or procedure from a myriad of possibilities contained in the NATOPS manual and must use some sort of structured or logical analysis to do so. Much of this is learned through training and rote memorization of stimulus-response scenarios and requires little in the way of judgment or experience. Almost all of the hazreps in the rule-based category involve situations that can be handled by use of an analytical decision making strategy. Analytical decision making situations are characterized in the following way:

-A choice among clearly defined options exists;

-Complete and reliable information is available;

-An optimal decision is desired;

-Decisions must be justified.

However, the ability to correctly assess a situation and choose the proper procedure may use cognitive skills that are based on experience and pattern recognition, thus exhibiting characteristics of the naturalistic decision making process. Further, some situations do require judgment (10% of the rule-based class in this study) and the pilot is more apt to use experience and knowledge of previous situations to assist in the decision regarding which procedure to invoke. This use of experience is characteristic of the pattern matching found in the recognition-primed decision strategy (a strategy that is part of the NDM methodology). Decisions categorized as using a rule-based behavior cannot, therefore, be characterized as relying solely on an analytical decision making strategy.

2. Knowledge-based Decisions

Knowledge-based. Eighteen percent of the hazreps analyzed were categorized as involving knowledge-based behavior. These situations involve complex decisions where experience and judgment are critical. The problems are such that determination of a clear-cut situation assessment can be difficult or the situations may be compounded by ambiguous information or multiple malfunctions. Judgment is required in 100% of these scenarios. Pilots faced with this class of decision require vast experience and years of training to properly assess the situation and arrive at appropriate courses of action. Therefore, situation assessment becomes at least as important a step as selecting from a checklist or implementing a procedure. A critical component of performing situation assessment for these situations may be to know when a situation is unusual and does not have a corresponding procedure. This requires that the decision maker possess a wealth of knowledge concerning typical malfunctions and scenarios, and that he be able to relate these to the current situation. Rule-based procedures may eventually be used in these situations, but the process used to decide on which procedure to use requires pattern matching, mental simulation and intuition.

a) Cognitive Decision Strategy Used

Experience and judgment are critical when dealing with situations that are ambiguous in nature or are compounded by multiple malfunctions. As the situations encountered increase in complexity the decision maker relies on familiarity developed through experience gained as a result of having dealt with similar types of previous events.

This experience base also enables the decision maker to engage in mental simulation to attempt to gain situational awareness and "role-play" how a particular course of action might play out before implementing it. Both Klein's RPD and Noble's Situation Assessment models describe the behaviors exhibited by the decision makers in these complex decision making situations. Using past experience to recognize a familiar situation, mental simulation and role-play of future events typify recognition-primed decision making and are the core of knowledge-based decision methods. Almost all of the situations encountered in these hazreps fit the conditions that describe recognition-primed decision (a strategy of the NDM methodology):

-There is a high degree of uncertainty;

-There is ambiguous or changing information;

-Innovative or creative thought is required;

-Decision makers are knowledgeable and experienced.

It must be noted that decisions made in the knowledge-based class are under the same scrutiny as those in the rule-based class and the decision maker must often choose the optimal course of action. Based on this requirement, one could argue that Analytical decision making is best suited for knowledge-based situations. Actually, analytical behaviors are invoked in deciding on a course of action once the decision maker clarifies the situation and begins to evaluate possible courses of action. The author believes that this aspect of decision making (i.e. evaluating courses of action) is better suited to the structured and evaluative approach of analytical decision making. However, the use of the recognition-primed cognitive strategy (pattern matching, mental simulation, expert situation assessment) is also critical to properly execute the process in its entirety. Therefore, as is the case with the rule-based class, knowledge-based situations require cognitive strategies from both the analytical and naturalistic methodologies.

3. Skill-based Decisions

Skill-based. Four percent of the hazreps analyzed were categorized as involving skill-based behaviors. These situations requiring skill-based behavior dealt primarily with preflight errors and the results associated with the improper performance of procedures. Since the hazreps in these instances were usually a result of previous behavior, the decision making process cannot be characterized due to a lack of information in the hazrep. The event described in the hazrep was an explanation for the handling of the resultant malfunction and did not address behaviors that caused the performance of improper procedures in the first place. Based on the experience and expertise of the author (often in corroboration with remarks made by the Commanding Officer in the hazrep) it is apparent that most of the errors were caused by a lack of situational awareness. The skill-based class is included in the study to illustrate the ensuing problems that can occur with an error in skill-based behavior, such as when a flight engineer leaves the oil cap unfastened which results in an oil leak inflight and a subsequent three engine landing.

Also included in this class are the basic stimulus-response, or automatic reactions, to near mid-air collisions. No judgment is required as this is an instantaneous reaction to a life-threatening situation. This is an example of a learned response that is so well learned that the resulting behavior is almost innate to the decision maker and requires very little conscious effort or thought. An error in this skill-based behavior would obviously have grave consequences.

a) Cognitive Decision Strategy Used

The limited information contained in these situations categorized as involving skill-based behavior makes it difficult to determine what type of decision making cognitive strategy is being used when preflight errors occur. Based on the characteristics of the recognition-primed decision making strategy, the instantaneous, or intuitive, reaction to an approaching aircraft could be considered a case of very rapid pattern matching and could be considered to fit in this category.

4. Type of Aircraft System

Engine and propeller malfunctions were the major system contributors across the entire sample of 438 hazreps. This pair of system contributors was expected, as the engine and propeller systems are the two most complex systems on the aircraft and have far more moving parts and accessories than other aircraft systems. Categorizing by type of system contributing to the malfunction does not provide much data in the analysis of decision making, but may provide valuable information for engineering, manufacturing and rework facilities for the P-3, as it highlights two relatively high failure systems.

5. Category Describing Situation

a) Rule-based Decisions

Simple procedural was the standout category leader in describing the situation encountered in the rule-based class, accounting for 85% of the total. As mentioned previously, this is expected, as the intent of the Safety/NATOPS program is to provide a simple "by the book" procedure for any encountered malfunction.

b) Knowledge-based Decisions

Situations involving compound factors (38%) and ambiguous indications (33%) combined to make up 71% of the situations encountered in the knowledge-based class. These situations were not covered explicitly in the NATOPS and require the decision maker to use judgment, expertise and experience to correctly assess the situation and decide on a course of action.

B. OUTCOME AND EXPLANATIONS OF HAZREP SITUATIONS

The results included in the hazreps regarding favorable and unfavorable outcome were quite informative and are discussed below. Table 4-2 presents the results of the analysis. It appears that the likelihood of a favorable outcome decreases as the complexity of the problem situation increases. Clearly interpretable, unambiguous and uncompounded situations are more likely to produce a favorable outcome, as rules and procedures exist to handle them.

1. Rule-based Decision Outcomes

The rule-based simple class comprised the largest category and had the highest percentage of favorable outcomes at 92%. This was expected, as the simple rule-based situations merely require a quick and easy situation assessment followed by the selection and application of the corresponding procedure. A high level of expertise is not

Class		%	Favorable outcome %	Favorable outcome Explanation	%	Unfavorable outcome %	Unfavorable outcome Explanation	%
Rule 78%	Simple	90	92	Correct decision	100	8	Equip malfunction	72
				Expert behavior	0		Improper procedures	12
							Lack of knowledge	0
							Lack of SA	8
							No NATOPS guidance	8
							Wrong decision	0
	Judgment	10	76	Correct decision	64	24	Equip malfunction	0
				Expert behavior	36		Improper procedures	50
							Lack of knowledge	0
							Lack of SA	12
							No NATOPS guidance	0
							Wrong decision	38
Knowledge 18%			65	Correct decision	27	35	Equip malfunction	29
				Expert behavior	73		Improper procedures	11
							Lack of knowledge	11
							Lack of SA	46
							No NATOPS guidance	0
							Wrong decision	3
Skill 4%			22	Excellent SA	100	78	Equip malfunction	0
							Improper procedures	29
							Lack of knowledge	0
							Lack of SA	71
							No NATOPS guidance	0
							Wrong decision	0

Table 4-2 Results by Outcome and Explanation of Hazrep Situations Encountered

necessarily required and the malfunction can usually be handled quickly and effectively through applying the clear guidance contained in the NATOPS flight manual.

Only 8% of the rule-based category had unfavorable outcomes, and the largest contributor for an explanation of these unfavorable outcomes was "equipment malfunction" (72%). This equipment malfunction is different from an equipment failure that is considered routine and expected (e.g. chips light or oil leak), and is the result of a failure of a detecting or indicating system (e.g. oil transmitter failure with oil system operating 4.0, or fire warning detection system that gives an erroneous indication). In fact, almost all of the pilots in these situations correctly performed procedures for the indications exhibited, but the outcome was still considered "unfavorable" since the malfunction was actually a false alarm and involved an unnecessary abort.

The rule-based judgment class is relatively small and there were fewer favorable outcomes (76% favorable) than in the rule-based simple category. This is probably due to the increased complexity of the decisions when judgment is required. Judgment relies on the expertise, experience and discretion of the pilot and is affected by the situation.

The rule-based judgment subclass involves decisions that are simpler than those in the knowledge class and have procedures more or less spelled out, but still have room for error in performing situation assessment and/or the selection of appropriate procedures. While most of the rule-based situations merely require a stimulus-response type behavior (e.g. "if 'x' occurs, execute 'y'"), there is a chance that the decision maker may misinterpret the stimulus "x" or fail to consider all the cues presented in the situation. The correct procedure in the decision maker's mind might actually be contrary to the actual procedure required. An example of this type of incorrect selection of the appropriate procedure is the pilot who mistakenly performs pitchlocked propeller procedures for a propeller that has not yet pitchlocked. In his assessment of the situation, the pilot mistakenly believes the propeller to have already pitchlocked and performs the procedures accordingly.

"Improper procedures" (50%) was the leading cause of unfavorable outcomes in the rule-based judgment subclass. It appears that incorrect situation assessment was the major basis for the performance of improper procedures and can possibly be explained by one of the following. The decision maker incorrectly assessed the situation and selected procedures based on this incorrect assessment (pitchlocked propeller case above); he assessed the situation correctly but performed the wrong procedure; or he was locked into a dominant alternative and failed to reassess a changing situation, thus performed the wrong procedure.

2. Knowledge-based Decision Outcomes

Ambiguous indications (33%) and compound factors (38%) combined accounted for 71% of the hazreps (as shown in Table 4-1) in the knowledge-based class. The percentage of favorable outcomes was 65% and was due largely to expert behavior (73% of the favorable outcomes were attributed to this). Commanding Officer's comments on favorable hazreps all referred to the experience, sound judgment and professionalism exhibited by the pilots in the favorable outcome situations.

Unfavorable outcomes (35%) were due primarily to a lack of situational awareness (46% attributed to lack of SA). This clearly illustrates the need for experience and expertise in the cockpit. Many of the hazreps with unfavorable outcomes contained Commanding Officer's comments regarding the inexperience of the crew or lack of sound decision making skills. "Equipment malfunction" (29%) was the second leading cause of unfavorable outcomes and it can be easily seen that erroneous indications (discussed previously under rule-based simple class) can complicate an already ambiguous situation.

Again, this was a system indicating problem and does not imply wrong-doing on the part of the pilot.

3. Skill-based Decision Outcomes

The favorable outcomes (22%) were all directly attributable to excellent SA on the part of the pilot in avoiding a mid-air collision. The 78% of unfavorable outcomes were attributed primarily to a lack of SA on the person responsible for the preflight error that caused the hazrep situation (refer to Class of Decision Making Behavior 'Skill-based' earlier in the chapter). Table 4-3 summarizes the results discussed above.

Class	% Favorable	#1 Explanation	% Unfavorable	#1 Explanation
Rule-based Simple	92	Correct decision	8	Equipment malfunction
Rule-based Judgment	76	Correct decision	24	Improper procedures
Knowledge-based	65	Expert behavior	35	Lack of SA
Skill-based	22	Excellent SA	78	Lack of SA

Table 4-3 Outcome synopsis of explanations for favorable and unfavorable situation outcomes

C. MODELLING DECISION MAKING

A simplified model of decision making based on the analysis conducted in this study is presented in Figure 4-1. It illustrates the inputs and outputs to memory as the processes of the OODA loop discussed in Chapter II. As can be seen, a decision maker attempts to gain situational awareness by first processing the observed cues in working memory. If an immediate response is not readily apparent, the decision maker must attempt a pattern match with templates of prior experience stored in long term memory. A decision is then derived in working memory and an appropriate action performed.

Figure 4-2 is a more elaborated model of the decision processes used by pilots for the problem situations encountered in this study. It is a hybrid model that combines properties of the OODA loop, cognitive hierarchy, pattern matching model and Rasmussen's (1983) decision behaviors. The figure shows two major processes working concurrently: the decision making processes of the OODA loop (Observe, Orient, Decide and Act) and the information processes of the cognitive hierarchy (data being transformed to information, and then to knowledge, and finally to understanding). The boxes (outlined in bold) of the OODA loop represent major stages in the processing of information, two of which are located in working memory. Although working memory is depicted as two separate levels, it should be thought of as one entity, as depicted in Figure 4-1.

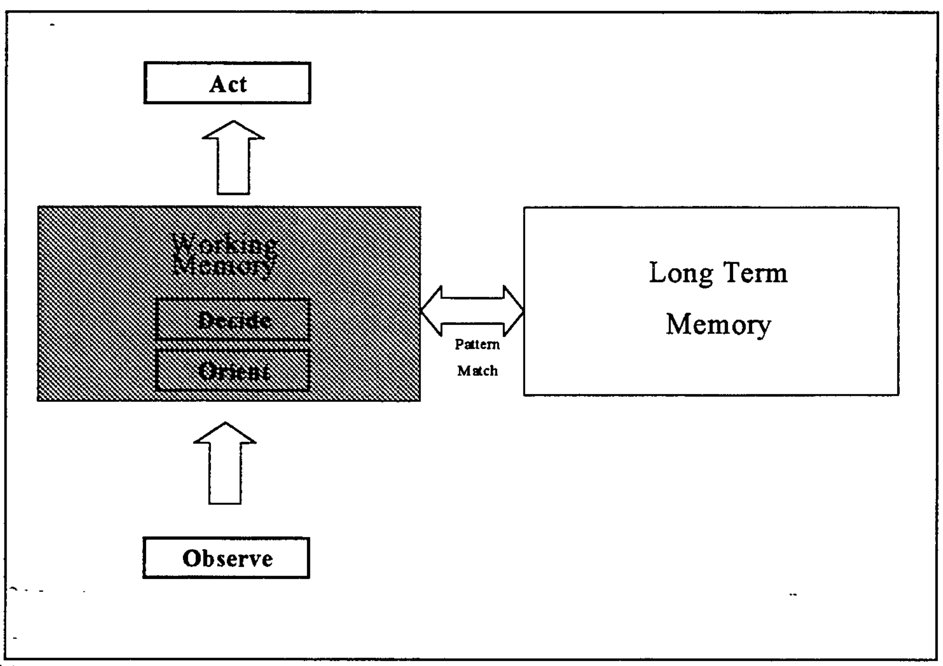

Figure 4-1 Simplified decision model depicting inputs and outputs to memory

As can be seen, skill-based and rule-based simple decisions require little effort from working memory. As the pilot processes the information and begins the orient phase, he either reacts immediately to the stimulus (e.g. near mid-air collision avoidance) or readily pattern matches the cue to a specific procedure or checklist. Errors resulting in unfavorable outcomes at this stage are caused primarily from erroneous systems indications and not human error. Extensive training and repetition of procedures produces pilots that are quite effective at matching the procedure to the malfunction and then performing the procedures correctly. Only when a pattern match is not obtained immediately does the decision maker have to process the information further and resort to long-term memory for a possible stored event that is congruent with the situation at hand.

This venture into long-term memory uses cognition and learned aspects of the domain (e.g., failure modes, operating characteristics, previous hazreps, etc.) and results in the pilot gaining a clearer situation assessment or "knowledge picture" (refer to cognitive hierarchy discussion in Chapter II) of the situation. The author believes that the more effectively the decision maker can perform pattern matching in working memory (after retrieving an experience from long-term memory), the more effectively the problem situation can be handled. This process is representative of the expert behavior seen in the knowledge-based hazreps and is best performed by more experienced pilots. Experienced pilots have a much broader knowledge base to draw from and can gain situational awareness faster.

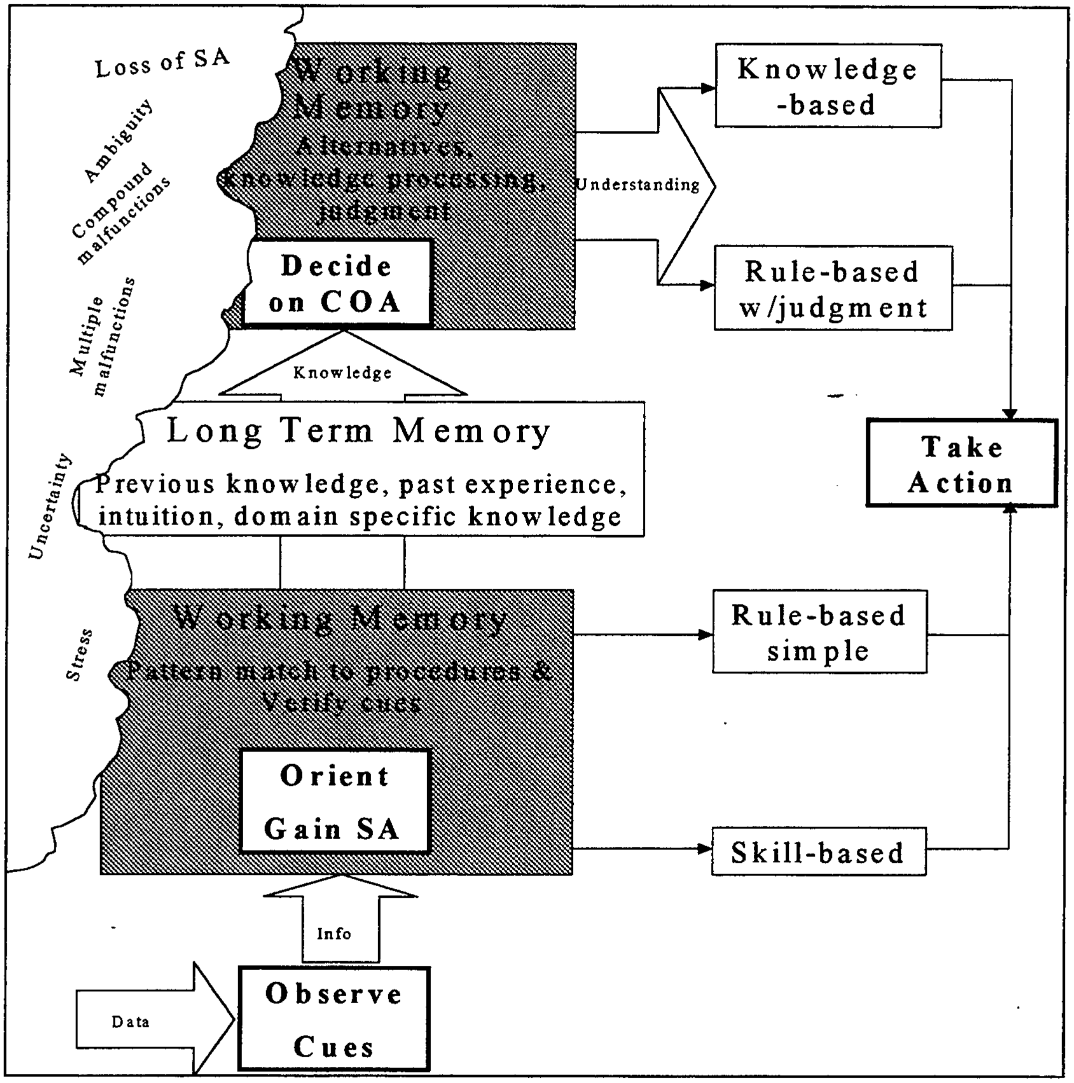

Figure 4-2 Hybrid decision model for P-3 pilot hazrep decision making in problem situations

Once situational awareness is obtained the pilot must decide on a course of action. This process is once again centered in working memory and can heavily tax the decision maker's attentional resources and reasoning ability. The rule-based judgment class is less demanding on working memory and does not require the greater understanding that knowledge-based decisions do. If previous knowledge, past experience or domain specific knowledge have not provided a pattern match (or similar match) then the pilot must integrate cues and generate an original solution to the problem. This creative process may further tax the attentional resources of working memory.

The "loss of SA" cloud shown in the upper left corner of the figure expands as stress and time-pressure increase, effectively reducing the capability of working memory. Losing situational awareness or performing improper procedures for the malfunction at hand most often causes errors in this region. Again, experience may be the critical component to alleviating this loss of SA as uncertainty and stress increase.

A caution regarding experience must be mentioned at this point. It is conceivable that a pilot with extensive past experience could "fixate" on an alternative that is not appropriate for the situation. As working memory capacity is taxed and the SA cloud grows, one alternative may dominate the decision maker's judgment so that it is seen as the only viable alternative. Under stress (e.g. ambiguous information, time-pressure, etc.) decision makers are prone to develop a type of "cognitive tunnel vision."

Not explicitly shown in the figure is a feedback loop that occurs after an action has been performed. This feedback presents itself as data entering the observation phase. Thus, the cycle is an iterative loop that allows for flexibility and change.

V. CONCLUSIONS AND RECOMMENDATIONS

This thesis examined decision making in a P-3 flight station during malfunction situations. An analysis of 438 hazreps was conducted to distinguish different kinds of decision situations encountered and whether a particular decision strategy from either the Analytical or Naturalistic decision making methodologies is more appropriate for a given situation. Situation outcomes were analyzed to pinpoint the cause of unfavorable results in an attempt to prevent their reoccurrence in the future.

It is clear from the results that the majority of situations analyzed involve rule-based decisions and can be performed with relative ease by matching a procedure to a malfunction. More complex decisions are required when the situation is clouded with ambiguity or compounded by additional factors. These knowledge-based decisions require judgment and experience on the part of the decision maker. Experience appears to be the critical component in gaining and maintaining situational awareness and making effective decisions. Strategies from both the Naturalistic and Analytical decision making methodologies have a place in the decision making processes of pilots in this study and must be considered when training new personnel. Table 5-1 summarizes the key aspects of the study and provides the following observations:

1) Rule-based decisions comprise the vast majority of situations encountered in the aircraft;

2) Knowledge-based decisions require experience, intuition, previous knowledge and expert behavior;

3) The probability of an unfavorable outcome increases as the complexity of the environment increases;

4) A need exists for better detecting and indicating systems for malfunctions;

5) Situational awareness is key to preventing unfavorable outcomes;

6) Recognition-primed and analytical decision making strategies are both required for effective decisions.

Class	%	Main decision making method	% Unfavorable	Explanation
Rule simple	70	Analytical	8	Equipment malfunction
Rule judgment	8	Analytical w/ NDM	24	Improper procedures
Knowledge	18	Naturalistic w/ ADM	35	Lack of SA
Skill	4	Naturalistic (NMAC)	78	Lack of SA

Table 5-1 Type of decision making strategy associated with class of decision type and explanations for unfavorable outcome

A. RECOMMENDATIONS

Recognizing the need for the use of strategies from both the Analytical and Naturalistic Decision Making methodologies is critical if the Navy wants to reduce the number of unfavorable outcomes in hazardous situations encountered in Naval Aviation. The recommendations below are intended to:

- Increase situational awareness among pilots in order to reduce the probability of errors associated with improper situation assessment;

- Alleviate erroneous aircraft indicating systems in order to reduce ambiguous situations and unnecessary aborts.

1. Train Pilots to Become Experts

The military conducts *ab initio* training; that is, it transforms complete novices into minimally proficient and safe pilots (Kaempf & Orasanu, 1997). The basic flight training takes approximately one year, followed by specific in-model training at a Fleet Replacement Squadron and an upgrade syllabus in an operational squadron. A typical P-3 Plane Commander requires approximately 18-24 months to complete the upgrade syllabus. After designation, a fully upgraded pilot has little in the way of training requirements other than annual refresher training. This type of training produces a vast number of competent pilots that have very little experience to draw from. In addition, a pilot's tour (especially Navy pilots) not only involves flying but also performance of a ground job and associated military duties and watches. Flying frequently becomes a secondary task. The result is a pilot who is proficient at handling the routine rule-based decisions but does not necessarily have the expertise to handle the more complex knowledge-based decisions.

The first prerequisite for improving situational awareness and the skills to perform the pattern-recognition strategy is to increase expertise. The more comprehensive a pilot's knowledge, the easier it is to find a pattern match in long term memory to deal with a hazardous situation. Pilots should practice decision making skills in time-limited and stressful situations on a daily basis. Training must not be confined to staff courses, annual refresher training or postgraduate education, but be instituted on a regular basis in operational squadrons. Decision training should be incorporated into flight training from the onset and continued throughout a pilot's career.

Personal experience is the best way to acquire expertise, but this is not always possible. The use of simulators, decision making exercises and "hangar flying" must be mandated. Simulation provides an excellent method of training on a large number of challenging and realistic scenarios in a short period of time. Situations can be programmed in simulators to replicate actual aviation hazards that have occurred in the past. Simulation also can present the decision maker with the problem of analyzing ambiguous or complex situations without the fear of failure (e.g., loss of life or aircraft). Using historical analyses of hazardous situations and real time feedback can vastly improve the decision making processes of pilots.

This is not to say that simulators are not currently used in the operational fleet; in fact, they are an integral part of all the training tracks that the author has been associated with. However, once a pilot completes his/her prescribed training and becomes a Plane Commander, there is a dramatic decrease in mandatory simulator training required. The time that is required in simulation is usually spent conducting instrument proficiency training rather than improving decision making skills.

Group decision making exercises and pilot forums also provide an excellent means of training junior (qualified and unqualified) pilots. Reviewing previous hazardous situations and discussing the way in which the they were handled by other decision makers can build a pilot's experience base. Further, a group discussion evokes other's opinions on alternative courses of action and the decision strategy used to arrive at that course of action. These opportunities provide an excellent resource for transferring experience and expertise directly from one pilot to another.

2. Utilize Existing Expertise

A Naval aviator frequently is given an enormous amount of responsibility while still very junior. For example, the author was a P-3 Plane Commander as a LTJG and a Mission Commander and Instructor Pilot as a junior LT. While this amount of responsibility is sought after and a tribute to one's abilities, it may not be in the best interest of properly training junior decision makers. A better approach may be to pair novice aviators with seasoned and experienced pilots for a longer period of time after the novice is qualified. This gives the newly designated Plane Commander the opportunity to hone the decision making skills necessary for making the more complex knowledge-based decisions. Furthermore, this also provides the experienced pilot a fresh "rule-based philosophy" from the junior decision maker that is not clouded by bias, prejudice or ego. This naïve, "book-learned" perspective from the junior aviator could alleviate unfavorable outcomes in hazardous situations caused by experienced pilots who persist in implementing undesirable (dominated) alternatives when better choices are available.

3. Incorporate Naturalistic Decision Making Strategies in the Training of Pilots

This study exemplifies the need for training decision makers in strategies from both the Analytical and Naturalistic Decision Making methodologies. However, the application of NDM research in aviation is still in its infancy. To the best of the author's knowledge, there are no courses presently taught in the P-3 aviation community that address NDM. Naturalistic decision making strategies are most applicable when encountering dynamic and continually changing conditions, real time reactions to these changes, ill defined tasks, time pressure, significant personal consequences for mistakes, and experienced decision makers. As this study illustrates, these conditions prevailed in *at least* 18% of hazardous situations; i.e., when knowledge-based decisions were required. Using the recognition-primed strategy, experienced decision makers assessed the situation and recognized familiar patterns. In fact, the recognition-primed strategy was probably used in virtually *every* situation encountered for the initial situation assessment. It is vital that pilots be aware and trained in a decision making methodology that may help them make a life saving decision in the future.

4. Improve Reporting Procedures to Include Decision Making Strategies Utilized

While conducting this analysis of P-3 hazreps the author discovered that the hazrep message was lacking in information that would have proved helpful in deciphering the decision making process used. The basis for the pilot's situation assessment (e.g., NATOPS, past experience, inferred from historical knowledge, etc.), discussions regarding how a decision was arrived at, alternatives considered, and whether time constraints played a vital role in the decision process could have shed more light on the subject. A "decision strategy" section of the hazrep could provide pilots a valuable discussion item for their group decision making exercises and "hangar flying" sessions. The practice of providing complete and forthright information in the hazrep must not only be encouraged, but enforced, to ensure that all the actions of the decision maker, right or wrong, are clearly explained and documented. In this way, junior decision makers can evaluate the situations and actions for themselves and build their own experience base.

5. Utilize a Decision Support System

Decision support systems can be utilized to provide the decision maker with timely and accurate information to aid the decision making process. Recall that the largest contributor for an explanation of unfavorable outcomes in the rule-based simple class was "equipment malfunction" (72%). This equipment malfunction is different from an equipment failure that is considered routine and expected (e.g. chips light or oil leak) and is the result of a failure of a detecting or indicating system. A decision support system could not only provide valuable insight to the decision maker to prevent these unnecessary aborts, but also could aid the pilot with situation assessment.

One such system currently under development by the USAF and NASA is Hazard Monitor (HM). Hazard Monitor is a knowledge-based aid designed to reduce the rate of preventable accidents regardless of the source of the problem (i.e., human, machine, or external environment). The idea for the system stems from the fact that in complex situations, hazards occur despite improvements in system design and advances in human-computer interaction. HM aids these situations by enhancing the problem recognition and identification process so that operators recognize deteriorating situations in time to avoid adverse consequences. (Ernst-Fortin et al., 1997)

6. Replace Faulty Aircraft Indicating Systems

In the absence of a decision support system, simply modifying the aircraft to reduce the number of false indications would greatly reduce the number of hazardous situations encountered. Faulty fire warning elements and oil pressure/quantity transmitters were the high failure items and accounted for a majority of the "equipment malfunction" category. Failures involving fire warnings and/or the oil system usually result in a three engine landing. While three engine landings are well trained for and often considered "routine" almost all Commanding Officers will tell you "four engines are always better than three." The cost of replacing faulty indicating systems would most likely be far outweighed by the benefits realized.

APPENDIX A. SAMPLE HAZREP ANALYSES

Appendix A contains selected sections from three sample hazreps from each of the classes (knowledge-based, rule-based and skill-based) with an accompanying analysis based on the rules and criteria outlined in Chapter III.

KNOWLEDGE-BASED DECISION EXAMPLE

EVIDENCE AND ANALYSIS. Immediately following takeoff at NAS JAX for a USW event, #1 chips light illuminated with no secondaries. PPC requested downwind, and once established, shutdown #1. The restart checklist was completed through PCO. The following items were then discussed: restarting #1, dumping the remaining fuel in tank 5, weather, and overweight landing. Two engine performance based on gross weight and OAT was determined. Of note, landing ground roll distance was not discussed. The PPC elected to perform an overweight landing based on the two engine performance and the forecast of Thunder I conditions prior to arriving at 114,000 lbs. The three engine landing was performed on runway 27 (dry, 8000 ft) at approximately 120,000 lbs, with 2000 lbs of fuel remaining in tank 5. Winds were 180/6. Landing touchdown speed was 142 kts with 6500 ft remaining. Brakes were not utilized until approximately 2500 ft remaining. The aircraft was stopped with approximately 200 ft remaining. Brake cooling was neither discussed nor performed. Taxiing into the parking spot and following engine shutdown, the lineman signaled hot brakes on port side followed by a brake fire signal. Crew called for assistance and egressed over starboard wing.

REMARKS. Postflight discussions about the decision to land heavy brought up items for concern. 1. Post flight determination of the landing ground roll distance was computed to be about 4200 ft with moderate braking. This figure probably would not have prevented the PPC from making the overweight landing but it should have spotlighted the need for brakes and perhaps brake cooling. 2. The PPC used the absolute worst case scenario to arrive at his decision to land the aircraft at 120,000 lbs; the potential loss of another engine and forecast convective weather. This decision path reduced his options and shortened his timeline.

CO COMMENTS. The PPC decided that the potential for another engine malfunction and worsening weather was more hazardous than the risks associated with an overweight three engine landing on a hot Jacksonville day. The crew discussed what could happen if they remained in the air but they failed to fully discuss what could happen if they landed in their present configuration. Overlooked were items including ground roll distance, moderate braking and brake cooling procedures. Although an "uneventful" landing ensued, the brake fire/hot brakes were only one of the many possible outcomes of this scenario. The more prudent course of action would have been to continue overhead the field, prepared to relight the feathered engine and burn down to a lower weight prior to landing.

ANALYSIS OF KNOWLEDGE-BASED HAZREP

Type: Engine (chips light)

Class: Knowledge (multiple alternatives available, thorough understanding of environment required before taking action)

Category: Compound factors (heavy aircraft, weather)

Judgment required: Yes (PPC elected to land heavy, PPC chose worst case scenario)

Favorable outcome: No (resulting brake fire could have been avoided if better decision made)

Explanation: Lack of SA (PPC perceived his worst case scenario as the deciding factor; crew failed to fully consider ramifications of landing heavy)

Comments: The question may arise, if the outcome had been favorable, would the explanation have been "expert behavior?" The answer is no. If the PPC had elected to wait overhead the field and commence the approach at a lighter gross weight, or if he had considered the use of brakes and brake cooling procedures, the explanation would have been "correct decision." Full consideration of performance factors and proper application of NATOPS procedures is not considered "expert" behavior. Expert behavior requires going beyond normal procedures and uses experience, judgment and (sometimes) prior knowledge to arrive at a decision.

RULE-BASED DECISION EXAMPLE

EVIDENCE AND ANALYSIS. On station at 2550 ft AGL, crew had two engines loitered at a gross weight of 100,000 lbs. Crew thoroughly discussed three and two engine loiter considerations and determined single engine rate of descent to be 420 FPM. Number one engine had been shut down for 5.5 hours and #4 engine for one hour when FE called out #3 RPM flux with decreasing RPM toward zero percent with no audible indications. With PPC concurrence, FE initiated restart on #4 engine. During restart, FE called #3 oil pressure low light, master electrical power light and master pressurization light. As FE called #4 normal restart, #3 chips light illuminated. Crew secured #3 engine and completed emergency shutdown checklist through item 6. With power on #4 limited due to low oil temp, the PPC initiated a 500 FPM rate of descent to maintain loiter airspeed. Engine #1 was restarted with normal indications. Crew completed emergency shutdown checklist for #3 engine followed by restart checklist for engines #1 and #4. Power became available on engine #4 within one minute of restart and within three minutes for engine #1. Aircraft minimum altitude 1800 AGL. Crew initiated climbout for RTB and checked offstation while discussing considerations for a second engine failure. Weather was updated, crew briefed three engine landing considerations, declared an emergency, and conducted an uneventful three engine landing.

REMARKS. Postflight inspection revealed a cracked idler gear in #3 reduction gearbox which resulted in loss of entire RGB accessory section.

CO COMMENTS. Solid crew coordination is required to safely conduct two engine loiter operation. Initial engine #3 malfunction indications did not require immediate action, so the PPC made the decision to restart #4 first. By the time additional indications required the shutdown of #3 engine, #4 was on line. Although #4 was available if needed, with sufficient altitude to accept a descent while waiting for engine oil temperature to increase, the PPC restarted #1. Total altitude lost was 700 ft, suggesting both engines were on line in less than 2 minutes. Clear understanding of the two engine loiter brief, sound decision making and professional execution ensured safe recovery from a situational risk a PPC accepts when he decides to loiter two engines.

ANALYSIS OF RULE-BASED HAZREP

Type: Engine (RGB, chips light)

Class: Rule-based (NATOPS dictates action)

Category: Compound factors (two engine loiter, altitude and rate of descent considerations)

Judgment required: Yes (PPC elected to restart #4 prior to securing #3, held emergency shutdown checklist prior to completion to perform restart on #1)

Favorable outcome: Yes (correct decisions made and actions taken fit the situation)

Explanation: Expert behavior (PPC fully aware of status of #3 engine, judgment used to delay securing of #3 engine with indications of pending failure, prioritization of procedures required to minimize altitude loss and acceptance of slight loss of altitude to maintain loiter airspeed)

Comments: This particular emergency situation could have easily ended in disaster for another crew faced with the same situation. A misinterpretation of the indications on #3 could have led a crew to securing it prior to initiating restart on #4. The aircraft would have then been operating on a single engine with a rate of descent of 420 FPM. Further, if a PPC disregarded the need to maintain loiter airspeed during the restarts, he could easily place the aircraft in a stall as airspeed bleeds off.

SKILL-BASED DECISION EXAMPLE

EVIDENCE AND ANALYSIS. The crew had just completed starting the #2 engine utilizing a huffer in preparation for a functional check flight (FCF). After making a quick scan of the instruments and noting a normal start, both the PPC and the CP noticed the aircraft was slowly moving forward. Both pilots quickly depressed the brakes, which immediately stopped the aircraft after an estimated six feet of movement. Simultaneously the lineman chocked the main landing gear, ensuring no further movement of the aircraft was possible. Neither pilot noticed if the brake handle was set prior to using the brakes to stop the aircraft. The aircraft was secured and maintenance informed. The entire brake system was checked with no discrepancies found.

REMARKS. After reviewing the scenario, the PPC decided that he must not have ensured the brakes were properly set during the before start checklist. With no specific recollection of any deviation from standard procedure, the only explanation can be inattention during the checklist.

CO COMMENTS. This highly qualified crew was faced with the challenge of a short notice FCF. Such flights occur in the course of normal operations and are a part of doing business. The learning point is the need for schedulers and crews to identify this type of added hazard in their ORM process. Heightened attention to detail could have prevented this scenario.

ANALYSIS OF SKILL-BASED HAZREP

Type: Other (basic skill error)

Class: Skill-based (procedure exists on "Before Start" checklist to set parking brake---a common skill)

Category: Improper procedures (did not perform checklist item)

Judgment required: No

Favorable outcome: No

Explanation: Improper procedures (see category)

Comments: None

APPENDIX B. LIST OF HAZREPS

Appendix B contains the complete list of hazreps (438) analyzed in this study (Excel format). The hazreps are sorted by class (knowledge-based, rule-based and skill-based) then by category that best describes the situation (ambiguous situation, compound malfunction, etc.).

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
Oil leak	Eng	k	Ambiguous indications	Unnecessary 3 eng ldg		Elected to secure based on unknown fluid; oil leak within limits	x	Equip	x
Oil press loss	Eng	k	Ambiguous indications	Unnecessary 3 eng ldg		Faulty indicator; no press light	x	Equip	x
Fluid leak	Eng	k	Ambiguous indications	Unnecessary 3 eng ldg		Unable to determine type of leak; oil was within limits	x	Equip	x
Oil quantity malf	Eng	k	Ambiguous indications	Unnecessary 3 eng ldg		Could not determine type of fluid leak; xmtr only was bad	x	Equip	x
Oil leak	Eng	k	Ambiguous indications	Unnecessary 3 eng ldg		Misdiagnosed oil leak as fuel leak; no indications of oil leak on gauges	x	Equip	x
Fire warning	Eng	k	Ambiguous indications	Unnecessary 3 eng ldg		Multiple fire warnings; warning element	x	Equip	x
Gen 4 failure	Elec	k	Ambiguous indications		Unique nature of this elec malf	Unable to locate; rapidly deteriorated; evacuated	x	K	x
FOUO	Elec	k	Ambiguous indications	Aircraft evacuated	Prior knowledge influenced	Unable to determine source; complacency in finding fumes; loss of SA	x	SA	x
TIT gauge failure	Inst	k	Ambiguous indications	Unnecessary 3 eng ldg		Stupid to shut down and not relight; gauge read zero after shutdown	x	SA	x
TIT gauge failure	Inst	k	Ambiguous indications	Unnecessary 3 eng ldg	Four eng are always better than three	Indications pointed to gauge failure	x	SA	x
Power lever freeplay	Eng	k	Ambiguous indications		Indicative of impending failure	CO reconsidered decision to let run	x	WD	x
FOUO	Elec	k	Ambiguous indications			Unable to determine cause of fumes; PPC delayed checklist till on deck	x	CD	
FOUO	Elec	k	Ambiguous indications			Unable to determine cause of fumes; left Bus A secured	x	CD	
Oil leak	Eng	k	Ambiguous indications	3 eng ldg		No indications of leak except for qty gage	x	CD	
Oil leak	Eng	k	Ambiguous indications	3 eng ldg		Oil press and qty normal despite leak	x	CD	
Oil leak	Eng	k	Ambiguous indications	3 eng ldg		Flt station indications normal; turbine oil leak	x	CD	

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
CDI failure without off flag	Inst	k	Ambiguous indications	Divert		Elected to divert for wx and suitable approach	x	CD	
#2 EDC failure & leak	Press	k	Ambiguous indications	3 eng ldg		Could not determine type of leak; secured engine	x	CD	
Prop deice boot	Prop	k	Ambiguous indications	Abort mission	Superb job....malf not addressed in NATOPS	Unable to determine cause of vibe	x	CD	
Binding rudder & rudder pwr lt	Airframe	k	Ambiguous indications	Rudder boost out ldg	Sound judgment		x	Exp	
FOUO	Elec	k	Ambiguous indications	Abort mission		Unable to determine cause of fumes; left hyd #1 system off; good call	x	Exp	
Oil leak	Eng	k	Ambiguous indications	3 eng ldg		Aft obs & FE disagreed observations	x	Exp	
Bird strike at rotate	Other	k	Ambiguous indications	Abort mission		Possible flame out #4 followed by eng operating normally	x	Exp	
Prop leak	Prop	k	Ambiguous indications	Abort mission		Unable to determine if prop fluid or condensate; opted for prop fluid, it was	x	Exp	
Prop pump light & leak	Prop	k	Ambiguous indications	Divert		Unable to determine if prop fluid; assumed worst case (it was)	x	Exp	
PFTF and fluid lk	Prop	k	Ambiguous indications	Unnecessary 3 eng ldg		Leak was oil, not prop fluid; eng could have been restarted	x	Equip	x
Oil pressure	Eng	k	Compound factors	4 eng IMC ldg	Some of our more senior pilots would have continued mission	Unnecessary abort; oil xmtr failed	x	Equip	x
Bleed air lk causes tire deflation	Eng	k	Compound factors	Flat tire ldg	Not prudent decision; suspended PPC designation	Get home-it is	x	IP	x
Pitchlocked prop	Prop	k	Compound factors	3 eng IMC ldg	EXTENSIVE comments	Initiated procedures for pitchlock counter to NATOPS	x	SA	x
Prop underspeed on t-off	Prop	k	Compound factors	Abort leads to brake fire	Never should have reached this point of extremis	Poor decision making; lucky not a mishap; didn't adhere to procedures	x	IP	x

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
Refer turbine failure	Press	k	Compound factors	Immediate ldg		Misdiagnosed; heavy a/c, traffic, language barrier; rt seat smoke mask ldg	x	SA	x
Chips light	Eng	k	Compound factors	3 eng ldg	Failed to fully address all options; could have been more prudent	Heavy ldg resulted in brake fire	x	SA	x
NMAC	NMAC	k	Compound factors			Miscommunication with ATC	x	SA	x
Prop leak	Prop	k	Compound factors	Continued to dest.	Should have gone to divert	Multiple diverts & factors considered	x	SA	x
Cracked windshield	Airframe	k	Compound factors	Continued to dest		Brunswick to Jax; poor wx on departure, cont to dest	x	Exp	
Cracked windshield	Airframe	k	Compound factors	heavy ldg	Sound ACT and good headwork	Elected to land heavy due to deteriorating windshield and bird activity	x	Exp	
Unsafe gear	Airframe	k	Compound factors	Returned to dest	sound judgment; sound decision making	Could have landed at divert	x	Exp	
FOUO	Elec	k	Compound factors	Abort mission		TACCO altered checklist procedures; night	x	Exp	
FOUO	Elec	k	Compound factors	Continued to dest.	Discretion and good judgment	Unable to secure power to cb; flare ups; continued to dest from intermediate stop	x	Exp	
FOUO	Elec	k	Compound factors	Continued to dest.	Off duty fe had just read hazrep of similar malf	Wx, IMC, icing conditions and prop deice problem	x	Exp	
Loss of fwd lighting bus	Elec	k	Compound factors	Land at divert	Good judgment	Destination IMC	x	Exp	
NMAC	NMAC	k	Compound factors	PPC turned after ATC denied request	Sound judgment and quick thinking saved the day	Decision to turn based on visual & impending collision	x	Exp	
NMAC on departure	NMAC	k	Compound factors	Workload, unsure of separation		Leveled to find traffic	x	Exp	
NMAC	NMAC	k	Compound factors			Dissimilar aircraft, workload; time to respond	x	Exp	
NMAC with civilian	NMAC	k	Compound factors			ATC incorrect call; evasive req'd	x	Exp	
NMAC	NMAC	k	Compound factors		Excellent SA	Immediate evasive action	x	Exp	
NMAC with DC-10	NMAC	k	Compound factors			Evasive action judgment	x	Exp	

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
Bird strike	Other	k	Compound factors	Aborted t-off	Sound crew coordination	Disparity between actions of PAC and PPC	x	Exp	
Pitchlock regulator failed	Prop	k	Compound factors	3 eng ldg		Occurred on deck at outlying field; multiple decisions	x	Exp	
#1 Flameout & #2 Fire Wrg	Eng	k	Compound factors	Unnecessary 2 eng ldg	Murphy really threw it at us	Caused fire warning; lots of good DM stuff	x	SA	x
Fire warn #3 , #2 EDC bad	Eng	k	Compound factors	3 eng ldg/loss of press	Proper ACT can't be over-emphasized in multiple malf scenario	Emerg descent after pulling e-handle, loss of SA	x	SA	x
Loss of press	Eng	k	Compound factors	3 eng ldg	Compound emergency	Loss of SA; crew didn't notice loss of press	x	SA	x
Engine flux, HF, compass	Eng	k	Compound factors	Abort mission	Compound aircraft malfunctions	Diverted to Whidbey enroute Hawaii	x	CD	
Fire warn & FOUO	Eng	k	Compound factors	3 eng ldg		Excessive noise, source of fumes undetermined, heavy wt ldg	x	CD	
Loss of attitude sources	Inst	k	Compound factors	RTB	Excellent job troubleshooting unusual malf	Exercised prudent judgment not going IMC	x	Exp	
Gen failure & earblock	Elec	k	Compound factors	Divert	Decision to RTB was correct one		x	CD	
FOUO	Elec	k	Multiple malfunctions	Evacuated aircraft	Encountered 2nd unrelated malfunction	Should've recognized 2nd problem; no evac necessary	x	SA	x
Oil leak and Gen malf	Eng	k	Multiple malfunctions	3 eng ldg	Complacency	Loss of SA, crew operated single generator	x	SA	x
Prop underspeed #1, chips #3	Eng	k	Multiple malfunctions	3 eng ldg	compound emerg; opinions differ on shutting down #3	Chips in delta with underspeed, shut down?	x	CD	
Prop leak #3 & chips #2	Eng	k	Multiple malfunctions	RTB 3 eng ldg	Effectively handled compound emergency	Secure chips It?	x	IP	x
#3 Gen. Malf & EDC malf	Elec	k	Multiple malfunctions	3 eng ldg	Sound decision making	Alternate consideration for winds, wx, etc.	x	Exp	
Chips light and oil leak	Eng	k	Multiple malfunctions	3 eng ldg		PPC elected not to shutdown for chips due to IMC	x	Exp	
Oil qty and PP light	Eng	k	Multiple malfunctions	3 eng ldg	Unusual compound emergency	Good discussion	x	Exp	

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
Oil leak with Chips	Eng	k	Multiple malfunctions	3 eng ldg		Eng shut down for oil qty, restarted, shut down for chips	x	Exp	
#3 Oil qty and #1 chips light	Eng	k	Multiple malfunctions	3 eng ldg(chips)	Understanding of current trends	A/C had history of oil consumption #3	x	Exp	
Low pwr #1, bind pwr lvr #3	Eng	k	Multiple malfunctions	Aborted t-off	Sound judgment on multiple malf		x	Exp	
Press controller malf	Press	k	Unique; no NATOPS guidance	Excessive neg cabin alt	Hopefully ready room discussions will help others handle emerg not found in the book	Could have prevented by dumping EDC	x	N,K	x
Oil leak	Eng	k	Unique; no NATOPS guidance	Abort mission	Not specifically covered in NATOPS	Elected not to secure eng	x	CD	
Uncommanded wpn release	Elec	k	Unique; no NATOPS guidance		Unique situation; importance of SA	Good troubleshooting	x	N, Exp	
Power lever linkage disconnect	Eng	k	Unique; no NATOPS guidance	3 eng ldg	Crew handled unusual malf well		x	N, Exp	
Failed fuel qty gages	Inst	k	Unique; no NATOPS guidance	Abort mission	Sound ACT/knowledge; unusual malf	NATOPS change submitted	x	N, Exp	
Decouple w/massive overspeed	Prop	k	Unique; no NATOPS guidance	3 eng ldg	Extensive experience	NATOPS guidance possibly wrong	x	N, Exp	
Press controller malf	Press	k	Unusual malfunction	Decompression sickness	Could have avoided hazard	NATOPS change submitted	x	N,K	x
Yaw oscillations	Airframe	k	Unusual malfunction	Abort mission	Tempted to continue, crew did safe and prudent thing		x	CD	
Yoke out of rig	Airframe	k	Unusual malfunction	Abort mission	Potential for disaster	Good troubleshooting	x	Exp	
Misrigged force link tab	Airframe	k	Unusual malfunction	Abort mission		Could not determine cause of binding; good troubleshooting	x	Exp	
Airframe vibration	Airframe	k	Unusual malfunction	Missed app to investigate		Good troubleshooting	x	Exp	
FOUO	Elec	k	Unusual malfunction	Abort mission	Good judgment	Used prior knowledge to reset warn lt cb prior to moving flaps	x	Exp	
Lost Comm	Elec	k	Unusual malfunction		Displayed excellent common sense	ICS speaker shorted and caused lost comms	x	Exp	
NTS inop light	Prop	k	Unusual malfunction	3 eng ldg	Numerous decisions re wx, dip clnc, terrain, crew used excellent ACT & DM skills	A799; NTS inop light caused by "delayed" indications of lightoff; crew fault?	x	Exp	

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
Prop deice boot	Prop	r	Ambiguous indications	Abort mission		Unable to determine cause of vibe	x	CD	
Prop deice boot	Prop	r	Ambiguous indications	Abort mission		Unable to determine cause of vibe	x	CD	
Cracked windshield	Airframe	r	Compound factors	Divert		Wx, ATC caused fuel planning problems, divert	x	CD	
Turbine failure	Eng	r	Compound factors	3 eng ldg		Wx, icy runway	x	CD	
RGB failure during 2 eng loiter	Eng	r	Compound factors	3 eng ldg	Sound decision making		x	Exp	
Binding pwr lever	Prop	r	Simple procedural	3 eng ldg	Crew overanalyzed situation	Improper procedures	x	IP	x
NTS inop light	Prop	r	Simple procedural	3 eng ldg	Good job evaluating situation and taking decisive action	TFE released fx button, IP pulled e-handle	x	IP	x
Prop leak	Prop	r	Simple procedural	4 eng ldg		Crew restarted prop leak for unfavorable winds	x	IP	x
Prop rotates backward FCF	Prop	r	Simple procedural	Unnecessary 3 eng ldg	4 eng ldgs are better than 3	NATOPS does not prohibit crews from restarting eng, PPC elected to land 3 eng	x	IP	x
Oil leak	Eng	r	Simple procedural	3 eng ldg	Failed to determine when troubleshooting should cease and corrective action begin	Engine shut down when qty reached 1 gal and press flux started	x	SA	x
Blown nose tire	Airframe	r	Simple procedural	Continued mission	CO does not agree with decision to continue; possibly a grave situation	Most exp JO IP	x	WD	x
E-handle vibration	Eng	r	Simple procedural	3 eng ldg	Safety compromised; clouded judgment	PPC troubleshot EDCs before securing engine	x	WD	x
Prop leak	Prop	r	Simple procedural	PP light on next leg	If aircraft not up for mission, it's not up for ferry	Should have stayed at intermediate stop?	x	WD	x
Flap asymmetry light	Airframe	r	Simple procedural	No flap ldg at intermediate stop	Good judgment	Why not return to home plate where support existed?	x	CD	
HF wire separation	Airframe	r	Simple procedural	Abort mission		Due to turbulence, did not open overwing exit to retrieve antenna	x	CD	
Brakes fail	Airframe	r	Simple procedural		Quick thinking		x	CD	
FOUO	Elec	r	Simple procedural	Continued mission			x	CD	

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
FOUO	Elec	r	Simple procedural	Evacuated aircraft	What point to secure power and evacuate aircraft		x	CD	
FOUO	Elec	r	Simple procedural	Continued mission			x	CD	
FOUO	Elec	r	Simple procedural	Continued mission	Good headwork and coordination		x	CD	
FOUO	Elec	r	Simple procedural	Continued mission			x	CD	
Generator failed	Elec	r	Simple procedural	RTB		No support at dest	x	CD	
PFTF	Prop	r	Simple procedural	3 eng ldg		55% RPM, elected to leave shutdown	x	CD	
PFTF	Prop	r	Simple procedural	4 eng ldg		44% rpm, restarted (other crews may have left shutdown)	x	CD	
PFTF	Prop	r	Simple procedural	4 eng ldg		Crew restarted; RPM 35%	x	CD	
Elevator boost package	Airframe	r	Simple procedural	Elevator boost out ldg		Marginal wx, landed at nearest suitable field	x	Exp	
Oil press flux	Eng	r	Simple procedural	4 eng IMC ldg	Crew's decision to restart was sound	Restarted eng for wx; press xmtr bad	x	Exp	
Oil leak	Eng	r	Simple procedural	3 eng ldg	Timely shutdown allowed restart if needed		x	Exp	
Fuel leak	Eng	r	Simple procedural	4 eng ldg		Clearing turns determined not a fire hazard; 4 eng	x	Exp	
Eng flameout	Eng	r	Simple procedural		Sound judgment	At rotate, crew landed, troubleshot, restarted, cont to dest	x	Exp	
Bird strike on short final	Other	r	Simple procedural	Returned to dest		W-off at outlying field, RTB	x	Exp	
Press controller malf	Press	r	Simple procedural		Correct assessment & timely action	Req'd emerg descent	x	Exp	
Blade ang, rotation @ PCO	Prop	r	Simple procedural	3 eng ldg		Crew troubleshot extensively based on knowledge	x	Exp	
TR 3 failure	Elec	r	Ambiguous indications	Abort mission		No gen 3 off light with loss of Bus B		Equip	
FOUO	Elec	r	Ambiguous indications	Abort mission		Unable to determine source of fumes		Equip	
FOUO	Elec	r	Ambiguous indications	Abort mission		Unable to determine source of fumes		Equip	
FOUO	Elec	r	Ambiguous indications	Abort mission		Unable to determine source of fumes		Equip	

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
FOUO	Elec	r	Ambiguous indications			Unable to determine source of fumes		Equip	
Fire warning	Eng	r	Ambiguous indications	3 eng ldg		Fire not indicated in flt station; aft called on restart		Equip	
Flame from engine	Eng	r	Ambiguous indications	3 eng ldg	Rare occurrence in community	No fire warning or abnormal engine indications		Equip	
Fire warning	Eng	r	Ambiguous indications	3 eng ldg		Fire indications went out before ehandle was pulled		Equip	
FOUO	Elec	r	Ambiguous indications	Abort mission	Good headwork and coordination	Unable to determine source of fumes		K	
FOUO	Elec	r	Ambiguous indications	Abort mission	Good headwork				
FOUO	Elec	r	Ambiguous indications	Abort mission	Situation was confusing	Rack overheat with NO horn			
FOUO	Elec	r	Ambiguous indications	Abort mission	Importance of routine performance of emerg drills	Source of fumes never determined			
Pitchlocked prop	Prop	r	Ambiguous indications	3 eng ldg	Malf rediagnosed; deliberately evaluated info	Decoupled vs. coupled			
PFTF	Prop	r	Ambiguous indications	3 eng ldg	Unusual indications				
Pitchlock w/out overspeed	Prop	r	Ambiguous indications	3 eng ldg	Malf not readily discernible				
Fire warning	Eng	r	Compound factors	Unnecessary 3 eng ldg		Heavy t-off; faulty fire warning element		Equip	x
Fire warn on sim EFAR	Eng	r	Compound factors	Aborted t-off	Acted quickly and correctly	Could not duplicate fire warning		Equip	
Blown tire on r/w	Airframe	r	Compound factors			During IUT sim. Malf on r/w; smoke & debris			
Gen failure	Elec	r	Compound factors	3 eng ldg		Gen off light deteriorated to sparks from engine			
Engine flameout	Eng	r	Compound factors	3 eng reversal		Occurred during sim 2 eng ldg			
No beta light	Prop	r	Compound factors	3 eng reversal		Occurred during sim 2 eng ldg			
No beta light	Prop	r	Compound factors	3 eng reversal		Occurred during 3 eng sim ldg			

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
Fire warning	Eng	r	Multiple malfunctions	Unnecessary 3 eng ldg	Reacted properly to compound emergency	Lightning strike after fire warn; faulty fire warning		Equip	x
FOUO	Elec	r	Multiple malfunctions		Some inaccurate assumptions			SA	x
FOUO	Elec	r	Multiple malfunctions			Source of fumes never determined; multiple component failures		Equip	
Cracked windshield, lightning	Airframe	r	Multiple malfunctions			And HF antenna sep			
Gen failure & FOUO	Elec	r	Multiple malfunctions	Abort mission					
FOUO and chips light	Eng	r	Multiple malfunctions	3 eng ldg		Good prioritization			
Engine failed to restart	Eng	r	Multiple malfunctions	3 eng ldg	Crew was lucky; 2 unrelated malf's at same time	Crew handled procedurally			
#2 oil qty & #3 EDC malf	Eng	r	Multiple malfunctions	3 eng ldg	Multiple malfunctions				
Oil leak #3 & prop leak #1	Eng	r	Multiple malfunctions	3 eng ldg					
Loss of press/eng acc failure	Press	r	Multiple malfunctions	3 eng ldg	Compound malfunction	No indications of master elec or press lights			
Pitchlock reg fail & underspeed	Prop	r	Multiple malfunctions	Aborted t-off	combo of 2 malfs; outstanding troubleshooting & technical expertise				
Decoupler failure	Prop	r	Multiple malfunctions	3 eng ldg	Indications after decouple not addressed in NATOPS	Gen 4 mech fail lt after #2 decouple			
Fire warning	Eng	r	Simple procedural	Evacuated aircraft		Unnecessary evacuation; fire warning element; 2 HRDs used on deck		Equip	x
Fire warning	Eng	r	Simple procedural	Evacuated aircraft		Unnecessary evacuation; fire warning element; 2 HRDs used on deck		Equip	x
Oil pressure flux	Eng	r	Simple procedural	Unnecessary 3 eng ldg		Xmtr bad		Equip	x
Fire warning	Eng	r	Simple procedural	Unnecessary 3 eng ldg		Fire warning element		Equip	x
Fire warning	Eng	r	Simple procedural	Unnecessary 3 eng ldg		Fire warning element		Equip	x

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
Oil press flux	Eng	r	Simple procedural	Unnecessary 3 eng ldg		Xmtr bad		Equip	x
Fire warning	Eng	r	Simple procedural	Unnecessary 3 eng ldg		Faulty fire warning element		Equip	x
Fire warning	Eng	r	Simple procedural	Unnecessary 3 eng ldg		Fire warning element		Equip	x
Fire warning	Eng	r	Simple procedural	Unnecessary 3 eng ldg		Fire warning element		Equip	x
Fire warning	Eng	r	Simple procedural	Unnecessary 3 eng ldg		Fire warning element		Equip	x
Fire warning	Eng	r	Simple procedural	Unnecessary 3 eng ldg		Fire warning element		Equip	x
Oil quantity malf	Eng	r	Simple procedural	Unnecessary 3 eng ldg		Xmtr bad		Equip	x
Oil press flux	Eng	r	Simple procedural	Unnecessary 3 eng ldg		Xmtr bad		Equip	x
Fire warning	Eng	r	Simple procedural	Unnecessary 3 eng ldg		Fire warning element		Equip	x
Oil press flux	Eng	r	Simple procedural	Unnecessary 3 eng ldg		Could not troubleshoot; cannon plug too short; xmtr bad		Equip	x
Fire warning	Eng	r	Simple procedural	Unnecessary 3 eng ldg		Fire warning element		Equip	x
Fire warning	Eng	r	Simple procedural	Unnecessary 3 eng ldg	Complacency	Fire warning element; failed to compute NATOPS ldg dist; poor airwork		IP	x
Oil leak	Eng	r	Simple procedural	3 eng ldg	Poor decision making	Aft obs not assertive, deferred to "experience"		IP	x
NTS inop light	Prop	r	Simple procedural	3 eng ldg		TFE released fx button, prop decoupled; improper procedures		IP	x
Flap asymmetry light	Airframe	r	Simple procedural	No flap ldg	Breakdown in ACT	Loss of SA; comm breakdown		SA	x
Prop leak	Prop	r	Simple procedural	4 eng ldg		Caused by improper servicing		IP	
EDC failure	Press	r	Simple procedural	3 eng ldg	Crew followed well established procedures	PPC and CP corrected FE on wrong fuel & ign switch; good SA		SA	
Hyd leak on deck	Airframe	r	Simple procedural	Evacuated aircraft	PPC's quick decision to secure power averted potential injury				

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
HF wire separation	Airframe	r	Simple procedural	Abort mission					
HF wire separation	Airframe	r	Simple procedural	Abort mission					
Unsafe gear	Airframe	r	Simple procedural	Abort mission					
Broken aileron cable	Airframe	r	Simple procedural	Abort mission					
Flap asymmetry light	Airframe	r	Simple procedural	Abort mission					
#2 hydraulic leak	Airframe	r	Simple procedural	Abort mission					
Binding rudder	Airframe	r	Simple procedural	Abort mission					
Ldg gear control lvr binding	Airframe	r	Simple procedural	Abort mission					
Flap asymmetry light	Airframe	r	Simple procedural	Abort mission					
Cracked windshield	Airframe	r	Simple procedural	Abort mission					
Cracked windshield	Airframe	r	Simple procedural	Abort mission		Helmet on ldg			
Unsafe gear up	Airframe	r	Simple procedural	Abort mission					
HF wire separation	Airframe	r	Simple procedural	Abort mission					
Binding elevator trim	Airframe	r	Simple procedural	Aborted t-off					
Blown tire on r/w	Airframe	r	Simple procedural	Aborted t-off					
Flap asymmetry light	Airframe	r	Simple procedural	Approach flap ldg					
Cracked windshield	Airframe	r	Simple procedural	Divert					
Flap asymmetry light	Airframe	r	Simple procedural	Maneuver flap ldg					
Flap asymmetry light	Airframe	r	Simple procedural	No flap ldg					
Flap asymmetry light	Airframe	r	Simple procedural	No flap ldg					
Flap asymmetry light	Airframe	r	Simple procedural	No flap ldg					

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
Flap asymmetry light	Airframe	r	Simple procedural	No flap ldg					
Flap control valve	Airframe	r	Simple procedural	No flap ldg					
Flap asymmetry light	Airframe	r	Simple procedural	No flap ldg					
Flaps frozen	Airframe	r	Simple procedural	No flap ldg					
Flap asymmetry light	Airframe	r	Simple procedural	No flap ldg					
Flap asymmetry light	Airframe	r	Simple procedural	No flap ldg	Practicing at night not worth the risk	Night			
Flap handle stuck	Airframe	r	Simple procedural	No flap ldg					
Flap asymmetry light	Airframe	r	Simple procedural	No flap ldg night					
Crash foil deployed	Airframe	r	Simple procedural	Returned to line					
Unsafe gear	Airframe	r	Simple procedural						
Loss of #1 hyd system	Airframe	r	Simple procedural						
Unsafe nose gear	Airframe	r	Simple procedural						
Unsafe gear up	Airframe	r	Simple procedural						
Brake accumulator failed	Airframe	r	Simple procedural			Mushy brakes			
Unsafe gear up	Airframe	r	Simple procedural						
Nose tires deflate	Airframe	r	Simple procedural						
Unsafe nose gear	Airframe	r	Simple procedural						
Loss of #1 hyd system	Airframe	r	Simple procedural						
Blown tire on T&G	Airframe	r	Simple procedural						
Ldg gear selector valve	Airframe	r	Simple procedural						
Cracked windshield	Airframe	r	Simple procedural						

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
Unsafe gear	Airframe	r	Simple procedural						
Cracked windshield	Airframe	r	Simple procedural						
Cracked windshield	Airframe	r	Simple procedural						
Cracked windshield	Airframe	r	Simple procedural						
Cracked windshield	Airframe	r	Simple procedural		Should practice this	Helmet on landing			
Cracked windshield	Airframe	r	Simple procedural			Helmet on ldg			
Hot brakes	Airframe	r	Simple procedural						
Cracked windshield	Airframe	r	Simple procedural						
Blown tire on r/w	Airframe	r	Simple procedural						
Binding rudder	Airframe	r	Simple procedural						
Cracked windshield	Airframe	r	Simple procedural						
HF wire separation	Airframe	r	Simple procedural						
HF wire separation	Airframe	r	Simple procedural						
Cracked windshield	Airframe	r	Simple procedural						
FOUO	Elec	r	Simple procedural		FE remembered what was recorded in ADB	Prior knowledge quickly isolated problem			
FOUO	Elec	r	Simple procedural	Abort mission					
FOUO	Elec	r	Simple procedural	Abort mission					
FOUO	Elec	r	Simple procedural	Abort mission					
Generator failed	Elec	r	Simple procedural	Abort mission					
FOUO	Elec	r	Simple procedural	Abort mission					
Gen mech fail light	Elec	r	Simple procedural	Abort mission					
FOUO	Elec	r	Simple procedural	Abort mission					
FOUO	Elec	r	Simple procedural	Abort mission					
FOUO	Elec	r	Simple procedural	Abort mission					
FOUO	Elec	r	Simple procedural	Abort mission					
FOUO	Elec	r	Simple procedural	Aircraft evacuated					
FOUO	Elec	r	Simple procedural	Taxi to line					

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
Interphone CB - lost Comm	Elec	r	Simple procedural						
FOUO	Elec	r	Simple procedural						
FOUO	Elec	r	Simple procedural						
FOUO	Elec	r	Simple procedural						
FOUO	Elec	r	Simple procedural						
FOUO	Elec	r	Simple procedural						
Oil press loss	Eng	r	Simple procedural	3 eng ldg		Confirmed with press light			
Oil press loss	Eng	r	Simple procedural	3 eng ldg		Confirmed with press light			
Oil leak	Eng	r	Simple procedural	3 eng ldg		Gage and visual			
Oil leak	Eng	r	Simple procedural	3 eng ldg		Gage and visual			
Turbine failure	Eng	r	Simple procedural	3 eng ldg					
Power lever rigging	Eng	r	Simple procedural	3 eng ldg					
Engine failed to restart	Eng	r	Simple procedural	3 eng ldg					
RGB failure	Eng	r	Simple procedural	3 eng ldg					
Start valve light on	Eng	r	Simple procedural	3 eng ldg					
Fire warning	Eng	r	Simple procedural	3 eng ldg					
Oil leak	Eng	r	Simple procedural	3 eng ldg					
Oil leak	Eng	r	Simple procedural	3 eng ldg					
Oil leak	Eng	r	Simple procedural	3 eng ldg					
RGB oil press flux	Eng	r	Simple procedural	3 eng ldg					
Oil leak	Eng	r	Simple procedural	3 eng ldg					
Oil leak	Eng	r	Simple procedural	3 eng ldg					
Engine failed to restart	Eng	r	Simple procedural	3 eng ldg					
Fire warning	Eng	r	Simple procedural	3 eng ldg		Turbine failure			
Oil leak	Eng	r	Simple procedural	3 eng ldg					
Oil leak	Eng	r	Simple procedural	3 eng ldg		Oil fed fire in tailpipe			
Engine failed to restart	Eng	r	Simple procedural	3 eng ldg					
Oil leak	Eng	r	Simple procedural	3 eng ldg		Oil fed fire in tailpipe			
Engine failed to restart	Eng	r	Simple procedural	3 eng ldg					
Fire warning	Eng	r	Simple procedural	3 eng ldg					
Oil leak	Eng	r	Simple procedural	3 eng ldg		Oil pooled in tailpipe			
Fire warning	Eng	r	Simple procedural	3 eng ldg		Bleed air			
Oil leak	Eng	r	Simple procedural	3 eng ldg					
Oil leak	Eng	r	Simple procedural	3 eng ldg					
Oil leak	Eng	r	Simple procedural	3 eng ldg					
Chips light	Eng	r	Simple procedural	3 eng ldg					
Oil leak	Eng	r	Simple procedural	3 eng ldg		Oil fed fire in tailpipe			
Chips light	Eng	r	Simple procedural	3 eng ldg					
Oil leak	Eng	r	Simple procedural	3 eng ldg					

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
Oil leak	Eng	r	Simple procedural	3 eng ldg					
Oil leak	Eng	r	Simple procedural	3 eng ldg					
Chips light	Eng	r	Simple procedural	3 eng ldg					
Chips light	Eng	r	Simple procedural	3 eng ldg					
Engine failed to restart	Eng	r	Simple procedural	3 eng ldg					
Oil leak	Eng	r	Simple procedural	3 eng ldg					
Oil leak	Eng	r	Simple procedural	3 eng ldg					
Fire warning	Eng	r	Simple procedural	3 eng ldg		Bleed air			
Oil leak	Eng	r	Simple procedural	3 eng ldg					
Engine failed to restart	Eng	r	Simple procedural	3 eng ldg					
RGB idler gear failure	Eng	r	Simple procedural	3 eng ldg		Manifested as oil press loss			
E-handle vibration	Eng	r	Simple procedural	3 eng ldg					
Engine failed to restart	Eng	r	Simple procedural	3 eng ldg					
Eng failure	Eng	r	Simple procedural	3 eng ldg					
Fire warning	Eng	r	Simple procedural	3 eng ldg		Bleed air			
E-handle vibration	Eng	r	Simple procedural	3 eng ldg					
Engine failed to restart	Eng	r	Simple procedural	3 eng ldg					
Oil press flux	Eng	r	Simple procedural	3 eng ldg					
Oil press flux	Eng	r	Simple procedural	3 eng ldg					
Engine flameout	Eng	r	Simple procedural	3 eng ldg					
Oil leak	Eng	r	Simple procedural	3 eng ldg		After shutdown for loiter			
Engine flameout	Eng	r	Simple procedural	3 eng ldg	Training allows us to respond correctly	#2 flameout with #1 loitered; good coordination			
Fire warning	Eng	r	Simple procedural	3 eng ldg					
RGB failure	Eng	r	Simple procedural	3 eng ldg					
Start valve light on	Eng	r	Simple procedural	3 eng ldg					
Engine flameout	Eng	r	Simple procedural	3 eng ldg					
Chips light	Eng	r	Simple procedural	3 eng ldg					
Fire warning	Eng	r	Simple procedural	3 eng ldg					
Fire warning	Eng	r	Simple procedural	3 eng ldg					
Fire warning	Eng	r	Simple procedural	3 eng ldg					
Chips light	Eng	r	Simple procedural	3 eng ldg					
Oil press flux	Eng	r	Simple procedural	3 eng ldg					
Fuel leak	Eng	r	Simple procedural	3 eng ldg					
E-handle vibration	Eng	r	Simple procedural	3 eng ldg	Crew reacted quickly & effectively in situation assessment				
Chips light	Eng	r	Simple procedural	3 eng ldg					
Chips light	Eng	r	Simple procedural	3 eng ldg					

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
RGB failure	Eng	r	Simple procedural	3 eng ldg	Fortunate this occurred high alt VMC; during critical phase and/or IMC result could have been disastrous				
Oil leak	Eng	r	Simple procedural	3 eng ldg					
RGB failure	Eng	r	Simple procedural	3 eng ldg					
RGB failure	Eng	r	Simple procedural	3 eng ldg					
Oil leak	Eng	r	Simple procedural	3 eng ldg					
Fuel leak	Eng	r	Simple procedural	3 eng ldg					
Fuel leak	Eng	r	Simple procedural	3 eng ldg					
Oil press loss	Eng	r	Simple procedural	3 eng ldg					
Fire warning	Eng	r	Simple procedural	3 eng ldg					
Compressor failure	Eng	r	Simple procedural	3 eng ldg					
Engine failed to restart	Eng	r	Simple procedural	3 eng ldg					
Oil leak during restart	Eng	r	Simple procedural	3 eng ldg					
Binding pwr lever during NTS	Eng	r	Simple procedural	Abort mission					
Anti-ice light on	Eng	r	Simple procedural	Abort mission					
Oil leak	Eng	r	Simple procedural	Abort mission					
E-handle vibration	Eng	r	Simple procedural	Abort mission		Discovered during taxi			
Fire warning	Eng	r	Simple procedural	Crew evacuated					
Torch during start	Eng	r	Simple procedural	Eng secured					
Fire warning	Eng	r	Simple procedural	Eng secured in washrack					
Bleed air leak	Eng	r	Simple procedural	Returned to line					
Erroneous airspeed indication	Inst	r	Simple procedural	Abort mission					
Lightning strike	Other	r	Simple procedural	Abort mission					
Lightning strike	Other	r	Simple procedural	Abort mission					
Lightning strike	Other	r	Simple procedural						
Lightning strike	Other	r	Simple procedural						
EDC failure	Press	r	Simple procedural	3 eng ldg					
EDC failure	Press	r	Simple procedural	3 eng ldg					
EDC failure	Press	r	Simple procedural	3 eng ldg					
Air multiplier failure	Press	r	Simple procedural						
Refer turbine failure	Press	r	Simple procedural						
Air multiplier failure	Press	r	Simple procedural						
Air multiplier failure	Press	r	Simple procedural						
Air multiplier failure	Press	r	Simple procedural						
RPM flux	Prop	r	Simple procedural	3 eng abort					
Prop leak after shutdown	Prop	r	Simple procedural	3 eng ldg					
PFTF	Prop	r	Simple procedural	3 eng ldg		Repeat gripe			
Fx pump failed to terminate	Prop	r	Simple procedural	3 eng ldg					

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
Fx pump failed to terminate	Prop	r	Simple procedural	3 eng ldg					
NTS inop light	Prop	r	Simple procedural	3 eng ldg					
NTS inop light	Prop	r	Simple procedural	3 eng ldg					
Blade ang, rotation @ PCO	Prop	r	Simple procedural	3 eng ldg					
Fx pump failed to terminate	Prop	r	Simple procedural	3 eng ldg					
Fx pump failed to terminate	Prop	r	Simple procedural	3 eng ldg					
Prop failed to unfeather	Prop	r	Simple procedural	3 eng ldg					
NTS inop light	Prop	r	Simple procedural	3 eng ldg					
Fx pump failed to terminate	Prop	r	Simple procedural	3 eng ldg					
RPM flux	Prop	r	Simple procedural	3 eng ldg					
Prop leak	Prop	r	Simple procedural	3 eng ldg		Discovered after shutdown			
Prop failed to unfeather	Prop	r	Simple procedural	3 eng ldg					
Pitchlock regulator failed	Prop	r	Simple procedural	3 eng ldg					
PFTF	Prop	r	Simple procedural	3 eng ldg					
PFTF	Prop	r	Simple procedural	3 eng ldg					
Fx pump failed to terminate	Prop	r	Simple procedural	3 eng ldg					
Prop leak	Prop	r	Simple procedural	3 eng ldg		Discovered after shutdown			
NTS inop light	Prop	r	Simple procedural	3 eng ldg					
Pitchlocked prop	Prop	r	Simple procedural	3 eng ldg					
Blade ang, rotation @ PCO	Prop	r	Simple procedural	3 eng ldg					
RPM flux	Prop	r	Simple procedural	3 eng ldg					
Fx pump failed to terminate	Prop	r	Simple procedural	3 eng ldg					
Prop failed to unfeather	Prop	r	Simple procedural	3 eng ldg					
RPM flux	Prop	r	Simple procedural	3 eng ldg					
NTS inop light	Prop	r	Simple procedural	3 eng ldg					
PFTF	Prop	r	Simple procedural	3 eng ldg					
PFTF	Prop	r	Simple procedural	3 eng ldg					
Pitchlock regulator failed	Prop	r	Simple procedural	3 eng ldg					
NTS inop light	Prop	r	Simple procedural	3 eng ldg					
NTS inop light	Prop	r	Simple procedural	3 eng ldg					
Fx pump failed to terminate	Prop	r	Simple procedural	3 eng ldg					
NTS inop light	Prop	r	Simple procedural	3 eng ldg					
NTS inop light	Prop	r	Simple procedural	3 eng ldg					
Binding pwr lever during NTS	Prop	r	Simple procedural	3 eng ldg					
Fx pump failed to terminate	Prop	r	Simple procedural	3 eng ldg					
Fx pump failed to terminate	Prop	r	Simple procedural	3 eng ldg					
Prop overspeed	Prop	r	Simple procedural	3 eng reversal					
No beta light	Prop	r	Simple procedural	3 eng reversal					
Binding pwr lever during NTS	Prop	r	Simple procedural	4 eng ldg					

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
Binding pwr lever during NTS	Prop	r	Simple procedural	4 eng ldg					
Binding pwr lever during NTS	Prop	r	Simple procedural	4 eng ldg					
Binding pwr lever during NTS	Prop	r	Simple procedural	4 eng ldg					
Prop pump light	Prop	r	Simple procedural	4 eng ldg					
Binding pwr lever during NTS	Prop	r	Simple procedural	4 eng ldg					
RPM flux	Prop	r	Simple procedural	4 eng ldg					
Binding pwr lever during NTS	Prop	r	Simple procedural	4 eng ldg					
Prop pump light	Prop	r	Simple procedural	4 eng ldg	Recent discussions...thought through well before this flight				
Binding pwr lever during NTS	Prop	r	Simple procedural	4 eng ldg					
Prop overspeed	Prop	r	Simple procedural	Abort mission					
Binding pwr lever during NTS	Prop	r	Simple procedural	Abort mission					
Prop leak	Prop	r	Simple procedural	Abort mission					
Prop pump light	Prop	r	Simple procedural	Abort mission					
Excessive negative SHP	Prop	r	Simple procedural	Abort mission					
Prop leak	Prop	r	Simple procedural	Abort mission					
Binding pwr lever during NTS	Prop	r	Simple procedural	Abort mission					
RPM flux	Prop	r	Simple procedural	Eng secured on taxi back to line					
Prop leak	Prop	r	Simple procedural	RTB 4 eng ldg					
Equipment arcing	Elec	r	Unique; no NATOPS guidance	Abort mission		New system		N	x
Crew ejected from bunks	Other	r	Unique; no NATOPS guidance	Didn't fasten lap belt in turb.		Not specifically covered in NATOPS for use of bunk belt		N	x
Frozen flap brake	Airframe	r	Unique; no NATOPS guidance	No flap ldg	Not specifically covered in NATOPS			N	
Fuel leak	Eng	r	Unique; no NATOPS guidance	3 eng ldg		FE scan recognized higher than normal ff; good coordination			
Fuel press low	Eng	r	Unique; no NATOPS guidance	3 eng ldg	Unique situation	Power loss w/ this light not usual			
Airframe buffet	Airframe	r	Unusual malfunction	Abort mission	Uncommon malfunction	Used previous event's knowledge to minimize			
Autopilot failed to disconnect	Airframe	r	Unusual malfunction	Abort mission		Change to tech man submitted for a/p preflight			
Elec shock	Elec	r	Unusual malfunction	Abort mission		ICS jackbox shocked co-pilot			

Subject Line	Type	Class	Category	Results	CO comments	My comments	Judgment	Explain	Unfav
RGB accessory failure	Eng	r	Unusual malfunction	3 eng ldg	Handled unusual malf well	Could have easily been misdiagnosed			
Failed feather valve	Prop	r	Unusual malfunction	3 eng ldg		Prop started rotating on restart then stopped			
Pitchlocked prop	Prop	r	Unusual malfunction	3 eng reversal		Prop fluid was "servicing" oil quantity			
Prop overspeed	Prop	r	Unusual malfunction	Abort mission		NTS light came on with no indications			
Fire warning	Eng	s	Improper procedures	3 eng ldg		Max wt t-off;high TIT & AOA		IP	x
Fire warning	Eng	s	Improper procedures	3 eng ldg		High TIT & AOA		IP	x
Oil quantity loss	Eng	s	Improper procedures	3 eng ldg	Chain of events should have been broken			IP	x
Tailpipe plug left in	Eng	s	Improper procedures	Abort mission	One that should have been avoided			IP	x
A/C rolled; brakes not set	Other	s	Improper procedures	PAC didn't set brakes		SA/failed to perform procedures properly		IP	x
Press controller malf	Press	s	Improper procedures	Crewman injured from press.	Malf outside of NATOPS	Better system knowledge might have prevented		N,K	x
Eng flameout	Eng	s	Improper procedures	Flameout on taxi	Loss of SA, crew coord, complacency	Improper crossfeed procedures		SA	x
Wrong altimeter conversion	Other	s	Improper procedures	Crew didn't convert properly		Loss of SA		SA	x
Low altitude	Other	s	Improper procedures	Didn't reset altimeter setting		Loss of SA; failed to perform procedures		SA	x
Decouple during NTS	Prop	s	Improper procedures	Unnecessary 3 eng ldg	Took immediate action w/out thinking	Loss of SA; did not evaluate; unusual self induced malf.		SA	x
Inadvertent HRD discharge	Eng	s	SA	Improper malf set-up		Loss of SA; broken habit pattern		SA	x
Loss of mag hdg	Inst	s	SA	Abort; no gyro approach IMC		Lack of system knowledge		SA	x
NMAC with IFR traffic	NMAC	s	SA		Should have queried twr	Wrong assumption		SA	x
Over press of aircraft	Press	s	SA		SA could have prevented	Gauge reading error		SA	x
NMAC	NMAC	s	Survival	Aggressive evasive 1 sec.				XSA	
NMAC with UAV	NMAC	s	Survival		Pilot's quick reaction	good scan		XSA	
Near collision w/ car on R/W	NMAC	s	Survival			Immediate rotate; unusual		XSA	

APPENDIX C. SUMMARY OF RESULTS

Appendix C contains a summary table of the results presented in Chapter IV. The table is only a summary of the three tables contained in Chapter IV and has no new or additional information.

Total # 438

Type	Class	Category	# requiring judgment	Total # favorable	Explanation favorable	Total # unfavorable	Explanation unfavorable
Airframe 8 10%	**Knowledge** 18% 80	Ambiguous indications 26 33%	26 100%	52 65%	Correct decision 14 27%	28 35%	Equip malfunction 8 29%
Electrical 15 19%		**Compound factors** 30 38%	30 100%		**Expert behavior** 38 73%		Wrong decision 1 4%
Engine 29 36%		Multiple malfunctions 10 13%	10 100%				Improper procedures 3 11%
Instrument 5 6%		Unique; no NATOPS guidance 6 8%	6 100%				**Lack of SA** 13 46%
NMAC 7 9%		Unusual malfunction 8 10%	8 100%				Lack of knowledge 3 11%
Other 2 3%							
Press 4 5%							
Prop 10 13%							
80		**Total requiring judgment**	80 100%	52			
Airframe 6 18%	**Rule** 78% 340	**Simple procedural** 28 85%	28 85%	25 76%	Correct decision 16 64%	8 24%	Equip malfunction 0 0%
Electrical 6 18%		Ambiguous indications (single COA) 2 6%	2 6%		Expert behavior 9 36%		Wrong decision 3 38%
Engine 8 24%		Compound factors (procedural) 3 9%	3 9%				**Improper procedures** 4 50%
Instrument 0 0%		Multiple malfunctions (procedural) 0 0%	0 0%				Lack of SA 1 13%
NMAC 0 0%		Unique; no NATOPS guidance 0 0%	0 0%				Lack of knowledge 0 0%
Other 1 3%		Unusual malfunction 0 0%	0 0%				
Press 1 3%							
Prop 11 33%			33				
33		**Total requiring judgment**	33 10%				
Airframe 63 21%		**Simple procedural** 261 85%	261 85%	282 92%	Correct decision 282 100%	25 8%	**Equip malfunction** 18 72%
Electrical 34 11%		Ambiguous indications (single COA) 15 5%	15 5%				Wrong decision 0 0%
Engine 121 39%		Compound factors (procedural) 7 2%	7 2%				Improper procedures 3 12%
Instrument 1 0%		Multiple malfunctions (procedural) 12 4%	12 4%				Lack of SA 2 8%
NMAC 0 0%		Unique; no NATOPS guidance 5 2%	5 2%				Lack of knowledge 0 0%
Other 5 2%		Unusual malfunction 7 2%	7 2%				No NATOPS guidance 2 8%
Press 10 3%							
Prop 73 24%			307				
307		**Total not requiring judgment**	307 90%				
Airframe 0 0%	**Skill** 4% 18	Improper procedures 10 56%	0	4 22%	Excellent SA 4 100%	14 78%	Equip malfunction 0
Electrical 0 0%		Situational awareness 4 22%	0				Wrong decision 0
Engine 6 33%		Survival 4 22%	0				Improper procedures 4 29%
Instrument 1 6%							**Lack of SA** 10 71%
NMAC 5 28%							Lack of knowledge 0
Other 3 17%							No NATOPS guidance 0
Press 2 11%							
Prop 1 6%							
18		**Total requiring judgment**	0 0%				

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