SCHOOL OF AVIATION SAFETY

A GUIDE TO HUMAN FACTORS FOR NAVAL AVIATORS.

A COMPENDIUM FOR AVIATION SAFETY OFFICERS AND CREW RESOURCE MANAGEMENT INSTRUCTORS

Naval Aviation Schools Command
Pensacola, FL

"It appears that the human factors "program" is another of the fruitless attempts to get things done by systems, organizations, and big words rather than by people…It is about as useful as teaching your grandmother how to suck an eggs."

Admiral Rickover, USN, the father of the nuclear Navy.

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1. INTRODUCTION

Safety research has shown that human performance problems are the greatest risks in hazardous industries. In fact, approximately 80% of aviation mishaps have been attributed to human error. We [psychologists] must convince aviators that human error is ubiquitous and inevitable and crack the defenses against admitting to human failings, and create an awareness of the sources of these failures (Helmreich & Merritt, 1998).

This guide is not designed to be an exact replica of either the Aviation Safety Officer (ASO) or Crew Resource Management (CRM) instructor courses. The purposes of this guide are:

- to serve as a resource to educates ASOs, CRM instructors and aviators on the human factors that should be considered when planning, flying, debriefing, investigating a mishap, and training;
- to provide a summary of current theory and research that is pertinent to aviation human factors; and
- to be an initial source document that provides resources to further information.

The human factors topics addressed in this guide include: human information processing, ergonomics, automation, situation awareness, decision making, communication, teamworking/leadership, stress and fatigue.

Resources

Flin, R., O'Connor, P. & Crichton, M. (in press) *Safety at the Sharp End*. Ashgate

Reason, J. (1990) *Human Error.* Cambridge: Cambridge University Press.

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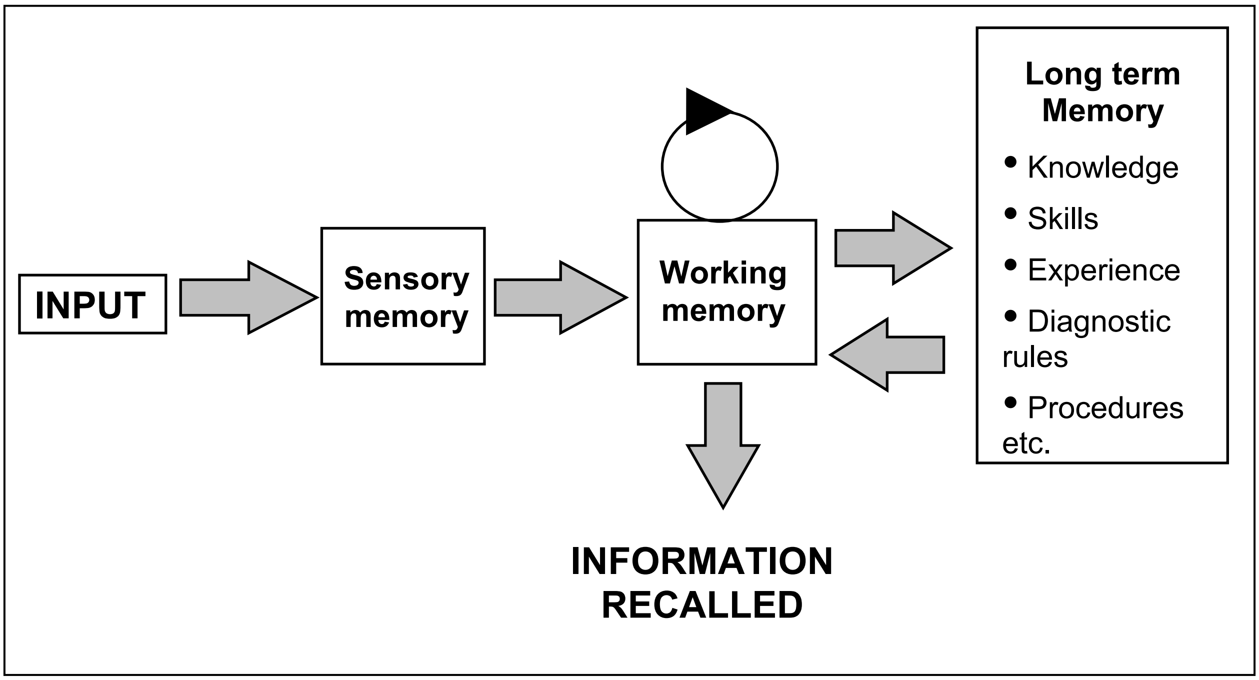
2. HUMAN INFORMATION PROCESSING

Prior to a discussion of human factors, it is necessary to have an understanding of the limitations of human information processing. The human brain functions as a very sophisticated information processing machine. Research into memory capacity and function has led to the development of a widely accepted model of the brain's storage and information processing system. A simplified view of human memory shows that there are three linked systems: sensory memory, working memory, and long term memory (see Figure 1), each of which is briefly described below.

Figure 1. Model of human memory (Adapted from Atkinson & Shiffrin, 1971).



Sensory Memory

The sensory memory holds incoming visual information for very brief periods of time - for vision, the iconic memory retains the image for about half a second and for acoustic signals, the echoic store lasts for about two seconds (Eysenck & Keane, 2005). We appear to have little conscious control of these stores, however the persistence effect allows us extra time to process incoming information.

Working Memory

Of more significance to aviators is the second memory store called working memory. Working memory essentially contains our conscious awareness. It is a limited capacity store, holding on average about seven 'bits' or chunks of information plus or minus two (Miller, 1956).

Working memory not only has a small storage capacity but it is also not very good at holding onto the information. Unless we rehearse the information in working memory (e.g. by repeating the information over and over again) we will forget it. Further, if we are distracted and switch our attention to something else, we may just lose the information in working memory.

Prospective memory (remembering to do something in the future, i.e. to perform actions after a delay) is especially vulnerable to task interruption and distraction. An mishap at Los Angeles International airport in 1991 occurred when an air traffic controller cleared an aircraft to hold in a take-off position and shortly afterwards directed another aircraft to land on the same runway, without clearing the first aircraft to take off. The controller forgot about the action required for the first plane because she had to switch her attention to other aircraft she was also managing (Loft et al, 2003).

With experience, tasks such as the physical skill of flying become automatic. The reason for this is procedures and actions are well known and stored in the long term memory. This frees up our working memory to attend to other tasks, such as talk on the radio, or dealing with an emergency. Flight simulators, EP trainers, and training flights help develop this experience base.

Long Term Memory

The main memory store is called long term memory. This is a huge repository for all kinds of information we have acquired and stored during our life. It holds all our personal memories of events we have experienced, (called episodic memory) as well as our whole store of knowledge. The latter is known as semantic memory and holds our likes and dislikes, the languages we speak, how to perform tasks such as flying, the procedure for what to do if we have an engine fire, etc.

Therefore, limitations of our memory, and particularly working memory capacity, govern an aviators ability to maintain situation awareness, manage workload, and make decision in the aircraft.

Resources

Baddeley, A. (1993). *Human memory: theory and practice*. Hove, UK: Lawrence Elbaum Associates.

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3. ERGONOMICS

Ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system (International Ergonomics Society, 2000). It encompasses how humans interact with hardware (e.g. the aircraft, cockpit, etc.) and software (e.g. emergency procedures, SOPs, etc.). Even the design of the pocket checklist, i.e. how easy is it to get to the relevant procedure is an issue of ergonomics.

Ergonomics should be considered in mishap prevention and investigation. For example, was there something in the design of the cockpit that made the aviator more likely to make a mistake?; was the procedure easy to understand?; were there two similar looking switches that do different tasks placed next to each other?

Display principles

Wickens (2003) identified seven principles of cockpit design that relate to, and flow from, an understanding of human information processing (see section 2). It is suggested that after a mishap or near-miss these principles should be considered and an assessment made as to whether the design of the cockpit contributed to the event.

1. Principle of information need.

The crew should only be presented with the information that is needed for the required task. The information needed most frequently should be displayed in locations that are more accessible (i.e. directly in front of the aviator).

2. Principle of legibility.

The displays must be legible, large enough to see details, have adequate contrast and brightness, and auditory displays must be attention getting . Examples of failures of this principle include faded text on instruments, instruments that become obscured by glare.

3. Principle of display integration/proximity compatibility principle

When eyes scan separate sources of information, it requires mental effort. When the relevant information is far apart, or information from different instruments must be integrated, this adds to the aviators workload. Therefore, frequently used information should be placed in front of the pilot. Information that must be integrated or compared should be placed close together (e.g. information concerned with engine performance).

4. Principle of pictorial realism

Display should look like, or be a pictorial representation of the information it represents. For example, a round altitude dial disobeys this principle, whereas a vertical ‘moving tape’ display obeys this principle.

5. Principle of the moving part

Moving element on the display should both move like an aviator’s “mental model” and move in the same direction. The moving horizon of the attitude gyro disobeys this principle as the horizon moves up to indicate the aircraft is pitching down, and rotates to the left (or right) to indicate the aircraft is pitching right (or left). If this principle was to be obeyed, the aircraft would be depicted moving around a stable environment.

6. Principle of predictive aiding

Aviation is dynamic, to have good situation awareness, an aviator must be able to take their current mental model and run it forward to predict the future state of the aircraft (see section 5). More modern aircraft may have instruments that support this principle. To illustrate, the J-1 Jayhawk has an indicated airspeed (IAS) vector that indicates what the IAS would be in 10 seconds time with the current rate of acceleration/ deceleration.

7. Principle of discriminability: status versus command

A displayed element must never look/sound like another displayed element in same display. Wickens (2003) also distinguish between status information and command intentions. Status information tells the aviator where the aircraft is at that particular moment (e.g. course deviation indicator). Command information tells the aviator what to do to reach a particular state (e.g. flight director). Therefore, the distinction between command and status information should be unambiguous.

Resources

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4. AUTOMATION

Automation can be defined as the execution by a machine of a function previously carried out by a human (Parasuraman & Riley, 1997). Automation has improved both the efficiency and flexibility of aviation operations. For the Naval aviator automation has benefits in terms of increasing the accuracy of bombing, aids in navigation, makes the task of landing on the boat easier, etc. For commercial aviation automation has been associated with a reduction in mishap (see Orlady & Orlady, for a review, 2001).

However, despite these undoubted benefits of aircraft automation, there are also concerns about the possible negative effects of aircraft automation. To illustrate, in a study of army rotary wing mishaps, Rash et al (2001) found the mishap rate for four of the five helicopters examined was higher in the glass-cockpit as compared to the traditional-cockpit aircraft (see Table 1).

Table 1. Mishap rates for all classes of mishaps per 100,000 flight hours for FY98-FY00 (Rash et al, 2001).

Aircraft	**Traditional**	**Glass**
OH-58 Kiowa	4.37	20.30
UH-60 Blackhawk	8.81	17.06
AH-64 Apache	18.36	23.00
CH-47 Chinook	6.97	3.94

Although Rash et al (2001) state that care should be taken in blaming the mishaps rates only on the glass cockpit (other possible explanations included: differences in aircraft handling qualities, added systems that increase workload, engaging in riskier missions.). Moreover, the mishap rate was only statistically significantly higher in the Kiowa (see Table 1). These findings raise the question as to whether automated aircraft are necessarily safer. A summary of the main concerns regarding cockpit automation that are discussed in the research literature are provided below.

1. Automation changes the role of the aviator.

In an automated aircraft, is the aviator still piloting the aircraft or are they a monitor of the computer that is piloting the aircraft? The consensus from the literature seems to be that automation should be in control of the basic stability and control of the aircraft. However, the aviators should carry out the higher-level functions such as flight planning, system status management, and decision making. Therefore, training should reflect the emphasis on the aviator's decision making, knowledge of systems, monitoring and crew coordination (CAA, 2006).

2. Automation dependency.

It is argued that aviators may become dependent on automation and complacent when using high reliability automated systems. Researchers have found that aviators are poor at detecting even catastrophic failures in automation when operating high reliability automated flight systems (Singh et al, 1993, 1997). Further, automation encourages pilots to adopt a natural tendency to follow the choice requiring least cognitive effort. In a study of aviators in the simulator, it was found that on 55% of occasions pilots committed errors because the automation presented incorrect information despite the fact that the correct information was available to them from other sources on the flight deck the presence of correct information to detect the anomaly (Mosier et al, 1998, 2001).

3. <u>Loss of manual flying skills</u>.

If the aircraft's automated systems are taking over the role of flying the aircraft from the pilot, it makes sense that the manual flying skills of the aviator may erode. It is consistently reported in the literature that a discernible reduction in manual flying skills is correlated with the use of automation (Woods, 2004).

4. <u>Loss of situation awareness</u>.

Aviators can become too involved in managing the automation. For example, fiddling with the flight management system makes aviators lose their awareness of the passage of time, their awareness of the situation, and of the flight path (Endsley, 1996). Care must be taken to ensure that someone is still flying the aircraft and the whole crew does not get sucked into managing the automation. A further issue is that a small error in input can have enormous consequences. To illustrate, on an approach to Strasbourg on 20 January 1992, the crew of ab Airbus A320 want to program a -3.3 degree, angle of descent, into the Flight Control Unit (FCU). The crew thought they were in TRK/FPA (track/flight path angle) mode. This would have resulted in a -3.3 degree descent angle (an 800 feet/min rate of descent). However, the FCU was actually in HDG/V/S (heading/vertical speed) mode. In HDG/V/S "-3.3" means a descent rate of 3,300 feet/min. Therefore, the aircraft went into a 3,300 feet/min rate of descent , and the crew crashed into some cloud covered mountains near Strasbourg, killing 87 people.

Conclusion

Traditional approaches to aviation training may not be adequate to train aviators to safely and effectively fly automated aircraft (Sarter et al, 1997). As automated aircraft are more complicated than traditional aircraft, it may take longer to train aviators to *become* proficient, and aviators may require more flight time to *remain* proficient. The distinction between flying pilot and non-flying pilot are less distinct in automated aircraft than traditional aircraft. Therefore, Crew Resource Management skills are arguably more important to crews of automated aircraft. Further, SOPs are required to ensure that there are adequate checks and balances to avoid the pitfalls associated with automation.

Resources

Key texts

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5. SITUATIONAL AWARENESS

Definition

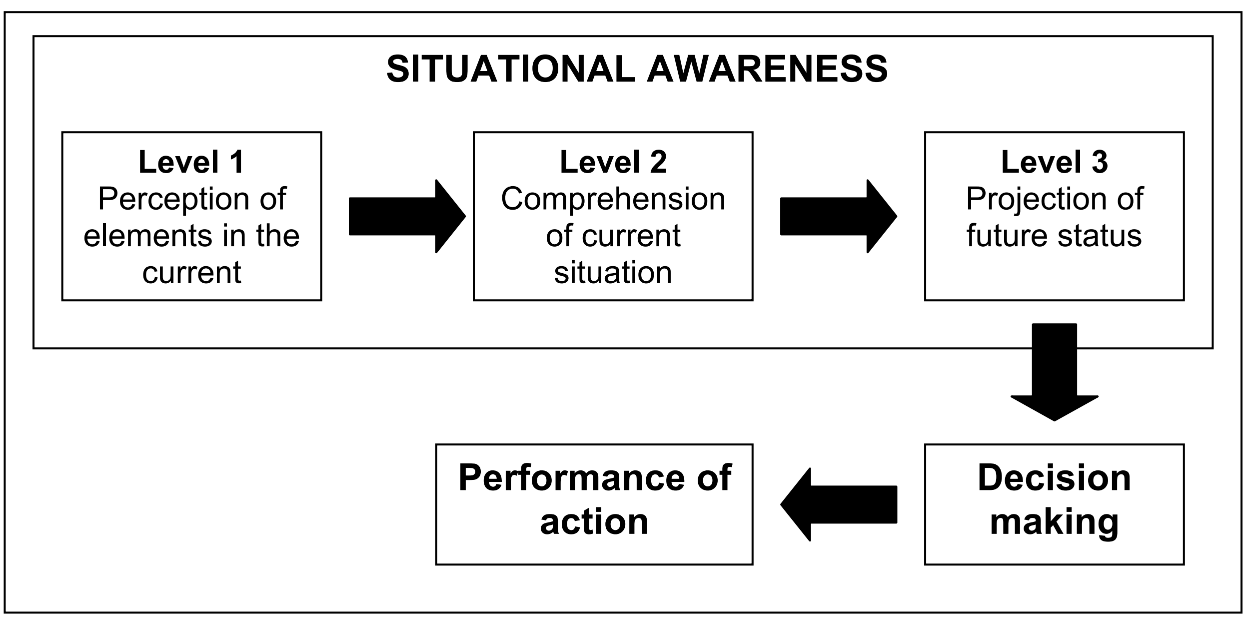
Situational awareness is an understanding of what is going on around you. The Navy CRM program defines situational awareness as "degree of accuracy by which one's perception of the current environment mirrors reality". Endsley (1988) has a similar, but more detailed definition of situational awareness. She defines it as "*the detection of elements in the environment within a volume of space and time. The comprehension of their meaning, and the projection of their status in the near future*." (p1388). The Endsley (1988) definition allows situational awareness to be separated into three distinct levels (see Figure 2).

<u>Level 1: Perception of the elements in the current situation</u>. An awareness of the individual elements required to build an accurate understanding of what is happening — e.g., weather, VFR traffic, engine performance, heading.

<u>Level 2: Comprehension of current situation</u>. Process the incoming information gathered in level one to make sense of the current situation in order to understand what is going on and build an accurate mental model of the situation — e.g. the aircraft is in a stall, we have an engine fire, we are receiving enemy fire.

<u>Level 3: Projection of future status</u>. The ability to use the current information to predict what will happen in the future — e.g., we will not have sufficient fuel to reach the airfield. Level 3 can be considered as carrying out a 'mental fast forward'.

Figure 2. Model of situation awareness (Endsley, 1996).



In 175 aviation mishaps, poor situational awareness was found to be the leading causal factor (Hartel, et al, 1991). Endsley (1995) reviewed major air carrier mishaps from 1989-1992 and found that situation awareness was a major causal factor in 88% of mishaps associated with human error. In December 1995, a Boeing 757 crashed into a mountain near Cali, Columbia, killing 159 people. Analyses of the voice recording showed that while trying to resolve an error resulting from entering an incorrect navigation code, the pilots had not maintained awareness of the position of their aircraft in relation to the mountainous landscape. Although a cockpit alarm warned of ground proximity, they were unable to climb the aircraft in time to avoid the mountain.

Jones and Endsley (1996) studied 143 aviation mishaps to determine what level of situational awareness failure was implicated for pilots and air traffic controllers. They found that 78% of the mishaps were problems relating to level one, not having the information that was needed to make sense of the situation. Further, the most common level 1 error is a failure of scan (35% of all SA errors; Jones & Endsley, 1996). Far fewer problems (17%) occurred when all the information had been gathered but was then misunderstood and only 5% were related to failures to think ahead when the situation had been correctly interpreted.

Clues that situational awareness has been lost

There are common 'clues' that can indicate signal that you, or your aircrew, are possibly 'losing' the correct situational awareness (CAA 2003; Okray & Lubnau, 2004):

- Ambiguity - information from two or more sources does not agree
- Fixation - focusing on one thing to the exclusion of everything else
- Confusion - uncertainty or bafflement about a situation (often accompanied by anxiety or psychological discomfort)
- Lack of required information
- Failure to maintain critical tasks (e.g. flying the aircraft, monitoring fuel)
- Failure to meet expected checkpoint or target
- Failure to resolve discrepancies - contradictory data, personal conflicts
- A bad gut feeling that things are not quite right

Maintaining good situational awareness

1. GET THE RIGHT INFORMATION

  - Maintain an awareness of how a flight is progressing.
  - Make extra efforts to get such information during abnormal situations.
  - After an interruption or distraction, back up several steps from where you think you left off, or double check all steps.
  - Be aware of environmental effects.

2. OVERVIEW

- Stand back and look at the problem.
- Double-check assumptions.
- Check assumptions with others.
- Stay focused on the goal, but avoid tunnel vision.
- Take time out and review objectively.
- Verbalize decisions.

3. REVIEW

- When possible, discuss how a particular situation was solved: identify both good and bad points.

Questions to calibrate situational awareness

It is suggested that periodically during a flight, you ask the following questions of yourself.

- What is the immediate goal of your team?
- What are you doing to support that goal?
- What are your concerns?
- What do you think this situation will look like in __ minutes, and why?

Resources

Key Texts

CAA (2006). *Crew Resource Management (CRM) Training. CAP 737*. Gatwick: Civil Aviation Authority. Download from: www.caa.org.

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Websites

Endsley's company www.satechnologies.com

Papers from Royal Aeronautical Society conference on situation awareness

www.raes-hfg.com/xsitawar.htm

ESSAI European project on situation awareness in aviation

www.nlr.nl/public/hosted-sites/essai/pages/reports.html

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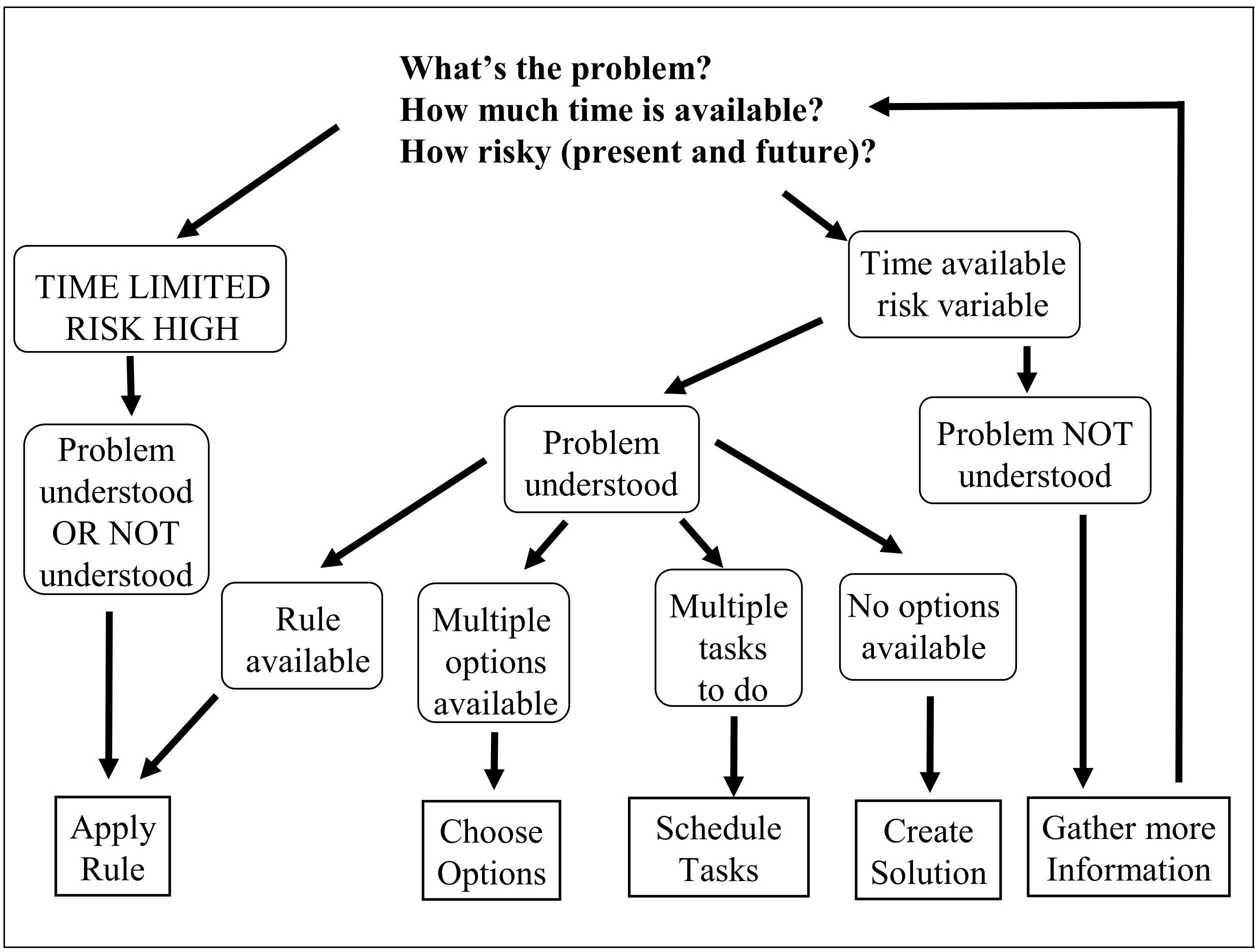
6. DECISION MAKING

Definition

The Navy CRM program defines decision making as the ability to choose a course of action using logical and sound judgment based on available information. It is the process of reaching a judgment or choosing an option, sometimes called a course of action, to meet the needs of a given situation (Flin et al, in press). In most operational work settings, there is a continuous cycle of monitoring and re-evaluating the task environment, then taking appropriate action.

An analysis of aircraft mishaps in the USA between 1983 and 1987 revealed that poor crew judgment and decision making were contributory causes in 47% of cases (NTSB, 1991). Based on the level of risk, the amount of time available, and the degree to which the problem is understood, the most appropriate decision making strategy is then chosen (see Figure 3).

Figure 3. Airline Pilots' Decision Making (Orasanu, 1995).



Four decision making strategies are used by people in high-risk environments (Klein, 2003):

(a) recognition-primed (intuitive),
(b) rule-based,
(c) choice through comparison of options, and
(d) creative.

Recognition-primed decision making

Recognition-primed decision making is a technique used by experts to make decisions in high-workload, time-limited situations. It is how experienced people make decisions rapidly. This technique is distinguished by:

- Actions and reactions being based on past experience.
- The emphasis being on reading the situation, rather than on generating different options for possible actions.
- Experienced reading of a situation, so that the selection of a course of action is obvious.
- The generation of a solution that, while it may not be the best, should result in a resolution that is workable.

Positives	Negatives
• Is a useful method when time is limited. • Requires little mental effort. • Can provide a satisfactory, workable plan. • Is useful in routine situations.	• Can be applied only in certain situations. • Requires that the user be an expert. • Can encourage looking only for evidence to support one's model, rather than considering evidence that may not support that model (confirmation bias).

Rule-based decision making

This technique is used to solve familiar problems in which solutions are governed by written rules or procedures. This is the most commonly used decision making strategy by aviators. Once the problem has been diagnosed, you need only to follow a series of rules. Therefore, you do not necessarily need to be an expert or to understand every step.

Positives	Negatives
• You do not need to be an expert. • You do not need to understand the purpose of every step.	• It is easy to miss a step in the sequence. • If the diagnosis is incorrect, you may blindly follow the wrong set of rules.

Analytical decision making

This method is used when time to come up with the best solution to a problem is plentiful. This method may involve thinking of a number of solutions, and then deciding which would effect the best outcome (an example of which is deliberate operational risk management). Four steps in using this method include:

1. Identifying the problem.
2. Generating a set of options for solving the problem/choosing among the alternatives.
3. Using a number of strategies (e.g., comparing the relevant features of the options) to evaluate these options concurrently.
4. Choosing and implementing the preferred option.

This technique usually produces the best solution, and it is most valuable in solving new problems. However, it is slow, laborious, and affected by stress.

Positives	Negatives
• Usually produces the best solution. • Useful when trying to solve a novel problem.	• Slow. • Laborious. • Affected by stress.

Creative Decision Making

This method is infrequently used in high time pressure environments, as it requires devising a novel course of action for an unfamiliar situation (i.e. you are now a test pilot). Aviators rarely appear to use this method successfully during an in-flight problem. A famous example is the DC-10 (United Airlines flight 232) 'one chance-in-a-billion' centre engine failure that caused severing of the hydraulic pipes and consequent loss of all flight controls. The crew worked out a novel solution using differential engine thrust on the remaining two engines to regain some pitch and roll control and managed to crash land the aircraft on the runway at Sioux City airport, saving many lives.

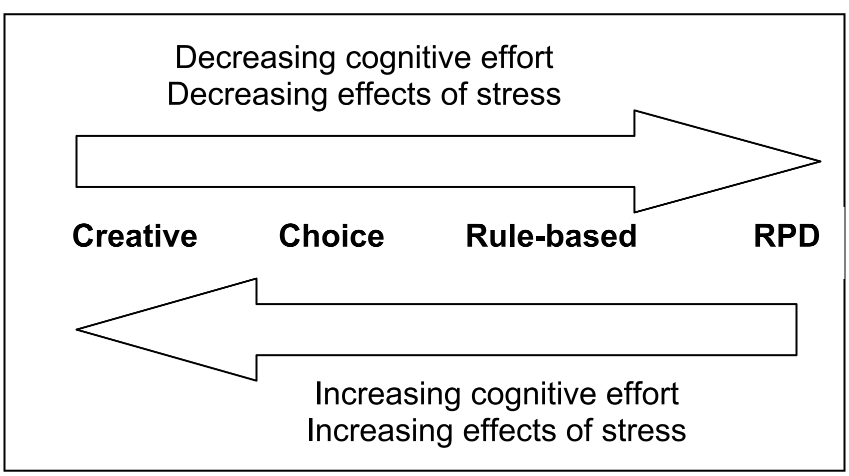
Positive	Negative
• Produces solution for unfamiliar problem • May invent new solution	• Time consuming • Untested solution • Difficult in noise and distraction • Difficult under stress • May be difficult to justify

Factors Influencing Decision Making

Competence in decision making is significantly influenced by technical expertise, level of experience, familiarity with the situation and practice in responding to problem situations. As decision making is a cognitive skill, it is affected by many of the same factors as situation awareness, namely stress, fatigue, noise, distraction, and interruption. In stressful situations, decision making may be particularly vulnerable, especially choice decisions where time and mental effort are required to evaluate and compare optional courses of action. The negative effects of acute stress on cognitive processes can be: over-selective attention (tunnel vision), reduction working memory capacity, restrictions in retrieval from long term memory, with simple retrieval strategies being favored over more complex ones (see section 2 for a discussion of human memory limitations). Shifts in strategy, such as speed/accuracy trade-offs, can be observed with people under stress behaving as if they were working under time pressure, when in fact there is none (Orasanu, 1997).

Of the four modes of decision making described, stress has most impact on choice and creative methods as these require heavy use of cognitive resources such as the working memory space, and we know working memory capacity is reduced under stress. In contrast decision methods such as recognition-primed decision making which are relatively light on cognitive processing, seem to be less affected by stress (Stokes et al, 1997). Similarly if rules can be easily recalled, or checklists easily located, then this method will also generally function well in stressful conditions (see Figure 4).

Figure 4. Relative effects of stress on decision making method (Flin et al, in press)



Fatigue is another common condition which can influence the quality of decision making (see section. Even one night of sleep loss can impair flexibility, increase perseveration errors and ability to appreciate an updated situation (Harrison & Horne, 1999). Other factors that can influence the quality of decision making relate to differences in personal style and social interactions with crew members. Walters (2002, p15) describes a number of what he calls decision traps for pilots:

- Jumping to solutions
- Not communicating
- Being unwilling to challenge the experts
- Complacency ('you worry too much')
- Assuming you don't have the time
- Failure to consult
- Failure to review

Resources

Websites

Klein Associates www.decisionmaking.com

Cognitive Engineering and Decision Making Technical Group of Human Factors and Ergonomics Society (naturalistic decision making) http://cedm.hfes.org

Society for Judgment and Decision Making (study of normative, descriptive and prescriptive theories of decision making) www.sjdm.org

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7. TEAMWORKING AND LEADERSHIP

The fact that teamworking is an important skill for effective team performance is not surprising. The consequences of failures of teamwork have been illustrated by many high-profile mishaps in complex systems (e.g., the shooting down of a commercial airliner by the *USS Vincennes, CG-49* [1988], the Three Mile Island nuclear plant mishap [1979]). Analysis of these mishaps identifies three main teamwork problems: (i) a lack of role definition, which allows tasks to "fall through the cracks"; (ii) a lack of explicit coordination, which facilitates a failure to balance goals; and (iii) miscommunication problems (Thordsen et al, 1990).

Leadership is also important to team performance. A study of civilian aircrew performance in a full-mission simulation found that the crews who performed well were led by captains who recognized the value of encouraging communication in the cockpit and the importance of maintaining good interpersonal relations between crew members (Helmreich, 1984). Crews who were given constant direction by the commander in a simulated helicopter mission have also been found to perform less well than crews who were given less direction (Foushee & Helmreich, 1988).

Teamworking: Dream teams

For a team to have basic effectiveness, the following characteristics are required:

- Individual task proficiency
- Clear, concise communication
- Task motivation
- Collective orientation — a belief that the team's goals are more important than those of the individual
- Shared goal and mission

These are the minimum requirements for an effective team, but for enhanced performance, the following are also required:

- Shared understanding of a task
- Shared understanding of other team members' roles and responsibilities
- Team leadership — the leader enables the team to think ahead
- Collective efficacy (a sense of "teamness")
- A sense of anticipation, of "getting ahead of the curve"
- Flexibility (i) to adjust the allocation of resources to fit the task, and (ii) to alter strategies to suit the task
- Implicit communication (an awareness of each other's needs)
- Monitoring of one's own performance

These requirements were made from investigations of more than 300 U.S. Navy teams (Salas & Cannon-Bowers, 1993).

Attitudes of ineffective team members

The Federal Aviation Administration (1991) has outlined five hazardous attitudes of ineffective team member performance.

1. Antiauthoritarian: “Don’t tell me what to do.”

This attitude is found in people who do not like to be told what to do. They may resent being told what to do, or they may regard rules, regulations, and procedures as unnecessary. However, listing this as a hazardous attitude is not to say that you should not question authority if you feel that authority is in error.

2. Impulsivity: “Do something — quickly.”

This is the attitude of people who just want to react quickly and do anything. They do not stop to think about what to do; they simply do the first thing that occurs to them.

3. Invulnerability: “It won’t happen to me.”

Many people feel that they will never be involved in an mishap. Divers who think this are more likely to take chances and run unwise risks.

> "When anyone asks me how I can best describe my experiences of nearly forty years at sea, I merely say uneventful. I have never been in an accident of any sort worth speaking about. . . . I never saw a wreck and have never been wrecked, nor was I ever in any predicament that threatened to end in disaster of any sort."
>
> CAPT Edward J. Smith (Captain of the *Titanic*)

4. Macho: “I can do it.”

People who always want to prove they can do a task may find themselves in a situation that is beyond their abilities and experience.

5. Resignation: “What’s the use?”

People with this attitude do not see themselves as making a big difference in what is happening. They leave the actions to others — for better or worse. They may even go along with unreasonable requests because doing so is easier than making a fuss.

Rersources

Key Texts

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8. COMMUNICATION

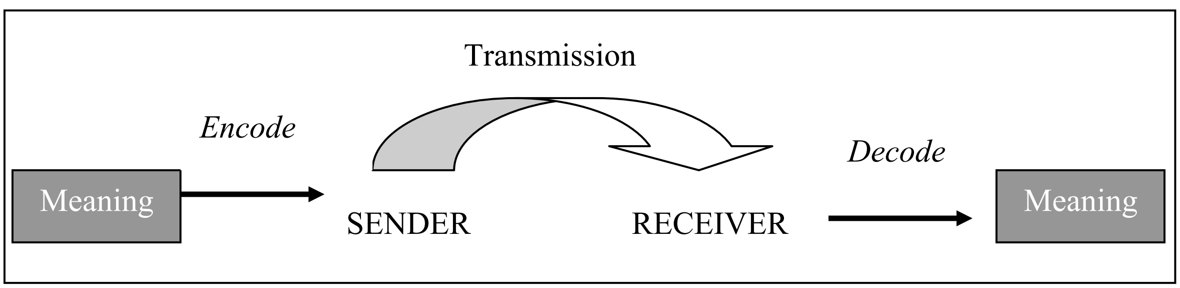
Communication is the exchange of information, feedback or response, ideas, and feelings (Flin et al, in press). The failure to exchange information and co-ordinate actions is one factor which differentiates between good and poor team performance (Driskell & Salas, 1992). Errors in communication can occur as individuals fail to pass on information, communicate incorrect information, and delay in making decisions.

The exchange of information is a core activity for decision making, situational awareness, team co-ordination, and leadership. Effective communication enhances information-sharing, perspective-taking, and genuine understanding. The importance of communication for effective performance, reducing errors and improving safety cannot be over-emphasized.

Models of communication

Communication can typically be described as either one-way or two-way. Each of these models of communication can be experienced in different situations. One-way communication, shown in Figure 5, appears simple. The information or message that the Sender wants to convey is encoded into words or other signals by the Sender which are then transmitted to one or more Receivers, who then decode the information to identify the meaning.

Figure 5. Simplified model of one-way communication.

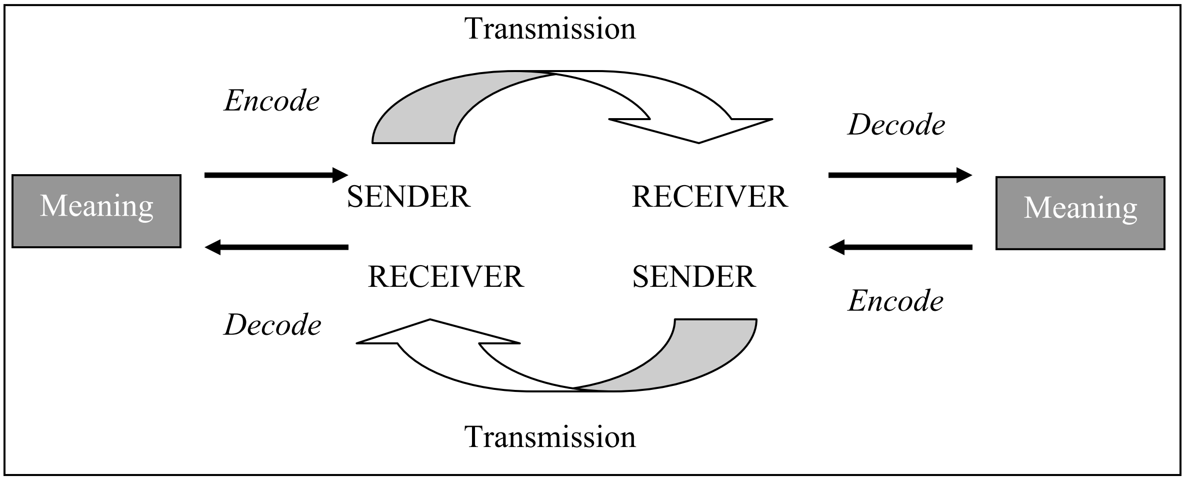


Examples of this form of communication include spoken or written instructions, email, voicemail, tannoy messages or television. There are certain advantages and disadvantages to one-way communication, as listed below.

Advantages	***Disadvantages***
• Rapid. • Looks and sounds 'neat'. • The sender feels in control.	• Generally requires planning. • The responsibility lies with the sender. • No feedback • The receiver may not pay adequate attention.

Two-way communication involves the Sender transmitting information to the Receiver who has the opportunity to respond and so in turn becomes the Sender and transmits information back to the Receiver, forming a closed feedback loop (see Figure 6).

Figure 6. Simplified model of two-way communication.



Two-way communication occurs during conversations, telephone calls, radio transmissions, email or other exchanges where information flows back and forwards between Senders and Receivers. The advantages and disadvantages of two-way communication as compared to one-way communication, are shown below.

Advantages	***Disadvantages***
• Potentially, more accurate, reliable and effective. • Permits checking and correction of details. • Requires less planning. • Receivers have more confidence, in themselves and make more correct judgments of accuracy. • Sender and receiver have responsibility. • Sender and receiver work together to achieve mutual understanding.	• Generally takes longer. • Receiver also has to communicate in return.

Although one-way communication is faster and hence more efficient, two-way communication is more accurate because it relies on both the sender and receiver to work together to ensure that information is understood. As can be seen in the Garuda Airlines crash outlined below (Box 1), even with two-way communication, it is possible for there to be confusion between the sender and receiver about simple direction commands.

BOX 1. A fatal failure in two way communication - Garuda Airlines Flight 152

On 26 September 1996, Garuda Airlines Flight 152 flew into a mountain 15 minutes before it was due to land at Medan, Indonesia on a flight from Jakarta, Indonesia. The aircraft crashed 20 miles from the airport. An air traffic control (ATC) error resulted in the plane being routed into mountainous terrain that was obscured by smoke and haze due to forest fires in the area. All 234 passengers and crew onboard were killed. The following is the ATC tower's conversation with the Garuda Indonesia Airlines (GIA) Airbus A300.

ATC:GIA 152, turn right heading 046 report established localizer.
GIA 152: Turn right heading 040 GIA 152 check established.
ATC: Turning right sir.
GIA 152: Roger 152.
ATC: 152 Confirm you're making turning left now?
GIA 152: We are turning right now.
ATC:152 OK you continue turning left now.
GIA 152: A (pause) confirm turning left? We are starting turning right now.
ATC: OK (pause) OK.
(Aviation Safety Network, 2004).

Components of effective communication

In an aviation environment, effective communication should be:

- Explicit - Clearly stating the desired action and who should do it;
- Direct - Degree of pressure to comply with the desired action; and
- Social appropriate - Sensitivity to the roles and status of speaker/addressees and to the seriousness of the situation.

McDonnell et al (2006) studied commercial pilots in a simulator, it was found that more effective communication strategies were used when *risk* was high. However, First Officers were less likely to challenge when *face threat* (degree of challenge to the other pilot's skill, judgment, or competence) was high (see Box 2 for an example of a failure of effective communication).

BOX 2. A failure of effective communication: Air Florida Flight 90 incident.

Air Florida Flight 90, a Boeing 737, was a scheduled flight to Fort Lauderdale, Florida, from Washington National Airport, Washington, DC on 13th January, 1982. There were 77 passengers and five crew-members on board. The flight's scheduled departure time was delayed about 1 hour 45 minutes due to a moderate to heavy snowfall that necessitated the temporary closing of the airport (NTSB, 1982).

Following takeoff from runway 36, which was made with snow and/or ice adhering to the aircraft, the aircraft failed to gain sufficient height and crashed into the barrier wall of the northbound span of the 14th Street Bridge and plunged into the ice-covered Potomac River. Four passengers and one crew member survived the crash. Further, when the aircraft hit the bridge, it struck seven occupied vehicles and then tore away a section of the bridge barrier wall and bridge railing. Four persons in the vehicles were killed.

The NTSB determined that the probable causes of this mishap were the flight crew's failure to use engine anti-ice during ground operation and takeoff, their decision to takeoff with snow/ice on the airfoil surfaces of the aircraft, and the captain's failure to reject the takeoff during the early stage when his attention was called to anomalous engine instrument readings by the first officer (the engines were set at substantially less than normal take-off thrust due to a partially ice-blocked probe causing false, high thrust readings on the engine gauges). The first officer was aware that there was something wrong, but the language he used was not sufficiently explicit and direct to get the captain's attention. "*the first officer commented 'that don't seem right does it?' 'Ah, that's not right'. The captain's only response was 'yes it is, there's eighty' (knots). The first officer again expressed concern 'Naw, I don't think that's right.' Again there was no response from the captain… The first officer continued to show concern as the aircraft accelerated through a 'hundred and twenty' (knots)*" (NTSB, 1982: 64).

Contributing to the mishap were the prolonged ground delay between de-icing and the receipt of Air Traffic Control take-off clearance during which the airplane was exposed to continual precipitation, and the limited experience of the flight crew in jet transport winter operations.

Assertiveness and listening

A lack of assertiveness was also found to be a key contributor to many aviation mishaps (the Air Florida crash described above is a perfect example). Assertiveness can be understood as a disposition situated between one that is too passive and one that is too aggressive.

> Passive — Failing to stand up for yourself, or standing up for yourself in such a way that others can easily disregard your words or actions.

Assertive — Standing up for yourself in such a way as not to disregard the other person's opinion.

Aggressive — Standing up for yourself, but in such a way as to disregard the other person's opinion.

It is important to attend to both verbal and nonverbal cues when you adopt an assertive stance (Koneya & Barbour, 1976).

Verbal	Nonverbal
▪ Content: – Decide what you want to say and state it specifically and directly. – Be honest: "I'm damn mad at what you did!" – Stick to the statement; repeat it, if necessary. ▪ Use "I" statements. ▪ Assertively deflect any responses from the other person which might undermine you. ▪ "Broken record technique": – "I hear what you are saying, but..." ▪ Offer a solution. ▪ Obtain feedback.	▪ Eye contact ▪ Body posture ▪ Gestures ▪ Facial expression ▪ Voice tone, inflection, and volume ▪ Timing

However, teaching team members to be assertive will not be effective unless they are also taught to listen. Below is a list of do's and don'ts that will aid in effective listening.

Do	Don't
• Be patient. • Ask questions. • Be supportive. • Paraphrase. • Make eye contact. • Use positive body language.	• Debate what is being said in your mind. • Detour (i.e., look for a key word to change the subject. • Finish the other person's sentence. • Preplan (work out what the person will say next). • Tune out.

Resources

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9. FATIGUE

Definition

Everyone knows what it is like to feel fatigue, and everyone has experienced it to some degree. However, researchers have found fatigue to be difficult to define. For the purpose of this description, fatigue can be defined as the state of tiredness that is associated with long hours of work, prolonged periods without sleep, or requirements to work at times that are "out of synch" with the body's biological or circadian rhythm.

Fatigue has been implicated in mishaps such as those at Three Mile Island, PA; at Chernobyl, Ukraine; and to the *Exxon-Valdez*. On U.S. highways, fatigue causes 100,000 crashes and 1,500 fatalities each year (Caldwell & Caldwell, 2003).

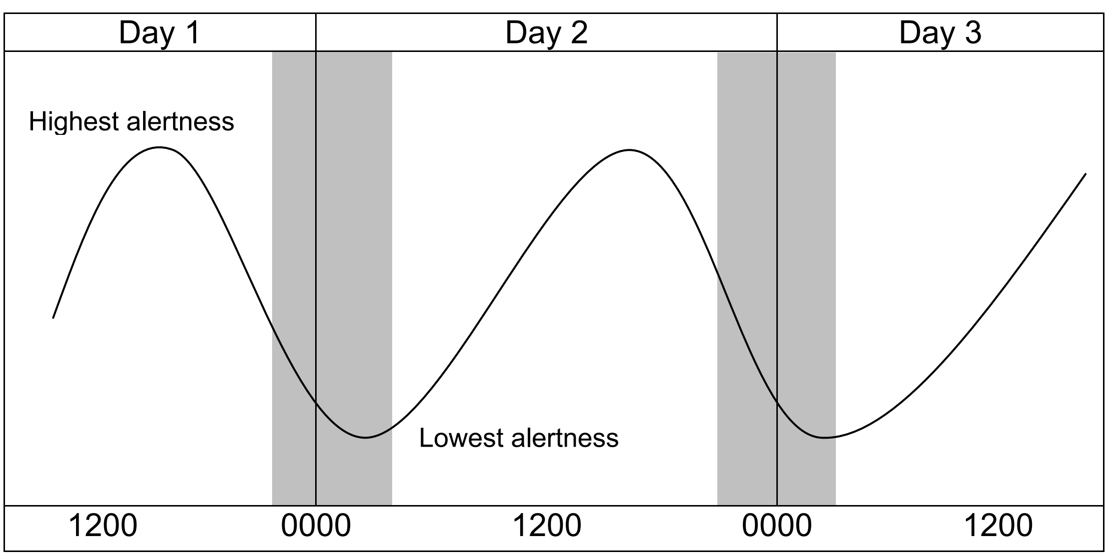
Causes of fatigue

The causes of fatigue include the obvious one of long hours of work as well as a lack of sleep. Factors such as stress, temperature extremes, noise (>80 dB), and physical work vibration are all fatiguing.

Circadian rhythm

The circadian rhythm is a name given to the "internal body clock" that regulates the approximately 24-hour cycle of biological processes in animals and plants. In a typical circadian cycle, performance peaks between 1200 and 2100 (usually around 1600) and falls to a minimum between 0300 and 0600 hours (see Figure 7).

Figure 7. A typical circadian cycle.



Evidence from traffic accidents and occupational accidents shows that a peak tends to occur in the early hours of the morning, when performance is at its lowest. It takes about seven cycles (during which the circadian rhythm is desynchronized) to adjust to working from daytimes to nighttimes. A single period of night work is much better tolerated than three or four consecutive periods of night work.

Types of fatigue

A guide on fatigue in Naval aviation identifies three different types of this condition (Naval Strike and Air Warfare Center, 2000).

Acute
• Produced by physical exertion or sleep loss • Alleviated by a single period of sleep
Chronic
• Results from depression or chronic fatigue syndrome • Treated as a medical or psychological problem
Operational
• Caused by continuous operations • Most commonly seen after 3 to 4 days of heavy tasking • Caused by sleep loss and circadian desynchronization • Not relieved by a single period of sleep

Effects of fatigue

The more boring the task, the more likely you are to suffer the effects of fatigue, which are outlined below. In studies of fatigue in a simulated driving task, people were more likely to leave the road when driving on a straight stretch rather than on a corner. The effects of fatigue include (Caldwell & Caldwell, 2003):

Thinking (cognitive)
• Adverse effect on innovative thinking and flexible decision making • Reduced ability to cope with unforeseen rapid changes • Less able to adjust plans when new information becomes available • Tendency to adopt more rigid thinking and previous solutions
Motor skills
• Less coordination • Poor timing
Communication
• Difficulty in finding and delivering the correct word • Speech is less expressive
Social
• Become withdrawn • More acceptance of own errors • Less tolerant of others • Neglect smaller tasks • Less likely to converse • Increasingly irritable • Increasingly distracted by discomfort

The effects of fatigue can also be compared to the effects of alcohol consumption (see Table 2). Even loss of two hours sleep produces a performance decrement equivalent to two or three beers.

Table 2. Comparison between sleep loss and alcohol consumption (Roehrs et al, 2003).

Sleep Loss (hr)	Equivalent U.S. Beers
8	10–11
6	7–8
4	5–6
2	2–3

Fatigue countermeasures

- **Sleep** is the most effective measure for reducing fatigue. Navy pilots are encouraged to get a minimum of four to five hours of sleep during sustained operations (Naval Strike and Air Warfare Center, 2000).
- **Napping** is also effective in reducing fatigue. Even a short nap of 10 minutes can improve functioning. However, longer naps can create a hangover — in which the individual may be sluggish or confused for about five minutes after waking up. The guide for flight surgeons recommends that commands should encourage, and at times mandate, napping during sustained operations (Naval Strike and Air Warfare Center, 2000).

- Fatigue is an aspect of operations that should be **considered and managed during planning**. Attempts should be made to avoid intricate or risky activities between 0300 and 0600.

- **If possible, rotate duties, talk to team members, and move around** to attempt to remain engaged in the job and to prevent boredom.

- In military aviation, stimulants or "go pills" such as **dexedrine** (dextroamphetamine) are used to increase alertness and maintain performance. Their use is carefully monitored by the flight surgeon and is authorized only during combat or exceptional circumstances of operational necessity (Naval Strike and Air Warfare Center, 2000).

- **Caffeine** can be as effective as other medical stimulants in maintaining performance when you are fatigued. Caffeine is most effective for people who do not normally consume large quantities on a daily basis. Two hundred milligrams of caffeine (one small cup) is recommended for consumption every two hours up to five hours before the next sleep break.

- **Monitor** team members for signs of fatigue.

- Just as managers plan for the number of personnel, equipment required, cost of operations, fatigue should be another factor that should be taken into account and managed during planning. Tools such as the **Fatigue Avoidance Scheduling Tool** (FAST^{TM}) are available to be used by the U.S. military.

Resources

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Flin, R., O'Connor, P. & Crichton, M. (in press) *Safety at the Sharp End*. Ashgate

Naval Strike and Air Warfare Center (2000). *Performance Maintenance During Continuous Flight Operations: A Guide for Flight Surgeons*, Fallon, Nevada: Author.

Website

Eurocontrol Fatigue & Sleep Management Brochure:

www.eurocontrol.int/humanfactors/public/subsite_homepage/homepage.html

NASA Ames fatigue countermeasures group: /human-factors.arc.nasa.gov/zteam/

National Sleep Foundation: www.sleepfoundation.org

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10. STRESS

What is stress?

Although many different definitions of stress exist, in this guide *stress* will denote a situation in which certain environmental demands evoke an appraisal process in which perceived demand exceeds resources and results in undesirable physiological, psychological, behavioral, or social outcomes (Salas et al, 1996)

Within the context of work-related stress, distinguishing between chronic and acute stress is important. Chronic stress, usually called occupational stress, is related to conditions in the workplace and the individual's reaction to these, usually over a protracted time. An individual suffering from occupational stress is likely to be increasingly at risk from the effects of fatigue and thereby vulnerable to acute stress.

Often known as emergency stress or critical incident stress, acute stress is sudden, novel, intense, and relatively short in duration. At its most extreme, acute stress occurs where the individual — suddenly exposed to a threatening situation such as a life-endangering event or traumatic scene — experiences a pronounced physiological and psychological reaction.

Why is stress relevant to aviators?

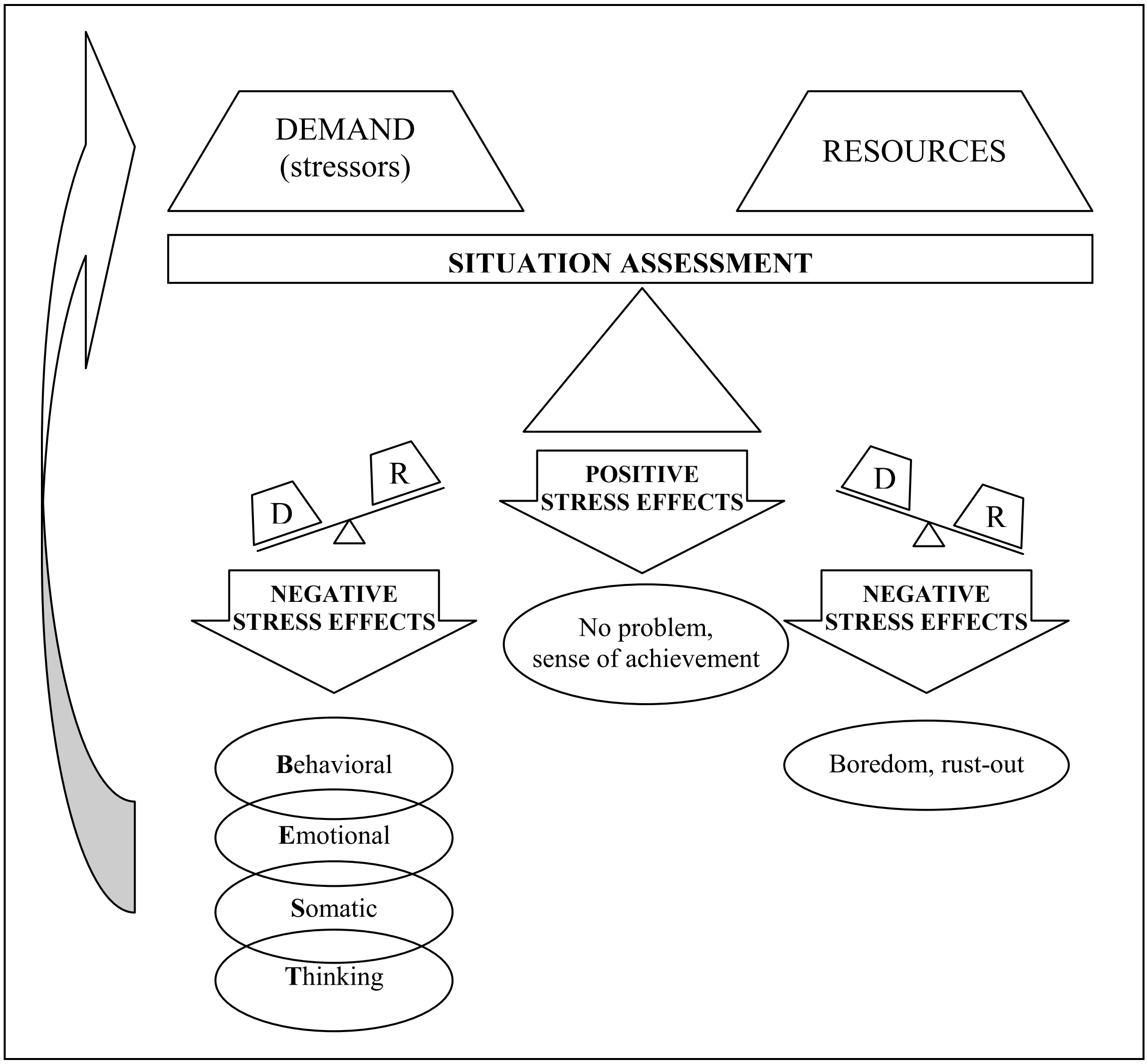
Both chronic and acute stresses are potential problems for aviators. Chronic stress could be relevant to any protracted period of work, in which there are deadlines and pressure to complete tasks. Acute stress, by contrast, may occur during an emergency situation, or during periods of high workload and production pressure.

Theory of stress

This theoretical model of stress can be portrayed as a balance mechanism (Figure 8), a model applicable to both chronic and acute stress.

When the available resources are judged to be equal to the demands, then the individual feels in control and comfortable: the scale is horizontal. In this state, moderate increases in demand may actually increase motivation and performance, since low levels of stress have a beneficial effect on performance. But when stressors, the *perceived* demands, outweigh the *perceived* resources to cope with those demands, stress reactions begin to occur. These reactions — a complex and interacting package of responses with behavioral, emotional, somatic (physical), and thinking effects — then feed back into the individual's assessment of the situation. For instance, an awareness of added symptoms of stress increases one's sense of a loss of control, increases the imbalance, and thereby increases the individual's stress.

Figure 8. The Balance Model of Stress (Cox, 1993).



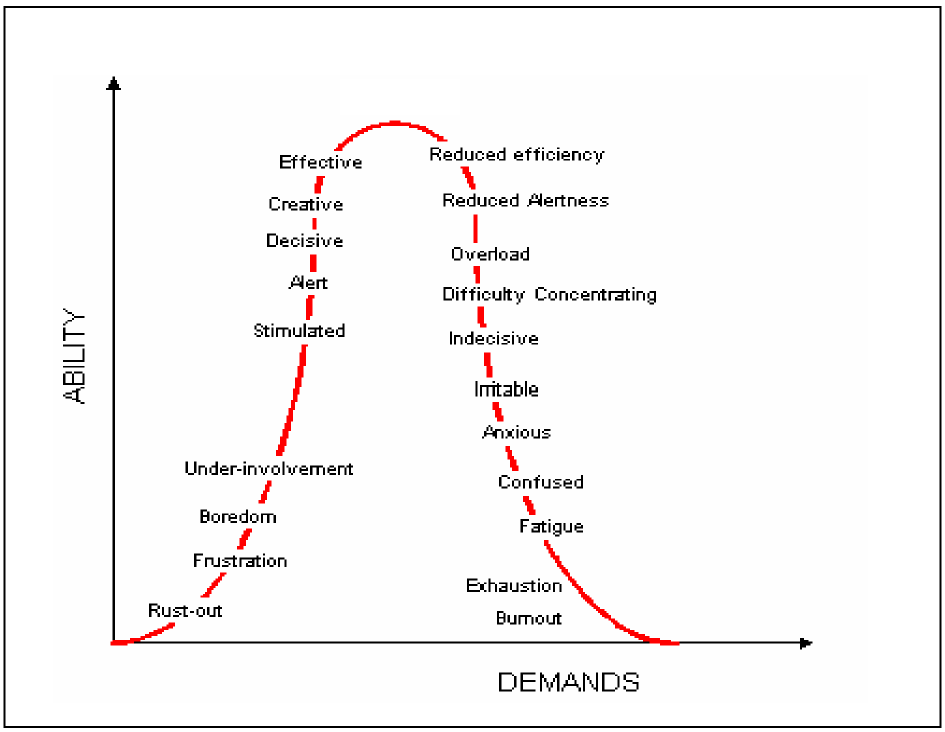
The individual's *perception* of the demands on him or her and his/her capabilities to meet these demands are crucial. No absolute level of demands appears to be important. Only the discrepancy that exists between the individual's perception of the demands and his or her perceived ability to cope is significant. Critical appraisal of demands and coping resources is based on an array of factors such as previous experience, training, and personality. Consequently, one aviator faced with a particular incident may feel calm, confident, and totally in control; another aviator in the same situation may be uneasy, irritable, and losing a grasp of the situation.

Chronic stress

In the developed world, chronic stress is the greatest challenge to the health of working people and to the healthiness of their work organizations. Furthermore, stress-related problems are the second most commonly reported cause of occupational ill health. Everyone has a level of stress at which he or she is unable to cope. However, the individual differences are large.

The relationship between stress response and performance is typically depicted as an inverted "U" curve (Figure 9). Performance improves with increases in stress; however, an optimal range exists where performance peaks. With additional increases in demands, performance decreases. This curve is not the same for every individual — e.g., some people have lower tolerances to stress — and even for one person it may vary from day to day: e.g., if one does not get sufficient sleep, his ability will be reduced. People probably should not be operating at the top of the curve without a break for days at a time.

Figure 9. Stress and performance curve.



A model of chronic stress (Figure 10) consists of stressors, mediating factors that can either increase or decrease stress effects (Table 3), symptoms of stress, and disease.

Figure 10. Model of chronic stress (Flin et al, in press).

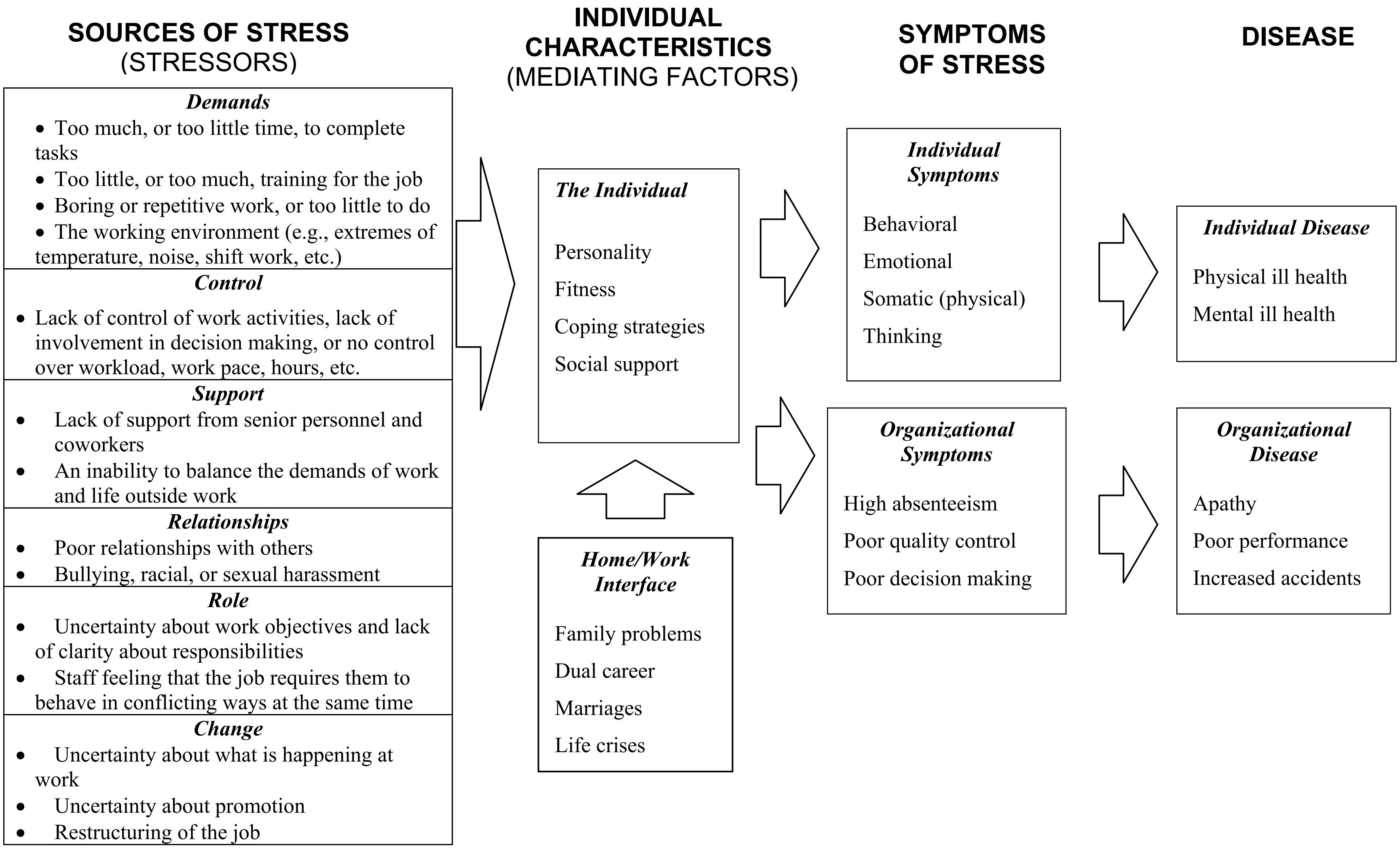


Table 3. Chronic stress mediating factors.

Mediating factor	Explanation
Personality	Some people are just better able to cope with a high-stress work environment. However, research findings about how personality acts to mediate stress are not clear.
Social Support	In almost all models of occupational stress, social support — from family, friends, and colleagues — is a mediating variable.
Fitness	Fitness and general well being is a good buffer against stress. Feelings of tiredness or ailments such as cold or flu are well-known sources of increased sensitivity to stress.
Coping Strategies	Whether people experience stress depends largely on their coping strategies.
Change	Any change in the routines of a life can be stressful — even a positive change.
Home/Work Interface	Managing the demands of work and family life, particularly in terms of time commitment, can also be a stressor. Long periods of deployment, or families in which both parents work, can add to levels of chronic stress.

No single way exists to identify whether a colleague is suffering from chronic stress. Since people often may not wish to admit to themselves, or to others, that they are suffering from stress, this reluctance can then contribute to a much more catastrophic result than if the problem could be easily identified. Indicators of chronic stress can be divided into four categories (Table 4).

Table 4. The BEST indicators of chronic stress (Flin et al, in press).

Category	Indicators
Behavioral	Apathy Reduced productivity Absenteeism Abuse of drugs (e.g., increased alcohol use or smoking) Hostile behavior
Emotional	Expressions of anxiety and hopelessness Irritability Appearance of boredom or apathy Cynicism and resentfulness
Somatic (physical)	Health complaints such as headaches, chest pains, or stomach complaints Decline in physical appearance Chronic fatigue Frequent infections
Thinking	Impaired decision making Lack of concentration

Once symptoms of stress are present, they can result in disease at both an individual and a team level. Diseases that are associated with chronic stress include bronchitis, coronary heart disease, mental illness (e.g., depression), thyroid disorders, skin diseases, types of rheumatoid arthritis, obesity, tuberculosis, headaches and migraines, peptic ulcers, and ulcerative colitis (Cox, 1993).

At the squadron level, even if one member is suffering from chronic stress, productivity can be reduced and a likelihood of mistakes can increase. Evidence suggests that individuals who are experiencing chronic stress are increasingly likely to be involved in an mishap. To illustrate, retrospective studies of U.S. Navy pilots have linked stressors such as career strain, financial difficulties, and interpersonal problems to aircraft mishaps (Alkov et al, 1982).

Dealing with chronic stress

All aviators should monitor themselves and squadron members for signs of chronic stress. Research generally divides techniques for preventing chronic stress into three types:

1. <u>Attempts to modify or eliminate sources of stress that are intrinsic to the work environment</u>. Obviously certain stressors (abnormal hours, flying off boats, etc.) are just part of the job of Naval aviation and cannot be changed. However, some stressors (e.g., flight schedule) may be possible to manage, particularly by individuals in senior positions.

2. Use stress management techniques. Typical stress management techniques include:
   - Muscle relaxation — this involves tensing (for 5 to 10 seconds) and releasing one muscle group at a time in a specific order, generally starting with the lower extremities and finishing with muscles of the face, abdomen, and chest.
   - Meditation — the purpose of this is to quiet the mind, emotions, and body.
   - Biofeedback — this is a training technique in which an individual learns to control the physiological reactions (e.g., increased heart rate and muscle tension) to stress.
   - Cognitive-behavioral stress management — this involves changing the way the individual thinks about stress. The aim is to help him or her to recognize negative or inaccurate thoughts and to alter the behavioral responses to these thoughts.

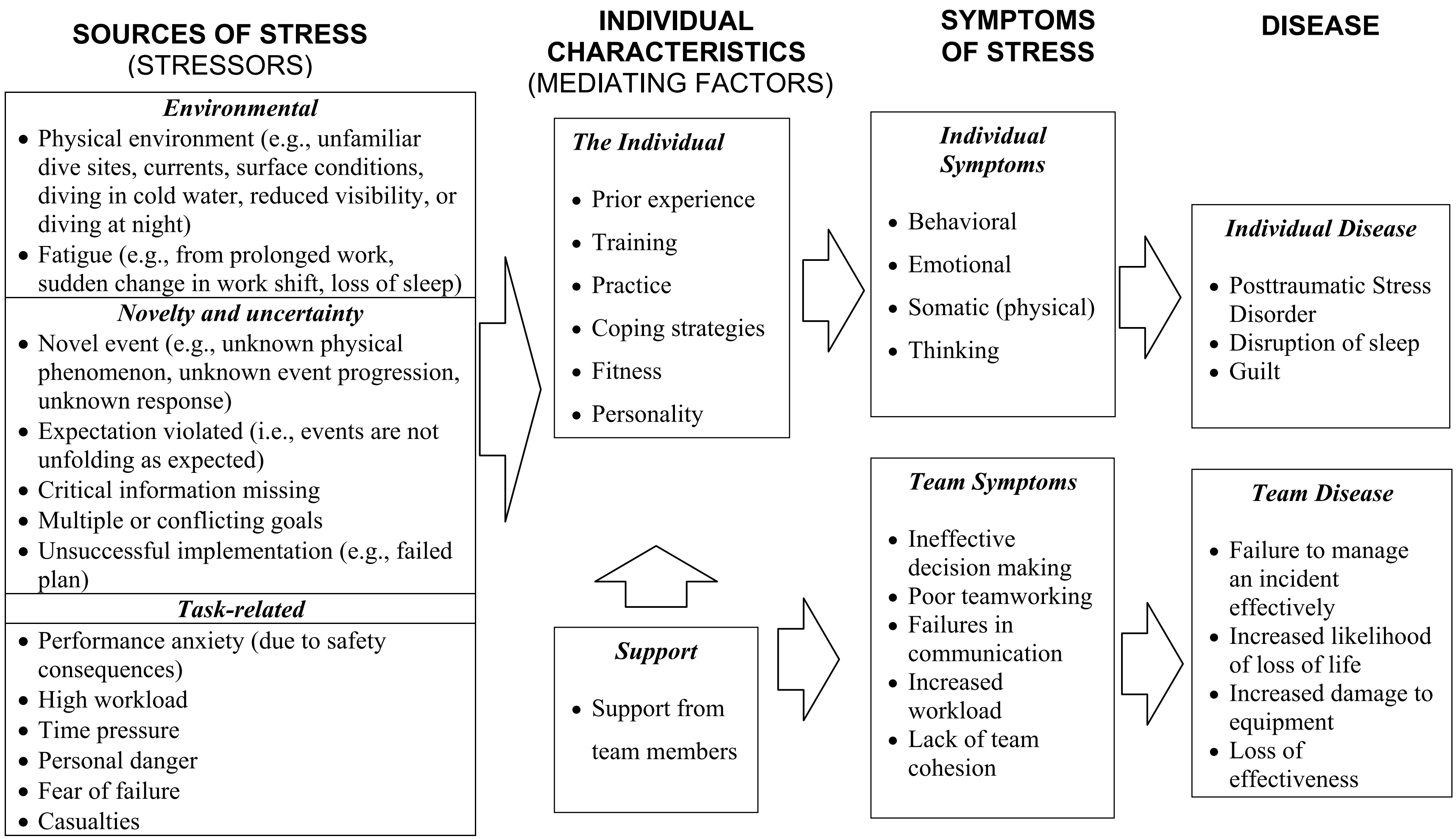
   Research has found that a combination of these techniques is most effective in reducing the effects of stress.

3. Those who think they are suffering from chronic stress that is affecting their job performance should talk to their flight surgeon. They may be referred for professional counseling for work or personal problems. If any member of the squadron is suffering from chronic stress, he or she should be directed to seek help. Further, human factors councils should be used to identify ‘at-risk’ aviators.

Acute stress

Aviators are at risk not only from chronic stressors but also from acute stressors such as periods of high workload, emergencies, attempts to diagnose an unusual problem, or high costs of failure. A model for acute stress (Figure 11) consists of the same framework of sources, mediating factors, symptoms, and disease as the model of chronic stress (Figure 10) but is specific to acute stress situations.

Figure 11. Model of acute stress (Flin et al, in press).



The indicators of acute stress include:

Behavioral	
Fight/flight: • Hyperactivity • Anger • Argumentativeness • Irritability • Jumpiness • Aggressiveness • Swearing • Emotional outbursts	Freezing: becoming • Withdrawn (“switched off”) • Detached • Apathetic • Disengaged from surrounding activities
Emotional	
• Fear • Anxiety • Panic	• Fear of failure • Vulnerability • Loss of control
Somatic (physical)	
• Energy surge • Increasing heart rate • Sweating	• Muscle tension (trembling) • Heightened sensitivity (e.g., to noise) • Effects on digestion (butterflies in stomach)
Thinking (cognitive)	
Impairment of memory	• Prone to distraction • Confirmation bias (tending to ignore information that does not support following a chosen model or course of action • Information overload • Task shedding (the abandonment of certain tasks when stress or workload makes it difficult to concentrate on all of the tasks simultaneously)
Reduced concentration	• Difficulty prioritizing • Preoccupation with trivia • Perceptual tunneling (attention becoming narrowly focused on salient cues)
Difficulty in decision making	• Availability bias (resorting to familiar routines and considering plans that are only immediately available in memory) • “Stalling thinking” — mind blank

For the individual, involvement in a critical incident such as a death of a squadron member, a near miss, or an injury can have a profound effect and can result in posttraumatic stress disorder, a result that may necessitate some counseling or specialized debriefing. For the squadron, acute stress can result in a failure to manage a situation effectively and can end in loss of life, equipment damage, or loss of an aircraft.

Managing acute stress

1. Practice performing in simulated stressful scenarios. The only way to see how aviators will cope with stress is to put them into a stressful situation. The best way to improve performance in stressful situations is to conduct simulator flights in which individuals are forced to react quickly and think on their feet.

2. Practice using cognitive control techniques. This technique trains individuals to regulate emotions (e.g., worry) and distracting thoughts so that they maintain concentration on the task. They can become aware of what their bodies are telling them. If their muscles are very tense or their hearts are racing, they can attempt to regain control of them by briefly stepping away from a situation, if they feel overwhelmed.

3. Use a procedure to regulate stress reactions.
   - **Stop** — Stressed personnel should stop what they are doing.
   - **Breathe** — They should focus on slowing their breathing rate, and calming down.
   - **Think** — They should think about the problem and decide what they are going to do next.
   - **Act** — They should select an option and, finally, act on it.

4. Monitor team for signs of acute stress. If any member of the team is failing to perform effectively, monitoring will enhance mission success and safety.

5. Debrief the team after a stressful event. Debriefing has been shown to be a highly effective strategy to help team members to develop skills and understanding (Norton et al, 1992). Debriefing allows the team members to discuss what has happened, both good and bad, and to realize that it is normal to experience stress in that situation. Further, if people are placed in a stressful situation and do not perform well, then they are unlikely to cope well when faced with another stressful situation unless they are given a thorough debriefing about what went wrong, why it went wrong, and what they can do to avoid the same mistakes in the future (recall the balance model of stress in Figure 5).

Resources

Chronic stress

Cooper, C. & Clarke, S. (2003) *Managing the risk of workplace stress: Health and safety hazards.* London: Routledge.

Flin, R., O'Connor, P. & Crichton, M. (in press) *Safety at the Sharp End*. Ashgate

U.K. Health and Safety Executive stress web page:
www.hse.gov.uk/stress/standards/index.htm

National Institute for Occupational Health stress website:
www.cdc.gov/niosh/topics/stress/

Acute stress

Cannon-Bowers, J.A. & Salas, E. (Eds., 1998). *Making decisions under stress. Implications for individual and team training*. Washington, DC: American Psychological Association.

Flin, R. (1996). *Sitting in the hot seat: Leaders and teams for critical incident management.* Chichester: John Wiley & Sons.

Flin, R., O'Connor, P. & Crichton, M. (in press). *Safety at the Sharp End*. Ashgate.

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Alkov, R,A , Borowsky, M.S. & Gaynor, J.A. (1982). Stress coping and the U.S. Navy factor mishap. *Aviation, Space, and Environmental Medicine*, 53, 1112-1115.

Cox, T. (1993). *Stress research and stress management: Putting theory to work*. Sudbury: HSE Books.

Flin, R., O'Connor, P. & Crichton, M. (in press). *Safety at the Sharp End*. Ashgate

Norton, N (1992). Peer assessment of performance and ability: An exploratory meta-analysis of statistical artifacts and contextual moderators. *Journal of Business and Psychology*, 6, 387–399.

Salas, E., J.E. Driskell, J.E. & S. Hughes, S. (1996). Introduction: the study of stress and human performance. In J. Driskell & E. Salas (Eds.) *Stress and Performance*. Hillsdale, NJ: Lawrence Erlbaum.

11. CONCLUSION

This guide has provided a brief summary of the human factors that should be considered when planning, flying, or debriefing a mission. Further, it also contains material that should be considered when designing training, or investigating a mishap. Unfortunately, there are no checklists or mnemonics to ensure that Navy and Marine Corps aviators have the human factors skills to be safe and effective aviators. Just as a knowledge of weapons systems, tactics, aircraft systems, standard operating procedures, emergency procedures, and a knowledge of the limitations of the aircraft, are necessary safe and effective flight operations, so is an understanding of human factors and how they pertain to the role of Navy and Marine Corps aviators.