National Defence | Défense nationale

SÉCURITÉ DES VOLS
FLIGHT SAFETY

ON TARGET

HUMAN FACTORS

Canada

DIRECTORATE OF FLIGHT SAFETY
Director of Flight Safety
Colonel G.R. Doiron

EDITOR
Captain K. Ashton

GRAPHICS AND LAYOUT
Corporal E. Jacques
Ryan/Smith Creative

On Target is a focus magazine produced once per year by the Directorate of Flight Safety. It is distributed to subscribers of the *Flight Comment* magazine. The contents do not necessarily reflect official policy and, unless otherwise stated, should not be construed as regulations, orders or directives. Contributions and feedback are welcome for future issues of *On Target*. Contributions become the property of the Directorate of Flight Safety and may be edited for content, length or format.

Reasonable effort has been made to obtain permission from photographers for the photos contained herein, but it has not been possible to locate and contact the photographer in every case. Please contact the editor if you see your photo and would like to have your credits inserted in the electronic copy.

Send submissions to:

Editor
Directorate of Flight Safety
National Defence Headquarters
101 Colonel By Drive
Ottawa, Ontario Canada
K1A 0K2

Telephone: (613) 992-0198
FAX: (613) 992-5187
Email: dfs.dsv@forces.gc.ca

Subscription orders should be directed to: Publishing and Depository Services, PWGSC CGP/EGC, Ottawa, ON K1A 0S5, or by telephone: 1-800-635-7943

The annual subscription rate for Canada is $19.95, or $7.95 single issue; for other countries, $19.95 US, single issue, $7.95 US. Prices do not include GST. Payment should be made to Receiver General for Canada.

To contact DFS personnel on an **URGENT** Flight Safety issue, please call an investigator who is available 24 hours a day at 1-888-WARN-DFS (927-6337). The DFS website at www.airforce.gc.ca/dfs offers other points of contact in the DFS organization or write to dfs.dsv@forces.gc.ca.

Art Direction by ADM(PA) DPAPS CS09-0017
ISSN 1916-5250
A-JS-000-006/JP-030

ON TARGET

Editors Note

DFS would like to graciously thank all of those who submitted contributions for this magazine. The articles contained in this magazine reflect the opinions of the authors. The Canadian Forces official document regarding investigating Human Factors is the A-GA-135-001/AA-001, Flight Safety for the Canadian Forces.

Published 01 July 2009.

TABLE OF CONTENTS

Lieutenant-General W.A. Watt

Chief of the Air Staff

As the Airworthiness Authority for the Canadian Forces, I am delighted to present the second edition of *On Target* focusing on Human Factors. As we commemorate the achievements in aviation over the past 100 years in Canada, we recognize that further education is required in understanding the multitude of human factors affecting day-to- day Air Force operations. As our flying machines have become significantly more robust and technologically sophisticated, the majority of occurrence related cause factors have shifted from mechanical to predominantly personnel cause factors, which we refer to as Human Factors.

Human Factors play a role in many Flight Safety occurrences and they account for eighty percent of cause factors for all A and B category accidents in the Canadian Forces over the past ten years. The variety of Human Factor related topics discussed in this magazine reflect the complicated nature of human interaction in aviation. As the Air Force continues to introduce new aircraft and capabilities, it is critical that as an organization we understand the importance of establishing a climate that embraces a pro-active Flight Safety program.

The Oxford dictionary states that to be human is 'to be susceptible to the weaknesses of humankind'. The Air Force is operating new aircraft with advanced technological capabilities and our members are operating in a variety of physical environments each with its unique challenges. Supervisors at all levels must consider and understand the significant impact human factors have in Flight Safety mishaps. As well, every individual must ensure that personal physical limitations such as fatigue and task saturation are monitored and their physical fitness and nutritional needs are adequately met.

As your Chief of the Air Staff, I urge all personnel involved in aircraft operations to familiarize themselves with the concepts of Human Factors and to understand the importance of using these tools in your daily activities in order to be proactive in preventing a Flight Safety occurrence.

Remember, **you** are an essential part of the Canadian Forces Flight Safety Program.

Colonel G.R. Doiron

Director of Flight Safety, Ottawa

Welcome to the second instalment of *On Target* with its focus on Human Factors. Since the first powered flight in Canada we have seen tremendous improvements in how aircraft are designed, manufactured, maintained and operated. This success has been in large part due to the advancement in technology, materiel and perseverance of man to fly.

Those of us involved in air operations must recognize that many of the technical achievements in aviation today have been in large part due to human innovation. The systems that are into today's modern aircraft are very complex, highly integrated and introduce higher levels of automation, which require the ground crew and aircrew to continually adapt to the constantly changing work environment.
We have benefited from the great achievements such as those experienced by those aviation pioneers on the Bras d'Or Lakes in Cape Breton, Nova Scotia a century ago. While we can be very innovative, we must also realize our innate capacity, as humans, to make errors.

With improvements in aircraft design and manufacturing over the decades we have seen a decrease in material cause factors while we have seen a proportionate percentage increase in the number of Human Factors, which now make up 80% of the cause factors in today's flight safety occurrences. Our Flight Safety program came into being post WW II with the aim of minimizing losses of aviation resources. That aim is still true 63 years later. Through flight safety occurrence/hazard investigations we learn valuable lessons that lead to the development of preventive measures to mitigate or ideally eliminate a repeat of a similar occurrence. We have been very successful in completing our missions around the globe every day and doing so while maintaining a low accident rate. Our mission success has been enabled by our Flight Safety program, which requires our continual active participation in preventing that next accident.

This issue of *On Target* is intended to refresh some of those valuable lessons previously learned where human factors played a significant role. It is also intended to serve as a source of some valuable insight about human factors so that each and every one of us can increase our collective awareness and guard against the potential of an occurrence stemming from human factor errors.

Plan ahead and fly safe!

SECTION ONE

SECTION ONE **DOSSIERS**

Human Factors Introduction

By Doctor Douglas A. Weigmann and Doctor Scott Shappell, Authors of 'A Human Error Approach to Aviation Accident Analysis'.

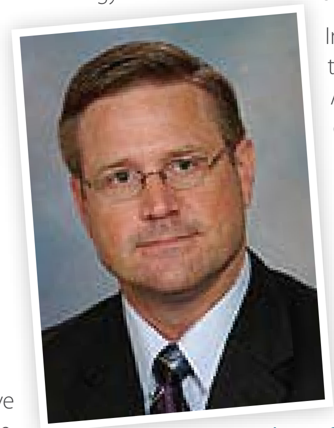
We are delighted to introduce this landmark Human Factors publication. Your Canadian Air Force has the unique status of being one of the first organizations to officially integrate Human Factors Analysis and Classification System (HFACS) into their safety program. You were also the first to systematically train a large core group of safety professionals and to develop a database for tracking HFACS causal factors. The Canadian Air Force has also been instrumental in helping us expand and improve HFACS by including such variables as environmental and technological factors. Since the late 1990's, you have been a persistent leader in the advancement of HFACS in military organizations throughout the world. Your philosophy that safety and defence capabilities go hand in hand is highly commendable.

So, what's next for HFACS? Well, we'd like to think that our mission is complete. However, the truth is that much more needs to be done. We are continuing to extend HFACS beyond the cockpit, to encompass maintenance and air traffic control, as well as to other industries such as mining, manufacturing, and medicine, to list just a few. Still several challenges remain. These include standardizing the training process so that the quality of education and application of HFACS can be maintained and sustained over a long period of time. There is also a need for the development of more sophisticated tools and technology for applying HFACS such as software, decision aids, and checklists. Such tools are needed to facilitate the application of HFACS in the field when reactively investigating accidents to identify the human factors issues associated with these events.

Better yet, we are beginning to develop ways of using HFACS proactively to improve safety programs. For example, we are now using HFACS for evaluating near-miss events to identify not only the things that went wrong, but also more importantly, the things that individuals may have done RIGHT to prevent the occurrence from being much worse. HFACS can also be used proactively to evaluate existing safety programs to identify "gaps" in current efforts and to help determine where additional emphasis should be placed. In addition, we are developing ways in which HFACS can be used to facilitate "the management of change" such as evaluating the human factors consequences of implementing new technology and processes in the field BEFORE problems occur.

Finally, over the last few years, we have also been focusing our efforts on developing a new methodology for generating interventions that map onto problems identified during an HFACS analysis. This new methodology called the Human Factors Intervention Matrix (HFIX) provides a reliable means of ensuring that multiple strategies can be generated and evaluated prior to implementation. However, challenges similar to what we have encountered with HFACS remain such as the need for standardized training, the development of tools and technology, and effective application strategies. These issues, along with those listed above, are ones that we are eager to pursue with organizations such as the Canadian Air Force over the next several years.

In summary, we are pleased to see that the Canadian Air Force continues to be on the leading edge of safety. We look forward to future collaborative efforts to ensure that these activities are successful and that your Canadian Air Force continues to be among the elite and safest fighting forces in the world.



Doctor Douglas A. Weigmann

Doctor Scott Shappell

About the Authors

Dr. Shappell is a Professor of Industrial Engineering at Clemson University. Before joining the faculty at Clemson, Dr. Shappell was the Human Factors Research Branch Manager at the Civil Aerospace Medical Institute. In addition, he has served over 16 years in the U.S. Navy as an Aerospace Experimental Psychologist He has published/presented well over 200 papers, books, and presentations in the fields of accident investigation, system safety, spatial disorientation, sustained operations and fatigue. Dr. Shappell received a B.S. in psychology (1983) from Wright State University graduating Summa Cum Laude with honors in psychology and a Ph.D. in Neuroscience from the University of Texas Medical Branch in 1990.

Douglas A. Wiegmann is an associate professor of industrial and systems engineering at the University of Wisconsin. Before joining the faculty in Madison, Wisconsin he was a National Institutes of Health Roadmap Scholar at the Mayo Clinic College of Medicine where he also served as the Director of Human Factors and Patient Safety Research within the Division of Cardiovascular Surgery at Mayo. A private pilot, Dr. Wiegmann has also been an associate professor of Human Factors at the University of Illinois in Urbana-Champaign. Dr. Wiegmann received his Ph.D. in cognitive psychology in 1992 from Texas Christian University and formerly served as an aviation psychologist and accident investigator for both the National Transportation Safety Board and the United States Navy.

Aviation Technology and the Role of Human Factors Design

By Tara Foster-Hunt, Directorate of Technical Airworthiness and Engineering Support, Ottawa

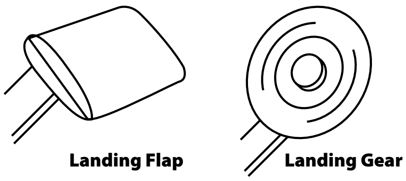
On January 20, 1992, Air Inter Flight 148 struck trees and impacted a 2710 foot high ridge at the 2620 foot level near Mt. Saint-Odile, France while on approach into Strasbourg-Entzheim Airport. 87 of the 96 passengers and crew were fatally injured.

Although human error was identified as the primary cause, one of the proposed underlying issues contributing to the crash was a design weakness in the Flight Control Unit (FCU). This design weakness allowed the flight crew to inadvertently select a 3,300 fpm descent rate on approach instead of the desired 3.3° flight path angle (FPA). Following this accident, design changes were implemented by Airbus. These changes resulted in the FCU digital vertical speed mode read-out having 4 digits and the FPA read-out having 2 digits.[1]

This example illustrates the consequences of human error in highly complex systems. As technology advances and complex systems become more reliable, the consequences of human error become more apparent. Technological advances come with an increasing need to redefine how humans use and interact with technology. The notion that there is more to pilot error than simple poor performance has been around since the shifts in technology that resulted from the demands of World War II. It was around this time that Alphonse Chapanis, studying runway crashes of the Boeing B-17, discovered that the aircraft had identical cockpit controls for flaps and landing gear. Upon investigation of the impact and design of the controls, Chapanis concluded that many of the documented incidents and accidents attributed to "pilot error" were in actuality caused by "design error".[2]

Over the past several decades there has been much emphasis applied to system reliability with a subsequent advancement in aviation safety. Reductions in mechanical failures highlight the significance of a human-technology component within aviation accidents. Despite rapid gains in technology and system reliability, human error is still identified as a factor in 70 to 80% of all aviation accidents.[3] This has lead to the realization that technology alone cannot ensure the success and safety of the aviation industry.[4]

Figure 1 – Shape Coded Controls



The Role of Human Factors

For over two decades, Human Factors practitioners have been using a multi-disciplinary approach based on their knowledge of anatomy, physiology, and psychology. They have applied this knowledge through a systems based iterative application consisting of analysis, design and verification, to the areas of aviation, human cognition, and automation. This approach is applied to complex systems by considering how the person interacts with tools, tasks and the environment. Through this systems approach, Human Factors practitioners strive to prevent system design from occurring in a vacuum where each system is designed without thought to the person who will be using it, and its integration with other system components. Where systems design does not consider Human Factors issues, barriers to problems stemming from human error, integration, and multi-system interaction are limited. This potentially leads to higher risk in the operational setting. Thus, Human Factors needs to be considered during all phases of the design cycle.

Looking at the example put forth by Chapanis, the B-17 had a reliable, working system for both aircraft flaps and landing gear; each system responded appropriately to its control.

However the lack of appropriate and unique control design created the condition for pilot error by placing the two identical controls in close proximity to each other. During a critical phase of flight such as landing, with higher cognitive workload constraints, the use of incorrect controls by the pilot was all too easily made. This was corrected by designing controls to reflect the system they were linked to. (See Figure 1).

In highly reliable, automated systems such as the modern aircraft cockpit, the potential for concealed and therefore less predicable errors are embedded in the system. In highly automated systems, the operator's role is to remotely monitor system function as opposed to participating fully in its operation. Therefore, when events occur, infrequently such as system failure or error (typically with high consequence) the ability for the operator to be alerted, successfully diagnose and take appropriate corrective measures becomes more difficult. In these environments the system control, display, and feedback design become crucial in providing the operator the ability to maintain both system and situational awareness. An environment that is designed with consideration of human factors issues greatly increases the likelihood of successful whole system performance.

Technology continues to evolve faster than our ability to predict how humans will interact with it. As such, critical industries such as aviation can no longer depend as much on experience and intuition to guide design decisions related to human performance. Instead, a sound scientific basis is necessary for assessing human performance implications in design, training, and procedures. Just as developing a new helicopter rotor requires sound aerodynamic engineering, the design of the technological envelope in which humans work requires sound human factors involvement at all stages of the development life cycle.[5]

References

1 http://aviation-safety.net/database/record.php?id=19920120-0

2 Chapanis Chronicles

3 www.boeing.com/commercial/aeromagazine/aero_08/human_story.html

4 www.boeing.com/commercial/aeromagazine/aero_08/human_story.html

5 www.boeing.com/commercial/aeromagazine/aero_08/human_story.html

Towards a Proficiency Based Spatial Orientation Training

By Doctor Bob Cheung, Major John Valade, Colonel Carl Walker, Defence Research & Development Canada, Toronto

During peace time, two of the most life threatening aeromedical problems that air force personnel might encounter is G induced loss of consciousness (G-LOC) and spatial disorientation (SD). G-LOC is primarily a problem of "cardiovascular hydraulics", with blood flowing down to the leg when "pulling Gs". The lack of blood and hence oxygen in the head causes blackout and the pilot becomes unconscious very quickly. G tolerance has been greatly improved in the past 60 years due to improved training in the human centrifuge, the indoctrination of anti-G straining manoeuvres and the refinement of anti-G suits. The challenge for acceleration research and protection in the future will be in the area of super-agile manoeuvrability (F-22 Raptors and Joint Strike Fighters) where rapid G transition (from positive G to relative negative G and vice versa, Cheung & Bateman 2001) in multi-axes will be compounded with rapid rolling and pitching.

Photo: MCpl Robert Bottrill

Spatial disorientation is when the pilot fails to sense the position, motion and attitude of his/her aircraft with respect to the earth or with other aircraft while in formation flight. SD is a more difficult problem to solve and it probably requires a multi-pronged solution. We use information from our vision, our sense of balance, touch and pressure cues and to a lesser extent our hearing to maintain orientation. Furthermore, our past experience also plays an important role. Laboratory studies suggest that there is a general deterioration of cognitive performance even after a brief episode of SD. For example, incorrect crosscheck pattern and an increase in reaction time to perform an assigned task (Cheung et al. 2003, 2004). The environment in which SD is likely to occur is less well defined than is the case with G-LOC. We can always anticipate when we need to 'pull Gs' but we are never certain when SD seeps in. The amount of time pilots fly in conditions in which SD can occur is an appreciable percentage of their flying time, and the fact that a particular condition can precipitate SD is not always obvious to the pilot (Gillingham 1996). In addition, proof of SD is often absent following an accident, what was sought was the most accurate picture rather than the picture that was most "provable".

Photo: MCpl Charles Barber

It has been proposed that research on the underlying mechanisms and hardware improvements will eventually provide substantial protection against SD. For the past 60 years, with better understanding of the various mechanisms of our sensory systems we have indeed gained better understanding of the roles played by sensations of motion or motion cues in piloting techniques. Simultaneously, a great deal of effort has been concentrated in acquiring mechanical devices that can reproduce different types of SD illusions (leans, graveyard spins, graveyard spirals etc). Partly as a result of aggressive marketing, a perception surfaced that disorientation demonstrators/trainer exist commercially and are effective in training pilots against SD in flight without comprehensive research into their feasibility. These devices are largely suitable for demonstrating the inadequacies of our sensory systems, but their ability to reproduce some of the "classic" illusions described in textbooks varies. In some cases, the simulation relies on deception and/or contaminated by artefacts as ground based rotating devices cannot reproduce the flight envelope. This type of device also raises the possibility of negative transfer training. Very often, the demonstration of specific illusion ends abruptly without further explanation or demonstration of how these illusions can affect pilot performance. It is also the general belief that if one were to be exposed to a specific type of illusion, one can prevent or avoid SD mishaps. However there is no evidence to suggest that exposure to a particular or a series of illusions would prevent SD in flight. Moreover, it has been documented that classical illusions commonly described are not a frequent cause of SD accidents among military pilots. Such accidents are more frequently caused by a loss of awareness concerning the aircraft flight

path and failure to detect a dangerous flight path, in other words, unrecognised spatial disorientation where the pilot is not consciously aware of any of the manifestations of SD.

Our recent voluntary and anonymous survey of 96 fixed-wing pilots suggested that in the category of:

- Time since last in-flight SD incident, <1mo: 1; <6mos: 3; <1yr: 15; >1yr: 72
- Severity of most recent SD incidents, there were 67 minor; 8 significant and 1 severe cases
- Severity of worst ever SD incidents, there were 44 minor; 22 significant and 6 severe cases

Most recent CF accidents suggest that SD is a common contributing factor and in some cases SD may trigger the cascading events that lead to the fatal accident. For example, in a recent mishap, several contributing cause factors included the "ill conceived" SOPs, CRM issues, poor management decisions, personal problems, and the crew's lack of experience. These cause factors all become meaningless once the crew became disoriented. Even an experienced, qualified, competent crew, given the same circumstances that this crew were presented with, would have, in all likelihood, encountered SD.

Based on the analysis stated above, the potential for SD in this type of operation is highly likely, if not the cause factor. Two emerging questions are:

i. Was the crew aware of the potential for SD given the nature of the mission: "night flying, calm sea, inadequate vertical translation cues, possibility of visually induced sensation of motion, mixed NVG use, pilot-monitored approach"?

ii. Did/does the squadron mission brief review SD potential and brief reactions and responses should SD be encountered by any crewmember?

Cost Effective Proficiency Based Spatial Orientation Training

Spatial orientation training enhancements where appropriate, can be useful, readily achieved and can be addressed without delay. A formal lecture approach in providing factual knowledge is effective and appropriate for novice pilots or pilot candidates. On the other hand, experienced pilots (at Operational Training Units or on Squadrons) will appreciate learning the characteristics of disorientation related to the aircraft that they are/will be flying. Individuals learn best by doing and that learning also takes place when confronted with reality.

We propose that pilots should be provided with skills that will permit them to assess the risk of SD during their planned mission. This strategy will allow them to anticipate the potential for the occurrence of SD and plan accordingly. In other words, potential SD traps should be discussed during all pre-mission briefing. We follow the motto of: "Train as you fly, be prepared, anticipate and react properly." Therefore, it will be more beneficial to draw the pilots' attention to the "SD traps" that are common to their current type-specific aircraft and mission scenarios.

While skill in instrument flying is the most important strategy for dealing with recognised disorientation, anticipation is the only strategy to convert unrecognised into recognised disorientation. Protection against unrecognised disorientation can only be achieved by maintaining awareness of the circumstances in which this type of disorientation can arise. Proficiency based training will also change the pilots' attitude towards SD, for example SD is part of the risk of flying; it can happen anytime in any weather, it can happen to experienced pilots as well as novice pilots, no one is immune. SD is a normal physiological response to an abnormal environment, it cannot be entirely prevented even if you have the "Right Stuff". Pilots should be shown techniques in the cockpit for counteracting or reducing the impact of SD. A proficiency based spatial orientation training program will be a good start.

References

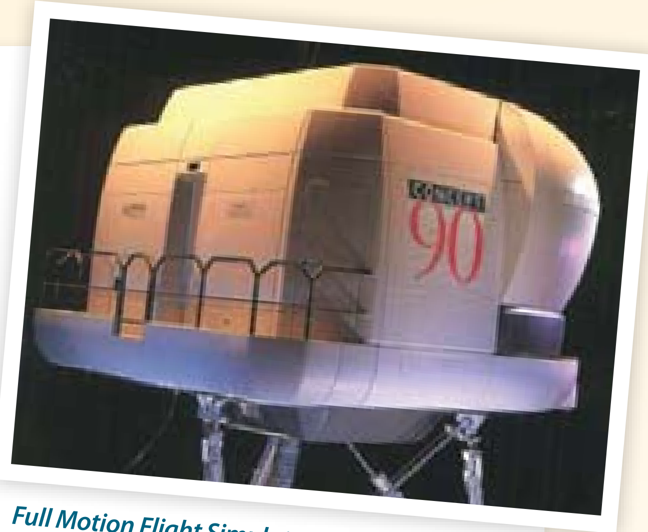
Bob Cheung (1998) Recommendations to enhance spatial disorientation training for the Canadian Forces. DCIEM No. 98-R-32.

Bob Cheung and W Bateman (2001) G-transition effects and their implications. Aviat Space and Environmental Med, 72:758-762.

Bob Cheung, Kevin Hofer. (2003) Eye Tracking, Point of Gaze and Performance Degradation During Disorientation. Aviation Space Environmental Medicine, 74(1): 11-20.

Bob Cheung, Kevin Hofer, Raquel Heskin, Andrew Smith. (2004) Physiological and Behavioural Responses to False Sensation of Pitch. Aviation Space and Environmental Medicine;75:657-665.

Gillingham KK (1992) The spatial disorientation problem in the United States Air Force. Journal of Vestibular Research, Vol 2, 297-306.



Full Motion Flight Simulator

The Human Factors Considerations

By Lieutenant-Colonel Keiver, 1 Canadian Air Division, Winnipeg

In the latter part of the 20th century, the role of simulators in the training and evaluation of aviation personnel has expanded significantly. This has been primarily due to advances in technology that have permitted simulation of the equipment, tasks and aviation environment to a very high level of fidelity. In today's modern aviation training systems, it is not uncommon for a pilot to achieve an initial qualification and maintain that qualification without ever actually touching the actual aircraft during anything other than line operations. The use of simulation has expanded significantly within other aviation occupations as well, such as the maintenance world. Achieving the advertised benefits of simulation, such as increases in quality and throughput, risk reduction, and cost savings can only be accomplished if the human factors aspects of simulation are deliberately considered and implemented.

Generally, operators express the belief that ***realism*** is the most important aspect of simulation. In fact, it is the ability of the simulator to depart from realism that gives us the greatest benefit. Aircrew are able to fly without burning fuel, in multiple different environments within the same day, the aircraft can be paused in mid-flight, complex and dangerous emergency situations can be practised without risking either the crew or the aircraft, and maintenance personnel are able to replicate and rectify fault conditions without actually working on a broken aircraft. In the area of flight simulators, the debate over fidelity has existed for almost as long as there have been simulators. Generally, fidelity can be expressed in two ways: objective and perceptual. Objective fidelity refers to the physical correlation between the simulator and the aircraft while perceptual refers to the relationship between a pilot's subjective perceptions of the simulator and the aircraft. Interestingly, there is very little evidence to support the widespread belief in the aviation community that more fidelity leads to better training value. The National Academy of Sciences report on simulation (Jones, Hennessy and Deutsch, 1985, p. 28) issued over 20 years ago summarized this quite well:

> "The purpose of a simulator is to provide the conditions, characteristics, and events present in the operational situation necessary for the learning of skills that will be performed with actual equipment… Two related principles derive from this premise. First, the characteristics and methods of using simulators should be based on their behavioral objectives. Second, physical realism is not necessarily the only or optimal means for achieving the behavioral objectives of simulation. Because the history of simulator development is characterized by striving for improved realism through the advancement of technology, it is easy to forget that the learning or performance—not physical duplication—is the primary goal."

The fidelity debate is most pronounced in the area of simulator motion and whether or not it is required. Spatial orientation is a fundamental and primitive need for humans to effectively operate, particularly in aviation. We have evolved multiple, overlapping sensory mechanisms to accomplish the job (Young, 2003), namely the senses of visual, vestibular, and proprioceptive (the body's ability to sense the movement and position of muscles). The ambient visual system, which is particularly strong in the peripheral retina, is the primary source of information for orientation and motion perception. Wide field of view visual systems create a strong sense of "vection," or the illusion of self-motion. In fact, our sense of motion and orientation actually begins to break down without visual input (Previc, 2004). The accuracy and reliability of the orientation sensory systems are significantly altered when exposed to unusual gravity / inertial environments such as those encountered in flight. Vestibular and proprioceptive information can no longer be relied upon. Consequently, all responsibility for acquiring reliable information depends on vision (Cheung, 2004). It is for this reason that pilot training systems emphasize the utilization of the horizon or instruments over vestibular and proprioceptive cues to safely and effectively fly aircraft.

In Longridge et al (2001), an extensive review of research on motion in simulators showed that simulator platform motion might improve pilot acceptability of the simulator, at least when pilots are aware of the motion manipulation. Also, motion seems to improve pilot performance and control behavior in the simulator, particularly for disturbance tasks (such as turbulence) and in aircraft with low dynamic stability (such as helicopters and fighter aircraft). However, their review found no evidence that any

C130J Cockpit

benefits of platform motion result in training transfer to the aircraft, even though it may have contributed to flying the simulator better. This is a significant finding when considering the costs of full-motion flight simulators in light of other advances in motion cueing devices such as G seats, G suits, seat shakers, and helmet loaders and their ability to convey sensory information to the aircrew. Recent research (Bürki-Cohen and Sparko, 2007) has actually shown that the level of practicable motion achievable today, as in the past, falls far short of accurately simulating the motion cues of flight and that "pilots have been trained totally and successfully in simulators without adequate motion for longer than a quarter century. It could be argued, then, that this alone shows that full platform motion is not needed for a successful training outcome." (Burki-Cohen and Sparko, 2007, p.18).

Whether it has motion or not, a modern simulator should be designed to replicate the task demands on an individual in terms of perception, attention, decision making, memory, and action while allowing the crew to juggle multiple tasks, supervise automated subsystems, maintain situational awareness, and develop an accurate mental model of aircraft dynamics in order to achieve mission success (Kaiser and Schroeder, 2003). Since pilots rely on visual information for nearly all flight tasks, accurate representation of the visual world, both inside and outside the aircraft, is essential in a flight training simulator (McCauley, 2006, p. 32). The simulator must be capable of achieving a high level of perceptual fidelity. This conclusion is especially relevant in aviation today considering the increasing need for simulators, driven by a shortage of qualified individuals, reductions in overall experience levels, and an increase in complexity of the tasks due to increased automation (Bürki-Cohen and Sparko, 2007).

The increasing complexity of the task is an important consideration in simulation. Modern aircraft have become highly integrated and automated. As an example, on a CC130H, there are a total of approximately 60 aural warnings or annunciations (warning, cautionary, and advisory lights) that the aircrew are expected to react to during operations and that maintenance personnel are expected to use in fault analysis and rectification. On a C130J, there are in excess of 780. Replicating the warnings, cautions, and advisories associated with the failure of multiple inter-connected subsystems on modern aircraft, and training the required reactions / interactions to effectively deal with those situations, is simply not possible in the actual aircraft. Attempting to do so is neither effective nor safe and the training must be done in a simulator. Given the findings of recent research related to the overall effectiveness of motion, any potential savings on platform-motion hardware and facility costs should be applied to upgrade the fidelity in other important areas, such as assuring that the flight simulator cockpit does in fact match the equipment and layout in the target aircraft and that the simulation includes realistic operational representation of the air space, including the air-traffic-control environment (Bürki-Cohen and Sparko, 2007). Again, the importance of perceptual fidelity, vice objective fidelity, must be the prime consideration in the development and procurement of simulators.

Perhaps the most important human factors consideration related to the use of simulation lies not in the simulators themselves but in their use. As pointed out over 30 years ago (Caro, 1973), quality instructional design, implemented by quality instructors, will result in positive transfer of training. Research on training effectiveness has shown that how a simulator is used is more important than specific training technologies (Salas, Bowers, & Rhodenizer, 1998). Achieving training value with a simulator therefore becomes more reliant on instructional system design and content rather than the actual technical capabilities of the simulator itself and its ability to achieve realism. In an analysis of simulation by the National Academy of Sciences (Jones et al, 1985, p. 92), it was concluded that "Physical correspondence of simulation is overemphasized for many purposes, especially training" and that "… the concern with fidelity should shift from what is technically feasible in a hardware sense toward achieving greater effectiveness and efficiency in terms of behavioral objectives." Contrary to the opinion of simulator engineers and operators around the world, ***realism*** alone will not deliver the desired effects.

The ability to achieve desired levels of performance and competence through the use of simulation is entirely dependant upon the ability of the training system to create and deliver Line Operational Simulation (LOS), or training conducted in a "line environment setting". As articulated by the Federal Aviation Administration (FAA, 2004), the use of LOS must be done within the context of instruction and training being based on learning objectives, behavioral observation, assessment of performance progress, and instructor debriefing or critique (feedback). Given the human factors nature of most aviation accidents, training curriculums must develop proficiency in both technical and Crew Resource Management (CRM) skills. Referred to as Human Performance in Military Aviation (HPMA) within the Canadian Forces, it must be integrated into other training steps and activities in a systematic way. The proper use of simulation permits and encourages the application of technical and CRM concepts to a situation in a manner that enables conceptual knowledge to become working knowledge. Instead of being programmed with a solution, and then evaluated on whether or not he or she is able to successfully execute that programmed solution, the trainees manage the operational environment and process available information to learn its limits, properties, and operational relevance.

The benefit of LOS is that it allows the trainees the opportunity to practice line operations (e.g., maneuvers, operating skills, systems operations, and procedures) with a full crew or team in a realistic environment.

The King Air C–90B flight simulator is used by 3 Canadian Forces Flying Training School at the Canada Wings Aviation Training Centre in Southport, Manitoba.

The trainees learn to handle a variety of real-time scenarios that include routine, abnormal, and emergency situations. They also learn and practice CRM skills, including crew coordination, judgment, decision-making, and communication skills. The overall objective of LOS is to improve team (flight crew or maintenance) performance, thereby preventing incidents and accidents during operational flying. The integration of CRM skills allows and encourages crews to become better problem-solvers and resource managers. The LOS context must be structured to enable CRM behaviors to emerge and the crew to become aware of them; that is, the scenario must last long enough for crew traits to become evident and require CRM skills to be displayed in response to specific circumstances. It must also include formal evaluations in which both technical and CRM skills are evaluated and in which crews are expected to handle failures and their consequences. Traditional training methodologies have generally focused on the individual attaining certain proficiency levels, vice the ability of the team to effectively recognize and mitigate the inevitable human error that occurs. While there is still a requirement for basic technical proficiency, achieving the full benefit of simulators mandates that the focus of training be expanded beyond just technical skills to include the higher level cognitive functions associated with operating a complex system comprised of both equipment and multiple personnel with varying responsibilities.

Finally, the ability to effectively train LOS requires significant emphasis on the instructor / evaluator. Traditional instructors have focused on individual vice crew or team performance. Fully exploiting the capabilities of a simulator to teach higher level cognitive functions mandates training and qualification in areas not previously addressed in the development of instructors and evaluators. As the FAA points out (FAA, AQP, 2006), there are several difference between traditional instructors and those able to successfully teach LOS. These include robust training in CRM and human factors, standardization and rater/ reverent reliability, data gathering procedures, effective use of, and qualification in, specific training devices, limitations on use of the training equipment, and the evaluation of performance against objective standards for both technical and CRM skills. With the heavy reliance on simulation to achieve training objectives, the role of the simulator instructor assumes a critical role. In many cases, the simulator instructor will be the first instructor the trainee is exposed to and the one that the trainee spends the most time with. There are now some ab-inito pilot training programs where over 80% of the training is conducted in the simulator, including all evaluations. Clearly, increased emphasis on the training and qualification of simulator instructors is essential to the effective use of simulators.

Modern aircraft and their highly integrated nature demands that training be conducted in simulators. A significant body of research demonstrates the effectiveness of simulators in aviation. When designed with perceptual fidelity in mind, simulators are unquestionably valuable for accomplishing training safely. Interestingly, there is little or no scientific evidence that supports the training effectiveness of motion other than contributing to the in-simulator performance of pilots with some exceptions, such as flight training in unstable aircraft and tasks involving disturbance cues. Motion, noise and vibration generally contribute to the realism, sense of presence, and pilot acceptance of the simulator however these areas are able to be replicated with other, less costly methods of conveying sensory information and perceptual fidelity. While the perceptual fidelity of the simulator is important, instructional design is critical. Training systems must integrate both traditional technical skills with CRM skills to levels that ensure the development and maintenance of higher-level cognitive functions. The long-entrenched belief in ***realism*** has caused significant resources to be put into developing complex and expensive motion systems often at the expense of other areas within the training system. Only when the various human factors considerations of simulation are considered and resources expended on the areas of fidelity and training which deliver measureable results can the true benefits of simulation be realized.

About the Author

While on a Canada – U.S. exchange from 2001 - 2004, LCol Colin Keiver was the Director of Safety and Standardization at the first United States Marine Corps KC-130 squadron to convert to the KC-130J. His 'love-affair' with the field of aviation human factors was born during that time. In 2004 he was posted to A3 Transport in 1 Cdn Air Div HQ where he was heavily involved in the introduction to service of the C-17 and the development of the C130J project, which includes extensive reliance on simulation to achieve training objectives. He recently functioned as the Project Authority for the 1 Cdn Air Div Automation Policy and Planning Development (APPD) Project which measured the overall status of 1 Cdn Air Div to fully exploit the technologies being delivered to it while increasing operational effectiveness and safety. He is now the Co-Project Authority for the Air Standards, Training, Readiness and Automation (ASTRA) Project charged with implementing, throughout the Canadian Air Force, the recommendations contained in the APPD Report. These include significantly changing the way in which the Canadian Air Force approaches the use of simulation.

References

Bowen, S. A., Oakley, B. P., and Barnett, J. S. (2006). "Effects of Motion on Skill Aquisition in Future Simulators," United States Army Research Institute for the Behavioral and Social Sciences, 2006-07.

Bürki-Cohen, J., Soja, N., & Longridge, T. (1998). Simulator platform motion—The need revisited. *The International Journal of Aviation Psychology, 8,* 293-317.

Burki-Cohen, J. & Sparko, L. (2007). Training Value of a Fixed-Base Flight Simulator with a Dynamic Seat. *American Institute of Aeronautics and Astronautics Modeling and Simulation Technologies Conference and Exhibit.* Hilton Head, SC: American Institute of Aeronautics and Astronautics.

Caro, P. W. (1973). Aircraft simulators and pilot training. *Human Factors, 15,* 502-509.

Cheung, B. (2004). Nonvisual spatial orientation mechanisms. In F. J. Previc, & W. R. Ercoline (Eds.), *Spatial disorientation in aviation* (pp. 37-94). Reston, VA: American Institute of Aeronautics and Astronautics.

Federal Aviation Administration (2004). *AC 120-35C: Line Operational Simulations: Line Oriented Flight Training, Special Purpose Operational Training, Line Operational Evaluation.* Washington, D.C.: Flight Standards Division.

Jones, E. R., Hennessy, R. T., & Deutsch, S. (1985). *Human factors aspects of simulation.* Washington, D.C.: National Academy Press.

Kaiser, M. K., & Schroeder, J. A. (2003). Flights of fancy: The art and science of flight simulation. In P. S. Tsang, & M. A. Vidulich (Eds.), *Principles and practice of aviation psychology* (pp. 435-471). Mahwah, New Jersey: Erlbaum.

Kobierski. R.D. and Stickney,C. (2008). *Automation Analysis Report*. Ottawa, ON: PWGSC Contract No. W8485-0-XKCF/01/BQ prepared for DND.

Lee, A. T. (2005), *Flight Simulation: Virtual Environments in Aviation* Hampshire, UK: Ashgate.

Longridge, T., Burki-Cohen, J., Go, T. H., & Kendra, A. J. (2001). Simulator fidelity considerations for training and evaluation of today's airline pilots. *Proceedings of the 11th International Symposium on Aviation Psychology, Columbus, OH.*

McCauley, M.E. (2006). *Do Army Helicopter Training Simulators Need Motion Bases?* Arlington, VA: US Army Research Institute for the Behavioral Sciences, Technical Report 1176.

Previc, F. J. (2004). Visual orientation mechanisms. In F. J. Previc, & W. R. Ercoline (Eds.), *Spatial Disorientation in Aviation* (pp. 95-143). Reston, VA: American Institute of Aeronautics and Astronautics.

Salas, E., Bowers, C. A., & Rhodenizer, L. (1998). It is not how much you have but how you use it: Toward a rational use of simulation to support aviation training. *International Journal of Aviation Psychology, 8,* 197-208.

Young, L. R. (2003). Spatial Orientation. In P. S. Tsang, & M. A. Vidulich (Eds.), *Principles and Practice of Aviation Psychology* (pp. 69-113). Mahwah, New Jersey: Erlbaum.

Maintaining the Human Machine

By Captain Mark Rutley, M.Sc., Canadian Forces Environmental Medicine Establishment, Toronto

A lot of flight safety is about balance. For example, we balance the risks of flying in adverse weather conditions against the requirement to conduct a vital search and rescue mission with life-or-death consequences for both the rescuers and the rescued. We balance operational tempo against our human and material resources. Every decision that is taken, and every risk that is assessed and mitigated, is part of our balancing the inherent dangers associated with operating in a complex, dynamic and unforgiving environment against the need to perform missions as safely and efficiently as possible. As operators and professionals, we all know that most incidents and accidents have a human factors causal component. Yet, how often do we apply the same rigor in balancing ourselves and our personal lives to maximize the efficiency of this most common accident cause factor?


Photo: Cpl J.F. Lauzé

For example, how many days has competing demands on our time stopped us from taking just 30 minutes to get a little exercise? How often have we skipped a breakfast, or a lunch, or drank nothing but dehydrating coffee all day? How many nights have we stayed up late and woken up early? Loss of balance in operators leads to failures in personal readiness, which can ultimately have drastic and lethal consequences on our carefully prepared operations.


Photo: Cpl Kevin Sauvé

Many authors tend to equate the human body to a machine, which in its simplest terms it is. For example, as a machine an aircraft requires aviation gas as an energy source, oil to protect and lubricate the moving parts, and a coolant medium of air, water or some other fluid. Similarly, the human "machine" requires fuel in the form of sugars, proteins and fats, protective materials such as vitamins, minerals, ions, and fatty acids, and coolant in the form of water (Kroemer and Grandjean, 2003). Added to the complexity of the biological machine, humans must also deal with their cognitive aspects, which are greatly affected by sleep, circadian dysfunction, and life stressors. Problems in any one of these areas will quickly, and in some cases fatally, degrade human performance.

The food that we eat is broken down through digestion, passing through the lining of the small intestine into the blood and then on to the liver. There the nutrients are stored as glucose, glycogen and fat. These products circulate in the blood, and are metabolized at a cellular level in the presence of oxygen to generate carbon dioxide, water, heat and chemical energy to be converted to mechanical energy. The body will use glucose and glycogen first before turning to fat as a last source of fuel. These fuels are used to power all cellular activity, including neurological activity.

If a person has low levels of glucose in their system, either due to an illness like diabetes or due to missing or inadequate meals, they are called "hypoglycemic". The effects of hypoglycemia on human performance are well documented, and can lead to feelings of weakness, drowsiness, and reduced performance. A study with eight healthy male volunteers showed that when their blood glucose levels were artificially dropped below what is considered the normal level of hypoglycemia, significant cognitive deficits were measured almost immediately (Evans, Pernet, Lomas, Jones, Amiel, 2000). What is interesting is that many of these deficits were measured up to 20 minutes prior to the volunteers themselves stating that they didn't "feel right" (Evans, et. al., 2000). In other words, the volunteers showed evidence of cognitive impairment prior to realizing that they were impaired (Evans, et. al., 2000).

Photo: MCpl Robert Bottrill

Further, the cognitive deficits continued for up to 20 minutes after blood glucose levels were returned to normal levels (Evans, et. al., 2000).

Note that this is a case of acute hypoglycemia in which blood glucose levels are aggressively lowered in a short period of time. However, the same cognitive impairment effects can occur in slow-onset hypoglycemia, we are just more aware of the situation and often are able to take steps to remedy things. The problem arises when a person gets in a hypoglycemic state and does not have ready access to food, such as during long duration flights in small aircraft. The implications for flight safety are clear – low blood sugar levels mean reduced mental and physical performance, and hence an increase in the probability of errors.

Similarly, fluid intake is vital for effective performance, although the effect of dehydration on cognitive performance is less well documented in scientific literature. However, water is absolutely essential in many physiological reactions inside the body, including the metabolism of glucose into cellular energy. Not to mention that water is vital as a coolant for the body, as anyone who has spent time in a hot environment will attest to. Without adequate levels of water, the metabolic pathways will become less efficient or stop completely, leading to reduced physical and mental performance.

Another aspect of personal readiness that must be balanced is the effect of other life stressors on our work performance. Stress can be generated from many different sources, not all of them bad. For example, a person may experience stress from a posting, a death in the family, conflicts between family members or with co-workers, change in a relationship (either good or bad), or due to chronic illness. Such life stressors are subjective – what may be a stressor to one individual may seem like a non-event to another. It is therefore difficult to tell at the outset how a life event will affect the performance of a team mate. Generally speaking, if a person is undergoing a significant event or change, and does not feel that they have the required capacity to deal with the change, they will experience a certain level of stress.

Stress affects the body in many ways and comes in two forms, "acute" stress and "chronic" stress. Acute stress is the classic "fight or flight" reaction – that feeling that occurs when something has gone drastically wrong and you are dealing with consequences that could lead to injury or death. Generally speaking, physiological responses include pupil dilation, deeper and faster breathing, increased heart rate, constriction of blood vessels in less important portions of the body so that blood can be circulated to the lungs, brain and large muscles for improved oxygen flow (Gleitman, Fridlund, Reisberg, 2000). These responses are not only natural, but a vital element in personal survival. What can cause problems, however, is if these responses become chronic. Chronic stress can lead to neurochemical imbalances, and generate a host of medical ailments within the body. The net result is feelings of fatigue, reduced cognitive performance, reduced memory recall and in extreme cases, clinical depression. Stress can also lead to increases in mental workload due to the continual processing of the stressor event. Because humans have limited capacity for mental workload, this increase in demand can cause people to become forgetful or to be easily distracted, with obvious implications on flight safety.

To further complicate matters, none of these cause factors will act in isolation, and often will compound each other. Chronic stress can lead to a poor diet, or conversely, the negative health affects of a poor diet can lead to chronic stress. In an attempt to offset some of the negative symptoms of poor diet, inadequate hydration or chronic stress, many people will self-medicate, treating the symptoms generated by these conditions rather than the underlying causes themselves.

The magnitude of the impact that human factors has on our flight safety is undisputed. To minimize the negative consequences of these human factors means ensuring that all operators are operating at peak physical and mental efficiency. This requires that we all take as careful an approach to managing and balancing our own personal lives as we do in our flight operations.

References

1. Kroemer, K.H.E. and Grandjean, E., (2003). *Fitting the Task to the Human*. Taylor and Francis. Page 250.
2. Evans, M.L., Pernet, A., Lomas, J., Jones, J., Amiel, S.A., (2000). "Delay in Onset of Awareness of Acute Hypoglycemia and of Restoration of Cognitive Performance During Recovery." Diabetes Care, Vol. 23, Num 7.
3. Gleitman, H., Fridlund, A.J., Reisberg, D., (2000). *Basic Psychology*. W.W. Norton and Company. London and New York. Pages 710 to 717.

Military Flight Operations Quality Assurance (MFOQA)

By Second Lieutenant Eric Seedhouse, Ph.D., FBIS, AsMA, Canadian Forces Environmental Medicine Establishment, Toronto

"Flight Operational Quality Assurance (FOQA) is a voluntary safety program designed to improve aviation safety through the proactive use of flight-recorded data."

FAA Order 8400.10, Aug 9, 2006, Air Transportation Operations Inspector'sHandbook

Flight Operations Quality Assurance Overview

In the last decade the civil air transportation industry has investigated additional means of identifying air safety problems. After conducting several studies, many of which were sponsored by the Federal Aviation Administration (FAA), the FAA has concluded the implementation of Flight Operational Quality Assurance (FOQA) has the potential to significantly reduce air carrier incident rates.

FOQA is a knowledge management (KM) process or program designed to provide the operator with quantitative information concerning aircrew and aircraft systems. By using data downloaded after every flight, aircrew and operators can improve operational efficiency and readiness, improve training and reduce the risks associated with flight operations. A FOQA process can also identify human error, a causal factor of 70 to 80 % of aviation accidents, by comparing aggregate data from multiple aircraft operations with occurrences or conditions occurring outside standard operating procedures.

Technology Supporting FOQA

Until recently, global acceptance of FOQA has been muted in the civil aviation world. Many airlines cited the system as relatively immature, but recent advances in computer hardware by companies such as UHL Research Associates and Aerobytes, has resulted in a versatile and low-cost Flight Reconstruction System (FRS). The FRS is capable of providing immediate post-flight reconstruction using a single GPS recording of a digital snapshot of what the aircraft is doing every tenth of a second. The fidelity of the system is so advanced that not only does the system record the standard GPS outputs of position, heading, and ground speed, it also provides data-points showing indicated airspeed, yaw-pitch-roll, G-loading, angle of attack, and rate of climb. When the GPS feed is combined with regular flight information, a precise flight reconstruction is generated using sophisticated Post-Flight-Processing (PFP) software, presented via a realistic computer-generated image (CGI). Much like the options available on Microsoft's Flight Simulator, the PFP software is able to present the image either externally from any perspective, from a godseye perspective, or from an out-of-the-cockpit view showing the instrument panel. The system is so versatile it can combine data from as many as 32 aircraft to provide reconstructions of formation flying.

The key to the system is the Flight Data Acquisition Unit (FDAU), which acquires aircraft data via digital and analog inputs and formats the information for output to the flight data recorder. Another element of the FOQA process is the Monitoring Team, comprised of representatives from the pilot group, and personnel involved in flight safety. The Monitoring Group, by systematic reviewing and analysing of flight and event data, can identify off-nominal events and/or actions and recommend corrective actions.

Photo: Ghislain Madgin

How the Software and Hardware works

When the aircraft is in flight, the PFP software receives timed flight position from the GPS data recorder. The PFP then deduces factors such as latitude and longitude, indicated airspeed, rate of climb, flight path elevation, bank angle, and angle of attack with an accuracy of +/-5%, according to flight testing conducted by the United States Air Force on their F-15, F-16, and T-38 aircraft. To analyze a one-hour flight and produce a three-dimensional wire frame reconstruction of that flight takes the system about twenty seconds. Once the flight is reconstructed, it can be viewed either in real time, or at any specific point in the flight. For ease of assessment, the path of the aircraft through the air is depicted by a blue

line, whereas a green line shows the path of the aircraft across the ground.

The Military FOQA Perspective

The benefits of a Military FOQA (MFOQA) lie in its potential to provide integration of data pertaining to the aircraft squadron's operations, maintenance, training and safety into a single program. MFOQA can be thought of as a proactive and enabling tool that, if implemented by the CF, would permit squadrons to take 'self-corrective' actions based on quantitative data stored in a central CF data repository containing aggregate data for each airframe.

The relative plateau of mishaps in CF aviation in the previous ten years reflects the safety systems and programs implemented by the CF evolving as a result of various programs and initiatives. To further reduce the number of mishaps the CF has the opportunity to improve operational readiness and quality of training by adopting a more proactive approach as exemplified by MFOQA. Each airframe lost compromises the CF's operational ability and each life lost results in a significant negative impact upon personnel, which is the CF's most valuable resource. The primary causal factor implicated in the majority of aviation incidents is human factors, a quantity that MFOQA is well equipped to address since one of the integral components of the system is to use a KM process to address these factors.

The MFOQA system, by aggregating skill-based errors associated with flight operations and identifying trends and occurrences, can provide the CF with quantitative data that may be used to implement procedures to reduce risks and increase level of awareness. Furthermore, the MFOQA concept has the potential to significantly improve the capacity to contribute to the flight debrief by the timely downloading and processing of flight data. In the latter case, the MFOQA concept may be used as a tool to detect predefined flight parameter exceedances and visualization of flight data depicting crew performance. This information may then be presented to the crew to ensure the flight debriefs and aircrew performance is improved.

MFOQA also has the potential to play a role in improving the effectiveness of the maintenance of CF airframes by providing maintenance personnel with a high fidelity tool capable of trouble-shooting complex aircraft systems.

MFOQA in the Canadian Forces

A MFOQA system adopted by the CF would employ an architecture similar to the one outlined here. A Quick Access Recorder (QAR) would be installed into the avionics bay prior to each flight. Data would be recorded during the flight and would be retrieved by a squadron technician using a small hand-held device. Typical file sizes for a one hour flight will be approximately 2MB and take thirty seconds to download. The file would then be uploaded to a workstation and analytical software applied to detect any values exceeding predetermined threshold limits, upon which a formatted report would be generated. This information would then be recorded in the squadrons and nationwide repository databases.

"MFOQA is a concept of operations that provides the warfighter with timely and quantitative information regarding aircrew and system performance. It can be used to improve safety and operational efficiency on every flight."

Capt. Mike Williamson, Program Manager, NAVAIR Air Combat Readiness Program Post-Accident Analysis

FOQA is Not a Four Letter Word

In the civil aviation world and increasingly in the U.S. military, FOQA programs have demonstrated a capability to provide objective safety information not otherwise obtainable. For the CF to be proactive in flight safety, a MFOQA program may be implemented to detect the unforeseen and often unpredictable information lying deep within flight data. Although no such system exists within the CF, the adoption of MFOQA, as experience has demonstrated in the civil aviation world, will result in benefits that will increase as the program evolves. The evolution of a CF MFOQA will be determined by the commitment of resources to implement such a program, which may require a shift in the CF aviation community to embrace the MFOQA concept as a tool for self-correction. MFOQA is not a smoking gun or a quick fix for aviation incidents, but represents an opportunity for the CF to take action that will result in a sustainable reduction in aviation mishap rates.

Fatigue Countermeasures in Selected CF Air Transport Operations

By Michel Paul, Defence Scientist, Defence Research and Development Canada, Toronto

The human body is designed to perform best after 8 to 10 hrs of daily nocturnal sleep. Since Thomas Edison invented the light bulb, we have rapidly evolved into a 24/7 society. Modern military organizations must be vigilant 24/7 and military operations are often also 24/7. As a consequence of this 24/7 imperative certain segments of our society and our military are sleep-deprived. Certainly, the foreign policy imperatives that drive military taskings don't allow those taskings to be planned in such a manner that our soldiers, sailors, and airmen routinely achieve a minimum 8-hour nocturnal sleep.

One of the most compelling Canadian statistics with respect to deleterious effects of sleep deprivation is based on over one million motor vehicle accident records around the seasonal clock changes; i.e. moving our clocks forward in the spring (losing an hour of sleep) and moving our clocks back in the fall (gaining an hour of sleep). Essentially, on the Monday morning after the Saturday night spring clock change, motor vehicle accident rates are up by 7%, and by later in the week this 7% increase in accident rates has disappeared. In the fall, when we move our clocks backward and gain an additional hour of sleep, motor vehicle accident rates fall by 7%, but by later in the week the accident rates are back up to normal. The only place in Canada where this does not happen is Saskatchewan where they don't conduct seasonal adjustments of their clocks in the first place[1]. If a 2-dimensional task like driving is that sensitive to an acute 1-hour change in sleep, consider the effects on military personnel who are often much more sleep deprived than a single hour. What are the implications of such fatigue for a 3-dimensional task like flying or managing a sophisticated weapons system?

My first involvement with Aircrew Fatigue issues occurred during Op Alliance (sometimes referred to by aircrew as 'operation deny Christmas'), a 6-week long airlift into Split (what is now Croatia) with 18 CC-130 Hercules aircraft in the flow whereby an aircraft was landing in theatre every 4 hours, and the crews were rotated out of the flow after achieving their maximum flying time of 120 hours per 30-day period in as little as 2 weeks[2]. By the time we had an approved protocol in place to collect data during these missions, the initial airlift was over. Instead of 6 flights per day with 14 hours on the ground between mission legs (Trenton, RAF Lyneham, Split, RAF Lyneham, Trenton) we were now into a sustainment operation with 3 flights per week (this time into Zagreb) with 32 hours on the ground between mission legs. We measured aircrew performance (in the air) and daily sleep (with wrist actigraphs) on 10 of these sustainment flights. Wrist actigraphs detect movements every 0.1 seconds, and based on a reduction algorithm, daily sleep can be quantified to the nearest minute for up to several weeks at a time. We found a fatigue-induced decrease in performance on the long outbound transatlantic leg. We also found that the crews were having difficulty getting sleep in the UK since they were going to bed in the UK around 2200 h but that was only 1700 h body clock time and therefore out of phase with the body's melatonin circadian rhythm.

Melatonin is the master hormone that regulates circadian rhythms (i.e. daily rhythms). Melatonin is made in the human brain each day in the absence of light. During the day, melatonin levels are barely detectable, but once the sun goes down, with the stimulus of darkness melatonin is released into the circulation. When the sun rises in the morning, melatonin production in the brain ceases. This is why some people refer to melatonin as ***'a biochemical expression of darkness'***. The daily time that nocturnal melatonin starts to flow is called 'dim light melatonin onset' (DLMO). In the temperate mid-latitudes for normally entrained individuals (bed-time at 2300 h and arise at 0700 h), DLMO occurs on average around 2100 h, but is earlier in the winter and later in summer due the different lengths of daylight in those seasonal extremes.

In response to our findings that our Air Transport Aircrews were having difficulty obtaining early circadian sleep (i.e. going to bed at 1700 h body clock time and therefore before the daily expression of melatonin was evident in their blood) we ran a study in our Toronto laboratory. In this study the subjects went to bed at 1700 h immediately after ingesting a tablet containing melatonin, or zopiclone (a sleep-inducing medication), or a matching placebo. The subjects wore wrist actigraphs to quantify sleep. They were awakened at midnight, and underwent performance testing every hour from midnight to 0700 h. There was no evidence of a 'performance hang-over' from either medication. Wrist actigraphic analysis demonstrated that the subjects got significantly more sleep when they were on melatonin or zopiclone relative to when they were on placebo[3].

With this laboratory success of demonstrating that melatonin and zopiclone were equally effective facilitators of early circadian sleep and did not cause any impact on performance, we asked for and received permission to run a similar study (to evaluate melatonin and zopiclone as facilitators of early circadian sleep in an operational setting) on aircrew during weekly re-supply missions to Zagreb. This data collection involved 70 missions and 219 aircrew over a 2.5 year period. In spite of reduced dosages (as an extra margin of safety) and despite the fact that unlike in the laboratory, we had no control as to when the aircrew went to bed, we got similar results as we previously obtained in the laboratory study[4] re-confirming the efficacy of melatonin and zopiclone as facilitators of early circadian sleep in an operational setting.

Subsequent to this effort, we returned to the laboratory to run additional studies to investigate several sleep-inducing medications and a new time-released formulation of melatonin in order to quantify the depth and duration of any performance impact caused by each of the study medications[5]. The knowledge obtained from this study was used by the then Central Medical Board (now the Aeropsace and Undersea Medical Board) to draft aeromedical policy for the short-term, flight-surgeon-supervised use of sleeping medications by aircrew during missions that are known to impact on crew sleep hygiene. This policy allows that use of Imovane (zopiclone) or Restoril (temazepam) under Flight Surgeon supervision to facilitate sleep when the body's internal clock would be telling it to stay awake. While melatonin preparations have also proved effective, the lack of a pharmaceutically pure preparation in Canada has prohibited its use in CF personnel. Since Health Canada has recently approved pharmaceutically pure melatonin in Canada, it is possible that in the near short term, melatonin could be available in the CF pharmacy system.

In December 2003, there was concern about the Op Tempo of the TAL (being run out of Camp Mirage). With only two CC130 crews to conduct daily chalks into Kabul, the maximum 30-day flying time limit of 120 hours was being exceeded, so the crews were given waivers to fly up to 150 hours per 30 day period. Since the TAL was experiencing an unusually high number of flight safety incidents (personal communications with A3 Transports, 1 CAD, November 2003), we were asked to evaluate the Op Tempo. The crews wore wrist actigraphs to quantify their daily sleep times. The sleep data along with crew duty day data were used as inputs to a cognitive effectiveness modeling program called FAST (Fatigue Avoidance Scheduling Tool)[6]. The main output of FAST is modeled percent cognitive effectiveness. Below are 3 graphs illustrating our findings from the Camp Mirage TAL. Some details regarding these graphs are as follows:

- The vertical axis on the left side of the FAST™ graphs represents human performance effectiveness and is demonstrated by the oscillating line in the diagram representing group average performance as determined by time of day, biological rhythms, time spent awake, and amount of sleep.
- The green band represents performance effectiveness for skilled workers, the lower limit of which (90%) is an indication of when it is time to sleep.
- The yellow performance band (from 60% to 90% cognitive effectiveness) indicates caution. Personnel engaged in skilled performance activities such as aviation should not be functioning in this performance band.
- The black dotted line at 77.5% cognitive effectiveness represents performance equivalent to being intoxicated to a blood alcohol level (BAC) of 0.05%.
- Cognitive effectiveness at 70% represents performance equivalent to a BAC of 0.08%.
- The area from the dotted line to the pink area represents cognitive effectiveness during the circadian nadir and during a 2nd day without sleep.
- The pink performance band (below 60%) represents performance effectiveness after 2 days and a night of sleep deprivation. Under these conditions, no one can be expected to function well on any task.
- The red line represents acrophase (is the time of day at which peak cognitive effectiveness occurs; normally, in the late afternoon or early evening. Acrophase is easily disturbed by night work, shift rotation (shift lag) and time zone changes (jet-lag).
- The horizontal axis illustrates periods of work (red bars), sleep (blue bars), and time of day in hours. The red bars in these graphs correspond to thickening in the cognitive effectiveness line (immediately above them) which represents the last 30 minutes of crew day (approach and landing back into Camp Mirage).

Figure 1 shows recovery from the 9 time zone jetlag (follow the red acrophase line) of a CC130 co-pilot. During the first mission (Sun Dec 14) the best performance was attained at the dotted black line (BAC of 0.05%). Otherwise performance was extremely worrisome. Performance improved slightly each subsequent day. A look at the acrophase line (related to the right hand ordinate) shows that full recovery from this level of jetlag takes 9 to 10 days, although the crews were relatively safe to fly from day 5 (Dec 19) or 6 (Dec 20).

The model in Figure 2 represents the crew which had been in theatre for the previous month and was therefore no longer jetlagged. Throughout the model, cognitive effectiveness is essentially within limits for safe flying and shows no evidence of decreasing performance over time. This indicates that the Op Tempo does not impact on performance.

Figure 3 illustrates the impact of night operations on cognitive effectiveness. Essentially the crew has undergone a circadian inversion. They are flying when they should be sleeping and they are sleeping when they should be flying. In this model, the red bands in the abscissa represent the entire missions rather only the last 30 minutes as in Figures 1 and 2. Again, these red bands correspond to thickening in the cognitive effectiveness lines. These data show marked reductions of performance during night missions.

Essentially, the Camp Mirage Op Tempo did not cause attrition of performance over time. However, if aircrew commenced flying operations within 36 hours of arrival in theatre their performance was severely compromised during the first mission, however performance improved each day to the point where they were relatively safe to fly after 5 or 6 days in theatre[7]. The recommendations of this report were to allow more time for the

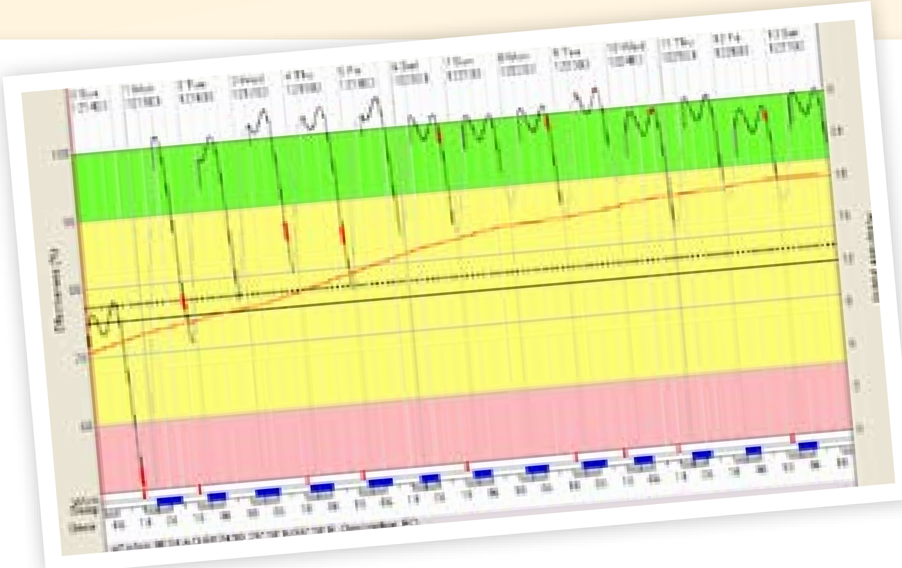


Figure 1

Figure 2

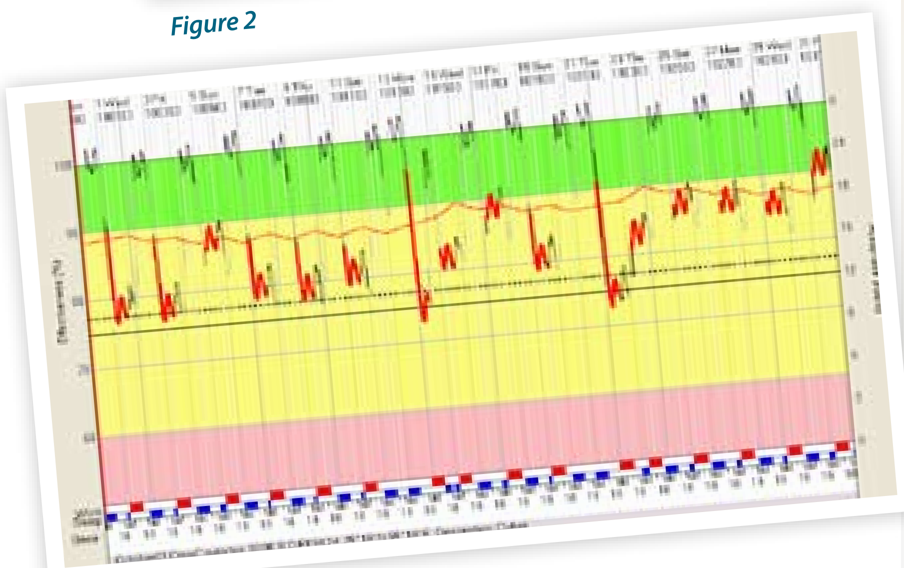


Figure 3

crews to adapt to local time after arrival in theatre, before they commenced flying operations. A second possible option, only if operational exigencies dictated, was to use a daily dose of melatonin to adjust circadian rhythms over a 6-day period beginning just prior to deployment. Such a protocol would move circadian rhythms forward up to about 1.5 hours per day for a total of 9 hours over the 6 days, thus significantly decreasing, if not completely eliminating jetlag, allowing the crews to commence flying operations upon arrival in theatre, after a suitable rest to recover from the deployment flight.

The Air Force response to these recommendations was a mandatory 5-day acclimation period (after arrival in theatre) prior to commencement of flying operations. The Air Force also provided funding for a 4-year project to optimize our ability to manipulate circadian rhythms (forwards or backwards) to counter jetlag and shiftlag. The 2 circadian entrainment modalities of this project involved the use of appropriately timed ingestion of melatonin (afternoon ingestion for phase advance and morning ingestion for phase delay) and/or appropriately timed light treatment (evening light for phase delay and early morning light for phase advance). The data collection for this project was just completed in December 2008. We are currently completing data analysis from the project and writing scientific publications. The operational output will be a circadian entrainment manual to guide CF physicians in the process of effecting optimally efficient circadian entrainment across a broad range of operational scenarios.

There are many causes of fatigue ranging from physiological (prolonged physical work, sleep loss, circadian desynchronosis as mentioned above, sudden changes in work/rest schedules, exposure to harsh environment, poor physical conditioning, inadequate nutrition and fluids) to psychological causes (such as prolonged mental work/stress, extended periods of anxiety, boring monotonous tasks). In parallel with the circadian entrainment manual, we are also reconciling aeromedical literature on Fatigue Management and expect to develop a Commander's Guide to Fatigue Management for the Air Force leadership by the end of this fiscal year.

References

1. Coren S. Sleep Thieves: An Eye-Opening Exploration Into the Science and Mysteries of Sleep. New York, NY.: The Free Press 1996.

2. Paul MA, Pigeau RA, Weinberg H. Human Factors of CC-130 Operations. Volume 6: Fatigue in Long-haul re-supply missions. Toronto, Canada: Defence and Civil Institute of Environmental Medicine; DCIEM Report No. 98-R-19; 1998. Report No.: Report No. 98-R-19.

3. Paul MA, Brown G, Buguet A, Gray G, Pigeau RA, Weinberg H, et al. Melatonin and Zopiclone as Pharmacologic Aids to Facilitate Crew Rest. Aviat Space Environ Med. 2001;72(11):974-84.

4. Paul MA, Gray GW, Sardana TM, Pigeau RA. Fatigue Countermeasures In Support Of CF CC130 Air Transport Operations: from the operation to the laboratory and back to the operation: Defence Research and Development Canada--Toronto, 2003; Report No. TR 2003-106.; 2003 October. Report No.: TR 2003-106.

5. Paul MA, Gray G, Kenny G, Pigeau R. Impact of Melatonin, Zaleplon, Zopiclone, and Temazepam on Psychomotor Performance. Aviat Space Environ Med. 2003;74(12):1263-70.

6. Eddy DR, Hursh SR. 2001. Fatigue Avoidance Scheduling Tool (FAST). AFRL-HE-BR-TR-2001-0140, SBIR Phase I Final Report, Human Effectiveness Directorate Biodynamics and Protection Division, Flight Motion Effects Branch, Brooks AFB TX, 78235-56105.

7. Paul MA, Miller JC. Fatigue Assessment in Camp Mirage CC130 Aircrew: recommendations for pharmacologic intervention: TR 2004-021. DRDC Toronto; 2004 February 2004. Report No.: TR 2004-021.

Why All the Fuss Doc?

By Lieutenant-Colonel Bruce Bain, Canadian Forces Environmental Medicine Establishment, Toronto

"Time for that *&^% aircrew medical again! Darn Flight Surgeons, why can't they just leave us alone? All they want to do is pull our tickets and ground us anyway. Why can't I just go to the civvie doc down at the local clinic? She'd sign me off no questions asked I mean really, look at me! What a specimen!"

Sound familiar? If you're aircrew of any type, you've probably gone through that internal angst more than once in your careers. And it started right at the very beginning, during selection. We just won't leave you alone. Why is that anyway? Is that aircrew medical just there to see how high we can get your blood pressure? Or is there maybe, perhaps, a slightly less sinister reason for all that poking, prodding, blood work and all that other nasty stuff we do to you on what seems to be a far too frequent basis? The answer to that is simple: It's all about Flight Safety.

Photo: MCpl Walsh

So that's it! DFS is behind it all!! No, wait. They're all aircrew too! Most of 'em pilots even and they really don't like the flight docs! Nope, it's not a plot by DFS, although they certainly have a vested interest in the overall outcome. Let's have a look at why we go through all this medical stuff, especially at the point of aircrew selection.

For the purposes of this article, I will concentrate on medical selection for pilots but the principles apply to all aircrew. As any pilot can tell you, "getting in the door" to become a CF pilot is no easy task. After going to the Recruiting Centre and filling in all the usual paperwork to ensure you are not a drug-taking psychopathic megalomaniac who wants nothing more than to strap on a CF-18 and go fire missiles at someone who really got under your skin in high school and having a screening medical to ascertain you in fact have the normal compliment of limbs and organs, you are sent off to the aircrew Selection Centre in Trenton where, after a number of paper and pencil tests they strap you into a flight simulator where you are expected to fly a circuit making few if any errors while talking on the radio, scratching your head and rubbing your belly! If you manage to make it through all that, you are sent to see us here at Canadian Forces Environmental Medicine Establishment, at DRDC Toronto (formerly DCIEM for you old guys) so that the doctors and technicians in our consult service can have a go at you. Here, you will have another history and physical done and a whole battery of tests including blood work, echocardiograms, lung function tests, vision tests and others. The purpose of these tests is to attempt to determine to the extent possible,

Photo: Pte Kelly Mitton

if you have any medical conditions that could cause sudden incapacitation or conditions that might pre-dispose you to longer term problems that are incompatible with flying operations in the future, essentially an evaluation of training investment.

The rationale behind this kind of an evaluation began way back when aviation was the new kid on the block but especially as a tool in modern warfare, that is during WW1. At the beginning of the war, the nascent Royal Flying Corps (RFC) had no particular medical standards for anyone, including pilots and observers (the latter to eventually become navigators, now Air Combat Systems Officer (ACSOs) in our Air Force). Essentially, if you could walk to the airplane, get in and start it up, you were pretty much good to go. They did have a selection process but it was more of an operational and cultural assessment. For example, a pilot had to be an officer and would have to come from the right class (of course to be an officer required that as well). They should have a "fighting temperament" and it was thought that being able to shoot would be a good


Photo: Sgt Roxanne Clowe

thing as weapons were quickly being introduced into aircraft. The ability to ride a horse was considered (none other than Billy Bishop, the top Canadian/British Empire fighter ace in WWI was rumoured to have been asked if he could ride a horse in his RFC application interview)! However, a year or so into the war, with aircrew losses abysmally high, the RFC started actually doing some statistics to determine the causes of these terrible losses. From the review of casualty lists they discovered that of every 100 flyers lost, two died from enemy action, 8 died due to aircraft defects and 90 deaths were attributable to individual deficiencies including recklessness, carelessness and **physical defects**. A further evaluation suggested that at least 60% of the 90 were due to physical defects! Because of the dismal statistics and issues that were beginning to be understood such as cold, hypoxia and even G forces, the RFC established a special medical service to deal with the problems of the aviator. Determinants of medical fitness to fly were established such as 20/20 vision, good hearing, balance testing and others. While many of these tests were rudimentary and admittedly not always backed up by research (it hadn't been done yet), overall the proof would be in the pudding. The following year, the RFC noted a reduction in deaths due to physical defects from 60% to 20%! The following year, that statistic was reduced to 12%, a most impressive outcome over a fairly short period of time. Compare this to the reduction in aircraft loss rates due to engineering improvements and I suspect it would be a much longer timeline to see this level of improvement.

Medical evaluation and re-evaluation - **fitness to fly**- became one of the main raison-d'êtres of the aviation medical physicians (or Flight Surgeons as they became known in the United States and subsequently in Canada). In the CF, our "Bible" is Chapter 7 in the newly created A-GA-005-000/AG-001 DND/CF Airworthiness Program, entitled Medical Standards for CF Aircrew (also accessible through the 1 Cdn Air Div, Div Surg website). This document describes the medical conditions considered to be incompatible for performance as CF aircrew. It is built upon a rich history of international research and aviation medicine specialist opinion developed and learned over many years. It is also a living document and can and has been modified in the light of new medical and operational evidence. For example, after 80-90 years of insisting on 20/20 vision for pilot applicants (V1), we were able to determine through a study, that V2 would be acceptable for applicants. On review of available evidence and in conjunction with the experiences of our colleagues in the United States and internationally, we felt we could recommend to the Chief of the Air Staff (CAS) that laser eye surgery could be safely allowed for CF aircrew including pilot applicants. There are many more examples but I think the point is clear.

The aircrew medical is a key link in the Flight Safety chain. We talk about Fitness to Fly but we are really talking about Fitness to Fly Safely. That includes determination of fitness to complete the mission. At the point of the initial aircrew medical, we are trying to make sure that you can withstand the rigours of the aviation (and military) environment on behalf of the CAS, to make sure you are safe to fly. On an ongoing basis, the periodic aircrew medical does the same thing. Just as the maintainers haul your aircraft off the line to do periodic checks and maintenance, we haul you in to do the same. You expect your aircraft to be "Fit to Fly". You should expect no less from yourselves. After all, you are the most important (and most expensive) link in the Flight Safety chain!

The Human Factors of Uninhabited Aerial Vehicles

By Captain Mark Rutley, M.Sc., Canadian Forces Environmental Medicine Establishment, Toronto

As technology changes the way in which wars are fought, the Canadian Forces increasingly finds itself in possession of ever newer and more sophisticated uninhabited aerial vehicles (UAVs). UAVs, while currently very topical, are not a new phenomenon. Wheatley (2004) briefly traces the history of the UAV from the Second World War. He states that the first UAVs were converted from existing target drones and were used for reconnaissance. These early vehicles were large and cumbersome to control, often requiring as much or more support staff as manned aircraft. With the advent of increasingly sophisticated computer technology, UAVs have rapidly become more capable and intelligent. Since the advent of the "War on Terror" nation after nation has realized the potential of UAV and Unmanned Ground Vehicles (UGVs) in traditional reconnaissance roles, and more direct roles such as the use of Predator Unmanned Combat Air Vehicles (UCAVs) to deliver anti-armour or anti-personnel ordnance. As research and development accelerates there has been an explosion of different sizes, makes, mission profiles, and mechanisms of flight, which has generated a whole new realm of human factor problems to overcome. This article will attempt to outline some of the human factor challenges inherent to UAVs, and provide suggestions for mitigating as many as possible.

All UAVs, no matter the size or range, have ultimately the same goal – to provide the war fighter with an increased situational awareness of the battlefield environment. All of them require some form of Ground Control Station (GCS) that incorporates a user interface. Endsley (1988, 1998 and Endsley, Bolté and Jones, 2003) have variously described three levels of situation awareness (SA) with respect to user interfaces. Endsley has labeled level 1 situation awareness as Perception (Endsley, 1988, 1998 and Endsley, Bolté and Jones, 2003). At this level, the interface must allow the user to perceive the relationship between the device and the world, while at the same time not overwhelm the user with unnecessary information. Level 2 situation awareness is comprehension (Endsley, 1988, 1998 and Endsley, Bolté and Jones, 2003). Here the user must combine perceptual data taken from Level 1 SA and comprehend how this data relates to an overall goal. Level 3 SA is projection (Endsley, 1988, 1998 and Endsley, Bolté and Jones, 2003). Here the user must have developed sufficient understanding in the current state of the system to predict what will happen to that system in the near future.

Maintaining situation awareness, both of the state of the device being controlled and of the immediate environment around the operator is vital to effective task performance when using remote sensing robots (NCR, 2005). Any human-machine interface designed for a remote sensing platform must therefore fulfill these three basic situation awareness requirements, and each class of UAV will have a different subset of ergonomic requirements to do so.

For UAVs, most of the ergonomic issues are generated because the user and the vehicle are not co-located. Because of this the operator is deprived of the range of sensory cues available to traditional aircraft pilots. These cues allow a pilot to develop a strong situational awareness of his immediate surroundings, and fulfill the 3 levels of SA detailed by Endsley, et. al. In an UAV, the camera enforces a narrow field of view, resulting in the operator missing ambient visual information (i.e.: "ground rush") (McCarley and Wickens, 2005). Also missing are kinesthetic and vestibular input (i.e.: "seat of pants" feel of G-forces), and auditory input (i.e.: engine and wind sounds) (McCarley, et al. 2005). The time lag between operator control input, response of the vehicle, and indication of vehicle response on the operator's screen generates additional problems. Further, data link bandwidth limitations will reduce temporal resolution, spatial resolution, and color discrimination capabilities for the operator. This results in extra mental processing requirements on the part of the operator to discern what he or she is looking at and to build up an adequate mental model of the situation (McCarley, et al., 2005). Further, lag in image update times due to bandwidth limitations not surprisingly limit an operator's ability to effectively track a target (Van Erp & Breda, 1999). These general UAV problems result in the fact that it is very difficult for an operator to directly "fly" a UAV in the traditional sense of the word.

Attempts to overcome impoverished environmental sensing can be done through the use of multimodal displays. Multimodal refers to using one sensory modality at a time (i.e.: providing a stall warning

Photo: Sgt Carole Morissette


Photo: MCpl Robert Bottrill

horn, a flashing light and a "stick shaker" in conventional aircraft). Calhoun, et al. (2002) found that offloading data from the visual channel improves flight-tracking performance. To do this, many designers resort to touch-based, or "haptic", control systems that shake to alert the pilot to a situation (Ruff, et al., 2000). Sensing the machine's state is not the only part that can benefit from multimodal techniques. Draper, et al. (2003) and Gunn, et al. (2002) have investigated multimodal input commands to the UAV using speech recognition technology and found that being able to "talk" to the machine may prove useful as well.

Another method that shows promise in overcoming the issue of developing adequate situation awareness may be through a synthetic vision system, which will augment sensor input with additional information. Such systems can improve target identification accuracy, reduce target tracking problems, and subsequently reduce an operator's mental workload (Van Erp, et al. 1999). Doing so invariably frees up more mental "resources" to devote to operating the UAV, thus improving flight efficiency and safety.

Each phase of the UAV's flight generates its own problems as well. For example, in a paper by Williams (2004) exploring the Human Factors issues associated with UAV accidents in the United States, it was found that human factors accounted for about half[1] of all UAV accidents. Of the accidents that are attributable to the operator, many of them were a result of human control during the landing phase, especially for pilots who were required to land the UAV visually like a hobby remote control aircraft (i.e.: standing outside and watching the aircraft visually). Others were procedural based (i.e.: improper handover between controllers) and the rest were related to poorly designed interfaces (Williams, 2004). Williams concludes that a "paradigm shift" is required. This means that designers should think of operators not as vehicle "pilots", but rather system "commanders". The operator tells the machine what to do and then monitors it to ensure the commands given are carried out – essentially stating that the UAV should be an autonomous, "thinking" vehicle that is merely told where to go and what to do. Automation of some or all of the vehicles systems, therefore, may be one of the easiest methods for reducing pilot workload and increasing UAV flight safety.

Current larger scale UAVs differ markedly in the degree of system automation they possess, ranging from full pilot-in-command, to pilot selecting desired flight characteristics (i.e.: setting heading and airspeed), to pilot selecting waypoints on a map, and leaving the UAV to decide how to get there (McCarley, et al., 2005).

Further, current UAV systems differ in levels of automation between flight regimes. Some UAVs can be fully automated during route following tasks, but require human control for take-off and landing. Different types of automation can positively or negatively affect operator task efficiency as well. For example, Dixon and Wickens (2003) found that target tracking was improved when the UAV flew a course via accurate autopilot. However, operator efficiency in piloting the UAV was not maintained when the interface provided operators with automated auditory warnings signaling failures of UAV systems (Dixon, et al. 2003). Sheridan (1992) proposed 10 degrees of control and automation, ranging from complete human control to complete machine control. The levels are as follows (Adapted from Sherry and Ritter, 2002):

1. The computer offers no assistance. The human must do it all.
2. The computer offers a complete set of action alternatives.
3. The computer narrows the selection down to a few.
4. The computer suggests one action.
5. The computer executes that suggestion if the human approves.
6. The computer allows the human a restricted time to veto before automatic execution.
7. The computer executes automatically, and then necessarily informs humans.
8. The computer informs the human after execution only if asked.
9. The computer informs the human after execution if it, the computer, decides to.
10. The computer decides everything and acts autonomously, ignoring the human.

Different modes of automation will also have an affect on the efficiency of the operator. Ruff, et al. (2002) found that there are different operator benefits for automation by consent (UAV suggests a course of action but won't engage until given approval by the operator) and automation by exception (UAV follows a self determined course of action unless told to do otherwise by the operator). Further, Inagaki (1999) argues that there are situations where it is imperative that the machine operates fully autonomously, ignoring any input (or more specifically lack of input) from the human. He cites safety critical and/or extremely time pressured situations such as during aircraft or terrain collision avoidance. In these situations, involving humans in the decision-making loop could well have catastrophic consequences.

Parasuraman (1997) discusses four types of problems that can arise as a result of automation. First is **Loss of expertise** – this occurs whenever a machine replaces a human in performing a function or task. Because the human is no longer performing the skills required to complete the function or task, their performance is degraded should they need to perform that task in the future (due to machine failure). Second is **Complacency** – here the human develops trust with the machine over time due to repeated successful performance. This could cause the operator to become overconfident in the reliability of the automation, thus missing errors the machine may make. Third is **Lack of Trust** – here lack of reliability in a system will cause the operator to lose trust, and thus not use the system fully. Finally, Parasuraman discusses **Loss of Adaptivity** – here the automatic functions and actions of the machine counteract the normal adaptive behaviour of the operator.

Sherry and Ritter (2002) state that introducing automation into the complex environment of UAV flight does not automatically reduce operator workload. Rather, automation shifts workload between human and machine, changes the character of the work performed by the human, introduces new workloads, and forces new communication and coordination requirements on the human (Sherry, et al. 2002). Automation apparently, is not the immediate panacea for all UAV problems. Therefore, more research will be needed to determine what level of automation is best suited for what UAV phase of flight, what automation management style, and whether or not the UAV is currently experiencing any system failures.

There are other problems associated with automation as well, and not all of them ergonomic in nature. In a workshop run by the National Research Council (NRC) that explored interfaces for ground and air military robots, the workshop committee members stated that completely autonomous systems of the type seen in non-military robots are predictable, and therefore impractical against a thinking adversary (NRC, 2005). Therefore some form of human-in-the-loop control is still required to maintain flexibility, adaptability and unpredictability while the robot is operating in the battle space (NRC, 2005). Further, only the functions that are reliable enough should be automated and those that display reliability below 70 or 80% degrade system performance and should be avoided (NRC, 2005).

This same workshop identified other interface issues, including the fact that any interface design must account for operator attention issues, such as the operator's attention being diverted from the task during critical moments or because of "cognitive tunneling" (NRC, 2005). Cognitive tunneling occurs when an operator's attention is focused on one task to the detriment of others. Any UAV and associated GCS must therefore be forgiving enough such that if critical control input timings are missed, catastrophic failure of the UAV or interface does not occur. The other side of the diverted attention coin means that when an operator returns their attention to the controller, they must be able to instantly recognize what state the device they are controlling is operating in, or else mode errors will occur. The workshop recommended that the interface be designed so that it is as simple as possible to avoid overloading the operator with information (NRC, 2005). Interestingly enough, the workshop concluded that standardization of the interface across several remote sensing platforms (i.e. a single GCS controlling a number of UAV classes as well as mobile ground sensors) can lead to confusion and mode errors on the part of the operator (NRC, 2005). This can be the result of the operator not developing separate mental models for each platform being controlled (NRC, 2005). Finally, the workshop found that an operator will need to access detail at various points during task performance, but still have a method for maintaining overall situation awareness (NRC, 2005).

It is also interesting to note that one of the NRC workshop members brought up the point that stealth was not only a concern for mission accomplishment, but also for moral reasons. It was found that while operating UGVs in Afghanistan, the first in-country

Photo: MCpl Robert Bottrill

people to encounter the deployed remote sensing platform were village children, who were naturally drawn to such a novel and unusual device (NRC, 2005). For UAVs, there is less of a risk of inadvertent discovery by locals. Nonetheless, it behooves designers to ensure that either the machine, or the operator controlling the machine, has a very strong capability to discriminate legitimate from non-legitimate targets.

A final moral issue raised by the NRC workshop was the question of modeling future GCS units on current video game controllers (NRC, 2005). Doing so provides an immediate and strong link between the soldier, who is generally young and no stranger to such devices, and the machine itself. The soldier will intuitively understand joystick deflections and how they relate to either camera angles or vehicle movement because he/she has likely been exposed to such a system in video games. However, this again raised a moral issue for the NRC members, who felt that providing a video game interface will mentally distance the soldier from the physical reality of what it is they are engaged in, which is the direct application of the profession of arms (NRC, 2005). This in turn may lead soldiers to be less discriminatory in target selection, with possible non-combatant or blue-on-blue engagements.

Single-Operator and Multiple-Machine Human Factors

As UAV technology advances, operators may find themselves commanding a UAV "Swarm". "Swarm" technology refers to multiple telerobotic machines, operated by one or many humans, capable of gathering together from different locations and cooperating with each other to achieve a single goal before dispersing (Kim, Hubbar and Necsulescu, 2003). For example (as adopted from Johnson, 2003), in a future war scenario, a human controller of swarm of Uninhabited Combat Air Vehicles (UCAV) has been given an order to conduct a Suppression of Enemy Air Defense (SEAD) mission. The human controller sets goals that the UCAVs must complete, such as one UCAV is to act as a communications relay, taking a high orbit over the target area and relaying information to and from the remote operator. Two UCAVs could be designated as information processors, converting environmental data and human input into commands for the remaining swarm. Two UCAVs are used to sense enemy radar emplacements, and two UCAVs are used to attack and destroy those emplacements.

To complete such a mission, an extremely high level of cooperation must exist between not only the machines themselves, but between the machines and the human controller. This technology raises different ergonomic requirements, such as ensuring that the machines don't collide with each other, that all work cooperatively to complete a mission, that the swarm is capable of adapting to the loss of agents, and that the operator is capable of quickly and easily understanding not only the status of the overall swarm (and mission) but also what any one machine in the swarm is doing at any moment without causing cognitive overload (NRC, 2005).

One problem associated with multiple vehicles and a single operator is that on the battlefield, a high level of mental processing has to occur so that a unit (either human or machine) can make the decision to maneuver, communicate, or shoot depending on circumstances (NRC, 2005). Humans are capable of learning the rules that govern such decisions, but currently machines are not. Therefore, a human must be present to make these decisions for the machine. During slow moments, it is possible for one person to control more than one machine. However, when events begin quickly following each other (such as when a unit comes under fire) it is impossible for one person to provide decision-making guidance to a large number of robots. Thus, some method is needed to either reduce the amount of human-in-the-loop control the robot requires (i.e. building a "smarter" robot), or a dynamic control method must be employed where human operators who are not overtaxed can take control of some of the machines from an operator that is overtaxed (NRC, 2005). In this way, machines are swapped seamlessly back and forth between human controllers. While this method will work, it does present many problems. And clearly, if all human controllers have reached their cognitive limits, some machines will have to go unsupervised, reducing their combat effectiveness.

All the problems discussed above concerning automation in a single-operator/single-machine scenario apply to a single-operator/multiple-machine environment. Nevertheless, it is likely that single-operator/multiple-machines scenario will be developed for the future war situation. Consequently it is imperative that an understanding be gained of what is required for the operator to develop a functional mental model of the battle space in a single-operator/single-machine scenario before this occurs. This knowledge can then be adapted and applied to the single-operator/multiple-machine scenario.

Conclusions

1. Some form of automation of flight control is mandatory for UAVs. This requires the vehicle to know where it is in space, and what obstacles are around it such that obstacle avoidance does not have to be performed by the user. Any automation must support the human during all task sequences and under any mental workload, and aid in the development of accurate situation awareness. The nature and degree of automatic control required to do so is still unknown for both single-operator/single-machine and single-operator/multiple-machine situations. Therefore, much research will be required to determine the best ways to dynamically allocate tasks between human and machine, and under what conditions this allocation should be changed.

2. A multimodal interface will reduce overloading a single sensory modality.

3. Any interface should have some means of providing immediate feedback to the user with respect to any command inputs, and despite the time lag required to transmit those commands to the vehicle and receive the response from the vehicle.

4. A human should not have to land the UAV.

5. Any automation used in a military setting should not be predictable, and should not draw attention to the user. For example, any automatic loiter or orbit pattern should be randomized such that it gives no indication of where the operator is on the battlefield.

6. The interface should be robust enough that if the operator is unable to devote attention to the vehicle under control for several minutes (for whatever reason), there is no catastrophic failure of the vehicle.

7. There should be unambiguous indications of what mode the interface and vehicle is in.

8. Flexibility – the interface should be able to control a host of current and planned future remote sensing platforms (NRC, 2005).

9. Adaptability – the interface should be able to support different operators and different skill levels (NRC, 2005).

10. Robustness – the robot and control system should be able to succeed despite operations in an uncertain, dynamic and hostile world (NRC, 2005).

11. Responsiveness – the robot and control system should be able to provide a mission-centric perspective that enables operators to react in tactical timeframes (i.e.: "on-the-fly" reprogramming for changing missions) (NRC, 2005).

Until a clear understanding of these issues is developed, militaries the world over, including the Canadian Forces will continue to experience a high rate of loss for unmanned aerial vehicles.

References

Calhoun, G.L., Draper, M.H., Ruff, H.A., and Fontejon, J.V. 2002. Utility of a tactile display for cueing faults. Proceedings of the Human Factors and Ergonomics Society 46th Annual Meeting. Human Factors Society, Santa Monica, CA. Pp 2144-2148.

Dixon, S.R., Wickens, C.D., and Chang, D. 2003. Comparing quantitative model predictions to experimental data in multiple-UAV flight control. Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting. Human Factors Society, Santa Monica, CA. Pp 104-108.

Draper, M., Calhoun, G., Ruff, H., Williamson, D., and Barry, T. 2003. Manual versus speech input for unmanned aerial vehicle control station operations. Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting. Human Factors Society, Santa Monica, CA. Pp 109 – 113.

Endsley, M. R. 1988. Design and evaluation for situation awareness enhancement. Proceedings of the Human Factors Society 32nd Annual Meeting. Human Factors Society, Santa Monica, CA. Pp 97-101.

Endsley, M. C. 1998. Situation awareness, automation and decision support: designing for the future. CSERIAC Gateway 9(1): 11-13.

Endsley, M. R., B. Bolté, Jones, D.G. 2003. Designing for situation awareness: an approach to user-centred design. London, Taylor & Francis.

Gunn, D.V., Nelson, W.T., Bolia, R.S., Warm, J.S., Schumsky, D.A., and Corcoran, K.J. 2002. Target acquisition with UAVs: Vigilance displays and advanced cueing interfaces. Proceedings of the Human Factors and Ergonomics Society 46th Annual Meeting. Human Factors Society, Santa Monica, CA. Pp 1541 – 1545.

Hundley, R.O., and Gritton, E.C. 1994. Future Technology-Driven Revolutions in Military Organizations. RAND Corporation. Document No. DB-110-ARPA-, 1994.

Jeannot, A. 2000. Situation awareness, synthesis of literature research. Bretigny-sur Orge, EUROCONTROL Experimental Centre.

Johnson, C.L. 2003. Inverting the Control ratio: Human control of large, autonomous teams. The Mitre Corporation. McLean, Virginia, USA. Available online at http://www.traclabs.com/~cmartin/hmas/wkshp_2003/papers/Johnson.pdf.

Jordan, P.W. 2002. An Introduction to Usability. Taylor and Francis Ltd. London, UK. ISBN 0-7484-0762-6.

Kim, B., Hubbard, P., Necsulescu, D. 2003. Swarming unmanned aerial vehicles: Concept development and experimentation, a state of the art review on flight and mission control. Technical Memorandum. DRDC Ottawa 20003-176. Ottawa, Canada.

National Research Council (NRC) 2005. Interfaces for Ground and Air Military Robots: Workshop Summary. Tal Oron-Gilad, rapporteur. Planning Committee for the Workshop on Scalable Interfaces for Air and Ground Military Robots, Committee on Human Factors. Board on Behavioral, Cognitive, and Sensory Sciences, Division of Behavioral and Social Sciences and Education. National Academies Press. Washington, USA. ISBN 0-309- 549191-1. Available online at: www.nap.edu/catalog/11251.html.

McCarley, J.S., Wickens, C.D., 2005. Human Factors Concerns in UAV Flight. Technical Report AHFD-05-05/FAA-05-01. Institute of Aviation, Aviation Human Factors Division. University of Illinois at Urbana-Champaign.

Michealson, R.C., Reece, S. 1998. Update on Flapping Wing Micro Air Vehicle Research: Ongoing work to develop a flapping wing, crawling Entomopter. 13th Bristol International RPV/UAV Systems Conference Proceedings. Bristol England, 30 March 1998 - 1 April 1998, pp. 30.1 - 30.12

Parasuraman, R. 1997. Humans and automation: Use, misuse, disuse, abuse. Human Factors, 39, 230-253.

Ruff, H.A., Narayanan, S., and Draper, M.H. 2002. Human interaction with levels of automation and decision-aid fidelity in the supervisory control of multiple simulated unmanned aerial vehicles. Presence. Vol 11. Pp 335-351.

Sheridan, T. B. 1992. Telerobotics, automation, and human supervisory control. Cambridge, MA: MIT Press.

Sherry, R.R., Ritter, F.E. 2002. Dynamic task allocation: Issue for Implementing Adaptive Intelligent Automation. Technical Report No. ACS 2002-2. School of Information Sciences and Technology. Pennsylvania Statue University. Available online at http://acs.ist.psu.edu/misc/reports/sherryR02.pdf.

Van Erp, J.B.F., and Van Breda, L. 1999. Human factors issues and advanced interface design in maritime unmanned aerial vehicles: A project overview. Report TNO TM-99-AOO4. Soesterberg, the Netherlands. TNO Human Factors Research Institute.

Wheatley, S. 2004. The Time is Right: Developing a UAV Policy for the Canadian Forces. CDAI-CDFAI 7th Annual Graduate Student Symposium, RMC. October 29-30.

Williams, K.W. 2004. A Summary of Unmanned Aircraft Accident/Incident Data: Human Factors Implications. For FAA Civil Aerospace Medical Institute. Oklahoma City, OK.

End Notes

1. It is interesting to note that the literature states the Human Factor component of accidents with manned aircraft is around 80%. Williams also stated that UAVs have more accidents per flight hour than manned aircraft. This then indicates that mechanically, UAVs are not as robust as piloted aircraft, and this type of accident is contributing to a reduced HF component in the ratio.

Culture and Human Factors

By Graham Braithwaite Ph.D. and Matthew Greaves Ph.D., Safety and Accident Investigation Centre, Cranfield University, United Kingdom

Remember how it feels to be mistaken for an American rather than a Canadian? It may be only just across the border, but there are so many things about being a Canadian that are different. Many of these differences are cultural – the shared beliefs and attitudes we may have about everything from the shape we think a football should be, to the way in which we perceive and respond to errors or accept risks.

With the recent prominence of Safety Management Systems has come a focus on safety culture, but this is in fact just one way in which culture can affect safety.

In the 1990s, two Dutch scientists, Geert Hofstede[1] and Fons Trompenaars[2], studied in detail the differences between national culture and the way that this affects business and life-style decisions. Their work examined topics ranging from the way we perceive hierarchy in society (the so-called 'power-distance' effect) to the way in which an individual prioritizes things for their own benefit, or for the greater good of society (individualism or collectivism). Understanding how various nationalities may react to each other, their boss or subordinate; the amount of uncertainty they are prepared to accept; the power they think they have over their destiny and so on, is not just interesting for academics, it has a direct impact on operational staff.

The rise of Crew Resource Management (CRM) in aviation was, in part, aimed at dealing with cultural barriers to communication. Professional culture, the effects of seniority and the ease with which individuals can question their senior officers have all been factors in accidents. The switch from military to civilian flying also provides potential barriers – something that was seen with tragic consequence within Korean Airlines where several fatal accidents occurred, partly because junior crew-members felt unable to challenge their colleagues, partly because of their relative ranks during previous military service.

As CRM became popularized in the 1990s, the problem of cultural compatibility became apparent. A course designed for American pilots is not, for example, appropriate for, say, China or Japan. For example, a course was given to pilots in a particular airline where a strong power-distance effect existed – in other words where junior pilots felt unable to speak up. The instructor was delighted when throughout the course the senior captains enthusiastically agreed with the instructor that junior crewmembers should feel empowered – surely this CRM training was really working? However, the autocratic management style returned as soon as they were back on the flight deck. The instructor was the 'senior officer' in the class and could not be questioned, but then back on the fight deck, the captain was in charge again.

Matthew Greaves Ph.D., Research Officer, Department of Transport, Cranfield University (on the left) Graham Braithwaite Ph.D., Head of Department of Air Transport, Cranfield University. (on the right)

Photo: MCpl Kevin Paul

Of course, like so many things in human factors, there is no simple rule. There is no such thing as an 'unsafe' national culture. Indeed, different combinations of cultural traits can be assembled to produce the same successful outcome – for example, a culture where questioning of authority does not come easily, can be balanced with strict adherence to standard operating procedures which include cross-checking.

Professional culture is also very different across the aviation industry. Pilots and air traffic controllers, maintenance engineers and flight attendants may, at times, feel like they are from different planets. The words they use, the clothes they wear, and the nature of the tasks they undertake all indicate different approaches to work. Remember the joke that says, *How do you know when there is a pilot at your party? They are the one that says 'Hello, I am a pilot!'* – I am not sure I have every heard the same one about air traffic controllers or maintenance engineers!

Safety culture; a term which was developed after the fire at the Chernobyl nuclear reactor in 1986 has become all too popular, thanks to work in Safety Management Systems. James Reason[3] points out "few phrases are so widely used yet so hard to define as *safety culture*". Simply put, safety culture relates to an organization's attitudes and responses to safety. A mature safety culture is reflected in a shared responsibility and enthusiasm for safety; not just about compliance or lip-service. It is not something that can be switched on and off or bought from a vendor or consultant. The American Institute of Chemical Engineers observes, "Safety culture is how the organization behaves when no one is watching."

How an organization reacts to error or deals with failure is probably the greatest test of its culture. It is seen to be just and fair in punishing willful violations, but at the same time accepting that most errors and indeed some violations come about because most staff are trying to do a decent job? Changing a culture for the better can take five or even ten years, but changing it for the worse can happen very quickly. The reaction to an incident or accident will tell the staff all they need to know about the organization's attitudes to safety.

In 2006, a B737 cargo aircraft suffered a landing accident at Birmingham airport, UK. During an approach to another airport, the pilot inadvertently disconnected the autopilot leading to a high rate of descent. A go-around was called, but it was too late to avoid contacting the ground, breaking off the right main landing gear. The aircraft diverted to Birmingham where an emergency landing led to a hull-loss, albeit without injury.

The resulting investigation report[4] highlighted a number of causal and contributory factors including inappropriate transmission of a company message at a late stage (500 feet) of a Cat III automatic approach, and ineffective training of the co-pilot - the latter prompting a recommendation that the regulatory authority require the operator to review their standard operating procedures. As a result of the accident, approximately one month later, the operator sacked the pilot and they were quoted in the Mail Reporter newspaper[5] as saying, "Although the Air Accidents Investigation Branch investigation continues, it has been established that the automatic pilot was disengaged. That is down to human error. Although the pilots did manage to recover superbly and made a text book emergency landing at Birmingham airport, they instigated the incident with a momentary lapse and the company operates a zero accident tolerance level."

What do you think the other crews interpreted a zero accident tolerance level to be? Was ineffective training of the co-pilot not perhaps a symptom of a greater, systemic problem? Was this not an opportunity to learn the lessons of what went badly and at the same time what went well? – the pilots did manage to recover superbly and make a text book emergency landing. An event badly handled by an organization may change the culture of that organization significantly?

ICAO[6] reminds us because a culture is shaped by its environment and evolves in response to changes in that environment, culture and context are really inseparable. Deployment to operational theatres or postings to overseas locations have the potential to change the culture of any group. The change may be subtle and slow – culture is often described as being like a fish in water; it is all around you, but you can't see it. In other words, the potential for cultural drift or 'risky shift' can be dangerous and invisible.

Take the example of the introduction of night vision goggles and helmet mounted displays into helicopter operations in an overseas air force. The need for such equipment was heightened by an imminent major sporting event, which was also identified as a major terrorist target. Although there were crashworthiness concerns raised by the air force's airworthiness group, the operational need was such that, the perceived risk was temporarily accepted. The event passed with no incident and the crews became happy to use the new equipment. Soon after, a heads of government meeting was to be hosted, so again a special case argument was made and the equipment used again, still without survivability issues being addressed. Slowly, the new equipment had become accepted without appropriate testing and was becoming the way we do things around here. This is a dangerous slide and eventually the airworthiness group became quite unpopular by demanding the equipment withdrawn until properly assessed. Did the lack of incidents mean it was safe? Should the operational need always come first? If the latter, then at what point will someone speak up – that may be down to culture.


Photo : Cpl Marc-André Gaudreault

References

i Hofstede, G. (1997) *Cultures and Organizations: Software of the Mind.* McGraw-Hill, New York.

ii Trompenaars, F. (1993) *Riding the Waves of Culture - Understanding Cultural Diversity in Business.* The Economist Books, London.

iii Reason, J. (1997) *Corporate Culture and Safety.* Paper presented at the National Transportation Safety Board Corporate Culture and Transportation Safety Symposium. 24-25 April. Arlington, Virginia.

iv AAIB – Air Accidents Investigation Branch (2008) Report on the accident to Boeing 737-300, registration OO-TND at Nottingham East Midlands Airport on 15 June 2006. UK Department for Transport, London.

v Mail Reporter (2006) Crash Land Crew Axed [WWW] http://www.redorbit.com/news/business/591262/crash_land_crew_axed__drama_pilot_error_behind_aircraft/index.html (28 May 2008)

vi ICAO – International Civil Aviation Organization (2004) Cross-Cultural Factors in Aviation Safety. Circular 302-AN/175, ICAO, Montreal.

Where We Are Now, Where We Might Go

By Wing Commander Jon Taylor MSc, BSc(Hons), MCMI RAF and Doctor Sue Taylor Ed D, MA Ed, Ad Cert Ed, BEd, Cert Ed.

This article was originally published in the Defence Aviation Safety Centre Journal 2008. It is reproduced with the kind permission of the United Kingdom Directorate of Aviation Regulation and Safety.

Introduction

Since the advent of powered flight, aircraft accidents and incidents have occurred and for many years 'the implicit assumption was that the person closest to the failure was the cause'[1]. Consequently 'pilot error' was seen as the major cause of accidents and incidents. In 1947, Fitts and Jones showed how cockpit design had considerable influence on the errors pilots made, and the 'human factors' was borne. Until the late 1970s, human factors remained the domain of aircraft designers, but NASA identified human failings of communication, decision-making and leadership as responsible for 70% of air transport accidents.[2] As a result, Crew Resource Management (CRM) training was introduced to 'reduce 'pilot error' by making better use of the human resources on the flight deck'.[3]

CRM training developed through much iteration, being subsumed under the umbrella term of human factors that has 'come to be used to encompass all of those considerations that affect man at work'.[4] Human factors reach beyond the cockpit, and are applicable to all involved in the aviation endeavour. Reduction of the 70% of accidents perceived to be caused by human error is the rationale underpinning mandatory human factors training programmes within civil aviation, and with a similar level of military human factors occurrences, CRM training was introduced into UK military aviation. This introduction was not wholly successful and formalized CRM training ended two years later. Since 1997, there have been various attempts to re-introduce human factors training, including the use of Civil Aviation Authority (CAA) accredited instructors at unit level, and foundation-level human factors instruction within some initial training courses.

Currently, a stated aim for a pan-defence human factors policy is to introduce a coherent human factors training programme throughout UK military aviation 'to control exposure to risk and deliver safe and effective aviation operational capability'.[5] In October 2006, the then Director DASC commissioned research to examine military human factors, to provide a foundation for both future human factors policy and training. The focus was on gaining knowledge of the understanding, relevance and application of human factors within UK military aviation, as perceived by those currently conducting military aviation activities. The first stage was completed with delivery of a research report in August 2007. This article presents a condensed version of the Report, explaining the research process, and discussing the main research findings.

How the Research was Conducted

Within civil aviation there has been considerable empirical research into human factors awareness, attitudes and behaviour, often as justification for the continuation of human factors training. Awareness of, and attitudes towards human factors have shown improvement following training[6] but decay over time, and it has been difficult to demonstrate any clear impact on safety.[7] Within civil aviation, the main concern remains 'ensuring what is taught in CRM courses...transfers to the flight deck and... improves operational performance'.[8] While there are similarities between military and civil aviation, and some human factors might remain valid, there are also considerable differences particularly within the operational context. Replicating previous studies was therefore discounted in favour of an exploratory approach to gain a greater level of understanding of human factors issues within UK military aviation.

A multiple case study used six homogeneous groups: fast-jet aircrew; helicopter aircrew; multi-engine aircrew; training aircrew; engineering personnel, and Air Traffic Control/ Fighter Control/Ops personnel. Within each group, participants were selected to reflect a wide range of experience levels that reflected a wide range of military ranks, because 'any common patterns that emerge from great variation are of particular interest and value in capturing the core experiences and central, shared aspects or impacts of a program'.[9] An anonymous open questionnaire obtained participant's perceptions of human factors issues, enabling free expression of views in response to a range of broad questions about understanding, relevance and application of human factors. In addition, a single empirical question was used to rate the relevance of a variety of human factors. An unusually high level of response was achieved;[10] indicating the level of importance attached to human factors issues by participants.

While minor differences emerged between groups, three major issues were apparent, and these similar phenomena enabled the production of a single narrative using a case-comparison research methodology most notably used to investigate the Challenger Space Shuttle disaster.[11]

Discussion of the Research Findings

Three main findings emerged:

- First, the term human factor is broad-ranging but lacking definition. More clarity of both meaning and purpose are essential, not only in terms of understanding where we are now, but also in identifying how the human factors endeavour might develop in the future.
- Second, realizing any potential improvements in safety that might be offered by bringing increased clarity and purpose to human factors appears dependent on the prevailing safety culture that influences both organizational and individual commitment to safety initiatives. Further examination of the requirements for a successful safety culture is therefore necessary.
- Third, current human factors training provides knowledge that is often perceived as interesting, but there are clear difficulties in linking knowledge of human factors theory to practical application that offers solutions to perceived human factor issues in the workplace. Training as currently envisaged and delivered has practical limitations, and a more effective solution needs to be sought. Each of these issues is discussed in turn, supported by brief illustrative data excerpts, presented as participant's own voice denoted by hand-script.

Bringing Clarity to Human Factors

Frequently, human factors are examined from an external theoretical perspective, but this approach does not necessarily provide understanding from the practitioner's perspective. This research identified two broad meanings of the term human factors in general use: a term used to describe a wide-ranging variety of issues that relate to and potentially affect human performance, and a term used as the cause of occurrences. A third meaning of the term, as a means of reducing safety occurrences was noted by a minority.

Defining Human Factors

The broad nature of 'human factors' was shown by both empirical and qualitative data. A 5-point Likert Scale was used to determine participant's rating of the relevance of a 28 potential individual factors, including the 12 human factors currently used in flight safety publicity, termed the '*Dirty Dozen*'. These ratings are at Table 1.

The factors listed above are unlikely to be exclusive, and it is notable that **new** factors of 'attitude', 'family' and 'unit leader' were also rated 'highly relevant'. More clarity is necessary to further understanding of this wide range of issues.

The term human factors 'encompasses many things such as human error, situational awareness, communication, and decision-making'. Situational awareness, communication, decision-making and teamwork are currently described as 'human factor competencies', but this is misleading as a competency, once acquired, should be capable of being consistently reproduced, observed and measured following appropriate training.

Rating	5 (High)	4	3 (Medium)	2	1 (Low)
Factors	Attitude	Aggression	Ability	Beliefs	
	Awareness*	Assertiveness*	Fear		
	Complacency*	Brief/Debrief	Lifestyle		
	Communication*	Knowledge*	Loyalty		
	Distractions*	Motivation	Norms*		
	Family	Task	Personal Relations		
	Fatigue*		Rank		
	Pressure*		Regulations		
	Resources*		SOPs		
	Stress*				
	Teamwork*				
	Unit Leader				

Table 1: Modal Ratings of the Relevance of Human Factors (Dirty Dozen highlighted by asterisk).

This table places factors in perceived order of importance, and factors assessed as highly relevant are perhaps predictable. More significantly, all factors except 'beliefs' were rated medium relevance or higher, confirming the broad range of issues under the single human factors label.

A more accurate term is **outcomes**, as achieving the required outcome is dependent on a combination of individual factors that is likely to be unique within any particular context, and achieving any of these outcomes that are essential for flight safety is therefore highly context-dependent.

Three distinct types of human factors combine to influence the achievement of outcomes. **External factors** include tasking, resources, distractions and the prevailing operating environment. External factors are frequently imposed on an individual by the organization and organizational structure in which an individual works. The effect of external factors is to create pressure on an individual that manifests as either mental stress or physical fatigue. Pressure, leading to stress and fatigue are termed **conditional factors**, as their level and subsequent effect may vary considerably depending on context. Finally, within every individual reside a variety of internal factors including knowledge, experience, ability, cognitive capacity and other psychological characteristics. Internal factors are always present and are influenced by conditional factors within context. **Internal factors** may also generate feedback into both external and conditional factors, for example through task review or risk assessment. These three types of factors are closely inter-related. Table 2 shows individual factors re-grouped into this classification, together with outcomes.

The relationship between these groups is illustrated by data excerpts. In many areas of military aviation there is 'the requirement to try and maintain output with dwindling resources and reduction of experience' that results in 'personnel being overworked, and manpower being stretched to the maximum. Fatigue is a serious problem'. In addition 'tasks keep increasing...and it's all operational tasking' and 'the word 'operational' is quite often misused to bend or break regulations that are designed to be a safety net'. There is also a 'great deal of pressure outside primary duties, many distractions' that is described as 'the constant and relentless deluge of trivia...Promotion Board obsession with secondary duties means that people cannot devote time to becoming really good at their jobs'. Within military aviation, external factors often generate multiple competing goals, with insufficient time and resources, and there are a variety of distractions. Consequently both stress and fatigue may result, and may impair the use of internal factors, giving rise to incomplete or erroneous outcomes that may endanger flight safety. Individuals consider the potential impact of external factors but there is not an effective regulatory mechanism. Consequently most consideration at individual/unit level is given to conditional factors where 'stress and fatigue are the major factors, especially with today's operational role'.

During operations, there is awareness that 'higher risk may be acceptable' but this leads to 'more Op focus, less HF focus', implying a straight choice between operational and human factor requirements. There are 'enormous pressures put on crew to complete the task' with 'more 'press-on-it-is' from commanders not wanting to fail in tasking and therefore 'during deployed ops they [human factors] seem to be set aside'. This clearly suggests prioritisation of external factors, with the resulting increase in stress and fatigue being passed to the individual. Also 'tasking comes first – if there is time then human factors are considered. If something goes wrong, then human factors come back to the fore', suggesting that external factors are not necessarily challenged until an accident or incident occurs, and that the focus of human factors is on the individual rather than the organization. The apparent inability to regulate external factors leads to the view 'I don't think it's taken seriously by commanders. We on the shop floor are well aware of the consequences of pressure/distractions/fatigue etc, but our concerns don't seem to be shared by the hierarchy'. It was noted that 'often on ops all the trivia is removed, you are properly supported, and you can focus on doing your job', a situation that appears desirable in all military aviation contexts.

Current human factors policy[13] focuses on achieving outcomes at an individual level, and whether this produces any tangible benefit is not clear. Any gains that might be achieved from an individual approach will be more difficult to realize unless external factors and their subsequent effect on conditional factors are adequately controlled.

External Factors	Conditional Factors	Internal Factors	Outcomes
Distractions*	Pressure*	Ability	Communication*
Family	Stress*	Aggression	Crew Co-operation
Lifestyle	Fatigue*	Assertiveness*	Decision-making
Norms*		Attitude	Leadership
Personal Relations		Awareness*	Situation Awareness
Rank		Complacency*	Teamwork*
Regulations		Fear	
Resources*		Knowledge*	
SOPs		Loyalty	
Task		Motivation	
Unit Leader			

Table 2: Factor Groups and Outcomes (Dirty Dozen highlighted by asterisk).

Human Factors and Human Error

While some participants associate human factors with the prevention of accidents and incidents, the prevailing view is that 'human factors are used to describe circumstances during an incident that are **caused** due to human error'. This view is unsurprising as it drives the rationale to reduce the 70% of accidents perceived as being attributable to human factors. The 'retrospective analysis of human performance is dogma and doctrine in aviation when assessing system performance and conducting safety breakdown investigations',[14] and the inevitable starting point for any safety investigation is an accident or incident. Today, 'the term 'human factors' embraces a far wider range of individuals and activities than those associated with the front-line operation of a system' [15] but nonetheless the search for causes tends to stop when we can find the human or group closest to the accident who **could have acted differently**...that would have led to a different outcome. These people are seen as the source or 'cause' of the failure.[16]

The label human error explains little and working back, the next consideration is inevitably potential failure of outcomes. The terms effective communication, complacency, crew co-operation, CRM, decision-making, situation awareness, teamwork were introduced by 'human factors professionals to…cover and explain large portions of human behaviour'[17] and are now frequently used as causal explanations. Further investigation expands the apparent cause to indicate 'distraction of attention' or 'lack of concentration'.[18] This approach is described as 'the old view of human error'[19] where human error is assumed to be the cause of accidents, and evidence for errors, mistakes or inappropriate behaviour is sought, and bad decisions, poor assessments and departures from SOPs are highlighted. Safety can be improved by procedures, training and discipline, and a reporting policy is one of the dominant safety features[20] to enable 'lessons' to be learnt from previous incidents.

There Are Difficulties with this Position

The widespread use of a range of terms (complacency, decision-making, situation awareness etc) to explain complex human performance is 'intuitively meaningful',[21] but the briefest consideration reveals that these terms do not specify any underlying processes, and while these terms may indicate what happened, they do not explain why. These terms are commonly 'endowed with the necessary causal power without any specification of the mechanism responsible for such causation',[22] and their use simply substitutes one label for another. This difficulty is perpetuated by many reporting systems, where statistics show 'categorically' how such issues as loss of situation awareness, breakdowns in communication and defective decision-making result in human errors leading to incidents or accidents. This circular argument is incapable of explaining why the accident or incident occurred, but provides statistics supporting the continuation of the '70% quest', and training programmes designed to remedy this apparent malady.

Perhaps most pernicious is the continued focus on the individual as the 'cause' of human error. After the occurrence judgments of causal attribution are made with knowledge of the outcome and the benefit of hindsight[23] and 'it is always easy to be wise with the benefit of hindsight, but it is questionable whether such wisdom serves other than for the allocation of blame'.[24] By following this course we react, after the fact, as if the knowledge we now possess was available to the operators then. This oversimplifies or trivializes the situation confronting the practitioners, and masks the processes affecting practitioner behaviour before the fact. As a result, hindsight and outcome bias blocks our ability to see the deeper story of systematic failures that predictably shape human performance.[25]

The achievement of safe flight can not be captured as a set of rules or procedures, of simple empirical observable properties, of externally imposed training or management skills, or of decomposable cognitive or behavioural frames.[26] Rather, safety is constructed through a dynamic interaction between front-line operators, their supervisors and commanders, and the prevailing operational and organizational conditions. All of this takes place within the culture, particularly the safety culture of the organization:

> A contemporary safety paradigm should therefore consider errors as symptoms rather than causes of safety breakdowns, because error-inducing factors are latent in the context, largely bred by the balancing compromise between safety and production.[27]

Human error and de facto human factors should be seen as the starting point for any safety investigation, rather than the cause. Fundamental to this view is the principle of 'local rationality'[28] that argues that individuals within a local and specific context act rationally given their knowledge, their resources, their task and their view of the prevailing environment. To argue against this position would be to accept widespread irrationality within military aviation. Focus must therefore shift from the search for a human error that caused an incident, to a search to 'understand how limited knowledge (missing knowledge or misconceptions), how a limited and changing mindset, and how multiple interacting goals shaped the behaviour of the people in the evolving situation'.[29]

Photo: Cpl Eric Jacques

This approach is described as 'the new view of human error'[30] where errors are indications of competing goals and organizational pressure, where there are assumptions that systems are not inherently safe but rather, people within those systems have a central role in creating safety. A number of participants commented that they were surprised there were not more accidents particularly considering current operational demands. During peacetime training, the military aviation accident rate remains low, and it is also clear that many are highly capable of adapting to difficult operational situations to enable the task to be achieved as safely as possible. For the majority of the time, the necessary outcomes that ensure both safe operation and task completion are being achieved, and suggesting strong support for the notion that people create safety.

There are two implications within this view:

First, attention must be focused on 'beginning to understand how operational people see and create safety in practice'[31] and more research is necessary to further our understanding into how successful flight safety is achieved: 'what we need to understand better are the success stories to see if we can somehow 'bottle' their mechanisms and export them.'[32] Second, 'the same mixture of causes is unlikely to recur; efforts to prevent the repetition of specific active errors will only have limited impact on the safety of the system as a whole. At worst, they merely find better ways of securing a particular stable door once its occupant has bolted.'[33]

Searching for the 'cause' of a human factor occurrence is not productive. Rather, the underlying reasons why occurrences happen must be sought. Gaining a deeper level of understanding is more difficult and time-consuming, but may detect systemic patterns of failure that can be subsequently addressed. Organizational reporting should follow a similar approach for human factors occurrences, enabling the organization to learn and respond appropriately. The willingness of an organization to learn is an essential part of its safety culture.[34]

Requirements for a Successful Safety Culture

There is currently a stated requirement for a just culture[35] however, for a successful safety culture three requirements are necessary:[36] 'a reporting culture, a just culture, and a learning culture.'[37] A 'just culture' by itself is necessary, but not sufficient for a successful safety culture. Safety culture is a relatively recent introduction that can be traced back to the Chernobyl accident in 1986, and there are two essential and common features: that attitudes and opinions about safety are shared at both individual and organizational levels; and that there is stability over time.

Perceptions of the current safety culture lie on a continuum between an outright blame culture where 'safety culture = blame culture & hang the culprit' and a culture that enables 'no blame reporting'. Some view the balance as moving towards a just culture but the current safety culture remains 'varied, some incidents/accidents seem to attract a 'no blame' approach, but others seem to be more directed to 'getting' the individual/system without working into the wider picture affecting service life, particularly busy, under-resourced areas'. The considerable variation in attitudes and opinions about the safety culture indicate that the first essential feature, consistent, shared views, has not yet been established.

Trust, Reporting and Just Cultures

The first requirement[38] for a safety culture is to establish trust, as trust[39] is an essential requirement all three constituents of a safety culture. A just culture encourages the provision of safety-related information by individuals within the organization, but it must also clearly delineate acceptable and unacceptable behaviour. This is not the same as a no-blame culture where 'a blanket amnesty on all unsafe acts would be seen to oppose natural justice.'[40]

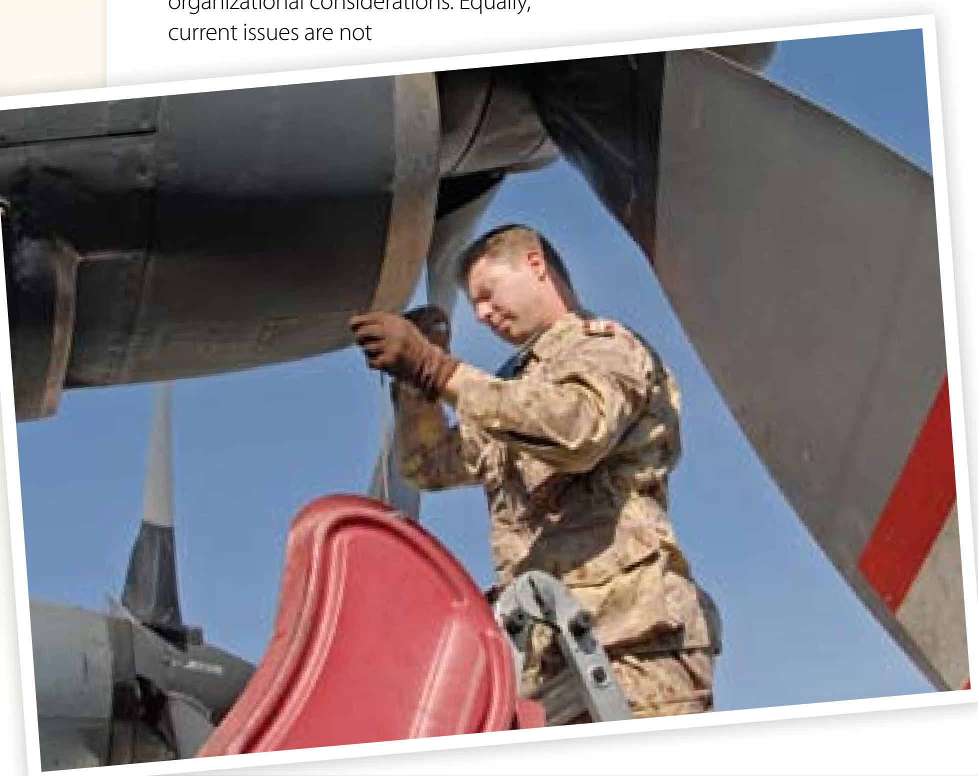
With a just culture in place, a reporting culture becomes viable. Within UK military aviation, a reporting culture has been established for some time and at surface level, some degree of trust appears present. Nonetheless, while some perceive the safety culture to be improving, others still perceive a blame culture to be in existence, and levels of trust and distrust[41] appear variable, and consequently useful or perhaps critical information is being withheld. The existing reporting culture may therefore not be as good as it might be.

Organizational Commitment and Learning

A number of participants commented that higher levels of the military aviation organization do not take flight safety and human factors as seriously as aviation practitioners. Perhaps there is awareness of current issues but little can be done because of higher organizational considerations. Equally, current issues are not effectively reaching an appropriate organizational level for consideration. Both situations suggest organizational communication is less than fully effective and this does not enhance existing safety culture.

Perhaps the most critical issue for safety culture is an effective organizational learning culture that has two components: it must be 'flexible...in the face of a dynamic and demanding task environment' and have 'the willingness and competence to draw the right conclusions from its safety system, and... to implement reform when it is required.'[42] There is widespread understanding that during operations and other demanding environments there is a need for change to 'peace-time' rules and procedures, yet great reliance is placed on 'a massive 'can-do' attitude which means going outside the rules and regulations' to ensure that the task is completed. This does not suggest organizational flexibility.

Discussion has already highlighted the predominant way in which human factor occurrences are investigated and categorized, and how this could be changed to ensure better understanding of the organizational and systemic reasons why these events occur. Maintaining focus on human factors alone may avoid difficult organizational questions, but it also blocks the ability of an organization to learn and improve.[43] It is important to get behind appearances to access organizational processes however, 'this approach to safety inevitably meets resistance'[44] as it rejects the reduction of safety to simple numbers, the very numbers that continue to fuel the misguided '70% quest'. Without this level of understanding the right conclusions from safety occurrences are unlikely to be drawn, and organizational learning is problematic. A 'process of feedback, learning and adaptation should go on continuously across all levels of an organisation.'[45] It is essential that an organizational learning culture, the third part of the triad necessary for a successful safety culture, is fully developed.



More Effective Training

Participants views on current human factors training varied considerably, ranging from 'very useful and thought provoking' to 'very boring, feel like falling asleep when most of it is PowerPoint', highlighting considerable variations in the quality of training. Early exposure to training is 'useful as it highlighted HF from early stage of career' but for others, 'by the time I got to a workplace, the lessons learnt were forgotten' and timing of initial training is also a consideration. More importantly, human factors 'is introduced but not developed' with subsequent training being 'limited, very much self-help' and follow-on training is just one of many competing training demands that 'took me from my place of work thereby reducing the time available to do my job'. This suggests a lack of appropriate follow-on training. It was also noted that *human factors* training continues to be largely focused on aircrew, at the expense of other aviation roles, making it less relevant and engaging. Most importantly, it was noted that training focused on 'how to identify human factors and not enough on how to solve them' and that *human factors* training is 'not as useful as gaining personal experience of HF events'. These latter points are of considerable importance as they not only reinforce the extant retrospective approach that identifies human factors post-occurrence, but also highlight the difficulty in making links between human factors theory and practical application. The inability of current human factors training to provide solutions was a recurring issue with considerable implications.

Current Approach to Training

The Joint Service Systems Approach to Training[46] is widely used within the armed forces and is a systematic process using a behaviourist approach, where output following training is both observable and measurable. Training objectives define what trainees should be able to do and the overall aim is to develop 'competencies'. The behaviourist approach uses principles of reduction and reinforcement to shape learning, and has been used extensively for the development of low level psychomotor skills,[47] and has also influenced programmed learning and computer based training.There are considerable difficulties in approaching human factors training in this way.

As discussed, human factor outcomes are the product of an often-unique combination of external, conditional and internal factors that are highly context-dependent. There is no clearly defined process, and it is difficult to reduce outcomes to consistently occurring component parts. Many outcomes are the product of automatic internal processes, and in normal use to save mental resources, 'people tend to satisfy rather than optimise, settling on a solution that is good enough even though it may be sub-optimal'.[48] Unless outcomes fail, they are largely resistant to observation and cannot be measured against a pre-determined standard. Consequently, situation awareness, satisfactory decisions, effective communication and co-operation cannot be classified as 'competencies' that can trained and the 'Systems Approach' is inappropriate for human factors training.

Current human factors training is designed to provide knowledge about the various factors involved, based on an assumption that training provides effective learning. The provision of knowledge by itself does not usually offer solutions and 'transfer of learning has been a major issue in...training and development...for many years'.[49] There is considerable difficulty in translating current human factors training into practical application, strongly suggesting that theory-practice links are either not being, or cannot be made. This situation is prevalent throughout aviation where despite mandated initial and annual refresher courses within commercial aviation there remains considerable concern that human factors 'training' has not been seen to transfer to the cockpit (and other associated areas of aviation).[50] Training as currently envisaged is not effective.

An Alternative Approach to Human Factors Training

It could be argued that in the 'new view' of human error, with less focus on individual error, there is little point continuing individual human factors training. While the focus of the 'new view' also encompasses systematic and organizational issues, prevention of individual error clearly remains important for flight safety. Training needs to be changed, but not abandoned. Analysis suggests many view their experience of human factors occurrences as more useful than training, suggesting learning occurs through experience, leading to increased professional expertise. This emphasizes the difference between training and learning where 'training is often based on the prediction of outcomes...whereas learning can lead to...increased motivation and self-confidence, changing attitudes and insights which shape future actions'.[51] The underlying concepts that lead to successful outcomes appear to be strengthened through experience, but are as yet unknown, and further research is necessary to gain a deeper understanding of how flight safety is achieved, and what these underlying concepts are. Few would deny that progression towards professional expertise in all aviation domains is highly desirable, and while progression can be achieved through experience alone, this requires an extended time period to achieve. Consequently, in many occupations following basic training, continued professional development is used to reduce the timescale necessary to achieve higher levels of performance.

A Spiral Curriculum

Adult learners 'like their learning activities to be problem centred and to be meaningful to their life situation, and they want the learning outcomes to have some **immediacy of application**'.[52] This was also a common theme within this research. When the underlying concepts necessary for the production of successful outcomes are identified, they might be used within continued professional development to improve performance towards expert status. Professional development must introduce underlying concepts and the knowledge necessary to support those concepts at an early stage, and subsequent learning activity must be centred on the application of those concepts to real-life situations, and in particular to the resolution of new and novel situations. This professional development concept is termed the spiral curriculum, and while the spiral curriculum was previously mooted,[53] its suggested use was for **topic-based** 'training' using the Systems Approach, already argued as inappropriate. An effective spiral curriculum[54] requires initial understanding of essential key concepts, and subsequent application of these key concepts in increasing depth to novel situations, with the goal of enabling generative learning to occur. A concept-based spiral curriculum therefore offers a potential and practical solution to the military requirements for human factors training.

In Conclusion

Three key issues for military human factors emerged from this research. Much human factors attention is focused on the individual, but every individual operates within the wider military aviation organization that can have considerable impact on individual performance. The close relationship between external, conditional and internal factors that lead to successful human factors outcomes and safe flight has been highlighted. This close relationship suggests that focus should not remain on the individual as the cause of human error, but rather that deeper levels of understanding of both systemic and organizational issues are also necessary to gain knowledge of why occurrences happen. Safety culture appears to be improving, but a just culture has not yet been achieved and current reporting systems are not optimised. Critical to a successful safety culture is the establishment of an effective organizational learning culture that would connect all organizational levels involved in the aviation endeavour with the achievement of safe flight. Training as currently delivered is only partially effective due to difficulty in making theory-practice links. The basis for training should not remain solely wedded to past failures, but should also seek to exploit the considerable successes demonstrated by the achievement of a high level of military flight safety in often difficult and very demanding circumstances.

References

Amalberti, R. (2001) 'The paradoxes of almost safe transportation systems', *Safety Science*, 37, pp.109-26.

Antonacopoulou, E.P. (1999) 'Training does not imply learning: the individual's perspective', *International Journal of Training and Development*, 3(1), pp.14-33.

Antonacopoulou, E.P. (2001) 'The Paradoxical Nature of the Relationship between Training and Learning', *Journal of Management Studies*, 38(3), pp.327-50.

Besnard, D., Greathead, D. and Baxter, G. (2004) 'When mental models go wrong: co-occurrences in dynamic, critical systems', *International Journal of Human-Computer Studies*, 60(1), pp.117-28.

Brookfield, S.D. (1986) *Understanding and Facilitating Adult Learning*. Buckingham, Open University Press.

Burns, C., Mearns, K. & McGeorge, P. (2006) 'Explicit and Implicit Trust Within Safety Culture', *Risk Analysis*, 26(5), pp.1139-50.

Cheetham, G. & Chivers, G. (2001) 'How professionals learn in practice: an investigation of informal learning amongst people working in professions', *Journal of Industrial Training*, 25(5).

Cooper, G., White, M. & Lauber, J. (1980) 'Resource management on the flightdeck', *Proceedings of a NASA/Industry Workshop (NASA Conference Proceedings-2120)*, NASA-Ames Research Center, Moffatt Field, CA.

Dekker, S.W.A. (2002) *The re-invention of human error*, Technical Report 2002-01, Lund University School of Aviation, available from http://www.lusa.lu.se/o.o.i.s/6131 accessed 10 May 2007.

Dekker, S.W.A. (2003a) *Human Factors in Aviation – A natural history*, Technical Report 2003-02, Lund University School of Aviation, available from http://www.lusa.lu.se/o.o.i.s/6131 accessed 10 May 2007.

Dekker, S.W.A. (2003b) 'Illusions of Explanation: A Critical Essay on Error Classification', *The International Journal of Aviation Psychology*, 13(2), pp.95-106.

Dekker, S.W.A. & Hollnagel, E. (2004) 'Human factors and folk models', Cognition, *Technology & Work*, 6, pp.79-86.

Flin, R., O'Connor, P. & Mearns, K. (2002) 'Crew resource management: improving teamwork in high reliability industries', *Team Performance Management: An International Journal*, 8(3/4), pp. 68-78.

Gordon, R., Flin, R. & Mearns, K. (2005) 'Designing and evaluating a human factors investigation tool (HFIT) for accident analysis', *Safety Science*, 43, pp.147-71.

Gorton, A.P. (2005) Report on the *Scoping Study of Human Factors Training in the RAF*, Central Flying School Flying Training Development Wing, RAF Cranwell.

Green, R.G., Muir, H., James, M., Gradwell, D. & Green, R.L. (1996) *Human Factors for Aircrew*. Aldershot, Ashgate Publishing Ltd.

Helmreich, R.L. & Merritt, A.C. (2000) 'Safety and error management: The role of Crew Resource Management', in B.J. Hayward and A.R. Lowe (eds.), *Aviation Resource Management*, Aldershot: Ashgate.

Höpfl, H. (1994) 'Safety Culture, Corporate Culture: Organizational Transformation and the Commitment to Safety', *Disaster Prevention and Management*, 3(3), pp.49-58.

Lewicki, R.J., McAllister, D.J. & Bies, R.J. (1998) 'Trust and distrust: New Relationships and Realities', *Academy of Management Review*, 23(3), pp.438-58.

Maurino, D. E. (1999) 'Safety Prejudices, Training Practices, and CRM: A Midpoint Perspective', *The International Journal of Aviation Psychology*, 9(4), pp.413-22.

Maurino, D. E. (2000) 'Human factors and aviation safety: what the industry has, what the industry needs', *Ergonomics*, 43(7), pp.952-959.

Parker, D., Lawrie, M. & Hudson, P. (2006) 'A framework for understanding the development of organisational safety culture', *Safety Science*, 44, pp.551-62.

Patton, M.Q. (1990) *Qualitative Evaluation and Research Methods* (2nd Ed.). London: Sage.

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

Reason, J. (1997) *Managing the Risks of Organizational Accidents*. Aldershot: Ashgate Publishing.

Rochlin, G.I. (1999) 'Safe operation as a social construct', *Ergonomics*, 42(11), pp1549-60.

Salas, E., Burke, C.S., Bowers, C.A. & Wilson, K.A. (2001) 'Team Training in the Skies: Does Crew Resource Management (CRM) Training Work?', *Human Factors*, 43, pp.641-74.

Taylor, S. (2006) *An Advanced Professional Development Curriculum for Developing Deep Learning*. Unpublished Doctoral Thesis, Institute of Education, University of London.

UK Ministry of Defence, Defence Council Instruction, Joint Service 73 (2002) *Joint Services Systems Approach to Training (JS SAT) Quality Standard*.

UK Ministry of Defence, Joint Service Publication 551 (2006) *Military Flight Safety Regulations*, Volume 1, Section 400.

Vaughan, D. (2004) 'Theorizing Disaster. Analogy, historical ethnography, and the Challenger accident', *Ethnography*, 5(3), pp. 315-47.

Woods, D.D. & Cook, R.I. (1999) 'Perspectives on Human Error: Hindsight Biases and Local Rationality', in F.T. Durso (ed.), *Handbook of Applied Cognition*, New York: John Wiley & Sons, pp.141-71, available from http://csel.eng.ohio-state.edu/woods/error/app_cog_hand_chap.pdf accessed 22 Feb 07.

Woods, D.D. & Cook, R.I. (2002) 'Nine Steps to Move Forward from Error', *Cognition, Technology & Work*, 4(2), pp.137-44.

Notes

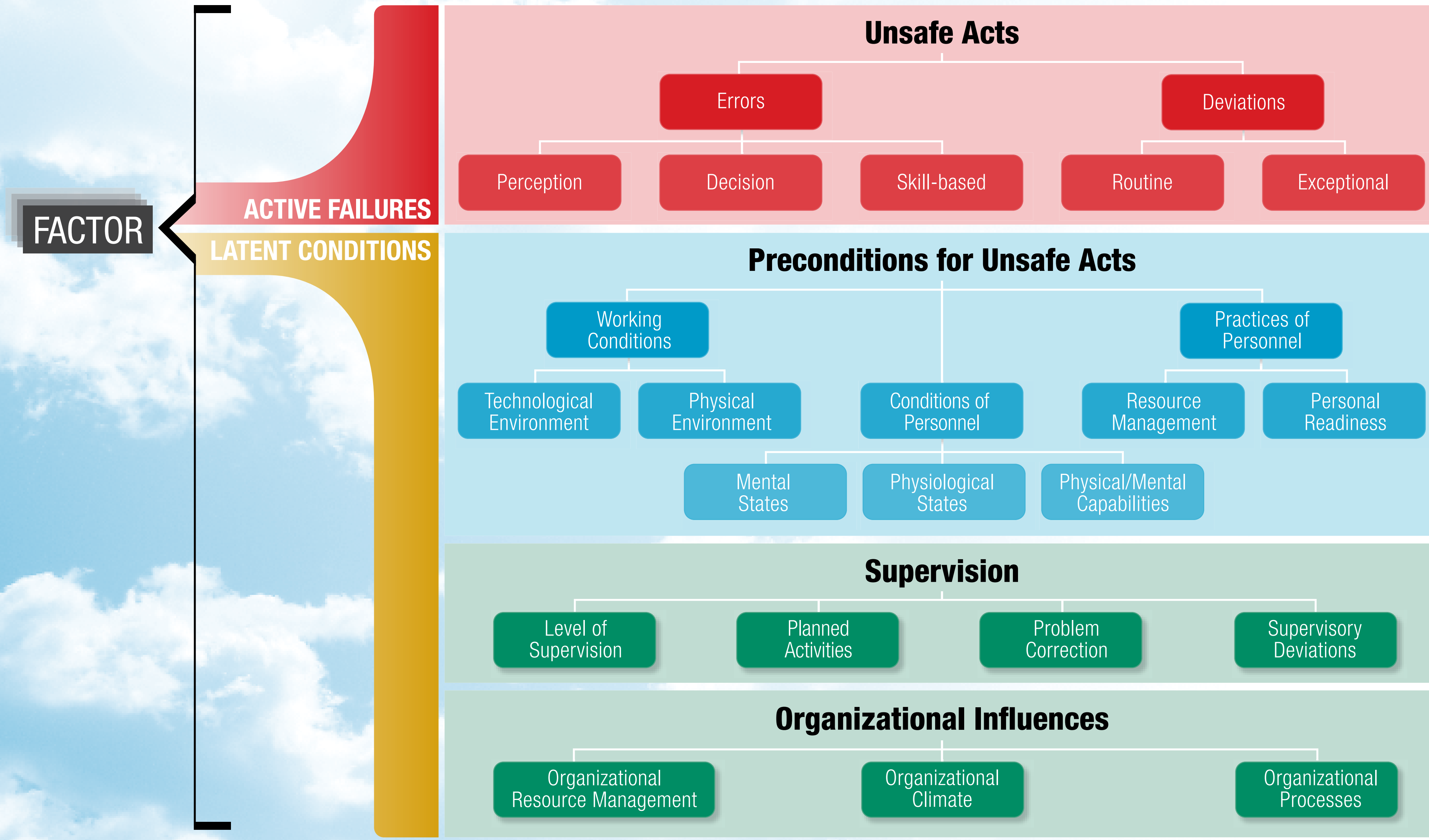
1. Woods & Cook, 1999, p.142.
2. Cooper *et al*, 1980.
3. Helmreich *et al*, 1999, p.19.
4. Green *et al*, 1996, p.ix.
5. JSP551, Vol 1, Sect 400, p.1.
6. Helmreich & Merritt, 2000.
7. Salas *et al*, 2001.
8. Flin *et al*, 2002, p.76.
9. Patton, 1990, p.172.
10. Greater than 84%.
11. Vaughan, 2004.
12. Woods and Cook, 2002.
13. JSP 551, 2006.
14. Maurino, 1999, p.413.
15. Reason, 1990, p.174.
16. Woods & Cook, 1999, p.143, original emphasis.
17. Dekker & Hollnagel, 2004, p.79.
18. Gordon, Flin & Mearns, 2005, p.151.
19. Dekker, 2002, p.3.
20. Amalberti, 2001.
21. Dekker & Hollnagel, 2004, p.79.
22. *ibid*, p.80.
23. Woods & Cook, 1999.
24. Maurino, 2000, p.954.
25. Woods & Cook, 1999, p.147.
26. Rochlin, 1999, p.1558.
27. Maurino, 2000, p.956.
28. Woods & Cook, 1999.
29. *ibid*, p.10.
30. Dekker, 2003a, p.9.
31. Dekker, 2003b, p.104.
32. Maurino,1999, p.417.
33. Reason, 1990, p.174.
34. Reason, 1997.
35. JSP 551, 2006.
36. Reason, 1997.
37. Burns *et al*, 2006, p.1139.
38. Helmreich *et al* 1999.
39. No division is made between explicit and implicit trust: for further discussion see Burns *et al*, (2006).
40. Burns *et al*, 2006, p.1140.
41. Trust and distrust are sometimes viewed as a bipolar construct, but recent research suggests these are 'separate but linked dimensions' (Lewicki *et al*, 1998, p.439).
42. Parker *et al*, 2006, p.552.
43. Woods & Cook, 2002.
44. Höpfl, 1994, p.56.
45. Woods and Cook , 2002, p.140.
46. DCI JS 72, 2002.
47. Cheetham & Chivers, 2001.
48. Besnard *et al*, 2004, p.119.
49. Antonacopoulou, 1999, p.18.
50. Salas et al, 2001; Flin et al, 2002.
51. Antonacopoulou, 2001, p.340.
52. Brookfield, 1986, p.31, emphasis added.
53. Gorton, 2005.
54. Taylor, 2006.

Photo: WO Serge Peters

SECTION **TWO**

SECTION TWO **HUMAN FACTORS DESCRIPTION**

Human Factors Analysis and Classification System



Human Factors – **Introduction**

FACT: *In this day and age, when asked: "In your opinion, what would you say caused or contributed to this accident?", more often than not aircrew and ground crew alike, as well as witnesses, stakeholders or outside observers, still throw on the table, often without hesitation, the archaic expression: **"Pilot Error"**!*

Human Factors 101

By Major Martin Clavet, Directorate of Flight Safety, Ottawa

Pilot Error

Errare humanum est. To err is human. That is a fact of life, and it will not change in the near future. All right then, let's pack our things and go home. The pilot was flying, and the aircraft crashed. So it must be "Pilot Error". Or is it?

Yes, human error continues to plague modern aviation, both military and civilian. Yet, simply writing off aviation mishaps as "Pilot Error", or even "Technician Error" or "Controller Error", is a simplistic, if not naive, approach to mishap causation. Mishaps cannot be attributed to a single cause, or in most instances, even a single individual. Rather, accidents are the end result of a myriad of latent and active failures, the overall cause factors.

Personnel Cause Factors

A cause factor could be defined as being any event, condition, or circumstance the presence or absence of which, within reason, increases the likelihood of a flight safety occurrence. If we refine it a little more, looking at "personnel" cause factors, as opposed to material or environmental cause factors, is looking a "Human Factors" per se.

When an accident or unsafe condition involves personnel, the study of "Human Factors" comes into play and has shown that there are two general categories for the causes associated with the situation. These categories are referred to as "active" and "latent" causes. Flight Safety investigations need to identify both the active and latent causes for occurrences and hazards so that effective preventive measures can be implemented to reduce the likelihood of recurrence.

Active and Latent Cause Factors

Active failures (or causes) are errors, events or conditions **directly related to** the occurrence. Usually active causes are the last action leading to the condition or act. They are traditionally referred to as "Pilot Error" or something similar, i.e. the so-called "unsafe acts" committed last by individuals, often with immediate and tragic consequences.

Latent failures (or causes) are, on the other hand, events, circumstances or errors associated with the individuals, or conditions present anywhere in the supervisory chain of command or the system of management of the individuals, which **predispose to** the tragic sequence of events characteristic of an accident. For example, it is not difficult to understand how tasking crews at the expense of quality crew rest, can lead to fatigue and ultimately errors (active failures) in the cockpit. Viewed from this perspective then, the "unsafe acts" of aircrew are the end result of a chain of causes originating in other parts (often the upper echelons) of the organization. Latent causes **contribute to** the final sequence of events of the occurrence or hazard by predisposing it to happen. Though they are not the direct cause, **they can have as much of an impact on the negative outcome as the direct cause, or active failure**. The problem is that these latent failures **may lie dormant or undetected** for hours, days, weeks, or longer until one day an "unsafe act" occurs or an "unsafe condition" is recognized, which can bite the individual who then makes the active failure.

Looking at the "Human Factor" causal model as a whole, it can be seen that active cause factors can be the end product of a long chain, the roots of which originate in other parts of the organization (latent causes). For instance, latent failures such as fatigue, complacency, illness, and the loss of situational awareness (SA) all effect performance but can be easily overlooked. Likewise, supervisory practices can promote unsafe conditions within operators and ultimately unsafe acts will occur.

But the idea is not to stop at the supervisory level either, the organization itself can impact performance at all


Photo: Sgt Paz Quillé

levels. For instance, funding could be cut and as a result training and flight time is restrained. Supervisors are therefore left with tasking "less-proficient" aircrew with, sometimes, complex missions. Not surprisingly, causal factors such as task saturation and the loss of SA will begin to appear and consequently performance in the cockpit will suffer. As such, causal factors at all levels must be addressed if any mishap investigation and prevention system is going to work.

The purpose of flight safety investigations is to identify these active and latent failures in order to understand **why** the mishap occurred and **how** it might be prevented from happening again in the future. The goal is to prevent future accidents through the careful determination of cause and the formulation of recommended preventive measures to mitigate the active and latent failures.

Human Factors

Human Factors means a variety of things to a variety of people. A human engineer might tell you it has to do with crew station design an anthropometry. A physiologist might emphasize the effects of flight, such as altitude, cold, acceleration or movements along a 3-axis reference system, on bodily processes.

A psychologist might tell you that Human Factors has to do with information processing, emotion and motivation. A sociologist will tell you that it concerns personality, life event stresses and social relationships. A life support specialist might emphasize egress systems and life support equipment. In fact, Human Factors includes all that, and even more, which affects human behaviour.

In relation to the Human Factor aspects of aircraft accidents, this suggests that so-called "Pilot Error" accidents can be described, if not explained, in terms of anomalies or deficiencies within one or more of these categories of attributes.

A comprehensive study of Human Factors would therefore include the physical, physiological, psychological, psychosocial and pathological attributes of humans in the context of their influence on the interface of the human with the environment.

The environment includes factors external to the person that determine or modify human behaviour. It also includes the total organizational system design to prepare the person to cope with the external demands.

The interface of the human with the environment consists of the crucial human and environment interactions that proved to be incompatible and ended in an accident.

Wisdom at Last…

Statistics suggest that the greatest single cause of aircraft accidents and incidents is human failure. The human is present at all levels where flight safety is concerned: in the aircraft, on the flight line, in the control tower… even at the decision making level in the office. The key role that the human plays explains why the Human Factor, not the "Pilot Error", by itself or in combination with other factors, is present in as much as 80% of air accidents (if not 100%!). Numbers do obviously depend on the statistical source and how one looks at things; nonetheless, they are huge and cannot be overlooked.

To minimize the reality, importance and salient role that Human Factors have in the investigation of aircraft accidents by the simplistic expression "Pilot Error" would be not only fallacious but also missing the point.

Errare humanum est. To err is human. And one would err if one kept referring to "Pilot Error" as the all inclusive bin into which we could shove anything that goes wrong on the human side of the house when aircraft accidents and tragedy occur.

Photo: WO Serge Peters

Human Factor – **Perception Error**

Perception can be seen as the result of a three steps process: detection, awareness and understanding of the situation. A Perception Error can occur when the individual involved has detected elements (object, threat or situation) of the environment inaccurately (detection failure), whether the misperception is visual, auditory, olfactory, proprioceptive (seat-of-the-pants) or vestibular in nature. However, a Perception Error can still occur even if accurate detection takes place if the individual fails to attend to the information (awareness failure). Even if accurate detection and awareness of the elements are achieved, a Perceptual Error can still occur if absence of, or inaccurate, understanding of their significance takes place (understanding failure). Indeed, experience plays a role at this level, in that the information about the environment is processed by comparing it with what the individual already knows.

Squawk 7700 – An Exercise in Decision Making

By Captain Daniel King, Bio Science Officer, Defence Research and Development Canada, Atlantic

As a Human Factors (HF) aircraft accident investigator, I am often asked how to differentiate between an operator error due to perception issues and just a poor decision made by the operator. I'm also often asked why it is necessary to differentiate between the two. The short answer to the second question is because CF-HFACS dictates that I should but I will talk about why it does.

During my time as a radar air traffic controller, an infrequent phenomenon was a 7700 squawk code with certain VFR and IFR aircraft. If an aircraft declared an emergency, the flight crew would change the aircraft's transponder to squawk 7700. When this occurred, the target representing the emergency aircraft on the radar scope would begin to flash and a loud audible tone would sound to alert the controller that there may be a problem. This is the scenario through which we will navigate to explain the human decision making process.

When a 7700 target begins to flash on the scope and the audible tone sounds, the controller is first at the detection phase of the perception process. During the conduct of an HF investigation, it is important to determine whether or not the individual(s) involved were able to "detect" the cues available from the environment. Asking what they saw, heard, smelled, felt etc is very important. In addition, looking into the individual's physiological condition such as whether or not eye glasses are prescribed or being worn, whether the individual involved suffered from hearing impairments etc is important. It is also prudent to determine whether or not the system worked properly. If there was no flashing target or audible tone generated by the radar system, then it is impossible for the controller to detect them. Let's assume the controller sees the flashing target and hears the tone produced by the 7700 code. We conclude that there was no failure at this initial level of perception (detection) and the controller will then progress to the next level as outlined in CF-HFACS.

After detecting the cues available, the individual(s) must then pay attention to them. This is the awareness level of perception. If the individual(s) is very busy at the time and therefore notices the flashing target and tone but then diverts attention to something else, the emergency situation is not dealt with. Again it is important during an investigation to determine whether or not the individual(s) involved recalls attending to the cues. Information such as what other tasks were being executed at the time could be helpful in determining this. If the individual was busy performing several tasks, it is possible that the cues were detected but not attended to. Someone may recall hearing the emergency tone when the telephone rang and shifted attention to it. Let's assume that the controller detected the flashing target and the audible tone and dedicated sufficient attention to deal with it. We conclude that there was no failure in the second level of perception (awareness) and the controller will then progress to the next level as outlined in CF-HFACS.

To this point, we have a 7700 emergency squawk on the radar scope, a controller that detected the visual and audible indications and paid attention to those indications. What if the controller doesn't know what they mean? This is the next level of perception, namely understanding of the cues detected and attended to. Whether or not the individual(s) understands the cues they are receiving from their environment is an important question to answer during an HF investigation. It is useful to ask the individual(s) involved what


Photo: WO Serge Peters

such a cue / indication means to them and to determine if their understanding is accurate. Let's assume the controller understood accurately the significance of the flashing target and audible tone. According to CF-HFACS we have no failure in perception as we have no failure at any of the three levels. The controller accurately detected the information cues available (detection), attended to the information (awareness) and understood that this flashing target and audible tone indicated an emergency squawk (understanding).

The next step of the process is to use this perception of the situation to make a decision about it and then finally to act based upon the decision taken. Given that an individual(s) has achieved an accurate perception of what is occurring, one would think that a correct and appropriate decision would be made and action chosen. However, this is not always the case.

In our example understanding that the aircraft is having trouble does not ensure that the controller knows what to do about it. The controller may decide on an action and carry it out only to find out that this action does not fix the situation (and in many cases may make the situation worse). Generating a large number of radio transmissions to an emergency aircraft is an approach that the controller may choose. However, controllers have checklists, SOPs and training scenarios to ensure that essential information is obtained from an emergency aircraft with the least amount of RT possible so as not to burden an already extremely busy flight crew. The shortage of knowledge possessed by the controller with respect to how to deal with the emergency aircraft properly, results in a knowledge - based / information decision error (i.e. making too many radio transmissions). Simply stated the controller did not know how to act to achieve the best outcome. During an HF investigation, it may be necessary to have the individual(s) involved explain the proper procedure and identify what information they used to choose that course of action. SOP's, technical orders, tactics and training manuals etc may also need to be consulted to ensure that they are accurate and understandable by all. Let's assume in our example that the controller is well versed in emergency procedures and decides on the correct course of action.

Knowledge – based or information decision errors described above deal with scenarios for which established procedures exist. In aviation, individual(s) also face novel situations for which there are no established procedures. Using our ATC example, while the controller deals with the initial emergency aircraft, a second aircraft declares an emergency and squawks 7700. Both are 20 miles from the aerodrome and the controller must determine which aircraft will be first to land. This is not something that is written in an SOP or a tactics manual. In this case, the decision should be based upon the flight characteristics of the respective aircraft (i.e. speed), the amount of control that the pilot of each aircraft has, the nature of the emergency etc. However, the controller is on duty alone and is controlling 8 other IFR aircraft in addition to the two 7700 ones. The controller sequences the initial emergency aircraft to land first based solely on the fact that it had declared an emergency first. The controller has an accurate perception of the situation and has all of the baseline knowledge to deal with it appropriately but simply bases the decision on one piece of information while not taking all aspects into account in the reasoning or risk - management process. According to CF-HFACS this represents a problem solving or risk management decision error. Questions concerning what else the individual(s) was doing at the time and what the individual(s) intended to achieve with their actions would be excellent starting points to investigate this.

At times of high traffic intensity, (with numerous VFR and IFR targets on the radar scope) several targets can merge together on the scope. Occasionally when this happened the system would generate a false 7700 target complete with target flashing and an audible tone. The immediate response to a 7700 code should be to determine what is occurring and what needs to be done about it. However, due to the fact that the system can generate these false emergency codes from time to time, it is possible for the controller to believe that a real 7700 squawk is just another false indication due to targets merging and therefore simply ignore it. In this case, we have an event (a 7700 squawk) that should have led to a structured response (dealing with


Photo: Cpl Kevin Sauvé

the emergency, checklists etc). However, the situation is misdiagnosed as a false 7700 indication and no structured response resulted. This represents a procedural or rule – based decision error according to CF-HFACS.

Now that we've differentiated between a perception error and a decision error according to CF-HFACS and identified the different types of perception errors and different types of decision errors, it may be asked "what is the purpose of dissecting the event to this level"?

To answer that question we need to look back at why we conduct investigations in the first place. We are attempting to determine what went wrong and to reduce the possibility and/or severity of it happening again. Basically we wish to learn from our mistakes and to institute a "fix". Let's assume that I performed an investigation and reported back to my superiors that I determined that the operator made a bad decision and left it at that. What is the "fix" to that situation? Briefing the individual not to make that bad decision the next time? The point is, the further we define the nature of the error, the more effective is the "fix" that we institute to reduce the possibility and/or severity of it happening again.

In the 7700 squawk example used, if the controller was unable to "detect" the flashing target or unable to hear the audible tone then the "fix" may be to either increase the volume of the tone or the visibility of the flashing target or maybe there was an issue with the controller's vision and/or hearing that would need to be addressed. If the controller accurately detected the visual and audible cues but didn't really attend to them then the "fix" may be in the informed of the individual or the nature of the task. The controller may need to be trained that if these types of cues occur, it becomes of paramount importance to attend to and deal with them immediately. Alternatively, maybe it is determined that the individual didn't attend to the information because the task being performed at the time was too busy. If that is the case either the task may need to be changed or the individual may not have the mental capacity to deal with such complex situations and selection / recruitment issues may need to be addressed. If the controller detects and attends to the cues but doesn't know what they mean, again a training issue may be occurring and the "fix" would be training (however a different type of training than if an awareness error had occurred).

If it was determined that a knowledge-based or information error occurred, manuals or orders may need to be revisited or maybe even training for the task may be required. If a problem-solving or risk management error occurs the task itself may need to be re-evaluated or the individual's ability to think through or risk manage a situation may need to be looked into. If it is determined that a procedural or rule-based decision error occurred in our example, the "fix" may be to rid the radar scope of the ability to generate false 7700 codes or further training / briefings on the importance of treating all emergency indications as real ones until proven otherwise.

The key to getting to the most accurate "fix" is the quality of the information gathered during the investigation. It must be remembered that CF-HFACS is only a tool to be used by investigators to help them navigate through the possible failure mechanisms and is not a substitution for effective investigation / interviewing methods.

Photo: WO Serge Peters

Human Factor – **Decision Error**

Decisions are made to achieve a goal or an intention where the perceived elements are used to initiate the process. Success in achieving this is a function of relevant training and knowledge of the task at hand, the system, operations, tactics, previous exposure, experience and proficiency. Decision Errors represent deliberate and conscious acts and occur when behaviour proceeds as intended, yet the plan proves inadequate or inappropriate for the situation. A decision to achieve the desired end-state is not made appropriately, which results in an unsafe situation. Often referred to as "honest mistakes", they typically represent poor conscious choices, improper procedural selection and application, or the misinterpretation or misuse of relevant information. Insufficient time, inexperience or lack of proficiency, or outside pressures such as overload and task saturation may preclude safe decisions.

Perceived or Actual Pressure?

By Major Gary Cherwonick (retired), Sea King Pilot

Our venerable old Sea King was "maintenance challenged" throughout the first three months of our NATO deployment. The other smaller helicopters ended up doing much of the fleet logistics re-supply missions that would normally have been our role. What had started out as friendly ribbing from our allies was soon replaced by genuine sympathy; our morale was at an all time low.

At about mid-deployment, many members of the ship's company had airline flights booked to fly home for some leave so we detached from the fleet for an extended port visit to the eastern Mediterranean. There, we finally got out of our slump. With a long transit ahead, we only had a three-hour window to pick up a several week backlog of cargo and mail from our logistics airfield. As the ship sailed by south of Italy, we planned to get the goods, with mail as the top priority.

The weather was okay; the seas and winds were relatively calm, both the ceiling and visibility was good and there was a light drizzle. Just prior to take-off, I told the co-pilot to turn the wipers on and clear the windscreen. They swept once and stopped. The windscreen was clear enough and the rain was light, so we decided to launch. Besides, light rain was not a huge problem as airflow would help reduce the water layer and perhaps the wipers would start working later on. If we had shutdown for repairs, our window would be gone and there would be NO MAIL!!!

The first run went reasonably well, despite some minor restrictions to visibility. (The airflow on the windscreen was not as effective as we thought it would be!) On our second return trip to the ship, the rain was heavier, the wind was freshening, and the deck was no longer steady. However, the landing was okay, despite the almost obscured windscreen. With one more trip to go and the weather worsening, we got a meteorology update and were told that the light drizzle and shower were supposed to end soon. As we sat on the deck mulling this over and looking at a very blurry hangar face, the shower started to dissipate, just as we were told. Finally, the weather was good enough to go!

The third outing was somewhat trickier. It became obvious that we had launched in a "sucker hole" earlier. Heavy rain, strong winds, and a rough deck greeted us. With insufficient fuel to fly ashore on our instruments, the ship was our only option. As we hovered over the deck during the hook-up with only peripheral vision and the hangar face only fifteen feet ahead of the rotor arc, I really wished that either the wipers were working or that I wasn't in this scenario. We did get aboard without an incident, and we wrote up a report on the wipers. The ship's company was ecstatic, since mail at sea is a huge morale boost.

We have all either heard about or experienced pressure to get the job done. This pressure is sometimes referred to as "perceived" but, in most cases, when someone perceives pressure to do something, that event is most likely "actual" pressure. What kind of pressure were we under? After a long period of serious aircraft problems, the only problem that day was windshield wipers. To end the mail pick-up when the weather wasn't really that bad, would no doubt be an unpopular choice. Hadn't we mitigated the problem through discussion with all the crewmembers? Not having wipers is a minor nuisance that can easily be overcome – or is it?

What if we had experienced a flight control problem over the rough deck?

After the mission, we analysed the day's events and concluded that the mail issue influenced our decision. We all agreed that most operational missions would have been cancelled without a second thought, but for a mail run it seemed okay at the time. Why? In hindsight, the pressure to launch was predicated on ship's morale and perhaps our desire to restore our sense of purpose and value. Were we influenced by perceived or actual pressure? Does the type of pressure really matter? At what point would **you** have called it a day?


Photo: WO Serge Peters

Photo: Cpl Gayle Wilson

Human Factor – **Skill-Based Errors**

Operation, workmanship or mechanical skills become automatized with extensive practice. As a result, the execution of such activities becomes routine and therefore occurs without significant conscious thought. Skill-based Errors can occur when automatized activity is performed incorrectly. Unlike Decision Errors, which result from intended courses of action, Skill-based Errors are the result of unintended actions. These types of errors can result from Inadequate Technique, Attention Failures or Lapses in Memory. Examples of preconditions that could lead to this kind of error are inadequate proficiency (i.e. degraded or sub-optimal capabilities with regards to procedures and emergencies, limited total experience), lack of appropriate training or a deficient level of currency (i.e. limited recent experience, inability to achieve number of hours to be flown and / or sequence to be performed over a specified period of time, leading to erosion of skills and knowledge) with the task being performed.

Always Go Back to the Attitude Indicator

By Captain Kevin Big Canoe, 429 Transport Squadron, 8 Wing Trenton

For those of us involved in aviation, it does not matter what occupation we are, we all remember some of those important phrases imparted on us during our training. I remember from my Moose Jaw days during the early part of the instrument-training phase, my instructor constantly reminding me to, "always go back to the attitude indicator during your instrument scan." I also remember him saying, "It might even save your life one day." Now just keeping pace with the syllabus was hard enough, let alone perfecting an instrument scan that quite often made me dizzy. Little did I know that very soon after ab-initio and OTU training, I would be reflecting on those words of wisdom that never let you down.

Only months after my Hercules OTU and with only a handful of hours on the aircraft, I found myself part of a very experienced crew during summer Boxtop '03. What a great experience for a young – well, an enthusiastic first officer. The PAR approach in Alert was not yet fully functional and as such, we relied on the NDB approach into Alert. The weather was typical: one half statute mile in light snow with clouds hovering 200 feet off the deck. Not very promising for a non-precision approach, but we had lots of gas and the forecast was to improve with some openings reported from the ground. As we approached Alert without an improvement in the weather, our plan was to shoot three approaches, then return to Thule if we did not get in. I was in the right seat and our alternate weather required the non-precision pilot monitored approach (PMA) – simply – an approach flown from the right seat.

Having not flown a lot on the dials lately, I opted to hand fly the approach in an attempt to take the rust off. Mistake #1. In retrospect, I should have let the autopilot fly the approach. The first approach was safe and effective, which I now believe means, ropey and hang on. We started the second approach after the missed, utilizing the autopilot on the advice from my Aircraft Captain (AC). We entered cloud at 2000 feet MSL and did not see anything as we flew the approach. I started the missed approach, which requires an immediate climbing right hand turn to avoid some cumulus granite at the other end of the runway. While climbing, turning, and retracting the gear, I allowed the aircraft to bank beyond 30° and to level off with a corresponding increase in airspeed. Mistake #2. At the same time I noticed the excessive angle of bank, I heard "BANK" followed by "AIRSPEED" in stereo from the other crew members. Decreasing the bank followed by a slight pull could not stop the airspeed from climbing through 165 kts to 172 kts. Seven knot gear overspeed while in transit. After a third flawless approach, we returned to Thule where the aircraft would require a visual inspection and I would be buying the beverages. The aircraft was fine and the remaining two weeks were uneventful with lots of great experiences and I got some practice filling out my first Flight Safety Report.

Reflecting later that day, I was reminded of those enduring but tried and true sayings. Had my instrument scan been more aggressive, I would not have let the bank angle develop to the point of the gear overspeed. With proficiency becoming an issue in some communities, due to a myriad of reasons, it is imperative that we all reach back from time to time and rely on the training, as well as those words of wisdom, that have been passed on down from those before us. "Always go back to the Attitude Indicator."

Photo: Cpl David McVeigh

Human Factor – **Deviations**

A Deviation represents the wilful disregard of orders, regulations or other rules. Unlike errors, deviations are deliberate. There are two forms of deviation: Routine and Exceptional. The two types are not differentiated by the nature of the act but by whether or not the act had become the norm within the organization, whatever its level.

Routine Deviations *are considered "bending the rules" by individuals and are tolerated or condoned by supervisory / leadership authorities. They are the result of individual behaviour that is known not to follow established rules or regulations (wilful disregard). Routine Deviations tend to be common or habitual behaviours by nature and are often enabled by a system of supervision or management within an organization that tolerates such departure from the rules or regulations. If a Routine Deviation is identified, further investigation up the supervisory chain is required to determine the extent of the acceptance of this behaviour. Routine "work-arounds" and unofficial procedures or habitual deviations of a single individual or small group of individuals within a unit / setting that are condoned by leadership are examples of such Routine Deviations.*

Exceptional Deviations *are isolated departures from established rules or regulations (wilful disregard). They are unusual or isolated to specific individuals rather than larger groups and are not sanctioned or condoned by supervisory / leadership authorities. While most Exceptional Deviations are flagrant, it is important to note that they are not to be considered exceptional because of their extreme nature. Rather, they are to be considered exceptional because they are neither typical of an individual's behaviour pattern nor are they condoned by authority. Signing-off an aircraft repair without inspection, not using the required / authorized equipment, flying an improvised / unapproved low-altitude manoeuvre or conducting a task / mission despite a lapsed currency or without proper qualification or authorization are examples of Exceptional Deviations. In a "just culture", the presence of an Exceptional Deviation should be considered for resolution outside of flight safety.*

The Trick

Author unknown

In the Air Cadet Gliding program it is common for us to try to be as efficient and operational as possible. In our case this means doing as many flights as possible in a day. Sometimes the gliding operation can be sped up without jeopardizing safety, other times it is as efficient as it can get.

One of the "tricks" that I had learned during training was about fuel management. In the Bird Dog (our tow plane) it is common for one of the fuel tanks to empty itself faster than the other. However, when both fuel indicators reach "NO TAKE OFF" no more takeoffs may be performed. Even though the needles indicate "NO TAKE OFF" there is still fuel in both tanks. The "trick" that I was shown was that by draining one tank completely first and then switching the fuel selector to both, a maximum amount of flight time could be obtained. The important thing was to make sure the fuel selector was on both for take-offs and landings.

The operations manuals and flying orders did not say anything against this practice so it seemed like an acceptable way of improving the number of flights possible before re-fueling was necessary.

After my training I continued this practice, in order for us to be more operational. However, one day during gliding operations, while concentrating on the other traffic during my approach I forgot to set the fuel selector back to both for the landing. Everything was going fine, until the flare, when the engine cut out. The aircraft touched down without incident and came to a stop as it would during a normal landing.

I quickly set the fuel selector back to both and restarted the engine and immediately taxied for the fuel pumps. I didn't think too much of it at first, but then I later realized the unnecessary danger that I put myself and those around me in.

Had an overshoot been required, the engine could have flamed out forcing me to land in the trees ahead. Had I been able to do another take-off and possibly forget to put the fuel selector back to both, I would also have been endangering the lives of those on board the glider.

I wasn't the only tow pilot that was routinely following this practice, but I was lucky that it happened without serious incident. Hopefully it served as a lesson for other tow pilots – new and old. The flying orders were amended to ensure that this does not occur again.

Photo: Pte Pierre Theriault

Human Factor – **Physical Environment**

The Physical Environment sub-category is present when the immediate surroundings, such as weather / exposure and workspace, impede the ability of personnel to complete the task / mission effectively. Physical hazards that contribute to the occurrence will also be included in this precondition category.

Ask The Right Questions To Get The Right Answers

By Major Steve Valko, Wing Flight Safety Officer, 4 Wing Cold Lake

The pre-flight ops brief from the duty pilot was all that was required before heading out to the CF-18 for a Monday morning sortie. Parked at the far end of the row was always an annoyance however it was a good opportunity to carry out an initial pre-flight scan of the aircraft, looking for things that just didn't seem right. The walk-around was carried out; tires were kicked and checked for the appropriate pressure and all other accumulator gauges were within normal tolerances. Panels were closed, pins were removed, and there were still two engines that were ready to make 32,000 pounds of thrust. It was time to climb up the ladder, get strapped in, adjust the rudder pedals forward to the bulkhead, and get this jet started. The start up went smoothly. After getting a clearance from ground control, it was time to taxi. The parking brake was released, the initial brake check was carried out, the inertial navigation system (INS) was turned to navigation mode, and the aircraft was now taxiing for the active runway at about 20 knots. All things seemed normal during the taxi sequence, except for a minor pull to the left. The winds were moderate but it didn't seem like enough to cause the jet to drift.

As the aircraft came to a stop at the arming point, I looked over to my wingman, who was in the jet on the left side of the aircraft. "CAT 42 from lead, look at the left main gear. Does the tire seem low?" "Negative," he replied, "I'll make another basic check during the initial take-off roll." Clearance was received from air traffic control and I was now rolling down the active runway. I was airborne at 165 knots, without a shimmy or any other noticeable problems. The sortie was uneventful. With Bingo (minimum level of fuel required to return to base and land with a very small buffer to account for any delay that might postpone your landing) reached and time to return to base, we carried out our checks and returned for an overhead break. The landing was uneventful, with winds less than five knots and plenty of room to exit the active runway onto the high-speed taxiway. Ground control was contacted and we taxied back to the squadron. Once again, there was a slight pull to the left. The required power was slightly higher than normal, but not really cause for alarm.

Turning to park the aircraft was when the tire finally failed. It was not catastrophic, just a release of the pressure from the sidewall. The aircraft was shut down just prior to the parking spot and was quickly fixed soon afterwards by the ground crew. The tire change was entered into the aircraft log and it was ready for the afternoon sortie. A few days later, I was signing out the same jet from Operations. A review of the aircraft snag history showed that the last entry was the tire change. Other than that it was working fine. The engine start and taxi was normal and the trip was uneventful however, once again on taxiing back after a flight, the tire gave out. Now questions needed to be answered. How much fuel did you have? What were you doing after landing? Were you on the brakes too fast trying to make the high-speed taxiway? The answer was always the same. "I stopped the way I usually do." The odd quip about "sounds like braking technique" was heard a few times. The questions were tiresome but in reality it was good to have a group that was so curious about the problem.

The maintenance crew inspected the tire assembly for brake problems and found nothing of interest. The tire was changed and a taxi test was carried out with nothing abnormal discovered. The Hornet was once again back on the line and flying. A few months went by and I spent more time than usual assessing my braking technique. The jet was eventually borrowed from the squadron two hangars down for a few trips to support a request from their Operations Officer. That same day, I was taxing out for a sortie, as usual, and heard an aircraft ground abort for a flat tire. It turned out to be the same aircraft. Three flat tires in three months. Bizarre, however, between the incidents the aircraft had flown several times with nothing popping up in the pilot debriefing page of the aircraft log. The other squadron inspected and fixed the jet with the end result always being the same. Tire changed, gear inspected, taxi test carried out and no fault found. Two months went by and another pilot had a flat tire on the same aircraft. By this time, our maintenance crew had realized the need for a complete inspection of the braking system. Finally the problem was discovered. Upon inspection of the rudder pedal assembly, the wiring of the brake cable was found incorrectly installed. It seemed like a simple thing

to discover but here was what delayed the finding.

It took a few minutes of looking directly at the photo to see the routing problem. The difficulty of access only compounded the difficulty of the discovery. Why was the pull to the left intermittent? It turned out that this snag only affected the taller pilots on the squadron. We were the ones that extended the rudders to the bulkhead. It was only upon complete extension of the pedals that there would be enough pressure on the cables to cause pressure to the braking system. Shorter pilots were completely unaffected by the misrouted cable. The pilot that made the "sounds like personal technique" was one of the other pilots that eventually had a flat tire in the aircraft, and the questions that I raised about "what am I doing that's causing this" were finally answered.

What would have happened if the runway was wet or the braking pressure required to stop with a heavy weapons configuration was required? What would have happened if the tire failed during a wing take-off departure? How many people would have been involved if the aircraft was enroute to a deployment destination and the tire went flat at a remote facility? How much time was required for the groundcrew to change the same tire four times? What thoughts were in the minds of the pilots who thought that maybe they were the problem? What would have happened if the landing was a bit rough or the arrestor gear was not available?

What can be learned from a pretty benign set of occurrences such as this? The first thing is that problem solving takes time and a coordinated effort. Attention to detail certainly solved the problem, however could it have been made earlier? The pilot with the occurrence should always give as much detail as possible to those that are about to fix the snag, and the groundcrew have to ask questions and look past the obvious. A history of related occurrences was the key that resulted in the larger inspection of the rudder assembly.

The ability to fix this minor recurring snag took time and effort from a number of people. Does this happen often? It happens all the time. Sometimes the fix is quick and sometimes the solution takes time. The delay in finding this problem was due to the problem-solving process and the inability to take a look at all the factors. The trouble in this case was not the blown tire. The error was the rudder/brake cable assembly. The tire failure was only a result of the problem. This is the type of difficulty that experienced personnel will be able to solve quicker, usually because the questions they ask will be different and related to previous experiences. I've learned to pass on more information and the groundcrew involved have learned to ask for more details.

Sometimes, a snag is not what it appears to be. You start looking in one place and find the problem and, therefore, the answer somewhere completely different.

Human Factor – **Mental States**

The Mental States sub-category involves those mental conditions that directly affect performance. The complexity of most aviation related tasks and missions require the individual(s) performing them to be mentally prepared. A deficiency in mental preparedness, and therefore cognitive performance, can result from Fatigue, Attention Deficiencies and Personality Traits / Attitudes.

Doing Your Best and Still Making Errors… What's Up With That!

By Master Warrant Officer Gillis, 410 Tactical Fighter Operational Training Squadron, Cold Lake

Writing a human factors article might be easy if you regurgitated someone's research and filled the text with all kinds of statistics but I believe personal experiences are much more interesting and beneficial. It wasn't until late in my career that I started receiving human factors training as the newly appointed flight safety Warrant Officer in an extremely busy fighter squadron. Following the training I began to reflect on past incidents and accidents that not only happened to me but also to my co-workers. I began to realize a substantial number were often linked to human factor causes.

One such incident I recall happened to me in Summerside, PEI, back in the early eighties. We frequently were responsible for early morning launches for fisheries patrols and usually the aircraft departed at 6:00 am; therefore our servicing crew was often at work before 5:00 am, to get the aircraft mission ready.

One morning after the early launch, I decided to help out the morning shift by before flight checking the other aircraft that were schedule to fly later in the day. In the next two hours, I had five additional aircraft "B" checked and was pleased with the recognition from the crewmembers as they showed up for work and to their surprise much of the morning work was completed. It wasn't until 9:00 am that my MCpl came and talked to me and asked me to go with him to one of the aircraft I had inspected. He asked me to go in the right wheel well and see if I saw anything. I entered the wheel well and did not see anything out of the ordinary until he asked me to look over my right shoulder. It was then to my astonishment that I saw a hole puncture through the right main landing gear door. The damage was severe and if left un-noticed could have caused the landing gear to get hung up in flight. The aircraft was subsequently pulled from the flying program and under went two days of repair to correct the damage.

At the time I could not understand how I could have made such an obvious error and for months my confidence was affected by the incident. I truly believed at the time I was immune to errors and they only happened to less competent technicians, was I ever wrong.

For the next few years I worked on several different aircraft and was lucky that I did not run into any similar occurrences and over time I got my confidence back to where it once was. However, I never did forget the incident with the damaged main landing gear door and often tell the story to junior personnel as part of their human factors training.

Today when I think about this incident, I begin to realize that several human factors played a role in why I missed seeing something very obvious. Firstly, I was often working fatigued having young children that were up frequently in the night. Secondly, I was rushing the inspections as I had a specific process of doing my before flight checks and besides very rarely did I ever find anything wrong. Thirdly, I was extremely confident in my abilities and after all we got rewarded for working beyond what others could tolerate. I even had a letter of appreciation for working 23 hours in my personal file. Finally and most importantly, I had no human factors training and had no idea how outside influences, circadian rhythm or how human engineering plays a role in error.

Thankfully twenty plus years later we are getting the human factors message out early in a technician's career. This is a huge step in the right direction and with time will change the culture on how we as an organization understand errors. However, in order for this program to be most successful it must be relevant to the issues of the day and unique to the needs of the maintenance community we function in. Homegrown human factors training works best when incidents or occurrences close to home are discussed and supervisors and senior personnel actively support the program. In addition, one of the best ways to advance human factors training is to develop case studies and discuss them on training days or weekly safety meetings.

So what is human factors training? I can tell you what it is not. It is not achieved when you get a tick in the box from an annual training day and now you're good to go for another year. If this is what you believe your attitude maybe your greatest inability to advance your human factors knowledge. I believe personnel can function in a higher level of awareness of the daily hazards, understanding the implications to those hazards and finally plan and act on the plans. With time, human factors discussions will become as normal as tool control use is in the work place. Cultural change is often difficult to measure but I am confident that the technicians we are training today are receiving knowledge that years ago we were providing only to our senior personnel investigating flight safety incidents. Today, during my many initial interviews with the new apprentices, I walk away pleased with the level of human factors knowledge and I am confident we are providing them with the tools to be true professionals in the work place.

Photo: Pte Pierre Thériault

Human Factor – **Physiological States**

The Physiological States sub-category refers to a medical or physiological condition that precludes safe operations. Certain medical or physiological conditions make individual(s) particularly susceptible to adverse reactions and inaccurate sensations in an aviation environment. Particularly important to aviation are physiological conditions that increase the susceptibility of the individual(s) to spatial disorientation, illusions, G-induced loss of consciousness (G-LOC), almost loss of consciousness (A-LOC), hypoxia, physical fatigue as well as the numerous pharmacological and medical abnormalities known to affect performance. This can occur, for example, when a pilot flies while suffering from an ear infection, rendering the pilot more susceptible to spatial disorientation or a maintenance technician on prescription medication who is more susceptible to increased drowsiness while working at heights or operating specialized machinery.

Good Old Military Training

By Paul Molnar, Pilot, Top Aces

My story takes me back almost 10 years to beautiful postcard setting in northern Arizona. After 11 years in the Canadian Forces, instructing and flying CF-18 Hornets and participating in Desert Shield and Desert Storm, I was now running my dream company, providing aerial combat adventures and two-ship air show demonstrations to thousands of people throughout North America. Currently, we were deployed from our Niagara, Canada home with two Extra 300L aerobatic aircraft, engaged in the filming of an IMAX movie in the Grand Canyon region. At the completion of shooting (the 'wrap') in May of that year, my business partner and I decided to stay in place in Page, Arizona, where we could concentrate on our work-ups for the upcoming air show season, without any distractions of our business back home in Niagara.

We had been there almost a six weeks, so we were very familiar and 'comfortable' with the local conditions, airfield and surroundings. Did I just say 'comfortable'? Our first show was also only two weeks away, so we had a ton of work to do in preparing for the season, before 'rushing' northeast back to Ontario. Did I say 'rushing'?

Our two Extra 300L rocket-ships fit like us like gloves – I could do anything in that aircraft!! Anything!!

We prided ourselves on accurate and seemingly 'death defying' crossing passes and also prided ourselves on keeping the show in front of the crowd throughout our 10 minute performance. On this one particular day, I was adding a newly devised manoeuvre that would require a 'cross', with both aircraft performing lomcevaks, with the wingman (me), holding the manoeuvre just a bit longer than normal, in order to allow a quick cross-circle rejoin, just in time to be back at show centre for the formation 'heart in the sky'. Yes, yet another manoeuvre slightly borrowed from the Snowbirds!

It was a beautiful Arizona afternoon - beautiful weather, temperature in the high 90's and density altitude pegged well above 5000 feet! We began a full program rehearsal, with our coach on the ground watching, monitoring us also on a handheld radio. Everything was very normal, except for the next segment – I was about to step it up a notch and 'add a manoeuvre'!

We performed Reverse Half-Cuban repositions 6000 feet away from each other, then pointed our aircraft back toward show centre, racing at each other with 300 mph closure. 'Lead – contact', 'Two - contact' and the cross begins. A left to left pass begins with no movement on the windscreen and with a slight twitch of right bank (using a tad of right rudder), the right to left movement on the windscreen means the miss will occur. For this pass, lead calls 'Pull' to initiate the 45 degree up-line and just when we are to merge, we perform simultaneous tumbles – finally, something the Snowbirds can't do. Now, we've done this move hundreds of times and its effect has been recognized as pretty spectacular. But today, without a viewing audience I have decided to add an additional ¾ of a turn to accelerate the rejoin and the follow-on 'looping heart'. No practicing of this move on its own, without another aircraft in close proximity. No practicing of this move at a higher altitude, just in case it goes a little 'funky'. Did I mention that the Extra 300L fit like a glove and felt like it was a part of my body? Did I mention I could do anything in that airplane?

Well.....if you've ever heard the phrase 'out of control like a bronco buck', multiple that by 10! The Extra did not stop at that extra ¾ rotation, instead it went for multiple rotations, finally arrested by my strong-armed anti-tumble inputs of opposite rudder and aft stick.

Photo: Cpl J.F. Lauzé

The aircraft came out of the tumble in a 45 degree nose low, inverted dive, at 800 feet AGL, with full power, but no airspeed.

Now for the first good news to occur in the past 15 seconds. I actually recognized this 'attitude' from as far back as my initial Unusual Attitude training in the CT-114 Tutor in Moose Jaw. Using a standardized procedure for a Nose Low Unusual Attitude, I quickly, but methodically:

- Kept power at 'Full' – I was going to need that energy addition real soon!
- Unloaded the aircraft by pushing forward on the stick;
- Rapidly rolled the Extra 300L upright to the 'Nearest Horizon' vice pulling through;
- Once my wings were level, I did nothing! Pulling without energy and I was dead!
- As energy increased (based on potential and kinetic), I was then able to smoothly, but aggressively pull symmetrically above the horizon and initiate a climb… with 50 feet to spare!

Asked by our coach over the radio whether I needed to land (to his perspective, I actually disappeared beyond the edge of the mesa, so he thought I had bought the farm), I responded, 'Negative, debriefed. Let's move onto the next sequence'

We finished that practice and landed for a full debrief of all the manoeuvres, including the infamous 'Tumbling Cross Rejoin'. The 3 of us knew that I had dodged a bullet and we knew the Preventative Measures for such a situation had been cast in stone many times before. The problem is, I actually knew that and still decided that I was capable of bypassing many stages of preparation for a new manoeuvre and it nearly cost me my life.

While I reflect on this situation, I can easily identify a few basic throwbacks or lessons that were re-learned that day.

1. Always employ a methodical and safe building block approach when tackling a new manoeuvre or tactic for the first time.
2. Brief emergency procedures and recovery techniques for every mission – they will probably be required some day and could save your life!
3. Mixing business with safety doesn't work!
4. Stupid pilot tricks 101 – graduation not guaranteed!
5. Unusual attitude training – it works!!
6. If too comfortable, your spider senses should be tingling!!
7. Be comfortable sleeping, not flying!!
8. Centralize, Analyze, React – with the appropriate procedure!

Human Factor – **Physical/Mental Capabilities**

The Physical / Mental Capabilities sub-category refers to those instances when the task / mission requirements exceed the capabilities of the individual(s) involved in the activity. This could be the result of the limitations in the capabilities of human beings in general or capability limitations of the individual(s) involved. If the task / mission exceeds the capabilities of humans in general, the human-machine interface or the task itself needs to be addressed. If however the task / mission exceeds the capability of the individual(s) involved, then re-assignment, training or adjustment of the recruiting / selection standard may be required. This sub-category includes aptitudes or other physical characteristics over which the individual(s) involved may not have much control. This can occur, for example, when a pilot cannot reach the rudder pedals of aircraft because the legs are too short. It also includes qualification and training issues over which remedial approaches may be possible. Additionally, this can occur when a maintainer lacks proficiency with the task being performed.

Lesson on Instinct

***By Captain David Schell,
2 Canadian Forces Flying Training School, Moose Jaw***

As a newly winged pilot and first tour Instructor Pilot I am constantly picking up new techniques both to improve my flying skills and to teach my students safe and efficient flying. One lesson I have learned when it comes to instructing is that things that may be instinctive to me may not be to a new Student Pilot [SP].

Recently I flew with a pre-solo SP on an early Clearhood mission. Amongst the new work on this trip was landing the aircraft. The mission progressed well and the SP successfully landed the aircraft with minimal guidance. This particular day saw a slight crosswind. During the downwind portion of the pattern the SP was reminded of the crosswind landing technique - which involves rudder and aileron inputs. The SP acknowledged and indicated he would apply crosswind inputs on the subsequent landing.

The next approach unfolded successfully and during my reverse follow through I noted that the SP was applying the correct inputs. Immediately upon touchdown I felt a slight "tug" on the upwind side of the aircraft and heard a "pop". I took control of the aircraft and felt, what I knew directly to be, a flat tire. We rolled out without further incident, coordinated with tower to shut down on the taxiway and waited for the technicians to arrive.

During the debrief I asked the SP if he applied brakes on landing. As it turned out the SP was flying with his feet completely on the rudder pedals. This creates the potential to inadvertently apply brake pressure when applying rudder input. With heels placed on the floor the rudders may be manipulated without any effect on the brakes. Brake pressure is achieved by applying pressure on the top of the rudders with the toes.

The SP indicated that all previous trips had been flown with feet fully on the rudder peddles. I debriefed the SP to slide his heels to the floor upon brake release on take-off and have them remain there until the brake check on a full stop landing.

I learned that some things we do purely on instinct, while other things need to be taught. Being aware of even the simplest technique can make the difference between an uneventful landing, and a flight safety incident and lost material. Now I teach students this technique and explain why in order to mitigate additional incidents of this nature. Further, this has provoked me to think more critically about other "instinctive" things I do when flying which has garnered new techniques that I apply when instructing.

Human Factor – **Technological Environment**

Technological Environment relates to the equipment used to perform a task / mission or the interaction of the individual(s) with that equipment. This sub-category encompasses individual(s) using equipment that is inappropriate for the task / mission, the unavailability of the right equipment for the job, or an individual's sub-optimal interface with equipment. These characteristics create the circumstances whereby an individual(s) is forced to "make do", thereby increasing the potential for error.

5 Seconds to Impact

By Capt Sheldon Tuttosi, 410 Tactical Fighter Operational Training Squadron

The day started out as a routine training flight in support of some United States Air Force (USAF) Starlifters that had deployed to 4 Wing Cold Lake on exercise, in much the same way as many other days at 417 Combat Support (CS) Squadron (Sqn) unfolded. This was soon to change however.

Our role at the Sqn was to provide combat support using the venerable T-33 aircraft. We would be utilised by the Fighter Squadrons who called Cold Lake home, as well as by any other units who deployed to 4 Wing Cold Lake and required support. I had arrived at the Squadron only a short 2 months prior and was in the process of completing upgrade training to enable me to fly the sorties solo. On this particular day, I was in the backseat with a qualified Squadron pilot up front.

The mission was fairly routine in that the Starlifters were flying a low level route, and we were to fulfill the role of red air fighters that were attempting to sneak up and "shoot" the Starlifters down. This would enable the USAF crews to hone their visual lookout skills and to practice their low level evasive manoeuvres. One of the approaches that we liked to use was to fly low (200 feet AGL) and fast (450 KIAS) and attempt to get the rather large Starlifter visual before they saw us. Once we had them visual and closed to within a couple of miles, we would pop up to about 1000 feet AGL to commence the attack.

The T-bird was perfectly suited to this type of mission, and was a very capable old bird. However, there were a couple of issues that had yet to be resolved with the aircraft. As had happened on occasion in the past, after it rained, water tended to accumulate in the stick well of the aircraft, and would short out the trim (causing a runaway) at the most inopportune time. This had happened in the past, and the fix was simple: the T-33 needed a trim isolate button like the Tutor aircraft had. The fix however had not yet been implemented despite pilot rumblings about the need for one. But I digress…

This day, the weather was CAVOK and we had not had any rain in several days, so this particular issue was far from our minds. I had just completed a run on one of the USAF aircraft and we were currently at about 1000 feet AGL when I felt the stick ripped from my hands and my head jammed against the top of the canopy in a negative 3 'G' bunt toward the ground. The first thought in my head was "what is that guy up front doing? He didn't even ask for control." The front seat pilot told me later that he had a similar thought about what in the world the new guy was doing! We both soon realized that something had happened with the aircraft and grabbed the stick and pulled back hard. We recovered at about 100 feet AGL. At this point we knocked off the exercise and returned to base.

Investigation after the incident revealed that there was a small amount of water in the stick well that must have shorted out the trim nose down. A quick bit of math after the fact revealed that at the speed that we were going, full nose down trim resulted in excess of 80 lbs of stick force to overcome. Additionally, from 1000' AGL and negative 3 'G' we would hit the ground in 5 seconds. Thankfully both of us had the presence of mind (read survival instinct) to grab the stick and pull up rather than try to figure out what the other guy was doing. Just a couple more seconds wasted asking what was going on would have resulted in another statistic. After some flight safety paperwork and the ensuing investigation, a trim isolate button was incorporated into the aircraft. After 45 years of T-bird service, better late than never, right?

Photo: Cpl Guillaume Gagnon

Human Factor – **Resource Management**

All phases of air operations and maintenance require effective teamwork. Effective teams make use of the knowledge, skills and abilities of all members involved and take advantage of proper interactions among them; deficiencies and breakdowns in Communication / Coordination and Planning can be detrimental to their cohesion, impact performance negatively and impede safety.

The LZ is a Little Tight

Author Unknown

We had set out as a two-ship of Griffon helicopters. We were using night-vision goggles (NVG's) and were deployed in the Ottawa region in support of an exercise. Our task was to rendezvous (RV) with soldiers at a pre-determined pick-up zone (PZ), go through a briefing and then fly the troops into their desired landing zone (LZ). Our detachment commander (Det Comd) had done an LZ reconnaissance (recce) earlier in the week, and the only known hazard was from our rotor wash to a nearby cemetery. Following the ground briefings at the PZ, we promptly took off and flew directly to the LZ. We were the second helicopter and had about two minutes spacing behind the lead chopper. When the lead Griffon called clear of the LZ, he informed us that we could expect the confined area to be "*a little tight*" so the aircraft commander (AC) decided to take control for the approach and landing. The cemetery was identified and we moved well forward prior to our descent. As the crew flight engineer (FE), it was my responsibility to steady the aircraft down and to marshal towards the left to give our machine a "very conservative" half-rotor clearance. The AC informed me that there was very little room to move left. I didn't figure that this was a problem, as we could move down in smaller increments and re-evaluate half-rotor clearance on the way in. After our next downward increment we again stopped and re-evaluated, at which point I detected aft and right drift of the helicopter followed by downward drift. We were rapidly drifting into the trees. *Drifting back, drifting right, drifting down*…"**up..up..up..up**". I repeated hurriedly and urgently. Our AC had arrested the drift and was already in the over-shoot when the non-flying pilot called "**overtorque…105**". At that point, we elected to cancel the mission and return the unserviceable aircraft to our deployed base.

We had done our job, avoided a collision, and only incurred a minor overtorque requiring a precautionary inspection. Our use of standard terminology and crew resource management (CRM) had come through and averted what may have a serious accident. However, in the end, it didn't make me feel any better and I found myself soul-searching and questioning myself as to what I may have done better. In this process I came up with several conclusions. I knew the obvious, but there were several other somewhat insidious factors contributing to this occurrence.

- Rest - although given adequate rest, we had been working a peculiar schedule of days and nights during the week. I had been up the morning before the mission and was later sent for crew rest when told that we would be flying just over fourteen hours later, early the next day. Although feeling ready to go, I knew I wasn't 100%. Due to inclement weather, we had given little support to the exercise all week long and I, for one, didn't want to "let them down".

- Expectancy - our crew had expected a very routine and easy confined area landing. Further to that we had a genuine concern for property damage to the cemetery in the proximity of the LZ.
- Complacency and Overconfidence - I had over 1000 hours total, with 175 hours of NVG experience. I had performed similar missions numerous times before, often under more difficult and austere circumstances. To me, this would only be a simple and routine mission requiring but one troop insert.
- Environmental - flying with NVG's under conditions of poor illumination.
- Procedures - the FE normally situates himself on the side of the flying pilot for lookout purposes. I had been in this position, but when the AC took over the approach into the area, I was unable to reposition myself due to the troops occupying the cabin area. I was unaware of it until well into the confined area sequence.
- Judgement - when confronted with a seemingly more difficult confined area than originally anticipated, I should have called for an overshoot and suggested a thorough recce of the confined area. A confined area recce procedure does exist in our Standard Maneuver Manual, and I should have used it.

In the process of soul-searching, I had identified numerous underlying factors contributing to this flight incident. Those are the things that our training and instincts have taught us to avoid. It's a number of not so obvious events and factors that will lead up to a situation that can sting you, or worse, kill you!

Photo: Cpl David Hardwick

Human Factor – **Personal Readiness**

In any occupational setting, individual(s) are expected to show up for work ready to perform at optimum levels. This is even more so in aviation. If personal habit patterns or behaviours interfere with this requirement, then this sub-category is present. A breakdown in Personal Readiness can occur when individual(s) fail to prepare physically and mentally for the task / mission they must perform, which in turn can be detrimental to their performance, lead to errors and impede safety. Not all Personal Readiness failures occur because rules and regulations have been disregarded or broken. While certain behaviours or conditions may not be governed by any rule or may not be against any existing regulation, individual(s) must use good judgement when deciding whether there are "fit" to work. A person arriving at work just after over-exercising (e.g. dehydrated after a long-distance run in a hot and humid environment), a person arriving at work without adequate rest, hung over (e.g. under the influence of residual effects of alcohol despite a bottle-to-work period that was in accordance with regulations) or with impaired vigilance (e.g. from direct, secondary or residual effects of drugs / medication) are examples within this sub-category. Such individual(s) are not ready to function effectively and at optimum levels in the workplace.

I Can Hack It!

By Lieutenant Commander Coupe, US Navy

Reprinted with kind permission of "Approach" magazine.

Have you ever had a cold and felt pressured to fly, saying to yourself, "I can hack it"? I was flying in the last phase of workups, when I awoke feeling run-down. I had the typical cold symptoms: stuffy nose, headache, tiredness, and chills. I took myself off the flight schedule, ignored the Operations Officer's (Ops O's) snide comments, self-medicated and went back to bed. I felt much better the following day; the cold symptoms were gone, except for a runny nose. I easily could clear my ears, and I told the Ops O to put me on the schedule.

We briefed at 0300 hrs the following day, which was the first day of the exercise war. The skipper asked if I really was OK to fly, and I told him I was fine and not to worry. We launched at 0500 hrs. I sneezed and blew my nose a few times during the climb out and mission. As we made the initial descent on our approach, I felt pressure in my ears and cleared them with a valsalva. Further along the descent, the pressure came roaring back. A valsalva again cleared my ears, but the pressure in my forehead continued to intensify. Around 5,000 feet, the pain became unbearable – toe curling, sharp and more intense – like a needle was being jabbed between my eyes.

The person next to me asked if I was OK; I barely was able to answer. The pilot levelled off and, after a few moments, the pressure subsided enough to where I could continue. I told him I was well enough to press on with the approach. About 2,000 feet later, the blinding pain was back, but I didn't say anything. I merely wanted to land and end the torture session.

The sinus pain suddenly disappeared on touchdown, much to my relief. In exchange, I now had a wicked headache. In the ready room, I told my story during the debrief, not fully aware of the chastising I was about to receive – my boss was not pleased. He ordered me to see the flight surgeon. I left the ready room slouched over and feeling defeated.

The thorough exam included sinus X-rays, which revealed I had torn my frontal sinus. That explained why the pressure had subsided, but I had been left with the headache. I was grounded for thirty days, placed in the "healing chair" (night time squadron duty officer); forbidden to fly home on the C-9 or on a commercial aircraft, and advised not to drive or to take a bus over the Rockies.

The carrier pulled into Mayport two weeks later. My very pregnant wife was in Whidbey Island and Christmas was in five days. How was I going to get home? Hours later, I was in a taxi heading to the AMTRAK station for a cross-country journey, in coach class and not a sleeper car. The next three days gave me plenty of time to determine if it was worth trying to hack it.

Photo: Cpl Eric Jacques

Human Factor – **Supervision**

Supervisors influence the conditions and practices of individuals and the type of environment they work in. Supervision is a factor in an occurrence if the methods, decisions or policies of the supervisory chain-of-command directly affect practices, conditions or actions of individuals or their working conditions and result in human error or unsafe situations.

Supervision factors are often part of the causal chain of events. As latent conditions, such factors found within the individual(s) immediate supervisory chain are not considered to be the direct cause of the occurrence. However, though they may lie dormant or undetected for a while, they can contribute to the final sequence of events to which they are associated by predisposing it to happen. In that sense, Unsafe Acts can be "set up" by Supervision factors. Supervision factors are sub-divided into: Level of Supervision, Planned Activities, Problem Correction and Supervisory Deviations.

I Have Control

By Capt Jillian Bristow, 430 Tactical Helicopter Squadron, Valcartier

As a new pilot trainee flying Canada's new advanced trainer, the CT 156 Harvard II, I was preparing for my first solo. The flight involved leaving the Moose Jaw training environment to fly some circuits at the nearby Regina International Airport. Having had some previous flying experience, I was confident that this trip would not be a problem.

The first half of the trip was standard as we went to our training area to perform some basic aerobatics and a slow flight stall sequence. During the recovery from the slow flight, I applied full power and put the flaps to half to let the plane accelerate before fully retracting them. During this transition, my instructor called from the back seat that he had control and proceeded to unload the aircraft to continue accelerating. At this time, assuming that he had control of the aircraft, I looked out the window to take in the scenery, one of the few times where a student gets to admire the view. As we accelerated down to an appropriate VFR altitude, we couldn't get the plane to accelerate faster than 248 kts which is unusual for the Harvard II aircraft. It was then that we discovered that the flaps had been left extended from the previous manoeuvres and the flaps had been over sped by nearly 100 knots as the gear and flap speed for the Harvard II is 148 knots. We retracted the flaps and proceeded to carry on to Regina for some overhead breaks and touch and goes. We discussed as a crew what the possible implications of this overspeed could have on the aircraft and recovered via the straight in for a full stop back in Moose Jaw. Upon touchdown, the speed brake light illuminated indicating that it was at least partially extended. My instructor extended and retracted the speed brake a couple of times with no change to the condition.

We called our Ops and maintenance to inform them of the problem and they told us to shut down the aircraft and it could be checked over once the propeller stopped. As we walked around to the right fuselage a few of the techs were staring at the fuselage with surprised looks. We discovered that the hydraulic panel had somehow opened and was being crushed by the speed brake when it was being opened and closed.

After this experience I have come away with several lessons learned. The first being the importance of a proper hand over of controls in that both the student and instructor are responsible for the configuration of the aircraft. Secondly, I have learned that once a limitation has been exceeded on the aircraft, the aircraft is now unserviceable and continuing the flight for training purposes was not the right decision. Return to base, ensure the technicians inspect the aircraft and start filling out the Flight Safety Occurrence report!!

Human Factor – **Organizational Influences**

Unsound decisions by upper-level leadership, although latent in nature, can have a direct impact on the organization; moreover, they can have a direct negative effect on supervisory practices or the conditions and actions of individuals. Although the impact of organizational influence on the areas in question is direct, it is considered an indirect latent condition because it does not play an active role in the condition or act under examination. These latent Organizational Influences are sub-divided into three categories: Organizational Resource Management, Organizational Climate and Organizational Processes.

Search and Rescue Swiss Cheese

By Captain Graeme Cook, 413 Transport and Rescue Squadron, Greenwood

It was warm for a December morning in Goose Bay when my crew woke up in a field location after a simulated SAR exercise the previous day and night. Knowing that a hot breakfast was awaiting us back at the Squadron we packed our gear, and prepared the CH-146 Griffon helicopter for the short hop back to the airfield.

It was a normal start on number one engine, with the Cold Weather Start (CWS) procedure used. On starting number two engine the idle was normal, so a CWS procedure was not used. To use the famous flight safety analogy of a swiss cheese model: this is where the holes began to line up. But first a little background on the CWS procedure, its purpose, and some recent changes to the procedure.

The CWS procedure prevents uncommanded engine accelerations, caused by ice blockages in the governor's pressure lines. The procedure warms the engine, including the governor and pressure lines, to clear any blockages.

Changes have recently been made to the procedure, but before they were implemented, three parameters dictated the use of the procedure. Outside air temperature, engine oil temperature, and engine idle speed. Failing to meet one parameter for the CWS procedure meant that it did not have to be used. On the morning in question, the idle speed on number two engine was normal, and therefore the CWS procedure was skipped.

This brings us the next point involving recent changes to the CWS procedure. A fleet wide message was released in November 2006 which amended the procedure by removing the Engine Idle Speed criterion. My squadron had not implemented this procedure, because the change had not "officially" come to the SAR squadrons. As well, the message was sent, but could not be read by our base software in use at 5 Wing Goose Bay.

Coming back to the incident, we had started both engines now, and were a few minutes into the system checks. The Aircraft Captain (AC) was in the right seat, doing the force trim check, and I was in the left seat, with my head down working on the control display unit. Number two engine had already crept up a bit earlier, but was responding to throttle inputs. Suddenly number two engine decided it was time to take off. It happened very fast, the sound was unmistakable, and all three crew members immediately recognized that it was a governor overspeed. By the time the engine was shut down the damage was already done, resulting in replacement of an engine, combining gearbox, transmission, drivetrain, and a major overhaul for the aircraft.

Could the overspeed have been avoided had we used the CWS procedure? Possibly. Would we have shut off the engines sooner had we not spent the last night in the field, and not had a mild case of get-home-itis? Maybe. One thing for sure though, is that had we received and used the procedure amendment, we could have plugged up some of these holes in the swiss cheese model, and possibly prevented millions of dollars in damages.

Flight safety isn't just about flying, or even ground operations. It's also about fast and concise dissemination of information, proper communication and the responsibility of flight crews to stay abreast of current developments in their field.