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“Line Operational Simulation: Towards Optimizing Human Performance in the Canadian Air Force”

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Abstract

The Canadian Air Force has begun a modernization program that is unprecedented in its history. The findings and conclusions in this paper as they relate to the synthetic environment and the optimization of human performance are a means to ensure the Air Force is able to fully exploit the potential of not only the systems it possesses or will possess in the future but also the potential of its personnel. This paper proposes a road map to operational success and safety that fully exploits the synthetic environment to build upon what has always been one of the fundamental strengths of the Air Force – its people. To achieve these goals, it recommends the creation of behavioural performance markers within the Air Force that are taught and evaluated to the same level as technical skills. Once created, these skills are best taught in the synthetic environment in what the aviation industry refers to as Line Operations Simulation (LOS).

While there are no quick answers to the human factors issues that the Air Force is wrestling with, this paper concludes that solving them is not difficult. It will take deliberate effort and resources. Once that effort is begun, and a common language of aviation human factors is established across the Air Force, other areas such as Human Performance in Military Aviation (HPMA) and the Human Factors Analysis Classification System (HFACS) used by Flight Safety will also begin to deliver promised results that have yet to be achieved. There is significant potential to adopt other industry solutions, such as Line Operations Safety Audits (LOSA), once human factors are fully integrated into Air Force training and operations. Implementing LOS and maximizing the use of the synthetic environment across all fleets within the Canadian Air Force is a critical first step in that transformation.

Table of Contents

List of Tables and Figures

Tables

Figures

Glossary of Abbreviations

AC	Advisory Circular
ACP-T	Airlift Capability Project - Tactical
ACRM	Advanced Crew Resource Management Training
ADM	Aeronautical Decision Making
APPD	Automation Policy and Planning Development
AQP	Advanced Qualification Program
ASRS	Aviation Safety Reporting System
ASTI	Advanced Technology Skills Inventory
BOT	Behavioural Observation Training
CAA	Civil Aviation Authority (United Kingdom)
CAP	Civil Air Publication (United Kingdom)
CF	Canadian Forces
CRM	Crew Resource Management
FAA	Federal Aviation Administration (United States)
FOQA	Flight Operations Quality Assurance
GIHRE	Group Interaction in High Risk Environments
HFACS	Human Factors Analysis and Classification System
HPMA	Human Performance in Military Aviation
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
I / E	Instructor / Evaluator
IRR	Inter-Rater Reliability
IRT	Instrument Rating Test
LOE	Line Operational Evaluation
LOFT	Line Oriented Flight Training
LOS	Line Operational Simulations
LOSA	Line Operations Safety Audit
MHP	Maritime Helicopter Project
NASA	National Aeronautics and Space Administration
NOTECHS	Non-technical Skills
RRR	Rater-Referent Reliability
SPOT	Special Purpose Operational Training
UK	United Kingdom
USAF	United States Air Force

Chapter 1

Introduction

"The quality of the box matters little.
Success depends upon the man who sits in it."[1]

Manfred von Richtofen
The Red Baron

What Manfred von Richtofen wrote prior to his death in 1918 refers to the critical importance of the human sitting in the aircraft as the fundamental determinant of success in battle. Without a well-trained and capable individual at the controls, the potential capabilities of the 'box' the aviator found themselves sitting in would not be realized. Von Richtofen's simple and prescient words sum up that which would, in the modern context, be referred to as human factors in aviation. Today, just as in 1918, it is the human that will make the difference in the execution of aerospace power. Achieving a high level of human performance from the individuals operating and supporting today's complex weapons systems requires a high level of training. While the principles remain largely unchanged, the methods in which that training is delivered continue to evolve.

In the latter part of the 20th century, the introduction of simulators to aviation marked a dramatic evolution in the way the aviation community develops human potential. No longer restricted to conducting training with an actual aircraft, simulators have allowed the industry to teach and practice sequences and events considered too dangerous in a real aircraft while replicating, to a high level of fidelity, the actual operating environment. In modern aviation training systems, it is not uncommon for

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[1] Manfred von Richtofen, *The Red Fighter Pilot* translated by J. Ellis Barker (London, UK: 1918) Chapter 12. http://www.richtofen.com/index.html; Internet, accessed 21 January 2010. Originally published as *Der Rote Kampflieger* (1917).

someone to achieve an initial qualification, and then maintain that qualification, without ever touching an actual aircraft except during the conduct of operations. While originally oriented towards training aircrew, the use of simulation has expanded to include all personnel involved in aviation. This includes both maintainers and air traffic controllers.

This movement towards the use of the synthetic environment to achieve training objectives has been mirrored within Canada's Air Force. It began with the introduction of the first LINK Trainers during the Second World War and continues to this day with highly capable simulators found in programs like the Maritime Helicopter Project (MHP) and the Airlift Capability Project Tactical (ACP-T), more commonly referred to as the C130J project. These projects will deliver not only modern aircraft to the inventory; they will also field numerous sophisticated training devices heavily reliant on simulation to achieve training objectives for both aircrew and maintainers. Today most Canadian Forces aircraft fleets possess, or have access to, synthetic training devices used for the training and qualification of personnel within those fleets. In an effort to increase human performance, the CF has expended significant resources on the acquisition of synthetic training devices.

The technological development that has been put into the aviation synthetic training environment has been significant – but does it deliver corresponding increases in human performance? Research has shown that without significant investment in other critical areas, with a focus on behavioural and learning objectives, simply procuring the device will not achieve the desired results. As articulated by Eduardo Salas, Clint A. Bowers, and Liza Rhodenizer, how a simulator is used is actually more important in the attainment of training objectives than the specific training technologies themselves.[2] Simply put, a simulator or a full suite of synthetic training devices is not a training program. The fundamental issue then becomes how best to design the training so as to take full advantage of what the synthetic environment has to offer. Achieving optimization of human performance through the synthetic environment mandates the development of not only the devices, but also the means by which they are employed based on a solid understanding of the behavioural objectives to be achieved.

This study will demonstrate that the adoption of Line Operational Simulation (LOS) concepts, similar to those developed and implemented by the civilian aviation industry, will significantly contribute to an increase in human performance in the Canadian Air Force and allow it to fully exploit the potential of the synthetic environment. To do so, it will examine the following areas of human factors and simulation within industry and the Canadian Air Force:

a. the critical role of human factors in aviation, in addition to traditional technical skills;

b. the rationale behind Line Operational Simulation (LOS) to address human factors in aviation;

c. the critical role of the instructor in ensuring the development of appropriate human factors skills to reduce their impact on aviation mishaps; and

d. the current state of simulator utilization and human factors training within the Canadian Air Force.

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[2] Eduardo Salas, Clint A. Bowers and Lori Rhodenizer. "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(3) 1998, 197

The majority of the aviation regulatory and research material used in the development of this thesis will be taken from the United States Federal Aviation Administration (FAA). Although similar documentation has been published by Transport Canada, the majority of it uses FAA policy and guidance as a primary reference. As an example, Transport Canada guidance on the development and implementation of an Advanced Qualification Program (AQP), a training program which incorporates extensive use of LOS, specifically refers to the fact that the FAA standards for AQP "have been used as the basic model for the Canadian AQP standards."[3] For that reason, the FAA documentation will be used as the primary sources for the development of this paper.

This study will capture the delta that currently exists within the Canadian Air Force as it relates to the optimization of human performance and the use of the synthetic environment in comparison to the broader aviation industry. It will recommend that a comprehensive LOS program be developed and implemented across all aircraft fleets to address identified deficiencies in fully integrating the field of aviation human factors into military training and operations. The development of behavioural performance markers and ensuring the instructor / evaluator cadre is prepared to deliver the required training and evaluations with those behavioural performance makers will be emphasized in this paper. Air Force instructors and evaluators are the front line of standards and operational effectiveness and they are the engine by which the Air Force will achieve its synthetic environment and human factors goals. A dedicated human factors program, delivered by qualified instructors and evaluators through a robust LOS program, can have a significant

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[3] Government of Canada, Transport Canada, *Development and Implementation of an Advanced Qualification Program (AQP),* (Ottawa, Transport Canada, 2005),

impact. Finally, this study will discuss the ways in which simulator scenarios should be designed to fully integrate both behavioural and technical skills that can be taught and evaluated. As the Air Force develops a common language of human factors, essential to the development and maintenance of an effective LOS program, other complementary areas will begin the transformation as well that will have significant benefit for the organization in both safety and operational effectiveness.

In keeping with the focus on the methods of employment, rather than the device itself, this study will not address the issue of motion in the synthetic environment and its applicability to aviation. While much of the study will focus on the development of aircrew specific training, the lessons contained within it are equally applicable to all aspects of the Air Force if it is to optimize human performance across the spectrum of its activities.

Many aviators affectionately refer to the simulator as ‘the box’. The aim of this paper is to identify, within the Canadian Air Force, the requirement for LOS and the means by which to implement it, thereby achieving a high level of human performance. It will demonstrate that the lesson offered by the Red Baron more than 90 years ago, and the importance of the human over ‘the box’, is as relevant today as it was when it was written. More importantly, it will also demonstrate that the heavy reliance on technology, which the Air Force has always exploited to its fullest, will only deliver its promised results if the human element is considered and fully integrated across all aspects of the military flight domain. How the Air Force uses its synthetic environment to address aviation human factors will play a significant role in how successful Air Force transformation really is.

Chapter 2

Human Factors in Aviation

Introduction

Three years before the Red Baron identified the critical role of the human to achieving success in aviation, the first Canadian in uniform took to the air. Lieutenant William Sharpe enrolled in the Canadian Expeditionary Corps in September 1914 and, already possessing a pilot's licence, found himself the first and only pilot in the Canadian Aviation Corps.[4] With his Burgess Dunne aircraft still in pieces after being shipped to England, he began flying training with No 3 (Reserve) Squadron of the Royal Flying Corps. William Sharpe died on the 4th of February, 1915 when the aircraft he had taken up solo crashed, thereby earning the distinction of not only being the first Canadian military aviator but also the first to be killed while on service.[5]

Accidents in Canadian military aviation have been occurring ever since, just has they have in the broader aviation environment. This chapter will briefly examine that history and demonstrate the critical importance of human factors in aviation to not only understanding the causes of accidents, but also in developing potential solutions. It will provide an understanding of how best to shape training and operations to support the fundamental role of the human in aviation and it will conclude with an emphasis on the development and introduction of Line Operational Simulation (LOS) as a critical enabler to addressing the human factors issues embedded within aviation and which have been

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[4] Brereton Greenhous, Hugh A. Halliday, *Canada's Air Forces 1914-1999*, (Montreal, Art Global: 1999), 14.

[5] *Ibid.*, 15.

wrestled with since man first took to the air. The purpose of this chapter is to provide a contextual background to human factors in aviation, their significance, and clearly link human factors to the development of LOS as a critical enabler to reducing the attribution of human factors to aviation accidents.

Human Factors Defined

At its most fundamental level, human factors are about people. It is, as Frank Hawkins put it in 1987, about people in their living and working environments, their relationship with the technology in those environments, with the procedures they use to conduct activities and, most importantly, their interactions with other people.[6] In a more formal sense, it can best be defined as a science oriented to "optimise the relationship between people and their activities by systematic application of the human sciences, integrated within the framework of systems engineering".[7] Its objectives are articulated as achieving overall effectiveness of the system, in the areas of safety and efficiency, while maintaining the well-being of the individual within the system.[8]

The Birth of Aviation Human Factors

The International Air Transport Association Technical Conference held in Istanbul, Turkey in 1975 is widely viewed as the turning point in the recognition of the importance of human factors in aviation.[9] By this point in time, aviation technology had reached a level of maturity that allowed for high levels of reliability yet accidents were still occurring. The general consensus of the meeting was that "something was amiss

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[6] Frank H. Hawkins, *Human Factors in Flight*. (Aldershot, Gower Technical Press Ltd, 1987), 18.
[7] *Ibid.*, 18.
[8] *Ibid.*, 18.
[9] Hawkins, *Human Factors*, 17.

related to the role and performance of man in civil aviation" and that a "basic Human Factors educational gap existed in air transport."[10] Thus was born the modern field of aviation human factors and the catastrophic accident in Tenerife just 17 months later in which 695 people lost their lives due to crew error, has been described by Frank Hawkins as a call to "aviation to put its Human Factors house in order."[11] With that recognition, the industry began moving forward on a number of initiatives. However, was this really a new problem within aviation?

The Role of Human Factors in Aviation

It has generally been accepted that airworthiness issues, such as mechanical unreliability and structural weaknesses in the aircraft, were primarily responsible for the majority of accidents through much of aviation history. The theory states that in the beginning, more accidents were caused by technical failures than by human factors and as the technical side has matured, human factors take on more prominence. Now that the technical problems have largely been solved, the general hypothesis of the theory is that human factors have emerged as the final frontier in addressing and solving aviation complexity. This can be graphically depicted as a relationship and is shown in Figure 1-1. This diagram was first published in the International Civil Aviation Organization (ICAO) *Accident Prevention Manual* in 1984 and has been widely referred to across the aviation industry since.[12]

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[10] Hawkins, *Human Factors*, 18.

[11] *Ibid.*, 18.

[12] Alan Hobbs, "Human Factors: The Last Frontier of Aviation Safety?" *International Journal of Aviation Psychology* 14 , no.4 (Fall 2004): 335.

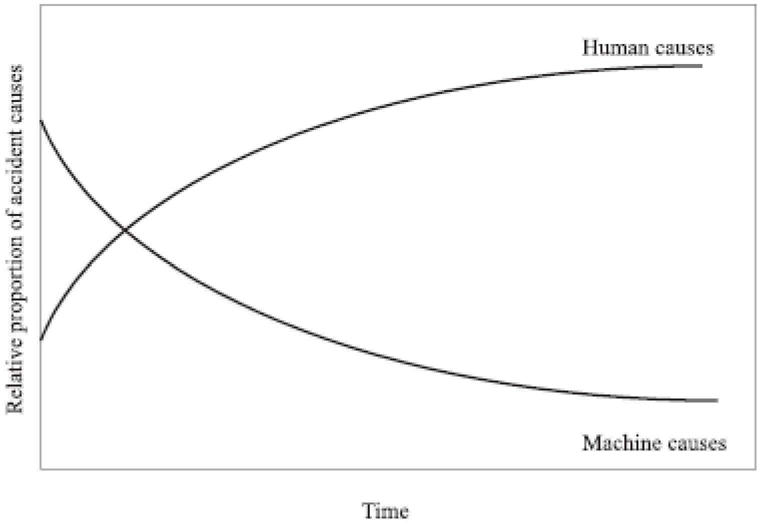

Figure 1-1: Alleged Relative Importance of Technical and Human Factors As Causes of Aviation Accidents Related to Time[13]

This was not viewed as a trend unique to aviation and was observed in other areas such as the nuclear and manufacturing industries in which it has been noted that there has been an increase in the numbers of accidents attributed to human error.[14] While it is certainly possible that increases in mechanical reliability have led to these observations, it is also possible that changes in the focus of the investigation have led to these differences.[15] If that is in fact the case, then it is necessary to re-examine aviation accidents throughout history to determine whether the role of the human has changed or remained relatively constant.

The Historical Context

Several reviews of historical records have been conducted in which the role of human factors in aviation has been re-examined. One of the best was that conducted by Alan Hobbs in the latter part of the 20th century in which he examined accident records

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[13] Hobbs, “Human Factors: …”, 336.
[14] *Ibid.*, 336.
[15] *Ibid.*, 336.

and statistics in Australia from 1921 to 1932.[16] What he uncovered represents a significant departure from the widely held belief on the evolving role of human factors in aviation.

Hobbs utilized causal factor categories employed by the Australian Bureau of Air Safety Investigation until the 1990s and was able to identify 84 accidents during the study period in which sufficient data was available to conduct an analysis. What his analysis showed was that the largest proportion of cause factors attributed to aviation accidents during the period was in fact personnel as depicted in Figure 1-2. While mechanical failures contributed to slightly more accidents, they did not do so to a degree that supports the widely held theory of mechanical versus human factors causes in aviation.[17]

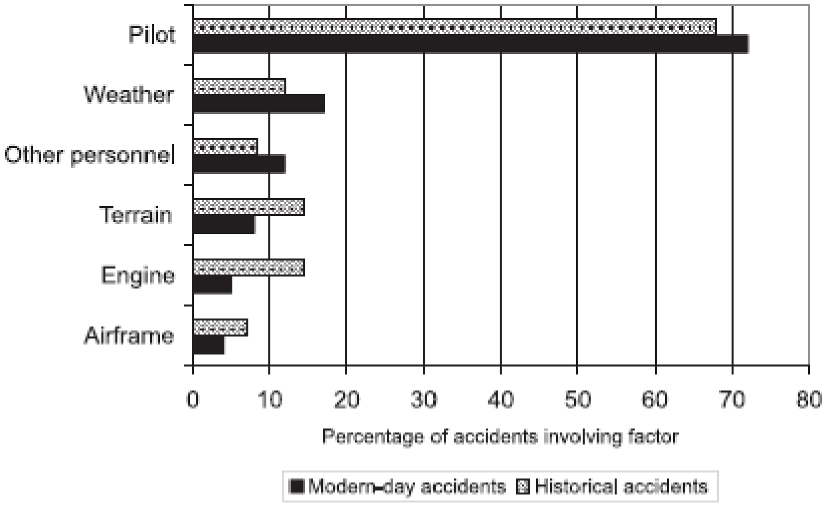

Figure 1-2: Contributing Cause Factors Identified by Hobbs (1921-1932) versus Modern Cause Factors in Aviation.[18]

What Hobbs also discovered in sifting through the historical record is that this finding was not unique to the early days of Australian aviation. He identified a study done by W.H. Wilmer in 1935 which stated that fully 90% of all British aviators who lost

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[16] Hobbs, "Human Factors: …", 336.
[17] *Ibid.*, 337 - 340.
[18] *Ibid.*, 339.

their lives in the initial year of the First World War did so due to “individual deficiencies”, 8% due to mechanical defect, and only 2% at the hands of the enemy.[19] He uncovered another study done by G.E. Anderson in 1918 on British Naval Aviation accidents during the same war in which fully 91% were related to pilot factors which were primarily categorized as “error of judgement” but also included “loss of head” and “brain fatigue.”[20] Finally, he uncovered German studies that revealed the same patterns, including one done by O. Selz in 1919 which analyzed 300 German flight school accidents in 1918 and which identified that 66% of all accidents “involved factors associated with the individual”.[21]

What the Hobbs study clearly states is that human factors have played a dominant role in aviation, both military and civil, since its earliest days. In fact, what it demonstrates is that “the last frontier of view of human factors is little more than a persistent myth”.[22] The reality is that human factors have always played a dominant role in aviation since the beginning. Considering the modern definition of human factors, in which the role of the human interacting with the external environment is the established baseline, that conclusion should come as no surprise.

The Modern Context

In not much more than 100 years, aircraft have evolved significantly, having a dramatic impact on the role of the pilot. Initial aircraft were very basic platforms in which the pilot obtained almost all vital flight information through the pilot’s own senses and in which the principle goal of the pilot was “getting into the air and returning to earth

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[19] Hobbs, “Human Factors: …”, 338.
[20] *Ibid.*, 338.
[21] *Ibid.*, 339.
[22] *Ibid.*, 339.

safely."[23] Today's modern and complex aircraft have increasingly removed the pilot from direct contact with aircraft controls while creating additional tasks in the realm of working with other crew members and interacting effectively with advanced technologies on the aircraft itself.[24] In reality, these changes have affected all aspects of aviation as systems move towards automation with the human moving increasingly towards an input and monitor role as compared to a direct physical manipulation of controls.

Research has demonstrated that the introduction of complex systems, such as the flight management system, has had a significant impact on the ability of the operator to "grasp at the same level all the details of system architecture."[25] What this translates to in operations is that traditional skill sets associated with detailed systems knowledge to both analyze and correct emergency or abnormal situations creates high levels of task workload and reduced cognitive effectiveness.[26] This research has also shown that the modern cockpit is extremely sensitive to crew relationships, particularly conflict, and especially so when "intuitive and non-educated cooperation is required."[27]

This has a significant impact on training objectives in that the requirement for the crew to effectively interact with one another is greater than ever because of the need for more coordination, optimum task allocation and sharing, and the avoidance of conflict.[28] In short, the emphasis must shift from teaching the operators all the details of the system they are operating to teaching them to be more aware of what they do and do not know,

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[23] Pamela S. Tang and Michael A. Vidulich, *Principles and Practice of Aviation Psychology* (New Jersey: Lawrence Erlbaum Associates, 2003), 4.

[24] *Ibid.*, 8

[25] Rene Amalberti, Jean Paries, Claude Valot and Florence Wibaux, "Human Factors in Aviation: An Introductory Course" in *Aviation Psychology: A Science and a Profression*, ed. Klaus-Martin Goeters, 19-39 (Aldershot, Ashgate Publishing, 1998), 27.

[26] *Ibid.*, 29

[27] *Ibid.*, 29

[28] Rene Amalberti et al "Human Factors in Aviation", 29.

supported by effective strategies and solutions to regain control of any unexpected situations in which they find themselves.[29] The technological evolution that has occurred in aviation has placed even greater emphasis on the critical role of human factors, and as the International Civil Aviation Organization noted in 2005, "in the rush to embrace new technologies, the fallible mortals who must interface and use this equipment are often overlooked."[30] This is a significant lesson to organizations undergoing a significant revitalization of its equipment, especially if that revitalization involves transcending several developmental stages of technology.

Modern Aviation Incidents and Occurrences

With the increased acceptance of human factors in the aviation industry, its overall impact has been much better articulated. In 2005, the International Civil Aviation Organization (ICAO) released the *ICAO Accident Prevention Manual*, in which it was noted that "at least three out of four accidents involve performance errors made by apparently healthy and qualified individuals."[31] In considering the reasons for this, the ICAO document states an intuitive approach to human factors misses the mark. It must be considered and deliberately applied to all facets of operation if accidents are to be reduced.[32] It is no longer sufficient to describe something as human error: it must be understood why that error occurred in the first place.[33]

In a comprehensive study of the airline industry, Boeing publishes an annual statistical summary of commercial jet airplane accidents. The data used in the study is

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[29] Rene Amalberti et al "Human Factors in Aviation", 29.

[30] International Civil Aviation Organization, *ICAO Accident Prevention Manual* (Montreal: ICAO, 2005), 3-10.

[31] *Ibid.*, 3-10.

[32] ICAO, *Accident Prevention Manual*, 3-10.

[33] *Ibid.*, 3-10.

derived from flight operations data, government accident report, operators, manufacturers, various government and private information services and press accounts.[34] During the period 1959-2008, it examined a total of 1,630 commercial accidents for causal factors. When refining the data specifically for the period 1999-2008 (the most recent ten-year period), it found that human factors were attributed to more than 80% of all fatal accidents in aviation.[35] In military aviation, the same trends are observed. In a human factors study conducted by the United States Air Force in 2008 of all major accidents during the period 1992 – 2005, the report found that "most Air Force accidents are attributed to human error".[36] Other Western Air Forces are experiencing the same trends and as recently as February 2010, the French Air Force identified the fact that fully 80% of all accidents can be attributed to human factors.[37]

The Nature of Human Factors Incidents and Occurences

The requirement to teach operators basic systems knowledge and how to deal with specific published emergencies and abnormalities is a long-established practice in aviation, as already discussed in this chapter. Several studies have examined whether or not this training has translated into a reduction of error in operations, including the National Aeronautics and Space Administration (NASA). The results are surprising and

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[34] Boeing, "Statistical Summary of Commercial Jet Airplane Accidents: Worldwide Operations 1959-2008," http://www.boeing.com/news/techissues/pdf/statsum.pdf; Internet; accessed 21 January 2010.

[35] *Ibid.*, 23.

[36] Randall W. Gibb and Wes Olson, "Classification of Air Force Aviation Accidents: Mishap Trends and Prevention", *International Journal of Aviation Psychology* 18 no. 4, (Fall 2008); 307.

[37] France, Ministére de la defense. "Facteurs humain," *Air actualités* 628, (Février 2010); 35.

challenge conventional thinking on not only what should be taught to aviators, but also the methods in which it is taught.[38]

Utilizing data from the Aviation Safety Reporting System (ASRS), a team of researchers from NASA began examining the issue in 1999.[39] Using terms like "emergency" and "abnormal" within the ASRS database, which is populated anonymously by airline pilots across the United States, they were able to identify 107 reports for further analysis. What it revealed was that while aviators handle those specific situations for which they are trained, such as emergency procedures, they frequently were "ill-quipped and ill-prepared for what they had to face" in line operations. The general theme within the reports was that for many pilots, completion of the checklists led them to conclude that the flight had returned to a normal status.[40] The study found that pilots generally oriented themselves from a systems perspective in which the focus was on responding to a specific checklist procedure for a systems abnormality as compared to appreciating what implications that abnormality might have on the remainder of the flight. While the majority of the 'textbook' emergencies were well-handled, these only comprised 22 of the 107 incidents examined. In the remaining 85 reports, the incidents involved non-textbook situations which were generally poorly handled with concerns noted in the way in "which the crew or others responded to the situation."[41] This is graphically illustrated in Table 1-1.

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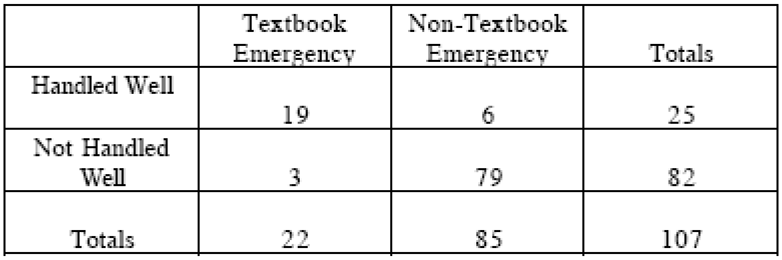
[38] Barbara K. Burian, Immanual Barshi and Key Dismukes, *The Challenge of Aviation Emergency and Abnormal Situations*, Report Prepared for the National Aeronautics and Space Administration, Ames Research Center (Moffat Field, California: NASA, 2005), 1.

[39] Barbara K. Burian and Immanuel Barshi, "Emergency and Abnormal Situations: A Review of ASRS Reports," In R. Jensen (Ed.) *Proceedings of the 12th International Symposium on Aviation Psychology*, (Dayton, Ohio: Wright State University Press, 2003): 1.

[40] *Ibid.*, 6.

[41] Burian and Barshi, "Emergency and Abnormal …", 6.



	Textbook Emergency	Non-Textbook Emergency	Totals
Handled Well	19	6	25
Not Handled Well	3	79	82
Totals	22	85	107

Table 1-1: Type of Emergency and How it was Managed

In a follow-up report published in 2005, the NASA researchers made several observations on why these differences appeared in relation to the type of emergencies crews encountered.[42] As it noted, many non-normal situations have no published procedures or checklist that the crew can rely upon to resolve and this challenges the crew to "determine the appropriate response." When training is largely focused on the most common abnormalities and procedures, they rarely face a situation in which there is no published response.[43] As a result, in many cases the training that aircrew receives simply does not reflect the situations they are likely to encounter in the conduct of operations. Consequently, the quality of the response is hampered by the shortcomings in the quality of communication and coordination amongst all those involved.[44]

These findings are important and reinforce the assertion earlier in this chapter, and published by Almaberti et all in 1998, that training must also focus on the need for more coordination, optimum task allocation and sharing, and the avoidance of conflict.[45] It is no longer enough to focus on systems knowledge and published procedures. Training must be shifted from teaching the operators all the details of the system they are operating to teaching them to be more aware of what they do and do not know. This

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[42] Burian, Barshi, and Dismukes, "The Challenge of …", 1.

[43] *Ibid.*, 2.

[44] *Ibid.*, 11.

[45] Rene Amalberti et al "Human Factors in Aviation", 29.

must be supported by effective strategies and solutions to regain control of any unexpected situations in which they find themselves.[46] Basic ‘stick and rudder’ or ‘hands and feet’ skills remain essential elements of any aviator’s training, but the modern aviation environment demands additional skill sets that the training organization must provide if they are to be successful in the conduct of operations.

These are issues that have been identified within the aviation industry for some time now and it is worthwhile to examine how the industry has addressed them. One particular strategy that has been adopted across the industry as a means of teaching and evaluating areas human factors areas such as workload management, communication, and decision-making is Line Operational Simulations (LOS).

The Introduction of Line Operational Simulation

Concurrent with the breakthrough in human factors at the IATA Istanbul conference in 1975, the concept of LOS was first introduced as Line-Oriented Flight Training (LOFT) in the same year when Northwest Airlines sought permission from the Federal Aviation Administration (FAA) in the United States for a new type of training. This was done for two major reasons. First, simulator technology had improved to the point that permitted the replication of the operational environment to a high level of fidelity.[47] Second, safety data showed that at the time over 70% of all accidents and incidents over the previous 20 years could be attributed to “inadequacies in leadership qualities, communication skills, crew coordination, and decision making.”[48] What the

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[46] Rene Amalberti et al “Human Factors in Aviation”, 29.

[47] William R. Hamman et al, “The Future of LOFT Scenario Design and Validation,” in R. Jensen (Ed.) *Proceedings of the Seventh International Symposium on Aviation Psychology*, (Dayton, Ohio; Wright State University Press, 1993): 589

[48] *Ibid.*, 589.

data was telling the industry was that accidents were primarily caused not by technical malfunctions, but by the inadequate use of resources readily available to the crew. When combined, it was recognized that addressing the issues of human factors in aviation could be better accomplished through the use of the synthetic environment.[49]

At the same time that it received this request from Northwest Airlines, the FAA began to deal with the regulatory issues associated with the burgeoning synthetic environment. Recognizing that the new synthetic technologies were significantly enhanced and complex, and at the request of the airline industry, the first step was for the FAA to address standards for the design of simulators. This effort culminated in the release of the Advanced Simulation Program in 1980, and since that time the FAA has been focused on addressing the second part of the equation, the training systems that use the synthetic environment.[50]

The Delivery of LOS

Since the introduction of the first synthetic training device, significant effort has been put into the technological development of the devices. The inherent problem, as identified by Eduardo Salas, Clint Bowers, and Lori Rhodenizer, is that "aviation training has not evolved but simulations and simulators have."[51] As they described it, simulators are still largely used in the same manner they have been used since they were introduced

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[49] Hamman et al., "The Future of LOFT …", 589.

[50] United States, Federal Aviation Administration, *Developing Advanced Crew Resource Management (ACRM) Training: A Training Manual*, (Washington, D.C.: Office of the Chief Scientific and Technical Advisor for Human Factors, 1998), ii.

[51] Salas et al., "It is Not How Much You Have …", 199.

without any consideration being given to the considerable amount of information learned about individual and team training.[52]

To fully exploit the potential of simulators, organizations must shift focus from achieving optimum levels of realism to the "design of human-centered training systems that support the acquisition of complex skills."[53] In other words, training with simulators must embrace the fundamental concepts of training if it is to be successful. As Salas et al pointed out, training must be a deliberate approach to learning that encompasses several phases and the design of the learning environment. It is "the instructional features embedded in the simulation" that will determine the success of the training rather than the device itself and those tools must include "performance measurement, cognitive and task analsyis, scenario design, and feedback and debriefing mechanisms."[54]

An additional consideration in relation to the synthetic environment that must be considered is that higher fidelity does not equal better training without corresponding improvements in the delivery of that training. The most capable devices in the world will not deliver the promised results and in fact, less-capable devices can actually significantly improve training quality if used properly. With an industry predilection towards costly, high-fidelity devices, hard to obtain funding to support the development of a robust training system to support their utilization is often neglected.[55] The clear lesson to be taken from this is that it is not simply enough to invest in the devices; investment must also be put into the development of a training system that embraces the

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[52] Salas et al., "It is Not How Much You Have …", 199.
[53] *Ibid.*, 199.
[54] *Ibid.*, 201.
[55] *Ibid.*, 205.

behavioural environment to increase training effectiveness.[56] Much of industry has now embraced this lesson and this is reflected in the way in which LOS is delivered within aviation today.

LOS Today

Beginning in the early 1980s, the FAA has issued significant guidance on the development of Line Oriented Flight Training (LOFT). The name itself has evolved to Line Operational Simulation (LOS) which includes traditional LOFT, Special Purpose Operational Training (SPOT), and Line Operational Evaluation (LOE). As clearly stated in the FAA documentation, "due to the role of Crew Resource Management (CRM) issues in accident causation, it has become evident that training curriculums must develop pilot proficiency in both technical and CRM skills."[57] From a human factors perspective, if CRM-type training is to be effective, it must be deliberately built into all training steps and activities and that is why LOS has been widely adopted across the aviation industry. The key to LOS is that it permits the development of a training environment that encourages the application of both technical and CRM concepts to a situation that "enables conceptual knowledge to become working knowledge".[58]

A key component of LOS is that rather than the training event being programmed with a single solution, the crew is allowed to manage the situation and the environment while processing available information to arrive at a satisfactory resolution.[59] Emphasis is placed on the team developing a solution to the problem that satisfies the primary

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[56] Salas et al., "It is Not How Much You Have …", 205.

[57] United States, Federal Aviation Administration, AC 120-35C *Line Operational Simulations: Line Oriented Flight Training, Special Purpose Operational Training, Line Operational Evaluation* , (Washington, D.C.: FAA Flight Standards, 2009), iv.

[58] *Ibid.*, iv.

[59] *Ibid.*, iv.

objectives of ensuring safety of flight and mission accomplishment. In order to do this, the crews must operate together at high levels of effectiveness while prioritizing and managing workload. With the majority of aviation incidents and accidents caused by ‘non-published’ abnormalities or emergencies in which crews fail to properly use all of the resources available to them, the purpose of LOS is to give the crews the skill sets necessary to handle often ambiguous and contradictory situations. As stated by the FAA, the objective of LOS “is to improve total flight crew performance, thereby preventing incidents and accidents during operational flying.”[60]

As already identified, the additional areas that have been added to LOFT to comprise what is today referred to as LOS are SPOT and LOE. Their specific purposes are described below:

a. **SPOT**: Used to introduce new training requirements such as those associated with the introduction of a new aircraft subsystem as a result of modification, it is a specifically tailored training session that incorporates both technical and CRM skills. It can consist of “full or partial flight segments depending on the training objectives for the flight.”[61]

b. **LOE**: This is the primary means of evaluation in which the individual is assessed for both technical and CRM proficiency in accordance with those identified as being required to safely and effectively operate in a mission environment.[62]

The Basic Elements of LOS

There are several key elements of LOS that must be considered during its design and implementation. If aviators are to fully develop CRM skills, which include techniques that facilitate better problem solving and resource management, any LOS event must be structured to “enable CRM behaviours to emerge and the crew to become

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[60] FAA, AC 120-35C, *LOS*, v.
[61] *Ibid.*, v.
[62] *Ibid.*, vi.

aware of them; that is, the scenario must last long enough for crew traits to become evident and require crew skills to be displayed in response to specific circumstances."[63] This basic philosophy must be adhered to in the design of all LOS events if they are to deliver the desired effects.

A second key consideration is that any training conducted under the auspices of LOS should take place with the full crew complement, or all of the actors that would be involved in line operations. This permits the full participation of all members of a crew or team to fully exploit available resources and employ creativity in the solving of complex and ambiguous situations. It is also critical that, to the maximum extent possible, the scenarios employed in LOS replicate the real world environment that personnel will be exposed to in line operations. These scenarios need to progress in real time and need to representative of segments where an entire operation can be completed. Finally, both LOFT and SPOT must be viewed as 'no-jeopardy' training events in which crews are allowed to make errors without fear of career implications. This ensures that the trainees are free to employ all of their resources and creativity.[64]

With the basic elements of LOS clearly established, scenario design and performance levels can be readily determined in both technical and CRM skill areas. The challenge from this point on moves towards implementation and in this area, it is again the role of the human that is critical to the eventual success of a LOS program. In this case, it is the instructors and evaluators who will determine whether or not the LOS program achieves its aims.

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[63] FAA, AC 120-35C, *LOS*, 1.

[64] *Ibid.*, 2.

The Critical Role of the Instructors and Evaluators

Several industry papers have been written on the critical nature the instructors and evaluators play in both implementation and maintenance of any new program. In 1998, the FAA published a guide to the integration of CRM into aviation operations entitled *Developing Advanced Crew Resource Management Training (ACRM): A Training Manual*. The documents identified the fact that "instructors / evaluators represent the front line."[65] Only through early and continuous involvement of that critical cadre will a successful human factors program be fully integrated into operations. Not only can they assist in the development of the training programs, but their early 'buy-in' allows them to become a role model for the remainder of organization, a critical first step in organizational change.[66]

Yet it is not enough to simply get instructors and evaluators involved in the process. They substantial practice to develop adequate assessment skills and that practice needs to be as standardized as much as possible.[67] This is best delivered using 'Rater Reliability' methods in which instructor / evaluators are given the training necessary to not only assess the individuals, but also deliver assessments that are stable and consistent in relation to the rest of the instructor / evaluator (I/E) population. This stability and consistency becomes a critical factor in providing reliable data that allows the organization to measure the overall effectiveness of its various training programs. [68] At a

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[65] FAA, *Developing ACRM*, 7.

[66] *Ibid.*, 14 - 15.

[67] *Ibid.*, 5.

[68] Robert W. Holt, Jeffrey T. Hansberger and Deborah A. Boehm-Davis, "Improving Rater Calibration in Aviation: A Case Study", *International Journal of Aviation Psychology* 12 no.3, 2002, 305 - 306.

minimum, instructors and evaluators need to be trained "in the philosophy, skills, and conduct of LOS and CRM" and they "should be able to effectively observe and critique both individual and crew performance during the scenario."[69] If LOS is to be used effectively to address the human factors issues within aviation, then significant effort must be expended on training and standardizing the instructor / evaluator cadre responsible for delivering that instruction.

The Effectiveness and Benefits of LOS

When developed in accordance with its basic, fundamental principles, and recognizing the critical nature of the instructor cadre in delivering LOS, data within industry shows that it is effective at increasing CRM skills within aviators while maintaining traditional technical skills. A 2008 study published in the *International Journal of Aviation Psychology*, in which 16 empirical studies of crew resource management (CRM) training effectiveness were subjected to meta-analysis, revealed that behavioural training like that conducted during LOS "had large effects on the participants' attitudes and behaviours".[70] These positive impacts were further enhanced when participants were allowed to practice in simulators the behaviours they had been taught in a classroom.[71]

Regulators outside of the US and Canada have noted the effectiveness and benefits of a LOS program. As early as 2002, the Civil Aviation Authority (CAA) in the United Kingdom commented extensively on this in Civil Air Publication (CAP) 720

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[69] FAA, AC 120-35C, *LOS*, 23.

[70] Paul O'Connor et al, "Crew Resource Management Training Effectiveness: A Meta-Analysis and Some Critical Needs", *International Journal of Aviation Psychology* 18 vol 4, 2008, 353.

[71] *Ibid.*, 364.

Flight Crew Training: Cockpit Resource Management (CRM) Training and Line-Oriented Flight Training (LOFT) in which it was noted that "LOFT can have a significant impact on aviation safety through improved training and validation of operational procedures."[72] In short, what industry is discovering is that a well-developed LOS program not only trains individuals to safely and successfully discharge their assigned duties, it also provides a high degree of insight into the internal workings of the organization as well as its training programs.[73] This is an incredibly powerful benefit that when fully utilized, allows the organization to rapidly make changes and improvements to its crew procedures and training programs. It becomes not just a check of the individual, but "a validation of training programs and operational procedures."[74] For organizations in the midst of significant change, LOS has the potential to identify and capture those policies and practices that are no longer relevant to its operating environment but are being maintained by its culture. When implemented properly, LOS can be a powerful engine of change.

Summary

Despite the long-held belief that human factors are a relatively recent development and are widely considered the last frontier of aviation, an examination of the historical record dispels that assertion. Since the beginning of manned flight, the importance of the human in the system has always played a dominant role in whether or not aviation is successful. With current incident and accident statistics showing that

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[72] United Kingdom, Civil Air Authority, CAP 720 *Flight Crew Training: Cockpit Resource Management (CRM) Training and Line Oriented Flight Training (LOFT)* (Gatwick, UK: Safety Regulation Group, 2002), Chapter 5 page 1.

[73] *Ibid.*, Chapter 5, page 1.

[74] *Ibid.*, Chapter 5 page 1.

human factors account for between 70 – 80% of all occurrences, there clearly remains much to be done in this field and one of the key components within industry is the introduction of Line Operational Simulation (LOS). Designed to specifically address shortcomings in leadership, communication, crew coordination, and decision making, it represents an incredibly effective tool for addressing human factors.

Addressing human factors through training in the synthetic environment requires consideration of several key elements of the modern aviation environment. The first is the mandate to recognize that as technology evolves so too must the training. Traditional, well-proven training methodologies valid in systems in which the human was the exclusive actor have proven to be inadequate as increasing levels of automation are brought into the industry. Concurrently, it needs to be recognized that the majority of the incidents and accidents in aviation are as a result of crews failing to use all available resources in situations for which there is no ‘book’ answer. The modern and sophisticated aviation environment has further complicated the ability of the crew to gather information and act deliberately and decisively. Finally, the research has demonstrated that the first line of defence when it comes to human factors in aviation is not just the training program itself, but the instructors and evaluators embedded within that program. The training devices will deliver the potential to increase human effectiveness but it is the humans conducting the training, within a deliberately designed training program, which will make the difference and allow the organization to achieve optimized levels of human performance.

These are all aspects on which much has been written and discussed within the aviation industry. Various civil and military organizations have explored, to differing levels, the concepts and methodologies discussed in this chapter in an ongoing effort to address human factors. One of those has been the Canadian Air Force. Therefore, to continue this study, it is necessary to examine the current state of affairs within the Canadian Air Force as it relates to the field of aviation human factors and LOS.

Chapter 3
The Canadian Air Force

Introduction

While the aviation industry at large has recognized the critical nature of human factors in the safe and successful execution of operations, and the means by which to optimize them through the use of the synthetic environment, the Canadian Air Force struggles with fully implementing and adopting the same methodologies and focus. This chapter will examine, in detail, the desired end state the Air Force hopes to achieve with regards to human factors and the synthetic environment and measure where it is in relation to that desired end-state. This determination will be made through the use of research conducted in the Air Force under other auspices and through an examination of current Air Force publications related to human factors and the synthetic environment.

Desired End State

In 2004, the Chief of the Air Staff published *Strategic Vectors*. Considered a landmark document, it maps out the means by which the Air Force will achieve transformation “from a primarily static, platform-focused Air Force to an expeditionary, network-enabled, results-focused Aerospace Force for the 21st Century.”[75] One of the critical enablers to achieving Air Force transformation is the creation of a “distributed synthetic environment for flying training and operational mission rehearsal.”[76] In 2008, the Commander of 1 Canadian Air Division, the operational commander of all Canadian

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[75] Department of National Defence. *Strategic Vectors* (Ottawa: Department of National Defence, 2004), 2

[76] *Ibid*., 48

Forces aircraft, published a directive to the Air Mobility community in which he stated that "the use of simulation, to accomplish training objectives, both initial and recurrent, is to be exploited to the maximum extent possible to both reduce training requirements on the aircraft and increase pilot production".[77] Clearly, the Canadian Air Force views the exploitation of the synthetic environment as being a critical enabler to not only achieving transformation, but also excellence in operations.

All predictions point to the continued growth of the synthetic environment to deliver training objectives in the Air Force. Whether influenced by industry developments or internal pressures to achieve increased cost effectiveness and improvements in quality with limited resources, the synthetic environment will continue to expand in importance. In "Projecting Power, Canada's Air Force 2035" the Canadian Forces Aerospace Warfare Centre states that "the employment of virtual environments *will* be a key resource at all levels of training and education".[78] It also predicts that "superiority in the cognitive or human dimension will be essential if our values and prosperity are to remain viable in the future."[79] When viewed together, these two statements articulate the requirement for the Canadian Air Force to fully exploit the synthetic environment to achieve human superiority. If that is the desired end-state, then it is necessary to examine the current status of the synthetic environment and the optimization of human performance to determine the delta that exists between the two. Only once that is completed can the Air Force begin to implement policies and resources that ensure it achieves the desired end-state.

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[77] Major General J.A.J.Y. Blondin, *Air Mobility Training Directive FY 08/09 through 13/14* (1 Canadian Air Division Headquarters: Comd 078, 101413Z Jul 08)

[78] Department of National Defence, *Projecting Power: Canada's Air Force: 2035* (Ottawa, Canadian Forces Aerospace Warfare Centre, 2009), 47

[79] *Ibid.*, 47

The Canadian Air Force Today

On the night of July 12th, 2006, a CH149 Cormorant Search and Rescue helicopter from 413 Squadron, Greenwood, departed on a routine training mission. Its purpose was to operate in the vicinity of Sydney, Nova Scotia in coordination with the Canadian Coast Guard to practice recovery operations, which was to include night boat hoists. Tragically, while approaching the hover, the aircraft impacted the water and three crewmembers lost their lives. The causes of the accident were thoroughly investigated by the Directorate of Flight Safety and their findings clearly indicated several human factors causes, including a loss of situational awareness.[80]

Recognizing that the loss of the Cormorant potentially indicated wider, systemic failings, Commander 1 Canadian Air Division began a series of initiatives to identify those shortcomings against a clearly defined desired end-state and begin defining the means by which to address them. These initiatives were based on the "Four P" model articulated by Drs Asaf Degani and Earl Weiner, of the National Aeronautics and Space Administration (NASA) in 1994. The premise of the model is that in order to achieve the desired 'Practice' (the fourth P) in flight operations, it is necessary to first develop Philosophy, Policies, and Procedures.[81] Only once these three have been aligned is it possible to achieve the desired levels of performance. With this in mind, the Commander of 1 Canadian Air Division published the 1 Canadian Air Division Automation Philosophy in June, 2007.[82] Included within the automation philosophy was clear

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[80] Department of National Defence, *Flight Safety Investigation Report 1010-149914* (Ottawa: Directorate of Flight Safety, 22 January 2008)., 62.

[81] Asaf Degani and Earl L. Weiner, *On the Design of Flight Deck Procedures* (Moffat, CA: NASA Contractors Report 177642, 1994), 6

[82] Major General J.C.C. Bouchard, *Air Division Fleet Modernization and Aricraft Automation Philosophy.* 1 Canadian Air Division Headquarters: file 3030-1 (Comd), 12 December 2007

direction to ensure that all "Flying Orders, flying training programs, assessment and evaluation criterion…"[83] are aligned with the automation philosophy.

The APPD Project

With the publication of the Automation Philosophy, the next logical step was the development of policy to support the philosophy. To this end, the Commander of 1 Canadian Air Division initiated the Automation Policy Planning and Development (APPD) Project in December 2007. The fundamental tenant of the project was the development of Air Force policy that instills and maintains a robust human factors program to not only optimize human performance, but to ensure that that performance is in alignment with the new technologies being delivered to the Air Force.[84] The critical first step in creating that policy was measuring the delta between the desired level of performance as articulated in the Automation Philosophy and the current state of the Air Force. To accomplish this, the APPD Project reviewed all existing Air Force documentation and orders and visited several Wings and units across the country. When it was complete, the project delivered a report to the Air Force with several conclusions and recommendations. Some of those were directly related to the areas of human factors and the synthetic environment and these will be discussed in-depth in the following sections.

Simulation in the Air Force

Indications that the Air Force was not taking full advantage of the synthetic environment available to it were evident in the Cormorant investigation in which

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[83] MGen Bouchard, *Air Division Fleet Modernization…*, 2/3

[84] Major General M. Duval, *Aircraft Automation Philosophy*, (1 Canadian Air Division Headquarters: file 3030-1 (Comd), 12 December 2007), 1/3

investigators concluded that "the overall proficiency of the CH149 crews was less than might have been achieved given a more rigorous approach to simulator training, and training in general".[85] The APPD analysis confirmed that the use of the synthetic environment is lacking in almost all areas of the Air Force. It concluded that one of the strengths of the Air Force is the synthetic devices it possesses; it is failing to take advantage of them to deliver training.[86] The impact of this, as summarized in the APPD Report, is that "the tangible training benefits of access to high quality, high fidelity simulators are not being realized, and aircraft flight hours and their associated costs are being used to support training events in the aircraft that are better performed in the simulator".[87]

These findings should not be surprising given the Air Force policy framework related to the synthetic environment. After a complete review of 1 Canadian Air Division Orders applicable to the use of simulation, the APPD Project concluded that "the overall tone and final recommendations can best be described as *"SIM-Phobic"*".[88] This is best captured in the 1 Canadian Air Division Orders statement that says "normally using the simulator as a platform for performing Instrument Rating Tests (IRTs) will be approved as a backup to the IRT being flown in the actual aircraft."[89]

When viewed in light of industry advances in the use of the synthetic environment, and as discussed in the previous chapter, this is a significant finding. Most of the aviation industry, both civil and military, is exploring the limits of what can be

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[85] DND, *FSIR 1010-149914*, 44/69

[86] Kobierski and Stickney, *Automation Analysis Report*, 4.25

[87] *Ibid.*, 3.27

[88] *Ibid.*, 3.26

[89] Department of National Defence, 1 Canadian Air Division Orders Vol 2, Annex A, *IRTs on Flight Simulators – Simulator Approval Process/Conduct of IRTs* (Winnipeg: 1 Canadian Air Division, 2008), A-3/5

accomplished with the synthetic environment while the Canadian Air Force seeks to restrict its use. The policy issue was identified within the APPD report as a significant constraint on the ability of the Air Force to fully exploit the synthetic environment and one that needed to be changed immediately.[90] Like all organizational change, simply rewriting policy will not deliver the desired results. The culture of the organization will determine whether or not the policy is implemented and again, the APPD analysis provides us insight into that culture particularly as it relates to Air Force instructors and evaluators.

The practice of conducting single pilot training and evaluations is manifested in the Air Force use of simulation. Although the synthetic environment is a "vital piece to effective training in modern aircraft"[91] there are "limited applications"[92] of crew evaluations being conducted in Air Force simulators. Instead, there are "strongly embedded legacy Air Force training issues that are counterproductive to automated flight training and evaluation".[93] Air Force instructors and evaluators have created "a very strong culture of the single pilot being able to fly their aircraft to touchdown under all circumstances – "Hands and Feet"".[94] The emphasis on traditional technical skills does so "to the detriment of other flying skills".[95] Again, when viewed within the context of what the aviation industry has learned in relation to the critical role of human factors in aviation incidents and accidents, "the current method of individual evaluation does not promote the requirement for close coordination of tasks"[96] The Air Force culture,

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[90] Kobierski and Sitckney, *Automation Analysis Report*, 4.26
[91] *Ibid.*, 3.27
[92] *Ibid.*, 3.30
[93] *Ibid.*, 3.26
[94] *Ibid.*, 3.26
[95] *Ibid.*, 3.26
[96] *Ibid.*, 3.26

manifested through its methods of training and evaluation, runs counter to what industry has learned are the most effective means of developing optimum levels of human performance in a team environment. To understand this culture, it is necessary to examine the human factors programs within the Air Force as well as the standards by which Air Force instructors and evaluators are trained and qualified.

Human Factors in the Air Force

In 2001, the Air Force created the Human Performance in Military Aviation (HPMA) program to replace the Crew Resource Management (CRM) program. Designed for all personnel directly or indirectly involved in the operation of aircraft, the purpose of HPMA is "a systematic approach to Human Performance training with the aim of increasing operational effectiveness through individual and team performance training".[97] The development and implementation of the HPMA program within the Air Force has been specifically designed to exploit "the strengths of the human factor" while "compensating for our individual limitations through high quality training" to ensure that Air Force personnel equipped "with the superior skills necessary to accomplish their mission".[98] HPMA is viewed as a critical enabler to mission success and safety within the Air Force and significant effort has been expended on its development and implementation.

The APPD Project analysis revealed that HPMA "has not migrated effectively into the cockpit either through flight procedures or daily flight operations" and that the absence "of an effective HPMA program crossed virtually all communities observed

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[97] "Air Force's Human Performance in Military Aviation Program Enters New Phase," *Maple Leaf* 9, no. 12 (22 March 2006): 15

[98] *Ibid*., 15

during the APPD site visits".[99] The primary reason for this is that Air Force crews "are educated in the elements and skills of HPMA Program but they are not *trained* in HPMA".[100] The Air Force has never developed HPMA performance measures. This shortcoming means that "although crews are exposed to the terms and concepts of HPMA, they are not measured or held accountable for HPMA knowledge and the ability to employ the skills in the cockpit".[101]

The lack of HPMA performance measures is reinforced through training and evaluation cultures within the Air Force that emphasizes the individual at the expense of the team within which that individual is operating. Whether it be a CF-18 lead and his wingman conducting an intercept over the high arctic, the crew of a CC177 Globemaster III on approach into Kandahar, Afghanistan, or the maintenance crew repairing a CH124 Sea King at sea, their ability to function as a team at a high level of competency will be the eventual determinant of success. As the broader aviation industry has demonstrated, and as discussed in the previous chapter, the focus on evaluating the individual "can reinforce negative training".[102]

As the APPD Report states, "complex aircraft fail in complex ways, and without the flight crew's ability to (realistically) work together and process and organize the data presented by the aircraft during training and evaluation rides, crews lose the opportunity to maximize the value of training".[103] The same is true of any complex system in which groups of individuals are required to work together to deliver optimum levels of

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[99] Kobierski Stickney, *Automation Analysis Report*, 3.35
[100] *Ibid.*, 3.36
[101] *Ibid.*, 3.36
[102] *Ibid.*, 3.30
[103] *Ibid.*, 3.30

performance. If the Air Force is to fully develop its human potential, it must find the means to measure and evaluate the teams it employs to accomplish its tasks.

The Flight Safety System

Within the APPD analysis, the Flight Safety system of the Canadian Forces was also examined. What it uncovered was that the Air Force struggles to capture the real causes of its incidents and accidents and subsequently learn from them. As a result, the Directorate of Flight Safety is not able to maximize flight safety within the Canadian Forces.[104] This becomes evident when one considers that in the aviation industry at large, both military and civil, human factors play a role in 70-80% of all aviation incidents and accidents yet within the CF, the 2008 Flight Safety Annual Report states that personnel cause factors are attributed in 44.3% of all air occurrences and 77.1% of all ground occurrences.[105] This has existed in all annual reports published since DFS began publishing annual reports in 2005 as illustrated in Table 1 below.

Annual Report	Air	Ground
2005	39 %	68 %
2006	47.3 %	74 %
2007	47.9 %	82.4 %
2008	44.3 %	77.1 %

Table 2-1:
Personnel Cause Factor Attribution in CF[106]

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[104] Kobierski and Stickney, *Automation Analysis Report*, 4.27.

[105] Department of National Defence, *2008 Annual Report on Flight Safety* (Ottawa: Directorate of Flight Safety, 2009), 32.

[106] DND, *2005, 2006, 2007, and 2008 Annual Report on Flight Safety*.

This discrepancy was noted by the Directorate of Flight Safety (DFS) with a statement in both the 2007[107] and 2008[108] annual reports that DFS "will investigate the cause of the marked difference". A review of the annual reports highlights the issue and offers potential solutions as it relates to capturing human factors within the flight safety system.

The Human Factors Analysis Classification System (HFACS) was introduced to the Canadian Forces in 2004. In its 2005 annual report, DFS noted that the system was new and that flight safety staffs were struggling with its introduction and use. The report noted that feedback from the various units indicated that workload within the flight safety staffs prevented them from fully implementing HFACS. As a result, it was noted that only a year into the introduction of the program, flight safety staffs were no longer investigating all occurrences and that the solution may lie in reducing HFACS investigations even further to manage workload. Within the investigations that HFACS was considered, the 2005 report noted with concern that the majority of the analysis was still focused on the active crew failures at the expense of the organizational, or latent, failures.[109] The 2005 annual report actually begins to describe the very causes of the issues with HFACS and causal factors identified in subsequent reports. When considered against the backdrop of the lack of human factors integration into Air Force training and operations for all Air Force personnel, it should not be surprising that Flight Safety personnel are struggling to define and capture human factors issues within the organization.

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[107] DND, *2007 Annual Report on Flight Safety*, 22.
[108] DND, *2008 Annual Report on Flight Safety*, 32.
[109] DND, *2005 Annual Report on Flight Safety*, 18

Notwithstanding the issues the Flight Safety system is having with human factors and the reasons why, the data has consistently demonstrated that the single largest proportion of causal factors has consistently been attributed to personnel since the 2006 annual report. The 2005 numbers do not reflect this but that was also the first year in which HFACS data was collected. This is illustrated in Tables 2-2 and 2-3 and while the actual percentage of personnel cause factors is lower than industry for air occurences, the fact that it constitutes the single largest attributed factor indicates that the Air Force has potential work to do in this area. The data confirms other observations, such as those within the APPD report, that the Air Force is struggling with introducing and maintaining a robust human factors program. Of note, even though the HPMA program was introduced in 2001, there has been no appreciable decline in personnel cause factors in either air or ground occurences.

	Flight Safety Annual Report Air Occurences			
Cause Factor	**2005**	**2006**	**2007**	**2008**
Personnel	39 %	47.3 %	47.9 %	44.3 %
Materiel	43 %	32.2 %	33.7 %	36.6 %
Environment	8 %	13.0 %	12.2 %	13.1 %
Undetermined	9 %	7.1 %	6.1 %	5.4 %
Foreign Object Damage	1 %	0.2 %	0.1 %	0.05 %
Operational	0 %	0.2 %	0.1 %	0 %

Table 2-2:
Air Occurrence Causal Factors[110]

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[110] DND, *Flight Safety Annual Report 2005, 2006, 2007, 2008.*

	Flight Safety Annual Report Ground Occurences			
Cause Factor	**2005**	**2006**	**2007**	**2008**
Personnel	68 %	74.0 %	82.4 %	77.1 %
Materiel	21 %	15.1 %	12.6 %	16.1 %
Environment	2 %	2.1 %	1.4 %	3.1 %
Undetermined	8 %	8.1 %	2.9 %	2.6%
Foreign Object Damage	1 %	0.5 %	0.7 %	1.0 %
Operational	0 %	0.2 %	0 %	0 %

Table 2-3:
Ground Occurrence Causal Factors[111]

Air Force Instructors and Evaluators

As discussed in the previous chapter, the role the instructor and evaluator plays in ensuring the desired levels of human performance are achieved during training is critical. A review of Air Force manuals outlining how Flight Instructors and Evaluators are trained and qualified confirms the legacy practices of single-pilot evaluation with little or no emphasis on HPMA skills.

Flight Instructor Standards

All Air Force personnel engaged in the conduct of flying training are required to be qualified as a Flight Instructor. Personnel selected for evaluator responsibilities are generally selected from those already possessing a Flight Instructor qualification. In 2009, the Air Force released version 1.2 of the qualification standard AIMB for Flight Instructor.[112] The primary reference document for the Flight Instructor qualification

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[111] DND, *Flight Safety Annual Report 2005, 2006, 2007, 2008..*

[112] Department of National Defence, Air Force Training and Education Management System, *Qualification AIMB Flight Instructor* (Winnipeg, 1 Canadian Air Division, 2009), i.

standard is the *Flight Instructors Handbook* released in 2005.[113] A review of these documents for reference to both HPMA and the synthetic environment is revealing.

Within the Flight Instructor Qualification, there are only two references to HPMA. The first occurs in Performance Objective 404 – Conduct a Training Mission, in which the standard is articulated as “with due regard to HPMA, situational awareness and airmanship in accordance with applicable references…”[114] The second is contained in Annex A – References which refers to the Human Performance in Military Aviation Handbook. With regards to prerequisites an individual must hold prior to being trained as a Flight Instructor, there is no requirement to be a qualified HPMA Facilitator. There is no reference to the use of the synthetic environment at all within the Flight Instructor Qualification Standard and a corresponding acknowledgement that there are distinct skill sets required of simulator instructors and evaluators. The Qualification Standard is primarily oriented towards ensuring individuals are qualified to train individuals in traditional legacy type skill sets, thus reinforcing the prevalent culture that prevents the Air Force from fully exploiting the synthetic environment.

The primary reference document for Flight Instructors, the Flight Instructors Handbook, includes limited references to both HPMA and the synthetic environment. Out of a total of 298 pages, the Flight Instructor Handbook contains a single HPMA annex of 14 pages embedded within module 9. Significantly, the annex begins with the statement that “up to 80% of all aviation accidents and incidents are the result of Human Performance issues” notwithstanding the fact that this is not supported by Air Force safety data but is instead reflective of industry data. Included within this annex are

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[113] Department of National Defence, Central Flying School, A-PD-050-001/PF-001 *Flight Instructor’s Handbook* (Winnipeg, CFTPMC, 2005)

[114] DND, *Flight Instructor Qualification Standard,* 4-7

references to the broad objectives of the HPMA program, its policy, and general examples of HPMA Procedures. It includes reference to the requirement for elevated levels of team performance and concludes with a statement that “Part 2 of the HPMA Handbook details effective HPMA behaviours and instructor guides for use in aviation instruction”.[115] It must be emphasized again that there is no requirement for a Flight Instructor to be qualified as an HPMA Facilitator and any references to HPMA in the Flight Instructor syllabus or references are largely symbolic without well-developed HPMA performance measures against which all instructors are trained to and evaluated.

The Flight Instructor Handbook, within its 298 pages, also contains a two page reference to simulation embedded within Module 4 – Instructional Methods. Making specific reference to the FAA Advisory Circular 120-35C on Line Operational Simulations (LOS), it provides a short and concise summary of what LOS is and its benefits to aviation. Significantly, it describes the specialized nature of simulator instructor / facilitator training as a disadvantage of simulation.[116] Considered within the policy framework that currently exists within the Air Force, this statement does not come as a surprise and reinforces the desire of the Air Force to use the aircraft over the simulator as an effective training and evaluation tool. Notwithstanding the marginal attempt to include reference to simulation in the Flight Instructors Handbook, it has been done so in a way that ensures flight instructors do not view it as a primary means to achieve training objectives.

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[115] DND, *Flight Instructor Handbook*, Module 9, Annex A, 19

[116] DND, *Flight Instructors Handbook*, Module 4, 15-16

The Reasons for the Shortcomings

The problems within the Air Force are not unique and have been widely discussed within aviation industry literature. In 2001, the Federal Aviation Administration (FAA) issued a report in which Douglass Wiegman and Scott Shappell noted similar issues in commercial aviation and identified their likely causes.

The FAA study examined all commercial air carrier accidents between 1990 and 1996 in which the accidents were attributable, to some extent, to the aircrew. In total, it considered 119 occurrences. What it discovered was that notwithstanding the significant effort expended on the development and introduction of CRM training and aeronautical decision making (ADM) strategies, these areas still account for the highest proportion of causal factors. It gave two reasons for this. The first was that most CRM and ADM training focuses on specific case studies rather than on the fundamental causes of these problems through the use of a systemic analysis of accident data. The second reason given was that most CRM and ADM training programs involve classroom exercises that are not reinforced by simulator training in which the concepts are applied and evaluated.[117] As already discussed in this chapter, the problems with HPMA and the Air Force's approach to the synthetic environment are eerily similar and were explained in the same manner within the APPD Report.

The FAA study also discovered that most accident investigations focused almost exclusively on the active failures in the cockpit while ignoring the latent or organizational factors. Very few of the accident reports cited supervisory or organizational

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[117] Douglass A. Wiegmann, Scott A. Shappell, Report Prepared for the Federal Aviation Administration, DOT/FAA/AM-01/3 *A Human Error Analysis of Commercial Aviation Accidents Using the Human Factors Analysis and Classification System (HFACS)* (Washington, DC: Office of Aviation Medicine, 2001), 11 – 13.

shortcomings as causes and as a result, held the aircrews almost exclusively responsible. In order to rectify this, the study made the observation that "more thorough accident investigations may need to be performed to identify possible supervisory and organizational issues associated with these events." [118] Again, the similarities to the Air Force HFACS program and the issues identified with ensuring it achieves its aims are remarkably similar. Clearly, the Canadian Air Force is wrestling with the same issues the broader aviation industry is wrestling with.

The Air Force of Tomorrow

The Canadian Air Force has begun a significant revitalization of its capability and considering the technological leaps some of the communities are making, this is not without risk. There is a therefore a requirement to make significant changes in training methodologies as identified by ICAO in 2005 and discussed in Chapter 2.[119] The CF-18 and CP-140 Aurora fleets are completing major upgrades, the C-17 Globemaster III has been delivered and is now flying operations around the world, the majority of the CC130 fleet is about to be replaced by the C130J, the Sea King is being replaced by the CH148 Cyclone, and CH-147 Chinooks have been ordered for delivery. In all cases, the technology being delivered represents a significant leap forward over that it is replacing and in some, such as the CC130 and Sea King, firmly moves the roles of the systems operators from direct manipulation of the controls to the higher level functions of monitoring and interacting with others in the system as well as the aircraft itself. What is happening in military aviation today is reflective of what is happening in the broader

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[118] Wiegmann and Shappell, *A Human Error Analysis* …, 17.
[119] ICAO, *ICAO Accident Prevention Manual* 3-10.

aviation industry in which, increasingly, software and computers are being used to augment the human in the system and deliver supposed increased levels of efficiency and safety across the spectrum of aviation activities. As an example, the Boeing 777 utilizes more than "2.6 million lines of code to support the autopilot, flight management, navigation, and maintenance functions."[120]

What this means for the Air Force are the same lessons the rest of the aviation industry has learned during this evolution. The traditional, 'legacy' style of training which focuses primarily on aircraft handling skills must be expanded to include a deliberate human factors element that includes critical areas such as "attitude development, stress management, risk management, flight deck management, crew-coordination, and psycho-motor skills".[121] Without a deliberate effort to develop, introduce and maintain these new essential skill sets, the Canadian Air Force will not be able to fully exploit the technical potential it either possesses or will soon possess.

Summary

The organizational pressures being exerted on the Air Force through the introduction of new platforms, from a human factors perspective, are significant. While the Air Force aspires to optimizing human performance through the creation of the HPMA Program, the use of the synthetic environment in training and evaluation, and the implementation of HFACS, the policy framework it has created as well as the tools it has given its instructors and evaluators ensures it will never achieve the desired end state. There exists a significant delta between the Air Force ideal and the current situation and

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[120] Tsang and Vidulish, *Principles and Practice of ...*, 7.

[121] Campbell and Bagshaw, *Human Performance and Limitations…*, 5

addressing that delta will take a deliberate and dedicated effort to overcome. Critical to that effort will be a focus on the flight instructors and evaluators so that they are not only conversant, but highly proficient with the methods by which human performance is taught and evaluated.

The delta that has been identified is not insurmountable and reflects problems common to those experienced by many other operators within the aviation industry. For that reason, the lessons of industry, and its ‘best practices’ in the exploitation of the synthetic environment to address the area of human factors, are useful in determining how best to implement an effective LOS program. By considering what has and has not worked for those organizations, both military and civil, it is possible for a plan to be developed that systemically develops and implements a robust training program centred on the synthetic environment that is not only viable, but is also sustainable and delivers the promised benefits in the realm of aviation human factors.

Chapter 4

Solving Human Factors With LOS

Introduction

Considering the role that human factors plays in aviation, including within the Canadian Air Force, there can be little doubt that efforts aimed at addressing them will yield increases in both safety and operational effectiveness. As discussed in Chapter 2, several aviation regulatory authorities, including the United Kingdom's Civil Aviation Authority, have concluded that training such as LOS in which both technical and behavioural skills are emphasized and evaluated "can have a significant impact on aviation safety through improved training and validation of operational procedures."[122] The question then becomes how best to implement these concepts to ensure they achieve their aims.

As discussed in the previous chapter, the Canadian Air Force struggles with its human factors programs. Issues identified by the APPD Analysis in relation to the synthetic environment and HPMA as well as the inability of the CF Flight Safety system to deliver an effective HFACS program are symptoms of a broader failure to fully integrate human factors into all aspects of training and operations. Rather than complement existing processes, they have become additive and when combined with already overworked and undermanned staff, they fail to live up to their promises.

While there are several potential areas of aviation human factors that the Canadian Air Force could address, this chapter will specifically target LOS as the means by which the CF can improve its human factors programs to deliver significant

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[122] United Kingdom, CAP 720 *Flight Crew Training:* …, Chapter 5, page 1.

improvements in safety and effectiveness. It will first consider the critical requirement to clearly define and articulate behavioural performance markers that capture the required behavioural skills to the same level in which the Air Force currently captures technical skills. This chapter will include examples of behavioural markers developed by industry that can be used as a template for the development of behavioural markers in the CF. With those performance markers created, the next logical step is ensuring the instructor / evaluator cadre within the Air Force is capable of employing them across the spectrum of Air Force activities. As this chapter will demonstrate, doing so will require dedicated effort and resources to deliver. Once those two areas are addressed, the design of LOS scenarios will be briefly explained as well as the potential additional benefits the Air Force can derive from a well-developed LOS program.

By focusing on these specific elements, the Air Force will begin the long process of cultural change and transform human factors into a fully integrated method of approaching training and operations. Areas like HPMA and HFACS, currently identified as needing attention, will begin to be addressed within the broader framework of an organization that clearly understands what its goals and objectives are in relation to human factors and that refers to them in a common language. Only then will the Air Force begin to move towards its transformational goals.

Behavioural Markers

There is widespread agreement within the aviation industry on the importance of incorporating reliable and valid measures for assessing an individual or crew's non-technical skills. Within the United States, the adoption of the Advanced Qualification Program (AQP) has driven many organizations to conduct a comprehensive technical and non-technical skills analysis as part of instructional system design, provide specific human factors training (i.e, CRM) and LOFT to all flight crews, and evaluate their CRM skills through the use of LOE. To accomplish these goals, many have developed substantial and detailed lists of required CRM knowledge and skills and some have even begun to incorporate critical CRM behaviours into their cockpit checklists.[123] In Europe, licensing requirements now mandate the evaluation of CRM skills in multi-crew operations and robust behavioural markers have been developed to facilitate this assessment.[124] While there are several variances, they generally share common characteristics.

The vast majority of CRM skills "are complex cognitive skills that involve problem solving, efficient chunking or grouping of information, or utilize specialized forms of mental representations."[125] A behavioural marker can be described as a "prescribed set of behaviours indicative of some aspect of performance" and are generally listed in relation to component skills.[126] Most behavioural markers developed across the industry have fallen into three clusters, two of which are related to CRM performance. The two CRM clusters are cognitive (problem solving, task prioritization, and workload management) and interpersonal (teamwork, communication, group dynamics, and leadership – followship). The third cluster relates to technical assessment: skills already identified in traditional aviation training systems. Further study into aircrew revealed that the "four cognitive categories made up a substantially larger percentage of

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[123] Rhona Flin and Lynne Martin, "Behavioural Markers for Crew Resource Management: A Review of Current Practice", *International Journal of Aviation Psychology* 11 vol 1, 2001, 96.

[124] *Ibid.*, 96.

[125] Thomas L. Seamster, Frank A. Pretiss, and Eleana S. Edens, "Implementing CRM Skills within Crew Training Programs", *Neil Krey's CRM Developers*, http://s92270093.onlinehome.us/CRM-Devel/resources/paper/Training%20CRM%20skills%20seametal99.pdf; Internet, accessed 30 Mar 10, 5.

[126] Flinn and Martin, "Behavioural Markers for …", 96.

crew problems (68%) than the four interpersonal categories." This has significant implications for the design of training and evaluation scenarios that will be discussed later in this chapter. Finally, extensive research has revealed that it is extremely important that the wording of the markers is as concise and simple as possible and that the verb used to describe the marker is clearly observable.[127] Several different studies have identified skill verbs appropriate for use as behavioural markers including those depicted in Table 4-1.

Acknowledge	Analyze	Brief	Coordinate
Adhere	Ask	Choose	Decide
Advise	Assess	Communicate	Define
Advocate	Assign	Compare	Delegate

Table 4-1: Sample CRM Skill Verbs[128]

FAA Behavioural Markers

In the 1990s, the University of Texas, working in conjunction with NASA and the FAA, produced what is generally considered the seminal work on behavioural markers in aviation referred to as the *Line/LOS Checklist: A behavioural based checklist for CRM skills in assessment.* This work has been widely used throughout the aviation industry.[129] Developed through an in-depth analysis of incidents and accidents that have clear human factors causation, and relying on extensive psychological research, the checklist invokes ratings for four distinct phases of flight (pre-flight / taxi, departure,

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[127] Seamster et al., "Implementing CRM Skills …", 5.
[128] *Ibid.*, 5.
[129] Flin and Martin, "Behavioural Markers for CRM …", 97.

enroute, arrival) within six categories of behaviour. These behaviours are described as "team management and crew communications, situational awareness and decision making, automation management, special situations, technical proficiency, and overall observations."[130]

The behavioural markers developed by the University of Texas have been incorporated into Line Operations Safety Audit (LOSA) programs widely adopted across the aviation industry as a means of assessing crew performance during the conduct of line operations. LOSA is a deliberate and systematic program of line observations "to provide safety data on the way an airlines flight operations system is functioning."[131] Data generated during the conduct of LOSA provides an organization with diagnostic indicators of its strengths and weaknesses as well as crew performance. With this data, the organization is then able to develop and implement countermeasures to operational threats and errors.[132] An example of the University of Texas behavioural markers and the rating scale utilized in LOSA are displayed in Figure 4-2.

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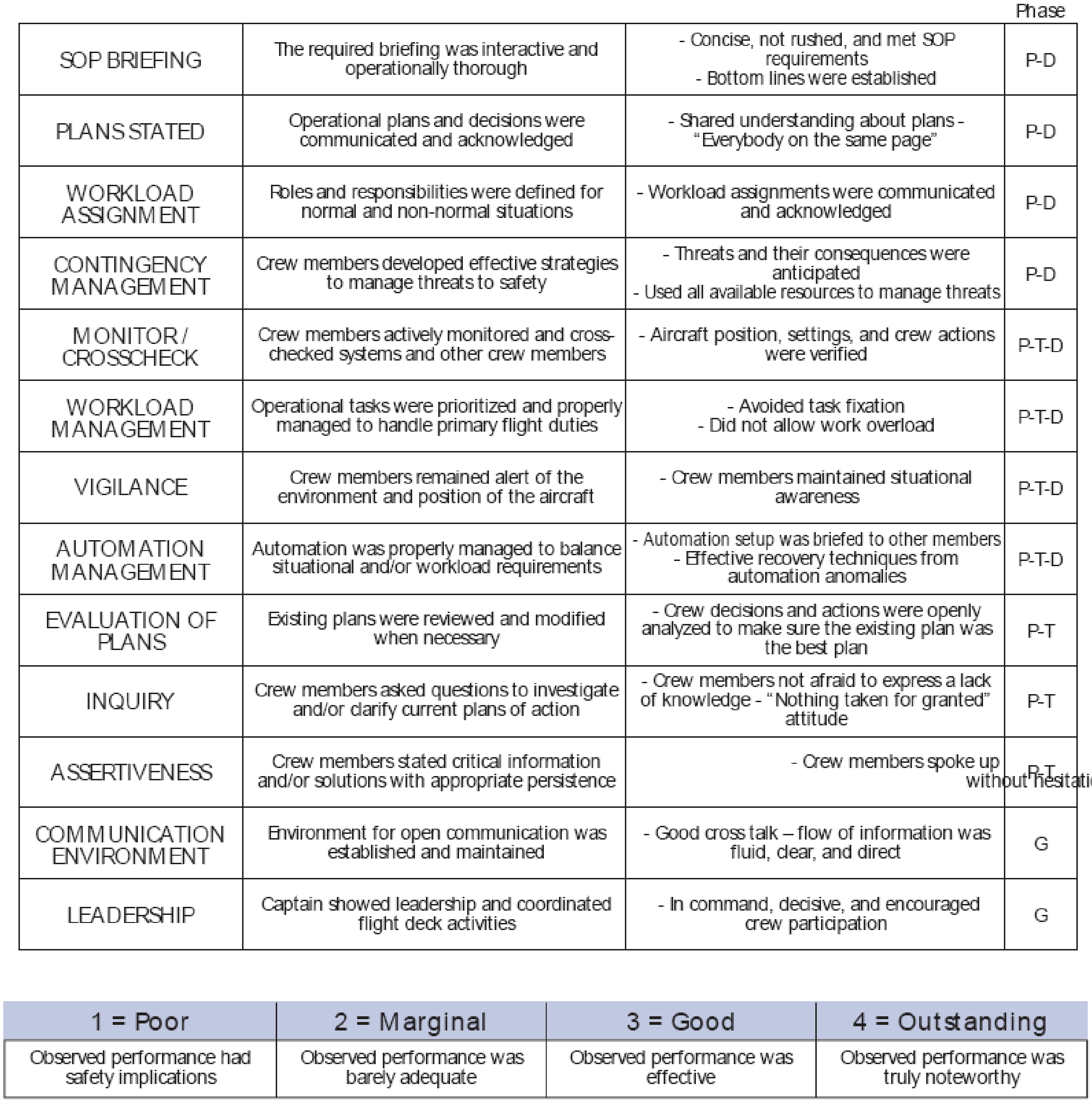
[130] Flin and Martin, "Behavioural Markers for CRM …", 97.

[131] International Civil Aviation Organization (ICAO), DOC 9803 *Line Operations Safety Audit*, (Montreal, ICAO: 2002), 16.

[132] *Ibid.*, 16.

**Key to Phase: P = Pre-departure/Taxi; T = Takeoff /Climb;
D = Descent/Approach/Land; G = Global**



			Phase
SOP BRIEFING	The required briefing was interactive and operationally thorough	- Concise, not rushed, and met SOP requirements - Bottom lines were established	P-D
PLANS STATED	Operational plans and decisions were communicated and acknowledged	- Shared understanding about plans - "Everybody on the same page"	P-D
WORKLOAD ASSIGNMENT	Roles and responsibilities were defined for normal and non-normal situations	- Workload assignments were communicated and acknowledged	P-D
CONTINGENCY MANAGEMENT	Crew members developed effective strategies to manage threats to safety	- Threats and their consequences were anticipated - Used all available resources to manage threats	P-D
MONITOR / CROSSCHECK	Crew members actively monitored and cross-checked systems and other crew members	- Aircraft position, settings, and crew actions were verified	P-T-D
WORKLOAD MANAGEMENT	Operational tasks were prioritized and properly managed to handle primary flight duties	- Avoided task fixation - Did not allow work overload	P-T-D
VIGILANCE	Crew members remained alert of the environment and position of the aircraft	- Crew members maintained situational awareness	P-T-D
AUTOMATION MANAGEMENT	Automation was properly managed to balance situational and/or workload requirements	- Automation setup was briefed to other members - Effective recovery techniques from automation anomalies	P-T-D
EVALUATION OF PLANS	Existing plans were reviewed and modified when necessary	- Crew decisions and actions were openly analyzed to make sure the existing plan was the best plan	P-T
INQUIRY	Crew members asked questions to investigate and/or clarify current plans of action	- Crew members not afraid to express a lack of knowledge - "Nothing taken for granted" attitude	P-T
ASSERTIVENESS	Crew members stated critical information and/or solutions with appropriate persistence	- Crew members spoke up without hesitati	P-T
COMMUNICATION ENVIRONMENT	Environment for open communication was established and maintained	- Good cross talk – flow of information was fluid, clear, and direct	G
LEADERSHIP	Captain showed leadership and coordinated flight deck activities	- In command, decisive, and encouraged crew participation	G

1 = Poor	2 = Marginal	3 = Good	4 = Outstanding
Observed performance had safety implications	Observed performance was barely adequate	Observed performance was effective	Observed performance was truly noteworthy

Figure 4-2: LOSA Behavioural Markers and Rating Scale[133]

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[133] B. Klampfer et al., "Behavioural Markers Workshop", *Group Interation in High Risk Environments (GIHRE) – Aviation*, (Zurich; Swiss Federal Institute of Technology, 2001), 23.

European Behavioural Markers

The Europeans have developed a behavioural marker system referred to as NOTECHS (non-technical skills). NOTECHS was developed as a generic system to permit the evaluation of individual pilots' non-technical skills to enable individual licensing events which the original FAA criteria were not designed to support. Although designed for different purposes, the behavioural elements of NOTECHS are very similar to the University of Texas model. Fundamental to the development of NOTECHS was the belief that the system should contain the minimum number of categories and elements required to capture the required behaviours, that it would use simple language, and that the skills listed should be directly observable, in the case of social skills, or able to be inferred from communication in the realm of cognitive skills. NOTECHS consists of three levels; elements, categories, and pass / fail as depicted in Figure 4-2. By beginning at the element level, and applying clearly articulated ratings at the category level, the instructor evaluator is able to determine if the candidate has passed or failed. [134]

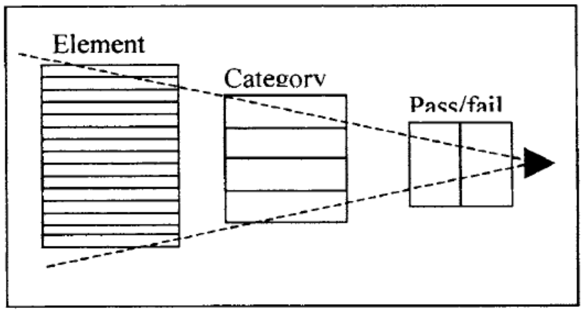

Figure 4-3: The Levels of NOTECHS[135]

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[134] O'Connor et al., "Developing a Method for …", 266 - 267.
[135] *Ibid.*, 267.

The category level of NOTECHS has been “divided into two social skills (cooperation and leadership and management skills) and two cognitive skills (situation awareness and decision making).” The four categories are then divided into three or four elements as depicted in Figure 4-3. Attached to each element are several examples of both positive and negative behaviour.[136] It should be noted that NOTECHS does not capture communication as a separate category like the FAA model does. The view within NOTECHS is that communication is in fact an observable within all categories and cannot be separated on its own.

In 1998, a project team was created to conduct tests on the reliability, usability, and adaptability of NOTECHS to the European culture. This team conducted a literature review, a small group study with 105 training captains, and a final study in which several airlines were examined. In all cases, the NOTECHS model has proven to be a reliable and valid method of assessing behavioural skills in individuals.[137]

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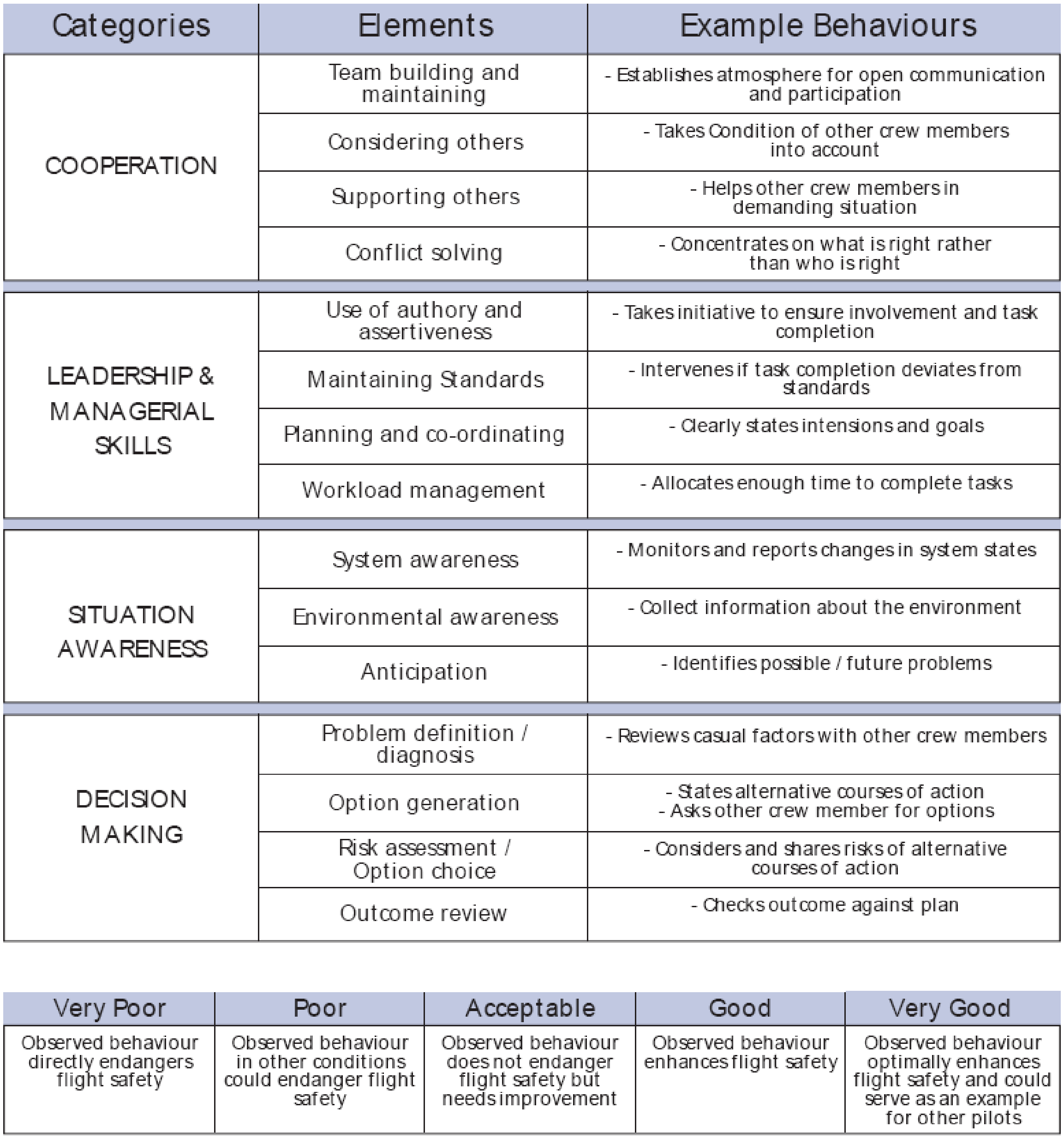
[136] O’Connor et al. “Developing a Method for …”, 267 - 268.

[137] B. Klampfer et al., “Behavioural Markers Workshop”, 25.



Categories	Elements	Example Behaviours
COOPERATION	Team building and maintaining	- Establishes atmosphere for open communication and participation
	Considering others	- Takes Condition of other crew members into account
	Supporting others	- Helps other crew members in demanding situation
	Conflict solving	- Concentrates on what is right rather than who is right
LEADERSHIP & MANAGERIAL SKILLS	Use of authory and assertiveness	- Takes initiative to ensure involvement and task completion
	Maintaining Standards	- Intervenes if task completion deviates from standards
	Planning and co-ordinating	- Clearly states intensions and goals
	Workload management	- Allocates enough time to complete tasks
SITUATION AWARENESS	System awareness	- Monitors and reports changes in system states
	Environmental awareness	- Collect information about the environment
	Anticipation	- Identifies possible / future problems
DECISION MAKING	Problem definition / diagnosis	- Reviews casual factors with other crew members
	Option generation	- States alternative courses of action - Asks other crew member for options
	Risk assessment / Option choice	- Considers and shares risks of alternative courses of action
	Outcome review	- Checks outcome against plan

Very Poor	Poor	Acceptable	Good	Very Good
Observed behaviour directly endangers flight safety	Observed behaviour in other conditions could endanger flight safety	Observed behaviour does not endanger flight safety but needs improvement	Observed behaviour enhances flight safety	Observed behaviour optimally enhances flight safety and could serve as an example for other pilots

Figure 4-4: The NOTECHS Framework[138]

Behavioural Markers Used in the APPD Project

As in LOSA, some models have taken the basic behavioural markers framework and merged them with the required technical skills to create a comprehensive approach to defining the skills and knowledge required on the modern, complex flight deck.

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[138] O'Connor et al. "Developing a Method for …", 268.

Although they share basic similarities with other behavioural models, the incorporation of technical skill sets makes them an extremely powerful tool in assessing an aviator's comprehensive ability to manage the complex and demanding environment of the modern flight deck.

For example, the APPD Analysis used a model developed by Convergent Performance, LLC, referred to as the Advanced Technology Skills Inventory (ATSI)©. Developed in 2004, and utilized as performance measures in several other military organizations including the United States Marine Corps and the United States Coast Guard, the ATSI© examines 12 discreet flight crew skills "in which automation plays a significant role."[139] The 12 performance measures used in the ATSI© during the conduct of line observations were as follows:

a. Mission Preparation Best Practices;
b. Briefing and Debriefing Best Practices;
c. Crew Communication Best Practices;
d. Data Entry Best Practices;
e. Authority Management Best Practices;
f. Task and Workload Management Best Practices;
g. Situation and Mode Awareness Best Practices;
h. Automation Transition Best Practices;
i. Alert and Warning Management Best Practices;
j. Failure and Deviation Response Best Practices;
k. Automation Confidence Best Practices; and

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[139] Kobierski and Stickney, *Automation Analysis Report*, 3.4.

l. Automation Systems and Logic Knowledge.[140]

These 12 areas were targeted during the APPD Project and formed the baseline for the conclusions and recommendations contained in the APPD Report. By directly measuring the skill levels of several Air Force crews conducting both line operations and training in these functional areas, in addition to examining Air Force policies and procedures that facilitated or enabled that crew performance, the APPD Report was able to capture the current state of the Air Force.[141] In effect, the APPD Project conducted a LOSA on the Air Force with emphasis on advanced technology aircraft and the implications of their introduction into the inventory.

These are but three examples of models employed within the aviation industry for measuring behavioural skills; there are several others in use throughout the world.[142] One of them, the ATSI©, has already been used in the Canadian Air Force to conduct the APPD analysis. Clearly, it is possible to develop behavioural markers that allow an organization to effectively evaluate behavioural skills to the same level as traditional skills.

The Development of Behavioural Markers in the CF

The Group Interaction in High Risk Environments – Aviation, *Behavioural Markers Workshop*, held in Zurich, Switzerland in 2001 published an excellent guide to the development and implementation of behavioural markers. Published as a simple guide, it focuses on general concepts and their application vice a specific behavioural

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[140] Kobierski and Stickney, *Automation Analysis Report*, 3.4 – 3.5.
[141] *Ibid.*, 2.2.
[142] Flinn and Martin, “Behavioural Markers for CRM …”, 95.

marker system. The intent of the workshop was to publish a set of guidelines useful to those either employing, or considering employing, behavioural markers. It consists of questions and answers to 17 frequently asked questions on the subject.[143] Many of the details in the publication relate directly to what constitutes good behavioural markers and how to develop them, much of which has already been discussed in this chapter. Where the publication is particularly strong is in its discussion of the change management requirements and resource implications an organization will have to contend with when considering the implementation of behavioural markers. It is these that will be specifically discussed in this section.

The adoption of behavioural markers within the Canadian Air Force will require a deliberate effort and while the ATSI© has already been employed, its full-scale implementation would require some effort to align it with organizational culture and terminology. As stated by the *Behavioural Markers Workshop,* "behavioural marker systems do no transfer across domains and cultures without adaptation."[144] The workshop also noted that the adoption of any behavioural marker system must be properly introduced into an organization, with the addition of management and workforce to support the system, through a phased approach. This enables the building of confidence in both trainers and trainees in the system being implemented. Finally, any introduction of a behavioural marker system must be sensitive to the level of professional development of not only the individuals that will be subject to the behavioural markers but also the maturity and professional culture of the organization.[145]

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[143] B. Klampfer et al., "Behavioural Markers Workshop", 7 – 8.
[144] *Ibid.*, 12.
[145] *Ibid.*, 13.

When this last consideration is weighed against the APPD Project, it can be concluded that the ATSI© was successfully used as a diagnostic tool within the Canadian Air Force by a small pool of highly trained individuals expert in its use. Utilizing it as an internal training and / or evaluation tool would require a correspondingly higher level of effort across the organization to ensure policies and procedures are aligned to support it and, more importantly, personnel are able to use it. This is the most significant consideration within the *Behavioural Markers Workshop* and one that the Canadian Air Force will have to contend with if it is to develop and implement behavioural performance markers to address human factors in aviation.

The Criticality of the Instructor

As already mentioned in Chapter 2, instructors and evaluators are the ‘front-line” in any efforts to either introduce or maintain new methodologies and as such, they are critical to the eventual success of any attempt to introduce behavioural markers. Without this group of individuals being given appropriate training, any efforts to apply behavioural markers will not deliver the desired results. This training must consist of formal training in: human factors skills; the use and limitations of performance marker systems; and the use of the specific behavioural marker system adopted by the organization. It must include a formal assessment, calibration in the environment in which the training or evaluation will be delivered (i.e., simulator), and periodic recalibration to ensure the instructor / evaluator is still conducting training and evaluations in accordance with organizational performance standards.[146]

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[146] B. Klampfer et al., “Behavioural Markers Workshop”,

The FAA LOS Advisory Circular, AC 120-35C, expands upon the general requirements of an effective LOS instructor / evaluator in several key areas, including defining minimum qualifications. Fundamental to their ability to execute LOS is their ability to “effectively observe and critique both individual and crew performance during the scenario.”[147] Minimum requirements for an effective LOS instructor include being line familiar, qualified as a LOS instructor, trained in CRM skills (HPMA in the CF context), and trained in methods for briefing, debriefing and critique. The primary role of the instructor in LOS should be viewed as communicator, observer, and moderator. They are not an instructor in the traditional sense and must resist the temptation to instruct or intrude in any way into the training scenario. Rather, the instructor is the facilitator of the flight and must be “prepared to accept and manage alternate courses of action that the crew may wish to follow.”[148]

Instructors as Facilitators

As discussed in Chapter 2, the purpose of LOFT is expose the crews to complex situations that cannot be solved simply by consulting a checklist but rather forces them into problems that are ambiguous and for which there is no set solution.[149] This mandates that instructor training be focused on being able to manage and assess ambiguous situations as compared to measuring compliance against a standard solution. A critical component to an effective LOS program is the instructor / evaluator’s ability to facilitate “self-discovery and self-critique by the crew rather than lecture on what they did right and wrong”, the latter being something technical oriented programs tend to

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[147] FAA, AC 120-35C, *LOS*, 23.

[148] *Ibid.*, 23-24.

[149] Hamman et al., “The Future of LOFT Scenario …”, 590.

focus on delivering.[150] These areas represent skill sets that legacy training systems do not develop in instructors and are the primary reasons why specific LOS instructor training programs and standards must be developed and implemented.

Facilitation, when conducted properly, significantly enhances the overall training experience. In 1956, B.S. Bloom argued in his *Taxonomy of Educational Objectives* that there are "six levels of mastery, arranged hierarchically by the level of mental complexity involved."[151] In ascending order of complexity, these six levels are knowledge, comprehension, application, analysis, synthesis, and evaluation. A LOS event and its debrief should provide an opportunity for individuals to achieve the highest levels of mastery, analysis, synthesis, and evaluation. Through facilitation, the crews analyze what happened during the simulation event, synthesize their ideas on how to deal with complex situations in the line environment, and evaluate their own actions. In short, it develops skill sets critical to the modern and complex aviation environment. As a facilitator, the instructor becomes a "catalyst, one who uses skilled questioning techniques to help students draw their own conclusions from their personal experiences and create their own prescription for change."[152]

Traditional instruction is oriented towards information flowing to the student from the instructor, who generally has significantly more knowledge on the subject. Facilitation draws on knowledge already resident within the trainee, such as HPMA concepts taught in a classroom, to gain insight into the concepts and master them. A

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[150] R. Key Dismukes, Kimberly K. Jobe, and Lori K. McDonnel, *LOFT Debriefings: An Analysis of Instructor Techniques and Crew Participation*, NASA Technical Memorandum 110442 DOT/FAA/AR-96/126 (Moffat, CA: NASA Ames Research, 1997),1.

[151] R. Key Dismukes et al., "What is Faciliation and Why Use It?" in *Facilitation and Debriefing in Aviation Training and Operations*, eds. R.K. Dismukes and G.M. Smith (Aldershot, UK: Ashgate, 2000), 4.

[152] *Ibid.*, 4 - 5.

NASA study entitled *LOFT Debriefings: An Analysis of Instructor Techniques and Crew Participation* conducted on several airlines in the 1990s revealed that instructors who have not been taught facilitation methods, but are familiar with traditional instructional techniques, run a debrief session that revolves almost exclusively around themselves rather than the students. In these cases, the debrief is approached from a "teacher tell" perspective and as a result, there is little benefit to it. The NASA study provided empirical evidence of the benefit of facilitation in crew training but noted that instructors "need additional training in facilitation."[153] Concurrent with the 1997 study, NASA released *Facilitating LOS Debriefings: A Training Manual* to assist aviation organizations with improving facilitation.[154] The second release was driven by one particularly significant finding in the study related to instructor standardization.

LOFT Debriefings revealed that there was significant discrepancy amongst LOS instructors at all five airlines examined. From effectiveness as facilitators to the emphasis they placed on various CRM skill sets and crew participation, the instructors crossed the entire spectrum from very good to poor. As argued in the study, this indicates "an urgent need for additional training and standardization within each airline."[155] To address this issue, the aviation industry has adopted programs aimed at instructor standardization, commonly referred to as 'rater reliability'.

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[153] Dismukes, Jobe and McDonnel, *LOFT Debriefings: An Anlysis …*, 4.

[154] R. Key Dismukes, Kimberly K. Jobe, and Lori K. McDonnel, *Faclilitating LOFT Debriefings: A Training Manual*, NASA Technical Memorandum 112192 DOT/FAA/AR-96/126 (Moffat, CA: NASA Ames Research, 1997). Readers are encouraged to consult this manual when considering developing a LOS program. It is a comprehensive document that clearly outlines how to effectively implement and maintain facilitation within an aviation organization.

[155] Dismukes, J obe, and McDonnel, *LOFT Debriefings: An Analysis…*, 14.

Rater Reliability

Within any training and evaluation system, “the assessment of individual performance relies on systematic observation and assessment by a trained rater or instructor/evaluator (I/E).”[156] Only through standardization can the rating and evaluation process used by the I/Es provide reliable and valid data from which to address individual and organizational deficiencies. This mandates that rating criteria remain stable over time and that ratings are consistent across the instructor / evaluator population. Given the traditionally subjective nature of behavioural measurements, the aviation industry has turned to psychometric methods of assessment in which reliability is a precondition for validity.[157]

The aviation industry has generally adopted two types of rater-reliabilty methodologies; inter-rater reliability (IRR) and referent-rater reliability (RRR). The first method, IRR, relies on achieving inter-rater consistency, or inter-rater agreement. In this method, groups of I/Es conduct observations on the same event and rate them. Upon completion of the rating, the various I/E ratings are then analyzed, compared, and discussed to achieve a high level of congruency amongst the I/Es. IRR establishes a group norm that I/Es can then utilize in their own evaluations as a baseline. The second method, RRR, seeks to achieve rater consistency with an already developed standard of

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[156] Robert W. Holt, Jeffrey T. Hansberger, and Deborah A. Boehm-Davis, “Improving Rater Calibration in Aviation: A Case Study”, *International Journal of Aviation Psychology* 12 no. 3, 2002, 305.

[157] *Ibid.*, 306.

measurement. While generally more reliable, and therefore more valid, RRR demands a higher level of effort to develop the referent against which I/Es are trained.[158]

Regardless of the methodology chosen to achieve reliability and validity, training generally employs the same methods. Potential instructors and evaluators are provided with formal training in CRM concepts and applications, training in the specific behavioural markers to be used, practice in observing specific behaviours, and practice in utilizing all performance markers concurrently to develop a rating. Included within this training must be Behavioural Observation Training (BOT) which teaches raters "to accurately detect, perceive, recall, and recognize specific behavioural events" as well as training in note-taking skills.[159] Generally, this is conducted through formal classroom training and the observation of prepared videos in which multiple observers rate the same crew performance. Feedback and discussion throughout the training, particularly with regards to how individual grades compare with peers, is critical to developing a common baseline in the trainees through the use of both traditional instruction and facilitation.[160]

Studies into the effectiveness of reliability training have shown that IRR evaluation standards can be obtained in an environment of "constrained resources of personnel and training time."[161] Generally, both IRR and RRR deliver high values of correlation to referent grades. The distinction between the two is that while a high level

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[158] Robert W. Holt, Peder J. Johnson, *Application of Psychometrics to the Calibration of Air Carrier Evaluators*, Report prepared for Chief Scientist for Human Factors, Federal Aviation Administration (Washington, FAA: 1998), 2 – 3.

[159] J. Matthew Beaubien et al., "Improving the Construct Validity of Line Operational Simulation (LOS) Ratings: Lessons Learned from the Assessment Center", *International Journal of Aviation Psychology* 14 no. 1, 2004, 12.

[160] Michael T. Brannick, Carloyn Prince, and Eduardo Salas, "The Reliability of Instructor Evaluations of Crew Performance: Good News and Not So Good News", *International Journal of Aviation Psychology* 12 vol. 3, 2002, 250.

[161] Holt, Hansberger, Boehm-Davis, "Improving Rater Claibration …", 323.

of referent reliability implies inter-rater reliability, high levels of inter-rater reliability do not imply referent reliability. It is quite possible for a group of instructor / evaluators to come to agreement amongst themselves while disagreeing with the published standard. For this reason, RRR is deemed the more valid of the two methods. What this means for the Air Force is that the 'gold standard' is RRR but reliability can still be achieved through the implementation of IRR. Another advantage to RRR is that "because it is based on qualification standards, it provides an explicit training objective for evaluators."[162] Regardless of the method chosen, achieving an ability to teach and assess behavioural skills within the Canadian Air Force is entirely in the realm of possibility: all that is required is a dedication to implementing it and ensuring the resources required to support it are put in place.

With behavioural markers developed and an instructor cadre trained and prepared to teach and assess behavioural performance, the last step is the development of the training scenarios in which that performance will be assessed in the synthetic environment. Again, industry provides significant insight on how best to design training scenarios that support the attainment of both technical and behavioural objectives.

Simulator Scenario Design

The baseline for all LOS scenario development is that it must create "a functional environment which provides the opportunity to combine CRM and technical skills."[163] The basic framework of LOS scenario design is to integrate technical and CRM

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[162] Timothy E. Goldsmith and Peder J. Johnson, "Assessing and Improving Evaluation of Aircrew Performance", *International Journal of Aviation Psychology* Vol 12 no. 3, 2002, 231.

[163] Hamman et al., "The Future of LOFT Scenario …", 589.

objectives into a single training program that elicits the desired responses.[164] These are then matched with primary technical objectives to complete overall scenario development. The FAA Advisory Circular on LOS, AC 120-35C, discussed scenario design at length.

For LOS to be effective, it must be as realistic as possible. This makes the scenarios operationally relevant, believable, and a valid test of the crew's ability to execute an actual mission. The purpose is to simulate operational situations that require good CRM and technical skills to successfully resolve while creating the requirement for decision making. They need to create an open atmosphere in which all crewmembers are able to engage in free and open communication as required and when appropriate. LOS scenarios are most effective when they are straightforward and the crew should live with the situation until it is either resolved or the aircraft has been safely landed. Any disruption of a LOS event, for comments or instruction, significantly detracts from its overall effectiveness.[165]

Scenario Design Process

Specific training objectives should be developed for each LOS scenario. These objectives are generally related to items identified as being required within the organization such as winter operations or the incorporation of new systems. Operational deficiencies identified though evaluations or LOSA are also included in scenario development. Generally, scenarios in the commercial aviation industry are comprised of some or all of the elements below:

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[164] FAA, AC 120-35C, *LOS*, 30.

[165] *Ibid.*, 4.

a. Pre-flight activities such as icing or cargo loading anamolies that the crew must address;

b. Taxi operations;

c. Origin, routing and destination;

d. Revised arrival procedures such as an unexpected runway change;

e. Alternate operation of flight management systems;

f. Abnormal and Emergency conditions, including simple conditions (i.e., a hot start) and complex conditions that continue for the entire flight (i.e., a failed essential alternating current bus);

g. Adverse weather conditions; and

h. Partial or full loss of integrated flight management systems.[166]

As stated in AC 120-35C, "one misconception is the belief that LOS training should continuously increase crew workload until the crew becomes overloaded. This is not the purpose or intent of LOS and can actually help to defeat its effectiveness."[167] A well-designed LOS scenario does not need to be technically complex, it needs to be ambiguous to force desired crew behaviours to exhibit themselves. As discussed at length in Chapter 2, the majority of accidents are not caused by complex technical failures but rather seemingly minor discrepancies that lead to crew errors.[168] With these basic principles in mind, it is possible to build an appropriate LOS scenario.

The Event Set

The primary design component of LOS is referred to as the 'event set', a group of related events that are part of the scenario and which achieve specific training

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[166] FAA, AC 120-35 *LOS*, 3.

[167] *Ibid.*, 25.

[168] Hamman et al., "The Future of LOFT Scenario …", 591.

objectives.[169] Each event set is comprised of triggers, distracters, and supporting events. The event trigger is the condition which initiates the event, distracters are conditions inserted into the training period to divert the trainee’s attention from events that are occurring or about to occur, and supporting events are other elements taking place within the event set that further both technical and CRM training objectives.[170] The purpose of the event set is to provide a reference source for specific items to be accomplished during the conduct of the LOS and ensure all training objectives are achieved.[171] Breaking the training event into specific sets, or timeframes, allows observable behaviours to be focused “if a clearly definable unit of action or time is specified and used to delimit the observable crew behaviours.” This has the added benefit of reducing instructor workload through focusing on key CRM behaviours for that specific event set rather than trying to having to monitor for all categories.[172] Event set-based scenarios require the coordinated and effective actions of all crewmembers to successfully complete.[173]

As each event set is built, with its specific technical and CRM training objective, the overall scenario will eventually be captured in an event set matrix. This matrix allows the organization to categorize the levels of complexity the crew will have to contend with throughout the scenario.[174] An example of an event set matrix used in LOS

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[169] Hamman et al., “The Future of LOFT Scenario …”, 590.

[170] William R. Hamman et al., “The Future of Loft Scenario Design and Validation”, in R. Jensen (Ed.) *Proceedings of the Seventh International Symposium on Aviation Psychology* (Dayton, Ohio: Wright State University Press, 1993), 590.

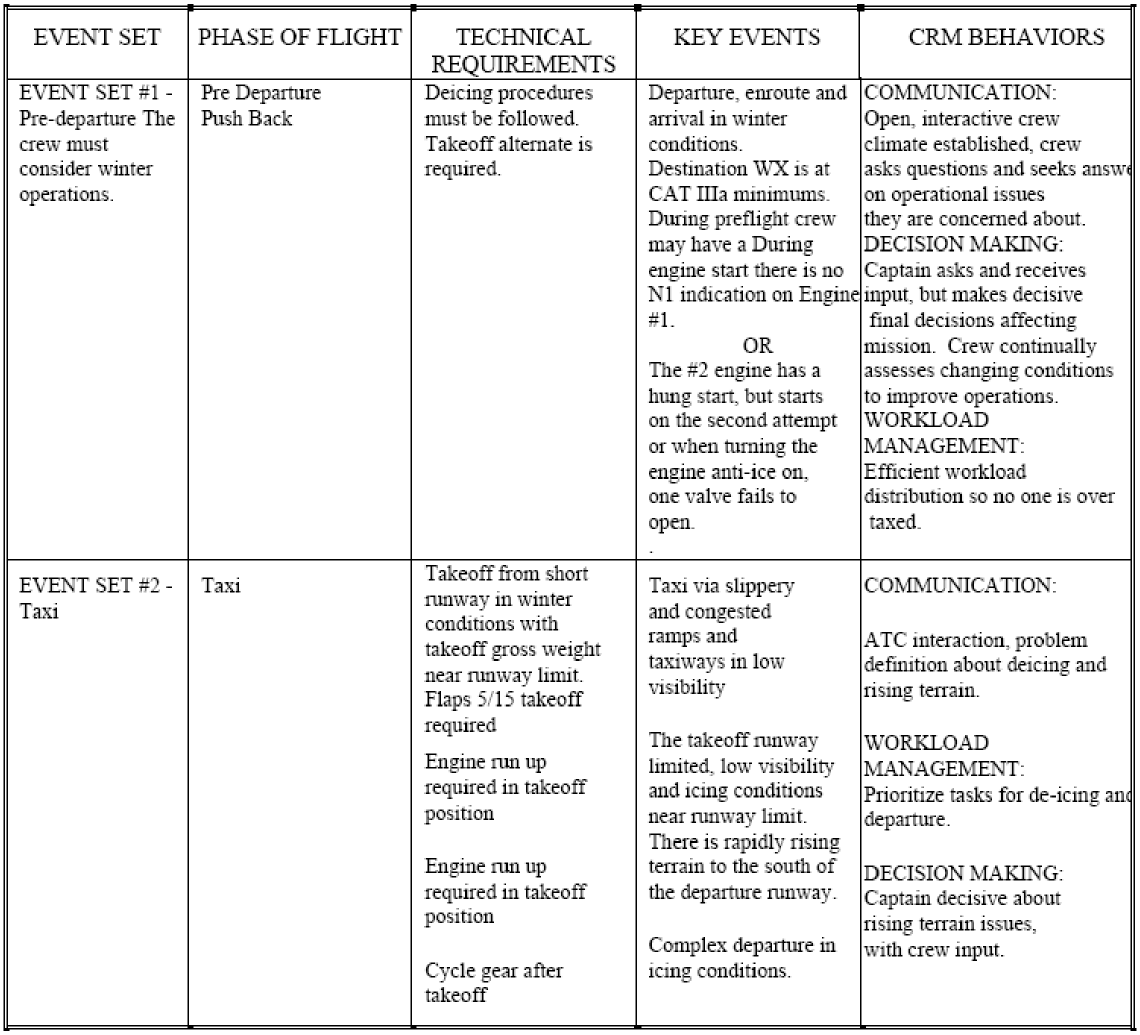
[171] FAA, AC 120-35C, *LOS*, 35.

[172] Flinn and Martin, “Behavioural Markers for CRM …”, 100.

[173] FAA, AC 120-35C, *LOS*, 26.

[174] *Ibid.*, 35.

is shown in Figure 4-5 below.



EVENT SET	PHASE OF FLIGHT	TECHNICAL REQUIREMENTS	KEY EVENTS	CRM BEHAVIORS
EVENT SET #1 - Pre-departure The crew must consider winter operations.	Pre Departure Push Back	Deicing procedures must be followed. Takeoff alternate is required.	Departure, enroute and arrival in winter conditions. Destination WX is at CAT IIIa minimums. During preflight crew may have a During engine start there is no N1 indication on Engine #1. OR The #2 engine has a hung start, but starts on the second attempt or when turning the engine anti-ice on, one valve fails to open. .	COMMUNICATION: Open, interactive crew climate established, crew asks questions and seeks answ on operational issues they are concerned about. DECISION MAKING: Captain asks and receives input, but makes decisive final decisions affecting mission. Crew continually assesses changing conditions to improve operations. WORKLOAD MANAGEMENT: Efficient workload distribution so no one is over taxed.
EVENT SET #2 - Taxi	Taxi	Takeoff from short runway in winter conditions with takeoff gross weight near runway limit. Flaps 5/15 takeoff required Engine run up required in takeoff position Engine run up required in takeoff position Cycle gear after takeoff	Taxi via slippery and congested ramps and taxiways in low visibility The takeoff runway limited, low visibility and icing conditions near runway limit. There is rapidly rising terrain to the south of the departure runway. Complex departure in icing conditions.	COMMUNICATION: ATC interaction, problem definition about deicing and rising terrain. WORKLOAD MANAGEMENT: Prioritize tasks for de-icing an departure. DECISION MAKING: Captain decisive about rising terrain issues, with crew input.

Figure 4-5: Sample Event Set Matrix[175]

Optimizing LOS Effectiveness

LOS has been in use throughout the aviation industry for several years. As a result, several studies have been done into methods to increase its overall effectiveness. The majority of these measures relate to either "reducing the cognitive demands of the

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[175] FAA, AC-120-35C, *LOS*, 39.

rating task" and "selecting, training, and retaining qualified pilot instructors."[176] The instructor areas have been previously covered in this chapter so this section will focus exclusively on increasing the ability of the rater to effectively rate the event.

In order to increase rater effectiveness from a cognitive perspective, the workload of the instructor must be considered in the design of the scenarios. As experience with LOS has increased across the industry, several strategies have been developed that can be employed to reduce that workload. These include the following:

a. Evaluating fewer skills per event set;
b. Increasing the length of each set;
c. Creating a user-friendly evaluation form;
d. Automating the simulator as much as possible to run the scenario;
e. Using a behavioural checklist instead of rating scales;
f. Clearly specifying skill definitions and example behaviours;
g. Provide multiple opportunities for the instructor to observe required skills;
h. Videotape the crew performance;
i. Provide decision tools to help instructors make their final ratings; and
j. Document all skill ratings, not just those above or below average.[177]

All of these strategies, when implemented, have proven to significantly increase overall rater effectiveness in LOS. While they are all relatively straightforward, three of them will be examined in some detail to further develop an understanding of how they increase overall LOS effectiveness.

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[176] Beaubien et al., "Improving the Construct Validity …", 8.

[177] *Ibid.*, 8 – 11. Readers are encouraged to consult the reference document for a full explanation of all rater workload mitigation strategies.

Increasing the Length of the Event Set

Increasing the length of the event set provides additional time to the instructor to complete ratings, make notes, compare performance on the current event set to previous event sets, and prepare for the next set. However, this needs to be deliberately managed against the requirement to maintain a high level of realism in the scenario. Increasing time within the event set may impact the ability of the scenario to manipulate stress in the crew being observed through the introduction of time pressures.[178] The FAA has regulated that each LOS scenario be scheduled for at least four hours to include cockpit preparation, pre-flight activities, crew briefings and interactions with agencies such as Air Traffic Control (ATC).[179] Clearly, the design of any LOS scenario mandates deliberate consideration and weighing of training objectives against time available to optimize instructor workload and ensure a high level of rater reliability.

Design a User-Friendly LOS Evaluation Form

Simulator instructors are located at the back of the simulator, often in cramped conditions with low-light. This mandates the construction of forms that employ large print and brightly coloured paper to increase contrast and they should be contained in a spiral-bound booklet that can be easily folded to mitigate the cramped space. The form itself should be designed to provide background information, such as skill definitions or simulator manipulations, on the left hand page while the right hand page contains the rating form. Simple “check in the box” formats should be used instead of formats that

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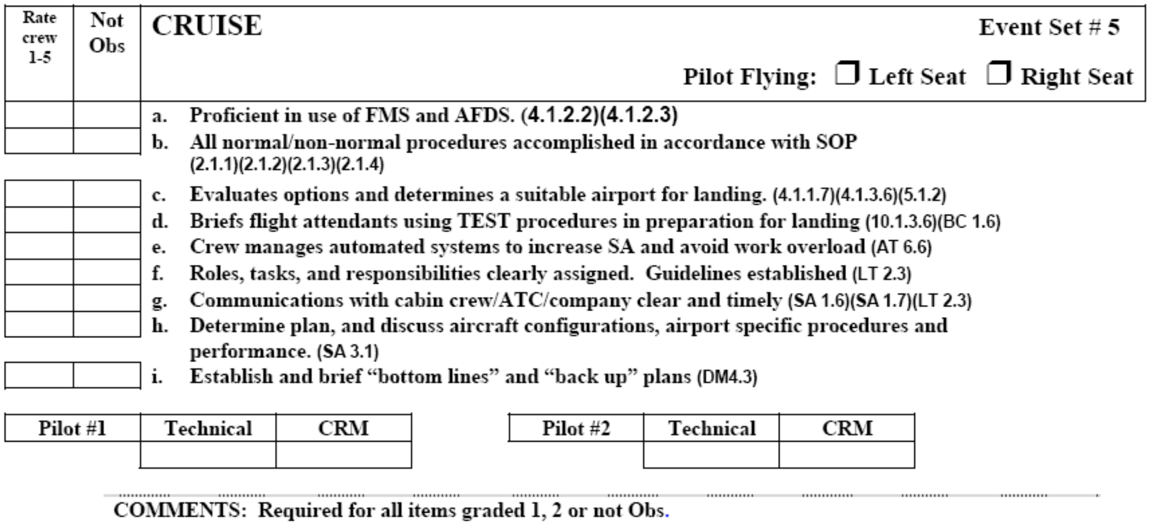
[178] Beaubien et al., “Improving the Construct Validity of ….”, 8.

[179] FAA, AC 120-35C, *LOS*, 3.

require extensive input.[180] Evaluation sheets play a critical role in the ability of the evaluator to rate the crew's performance and fundamental questions about issues such as how the ratings are worded, whether they are general or specific, and whether or not to use a numerical rating scale versus behavioural checklists are all questions the Air Force will have to wrestle with if it is to develop an effective LOS program.[181] A sample grade sheet, taken from the FAA Advisory Circular on LOS, is included below in Figure 4 – 5.



Rate crew 1-5	Not Obs	**CRUISE** Event Set # 5 Pilot Flying: ☐ Left Seat ☐ Right Seat
		a. Proficient in use of FMS and AFDS. (4.1.2.2)(4.1.2.3)
		b. All normal/non-normal procedures accomplished in accordance with SOP (2.1.1)(2.1.2)(2.1.3)(2.1.4)
		c. Evaluates options and determines a suitable airport for landing. (4.1.1.7)(4.1.3.6)(5.1.2)
		d. Briefs flight attendants using TEST procedures in preparation for landing (10.1.3.6)(BC 1.6)
		e. Crew manages automated systems to increase SA and avoid work overload (AT 6.6)
		f. Roles, tasks, and responsibilities clearly assigned. Guidelines established (LT 2.3)
		g. Communications with cabin crew/ATC/company clear and timely (SA 1.6)(SA 1.7)(LT 2.3)
		h. Determine plan, and discuss aircraft configurations, airport specific procedures and performance. (SA 3.1)
		i. Establish and brief "bottom lines" and "back up" plans (DM4.3)

Pilot #1	Technical	CRM

Pilot #2	Technical	CRM

COMMENTS: Required for all items graded 1, 2 or not Obs.

Figure 4-6: Sample LOS Grade Sheet[182]

Document all Skill Ratings

Research has shown that evaluators tend to rate crews as "average" when the grade sheet only requires justification or amplification for ratings of above or below average. Including ratings of average performance reduces this probability and also creates a significantly larger data set with which to grade the overall effectiveness of the LOS program. Adopting this methodology requires deliberate effort in clearly

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[180] Beaubien et al., "Improving the Construct Validity of …", 9.
[181] Goldsmith and Johnson, "Assessing and Improving Evaluation ….", 235.
[182] FAA, AC 120-35C, *LOS*, 40.

articulating rating skills that are easy for the instructor to use to avoid other potential issues, such as instructor workload.[183]

The Conduct of LOS

The FAA recommends that all LOS scenarios contain four distinct phases: briefing, pre-flight planning documents and activities, the flight segment, and the debriefing.[184] Research into the effectiveness of LOS has shown that weaknesses in the debriefing phase are the most significant contributors to a weak or ineffective LOS program.[185] A brief explanation of each phase is included below.

a. **Briefing**. The instructor will brief the LOS scenario, including the training objectives and the role of the instructor and flight crew during the scenario. Background information, such as the environmental setting of the scenario, will also be discussed. Frequently, inadequate LOS briefings result in poor LOS events. The most common problem is a failure to convince the crew that the instructor is not present during the event and cannot be used as a resource by the crew. The brief should also include a review of the CRM (HPMA) concepts to be covered in the scenario, with the crew taking the lead in this part of the briefing.[186]

b. **Preflight Activities**. The instructor will provide the crew with all pre-flight documentation required to complete a flight. Weather sequences, weight and balance, and other normal pre-flight documentation should be the same as that provided for a real flight. The crew needs to be in the simulator early enough to properly set up the aircraft in accordance with established pre-flight procedures.[187]

c. **Flight Segment**. As already mentioned, the flight segment unfolds in real time with the crew performing their normal duties. The only exception to this is during the conduct of SPOT which can be interrupted for the purposes of accomplishing specific training objectives. Realism must be adhered to at all

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[183] Beaubien et al., “Improving the Construct Validity of …”, 11.
[184] FAA, AC 120-35C, *LOS*, 2.
[185] Dismukes, Jobe, and McDonnel, *LOFT Debriefings: An Analysis …*, 4.
[186] FAA, AC 120-35C, *LOS*, 4 – 8.
[187] *Ibid.*, 8 – 9.

times to include the crew donning headsets, emergency breathing equipment, or any other piece of equipment necessary for the conduct of flight.[188]

d. **Debriefing**. This is the most critical component of the LOS session. The instructor must resist the urge to instruct and allow the crew to explore their own strengths and weaknesses. Research has shown that crews will not all be capable of conducting this type of activity to the same level, depending on experience and maturity. This means that instructors must be prepared to facilitate to varying levels depending on the crew they are dealing with. Instructor requirements during LOE are different than those of LOFT and SPOT and this must be taken into account during instructor development.[189]

Scenario Validation and Update

Developing an effective LOS program requires deliberate effort and the consideration of several key factors as articulated in this chapter. One additional requirement relates to the validation of the scenario prior to its use with line aircrew. In the United States, all commercial operators are required to submit their scenarios to the FAA for approval prior to their use. Approval is based on compliance with Advisory Circular 120-35C *Line Operations Simulations*.[190] Once validated, LOS instructors are then trained in the conduct of the new LOS scenarios. The development of LOS within the Air Force would mandate a similar regulatory approach to ensure that various fleets are complying with Air Force objectives related to teaching and evaluating behavioural skills.

The last item to consider in the implementation of LOS is a recognition that the scenario design effort does not stop with the delivery of the first scenarios. Scenarios need to be updated regularly (the FAA recommends at least annually) to ensure that students do not become overly familiar with them. This final step would ensure that Air

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[188] FAA, AC 120-35C, *LOS*, 9 and 12.

[189] Dismukes, Jobe, and McDonnel, *LOFT Debriefings: An Analysis of …*, 20.

[190] FAA, AC 120-35C, *LOS*, 4. For a detailed breakdown of LOS Design Methodology, readers are encouraged to consult Table 6-1 in this document. It provides a step by step process that organizations can follow to develop LOS.

Force crews are exposed to “new technologies, procedures, and current operational problems”.[191]

Once these various methodologies and considerations have been completed, the Air Force would find itself in a position to implement and sustain an effective LOS program. As this chapter has demonstrated, it is simply not enough to state that the Air Force is going to fully exploit the synthetic environment while optimizing human performance without ensuring the appropriate level of resources and effort are in place to support the attainment of that goal. The APPD report discussed in Chapter 3 summarized the result when that does not happen and as a result, the Air Force has yet to optimize its training and operations for aviation human factors. Implementing and sustaining an effective LOS program is within the reach of the Air Force if the lessons of industry are considered. While LOS is single component of a broader human factors effort, the deliberate effort required to successfully introduce it into the Air Force would have significant ‘ripple’ effects across the organization.

Additional Benefits of a LOS Program for the Air Force

The implementation of LOS throughout the Air Force mandates that certain critical activities take place as discussed in this chapter. First, the Air Force will have to clearly define the behavioural skills it expects its personnel to achieve and publish the behavioural markers it will measure their performance against. Second, it will have to teach its instructors and evaluators to use those behavioural markers during the conduct of training and operations to ensure the Air Force is achieving its goals. Finally, deliberate effort will be required to develop and implement LOS scenarios that capture

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[191] FAA, 120-35C, *LOS*, 13.

both the technical and behavioural skills the Air Force wants to enforce and evaluate. All of these activities will cause the organization to develop a common language of aviation human factors. Out of that common language will develop the means by which the Air Force begins to address its other human factors related challenges such as HPMA and HFACS. In the case of HPMA, which already contains the foundation and concepts of a robust human factors program, all that is really missing is the evaluation portion. HFACS, although a Flight Safety function, will also begin to correct itself as the organization develops a broader appreciation of what it is that it wants to achieve in the field of aviation human factors. These two areas are relatively straightforward to address when considered within the context of developing and implementing a LOS program across the Air Force.

There are other potential benefits as well that have already been briefly discussed in this paper. One of the most important benefits that would logically follow the implementation of a LOS program would be the introduction of a Line Operations Safety Audit (LOSA) or Flight Operations Quality Assurance Program (FOQA). With clearly defined technical and behavioural performance markers already in place to support a LOSA program, it would become relatively simple for the Air Force to begin wide scale safety audits of its operations. As described in the ICAO LOSA manual, “LOSA uses expert and highly trained observers to collect data about flight crew behaviour and situational factors on “normal” flights.”[192] With LOS teaching and evaluating the baseline expectations, LOSA operates on a non-jeopardy basis in which flight crews are not held accountable for their actions and errors that are observed. Rather, the purpose of

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[192] ICAO, *LOSA Manual*, vii.

LOSA is to assist the organization and identify potential shortcomings in its training and operational procedures.[193] LOSA becomes to the operational community what HFACS is designed to be to the Flight Safety system – the means by which the organization identifies and addresses deficiencies in the way it conducts operations from a human factors and technical perspective. LOSA represents an organizational maturity that can only be achieved by taking the first critical step. That critical first step is the development and implementation of a robust and effective LOS program.

Summary

LOS is a thoroughly researched and highly substantiated means of optimizing human factors in aviation. Several regulatory agencies, including those in Canada, the United States, and Europe, advocate and in some cases mandate its implementation to reduce the attribution of human factors in aviation incidents and accidents. Multiple manuals and research papers have been written on its effectiveness, how to develop it, and how to introduce it, and these have been continually refined as the concept has matured. What the APPD report demonstrated is that the Canadian Air Force has yet to optimize either its human factors programs or its use of the synthetic environment. It is simply not enough to say that the Air Force is going to fully exploit the synthetic environment and optimize human performance. It must provide the resources and dedicate the effort required in the areas of behavioural marker definition, training of the instructor / evaluator cadre, and scenario design and validation if it is to achieve its goals.

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[193] ICAO, *LOSA Manual*, vii.

The adoption of a robust and effective LOS program can effectively address the issues of HPMA and the synthetic environment identified in the APPD report and in so doing, will begin to address other issues the Air Force is wrestling with. This is the real benefit of introducing a LOS program to the Canadian Air Force – the follow-on capabilities that become achievable once behavioural markers are defined and evaluated to the same level as today's technical skills. As the LOS program matures across the Air Force, and its personnel start to speak in a common language in relation to behavioural skills, the Flight Safety system would find itself in a position to begin full implementation of HFACS. Follow-on programs, like LOSA, would allow the Air Force to truly become a learning organization.

Chapter 5

Conclusion

William Sharpe and Manfred von Richtofen were aviators at a time when simulators and the synthetic environment were distant years in the future. The first met his fate in an accident in 1915 and the second finally fell in battle in 1918. Would better training have prevented the accident which took William Sharpe's life? Would the synthetic environment have allowed the Red Baron to teach his deadly skills to a wider cross section of the German Air Force in First World War thereby potentially altering the outcome of that conflict? There can be no answers to those questions but perhaps the most pressing question that comes to mind when thinking of those two today is whether or not they would have something to tell us about what they learned so long ago. Is the message on the importance of the human in aviation that was passed on to us by the Red Baron in 1917 still valid?

This paper began with a demonstration of the enduring prevalence of the role that human factors plays in aviation. Since man first took to the air, it is the human spirit that has sustained it and kept it aloft. As the historical record shows, it is also the human that has played a significant role in bringing it to earth when least expected. While the aircraft matured and achieved high levels of reliability in little more than half a century, aviation continues to find itself wrestling with the way in which the human functions as a result of thousands of years of evolution. It has been argued in this paper that the field of aviation human factors did not really come into being until the latter part of the 20th century. Since that time, the field has expanded rapidly and begun to systematically address the role of human factors in aviation. Recent statistics show that between 70 and 80% of all aviation incidents and accidents are attributed to human factors. Even more significant, the research shows that many of those accidents are not a result of complex technical problems with the aircraft, but are caused by fundamental breakdowns in leadership, crew coordination, communication, and decision making. The introduction of advanced technology aircraft, with sophisticated onboard systems, has further elevated the criticality of the role of the human and the need to ensure that aviators are properly trained to deal with the increasingly complex environment of aviation.

One of the most significant developments in aviation in recent years has been the incorporation of the synthetic environment to address aviation human factors. Significant research has been conducted into how best to structure the exploitation of the synthetic environment to achieve high levels of human performance which, in turn, deliver higher levels of operational effectiveness and safety. Referred to as Line Operational Simulation (LOS), the development and implementation of a robust simulator training program to teach Crew Resource Management is widespread across the industry. This paper has captured the development of LOS and the means by which it is delivered. It has also highlighted the critical role that instructors and evaluators play in any effort to optimize the synthetic environment. Without training and standards firmly rooted in clearly defined behavioural performance markers, the ability of the instructor and evaluator cadre to properly teach and assess behavioural skills is severely impacted. Industry has recognized the relationship between these elements and many of the aviators in today's civilian world are exposed to levels of training and evaluation in behavioural skill sets that the Canadian Air Force aspires to now and in the future.

This study also considered the current state of the Canadian Air Force in relation to aviation human factors and the synthetic environment. What it concluded was that there remains much to be done if human performance is to be optimized and the long term vision for transformation achieved. The APPD Project uncovered several issues linked to the areas of human factors and the synthetics environment that are not insurmountable considering the lessons from industry. It must be remembered that the Air Force already possesses a robust suite of synthetic training devices but it is simply failing to use them to their full potential. As Eduardo Salas, Clint A. Bowers, and Lori Rhodenizer said in 1998, "it is not how much you have but how you use it" and in this regard, the Air Force needs some work.[194] This study also uncovered other areas directly linked to human factors that are hindering the ability of the Air Force to sufficiently capture the true causes of its accidents and learn from them. Again, the lessons of industry if applied properly, can be used to make the Human Factors Analysis and Classification System (HFACS) currently employed by the Directorate of Flight Safety. Most importantly, this paper demonstrated that these problems are not unique to the Canadian Forces and that others have been able to address them.

The final chapter of this paper discussed the specific ways in which the Air Force can begin to comprehensively optimize its approach to aviation human factors through the use of the synthetic environment. By focusing on the development of behavioural markers, creating instructors and evaluators that are able to use them, and implementing a

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[194] Salas, Bowers, and Rhodenizer, "It Is Not How Much …", 197.

robust LOS program across the Air Force the Air Force can begin to move towards its transformational goals. Dedicated resources and personnel will be required as it is no longer sufficient to simply state that it is going to be done.

With those resources and personnel in place, and utilizing the lessons of industry, it is entirely possible for the Air Force to create a LOS program that is both sustainable and operationally relevant. In so doing, it will set the conditions for success in other areas related to human performance such as the HPMA program and the HFACS program. As the organization creates a common language and culture of human performance, the implementation of programs like Line Operations Safety Audits (LOSA) become achievable as well. All that is required is for the Air Force to take that first critical step of creating markers to teach and evaluate behavioural performance in the same way that it already teaches and evaluates technical skills.

Manfred von Richtofen’s recognition of the criticality of the human to achieving success in aviation is as true today as when it was written in 1917. While the box he was referring to was the aircraft, today the Canadian Air Force finds itself with the opportunity to fully exploit another box, the simulator. Doing so will allow it to optimize not only the human sitting in the aircraft, but also achieve levels of operational effectiveness and safety not previously known. It will also ensure that it is able to fully exploit the technology it either currently possesses or will possess in the future. Air Force strategy clearly indicates that the will exists. All that remains is for the Air Force to dedicate the resources and the effort to making it happen and optimization of the synthetic environment to deliver optimized human performance is entirely within its grasp.

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