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EXERCISE/EXERCICE NEW HORIZONS

"to err is human…"

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Abstract

Since the cost of aircraft accidents has risen to a height of virtual expectance of perfection, and the prime cause of accidents is the man at the controls, then it is clear that a concerted effort to dramatically reduce, prevent, and manage errors in the cockpit is necessary. To tackle this problem effectively we must first answer the question: "Why do people make mistakes?" The best way to make the necessary improvements to aviation safety is through a better understanding of the underlying causes of pilot error. This paper will present the consequence and severity of the problem of pilot error; demonstrate the importance of understanding human error; show the unique types of errors made in the cockpit; and, express recent initiatives in the prevention, detection, and management of pilot errors that require greater attention if we hope to solve the problem.

to err is human…

People make errors all the time. Usually our errors are slight, like typos on the keyboard, and are easily correctable. Other times, our errors are a result of unwise practices, like tailgating on a slippery highway, and can be more consequential. Understanding why people make mistakes has been of scientific interest for many years and though scientists have been successful in developing theories about the causes of human error the fact remains – to err is human.[1]

Human error has been studied in great detail within the realm of aviation safety where the consequence of a pilot's mistake has grown along with the size of the newest jets. Contrasting the tragic crash of a DC-3 in the 1950's, which might have killed all 25 passengers, with the potential loss of a soon to be operating Airbus A-380 with 555 passengers on board, highlights the importance that aviation safety plays today. Industry efforts to improve system safety have been enormously successful in the relatively short lifespan of flying, yet accidents attributable to pilot error continue to make up the vast majority of the aviation fatalities. In fact, most research papers on the subject of pilot error start with a statistic such as "60-80% of all aviation accidents are attributable to pilot error." [2]

If the cost of accidents has risen to a height of virtual expectance of perfection, and the prime cause of accidents is the man at the controls, then it is clear that a concerted effort to dramatically reduce, prevent, and manage errors in the cockpit is necessary, but to tackle this problem effectively we must first answer the question: "Why

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1 Alexander Pope (1688–1744), *An Essay on Criticism.* London: Lewis, 1711.

2 United States Air Force. Human Factors Project. USAF Safety Center. Internet; available at: http://afsafety.af.mil/AFSC/RDBMS/Flight/SEFL/SEFL%20Files/AsMA_'02_USAF_HF_A_New_Vision.

do people make mistakes?" In short, the best way to make the necessary improvements to aviation safety is through a better understanding of the underlying causes of pilot error.

This paper will first present the consequence and severity of the problem of pilot error. Next, it will demonstrate the importance of understanding human error from a scientific point of view. Then, the paper will show the unique types of errors made in the cockpit, as they are understood today in order to reveal the inadequacies of our comprehension. Finally, it will express recent initiatives in the prevention, detection, and management of pilot errors that require greater attention if we hope to solve the problem.

According to the International Civil Aviation Organization (ICAO) the fatal accident rate for scheduled operators has steadily decreased from 3 fatalities per million flying hours in 1965 to only 1 fatality per million flying hours in 1985.[3] Flying done by charter airlines, general aviation, and militaries, while statistically less safe in comparison, has seen a similar improving trend over the years.[4] These statistics should surprise no one as the technological advances used in the manufacturing and maintenance of aircraft coupled with improved aids to navigation and air traffic control methods have dramatically improved since early days of the airline industry.[5]

The impetuses for such an impressive safety record is inextricably linked with the overriding desire for continued improvement – public concern over the danger associated

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with flying.[6] Undoubtedly, people's perceptions are often more important than reality. In the airline industry this is particularly true.[7] While the accident rate over the past 20 years has not changed significantly, the number of flights has more than doubled.[8] Consequently, the steady repetition of 3 or 4 fatal accidents each year coupled with increased media attention leaves the public with the impression that accidents are on the rise.

> Formerly permissible safety standards are no longer acceptable. The industry seems fairly close to achieving the maximum number of accidents or fatalities, each month or year, that the public will tolerate without inducing political and often emotional and unproductive action.[9]

Certainly the airline safety record must continue to improve at least as fast as industry expansion since the support of the paying public is required for a healthy industry.

While airline accidents will negatively affect public support, the enormous cost of replacing lost aircraft has become another matter of airline industry survival. A new Boeing 777 costs over $200 million![10] Aircraft replacement costs coupled with the costs associated with personal liability claims resulting from a fatal accident are powerful drivers towards increased system safety.

Air forces face a similar motivation from a replacement cost factor. Military aircraft cost millions of dollars and budgets for replacements are small.[11] If air forces

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6 C. Prince & E. Salas "Training and Research for Teamwork in the Military Aircrew" E. Wiener, B Kanki & R. Helmreich, ed. *Cockpit Resource Management*. Academic Press. 1993. P338.

7 Jerome Lederer. Forward to: *Human Factors in Aviation* Earl Wiener & David Nagel ed. Academic Press. 1988. Pxv.

8 United States. U.S. National Transportation Safety Board: Accidents, Fatalities, and Rates, 1983 through 2002 for U.S. Air Carriers Operating Under 14 CFR 121, Scheduled Service (Airlines)

9 C. Prince & E. Salas, *Training and Research for Teamwork in the Military Aircrew…* P338.

10 Boeing Commercial airplanes website. Internet. Available at: http://www.boeing.com/commercial/prices/ accessed: 6 Apr 04.

11 "Several external political changes, including the end of the Cold War, have caused the [US]Air Force to change their approach to force management. As a result, the Air Force budget to develop new aircraft systems has been reduced. Because strategic policies have not been altered greatly, Air Force managers have concluded that the only way to meet the mission demands is to extend the service life of

hope to achieve their operational mandate it is essential that they protect this valuable commodity. Additionally, they must consider the sizable investment they have made in the training of their lost airmen. Not only are these costs substantial from a budget standpoint but they can also be overwhelming from a human cost. Witness the affect on the Squadron, the military community at large, and Air Force search and rescue (SAR) operations after the tragic loss of *Labrador* 305, a helicopter and its six crewmen which crashed returning from a search and rescue mission over the Gaspe region of Quebec in 1998. Chief of the Air Staff, Lt.-Gen. David Kinsman, stated, after lifting a three week grounding on the entire *Labrador* fleet,

> Let me assure the air force community, their families, and all Canadians that we will do everything possible to find the cause of the *Labrador* crash. If we find anything new to suggest that the aircraft is unsafe, I will not hesitate to restrict the fleet once again. With respect to the crews and families at 413 Squadron, we will certainly allow them the time they need to recover from the loss of six comrades and, if necessary, regain their confidence in the *Labrador*.[12]

Certainly neither airlines nor air forces can afford to have accidents and ought to be highly motivated to take steps to reduce them.

Aircraft accidents today are mainly attributable to three causes: mechanical failure, weather, and pilot error.[13] They are not distributed equally, however - pilot error accounts for at least 2/3 of these accidents.[14] Can anything be done to address this problem? "The same dedication to the reduction of losses that industry has applied to

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some of their aircraft forces." United States. Committee on Aging of U.S. Air Force Aircraft, Commission on Engineering and Technical Systems, National Research Council. *Aging of U.S. Air Force Aircraft: Final Report* (1997) National Materials Advisory Board, Internet. Available at: http://books.nap.edu/books/0309059356/html/13.html, accessed 27/04/04.

[12] Lt.-Gen. David Kinsman. DND/CF News release. NR-98.088 - October 27, 1998. Available at: http://www.dnd.ca/site/newsroom/view_news_e.asp?id=592

[13] David O'Hare & Stanley Roscoe. *Flightdeck Performance: the human factor*. P186.

[14] Nadine Sarter. "Error Types and Related Error Detection Mechanisms in the Aviation Domain." *International Journal of Aviation Psychology*: 2000, Vol 10 Issue 2, P189.

technical and procedural problems has the potential, when applied to human factors, of doubling safety performance."[15]

The consequence and severity of the problem is clear. Firstly, the airline industry has been very successful at reducing accidents but at the same time the number of flights have increased at a rate that has conspired to sufficiently concern the flying public over their safety. Secondly, the financial penalties of an accident are exorbitant both for airlines and militaries. Additionally, the mammoth disruption following a crash is a great strain on emotional and operational effectiveness. These factors motivate the aviation community to substantially reduce accidents, and since 60-80% of accidents are a result of pilot error; the path is clear. Thus, to significantly improve aviation safety new methods need to be developed to reduce the errors that pilots make.

How do we go about reducing critical pilot errors? Aren't they an inevitable result of human fallibility? Can't we regulate pilots into complying with strict procedural regulations? Can't technological innovation be used to replace the pilot with a perfect computer? A good starting point in the development of a better understanding of the root causes of pilot error is in scientific knowledge of the causes of human errors in general. An exploration of human error in everyday life will assist us in the comprehension of human vulnerability to error in the cockpit. The questions that need to be answered first are: why do humans make mistakes? Can the mistakes be prevented? And, are we able to recover from our mistakes when they happen?

Why do pilots make errors? Simply put – because they are human, and, as long as humans are on the flight deck, they will continue to make mistakes. Arguably, the solution might be to replace the pilot with an automated system that is not susceptible to

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[15] Earl Wiener & David Nagel ed. *Human Factors in Aviation*. Pxv.

errors. The joke goes something like this: *cockpits of the future will be manned by a single pilot and a dog – the pilot in order to monitor the flights progress and the dog in order to bite the pilot if he tries to touch anything*. Alas, so far computers cannot perform all of the complex tasks of the pilot. Humans remain in the cockpit because of their "unique capability to analyze incomplete or conflicting information from diverse sources, to assess novel situations and to devise appropriate solutions."[16] This is the catch[17] – we are dependant upon the pilot's unique cognitive abilities; but we are vulnerable to his inevitable fallibilities. [18]

Faced with the fact that humans will remain in the cockpit for the foreseeable future and that they will make mistakes, we must look at the kinds of errors which are the most consequential and determine methods to fend them off. In his book, Human Error, James Reason explains that that there are three basic error types: skill-based slips (and lapses), rule based mistakes, and knowledge-based mistakes.[19] Slips & lapses are execution failures, while mistakes are planning or problem solving failures. Skill-based failures are usually the result of inattention (monitoring); rule-based failures are the result of either the application of bad-rules or the misapplication of good-rules; and, knowledge-based failures are the result of the rational mind (reasoning), or incomplete or inaccurate information.

Laboratory studies have shown that while execution errors, such as entering an incorrect waypoint in the flight management system, are the most prevalent, they are also

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16 Key Dismukes & Frank Tullo. "Aerospace Forum: rethinking crew error." *Aviation Week & Space Technology*. July 17, 2000.

17 Ibid.

18 Cognitive ability**:** capacity to perceive, reason, or use intuition. MSN Encarta.

19 James Reason. *Human Error*. Cambridge University Press. 1990. Ch2.

the easiest to detect and correct.[20] On the other hand, knowledge-based errors, such as inappropriate decisions or judgments occur less often but are rarely detected. This laboratory research into the understanding of human error correlates with studies that showed that major aircraft accidents were caused by judgment errors and minor accidents were caused by procedural and execution errors. [21] The study and categorization of human error has also allowed scientists to conclude that human error is scientifically repeatable and predictable. This leads us to expect that they are also avoidable and manageable.[22]

This section has shown that a better understanding of human error in every day life reveals lessons that can be used in the development of methods to battle pilot error in the cockpit. Human error researchers have contributed theories about the circumstances surrounding errors and have developed classification models to further their studies. Significantly, they have shown that 'judgment errors' are the most dangerous and the most difficult to detect and mitigate. But, "despite the obvious importance of the topic, the psychological literature contains very little in the way of empirical studies of error detection."[23] In sum, more basic research into human error vulnerabilities, detection processes, and recovery tactics are required before strategies to alleviate them can be developed. This research is a critical seed that must be tended if we hope to seriously affect the incidence of aircraft accidents.

The study of human psychology is not the only method at our disposal in the development of a better understanding of pilot error. Aircraft accident investigators,

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[20] Ibid. P60.

[21] Douglas Wiegmann & Scott Shappell. "Human Error Perspectives in Aviation." *The International Journal of Aviation Psychology*, 11(4), 341-357.

[22] Earl Wiener & David Nagel ed. *Human Factors in Aviation*. Academic Press. 1988. P267

aviation human factors professionals, and government regulators, faced with aircraft crash sites and public outrage have expended tremendous effort inventing ways to prevent errors from occurring. These industry specialists have compiled a body of knowledge from 'lessons-learned the hard way' that are often unique to the aviation environment. From this knowledge they have categorized human errors that happen on the flight deck into five broad categories:[24]

1. The normal functioning of our perceptual systems.
2. The design of aircraft systems.
3. Stress and fatigue imposed by working conditions.
4. Decision-making.
5. Social influences.

We will now look at each category in turn in order to reveal inadequacies in our understanding and to further underline that the best way to improve aviation safety is through a better understanding of the underlying causes of pilot error.

Human senses in flight. "Countless accidents occurred before the characteristics and peculiarities of our sensory systems in the demanding aviation environment were fully appreciated."[25] The human perception 'system' is adapted to the ground environment and when put into the air it often misinforms us. The errors associated with illusions in flight are fairly well established and are taught in the early stages of pilot training. They now make up a small part of the causes of accidents in the airline industry but remain of significant concern in general aviation, where pilots are not as thoroughly

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23 Reason. *Human Error*… P148.

24 David O'Hare & Stanley Roscoe. *Flightdeck Performance: the human factor*. P229.

25 Herschel W. Leibowitz. *Human Senses in Flight* in "Human Factors in Aviation." Earl Wiener & David Nagel ed. Academic Press. 1988. P109. .

trained, and in military aviation, where pilots are exposed to environmental extremes. Gravity induced loss of consciousness (G-LOC) and flight using night vision goggles are two such examples. As new technologies develop it is essential that this aspect of human physiology is well understood before the technologies are applied.

Aircraft system design. Aircraft system design involves the man-machine connection. The pilot is connected to the aircraft through the controls, the instruments, and the operating procedures/manuals. Aircraft instrumentation is designed to allow the pilot to maintain an awareness of all the parameters of the flight. These include: navigation, altitude, airspeed and system status instruments (fuel, hydraulics, environmental control system, etc) Errors due to aircraft instrumentation are usually centered around misinterpretation (observation) by the pilot, or misreading (incorrect depiction) by the instrument.

Poorly designed aircraft control systems can also lead to pilot errors.

> The control of the auto-flight control system (AFCS) is the most complicated and troublesome system from a pilot's standpoint…there are too many options or modes of operation. For instance, climbing to a higher altitude can be made in three different ways automatically. Each of these modes has different characteristics and possible sources of error.[26]

A thorough understanding of the fallible pilot is necessary to design safe modern aircraft systems that not only prevent errors but also rescue crews from already committed errors.

Stress and fatigue. Fatigue is recognized as a hazard in most industrial pursuits and has been implicated as a causal factor in such disasters as 'Three Mile Island', 'Chernobyl', and the space shuttle 'Challenger' accident. Fatigue in aviation is related to

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[26] R Stone and G Babcock. *Airline Pilot's Perspective* in "Human Factors in Aviation." Earl Wiener & David Nagel ed. Academic Press. 1988. P558.

upsets in the biological rhythms of the body due to jet-lag (trans-meridian flight), long duty days, and day/night shift work schedules. Fatigue, associated with sleep deficit, results in an 8-10% decrease in the performance quality of activities such as reaction time, hand-eye coordination, logical reasoning, and vigilance. This degradation corresponds to the effect of moderate alcohol consumption.[27]

Stress can also adversely affect pilot performance. Stress originates from the physical environment – heat, noise, turbulence; from the physiological environment – sleep loss, blood sugar level, hypoxia; or from the psychological environment – life stress (illness of children), fear, frustration.

> It appears that…the immediate impact of stress on pilot performance is quite similar to the effects of an increase in workload. Both result in a decreased ability to attend to secondary tasks as attention becomes more narrowly focused on the central task[28]

The effects of stress and fatigue and their association with pilot error are well understood by the scientific community and have gained widening acceptance by regulators and operators, but, as emerging technologies are applied, it will be necessary to deepen our knowledge of the effects of stress and fatigue on human error. For example, to exploit the stealth of darkness, more and more military flying is carried out at night. Consequently, the use of fatigue countermeasures such as the 'Go/No-go' pill is increasingly obligatory for USAF pilots during operations.[29] The adverse effect of the

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27 Giovanni Costa. *Fatigue & Biological Rhythms* in "Handbook of Aviation Human Factors." Daniel Garland, John Wise & David Hopkin ed. Lawrence Erlbaum Assoc. Mahwah, NJ. 1999. P235-255.

28 David O'Hare & Stanley Roscoe. *Flightdeck Performance: the human factor*. P163.

29 While the USAF maintains that use of the medication is voluntary, high-level commanders can make its use mandatory for all pilots conducting certain types of operations. Pilots who do not 'voluntarily' accept use of the pills are therefore excluded from participation in the operation. According to Lt. Norak Chhieng, USN in his article *Max Hours in Sheik Isa, the Go Pill Experience* "…during OSW [Operation Southern Watch]… the Air Force Wing directive required all air assets operating in the AOR to be ground-tested and to carry the Go pill in-flight. United States Navy Safety Center. Available at: http://www.safetycenter.navy.mil/media/approach/issues/sep03/MaxHours.htm. Also see: United States

medication, however are not fully understood and has been cited as a contributing factor in the tragic Tarnak farms friendly fire incident near Khandahar, Afghanistan.[30] [31]

Decision-making. As stated earlier, decision errors are the most likely to be consequential and are usually the most difficult to detect and correct. As a result, pilot decision-making has become focal point in the study of pilot error. The decision making cycle is characterized by four stages: *detection, diagnosis, decision, and action.* Errors can occur at any of the stages.[32] For example, too high of a workload could cause a crew to fail to detect a critical navigation error as in the case of the Boeing 757 which crashed into a mountain while making an instrument approach into Cali, Columbia in 1995.[33] Or, inadequate training could lead to a misdiagnosis of a problem as in the Air Florida

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Air Force 51ST FIGHTER WING INSTRUCTION 44-102, 25 NOVEMBER 2003. MEDICAL ADJUVANT "GO PILLS,"“NO-GO PILLS,” CIPROFLOXACIN AND DOXYCYCLINE FOR FLYING OPERATIONS. Available at: http://www.google.ca/search?q=cache:X_IcqG8N3RoJ:www.e-publishing.af.mil/pubfiles/51fw/44/51fwi44-102/51fwi44-102.pdf+go+pill+USAF+mandatory&hl=en.

[30] United States. *Summary of Facts: Tarnak Farms Friendly Fire Incident Near Kandahar, Afganistan, 17 Apr 2002.* Available at: http://www.centcom.mil/CENTCOMNews/Reports/Tarnak_Farms_Report.htm

[31] Tina-Marie O’Neill. *US pilots blame drug for Canadian bombing*. “Sunday Business Post On-line.” 19/01/03. Internet; available at: http://archives.tcm.ie/businesspost/2003/01/19/story334330.asp accessed 32/02/04.

[32] David O’Hare & Stanley Roscoe. *Flightdeck Performance: the human factor* P199-203.

[33] On December 20, 1995, American Airlines Flight 965, a Boeing 757-223, crashed into mountainous terrain during a descent from cruise altitude in visual meteorological conditions. The evidence indicates that AA965 continued on the appropriate flight path until it entered the Cali Approach airspace. After contacting the Cali approach controller, the flightcrew accepted the controller's offer to land on runway 19 at SKCL, rather than runway 01 per the flight planned route. After receiving clearances to descend, lastly to 5,000 feet msl, neither flightcrew member made an attempt to terminate the descent, despite the airplane's deviation from the published approach 0.02 0 0 10.02 325.362ith904 Tm(p)Tj220004 Tj10.02 0 0 10.02 267

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Boeing 737 that crashed on a snowy day in Boston in 1982 because the crew was unfamiliar with the proper operating procedures in icy conditions.[34]

Many questions surrounding the way in which pilots arrive at decisions remain unanswered, particularly – is experience the only way to develop good judgment or can it be taught?[35] Researcher Richard Jenson believes so,

> It is my belief that, as pilots are aware of biases that exist in normal human decision making, that awareness is sufficient to reduce those same errors in rational judgment. For example, knowing that our visual/perceptual system will deliver a bias in our perception of distance to the runway depending on the slope of the terrain on the near end, is sufficient to cause a pilot to attempt to control his mental view of the situation and counter the perception given by his or her eyes using other information (e.g. altimeter indications).[36]

Social influences. "Sources of social pressure that could affect pilot judgment include fellow pilots, family members, air traffic controllers, passengers, superiors and friends."[37] Pilots subjected to undue social influences may make inappropriate decisions even though they 'know better'. Programs, such as crew resource management (CRM) and aircrew coordination training (ACT), attempt to reduce pilot errors by improving

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[34] The investigation of the crash concluded that the combination of the crew's use of thrust reverse on the ground, and their failure to activate the engine anti-ice system, caused the crash. By failing to activate the engine anti-ice, the large amounts of snow and ice that were sucked into the engines during reverse thrust use was allowed to remain there, unchallenged. The ice buildup on the compressor inlet pressure probe, the probe which measures engine power, can cause false readings, as was the case here. The indications in the cockpit showed an Engine Pressure Ratio of 2.04, while the power plants were in reality only producing 1.70 EPR, or about 70% of available power. The combination of the ice covered wings and low power caused an immediate stall on takeoff that resulted in 74 lives lost. Source: Chris Kilroy. Internet. Available from: http://www.airdisaster.com/special/special-af90.shtml

[35] R. Jenson & R. Benel, (1977). *Judgement Evaluation and Instruction in Civil Pilot Training*. Springfield, Va: National Technical Information Service, Final Report FAA-RD-78-24.

[36] Richard Jenson. *Pilot Judgment: and crew resource management.* Ashgate. 1995. P4.

[37] Ibid. P25.

teamwork on the aircraft. These programs focus on areas such as: leadership, crew climate, distribution of workload, advocacy & assertion, and cross-cockpit monitoring.[38]

Because of airline accidents attributed to poor crew coordination in the late 1970's, particularly the Eastern Airlines L-1011 crash into the Florida everglades, considerable research activity has been devoted to understanding and solving these types of problems.[39] Success is still tenuous. While statistical evidence supporting a positive effect of CRM programs on the accident rate are inconclusive, "…no airline having set up a CRM program, would now consider killing it."[40]

This section has demonstrated that a great deal of study into the causes of pilot error has been accomplished, but many key questions remain unanswered. As new technologies are developed more effort needs to be directed towards a thorough understanding of their effects upon human physiology, including our perceptual system and our vulnerabilities to stress and fatigue. Additionally, while it is recognized that aircraft systems need to be designed mindful of the error prone pilot, it is only through a better understanding of the underlying causes of error that we can hope to 'design through' them. The advent of modern technology has seen the replacement of the 3rd crewmember in the cockpit or the back-seater in the fighter jet with what has become a 'taskmaster' of a flight computer. The 'extra' brain in the cockpit, while primarily used

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38 Geis-Alvarado & Assoc, Inc. Napa Ca. 1995 *CRM Evaluator's Course Manual.*

39 In this accident the aircraft was forced to break off its approach to Miami International Airport after the nose-gear light failed to illuminate, indicating that the gear was properly lowered. While in a holding pattern at 2,000 feet over the Everglades National Park, the Captain bumped his control column, leading to the disconnection of the autopilot. With the attention of all three crewmembers focused on the landing gear and the extinguished light, the aircraft descended unnoticed into the ground. United States. National Transportation Safety Board (NTSB) report NTSB-AAR-73-14. Internet. Available from: www.super70s.com/super70s/tech/aviation/disasters/72-12-29(eastern).asp Accessed 1 Apr 04.

40 Paries and Amalberti. *Recent trends in aviation safety: From individuals to organizational resources management training* in "Handbook of Aviation Human Factors." Daniel Garland, John Wise & David Hopkin ed. Lawrence Erlbaum Assoc. Mahwah, NJ. 1999. P215.

for task completion, was often exploited as a sounding board for problem solving during routine and emergency situations. A better understanding of pilot error will enable the design of similar decision support systems which are able to help prevent and to discover

The NASA Ames Research center developed the first CRM training program to address this concern.[43] CRM has since become a 'catch-all' realm that includes "…the effective use of all available resources including human resources, hardware and information."[44] Critics contend that "given the broad definition one might expect that the only accident not attributable to CRM would be the deliberate crashing of the aircraft by a disturbed crewmember."[45] While CRM has its critics, it cannot be denied that it has laid a solid foundation for further study.

CRM is a product of social psychologists.

> According to the psychosocial perspective, pilot performance is directly influenced by the nature or quality of the interactions among group members. The major theme of psychosocial models, therefore, is that errors and accidents occur when there is a breakdown in group dynamics and interpersonal communications.[46]

Since the first program in 1980, research has driven CRM development through what is said to be five generations.[47] Unfortunately, over the past 25 years, as the application of this research evolved, it has lost its focus on the underlying reason for its creation - a way to avoid error. 5th generation CRM is a result of continuing attempts to validate the research and to return its application to its foundation principles: prevention, detection,

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43 G.E. Cooper, M.D. White, & J.K. Lauber (Eds.) (1980). *Resource management on the flightdeck: Proceedings of a NASA/Industry workshop* (NASA CP-2120). Moffett Field, CA: NASA-Ames Research Center.

44 United States. Federal Aviation Administration. *Developing Advanced Crew Resource Management (ACRM) Training:A Training Manual.* 1 Aug 1998.

45 Douglas Wiegmann & Scott Shappell. *Human Error Perspectives in Aviation*. "The International Journal of Aviation Psychology", 11(4), 341-357.

46 Ibid. P341-357.

47 Robert Helmreich, Ashleigh Merrit, John Wilhelm. *The Evolution of Crew Resource Management Training in Commercial Aviation*. "International Journal of Aviation Psychology" 1999. Vol 9 Issue 1. P14-19.

and mitigation of the consequences of human error. This 'new' area of study is termed 'error management' and is widely considered to be the way ahead.[48]

Error management has its roots in a Continental Airlines human factors manager's desire to validate his CRM program. He wanted to find out if his program was being successful at reducing errors in the cockpit. Together with human factors research scientists at the University of Texas, he developed a program to systematically collect information about crew responses to threats to safety, such as severe weather or congested airports.[49] This program, entitled the Line Operations Safety Audit (LOSA) provided the essential data required, not only to validate Continental's CRM program, but to spawn the 5th generation of CRM: error management.

LOSA uses trained observers and check pilots to monitor and record (from the jump seat) crew reaction to various threats, the types of errors committed, and how flight crews manage these situations to maintain safety.[50] The safety audit also includes a post flight interview with the pilots to collect information on attitudes about safety issues. The information from the anonymous reports are entered into a database and analyzed by researchers.

Another method of collecting data is confidential reporting systems. The US FAA system, called the Aviation Safety Reporting System (ASRS) receives, processes, and analyzes reports of unsafe occurrences and hazardous situations that are voluntarily submitted by pilots and air traffic controllers. Information collected by the ASRS is used

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48 Robert Helmreich. *Managing Human Error in Aviation*. "Scientific American." May 97 Vol 276 Issue 5 p62.

49 John Croft. *Researchers Perfect New Ways to Monitor Pilot Performance*. "Aviation Week & Space Technology." New York. Vol 155. Iss 3 P76. July 16, 2001.

to identify hazards and safety discrepancies in the National Airspace System. It is also used to formulate policy and to strengthen the foundation of aviation human factors safety research.[51] Anonymous incident reporting systems encourage pilots to 'tell-all' about errors they made in flight, with the expectation that, if assured of immunity from reprisal, pilots will share their experiences so that others can learn from them.

Analysis of the cockpit voice and flight data recorders (black boxes) is another means of collecting data. Flight data recorders (FDR) log selected flight parameters that can be downloaded post flight for analysis. FDRs, together with cockpit voice recorders (CVR), are one of the best tools used by the accident investigator in determining the circumstances around an accident.

Professional analysis of the accumulated data from the many sources has resulted in some important results. For example, analysis of 1500 'jump seat' safety audits has revealed that "60% of consequential errors were caused by pilot's lack of knowledge about automation features in the aircraft's flight deck."[52] The uncovering of this type of information should support further work on improved 'error-tolerant' cockpit designs. In another example the detailed analysis of accident investigator's reports and ASRS reports showed that "nearly half [of the accidents] involved lapses of attention associated with

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50 University of Texas. *Human Factors Research Project*. Line Operations Safety Audit. Internet: http://homepage.psy.utexas.edu/homepage/group/HelmreichLAB/Aviation/LOSA/LOSA.html; accessed 1 Mar 04.

51 United States. Federal Aviation Administration website. Inernet; available at: https://www.nasdac.faa.gov/servlet/page?_pageid=72,78&_dad=nasdac&_schema=NASDAC; accessed 7 Mar 04.

52 John Croft. *Researchers Perfect New Ways to Monitor Pilot Performance*. "Aviation Week & Space Technology." New York. Vol 155. Iss 3 P76. July 16, 2001. Consequential errors are defined as: the mistakes that compromise safety because the aircraft is in an unintended state.

interruptions, distractions, or preoccupation with one task to the exclusion of another."[53] Additionally, the analysis spawned further study, through targeted 'jump-seat' observation, aimed at "revealing system deficiencies."[54] This study showed that uncertainties, intrusions, and general distractions could quickly sidetrack any pilot and lead to potentially disastrous mistakes. So insidious are the effects of distractions that pilots will express an experience of amazement when an error is made:

> *"*... I have flown this airplane for 10 years and never set this (pressurization control) wrong. I am unsure how it happened except that possibly I was interrupted during my preflight check ... *"* [55]

This study resulted in educational circulars and improved training on 'distraction management' during recurrent simulator training sessions.

Programs such as line audits, anonymous reports, and flight data recorder analysis have dramatically improved our understanding of the underlying causes of pilot error and their role in aircraft accidents. These combined data sources provide analysts with the requisite raw information to conduct analysis and to draw conclusions about *how*, *when*, *where*, and most importantly *why* errors happen on the flight deck. Thus, we see that recent programs geared towards improving our understanding of the underlying causes of pilot error have led to constructive initiatives towards the prevention, detection and mitigation of errors and ultimately towards improved system safety.

We have seen previously that the most dangerous type of error is the 'judgment error' because of the inherent difficulty with its detection. This is because there is often

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[53] Key Dismukes. NASA Ames Research Centre. in *Crew Distractions Emerge as a New Safety Focus*. By Michael Dornheim. "Aviation Week & Space Technology." July 17, 2000.

[54] Loukia D. Loukopoulos, Key Dismukes and Immanuel Barshi. *Cockpit Interruptions and Distractions: A Line Observation Study*. US Navy/NASA Ames Research Center Moffett Field, CA

little feedback as to the inappropriateness of the chosen course of action until it is too late. To date, laboratory research on human error has focused primarily on the development of error classification schemes, the design of error-tolerant systems, and error prevention through training and design. Consequently very little data exists on error detection processes and their relation to various error types and performance levels.[56] In fact, in one study, knowledge based errors made up only 10% of the analyzed errors.[57] Clearly, more research into ways to better detect misjudgment and to improve the development of pilot decision-making skills is necessary if we hope to reduce accidents significantly.

Recently many aviation safety professionals have focused their energy on error prevention through the identification of hazards that lie dormant in an organization. According to researcher James Reason:

> There is a growing awareness…that attempts to discover and neutralize these latent failures will have a greater beneficial effect upon system safety than will localized efforts to minimize active errors. To date, much of the work of human factors specialists has been directed at improving the immediate human-system interface (i.e., the cockpit). While this is undeniably an important enterprise, it only addresses a relatively small part of the total safety problem, being aimed primarily at reducing the 'active failure' tip of the causal iceberg.[58]

Reason's approach to understanding the underlying causes of aircraft accidents suggests that failures are the result of a series of pre-conditions that can promote an unsafe act. The pre-conditions are the result of 'traps' that are laid out from organizational or

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55 Loukia D. Loukopoulos, Key Dismukes and Immanuel Barshi. *Cockpit Interruptions and Distractions: A Line Observation Study*. US Navy/NASA Ames Research Center Moffett Field, CA

56 Sarter, Nadine. *Error Types and Related Error Detection Mechanisms in the Aviation Domain*. "International Journal of Aviation Psychology"; 2000, Vol 10 Issue 2, P189.

57 Ibid, P189.

supervisory influences. These 'traps' do not make themselves apparent until a pilot makes an active error. For example, a pilot's decision to continue an approach at his destination despite severe thunderstorms could be construed as a 'judgment error', but deeper scrutiny might reveal that pressures, such as, a chronic shortage of spare parts in the supply system [organizational] or a flight commander's concern for avoiding the cost of an unscheduled overnight stay at an alternate airport [supervisory], conspired to 'trap' the pilot into his decision failure. Accident investigators need to search for latent failures in causal determination and safety professionals need to aim efforts at the detection of the 'traps' in order to correct them before an accident happens.[59]

So we see that research, enabled by data collection and analysis, has led to a better understanding of why pilots make errors and has guided practitioners in the development of defensive measures. Yet it is important to recognize that data collection is not as well conducted as is needed by researchers. Accident investigator's reports rely heavily on FDR/CVR's to reconstruct accidents but many military and general aviation aircraft are not equipped with the devices, and, because FDR/CVR's only provide the 'what-happened' in an accident, it is left up to the investigator to determine the 'why' – often an impossible task. Additionally, anonymous reporting systems are criticized as under-representative since pilots do not report all error incidents and those incidents that are reported often do not contain sufficient detail about the cause of the error or the means used to detect it.[60] Further, data collected through observation, such as LOSA, can be flawed as the pilots may behave differently when being watched. Finally, the notion

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[58] Reason. *Human Error*…P174.

[59] National Defence. A-GA-135-001/AA-001 Canadian Forces Flight Safety Manual. Chapter 11 – Cause Factors. (Canada)

[60] Sarter, Nadine. Error Types… P189.

that accidents are the result of a 'system' of errors, both latent and active, is widely acknowledged as the best approach to improved system safety, however, attempting to connect supervisory and organizational error to accidents remains problematic. As important as all of these means have become in aiding a better understanding of the underlying causes of pilot error, it is apparent that they need to be further refined to provide accurate answers.

> During the early 1970's, many experts were pointing to the lack of accidents caused by mechanical malfunctions. The focus changed to the human operator as the weakest part of the system.[61]

The cost of accidents has become far too heavy for us to maintain the 'path well worn' - it is time for a change, it is time to solve this problem. Business interests are becoming increasingly more global in today's economy and tourism has become an enormous engine of many economies around the world. A safe and reliable aviation industry is key to their continued health. One need only witness the effect that the September 11th suicide highjackings had on the airline industry to comprehend the impact that a lack of public faith in airline safety can have. With up to three quarters of all accidents attributable to pilot error it is clear that aviation has reached a stage of maturity where the only way to markedly reduce accidents is to halt the human error chain before accidents happen. But we can't simply regulate errors out of the cockpit. "If the aviation industry is serious about improving safety it must recognize that crew errors are symptoms, and that the symptoms can be ameliorated only by treating the underlying

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[61] R. Stone & G. Babcock. *Airline Pilot's Perspective*. In "Human Factors in Aviation." Earl Wiener & David Nagel ed. Academic Press. 1988. P559.

causes."[62] The causes emanate from the inherent vulnerability of the human to make mistakes. An understanding of the causes of distraction, visual illusion, task saturation, fatigue, etc., is rooted in a comprehension of the limitations of human information processing ability. Without this level of understanding there is little chance of defining mechanisms for prevention. "Psychological research in aviation is still in its comparative youth…and the sum total of human experience in all its richness and complexity is far from adequately understood"[63] Knowledge gained from accident investigations, flight data recorders, line observation studies, and from pilots themselves has proven that concrete steps can be taken to develop and teach countermeasures which will make pilots less vulnerable to their errors.

Yes, people make errors all the time, but pilot errors resulting in accidents are no longer tolerable. An earnest effort to better understand pilot error is needed. While it is true that 'to err is human' it is also true that "knowledge of the self is the mother of all knowledge."[64]

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62 Key Dismukes & Frank Tullo. *Aerospace Forum: rethinking crew error*. "Aviation Week & Space Technology." July 17, 2000.

63 David O'Hare & Stanley Roscoe. *Flightdeck Performance: the human factor*. P230.

64 Khalil Gibran. *The Vision: Reflections on the Way of the Soul*. Penguin Group (USA) Inc 1994.

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