Winter 2011

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ACCIDENT REDUCTION THROUGH CREW RESOURCE MANAGEMENT

Darryl P. Broome

Abstract
The advent of technology has aided pilots navigate challenging terrain and avoid potentially disastrous weather systems, but the large amounts of information required to process have significantly hindered crews, some to overwhelming proportions with catastrophic results. Crew Resource Management (CRM) is a skill set utilized by crews to recognize, avoid, and mitigate risk. This report discusses some of the factors facing crews in today's flight environment and looks at some recent accidents that were attributed to CRM failures. Also, we'll analyze recommended changes to the traditional CRM concept and how they are being incorporated in commercial and general aviation. I'll also discuss the technological upgrades and the pitfalls associated with the advancement of avionics and computerized flight control.

United Airlines Flight 173 was on final approach to Portland International Airport after an uneventful flight on December 28, 1978. The pilot noticed that he had not received the proper indication that the landing gear was down and locked into position. The nose gear light failed to illuminate green, the safe indication. The aircrew notified the air traffic control center and requested additional flight time to resolve the situation. The crew initiated the appropriate checklists while circling near the airfield. In spite of the crew’s efforts, the nose gear landing light continued to glow red, still indicating the gear was not locked into position. Throughout the troubleshooting process the first officer and flight engineer informed the pilot that the plane was running low on fuel. The pilot either ignored the warnings or did not comprehend the messages. Approximately six miles southeast of the airport the aircraft crashed into a wooded residential neighborhood. This was the result of the engines being completely starved of fuel. Eight passengers and two crew members were killed, and 23 people were seriously injured. Since there was no fuel to feed the fire, the death toll was relatively low for this type of disaster. The lack of communication skills under stress, situational awareness, team building, decision making and task allocation were all contributing factors in this accident. The post crash analysis determined that the green light indicator for the nose landing gear had a burned-out bulb. The nose gear had been down and locked the entire time. (NTSB, aviation-safety.net, 2007)

Fast forward 28 years later.

On August 27, 2006, about 6:06 a.m. eastern daylight time, Comair flight 5191, a Bombardier CL-600-2B19, crashed during takeoff from Blue Grass Airport, Lexington, Kentucky. The flight crew was instructed to take off from runway 22 but instead lined up the airplane on runway 26 and began the takeoff roll. The airplane ran off the end of the runway and impacted the airport perimeter fence, trees, and terrain. The captain, flight attendant, and 47 passengers were killed, and the first officer received serious injuries. The airplane was destroyed by impact forces and post crash fire. The National Transportation Safety Board determined that the probable cause of this accident was the flight crew members’ failure to use available cues and aids to identify the airplane’s location on the airport surface during taxi and their failure to cross-check and verify that the airplane was on the correct runway before takeoff. Contributing to the accident were the flight crew’s non-pertinent conversations during taxi, which resulted in a loss of positional awareness. (NTSB, 2006)

Flight 173’s disaster was the catalyst for the aviation industry’s recognition that technology alone was...
not the cause of air mishaps. An evolution in how crews interacted in flight has begun. The DC-8 used by Flight 173 was a fully functional, mechanically sound airframe that crashed because the humans flying the machine channelized their attention towards a burned-out light bulb. The pilot became so absorbed in the burned-out bulb that he forgot to fly the plane. As a result of this mishap and many similar ones, a new training program was implemented that sought to capture and minimize human frailty. Cockpit Resource Management (CRM) had been what researchers thought at the time a solution to break the human error chain. CRM has been in place for over 30 years and is universally taught to aircrews throughout civilian and military flight training as well as other careers including medical, fire fighting, and others that require risk analysis.

Still, research suggests that 80% of all aviation accidents continue to be the result of some form of human error. Development of new technology such as Synthetic Vision Systems (SVS) that allow a GPS overlay view of the terrain are direct results of these accidents and are designed to prevent, intervene, and/or mitigate pilot error. These new technologies require a modification to the original CRM model to allow for the added information and capabilities.

Barriers to Effective CRM

CRM is a process that allows crews to overcome challenges to day to day operations as well as effectively handle unforeseen situations. Barriers to effective CRM minimize the crews’ ability to handle an event in a safe and timely manner. Barriers are any factors that inhibit communication, situational awareness, decision making and teamwork. Barriers can be external (physical) or internal (prejudice, opinions, attitudes, stress). Once these barriers are identified, crew can then properly apply appropriate skills to mitigate those barriers. The difficulty lies in identifying the barriers, especially internal. While the following examples are not all inclusive, they address some of the common barriers crews face.

External Barriers

External barriers include the physical forces surrounding a crew in their mission. Some examples include:

- Weather
- Air Traffic Control
- Aircraft Systems
- Location (familiar vs. non-familiar)

A relatively new external barrier that must be addressed is the congestion of the National Air Space (NAS). With the influx of aircraft and degraded performance of Air Traffic Control (ATC) equipment, airspace is at a premium, especially in the highly populated areas of the U.S. and around the world. This creates challenges that aircrews must face on a daily basis. It is well known that the current air transportation system does not meet the growing needs of the 21st century. The ability of the NAS to meet future demands is constrained by the limited capacity caused by the traditional hub-and-spoke method currently utilized by air carriers. This bottle-neck has also led to a large number of corporately and privately owned aircraft to infiltrate the airways further causing the congestion. (Federal Aviation Administration, 2004)
The one thing that these external barriers have in common is that they can be observed and analyzed by all pertinent crewmembers, whereas internal barriers cannot and it is incumbent upon the individual to address the barrier and properly communicate his/her concerns or agendas to the other crewmembers.

**Internal Barriers**

Internal barriers are difficult to identify and analyze. Each human being is created differently and has different forces acting on their lives at any given time. These are the issues that don’t readily appear until a chain of events force the crewmember to react in a way that reflects his/her mental state or capabilities. (Federal Aviation Administration, 2004) Some typical internal barriers include:

- Stress / Fatigue
  - Anxiety
  - Frustration
  - Fear
  - Anger
- Task Overload / Underload (compliancy)
- Group Mindset
- “Press on Regardless” Philosophy
- Insufficient Communication
- Hazardous Attitudes

Although CRM is a widely accepted program, there is a small subset of pilots that reject the concept. These individuals can be found in every flying environment and are known to their peers and leadership. Efforts at remedial training for these pilots have proved ineffective. It’s incumbent upon senior leadership that these individuals not be put in a situation that their attitudes/personalities jeopardize the safety of others or be influential on junior crewmembers. (Helmreich & Butler, 1991)

**Is it Human Error?**

Currently there is a trend towards the notion that a single causal failure is an inadequate explanation in failure generation. (Reason, 1997) The incidence of failure attributed to human causes has risen from an estimated 20% in the 1960s to some 80% in the 1990s. (Hollnagel, 1993) Could the advent of CRM be the cause of this attribution? Is it simply easier for investigators to say that the pilot made an error or the crew made a series of errors that led to a mishap? This increase is believed to be a reflection of the increasing complexity of technical systems and the resulting inability of humans involved in all stages of design, manufacturing, and operations to exercise control over the system. In almost all accidents, the failure events cannot be attributed to a single root cause, but rather the result of the complex interaction that occurs between the elements. This complexity requires the crews to be able to deal with a range of non-design emergencies which lie outside of the known failure envelope designated by the engineers. (Reason, 1990) While contingency plans may be available for many events, there will always be the unforeseen through the system which was either not considered, or possibly even dismissed, by designers as being so improbable as to be impossible. (Perrow, 1984) Thus, a full analysis of the causal factors cannot be truly accurate.

**Train as you Fight, Fight as you Train**

The initial introduction of CRM focused on the personalities and attitudes of the crew members and did not necessarily combine the crews in a scenario that would test and evaluate their “CRM” skills. Further enhancement of the program instituted simulators that focused on the crew interactions during normal operations and then presented them with one or multiple distracters (poor weather, mechanical malfunction, unruly passenger, etc). This gave the crewmembers the opportunity to apply their skills in a safe environment and to review their actions after the simulator was complete, since most events were video recorded for playback. The results from these simulator events eventually began to migrate to the aircraft.

When crews are placed under stress during actual situations, many have said that it was at that point that their training went into effect. So without proper training, how can someone be in a position to let the training take effect and handle an emergency appropriately? It is imperative that crewmembers be given the proper training and the opportunity to put into practice the concepts learned in a classroom environment.

**General Aviation Resource Management**

Although the commercial aviation industry is continually highlighted when an air carrier crashes, the number of small general aviation (GA) aircraft accidents far exceed the commercial accidents. GA accidents also account for a much larger number of people injured or killed. GA accidents can be attributed to several factors, but the most common factors to emerge from research conducted into GA accidents and incidents, are those of poor judgment and decision making. The single-pilot operations in GA are arguably one of the most demanding civil aviation tasks.

Traditional GA training does not incorporate the CRM skills, but rather the technical aspects of flight and an individual’s skills to manipulate the aircraft in a safe manner. Those skills concentrated on by the use of CRM are just now being utilized in small aircraft and single pilot operations. A research panel concluded that providing a
CRM based training to single-pilots would improve their decision making processes, leading to an overall reduction in the rate of accidents and incidents, and to an improvement in the efficiency of flight operations. This finding was consistent with a study by Alan Diehl which found that judgment training can lead to a significant reduction in aircrew error. (Diehl, 1990)

There is a push to require GA pilots to attend some form of CRM training tailored to meet the demands of single-pilot operations. One concern of this is that there is the likelihood that the training will only be a “check in the box” and not truly meet the needs to train the pilots properly enough to be effective. However, if the program is developed in a manner as to require some form of observable evaluation, surely there will be an effective tool in reducing the large number of GA accidents.

Technology and CRM

Shortly after the dawn of manned flight, aviators began to acknowledge the limitations of flight based on weather conditions. Instrumentation and ground-based radio navigation aids were developed to assist and eventually replace out the window information during IMC. An example of one such aid is the Instrument Landing System (ILS). The ILS consists of two radio beams that present both lateral and vertical course guidance information. The goal of the pilot flying the ILS is to keep the aircraft centered on this course until decision height (DH), a predetermined height above the ground.

To assist the pilot in flying the ILS, a flight director system was later developed to calculate a course that allows the aircraft to intercept and fly the ILS signal down to DH. The change in roll and pitch calculated by the flight director is then presented to the pilot by pitch and roll bars on the attitude indicator. The flight director provides improved course guidance, but is not intuitive and provides very little real time situational awareness.

The next large breakthrough was the incorporation of a Heads Up Display (HUD). The HUD allowed a level of integration not before possible by superimposing flight symbology on either a panel- or head-mounted display. Instead of using the panel-mounted ADI for attitude indication, the HUD allows presentation of attitude information with an artificial horizon which is conformal with the outside scene, with additional information immediately available on one display. The HUD also presents the flight path information (the actual direction of the aircraft vs. orientation of the aircraft), allowing for a more intuitive method of control. With this flight path display, the pilot can determine required trajectory needed to intercept desired course (Foyle, Ahumada, Larimer, & Sweet, 1992).

Currently, with GPS navigation and approaches becoming the norm in aviation, the integration of moving maps and overlay approaches provide the aircrew with a top down view of the surrounding area, normally displayed on either a stand-alone GPS or via a multi-function display (MFD). This provides improved situational awareness based on the aircraft’s position over the ground, but does not provide pertinent real-time information in relation to the aircraft’s attitude or current trajectory.

Synthetic Vision Systems

Synthetic Vision Systems (SVS) are aircraft technologies that depict computer generated displays of terrain surrounding an aircraft in order to provide a visual solution during instrument meteorological conditions (IMC) to prevent incidents such as controlled flight into terrain or loss of situational awareness. Improved pilot situational awareness (SA) during low visibility conditions is potentially offered by SVS displays because of the natural cues offered by a 3D perspective of the outside world showing unlimited ceiling and visibility conditions. New technological developments in navigation performance, low-cost attitude and heading reference systems, computational capabilities, and display hardware allow for the prospect of SVS displays for virtually all aircraft classes.
A fundamentally new approach is needed to fully integrate the human-machine interface. While it is unlikely that conventional display concepts can significantly increase safety as new technology cannot simply be layered onto previous concepts since the current system complexities are already too high (Theunissen, 1997). One such approach applies the fundamental advantage of perspective flightpath displays relative to conventional displays. Rather then directing the pilot what to do, SVS navigational displays can now provide information about the margins within which the pilot is allowed to operate. These additional display elements provide guidance that does not force the pilot to apply a continuous compensatory control strategy.

Only in this way can human flexibility be exploited. This is a fundamental difference between current and SVS displays – that synthetic vision embodies the concept of “human-centered” design by providing natural versus coded information to the pilot (Theunissen, 1997).

Synthetic vision technology will allow the issues associated with limited visibility to be solved with a vision-based solution, making every flight the equivalent of a clear daylight operation, which will help improve situation awareness and lower workload. Therefore, SVS can have a most significant impact on improving aviation safety, as limited visibility has often been cited as the single greatest contributing factor in fatal worldwide airline and general aviation accidents (Boeing, 1998).
Table 1

Phase of Flight Accidents

<table>
<thead>
<tr>
<th>Accidents</th>
<th>Taxi, landed, parked</th>
<th>17%</th>
<th>Percentage of accidents/fatalities</th>
<th>51%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Takeoff</td>
<td>Initial climb (Raps up)</td>
<td>Climb</td>
<td>Cruise</td>
</tr>
<tr>
<td>Accidents</td>
<td>5%</td>
<td>12%</td>
<td>5%</td>
<td>8%</td>
</tr>
<tr>
<td>Fatalities</td>
<td>0%</td>
<td>8%</td>
<td>14%</td>
<td>25%</td>
</tr>
</tbody>
</table>

Exposure = percentage of flight time based on flight duration of 1.5 hours

1% 1% 14% 57% 11% 12% 3% 1%

Consider that one of the major classifications of aviation accidents involving visibility issues is CFIT and that CFIT is the greatest cause of aviation fatalities. A CFIT accident is defined as one in which an otherwise-serviceable aircraft, under control of the crew, is flown (unintentionally) into terrain, obstacles or water, with no prior awareness on the part of the crew of the impending collision. (Comstock, Glaab, Prinzel, & Elliott, 2002) It should be noted that worldwide, the chances of CFIT accidents are 5 times higher in non-precision approaches. As shown in Table 1, over 50% of all accidents occur during the final approach and landing phase of flight. Also note that the aircraft is only in this regime an average of 4% of the time. This is especially true for third-world countries where money is not available for updated equipment and aircrews are forced to fly the most basic of non-precision approaches. For commercial transport aircraft, instant recognition and correction of visibility-induced errors may eliminate CFIT. For general aviation aircraft, a lower cost implementation of such a system could help to prevent visibility-induced loss-of control accidents by providing an intuitive, easy-to-fly visual reference for VMC-like operations in IMC. SVS also can reduce the strain on the NAS by approving more aircraft in particular airspace based on available equipment.

Studies have shown that problems with avionics use were strongly associated with cognitive performance problems. Most new aircraft have highly advanced, integrated glass cockpits, so problems using avionics are becoming more common. These problems occur mostly during three phases of flight: climbout, cruise, and arrival/approach. These periods of flight are highly demanding and errors due to programming or being “heads down” will show themselves during these phases. During one recent study, when a reported problem with avionics usage occurred, 97% of the time there was a loss of situational awareness. Some of those problems were related to not using the equipment correctly, others were related to having one’s head down to program or trying to figure out...
how to use the avionics and losing track of what was occurring around them (Burian, 2007). SVS and other systems are there to provide an additional link in the safety chain, but does not override the pilot's responsibility to make sound decisions for the safety of the flight and the crew.

These additional systems being integrated into the aircraft are in essence an additional crewmember, thus changing crew dynamics and the man-machine interface. Researchers studied the CRM model and developed observer-based measures sensitive to the insertion of advanced flight deck technologies such as SVS (Table 2). (Alexander, Estock, Beaubien, & Holbrook, 2007) This particular model accounts for the integration of automation and also the amount of data that crews now have to process and monitor.

Table 2

<table>
<thead>
<tr>
<th>CRM Skills</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
<td>Ability of crew members to clearly, concisely, and accurately send and receive information in a timely manner, and to provide useful feedback.</td>
</tr>
<tr>
<td>Anticipating &amp; Planning</td>
<td>Ability of crew members to predict likely future states and develop a course of action by organizing resources, activities, and responses to ensure that tasks are completed and synchronized.</td>
</tr>
<tr>
<td>Coordination</td>
<td>Ability of crew members to accurately monitor and assess their own and other team members' performance. Ability of team members to sequence, pace, and deconflict activities, and to balance individual workload.</td>
</tr>
<tr>
<td>Leadership</td>
<td>Ability of crew members to encourage team members to work together, motivate each other, and establish a positive team atmosphere.</td>
</tr>
<tr>
<td>Decision Making</td>
<td>Ability of crew members to gather and integrate information, and to make logical and sound judgments.</td>
</tr>
<tr>
<td>Adaptability</td>
<td>Ability of crew members to alter their behavior or strategies based on contingency planning and/or as new information becomes available.</td>
</tr>
<tr>
<td>Situation Monitoring</td>
<td>Ability of crew members to develop and maintain an understanding of the task, aircraft systems, and environment.</td>
</tr>
</tbody>
</table>
Conclusion

Uncertainties, intrusions, and general distractions all pose a significant threat to the safe operation of an aircraft. Fortunately there are concepts developed to provide checks and balances to establish and maintain safe operations. Pilot induced mishaps do still occur, but at a far lower rate than during the period prior to the inception of CRM. Is any rate other than zero an acceptable number? No, but crews now are more equipped with the tools to make sound decisions based on conditions and personal experience. What can never be fully understood is the total number of aircraft and lives that have been saved because of the implementation of CRM. There are many examples of crews working diligently to get a crippled aircraft safely on the ground. Most recently, the crew of US Airways Flight 1549 safely ditched an Airbus A320 into the Hudson River after losing all thrust in both engines. The pilot had been instrumental in the integration of CRM at the airline, and fully believes the concepts and skills learned aided their ability to safely land the airplane.

The crew members of the flights at the beginning of this report were experiencing two different situations. One crew focused their attention on troubleshooting an emergency they thought could have serious consequences; the other crew, complacent, failed to use available resources to verify their location prior to departure. Another difference is that the second crew had been trained to use CRM to become more acutely aware of their surroundings, unfortunately they failed to maintain a sharp awareness. However, both met similar fates. For CRM to be successful, it must be incorporated all the time, every time. The skills and concepts must not be watered down or allowed to decay over time. Management must support it and those that evaluate the process must enforce its practice. General aviators need to fully comprehend the CRM process. New technologies such as SVS need to be readily available to both commercial and civilian aviation. We as human beings will continue to make mistakes, but by utilizing the concepts and practices of CRM and ensuring they are adhered to during all phases of aircraft operations; we can see a decline in aviation mishaps and prevent further accidents.

Darryl Broome grew up in South Carolina where he attended the University of South Carolina before joining the United States Air Force in 1993. He received his Bachelor's of Science from Southern Illinois in 1998 in Industrial Technology and attended Specialized Undergraduate Pilot Training shortly thereafter. Major Broome is the assistant director of operations and an evaluator pilot for an Air Force Special Operations Command training detachment in North Carolina. He is currently attending East Carolina University where he is completing his MS in Technology Systems with a concentration in Performance Improvement.
References


