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The Human Space Flight Approach to Crew Resource Management (CRM)

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Introduction

She was carrying more than 2220 passengers when she left the Southampton docks just after noon on that April day. This maiden voyage of discovery and adventure would soon become one of the most devastating maritime disasters of all time as the great ship collided with an iceberg, only minutes before midnight on April 14, 88 years ago. In just under 3 short hours, the freezing waters of the North Atlantic swallowed the Titanic ending the lives of over 1500 of her passengers and crew, forever changing those of the 707 survivors.

In the early hours of the morning on April 26, 1986 a routine test of the reactor went very wrong. The nuclear power control engineers at Chernobyl unit 4 had no idea that their actions were about to produce the worst nuclear disaster of all time. Several human errors led to an uncontrolled reaction in the core resulting in explosions that lifted the cap off the containment facility. In all some 8 tons of fuel containing highly radioactive plutonium and other fission products were ejected from the reactor into the surrounding atmosphere.

There were no mechanical failures that caused the Titanic to hit the iceberg. The nuclear reactor test was routine, done at reduced power. Why then were these events so tragic, and what was the common thread that made these some of the worst human disasters of all time?

During the last few months of 1999, local newspapers were filled with accidents caused by human errors. These included a nuclear incident in Japan, a terrible train crash at Paddington Station in London, and an unmanned space craft that was destroyed in the Martian atmosphere because of confusion over English versus metric units. Also, recent information released concerning the medical profession indicated that over 99,000 deaths occur each year due to erroneous medical practices caused by human errors.

Human errors in technical environments have been with us for a long time. They can probably be traced back to the era when humans and even the simplest of machines first got together. As these machines became more complex, mechanical failures became a significant factor in accidents or incidents. However, as the technologies improved and the humans learned, mechanical failures dwindled and the primary cause of accidents and incidents became the human factor.

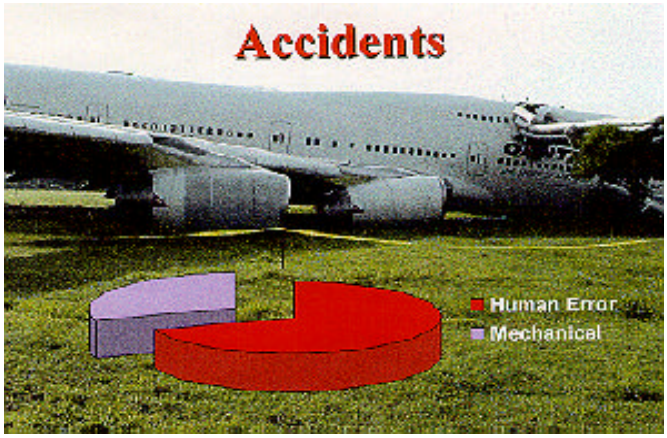
Commercial aviation has had its share of these types of accidents almost from the time the first passenger ticket was written. As technology improved and mass media proliferated, aviation accidents have had a tendency to embed themselves into our own subconscious. Most of us remember the Eastern Airlines L1011 that crashed in the Florida everglades on the 29th of December 1972. Accident investigators determined that the crew was so focused on a burned out landing gear down light bulb that no one noticed the autopilot was disconnected and a perfectly good aircraft simply flew into the water. Mention the island of Tenerife and it conjures up the terrible 1977 tragedy of the Pan Am and the KLM 747s that collided on the runway resulting in over 673 fatalities, again caused by human error.

Human errors have manifested themselves in the human space program as well. While the crew was not responsible for the malfunction that caused the destruction of Challenger 73 seconds after liftoff, the mitigating circumstances regarding the decisions leading up to the launch are ripe with mistakes and errors in communication and judgement by NASA and contractor personnel. (Presidential Commission, 1986). And, some of the incidents aboard the Russian built MIR space station can be attributed to human errors as well (Burrough, Bryan, 1998). But these are just some of the most visible examples.

Commercial aviation was probably the first large visible organization to officially act on human factors issues toward the ladder part of the 20th century. It was the tremendous effort by a variety of organizations including research, academia, NASA, the Federal Aviation Administration and the airlines themselves that brought the human causal factor into focus. It was here that Crew Resource Management or CRM programs were first identified, created and implemented with the goal of eliminating costly accidents or incidents caused by human error.

Purpose and History

Investigations into the causes of air carrier accidents have shown that human error is a contributing factor in 60 to 80 percent (FAA AC 120-51D). Long term NASA research has demonstrated that these events share common characteristics. Many problems encountered by flight crews have very little to do with the technical aspects of operating in a multi-person cockpit. Instead, problems are associated with poor group decision-making, ineffective communication, inadequate leadership, and poor task or resource management. Unfortunately most aircrew training was associated with the technical aspects of flying, and not the human error element.



Cockpit Resource Management (CRM) programs as initially called in this country can be traced back to a NASA sponsored workshop called *Resource Management on the Flightdeck* in 1979 (Cooper, White & Lauber, 1980). This conference was the outgrowth of NASA research that began as early as 1973. This initial cutting edge human factors research began to delve into the realm of "pilot error" as the principle cause of most air carrier accidents and incidents. The research presented at this meeting identified the pilot error aspects of the majority of air crashes as failures of such things as interpersonal communications, decision making and leadership. Because of the identified need in commercial aviation to minimize human errors and their effects, many programs were conceived to enhance flight crew training and improve aviation safety by reducing the probability of pilot/crew-related errors. The term Cockpit Resource Management was applied to the process of training crews to reduce this error and make better use of the human resources on the flight deck. The term Cockpit was later changed to Crew to reflect the evolution of the program.

The first US air carrier to initiate formal CRM training was United Airlines in 1981. This came as a result of a serious crash of a UAL DC-8 in Portland Oregon in 1978. While working another landing gear type problem, the captain of this jetliner ignored the advice of other crewmembers when they were seriously short of fuel. This jetliner ultimately flamed out and crashed short of the runway, causing 10 fatalities and many very serious injuries. The National Transportation Safety Board (NTSB) singled out

the captain's failure to accept input from junior crewmembers and a lack of assertiveness by the flight engineer as causal factors. Better "human" resource management could have prevented this accident.

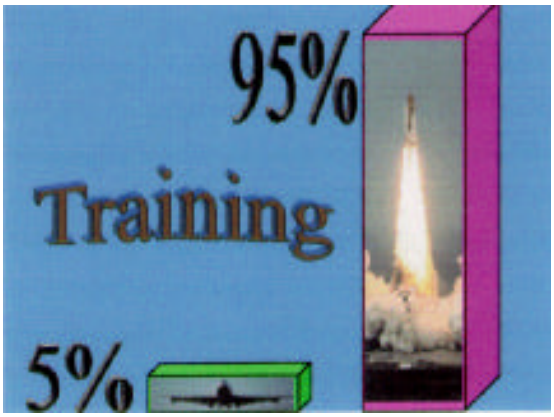
While these programs are not revolutionary, they certainly are evolutionary in their scope. Early crew resource management programs were derived from managerial improvement programs for corporations. The United Airlines Command, Leadership, and Resource Management (CLR) program was closely modeled on a form of training called the "Managerial Grid" developed by psychologists Robert Blake and Jane Mouton in the early 60s (Helmriech, Merritt, & Wilhelm, 1999). Gradually this type of "management style" training began to spread throughout commercial aviation communities both here in the US and abroad. These programs tended to focus on correcting individual behavioral traits including more assertiveness for junior crewmembers and a lessor authoritarian approach for captains.

Throughout the early 80s many operational crews complained that these first generation courses tended to be too psychological in nature. They became focused on psychological testing and more generic concepts of teamwork and leadership skills. While they appeared to focus on the human factor issue, the application of the training was difficult for operational crewmembers to understand. So these programs earned a bad reputation early on and had the appearance of being force-fed. As airlines took a more operational approach to this training, Crew Resource Management training became more widely accepted and is now a regular part of airline culture.

Following CRM implementation, air carriers began to notice decreases in their accident rates. Military application of these principles lagged behind the civilian sector but during the 1980s, the Naval Safety Center and the Air Force's Air Mobility Command (AMC) began to implement airline-style programs with good results. CRM programs have become so important in both sectors it has become a FAA mandate for all aircrew members in commercial aviation and a directive for military aviation communities (Kern, Tony, 1996). The FAA has also taken a much larger step and has mandated that all dispatchers and flight attendants attend CRM training after March 19, 1999.

If there is a lesson that can be learned from experience it is this: Humans will interact with each other the same way in virtually any environment including space (Stuster, Jack 1996). And, as space vehicles grow in size, cost, complexity and automation, the need for accurate and efficient management of the human resources within these vehicles becomes paramount to the success of the conquest of space. While the human journey thus far has kept us reasonably close to the planet, there will be a time when great interplanetary ships will traverse the stars much the same way as we would have liked to cross oceans in ships like the Titanic. Our present space vehicles are limited to the Space Shuttle and the International Space Station. But even though they are physically limited, their mission requires tremendous human interaction and participation. As learned in aviation communities, good effective crew resource management programs in multi-place highly technical vehicles are absolutely necessary in the interest of safety and mission success.

While there are many similarities between space flight and aviation, there are also significant differences. Commercial airline crews spend less than 5 percent of allocated time in training and the other 95% in a given year doing their assigned mission flying airplanes. These pilots rarely train with the same crewmembers that they fly with. For all space flight missions from the early Mercury days, the training/mission ratio has been about 95% in training with five percent of the time doing the actual mission.



Until recently there were no institutionalized CRM training programs in human space flight programs. It can be argued that many of the ideals were regularly practiced. Apollo 13 was a tremendous example of how human resources both in the vehicle and on the ground were managed and utilized to overcome huge obstacles and become "NASA's finest hour" as Gene Kranz would say. While most airline crews train as individual crewmembers, space flight crews have always trained as a team, formed many months prior to their space mission. And the team is not just the crew in the vehicle. The team extends to the training, launch and mission control centers, all focused on accomplishing a specific mission.

Necessity for CRM in Human Space Flight Operations

How individuals react in crew/team type environments has dictated a need for Crew Resource Management programs in aviation. This same concept can be applied to space vehicles. And much the same as in commercial aviation, the multi-place space vehicles beginning with Gemini has generated a need for human factors CRM type training. Multi-place vehicles like the Space Shuttle where up to seven crewmembers of varying backgrounds and experience must coexist for varying lengths of time parallel the commercial aviation world in the need for crew resource management programs. Add to this mixture the fact that many of today's crews are comprised of multi-cultural personnel as well as multi-national, multi-disciplined, and multi-serviced individuals. Most of the astronauts occupying the upper deck of the space shuttle come from varying military aviation venues. There is the occasional Commander, Pilot or Mission Specialists positions that are staffed by civilian astronauts but it is more the exception than the rule. Additional Mission Specialists and Payload Specialists may or may not have an aviation back ground. In many cases their disciplines may not include aviation so their knowledge of cockpit crew type environments may be extremely limited.

There have been many attempts to employ Crew Resource Management training in the space program. In the late 1980's following the Challenger accident, a team from NASA Ames and NASA UT approached flight operations regarding the CRM movement. There was already a tremendous involvement by NASA Ames with research involving aircraft accidents. This being the case it was thought that the CRM training generated by their research could be supplanted to the Space Shuttle program. Unfortunately the theory and concepts were not readily accepted so subsequent programs met with limited success.

The Focus of CRM Training Programs

"Those who cannot remember the past, are condemned to repeat it!" George Santayana

The focus of CRM training programs addresses the human factors issues associated with the technical environment. Human factors can be defined as a multidisciplinary field devoted to optimizing human performance and reducing human error. It incorporates the methods and principles of the behavioral and social sciences, engineering, and physiology. Human factors is the applied science that studies people working together in concert with machines. It embraces variables that influence individual performance and variables that influence team or crew performance. It is recognized that inadequate system design or inadequate operator training can contribute to individual human error that leads to system performance degradation. Further, it is recognized that inadequate design and management of crew tasks can contribute to group errors that lead to system performance degradation (FAA AC 120-51D).

CRM programs are one way of addressing the challenge of optimizing the human/machine interface and accompanying interpersonal activities. For the last two decades, formalized CRM training programs have evolved to include a variety of the elements including the concepts of communications processes and decision behavior, team building and maintenance, workload management and situational awareness. These elements are listed in a variety of different ways depending on the culture of the organization. Regardless of the makeup of the individual programs, the goal is the same: To minimize human errors and the effects of human errors in a technical environment.

One of the major outgrowths of CRM training with the commercial air carriers was the birth of the Advanced Qualification Program (AQP) which is a voluntary alternative to the traditional regulatory requirements Federal Aviation Regulations 121 and 135 for pilot training and checking. This program was designed and implemented using the ISD process and takes a more scientific approach to aircrew training. The significant difference between traditional pilot training programs and AQP is that pilots are now assessed on not just their technical abilities, but also how they function regarding crew resource management skills. This new effort by the FAA has had a global impact on how pilots are trained to operate both in their technical and crew environments.

Evolution of CRM Programs toward Space Flight Resource Management

Even though an identified need existed for CRM training programs, there were no coordinated attempts to establish an official program. Throughout the 1990s, several vendors provided some forms of CRM training to various elements of the space program. These vendors included contractors that provided their own unique brand of CRM courseware. This training was given to a variety of flight operations personnel including instructors, engineers, flight controllers and astronauts. While this training provided the basic premise regarding the human factor in accidents and incidents, it did not provide the necessary follow-on training that would give the redundancy and application necessary for space flight operations. Talking and working with aircraft accidents had a degree of relevancy to the space program, but these programs failed to address the real problems of space flight. A program was necessary to focus on the uniqueness of the human space flight environment.

Throughout this period in time, commercial airlines began to expand CRM training to other organizations within their structure. Along with a much more "operationally oriented curriculum" they began to include the flight attendants as well as dispatchers and mechanics. This thought process highlighted the fact that CRM training was not just for the cockpit crew. It should include all of the

human resources involved in the process of making the technological machine work efficiently and effectively. This "global" approach to CRM training has had a very positive effect on the airline industry.

On November 19, 1997, STS – 87 was launched. On board this mission included the Shuttle Pointed Autonomous Research Tool for Astronomy (SPARTAN) 201-4. The crew consisted of six personnel, two of which had flown before. Due to a variety of other mitigating circumstances, the deployment of the multi-million dollar SPARTAN satellite was delayed from flight day 2 to flight day 3. All elements of the flight plan were going well and on time. There were no indications of any problems up until the SPARTAN was deployed. After its release from the Remote Manipulating System (RMS), the satellite failed to do its programmed pirouette maneuver following the release.

Following coordination with the Mission Control, the crew tried to re-grapple the SPARTAN with the RMS. A tip-off force was imparted to the spacecraft by contact with the grappling device that resulted in a multi-axis rotational rate in excess of 2 degrees per second. This rate was judged too large for a re-grapple, so the crew attempted to match rotational rates of the SPARTAN by using the orbiter. Too much propellant was used in the attempt to match this rotation so the rendezvous was called off. Finally, it was determined that the satellite could only be recaptured at a later time manually by two EVA crewmembers. This was successfully accomplished 2 days later and the SPARTAN was reberthed. Re-deployment was considered but there was insufficient Reaction Control System (RCS) propellant available to accomplish the mission. Because of the failure of the SPARTAN deploy, a Close Call Board was convened following the mission. One of the contributing causes of the incident was directly related to the application of CRM. On page 8-2 of the Close Call Report dated March 2, 1998, it states:

> "**(2) Rigorous Cockpit Resource Management (CRM) as applied in other critical phases of a mission was not applied to SPARTAN operations. There was no plan or procedure to verify that all necessary steps had been accomplished in a positive manner or by independent means prior to deploy**."

One of the action items that came as a result of this Close Call Report was to establish a standardized CRM program for human space flight. This initial step was conducted by a team from the Guidance and Control/Propulsion section of the Training Division at the Johnson Space Center. It was determined during these initial steps that a human space flight CRM program should not just focus on the crew, but also on the entire spectrum of the industry, to include the trainers, the maintainers, the designers, builders and controllers. It was here that the term, Space Flight Resource Management was coined to more closely identify with the task.

This team did considerable research regarding current active CRM programs that are employed by the commercial aviation community as well as programs created for the Nuclear Power industry, the Chemical Industry and expeditionary type programs. This additional research was aimed at the expeditionary qualities of the International Space Station and future interplanetary expeditions where small groups of individuals would be confined for long periods of time. The guiding premise of all this research was to find out what was working well with these organizations, and avoid those activities that were not well received. The resulting program determined that SFRM should focus on six performance elements that are closely related to the space flight environment.

The Space Flight Resource Management program is built around these six performance elements. Their definitions are listed below:

- **Command**. The process used to get tasks accomplished. This is normally seen as the right to exercise authority of the crew or team member.

- **Leadership**. The techniques employed to get tasks accomplished. Effective leadership ensures a safe, efficient and successful mission. Good leadership is realized when individual members take the initiative to promote teamwork and professionalism.

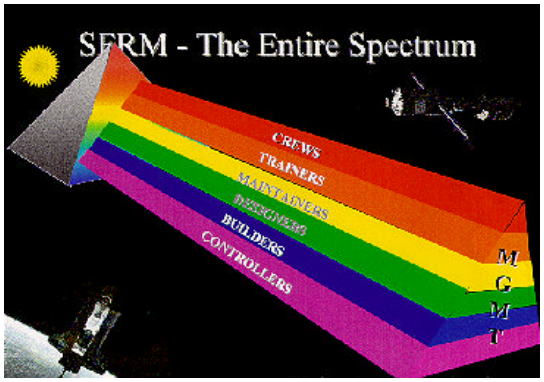
- **Communication.** The act of exchanging information, ideas and thoughts in an accurate and timely manner so the message is clearly received and understood.

- **Decision-Making**. The method of determining and implementing the best course of action and critiquing the outcome. Good decision making skills involve risk evaluation, timeliness, and alternate courses of action.

- **Situational Awareness.** The continuous ability of a crew or team member to accurately perceive the relationship between themselves and their surroundings.

- **Workload Management**. The process of evenly distributing the activities of crew or team members. It is accomplished by planning, prioritizing and then appropriately assigning tasks.

Currently three courses have been developed for the human space flight program. The first is the Overview Course that baselines all training and operational personnel on these six performance elements. The second course is called Applied Methods. It focuses on the application of these elements to the task. It demonstrates real world application of these elements to situations and scenarios that illustrate their importance. And finally the third course is called SFRM Facilitation. Facilitated learning is an important tool in the application of CRM training curriculum. These courses are designed for not only the space flight crews and flight operations personnel, but also personnel within Mission Control, maintenance, launch control teams, and designers of future space vehicles. In other words, SFRM is designed to accommodate the entire spectrum of the human space flight industry.



Space as popularized by a famous TV show, is the final frontier. But to successfully conquer space as human beings, we must put to use our knowledge of human factors and lessons learned from all the venues where humans and machines have ever existed. Tremendous knowledge can be gained by looking at the past. That is why lessons learned in Titanic, Chernobyl, Apollo, Challenger and aviation accidents and incidents are so important to the future of the human space flight environment. While space is unique, the human factors will remain familiar, regardless of the vehicles and the environment for which they exist. Space Flight Resource Management is linked to the past by the very nature of its roots. It is poised ready to help propel the human element to present and future explorations beyond our own planet and perhaps the solar system.

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