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Tailoring Airlines for Space Operations

By Jay Rollins

The new millennium is upon us!

It is April 2, 1968 and MGM Studios releases Stanley Kubrick's epic science fiction feature film, *2001: A Space Odyssey* to huge fanfare, colossal commercial success, and ultimately an Academy Award. The very next year, after only an eight-year national commitment to do so, real-life astronaut Neil Armstrong triumphantly sets foot on another world for the first time in human history.

The heady zeal of the space age's golden years cannot be overstated. It was no "giant leap for mankind" that wildly optimistic audiences eagerly embraced the central vision of a movie that predicted 2001 might have been the year when Pan American World Airways would offer scheduled space flights. But judge the vision in the harsh hindsight of 2016, where Pan Am no longer exists and American astronauts routinely hitch rides aboard Russian rockets, and suddenly the movie might only be remembered as a Space Oddity: Never Meant to Be.

In reality, the new millennium has already begun.

Sadly, lofty dreams of routine space travel crashed back to earth beneath the weight of earthbound priorities long ago. Yet today hope survives like a great phoenix, that regular space transport may yet arise from the ashes.

Multiple nations, commercial interests, and NASA are all gearing up not only to land people on Mars, but also to colonize it. Unfortunately, nasty, real-life experiences have uncovered not just technical challenges, but worrisome human failings that stand to threaten such a mission.

The reader may recall the bizarre 2007 incident in which a NASA Space Shuttle astronaut reportedly donned adult diapers to facilitate an overnight, 950-mile nonstop drive from Houston to Orlando. Police initially charged married-with-children Navy Captain Lisa Marie Nowak with attempted kidnapping after she confronted a love rival over the illicit passions of fellow astronaut, Commander Bill Oefelein. But then police upped the charges to attempted murder, and the judge denied bail once they uncovered that aside from diapers, Nowak had packed a steel mallet, a knife, a BB gun, and a map to her love rival's home.[1]

One observer quipped that the judge had little choice but to deny bail, since the defendant had the means not only to leave the community but the entire planet!

The incident might seem comical until one realizes that to be selected to fly NASA spacecraft, the perpetrator had slipped past an intense screening alongside the nation's finest, most qualified pilots.

[1] See www.nytimes.com/2007/02/06/us/06cnd-astronaut.html?_r=0.

What went wrong?

Even more concerning, a survey of airline incidents reveals even worse human failings – and they are anything but funny because some were deadly. If humankind is ever to launch a successful reboot of space travel, then we simply must recognize and solve not just technical deficiencies, but also emerging human threats to safety as well.

To address the challenge, it is prudent to reflect first upon the extraordinary technical achievements of today's airline system against the even more serious human challenges that lie in wait for travel in space.

20th Century Challenges and Resolution

After years of high accident rates and subsequent safety analyses, the FAA and other regulatory agencies around the world developed a body of regulations that specifically address crew manning, rest, crew management, maximum duty times, and training requirements. This article first examines long-haul airline flight operations as they exist today and catalogues how well flight crews manage danger for better or for worse. The idea is to ferret out what works and what does not with an eye toward developing better strategies for going forward into space.

Virtually all airline operations require a captain charged with command authority over passengers and crew, and who is ultimately responsible for the safe conduct of the flight. The captain is assisted by a (second-in-command) first officer, who is ready to take charge whenever the captain is unable to do so.

Long haul flights (generally considered to be more than eight hours) will add a (third-in-command) second officer or, as some airlines prefer to call him or her, an international officer to allow for one-pilot-at-a-time rest breaks in the cabin at the captain's discretion. During takeoff and landing or periods of heavy workload such as serious emergencies, all three cockpit crewmembers will be stationed in the cockpit.

Very long flights (more than twelve hours aloft) carry two complete cockpit crews: not only a captain, a first officer, and sometimes an international officer working the first half of the flight, but also a second cockpit crew resting in the cabin to assume command for the latter half of the journey.

Safety rules also require one flight attendant aboard for every 50 passenger seats with which an aircraft is equipped (regardless of the actual passenger count), while extra flight attendants are often added for crew rest and an efficient in-flight cabin service.

For the actual conduct of the flight, the FAA requires captains to employ a management philosophy known as Crew Resource Management (CRM). CRM stipulates the use of challenge and response checklists for normal, abnormal, and emergency flight operations, among other means to assure safe passage.

Crewmembers are expected to follow the captain's commands, consistent with aviation's over-arching axiom that empowers a pilot in command to deviate from any rule to the extent necessary to assure a safe outcome. CRM further obligates subordinate crew to offer independent observation, insight, and cross-checks for the captain's consideration. This is especially true whenever a crewmember believes the aircraft is being operated in such a way as to jeopardize the safety of the flight. Indeed, subordinate crew are obliged to offer such advice regardless of whether or how often they may be rebuked for doing so.

This important policy assures that captains have not only ALL pertinent information before them, but also the benefit of independent thinking from which to make sound judgments.

Non-routine events such as severe weather, passenger illness, and serious mechanical failure can tax individual crewmembers to the point of overload and therefore seriously compromise the safety of the flight. Consequently, in the moment that routine turns non-routine, CRM urges captains to analyze and prioritize tasks such that workloads stay manageable.

Depending upon the situation, an international officer on break might be recalled to the cockpit to assist with a problem. Cabin service might be discontinued and crewmembers reassigned to accomplish more critical tasks. The entire crew will seek to protect the function of vital equipment to the exclusion of creature comforts such as cabin lighting, entertainment systems, or galley power.

To prevent crew distractions during periods of heavy workload such as takeoff, landing, or handling emergencies, captains enforce "sterile cockpit" rules where cockpit conversation is restricted to matters pertinent to the flight and where cockpit visits and casual chat are prohibited.

Passenger aircraft are replete with all measure of backup systems, often utilizing completely different plumbing and even design functionalities from the primary systems. GPS navigation is backed up by extra units, and often these radios are further backed up by conventional radio broadcast navigational systems – and sometimes even paper charts for old-fashioned navigation using time/distance position plotting.

Aside from mechanical failures, hazardous materials (known as HAZMATs) aboard an aircraft can present crews with a somewhat different but very dangerous threat nonetheless. For this reason, the FAA bans certain substances outright and promulgates extensive regulations and safeguards for the safe carriage of others.

Obvious dangers such as flammable liquids and corrosives together with not-so-obvious dangers such as infectious agents, aerosol cooking sprays, bleach, and even 151-rum are all strictly banned. And while dry ice and lithium batteries are permitted, their quantities are highly restricted. In addition, crews are specifically trained how to handle toxic fumes or chemical fires for those instances in which a volatile material might pose an imminent danger.

Most importantly, CRM urges captains to utilize ALL available resources for solutions – both inside and outside the aircraft.

By way of example, consider what happens when a red warning light illuminates (often accompanied by warning bells or buzzers) to warn that a serious mechanical breakdown has occurred. In such cases, action must be taken immediately to protect aircraft integrity and the safety of its occupants. For this example, we shall assume a total loss of pressurization emergency, a crisis situation in which the occupants of the aircraft can lose consciousness in a matter of seconds and die within minutes.

As with any emergency, pilots must prioritize tasks in order to protect the physical safety of the occupants effectively. Aviation learned this important lesson the hard way following the infamous demise of Eastern Flight 401: a loaded Lockheed Tri-Star jet that crashed in the Florida Everglades one dark night in 1972. The three-man cockpit crew became so engrossed in handling a landing gear anomaly that they never noticed the autopilot had disconnected and that the aircraft had begun a slow descent to the demise of all aboard.

Consequently, in our example where the aircraft experiences a loss of pressurization, crews are expected to follow the credo: aviate, navigate, and communicate to ensure corrective tasks are executed according to their importance.

Since the highest priority is always to *aviate*, or to keep the airplane safely flying aerodynamically, one pilot is always assigned the sole priority of physically manipulating the flight controls and keeping the plane safely airborne.

Saving lives is paramount. Therefore, in the case of a loss of pressurization at high altitude, the crew's first action must be to don their personal oxygen masks, ensure oxygen is flowing, and then ensure passenger oxygen has been automatically deployed. The next step will be to descend the aircraft to a safe operating altitude immediately.

For a time-critical emergency such as a pressurization failure, these so-called "red-box" items are accomplished immediately from memory, even as the crew seamlessly *navigates* a safe course appropriate to the new circumstances.

Once *aviate* and *navigate* are addressed, *communicate* urges the crew to notify Air Traffic Control, declare an emergency, and advise them of the extent of the problem and how air traffic controllers might assist.

"Mayday, Mayday, Mayday – This is NoProblemsAir Flight 222 declaring an emergency! We're experiencing a total loss of pressurization. We've started an immediate descent to 10,000 feet," might be an example of such a radio transmission.

The crew then turns to appropriate checklists in an attempt to restore the lost system, time permitting, or at least to reconfigure the aircraft for the new operation. For these reasons, the pilot-not-flying is typically charged with running the appropriate checklist with the flying pilot cross-checking the progress. Of course, all of this is in addition to the crew's routine preparations for a safe landing.

Communicate further requires crews to reach beyond immediate aircraft resources for relief. CRM encourages crews to reach out to Air Traffic Control, company maintenance and dispatch personnel, and by extension experts of every stripe for further assistance as needed to assure a successful outcome.

This comprehensive response to mechanical failures, honed over many years, has proven to be highly successful and worthy for adaptation to space flights. This conclusion is backed by falling accident rates such that today, most aircraft accidents are attributed to human failings often associated with the highly automated cockpits common in modern aircraft.[2]

Yet, for all the panoply of protocols so effective at ensuring success in the face of mechanical failure, the success paradigm is dramatically diminished when the threat is set in motion by deliberate human action. Hostile actions of unruly passengers, terrorists, or even crazed fellow crewmembers can thrust a routine flight into life-and-death chaos in the blink of an eye – with successful outcomes far short of certain.

A Range of Organic Threats

Passenger misconduct was virtually unknown during the genteel dawn of commercial air travel of the 1940s and 50s. But today we live in a coarser world. Even so, armed hijackings occurred so frequently as far back as the 1970s that the FAA ordered airlines to begin routine passenger screenings for weapons.

At first, aircrews were instructed to remain passive with hijackers. Then, just as airlines came to believe that this was sufficient, the horrific terrorist strikes of September 11, 2001 proved them utterly wrong. Not only did that event force sweeping screening protocols, but some air crews were armed. Federal Air Marshals and even military jets were deployed and authorized to protect the public using lethal force if necessary.

Unfortunately, neither federal agents nor military fighter jets are economically feasible for every flight, and the introduction of heavily reinforced cockpit doors meant to protect pilots from danger in the cabin also prevents them from directly attending to it. Effectively, today's travelers tacitly accept that maintaining order is largely left to flight attendants and fellow passengers. But arguably, the worst-case scenario emerging today is one in which a crewmember goes rogue.

Pilot suicides are extremely rare yet remain a threat. Generally speaking, airline pilots are a highly responsible, disciplined group of individuals. They are committed to safety and notoriously calm in the face of danger. But pilots are still human beings, and as such they remain vulnerable to gross misjudgment, total emotional breakdown, and even suicidal acts when stressed sufficiently.

In the days leading up to April 7, 1994, FedEx Flight Engineer Auburn Calloway knew he would soon face a hearing likely to result in his termination after lying about his flight hours during the hiring process. Police investigators would eventually learn that he had purchased a large life insurance policy for his family and then plotted a terrible revenge for FedEx and its people. That particular day, police accounts say Calloway hitched a ride aboard one of the company's DC-10 cargo flights secretly armed with multiple

[2] www.denverpost.com/2010/02/13/human-error-is-biggest-obstacle-to-100-percent-flight-safety/.

hammers, a knife, and a spear gun for good measure. Police say his diabolical plan was simple yet far-reaching in its devastation: he intended to kill first the crew and then himself by crashing the enormous cargo jet into FedEx's headquarters in Memphis, Tennessee.

Once in flight and without warning, he viciously attacked Captain David Sanders, First Officer Jim Tucker, and Flight Engineer Andy Peterson with the hammers in an attempt to bludgeon the three to death. Two of the men suffered cracked skulls, yet they still managed to thwart his attack to the extent that Calloway was forced to resort to his backup spear gun to finish the job.

The three crewmembers heroically managed to overpower their attacker, who is now serving two consecutive life sentences in prison, but the industry was shocked into a new reality that a life-or-death struggle could erupt in the cockpit due to the actions of a single deranged crewmember.[3]

In early 2014, one of the great aviation mysteries of all time unfolded after a fully loaded Malaysian Air Boeing 777 traveling from Kuala Lumpur to Beijing, China disappeared altogether. The author of this article personally appeared as an aviation analyst on national news programs for a solid month in an effort to unravel what likely happened.

With no flight or voice recorders ever recovered to prove things one way or the other, theories based upon mechanical failure always seemed inadequate to explain the sudden loss of communication and erratic flying, both of which unfolded in such a way as to occur along serpentine national airspace borders for miles and miles. We eventually learned that the aircraft also made a wide turn directly over Penang Island – the captain's family homeland – and then indirect electronic evidence suggested that the flight then traveled out to sea until fuel exhaustion.

Investigators never definitively determined exactly what happened, but in the opinion of this author, rather than an inanimate mechanical breakdown, these events reveal the signature of a deranged intellect. Mechanical failures remain true to the rules of math and physics. When a wing falls off, an airplane immediately spirals downward – every time. But when a plane's trajectory no longer follows a logical path consistent with mechanical failure, it can only mean human intervention. Pieces of the plane finally washed ashore near Madagascar, Africa two years later.[4]

Implications for Space Transport

Safety planners must heed the warnings of danger from wherever they come. The aerospace community was warned to beware the danger of malevolent threats as far back as the fictional story presented in the 1968 movie, *2001: A Space Odyssey*.

During the long journey to one of Jupiter's moons, space scientists are rendered immobilized beneath the deep slumber of cryogenic hibernation, while Drs. Dave

[3] The actual radio transmissions from the FedEx incident are available at www.youtube.com/watch?v=CvMTo_nWxZM.
[4] An excellent account of the tragedy can be found at www.bbc.com/news/magazine-31764488.

Bowman and Frank Poole are left to supervise the ship's human-like HAL-9000, an artificially intelligent, apparently sentient computer hard-wired throughout the ship and entrusted with navigation, life support, and virtually all technical functions on behalf of the greater mission.

The two men grow deeply concerned when HAL – a system touted to be incapable of error – warns of the imminent failure of an exterior component. However, after retrieving the component, the men can find nothing wrong with it. Worse, Mission Control on Earth suggests that HAL is the one likely to be in error, since their identical ground-based HAL-9000 found nothing wrong with the component either.

When questioned about the discrepancy, the shipboard HAL sniffs to the crew that previous accusations of error have always turned out to be human error instead. He further challenged the astronauts simply to reinstall the device, wait for it to fail outright, and then definitively determine the cause. But before they follow this advice, the two men wisely hold a secret meeting inside a pod where HAL cannot hear them.

In the surreptitious discussion, they decide to follow HAL's advice but agree that if the device does not fail as HAL predicted, then the artificial crewmember could no longer be trusted, and they would therefore be forced to shut it down. Unfortunately, the astronauts were entirely unaware that although HAL could not directly hear their conversation, he did manage to read their lips!

When Poole leaves the ship in a transport pod and begins his spacewalk to reinstall the questionable component, HAL takes command of his pod by making it appear that it broke free of its moorings. The pod then rams the defenseless scientist, setting him adrift in space.

When Bowman leaves in a second pod to rescue Poole, HAL promptly shuts down shipboard life support and so murders all the crew in hibernation.

It is a chilling moment indeed, when Bowman returns with Poole's lifeless body, and HAL refuses to open the bay to allow him safe reentry aboard the ship. Instead, after a long silence the computer replies with cold condescension,

"I'm sorry Dave; I can't do that."[5]

Only one year ago, a GermanWings first officer commandeered his own flight when he locked his captain outside of the cockpit by abusing security protocols for the hardened post-9/11 cockpit door intended to protect the crew from hijackers. The demented first officer then calmly initiated a controlled descent directly into the French Alps resulting in a devastating crash, killing all aboard. The parallels to HAL are unmistakable.

The murderously suicidal FedEx pilot, introduced earlier in this article, hated his company because he knew his lies would soon be exposed. The GermanWings first

[5] www.youtube.com/watch?v=ARJ8cAGm6JE.

officer likewise turned sociopathic, because he too harbored a devastating secret inevitably set to end his career.

In the latter case, the first officer's psychiatrist had identified the pilot's suicidal tendencies as a disqualifying mental disorder the very same day of the crash. He advised the pilot that he was too ill to work, but misguided privacy protection laws required the doctor to rely upon the integrity of the mentally disturbed pilot to self-report the medical findings to his employer. In the aftermath of the crash, authorities reportedly found the torn-up doctor's note amongst the dead pilot's belongings.

Clearly, the aviation community failed to heed the warnings of the fictional account of *2001*, and so real-life GermanWings passengers died victims of virtually the same misplaced trust so deftly manipulated to execute the hibernating crew in the movie.

In the end, the real-life airline, a low-cost subsidiary of Lufthansa, hired a mentally unstable co-pilot with barely enough flight experience even to qualify for the licenses he held, let alone to justify the trust they vested in him to protect the lives of innocent passengers faithfully. Even the pilot's movie counterpart HAL had been subjected to a more rigorous vetting prior to installation.

Both the real-life and fictional examples cited in this article drive home the urgent point that hostile crewmembers (even sentient artificial intelligences) can present the gravest of threats to flight safety. Systematic procedures can be highly effective for addressing inanimate, mechanical threats in flight, and they will likely serve the 21st-century space-faring community well. But clearly, the extreme danger posed by malevolence let loose in the cockpit demands bold, creative countermeasures.

Space Crew Design and Training Criteria

Safety planners should look to non-systematic, out-of-the-box solutions to deal with malevolent threats. Aerospace operations that rely upon rigid, check-listed responses will likely fall short, since rogue crewmembers will have full access to this information with the added advantage of unlimited time to invent ways to defeat them. The GermanWings co-pilot felt confident that he had the means to defeat the static design of the cockpit door.

Not only must security system designers invent less rigid security solutions, but also individual crewmembers should be educated on malevolent threats to safety, and then encouraged to develop dynamic personal strategies of their own to counter such threats. Their unique solutions would inject a much-needed element of uncertainty into the mix. The last thing a banker should do is to yield the advantage to would-be robbers by revealing the trajectory for each arrow in the quiver.

Medical exams for space operations should be expanded to include aggressive protocols to check both body and mind so as to detect physical and psychological aberrations before they become dangerous threats to flight. Current FAA physicals focus mainly upon the function of vital organs with special attention to the eyes and heart, but brain function is measured mostly for neurological function. However, much more attention should be paid to psychiatric review:

- Psychiatric surveys of successful, retired pilots should be commissioned to develop a psychological control standard going forward. Such a template can then be used as a baseline against which to recognize and quantify psychological anomalies for pre-hire and active crewmembers.

- Pre-hire screenings must include appropriate psychiatric review. In order to accomplish the task, authorities must be granted legal authority to subpoena crewmember medical records.

- New-hire psychological profiles should be maintained throughout their careers so as to further refine the psychological baseline described above.

- Develop protocols appropriate for therapy, grounding, or dismissal of active crewmembers as determined by competent authority.

- Peer reports should be encouraged, reviewed, and then addressed as deemed prudent by competent professionals

- Non-disciplinary, mental health self-reporting should be made available to all crewmembers who voluntarily disclose emotional difficulties.

- Post-hire counseling and psychiatric review should be triggered automatically wherever significant life stressors such as divorce, profound personal or financial losses, alcoholism, drug abuse, or public disgrace are uncovered.

- Pilots caught actively lying, omitting, or hiding disqualifying information from an employer should be grounded immediately pending swift dismissal.

Importantly, due to the extraordinary distances involved space travel to Mars, Jupiter, and beyond will require months and months of cooperation amongst the crew complement to arrive safely. And if plans hold for one-way missions to colonize Mars, then following touchdown they would live together in a brand new world apart from the rest of humanity, perhaps forever. Consequently, the collective mental health of the travelers will affect not only the initial flight, but also the future of the entire colony once established upon the planetary body.

Having personally flown multiple cockpit crew positions with all sorts of personalities under virtually all conditions, even if only for hours at a time, I can personally attest that the safest flights occurred when mature, safety-minded professionals worked harmoniously together. This principle will prove to be of paramount importance for interplanetary travel.

Space crews of the 21st century must be hired based upon strong bodies and minds, flight skills and scientific acumen, but staffers must also ask the question, how well will this candidate perform in the group as a team member? How well will the personalities blend together as a harmonious team? The answers will be critical if permanent settlements are to thrive.

Training cycles are excellent laboratories by which staffers can evaluate individual and group performances prior to selection of final crew complements.

Finally regarding malevolent threats in flight, the author anticipates that coded protocols might one day be developed, such that crewmembers might independently notify ground stations of inflight emergencies involving human threats to safety. Aside from open microphones, such a system might even include active countermeasures to allow for real-time intervention from the ground.

Space flights already routinely employ the use of ground-monitored medical telemetry. By comparing baseline brainwave patterns, the day may come when computer-analyzed brainwave telemetry might accurately warn when a crewmember is experiencing aberrant thought patterns.

Concluding Thoughts and Recommendations

It will be vital for space planners to anticipate and counter looming danger from all sources if commercial space transport is ever to become a reality. The airline's CRM model works well for standard mechanical breakdown, but only sound policies and creative foresight will carry the day where a malevolent threat appears before space travelers of the future.

- Retain the CRM model for routine, abnormal, and emergency training and flight operations.
- Hire space crews based upon scientific acumen and flight skills, physical stamina, and thorough psychiatric review.
- Provide for post-hire physical and psychiatric monitoring by qualified professionals and fellow crewmembers, as well as self-reporting protocols.
- For any given mission, assemble the crew complement to allow not only for the correct mix of technical skills, but also for their ability to work together as a harmonious group.
- Develop dynamic and creative countermeasures for ground personnel and in-flight crew sufficient to neutralize malevolent threats.

- Challenge crewmembers to formulate effective personal strategies in the event that despite all efforts to the contrary, malevolence still arises to threaten the safety of the mission.

It would seem that successful space transport crews will of necessity be selected not only for the technical prowess, skills, and finesse of the safest airline operators, but also for the psychological fortitude heretofore only required of nuclear submarine crews.

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Jay has also provided on-air analysis for major TV news programming at NBC, MSNBC, and CNN with his commentary often rebroadcast overseas. During the mysterious disappearance of the Malaysian Air Boeing 777 airliner over the Western Pacific, he appeared on camera under exclusive contract as sole aviation analyst for one of the cable TV news providers.

Jay holds both an MA in TV Broadcast Journalism from the University of Miami (Florida) and a BS in Aerospace Engineering from the University of Texas at Austin.

Editors' Notes: We thank Jay Rollins for this important article about flight safety. While airlines and, by extension, space programs can and do take sensible precautions against mechanical failure and unauthorized access to cockpits and other sensitive areas of aircraft/spacecraft, ensuring the mental and physical health of flight crews is also essential. Jay's suggestions for improvement may constitute valuable advice for airlines. Jay is a valued active member of Kepler Space Institute (KSI). His statement in this article, "If humankind is ever to launch a successful reboot of space travel, then we simply must recognize and solve not just technical deficiencies, but also emerging human threats to safety as well," contributes to the KSI research program, begun at ISDC-2016 in Puerto Rico, for the Human Factors problems flowing from pathological human behavior well documented in the Psychology and Policy Sciences literature. ***Bob Krone and Gordon Arthur.***