Enhancing Flight-crew Monitoring Skills Can Increase Flight Safety

Captain Robert L. Sumwalt, III
Chairman, Human Factors and Training Group
Air Line Pilots Association, International

Captain Ronald J. Thomas
Supervisor, Flight Training and Standards
US Airways

Key Dismukes, Ph.D.
Chief Scientist for Aerospace Human Factors
NASA Ames Research Center

To ensure the highest levels of safety each flight crewmember must carefully monitor the aircraft's flight path and systems, as well as actively cross-check the actions of each other.[1] Effective crew monitoring and cross-checking can literally be the last line of defense; when a crewmember can catch an error or unsafe act, this detection may break the chain of events leading to an accident scenario. Conversely, when this layer of defense is absent the error may go undetected, leading to adverse safety consequences.

Following a fatal controlled flight into terrain (CFIT) approach and landing accident (ALA) involving a corporate turbo-prop the surviving pilot (who was the Pilot Not Flying) told one of the authors of this paper, "If I had been watching the instruments I could have prevented the accident." This pilot's poignant statement is quite telling; in essence, he is stating that if he had better monitored the flight instruments he could have detected the aircraft's descent below the minimum descent altitude (MDA) before it struck terrain.

This pilot's statement is eerily similar to a conclusion reached by the U.S. National Transportation Safety Board (NTSB) after an airliner descended through the MDA and impacted terrain during a nighttime instrument approach. "If the First Officer had monitored the approach on the instruments...he would have been better able to notice and immediately call the Captain's attention to the altitude deviation below the minimum descent altitude."[2]

Inadequate monitoring is cited by a number of sources

These two examples are far from being isolated cases; inadequate flight crew monitoring and cross-checking has been cited by a number of sources as a problem for aviation safety. Referring to accident statistics, the NTSB determined in a safety study of crew-caused air carrier accidents that 84 percent of the 37 reviewed accidents involved inadequate crew monitoring or challenging.[3] The safety study showed that monitoring/ challenging errors can play a significant role in an accident's causation. "Among all 37 accidents, 53 (76 percent) of the 70 monitoring/

challenging errors failed to catch errors that [NTSB] had identified as causal to the accident," said the report. "An additional 12 monitoring/challenging failures (17 percent) were failures to catch errors that contributed to the cause of the accident." Further, research conducted to support the Flight Safety Foundation's Approach and Landing Accident Reduction (ALAR) efforts revealed that 63 percent of the reviewed ALA accidents involved inadequate monitoring and cross-checking.[4] Additionally, inadequate monitoring was a factor in 50 percent of the CFIT accidents reviewed by ICAO.[5]

Incident data also illustrate how inadequate crew monitoring can lead to safety problems. In 1997, researchers at the U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) explored inadequate monitoring by examining 200 incident reports submitted to ASRS.[6] These reports provided evidence that monitoring errors can lead to adverse safety consequences. Some serious monitoring errors revealed in their study include altitude deviations, controlled flight towards terrain, stall onset, loss of aircraft control, and course/ heading / track deviations. The research team concluded that "the consequences of inadequate monitoring can be hazardous, and a proactive plan to improve crew monitoring is appropriate."[7]

Data collected in over 2000 audited airline flights using Line Operations Safety Audits (LOSA) further demonstrate the importance of crew monitoring. Sixty-four percent of "unintentional errors" in the University of Texas LOSA archives went undetected by flight crew.[8] In one LOSA conducted in 2000, 19 percent of errors and 69 percent of "undesired states" could have been eliminated by more effective crew monitoring and cross-checking. "Undesired state" refers to any unwanted situation or occurrence affecting aircraft safety or operations, such as exceeding an aircraft limitation or landing on a closed runway. These figures suggest that better monitoring performance by the flightcrew can improve safety by detecting and correcting errors before they get out of hand.

Underlying causes of poor monitoring and cross-checking

We determined there are at least four underlying causes of poor monitoring. One is that the industry has not made monitoring a primary task. For example, when listing Pilot Not Flying (PNF) duties, typically an operator will list duties such as handling radio communications, operating gear and flaps upon request of the Pilot Flying (PF) and keeping a flight log. Monitoring is not one of the duties primarily listed. Instead, it appears that monitoring is more or less a secondary task.

Another cause is that the current system does not "reward" proper monitoring, and will "punish" those who fail to do non-monitoring duties. For example, during taxi-out the First Officer (FO) is supposed to load takeoff data into the Flight Management System (FMS). If the FO delays loading this information because he/she is busy monitoring and backing-up the captain during a complex taxi-out, the Captain may focus only on the delay caused if the takeoff data is not loaded when the aircraft reaches the runway, and the Captain may fail to appreciate that the FO gave appropriate priority to safety over speed.

The third underlying cause of poor monitoring is that although monitoring may seem intuitive and easy, in reality, continuous and effective monitoring is not natural. In fact, it is most natural to do things as you think of them, instead of delaying them until later. However, as this paper will illustrate, an effective monitoring strategy involves sometimes delaying some tasks until less vulnerable periods. It is also not natural to stop doing something in the middle of the task to scan instruments (monitor). Instead, people prefer to compete the task before stopping. However, effective monitoring requires a more-or-less constant scan of instruments.

Finally, there seems to be a paradox that works against effective monitoring. According to a document published by the U.S. Air Transport Association (ATA) Automation Sub-committee, serious errors do not occur frequently which can lead to boredom and complacency.[9] "A low-probability, high-criticality error is exactly the one that must be caught and corrected," states the document.

Monitoring performance *can b*e improved

As an industry, we seem to have accepted the axiom that, "Humans are not good monitors." While it may be true that humans are not *naturally* good monitors, we firmly believe that crew monitoring performance can be significantly improved through policy changes and crewmember training.

Traditional CRM courses have generally improved the ability of crewmembers to challenge others when a situation appears unsafe or unwise; however, many of these courses provide little or no explicit guidance on how to improve monitoring. Captain Frank Tullo wrote in a recent *Aviation Week and Space Technology* editorial, "First, we must change our approach to monitoring. Instructors must insist that the non-flying crewmember monitors the flier effectively. A system that grades monitoring must be established… Good monitoring skills are not inherent in a pilot as they progress in their careers. Therefore, effective monitoring techniques must be trained and rewarded."[10]

A plan to improve monitoring

US Airways has developed an "active monitoring concept" to improve crew monitoring skills. This program is multi-faceted, beginning with a management commitment to develop Standard Operating Procedures (SOPs) and training to support improved monitoring. Development of this program has been a joint effort between US Airways and the Air Line Pilots Association (ALPA), similar to other highly successful safety programs co-developed between these two organizations.[11] Additionally, we have entered into an informal collaboration with the Human Factors Research and Technology Division of NASA Ames Research Center to better understand the human factors associated with human monitoring capabilities and limitations.

There are four components to the US Airways active monitoring concept: developing well thought-out SOPs, training monitoring skills, practicing those skills, and evaluating the program's effectiveness.

Developing well thought-out SOPs

A first step in improving monitoring was ensuring that our SOPs supported the monitoring function. We found that over the years various procedures had crept into our operations manuals and some of these procedures actually detracted from monitoring. We therefore devoted considerable effort to reviewing our procedures and making changes where necessary to emphasize monitoring.

Two high-level changes were made to send an over-arching message that monitoring is a very important part of our cockpit duties. First, the title of the traditionally used term "Pilot Not Flying" (PNF) was changed to "Pilot Monitoring" (PM). Although this change may seem small, we felt that it was important because it described what that pilot should be doing (monitoring) versus what he/she is not doing (not flying). Further, our Flight Operations Manual (FOM) now has a "monitoring responsibility" section that explicitly states that a primary responsibility of each pilot is to monitor the aircraft.

To improve monitoring in the taxi phase we now specify that both pilots will have taxi charts out and available. To ensure that both pilots hear the initial call for taxi clearance, we formally state that both pilots should monitor the taxi clearance. The Captain is required to verbalize to the FO any hold short instructions and the FO will request confirmation from the Captain if this confirmation is not received. When approaching an entrance to an active runway, both pilots will ensure the hold short or crossing clearance is complied-with before continuing with non-monitoring tasks, such as FMS programming, ACARS, company radio calls, etc.

The above-cited ASRS monitoring study revealed that three-quarters of the monitoring errors in that study occurred while the aircraft was in a vertical phase of flight, i.e., climbing, descending or approach. We used that finding to guide us towards other SOP changes to enhance monitoring at US Airways. Some of these new policy changes include: Specifying that crews should perform non-essential duties/activities during lowest workload periods (e.g., cruise altitude or level flight); When able, brief the anticipated approach prior to top-of-descent; PF will brief PM where or when a delayed climb or descent will begin; During the last 1000 feet of altitude change, both pilots will focus on making sure the aircraft levels at the assigned altitude. We also replaced our "10,000 ft PA announcements" with a two-bell signal and now specify that the pre-arrival announcement be conducted just after leaving cruise altitude.

Also gleaned from the ASRS monitoring study was that 30 percent of the monitoring errors in that study's dataset occurred when a crewmember was involved with programming a Flight Management System (FMS). We used that finding to refine our automation policy, including development of the acronym "CAMI." Our FOM now states, "When making autoflight systems inputs: Confirm FMS inputs with the other pilot when airborne, Activate the input, Monitor mode annunciations to ensure the autoflight system performs as desired, and Intervene if necessary. Also stated is during high workload FMS inputs will be made by the PM, upon the request of PF. Examples of high workload include when flying below 10,000 feet and when within 1000 feet of level off or Transition Altitude.

Training monitoring skills

An important realization was that although humans are not naturally good monitors, monitoring performance can be significantly improved by training these skills. Essentially, we realized that we were hoping our pilots would do better at monitoring but we had not formally trained them how to improve these skills. To illustrate the point, no pilot could be expected to successfully and correctly perform an engine failure at takeoff maneuver unless that pilot had been properly trained. By the same token, if we are going to achieve a significant improvement in crew monitoring, we must first train these skills.

We noted the NTSB's safety study of crew-caused accidents stated that simulator training is a good place to teach and practice monitoring and cross-checking. Therefore, we changed our training curricula to state that beginning with the first day of training, instructors must ensure all monitoring/ cross-checking SOPs are followed. To emphasize proper monitoring, occasional, subtle failures are introduced during simulator training, such as failure of automation to level off at the proper altitude or intercept a course. The students will likely miss these items the first time they are introduced, but it provides an opportunity for the instructor to debrief those monitoring errors. The student may even miss these items on the next simulator session, by usually by the third simulator session, they clearly understand the importance of monitoring and how it can be improved. True transfer of knowledge has taken place and the students have literally learned to become better monitors. It is important, however, that the instructors not be over-zealous with introducing these failures; otherwise it may be construed as harassing the students, and therefore, counter-productive to a positive learning environment. Further work is needed to identify and train specific techniques pilots can use to maintain monitoring in each phase of flight.
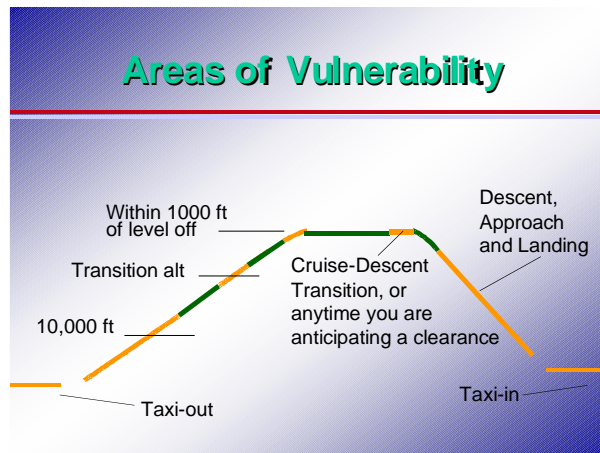
Practicing monitoring skills

The best developed and trained skills do no good unless pilots actually use (practice) these skills. Therefore we advise our pilots to know and comply with the SOPs. We ask our pilots to "actively monitor" the aircraft, meaning that they must mentally fly the aircraft, even when the autopilot or other pilot is flying. "Monitor the flight instruments just as you would when hand flying. If the aircraft (or other pilot) is not doing what it is supposed to do, action should be taken to rectify the situation," states advisory information to our pilots.

In 1997, researchers Jentsch, Martin and Bowers completed a study of training needs. They found that in approximately one-third of the ASRS reports they reviewed, pilots "failed to monitor errors, often because they had planned their own workload poorly and were doing something else at a critical time."[12] Further, a 1998 NASA research project of cockpit interruptions and distractions reviewed 107 ASRS reports to determine types of tasks that crews typically neglected at critical moments while attending to other tasks.[13] "Sixty-nine percent of the neglected tasks involved either failure to monitor the current status or position of the aircraft, or failure to monitor the actions of the pilot flying or taxiing," said the NASA report. To avoid such problems the study suggested that crews "schedule/reschedule activities to minimize conflicts, especially during critical junctions."

We used those workload management findings to develop strategies to improve monitoring. Our program emphasizes that pilots should recognize those flight phases where poor monitoring can be most problematic. We ask our pilots to strategically plan workload to maximize monitoring during those areas of vulnerability (AOV). Examples of non-monitoring tasks that should be conducted during lower AOV include stowing charts, programming the FMS, getting ATIS, accomplishing approach briefing, PA announcements, etc. A chart that graphically depicts higher AOV is shown here. The orange (lighter) lines represent higher AOV.

For example, we ask pilots to brief the anticipated instrument approach prior to beginning their descent from cruise altitude. By pre-briefing the approach during a lower-workload period, greater attention can be devoted to monitoring/ cross-checking during descent. This practice is consistent with the FSF ALAR Task Force recommendations. Further, data from our LOSA indicates that crews who briefed the approach after top-of-descent (TOD) committed 1.6 times more errors during the descent/ approach/land flight phase, compared to crews who briefed prior to TOD.

Areas of Vulnerability

The ASRS monitoring study highlighted that crews cannot be expected to remain 100 percent vigilant during low workload portions of all flights, especially long-haul flights. We have made use of that finding to inform pilots that it is acceptable for them to take turns monitoring during low workload periods, as long as they inform the other pilot when they will relax their monitoring. The idea is that we want our pilots to remember that at least one pilot must actively monitor the aircraft at all times during low workload, and both pilots must actively monitor as much as possible during high workload and in areas of vulnerability (vertical flight, FMS entries, taxiing, etc.).

The ASRS monitoring study indicates that 89 percent of the monitoring errors occurred when pilots were involved with one or more non-monitoring tasks. This provides strong evidence that monitoring can break down when pilots become involved with non-monitoring tasks. One antidote for this is for pilots to recognize the inherent risks of having both pilots become involved with the same task. For example, both pilots should not concentrate on programming the FMS at the same time. Instead, one pilot should be designated to monitor the aircraft while the other pilot programs the FMS. This is not to imply there should be no cross-check of each other's work, but rather to state that one pilot must always actively monitor the aircraft. The pilot monitoring can cross-check the other pilot's entry prior to activation. Also, in those situations in which one pilot's attention is called away from monitoring, such as programming the FMS, that pilot should inform the other pilot he/she will be "out of the loop" and make a conscious effort to frequently shift their attention back to monitoring the aircraft.

We wanted to give our pilots a tool they could use to assess their current monitoring ability. We have found that during vertical phases of flight one of the first signs of poor monitoring is missing the "1,000' to level-off altitude callout." We suggest that if they frequently miss this callout, it could imply that they are not adequately monitoring the aircraft.

Evaluating the program's effectiveness

Professor Earl Wiener suggested that when procedures are developed or changed it is important for operators to evaluate the efficacy of these programs to ensure they are accomplishing their intended goal.[14] With that in mind, we wanted to ensure this program was on the right track. Several things are being done to accomplish this. With the inception of the active monitoring program we have asked instructors and check airmen to train and evaluate students' monitoring/ cross-checking skills from the first day of training. Also, our fleet captains are actively soliciting advice on how to further enhance our monitoring/cross-checking training.

Once we have effectively trained and evaluated monitoring/cross-checking skills during training events, we will begin evaluating these skills during checking events. All training, evaluation and feedback forms will be modified to include spaces to denote a pilot's monitoring / cross-checking skills.

We are exploring methods to statistically compare monitoring performance before the program's initiation with performance after beginning the program.

Follow-on Efforts

Beyond the efforts described in this paper we are starting a research collaboration to explore specific techniques pilots can use to reduce vulnerability to lapses in monitoring. We hope to answer several questions: Are some pilots better than others at monitoring and if so, what techniques do they use? Is monitoring a generalized skill or must one learn specific techniques for each type of monitoring task? To what extent can monitoring be performed reliably with other concurrent tasks?

We believe that in order for industry-wide improvements to be made in monitoring, it must become accepted that monitoring is a "core skill." In other words, it is currently accepted that a good pilot must possess good "stick and rudder" and effective communicational skills. Effective monitoring must be added to that list.

Advisory Circular AC 120-51D, "Crew Resource Management" has a few scant references to monitoring.[15] We would suggest that wording in this document be strengthened to showcase the importance of monitoring and describe how monitoring performance can be improved.

Summary

Inadequate flight crew monitoring has been cited by a number of sources as a problem for aviation safety. While it is true that humans are not naturally good monitors, we firmly believe that crew monitoring performance can be significantly improved through policy changes, training and by pilots following an active monitoring concept.

We offer the concepts in this paper as a prototypical program that could be emulated by other operators. We would appreciate comments to further refine the program.

About the authors

Robert L. Sumwalt is an Airbus A320 Captain for US Airways. He began his airline career in 1981 and has served as an airline check airman, instructor pilot and air safety investigator. He is Chairman of the Human Factors and Training Group for Air Line Pilots Association, International (ALPA). Robert is a member of the Executive Committee of the Flight Safety Foundation's Icarus Committee. He has served the U.S. NASA Aviation Safety Reporting System (ASRS) as a research consultant, where he was Principal Investigator on three large ASRS research projects, including one that studied problems associated with inadequate monitoring. He has published more than 75 articles and papers on aviation safety issues, accident investigation and aviation human factors.

Ronald J. Thomas is an Airbus A320 Captain for US Airways and serves as the Supervisor of Flight Training and Standards. He has performed detailed research in developing policies and procedures and led the development of the US Airways Quick Reference Handbook for aircraft non-normal procedures. He began his airline career in 1985 and has served as an airline instructor pilot, designated examiner, check airman, senior check airman and flight manager. He is also the Editor of *Flight Crew View*, a training publication issued to all US Airways pilots. He and Captain Sumwalt were co-developers of the US Airways Error Management program.

Key Dismukes is Chief Scientist for Human Factors in the Human Factors Research & Technology Division at NASA Ames Research Center. His current research addresses cognitive issues involved in the skilled performance of pilots, their ability to manage challenging situations, and their vulnerability to error. Among the topics investigated by his research group are prospective memory (remembering to perform deferred intentions), management of attention in concurrent task performance, and training crews to analyze their own performance.

Previously, Dr. Dismukes was Director of Life Sciences at the Air Force Office of Scientific Research. He received his Ph.D. in biophysics from Pennsylvania State University and received postdoctoral training at the Johns Hopkins University School of Medicine. He has published papers in basic and applied psychology, neuroscience, and science and social policy. He holds ATP B737 and Citation type ratings, commercial ASEL, and glider instructor ratings. The primary reason he holds a paying job is to support his addiction to flying sailplanes.

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ASRS acknowledges that its data have certain limitations. *ASRS Directline* (December 1998) said, "Reporters to ASRS may introduce biases that result from a greater tendency to report serious events than minor ones; from organizational and geographic influences; and from many other factors. All of these potential influences reduce the confidence that can be attached to statistical findings based on ASRS data. However, the proportions of consistently reported incidents to ASRS, such as altitude deviations, have been remarkably stable over many years. Therefore, users of ASRS data may presume that incident reports drawn from a time interval of several or more years will reflect patterns that are broadly representative of the total universe of aviation-safety incidents of that type."

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