WHAT ASRS DATA TELL ABOUT INADEQUATE FLIGHT CREW MONITORING

by

Robert L. Sumwalt, Principal Investigator[1]; Rowena Morrison; Alan Watson; and Elisa Taube[2]

INTRODUCTION

Inadequate flight crew monitoring has been cited by a number of sources as a problem for aviation safety. In a review of 24 Controlled Flight Towards Terrain (CFIT) accidents, the International Civil Aviation Organization found that in half, the "crew did not monitor properly" (ICAO, 1994). The National Transportation Safety Board determined in a special study of crew-caused air carrier accidents that 84 percent of the 37 reviewed accidents involved inadequate crew monitoring or challenging (NTSB, 1994). Following a 1995 accident involving an air carrier collision with trees on final approach to Hartford, Connecticut, the NTSB stated, "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" (NTSB, 1996). In addition to NTSB data, prior reviews of ASRS reports related to problems associated with poor intra-cockpit relations reveal that many of these reports also involve inadequate monitoring.

Our research team conducted a brief review of the human factors literature in the areas of supervisory control and monitoring behavior, and confirmed that little has been published on the subject of improving monitoring performance for flight crews (Sheridan, 1987; Moray, 1986). Informal contacts with aviation industry sources strengthened the research team's belief that monitoring is a comparatively neglected subject in flight deck procedures. While traditional Crew Resource Management (CRM) courses deal with improving the ability of crew members to challenge others when a situation appears unsafe or unwise, many of these courses provide little explicit guidance on how to improve monitoring. We feel that carefully developed procedures and guidelines to enhance flight crew monitoring can make a significant contribution toward improving aviation safety. This analysis of ASRS data is an effort to develop a better understanding of the problems associated with inadequate monitoring.

OBJECTIVES AND SCOPE

The objectives of this research were to identify factors that contribute to monitoring errors and to offer operationally-oriented recommendations aimed at improving crew monitoring. The study focused on monitoring errors in air carrier operations. We defined a monitoring error as a failure to adequately watch, observe, keep track of, or cross check any or all of the following:

1) The aircraft's trajectory, i.e., taxi and flight path, speed management, navigation;
2) Automation systems and mode status, i.e., Flight Management System (FMS) entries, Mode Control Panel (MCP) settings/selections, awareness of automation mode;
3) Aircraft systems and components, i.e., fuel quantity, aircraft configuration, system status.

---

[1] Robert L. Sumwalt has served ASRS as a Research Consultant since 1992. His duties have included acting as Principal Investigator for three major research projects, as well as authoring several documents for ASRS publications. Additionally, he is an active Captain for a major U.S. air carrier. He has also worked as airline check airman, instructor pilot and air safety investigator. He has published more than 55 articles and papers on aviation safety issues, including presentations at the past four OSU International Symposiums on Aviation Psychology.

[2] Rowena Morrison is the ASRS Research Coordinator and a Battelle Senior Research Scientist. Alan Watson is an ASRS Aviation Safety Analyst. Prior to joining ASRS, he served as a pilot for a major U.S. air carrier for 29 years. Elisa Taube is a member of the Battelle ASRS research staff. She is currently pursuing a M.S. in Human Factors/ Ergonomics at San Jose State University.

If a report did not fall into one or more of the above categories, it was excluded from our data set. Also, to avoid duplication of previous ASRS research, reports related to difficulties in monitoring communications (radio or intra-cockpit) were excluded.[3]

APPROACH

Data

Our study set consisted of 200 ASRS reports that were submitted to ASRS between February 1992 and February 1996. During retrieval of these reports from the ASRS database, the search strategy eliminated communications-related reports, for the reasons cited above.[4] Of the some 800 reports that we drew from the ASRS database, we coded the first 200 that met the scoping criteria. ASRS data, including those in this study, may reflect reporting biases. Chappell (1994) notes that reporters' incident descriptions are influenced by their individual motivations for reporting, and that reports often give only one perspective of the event which is not balanced by additional investigations or independent verification. Not withstanding these caveats, Chappell observes, "If large numbers of reports on a topic are available, it is reasonable to assume that consistently reported aspects are likely to be true. It is doubtful that a large number of reporters would exaggerate or report erroneous data in the same way" (pp. 154-155).

Method

A seven-page coding instrument was developed to collect relevant data from each of the 200 reports. Information gathered centered on the initiation, detection and correction of the monitoring error, as well as its safety consequences. It is noteworthy that several questions in the coding instrument could yield multiple responses. In these cases, the sum of responses exceeds the total number of reports reviewed, and percentages therefore exceed 100 percent.

FINDINGS

By design, the scoping criteria ensured that each report in the data set fell into one or more categories of monitoring errors: aircraft trajectory, automation or aircraft systems. Of the 200 reports in the data set, 187 (93.5 percent) involved inadequate monitoring of the aircraft trajectory. Of these, 160 concerned monitoring errors of the aircraft flight path, such as altitude deviations or course, heading or track deviations, while 17 reports involved monitoring errors of the aircraft taxi path, such as runway incursions or excursions from taxiway or runway surfaces.

In 64 of the 200 reports (32 percent), there was evidence of failing to adequately monitor aircraft automation. Forty-seven reports in this sub-set involved monitoring flightdeck automation "mode status" errors; for example, trying to navigate along an airway while in the "Heading" mode, or attempting to conduct an instrument approach while in a non-approach mode. Inadequate monitoring of pilot-selected automation or flight guidance systems, such as selecting a wrong altitude or depressing a wrong button on the MCP, was noted in 46 reports.

We found evidence of inadequate monitoring of aircraft systems or components, such as fuel, hydraulic, or pressurization systems in 35 of the 200 reviewed reports (17.5 percent).

[3] For more information on communication-related problems, the following ASRS publications may be obtained from NASA ASRS, PO Box 189, Moffett Field, CA 94035: ASRS Publications 2,15,16,17,18,34,38,40,46, 51.

[4] Because of these database manipulations, it cannot be assumed that the distribution of errors related to inadequate monitoring cited in this study are a representative sampling of the total number of such errors in the ASRS database. Further, as with all ASRS data, no inferences can be drawn as to how these numbers relate to the total population of all errors related to inadequate monitoring.

Initiation of the monitoring error

All but one report provided information concerning the phase of flight in which the monitoring error was initiated. **Figure 1** shows the distribution of flight phases in which the errors were initiated and detected. It is apparent that the vast number of monitoring errors (76 percent) were initiated when the aircraft was in some "vertical" flight mode-climb, cruise-descent transition,[5] descent and approach phases.

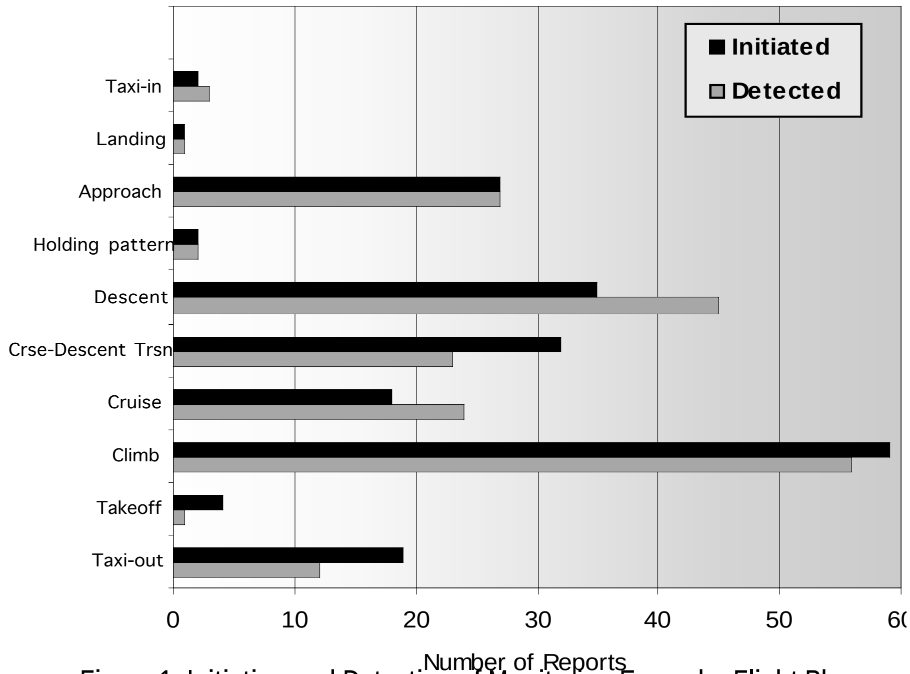

Figure 1. Initiation and Detection of Monitoring Errors by Flight Phase.

The following report excerpt is typical of crews' problems with cruise-descent transitions in automated cockpits.

> *We were...cleared to cross RIDGY intersection at FL240. We set 24,000 into the MCP altitude window. VNAV and LNAV were engaged...The aircraft should have descended to cross RIDGY at FL240. It did not, and I failed to monitor the descent...* (ASRS Record Number 258730)

We noticed that conventional "steam gauge" cockpits also had their share of cruise-descent transition problems. Often problems arose when a clearance was given to cross a point somewhere downstream, and pilots were given the discretion to remain at cruise altitude for a period of time, as long as the altitude crossing restriction was complied with. Reporters stated that reasons for failing to comply were forgetting the crossing restriction or relying on the automation to meet the clearance.

One hundred fifty reports provided information concerning which pilot was acting as the "Pilot Flying" (PF) when the monitoring error began. The Captain was the PF in 80 reports while the First Officer was the PF in 70 reports.

Concurrent Flight Crew Tasks. Our literature review of supervisory control and monitoring behavior suggested that the effectiveness of monitoring decreases as the number of non-monitoring tasks increases. We were therefore interested in identifying and categorizing flight-related tasks/functions that the flight crew reported as performing shortly before or during the monitoring error. This information was provided in 170 of the 200 reports. **Table 1** illustrates these categories and the number of reports cited in each category.

[5] Cruise-descent transition was defined by the research team as the period between receiving a descent clearance and actually commencing the descent.

FMS programming, the single largest sub-category, was cited in 52 reports. Typical were remarks like those from this ASRS report excerpt:

> *I was so engrossed in the FMS entries that I had not noticed [the altitude deviation].* (ASRS Record Number 202697)

In 36 of these reports, pilots indicated some difficulty in programming the FMS.

Table 1. Flight-Related Tasks or Functions Reported Shortly Before or During Monitoring Error. (350 Citations from 170 of 200 Reports)

Flight Related Tasks or Function	Number of Reports Citing These Items	Percent of 170 Reports
Cockpit Automation/Navigation (FMS programming, MCP selections or settings)	76	45%
Radio Communications (ATC, company radio, obtaining ATIS)	72	42
Cockpit Documentation (checklists, chart review, paperwork)	67	39
Aircraft Systems (setting system components, system malfunctions)	42	25
Weather, Terrain, or Traffic-Related Activities (searching for traffic, responding to TCAS advisories)	38	22
Intra-Cockpit Communications (briefing actions or intentions)	32	19
Passenger Cabin-Related Activities (PA announcements, cabin problems)	23	13
Totals	350	205%

Throughout all of the categories cited in **Table 1**, we noted that a large number of these activities were being performed during a climb or descent. Stated one ASRS reporter:

> *The aircraft never stalled, but it was literally only a few seconds/ knots from doing so... My failure to maintain an adequate scan was the primary cause of this near stall incident. I relied too much on the autopilot and allowed myself to become distracted with my chart review. That should have been done at cruise, with the Captain 'covering' for me while I had my head in the books. Also, the PNF [Pilot-Not-Flying] might have noticed the low speed sooner if he'd made his PA announcement at level-off, not in climb.* (ASRS Record Number 278353)

We found it interesting that flight-related tasks/functions were referenced in such a high percentage (80 percent) of the reports in this study. On the one hand it could be argued that because these functions are required for flight (radio communications, checklists, navigation, etc.), they would be mentioned in most of the reports. On the other hand, many report narratives suggested that crews were performing these tasks in lieu of the monitoring task. As in the two preceding report excerpts cited, it appeared that crews became absorbed in these flight-related activities and just assumed that the aircraft or its systems would not deviate from desired parameters.

We also counted the number of these flight-related tasks/functions that the crew reported that they were performing shortly before or during the monitoring error. **Figure 2** depicts this distribution. Sixty of the 200 reports involved crews performing two or more flight-related tasks. As illustrated in a

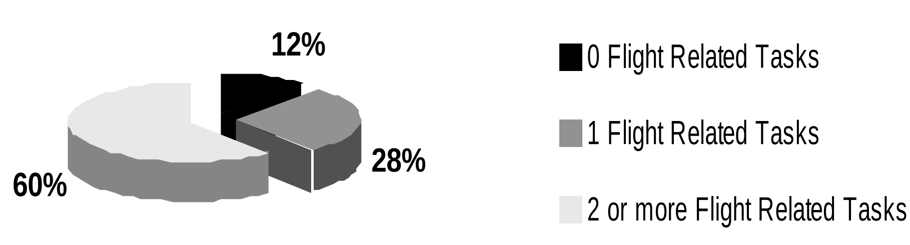

Figure 2. Number of Flight-Related Tasks or Functions Performed by Crew at Onset of Monitoring Error

previous report excerpt (ASRS Record Number 278353), the division of cockpit duties often involved the Pilot Flying performing non-monitoring tasks, while other crewmembers were also conducting peripheral tasks. In these reports, this task allocation was at the expense of aircraft monitoring. Following a high workload flight that resulted in an altitude deviation, a pilot wrote,

> *Corrective action: One pilot should be solely involved in flying or monitoring the aircraft performance.* (ASRS Record Number 288552)

Our finding concerning multiple tasks was predictable and consistent with the literature review; the busier the crew is in performing non-monitoring tasks, the more likely it is that monitoring performance will decrease. However, we were surprised to find that in 40 percent of the reports in this study, crews reported zero or at most, one flight-related task as being conducted. This shows that monitoring errors are not limited to high workload, multiple task periods, and it implies that monitoring is a discipline which must be practiced constantly and consistently, regardless of workload.

Contributing Factors. In 190 of the 200 reports in our data set, reporters identified factors that contributed to the monitoring error. Some of these factors are highlighted below.

There were 78 citations[6] of physical, physiological, psychological and psychosocial factors affecting crew members. This category includes fatigue, stress, and illness, which were cited in 27 cases. Boredom, complacency and over-reliance on cockpit automation were cited in 24 cases.

Ergonomic factors received 40 citations. Within this category, flight deck design, layout or lighting issues were cited in 26 reports. Another category, with 27 citations, involved inadequate planning and preparation and attention management issues such as workload and crew conversations or discussions. This ASRS report exemplifies:

> *We had the distraction of the passenger illness and communicating with the company in a very busy, 2-man crew environment, and I failed to remember the 'Number 1 Job' - fly the airplane.* (ASRS Record Number 286939)

Detection of the monitoring error

We were also interested in the relationship between the flight phases during which monitoring errors began and those when they were detected (see **Figure 1**). Do monitoring errors usually begin and end within a single flight phase? Does the initiation/detection relationship vary significantly among flight phases? When we examined the data, it appeared that errors that began during climb, cruise, or the cruise-descent transition were generally detected within the same phase. However, monitoring errors that began in taxi-out, take-off, or the descent-landing phase were often not detected until a later flight phase. We tested this apparent relationship using the Chi-Square method. Our null hypothesis was that the phase in which a monitoring error was detected (same flight phase vs. a later one) was independent of the flight phase in which the error first arose. The null hypothesis was rejected at the .05 significance level $\chi 2(df=5, N=193)=28.82$.

One hundred eighty-seven reports provided information concerning who or what aided in detecting the monitoring error (see **Figure 3**). In 16 of these reports, there was a simultaneous detection by more than one means; for example, ATC and the flight crew caught the error at the same time. In reports where flight crew members

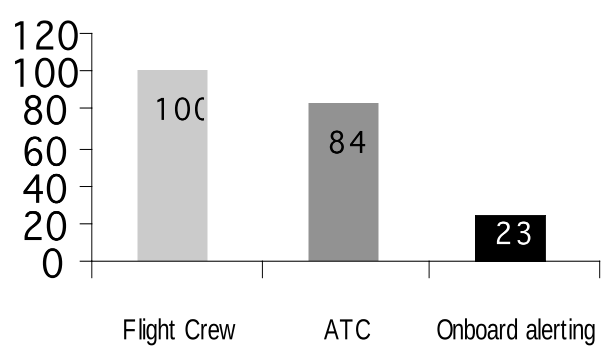

Figure 3. Aids in Detecting Monitoring Errors

[6] A single ASRS report may reference more than one situation or problem ("citations," in ASRS terminology). Therefore, the total citations may exceed the total number of reports. For example, one ASRS report cited FMS programming and communications with ATC as occurring shortly before or during the monitoring error. Thus, this ASRS report yielded two "citations."

first detected the monitoring error, Captains detected the error slightly more often than First Officers, and PNFs slightly more than PFs. However in these data, seat position and role did not appear to be important factors in who detected the monitoring error.

We had initially hypothesized that the preponderance of error detection would come from onboard alerting systems such as altitude alerters, Ground Proximity Warning Systems (GPWS), and over/underspeed warning systems. We were surprised, however, to discover that these were cited in only 23 reports.

We were interested in tracking the amount of deviation from assigned altitude or distance flown before the monitoring error was detected. Almost half of the reports in the data set provided information for at least one of these measures. Deviation from assigned altitude ranged from 100 feet to 12,000 feet, with a mean value of 1100 feet. Distance flown before detection ranged from three to 28 miles, with an average of 11 miles. Considering the speeds of modern aircraft (in terms of speed across the ground, as well as rapid climb/descent capability), it is important to note that these distances can be traveled within seconds, or at most a few minutes.

From these findings, we concluded that while crew members in our study set proved effective in detecting their errors, this detection was often delayed (at times by only a few seconds) and at the expense of substantial deviations from course or altitude.

Table 2. Safety Consequences of Monitoring Errors. (228 Citations from 200 of 200 Reports)

Safety Consequences	Percent
Altitude Deviations	54%
Course/Heading/Track Deviations	17
Significant Departure from Assigned or Desired Speed	6
Controlled Flight Towards Terrain	4
System or Equipment Damage or Shutdown (including engine shutdowns and failures)	4
Runway Incursions	3
Stall Buffet or Warning or Loss of Aircraft Control	3
Departure from Taxiway or Runway Pavement	3
Other	6
Totals	100%

Consequences of monitoring error

For each report in our data set, some adverse safety consequence arose from the monitoring error. Some reports had more than one safety consequence; safety consequences were cited 228 times in the 200 reports. **Table 2** highlights the significant safety consequences and their percentages of the 228 total citations of safety consequences.

DISCUSSION

This study identifies factors that contribute to monitoring errors, and reinforces the conclusion that monitoring errors can permit adverse safety consequences-some quite serious, including altitude deviations, controlled flight towards terrain, stall onset, loss of aircraft control, and course/ track/ heading deviations. More specifically, nearly three quarters of the reported adverse safety consequences involved either altitude or course deviations, and these deviations averaged 1100 feet and 11 miles, respectively. To place these values in perspective, in the United States, air traffic below FL290 is nominally separated by 1000 feet vertically and 5 miles laterally. Internationally, vertical separation over the North Atlantic Ocean was decreased from 2000 feet to 1000 feet in March 1997. When these nominal separation values are compared to the mean altitude and course deviation values observed in this study, we conclude that the consequences of inadequate monitoring can be hazardous, and that a proactive plan to improve crew monitoring is appropriate.

In offering a framework for improving crew monitoring, we note the work of James Reason, the keynote speaker for this Symposium. Reason (1990) says that when trying to minimize human error in a complex system such as aviation, we must look not only at the actions of the "front line operators " (flight crews in this case), but we must also focus on the "system" in which these errors occur. In keeping with this philosophy, our recommendations are anchored to two key points:

- Management of air carriers and other aviation operations, as well as regulatory officials, must realize that it is incumbent on them to provide crews with clearly thought-out guidelines to maximize their monitoring of aircraft trajectory, automation, and systems. Procedures that conflict with crew monitoring must be minimized or eliminated.
- Flight crews must constantly exercise monitoring discipline and practice the operational guidelines designed to improve monitoring.

Vertical flight phases

Seventy-six percent of the monitoring errors were initiated when the aircraft was in a "vertical" flight phase, i.e., climbing or descending, or at the top-of-descent as the aircraft was transitioning from cruise to descent. Translating this finding into a healthy operational practice is straightforward: while the aircraft is climbing and descending, crews should plan to avoid activities such as searching for the next destination's approach charts, setting up advance radio frequencies for destination ATIS and company radio, eating, paperwork and PA announcements. Many of these activities can wait until the aircraft is level, which minimizes the chance of a monitoring error during these highly susceptible flight phases (Sumwalt, 1995). However, the findings also show that monitoring errors can also occur during level flight, so crews must continue to practice effective monitoring during this phase, too.

Cockpit procedures can also be employed to minimize problems with "cruise-descent transition" (pilots being issued a clearance to descend to meet a crossing restriction, but being allowed to maintain cruise altitude until some later point, as determined by the pilot). We recommend that crew members be encouraged to brief the other pilot(s) on when or where they or the FMS plans to begin the descent. A reference to distance or time is recommended; for example, "we'll begin our descent at 80 DME" or "we will start down at 52 minutes past the hour." This cross-cockpit verbalization is in line with healthy CRM practices, and allows the other pilot to "back up" the planned descent point. This procedure will increase redundancy and help ensure that the descent will begin at the proper point.

Concurrent flight crew tasks

Our data set contained 177 reports that referenced crews performing flight-related tasks or functions, such as dealing with automation, radio communications, cockpit documentation, traffic, or passenger cabin issues. The research team noted that for many of these tasks or functions, several operators have established practices to improve crew performance. For example, some airlines have specified which pilot programs the FMC and which pilot sets the MCP. Some operators heavily stress proper ATC communications, while others have programs to enhance checklist usage. The team learned of one airline that published a 38-page pamphlet on making PA announcements. While many of these tasks are vital to flight, the study's findings suggest that greater emphasis needs to be placed on balancing these tasks with the critical task of monitoring the aircraft.

FMS programming

Several reporters stated that shortly before or during the commission of the monitoring error they were engaged in programming the FMS. This factor was cited in 52 of the 170 reports (30 percent) that mentioned flight-related tasks, and was the single largest sub-task cited. Therefore, we recommend that operators carefully review their automation philosophies, policies, and procedures to ensure that they are not conducive to monitoring errors.

There are several schools of thought among operators regarding automation programming. Some operators are dogmatic about requiring pilots to perform specific tasks at set times, while others are not so strict. We believe the main objective should be to make the needed input without sacrificing monitoring of the aircraft or its systems. This study of ASRS data suggests that the ability to effectively monitor the aircraft trajectory decreases when a pilot diverts his/her attention from the flight instruments and then begins making FMS entries.

During the course of this study we compared the FMS procedures of several carriers. We cite several contrasting procedures to highlight how automation philosophies may conflict with, or support, the monitoring function. One procedure states that "one pilot will be exclusively dedicated to monitoring/controlling the aircraft, regardless of the automation level employed." This procedure requires the PF to make FMS inputs when the aircraft is flying on autopilot. If the PF is dedicated to monitoring the aircraft, as specified in this case, and this pilot is the one designated to make FMS entries, then what happens to the monitoring function when this pilot goes "heads down" to program the FMS?

Another carrier recently changed the title of the Pilot-Not-Flying (PNF) to the "Monitoring Pilot" (MP), to reinforce the notion that it is this pilot's function to monitor the aircraft. Regardless of activities the PF performs, this policy ensures that the aircraft will continue to be monitored by the MP. An ASRS reporter summarizes this same idea:

> *...One pilot must monitor the automated flight system 100 percent of the time...*
> (ASRS Record Number 203379)

A large international air carrier recently published a procedure stating that when the aircraft is climbing or descending, FMS entries will be commanded by the PF, and executed by the PNF. Considering the number of reports in this study that involved problems in climbs and descents and those involving FMS programming, this procedure appears quite sound in terms of supporting the monitoring function.

Monitoring on long flights

While crews cannot be expected to remain 100 percent vigilant during low workload portions of all fights (especially long-haul flights), this study points to two particular areas of the flight that need careful attention: vertical phases of flight and course change points. As noted earlier, these two areas accounted for nearly three-quarters of the safety consequences cited in this study. On long flights, we suggest that non-monitoring tasks be scheduled around these two areas, so that proper monitoring can be particularly devoted to altitude and course changes.

CONCLUSIONS AND RECOMMENDATIONS

From these findings we recommend that:

- ✓ Improved effectiveness of crew monitoring must begin with a commitment from management to provide clearly thought-out procedures that do not conflict with the monitoring function.
- ✓ Crews should balance non-monitoring tasks with the critical task of monitoring the aircraft, especially when the aircraft is in vertical flight phases (climb and descent).
- ✓ Operators should carefully review their FMS and related automation philosophies to ensure that they enhance flight crew monitoring, not detract from it.
- ✓ On long-haul flights in which crew monitoring may not be sustained, particular attention should be devoted to altitude and course changes.

Monitoring the aircraft must be considered the lifeblood of safe flight operations. The flow of attention to monitoring must not stop, or the consequences may be grave. Carefully thought-out philosophies, policies and procedures that are implemented by management after validation in line operations, combined with strong training emphasis, can result in practices that minimize monitoring errors and promote safer flight operations.

REFERENCES

Chappell, S.L. 1994. "Using voluntary incident reports for human factors evaluation," in N. Johnson, N. McDonald and R. Fuller (Eds.), *Aviation Psychology in Practice*, Aldershot, England: Ashgate.

ICAO. 1994. *Safety Analysis: Human Factors and Organizational Issues in Controlled Flight Into Terrain (CFIT) Accidents, 1984 -1994.* Montreal, Quebec: ICAO.

NTSB. 1994. S*afety Study: A Review of Flightcrew-Involved, Major Accidents of U.S. Air Carriers, 1978 through 1990.* NTSB/SS-94/01. Washington, DC: NTSB.

Moray, N. 1986. "Monitoring behavior and supervisory control." In K. R. Boff, L. Kaufman & J. P. Thomas (Eds.), *Handbook of Perception and Human Performance* (Vol. 2, Chap. 40). New York: Wiley.

NTSB. 1996. *Aircraft Accident Report: Collision with Trees on Final Approach. American Airlines Flight 1572, McDonnell Douglas MD-83, N566AA, East Granby, Connecticut, November 12, 1995.* NTSB/AAR-96/05. Washington, DC: NTSB.

Reason, J. *Human Error*. 1990. Manchester. UK: Cambridge University Press.

Sheridan, T.B. 1987. "Supervisory Control." In G. Salvendy (Ed.), *Handbook of Human Factors* (1243-1268). New York: Wiley.

Sumwalt, R.L. 1995. "Altitude Awareness Programs Can Reduce Altitude Deviations," *Flight Safety Digest*. 1-10.