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KAL Flight #801: Lessons on the Modification and Adaptation of the MSAW

On August 6, 1997 Korean Airlines flight 801 on route to the island of Guam crashed into a hill just three miles from the runway. The crash appeared to be a controlled flight into terrain (CFIT) -- a case of "an otherwise-serviceable aircraft, under control of the crew is flown (unintentionally) into terrain . . . with no prior awareness on the part of the crew of the impending collision" (1). An initial analysis of the 747's "black boxes" -- the flight data and cockpit voice recorders, which had been sent to Washington -- and an inspection of the crash site revealed an eerie ordinariness. The evidence of the crash indicated that the pilot was preparing for an ordinary landing when the final minutes of flight 801 turned to tragedy. Of the 254 people on board, 228 died as a result of the accident (2). Both the aircraft and the airport had equipment expected to create a system of redundancy for altitude safety, yet one piece of safety equipment on the ground failed and its effects rippled across other airports throughout the United States: the Minimum Safe Altitude Warning system. Although the MSAW system was "not the cause [of the accident] -- it might have possibly been a prevention,"

Fig. 1: Guam

according to George Black, head of the National Transportation Safety Board's (NTSB) investigation in Guam. With the close of the NTSB hearings last March in connection with Korean Airlines flight 801, assessments can now be made regarding the true nature of the MSAW failure, the costs of this failure, and, finally, the responsibility for this failure.

Technical Failure

As a result of the 1972 crash of Eastern Airlines 1011 in Miami, Florida, the NTSB recommended "development of procedures to aid flight crews when marked deviations in altitude are noticed by air traffic control." In December 1973, the FAA contracted with Univac to develop hardware and software modifications to the existing Automated Radar Terminal Systems (ARTS) in order to implement the recommendation (3). The MSAW system was designed to match an approaching aircraft's altitude against the minimum safe altitude for terrain under the approach and issue visual and aural alerts to tower controllers if they are merging (4). In 1977, MSAW was implemented into the ARTS III program and in 1990 into the ARTS IIA program (3).

The MSAW system at an air traffic control terminal processes radar data in a variety of ways, but the prediction alarm and the projection alarm are the elements which could have saved KAL 801. A prediction alarm sounds within 30 seconds of when a pilot is less than 500 feet above the digital terrain map which is created by the National Oceanic and Atmospheric Administration based on certified data. This time is ample for a pilot to change the flight trajectory. A projection alarm sounds when the system has calculated that a pilot will be unable to clear all obstacles within eight minutes flying time on the present course. Each airport then designates an inhibit area which will not be monitored by the MSAW system. The inhibit area normally covers a one mile radius around the airport to avoid a "tremendous amount of nuisance alerts" (3).

On the island of Guam in the fall of 1994, air traffic controllers complained that the MSAW system at their location issued a high number of false alarms. As a result, technicians at the FAA's Technical Center in New Jersey developed and installed in February 1995 a software patch for the Guam system to reduce the false alarm rate. It was this software patch that rendered Guam's MSAW system useless (4). The adaptation of the system to the location specific data after the modification left the MSAW working within a ring 1 nautical mile wide at a distance of 54 nautical miles from the radar antenna. The MSAW system was inhibited from processing within 54 nautical miles of the airport (3). As a result, the tower at Guam never received either visual or aural warnings from the MSAW system. In the case of KAL 801, the terrain maps were accurate, but the inhibit zone was drastically wrong. Ultimately, the MSAW at Guam failed "due to a bug introduced into the MSAW system by a software upgrade developed by the FAA Technical Center in New Jersey intended to reduce the number of false-positive alarms the system was generating, in response to complaints by the [tower] operators" (4).

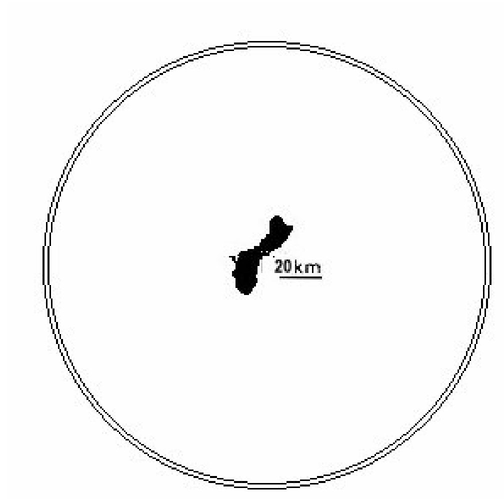

Fig. 2: Guam's MSAW inhibit area

Responsibility for Failure

On March 24, 1997 the NTSB held a public hearing in connection with the investigation of the crash of KAL flight 801. The hearing was not held to "deal with any analysis of what happened nor [to] deal with any causal issues," but, rather, to gather evidence regarding the "Minimum Safe Altitude Warning systems and practices related to this system at Guam and nationwide" and other issues of concern (3). Although the explicit purpose of the hearing was not to assess responsibility in the crash, many responsible parties came to light as a result. The FAA issued an official statement on the first day of the hearing: "There are multiple safety features in the air traffic control system, but pilots are ultimately responsible for operating their aircraft safely in accordance with published procedures" (5). This statement did not, however, explain who was to blame in the failure of the MSAW system.

> "Pilots are ultimately responsible for operating their aircraft safely."
> - FAA Press Release 3/24/98

According to the transcript from day one of the NTSB hearing, the FAA was admitting much of the responsibility for the software failure. The process for modifying Guam's MSAW system hinged on the adaptation data provided by the Guam facility to the FAA for software programming. In their investigations into the software failure, the Guam facility was unable to find documentation providing guidance to the FAA for the inhibiting of the MSAW: "[The modifications] took place prior to the present Center Radar Approach Control management staff. We have searched all administrative, correspondence, and project files and have been unable to locate any correspondence that would explain the MSAW configuration." Furthermore, according to David Canoles, manager of FAA evaluations and investigations staff, "[the FAA handbook] allows facility managers to otherwise modify MSAW temporarily if it's disruptive to the operation. We were advised that was the action that had taken place." Clarification during the hearing revealed that FAA regulations regarding MSAW systems did not define "temporarily," nor did they provide adequate evaluation of the system. In fact, an evaluation of the MSAW occurred in February 1995 and consisted merely of a memo to FAA regional managers to check the site parameters on MSAW. The FAA admits "there was a diligent effort by the Washington office that had that responsibility to track and report the progress. And there was some indication that each facility reported back" (3).

With the FAA admission of responsibility, "we have since learned that [relying on facility reports] that's probably not the best way to do that type of thing," many layers of the FAA's responsibility in the failure of the MSAW system at Guam came to light. Carl Schellenberg, former deputy associate administrator for Air Traffic Services for the FAA testified that "there was no single entity at that point clearly responsible for the quality of programs and the total service delivery of the MSAW program." The organization of the FAA since the time of the crash has changed. Unlike before KAL flight 801, a single organization, Air Operation Services, now holds clear responsibility for the MSAW program. Additionally, documentation regarding MSAW was inadequate before the recent investigations. Now, uniform site adaptation and system parameters have been

> "That's probably not the best way to do that type of thing."
> \- Carl Schellenberg, FAA 3/24/98
> Assessment of FAA procedures at the time of the KAL801 crash

established for all MSAW equipment operation. Prior to the crash, the MSAW system at Guam had never been evaluated during any FAA evaluations due to a lack of complaints about the system. Another FAA provision has been made for periodic evaluation of field facilities, including full testing of the MSAW systems. Finally, as a result of the lack of documentation of changes made to the system at Guam, configuration management of all MSAW software must now be reflected in appropriate documents and be approved by the AOS (3).

Costs of Failure

Operating under the assumption that, had an MSAW alarm sounded in the tower as KAL flight 801 approached the airport at Guam, the pilot could have successfully avoided the terrain, the greatest cost of the software failure was loss of life. Additional costs were incurred due to MSAW failure in the form of investigations, study, and modifications to the FAA systemic structure. But MSAW system failure at Guam was by no means an isolated incident of poor adaptation.

Prior to the failure at Guam, a Lear jet crash at Dulles Airport alerted the NTSB to an MSAW adaptation problem in which the wrong minimum distance allowed on one runway's approach was entered into the system. At that time, the FAA had specific standards applicable to MSAW systems. This crash prompted the evaluation process of merely alerting local facilities to the problem and expecting a report on the MSAW operations. As mentioned earlier, this evaluation process was ineffective in finding the errors at Guam. Therefore, after Guam, the FAA quickly began checking all MSAW systems in operation. These checks found errors in Chicago, Dallas, and New York, but these errors had not resulted in any problems. "All of these airports adapted the MSAW approach path monitor altitude to be above ground level when the system expected mean sea level values. This resulted in altitudes to be between 600 and 800 feet too low." The recertification guidance and additional flight checks required at other airports were further costs of the software failure at Guam (3).

After the FAA initiated checks and modifications of MSAW systems, in January 1998, another Lear jet crashed resulting in loss of lives, this time on approach to Houston Intercontinental Airport. Investigation of this crash revealed incorrect setting of approach altitudes identical to the error found at Dulles. Again, the failure of the MSAW system resulted in loss of life (3).

Although the Minimum Safe Altitude Warning system has never been viewed as the cause of any airline crash, it could easily have prevented several. The fact that the MSAW system operates as one in a series of redundant safety measures for aircraft on approach relegates perfect operation of this system to a back burner. As a result of the apparently low priority given to this system, the absence of checks and balances from the FAA in conjunction with local facilities, a lack of MSAW adaptation standards, and a deficiency in the testing process, the MSAW software error was overlooked at many facilities. This software failure can only lead the public to wonder what else is overlooked in the realm of national transportation and safety.

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