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Memory Lapses, Miscommunication, Inadequate Coordination Cited as Most Common Causes of Tower Controllers' Errors

The U.S. Federal Aviation Administration says that reports on operational errors at U.S. airport traffic control towers show that the most common contributing factor was that the controller forgot crucial information, such as an aircraft clearance, a vehicle on a runway or a closed runway.

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FSF Editorial Staff

Controllers in airport traffic control towers should have improved memory aids, improved means of communicating with pilots, improved means of coordinating actions with their colleagues and improved surveillance-and-monitoring equipment, said a report prepared for the U.S. Federal Aviation Administration (FAA).

The report, prepared by the John A. Volpe National Transportation Systems Center of the U.S. Department of Transportation Research and Special Programs Administration, was based on the analysis of data from several sources to determine the types of errors made by airport traffic controllers and by pilots operating in the airport environment; to identify significant factors associated with the errors; and to determine what improvements could be made to prevent or to lessen the errors.

The study data included FAA reports of tower operational errors, U.S. National Transportation Safety Board (NTSB) accident reports and incident reports, NTSB recommendations to FAA, reports filed by tower controllers with the U.S. National Aeronautics and Space Administration Aviation Safety Reporting System (ASRS),[1] ASRS reports filed by pilots about runway transgressions[2] and FAA reports about pilot deviations in tower-controlled airspace.

The database contained 256 FAA reports of tower operational errors in the busiest airport traffic control towers in the United States between January 1997 and June 1999. Of the 256 reports, 89 reports involved level 3 towers, 68 reports involved level 4 towers and 99 reports involved level 5 towers. [During the years studied, airport traffic control towers were classified as level 1 through level 5, depending on the number of arrivals and departures per hour. Level 5 towers recorded the most activity, with more than 100 arrivals and departures per hour; level 1 towers recorded the least activity, with fewer than 35 arrivals and departures per hour.[3]] The reports were analyzed, and recommendations were developed that focused on problems directly associated with tower operations — not on training, procedures or problems specific to an individual facility.

FAA reports of operational errors are detailed reports prepared by FAA investigators (usually facility supervisors or quality-assurance specialists). The reports provide details about the operational environment when the error occurred, including a description of the event, the contributing factors ("such as traffic complexity, weather, number of aircraft or whether training was in progress at the time," the Volpe report said), and cite "controller contributions" to the errors (such as incorrect phraseology or a readback/hearback error, which

occurs when a pilot incorrectly reads back a clearance to a controller and the controller fails to recognize and correct the error).

Analysis of the contributing factors identified in the 256 FAA reports showed that the top five factors were "aircraft observation," "coordination," "communication error," "visual data" and "ground operations" (Figure 1).

The most common controller contributions cited overall were in the following categories: "aircraft observation — actual observation of aircraft," 42 percent; "improper use of visual data — taking off," 28 percent; "ground operations — taxiing across runway," 22 percent; "improper use of visual data — landing," 16 percent; and "communication error — misunderstanding," 16 percent.

Figure 2 (page 3) shows the results of a human factors analysis — conducted for the Volpe report — of 251 of the 256 FAA reports. (Five reports from level 5 towers were eliminated because they lacked adequate detail for analysis.)

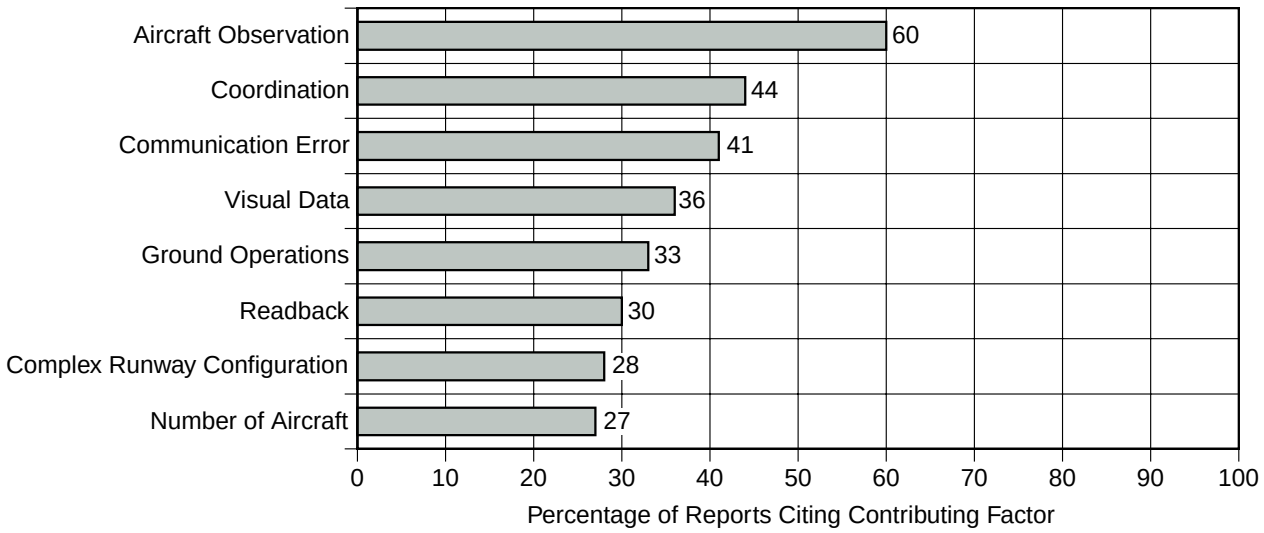
The human factors analysis of the 251 reports was designed to determine the following:

- Whether the controller forgot about an aircraft (for example, forgot that he or she had cleared an aircraft to take off, to land or to taxi across a runway), forgot about a vehicle on the runway or forgot that a runway was closed;
- Whether a communication error occurred between controller and pilot;
- Whether there was inadequate coordination between controllers;
- Whether there was a supervisor on duty who was not also working a control position;
- Whether improved memory aids would have been useful; and,
- Whether improved surveillance-and-monitoring equipment would have been useful.[4]

The most common contributing factor — cited in 27 percent of the 251 reports — was that the controller forgot something. Fifteen percent of the reports said that the controller had forgotten about an aircraft (such as an aircraft that had been cleared to land or an aircraft holding at the end of a runway). Three percent of the reports said that the controller forgot that there was a vehicle on the runway. Five percent of the reports said that the controller forgot that the runway was closed. Other memory lapses were cited in 4 percent of the reports.

The second most common contributing factor was controller-pilot communication error; miscommunication was cited as a factor in 19 percent of the reports. Nevertheless, FAA

General Factors Contributing to Airport Traffic Control Tower Operational Errors, January 1997–June 1999

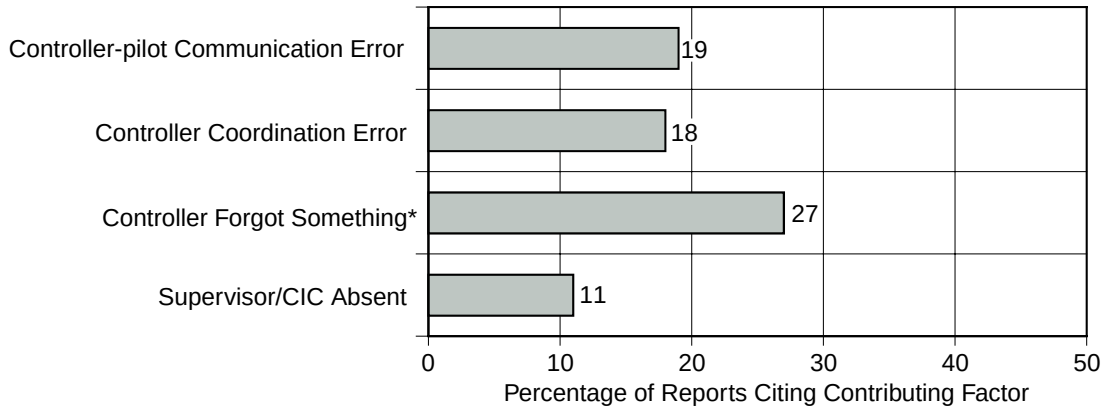


Note: Information was obtained from 256 U.S. Federal Aviation Administration reports on tower operational errors and deviations.

Source: Kim Cardosi, Ph.D., and Alan Yost, John A. Volpe National Transportation Systems Center, U.S. Department of Transportation Research and Special Programs Administration

Figure 1

Human Factors Contributing to Airport Traffic Control Tower Operational Errors and Deviations, January 1997–June 1999



Note: Information was obtained from a human factors analysis of 251 U.S. Federal Aviation Administration (FAA) reports on tower operational errors and deviations. Five other FAA reports for the period were not analyzed because they lacked necessary details.

*15 percent forgot that an aircraft was on the runway
5 percent forgot that a runway was closed
3 percent forgot that a vehicle was on the runway
4 percent involved other memory failures

CIC = Controller-in-charge

Source: Kim Cardosi, Ph.D., and Alan Yost, John A. Volpe National Transportation Systems Center, U.S. Department of Transportation Research and Special Programs Administration

Figure 2

investigators specified in 41 percent of the reports that errors involving "communication" had occurred. Communication error was cited in a variety of situations, such as when miscommunication occurred between a controller and a pilot, between two controllers, or between a vehicle driver and a controller; or when incorrect phraseology was used. In the Volpe report, a "communication" error was considered to be a miscommunication between a controller and a pilot (usually a readback/hearback error); a miscommunication between two or more controllers was coded as a "coordination" error.

"Coordination" was a contributing factor in 18 percent of the reports. Coordination errors typically involved a controller's failure to relay needed information to another controller or failure to obtain approval for a specific operation (such as a runway crossing).

Eleven percent of the reports said that the supervisor or controller-in-charge (CIC) was absent. Many reports, however, did not contain specific information about the presence/absence of a supervisor/CIC or what tasks were being performed by a supervisor/CIC. For example, some reports said that the supervisor/CIC was "unaware" that an error was developing but did not specify whether the supervisor/CIC was in the airport traffic control tower cab or whether the supervisor/CIC also was working in a control position.

Analysis of the 251 reports suggested a need for further research in the following areas:

- Peripheral traffic management duties — Additional duties required by automated traffic management systems, such as recording delays, can distract controllers from awareness of the traffic situation;

- Land and hold-short operations (LAHSO) — Seven percent of the reports from level 5 facilities said that LAHSO operations were in effect when the error occurred. Some errors resulted from LAHSO operations. There were occurrences in which a pilot acknowledged a clearance but did not comply with the clearance, and in one occurrence, a controller believed that he had issued a hold-short clearance and wrote it on a flight progress strip — but he had not issued a hold-short clearance. In other occurrences, while a controller's attention was focused on ensuring that the pilots of one aircraft complied with hold-short instructions, an incident occurred elsewhere;

- Combined positions — Ten percent of the reports said that the controller was working combined positions at the time of the incident. Some reports said that this was a contributing factor to the complexity of the traffic;

- Situational awareness upon assuming a position — Twenty percent of operational errors occurred during the controller's first 10 minutes on position. The Volpe report said that, although this "may suggest that an inadequate position-relief briefing may be partly responsible [for the operational error], this factor was cited in only 4 percent of the reports"; and,

- Intersection takeoffs — In some occurrences, a controller assumed that a pilot would taxi the airplane to the departure end of the runway, but the pilot taxied to a runway intersection.

Some of the 251 FAA reports on operational errors included recommendations to prevent the errors. For example, one report recommended that the facility "aggressively pursue the acquisition of AMASS [airport movement area safety system]" because "the redundancy provided by the installation of AMASS may have prevented this surface error." [AMASS is a ground movement monitoring system that uses ground radar, airspace radar and prediction software to prevent runway incursions.] Because such specific recommendations usually were not contained in the reports, the circumstances of the error were examined for indications about what tools — such as memory aids or surveillance and/or monitoring systems (similar to AMASS) — could have been helpful in preventing, or lessening the consequences of, these errors.

Memory aids, or improvements in memory aids, were cited as potential remedies in 9 percent of the FAA reports. Although memory aids and other similar devices often are developed at individual airport traffic control towers, a method is needed for towers to share the ideas and to study their effectiveness. An illuminated airport diagram that indicates active runways is one example of a memory aid.

The Volpe report said that a surveillance-and-monitoring system that indicates to a controller that an aircraft is on approach to a runway occupied by another aircraft or some other vehicle or to a closed runway might be useful if the false alarm rate was acceptably low and the alerts were timely. Many operational errors involve situations in which an error develops so quickly that no warning system would be effective. Nevertheless, a surveillance-and-monitoring system (such as runway-status lights, AMASS or ground induction loops) might have been useful in 51 percent of the operational error reports that were examined. (Runway-status lights are lights at runway intersections and runway hold-short positions that turn red automatically when an aircraft is on final approach to the runway or when an aircraft is accelerating or decelerating on the runway; at other times, runway-status lights display a light of another color to indicate to pilots that the system is functioning.) [Ground induction loops are electrical conductors that sense the passage of aircraft and other vehicles along runways and taxiways and relay the information to controllers.]

The Volpe report said that safe operations require adequate staffing — a concept that implies the presence of a supervisor/CIC. When supervisors/CICs also work a control position, however, they are unable to focus adequate attention on their supervisory work.

Controllers' Reports to ASRS Discuss Equipment, Pilot Deviations From Clearances, Controller Errors

Analysis of 249 ASRS reports submitted by tower controllers showed the following:[5]

- Thirty-five percent of the reports involved issues that concerned controllers, especially equipment issues; 32 percent of the reports described occurrences of pilot error, including deviations from clearances, and other events not related to controller errors; and 30 percent of the reports described errors that the controllers had committed, primarily memory lapses, problems involving coordinating activities with other controllers and judgment errors in predicting separation;

- The equipment issues cited in the reports included radar outages or radar malfunctions (17 reports); statements about the need for radar (two reports); communication equipment (13 reports); weather equipment (21 reports, including five statements of the need for wind information, five statements of the need for low-level wind shear indication and 11 statements about problems with the automated surface observing system [ASOS]); "unnecessary" traffic-alert and collision avoidance system (TCAS) resolution advisories (three reports); and the need for an indication of inoperative approach lights (three reports);

- The reports of pilot error cited 28 deviations from a clearance or operations without a clearance while the aircraft was in the air, 23 of which involved deviations from heading and/or altitude and five of which involved entering controlled airspace without authorization. Results of the pilots' actions were 16 near-midair collisions and 12 potential conflicts;

- Twenty-seven reports involved pilot deviations from a clearance or operations without a clearance while the aircraft was on the ground, resulting in 21 runway incursions and six surface incidents. (A "surface incident" is defined in the Volpe report as "any event where unauthorized or unapproved movements occur within the movement area or an occurrence in the movement area associated with the operation of an aircraft that affects or could affect the safety of flight.");

- Three reports involved vehicles that were moved onto a runway without authorization;

- Twenty-two reports cited pilot errors that did not result in incidents, including 16 occurrences in which pilots did not proceed as instructed, one occurrence in which an aircraft was landed without a clearance, three occurrences in which airspace was entered without authorization and two occurrences involving a pilot error in judgment;

- The reports citing controller error comprised 22 reports about controllers who forgot crucial information, including aircraft cleared to land (eight reports); closed runways (four reports); vehicles on runways (four reports); aircraft holding in position (four reports); aircraft cleared for takeoff (one report) and aircraft on approach (one report). The results included 18 runway incursions, two occurrences of aircraft being taxied to closed runways and two occurrences of aircraft being landed on closed runways. The contributing factors mentioned by the controllers who filed the reports included combined positions (seven reports), fatigue (three reports), workload (two reports), inadequate position-relief briefing (one report), distraction caused by visitors (one report) and exhaust fumes in the tower (one report);

- Four reports said that controllers did not know about an aircraft or did not know an aircraft's position;

- Eighteen reports cited inadequate coordination between controllers that resulted in two runway incursions, six near-midair collisions and 10 losses of separation or potential losses of separation. The contributing factors were inadequate position-relief briefings (four reports) and combined positions (one report);

- Fourteen reports cited controller error in projecting separation of airborne aircraft. Results included one near-midair collision and 13 losses of separation, four of which involved controllers working combined positions;

- Ten reports cited controller error in projecting separation of aircraft on the ground. Results included nine runway incursions and one loss of separation; and,

- Six reports said that controllers misidentified aircraft or issued a clearance to the wrong aircraft. Results included one near-midair collision and five losses of separation.

Pilots' Reports to ASRS Discuss Miscommunication, Need to Improve Airport Markings

Analysis of 76 ASRS reports of runway transgressions submitted by pilots showed the following:[6]

- Nineteen reports involved runway incursions, and 57 reports involved other surface incidents. Fifty-one percent of the reports said that there was a need for better airport markings, and 35 percent of the reports said that the incidents could be attributed to controller-pilot communication errors. (Thirty-six percent of the communication errors involved pilots who accepted clearances intended for other aircraft.);

- Thirty-seven (49 percent) of the 76 reports involved aircraft crossing the hold-short line. These occurrences resulted in 12 runway incursions (six rejected takeoffs and six go-arounds) and 25 surface incidents. Twenty-five of these 37 errors were attributed to a pilot's inability to see the hold-short line or to inadequate markings; in seven reports, pilots said that there was miscommunication or that they misunderstood the clearance; and,

- Twenty-seven (36 percent) of the 76 reports involved pilots taxiing onto, or crossing, runways without authorization, resulting in 22 surface incidents and five runway incursions. Among the causal factors cited were communication errors between controllers and pilots (11 reports) and the need for better airport markings (12 reports).

The Volpe report said that the ASRS reports indicate a need to prevent errors resulting from failures of controller memory, miscommunication between pilots and controllers, failures of coordination among controllers and failure of controllers to accurately project separation between aircraft. The reports from the controllers and pilots support recommendations for improvements in:

- Surveillance-and-monitoring equipment for controllers;

- Methods of communication between pilots and controllers; and,

- Airport markings and airport signage, especially more conspicuous hold-short markings.

ASRS reports from controllers also identify a need for better coordination among tower controllers and a need for controllers to verify that the runway is clear of other aircraft and vehicles before allowing an aircraft to take off or to land. This task could be aided by a system (for pilots and/or controllers) that displays whether the runway is occupied.

ASRS reports from pilots indicate a need for standard operating procedures for ground operations to help ensure that nonessential tasks are completed during periods of relatively low workload and non-critical phases of operation, and that pilots are "aware of the location of their aircraft on the airport surface, the location of all critical elements in the airport environment (e.g., hold-short points, intersecting runways, aircraft on approach) and their ATC [air traffic control] clearance," the Volpe report said.

Accident, Incident Reports Cite Failure to Ensure Clear Runways

Analysis of NTSB reports involving six accidents and 18 incidents in airspace controlled by airport traffic control towers from December 1983 to July 1995 showed the following:

- The accidents and incidents included eight near collisions between aircraft, one collision between aircraft, seven collisions with objects (six "objects" were stationary aircraft; one was a snow sweeper), six runway incursions and two losses of standard separation during takeoff because of controller error. (The losses of separation did not result in near-midair collisions or surface incidents.);

- Of the 22 accidents and incidents in which separation was maintained, the most frequently mentioned factor (in 70 percent of the reports) was the failure to "verify that the runway was clear before allowing an aircraft to take off or [to] land," the Volpe report said. In three reports, pilots said that their aircraft were clear of the runway when they were not; in one report, a fleet of vehicles was reported erroneously as clear of the runway. Five reports involved miscommunication between pilots and controllers; in three of these occurrences, pilots accepted a clearance intended for another aircraft. Three reports involved a controller's memory lapse (forgetting that he or she had cleared an aircraft to land, to take off or to taxi into position and hold on the runway). One report involved a controller working combined positions, and one report said that the supervisor was working a control position. Two reports cited inadequate airport markings, including one occurrence in which a sign had been blown over; and,

- Of the six accidents, one occurred in day visual meteorological conditions (VMC), two occurred in day instrument meteorological conditions (IMC), two occurred in night VMC (including one accident that also involved fog), and one occurred in VMC at dusk. Of the 16 incidents in which separation was maintained, eight occurred in day VMC (including one incident that also involved haze and another that involved rain and haze), five occurred during night VMC (including one incident that also involved haze and another that involved snow), two occurred during night IMC, and one occurred during day IMC.

NTSB recommendations to FAA, some first issued in the early 1990s, have included improved surveillance-and-monitoring systems, specifically AMASS and airport surface detection equipment (ASDE), which is a surface radar system designed to provide controllers in airport traffic control towers with position information on aircraft and other vehicles on runways and taxiways.

FAA Data Show Half of Pilot Deviations in Tower Airspace Involved Unauthorized Entry

Analysis of 65 FAA reports involving pilot deviations in tower-controlled airspace showed that 33 reports (51 percent) involved pilots entering controlled airspace without authorization. Fifty-two percent of the 33 deviations resulted in near-midair collisions, 6 percent resulted in runway incursions, and the remainder were classified as "other — no near-midair collision."

Reports on 20 other deviations (31 percent) said that the pilot did not follow ATC instructions. Three reports involved pilots entering active runways or crossing active runways without authorization, including one occurrence that resulted in a near-midair collision and another that resulted in a runway incursion. Three reports involved pilots who said that the traffic was "in sight" but then lost separation with that traffic; two of these occurrences were classified as near-midair collisions. Two reports involved aircraft that were landed on taxiways.

More than half of the deviations in tower-controlled airspace involved aircraft entering the airspace without authorization. Thirty-two deviations (49 percent) involved surface incidents.

Most Common Controller Errors Include Forgetting, Miscommunication

The Volpe report said that the most common controller errors found in the FAA, NTSB and ASRS reports were the following:

- Forgetting about an aircraft, forgetting about the closure of a runway, forgetting about a vehicle on the runway, and/or forgetting about a clearance that he or she had issued;

- Communication errors, including readback/hearback errors and issuance of an instruction other than the one that the controller intended to issue; and,

- Lack of adequate coordination between controllers.

Failure to anticipate the required separation between aircraft or miscalculation of the impending separation was an implied factor, and more study is required to determine the degree to which the absence of a supervisor was a factor, the Volpe report said.

The Volpe report identified a need for improvements to correct several problems in tower operations, including:

- "Improved surveillance-and-monitoring equipment that is most appropriate for a specific airport or part of an airport; (e.g., [ASDE], AMASS, runway-status lights and [ground induction] loops," the Volpe report said. Pilots

and/or controllers need a means of determining whether an aircraft is clear of the runway. The Volpe report said that sophisticated systems, such as AMASS, "require significant investment for site adaptation and will be useful if the warnings are timely and the false alarm rate is acceptably low." Nevertheless, because of their lower cost, less sophisticated systems such as ground induction loops and runway-status lights, and unsophisticated solutions such as markings (especially more conspicuous indicators of runway hold points) and lighting also show potential;

- Better memory aids, and more consistent use of memory aids;

- Improved methods of controller-pilot communication to reduce frequency congestion, to eliminate simultaneous transmissions and blocked transmissions and to reduce the probability that a flight crew will accept a clearance intended for another aircraft; and,

- Improved methods of coordinating controller actions, either with shared displays, improved methods of voice communication or changes in procedure.

The Volpe report also recommended to FAA the following:

- Revise the methods for investigating controller operational errors and for collecting and recording information about those errors. The information should be more consistent and more useful in determining the causes of incidents and potential remedies. The methods should be standardized with "unambiguous categories (e.g., contributing factors)," and the categories should be revised to include the most common types of controller errors (such as forgetting), the Volpe report said. The report said that the categories also "should include operational variables that would benefit from more research, such as whether the supervisor or [CIC] was working a position [when an error or deviation occurred], whether positions were combined (and if the combination was normal for that facility at the time), LAHSO and intersection takeoffs";

- Survey airport traffic control tower personnel for "homemade" memory aids, runway-incursion-prevention mechanisms and other inventions unique to a particular facility so that the effects of these aids can be studied and the information can be shared with personnel at other towers;

- Provide support to expedite the acquisition of needed equipment or other resources for airport traffic control towers;

- Encourage airport traffic control tower personnel to identify significant factors in the incidents that occur in their airspace or on the ground at their airports (such as intersections or other locations on the airport surface where incidents are likely to occur and the type of aircraft operators involved), to determine what can be done to prevent future occurrences and to provide the resources to assist tower personnel in studying these problems and implementing the remedies; and,

- Investigate more conspicuous methods of indicating runway-hold locations.♦

[FSF editorial note: This article, except where specifically noted, is based on *Controller and Pilot Error in Airport Operations: A Review of Previous Research and Analysis of Safety Data* (DOT-VNTSC-FAA-00-21). The report was written by Kim Cardosi, Ph.D., and Alan Yost of the John A. Volpe National Transportation Systems Center of the U.S. Department of Transportation Research and Special Programs Administration. The 63-page report contains figures, tables and appendixes.]

Notes and References

1. The U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) is a confidential incident-reporting system. The ASRS Program Overview said, "Pilots, air traffic controllers, flight attendants, mechanics, ground personnel and others involved in aviation operations submit reports to the ASRS when they are involved in, or observe, an incident or situation in which aviation safety was compromised. … ASRS de-identifies reports before entering them into the incident database. All personal and organizational names are removed. Dates, times, and related information, which could be used to infer an identify, are either generalized or eliminated."

   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 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."

2. ASRS defines a "runway transgression" as the "erroneous or improper occupation of a runway or its immediate environs by an aircraft or other vehicle so as to pose a

potential collision hazard to other aircraft using the runway, even if no such aircraft were actually present." The Volpe report uses the terms "runway incursion" and "surface incident." A "runway incursion" is defined as "any occurrence at an airport involving an aircraft, vehicle, person, or object on the ground that creates a collision hazard or results in loss of separation with an aircraft taking off, intending to take off, landing or intending to land." A "surface incident" is defined as "any event where unauthorized or unapproved movements occur within the movement area or an occurrence in the movement area associated with the operation of an aircraft that affects or could affect the safety of flight."

3. National Air Traffic Controllers Association. *Legislative Issues: Expanding the Federal Contract Tower (FCT) Program.* www.natca.org/legislativecenter/contracting/contracttower.html Aug. 9, 2001.

4. Improved surveillance-and-monitoring equipment was judged to have been potentially useful in cases in which the controller could not see the aircraft from the airport traffic control tower, the runway was occupied by a vehicle or another aircraft (while another vehicle was cleared to cross, take off from or land on that runway), and the situation was such that it would have been possible for an alerting system to provide a warning in time for the controller and/or pilot to take effective action.

5. Some reports cited multiple contributing factors; others cited none. Therefore, the number of errors does not equal the number of contributing factors.

6. As in the analysis of ASRS reports submitted by controllers, the reports submitted by pilots also lack a direct correlation between the number of errors and the number of contributing factors.

Further Reading From FSF Publications

FSF Editorial Staff. "Methods of Preventing Runway Incursions Evolve in Europe and the United States." *Airport Operations* Volume 26 (July–August 2000).

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Rosenberg, Barry. "Radar Technology, Satellite Systems at Forefront of Global Effort to Reduce Runway Incursions." *Airport Operations* Volume 22 (March–April 1996).

Koenig, Robert. "FAA Report Surveys U.S. Airline Pilots to Discover Factors that Promote Runway Incursions." *Airport Operations* Volume 21 (July–August 1995).

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