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Methods of Preventing Runway Collisions Evolve in Europe and the United States

Definitions of runway incursions and estimates of aircraft-collision risks at airports vary among air traffic management authorities in Europe and in the United States. Sharing lessons learned from experience with airport surface-movement procedures, technologies, training, incident-data analysis and airport signage and marking could have international safety benefits.

FSF Editorial Staff

Airports in Europe and in the United States, as elsewhere, have been challenged by rapid growth in airline-passenger traffic to identify factors that influence the risk of runway collisions — and to reduce the risk. Whether safety evaluations are conducted by national civil aviation authorities, airport operators, air traffic services or other organizations, data-driven decision making is preferred because of the complexity of prioritizing actions among many options and cost scenarios.

Despite operational similarities among airports in different regions of the world, differences exist in the conceptualization of airport-surface incidents and in the significance attached to such incidents. Some U.S. specialists also have said that innovations at European airports — including airport designs, procedures and technologies — should be taken into account as new methods for preventing runway collisions in the United States are implemented.[1]

Richard Marchi, senior vice president of technical and environmental affairs for Airports Council International – North America, said, "Runway collisions caused, overall, six-tenths of one percent of fatalities over the past 10-year period worldwide. Why is there such public concern, such political concern, such concern in the press about the runway-incursion problem? For one thing, the other types of accidents are very difficult for the layperson or the reporter or the politician to understand. In many other accidents, there is no single point of failure. In runway-incursion accidents, it is just the opposite: There was almost always a major error made by someone — especially in accidents that resulted in catastrophe."[2]

Marchi said that a 25-member Joint Safety Analysis Team (JSAT) of the Commercial Aviation Safety Team (CAST) — an effort by the U.S. Federal Aviation Administration (FAA) and industry to reduce U.S. aviation accident rates by 2007[3] — studied five accident reports by the U.S. National Transportation Safety Board (NTSB) since 1990, hundreds of FAA operational-error reports and pilot-deviation reports, and confidential air carrier pilot reports for more than one year. Flight Safety Foundation is a member of CAST.[4] CAST also includes the Joint Aviation Authorities (JAA) as a member from Europe, and other non-U.S. organizations as members and observers. The JSAT that studied runway incursions submitted to FAA and to CAST recommendations on how the data should be used. In August 2000, FAA said that the following 10 near-term initiatives to reduce runway incursions would be implemented in 2000 (with some exceptions): enhanced operational tower controller training; non-U.S. air carrier pilot training, education and awareness; an advisory circular for airport surface operations; airport markings (to increase the visibility of hold lines); education, training and awareness; memory-enhancement-techniques training for tower controllers; pilot/controller communications phraseology review; improved pilot evaluation and testing; air traffic teamwork-enhancement training for tower controllers; and technology assessment. The JSAT considered runway incursions in the United States as two distinct types: incidents involving general aviation aircraft; and potentially catastrophic incidents involving air carrier aircraft, Marchi said.

"In reducing the overall number of runway incursions — and I do not want to minimize the average runway incursion — we must be careful that we actually work to prevent those catastrophic accidents," Marchi said. "To do that, we must keep this a data-focused exercise. We must prevent the air carrier accident that results from a runway incursion, particularly when aircraft are operated in a regime where they do not have a lot of maneuverability, such as short final or high-speed runway operations."

Marchi said that about 22 percent of U.S. aircraft involved in the first 80 runway incursions in 1999 were air carrier aircraft. Twelve percent of the air carrier runway incursions occurred when an air carrier aircraft was on short final or operating at high speed on the airport surface; in about 6 percent, someone had to take evasive action, he said.

"These are the incidents that people are justifiably [concerned] about, and I think we ought to separate those from the overall gross number of runway incursions to make progress," he said. The long-term average has been air carrier aircraft involved in approximately 25 percent of runway incursions, he said.

In the United States, FAA defines a runway incursion as "any occurrence at an airport involving an aircraft, vehicle, person or object on the ground that creates a collision hazard or results in a loss of separation with an aircraft taking off, intending to take off, landing or intending to land." Related surface incidents are any other occurrences that would have been runway incursions, except that there were no other aircraft, vehicles or persons on the runway. FAA further categorizes runway-incursion incidents as resulting from pilot deviations, operational errors by air traffic controllers and vehicle/pedestrian deviations. Thus, such data have been tracked and reported publicly since 1991 and have been the basis of special intervention measures by FAA at some airports.

Work by the European Organization for the Safety of Air Navigation (Eurocontrol) — in collaboration with several international organizations — on the harmonization of incident definitions in air traffic management (ATM) recently has resulted in agreement among the 29 Eurocontrol-member nations to adopt a common incident-reporting form in 2000 and to contribute data to a common European database.[5]

Eurocontrol's Harmonization of European Incident Definitions for ATM (HEIDI Taxonomy), an initiative to standardize the definitions of incidents and the classification of causal factors, recently developed the following definition of a runway incursion: "Any unauthorized presence on a runway of an aircraft, vehicle, person or object that creates a collision hazard or results in a potential loss of separation."[6]

Jean-Luc Garnier, head of the Safety, Quality and Management Unit of Eurocontrol, said that the following differences exist between the FAA definition and the Eurocontrol definition:

- "For the FAA definition, there is a loss of separation (or a hazard) between an aircraft and another aircraft or vehicle or person or object, whereas for the Eurocontrol definition, there could be a situation classified as a runway incursion even if there is no loss of separation or no hazards; for example, a vehicle on a runway that did not have clearance to enter that runway and there were no other aircraft around; [and,]

- "For the FAA definition, two aircraft cleared to maneuver on the same runway — for example, to enter the runway and take off — would be considered a runway incursion, whereas for the Eurocontrol definition, the same incident would be recorded with one or more of the descriptors '[air traffic control (ATC)] clearance/instruction/information' and with one or more of the modifiers 'erroneous/incomplete/late.'"

Garnier said that few specific Eurocontrol initiatives have addressed runway incursions directly, but they have included the following work:

- Initial discussion of methods by which air traffic services (ATS) procedures could contribute to the mitigation of runway incursions, a project of Eurocontrol's ATM Procedures Subgroup;

- Implementation of Eurocontrol Safety Regulatory Requirement No. 2, which required collection of runway-incursion data beginning in January 2000 (using the HEIDI definition) to monitor safety levels in European Civil Aviation Conference nations. This work has not been designed to prevent runway incursions, however; and,

- Participation in new work by the JAA Safety Strategy Initiative to prevent runway incursions in Europe.

Gilles Le Galo, ATM expert in Eurocontrol's Safety-Quality and Standardization Unit, said, "My feeling is that runway incursions might be a lesser problem in Europe than in the United States, as few airports have the same complex infrastructure (such as multiple runways), and procedures such as land-and-hold-short operations are not very common practice. Some European airports, however, are planning to introduce simultaneous runway operations or other procedures that aim at increasing runway capacity. Without anticipating the results of the investigation, the recent accident at Charles de Gaulle Airport [Paris, France] shows that this issue should be a concern for us as well."[7]

Prior to such projects, identifying, tracking and analyzing safety occurrences that were not associated with an accident and quantitative comparisons of runway-safety incidents sometimes were impossible. European civil aviation authorities, airports, ATSs and safety specialists have been able to review without difficulty the runway-incursion experience of U.S. airports in the 1990s, however.

Denis Chagnon, public information officer for the International Civil Aviation Organization (ICAO), said that standardizing and harmonizing definitions of incidents in ATM has important benefits.[8]

Chagnon said, "It is critical to have common definitions and a common perception of the problem of runway incursions. ICAO's role is to look at incidents and accidents to update, modify or review international standards to be sure that such occurrences are not repeated when the cause of an occurrence is linked to standards."

Paragraph 7.3 of ICAO Annex 13, *Aircraft Accident and Incident Investigation,* said that nations "should establish formal incident-reporting systems to facilitate collection of information on actual or potential safety deficiencies." ICAO has supported such efforts in the past, Chagnon said. Nevertheless, there is no requirement in Annex 13 for nations to report to ICAO incidents other than serious incidents, he said. Annex 13 defines a serious incident as one "involving circumstances indicating that an accident nearly occurred."

Paragraph 6.7 of Annex 13 said, "If a state conducts an investigation into an incident to an aircraft of a maximum mass of over 5,700 kilograms [12,500 pounds] that state shall send, as soon as practicable after the investigation, the Incident Data Report to [ICAO], when the investigation has revealed matters considered to be of interest to other states." A note to paragraph 6.7 and Attachment D describe the types of incidents that are of main interest to ICAO for accident prevention studies and provide for guidance examples of incidents that are likely to be serious incidents. The list of examples includes "near collisions requiring an avoidance maneuver to avoid a collision or an unsafe situation or when an avoidance maneuver would have been appropriate … takeoffs from a closed or engaged runway with marginal separation from obstacles … landings or attempted landings on a closed or engaged runway … [and] takeoff [incidents] or landing incidents."

Chagnon said that Annex 13 requirements for reporting data about serious incidents are not changing but improvements in ICAO's tool for data collection and analysis — the Accident/Incident Report (ADREP2000) system — are being implemented.

"The objective is for the tool to enable [nations] to more efficiently and comprehensively collect data on incidents such as runway incursions, even though ICAO only would continue to receive data on serious incidents," he said. "No new data will be reportable. [Thus,] ICAO only gets notification of a serious runway incursion [and] we have limited overall data on runway incursions. From the United States, for example, NTSB provides to ICAO data [that] do not include runway incursions unless they are very serious."

NTSB said that the agency follows the recommended practices for the submission of accident/incident data reports in Annex 13. Data from all incidents selected by NTSB for investigation are reported to ICAO, but NTSB does not investigate all U.S. runway incursions, NTSB said.[9]

In the present system, ICAO expects that less serious runway incursions will be monitored and addressed at a local operational level, based on daily reviews of airport operations reports, ATM incident reports and similar sources, he said.

Chagnon said that North America has been the site of the most focused activity to prevent runway incursions. The experiences of the United States and European countries have been different, he said.

"A runway incursion is not as common in Europe because of two fundamental reasons: the procedures in place and the equipment installed at airports," Chagnon said. "These measures have reduced significantly runway incursions. From other parts of the world, ICAO has very little information. We do not have national reporting of that information because airport-surface incidents apparently are considered less significant compared with other types of aviation incidents."

Survey Examines Best Practices At Six European Airports

Against this backdrop of harmonization in Europe and informal reports about runway-collision prevention from specific airports, FAA's Europe, Africa and Middle East Office and the FAA Runway Safety Program Office conducted a survey.

Joseph Fee, international technical program manager, and James Nasiatka, international air traffic control specialist, both with FAA in Brussels, Belgium, said that FAA has been interested in runway-safety methods in other countries but previously had not studied extensively such methods outside the United States.[10] Fee and Nasiatka surveyed between April and June, 2000, six of the busiest European airports, based on aircraft movements, to examine current and proposed surface-movement technologies and operational procedures.

The airports were Brussels National Airport, Belgium; Munich Franz-Josef Strauss Airport, Germany; London Heathrow

Airport, United Kingdom; Charles de Gaulle Airport; Amsterdam Airport Schiphol, Netherlands; and Oslo Airport Gardermoen, Norway.

The research comprised a 65-question survey, interviews and site visits that included observation of airport control tower cabs and surface-monitoring equipment.

Fee said, "We have reason to believe that as things move along addressing the prevention of runway collisions internationally the FAA will have more technological linkage to Europe and there will be more of a common effort to develop standards, as we see the need for a general method. Our work on this report has started a dialogue with officials at these airports. We will continue talking with them."

As part of a separate analysis, the Safety Regulation Group (SRG) of the U.K. Civil Aviation Authority (CAA) provided to Nasiatka data on all aircraft accidents and incidents in the United Kingdom from 1989 to 1999. He reviewed the descriptions to identify incidents that met the FAA definition of a runway incursion and submitted the categorized data to the Runway Safety Program Office for analysis. The analysis was continuing as of August 2000. He said that the SRG's data classification is an example of one that considers runway-surface occurrences differently than FAA's data classification.

Nasiatka said, "I attend regional ICAO meetings in Paris and Eurocontrol meetings in Brussels; in both, there are incidents under discussion that are equivalent to runway incursions in the United States. Both ICAO and Eurocontrol are now looking at methods to study these incidents and to see how and where runway incursions are occurring.

"From the operational standpoint, there is no formal international definition of what a runway incursion is, according to ICAO. European aviation authorities are beginning to develop related incident definitions and to see exactly what causes such incidents. They recognize that communication is a problem and that the language factor may be part of the problem."

Nasiatka said that national perceptions of runway safety sometimes are influenced by different methods of measuring incidents.

"The United Kingdom has a well-defined tracking program through the SRG," he said. "Other nations have limited knowledge as to the frequency of runway incursions and surface incidents. Most officials of the six airports refer to runway incursions as incidents or occurrences in the same category with airborne operations. Airport officials in Munich and Oslo said that because of their runway configurations, runway incursions were not a problem (two parallel runways with [almost] all ramps and taxiways between the runways). French airport officials began a tracking and monitoring program last year, and since have learned that they have about two surface incidents a month."

The FAA report, written by Fee and Nasiatka, said, "One might expect that the number of runway incursions would be a function of airport complexity; [that is, that] an airport with twice as many runway access points would have twice as many incursions if both had the same number of operations. While there has been no definitive study on runway incursions in Europe … [this hypothesis] has not proved to be true in the United States."[11]

Surface-movement Solutions Have Surprising Similarities

Fee said, "The surprise for me in our survey was that so many people in Europe representing different professions and interests were going exactly the same way. The technology that these airports plan to implement to prevent runway collisions is very uniform. In the United Kingdom and Germany, the ATS providers — National Air Traffic Services and German Air Navigation Services [DFS], respectively — initiated work on technological solutions for surface-movement safety. In France and Norway, the ATM operational people were the initiators. Different groups did not communicate with each other, but developed plans with common technological characteristics for the next three years to four years.

"These organizations said that they were concerned about safety and collision prevention from the ATM view; and, from the airport view, they also wanted to increase airport capacity," Fee said. "They believe that they can do both with surface-monitoring systems. It is to the advantage of both ATS providers and airport operators to monitor and control movement on the airport surface, so there is synergy."

Except for Oslo, the airports plan by 2003 to have systems that provide tracking and incursion alerting through multilateration, in which Mode S transponders [capable of replying to ATC interrogations with a unique address and identification data] on aircraft and vehicles interact with an array of airport interrogator/receivers and receivers (sensors) to generate position data and identification data, eliminating radar-coverage gaps and blind spots, the report said.

"Their methods have much in common with FAA's method: primary surface-movement radar (SMR), secondary-surveillance radar (SSR) and, finally, multilateration subsystems," Fee said. "Unlike FAA, they cannot get a comprehensive list of runway incursions yet from European authorities. They deal with problems in a similar way compared with FAA personnel, but the way they deal with specifics varies."

European authorities are reevaluating methods of reviewing runway incursions relative to other airport safety incidents; the international differences in definitions do not mean that airport authorities are not reviewing their occurrences, Fee said.

Nasiatka said that runway-safety specialists in Europe conceptualize the prevention of runway collisions, in part, based on their methods of studying all safety occurrences at airports.

"Most European nations do not track this type of occurrence unless there is an accident," he said. "They do not deal with the incident as a specific type studied separately from other safety occurrences at airports. Thus, for the most part, it appears that most nations' airports have thought that runway incursions are not a problem at all. Nevertheless, other airports and ATM authorities see such incidents as a growing trend, and they are very concerned. Just as airports in the United States have varied records regarding runway incursions, we see the same type of variation among European nations."

Nasiatka said that the classification and tracking of runway incursions in Europe is at an early stage of development in some countries.

"Fourteen of 29 Eurocontrol member nations previously had no formal ATM-occurrence reporting system," Nasiatka said. He said that these nations are working on methods to track surface incidents more effectively because of interest in knowing the safety performance of airports.

Nasiatka is a member of the regional Aerodrome Operations Group (AOPG), part of the ICAO European Air Navigation Planning Group. Recently, the group has focused on airport operational safety issues such as crosswinds, tail winds, procedures and phraseology, he said. The group meets three times a year at the Europe and North Atlantic Regional Office in Paris.

"At the last AOPG meeting, runway incursion was on the agenda and will be a topic of discussion at future meetings," Nasiatka said. "This was the first time this subject has been brought up on that level. For now, it is not clear where in Europe this problem does occur."

Nasiatka said that FAA runway-safety specialists have recognized, based on research, that breakdown in communication is a predominant causal factor in incidents and accidents involving aircraft on runways. Disorientation of people on the airport surface is another major causal factor, he said.

"FAA has learned that we share some common problems with airports in Europe but European solutions have been varied," Nasiatka said. "They are still in a mode of information gathering and a definition mode. They just now have [begun] to put on the table all the information they have. We can see who has done what to prevent runway incursions — how parts of solutions could be applied to each potential situation — but there is no cookie-cutter answer [no single, identical method]."

Airports in Europe Plan Three Levels of Technology

The FAA report by Fee and Nasiatka said that the following three levels of surface-movement technology are being employed or planned for use at the six European airports within four years:

- Basic monitoring with primary radar only (Level 1) involves surface-monitoring radar that is mounted on the control tower to monitor aircraft and vehicles in limited-visibility conditions. Primary radar coverage typically is suitable for all runways and most taxiways, depending upon line-of-sight limitations and reflective surfaces. These systems sometimes are augmented by magnetic-loop detectors that are embedded in taxiways;

- Digitized primary radar data with SSR reports and flight-data processing (Level 2) provide aircraft identification and collision alerting. Data fusion, aircraft identification and collision alerting currently constitute the most advanced level of technology at major European airports. Such systems combine digitally processed SMR data with terminal SSR reports to detect an arriving aircraft and to label the aircraft's radar symbol automatically with its flight identification. When the aircraft is being operated on the surface, the data-fusion system maintains the label on radar displays during subsequent position reports from the SMR. Labeling on radar displays of departing aircraft is conducted manually. Level 2 systems have the capability of alerting tower controllers to impending runway collisions involving approaching aircraft and departing aircraft. Nevertheless, false targets generated by snow, foliage or other environmental causes constitute a major limitation of the alerting function. Other operational problems reported by the European airports have included the loss or swapping of identification tags of aircraft operating on the surface. Nasiatka said that swapping means that the radar identification tag of one aircraft electronically and unintentionally transfers (jumps) to the radar target of another object — such as an aircraft, vehicle or stationary object — when targets are in close proximity. The problem can occur with current systems, but multilateration subsystems, which interrogate transponders on the airport surface, should solve the problem, he said. Airport officials said that labeling departing aircraft and surface-support vehicles automatically — rather than manually — is desirable; and,

- Level 3 systems provide improved tracking and runway-incursion alerting through multilateration subsystems. Some airports plan to fit transponders on airport surface vehicles. "In a typical situation, a departing aircraft Mode S transponder is interrogated to obtain the Mode A code [a transponder reply] that is correlated with flight identification," the report said. "Then the Mode S squitter [the transponder's spontaneous transmission of its address

> once per second] of the aircraft is tracked without requiring further interrogation. Each aircraft is accurately tracked with flight identification correlation in each report over the entire surface of the airport. The accuracy and function of the Level 3 system is a strong function of the number and position of the transponder interrogators and receivers." Multilateration data, combined with the existing Level 2 fusion-and-data-integration processor, is expected to eliminate false targets.

Three of the airports surveyed — London, Oslo and Paris — currently have Level 2 systems, and three airports — Amsterdam, Brussels and Munich — have Level 1 systems, the report said. All the airport authorities, except Oslo, expect to have Level 3 systems by 2003 and Oslo expects to refine the current system without adding multilateration, the report said.

"An overwhelming majority of the airports are [adding] or soon will be adding a transponder-based multilateration subsystem to their surface-monitoring systems," the report said.

The implementation of these surface-monitoring technologies will establish precedents for other airports in these nations and, probably, the rest of the region, the report said.

"The Level 3 system to be implemented in Munich will be identical to the planned Frankfurt system, and the remaining major German airports can be expected to have this system within the next five years," the report said. "The Level 2 system at Heathrow is virtually identical to the systems at Gatwick and Birmingham, and the planned upgrade to Level 3 should continue throughout the major airports in the United Kingdom. The same progression is expected for France. … With generally similar paths of functionality and development, the systems in Germany, the United Kingdom and France probably will be replicated throughout Europe."

Advanced Surface Movement Guidance and Control Systems (A-SMGCS), now under development, are expected to provide automated vehicle guidance and aircraft guidance for low-visibility surface movement control after 2003. The concept of A-SMGCS is to augment or replace voice communication with visual information in the cockpit or vehicle.

"In many cases, this will take the form of active guidance lighting, which directs the aircraft through the ground-movement phase with appropriate alerts/warnings of restricted areas," the report said. "A specific guidance message also may be data-linked to each aircraft to drive a cockpit map display. The ground/local [controller] can monitor the position of all surface vehicles with great precision and is alerted to deviation from the desired path and potential collision situations. A-SMGCS is a work in progress, with three separate programs being [conducted] by ICAO, Eurocontrol and the European Commission. While all of the airports surveyed were familiar with the A-SMGCS program, there were no definite plans for its implementation."

ATC Procedures Comply With ICAO Standards With Varied Implementations

The FAA report said that the handling of airport-surface traffic generally complied with the ICAO standards and recommended practices (SARPs) in aircraft-separation minimums and phraseology. Differences among the airports primarily involved the division of responsibility and the method of implementing SARPs. While some airports assigned to ground control the responsibility for all movement areas except the runway, other airports assigned responsibility by airport area and used different runway-crossing methodologies, the report said.

"For active runway crossings at Brussels and Heathrow, the ground controller [tells the pilot to taxi] an aircraft up to the runway and instructs [the pilot] to hold short and contact local control. The local controller then [instructs the pilots of the aircraft on this frequency to cross the runway] and instructs the [pilots] to contact ground control again. Heathrow also [has] two lighting-control positions that fall under the ground controller's responsibility. The lighting controller monitors ground control and, based on the ground-control instructions, activates the appropriate taxiway stop bars and centerline lights to guide aircraft.

"At Charles de Gaulle, the local controller [has responsibility for] all taxiways within 150 meters [492 feet] of the runway in a type of 'zone' area of responsibility," the report said. "Oslo designates certain taxiways to the local controller to reduce frequency changes in the vicinity of the runway. Oslo is also very specific in its inactive-runway procedures. FAA and ICAO procedures allow an aircraft to cross a runway between its present position and its assigned clearance position. At Oslo, an aircraft is always instructed to either cross or hold short of the inactive runway in its taxi instructions. At Munich, local and ground control [personnel] coordinate who will handle taxiing arrival aircraft on a shift-by-shift basis."

The report said that most European nations, including the six airports surveyed, strictly comply with ICAO SARPs covering ATC procedures and airport visual aids. Nevertheless, vehicle operations varied among the airports.

"At Heathrow Airport, movement areas are divided into about 500 blocks of differing sizes, with the smallest block able to hold a Boeing 747-400," the report said. "Runways also contain blocks. At a runway hold-short position, the hold-short line will have a taxiway block on one side and a runway block on the other side. Ground control will instruct an aircraft to stop in a block, as in 'hold short of runway 27L in block 67 (which is a taxiway block).' [As a safety precaution, ground controllers avoid referring to] the adjacent runway block … [or] taxiway blocks that are adjacent to runway blocks, as in 'cross Runway 27L in block 68 (which is a runway block).'"

The block system is used in conjunction with Heathrow's low-visibility procedures, so that aircraft are moved with a prescribed number of blocks between them. Heathrow is the only airport in Europe that uses this system and “was under pressure to discontinue the block system and use the ICAO taxiway lettering, marking and signage standards,” said the report.

All six airports had implemented specific procedures for low-visibility conditions. Memory-jogging devices such as ticking alarms or flashing lights, for example, were used by some airports to indicate runway crossings in progress or the temporary use of a normally inactive runway.

The report said, “Signs, pavement markings and lights were [in compliance] or soon to be in compliance with the ICAO standard. Red stop bars and associated green taxiway centerline lights were also planned or in place at all of the airports except Schiphol, which only uses stop bars. Runway stop bars were usually controlled by the ground controller. Heathrow, which uses the block system of taxiing, has stop bars between each block. This gives Heathrow an approximate total of 500 stop bars [and] two lighting-control positions for purposes of controlling these stop bars (all except runway stop bars) and the associated green taxiway centerline lights.

“Stop bars were usually individually controlled and were both manual and automatic, with some using sensors, timers, radar or in-ground induction loops for automatic reactivation. Depending on runway flow configuration, some of the stop bars could not be deactivated for purposes of preventing errant surface movements. Specific times of stop-bar activation varied, with Heathrow using them most often, including [during] nighttime. All of the airports used their stop bars in low-visibility [conditions].”

The report said that the effectiveness of stop bars at these airports depends on consistent procedures and backup plans for malfunctions.

“The importance placed upon stop bars by both pilots and controllers was evident,” the report said. “Each of the airports surveyed [said,] ‘you never cross an illuminated stop bar’ and [said that their] stop bars [sometimes] were ‘stuck’ in the illuminated position. At Brussels, [the] stop-bar system does not allow for individual deactivation, and controllers are hesitant to deactivate multiple stop bars to allow a runway crossing [the airport plans to modernize the system]. Pilots at Brussels, however … refuse to cross the stop bar if instructed to do so by ATC. … At Oslo, a recent lightning strike left some of the stop bars in the ‘failsafe’ mode, which provides continuous illumination. While in need of those particular runway entrances and knowing that the pilots would refuse to cross the stop bars, [Oslo controllers directed] maintenance personnel to remove the stop-bar light bulbs. In Munich, when ATC needs … a pilot [to] cross an illuminated stop bar, [controllers] must turn the brightness setting to ‘zero intensity,’ which makes the bar appear to be deactivated to the pilot.”

All of the airports, except Schiphol, use or plan to use green taxiway centerline lighting.

“Munich and Heathrow, for example, could illuminate an aircraft’s entire taxi route and could produce breaks in the lighting for multiple aircraft on the same route,” the report said.

Vehicular Traffic Operations Require Various Restrictions

The FAA report said that mandatory driver training and licensing was the primary common factor among the six airports in preventing runway incursions by airport ground vehicles.

“A differentiation was generally made between vehicles on maneuvering areas (ramps and aprons) and vehicles on movement areas (runways and taxiways),” the report said. “Ramp and apron control was either performed by ATC, a modified ATC or the airport authority, and vehicles had relatively free movement in these areas. Movement-area access and communication rules varied — with some airports allowing vehicles on all taxiways by just monitoring [them] and other airports using more specific approval-and-communication procedures, including a dedicated vehicle frequency. Where [possible,] maximum use of airport roads was made to limit the number and frequency of vehicles on the movement area.”

Methods of conducting vehicle crossing of a runway varied from direct instructions by ground control to complex coordination networks, the report said.

“At Schiphol, a vehicle communicated with the airport authority on a separate frequency and requested a crossing,” the report said. “The airport authority then contacted the assistant local controller who, in turn, coordinated with the local controller for the crossing. Upon approval, the local controller activated a traffic light that changed from red to green to signify the approval. This system was considered too coordination-intensive, however, and plans are to replace the traffic lights with stop bars and to develop new crossing procedures.”

Procedures for airport operations in low-visibility conditions typically limited the operations of ground vehicles.

“Special restrictions [on vehicles] included Munich’s [policy of] no automatic taxiway crossings in Category III conditions [of visibility in which an instrument-landing-system approach and landing is conducted with a controlling runway visual range of 700 feet (213 meters) or less],” the report said. “Munich also displayed a continuous low-visibility warning on 100 monitors throughout the apron environment that let vehicle drivers know of the restricted conditions. At Oslo, two vehicle sentries were posted at the intersection of a busy ramp and taxiway to manually

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Model Forecasts Three Fatal U.S. Jet Aircraft Runway Collisions in 2003–2022

Arnold Barnett, Ph.D., a professor at the Massachusetts Institute of Technology (U.S.), said that a mathematical model based on recent data shows that 15 fatal runway collisions theoretically could occur from 2003 to 2022 in the United States — including three runway collisions in which one airline passenger jet collides with another airline passenger jet — causing 700–800 deaths and serious injuries to 200 aircraft occupants.[1] This scenario would be a 90 percent increase in the rate of fatal runway collisions compared to the 1990s, Barnett said. The estimated runway-collision death risk per flight for the period is one chance in 25 million on airline flights in the United States, he said.

Barnett said that the model considered U.S. data and worldwide data to prepare a "status quo" forecast, a projection based on no change in current methods of preventing runway collisions involving jets conducting passenger flights.

The model also showed that on a per-hour basis, haze and fog increased the risk of a runway-collision accident by an approximate factor of 12.

"Operations are substantially reduced during conditions of haze and fog so that a factor of 12 indicates that these are very dangerous conditions, and airports prone to such conditions may be at higher risk than airports at which these conditions are almost unknown," he said.

"Runway collisions could cause more U.S. domestic jet deaths over the next two decades than all other causes combined," Barnett said. "I am not saying that this definitely is the case, but comparing this forecast of 40 runway-collision deaths annually on average with recent airline fatalities from all accident causes, preventing runway collisions is quite reasonably the number one priority in terms of aviation safety in the United States. I thought at one time that people were 'crying wolf' [that is, overestimating the true risk of harm in runway incursions], but this may be the number one hazard. I believe these forecasts are valuable as a baseline level of risk, which we can compare with what actually happens to get a sense of how much progress we have made."

Barnett said that the forecast was developed to gain insight into the following questions:

- What kind of runway-collision problems are airlines facing in 2003–2022 in the United States?
- How great is the threat for U.S. domestic airports during this period?

Although such questions are difficult to answer, many U.S. data sets provided useful clues for assessing the frequency of runway incursions and collisions, Barnett said. Worldwide data were used to study the potential consequences of runway collisions involving transport category aircraft. He said that these consequences were considered to be independent of local factors and were applicable to U.S. forecasts.

The forecast calculations about future jet-to-jet runway collisions used the following data from the three such collisions that have occurred since 1970:

- In an accident at Tenerife, Canary Islands, Spain, 100 percent of occupants on one aircraft were killed and 76 percent of occupants on the other aircraft were killed, yielding a fatality proportion of 88 percent for both aircraft;[2]
- In an accident at Madrid, Spain, 100 percent of occupants on one aircraft were killed and 55 percent of passengers on the other aircraft were killed, yielding a fatality proportion of 69 percent for both aircraft; and,[3]
- In an accident at Detroit, Michigan, U.S., 19 percent of occupants on one aircraft were killed and no occupants were killed on the other aircraft, yielding a fatality proportion of 4 percent for both aircraft.[4]

The overall mortality rates were 58 percent of passengers based on the full capacity of these aircraft and 72 percent of passengers aboard these aircraft in the accidents.

"Fifty-eight percent was a reasonable estimate of the average proportion of passengers killed in future fatal jet-to-jet runway accidents," Barnett said. "For our first approximation, we also theorized that the risk of a runway accident would vary with the square of the annual number of operations [an n-squared hypothesis]. We were able to test this hypothesis against the empirical evidence."

The U.S. Federal Aviation Administration (FAA) analyzed information from 292 runway incursions that occurred in the United States in 1997 and classified each runway incursion for its accident potential. Although no runway-collision accidents occurred in 1997, some runway incursions were judged to be types that could have led to accidents involving high loss of life.

"Experts told us that not all runway incursions are equal," Barnett said. "They have said many are not really life-threatening; some of them are life-threatening. Just looking at the total group of 1997 runway incursions would have provided an imperfect indication of what is really happening in terms of the safety profile. We focused on the events that experts thought were the most ominous to test the n-squared hypothesis."

Barnett said that he and others focused on 40 of the runway incursions that were identified by FAA specialists as having "extremely high accident potential" and which occurred under conditions of reduced visibility (night, sunrise, sunset, haze or fog), he said. The distribution of these incursions among airports was used to test statistically whether or not risk varied with the square of the annual number of operations.

"It seemed that there was a concentration of the ominous events at the busier airports," said Barnett. "The n-squared hypothesis passed a stringent statistical test of data from these 40 runway incursions with flying colors." Alternative hypotheses proposed for a mathematical model — for example, that risk varied with the cube of the annual number of operations — failed the statistical test.

"The concentration of accidents toward the busier airports was too great to sustain the notion that the rate per thousand operations was the same everywhere," he said. "There were too many accidents at the busier airports, too few at the relatively sparse ones."

The forecast used projections of traffic growth and trends in meteorological data.

Barnett said, "This forecast is only a first approximation. Let me stress that these are midrange estimates, based on average values for variables. Clearly, the number is subject to errors from enormous statistical volatility."

Despite the risk shown by the mathematical model, Barnett said that he does not believe that the forecasted accidents actually will occur.

"Recognizing the problem is half way to solving it," Barnett said. "We want the forecast of 15 accidents to be a 'self-destructing prophecy.' We should remember solving the problem of thunderstorm-induced wind shear, in which five major accidents occurred in a little over a decade. Time and time again, mortal hazards to aviation have been rendered harmless by the progress of people in the industry."

Barnett said that the forecast used only reported runway incursions and that other research is needed to determine whether unreported occurrences are among the most serious, or the least serious, in their influence on runway-collision forecasting.♦

— FSF Editorial Staff

[Editorial Note — Arnold Barnett, Ph.D., is George Eastman professor of management science at the Massachusetts Institute of Technology (MIT) Sloan School of Management. His specialty is applied mathematical modeling in issues of policy importance. He has worked for 11 airlines, five airports and the U.S. Federal Aviation Administration (FAA). Barnett recently assisted FAA in conducting a safety-risk assessment to identify 25 U.S. airports scheduled to receive Airport Surface Detection Equipment Model X (ASDE-X), which combines ground-surveillance radar and software that alerts air traffic controllers to impending collisions on or near runways. ASDE-X has been designed for airports other than the nation's busiest and most complex airports. Airport Surface Detection Equipment Model 3 (ASDE-3) ground radar has been installed at 34 of the busiest U.S. airports, and FAA said that a collision-alerting computer enhancement — called Airport Movement Area Safety System (AMASS) — is scheduled to be operational at these airports by late 2002 after several delays.]

Notes

1. Barnett, Arnold. "How Great Is the Danger on the Runway?" Speech delivered during the Runway Safety National Summit, a conference in Washington, D.C., U.S., sponsored by the U.S. Federal Aviation Administration. June 28, 2000.

2. Airclaims said that during takeoff on March 27, 1977, a KLM Royal Dutch Airlines Boeing 747-200B struck a Pan American World Airways Boeing 747 being taxied at Los Rodeos Airport, Tenerife, Canary Islands, Spain. All 14 crewmembers and 234 passengers on the KLM aircraft were killed. On the Pan American aircraft, nine crewmembers and 326 passengers were killed, seven crewmembers and 52 passengers were seriously injured, and two passengers received minor injuries or no injuries. Both aircraft were destroyed. Visibility at the time of the accident was poor with fog and light rain. The Subsecretaria de Aviación Civil of Spain said that the cause of the accident was that the KLM captain conducted the takeoff without clearance, did not obey a "standby for takeoff" instruction from the control tower and did not reject the takeoff when the Pan American flight crew said that their aircraft was on the runway. Misunderstanding of orders and instructions, low ceiling and fog were contributing factors.

3. Airclaims said that on July 12, 1983, an Iberia Airlines Boeing 727-200 Advanced (B-727) was destroyed when the aircraft collided during takeoff with an Aviaco McDonnell Douglas DC-9, which had taxied onto the active runway at Barajas Airport, Madrid, Spain. One of nine crewmembers and 50 of 84 passengers were killed on the B-727. All five crewmembers and 37 passengers were killed on the DC-9, which also was destroyed.

4. The U.S. National Transportation Safety Board (NTSB) said that on December 3, 1990, Northwest Airlines Flight 1482, a McDonnell Douglas DC-9, and Northwest Airlines Flight 299, a Boeing 727 (B-727), collided near the intersection of Runways 09/27 and 03C/21C in dense fog at Detroit Metropolitan/Wayne County Airport, Romulus, Michigan, U.S. At the time of the collision, the B-727 was on its takeoff roll, and the DC-9 had just taxied onto the active runway. Eight of the 39 passengers and four crewmembers aboard the DC-9 received fatal injuries. None of the 146 passengers and 10 crewmembers aboard the B-727 was injured. NTSB, in its final report, said that the probable cause of the accident was "a lack of proper crew coordination, including a virtual reversal of roles by the DC-9 pilots, which led to their failure to stop taxiing their airplane and alert the ground controller of their positional uncertainty in a timely manner before and after intruding onto the active runway." Contributing to the cause of the accident were: "(1) deficiencies in the air traffic control services provided by the Detroit Tower, including failure of the ground controller to take timely action to alert the local controller to the possible runway collision, inadequate visibility observations, failure to use

progressive-taxi instructions in low-visibility conditions, and issuance of inappropriate and confusing taxi instructions, compounded by inadequate backup supervision for the level of experience of the staff on duty; (2) deficiencies in the surface markings, signage and lighting at the airport and the failure of [U.S.] Federal Aviation Administration surveillance to detect or correct any of these deficiencies; and (3) failure of Northwest Airlines to provide adequate cockpit resource management training to their line aircrews."

coordinate vehicles that [might] cross the path of [an] inbound aircraft. Charles de Gaulle Airport employs an ultra-high-frequency (UHF) vehicle-tracking system … that produces a labeled target on an airport-layout display in the tower cab. These UHF vehicles are equipped with a moving map that shows the [driver's] present location. In addition, there is an aural alarm that alerts the driver if the vehicle is within 150 meters of a runway or other predefined critical area. Oslo maintains a strict policy of vehicle procedure monitoring and enforcement. When the [airport] opened two years ago, a special 24-hour vehicle-security patrol was activated. … The patrol now only operates during normal business hours."

Airport Solutions Consider Human Factors Issues

The FAA report contained two examples of simple solutions to recurrent problems involving human factors. The Brussels airport had implemented a policy on airport construction requiring unobstructed line-of-sight for air traffic controllers. Heathrow officials, after three separate surface incidents at the same taxiway location, removed excessive and confusing pavement and improved the related signs and markings, the report said.

"Phraseology was an especially noted topic [during the survey]," the report said. "At Heathrow, the word 'cleared' is never used in conjunction with a runway crossing. This ensures that an aircraft will not mistakenly [begin] a departure roll with [another aircraft or vehicle] about to cross the runway. Heathrow also uses the word 'cross' only in conjunction with a runway crossing. At Munich [which has four different intersection-departure points for each runway] ATC is moving away from the ICAO-allowed conditional clearance, 'behind the landing [Boeing 737], line up and wait."… In Oslo, taxi clearance includes whether an aircraft should hold short of [the inactive runway] or cross the inactive runway. This type of 'pilot conditioning' [prompts pilots to] ask again if they are not sure."

Nasiatka said, "Most airports in Europe comply with ICAO SARPs [Annex 14, *Aerodrome Design and Operation*] to provide uniform airport signs and markings, and all other airports are moving toward full compliance."

The European airports also had incorporated special publications and information into their runway-safety programs, and most of the airports had published taxi routes, the report said.

"Munich [controllers] read each separate taxiway to all pilots," the report said. "Charles de Gaulle has an airport publication that showed expected taxi flows and indicated rights of way for particular taxiways."

The report said that the following preventive measures — in use by some or all of the airports surveyed — address breakdown of communication and disorientation of flight crews and vehicle drivers:

- "Defined responsibilities for ATC personnel;
- "Defined crossing procedures;
- "Flow-sensitive taxi routes;
- "Published taxi routes;
- "Published right-of-way instructions;
- "Clear and concise phraseology;
- "Specific usage of [the ATC instructions] 'cleared' and 'cross';
- "Clear and concise automated terminal information service broadcasts;
- "Full readback of taxi clearances;
- "Full readback of crossing clearances;
- "Elimination of assumed-inactive runway crossings;
- "Elimination of combined taxi [clearances] and crossing clearances;
- "Mandatory [procedure to] hold short of all runways;
- "Line-of-sight considerations [addressed in airport-construction policy];
- "Removal of excessive or confusing pavement;
- "Consistent and standard signs and markings;
- "Stop bars at all access points;

- "Stop bars at taxiway-conflict points;
- "Continuous stop-bar usage;
- "Automatic stop-bar reactivation;
- "Taxiway centerline guidance;
- "Training and licensing of vehicle drivers;
- "Enforcement of vehicle[-operating] procedures;
- "Clearly defined vehicular areas;
- "Restriction of vehicles on the movement area; and,
- "Video support for [viewing from the control tower the nonvisible] areas of [airports]."

Douglas Wiegmann, assistant professor of aviation human factors at the University of Illinois, U.S., said that runway-safety researchers believe there is a need for comparison of airports using standardized data collection and analysis procedures in strategies for preventing runway incursions.[12]

"[U.S.] data now being collected are not useful for analysis using the Human Factors Analysis and Classification System," Wiegmann said. "We should establish a universal database that provides a user-friendly, accessible repository for existing data [from runway incursions and related incidents]. Human factors data now are very narrow in scope and need to be restructured to address areas that are not yet fully examined, such as any commonality in airports with critical problems."

FAA's Nasiatka said that, ultimately, a harmonized worldwide system is needed.

"Rather than be so nationally focused in ATM safety, European airports should see if they are having the same runway-safety problems and what is being done to solve them," Nasiatka said.

Such a system should identify unsafe patterns developing in runway incursions and other ATM-related safety occurrences, he said. This could be done in a manner similar to the tracking of abnormal flight occurrences and mechanical occurrences worldwide for the benefit of aircraft operators and maintenance technicians, he said.♦

Notes and References

1. The following comparisons of Europe with the United States were among those presented during the Runway Safety National Summit conducted by the U.S. Federal Aviation Administration (FAA) June 26–28, 2000, in Washington, D.C., U.S. Raja Parasuraman, Ph.D., director of the cognitive science laboratory at Catholic University of America (U.S.), said that five recommendations of a regional human factors workshop included one to implement an automated command-light system (stop bars), such as that used by London Heathrow Airport, "to reduce confusion about runway status and to reduce frequency congestion." Kim Cardosi, Ph.D., manager of the air traffic control (ATC) human factors program at the Volpe National Transportation Systems Center (U.S.), said that the United States is "a little behind Europe" in the implementation of communication technology to address the "present serious threat of blocked or partially blocked [radio] transmissions" in controlling airport surface movements. Jerry Wright, manager of security and human performance for the Air Line Pilots Association, International, said, "We are lagging airports in Europe … [in implementing technologies such as] air traffic control [surface-]surveillance systems with conflict alerts … [and] data-linked transmission of ground-movement routes and clearances."

2. Marchi, Richard. Presentation to the FAA Runway Safety National Summit, Washington, D.C., U.S. June 27, 2000.

3. The goals of the *1998 FAA Strategic Plan* are to reduce by 2007 U.S. aviation fatal accident rates by 80 percent from 1996 levels. The goals include reducing, by 2007, the U.S. aviation fatal accident rate per aircraft departures, as measured by a year moving average, by 80 percent from the year average for 1994–1996; reducing the overall aircraft accident rate per aircraft departures; reducing the number and type of fatalities and losses from accidents that occur for each major type of accident; and reducing the risk of mortality to a passenger or flight crewmember on a typical flight. FAA Runway Safety Program. "Ten Initiatives for Reducing Runway Incursions." August 1, 2000.

4. Stuart Matthews, chairman, president and CEO of Flight Safety Foundation, is the Foundation's primary representative to the FAA Commercial Aviation Safety Team (CAST). James Burin, director of technical programs, is the Foundation's alternate representative to CAST.

5. Eurocontrol has charge of air traffic management in the upper airspace of Belgium, Luxembourg, Netherlands and part of Germany — providing services through a multinational team of air traffic controllers who work at the Upper Area Control Centre at Maastricht, Netherlands. The division between upper airspace and lower airspace in Europe, in general, is at Flight Level 245 (24,500 feet), but in some areas the division is at Flight Level 195 (19,500 feet). This basic division provides a practical method of managing controller workload by applying operating conditions to air traffic, such as prohibition of visual-flight-rules operations or the use of area-type control versus airway-type control. The agency also oversees the air traffic services providers responsible for the lower airspace of these nations. The following 29

nations are members of Eurocontrol: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, the former Yugoslav Republic of Macedonia, Malta, Moldova, Monaco, Netherlands, Norway, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom. The database that will serve as an international repository of incident data — known as the European Coordination Center for Aircraft Incident Reporting Systems (ECCAIRS) — is a project of the European Union.

6. Garnier, Jean-Luc. E-mail communication with Rosenkrans, Wayne. Alexandria, Virginia, U.S., August 1, 2000. Flight Safety Foundation, Alexandria, Virginia, U.S.

7. Le Galo, Gilles. E-mail communication with Rosenkrans, Wayne. Alexandria, Virginia, U.S., August 1, 2000. Flight Safety Foundation, Alexandria, Virginia, U.S. Airclaims said that on May 25, 2000, an Air Liberte McDonnell Douglas MD-83 collided with a Streamline Shorts 330 during the MD-83's takeoff roll at Charles de Gaulle Airport, Paris, France. One crewmember was killed and one crewmember received serious injuries on the Shorts 330, which was destroyed. No injuries occurred on the MD-83, which was substantially damaged. The report said that while the MD-83 was accelerating on the takeoff roll on Runway 27, the aircraft's left wing struck the cockpit and forward-fuselage areas of the Shorts 330. The Shorts 330 apparently had begun to enter Runway 27 at a taxiway intersection, located about halfway down the runway, while being taxied for departure, Airclaims said. The accident occurred in darkness.

8. Chagnon, Denis. Telephone interview by Rosenkrans, Wayne. Alexandria, Virginia, U.S., July 31, 2000. Flight Safety Foundation, Alexandria, Virginia, U.S.

9. Peduzzi, Lauren. Telephone communication with Rosenkrans, Wayne. Alexandria, Virginia, U.S., August 14, 2000. Flight Safety Foundation, Alexandria, Virginia, U.S.

10. Fee, Joseph; Nasiatka, James. Telephone interview by Rosenkrans, Wayne. Alexandria, Virginia, U.S., July 20, 2000. Flight Safety Foundation, Alexandria, Virginia, U.S.

11. Fee, Joseph; Nasiatka, James. "Runway Incursion Prevention in Europe: Surface Movement Technology and Operations." FAA, June 9, 2000.

12. Wiegmann, Douglas. Presentation to the FAA Runway Safety National Summit, Washington, D.C., U.S. June 27, 2000.

Further Reading From FSF Publications

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

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