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Action Must Be Taken to Further Reduce the Current Accident Rate as the Transport Fleet Increases in Size and Operation

Key issues that influence safety have been identified by The Boeing Company, which urges the aviation industry — manufacturers, regulators and operators — to take action to make improvements that will prevent accidents and ensure continued public confidence in flying.

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Commercial jet transportation will complete 33 years of service in 1992. Large commercial jets have logged more than 243 million flights and more than 361 million flight hours in worldwide operations. Today, the jet transport delivers its payloads dependably and safely throughout the world in a manner never envisioned by aviation pioneers.

Three areas of major significance to commercial jet aviation safety are identified below:

- Accident Statistics — Statistics show vast improvement during past years, but safety still calls for attention;

- Fifteen-year Projection — Projections of future operations predict continued growth in the industry with continued improvement in accident rate trends. Nonetheless, there are predictable offsetting influences on future accident counts; and,

- Safety Issues — Initiatives call for improvements using currently available technology in areas that offer high potential for accident prevention, distinct from crashworthiness.

Statistics Show Relatively Constant Hull-loss Accident Rates

The total loss of an airplane occurs in nearly 90 percent of all fatal accidents. Detailed investigations of these hull-loss accidents provide credible data for analysis.

Figure 1 (page 2) shows the commercial jet fleet (jet aircraft of 60,000 pounds gross weight or greater) hull-

Hull-loss Accidents for Worldwide Commercial Jet Fleet (1959 through 1990)

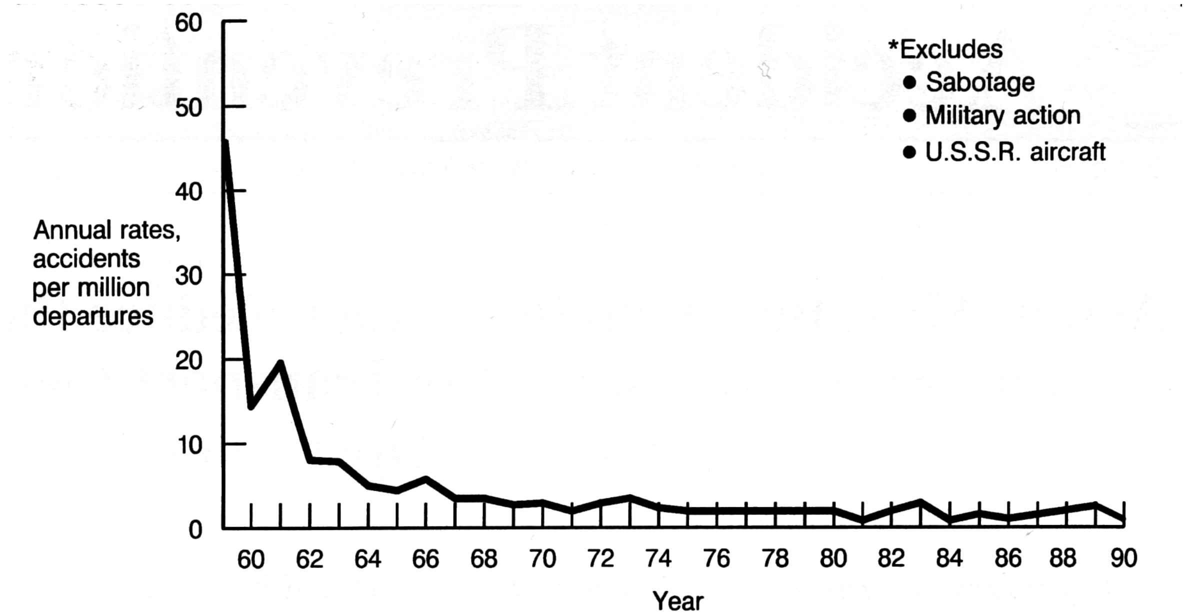

Figure 1

loss accident rates from worldwide operations between 1959 and 1990. The trend shows that during the last 15 years the overall accident rate has been relatively constant at about 1.5 accidents for every million flights.

The trend of fatal accidents is similar to hull losses. The annual number of fatalities, as shown in the bottom of Figure 2 (below), grew between 1960 and 1975 and leveled near 600 per year.

Traffic Increase Alone Will Boost Accident Numbers

The accident rate trend per million flights has declined in recent years, and is expected to continue to fall. How-

Fatal Accidents for Worldwide Commercial Jet Fleet (1959 through 1990)

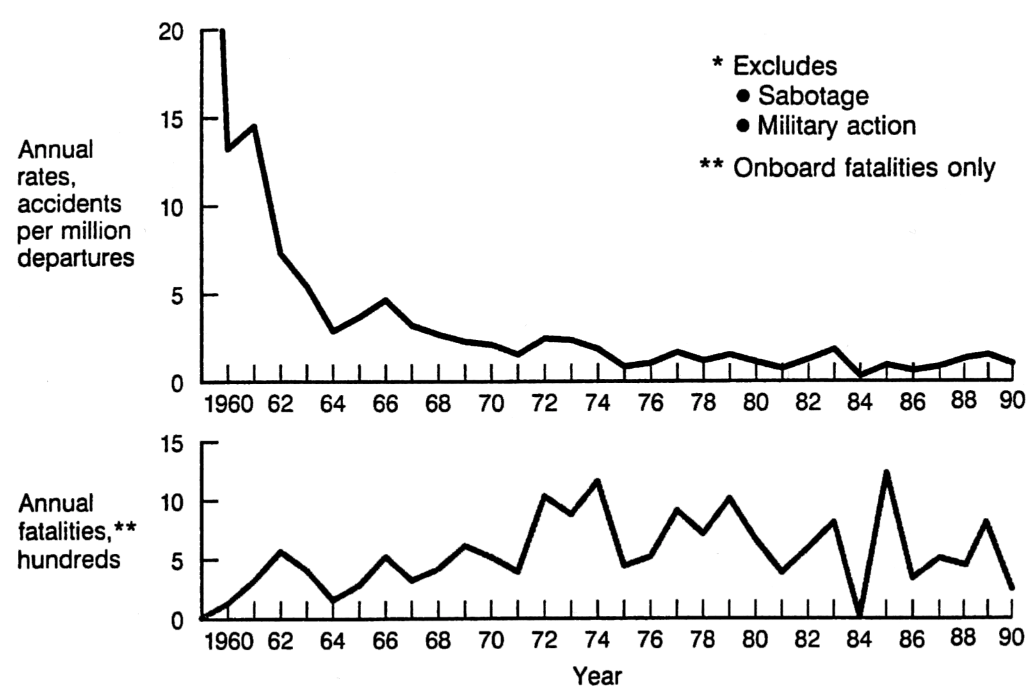

Figure 2

ever, the number of aircraft and annual departures for worldwide jet airline fleets is expected to continue increasing into the next decade. Even if the accident rate continues its gradual decline during the next 15 years, we could encounter five more accidents per year by 2005.

Figure 3 (below) explains the apparent discrepancy. The left side shows hull loss accidents per million departures between 1980 and 1990. The right side shows the decline in the projected composite fleet average accident rate. It reflects some replacement of older planes with newer, high technology models. This projection is represented by the upper dashed line on the right half of Figure 3. To keep the accident count from increasing as indicated, this accident rate must be decreased by the amount shown by the lower dashed line. In percentages, this is no small task.

Figure 4 (page 4) is a profile of a typical jet flight showing percentages of accidents occurring in each phase of flight. It also depicts the exposure of each phase in percentage of total flight time. Two-thirds of all hull-loss accidents occur during takeoff, initial climb, final approach and landing. This exposure represents only six minutes of a total flight time of 100 minutes.

Jet Fleet Generations Marked By Improvements

The modern jet transportation industry started serious growth when the Comet IV entered service, and it was joined by the Boeing 707 and DC-8 in the first generation of the commercial jet fleet. Flight operations in airplanes powered by reciprocating engines were characterized by low landing speeds, short runway length requirements for takeoff and relatively benign stability and control characteristics in contrast with their early jet replacements.

Figure 5 (page 4) shows hull-loss accident rates of airplane types ranked according to the period in which they were developed. The high accident record of early jet entries could reflect the limitations of older technology applied to a new operating environment. Design, maintenance and operational changes on succeeding airplane generations further improved performance and safety records. The results are impressive. Today, designs have been refined, flight crews are better organized, simulators are more realistic and there have been significant improvements in airports, navigation aids and approach aids.

Figure 6 (page 5) shows the primary cause factors for hull-loss accidents since 1959. Investigative authorities have said that flight crew causes account for 70 percent to 77 percent of accidents. That ratio has remained fairly constant throughout the 30-year period.

But the “single primary cause” rating system of flight crew contribution to an accident does not recognize that contributing cause factors such as maintenance, air traf-

Hull-loss Accident Rate Statistical Projection through 2005

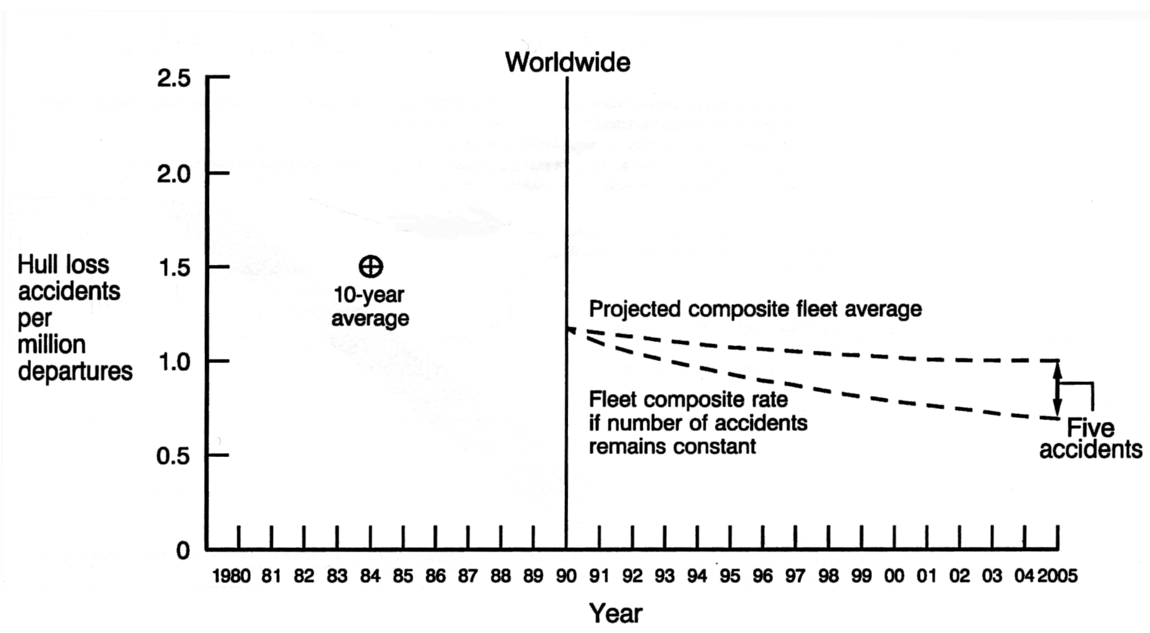

Figure 3

Hull-loss Accidents in Worldwide Commercial Jet Fleet (1981-1990)

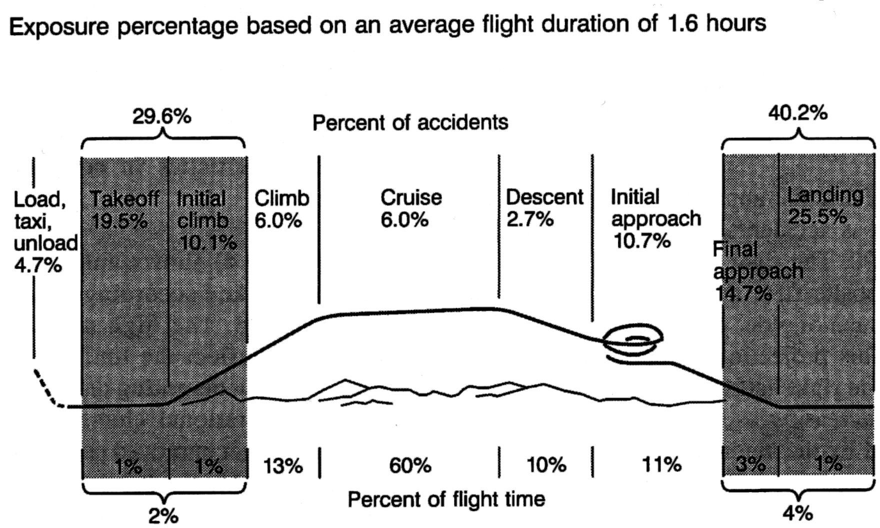

Figure 4

fic control and weather are often present before the accident occurs. In the chain of events leading to an accident, the crew is the final link influencing the outcome. The crew is usually identified as the primary cause factor when it fails to prevent an accident which, in the judgment of safety authorities, it should have prevented.

Safety Remains Paramount

The commercial jet transport accident rate during recent years has remained roughly within 1.5 to 2.0 accidents per million flights. Although these rates are significantly better than in earlier years, any rising accident count caused by the offsetting increase in departures will be perceived by the public as deteriorating safety performance. Action must be taken to improve in areas that offer great potential for accident prevention as opposed to excessive concentration on crashworthiness.

Key safety issues have been identified as follows:

Collision with Terrain

Collision-with-terrain accidents are commonly attributed to crew causes. They involve inadvertent controlled flight

Hull-loss Accident Rates for Worldwide Commercial Jet Fleet (1959 through 1990)

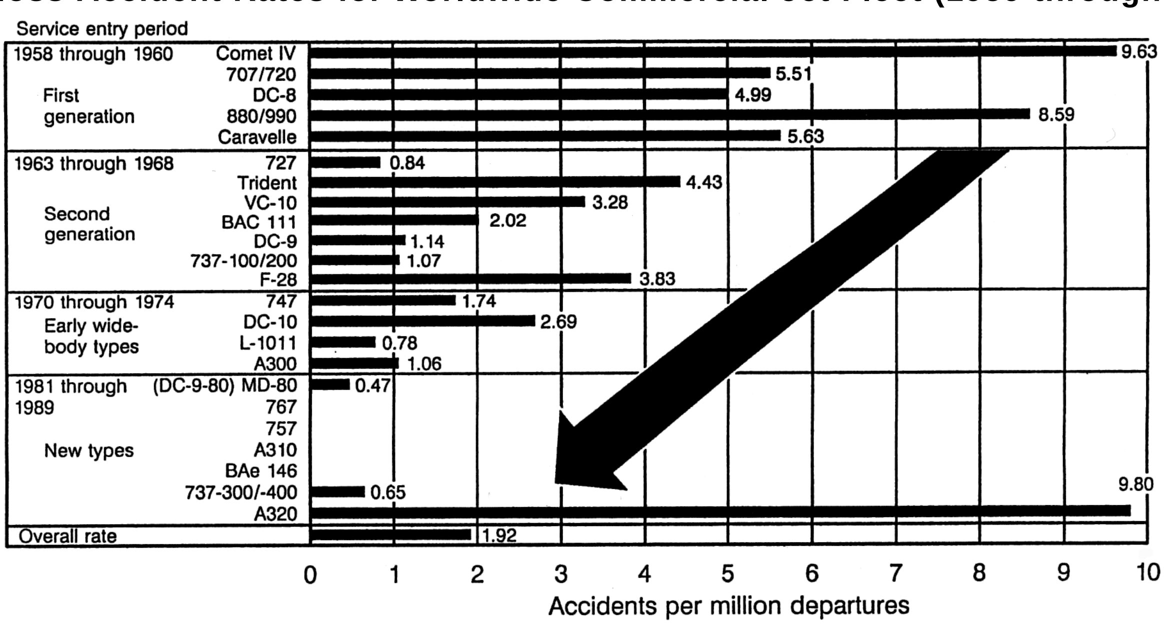

Figure 5

Primary Cause Factors for Hull-loss Accidents for Worldwide Commercial Jet Fleet (1959 through 1990)

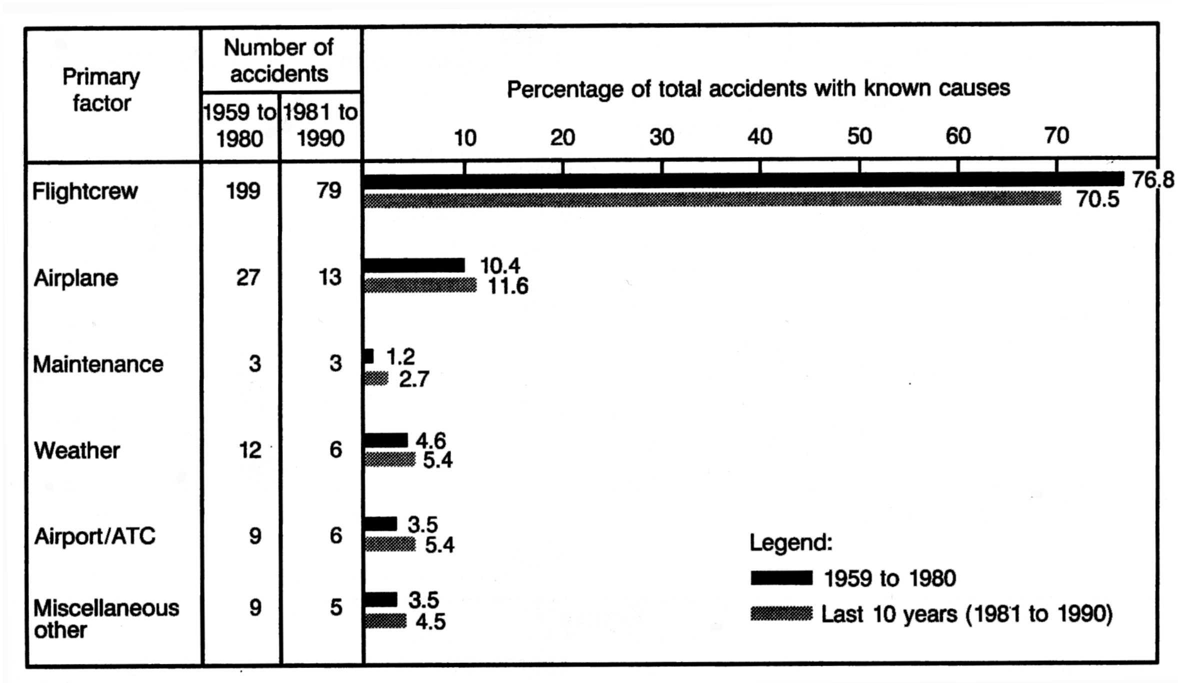

Figure 6

into the ground with impact occurring outside airport boundaries. The frequent outcome is a hull loss involving many fatalities. Contributing factors often include a navigational error, misreading of charts or simple distraction.

Seldom were the effects of a design change so strongly felt than in 1975 when the U.S. Federal Aviation Administration (FAA) ordered the installation of ground proximity warning systems (GPWS) in U.S. transport aircraft. As shown in Figure 7 (page 6), U.S. operators had been experiencing several terrain collision accidents each year until 1975. Accidents in that category then dropped to zero and stayed there until several recent events. Since 1975, collision-with-terrain accidents have tended to involve aircraft without an operating GPWS or crews who failed to heed GPWS alerts.

Interviews with flight crews provide insight about why GPWS has not been successful in eliminating collision-with-terrain accidents. Early versions of the equipment were prone to false warnings and pilots found them irritating. A common reaction was to troubleshoot the warnings and cross-check other cockpit instruments to further confirm the need for a pull-up response. Analysis of many accidents has confirmed that avoidance of a collision often requires initiation of a pull-up maneuver within a few seconds; there is no time for troubleshooting or for other assessments. Fortunately, early GPWS equipment designs have been improved to greatly reduce false warnings. Also, additional warning modes are available, particularly in relation to glide slope signals. Equipment improvements, available through retrofit, and implementation of pilot training to respond appropriately to GPWS alerts deserve top priority among safety initiatives. The following actions are recommended:

- Complete the worldwide installation of GPWS;
- Train pilots to ensure appropriate response to GPWS alerts; and,
- Update older ground proximity warning system installations to avoid nuisance alerts and to incorporate current warning modes.

Approach and Landing Accidents

Figure 8 (page 7) shows the kinds of landing accidents for one airplane type. It includes all accident damage categories. Forty-two of the 87 accidents occurred during approach and landing.

The first two (landing short on and off the airport) involve accidents in which the airplane was aligned with the runway on approach. These two categories, as well as hard landings and overruns, typically involve problems with vertical guidance or speed control. They can also result from a poor transition from instrument flight to

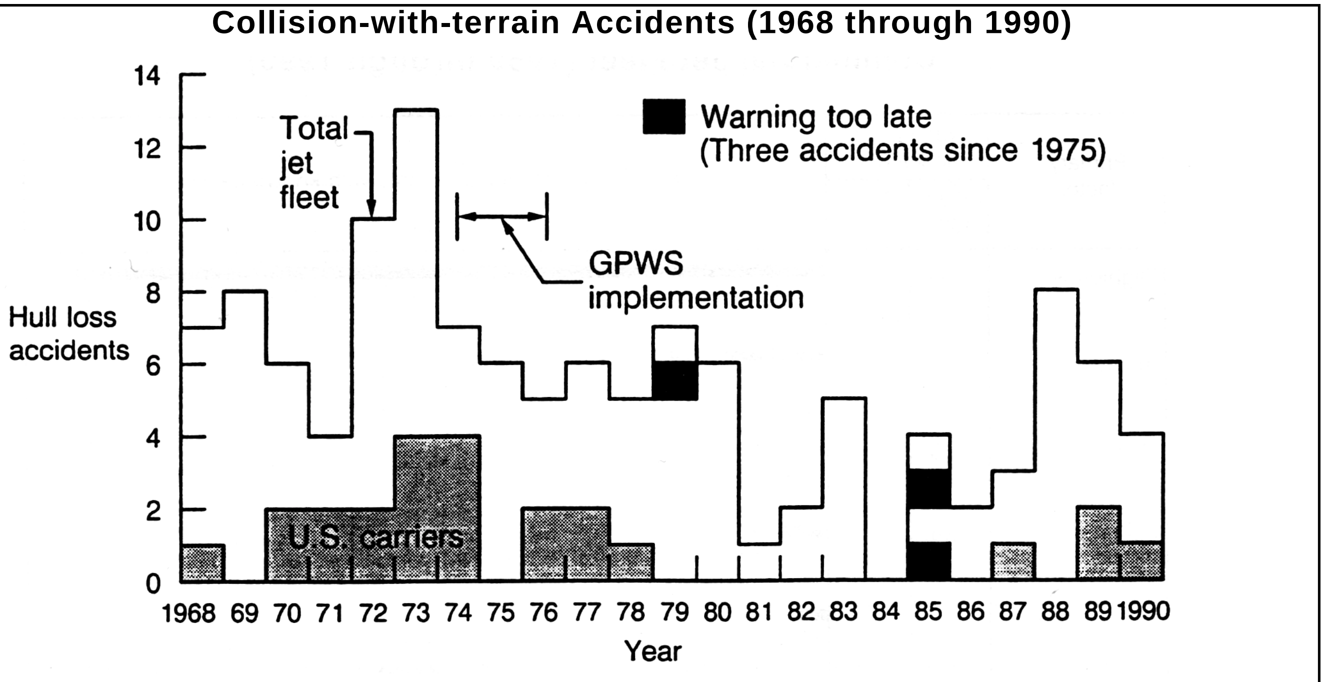

Figure 7

visual flight at or near approach minimums.

Approach and landing is the most critical phase of flight. It accounts for more than half of worldwide jet transport airplane accidents. Strong accident prevention resources should be directed to this area. The following actions are recommended:

- Every runway used by commercial jet transports should be equipped with precision glidepath information, such as an instrument landing system (ILS). ILS provides glide slope information through visual cues on a primary cockpit instrument and provides the vital glide slope information required by GPWS and automatic approach systems;

- Visual approach slope indicator (VASI) lights should be used to give the pilot a visual reference to the glide slope. Also, they are helpful in making the transition from instrument references to visual references on final approach. VASI is relatively inexpensive and belongs at the approach end of every runway; and,

- A judicious balance of automatic and manual landings will optimize safety and maintain pilot skills. No hull-loss accidents have resulted from a fully-coupled automatic landing.

Non-stabilized Approaches

Records of several approach and landing accidents show that these mishaps had their beginnings in non-stabilized approaches. The accident chain of events often starts with high, fast and close-in positioning. The pilot attempts to slow and configure the airplane for landing, but he or she is not able to stabilize airspeed and rate of descent before touchdown. The problem is particularly acute with modern airplanes if air traffic control (ATC) does not allow adequate descent distances for airplanes with lower drag characteristics.

A solution will require a combined effort by ATC, flight crews and airline management. The following actions are recommended:

- ATC procedures must assure positioning at the initial approach fix with ample time to configure the airplane before starting an approach;

- Controllers must be trained in the flight characteristics of various airplane types;

- Flight crew training must emphasize approach stabilization;

- Airline operators must define criteria for an acceptable, stabilized approach; and,

- Non-punitive airline policies must be established that mandate go-arounds for approaches not stabilized by 500 feet above ground level (AGL).

Go/No-go Takeoff Decision

The worldwide jet transport fleet experienced 67

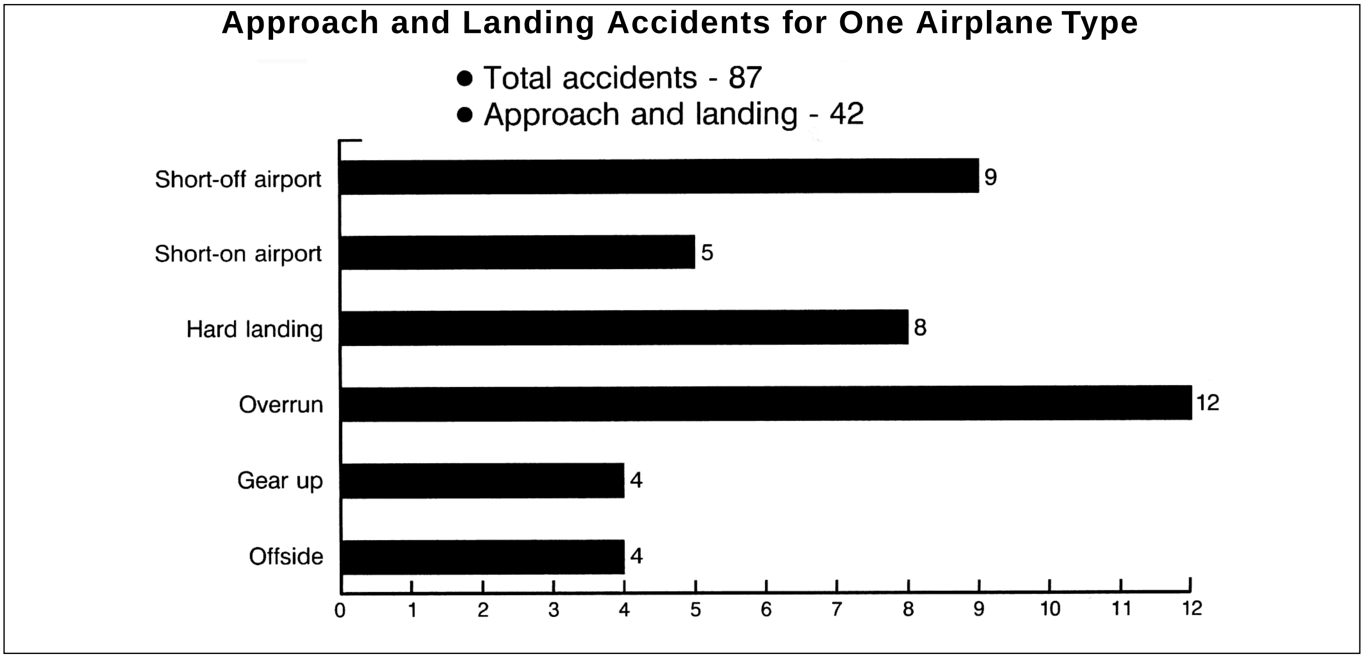

Figure 8

rejected takeoff (RTO) accidents through 1990. A go/no-go decision near V_1 is a rare event that occurs on average only once in 300,000 departures. A long-haul crew flying an 80-hour duty cycle, but making only eight flights a month, can expect to experience a critical RTO only once in 3,000 years.

Pilots are trained to properly stop an airplane on the ground. Also, they demonstrate their ability to do so during simulator checks. But about two-thirds of go/no-go decisions made during 67 RTO accidents were found to be incorrect.

Overall, go/no-go decision statistics are incomplete. We know about the events that failed, but much less is known about the successful events.

RTO accidents result from a variety of factors. Go/no-go choices are rare and too often incorrect. The reliability and correctness of decisions under the stressful circumstances of a go/no-go choice must be improved. The following actions are recommended:

- Set standards for high-speed refusals (U.S. and European regulators are at work on this);
- Establish consistent training and checking policies (U.S. and European regulators are at work on this); and,
- Develop realistic simulator exercises that replicate RTO accidents and stress realistic gross weights, tire and engine failures and engine vibrations.

Flight Data Recorder Monitoring

Flight data recorder monitoring, sometimes called operational quality assurance, is an effective flight safety tool. Digital flight data recorders (DFDR) provide considerable information for flight crew self-evaluation, flight operations and training departments.

Figure 9 (below) is an example of information that one airline collected during 2,100 flights. It shows 265 approaches in which pilots exceeded established parameters.

After analysis of the data, a standardization pilot can further investigate operational circumstances that lead to rushed approaches. He or she can then require corrective

Flight Data Recorder Monitoring Results of 265 Non-stabilized Approach

Number of nonstabilized approaches	Nonstabilized Parameters							
	Speed	Steep Approach	Flaps	Gear	Engines	Late Alignment	Shallow Approach	Low Speed
265	11 (4.2%)	130 (49.1%)	18 (6.8%)	—	152 (57.4%)	14 (5.3%)	99 (37.4%)	3 (1.1%)

Figure 9

training with emphasis on appropriate areas.

Flight data recorder monitoring is now in limited use. The system requires safeguards to prevent its punitive misuse. Its best use is to fix the system, fix the process and fix the procedure. To enhance the effectiveness of operational quality assurance, the following actions are recommended:

- All jet transport operators should adopt an operational quality assurance program;
- Monitoring and analysis techniques should be patterned after quality assurance programs already proven by experienced airlines; and,
- Managements and unions must cooperate to support a successful program.

The projected increase in the number of hull losses per year should not be accepted as inevitable. The trend can be reversed, but it will require the concerted efforts of the industry to be successful. This effort should make possible a level annual accident count with decreasing accident rates by the year 2005. ♦

Editor's Note

A 20-minute videotape version of this article is available to airline and corporate audiences. To obtain a copy of the video, contact Earl Weener: telephone (206) 234-9990, fax (206) 234-8162 or write to the author at The Boeing Company, P.O. Box 3707, M/8 6R-PJ, Seattle, WA 98124, U.S.

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Earl F. Weener leads the reliability, maintainability and safety engineering functions at Boeing Commercial Airplane Group. He assesses airplane in-service experience, supports design for reliability and maintainability, analyzes accident trends and product safety to ensure proper safety considerations in Boeing airplane design and operation and promotes industry-wide safety actions. He has served in a variety of management positions at Boeing, including an assignment as manager of aviation affairs at the company's Washington, D.C., office, where he worked with government and industry groups on engineering and technical issues. Weener also helped supervise flight deck integration for Boeing 747 and 767 programs, including production program design and technical support.

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