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Facing the Runway Overrun Dilemma

If speeds and procedures are correct, an aircraft should be able to stop on the runway after a takeoff is abandoned. So what's the problem?

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Whether the event is called a rejected takeoff (RTO) or an aborted takeoff, there has been growing concern about runway overruns following an abandoned takeoff, the meaning given to V_1, the "go/no go" decision and cockpit procedures for executing an aborted takeoff.

The U.S. National Transportation Safety Board (NTSB) has made a number of recommendations to the U.S. Federal Aviation Administration (FAA); Boeing Commerial Airplane Group has concluded a study on RTO runway overruns; and Delta Air Lines has published a standard policy regarding the takeoff and go/no go decision. Each sheds some light on the subject, but the most appropriate corrective action begs further analysis and discussion.

NTSB Special Investigation Report

It is NTSB's contention that although most RTOs are initiated at low speeds (below 100 knots) and are executed without incident, the potential for an accident or incident following a high-speed RTO remains high. In 1988, according to the NTSB, three RTO-related accidents, two overseas and one in the United States, resulted in injuries to passengers and crew members, substantial damage to a Boeing 757 and a Boeing 747, and in the destruction of a McDonnell Douglas DC-10.

NTSB conducted a special investigation of RTO-related issues to determine how the safety of RTOs can be enhanced and how the rate of RTO-related accidents and incidents may be reduced.

The NTSB reported as follows:

Pilot Training in RTOs

Some airlines may be conveying misinformation or insufficient information to their pilots during training in RTO procedures and in aircraft stopping capabilities. Some of the misinformation may arise from the FAA's definition of V_1 in CFR 1.2 and 14 CFR 25.107(2).

Simulator Cues

Pilot training and checking sessions almost always present RTOs as V_1, engine failure-related maneuvers despite the fact that RTO-related accident and incident data indicated that tire failures lead to more high-speed RTOs than do engine-related problems. As a result, pilots may not be fully prepared to recognize cues of other problems during takeoff.

False or Noncritical Warnings

False or noncritical cockpit warnings have activated as an airplane was approaching or had reached V_1 and led to a high-speed RTO that resulted in an accident or incident. In response to the number of false warnings, manufacturers have incorporated into newer airplanes internal system logic that inhibits all but the most important warnings just before and just after takeoff rotation. However, most airline aircraft operating in revenue service today, and those that will operate in the near future, do not have such systems. Without changes in pilot training, pilots of older model aircraft may continue to initiate high-speed RTOs in response to warnings that may be false, noncritical, or both.

Takeoff Scenarios

Some airlines may be using takeoff scenarios in which a simulator can be stopped with runway distance remaining, even though the pilot's execution of the RTO may not be optimal. As a result, pilots may inadvertently learn that an aircraft can stop on a runway in a shorter distance than is possible under actual operating conditions.

Crew Coordination in Performing RTOs

In many of the RTO-related accidents and incidents, the first officer was the pilot flying. This suggests that a delay may have occurred when control of the airplane was transferred from the first officer to the captain, the crew member authorized by most airlines to initiate an RTO.

Callouts

Most airlines require callouts for engine or thrust settings and callouts for V_1, V_r and V_2. However, the NTSB found variation among airlines in the callouts required during takeoffs, particularly during rejected takeoffs.

Autobrakes

Many airplanes in service today have been equipped with braking systems known as autobrakes, which automatically establish wheel braking upon landing or upon a predetermined throttle reduction once past a certain speed during takeoff. However, not all airlines require autobrakes to be set to the RTO mode during takeoff.

The NTSB made the following recommendations to the FAA:

1. Redefine V_1 to clearly convey that it is the takeoff commitment speed and the maximum speed at which rejected takeoff action can be initiated to stop the airplane within the accelerate-stop distance.

2. Require principal operations inspectors (POIs) to review the accuracy of information on V_1 and rejected takeoffs that FAR Part 121 operators provide to flight crews to assure that they provide correct information about pilot actions required to maximize the stopping performance of an airplane during a high-speed rejected takeoff.

3. Require Federal Aviation Regulation (FAR) Part 121 operators to represent to flight crews the conditions upon which flight manual stopping performance is predicated, and to include information about those factors which adversely affect stopping performance.

4. Require that simulator training for flight crews present, to the extent possible, the cues and cockpit warnings of occurrences other than engine failures that have frequently resulted in high-speed rejected takeoffs.

5. Require that simulator training present accurately the stopping distance margin available for a rejected takeoff initiated near or at V_1 on runways where the distance equals or just exceeds balanced field conditions.

6. Require that simulator training emphasize crew coordination during rejected takeoffs, particularly those instances that require transfer of control from the first officer to the captain.

7. Require FAR Part 121 operators to review their policies which permit first officers to perform takeoffs on contaminated runways and runways that provide minimal rejected takeoff stopping distance margins, and encourage the operators to revise those policies as necessary.

8. Require that the takeoff procedures of FAR Part 121 operators are standardized among their aircraft types to the extent possible, and that the procedures include appropriate callouts to alert flight crew members clearly and unambiguously when the airplane is entering the high-speed takeoff regime and when a rejected takeoff is being initiated.

9. Require FAR Part 121 operators to require pilots to adopt a policy to use the maximum brake capability of autobrake systems, when installed on the aircraft, for all takeoffs in which runway conditions warrant and where minimum stopping distances are available following rejected takeoff.

Boeing RTO Overrun Study

Boeing recently concluded a rejected takeoff overrun and runway excursion study spanning the 29-year period from 1959 through 1988 and found that more than 80 percent of the events could have been prevented through either procedural changes or improved crew training.

Of the 69 events in the study, 41 were accidents and 28 were incidents. Most occurred in the latter half of the study period, an average of three per year, but because of the markedly higher number of departures in the last 15 or so years, the rate is one-half that of the first 15 years.

Propulsion anomalies and wheel-tire problems caused almost 51 percent of all rejected takeoffs. Most rejected takeoffs were initiated at speeds above V_1, which was the greatest cause of overruns, followed by degraded stopping capability. The majority of events occurred on dry runways.

_"V_1 is the end of the go/no go decision process, not the beginning. If you have not applied the brakes by the time you hear the V_1 call, you have made the go decision by default."_

The April-June, 1984, issue of the *Boeing Airliner* has this to say: "Typically at V_1, the airplane rate of acceleration is about three to five knots per second with all engines operating. For every second that passes before a decision to stop or go is made, the speed of the airplane is increasing by approximately three to five knots and approximately 225 feet of runway is used. If the problem that is necessitating a go/no go decision occurs on the low side but in the vicinity of V_1, the combination of high acceleration rate, the state of mind of the crew and the probability of a more complicated set of circumstances surrounding the decision than experienced in the simulator all tend to indicate that the airplane speed will be above V_1 by the time the failure is recognized and any real stopping procedures have been implemented.

"By being predisposed to stopping, adequate thought may be given to the meaning of V_1 or airplane performance characteristics. The FAA defines V_1 as the speed at which an engine failure has been recognized and *action* initiated to either *continue* or *stop* the takeoff. It is simply the speed at which a pilot changes his pre-planned response. The time to begin the decision making process is not at, or near, V_1.

"If we realistically look at the airplane acceleration rate around V_1, the state of mind of the crew, the fact that maximum effort braking stopping is hardly ever practiced in normal operations and the fact that clearing slightly less than 35 feet at the end of the runway is not nearly as detrimental as running off the end of the runway, one might come to a conclusion that on a runway-limited takeoff, the go decision may be better than the stop decision."

Delta Air Lines

The February 1990, issue of Delta's flight safety publication *Up Front* is titled "Takeoff Performance Edition" and contains two articles pertinent to this discussion.

The first is "Go/No Go Decision — or How Do You Handle Rejection" written by Capt. Howard A. Long and John Tocher. Their article delves into the definition of V_1 and its effect on line operations. The authors state: "V_1 had been defined, explained, redefined, and re-explained many times. The current FAR Part 1 definition is simple: 'V_1 means takeoff decision speed.'

"This definition implies, and pilots have usually assumed, that at V_1 they could choose between aborting or continuing the takeoff. In other words, V_1 has been associated with the *beginning* of the decision making process. Most pilots when asked would estimate that the allowable decision time is about 2 or 3 seconds."

The article repeats the *Boeing Airliner* discussion of V_1 and goes on to say:

"The meaning under this definition is that V_1 is the 'Engine Failure Reaction Speed,' meaning that no time is allowed after V_1 for reaction or decision. The critical point in the above quote is that the action must be initiated before V_1. Clearly, the decision to stop has to occur before V_1.

"To further cloud this issue, for many of us V_1 has lost this direct relationship only to engine failure and frequently is misunderstood to be 'Any Failure Decision Speed,' i.e., the speed that we can stop with any malfunction.

"Over the years, many of us have incorrectly become accustomed to thinking of V_1 as the point in time when the abort decision needs to be made.

"Let us consider a new but absolute correct definition of V_1: "V_1 is the Critical Engine Failure *Recognition* Speed. If an engine failure is *recognized* before V1, an abort can be made within the remaining runway. If an engine failure is *recognized* at or after V_1, the takeoff can be continued within the remaining takeoff distance.

"The next question is what really constitutes engine failure recognition? FAA Advisory Circular 25-7 (the Flight Test Guide for Certification of Transport Category airplanes) clearly shows that the pilot's activation of the first deceleration device indicates recognition of the engine failure.

"A decision to stop must be completed and maximum braking initiated at or before V_1 to assure a safe abort when you are at or near runway length limiting conditions.

"V_1 is the *end* of the go/no go decision process, not the beginning. If you have not applied the brakes by the time you hear the V_1 call, you have made the go decision by default."

Factors which affect the go/no go decision, according to the Delta article, included the following:

1. Decision Time. In the certification demonstration, the test pilots didn't need time to make a decision — they knew that they were going to abort before they started their takeoff roll.

   The line pilot, on the other hand, must first recognize the unexpected condition when it happens, evaluate its significance, decide on a course of action, and then execute the decision. During this period of time, at the normal acceleration of 3 to 5 knots per second, the aircraft could easily accelerate well past V_1, particularly if the malfunction occurred near the V_1 speed.

2. Braking Force. Tests have shown that the typical pilot neither recognizes maximum braking nor applies maximum braking force when called for in line operations (although he might believe that he has).

   Furthermore, this same pilot is likely to apply braking in the same order he applies them during a normal landing — that is, apply the brakes only after retarding the throttles and extending the speed brakes, thus delaying the braking action.

   The proper sequence for a rejected takeoff at V_1 is clearly different from a normal landing. Braking provides the primary stopping forces, followed by spoilers and reverse thrust.

3. Line-up Allowance. Runway allowable weights are computed based on the full runway length, with no provision for line-up. In actual fact, an average of 200 feet is normally used to line-up on the runway. Therefore, that concrete is not available for stopping purposes in the event of an abort.

4. Runway Surface. Certification tests are normally conducted on clean and dry concrete surfaces. Very few of the runways in our normal line operations are perfectly clean concrete with no moisture, dirt, oil or rubber residue to affect deceleration. Wet or cluttered runways present additional problems outside the scope of this discussion, but the need to have brakes applied no later than V_1 does not change.

5. Brake and Tire Condition. During certification, stopping capability is based on all brakes and tires being intact, fully operational and capable of maximum energy stops.

   In our line operations, we make no adjustments for brake or tire wear or for residual heat buildup from previous landings or extended taxi time.

   If a high-speed rejected takeoff is made because of a blown tire, it is unlikely that the aircraft will stop on the runway at the Maximum Runway Allowable Weight. The lack of any braking forces from the blown tire reduces the stopping capability and adjacent tires may also blow during the abort, further degrading stopping capability.

6. Reverse Thrust. Reverse thrust is not utilized in aircraft certification and is therefore considered by some as a safety margin. However, the use of reverse thrust during a properly executed abort with maximum braking will have little effect on stopping distance. Use of reverse thrust from one engine may create directional problems. Braking has top priority and attempting to maintain directional control with differential braking will reduce total braking force, increasing the stopping distance.

The article suggests three major aspects to making the proper decision during a takeoff:

1. Possession of a good practical knowledge of aircraft performance.

2. Knowledge of how to perform a maximum effort abort, if critical circumstances demand it.

3. Use of training and experience to make good go/no go decisions.

Delta's Takeoff and Go/No Go Decision Policy

1. It is always the captain's responsibility to make the go/no go decision and that decision should be based on all available information with consideration given for gross weight, field length, field conditions and weather. A comprehensive takeoff plan should be formulated during the departure briefing. Prior to taking the runway, the captain should verify there are no changes to this plan.

2. The decision to continue or reject a takeoff rests solely with the captain. As the speed approaches V_1, a decision to stop is recommended only for an engine failure/fire or a malfunction where a safety of flight

condition exists. To reduce decision time, system malfunctions which do not affect flyability should be systematically disregarded by the captain as the speed approaches V_1.

3. On every takeoff, the captain shall be prepared to initiate maximum deceleration including maximum braking, throttles, spoilers and reverse thrust as required for that particular aircraft.

4. The captain's hand shall be on the top part of the throttles following initial power application until at least V_1. The pilot not flying shall make the V_1 callout precisely at V_1.

5. The decision to reject the takeoff should be made before V_1 and maximum braking should begin no later than V_1.

6. Nothing in this takeoff and go/no go decision policy should be interpreted as limiting the captain's emergency authority. These guidelines are based on the best available information and are designed to provide the maximum overall safety in our line operations.

Points to Consider

NTSB's recommendation to FAA to redefine V_1, to clearly convey that it is the takeoff commitment speed and the maximum speed at which rejected takeoff action can be initiated to stop the airplane within the accelerate-stop distance, could put a halt to individual interpretations and give birth to universal understanding.

For instance, Boeing's interpretation that V_1 "is defined by FAA rules as the speed at which an engine failure has been recognized and *action* initiated to either *continue* or *stop* the takeoff" apparently clouds the issue for Delta. Delta would present a "new but absolutely correct definition of V_1 as the Critical Engine Failure Recognition Speed."

If other aviation experts were asked for their precise definitions, the wording would probably be different but the point taken would be very similar.

What is extremely important is the pilots' understanding of exactly what V_1 means to them in their particular circumstance.

Time Allowed For Decision Making

There is little question that a decision to abort or take off must be made in a matter of seconds. That time frame does not cater to procrastination, and pilots are forced to evaluate the aircraft's problem, runway length, airplane speed and other factors correctly and quickly.

Simulator training can be a great value, but the NTSB points out that pilot training and check sessions almost always present RTOs as V_1, engine failure-related maneuvers. This sort of training is similar to instrument approach training where the same approach to the same airport is always on the agenda.

To change the pattern and introduce variations, simulator training should include an assortment of anomalies (blown tires, runway excursions, etc.) to test the pilot's ability to think and act quickly in a variety of rejected takeoff situations.

Crew Coordination

NTSB points out that in many of the RTO-related accidents and incidents, the first officer was the pilot flying, and suggests that a delay may have occurred when control of the airplane was transferred from the first officer to the captain. The NTSB implies that most airlines have a policy where the captain is the only pilot authorized to initiate an abort or rejected takeoff.

Delta's policy is specific. "It is always the captain's responsibility to make the go/no go decision…" and, "The decision to continue or reject a takeoff rests solely with the captain."

Can issue be taken with a policy which permits only the captain to make the abort or rejected takeoff decision?

From an airline point of view, the reasons for a captain-only policy could be based a number of factors such as:

1. All first officers are not equal in flying experience, decision making capability or familiarity with the captain. Airline deregulation created new airlines and a subsequent turnover in pilots which, in some cases, has resulted in first officers with low time in aircraft type being paired with newly appointed captains. Captains might not wish to delegate the responsibility for declaring a rejected takeoff to a lower-time first officer.

2. The captain, by virtue of training, flight experience and time in the aircraft type is presumably the best qualified to think and react in an emergency situation. The first officer may overreact to engine instrument readings and be prone to declare an emergency when none exists.

3. There is a reluctance to usurp the captain's authority by allowing a junior officer to take command of the aircraft.

Yet, the NTSB makes the point that in many of the RTO-related accidents and incidents, the first officer was flying and there may have been a problem with transferring control of the airplane from one pilot to another. In this circumstance, it is important to bear in mind that only three to five seconds are available to make a decision. The NTSB recommends that FAR Part 121 operators review policies which permit first officers to perform takeoffs on contaminated runways and runways that provide minimal rejected takeoff stopping distance margins and encourages operators to revise those policies.

In the Future

The U.S. National Aeronautics and Space Administration (NASA) Langley Research Center has developed a system designed to help pilots make the go/no go takeoff decision by consolidating summarized data into a single, easily understood display. (See "To Go — Or Not to Go; Situation Awareness on Takeoff," October 1989 FSF *Flight Safety Digest*.)

The Takeoff Performance Monitoring System (TOPMS) provides continual real-time information updates during acceleration down the runway, presenting the aircraft's progress relative to a normal takeoff for that aircraft and existing flight conditions. The system indicates graphically the aircraft's position on the runway, the points at which lift off and other events should occur, whether the engines are functioning properly, and if acceleration is adequate.

Whether TOPMS is the answer to the runway overrun dilemma remains to be seen. In the meantime, pilots who recognize the problem and are prepared to take timely action on a rejected takeoff reduce the possibility of being involved in a runway overrun. ♦

About the Author

John A. Pope established John A. Pope & Associates, an aviation consulting firm located in Arlington, VA, U.S., after retiring in 1984 as vice president of the U.S. National Business Aircraft Association. He specializes in developing comprehensive operation manuals for corporate flight departments.

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