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# *Rejected Takeoffs: Causes, Problems, and Consequences*

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# REJECTED TAKEOFFS: CAUSES, PROBLEMS, AND CONSEQUENCES

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> *..As we started our taxi, I asked the Captain if he preferred using normal or alternate takeoff power..My thoughts were occupied with the upcoming takeoff procedure since it was my leg. After receiving takeoff clearance, I advanced the throttles...to the normal takeoff power setting. I first heard the aural takeoff configuration warning horn..Looking down at the flap handle I was absolutely...surprised to see that it was in the up position. We aborted...before reaching 40 knots.* [ASRS record number 78074]

## INTRODUCTION AND MOTIVATION

Recent accidents involving air transport aircraft have renewed interest in the process and problems associated with rejected takeoffs (RTOs). The La Guardia B-737 runway overrun in 1989 involved flight crew performance deficiencies before, during and after the takeoff rejection. Contributing to these human performance errors were external conditions that were not perceived by the flight crew as being relevant to their operating decisions. The tragic 1987 Detroit DC-9 and 1988 Dallas B-727 no-flap takeoffs also underscored the possibility that flight crews could fail to properly configure their aircraft for takeoff, and not detect their acts of omission.

Rejected takeoffs introduce multiple risks–those associated with the takeoff abort process itself, and those associated with the events which may follow. They are also symptomatic of a breakdown in human performance that can lead to improper aircraft conditions or configurations. A successfully managed RTO involves a skillful blending of pilot perception and appropriate action in order to conclude the abort procedure safely and avoid dangerous follow-on events.

This paper presents a small part of a larger ongoing effort that seeks to categorize the causes, problems, and effects of rejected takeoffs events as reported through NASA's Aviation Safety Reporting System (ASRS).

## OBJECTIVE AND SCOPE

**Purpose.** This study was conducted to analyze the human factor errors associated with rejected takeoffs reported to ASRS. Incident reports were studied to gain an understanding of the flight-crew-related human factors which lead to RTOs; to identify decision-making and procedural issues associated with RTO initiation and execution; and finally, to analyze problems that occur in the wake of rejected takeoffs.

**Scope.** Initially, 507 incidents occurring between January 1, 1983 through November 30, 1990 were retrieved from the ASRS database. Of these, 168 were found to be relevant to flight crew decision-making and procedures. Only reports submitted by flight crew members of transport category aircraft (in excess of 60,000 lbs. gross weight) were considered. The findings of this study are based upon this 168-report subset, and focus on the flight crew performance problems that come into play before, during, and after an RTO.

## APPROACH

**Methodology.** The study set of 168 reports was read and analyzed for causal factors underlying the rejected takeoff event. Primary causal factors were labeled as flight crew procedural errors or conditions that predispose such errors. Secondary contributing factors were also considered. In each incident, the abort maneuver was examined for potential problems with its initiation and execution. Finally, flight crew decisions made in the wake of the rejected takeoff were also evaluated.

**Data.** The RTO study set was limited to reports submitted by a flight crew member since only they could shed light on the cockpit procedures employed, crew members' roles, and crew perceptions of the aircraft's operating condition.

In general, it should be noted that data collected by the ASRS are subject to both known and unknown biases. Since reports are voluntarily submitted, they constitute a non-random sample of the actual population of aviation safety incidents. In addition, reporters' incident descriptions are colored by their individual motivations for reporting. They usually give only one perspective of the event, and this is not balanced by any additional investigation or verification.

## FINDINGS

### Flight Crew Errors Leading to Rejected Takeoffs

Ninety-four of the study reports involved RTOs that were caused by flight crew errors. Five categories of flight crew induced rejected takeoff scenarios were identified. These were:

**Unauthorized Takeoffs.** An aircraft departed prematurely or used the wrong runway for takeoff. In wrong runway takeoffs, the aircraft was authorized onto a runway surface but then deviated from ATC directives (22 incidents).

**Taxiway Takeoffs.** An aircraft departed from a taxiway rather than a runway (7 incidents).

**Off-Runway Takeoffs.** An aircraft erroneously aligned with the runway edge lights while positioning for takeoff instead of the centerline lights (3 incidents).

**Aircraft Configuration Anomalies.** An aircraft was improperly configured before, during, or following the RTO. The aircraft configuration anomalies included four conventional "abnormals" often practiced in recurrent training: mis-set flaps; unstowed spoilers or spoiler handles; stabilizer trim not in agreement with pre-set parameters; and failure to observe that a cockpit window was unlatched (34 incidents).

**Loss of Aircraft Control.** An initial mismanagement of thrust levers created a loss of aircraft heading control. Loss of control was often worsened by misuse of primary ground steering devices (10 incidents).

The remaining 18 incidents involved aircraft discrepancies unrelated to configuration that were attributable to flight crew errors.

**DISTRIBUTION OF STUDY REPORTS**

| Category | Number of Incidents |
|---|---|
| Flight Crew Errors Leading to RTOs | 94 |
| RTO Initiation and Execution Problems | 13 |
| Post-RTO Problems | 84 |

(Some reports apply to more than one category).

In addition to identifying RTO event categories, flight crew procedural errors contributing to RTOs were also determined. Procedural errors were classified as *improper information transfer, deficiencies in task management and crew coordination,* and *aircraft configuration anomalies.*

**Improper Information Transfer.** Some reports revealed that the interaction between the flight crews and tower controllers was, at times, not effectively monitored by the Captain. The lack of an ATC response to a flight crew communication was often interpreted as approval by the flight crew. Other communication failures were associated with unauthorized and premature takeoff incidents. In these, flight crews failed to challenge partial or doubtful clearances. These findings suggest that intra-crew communications can be compromised by insufficient cross-checking.

**Deficiencies in Task Management and Crew Coordination.** Study data indicated that flight crews did not always choose the right time to perform a required function. Often, their error was in allowing the other pilot to go off-frequency to make a company radio call at an inappropriate time. Wrong runway takeoffs usually were associated with a rushed cockpit environment and poor crew coordination in the areas of cross-checking, mutual support, and use of proper charts. Off-runway takeoff and taxiway takeoff events also were characterized by rushing and lack of flight crew coordination. In the latter events (which usually occurred at night), it was common for one pilot to have his or her head down in the cockpit performing checklists during the runway entry.

Flight crews' failure to monitor control inputs and to detect inappropriate control movements led to five loss-of-control incidents. These typically were caused by improper throttle application and the resulting uneven spool-up of large bypass engines. Asymmetrical thrust was further exaggerated by snow, ice, moisture or rubber deposits on the runway surface. The surprise was sometimes so complete that a misapplication of corrective control and throttle movements placed the aircraft off the runway.

**Aircraft Configuration Anomalies.** Improperly performed checklists were the leading cause of aircraft configuration anomalies in the study data. Most reporters, when explaining how this occurred, stated that they missed a checklist item–most frequently the flaps–during a period of high cockpit activity or during interruptions of routine monitoring and cross-checking functions. There were eight incidents where leading edge flaps created a warning, usually because of a circuit breaker being out of normal position. Another six reports cited errors in trim setting.

Several conditions were identified as potentially predisposing flight crew procedural errors. These consisted of *frequency congestion, schedule pressure, environmental factors, and transfer of control to the First Officer.*

**Frequency Congestion.** This was often associated with clipped transmissions, missed clearances and readbacks, and flight crews responding to wrong call signs. Pilots were more prone to act on their expectations, rather than on ATC's actual instructions, during periods of excessive radio traffic. Frequency congestion was the most frequently cited predisposing condition described in the study data.

**Schedule Pressure.** Other reports in the study set reflected schedule-related pressures that compelled flight crews to hurry. Driven by company "on-time" considerations or ATC traffic flow priorities, flight crews improvised callouts and altered cockpit procedures to meet schedule demands. These procedural short-cuts led crews into incomplete readbacks, non-standard phraseology, and inadequate intra-cockpit communication. Hurrying also led to missed items in the aircraft checklist. The assumption of too many tasks in too brief a time overloads flight crews and results in "forgetfulness" that the FAA has identified as a causal factor in runway incursions. This workload-induced forgetfulness was also associated with many RTO events in the study data.

**Environmental Factors.** Weather adversely affected visibility and lighting conditions, and contributed to flight crew performance errors in ten of the study reports. In some cases runway lighting was also instrumental in creating disorientation and resulting in either wrong runway or taxiway takeoffs at night. A few flight crews requested that tower controllers dim or turn off the lights on non-active runways.

**Transfer of Control to the First Officer.** As represented by the opening report excerpt, a disproportionate number of RTOs occurred when the First Officer was conducting the takeoff and had control of the throttles. These events included off-runway and unauthorized takeoffs, improper aircraft configurations, and loss of aircraft control. From the character of these reports, it appeared that problems sometimes resulted from the First Officer's failure to execute the initial phase of the takeoff in the manner expected by the Captain. Captains' expectations were often shaped by the First Officer's past performance. However, when the First Officer and the Captain were unfamiliar with each other, Captains were prone to assess a First Officer's capabilities by his length of experience alone. In either circumstance, Captains exhibited complacency regarding their responsibility to monitor the First Officer's actions.

### Initiation and Execution of the Rejected Takeoff

The role of the *tower controller as a safety factor* in RTO events reported to ASRS was significant. RTOs were most often initiated by the tower controller during unauthorized, wrong runway, and taxiway takeoffs. These events were usually caught in the controller's scan, and a low speed abort resulted. In contrast, runway excursions and off-runway takeoffs were often detected by the flight crew. The flight crew disorientation inherent in these events usually resulted in relatively high speed rejections; however, off-runway incidents sometimes continued into takeoffs where potential aircraft damage went undetected by the flight crew.

Aircraft configuration problems that resulted from flight crew procedural errors were usually announced by the takeoff warning system and typically resulted in a low-speed abort. The low-speed RTO was generally a reactive closing of the throttles and coasting to the next turn off.

*Abort decisions* related to aircraft system failures–including engine failures–were more apt to be derived from multiple warnings, and to result in high-speed aborts. There were 13 reports where the abort speeds were at $V_1$, and in some cases the speed was as far as $V_r$ and into lift-off. Most crews seemed to base their go/no-go decisions not only on speed, but on the number of warnings received, runway remaining, and their perception as to whether the aircraft could safely fly. The sensory advisories stimulating crew decision- making were audibles, such as compressor stalls, tower alerts, and warning systems; visual indications of engine problems; and tactile sensing of vibrations. The most common audible was the compressor stall.

It appeared from the study data that if pilots received two related engine indications such as a compressor stall and a fire warning, they were more likely to abort at a speed above that which training dictates. Another decision factor was that aircraft vibration by itself appeared to create doubt in the flight crew as to the ability of the aircraft to continue safely. The visual aspects of runway remaining also entered into pilots' perceptions and decision-making. Lower speed aborts at $V_1$ or under were related to the pilot's perception of runway remaining and braking required. Tire considerations were the main decision factor in these cases.

### Flight Crew Decisions Following an RTO

Decisions made by flight crews in the wake of a rejected takeoff were based largely on their perceptions of aircraft integrity. These perceptions were shaped by warning system alerts, tactile sensing, engine instrument indications, aircraft-generated noises, and observations radioed by tower controllers or other external observers.

**Request for Emergency Equipment.** The perceived requirement for emergency equipment was again based on whether there were two or more warnings associated with the condition of the aircraft. A compressor stall by itself did not produce a call for the fire truck, but if it was accompanied by a tower warning or a system warning of an engine fire, the crew would usually call out the emergency equipment. Study data indicated that more often than not, a compressor stall would result in engine damage or engine fire. Severe vibrations also led to a call for assistance. Control tower operators were uniformly of great assistance to RTO aircraft, and in many cases actually initiated the call for emergency equipment when fire was indicated. Other RTOs were triggered by door light and other system light warnings. These were false warnings in many cases, but they usually appeared when the aircraft had achieved a high speed, thereby requiring not only a great deal of finesse in execution of the RTO, but also generating a great deal of heat within the braking systems.

In the aftermath of an RTO, flight crew decisions regarding emergency equipment were based largely upon their perceptions of aircraft integrity and passenger safety. Flight crews did not always call for emergency vehicles after the successful conclusion of an RTO if they thought that everything was under control. The same mind set that prevents a crew from declaring an emergency during takeoff or landing seemed to drive the crew's decision not to ask for assistance from the emergency vehicles. The study data indicates that this is not always a correct assumption or position to maintain.

**Use of Brake Energy Charts.** One of the decision tools available to flight crews in the wake of an RTO is the brake energy chart to determine tire condition. Study reports did not indicate that crews always thought of its use, and sometimes they misinterpreted the charts. A few reporters indicated that the charts did not take into account long taxi distances; because of this omission, subsequent takeoffs resulted in deflated tires. Another result of non-use or misuse of these charts was a return to the gate area with exceedingly hot brakes. In one incident, maintenance had to call the fire trucks to the gate area because the brakes were glowing red and the crew was not aware of the danger to the aircraft or to ground crew personnel. The study data indicated only occasional use of hot brake areas by flight crews following a RTO.

**Takeoff Attempts Following RTOs.** Some flight crews were more likely to attempt a second takeoff if their RTO was in response to a false or corrected cockpit warning. The decision factors involved were schedule pressure and the flight crew's assessment of brake and tire conditions. Schedule pressure at times allowed unqualified ramp personnel to verify cargo door integrity so as to preclude a return to the gate. There were many problems with landing on deflated tires as a result of second takeoff attempts.

**Crew Communication with Emergency Ground Vehicles.** Some reports indicated that flight crews would like to be able to communicate directly with ground vehicles, and that tower transmissions sometimes interfered with that capability. During one aircraft evacuation, the ground vehicle actually blocked an exit door as it was assisting the flight, and there was no communication capability with that vehicle. Another report indicated a problem with the fire with the fire crew's identifying which engine was actually on fire, where the number 2 engine was confused with the number 3 engine.

**Aircraft Evacuation.** A flight crew decision to evacuate an aircraft was most often driven by a concern for fire in the engine or landing gear. Smoke in the cabin was another reason for an evacuation. Although the study data did not consistently reveal the level and quality of flight crew interactions, there were some indications that, during aircraft evacuations, flight crews advised passengers of the situation and cabin crews functioned as trained. Calling for emergency equipment provided the flight crew with assurance regarding the condition of the aircraft, and in some cases led to a decision to evacuate when fire was discernible from outside the aircraft by emergency personnel.

## CONCLUSIONS AND RECOMMENDATIONS

*In these data, the most significant causes of flight crew induced RTOs appeared to be improper communications procedures influenced by external conditions of frequency congestion and schedule pressure.* These external factors induced a hurry-up attitude and lowered the exchange of information required to manage a well-coordinated cockpit. They also predisposed a lack of coordination and vigilance where one pilot could monitor the other, particularly in runway entries at night.

*Rushing due to schedule pressure and ATC traffic flow priorities also interfered with the accurate completion of cockpit checklists.* Data indicated that high workloads, operational distractions, and complacency were involved in most cases of checklist errors and omissions. The most serious of these resulted in no-flaps takeoffs, leaving the takeoff warning system as the only "safety strap."

*Some flight crews deviated from their training guidelines when a high speed abort decision was involved, and did not adhere to $V_1$ as a go/no-go boundary.* This may indicate that current training scenarios lack realism when modeling RTO conditions. The problem of risk assessment may have to be addressed in either simulator or ground school classes in order to reduce the potential for these errors.

*Some flight crews were overly optimistic in their assessment of aircraft condition after rejecting a takeoff.* Flight crews should be encouraged to ask for assistance even after just one indication of a problem, as external examinations and communication are vital for a true understanding of aircraft condition.

*Some flight crews failed to use brake energy charts following an RTO and often did not consider pertinent factors, especially taxi distances.* In some circumstances, it is possible that brake energy chart estimates may be unrealistically low. This can lead to inadequate cooling times, and may result in subsequent tire failure either on the ground or in the air.

*Simulator and CRM programs may improve aspects of pilot performance associated with aborted takeoffs by:*

- Incorporating real-life scenarios into simulator sessions, including the presence of vibrations and multiple warnings
- Introducing subtle equipment failures into simulator training such as engine instrument fluctuations, door warning light activation, stick shaker activation, and abnormal control column forces
- Demonstrating proper radio procedures using tower tape examples of misunderstood clearances. These could:
    - Promote the use of readbacks by flight crews
    - Encourage intra-cockpit communication procedures to verify or question vague clearances
- Promoting rigorous methodologies for the execution of checklists, especially with regard to flap settings

*Consider formal criteria for allowing takeoffs by the First Officer.* Such criteria might address:

- First Officer performance
- First Officer experience level
- Weather factors.

Captains' responsibilities during First-Officer takeoffs should also be formalized.

*Real-life scenarios, such as those described in ASRS reports, could serve as a beneficial element of a complete training curriculum.* Incorporating these reports into ground school video presentations and simulator LOFT programs would provide, at the very least, the realism that is needed to expose flight crews to the subtleties of the human factor problems of rejected takeoffs.