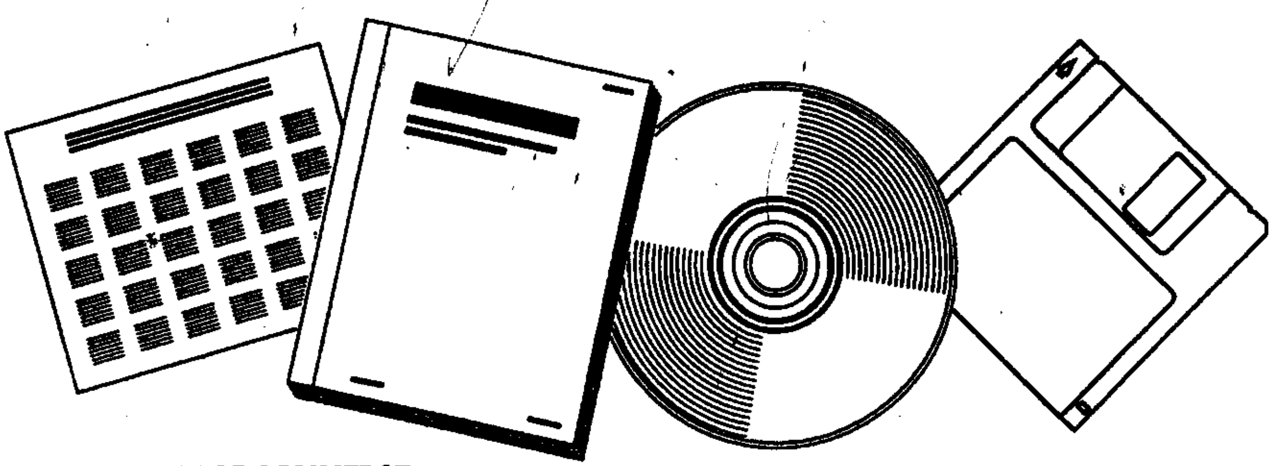
AIRCRAFT ACCIDENT REPORT. TRANS WORLD AIRLINES, INC. B707, N742TW, THE GREATER CINCINNATI AIRPORT, ERLANGER, KENTUCKY NOVEMBER 6, 1967

NATIONAL TRANSPORTATION SAFETY BOARD,
WASHINGTON, D. C

11 SEP 1968



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AIRCRAFT ACCIDENT REPORT

Adopted: September 11, 1968

TRANS WORLD AIRLINES, INC.

B-707, N742TW

THE GREATER CINCINNATI AIRPORT

ERLANGER, KENTUCKY

NOVEMBER 6, 1967

NATIONAL TRANSPORTATION SAFETY BOARD
DEPARTMENT OF TRANSPORTATION
WASHINGTON D.C. 20591

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SYNOPSIS

Trans World Airlines, Inc., Flight 159, a B-707, N742TW, crashed while attempting to abort a takeoff from Runway 27L at the Greater Cincinnati Airport, Erlanger, Kentucky, at approximately 1841 e.s.t., on November 6, 1967. The 29 passengers and 7 crewmembers all escaped from the aircraft. Eleven occupants were treated for injuries and one died 4 days later.

The first officer of Flight 159 was making the takeoff. In the takeoff roll, he heard a loud report from the right side of the aircraft, and experienced a yaw and movement of the flight controls as his aircraft passed a Delta Air Lines DC-9 which was mired adjacent to the runway. He concluded that his aircraft had struck the DC-9 and attempted to abort the takeoff. Just previous to the abort, he had checked his airspeed and believed that he was at or near V_1. The flight ran off the end of the runway approximately 421 feet. The main landing gear was sheared, and the aircraft was extensively damaged by the ground slide and fire.

The Board determines that the probable cause of the accident was the inability of the TWA crew to abort successfully their takeoff at the speed attained prior to the attempted abort. The abort was understandably initiated because of the first officer's belief that his plane had collided with a Delta aircraft stopped just off the runway. A contributing factor was the action of the Delta crew in advising the tower that their plane was clear of the runway without carefully ascertaining the facts, and when in fact their aircraft was not a safe distance under the circumstance of another aircraft taking off on that runway.

1. INVESTIGATION

1.1 History of the Flight

Trans World Airlines, Inc., B-707, N742TW, operating as Flight 159 (TWA 159) from New York to Los Angeles, with an intermediate stop at the Greater Cincinnati Airport, departed the ramp at Cincinnati at 1833. 1/ As TWA 159 was approaching Runway 27L for takeoff, Delta Air Lines, Inc., DC-9, N3317L, operating as Flight 379 (DAL 379), was landing. At 1838:16, TWA 159 advised the tower that they were ready for takeoff, and they were instructed to ". . . taxi into position and hold." The takeoff performance information, derived from previously computed company data by the first officer, who made the takeoff, was as follows:

V_1	V_R	V_2
132 knots	140 knots	150 knots

As DAL 379 was completing the landing roll, they requested and received clearance for a 180° turnaround on the runway in order to return to the intersection of Runway 18-36 which they had just passed. The captain of DAL 379 assumed control of his aircraft during the final stages of the landing rollout. He testified that he commenced the turn from the center of the runway, and stopped the turn after approximately 90° to check the position of the nosewheel in relation to the runway edge. After judging that approximately 1 foot remained, he again added power, but instead of the turn continuing, the aircraft's nosewheel slipped off the paved surface and the aircraft moved straight ahead off the runway. The throttles

1/ All times herein are eastern standard, based on the 24-hour clock.

were retarded to idle, and power was not increased again. The aft-most part of the aircraft was approximately 7 feet off the edge of the runway.

At 1839:05, as DAL 379 was in the process of clearing the runway, TWA 159 was cleared for takeoff. 2/ The local controller testified that before TWA 159 began moving, he observed that DAL 379 had stopped. He stated that although DAL 379 appeared to be clear of the runway, he was uncertain and asked, "Delta three seventy-nine you're clear of the runway, aren't you?" DAL 379 replied, "Yeah, we're in the dirt though." Following this report the controller stated, "TWA one fifty nine he's clear of the runway, cleared for takeoff, company jet on final behind you." They advised, "Okay, we're rollin'," at 1839:35.

The first officer of DAL 379 testified that when the controller inquired about their position, he looked to the right rear and observed the relationship of his position in the cockpit to the runway lights. He testified ". . . in my opinion and judgment I called clear of the runway." The captain of DAL 379 testified that several seconds later he confirmed the first officer's appraisal of their position, "I looked out and in my judgment we were well clear of the runway." About 4 seconds prior to TWA 159 passing to the immediate rear of DAL 379, the Delta crew advised the tower that ". . . we're stuck in the mud." At 1845:57, or approximately 5 minutes after TWA 159 had passed behind DAL 379, one of the Delta pilots remarked, "I guess we're off the runway, I don't know."

2/ The local controller testified that this clearance was issued in anticipation of departure separation as provided in AT P7110.8 Par. 412: "ANTICIPATING SEPARATION - takeoff clearance need not be withheld until prescribed separation exists if there is a reasonable assurance it will exist when the aircraft starts takeoff roll."

The captain of TWA 159 testified that, "We were cleared into position and subsequently cleared for takeoff. As we began to roll, I got an additional assurance that Delta was clear of the runway. I didn't have any idea of his position close to the runway until he began to loom up in my landing lights. I fully expected to see him taxiing in." He added, "I could see that he was off the runway. It may not have been far, but in my position I could measure it was five, six, seven feet or something of that nature." He stated that the normal procedure for a takeoff abort is to "Get the power off, get on the brakes and spoilers first, and then begin the reverse interaction"; however, in this case, once the first officer initiated the abort, "I tried to join him in every way possible, especially on the brakes, seeing that the reverse throttles were up as far as they could go . . . I gave him the spoilers as soon as he called for them. That may have been when I first realized an abort was taking place. I don't know." The captain also believed that he had called out V_1 as they passed that airspeed, but acknowledged that the cockpit voice recorder (CVR) negated this impression. (See Appendix C.)

The first officer of TWA 159 indicated that he did not notice DAL 379 until the captain commented on its proximity to the runway. Shortly thereafter, they passed abeam DAL 379, and he experienced a movement of the flight controls and the aircraft yawed. Simultaneously, he heard a loud bang on the right side of the aircraft. Assuming that he was at or near V_1, and that a collision had occurred, he elected to abort the takeoff. He testified that 120 knots was the last airspeed he observed. He closed the throttles, placed them in full reverse, applied maximum braking, and called for the spoilers which the captain extended. Although directional control was maintained, the aircraft ran off the end of the runway.

The consensus of witness statements and those from passengers on TWA 159 indicates that a loud bang and accompanying flash of fire occurred on the right side of the aircraft as they passed DAL 379.

Statements obtained from the passengers of DAL 379 revealed that after the aircraft completed the landing rollout, it commenced a right turn. After the aircraft had turned approximately 90°, the nosewheel left the paved surface. Tire scuff marks made by the aircraft were evident on the runway and formed a semicircular arc beginning near the runway centerline and terminating at the start of the nose gear rut. The aircraft then moved straight ahead, became mired, and power was reduced to idle. No further power applications were made. The engines of DAL 379 were at idle when TWA 159 passed behind DAL 379.

The accident occurred at approximately 1841, in darkness, at 39°03' North Latitude and 84°40' West Longitude.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	0	1	0
Nonfatal	2	8	0
None	5	20	

1.3 Damage to Aircraft

The aircraft was substantially damaged by the ground slide and subsequent fire.

1.4 Other Damage

None.

1.5 Crew Information

All crewmembers were properly qualified for their respective assignments. See Appendix A for details.

1.6 Aircraft Information

The aircraft had been maintained in accordance with Federal Aviation Administration (FAA) requirements, and was properly loaded at takeoff. See Appendix B for details.

1.7 Meteorological Information

The 1800 Weather Bureau surface weather observation for the Greater Cincinnati Airport was:

> Measured 7,000 feet overcast, 15 miles visibility, temperature 34°, dew point 19°, wind from 190° at 5 knots.

1.8 Aids to Navigation

No navigational aids were involved in the accident.

1.9 Communications

There were no reported problems with communications.

1.10 Aerodrome and Ground Facilities

Runway 27L is 7,800 feet long and 150 feet wide, of concrete construction. At the time of the accident, the runway surface was dry, and the high intensity lights were on.

1.11 Flight Recorders

TWA 159 was equipped with a flight data recorder and a CVR; both were recovered in satisfactory condition.

The flight data recorder was a Lockheed Aircraft Service Model 109C, Serial No. 197. The flight record medium did not show any mechanical damage, and all parameters were recording.

Since the flight recorder medium does not reflect the takeoff roll initiation point, the record was presented on a graph with a time scale of 70 seconds which included a period of time preceding the takeoff through that point where the traces became aberrant. The airspeed trace began increasing at a relatively uniform rate from approximately 10 to 15 knots at 21 seconds, to a maximum of 145 knots at 61 seconds. At this point, the airspeed decayed to 140 knots in 1 second, to 111 knots in the next 2 seconds, and finally decreased to 59 knots where it became aberrant at 70 seconds. The heading of approximately 270° was relatively constant until 61 seconds at which point it shifted momentarily to 265° and then returned to 270° at 64 seconds. The vertical acceleration trace also remained fairly constant until 66 seconds at which point accelerative forces were recorded ranging between + 0.3 g and + 2.2 g. The altitude trace varied between a low of 790 feet just prior to the maximum airspeed and a high of 930 feet which was recorded during the period of peak vertical acceleration forces.

The CVR was a Fairchild Model A100, Serial No. 1514. There was no evidence of damage to the recorder and the readability of voice transmissions was good. See Appendix C for excerpts.

DAL 379 was equipped with a flight data recorder and a CVR; both were recovered in satisfactory condition.

The flight data recorder was United Data Control Model F-542, Serial No. 1975. All parameters were functioning properly.

The CVR was a Fairchild Model A100, Serial No. 1230. The recorder was undamaged, and the quality of recorded voice transmissions was good. One unusual finding was the absence of normal recorded signals on the tape for the first 5 minutes 18 seconds of the recording. Although this portion appeared to be void of recorded data, amplification with maximum gain control of the readout machine revealed several extremely weak, but intelligible, transmissions. These were identified as the radio transmissions from the tower to DAL 379 after the flight had completed the landing rollout. According to the manufacturer, this condition is indicative of the bulk erase feature 3/ of the recorder having been applied.

1.12 Wreckage

TWA 159 overran Runway 27L, rolled across the terrain for approximately 225 feet to the brow of a hill, and became airborne momentarily. It next contacted the ground approximately 67 feet further down the embankment, the main landing gear sheared, and the nosewheel was displaced rearward which forced the cabin floor upward approximately 15 inches.

The aircraft continued sliding down the embankment and came to rest straddling a road approximately 421 feet from the end of Runway 27L. During the ground slide, the fuselage upper structure ruptured just forward

3/ The captain of DAL 379 testified that he instructed the first officer to activate the bulk erase feature of the CVR because of the profanity used when they became mired.

of the wing root, and the right wing failed inboard of the No. 4 engine. Engines Nos. 1 and 2 partially separated and engine No. 3 separated from the wing structure. The right wing area surrounding the break was damaged by ground fire.

All control surface attachments were intact, and cables which were separated failed in tension except the right outboard aileron cable, which failed from overheat. The flight spoilers were intact except for the right outboard spoiler, which was fire damaged. The spoiler control handle was in the "spoiler extended" position and cable continuity was confirmed from the cockpit to the operating mechanisms.

The clamshell doors for all engines were in the reverse thrust position and the fuel controls were in the "maximum reverse" position.

1.13 Fire

Ground fire occurred in the area of the right wing separation and the Nos. 3 and 4 engines. The two firemen on duty at the airport responded with the crash truck and a rescue vehicle. The fire captain instructed the crash truck driver to park the truck approximately 75 feet from the fire area, and they, along with two off-duty airport employees, began foam application with the turret nozzle and a side line. Nearby volunteer fire departments with two additional trucks responded and aided in extinguishing the brush fires in the area.

1.14 Survival Aspects

This was a survivable accident, although one of the eleven injured occupants died 4 days after the accident.

The forward galley door and aft main door were both opened by the assigned hostesses, but they were unable to inflate the slides before being forced from the aircraft by passengers. The hostess assigned to the main passenger loading door was unable to open it due to buckling of the cabin floor. After determining that there were no passengers in the area, she jumped from the forward galley door, which was approximately 7 feet above the ground. The aft galley door was opened by the assigned hostess, but she closed it because of the fire on the right side of the aircraft. She then assisted people to the aft main loading door and exited when no one else was in sight. This door sill was about 20 inches above the ground. The left aft overwing exit was opened and utilized by two passengers.

After closing the fuel shutoff valves, the flight engineer proceeded to the forward main loading door, attempted to help the hostess there, and then instructed her to go to the forward galley door. After a few moments he followed her, but finding no one in the area, he returned to the cockpit to make certain that the other crewmembers had escaped. He then exited through the captain's sliding window which was approximately 10 feet above the ground. The first officer went directly to the forward galley door and carried a crippled woman to safety. The captain also went to the forward galley area and inflated the slide at that door. Although the slide was doubled back under the aircraft, two or three passengers utilized it for descent to the ground. When no one else was seen or heard, the captain left the aircraft through the galley door.

Emergency lighting within the cabin was reported as satisfactory. However, several passenger service unit doors and oxygen masks were hanging down, and the chain locks on 84 of the drop-down tables failed to restrain the tables in the stowed position.

1.15 Tests and Research

In order to evaluate the performance of TWA 159, and to obtain a clearer understanding of the events surrounding the takeoff, a correlation of the flight and cockpit voice recorders was made. The time base for this correlation was predicated on 80 knots, and the callout of that airspeed, occurring simultaneously. Other occurrences were measured in time from this point, and plotted on a common time scale.

The CVR-flight recorder airspeed curve was then compared with a predicted performance curve provided by Boeing. (See Attachments 1 and 2). This comparison, utilizing the takeoff clearance as a time reference, revealed an apparent disparity between the predicted and recorded performance of the aircraft in both the acceleration and deceleration phases of the takeoff. Further study of the evidence prompted selection of the engine noise reaching its highest peak as the time reference for the takeoff roll initiation point. This resulted in closer comparison of the two airspeed traces at the higher, more accurately recorded values, and still provided exceptional correlation with the physical evidence. In addition to the time base reference point, there were three other factors affecting the compatibility of the predicted and recorded performance. First, the airspeed values during deceleration are apparently depressed due to static position error induced by disturbed airflow while reverse thrust is utilized. Second, the airspeed values depicted by the flight recorder in the lower regimes, below 80 knots, tend to be less accurate than at the higher values. Third, the flight recorder tape drive system was malfunctioning. While this had no effect on the airspeed values recorded, it did result in irregular tape advance prior to the accident, and may have caused some minor distortion of the time scale during this takeoff.

The final CVR-flight recorder correlation indicates that the first reference of the crew to the position of DAL 379 occurred at approximately 115 knots. At this point, TWA 159 had progressed about 3,350 feet along the runway in 31.5 seconds. Five seconds later, at 4,400 feet (200 feet prior to passing DAL 379), the flight reached V_1. Acceleration continued as TWA 159 passed DAL 379 at approximately 135 knots, the sound of a "pop" was recorded at 139 knots, the sound of the engine power cut was at 143 knots, and finally the airspeed peaked at 145 knots. During this time interval, between 36.5 seconds and 40.5 seconds, the flight traveled approximately 950 feet to 5,350 feet from the takeoff roll initiation point. The airspeed then dropped in the next second to 140 knots. At 42.5 seconds the sound of engine power resumed, followed at 43 seconds by the command of the first officer for spoilers. At this point, the aircraft was approximately 5,900 feet down the runway and a marked increase in the deceleration began. The sound of impact began at 7,575 feet.

1.16 Other

The JT8D-5 engines installed on DAL 379 would produce jet exhaust at idle power as follows:

Distance (feet)	Temperature (degrees)	Velocity (feet/second)
82	97	55
63	108	75

The distances selected would correspond to the centerline of the Nos. 3 and 4 engines respectively, if the aircraft centerline of TWA 159 were in the middle of the runway.

Pratt and Whitney studied the effect of the ambient atmospheric conditions and the jet exhaust on the JT3C-6 engine. They concluded, ". . . there is a possibility that JT3C-6 engine compressor stall could have occurred due to the flow disturbance at the JT3C-6 engine inlet which could have resulted from the combined effects of the temperature and the velocity of the JT8D exhaust." Additionally, their representative at the hearing testified that, under the conditions of the accident, he could not think of any other factors which would have generated a compressor stall. He also indicated that a short duration high power stall of the type being discussed may not even be reflected in the engine instruments.

DAL 379 came to rest on a heading of 004°, 4,600 feet from the takeoff end of Runway 27L. The aft-most point of the aircraft was approximately 7 feet north of the runway edge. However, the aft-most exterior lights, located on the wingtip, and the upper and lower anti-collision lights were approximately 45 feet from the edge. Because of the proximity of this aircraft to the runway, the crews of TWA 159 and DAL 379 and the local controller were asked for their personal interpretations of the phrase, "clear of the runway." The definitions included, "clear for use", "well clear", and ". . . no part of the aircraft on the runway or hanging over the runway." Neither the Federal Aviation Regulations nor the Terminal Air Traffic Control Procedures Manual of the FAA defines this expression. However, guidance for establishing criteria in the future can be inferred from Advisory Circular No. AC 150/5340-1A dated June 30, 1966. This circular describes runway and taxiway markings required to qualify under the Federal-Aid Airport Program. It states in part, "A taxiway holding line marking should be placed a distance of not less than 100 feet and not more than 200 feet from the nearest edge of the runway. . . ."

2. ANALYSIS AND CONCLUSIONS

2.1 Analysis

The elements which are pertinent to this accident include the proximity of DAL 379 to the edge of the runway, and the action of this crew; the performance of his duties by the tower controller; and the actions of the crew of TWA 159 during the takeoff.

The captain of DAL 379 testified that the turning radius of his aircraft was 72 feet, and that he attempted the 180° turn within the 75 feet of runway to the right of the centerline. When he stopped the aircraft after approximately 90° of turn in order to check the clearance of the nosewheel, he was unable to re-establish the turn before the thrust of the engines, almost on the centerline, forced the aircraft forward off the runway.

When DAL 379 finally came to a stop, the rearmost extremity of the aircraft was physically clear of the runway by 7 feet. However, the engines were operating at idle during the period TWA 159 was attempting to takeoff, and jet exhaust was being directed across the runway. Notwithstanding the variations in testimony as to the meaning of "clear of the runway," this phrase is generally construed by controllers and pilots alike to mean that the runway is available for unrestricted use by other aircraft. Since DAL 379, under the circumstances, constituted a hazard to other aircraft taking off on Runway 27, it was not "clear of the runway" within the generally accepted meaning of that phrase.

When DAL 379 was queried by the tower concerning their position, the first officer estimated from a cursory glance that their aircraft was clear of the runway. It is the conclusion of the Board that an airline crew in these circumstances should determine by physical means whether they are physically clear of the runway. Despite the fact that their aircraft was physically clear of the runway by 7 feet, it is highly unlikely that the crew could have ascertained this fact, under the circumstances at the time. Accordingly, safety required that before the crew advised the tower of their position relative to the runway, they should have taken the time to open the cockpit windows to get a better view, or even have utilized the air stairs to make an "on the spot" determination if that were necessary. The crew should also have advised the tower immediately that the aircraft could not be moved any farther without assistance.

The Board recognizes that there was no definitive standard, in terms of distance, to judge whether or not the aircraft was clear of the runway.

In this regard, the Board considers it appropriate to recommend that the FAA establish, and appropriately publicize to pilots and controllers alike, meaningful standards of safe clearance from runway edges for aircraft, as well as for ground-based vehicles, which will permit reasonable assurance to all concerned that no interference with flight operations on the runway will be caused by the presence of such movable obstructions.

The Board is of the view that such standards of safe clearance should take into account not only an intruding aircraft as an "obstruction," but also the fact that jet exhaust from a parked or moving aircraft perpendicular to the operating runway may well create the type of hazard (compressor stall) encountered here <u>even though</u> the intruding aircraft is more than a given number of feet physically "clear" of the runway.

In this connection the FAA issued a report 4/ in 1965 which contains a quantity of valuable information as to velocities of jet engine blasts at varying levels of thrust and at varying distances, and forms a usable base from which meaningful conclusions in this area might be derived.

Interestingly enough, despite the known facts about wind velocities generated by the thrust of jet engines, we are not aware that any official cognizance has been taken of them in terms of the environment they create under circumstances akin to those present in this case.

In reviewing the Air Traffic Control aspects of this accident, it is apparent that the provision of additional equipment and/or the establishment and following of certain procedures for airport traffic control would have

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4/ "Effects of Jet Blast," AC 150/5325-6, April 1965. See, in particular, pp. 2-5.

reduced materially the probability of this occurrence. However, there are other considerations which enter into the picture when this general area is explored.

The equipment referred to, which is not installed at the Greater Cincinnati Airport, is Airport Surface Detection Equipment (ASDE), a short-range K-band radar which is utilized at a few airports in adverse visibility conditions to provide tower personnel with data concerning the occupancy status of runways and taxiways beyond their range of effective vision. This is expensive equipment which requires continuous maintenance and which at present is not designed for daylight display, thus requiring the controller desiring data from the scope during daylight hours to view the scope through a hood.

Operational limitations are thus placed on the controller's capacity because his full time and attention must be directed toward determining the position of one aircraft to the detriment of his attention to the overall traffic flow. Further, if more than one aircraft is involved, which is usually the case at high activity airports where ASDE is presently installed, the controller has no immediate means of identifying the target of the aircraft of specific concern. In addition, ASDE is subject to precipitation interference which severely limits its capability at a time when it is most needed--namely, during periods of low visibility associated with precipitation.

The controller in the subject instance, because of his physical relationship to the location of DAL 379 (low angle of vision, nighttime, distance, etc.), was unable to make an unassisted determination as to the distance from the closest extremity of the aircraft to the runway edge when the aircraft stopped moving. In order to arrive at this determination, he enlisted the assistance of the Delta crew who, notwithstanding their visual limitations due to cockpit visibility angles, were closer to the scene and thereby better equipped to make this critical assessment. Their reply that they were clear of the runway, no matter how determined, was the critical factor influencing the controller against instructing TWA 159 to abandon takeoff. The Delta crew's remark ". . . we're in the dirt, though," was not in itself sufficient to cause the controller to cancel the takeoff clearance since there is no prohibition against taxiing aircraft out of such areas. No other indication of their own situation was communicated to the tower until about 4 seconds prior to TWA 159 passing the immediate rear of DAL 379 when the latter crew stated ". . . we're stuck in the mud."

The final consideration bearing on the accident is the action of the captain and first officer of TWA 159. The captain testified that at the start of the takeoff he was only vaguely aware of the location and predicament of DAL 379. Although the captain testified that he was not consciously aware of the lights on DAL 379, the aft-most exterior lights, as well as the anticollision lights, were approximately 45 feet from the runway edge, which might have created the impression that the aircraft was farther from the runway than it actually was. The first officer was not aware of any cause for concern until the captain commented during the takeoff roll on the proximity of the aircraft. Meanwhile, their aircraft continued its acceleration in a normal manner to beyond V_1 (132 knots).

TWA 159 passed behind DAL 379 at a speed of approximately 135 knots, and the jet blast perpendicular to its path generated a short duration compressor stall in the No. 4 engine. Although the stall resulted in a loud noise and the jet blast apparently moved the flight controls, the performance capabilities of the aircraft were not affected. However, the first officer, convinced that a collision had occurred, and believing he was at or near V_1, elected to abort the takeoff. He reduced power on all engines at 143 knots, 1 second after the sound of the compressor stall which triggered his decision. As the airspeed peaked at 145 knots, his next action was to call for assistance in holding the yokes forward, preparatory to the application of reverse thrust. His command was given 1 second after the power was reduced; however, the actual reverse thrust was not applied for an additional 2.5 seconds. During this 4.5-second interval, the only decelerative device applied was the brakes, and their effectiveness is appreciably reduced when the spoilers are retracted. One-half second later, or 5 seconds after the stall occurred, the first officer finally called for the spoilers which should have been extended as soon as the power was reduced. The captain was admittedly surprised when the abort occurred, and though he stated that he assisted the first officer with the braking effort, he did not extend the spoilers on his own initiative. Rather, he took no action until the first officer ordered the spoilers. Once the spoilers were extended, a sharp increase in braking effectiveness was indicated by the rapid deterioration in airspeed. However, there was insufficient runway remaining in which to stop the aircraft.

The significance of the crew's slow implementation of the abort procedure is apparent in the Boeing performance data. (See Attachments 1 and 2.) It shows that at an abort-decision speed of V_1 (132 knots), the total accelerate-stop distance of the aircraft is approximately 6,560 feet. The accelerate-stop distance for an abort-decision speed of 143 knots is approximately 7,850 feet. Although these data reveal that the overrun was inevitable, it is interesting to note that, even allowing for positioning of the aircraft on the runway, if the abort had been executed properly the aircraft would have stopped either prior to the brow of the hill (225 feet from the runway end) or at least would have arrived there at a sufficiently reduced airspeed so that it would not have become airborne as it did. Consequently, the resultant damage would have been greatly reduced.

The preceding discussion serves to illustrate that the outcome of any attempted abort is heavily dependent on the pilot's knowledge of the sequences in which actions must be taken, especially when the abort is executed at velocities near V_1 and the stopping distance is limited. In this instance, the company manuals indicate that aborting a takeoff at high speed is potentially dangerous, and should not be attempted unless an actual engine failure occurs prior to V_1. Such a position could not only mislead and prejudice the pilot and his thinking toward aborted takeoffs, but also fails to consider the likelihood of other emergencies which would require an abort. Additionally, the specific instruction for execution of the abort lists as the second step, "Extend spoilers and apply reverse thrust." Although this provides the correct sequence, it fails to stress the importance of the sequence or the consequences of either delayed or improper actions by the crew. The Board believes that the circumstances of this accident dramatize the need for a major reappraisal of the current training manuals and instruction provided by all airlines. It is abundantly clear that a new, positive approach toward abort procedures, with amplification and clarification of such procedures, including safety margins provided and the need for prompt and proper sequencing of each action, is needed.

In connection with a reappraisal of abort procedures, the Board believes that a reassessment and clarification of the respective duties and responsibilities of the captain and first officer during critical phases of flight would be in order. It is a common practice among airlines for the captain and first officer to alternate piloting the aircraft on various legs of a flight when several stops are made en route. In such instances, the first officer often makes the takeoff and subsequent landing, although the captain is still in command of the aircraft and may elect to "take over" from the first officer when the situation may warrant or dictate such action. Accordingly, when the first officer is flying the aircraft, the captain must be alert and in position to counteract actions of the first officer which are not in accordance with his own best judgment. To discharge effectively this responsibility, the Board believes that the captain should follow through on the flight controls and should either have his hands on the thrust levers or in a guarding position.

The foregoing discussion assumes that the "captain in command" concept is effective even under circumstances such as those involved in the subject accident. It may be that this assumption--viz., that a captain can effectively, and in timely fashion, countermand a decision of the first officer to abort a takeoff--is worth re-examination. It is at least arguable that the virtually split-second action required for implementation of the abort procedure near V_1 dictates that the pilot at the controls should also have the final decisional authority with respect to an abort. If a captain believes it is inadvisable to delegate the decisional authority in any given case, he can execute the takeoff himself.

In accordance with the Board's rules of practice, Parties to the Investigation were invited to submit to the Board their recommended conclusions to be drawn from the facts derived in the investigation. Accordingly, Delta Air Lines, Inc., (DAL) submitted a list of 15 conclusions to be drawn from the evidence gathered during the investigation. One of the substantive differences in their findings and the Board's report of the accident concerns the question of a compressor stall. DAL stated that, "The evidence is inconclusive as to whether TWA Flight 159 experienced a compressor stall . . . or what point in time and relation to Delta's Flight 379 such stall occurred, if in fact it did take place." In addition, they stated that the length of time which TWA 159 was in the jet exhaust wake of DAL 379 was not sufficient to cause a compressor stall. However, the Board believes that, notwithstanding the duration of exposure to the jet exhaust, the temperature rise and velocity were sufficient to disturb the airflow at the engine inlet and generate a momentary compressor stall.

DAL also maintains that the crew of TWA 159 could have successfully effected an abort when their landing lights illuminated DAL 379, thus enabling the TWA crew to observe visually the position of the Delta aircraft. Effective illumination would have occurred when TWA 159 reached a point within 500 to 700 feet of DAL 379, or about 3 seconds prior to passing abeam of it. Even though an abort initiated at this stage of the takeoff might have been completed successfully, the Board does not believe that the TWA crew acted unreasonably in continuing the takeoff. They had been advised DAL 379 was clear of the runway and both TWA pilots testified that they were convinced it was clear when it loomed up in their lights. Moreover, they could not have ascertained that the DC-9's engines were operating and that jet exhaust was being directed across the runway before they reached a point abeam of DAL 379. Another consideration is the fact that an abort initiated just prior to passing DAL 379 would have run the risk of causing TWA 159 to veer away from the runway centerline, possibly toward the DC-9, thereby increasing the possibility of a collision. Finally, to suggest that the TWA crew should have begun an abort <u>before</u> reaching DAL 379 not only imposes an unreasonable burden on the TWA crew but also concedes that the DAL aircraft <u>did</u> present a hazard to the flight.

DAL also contends that the attempt to abort the takeoff constituted pilot error on the part of the TWA first officer. For the reasons set forth below, however, the Board is of the opinion that the first officer's decision to abort was reasonable under the circumstances.

The Air Line Pilots Association (ALPA) recommended that this accident should " . . . direct the government's attention to the compromise of safety in runway length requirements and accelerate-stop computations for jet transport aircraft." The Association indicated that they believe the means of computing the V_1 takeoff speed and the accelerate-stop distance are not realistic.

However, it is the view of the Board, and ALPA agrees, that the concept of V_1 is not directly relevant in this particular case. That concept is intended to provide the crew with a decision speed at which they may either abort or continue the takeoff if they should lose power on an engine. However, in this case, the first officer who was making the takeoff believed that his aircraft was physically damaged by a collision and that it might not be capable of flight. It is the opinion of the Board that his decision to abort the takeoff, regardless of the airspeed, was reasonable under the circumstances.

Despite the lack of relevance of V_1 to this case, the Board recognizes that this accident has engendered a considerable degree of interest in that general subject. Accordingly, there is appended to the report a detailed discussion of V_1, with particular emphasis on those points raised by the ALPA recommendation. (See Appendix D.)

Conclusions

(a) Findings

1. The aircraft was airworthy and properly certificated.
2. DAL 379 was mired 4,600 feet from the takeoff end of Runway 27L, and the aft-most part of the aircraft structure was approximately 7 feet from the runway edge.

3. The local controller was unable to determine without assistance whether DAL 379 was clear of the runway.
4. The crew of DAL 379 should have made a greater effort to ascertain their position with respect to the runway and should have been more explicit in reporting their exact circumstances to the controller.
5. Although the phrase "clear of the runway" is generally construed by pilots and controllers to mean that a runway is available for unrestricted use, there is no definitive criterion, in terms of distance, against which to judge whether such clearance exists, nor is there any standard which takes into account the effect of the exhaust from jet engines.
6. The captain of TWA 159 failed to announce V_1.
7. TWA 159 sustained a compressor stall in the No. 4 engine as it passed behind DAL 379 due to the jet blast from the idling engines of DAL 379.
8. The first officer of TWA 159, believing his aircraft had collided with another plane, aborted the takeoff.
9. The abort procedure was not accomplished in the correct sequence, nor was it completed in a timely manner.
10. The takeoff was aborted beyond V_1, and the overrun was inevitable.

(b) Probable Cause

The Board determines that the probable cause of the accident was the inability of the TWA crew to abort successfully their takeoff at the speed attained prior to the attempted abort. The abort was understandably initiated because of the first officer's belief that his plane had collided with a Delta aircraft stopped just off the runway. A contributing factor was the action of the Delta crew in advising the tower that their plane was clear of the runway without carefully ascertaining the facts, and when in fact their aircraft was not a safe distance under the circumstance of another aircraft taking off on that runway.

Recommendations and Corrective Measures

1. The Board recommends that the FAA establish, and appropriately publicize to pilots and controllers alike, meaningful standards of safe clearance from runway edges for aircraft as well as for ground-based vehicles which will permit reasonable assurance to all concerned that no interference with flight operations on the runway will be caused by the presence of such movable obstructions. Such new standards should take into account the effect of the exhaust from jet engines.

2. The Board believes that the circumstances of this accident dramatize the need for a major reappraisal of the current training manuals and instructions provided by all airlines with a view toward a new, positive approach toward abort procedures. Such an approach would include

an amplification and clarification of such procedures, including safety margins provided and the need for prompt and proper sequencing of each action.

3. The Board believes that a reassessment of the respective duties and responsibilities of the captain and first officer during critical phases of flight is in order. In so doing, the "captain in command" concept should be re-examined with respect to its applicability in situations where time may not permit the captain to countermand effectively the decision of a first officer who is flying the aircraft.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ JOSEPH J. O'CONNELL, JR.
Chairman

/s/ OSCAR M. LAUREL
Member

/s/ JOHN H. REED
Member

/s/ LOUIS M. THAYER
Member

/s/ FRANCIS H. McADAMS CONCURRING AND DISSENTING
Member

Member McAdam's concurrence and dissent attached.

MEMBER McADAMS, CONCURRING AND DISSENTING:

Based on the facts of this case I have reached different conclusions than those of the Board.

The Board concludes that the probable cause was "the inability of the TWA crew to abort successfully their takeoff at the speed attained prior to the attempted abort." This is not a probable cause, it is merely a statement of how the accident occurred. Furthermore, it seems to imply that either the abort was not necessary or the crew with sufficient ability or competence could have successfully aborted. Such is not the case. Under the circumstances TWA had no reasonable alternative but to discontinue its takeoff at a speed in excess of V_1. At this speed, 143-145 knots, it is not possible to stop the aircraft on the runway. However, it was stopped within the approximate distance indicated by engineering test data. 1/ Therefore, since the decision of the TWA crew in aborting was not only reasonable but also adequately executed then TWA's action cannot be considered as the cause. The cause must be attributed to the factors which induced TWA to initiate the abort. In my opinion, the probable cause was the failure of the Delta crew to adequately advise the tower of its proximity to the runway, and of the tower to request additional and more precise information from Delta prior to clearing TWA for takeoff.

1/ See *infra*, p. 3.

A chain of events set in motion by Delta was the primary cause of the accident. Delta's turnoff was either executed with an insufficient turning radius or at an excessive speed resulting in the aircraft becoming mired in the dirt 7 feet from the runway where it constituted a hazard. If the turn had been started at the centerline after the aircraft had been stopped, as testified to by the Delta crew 2/ then it could have been successfully completed in the 75 feet of available runway since the turning radius of the DC-9 is 72 feet. Therefore, the aircraft was either too far to the right of the centerline or the turn was executed at an excessive speed. The tire scuff marks on the runway made by the nosewheel could possibly indicate a turn at excessive speed since if the aircraft was stopped before the turn was commenced the nosewheel should not have been fully deflected and there would have been no scuff marks. The Delta crew testified that the turn was normal and the nosewheel did not become fully deflected until it slipped off the runway. 3/

After Delta became "stuck in the mud" the crew advised the tower that the aircraft was clear of the runway; however, at 23.45, 5 minutes after the accident, Delta stated, "I guess we're off the runway. I don't know." 4/ Delta's transmission, clear of the runway, was not only

2/ Tr. 349.
3/ Tr. 349-350.
4/ Exhibit 12 B-1.

inadequate but inaccurate since they did not know whether they were physically on or off the runway and, in fact, they were close enough to the runway to have reasonably known that the aircraft constituted a definite hazard.

As a result of Delta's cryptic transmission, "Yeah, [clear of the runway] we're in the dirt though," the tower cleared TWA for takeoff. TWA reasonably believing it had collided with Delta, with the possibility of structural damage, discontinued the takeoff and brought the aircraft to a stop 8100 feet from where it began the takeoff roll. According to the engineering test data [5] and the testimony of Boeing's engineering test pilot, if the aircraft's speed peaked at 145 knots, as shown by the flight recorder, and the crew during the abort used brakes, spoilers, and all four thrust reverses, the aircraft could be stopped at 8100 feet. [6] From the above it would seem TWA's aborted takeoff was well executed despite the Board's conclusion that it was improperly executed.

With respect to the tower as a contributing factor, it seems to me, under the circumstances, it would have been reasonable to expect that the

5/ Exh. 2 J.

6/ Q. Sir, in previous testimony of the last witness he read from the flight recorder trace a maximum speed of 145 knots. Could you tell me on this chart where an airplane would stop, the same situation, [brakes, spoilers, and all four reverses functioning] if it did attain a speed of 145 knots. A. Yes. This chart shows that it should stop at about 8100 feet, which is near the reported position of this particular airport [aircraft]. Tr. 522.

tower should have requested additional and more precise information as to the position of the Delta aircraft in relation to the runway before clearing TWA for takeoff. The tower, based on the facts available to it, should have realized that the Delta transmission, "clear of the runway," an ambiguous phrase at best, needed further clarification. Additionally, the "in the dirt" portion should have alerted the tower to the possibility that a hazardous condition might be existing on or close to the runway. The tower, therefore, should have requested the exact proximity of Delta to the runway, the aircraft heading, and whether jet exhaust was being directed across the runway.

The controller observed Delta turning off the runway and cleared TWA for takeoff in anticipation that Delta would not only be physically clear but would also continue to taxi away from the runway when TWA reached the intersection. The controller testified that he determined by reference to the high-intensity lights and the lights of the Delta aircraft, both of which could be clearly seen, that Delta was physically clear of the runway. 7/ However, almost immediately and before TWA received its final takeoff clearance, the controller saw that Delta had stopped and from

7/ Q. What had you used as a reference point to determine whether the DC-9 was clear of the east-west runway? . . . A. [Tower controller] He was taxiing to the north. He is leaving the runway on that side. Just the lights down there as he taxies off the runway, you just look at the lights and watch him taxi off the runway, when they appear to be off the runway. Tr. 35-36.

this should have known that the aircraft was very close to the runway because of the short time interval between Delta's turnoff and coming to a stop. Furthermore, since he had determined that Delta was physically clear of the runway by the relationship of runway and aircraft lights he also should have been able to determine that Delta was in close proximity to the runway and at the very least closer than the required 100 feet for stopped or holding aircraft. 8/

Controllers are charged with the sole responsibility for issuing landing and takeoff clearances and, therefore, must exercise the highest degree of care in determining whether there are aircraft or other obstructions on or near a runway which would constitute a hazard. In some instances a controller because of visibility restrictions has no alternative but to rely upon pilot advice as to whether the runway is in fact clear; however, in this case there were no visibility restrictions since the controller testified that the high-intensity runway lights as well as the landing and other lights on the Delta aircraft could be clearly seen from the tower which is 40 feet above field elevation. 9/

One of the difficulties herein is the meaning and use of the phrase, "clear of the runway." Unfortunately, its meaning is equivocal. The controller, according to his testimony, was aware that the phrase was

8/ Exh. 3 F.
9/ Tr. 36, 50-51.

subject to different interpretations. 10/

In one situation when a controller clears an aircraft for takeoff or landing and at the same time another aircraft is either taking off or turning off the runway, "clear of the runway" means to both tower and pilot that the aircraft departing the runway is at that point in time physically clear and will under normal circumstances be well clear when the other aircraft reaches the departure point.

In a second situation it has quite a different meaning; for example, when an aircraft is stopped close to the runway, for whatever reason, it means to both pilot and tower that not only is the aircraft physically clear but it is also far enough removed so as not to constitute a hazard to other aircraft. In this case there was a combination of both situations. According to the FAA there are no definitive criteria in distance to serve as guidelines for the tower in this situation. However, the testimony clearly indicated that an immobile aircraft 7 feet from the runway is considered to be a hazard by the FAA and the runway should be closed. 11/

Despite the so-called lack of criteria there are regulations which state that taxiway holding line markings must be at least 100 feet and not more than 200 feet from the nearest edge of the runway. 12/ Obviously,

10/ Tr. 24-25, 35, 78.
11/ Tr. 31, 76-79.
12/ Exh. 3 F.

under this regulation a holding aircraft is considered a hazard to aircraft using the runway unless it is at least 100 feet from the runway. It would seem that the regulation should apply not only to aircraft approaching a runway but, a fortiori, to aircraft taxiing away from a runway since there is a greater hazard to other aircraft from jet exhaust. Furthermore, if a holding aircraft is considered to be a hazard unless it is at least 100 feet from the runway then any aircraft stopped for whatever reason and on any heading within 100 feet should also be considered a hazard.

Although not directly involved in the accident but constituting a safety problem is the fact that the tower cleared TWA 128 to land when it was known that TWA 159 had aborted. 13/ Even though TWA 128 was in its final approach it seems to me the more prudent course of action would have been to have advised TWA 128 not to land so that three aircraft -- one that had aborted, one stuck in the mud, and one landing -- would not be on the runway at the same time.

Additionally, I believe that there should be further study of the adequacy of the existing accelerate-stop distance requirements with particular attention to whether there should be an additional time allowance for pilot decision time. Present criteria allow for a reaction time of 3.44 seconds for a pilot with an emergency at or before V_1 to physically complete

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13/ Tr. 40-42.

the abort sequence but there is no allowance for a decision time. Apparently it is assumed that a pilot's decision in the case of engine failure at or prior to V_1 is already made with respect to the abort and he will automatically initiate the abort sequence. I am not convinced that this is a valid assumption and it may be that there should be additional time allowed for the pilot to recognize the precise difficulty, to decide on the appropriate corrective action, and then time to initiate the action. For malfunctions other than engine failure it would certainly seem that additional time is required for pilot decision.

In this connection it is significant that the instructions contained in the TWA Boeing 707 Flight Handbook read as follows:

> ". . . 5.a. Aborting a takeoff at high speeds is potentially dangerous and should not be attempted unless an actual engine failure has occurred prior to V_1. Under the balanced runway length concept an abort at V_1 that is perfectly executed will require every foot of the remaining runway. Anything less than a maximum effort throughout the entire stopping attempt will probably result in running off the end of the runway. Barring an actual engine failure (prior to V_1) the aircraft has a greater capability to successfully continue the takeoff than to stop.
>
> "Serious consideration should always be given to continuing the takeoff rather than abort where abnormal conditions, other than engine failure, are encountered prior to reaching V_1. Engine failure will manifest itself by yaw or loss of performance, either of which can be confirmed by multiple engine instrument indication." (Emphasis added) 14/

14/Exh. 2 E.

It appears from the above that an abort initiated at V_1 may or may not be successful. For this reason alone the existing accelerate-stop distance criteria should be reexamined. However, more important is the fact that if there is a malfunction other than engine failure the pilot is advised to give serious consideration to continuing the takeoff rather than aborting. Obviously if the pilot has to give a malfunction "serious consideration" this will require additional time over and above reaction time to decide whether the abnormal condition is indeed substantial enough to abort the takeoff.

/s/ Francis H. McAdams

Captain Volney D. Matheny, age 45, held airline transport pilot certificate No. 105464, with ratings in the Martin 202/404, Lockheed Constellation, Boeing 707/720, and airplane multi engine land. He had accumulated 18,753 total flying hours of which 1,532 hours were as captain and 4,672 hours as first officer in this type aircraft. His last proficiency check was completed on September 22, 1967, and his FAA first-class medical certificate was issued on May 9, 1967, with no limitations. He had been off-duty for 18:05 hours prior to this flight.

First Officer Ronald G. Reichardt, age 26, held commercial pilot certificate No. 1529342 with airplane single and multi engine land, instrument, and flight instructor ratings. He also held flight engineer certificate No. 1582586 with ratings for reciprocating engine and turbojet engine powered equipment. He had accumulated 1,629 total flying hours, of which 830 hours were in this type aircraft. His last proficiency check was completed on July 21, 1967, and his FAA first-class medical certificate was issued on October 26, 1967, with no limitations. He had been off-duty for 18:05 hours prior to this flight.

Flight Engineer Robert D. Barron, age 39, held flight engineer certificate No. 1276442 with ratings for reciprocating engine and turbojet engine powered equipment. He also held commercial pilot certificate No. 1066284 with airplane single engine land and instrument ratings. He had accumulated 11,182 hours as a flight engineer, of which 5,444 hours were in this type aircraft. His last proficiency check was completed on January 30, 1967. His FAA first-class medical certificate was issued on

April 4, 1967, without limitations, and was still valid as a second-class medical certificate at the time of the accident. He had been off-duty for 18:05 hours prior to this flight.

Hostess Janan Perkins, age 21, was hired on June 6, 1966. She completed her last emergency procedures training on July 5, 1967.

Hostess Roswitha Neal, age 25, was hired on June 6, 1966. She completed her last emergency procedures training on October 12, 1967.

Hostess Kathleen Fankhouser, age 21, was hired on July 11, 1966. She completed her last emergency procedures training on July 6, 1967.

Hostess Sara Muir, age 25, was hired on October 17, 1966. She completed her last emergency procedures training on October 23, 1967.

Appendix B

N742TW, a Boeing 707-131, serial No. 17669, had accumulated a total time of 26,319 hours at the time of the accident. The aircraft was equipped with four Pratt and Whitney JT3C-6 engines installed as follows:

Position	Serial No.	Time Since Overhaul	Total Time
1	629431	4600:28	16,273:08
2	629183	4419:08	16,045:45
3	629201	5878:41	17,502:47
4	629428	15:08	15,238:04

The aircraft was serviced with kerosene and had a computed takeoff gross weight of 212,231 pounds, which was below the maximum allowable takeoff weight of 218,500 pounds. The computed center of gravity was 28 percent, which was within the allowable range of 14 to 31.5 percent MAC.

Appendix C

COCKPIT VOICE RECORDING

The following is a partial transcript from the CVR's in TWA 159 and DAL 379:

2339:05	Tower	TWA one fifty nine cleared for takeoff
	TWA 2	One fifty nine Roger
:24	Tower	Delta three seventy nine you're clear of the runway, aren't you?
	DAL 2	Yeah, we're in the dirt though
	Tower	Okay, TWA one fifty nine he's clear of the runway, cleared for takeoff, company jet on final behind you.
:35	TWA 2	Okay, we're rollin'
:37.5		(Engine sound reaches highest pitch)
:57.5	TWA 1	Eighty knots, you got 'er
2340:09	TWA 1	Not very . . . far off the runway
	TWA 2	Sure . . . isn't
:15.5		(Sound of "pop" recorded)
:16.5		(Sound of engine power cut)
	TWA 2	Good God, I hit him
:17.5	TWA 2	Yokes
:20		(Sound of engine power resumption)
:20.5	TWA 2	Spoilers!

:32		(Sound of impact begins)
2344:03	DAL?	I, I just wonder if, if us sitting here - - - I don't know
45:57	DAL?	I guess we're off the runway, I don't know
49:07	DAL?	I wonder if the exhaust of our engines had any effect on him

Appendix D

The term V_1 refers to a speed at which the takeoff can be safely continued or safely aborted within the limits of the runway remaining, assuming that the critical engine failed at V_1. The accelerate-stop distance is the sum of the distances necessary to accelerate the aircraft from a standing start to V_1, abort the takeoff, and then come to a complete stop. The calculations on which the maneuver is predicated are based on the use of a smooth, dry, hard-surfaced runway. Certain allowances are also made for the human factor elements. These include consideration of normal pilot skill, pilot reaction time, and the number and complexity of the steps required to complete the maneuver.

In their recommendation, ALPA contended that the time values used to allow for transition and execution of the abort procedure are unrealistic and cannot be duplicated in normal airline operation. The most important factor in this is the element of surprise which exists in operational aborts but which cannot be duplicated in the flight tests upon which the performance data is based. ALPA further contended that these flight tests are conducted by experienced flight test pilots who have practiced the maneuver, and that the tests are performed in a new aircraft in prime condition and under ideal operating conditions. The Association concluded that for these reasons, under normal service conditions, a takeoff cannot be safely aborted if the emergency occurs just at the V_1 speed.

The determination of a realistic aborted takeoff concept has been the subject of considerable Government/industry effort. In 1963, the Federal Aviation Agency (now Federal Aviation Administration) issued a Notice of Proposed Rule Making in which an attempt was made to account for operations under adverse runway conditions by proposing rationalized requirements for accelerate-stop distances. For the purpose of determining the minimum runway length for takeoff, the proposed amendment would have required the addition of a constant distance margin of 800 feet to the accelerate-stop distance. Of this 800 feet, 600 feet were to provide a 3-second decision time (assuming an average speed of 200 feet-per-second) to the pilot, and 200 feet to account for the runway used in positioning the airplane for takeoff. However, the 800-foot margin was then misinterpreted by parties within and outside the Agency as implying that a 4-second reaction time was required for an average pilot to recognize the problem and to decide on and initiate the appropriate action.

This proposal was withdrawn because of the numerous comments received from interested parties. The comments noted that there were safety margins not recognized in the notice such as the substantial reduction in stopping distance made possible by use of reverse thrust, the low probability of engine failure just at V_1 speed, and time delays imposed during type certification. Other comments noted that, since the V_1 concept is based entirely upon engine failure, a decision time is inappropriate because the pilot's decision is already made depending upon his speed. Until V_1 is reached, he may either safely abort or continue the takeoff, and after V_1, he is committed to a takeoff. Thus, to abort a takeoff under this concept, a pilot need not first assess the effects on the aircraft of some emergency situation and then determine his ability to continue the takeoff based on the probable remaining performance of the aircraft. Instead, he need only recognize the failure of an engine and abort or continue the takeoff depending on his speed at the time.

In response to a 1965 recommendation by the Bureau of Safety (now Bureau of Aviation Safety) that the FAA either provide longer pilot reaction times or, in the alternative, ascertain that line pilots can meet the existing requirements, the FAA discussed its continuing study of the matter and outlined some of the conservatisms contained in the current requirements. The reply explained the arbitrary time delays which were added to the test pilot's normal reaction time to determine the total time to be allowed for completion of the abort sequence. In the case of the Boeing 707-131, the total time allotted is 3.44 seconds. In determining that time, Boeing pilots demonstrated the following reaction times: .35 seconds from recognition of the abort to brake application, .41 seconds from brake application to power reduction, and .68 seconds from power reduction to spoiler extension. The foregoing times add up to a total abort procedure time, including reaction, of 1.44 seconds.

To account for various operational factors, a 2-second delay was added, thereby arriving at the 3.44-second time period. The time added is predicated, in part, upon the number of motions required to activate the required decelerating devices other than brakes.

The ALPA recommendation also cited this accident as further evidence that the current means of calculating the V_1 speed is unrealistic. This contention was based on the fact that the initial study of the flight recorder and CVR data derived from the accident flight indicated that the accelerations of N742TW were appreciably slower than those predicted by the aircraft manufacturer. ALPA contended that by using the recorded takeoff acceleration to calculate the time and distance down the runway at which V_1 should have occurred, it is possible to show that the aircraft was not yet at V_1 when the abort was initiated. Therefore, according to those calculations, the aircraft should have stopped without overrunning the runway if the V_1 criteria were realistic.

The Board, however, has two main points of disagreement relative to the validity of the foregoing ALPA reasoning. First, after a detailed study and a comparison of the CVR and flight recorder records with the predicted data, the Board is convinced that the disparities were: airspeed data from the flight recorder are not considered valid below 80 knots, the effects of static position error induced by the engine reversing operation, and the fact that the precise initiation of the takeoff roll is not discernible from visual examination of the recorder tape alone.

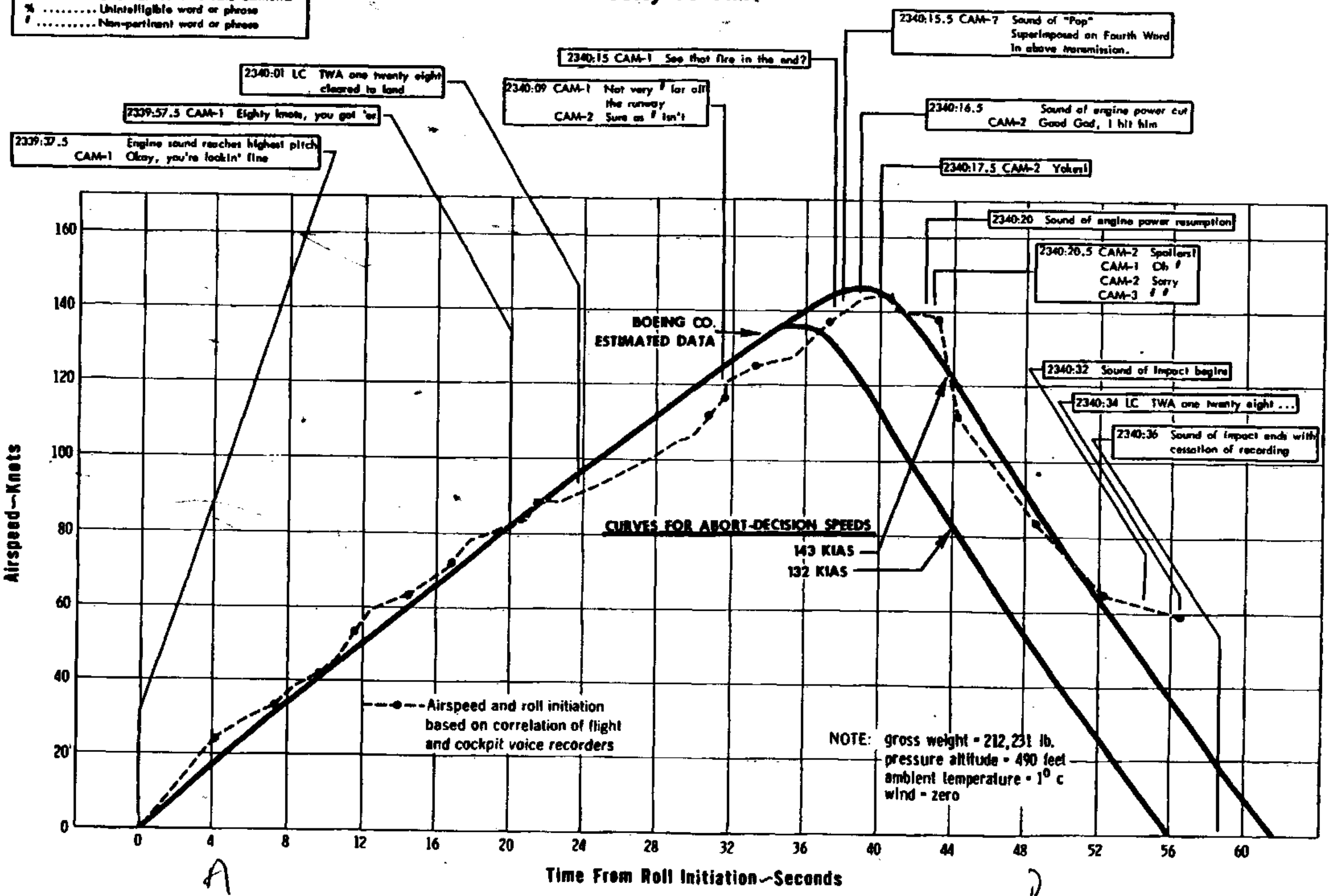
Attachment 1

CVR LEGEND

CAM ....Cockpit Area Microphone Channel (Number following indicates speaker where known)
RDO ....Radio transmission from TWA 159
CAM-1 .....Voice of Captain
CAM-2 .....Voice of First Officer
CAM-3 .....Voice of Flight Engineer
CAM-? .....Voice Unknown
LC ....Cincinnati Tower Local Controller
GC ....Cincinnati Tower Ground Controller
% ....Unintelligible word or phrase
# ....Non-pertinent word or phrase

TRANS WORLD AIRLINES INC.
B-707, N742TW
THE GREATER CINCINNATI AIRPORT
ERLANGER, KENTUCKY
NOVEMBER 6, 1967

Velocity vs Time



Attachment 2

TRANS WORLD AIRLINES INC.
B-707 N742TW
THE GREATER CINCINNATI AIRPORT
ERLANGER, KENTUCKY
NOVEMBER 6, 1967
Velocity vs Distance

CVR LEGEND

CAM ....Cockpit Area Microphone Channel (Number following indicates speaker where known)
RDO ....Radio transmission from TWA 159
CAM-1 .....Voice of Captain
CAM-2 .....Voice of First Officer
CAM-3 .....Voice of Flight Engineer
CAM-? .....Voice Unknown
LC ....Cincinnati Tower Local Controller
GC ....Cincinnati Tower Ground Controller
% ....Unintelligible word or phrase
# ....Non-pertinent word or phrase