SA-None File No. 1-0026

AIRCRAFT ACCIDENT REPORT

TRANS CARIBBEAN AIRWAYS, INC.

Boeing 727-200, N8790R

Harry S. Truman Airport
Charlotte Amalie, St. Thomas
Virgin Islands
December 28, 1970

Adopted: DECEMBER 29, 1971

NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D. C. 20591
REPORT NUMBER: NTSB-AAR-72-8

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. NTSB-AAR-71-8	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle TRANS CARIBBEAN AIRWAYS, INC., Boeing 727, 200, N8790R, Harry S Truman Airport, St. Thomas, Virgin Islands, U.S.A., December 28, 1970	5. Report Date December 29, 1971 6. Performing Organization Code
7. Author(s)	8. Performing organization Report No.
9. Performing Organization Name and Address Bureau of Aviation Safety National Transportation Safety Board Washington, D. C. 20591	10. Work Unit No. 11. Contract or Grant No. 13. Type of Report and Period Covered Aircraft Accident Report December 28, 1970
12. Sponsoring Agency Name and Address NATIONAL TRANSPORTATION SAFETY BOARD Washington, D. C. 20591	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Trans Caribbean Airways Flight 505 crashed during an attempted landing at Harry S Truman Airport, St. Thomas, U. S. Virgin Islands. Forty-six of the 48 passengers and the entire crew of seven survived the accident and the ensuing ground fire.

The flight, which originated at New York, was routine until the attempted landing at St. Thomas. At that time, the aircraft touched down hard and bounced to an estimated height of 50 feet. A right main landing gear attach structure failure was initiated on the second touchdown. The aircraft then bounced again, and after the third touchdown, the right wing tip settled to the ground. The aircraft departed the airport property and came to rest on the slope of a nearby hill.

The National Transportation Safety Board determines that the probable cause of this accident was the captain's use of improper techniques in recovering from a high bounce generated by a poorly executed approach and touchdovn. Lack of cockpit crew coordination during the approach and attempted recovery contributed to the accident.

17. Key Words Aircraft accident, landing accident, overload failure, loss of control, collision with ground, survivability, firefighting, evacuation	18. Distribution Statement Released to the public Unlimited distribution

19. Security Classification (of this report) UNCLASSIFIED	20. Security classification (of this page) UNCLASSIFIED	21. No. of Pages 55	22. Price

NTSB Form 1765.2 (11/70)

TRANS CARIBBEAN AIRWAYS, INC.
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SYNOPSIS

A Trans Caribbean Airways, Inc., Boeing 727-200, N8790R, operating as Flight 505, crashed during landing at the Harry S Truman Airport, St. Thomas, Virgin Islands, at 1442 Atlantic standard time on December 28, 1970. Of the 48 passengers and seven crewmembers aboard, two passengers received fatal injuries.

The weather at the airport was clear, with visibility in excess of 30 miles. The surface winds were reported to be from 110° at 10 knots at the time of the accident.

Flight 505 made a visual approach to Runway 9. The approach appeared to be normal until touchdown, after which the aircraft ascended to a height of about 50 feet above the runway. The aircraft touched down again very hard, became airborne again, and touched down a third and last time about 2,700 feet down the 4,650-foot runway. Almost simultaneously with the last touchdown, the right wing tip settled to the runway. The aircraft then veered off the right side of the runway, continued along a grass median strip parallel to the runway, passed through the airport perimeter fence, crossed over a paved highway, and came to rest against a hillside adjacent to the highway. A small fire ignited immediately but several minutes elapsed before a general conflagration developed. In the interim, 46 of the 48 passengers and all crewmembers escaped from the aircraft. The injuries to the survivors varied from none to serious.

The National Transportation Safety Board determines that the probable cause of this accident was the captain's use of improper techniques in recovering from a high bounce generated by a poorly executed approach and touchdown. Lack of cockpit crew coordination during the approach and attempted recovery contributed to the accident.

1. INVESTIGATION

1.1 History of Flight

Trans Caribbean Airways, Inc. (TCA), Flight 505, a Boeing 727-200, N8790R, was a regularly scheduled passenger flight from New York, N. Y., to St. Croix, Virgin Islands, with intermediate stops at San Juan, Puerto Rico, and St. Thomas, Virgin Islands.

On December 28, 1970, the New York to San Juan portion of the flight was completed routinely. Flight 505 departed San Juan at 1427 1/ on an Instrument Flight Rules (IFR) flight plan for St. Thomas. The flight was cleared via Route 2 to the St. Thomas VOR 2/ to maintain 7,000 feet mean sea level (m.s.l.). The en route time was estimated at 15 minutes. The weather throughout the area was generally clear and the visibility was in excess of 30 miles. At 1435, Flight 505 was cleared by San Juan Center to descend to 3,000 feet m.s.l., and at 1438 the flight cancelled the IFR flight plan and proceeded under visual flight rules. Contact was established with St. Thomas tower and Flight 505 was cleared via Savannah Island, a visual checkpoint about 7 miles west of the Harry S Truman Airport, for a straight-in approach to Runway 9. The surface winds were reported to be from 1200 at 5 knots. Flight 505 reported over Savannah and was given clearance to land. A wind check was requested when the flight was several miles from touchdown, and the St. Thomas tower controller reported the wind to be from 1100 at 10 knots.

The crew reported that the approach was conducted using the VASI 3/ for glide slope reference, with a sink rate of *600* to 700 feet per minute, and an airspeed approximately 5 knots over reference speed (117 knots) 4/. The first touchdown occurred approximately 300 feet down-the runway according to the tower local controller. In their statements, the crew all noted that the approach seemed normal. However, the captain stated that he broke his glide just over the end of the runway with no power reduction, but that the aircraft made a sudden and very hard contact with the runway approximately 1 second before he expected it to touchdown. The first officer noted that, after flaring, the airspeed dropped rather rapidly to 5 knots below reference speed, and the aircraft dropped or touched down an instant later.

The aircraft immediately rebounded into the air, ascending to a height estimated by several witnesses to have been 30 to 50 feet, with an attitude described by the flight engineer as "... nosed up more than I had seen before."

The captain recalls none of the events of the flight subsequent to the initial touchdown; however, both other flight crewmembers noted that the captain did not seem to be reacting as he normally would. The first officer, who followed the captain through this bounce with his hands on the yoke, did not think the captain was using sufficient control force. The flight engineer noted "Then as we crested the bounce, the captain reached for the speed brake handle, paused for a second, then pulled it back; then returned it just before, or as we touched the second time."

The second touchdown occurred about 1,500 feet from the threshold according to the tower controller. This touchdown was described as hard both by eyewitnesses and passengers. Two passengers commented: "... so hard it literally shook the stuffings out of the whole plane" and "... extremely violent bone jarring is an apt description - and there was a buckling effect with noise of grinding metal." Two passengers thought something on the right main landing gear broke on this touchdown.

The aircraft then bounced again, this time to an estimated height of 15 to 30 feet. The first officer noted "The aircraft bounced a second time, the nose over-rotating upwards. It was at this point that I took firm hold of the yoke and pushed forward. As the aircraft reached the crest of the bounce I pulled. all the way back on the yoke. The aircraft touched down the third time and stayed on the ground."

Several witnesses verified that the third touchdown occurred about 2,700 feet from the threshold, and that the right wing tip settled and began to drag on the runway immediately after the touchdown. The local controller said that the fire department was called just after this bounce. It was about this time that the captain called for a go-around, according to the other crewmembers, and the flight engineer advised him not to. The captain advanced the thrust lever, and he called for the flaps to be raised to 250. The flight engineer noted that he tried, first with his left hand and then with both hands, before he succeeded in raising the flap lever to the 25° setting. The aircraft veered off the runway 3,800 feet beyond the threshold, and the first officer helped the captain regain directional control.

At approximately this point in the sequence of events, witnesses recalled hearing "muted popping sounds" or "backfire" noises, and some saw flames extending from the tailpipes of one or more engines. One witness, an aircraft mechanic, stated that the No. 3 engine compressor was definitely stalling as it passed his position. This witness was located approximately 3,800 feet from the runway threshold.

The aircraft then continued, almost parallel to the runway, across the access taxiway to Runway 27 and through a chain link boundary fence at a point 4,950 feet from the threshold of Runway 9. The landing gear and right wing tip then struck a raised concrete sidewalk located about 4 feet beyond the fence. The aircraft passed over the sidewalk and an adjacent highway and crushed a truck thereon that had been hastily abandoned by its driver seconds earlier. The aircraft continued up the incline of a hill immediately east of the highway and began to break apart as it came to a stop. An explosion occurred in the vicinity of the left wing root immediately after the aircraft stopped. This was followed by a small fire in the same area, as the passenger evacuation began. Several minutes elapsed before the fire became intolerable; in the meantime 46 of the 48 passengers and all seven of the crewmembers had escaped from the aircraft. The flight engineer helped the captain, who appeared to be too stunned to leave the aircraft.

The accident occurred in daylight at an elevation of 11 feet m.s.l. The location was at latitude 18° 20' N. longitude 64° 58' W.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	0	2	0
Nonfatal	I	43	0
None	0	3	

The injuries sustained by the survivors varied from critical (1) to minor or none. There were 11 serious injuries, two of which were sustained by crewmembers. A total of 20 of the survivors required hospitalization.

1.3 Damage to Aircraft

The aircraft was destroyed by the ensuing fire.

1.4 Other Damage

A pick-up truck abandoned on the highway in the path of Flight 505 was substantially damaged.

Minor damage was done to the airport runway and taxiway light systems, to the airport boundary fence, and to an electric utility line near the wreckage site.

1.5 Crew Information

The flightcrew was properly certificated and had completed all training and proficiency requirements. A review of the records disclosed no discrepancies in training. Favorable comments had been made regarding the performance of both the captain and the first officer.

The purser and the three flight attendants had all received proper training in accordance with existing directives, and their emergency training was current.

The captain, who transitioned to the Boeing 121 from a DC-8 in September 1970, had a total of 169:34 hours in the B-727, of which 32:55 were training hours. He had made five previous entries into St. Thomas, three of which occurred in October , and two in December, 1970. His total flying time was 10,665:33 hours.

Both of the other crewmembers had more pilot time (second-in-command) in the B-727 than did the captain; the first officer had 1126:41 hours, and the flight engineer had 1519:54. Their total flying hours were 21,016:28 and 17,589:26, respectively.

For additional crew information, see Appendix B.

1.6 Aircraft Information

The aircraft was properly certificated and it had been maintained in accordance with existing regulations.

The weight and center of gravity were within the prescribed limits for the flight from San Juan to St. Thomas. The aircraft had been serviced with Type A aviation kerosene.

1.7 Meteorological Information

The surface weather observation for St. Thomas at 1350 was: scattered clouds at 2,000 feet, visibility 35 miles, winds 120° at 10 knots, altimeter 29.97, temperature 87° F., with towering cumulus clouds existent in all quadrants.

In response to a request from Flight 505 for a wind check, the tower controller reported the winds to be from 110° at 10 knots; this was given at 1341 when the flight was on final approach, several miles from the airfield.

subsequent to the accident, at 1443, the surface weather observation was: scattered clouds at 2,000 feet, visibility 30 miles, winds 110° at 10 knots, altimeter 29.95.

1.8 Aids to Navigation

Flight 505 made a visual approach to Harry S. Truman Airport using glide slope data from the VASI system installed on Runway 9. This was a non-standard system, comprised of two sets of boxes located on each side of the runway 550 feet and 1,050 feet from the threshold, respectively.

The system is normally aligned for a 2.5° (± 0.2°) glidepath angle. The aiming point is 800 feet from the runway threshold and, based upon a 2.5° angle, the threshold crossing altitude is approximately 35 feet.

In a flight inspection of the system conducted on December 28, 1970, the FAA determined that the glidepath angle on the right-hand system was 2.550, that of the left-hand system was 2.750, and the average glidepath angle for the entire system was 2.65°. This misalignment of the left-hand system was an out-of-tolerance condition and the FAA took the system out of service until the glidepath angle was correctly adjusted.

/

1.9 Communications

NO problems with communications were reported on the flight from San Juan to St. Thomas.

1.10 Aerodrome and Ground Facilities

The Harry S Truman Airport is located on the southern shore of St. Thomas Island at an elevation of 11 feet m.s.l., about 2.5 miles west of the town of Charlotte Amalie.

The island of St. ,Thomas is of volcanic origin. The airport site is on one of the few low, flat areas. The airport has a single bituminous surfaced runway, 9-27 (east-west), which is 4,650 feet long and 200 feet wide, with a 500- foot long by 100-foot wide overrun on the east end. A single parallel taxiway located 250 feet south of the runway centerline provides access to the runway.

The clear zone from the west to Runway 9 is over the sea, and the effective length of that runway is 4,650 feet. Landings on this runway are authorized for these aircraft only at 40° flap settings. Because of terrain obstructions consisting of hills rising to heights of 175 and 230 feet m.s.l., along the approach path, and adjacent to the end of Runway 27, landings to the west are not permitted for this type aircraft.

There are two wind cones available on the airport, one on each side of the runway. The first is on the south side of the runway, 500 feet from the threshold of Runway 9; the second is on the north side, 3,000 feet from the same threshold. An anemometer is 1,700 feet from the threshold and on the north side of Runway 9. Wind information is transmitted from the anemometer to the control tower.

1.11 Flight Recorders

(a) Flight Data Recorder

The aircraft was equipped with a United Data Control Flight Data Recorder, model F542, S/N 2469. This unit was recovered in good condition and all parameters were functioning, although the altitude trace contained a constant ± 250-foot error. A data graph was plotted beginning 3 minutes prior to a point on the vertical acceleration trace where a peak of +1.7 g's appears, and the beginning of this plot was labeled time zero.

The data plot is set forth in Attachment 1.

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(b) Cockpit Voice Recorder

The aircraft was equipped with a Collins cockpit voice recorder (CVR), model 642C-1, S/N 712. This unit produced a generally intelligible tape which contained, in addition to the voices of the crew, various sounds associated with the approach, landing, and subsequent phases of this flight. These sounds include those associated with gear and flap actuation, trim actuation, and various warning horns. A transcript was made of the portion of the tape from the early phase of the approach to the end of the recording. The times recorded on this transcript indicate the time in seconds prior to the end of the recording.

Soon after the flight was configured for the final approach, the flight engineer first noted that it was "a good day to slow up", and he then said, "I want you to slow it up once and see if ya feel it." Shortly thereafter, the following was recorded: (flight engineer) "And the VASI slope shows you ...." (captain) "A little high."

During the descent, both the first officer and the flight engineer commented on the rate of descent. The first officer first noted that the sink was 600 feet per minute (fpm), the flight engineer later stated that the captain was high on his sink, and 4.4 seconds before the sounds associated with touchdown, the first officer observed that the sink rate was 700 fpm.

Refer to Appendix C for a transcript of the cockpit voice recorder tape.

1.12 Wreckage

During the on-scene investigation, various markings were found on the runway which were associated with the landing of this aircraft.

Rubber scuff marks were noted approximately 365 feet from the runway threshold. The distance between the centers of these marks was equal to the spacing between the main landing gear of the E-727.

At a point 1,490 feet from the threshold, a 17-foot long groove was cut into the surface of the runway parallel to the centerline. The tailskid scuff block from the aircraft, which was worn flat, was removed from the wreckage and found to match the width of this groove.

The aircraft parts located nearest to the threshold were very small bits of lightweight material and parts of structural fasteners. These parts, which were scattered approximately 2,000 feet from the threshold, were not found at the time Board investigators surveyed the scene. The first parts documented in place were located 2,700 feet down the runway. These parts included plexiglass from the right wing tip, the aft panel of the right outboard flap, pieces of the right landing gear inboard attach link assembly, a section of floor beam web from Fuselage Station (FS) 940, a section of stringer from the same general area, and numerous fasteners or parts of fasteners.

The landing gear left intermittent tracks on the runway and in the grass area adjacent to the runway from a point just over 2,900 feet down the runway to a sidewalk located along the perimeter road. The nose wheel track ran off the right edge of the runway at 3,800 feet.

The aircraft passed through a chain link fence 4,750 feet from the threshold, struck the edge of the raised concrete sidewalk, struck the roof of a truck abandoned on the perimeter road, and impacted the slope of a hill located beyond the road. The fuselage sections came to rest, essentially upright, 300 feet from the end of the runway and 200 feet to the right of the runway centerline extended. These sections were rotated approximately 90° clockwise from the runway heading.

The airframe sustained extensive structural damage, with two complete fractures of the fuselage and a fracture of the vertical fin. The fuselage fractures occurred fore-and-aft of the wing center section, at FS 700 and in the area of FS 940. The vertical fin fractured at Fin Station 87, with control cables retaininq the broken section.

The various controls and their actuators were examined in order to determine the configuration of the aircraft at impact:

> The measurements between the lower stops and the moving nuts of the wing flap jackscrew assemblies were consistent with those which occur at a 40° flap extension;
>
> The wing leading edge devices were extended:
>
> All wing flight spoiler panels examined were in the retracted position;

The horizontal stabilizer was found positioned approximately seven to eight units airplane nose up.

The Nos. 1 and 3 engines were intact and in place on their pylons. The No. 2 engine was separated from its attach mounts and was found under the empennage. The engines bore no evidence of operating distress; no evidence of blade separation or disc failure was found, nor did the various engine filters display any evidence of contamination. The cockpit was destroyed by fire; however, the steel remains of the three thrust levers were recovered with the reverser levers in the forward and stowed position. The thrust reverser deflector doors were found in the stowed position.

Although the fuel line tunnels were almost entirely consumed. the engine fuel lines were intact, and were continuous from their respective engines to the area of the fuel tanks. The No. 1 engine fuel shutoff valve was consumed: the Nos. 2 and 3 valves were intact, and were found in the open position.

Because of evidence on the runway of a right main landing gear failure, the gear components and the gear attach structure were subjected to close scrutiny to determine if any incipient fault may have caused failure of the landing gear or its attachments.

A brief explanation of the structural design of the gear attach structure may provide a better understanding of this system. The loads applied to the B-727 landing gear are reacted by the wing spar at the forward trunnion points, by the landing gear beam at the aft trunnion point, and at the side brace support point. Those loads applied to the landing gear beam are, in turn, reacted by the wing spar at the outboard end of the beam and by the body-to-main landing gear (MLG) link at the inboard end. The major part of the link load is reacted into the body by the FS 940 frame, and bending moments resulting from further distribution of these loads into the fuselage are reacted, in part, by the FS 940 floor beam.

Considerable damage to the fuselage structure was evident in the area of the right gear attach structure. The FS 940 frame was recovered from the main wreckage, standing vertically beneath its normal position with respect to the fuselage. Few of the fasteners which attach the frame to the right-hand fuselage structure remained in place--most of them were separated, leaving vertically elongated holes in the frame and the fuselage skin. It was fasteners of this type and size which were found on the runway approximately 2,700 feet from the threshold. A portion of the FS 940 floor beam was also found on the runway in this area.

The nature of the failures of the landing gear attach structure was studied by the Boeing Company, and the findings of that study are reported in Section 1.15, Tests and Research. The broken pieces of the body-to MLG link, some of which were also found on the runway, were forwarded to the Boeing Company for examination. The results of this examination are also reported in Section 1.15.

The landing gear assembly and its attachments to the aircraft structure were examined minutely, with no evidence of any preimpact malfunction observed.

1.13 Fire

There was no evidence of the existence of fire until the aircraft came to rest against the western slope of Sara Hill. Witnesses reported that, at that time, an explosion occurred in the area of the left wing root, creating a large column of black smoke that dissipated rapidly. A small fire started in the area of the explosion but several minutes elapsed before it seriously jeopardized the evacuation efforts.

The airport fire department is located 200 feet north of the runway and about 800 feet west of the approach end of Runway 27. The station was manned by six firefighters. An additional nine auxillary firefighters had been trained and were available from personnel in the airport maintenance shop. The following equipment was available to the fire department:

1- Engine I (pumper) with a capacity of 300 gallons of water and 18 gallons of foam.

1- Engine II (fire boss) with a capacity of 1,500 pounds of dry powder, 500 gallons of water, and 100 gallons of foam.

1- Quick-dash truck with a capacity of 300 pounds of dry chemical powder and one 225-pound nitrogen bottle.

1- Standby water truck with a capacity of 1,000 gallons of water.

The crash sequence and impact were observed by several of the permanent firefighting personnel. Response to the crash was instantaneous with Engines I and II and an ambulance. This equipment was estimated to have arrived on-scene within 1-to-1-1/2 minutes.

The two fire engines were initially driven up the access road near the aircraft cockpit and the fire was attacked from that position with the turret nozzle of Engine II. The firemen were forced to retreat, however, because of the intensity of the fire. Other equipment. including the Insular Fire Department's (city of Charlotte Amalie) 750-gallon pumper, deployed hand lines from the main road. The fire was not extinguished until the fuselage was virtually consumed.

Virtually the entire fuselage from the nose to the rear pressure bulkhead at FS 1183 was concumed by fire. There was no fire damage aft of FS 1183; all 3 engines and the empennage remained undamaged by fire. The left wing was heavily damaged by the fire, and the right wing was consumed from Wing Station (WS) 414 to the tip. The portion of the right wing from WS 414 to the root was unburned, and the right main gear well sustained little fire damage. The left main gear well was destroyed by fire.

1.14 Survival Aspects

This was a survivable accident. Of the 55 persons aboard, all seven crewmembers and 46 of the 48 passengers survived. The cause of the two fatalities was attributed to burns. One fatality reportedly was trapped by debris between two seats in Row 22. The body of the other fatality was recovered, free from its seat, on the ground in the area of the aft break in the fuselage.

N8790R had a total passenger seating capacity of 134, apportioned into three separate seating areas. The forward thrift area had 21 seats, the intermediate first-class area contained 12 seats and the aft thrift area contained 101 seats. See Attachment 2, Passenger Seating and Escape Diagram. for details,

In the process of coming to a stop against the slope of Sara Hill, the aircraft fuselage broke into three major sections; forward, center and aft. The first break (identified as A in Attachment 2) occurred at FS 700. The second break (identified as B in Attachment 2), occurred around FS 940.

a. Forward Section

The forward section contained the cockpit, forward thrift area, and intermediate first-class area. This section was occupied by the flight deck crew, seven passengers and two flight attendants. It contained the left main entry door and the forward galley door. The latter was located on the right side of the fuselage. Both doors were equipped with inflatable evacuation slides. The galley door was opened by the two flight attendants with the assistance of several of the passengers and the evacuation slide was inflated without difficulty. However, the slide failed to reach to the ground because the forward section of the aircraft was resting on a 17-foot high embankment. Consequently, the lower end of the slide was about 6 feet above ground level and at least one of the evacuees from that section sustained serious injuries as a result of the 6-foot drop from the bottom of the slide. All 12 occupants of this section successfully escaped through the galley door exit.

b. Center Section

The center section of the aircraft consisted of that portion of the fuselage from FS.700 to FS 940; it contained 60 seats and was occupied by 19 passengers. The four overwing emergency exits were located in that section; however, none of these were used, as all 19 passengers escaped through the aft break in the fuselage at FS 940. Many reported that they had to crawl across broken seats and other debris to reach the aft break. A drop of 10 to 15 feet was required to reach level ground through the aft break. Many of the evacuees used conduits and cables exposed by the rupture to assist in their descent to the ground.

c. Aft Section

The aft section extended from FS 940 to the end of the aircraft. It contained 41 seats and was occupied by 22 passengers and two flight attendants. The aft main cabin entry and the aft galley service doors were located in that section, on the right and. left sides of the fuselage, respectively. Also, the rear ventral stair was located on the aft section. One of the flight attendants experienced difficulty in opening the aft main cabin entry door. However, with the aid of several passengers, she opened the door and inflated the evacuation slide. The other flight attendant attempted to reach her emergency station at the over-wing exits but was unsuccessful due to many obstructions and to passengers attempting to move fore and aft to other exits. She managed to get to the aft break at FS 940 where she directed the escape efforts of aft section evacuees. She recalled considerable smoke and heat in that area as the last passengers made their exit. Twelve evacuees of the aft section escaped through the fuselage break, and 10 used the slide out of the aft main door. The two passenger fatalities were located in the aft section.

d. Flight Deck

The captain could recall none of the events that occurred from the time immediately subsequent to the first touchdown until arrival at the airport terminal building quite some time later. He advanced the possibility that his seat locking mechanism may have malfunctioned on initial touchdown, allowing the seat to move in such a manner that injury was caused to his head from a blow against cockpit structures.

Although the captain's seatbelt and shoulder harness were secured, he sustained multiple bruises on his head and there were small hematomas on the top midline of his head, behind the left ear, and on the posterior midline.

The first officer protected his head with his arms when he realized that the crash was inevitable. His seatbelt and shoulder harness were fastened. He recalled that the aircraft impacted the hill with a severe jolt, but recalled no violent body movements. When the aircraft stopped he unfastened his seatbelt and shoulder harness, opened his cockpit sliding window, and attempted to move the start levers to the "off" position. He shook the captain, who appeared unconscious, and unfastened his seatbelt and shoulder harness. He then went aft to the forward cabin section and noted that all the occupants had departed. He returned to the cockpit and assisted in the evacuation of the captain.

The flight engineer, after he positioned the wing flap lever to the 25° position, subsequent to the final touchdown, moved his seat sideways against his work table, faced the engineer's panel, and grasped the table top tightly with his arms. He placed his head into the corner formed by the back of the first officer's seat and the flight engineer's panel. On final impact, his arms were forced from the table and flung backwards, and the first digit of the fourth finger on his left hand was amputated in the process. His shoulder harness was not fastened. When the aircraft came to rest, he unfastened his seatbelt and moved aft to the forward passenger area. His attempt to open the left main cabin entry door proved futile. He told the flight attendants to leave and surveyed the forward section for remaining passengers. He had intended to proceed to the rear of the passenger section, but the aisle was blocked by a partition which separated the first class and economy class section. He returned to the cockpit and assisted the first officer in removing the captain.

All three flight crewmembers escaped down the evacuation slide from the forward galley door.

There were eight known passenger seat failures in the aircraft. However, the frame of only one seat unit was found, the others having been consumed by the fire. The seat frame, which was that of a right-hand triple unit, was found near the break at FS 940. All of the legs of the seat were fractured, and the entire seat showed a lateral deformation to the left.

The passenger seats were designed for the ultimate inertia forces specified in FAR 25.561, which were: 2.0g upward: 9.0g forward; 1.5g sideward; and 4.5g downward.

The cockpit area, including the crew seats, was totally consumed by fire. The flight crewmembers reported no seat failures, with the exception of the captain's suggestion of a failure of the locking mechanism on his seat.

1.15 Tests and Research

A material failure, either of the captain's seat or of the right main landing gear, might have been a causal factor in the accident. The latter area was suspect because of the landing gear parts on the runway - the former area, because the captain indicated that his failure to remember any of the landing sequence after the initial touchdown might be the result of a seat malfunction which caused his head to strike some portion of the cockpit interior.

The pilot/copilot seats installed in this aircraft were model 808737 series seats manufactured in accordance with the Boeing Company Specification 10-61230 by Weber Aircraft, Burbank, California. The seats were of conventional design, with longitudinal and vertical linear adjustments, and with angular adjustments of the seat back (recline) and seat pan. The seat had a total horizontal travel of 8 inches and a vertical travel of 6 inches. The movement was controlled by hydraulic actuating cylinders that also locked the seat in any given location. Positioning of the seat is aided by sprinqs, and the seat is spring-loaded to the full up and full forward position. The seat was designed for the following crash loads: 16g forward; 7g aft; 10g vertically downward: 7g vertically upward; and 16g left and right (acting 20° from the forward direction).

Two Product Service Bulletins had been issued on the seat by Weber Aircraft. Both dealt with reduction of movement in the seat and the reduction of seat maintenance; the second bulletin, 161R2 dated June 11, 1970, called for replacement of the hydraulic vertical, horizontal, and recline locks with mechanical locks. Neither bulletin was considered urgent, and neither had been accomplished on this aircraft.

An investigation was conducted into the seat adjustment mechanism, with emphasis on injury potential due to a failure of this mechanism. With an individual of a size comparable to the captain sitting in a test seat, with seatbelt and shoulder harness fastened, and positioned with respect to the seat alignment indicators, a lateral clearance of about 6 inches and a longitudinal clearance of about 2 inches existed between his left ear and the bolts protruding from the top, aft end of the left sliding cockpit window. Normal movement did not permit the head to make contact with the protruding bolts - direct lateral movement of the entire upper torso was required to allow contact. Simultaneous failure of the horizontal and vertical locking mechanisms was simulated by lifting both locking control handles at the same time. With the seat occupied by a 195-pound individual (10 pounds heavier than the captain) the seat moved to the full aft and full down position at a controlled rate and against spring resistance. Head contact with the area of protruding bolts was not possible from the statically failed position, although lateral movement of the upper torso allowed head contact with the windows and other structures.

In addition to the above-mentioned test, a survey of some of the major air carriers using this equipment was conducted. This survey revealed that there had been problems with leaking cylinders, but that sudden failures of the locking mechanism had not occurred. Complaints received from pilots concerned adjustment and play in the seat because of wear. Weber Aircraft had no record of catastrophic failures of the hydraulic lock, and the company was of the opinion that a lock of this nature would not fail catastrophically.

It was noted that discrepancies on the pilot's seat had been entered in the flight log of N8790R on April 4 and April 22, 1970. The first related to the recline mechanism. The second was a repeat of the first, plus a problem of excessive vertical play after establishment of a vertical position. Both discrepancies had been cleared.

A study of the landing gear failures was conducted by the Boeing Company. This study consisted of two parts: a fracture analysis of the body-to-MLG beam attach link and associated parts, and a study of the failure sequence of the right main landing gear attach structure.

The body-to-MLG link was found, by spectrochemical analysis, to have a chemical content which met the specifications (QQ-A-367) of the 7075 aluminum material from which it was made. The Rockwell hardness and electrical conductivity were all normal for 7075 aluminum in the T73 condition. The landing gear beam-to-link pin had a Rockwell hardness of 46.5Rc, which corresponds to an ultimate tensile strength of 225ksi. 5/ This value is normal for 4330M steel heat treated to the 220-240ksi strength range. The report concluded that all fractures of the link were the result of rapid tensile separation.

In the report "Sequence of Structural Failure", Boeing suggested that the most likely sequence of failure involved an initial overload failure of the FS 940 floor bean compression chord. This overload was a result of excessive loads applied to the FS 940 frame through the body-to-MLG beam link. The report noted that vertical, drag and side loads on the gear together can produce compression loads in the link. Following failure of the floor beam chord, the remainder of the floor beam failed completely, and allowed the FS 940 frame to rotate inward. This inward rotation first failed the frame to fuselage skin fasteners, and then failed body stringers in the area. A short section of stringer S-15, which is located within the pressurized area of the fuselage, was found on the runway. Subsequent inward motion of the frame caused the body-to-MLG beam link to rotate until a part of it contacted the upper flange of the MLG beam. Further movement then resulted in the formation of high bending moments, and in the progressive failure of the various link attach arms.

Although other failure sequences were deemed possible, the report noted that the above sequence satisfied all the known failure information and that it is therefore a likely sequence of failure.

1-16 Additional Information

a. Flisht Operations Procedures

The flight operations department of Trans Caribbean Airways uses the Boeing Company B-727 pilot and flight engineer operating manuals for training and for establishment of operational procedures. Excerpts of pertinent portions of the Training Manual are set forth in Appendix D to this report.

The training manual, it was noted, points out that hard or bounced landings are generally made from high approaches at higher than normal rates of descent with excessive and/or late rotation. This manual also notes that proper recovery action involves holding or re-establishing a normal landing attitude and adding thrust as necessary. Attempts to push over or to increase pitch attitude may only cause another bounce. The manual further notes that if a high bounce occurs, thrust must be increased, either to control the rate of descent for the second touchdown, or to perform a go-around if excessive runway has been used.

b. Confisuration Warning Horns

The operations manual contains a section which discusses the various aural configuration warnings built into this model aircraft. These sounds were recorded by the CVR during the landing sequence. An intermittent warning is used to signal either an unsafe takeoff configuration while the aircraft is on the ground, or an unsafe inflight condition. Inflight, the intermittent warning horn will sound if the speed brake lever is moved from the 0° detent when the flaps are not fully retracted. The horn signal is continuous if the aircraft is in an unsafe landing configuration while it is in flight. The continuous horn sounds any time a thrust lever is retarded when the gear8 are not down and locked, or any time any gear is not down and locked when the flap lever is extended beyond the 25° detent, regardless of the thrust lever position.

2. ANALYSIS AND CONCLUSIONS

2.1 . Analysis

a. Causal Determination

In order to determine the cause(s) of any accident, one must follow the premise that all accidents are caused by a breakdown in one or more of the elements of the man-machine-environment concept.

In its analysis of the facts and circumstances of this accident, the Board assessed the evidence bearing on the man-machine-environmental relationships. This approach led, in turn, to the formulation of various hypotheses concerning the most probable causal areas of this accident.

The first hypothesis considered that a destructively hard first touchdown occurred which was caused either by improper crew techniques or by external factors such as wind shear or turbulence.

Another hypothesis considered that a mechanical failure which occurred sometime in the sequence of events was a direct cause of the accident.

A final hypothesis is concerned with a breakdown in the interaction of the flightcrew with their aircraft subsequent to the initial touchdown.

In the process of testing these hypotheses with observations made during the course of the investigation, the implication of the final hypothesis - the man/machine interface - became obvious. The factors which influenced the actions of the crew subsequent to the touchdown and the underlying factors prompted these events emerged as those of primary interest in determining the causal area of this accident.

Before the third hypothesis is considered, the findings which disproved the first two hypotheses concerning possible causal areas will be discussed.

Since the first causal area presumes a hard initial touchdown as the direct cause of the accident, the nature of this landing must be reviewed. This first touchdown took place, according to witnesses, quite close to the end of the runway - approximately 300 feet beyond the threshold according to a controller in the tower, or 365 feet, if the tire marks on the runway are accepted as those of this aircraft. This would place touchdown 435 to 500 feet prior to the VASI aiming point.

The intensity of the touchdown was generally rated by surviving passengers as "hard", but not so hard as those following it. One witness described it as firm, but not of an extreme nature. This witness was surprised at the height of the ascent that followed. In his statement, the captain described the landing as "very hard" and "very firm" - the flight engineer, as ". . . hard, definitely hard, but within safety bounds." The acceleration trace of the flight data recorder confirms these statements: the incremental accelerations recorded at the second and third touchdowns were both approximately three times that recorded at the first touchdown.

The physical evidence does not support the theory that the initial landing was catastrophic; the first evidence of structural failure was located approximately 500 feet down the runway from the point of second touchdown.

Finally, this theory is refuted by the lack of immediate concern shown by the crew. Only a few not-uncommon remarks concerning the hard touchdown were made in the cockpit. It was not until slightly before the second touchdown when the voice record began to show a sense of impending emergency in the tone of voice and the comments made by the crew.

Based upon the preceding evidence, the Board concludes that the initial touchdown was not of a destructively hard nature.

The next possibility explored was that some malfunction of the aircraft caused this accident. Malfunctions which might possibly have been involved include loss of thrust, control system malfunction, landing gear malfunction, and pilot seat failure. The first two malfunctions may be dismissed summarily since the crew did not report any problems in these areas and since no evidence of such malfunctions was observed in the Board's examination of the wreckage or of the flight recorder data.

The possibility that a malfunction of the right main landing gear (RMLG) caused this accident precipitated an extensive study of that system. This study produced no evidence that any preimpact malfunction existed in the landing gear or its attach structure; rather, it demonstrated that the parts examined were sound, and that all fractures were caused by overloads applied to the RMLG.

The probable failure sequence advanced by the Boeing Company seems reasonable to the Board. The second touchdown, which was described as the hardest of the three, overstressed the gear attach structure and the failure was initiated at that time. Passengers, it should be noted, described grinding sounds, and some thought that something on the RMLG broke at that time. The aircraft then apparently became airborne, after the FS 940 frame began to separate from the fuselage skin, but before the separation was complete. The pieces of fasteners reportedly found about 2,000 feet down the runway are consistent with this theory. The third touchdown then completed the failure of the gear attach structure. This final disruption of its attach structure then allowed the landing gear to be displaced upward until the right wing tip and the trailing edge of the outer wing flaps began to drag on the runway.

Having thus determined that the environmental and machine elements were not likely causal factors of this accident, we now turn to the man and man/machine aspects of the operation.

A study of the probable sequence of events which occurred during the approach and landing, and the factors which influenced those events, will show more clearly the involvement of the crew in the causal areas of the accident. In this respect, certain aspects of the approach of Flight 505 seem noteworthy.

One such aspect is the somewhat reversed student - instructor relationship which developed in the cockpit during the approach. This relationship was evident in the decision of the captain to experience the response of the aircraft at slower speeds while on final approach. The factors influencing this decision will be discussed later in this report.

Another noteworthy aspect of the approach was the profile flown. Although the heading was flown rather precisely, the indicated airspeed was never really stabilized. The airspeed underwent a short-cycle variation of 5 knots above and 3 below reference speed during the latter portion of the approach. Throughout the first half of the 3-minute final approach, the sink rate was approximately 600 fpm. This increased to a relatively steady rate of descent of 680 fpm during the final 50 seconds. That rate of descent, in conjunction with the averaqe airspeed during that period, corresponded to an average descent angle of 3.1°. The first officer noted that the sink rate was 700 fpm just 44 seconds before touchdown, and the flight data recorder readout shows a constant rate descent down to its "zero" altitude.

The Board does not consider the error in the VASI landing aid a significant factor of this accident. It should not have caused the crew to fly an approach angle steeper than the misaligned VASI setting of 2.75°. However, as has been noted, the aircraft actually flew a descent angle during the last portion of the approach which was significantly greater than that projected by the VASI system.

The initial touchdown must certainly be considered noteworthy. The Board did not arrive at any positive determination of the cause of this. Among the various causes considered possible were: a late flare, an encounter with wind shear or turbulence, failure of the pilot to flare at all, and performance of a "duck-under" maneuver by the pilot.

The possibility that the aircraft was flared too late to arrest the rate of descent before touchdown seems plausible, especially in view of the steep approach angle flown in this instance. Such a maneuver could also explain the high angle of attack the aircraft assumed upon becoming airborne again.

The comments of the crew indicate that a wind shear might have caused the short touchdown, or that the aircraft encountered a downdraft just after it crossed the threshold. However, no evidence that the flight encountered either phenomenon was found. The surface winds reported by the tower never exceeded 10 knots. Although the first officer referred to gusty winds during the approach segment of the flight, the Board must conclude that these conditions did not exist at the runway threshold; indeed, he did amend his comment "windy gusty" with the comment "Aw I mean windy out over the ocean there. . . ."

In addition to the possibility that it wa caused by a downdraft or gust, the short touchdown could be explained by a failure of the pilot to flare the airc:aft before touchdown. If the aircraft were flown in such a manner that the pilot's eyes were held right on the VASI .lide slope all the way to touchdown, the main landing gear would touchdown quite near the point (300 to 365 feet beyond tile threshold) where Flight 505 did touchdown. For example, calculations indicate that the main landing gear would contact the runway approximately 400 feet short of the aiming point, or 400 feet down this runway if the following representative conditions were assumed: distance from pilot aft to main landing gear of 70 feet; height of pilot's eyes above main landing gear tires of 14.8 feet; aircraft flown at 2.5° deck angle; and at a descent angle of 3.1°.

Another possible explanation for the short landing would be that the pilot performed a "duck-under" maneuver. This is a maneuver in which a pilot consciously positions his aircraft below the glide slope at a certain distance from the runway threshold in order to permit an earlier flare to a landing, thereby giving himself more available runway on which to stop the aircraft. This maneuver, however, is inherently dangerous if not fully understood. The descent below the original glide slope nay require an appreciable increase in thrust to maintain the aircraft on a new and more shallow glide slope to the desired touchdown point. If thrust is not increased, the aircraft will touchdown short of the desired touchdown point.

Although the exact cause of the initial hard touchdown could not be determined, this landing did not cause catastrophic failure of the aircraft, and it did not result in a subsequent uncontrollable maneuver. It is the opinion of the Board that, regardless of the physical or mental limitations imposed by the short runway and the surrounding hilly terrain, the pilot should have been able to recover from the bounce which followed the initial touchdown.

Based upon its examination of all evidence, the Board concludes that the high bounce was more the result of pilot input to the controls than of elastic rebound of the aircraft as a result of a very hard landing. This conclusion stems from the following facts: neither crewmembers nor passengers felt that the initial landing was excessively hard; the aircraft attained a great height (50 feet) on the first bounce; and the flight engineer stated that the aircraft assumed an excessive pitch attitude as it began the ascent.

Once this bounce occurred, the captain had two choices of action according to the Boeing Training Manual: (1) he could have completed the landing by performing the high bounce recovery technique; or (2) he could have executed a go-around to make a second approach. He attempted to salvage the landing. However, possibly because of limitations imposed by the short runway and the surrounding hills, he modified the bounce recovery technique in the following manner: (1) additional thrust was not applied to lessen the rate of descent durins bounce recovery; and (2) the wing flight spoilers were-deployed while the aircraft was airborne.

The timing of the spoiler actuation appears at first to be debatable. The flight engineer stated that he observed the captain actuate the spoilers shortly after the aircraft crested the first bounce. However, the initiation of the intermittent horn sound on the cockpit voice record did not occur until after the second touchdown. This horn is the warning signal of an unsafe flight condition which is believed to have occurred because the spoiler lever was moved from the 0° detent while the flaps were extended. Since the timing of the horn and the flight engineer's statement seemed contradictory regarding the timing of spoiler actuation, the Board investigated further to resolve this matter. The cause of this discrepancy appears to be the result of a 2-1/2 second delay between actuation of the spoiler lever and the initiation of the warning system. This delay was observed by a Board investigator in several similar model 727 aircraft. A delay of this magnitude would then place the actuation of the spoiler lever at a time 1 second before the aircraft touched down the second time. The physical data also agree with that interpretation. The impact of the tail skid at, or immediately after the second touchdown, indicates that the aircraft was operating at a high angle of attack at that time. Thus, in order to set up the high descent rate reflected by this second touchdown in spite of the relatively high angles of attack at which the aircraft must have been operating, it appears that the spoilers must have been used.

since the flight engineer stated that the spoilers were retracted shortly after their actuation, the Board can offer no reason for the failure of the intermittent signal to stop before the horn switched to a continuous signal 4.5 seconds later, unless the spoiler lever was not placed back in the 0° detent. However, the continuous signal is a warning of an unsafe landing gear configuration which is believed to have actuated in this case because the final failure of the RMLG attach structure broke the electrical connection to the landing gear downlock switch.

A question naturally arises concerning the reason or reasons that control of the aircraft was lost.

One reason considered was that the captain's seat locking mechanism failed at the initial touchdown, and caused him to strike his head on some portion of the cabin interior. This blow, it was reasoned, may have rendered the captain either unconscious or dazed, and this would account for his subsequent loss of control of the aircraft and his loss of memory. It was noted that the carrier had experienced problems with the adjustment and locking mechanisms on the pilot seats in that model aircraft, and in this particular aircraft, in April 1970.

Although the Board does not dispute the captain's statement that he suffered loss of memory, we cannot conclude that failure of his seat was the cause of this. Among the reasons for our belief that failure of the captain's seat was not a factor in this accident are the following:

(1) The results of the Board's tests indicate that lateral movement of the upper torso was required to permit the head to make contact with the cabin interior; however, the considerable lateral forces which would be required to cause this bodily movement were not likely generated in the initial touchdown. Numerous passengers described the various impacts, and no one mentioned other than vertical forces in the initial touchdown. High lateral accelerations would have been experienced, however, when the aircraft impacted the slope of Sara Hill. At that time, the aircraft was oriented approximately 90° to its direction of motion.

(2) Seat deficiencies of the type experienced by Trans Caribbean Airways and other users of that model seat were of the annoying, rather than the catastrophic, type; they involved a limited amount of play in the seat rather than large scale movement.

(3) The nature of the design of the seat locking mechanism is such that the Board concurs in the manufacturer's statement that it cannot fail catastrophically. The locking mechanism is a self-contained unit which operates with the displacement of fluid thru a narrow orifice within the unit. Even with rapid loss of fluid, seat displacement would be gradual.

(4) Finally, remarks made by the captain subsequent to the first touchdown and recorded on the CVR do not appear to the Board typical of those which would be expected from a person who was stunned by a blow to the head. About 3 seconds after touchdown, the captain made a remark commonly used in pilots' parlance to express dissatisfaction with an event or situation. Also, his later commands for his crew to raise the flaps to takeoff position after he elected to go-around were lucid.

The Board believes that the retrograde amnesia suffered by the captain was caused by the common defense mechanism in which the system blocks certain traumatic experiences in ordgr to alleviate psychic trauma. It is also possible that the blows on his head which occurred at final impact may have been the factor in initiating this amnesia.

The events which followed the second touchdown reflect the increasing confusion which prevailed in the cockpit. With three men attempting to control the aircraft, alternate periods of action and inaction resulted. While these measures cannot be considered causal factors, they did affect the severity of the accident.

The second bounce was a consequence of factors similar to those which caused the first bounce - touchdown at a high rate of descent with the aircraft operating at a high angle of attack. Again, thrust does not appear to have been used to arrest the descent rate, and the final touchdown was also quite hard. The forces generated at this time completed the previously initiated failure of the gear attach structure.

At some time during the second bounce, the captain relinquished control of the aircraft to the first officer, who replied "I have 'er." At that time, it is clear from the cockpit voice record that the crew was aware of a developing emergency situation. Shortly after the final touchdown, the captain resumed control when he elected to execute a go-around. At that time, there was approximately 1,800 feet of runway remaining, the continuous warning horn was signaling an unsafe gear indication, and the right wing tip was dragging.

The crew's reaction to the captain's go-around decision can only be considered negative. One voice is recorded on the CVR saying "No, don't go-around", and neither crewmember appears to have responded rapidly to the captain's command "Flaps up." According to the crew statements, it was the flight engineer who finally responded and who attempted to raise the flaps. It is worthwhile to note that actuation of the wing flaps is one of the cockpit functions of the non-flying pilot, and not the flight engineer.

Approximately 8 seconds after the initiation of the go-around, and after the flight engineer noted that the flaps were coming up, but that they were ". . . not going to make it. . . .", the go-around attempt was abandoned. However, evidence found in the wreckage indicates that a maximum stopping effort was not made; both the ground spoilers and the engine thrust reverser deflector doors were found stowed.

Having thus outlined the decisions and measures taken which led to this accident, the Board would be remiss if it did not comment on the underlying factors which prompted these events.

First, it appears that the captain was not certain of the characteristics of the aircraft in a full-flap configuration. This uncertainty seems to have led to a situation in which he was not in sole command of the aircraft - to a situation in which the roles of the captain and the other crewmembers were reversed. This relationship was evident when, shortly after the final approach configuration was established, the flight engineer first suqgested, and then told the captain to slow the aircraft in order to get the feel of it in slow flight with full flaps. The flight engineer continued in this instructional role throughout the approach and landing sequence of events, and the captain responded to this instruction. This situation led, in turn, to the choice of an inopportune time to accept instruction; that is, during the final approach segment of the flight. It was, perhaps, his preoccupation with these aspects of the approach maneuver which caused the captain to fly the aircraft into a situation from which a short and hard landing was inevitable.

Finding himself in a difficult situation immediately after the touchdown seems to have confused the captain and affected his further actions to salvage the landing. The Board feels that two factors may have combined to cause this response: (1) the captain's lack of familiarity with the characteristics of the aircraft, in conjunction with the limitations imposed by the short runway at the Truman Airport, made him uncertain of the corrective action required; and (2) his power of reasoning was disrupted by natural behavioral changes which can occur in situations such as that with which he was faced.

The second factor concerns an individual's natural response to dangerous situations. Experiments conducted by Davis and reported in his study "Human Errors and Transport Accidents" 6/ explain the nature of this response. Davis noted that man, like all animals, undergoes certain behavioral changes when danger appears imminent. These changes are intended to extract him rapidly and impulsively from that dangerous situation without having to go through a slower reasoning process. In experiments in an artificial cockpit, Davis showed that this so-called emergency mechanism is detrimental in a situation which requires deliberate responses because it cancels the functioning of reasoning. These experiments showed that when a person reacts toward a situation in a way that experience (and training) have taught him to be effective, and that specific reaction deteriorates the situation instead, the emergency mechanism may set in within seconds. This creates confusion, which in turn, increases the sense of danger. A vicious circle is then formed which leads either to total inaction or to fruitless measures.

In relating this theory to the circumstances at hand, it is interesting to note that the captain's attempts to salvage the landing by certain actions (such as an abrupt change in pitch attitude in the first place, and then by actuation of the spoilers during the bounce) only caused the situation to deteriorate, contrary to his expectations. From that point on, the actions taken by the captain do not seem to be entirely rational.

b. Post Crash Aspects

(1) Survivability

Based upon the most common means of measurement, this was a survivable accident: The fuselage remained relatively intact; most of the occupants remained restrained; and the occupants had various means of immediate escape from the post-impact fire.

Although the peak magnitude and duration of the crash forces cannot be calculated with any degree of accuracy, the known failures of eight passenger seats would indicate that the forces were of a magnitude close to the design strength of the seats. These were mostly lateral failures, according to the passengers, and they occurred as a result of the sideward impact force generated when the aircraft came to rest against the hill. This is not surprising since the present design criteria require a strength of only 1-1/29 in the lateral direction. The total forces generated by the impact with the hill are estimated to have been in the order of 5 to 10g's peak magnitude, applied in excess of 30° to the longitudinal axis of the aircraft. Since available literature indicates that the human tolerance to abrupt deceleration, when restrained by a seatbelt only, is about 15 to 20g's in the longitudinal direction and 10 to 15 g's in the lateral direction, the seat failures needlessly exposed the occupants to injuries which could have affected the success of their evacuation.

(2) Evacuation

Timely evacuation after a crash is governed both by the adequacy of emergency exits and by crew training and leadership. Both factors were present in this case. The two complete fractures of the fuselage provided the most expeditious means of escape for many survivors, and the four flight attendants handled the evacuation in a professional manner.

Because of the tilt of the aircraft, the stewardesses required help from the passengers to open the exit doors. The escape chutes were deployed without delay. The stewardess assigned to the overwing exit location could not reach her post because of the break in the fuselage, and that section was without crew guidance. Because the operation of overwing exits is not always understood by passengers, the Board has long maintained that it would be desirable to have at least one crewmember assigned to a seat near the overwing exits during takeoff and landing operations. However, in this case, all passengers in that area successfully evacuated thru the break in the fuselage.

(3) Post Impact Fire

The success of this evacuation is attributable to several factors:

The wings remained attached to the fuselage preventing immediate large-scale release of fuel.

The engines, which normally constitute a major source of ignition, remained isolated from the fuel source.

The aircraft fuel supply was Type A fuel, a kerosene grade of fuel which has a higher flash point and lower vapor pressure than either aviation gasoline or the Type B fuel (JP-4).

With respect to the use of one type of fuel as opposed to another as a safety measure in aircraft, there has been considerable variance of opinion. The two main factors governing the fire hazards of fuels are ease of ignition-and rate of propagation. The flash point (which is the lowest temperature of the fuel that will allow ignition by an external source) of Type A fuel (kerosene), is between 95° and 1450 F., as opposed to those of aviation gasoline and Type B (JP-4) which are approximately - 50° F., and -10° to 30° F., respectively. Rate of propagation or flame spread is probably influenced mostly by the vapor pressure of a fuel. Whereas kerosene has a vapor pressure of approximately 0.01 lb./sq. in. at 100° F., that of aviation gasoline is 5.5 to 7.0 lbs./sq. in. and that of JP-4 is 2.0 to 3.0 lbs./sq. in.

It may be seen, therefore, that kerosene does not give off ignitable vapors unless the fuel temperature is above 95° F., whereas gasoline may be ignited at about any temperature and JP-4, at most temperatures. Experiments at NASA have shown that the rate of propagation of gasoline and JP-4 is about 700 to 800 feet per minute while kerosene has a rate of less than 100 feet per minute under the same circumstances.

The reason for the explosiveness of fires in many aircraft accidents, no matter which kind of fuel is carried, is that the fuel is frequently released in a mist or atomized form. All fuels are readily ignitable in that form. The resulting flash fire then heats the bulk of the spilled fuel, destroying the beneficial effects of low volatility fuels.

The benefit of kerosene is found in accidents similar to the subject one, where the release of fuel is minimal. Although a fire may have started, the remainder of the spilled fuel must be heated to its flash point before further ignition can occur. The rate of propagation will then be lower than for other fuels.

(4) Firefighting

It is estimated that the first fire engine arrived at the scene of the accident 1-to-1-1/2 minutes after the aircraft came to a stop. Considerable smoke was being generated at that time and the fire had reached sufficient intensity to prevent early extinguishment. Although the type and amount of firefighting equipment available at this airport compared favorably with those at other airports having as much or more traffic, accident experience has shown that aircraft fires seem to impose problems beyond the capabilities of even the most sophisticated equipment. The value of the equipment must be found in its lifesaving capabilities. Immediate rescue of occupants and suppression of fire to afford escape become the decisive factors in accidents; saving of the equipment is secondary or does not play a role at all. The value of "Quick-Dash" trucks is undeniable. These trucks have limited firefighting capability, but they are equipped with rescue tools and have greater speed and terrain clearance capability than the heavy fire engine.

2.2 Conclusions

a. Findings

1. The preimpact condition of the aircraft was not a factor in this accident.

2. The weather was not a factor in this accident.

3. The physical environment of the Truman Airport is not considered to have contributed significantly to the cause of this accident, except that the relatively short length of the runway and the surrounding hilly terrain may have influenced the pilot's decisions during the approach and the attempted recovery maneuvers.

4. The pilot's relatively limited experience in this aircraft was a factor in creating a breakdown in the exercise of command in the cockpit. This, in turn, contributed to the creation of a situation conducive to a hard landing.

5. A relatively high rate of descent was continued until just before the aircraft touched down. At that time, an excessive pitch control input was used to initiate a flare for landing.

6. The combination of touchdown with a high rate of descent and a large pitch control input combined

to cause a high bounce of the aircraft.

7. The recommended action to recover from such a bounce was not taken; instead, the pilot deployed the spoilers in a circumstance in which that action could only result in a catastrophically hard second landing.

8. The RMLG attach structure was overstressed by this landing and structural failure followed.

9. Subsequent actions on the part of,the crew increased the severity of the accident, causing the aircraft to leave the airport boundary and impact on a near-by hillside.

10. The evacuation, which was accomplished within 1 minute, was well handled by the cabin attendants.

11. The success of the evacuation is attributed in part to the fact that fuel spillage was minimal and that the aircraft used a fuel with a combustibility which retarded the immediate intensity of the fire.

b. Probable

The National Transportation Safety Board determines that the probable cause of this accident was the captain's use of improper techniques in recovering from a high bounce generated by a poorly executed approach and touchdown. Lack of cockpit crew coordination during the approach and attempted recovery contributed to the accident.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ *JOHN H. REED*
Chairman

/s/ OSCAR M. LAUREL
Member

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

/s/ ISABEL A. BURGESS
Member

December 29, 1971

FOOTNOTES

1/ All times are local, Atlantic standard time, based on the 24-hour clock unless otherwise specified.

2/ Very high frequency omnidirectional radio range.

3/ Visual approach slope indicator.

4/ A computed reference speed based upon 1.3 times the stall speed of the aircraft in the landing configuration with the engines at zero thrust. This speed varies with the weight of the aircraft, and it may have speed increments added to allow for factors such as gusty winds.

5/ Kips (1,000 pounds) per square inch.

6/ D. Russell Davis, Department of Medicine, University of Cambridge - (1958) Ergonomics, 2.24.

APPENDIX A

INVESTIGATION

1. Investigation

The Board received notification of this accident at approximately 1400 e.s.t. on December 28, 1970. An investigating team departed from Washington, D. C., at 2107 that evening, and arrived at the Harry S Truman Airport, St. Thomas, Virgin Islands, at 0245 on the following morning.

Field working groups were established for the following areas of specialization: Operations, Witnesses, Human Factors, Structures, Systems, and Powerplants. Parties to the investigation were the Federal Aviation Administration, Trans Caribbean Airways, Air Line Pilots Association, The Boeing Company, and Pratt & Whitney Aircraft Division of United Aircraft Corporation.

The on-scene phase of the investigation was completed on January 8, 1971.

2. Public Hearing

No public hearing was held.

3. Preliminary Report

A preliminary report of the available facts and conditions was adopted by the Board on February 18, 1971, and released to the public on April 9, 1971.

APPENDIX **B**

CREW INFORMATION

Captain Fred J. Worle, age 40, possesses an airline transport pilot certificate No. 1368858 with type ratings in the Douglas DC-8 and Boeing 727. He also has an airplane multiengine land rating and commercial privileges in the Boeing 317. In addition, Captain Worle has a Flight Engineer certificate No 1513268. His first-class medical certificate is dated July 28, 1970, with no limitations.

The captain's total flight time prior to the accident was 10,665:33 hours, of which 350:59 was flight engineer time. His total pilot-in-command time in a Boeing 727, prior to the accident, was 169:34 hours, of which 32:55 were training. He had made five entries into St. Thomas prior to the accident. Three were in October 1970, and two were in December 1970. His last DC-8 captain proficiency check was flown on June 29, 1970. Due to a recent furlough and a reduction in force he transitioned to the Boeing 727, and he completed the initial training program on September 21, 1970, and satisfactorily performed an aircraft flight rating on October 2, 1970. He completed 25:07 hours of line training and route qualification on October 24, 1970. His training included rejected landings. His flight training personnel jacket contains the comment "excellent all around performance."

First Officer Raymond L. Hayles, age 45, possesses a commercial pilot certificate No. 483494 with airplane single and multiengine land, and instrument ratings. His flight navigator certificate is No. 1128430. He possesses a first-class medical certificate, dated July 1, 1970, with no limitations.

Mr. Hayles' total flight time prior to the accident was 21,016:28, of which 9,471:28 was pilot time, and 11,545:00 was navigator time. His total Boeing 727 time (second-in-command) prior to the accident was 1,126:41 hours, of which

33:08 were training. He was trained by Eastern Airlines, Inc., under contract to TCA and completed second-in-command initial qualification on June 10, 1968. His flight check was satisfactory. The training syllabus and check maneuvers included rejected landings and (three engine) missed approaches. His record shows completion of the B-727 "differences" training requirement on June 16, 1968. Mr. Hayles line qualification form contains the comment "very good work."

Flight Engineer Charles R. Ferrell, age 41, possesses airline transport pilot certificate No. 1646510, flight engineer certificate No. 1298354, and mechanic certificate No. 1108782. His pilot ratings are airplane single-engine land, and commercial privileges, airplane multiengine land. He is rated a flight engineer on reciprocating and turbo-jet powered aircraft. His mechanic ratings are airframe and powerplant. His first-class medical certificate is dated October 18, 1970, with the limitation, "Holder must wear correcting glasses for near and distant vision while exercising the privileges of his airman's certificate."

His total flight time prior to the accident was 17,589:26, of which 4,396:20 hours were pilot time and 13,193:06 were flight engineer time. His total Boeing 727 pilot time. prior to the accident flight, was 1,519:54 hours (second-in-command), of which 31:44 were training. His total Boeing 727 time as a flight engineer, prior to the accident flight, was 144:06 hours, of which 40:11 were training.

APPENDIX C

TRANSCRIPTION OF THE FINAL PORTION OF THE COCKPIT VOICE RECORDER FROM TRANS CARIBBEAN AIRWAYS BOEING 727, N8790R, FLIGHT 505, ST. THOMAS VIRGIN ISLANDS, DECEMBER 28, 1970

LEGEND

CAM Cockpit area microphone
-1 Identified as the Captain
-2 Identified as the First Officer
-3 Identified as the Flight Engineer
-? Unidentified
RDO-2 First Officer's Radio Transmission
TWR St. Thomas Tower Transmission
* Unintelligible Word
# Non-pertinent word
( ) Open to further interpretation
(( )) Editorial insertion
Time indicated is seconds prior to end of recording.

Time & Source

CAM-1 Flaps thirty --
CAM-2 Thirty
CAM-1 Right to forty
CAM-2 Goin' right on to forty
CAM-? *
CAM-? Check
CAM-? Check
CAM-? ****
CAM Sound resembling horizontal trim actuation

CAM-3 (Actually) a good day to slow up -- one one zero at eight
CAM-3 I want you to slow it up once and see if ya feel it
CAM-3 Sound of laugh
CAM Sound resembling horizontal trim actuation
CAM-2 The wind shifted
CAM-1 # slow though
CAM Sound resembling horizontal trim actuation
CAM-3 And the VASI slope shows you ----

TIME & SOURCE	
CAM-1	A little high
CAM-?	Sound of whistle
RDO-2	Trans Carib five oh five wind check
TWR	Five oh five one one zero degrees at ten knots
RDO-2	'Kay are we cleared to land?
TWR	Cleared to land
RDO-2	Thank you
CAM-2	I wasn't sure whether 'e'd given it to us or not
CAM	Creaking sound
CAM-2	Windy gusty
CAM-2	Aw I mean windy out over the ocean there ** even around San Juan
CAM-2 42.6	Sink rate is six hundred
CAM-3	High on your sink (now)
CAM-?	+*
CAM-2 40.1	Speed at about -- ten above reference speed
CAM	Sound resembling that of horizontal trim actuation
CAM-2 34.6	Sink rate is seven hundred
CAM-2 31.5	on reference
CAM 30.2	Sounds associated with touchdown includes a short period high frequency noise of undetermined source
CAM-3 28.4	# that thing
CAM-1 26.9	#
CAM-? 25.4	poor nose ((strained voice))
CAM 24.6	Sound of very loud thump noise
CAM 23.1	Sound of intermittent warning horn commences
CAM-? 22.0	(You) take it
CAM-?	**
CAM-2 20.1	I have 'er
CAM 18.1	Sound of very loud thump and continuous noise commences
CAM 17.6	Sound of continuous warning horn commences

CAM-1
15.4 Flaps up
CAM
15.0 NO don't go around
CAM-1
14.4 Flaps up -- come on, get 'em up
CAM-1
12.6 (Runway lights) *
CAM-3
12.1 Comin' up
CAM-1
0.1 Flaps up
CAM-3
7.6 They're comin' up -- but you're not goin' to make it--
you gonna kill us
CAM
00:00 End of recording

EXTRACT FROM BOEING 727 PILOT TRAINING MANUAL
BOUNCED LANDING RECOVERY

10-4 BOUNCED LANDING RECOVERY

(Not to be accomplished in the airplane. Discussion only).

In training, there probably will be opportunities to observe a recovery from a bounced landing. A bounced landing will not be deliberately performed.

Recovery

Hold or re-establish normal landing attitude and add thrust as necessary to control the rate of descent. If only a shallow bounce (skip) occurs, thrust need not be increased.

Do not push over, as this will only cause another bounce and possibly damage the nose gear.

Do not increase the pitch attitude above normal as this only increases the height of the bounce and may cause entry into stall warning. This results in a second hard touchdown.

As the airplane touches down the second time, use the normal landing procedures--speedbrakes up, brakes on, and engine reverse.

If a hard high bounce occurs and excessive runway is used, a go-around may be mandatory. Apply go-around thrust and use normal go-around procedures. A second touchdown may occur during the go-around. DO NOT RETRACT THE LANDING GEAR UNTIL A POSITIVE RATE OF CLIMB IS ESTABLISHED.

DISCUSSION

Poor landings usually follow poor approaches.'

A smooth touchdown can occasionally be made from a poor approach; however, good landings are made consistently from proper approaches.

Causes

Hard or bounced landings are generally made from high approaches at higher than normal rates of descent with excessive and/or late rotation. Plan ahead and monitor the approach angle so that steepening the glide path is not necessary. See 6-6, High Rate of Descent Demonstration.

Rapid rotation under the above conditions increases the g loading. At maximum landing weight, the stall speed increases approximately 4 knots for each 1/10 g. Thus, rapid rotation will momentarily decrease the rate of descent and then the rate will increase as the airplane speed decreases. As the speed decreases the power required for level flight increases.

Thrust must be added to decrease a high rate of descent when holding the proper approach speed (V_{REF}) and using a normal rotation. At rates of descent approaching 2000 feet per minute. nearly takeoff thrust may be required during rotation to stop the rate of descent while holding the approach speed. With flaps 40 and idle thrust, a rapid thrust application and nose up rotation to about 10 degrees will be required to stop the rate of descent. Approximately 250 feet will be lost if V_{REF} is held. g forces will be approximately 1.3.

If airspeed is also decreased the loss of altitude can be reduced.

When approaching on a steep glide slope, extra airspeed above V_{REF} must be maintained. This combined with an early and smooth rotation can result in a smooth landing. But this sequence requires very good judgment of both the amount of excess speed and the altitude to start rotation. Any error results in a poor landing. Steep approaches are not recommended. If possible intercept the normal glide path before reaching the field and establish a normal approach.

A normal approach aimed at the 1000 foot mark can result in a hard landing when the pilot unintentionally moves his eyes to the approach end of the runway as he wars the runway or 'breaks out" on an instrument approach. Thus, the nose is dropped and the rate of descent increases--unnoticed--until too late. See Figure 1.

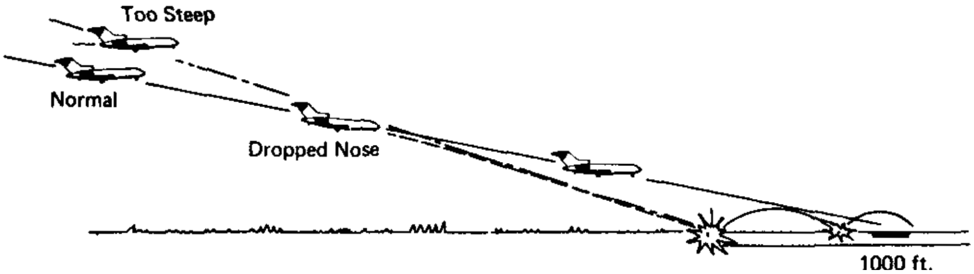
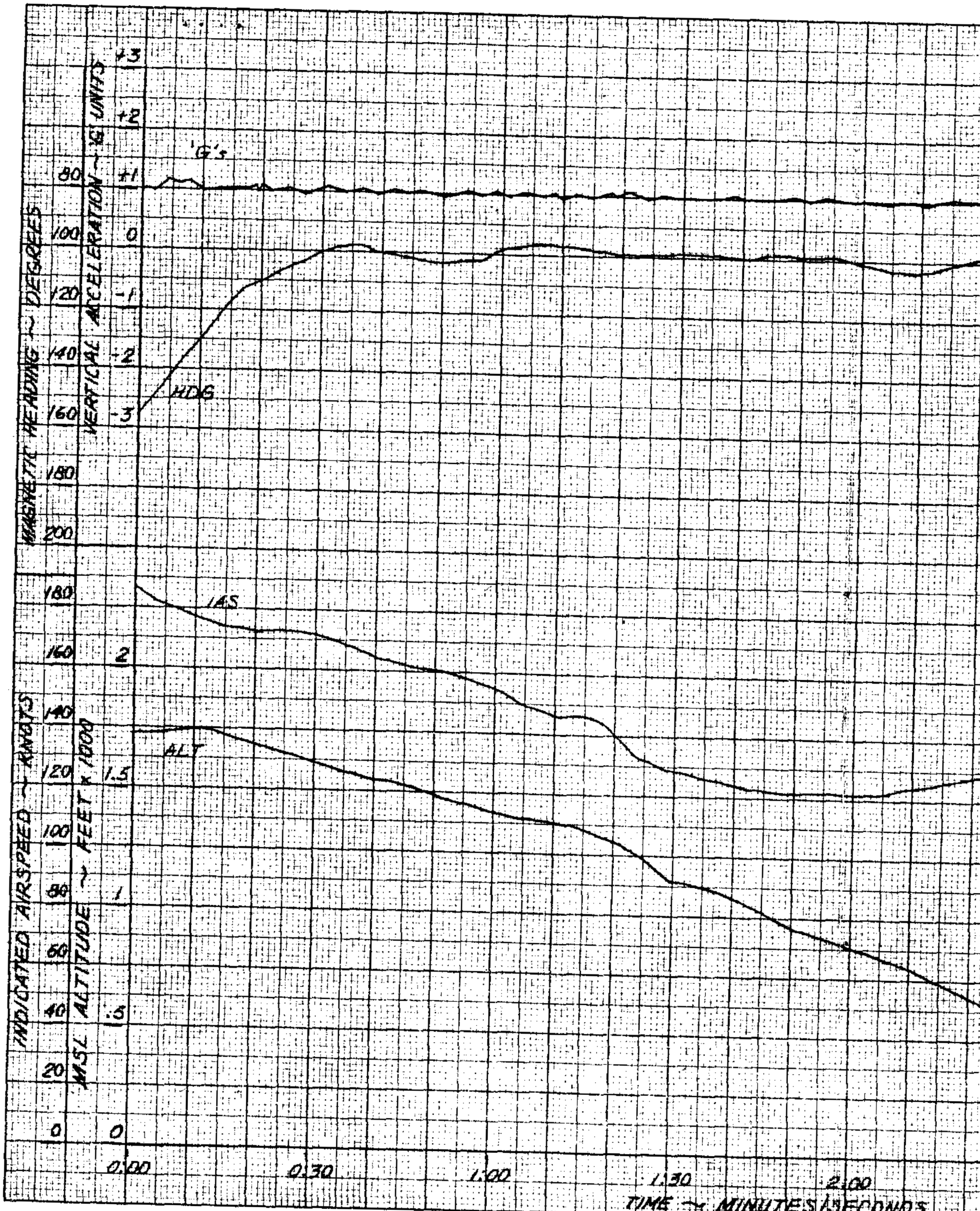


Figure 1. Bounce Landing

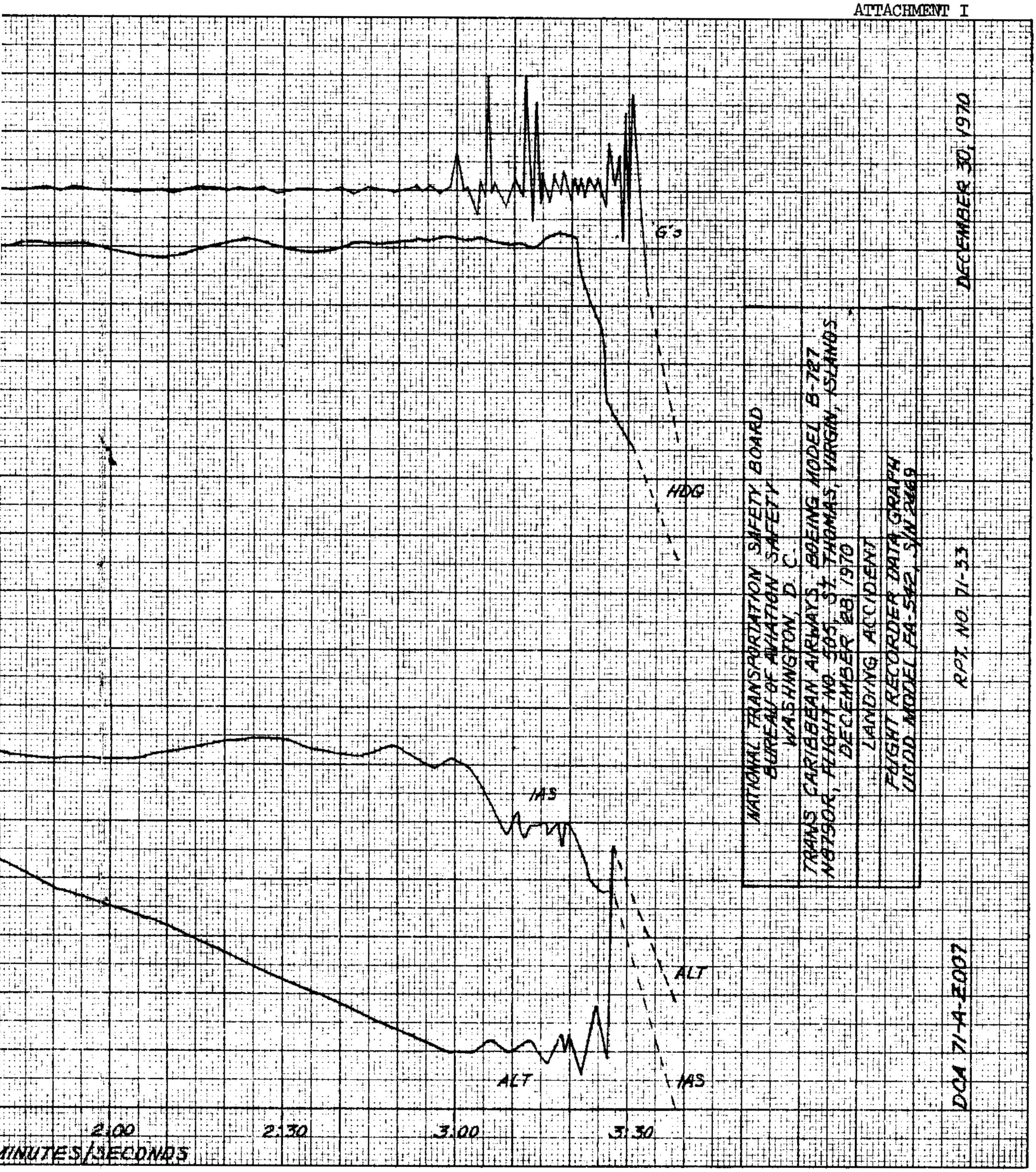
Hard landings, but rarely bounced landings, can result from a normal approach and over-rotation with excessive floating (holding the airplane off).

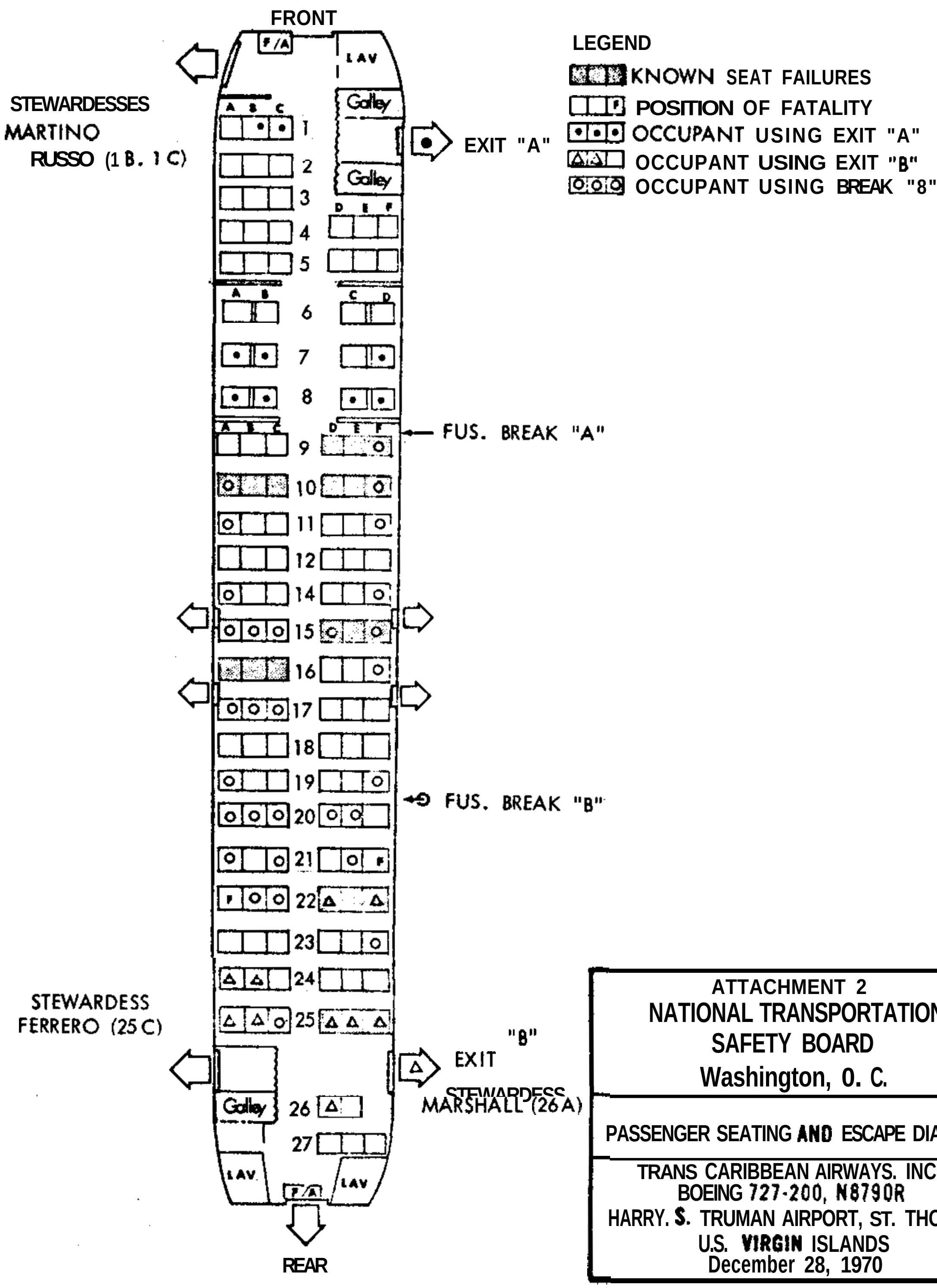
Thrust

If a high hard bounce occurs, the thrust must be increased to control the rate of descent for the second touchdown, or to perform a go-around if excessive runway has been used.


MAGNETIC HEADING ~ DEGREES
VERTICAL ACCELERATION ~ 'G' UNITS
'G's
HDG
IAS
ALT
INDICATED AIRSPEED ~ KNOTS
MSL ALTITUDE ~ FEET x 1000
0:00
0:30
1:00
1:30
2:00
TIME ~ MINUTES/SECONDS

ATTACHMENT I





ATTACHMENT 2

NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D. C.

PASSENGER SEATING AND ESCAPE DIAGRAM

TRANS CARIBBEAN AIRWAYS. INC.
BOEING 727-200, N8790R
HARRY. S. TRUMAN AIRPORT, ST. THOMAS,
U.S. VIRGIN ISLANDS
December 28, 1970

GPO 925-966