COMANDO DA AERONÁUTICA
ESTADO-MAIOR DA AERONÁUTICA

CENTRO DE INVESTIGAÇÃO E PREVENÇÃO DE ACIDENTES AERONÁUTICOS

FINAL REPORT

AIRCRAFT: F - GCBC

MODEL: BOEING 747-228B

DATE: DEC 02, 1985

AIRCRAFT	**Model:** BOEING 747-228B **Register:** F-GCBC	**OPERATOR:** COMPANIGNE NATIONALE AIR FRANCE
ACCIDENT	**Date:** DEC 02, 1985 **Place:** RIO DE JANEIRO INTERNATIONAL AIRPORT **City, ST:** Rio de Janeiro - RJ	**TYPE OF OCCURRENCE:** Loss of control on the ground

O único objetivo das investigações realizadas pelo Sistema de Investigação e Prevenção de Acidentes Aeronáuticos (SIPAER) é a prevenção de futuros acidentes aeronáuticos. De acordo com o Anexo 13 da Organização de Aviação Civil Internacional - OACI, da qual o Brasil é país signatário, o propósito dessa atividade não é determinar culpa ou responsabilidade. Este Relatório Final, cuja conclusão baseia-se em fatos ou hipóteses, ou na combinação de ambos, objetiva exclusivamente a prevenção de acidentes aeronáuticos. O uso deste relatório para qualquer outro propósito poderá induzir a interpretações errôneas e trazer efeitos adversos ao SIPAER. Este relatório é elaborado com base na coleta de dados efetuada pelos elos SIPAER, conforme previsto na NSCA 3-6.

1. Factual Information

1.1 History of the Flight

On December 1st, 1985, at 21:30 UTC, Air France Boeing B-747-228-B-Combi, F-GCBC took off from Charles de Gaule Airport – Paris, as flight AF-091, Paris-Santiago, with stops in Rio de Janeiro and Buenos Aires.

The flight crew, composed of a Captain, two copilots and two flight engineers (F/E) reported for duty at 20:00 UTC, 01:30 h prior to take off.

The flight to Rio de Janeiro took about eleven hours and was uneventful.

At 08:34.20 UTC the aircraft touched down on runway 14, 400 m from the threshold. After reversers were set, the aircraft deviated from the runway heading and at 2000 m from the threshold veered off the right side of runway.

The aircraft ran over the grass for 765 m more, until passing over a drainage ditch and the load apron concrete step, where the landing gears folded aft with the left wing gear completely separating. On the load apron concrete (TPS-5); the aircraft spun around for 275 m more until stopping, after its left outboard wing struck an illumination stand.

For a few seconds engines 2, 3 and 4 kept running at maximum reverse thrust, while engine number one run at full forward thrust.

After the engines were shut down, the passengers were slide evacuated using only three of the aircraft's left side escape slides.

The fire that started on the area near engines number 2 and 3 was extinguished at once by the airport fire fighters.

1.2 Injuries

Injuries	Crew	Passengers	Others
Fatal	-	-	-
Serious injuries	-	-	-
None	17	265	-

1.3 Damage to Aircraft

a. All landing gears were folded aft with the left wing gear completely separating. All engines were damaged with pylons l, 2 and 3 buckling upward.

b. The fuselage was buckled and bent just aft of the wing between doors 3 and 4. The lower body was significantly damaged. The left outer wing leading edge was damaged as well as the wing trailing edges which were struck by the landing gear. The aircraft was considered a total loss.

1.4 Other Damage

An illumination stand was destroyed. Part of the ramp's concrete surface and of a drainage ditch suffered light damage.

1.5 Personnel Information

a. The regular flight crew was composed of a Captain, a copilot and a flight engineer (F/E). Due to the extended flight time, it was reinforced with an extra copilot and an extra F/E for rotation.

b. Ratings and Licences

The crewmembers held valid airline licences and certificates.

c. Flight Experience

	Captain	Co-pilot	F. Engineer
Total hours	16.139:00	6.148:00	13.423:00
Total in last 30 days	44:50	57:50	65:30
Total in last 24 hours	11:00	11:00	11:00
On this type in aircraft	979:00	513:00	1.004:00
On this type in last 30 days	44:50	57:50	65:30
On this type in last 24 hours..........................	11:00	11:00	11:00

d. Types flown for Air France

- Pilot: DC-4, DC-3, SE-210, B-707, B-747.
- Copilot: SE-210, B-707, B-727, B-747.

- Flight Engineer: DC-3, DC-4, B-707, B-747.

e. Flight experience and Ratings

The pilots and the flight engineer had the flight experience and ratings required for their duties.

f. The copilots and flight engineers had rested according to regulations and declared that they had alternated duty and rest periods between themselves during the flight.

g. Prior to this flight the Captain had a two weeks vacation. According to his statements, ever since he was a copilot, about thirty years ago, he was trained not to sleep during flights.

h. During this flight, except for some walks to the passenger cabin on public relations, he was at his seat all the time, where he rested between flight tasks.

1.6 Aircraft Information

- Boeing 747-228B, F-GCBC, was manufactured in 1980.
- OWNER: Compagnie Nationale Air France, 1 Square Max Hymans, 75105 Paris.
- Registration Certificate: nº B 17081 issued on October 30, 1980.
- Airworthiness Certificate: nº 106837 issued on October 30, 1980, valid until October 22, 1986.
- Engine number 1: GE, CF6-50E, serial number 517.391.
- Total hours: 22.762.
- Hours after last inspection: 3.547.

a. The aircraft had flown 8.203 hours since its last inspection, type "Intermediate Layover" and 63 hours since the last inspection, type "A Check".

Maintenance services were considered periodical and adequate, except for the inspection and repair of the pulley support bracket and the replacement of the phenolic pulley by an aluminum pulley (Non-authorized).

b. The maximum allowable landing weight was 285.7 ton. At the time of the accident the aircraft had a gross weight of 234,6 ton, within limits.

1.7 Meteorological Information

METAR SBGL 0800K 33003 CAVOK 20/19 1012 2AC080

METAR SBGL 083SZ 35004 7000 10BR 1SC015 20/18 1012 VIS N/SE 9999

METAR SBGL 09002 360O4 6000 10BR 1SC015 21/19 1013 VIS NW/N 9999

The wind conditions provided by the control tower, at the time of the accident were 130/04. This factor did not contribute to the accident.

1.8 Aids to Navigation

Pertinent aids were in normal operation.

Radar vectoring was conducted to intercept the AIRJ runway 14 localizer.

1.9 Communications

Bilateral communication between the aircraft and air traffic control were normal.

1.10 Aerodrome Information

Rio de Janeiro International Airport has two landing runways: 09 X 27 and 14 X 32 (today 15 X 33). It is located 13 km NE from downtown and has an elevation of 30 feet.

The runway used - "14" - is paved and its dimensions are 3.180 m X 47 m. It is equipped with threshold lights, ALSF

(ALS category I - with FLASH) and VASIS with a ramp of 3º Its surface is porous, regular and was dry at the time of the accident. There are no obstacles to landing or take off operations.

Runway 14 X 32 is suitable for this type of aircraft.

All the obstacles in the aerodrome area are equipped with night and day markings.

The distance between the drainage ditch, located on the right side of runway 14 and the runway itself, is 106 meters. This distance follows the required international standards.

1.11 Flight Recorders

a. Both flight recorders, the "Digital Data Recorder" and the "Cockpit Voice Recorder" were recovered undamaged and provided valuable information to clarify the occurrence.

b. DFDR (Digital Flight Data Recorder)

Sundstrand P/N 981-5009-001, continually records the last 25 hours of operation on magnetic tape.

Serial Number: 3014 data code 7-78.

FAA Certificate: TSO-C51A.

Number of parameters: 41.

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One data point per parameter is recorded per second. For this reason, for the same engine we only have one engine data every four seconds, as follows:

- N1% for each engine.

- EGT for each engine.

- Thrust reverser position STOW/DEPLOY/TRANSIT.

- Time – G.M.T. (Hrs/min/sec).

- Amb Temp: 21° C (70° F).

Recorded data every four seconds during reverse operation makes exact timing of specific events impossible. However, based on known characteristics for engine acceleration and reverser deployment, the observations of the available data are considered to be an accurate reconstruction of events.

Hereafter time will be only referred to in minutes and seconds, being the hour implied at 08:00 UTC.

Approach power on all engines was from 68% to 71% N1. At an altitude of 28 feet (radio altimeter), at 34:15, engine power was reduced toward idle and touchdown occurred at 34:19.7, at 141 knots. Engine power at touchdown was 45% to 50% N1, reaching minimums of 38% to 42% N1 between touchdown and full reverser deployment.

Full reverser deployment probably occurred on engines 2, 3 and 4 at 34:25, 5 to 6 seconds following touchdown. By this time these three engines had already started to accelerate in reverse, 39% to 45% N1, indicating that engine acceleration started immediately after the interlocks had cleared.

The pilot had probably moved the reverse thrust lever past the interlock position prior to, or very close to the interlock clearing (approximately at 34:24).

During the same time period, engine number 1 power immediately started to increase (34:23), approximately one second before acceleration on engines 2, 3 and 4.

Three seconds elapsed from the time of the last known position of the thrust reverser on engine 1 and engine acceleration. The thrust reverser on engine 1 may have started to deploy, and cable "B" separation may have occurred before the interlock cleared.

This would result in thrust reverser stow being selected, and residual rigging tension in the "TIA-5" cable causing an increase on engine power. Although the exact time of "TIB-5" cable separation cannot be determined, the highest loads are imposed on "TIB-5" cable when the pilot brings the levers to the idle stop, and again when reverse thrust has been selected and the levers are being pulled against the interlock mechanism.

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Engines 2, 3 and 4 accelerated to maximum reverse in five seconds, consistent with a typical snap acceleration. Engine 1 initially responded rapidly and then slowed significantly taking a total time of 12 to 13 seconds to reach takeoff power.

Maximum reverse thrust on engines 2, 3 and 4 was maintained for 3 to 4 seconds during which time engine 1 was accelerating through 100% N1 in forward thrust.

At 34:34, 14 seconds after touchdown, reverse thrust was cancelled with thrust reversers 2 and 4 stowing 9 to 11 seconds later, 34:43/45. It is not clear if reverser number 3 completed the stow cycle. At this point engines 2, 3 and 4 had spooled down to minimum idle (25% N1), engine 1 had reached 118% N1 in forward thrust and the airplane had left the runway. Reversers 2 and 3 were again deployed (34:46) with indication that engines 2 and 3 had started to accelerate in reverse. Reverser 4 was in transit do deploy at this time and at 34:50, with the airplane still moving at approximately 90 knots, the DPDR recording stopped.

Summary/Conclusion of the Powerplant. Analysis

The airplane flew a normal approach, with engines well modulated to approach idle at touchdown.

Reversers selection was normal with reverse thrust levers against the interlocks probably 3 to 4 seconds following touchdown.

From voice recorder transcripts, at 34:24, it was recognized that only reversers 2, 3 and 4 had deployed. Recognition of this situation occurred immediately, DFDR data showing deployment complete at 34:25, at 40% to 45% N1.

Full left rudder occurred with maximum reverse on engines 2, 3 and 4 at 34:29/30.

DFDR data shows reversers 2, 3 and 4 were stowed, not complying with the request, at 34:33. Reverser 3 may not have completed the stow cycle.

Reducing reverse thrust on all 3 engines, not just on engine 4 as requested to minimize yawing movement on the airplane, contributed to the reduced aircraft deceleration. A nominal reverse thrust loss of 11.600 lb occurred from 34:34 to 34:42. The total deceleration loss was probably greater than 11.600 lb since positive forces are present during the later stages of reverser stow, when the engine has been operating at higher than idle reverse power.

Braking Analysis Based on DFDR Information

Upon review of Air France 747 F-GCBC DPDR data, the following observations on braking are noted:

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- Airplane horizontal deceleration averaged approximately 3.25 ft/sec^2 for the first 5 seconds after touchdown (34:19.7 to 34:24.5). Almost all of the stopping force can be attributed to airplane drag and it appears that little or no braking force was applied.
- Airplane deceleration increased to a peak of 5.43 ft/sec^2 six seconds after touchdown (34:25.5) then decreased to zero about 11 seconds later (34:36.5). During this time period, total engine thrust changed from net reverse thrust to net forward thrust, left control wheel position was increasing, and full left rudder was applied. Engine 1 thrust increased to near take off rating which contributed significantly toward accelerating the airplane. The positioning of the control wheel to the left decreased ground spoiler effectiveness causing a reduction in airplane drag and also limiting braking effectiveness. Full left rudder was applied about 10 seconds after touchdown (34:30). Data indicates that a relatively small amount of braking force was applied during this time period.
- The airplane was accelerating at about 0,5 ft/sec^2 for the next 2.2 seconds after zero deceleration value was attained (34:36.6 to 34:38.8). This can be attributed to the high net forward thrust supplied by the engines. Data indicates very little or no braking force was applied during this period.
- Airplane deceleration increased from zero to a peak of 6,93 ft/sec^2 for the next 6,7 seconds (34:38.8 to 34:45.5). Assuming that the airplane had left the runway, it appears that braking force increased to the near maximum achievable on dry grass.
- Airplane deceleration averaged 4 ft/sec^2 during the last 5 seconds before the DFDR data ends (34:45.5 to 34:50.5). Engines 2 and 3 thrust reversers were redeployed during this period, but because the thrust level on these engines was so low the net total engine force was still positive (i.e., forward thrust). The data indicates braking force is close to maximum achievable on dry grass.

Stability and Control Analysis Based on DFDR Information

- According to radio altimeter and accelerometer data, touchdown occurred between 34:19 and 34:20. The actual touchdown is estimated to have taken place at 34:19.7 based on the peak vertical acceleration. The airspeed at touchdown was 141 knots which is 6 knots above VREF.
- In order to control the yawing moment due to the asymmetric thrust, left rudder was gradually applied starting at 34:26 and reaching full deflection at 34:30. The heading angle remained within 2° of the value at touchdown. Full left rudder was maintained for the remainder of the recorded data. The control wheel was deflected to the left about 15° between 34:26 and 34:27 and reached about 25° at 34:33.
- A control wheel deflection of 20° left will retract spoiler panels 8, 10, 11 and 12 (on the right wing) from 45° to 36.5° with the speed brake handle at the ground position and the lateral control system in normal. Spoiler panels 1 through 7 remain open at 45° deflection. At 34:33, the aircraft started to swerve to the right. The airspeed was about 114 knots.

- During the right turn between 34:33 and 34:37, a skid to the left developed with the left wing gradually lowering. Full left control wheel deflection was also applied. Heading increased from 145.2° at 34:33 to 150.3° at 34:37.
- Full left control wheel deflection will fully retract spoiler panels 8, 9, 10, 11 and 12 (on the right wing) with the speed brake handle at the ground position and the lateral control system in normal. Spoiler panels 1 through 7 remain open at 45° deflection.
- Between 34:37 and 34:41, the yaw motion reversed and the heading decreased to 147.7°. Side force and roll angle reversed sign. The control wheel was gradually returned to neutral. The airspeed remained fairly constant between 110 and 112 knots. The pitch angle was about -1° compared to 0° between 34:29 and 34:36. The change in motion between 34:37 and 34:41 is possibly associated with the airplane leaving the runway.
- At 34:41, the turning motion to the right returned and continued until the end of data, at 34:50, when the heading had reached 162.2°, which is 18° clockwise from the heading at touchdown. The side force was to the right at about 34:42 and the roll angle remained between +1° and -1°. The airspeed decreased from 110 knots to 90 knots.
- For about 28 sec the elevators were in neutral and the horizontal stabilizer position was constant. The flaps were not moved.

c. Cockpit Voice Recorder (CVR)

SUNDSTRAND DATA CONTROL, INC. P/N: 103.600. Continuously records the last 30 minutes of operations.

Serial Number: 3071

PAA Certificate: TSO-C84

Number of Channels: 04

Sundstrand Data Control, Inc.

TIME	SOURCE	COMMUNICATIONS
08:33'53"	F/E OMN	Altimeter 300 feet.
08:33'55"	Co-pilot	Yes, we see the runway.
08:33'56"		See it better, hem! yes, yes.
08:33'57H	F/E OMN	300 feet.
08:33'58"	Captain	(Illegible) you see it's real. (Illegible) we think that (Illegible).
08:34'03"	F/E OMN	200 feet radio altimeter.
08:34'08"	F/E OMN	150 feet.
08:34'10"	F/E OMN	120.
08:34'11"	F/E OMN	100.
08:34'12"	F/E OMN	80.
08:34'13"	F/E ONN	50.
08:34'14"	F/E OMN	40.

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08:34'15"	F/E OMN	30.
08:34'16"	F/E OMN	20.
08:34'17"	F/E OMN	15.
08:34'17"	F/E OMN	10.
08:34'18"	F/E OMN	5
08:34'20"	F/E OMN	(Touchdown noise).
08:34'23"	Co-pilot	140 kts.
08:34'24"	F/E OMN	Speed brake up, 3 transits. Only inners. The outer one seems to be out of order.
08:34'29"	Co-pilot	I34 kts.
08:34'31"	F/E OMN	(Illegible)
08:34'32"	Co-pilot	130 kts.
08:34'33"	F/E OMN	Only the inners.
08:34'37"	CBD	Hou la la la aie.
08:34'40"	?	What's this?
08:34'43"	F/E OMN	Put reverses, the inner reverses.
08:34'50"		End of recording.

1.12 Impact and Wreckage Informations

The first impact occurred between the landing gears and a drainage ditch 1.3m wide by 0.9m deep located 106 meters to the right of the runway. A few meters ahead there was another impact against a concrete step about 0.25m high.

The left wing gear was completely severe. All others were folded aft.

Supported by its fuselage and engines the aircraft skidded spinning around for about 220°, running 275m on the concrete ramp until finally stopping when the left outboard wing struck an illumination stand. The fuselage was bent downward just aft of the wings trailing edges. Pylons 2, 3 and 4 buckled upward. The damage was beyond economic repair.

1.13 Medical and Pathological Informations

The crewmembers were examined at the Galeão Air Force Hospital after the accident. No abnormalities were found.

1.14 Fire

There was fire in the area next to engines 2 and 3 and also near the landing gears. It is probable that the friction between the engines and the fuselage against the ramp surface produced enough heat to ignite the oil from the landing gear hydraulic lines.

The fire was immediately extinguished by the aerodrome fire fighters.

1.15 Survival Aspects

a. After the aircraft stopped, the fire alarm was cancelled by the flight crew. This procedure prevented the stewards from hearing the evacuation emergency warning in the passenger cabin.

b. Since there was fire at the aircraft's right side, the captain ordered the evacuation on the left side.

The evacuation order, given through the Public Address system, was heard in the forward half of the passenger cabin (zones A and B). It was not heard in the aft passenger cabin (zones C and D) probably due to damage to the system during the accident.

B-747 Operations Manual recommended, at the time of the accident, on the Emergency Passenger Evacuation procedure, that the battery be switched off. As a result, after the battery was switched off, the Public Address became inoperative, preventing the crew from passing instructions to the passenger cabin.

Note - The "battery off" item is no longer used on the B-747 Emergency Passenger Evacuation.

c. Number 4 right side door and number 3 left side door emergency escape slides did not inflate.

d. A passenger opened the number 4 right side door. Since there was smoke and fire on this side, a flight attendant immediately closed the door. It is worth noting that the closing of the door was only possible due to the escape slide failure.

e. Fifteen passengers sustained minor injuries, most of them due to smoke inhalation.

1.16 Tests and Research

a. According to the acing Engineering Report there was no evidence of contact between the TIB-5 cable and the pass-through-holes on the pulley bracket and its support.

Most of the ruptures on the T1B-5 cable wires were due to fretting wear against the aluminium pulley. Only six of the 49 existing wires were not completely worn prior to the accident. No evidence of fatigue or corrosion was found on any of the wires.

b. According to the report from CTA's Institute for Research and Development, the Main Engine Control (MEC) lever was in the full forward thrust position. The Quadrant 6 Interlock Mechanism arm was in the full forward position too, corroborating the maximum power condition.

The cable rupture coincided with its passage on aluminum pulley PN MS20219A4.

One of the three screws that fixes the pulley bracket to the support bracket was torqueless and had one extra washer. A pronounced oblong pattern was observed in the hole through which the screw passes.

The pulley groove where cable T1B-5 passes, had a localized depth of approximately 1mm and was well scratched (cable marks), in all of its perimeter.

c. Escape slides research

From the escape slides used during passenger evacuation, 01 LH, 02 LH and 04 LH were teared.

The Bureau d'Enquet from France researched the facts and circumstances that involved the accident and came to the following conclusions:

- The escape slides had been checked in the recommended periodicity and were considered normal by Technical Standard Order (TSO C 69A) requirements.
- The perforating and tearing at the nail test represents the slide canvas resistance when passengers with shoes jump on the escape slides (toboggans).

The TSO, that defines the escape slides resistance conditions, currently fixes as permissible value to the trapezium tear the 6 daN limit.

Most of the canvas produced by industry today, presents resistance above 15 daN to the trapezium tear (they can reach till 20 daN) and a perforating resistance above 15 daN, frequently superior to 20 or 25, reaching till 30 daN.

- The tearing resulting from accidents during use were not attributed to the tissue exaggerated aging, but to its inferior quality concerning the perforating and tearing resistance.

Additional Considerations about Escape Slides Condition

a. For the last years, operators have found hydrolysis problems at the escape slide level, due to condensation that can exist into the escape slides boxes.

b. The maximum inflation times according to the TSO definition are:

- 10 seconds for door escape slides (with the exception of the over the wings exits) after starting to deploy.
- 15 seconds for the over the wing toboggans after the activation of the inflation command.

Depending on the kind of emergency these deployment times can be too long.

c. The over the door escape slide fixation kit, sustained damage due to static efforts, at the time of the accident.

This failure was a consequence of the excessive proximity of the holes to the edge of the plate, and to the inadequate design of this plate regarding thickness and strength.

1.17 Additional Information

Air Flight Manual (AFM) procedures related to the accident:

Note: The Operator AFM is issued in French. Due to some differences to the Manufacturer's AFM (in English), both of them will be mentioned:

a. Landing

- Auto brake switch.......as required
- On dry runways and when stopping distance is enough, do not use the Auto Brake. (AF-AFN, pg 63.61.01 Nov/84)

b. Deceleration (Landing roll procedures)

At main landing gear touchdown on the runway:

- Auto pilot........................Off
- Speed brake....................check up
- Thrust levers....................idle stop
- Reverse thrust levers.........pass the levers
- In all cases pull the four reverse levers together up to the interlock position (reverse thrust idle stop).
  At nose landing gear touchdown onto the runway
- Reverse lever...................as required.

From the time when the reverse levers are released the captain symmetrically sets full reverse thrust.

- If one or more N1 exceeds the limits, the F/E announces N1.
- The pilot them slightly reduces the four engines reverse power without trying to act more precisely on the one (or ones) that is (are) the announcement origin.

The F/E monitors with priority:

- N1 during the increasing phase and during full reverse thrust application.
- EGT during the reverse thrust reduction until at least ten seconds after forward thrust return.

Important Remarks

An overheat can occur during the reversers application command, and for the ten seconds following forward thrust return the F/E particularly monitors the EGT.

JT9D: For any EGT increase during the reverse thrust reduction or forward thrust change, the F/E advises the captain and immediately shuts down the engine placing the start lever in cut off.

Do not change command to the thrust reversers before they have had time enough to reach the end of the stroke (the extend reverse time takes two seconds and the return to forward thrust takes about five seconds).

Avoid applying alternate demands on reversers levers at the risk of pneumatic engine damage (even in case of reversers transit difficulties). At the time of the return of reverse thrust, the interlock position is hardly detectable. If the reverse thrust levers are positioned beside the reverse idle position, a new reverse thrust application may cause a reversion mechanism damage.

Trying better directional control through the use of asymmetrical reverse thrust is PROHIBITED.

In case of difficulty to maintain landing runway heading, restore all reverse levers to idle and do not use more than the nose wheel and the brakes. If necessary, repass to forward idle thrust. (AF-AFM pg. 63.63.01 Nov/84).

c. Landing Roll Procedure

Immediately at main gear touchdown, verify auto spoiler deployment and lift the reverse thrust levers to the interlock position while flying the nose gear onto the runway.

All crew members should be aware of the auto spoiler actuation. Simultaneously apply light pressure against the reverse interlocks and steady braking (if using manual brakes) to assist in flying the nose down.

NOTE: Spoilers deployment and reverse thrust tend to give a slight pitch up which is easily countered by initial auto brake or manual brake application and control column input. When the reverse interlocks release, reverse symmetrical engines as required.
04.50.05 (FCT 747 TM Oct 31/83).

d. Reverse Thrust

When the PF fully retards the thrust levers, the F/E should hold the F/E thrust levers against the closed stop to assist in the initial reverse thrust lever actuation. As reverse thrust is established, the F/E should move his hand from the thrust levers and be prepared to shut down an engine that has unrecoverable surge during reverse thrust operation.

During reverse thrust operation, the F/E should give his undivided attention to the monitoring of the engine instruments and be prepared to take immediate corrective action in the event of a nonrecoverable engine surge.

This vigilance should continue until the engines are out of reverse thrust and stabilized in forward thrust (ten to fifteen seconds).

NOTE: The F/E should call out the engine malfunction and wait for the Captain's command for shutdown. In any event, the immediate shutdown is vitally important to prevent exceeding EGT limits. As little as a two second delay can significantly increase overheat damage.

When the reverse interlocks release, apply symmetrical reverse thrust commensurate with stopping requirements. Reverse thrust is most effective at higher speed. For normal operation on runways of sufficient length and good

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braking action, maximum reverse thrust may not be required. However, do not hesitate to use maximum reverse thrust during adverse conditions.

NOTE: In an emergency, maximum reverse thrust may be used to a full stop.

To obtain maximum reverse thrust, after the interlocks release, pull the reverse levers up to the stops.

Maintain maximum reverse thrust until the airspeed approaches 60 knots. 04.50.06 (FCT 747 TH Jan 31, 1983).

Changes of command to the thrust reversers while in the midstroke between reverse and forward thrust or vice versa can damage the actuating mechanisms. They require approximately two seconds to extend and five seconds to stow for forward thrust. Because there is no reverse idle feel stop on the reverse thrust levers for early airplanes it is difficult to establish the exact reverse thrust position for reverse idle thrust.

If the reverse thrust levers are inadvertently positioned below the reverse idle position and reverse thrust reapplied, the actuator mechanism may be reversed in midstroke. Therefore, after normal application of reverse thrust on early airplanes, do not reduce reverse thrust below 30 to 40 percent N1 until it is clearly established that reverse thrust will not longer be required.

04.50.07 (FCT 747 TM, Jan 31, 83).

e. Auto-Brakes

It is estimated that manual braking techniques frequently involve a four to five second delay between main gear touchdown and brake pedal application even when actual conditions reflect the need for a more rapid initiation of braking. This delayed braking can result in the loss of 800 to 1.000 feet of runway. Directional control requirements for crosswind conditions and low visibility may further increase the above delays as can the distraction arising from a malfunctioning reverser system. For these reasons, it is strongly recommended that the autobrake system be used in preference to manual braking whenever runway limited or landing on slippery runways.

On long, dry runways, reverse thrust may be used as the primary method of slowing the airplane with manual braking used in preference to the autobrake system.

For normal operation of the auto-brake system, it is only necessary to arm it by selecting a deceleration setting.

Select the setting prior to landing according to circumstances and in accordance with airline policy.

04.50.09 (FCT 747 TM Jan 31, 1983).

1.18 New Technics of Investigation

None.

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2. Analysis

The flight was uneventful until final approach. Meteorological conditions at Rio de Janeiro were good. An ILS approach to AIRJ runway 14 was flown. Runway conditions were good for landing.

Touchdown occurred on the runway centerline at 400 m from the threshold, well lined up, with thrust levers at or reaching idle stop.

All reverses were set to maximum reverse thrust. Engine number one reverser did not deploy and accelerated to 118% N1 forward.

A cable/pulley system connects the thrust levers to the Quadrant & Interlock Mechanism in the engine pylon upper side of the corresponding engine. The reversers use the same cables, being necessary the correct positioning of the Quadrant & Interlock Mechanism, which is a motion transmission mechanism for the fan reverser (the positioning of this component is set by electrical and pneumatic actuators).

Cables T1A-5 and TIB-5, which work during forward and reverse thrust operations, run to this mechanism.

To use the reverse system it is necessary to pull the T1B-5 cable, which as a consequence of its own Quadrant & Interlock Mechanism functioning principle, causes the T1A-5 movement but in an opposite direction to its normal operation - forward acceleration.

Later on it was verified that the TIB-5 cable separated during the application of the reversers. The existing tension on cable TIA-5, under spring effect, adding to the weight of the interconnection arm from the power lever angle (PLA) to the MEC, was enough to rotate the mechanism to accelerate the engine to forward thrust. The acceleration was initially fast and then had its rate reduced due to the own frictional resistance of the strut control box system, taking ten seconds more to reach 118% N1.

There is no protection, in the Quadrant & Interlock Mechanism, to avoid the engine accelerating uncontrolled to full forward thrust if cable T1B-5 separates.

Cable T1B-5 passes through a pulley installed at a support assembly (thrust control cable pulley bracket) located near to the Quadrant and Interlock Mechanism.

Considerations about the support Bracket and the Aluminum Pulley Installation

Cable T1B-5 was installed on the aircraft on Jan 25, 1984, and on Jun 27, 1984, an aluminum pulley was installed. The last inspection of the cable and pulley assembly occurred on Jun 06, 1985, approximately six months prior to the accident. Since then the aircraft had flown 2.449 hours. In compliance to a manufacturer's recommendation, rework on the pulley bracket pass-through-hole was performed during this inspection, due to known cases of wear in that region.

According to the maintenance inspection card presented by the operator, except for the impossibility to get the manufacturer's recommended clearance between cable and support at the reworked hole, no abnormality regarding the cable-bracket-pulley assembly was registered, meaning in principle that, on that date, the pulley and cable did not present fretting wear indications and that the cable was in accordance with the Maintenance Manual specifications.

During research performed by CTA it was observed that the side brace had presented wear marks due to vibration and insufficient fixation at the operator inspection and rework, confirmed by the wear marks and eight shape hole elongation produced by the screw head.

This screw had been used with a washer close to its head, probably with the intention of increasing the contact area. The assembly screwhead-washer was inserted only in the lower elongation part.

In the upper part, where a dent was observed on the plate, only the inserting of the screw head was possible. That allows us to say, with reasonable assurance, that the fastener hole elongation was observed during the last inspection on Jun 06, 85. The reasons took the operator not to inform the manufacturer are unknown.

The washer used close to the screw head should be installed that next to the self locking nut (check nut), however an extra washer was found in this assembly. As a cult of this additional washer and of the use of the same screw length (10,0 mm) the resulting thickness (support plate, nut and washer) was of 10.1 mm. This allows us to say that there was not the necessary torque in the nut. This screw was found loose, torqueless, not fixing the base of the side brace to the support bracket, as was expected, and not giving the necessary stiffness to the side brace and support bracket assembly.

Regarding the use of aluminum pulley PN MS 20219A4, installed on Jun 27, 84, it does not conform to the manufacturer's specification, that recommends the use of a phenolic pulley.

The carbon steel cable and the aluminum pulley groove fretting resulted in aluminum oxide this being a highly abrasive agent (alumina).

The cable was worn in a well defined region (of about 35 mm length). This wearing presents itself under the form of a gradual reduction of its useful section (funnel-shaped) corresponding with the more accentuated pulley groove worn region. The pulley groove width, at the time of the cable fracture was about 2,3 mm, practically twice the cable mean thickness (1,2 mm) taking in consideration the reduction from 2.0 to 0,4 mm for a wire extent of 17,0 mm, in one of the segments of the ruptured cable. On the other hand, the pulley groove showed, besides the localized deepening, wear and evident chewing signs from the cable throughout its perimeter. Consequently the lack of stiffness, associated to the local existing vibration allowed a pulley and cable relative movement, still greater than the existing one, bringing great wearing on these parts, due to the abrasive agent generated by the aluminum pulley, besides the widening of the support bracket attachment screw hole.

Such fact culminated with the cable rupture at the moment when reverse was applied, six months after the last inspection.

As to the vibration, it has been admitted and explained by the manufacturer that its origin is due to the ripple produced by the hydraulic pumps, present in the rigid manifolds at the upper strut part (the pulley is located in the lower part). Due to the pump mechanics its ripple frequency is directly proportional to the engine rotation, while the magnitude of the pulsation pressure (ripple pressure) stays approximately constant in all its operation ranges. Therefore a relative movement between pulley and cable is to be expected during cruising, which corresponds to 93% of the total working time, period in which cable and pulley stay in contact at the same points. Nineteen other cable rupture cases but non associated to aluminium pulleys, were presented by the manufacturer, also as resulting from the hydraulic pump ripple induced vibration.

From the cases related to the bracket pulley, that could be completely analyzed in a laboratory by Boeing, the first one is relative to the TIB-5 cable of AFA F-GCBC, replaced on

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Jan 25, 1984, due to presenting 6/7 ruptured strands, corrosion by-products (with no attack) and lubricant grease contamination. All but this one case, present as main wear agents, corrosion by-products or grease contamination.

Up to the time of the investigation, this was the only case of cable wear/rupture connected to the aluminum pulley. However, the fact that other cases of TIB-5 cable wear/rupture occurred not being related to the aluminium pulley, is an indication that there is a deficiency of project at the pulley bracket, possibly related to the short contact area between the pulley and the cable (only 8° of pulley groove perimeter) that allowed for the occurrence of the localized wearing in these parts in the presence of contaminating or abrasive agents, due to the considerable vibration at that place.

It is worth mentioning that there is no connection between the above mentioned cases and those referred to in the Manufacturer's Service Bulletin, that recommended the rework on the T1B-5 cable-pass-through hole at the support bracket, to avoid friction between parts and cable wear.

Considerations about the Crew's operational performance

a. Capitain's performance

Due to the runway condition, long and dry, the landing was planned with the auto-brake in OFF. The "Air Flight Manual" (AFM), Manual Brakes Stopping instructions describes the captain's actions in case of a manual landing: "... the brakes and thrust reversers should be applied together. Due to the 3 to 5 second delay before build up of full effective reverse thrust, brakes will normally be operating before reverse thrust" (AFM 04.30.I3). Further on the same instructions anticipate to the pilot flying (PF): "... simultaneously apply light pressure against the reverse interlocks and steady braking (if using manual brakes) to assist in flying the nose down..."

"...when the reverse interlocks release, apply symmetrical reverse thrust commensurate with stopping requirements".

According to the Captain's statements, after applying the reversers, he felt a slight tendency to the right which smoothly but firmly, accentuated itself until became uncontrollable.

In an attempt to control the aircraft the captain stated that he acted on the reverse levers, rudder pedals and ailerons. He did not recall if had acted on the brakes prior to being on the grass.

According to DFDR data, the landing occurred at 08:34:19.7 UTC.

Full reverser deployment probably occurred on engines 2, 3 and 4 at 34:25. The N1 fast acceleration indicates that the pilot moved the reverse thrust levers to the full reverse position prior to or very close to the interlock clearing.

At 34:23 it is considered that number one reverser had started to deploy when T1B-5 cable separation occurred before the interlock cleared.

At 34:25, the F/E identified the failure and announced Speed brakes up, three transits, only inners, outer number one apparently didn't work"...

According to DFDR braking data analysis, during this period the brakes were not applied and all stopping force can be attributed to airplane drag.

Maximum reverse thrust on engines 2, 3 and 4 was reached in 5 seconds and maintained for about 3 or 4 seconds at this level.

According to the stability and control analysis, the rudder pedal was gradually applied starting at 34:26, and reached full left deflection at 34:30. The control wheel reached full left deflection at 34:33.

At this moment the F/E repeated: – "Only the inners".

At 34:34, not complying with the request, the reverse thrust levers were cancelled. Reversers 2 and 4 stowed 9 and 11 seconds later, at 34:43/45. It is not clear whether reverser number 3 completed the stow cycle.

Between 34:33 and 34:37 a left wing low hank and a skid to the left developed following a gradually increasing yaw to the right. The heading increased from 145.2° at 34:33 to 150.3° at 34:37.

The maximum reverse thrust application, prior to receiving the announcement of transit, did not contradict any published recommendation. Nevertheless, this rapid reverse acceleration without the knowledge of reverse operation conditions, caused the immediate generation of high asymmetric thrust, difficulting the landing roll aircraft control.

The necessary corrective actions to maintain the aircraft on the runway absorbed the Captain's attention. These facts contributed to the aircraft directional control loss.

According to the angle of attack data, the nose wheel left the runway at 34:37 on the 2000 meters mark. At this time engine number 1 was reaching 114% N1 accelerating forward, while the others were at 75% decelerating in reverse.

Between 34:37 and 34:41 the left yaw reversed, the heading decreased to 147.7°. The lateral and rolling forces changed signs and the aileron control returned to neutral.

Up to this moment, relatively little force was applied to the brakes. The engines net power went from reverse to forward power. Between 34:34 and 34:42 the nominal reverse power loss was higher than 11600 lbs.

At 34:36, after reaching zero deceleration, the aircraft was generally accelerated at 0, 5 ft/sec^2 for the next two seconds, from 110kt to 112kt.

From 34:38.8 on, the brakes were applied up to the maximum possible on dry grass, reaching a peak of 6.93 ft/s^2 until 34:45.

The reverse thrust reduction on the three other engines instead of only on engine number 4 as requested, added to engine number 1 high forward thrust, had as an aggravation the reduced or no application of brakes during the 18 seconds after touchdown.

Thirty seconds after touchdown, the aircraft was at 90kt. It had decelerated just 51k, a reduction of 1.5kt/s only.

These facts characterize the control loss over the aircraft deceleration and contributed to the accident.

At 34:46, N1 and EGT on engines 2, 3 and 4 started to accelerate indicating that the reversers where reapplied. The aircraft was at approximately 250 m away from the drainage ditch.

In his statements, the Captain said that when he saw the pluvial drainage ditch, wide and deep, he realized the accident imminence and only worried about stopping the aircraft. He pulled the four reverse levers up and then back fully. This statement concurs with the last seconds of DFDR data.

The maximum reverse thrust application on engines 2, 3 and 4 caused the ground loop that preceded the full stop and determined the accident.

b. Flight Engineer's (F/E) performance

Up to 34:37 the F/E actions were executed in accordance with B-747 AFM recommended procedures.

At 34:25, he observed and immediately announced the number 1 reverser transit failure.

At 34:33, eight seconds later he announced once more: "- Only the inners". Up to that moment it was not clear to the F/E that engine number 1 had accelerated to forward thrust.

At 34:37, number 2, 3 and 4 engines were reducing through 75% N1 (600°C EGT) while number 1 engine was accelerating through 115% N1 (820°C EGT) with no reverse deployment indication.

At 34:40, number 1 engine reached 118% N1 (883°C EGT) while the other engines were reducing through 40% N1 (470°C EGT).

According to the AFM recommended procedures, the F/E should monitor with undivided attention the engine N1 parameters during the selecting and full acceleration and the EGT during the reduction of reverse thrust. (Important remarks – AF – AFM –63.63.01).

Beginning at 34:37, the engine parameters clearly indicated that number 1 engine presented an abnormality in progress.

At 34:40, the N1, EGT and the "reverse deployed" warning light gave no doubt about the abnormal conditions under which number 1 engine was operating.

On the CVR, at 34:43, the F/E announces: "- Put the reverses, inner reverses".

At that time engine 1 was at 118% N1 and 910°C EGT while engines 2, 3 and 4 were running at about 25% N1 and 470°C EGT.

These facts indicate poor monitoring over the engine parameters. From 33:34 on, the F/E did not see or did not understand the abnormal operation of engine number 1 and for that reason did not advise the captain to shut down the engine.

This fact contributed decisively to the accident, because the simple engine shut down through the start lever would have permitted, immediately, the cancelling of 11.600 pounds of forward thrust and the recovery of directional control.

c. Flight crew performance under the Human Factors point of view

The flight crew reported for duty at Charles de Gaule Airport at 20:00 local time, one hour and a half before take off.

Adding to the 11:05 hours flight, the flight crew had 12:35 duty hours, from reporting to accident time.

The captain stated that he was educated, since the beginning of his career, not to sleep during flights.

On this particular flight he said that, except for some walks to the passenger cabin on public relations, he stayed at his seat all the time, where he rested between tasks.

The environmental conditions on any aircraft's cabin are very stressful due to factors such as vibration, noise, acceleration, pressurization, and low humidity that reaches values near 20%.

The aircraft cabin altitude was at at least 5.000ft during most of the flight.

Staying at his seat, the captain performed a long vigil, where he did not get away from the concerns and tasks inherent to his function. This situation had as an aggravating circumstance the fact that 12 hours from the total duty time, were night hours, period in which the human organism usually rests.

It is agreed among experts on this matter that westwards flights are more stressful to the human body. This east-west flight crossed three time-zones.

The sleep deprivation, conditioned or not, causes a significant reduction in human performance.

Several levels of fatigue are reached as this lack of sleep increases. The responses to the stimulus are proportionally slower. In emergencies, where immediate responses are required, the reactions and reflex actions tend to be compromised. This response varies from one individual to another depending on health conditions, training, motivation and age.

The reverse failure, on this accident, was aggravated by the same engine accelerating to maximum forward thrust. The abnormalities appeared very fast, requiring quick reactions from the pilot in order not to lose the aircraft control. While trying to maintain directional control, the pilot lost control over the deceleration. The captain's actions were not enough to avoid the aircraft damage.

On the other hand, the F/E did not monitor appropriately the engine instruments and could not recognize, at least for ten seconds, the abnormal conditions of operation on engine number 1.

The above described facts indicate that it is very likely that a compromise occurred regarding the concentration, attention and reflexes from the captain and the F/E during the abnormality.

There is no comment in the AFM regarding a reverse failure associated with an uncontrolled engine forward acceleration, during the landing roll (after touchdown deceleration phase).

The Manufacturer does not anticipate this specific kind of failure in the simulator training.

Consequently, it is possible to observe that in spite of the previous comments, the flight crew did not have the specific training for this kind of emergency.

3. Conclusions

a. Findings

- The crewmembers were experienced and qualified to conduct the flight.
- The crewmembers were properly licensed and held valid medical certificates.

- The aircraft had a valid Certificate of Airworthiness and its documentation was up to date.
- The periodical inspections had been performed and the aircraft had been maintained in accordance with established procedures except for the support bracket services and the use of the aluminum pulley, not in accordance with the manufacturer's recommendations.
- The pump ripple generated by the hydraulic pump from the CF6-50E engines caused a considerable vibration on the support bracket region.
- The vibration worked like a dynamic source to produce the cable oscillation and the relative movement between cable and pulley.
- The side brace inadequate service left the support bracket without the necessary fixation allowing for an increase of relative movement between cable and pulley.
- The reduced contact area between cable and pulley allowed the wearing of the components in the presence of abrasive agents.
- The contact between the carbon-steel cable T1B-5 and the pulley produced an abrasive agent that accelerated the wearing of the cable wires.
- Without any fatigue or corrosion evidence, forty three wires broke due to the fretting wear and the remaining six due to the reverse application overtension.
- After touchdown the pilot moved the reverse thrust lever from the interlock position to maximum reverse thrust prior to or very close to the interlock clearing.
- The F/E saw and announced at once that the number one reverser had not transited and that only the internal reversers should be used.
- With the reverser stowed, the number one engine accelerated to maximum forward thrust, while number 2, 3 and 4 engines accelerated to maximum reverse thrust.

The pilot did not act on the brake pedals simultaneously to reversers application.

In an attempt to regain control of the aircraft he cancelled all reversers, acting on the ailerons and rudder.

The F/E did not inform the pilot about the abnormal operating condition of engine number 1.

The asymmetric thrust, the high levels of power involved and the reduced decelerating forces conducted the aircraft to the accident.

b. Contributing Factors

(1) Human Factor

Physiological Aspect – The crewmembers physical conditions (fatigue) might have contributed to their delay in perceiving the engine failure and to the inadequate reactions during the emergency.

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(2) Material Factor

a) The hydraulic pump ripple of the CF6-50E engine caused considerable vibration on the pulley support region, which worked as a dynamic source to produce cable oscillation and relative movement between cable and pulley.

b) Pulley bracket design deficiency, possibly related to the reduced contact area between cable and pulley, allowing for the wearing of these components in the presence of abrasive agents, in association with the vibration on that area, knowing that there is localized contact between both (at the same points) in a almost permanent way (93% of the engine operating time in cruise range).

c) The tests performed by the Manufacturer confirmed the existing relative movement between cable and pulley, even after the introduction of modifications.

(3) Maintenance Deficiency

a) The use of an aluminum pulley, not authorized by the manufacturer as a substitution to the recommended phenolic pulley, made possible the formation of the abrasive agent (alumina).

b) The inadequate fixation of the pulley bracket due to the use, by the operator, of a screw of insufficient length for an additional washer, left loose the support side brace, allowing for the increase of the relative movement, already existing at that region, between cable and pulley.

(4) Flight Manual Deficiency

a) The B-747 AFM instructions allow the pilot flying to apply reverse thrust before knowing the effective transit of reversers.

b) The B-747 AFM has no instruction regarding a failure of reverser deployment associated with an engine runaway forward thrust. The lack of instructions on this specific kind of abnormality, contributed to the crew not noticing that the failure had occurred.

(5) Training Requirement Deficiency

The lack of simulator training requirement for this type of emergency contributed to the control loss.

(6) Crewmember Factor due to Operational Error

a) The captain did not observe the AFM instructions about the reverse levers and manual brake use.

b) The F/E did not observe the AFM instructions about the correct engine instrument monitoring during the reverse operation.

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4. Recommendations

a. The Manufacturer shall:

- Perform studies with the objective of adjusting the support bracket to the area in discussion.

- Perform studies to provide the means to eliminate the relative movement between the pulley groove and the cable (fretting wear) to avoid that localized contacts produce wear in both parts in the presence of the abrasive agents.

- Introduce in the pilot training simulator program the specific emergency of reverse failure associated with a full forward uncontrolled thrust during landing run.

- Reevaluate the AFM instructions regarding the reverse thrust application, adding the recommendation that the pilot flying should observe the reverse transit announcement, before applying thrust.

b. The Operator shall:

Observe that the use of component, parts and pieces not in accordance with the aircraft specification should be proceeded by authorizations from the manufacturer.

In 23 / 02 / 2006

ANTÔNIO CARLOS PRADO RODRIGUES – Cel Av
Chief of CENIPA

I APPROVE THE RECOMMENDATIONS OF FLIGHT SAFETY

Ten Brig Ar – JUNITI SAITO
Chief of EMAER