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EDITORIAL

In the previous issue, we discussed the errors that could occur in takeoff performance calculations, their consequences and the means to prevent them. In this issue, we look into two specific tailstrikes, which vividly bring out the circumstances leading to the errors and the accidents.

Strong winds at altitude and convection due to cumulonimbus can precipitate events during flights at altitude. One such event on an A320 and its implication on operational safety is briefed.

As always, we look forward to your feed-back, suggestions and contributions which can be sent to our office address given in this page. Happy reading and many more safe landings.

TALE OF TWO TAILSTRIKES

Dr.M.S.Rajamurthy

In the April issue, we discussed in detail the errors in takeoff calculations and their consequences. Wrongly entered weight and speed data can be deadly, and multiple defenses against human errors can be breached, particularly when the crew is under time pressure. The following two tailstrikes vividly bring out this.

1.Singapore Airlines(SIA) B747 Tailstrike at Auckland

On March 12,2003, at 1547(local time), Singapore Airlines flight SQ286, a Boeing 747-412(9V-SMT), started its takeoff at Auck-land International Airport for a direct 9-hour flight to Singapore. On board were 369 passengers, 17 cabin crew and 3 pilots. When the captain rotated the airplane for lift-off the tail struck the runway and scraped for about 1500ft until it became airborne. The airplane veered to the right before getting airborne.

During the takeoff the airplane moved close to the runway edge and the pilots did not respond correctly to a stall warning. There was an APU fire warning and tower controller advised the crew of " a lot of smoke" during the airplane rotation. The crew declared emergency and prudently decided not to dump fuel and made an overweight landing. The tail portion of the fuselage was badly damaged and some parts were dangling outside(See pictures below).

The tail strike occurred because the rotation speed was 33Kt less than the speed required for the airplane weight. The rotation speed was wrongly calculated for an airplane

© Chris Norton/airdisaster.com

SIA B747-412 with damaged tail © Chris Norton/airdisaster.com weighing 100 tons less than the actual weight of 9V-SMT.

With inappropriately low thrust and reference speed settings takeoff performance was degraded. This compromised the ability of the airplane to cope with an engine failure and hence compromised the safety of the flight.

As per regulations, New Zealand's Transport Accident Investigation Commission (TAIC) investigated this accident. The findings of the investigation follows:

The crew consisted of the captain and two First officers (FO) - the second of whom will be referred to as the relief pilot.

It all started with the captain noticing that 4.5 tons of fuel was loaded into the center wing tank, instead of a minimum of 7.7 tons required to ensure the pumps to be covered in fuel (a minimum fuel quantity designed to prevent an explosion of flammable vapors).

Adding the fuel delayed departure. Fuel weights had to be adjusted and the load sheet modified. Upon receipt of the final load sheet, the captain called out to the FO certain items, including the airplane's ZFW and the TOW. The FO duly entered these values on the bug card, and calculated the necessary thrust and speed settings for takeoff. In this process the FO had marked down on the bug card a TOW that was 100 tons below that in the load sheet.

As per the procedure, the captain entered the thrust and speed values calculated by the FO into the FMC (*The captain later told investigators that he checked the ZFW and TOW displayed by the FMC and found them in agreement with the values on the load sheet, from which he'd entered them into the FMC*). The FMC calculated its own takeoff speeds, but the captain did not notice that they were significantly higher than the ones provided by the FO. He entered the thrust setting and speeds provided by the FO, thus overwriting the FMC. Despite the significant difference in speeds, the FMC accepted the lower values!

The relief pilot, who normally would cross check the bug card and computations, did not do so, as he was busy explaining the departure delay to Singapore Airlines' station manager at Auckland.

As captain was the PF, the FO called "rotate" as the airplane reached 130Kts on its takeoff run. With insufficient speed to generate lift, the airplane remained on the ground, dragging its tail on the tarmac for a good 1500ft and veering to the right before finally becoming airborne in ground effect.

The stick shaker activated, warning of imminent stall as the airplane began its struggle into the sky. The captain ignored it as a spurious activation. Three seconds after stick shaker activation, there was an APU fire warning (*The APU is located in the tailcone, and when the tailcone was dragging on the runway, the damage to the fire wire loop triggered the APU fire warning in the cockpit*).

With an emergency declared, the airplane climbed slowly. The correct V2 of 172Kts was achieved 64 seconds after lift off, at about 1000ft. Had an engine failure occurred during this period, the airplane probably would have been lost.

With the warning of a fire, the crew prudently decided not to dump fuel and made an overweight landing.

The table given in this page summarizes various load and speed values highlighting the data input error and its implication on speeds.

After landing, crew had the following exchange dealing with the TOW, which the CVR had captured:

Captain: " Should be a three."
FO: " Takeoff weight?"
Captain: " Yeah."
Relief pilot: "Gosh- I should have checked it."

The captain and FO were both relatively inexperienced on the B747-400, with a total of less than 400 hours between them.

SIA procedures prohibited the pairing of two inexperienced pilots together. Among its criteria, experience in time was defined as 100 flying hours and ten sectors. The captain, with 54 hours, was making his eighth flight as B747-400 pilot in command. Since he was inexperienced on type, he was paired with a relatively junior FO who had more experience on type. The two pilots were backed up by a very experienced relief pilot with more than 3,300 hours in the B747-400.

The captain had recently transitioned from the Airbus A340, for which the typical rotate speed is around 138Kts. This value is pretty close to the incorrect rotate speed of 130Kts calculated by the FO for this accident flight.

It is well known that during times of stress (center fuel tank minimum quan-

Item	Load sheet data	Bug card data	What should have been 3	FMC data displayed	Override data	Data used for takeoff
Zero fuel weight (ZFW)	231 tons	231 tons	--	231 tons 4	--	--
Fuel weight for the flight	116 tons	116 tons	--	--	--	--
Takeoff weight (TOW)	347 tons	**247** tons 1	347 tons	347 tons 5	--	--
Thrust setting (EPR)	--	1.34 2	1.41	--	--	1.34 (-0.07, or 5%)
V1	--	123Kts2	151Kts	145 Kts 6	123Kts	123 (-18 Kts)
VR	--	130Kts2	163Kts	158 Kts 6	130Kts	130 (-33 Kts)
V2	--	143Kts 2	172Kts	174 Kts 6	143Kts	143 (-29 Kts)

1 FO's entry with 100 tons error; 2 FO computed engine power and speed thresholds; 3 The Values that should have actually been entered on the bug card ; 4 Captain's ZFW entry from load sheet; 5 FMS-produced TOW (same as on the load sheet) ; 6 Calculated by FMS on another airplane using same weights and settings as on the accident flight

Source: TAIC

tity error, in this case) people revert to their original or predominant training, experience and understanding. It is also conceivable that having spotted one mistake, the crew became slightly oblivious to spotting the other.

For those flights where a relief pilot was necessary, SIA had "no specific assigned duties." Tasks assigned were at captain's discretion. This is the second time this situation has been remarked upon in an accident report. The Aviation Safety Council of Taiwan noted the absence of specific third pilot duties in its investigation report of the fatal Oct. 31, 2000, SIA Flight SQ006 B747 takeoff crash on a closed runway at Taipei *(see Flight Safety Nov. 2006)*.

All three pilots had CRM training, yet good CRM was lacking - " The captain did not respond correctly to an impending stall condition and the two FOs did not exercise good CRM. A loss of control could have occurred."

In a test on another SIA B747-400, TAIC investigators found that the FMC would accept incorrect speeds without challenging them.

As a consequence, the simple transcription mistake breached multi levels of defense:

Level 1: The captain did not verify the TOW on the bug card.

Level 2: FMC computed V-speeds were discounted. "They knew they were on a direct flight to Singapore with a planned flight time in excess of nine hours with a planned fuel burn of over 100 tons."

Level 3: From *simple cognitive reasoning*, subtracting 100 from 247 will give a landing weight at Singapore significantly less than the empty weight of the airplane itself." "Even though the delay was only about 13 minutes, it could have been sufficient to pressure the pilots to unconsciously hurry through their procedures to minimize the time loss,"

Level 4: The relief pilot did not verify the entries on the bug card. He was busy explaining the delay to the station manager. "Time pressure could have contributed to the pilots' non-detection of errors."

Level 5: The operator's inadequate procedures, which did not require bug card data to be reconciled against FMC-generated V-speeds. In other words, a potential fifth line of defense did not exist.

Level 6: FMS itself lacked a potential line of defense. It would accept mismatched V-speeds and some erroneous gross weight entries without challenging them. "Had the FMS been programmed to challenge, or in certain cases not accept, erroneous or mismatched entries, then a valuable final defense against incorrect entries would have existed."

Following the investigation, TAIC made the following safety recommendations to SIA and Boeing.

a. Singapore Airlines :

1. Establish procedures to ensure independent verification of all essential takeoff data,

2. Reaffirm that safety should not be compromised in the face of delays,

3. Introduce similar errors in recurrent training for pilots to discover, and

4. Develop guidelines for use of the third pilot when one is aboard an airplane designed for two-pilot operation.

b.Boeing: Implement software changes to ensure that weight and V-speeds that are mismatched by a certain percentage are either challenged or prevented.

Both SIA and Boeing responded to the safety recommendations.

B. Air Canada Airbus 330 tailstrike at Frankfurt

On June 14,2002, Air Canada flight 875, an Airbus 330-343, was on a scheduled flight from Frankfurt, Germany to Montreal, Canada. On board were 253 passengers and 13 crew members. At about 0830(UTC) as the airplane was taking off on Runway 25R the underside of the tail struck the runway.

The flight crew could not detect strike, but were notified of the strike during the climb-out by Air Traffic Services (ATS) and by a cabin crew member. The flight crew requested a holding pattern to assess the situation. After discussion with the company, they decided to return to Frankfurt.

ATS vectored the airplane for an ILS approach to Runway 25R. While established at 4000ft ASL, on the localizer, at about 17 nm from the threshold, with the autopilot engaged, the airplane pitched up to 26.7 degrees. The auto pilot was disconnected and control of the airplane was recovered. The approach was completed manually, and an uneventful overweight landing was carried out on Runway 25R. There was substantial structural damage to the underside of the tail due to tailstrike. There were no injuries.

This occurrence was investigated by Transportation Safety Board (TSB) of Canada. Following is the chronology of events leading to tailstrike and subsequent landing.

The crew arrived on board the airplane about 45 minutes before the departure time of 0800 to complete the preflight checks. The flight crew listened to the information provided by ATIS.

At 0752, the flight crew received the initial load figures from ACARS, indicating an estimated takeoff weight of 222.7 tons and a centre of gravity (CG) of 23.7% MAC. A reduced takeoff thrust setting, using an assumed OAT of 48ºC, was planned for a takeoff from Runway 25R with a takeoff flap 1 configuration.

Flight crew enter data into the MCDU by typing onto the scratchpad. The data are then entered by pressing the line select key adjacent to the desired field. The takeoff speeds are typed on a keypad similar to that of a telephone. As per the SOP, the data were inserted by the PNF, cross-checked by the PF, and

AIR CANADA A330-343

reviewed in the takeoff briefing during the pre-departure review. The takeoff speeds inserted by PNF were: V1 156Kts, VR 157Kts, and V2 162Kts. These were valid for any takeoff weight of 219.1 to 223.6 tons.

At 0808, the ACARS provided the final load figures of 221.2 tons TOW and a CG of 23.8% MAC. As the load change was more than ±500Kg, as per the SOP, PNF reinserted load values. The speed values were still valid for the new loads. But, the PNF reentered these values. During this he inserted 126 instead of 156 as the V1. This error was not detected by either flight crew member.

The MCDU displays an error message if the data are out of range or not formatted correctly. *In the case of takeoff speeds insertion, the message will appear only if the speed inserted is below 100Kts.* The takeoff speeds inserted in the MCDU are displayed on the airspeed scale of both PFDs and are used as a reference by the PNF to call "V1"and "Rotate" during the takeoff roll. V1 is represented by "1" on the airspeed scale or by the V1 value when it is off the scale. VR is indicated by a blue circle and corresponds to the value inserted in the MCDU. V2 is represented by the target speed index.

According to the SOP, any time a crew member makes any adjustments or changes to any information or equipment on the flight deck, the other crew member is advised of the intentions and acknowledges the information.

The captain normally taxis the airplane while the FO makes any last minute changes to the planned routing, load, or performance data. After confirmation of correct data input and an updated briefing, the PF sets the PERF TAKEOFF page on his MCDU and, just prior to takeoff, reads the takeoff speeds off that page. At 0829:12, the airplane was cleared for takeoff. Captain was the PF. FDR data showed that the rotation was initiated at 133 Kts, and a pitch rate of 2.81 deg./sec was reached from rotation initiation to tail strike. The tail strike occurred at a pitch attitude of 10.4 deg. and lasted for about two seconds. The airplane lifted off at a speed of 152Kts at a pitch attitude of 13.7 deg.

In the majority of A330 takeoffs, the V1 and VR spread is in the range of 1-2 Kts. Since the spread between the two speeds is usually small, the VR blue circle is most often superimposed by the "1", and the PNF will typically call "V1" and "rotate" in quick succession. In this occurrence, the PNF called "V1" as the speed reference index approached the "1", and called "rotate" immediately after. This prompted the PF to initiate the rotation well below the calculated VR. Since the proper VR speed was inserted in the MCDU, the blue circle indicating the VR was probably off the scale and not visible to the flight crew.

The airplane tail struck the runway surface at a pitch attitude of about 10.4 deg. nose up. This suggests that the oleos were almost fully compressed due to insufficient lift, which decreased the clearance between the tail and the runway to a point that the tail struck the runway surface.

It could not be determined why neither the PF nor the PNF noticed the unusually large spread between V1 and VR when the PF read the speeds off the MCDU just before the takeoff roll. It is possible that the PNF did not notice the discrepancy at that time because, having entered the data himself, he heard what he expected to hear.

During takeoff, the PNF, as was his habit, called V1 as he saw the speed reference index reach the "1" on the PFD, followed immediately by the "rotate" call. Had both flight crew members maintained situational awareness during the takeoff roll, they would have noticed the absence of the blue circle, usually superimposed by the "1", or would have noticed that the actual indicated airspeed was well below the briefed rotation speed of 157 Kts.

The SOP offered several opportunities to cross-check the takeoff speeds inserted in the MCDU: during initial insertion; during the takeoff briefing, once reinserted; and prior to takeoff.

This class of error is known as a substitution error, where a character that was to be entered is substituted with erroneous information. Substitution errors result when information is initially misread, when information is misencoded at the time it is entered, or as a result of a human key entry error. It was not possible to determine the exact cause of the substitution error in this occurrence; however, it is possible that the number "2", which is located directly above the number "5" on the keypad of the MCDU, was accidentally hit.

When the PNF inserted 126 as V1 instead of 156, it was not detected by the captain. Cross-checking requires flight crew attention and implies that the validation of that which is being cross-checked is accurate. In this case, the takeoff speeds were cross-checked prior to reaching the takeoff position on the runway, but the accuracy was not validated. Without any cockpit warning or error messages, airmanship and situational awareness were critical to detecting the error and correcting it.

The speed insertion error was not detected, despite the safety defense provided by the SOP. Neither crew detected the unusually large and incorrect spread between V1 and VR, when read by the PF just before takeoff. The absence of the rotation speed blue circle on both PFDs was not noted during the takeoff roll nor during the takeoff calls.

During the approach, the flight crew did not validate the glide path interception with the information provided on the approach plate, which would have indicated that the airplane was too far from the threshold to intercept the glide path.

Contrary to the SOP, no deviation calls were called by the PNF during the pitch-up nor was the autopilot disconnected by the PF when he realized that the autopilot was not guiding the airplane as expected. Even though the tail-strike and the pitch-up events are not related, there was a demonstrated lack of situational awareness and airmanship related to the two events. It is possible that a flat authority gradient in the cockpit could have played a role in the occurrence.

Both pilots were experienced, senior pilots with the company, and both were ACP. While the atmosphere in the cockpit was professional, it is possible that this flat authority gradient contributed to a more relaxed attitude toward cross-checking each other's actions or confirming other information.

TSB listed the following as the Causes and Contributing Factors

- The PNF inadvertently entered an erroneous V1 speed into the MCDU. The error was not detected by either flight crew, despite numerous opportunities.

- The PNF called "rotate" 25 Kts below the calculated & posted rotation speed.
- The PF initiated rotation 24 Kts below the calculated & posted rotation speed and the tail of the airplane struck the runway surface.
- A glide path signal was most probably distorted by a taxiing airplane and provided erroneous information to the autopilot, resulting in a pitch-up event. The pitch-up could have been minimized if the autopilot had been disconnected earlier by the PF.

TSB listed the following as the risk.

- Other than proper cross-checking, as per SOP, and the speeds displayed on the PFD, the flight crew had no other means to know that an incorrect speed was inserted in the MCDU. A lack of situational awareness and airmanship contributed to not detecting the incorrectly set speed.
- No warnings in the cockpit were provided to the flight crew indicating that the on-board equipment was receiving a false glide path signal. Had the flight crew noted the information depicted on the approach plate, it is likely that the PF would have been better prepared and reacted accordingly.
- The flight crew was not directly informed of the possibility of glide path interference caused by a taxiing airplane because the airplane was not within 12nm from the threshold, in compliance with ATS procedure.
- The PF allowed the airplane to climb 1000 feet during the pitch-up, which could have caused a conflict with other aircraft.
- While the atmosphere in the cockpit was professional, it is possible that the flat authority gradient contributed to a more relaxed attitude toward cross-checking each other's actions or confirming other information.

References:

1. "Tailstrike on takeoff and aircraft pitch-up on final approach", Aviation Investigation Report A02F0069, TSB Canada, April 2003.
2. "Boeing 747-412 9V-SMT, flight SQ286, tail strike during take-off, Auckland International Airport", Aviation occurrence report 03-003, Transport Accident investigation commission (TAIC), New Zealand, Nov.2003
3. "Transcription Mistake lead to Tailstrike accident", Aviation Today, Jan.26, 2004.

TURBULENCE AT THE TOP OF CUMULONIMBUS

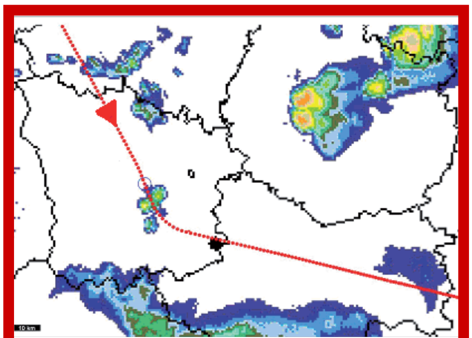
Adopted from Incidents in Air Transport, BEA Report no. 5, Dec. 2006

Strong winds at altitude and convection associated with cumulonimbus can precipitate events during flights at altitude. These are situations with rapid deterioration in conditions, late detection and possible inappropriate actions. One such example is the following.

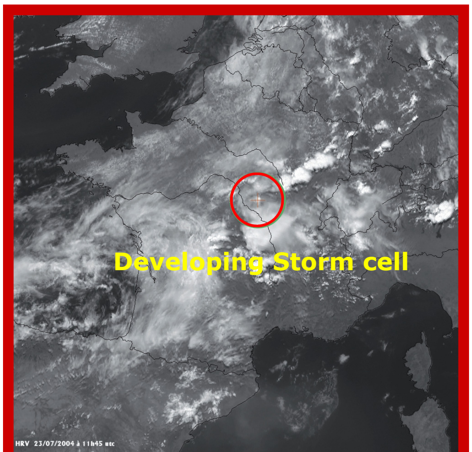
An A320 was performing a Paris-Geneva leg at the end of the morning. During the first rotation, the pilots had encountered storms around Geneva but not on the rest of the route. So, they didn't expect to encounter any on this flight during cruise. The airplane was flying at FL270 at a high Mach level (managed speed of 340Kt) in order to make up for lateness. The pilots had just finished their meal and were preparing the arrival. The co-pilot, PF, entered the information corresponding to a change of QFU in the FMGS for the landing. The cabin crew was finishing the trolley service. The airplane was flying on the edge of a cloud layer when the Captain noticed a cumulonimbus straight ahead, whose top was several thousand feet above. He disengaged autopilot and turned left in order to avoid it. He made the cabin announcement "This is the cockpit, turbulence, cabin crew seated, belts fastened". Seeing that he wasn't going to avoid the cloud, he selected Mach 0.77 and set the wings level and entered an area of heavy precipitation (hail) and turbulence. For about twenty seconds, it was subject to vertical accelerations varying from −0.7 g à +3 g. A momentary loss of the N1 generator led to the left side screens shutting down(certification envelope is −0.7g to +3g).

The airplane rose 750ft above its former level. In the cockpit, unsecured documentation and the meal trays were thrown about. The "Fasten seatbelts" signs were off at time of the turbulence. A passenger who was not attached was injured. Despite the announcement made by the Captain, the cabin crew did not have time to strap themselves in. At the aft, two flight attendants took the service trolleys into the galleys, without having time to stow them securely nor the time to strap themselves in. They were lifted above their seats, and then fell down, one of them being slightly injured. Forward, a flight attendant was taking the service trolley back towards the galley, preceded by the chief flight attendant. Both were lifted off their feet several times with the service trolley before hitting the ceiling and falling back down, injuring themselves slightly.

Met-info: The crew had a meteorological dossier made up of the TEMSI EUROC chart valid 6 hours before the event, forecasting cumulonimbus amidst the cloud mass on the route up to FL340, all of the TAF's and METAR's and a SIGMET for the Marseille FIR, whose validity had expired, that related to the development of storms in the



Radar image of the precipitation



Satellite image

cloud layer over the north of the Massif Central: EMBD TS OBS ON LFMM FIR, NORTH MASSIF CENTRAL, TOP CB FL 320/340 MOVE SLW NE, INTSF.

The crew received via ACARS the latest Geneva ATIS announcing a change in QFU nine minutes before passing through the turbulence.

The cumulonimbus they passed through had begun to be detected by the Bourges radar fifteen minutes before the event. A weak precipitation nucleus indicated that the cloud was not very developed at that time. The sky was full of more or less thick cirrus, from the cumulonimbus generated two hours previously to the southwest. The visibility was thus mediocre at altitude. The radar and satellite images (see page 5) show that the development of the cumulonimbus was very rapid.

The precipitation became significant four minutes before the airplane passed.

The top of the cumulonimbus being mainly made up of ice crystals, their detection by the onboard weather radar required an active search with changes to the gain, tilt and range, to be able to detect humid zones. This must be done in sufficient time to allow avoidance. In addition, the rapid formation of these clouds requires frequent repetition of the search.

During this flight, the radar was in WX mode, gain on AUTO, the tilt set at -2° and the distance selected on the ND at 160 NM on the Captain's side and 80 NM on the co-pilot's side. The Captain expected to encounter storm activity on arrival at Geneva, but not in cruise. The copilot focused his attention on programming the FMGS for the arrival. The crew did not carry out any particular search for storms with the aid of the radar *[The radar detects rain, wet hail and dry ice particles if their diameter is above 3 mm].*

The crew's meal can be taken during the flight, even if it is a short leg. The operation manual describes the procedure to follow in case of entry into a zone of severe turbulence:

- SEAT BELT ON
- CC ALERTED
- AP ON
- IAS/MACH SELECT*
- A/THR OFF
- N1 AJUSTED*

** The recommended speed in a turbulent atmosphere depends on the level and is listed in a QRH table. At FL270, it is 275Kts. The N1 required to maintain the recommended speed is on the same table.*

The flight bag, which had been secured before the flight behind the co-pilot's seat, did not move during the turbulence. However, the meal trays placed on the bag as well as the manuals placed in metal boxes flew around during the turbulence. The co-pilot's headset, hanging on its hook, was broken by falling objects.

Following are the lessons learnt from this occurrence.

1. Forecast: The TEMSI EUROC chart in the flight dossier mentioned cumulonimbus on the route, but these were not present on the first round trip. The crew stayed with this assumption without considering the possibility of rapid evolutions in storm phenomena.

2. Vigilance during the flight: The crew's attention was not drawn to the possible presence of cumulonimbus in cruise. Priority was given to making up the lost time by the choice of a high Mach speed *[the Operator's instruction for making up lost time require accelerating without suggesting any restrictions linked to environmental conditions].* Bearing in mind the short duration of the flight, the crew was busy with activities (meal, reprogramming the FMGS) which did not encourage surveillance of meteorological phenomena on the radar or outside.

3. Cabin safety: The failure to secure a part of the documentation in the cockpit created a risk for people and equipment in case of severe turbulence. The cabin crew, during the meal service, did not have time to secure the equipment and sit down. *Since then, the operator has added a procedure in case of severe unpredicted turbulence that allows cabin crew to block the equipment on the spot, sit down on the nearest seat and fasten seatbelts.*

PHOTO OF THE MONTH

UNCONTAINED ENGINE FAILURE

On July 2,2008, an Ilyushin Il-76TD while flying from Bagram, Iran to Sharjah at FL280 had an uncontained engine failure. No 3 engine exploded and caused damage to engine No 4. The aircraft was flying with 9 crew on board. The photo shows vividly the severity of damage to engine No.4.

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