Incidents in Air Transport

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Editorial

Reducing the risk of error, or limiting the effects, is a goal the entire aeronautical industry strives to achieve.

Pilots, for their part, through the aptitudes detected during their selection, initial and recurrent training, possess the appropriate tools to solve most of the problems they might encounter in normal or degraded flight conditions.

Given the large number of events that may occur during a flight, it is difficult to offer training for each specific case. Knowledge of difficulties previously encountered by others may thus provide food for thought and enrich existing skills.

With this in mind, this bulletin proposes three examples of excessive pitch attitude during critical flight phases: takeoff rotation and landing flare.

In addition to these events, the reader may also consult the results of other investigations described in detailed reports.

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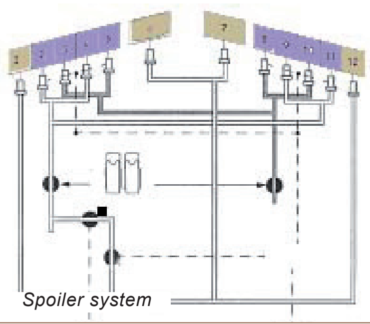
Sommaire

Bounced landing followed by tailstrike - 1

History of Flight

A Boeing 737-800 arriving from Paris Charles de Gaulle was on final ILS approach to runway 10 at Marrakech airport.
The Captain was the Pilot Flying (PF).
During the approach, he told the co-pilot that he was feeling a little tired due to the early morning departure.
Design landing weight was 62.7 tonnes (maximum landing weight was 65.3 tonnes).
The final approach reference speed with flaps at 30°, given by the FMS and confirmed in the user manual, was 145 kt, which was written on the landing sheet. Visibility was good, but the approach was made into the rising sun.
At around 1,300 feet, the co-pilot announced that the localizer had not been captured. The Captain disconnected the automatic pilot and the autothrottle to manually align the aircraft with the runway centreline and on the glide path at the approach speed (Vref + 5 kt).
The crew was given a wind of 160° at 8 kt. The presence of a temperature inversion between 450 metres and the ground caused an increasing downwind component on short final[1].
The PF noticed a slight settling of the aircraft when the GPWS announced a radio altimeter reading of ten feet. He increased thrust and was surprised by premature contact with the runway. The touchdown, occurring at Vref, was violent (recorded vertical acceleration was greater than 2 g). The PF immediately pulled the power lever back. Ground and flight spoilers deployed, the aircraft bounced and remained in the air for about a second. During the bounce, the flight spoilers retracted and the ground spoilers remained extended. Pitch attitude was between 5.1° and 7.7°. The aircraft touched down hard again at Vref - 2 kt, with attitude reaching 9.3°. An unusual noise was heard. While taxiing to the ramp, the chief flight attendant notified the Captain that the passengers and cabin crew had felt the strong impact on landing.
At the ramp, the Captain noticed that the tail skid and the lower left-hand part of the rear fuselage were scraped and dented.
He decided to cancel the return flight. The aircraft had to be ferried empty and underwent significant repairs, particularly to the structural framework aft the pressure bulkhead.



Spoiler system

Additional information

Spoiler operation

Normal operation is described in the manufacturer's flight manual.
The upper surface of each wing is equipped with four spoiler panels that ensure flight and ground operations, and two panels used only for ground operation.
In flight, the flight spoilers serve as speed brakes and contribute to roll control.
On the ground, all spoilers extend automatically, when extension conditions are met, to degrade lift and keep the aircraft on the ground. The conditions that must be met for automatic spoiler extension are as follows:
- SPEED BRAKE command set to ARMED and corresponding indicators lit,
- radio altimeter height less than 10 feet,
- oleo compressed on one of the main landing gears for the flight spoilers and right-hand gear oleo compressed for the ground spoilers,
- two power levers set to idle position,
- rotation signal (> 60 kt) for the main landing gear wheels, if the 'oleo compressed' condition is not met.

Procedure in the event of bouncing (information presented in the manufacturer's training manual): "during a bounce, if the extension phase has begun, the ground spoilers retract, since the oleo is no longer compressed, but the flight spoilers continue to extend"[2].

Information on tailstrikes featured in the training manual:

"A bounced landing may occur if the power levers are in a position beyond the idle position set on the last touchdown, preventing automatic deployment of the spoilers, even if they have been armed.
If the power levers are set to idle during the bounce, the flight spoilers are deployed automatically[3], causing a loss of lift and a stalling moment that may lead to tailstrike or a hard landing".
Note that the training manual is not included in the documentation that must be used by the operator, according to regulations. The part on tailstrikes figured as an optional item in the type qualification.

(1) The air speed decreased by 4 kt, while the ground speed decreased by 2 kt. The true wind in the last 50 feet was between 5 and 9 kt.

(2) The spoiler lever is switched UP and remains in this position, unless at least one power lever is advanced beyond the idle position (the spoiler lever then returns to the DOWN position and the spoilers retract automatically).

(3) The ground spoilers had started their deployment, since the power levers had been set to idle when the touchdown occurred (editor's note).

The update concerning this specific point had recently been received by the operator, but had not yet been distributed to pilots.

Landing techniques

The aircraft pitch attitude at the threshold for a stabilised final approach with flaps at 30º is between 2° and 4° and the landing flare is performed by increasing attitude from 4° to 7°.

The maximum landing attitude of the aircraft is 9.2°, not much different from that of the Boeing 737-400 (9.4°). With 7° pitch attitude and gear shock absorbers compressed, clearance is about 37 cm.

Note that there is a very small margin between the normal landing attitude and maximum attitude.

The flight manual specifies that 'if the aircraft bounces, wait or return to a normal landing attitude and add the thrust required to control the rate of descent. It is not necessary to increase thrust for a superficial bounce or a jump.

If a significant or hard bounce occurs, then perform a go-around.'

Factors modifying perception

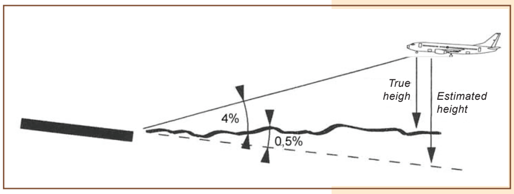
The profile of runway 10 is slightly uphill (0.5 %) and the glideslope angle is 2.5° (4 %). The runway is not equipped with a precision approach path indicator (PAPI).

The aircraft pitch attitude and the height of the pilot's eyes during the landing flare, for an approach with a glideslope of 2.5° (4 %) are slightly greater than they would be for an approach glideslope of 3° (5 %).

Furthermore, when an approach is performed on a runway with a rising slope, the apparent slope is greater than the true slope, which may lead to flying slightly under the glideslope.

Lessons learned

Since the glide path angle was lower than normal, the pilot was obliged to increase the aircraft pitch attitude on the final approach.

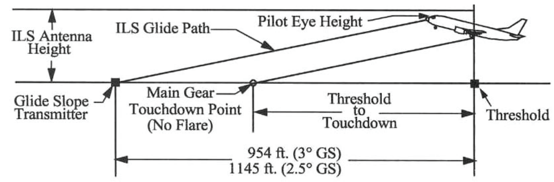


The rising runway slope magnified the perception of uncommon height with respect to outside visual references. These two reasons probably led the pilot to pass slightly below the glide path.

The aircraft touched down too early on the runway while flaring, before power had been reduced.

Because the power levers were set to idle while the aircraft landing gear was still compressed, all the spoilers extended before the bounce. Given the system's operating logic, flight spoiler extension continued during the bounce, whereas the ground spoilers retracted. Low speed combined with the stalling moment caused when the spoilers extended led the aircraft to exceed its maximum landing attitude.

Bounced landings are rare events on transport aircraft. Specific simulator training is not provided on the subject and knowing how to handle the event depends mainly on basic training. The operator had not yet provided the crews with the supplementary information from Boeing on how to deal with the specific problem of tailstrikes.



Model	Glide Path (deg)	Airplane Body Attitude (deg)	Main Gear (feet)	Pilot Eye Height (feet)	Threshold to Main Gear Touchdown Point - No Flare (feet)
737 - 800	2.5	2.9	33	49	753
	3.0	2.4	33	48	627

Aircraft pitch attitude and height of pilot's eyes at the threshold
Source: Boeing

Bounced landing followed by tailstrike - 2

History of flight

The crew of an Airbus A321 was flying its third and last short leg of the day.

The Pilot Flying (PF) was on line-oriented-flight-training, the Captain was in the left-hand seat, the Pilot Not Flying (PNF) was in the right-hand seat. It had been a hard day with many problems during stopovers[(4)] and very strong winds encountered on each leg.

Takeoff took place at night. Cruise flight began at FL270. A strong downwind was blowing at this level. The turbulent conditions led the crew to cancel flight service and request descent to FL230 to continue the cruise.

Approach

The crew prepared an ILS approach, began descent, and then turned towards the first approach fix. During descent, the real tailwind speed went from 40 kt at FL100 to 8 kt at 3,000 feet. The aircraft was held at FL120 for one minute, at the request of ATC. It flew over the IAF, located 23 nautical miles from the runway at FL100, i.e. about 3,000 feet above the normal[(5)] descent path. Speed was 276 kt at that time. The crew then switched off the AP and kept ATHR; they commanded landing gear extension. Three minutes later they intercepted the glide path from above, reaching 3,000 ft at about 200 kt. ATHR was disconnected.

The approach was stabilised at about 1,000 feet.

[(4)] All the weight and balance estimates had been established manually with several last-minute changes in the last leg.

[(5)] The instrument approach chart specifies that the aircraft must cross the IAF at a maximum of 5,000 ft.

(6)Masse maximum à l'atterrissage 73,5 t.

For an estimated weight of 71 tonnes[6], in full flap and slat configuration, the final approach speed was 140 kt (Vref 135 kt + 5 kt).

Landing

The landing was performed manually, in the rain. Between 100 ft and 50 ft, while vertical speed was less than 1,000 ft/min, the pilots felt the aircraft settle, and the instructor said 'Watch the vertical speed indicator'. The flare was initiated in the following second. Speed was decreasing slightly. The flare began as the aircraft reached 30 ft.

The initial pitch-up was normal and began to diminish when the PF increased power slightly. The aircraft then continued to pitch-up with greater amplitude, which increased the pitch attitude rate.

The aircraft touched down with a pitch attitude of 4.5° at a speed of 139 kt while N1 values were rising. The ground and flight spoilers began to extend.

On touchdown, the load factor reached almost 2 g. The aircraft bounced and flare mode was gradually replaced by ground mode. Speed decreased to 134 kt. With roughly a one-second delay after the order was given, thrust increased. The pitch attitude then went beyond 6° and its rate again increased slightly. The PF handed over control until neutral was reached and the pitch rate decreased, then he applied a slight nose-up again.

A second touchdown occurred, three seconds after the first one, at Vref – 1 kt. At that moment, spoiler deployment was complete. Pitch attitude reached the recorded maximum of 9.5[7]. Given the recording accuracy, this undoubtedly corresponds to the moment when the tailstrike occurred, since the angle at which the tail touches is 9.7° with the shock absorbers compressed. During the second touchdown, which was slightly softer than the first, the pilot reduced thrust and maintained pitch-up inputs. He set the thrust reversers when the pitch attitude started to decline and before the nose gear touched down.

(7)Neither pilot had the impression that pitch attitude was excessive.

The end of the landing procedure went normally.

While taxiing, the chief flight attendant informed the flight crew that certain members of the cabin crew had the impression that the tail of the plane had touched the runway. At the ramp, the instructor noted that the lower part of the rear fuselage had a scrape about one metre long.

Additional information

Flare Mode

In normal flight, elevator control operates in such a way that when the stick is set to neutral, the system maintains a normal load factor of 1 g, through the electrical flight control computers.

When the aircraft descends through a radio altitude of 50 ft, flare mode replaces normal mode.

The aircraft attitude is stored in memory and becomes the reference for pitch control. This implies that the pitch attitude is maintained, with the stick set to neutral, up to 30 ft.

When the aircraft descends through 30 ft, the reference attitude declines to reach 2° nose-down eight seconds later. This means that the pilot must apply a moderate nose-up action to achieve flare.

On the ground, the ground mode takes over gradually and a direct mode is applied.

Spoiler operation

The spoilers extend automatically on landing when the two main landing gears are compressed:

- if they have been armed and if the position of the power levers is less than 15°,
- or if at least one thrust reverser is selected, while the other thrust lever is set to idle.

The spoilers retract automatically when at least one thrust lever is pushed forward between 4° and 20° for at least 3 seconds, or as soon as it reaches 20°.

The spoiler lever remains fixed.

There is a function that partially extends spoilers when the aircraft touches down on only one main landing gear and at least one thrust reverser has been selected. This helps the second landing gear touch down and contributes to full extension of the spoilers.

Tailstrikes (Airbus FCOM Bulletin 22/3)

The tail of an A321 will touch if pitch attitude on landing reaches 9.7° with the landing gear shock absorbers completely compressed. The bulletin also indicates that a deceleration of eight knots occurs during the landing flare and that if the approach speed decreases by five knots, the aircraft pitch attitude at touchdown is increased by 1.3°.

The procedure recommended to avoid high pitch attitude angles is for the PNF to monitor the aircraft attitude on the PFD and make a callout when pitch attitude reaches or exceeds 7.5°.

Airbus also draws attention to the stall moment caused by ground spoiler deployment.

Flight Operations Briefing Note 'Bounce Recovery – Rejected Landing' (Airbus): 'Bouncing at landing is usually the result of one or a combination of the following factors:
- Windshear;
- Thermal activity;
- Excessive sink rate;
- Late flare initiation;
- Incorrect flare technique;
- Excessive airspeed; and/or,
- Power-on touchdown (preventing the automatic extension of ground spoilers, as applicable).'

In case of a slight bounce, the procedure recommends maintaining a 'normal' landing pitch attitude, keeping thrust at idle. In case of a high bounce, the recommended procedure consists of initiating a go-around while maintaining a normal landing pitch attitude. The recommendation advises that the pilot should not try to avoid a second touchdown. Maintaining reasonable pitch attitude will prevent damage to the aircraft.
This note also refers to the note on 'Preventing Tailstrike at Landing', which is to appear on their website.

Procedure
When the vertical speed is greater than 1000 ft/min below the lower stabilisation limit, the PNF must call out 'Watch vertical speed'.
When speed is 5 kt less than the approach speed, the call to use is 'speed'.
The number of steps to perform on the A321 is a factor to be taken into account during line-oriented flight training. The instructor had decided that the trainee Captain would carry out these steps during the day as the PF. Since this pilot was from another sector, he was combining training on a new aircraft and training for a function.
The operator's task-sharing recommendations stipulate that the Captain should decide when to perform a go-around.

Lessons learned
The settling of the aircraft felt by the crew combined with the PNF instructor's call to 'watch vertical speed' on short final led the PF to increase thrust shortly before touchdown.
Bouncing may have been due to slightly late input on the pitch control during the landing flare performed at night in the rain.
During the bounce, although the pilot had reduced the pitch-up attitude, it continued to climb due to the combined effect of increased thrust and extension of all the spoilers.
The second landing flare performed while pitch attitude was high led the pilot to exceed maximum pitch attitude. There was only one and a half seconds between the moment the aircraft reached the 7.5 pitch attitude and the moment it reached the maximum. It is very unlikely that a crew would have the time to detect, make the recommended calls, and act in such a short time. Making a callout that speed is low could, nonetheless, serve as a warning on this type of risk.
In a report from the AAIB[8], it was observed that this type of callout by the PNF (especially if it is the Captain) is not very realistic in the landing flare phase, given that the Captain's attention is usually focussed outside the aircraft and the pitch attitude margin is small.
For the A340-500 and A340-600, Airbus introduced an aural alarm and a visual indicator on the PFD to announce excessive pitch attitude and is studying the possibility of extending this modification to all aircraft using fly-by-wire flight controls.
Training constraints led the instructor to have the trainee Captain perform all the steps to familiarize himself with the A321, which could have affected his workload, and thus his state of fatigue. The specific structure of the flight crew makes it impossible to determine clearly, in this case, who should have given the order to initiate a go-around. Since both crew members had the possibility, each one might have waited until the other took the initiative. In this case, the PF had thought about initiating a go-around during the bounce, but did not follow through with this idea.

[8] Accident to an A320, registered C-GTDK at Bristol on 16 June 2003.

FMS input error tailstrike at takeoff rotation

History of flight
Flight preparation in operator's facilities
An A340-313 was scheduled for a long-haul flight of 11 hours and 35 minutes. The co-pilot, who was the PF, printed out a takeoff sheet for a weight of 270 tonnes (planned weight being 268.6 tonnes, close to the MTOW of 271 tonnes) using the computer system to query the takeoff weight limitations database.
He entered the planned takeoff parameters, including the takeoff weight.
The system prints out a computerized takeoff sheet that shows the takeoff parameters in a box (fictitious temperature, V1, VR, V2, N1

Flex and N1 TOGA). The sheet shows MTOW in the middle of the takeoff hypotheses. Last-minute corrections (not shown on the opposite illustration) are available on the sheet, but not in a way that allows weight changes to be taken into account.

```
WIND  00        QNH 1020      TEMP +21     MTOW   271.00
DRY   RWY       AC  ON APU    A/I   OFF

PLANNED WEIGHT     270.0  T
                                      ENG FAILURE PROCEDURE
REDUCED THRUST TEMP:  +36  C          ZAC :  1900    FT
      V1       143
      VR       153
      V2       161
      N1 FLEX  96.1
      N1 TOGA  99.0
```

Excerpt from flight preparation takeoff sheet

This sheet was checked by the relief co-pilot.

Departure phase in the flight compartment

The Captain checked the takeoff sheet parameters printed during flight preparation, and then left the flight deck to take care of the boarding phase.

The flight officer received a message stating that the takeoff weight would be reduced by 5.2 tonnes with respect to the forecast weight.

He printed a new takeoff sheet (referred to as the 'ATSU sheet'[9]) through the FMGS interface[10], used for remote queries to the database. He mistakenly entered a weight of 165 tonnes (close to the ZFW of 164.480 tonnes) in the 'PLANNED TOW' field on the FMGS screen.

The ZFW was entered correctly on the FMGS INIT page and complied with the final weight estimate.

[9] ATSU :Air Traffic Service Unit

[10] FMGS : Flight Management and Guidance System

```
                                  MASSE
MASSE EN COMPARTIMENTS            10398

PAX/BAG CABINE                    17922

CHARGEMENT TOTAL                  28320
MASSE DE BASE CORRIGEE           136160
MASSE REELLE SANS CARBU          164480
CARBURANT DECOLLAGE              100400
MASSE REELLE DECOLLAGE           264880
DELESTAGE                         87400
MASSE REELLE ATTERRISS           177480

CENTRAGE ET REPARTITION PAX
 0A  22 / 0B  21 / 0C  83 / 0D
ATTRIBUTION DE SIEGES
DENSITE CARB   0,791
DOI          42.8
LIZFW        39.5    MACZFW    28.2
LITXW        40.4    MACTXW    27.2
```

Excerpt from weight and balance estimate

ATSU takeoff sheet

The ATSU sheet was printed on the aircraft's printer and the First Officer entered the new parameters for V1, VR, and V2 and reduced thrust temperature on the FMGS.

When he returned to his seat, the Captain checked the parameters entered on the FMGS, using the ATSU takeoff sheet as the reference.

His attention was drawn to the MTOW (271 tonnes written among the request hypotheses) instead of the design weight shown as 'PLANNED WEIGHT' on the sheet. It was close to the weight estimate and the weight computed by the aircraft system.

He validated the parameters.

[11] F : flaps, S : slats et C : clean = green dot

[12] VLS : minimum speed

[13] 1,000 feet in 1 min 26 s

```
FLAPS  2      WIND  00      QNH 1020    TEMP +23   MTOW 271.00
              DRY   RWY     AC ON APU    A/I OFF

REDUCED       PLANNED WEIGHT  :  165.0  T
THRUST
*******************************************ENG FAILURE PROCEDURE
* RED THRUST TEMP:  52   C (FIVE TWO)       * ZAC  :  1900   FT
*                                           *
*           V1   129  (ONE TWO NINER)       *
*                                           *
*           VR   131  (ONE THREE ONE)       *
*                                           *
*           V2   137  (ONE THREE SEVEN)     *
*                                           *
* N1 FLEX   89.80%                          *
*                                           *
* N1 TOGA   99.30%                          *
*******************************************
```

Excerpt from ATSU takeoff sheet

Briefing

During briefing before takeoff, the co-pilot read the following:

- on the System Display (SD): the correct design takeoff weight that appeared after start-up: 265 t, sum of the entered ZFW and the fuel measured by the aircraft;
- on the FMGS takeoff performance page: the takeoff speeds entered manually (V1, VR and V2), which appeared next to the other characteristic speeds computed by the aircraft (F, S and clean[11]).

When the Captain checked the takeoff weight on the sheet, he read the MTOW again. Then he checked that the speeds entered on the FMGS were consistent with the speeds on the takeoff sheet.

The crew did not detect any anomalies.

Takeoff

Acceleration seemed normal, with a slightly slow feeling; rotation took place at VR which appeared on the PFD speed indicators. The PF felt that the aircraft was not reacting normally: certain heaviness required applying more stick than usual.

The pitch attitude fluctuated between 10° and 12.5°. The aircraft did not take off until several seconds after the end of rotation.

As soon as the aircraft took to the air, the PF observed that VLS[12] was greater than V2. TOGA thrust was not applied.

Vertical speed was low during acceleration[13].

The cabin crew in the rear of the aircraft heard a noise with no shock on rotation and one of the members heard scraping. The flight crew was informed and assumed that the fuselage had touched the runway during rotation. The Captain contacted maintenance and operational control and decided to turn back.

Note: there was no emergency procedure associated with a tailstrike at takeoff or TOGA.

The aircraft was directed to a holding pattern at FL 270 where fuel was jettisoned for an hour.

As the crew continued to analyse the situation, it found the weight error on the ATSU sheet.

The aircraft landed at a weight close to the maximum landing weight after 1 hour and 54 minutes of flight. The rescue and fire-fighting service was waiting and followed the aircraft up to its arrival at the parking area.

Phase	Procedures	Event
Flight preparation in operator's facilities	- Print sheet	- ESheet printed
Cockpit preparation	- Enter ZFW - Enter speeds	- New sheet printed with confusion between ZFW and TOW - Departure speeds entered (fuelling completed)
Departure	- Enter and check ramp fuel, check TOW - Check speeds entered based on takeoff sheet	- Captain checked TOW with reference to MTOW - Anomaly in speed data not detected (ATSU sheet was simply read)
Before takeoff	Check TOW Check speeds	- FMGS TOW = ZFW + fuel (no error) - Speeds compliant with ATSU takeoff sheet

Comparative table of planned and performed actions according to phases in the chronology

Traces of scraping with no visible dents on the structure were observed over an area of 1.2 m x 0.40 m.
The loading position and weight compliance were checked and no anomalies were found.
The fuselage had scraped along the runway over approximately 100 metres when the pitch attitude exceeded 10.1° with the shock absorbers compressed

Additional information

Programming the FMGS
The operator's instructions for this type of aircraft request that a new takeoff sheet be printed for any variation in weight exceeding 5 tonnes.
Procedures stipulate that weight and speed parameters must be entered on the FMGS during the 'departure' phase, which begins once refuelling has been completed.
- Pre-computed ZFW is entered on the initialisation page. Ramp weight is calculated by the FMS after refuelling, with measured or entered ramp fuel.
- The characteristic speed values calculated during flight preparation are written on the takeoff performance page. These parameters are updated as necessary during the 'pre-startup' phase, depending on any last-minute changes. The new sheet was printed before the speeds computed during flight preparation had been entered, i.e. before refuelling had been completed, which does not correspond to a last-minute change. Since the speeds on the sheet printed during flight preparation had not been entered, nobody compared the values between the two sheets.
This did not make it easy to detect the significant difference that occurred when data was entered.
The operator did not provide for the case where ramp fuel weight is entered before refuelling has been completed. The takeoff weight therefore does not appear on the FMS until refuelling is complete, and does not show on the SD until an engine has been started. This could have an influence at the time when the takeoff sheet request is entered via ATSU, since only the ZFW is displayed at that time.
The three flight crew members did not have much experience on this type of aircraft and were therefore unfamiliar with the specifics of this FMGS system. Each of them had performed between fifteen and thirty flights as PF.

Presentation of documents
Weight estimate:
Weight values were printed to the nearest kilo, whereas weight was entered in tonnes and hundreds of kilos on the screens. The labels 'true zero fuel weight' and 'true takeoff weight' were different from the weight labels on the data input views ('ZFW' and 'PLANNED WEIGHT', respectively). The difference between zero fuel weight and takeoff weight was close to 100 tonnes (164,480/264,880) and could have led to confusion when the numbers were read.

Takeoff sheets:
The difference in the way information is presented on the two sheets could have an influence on how data is selected. On the sheet printed out after flight preparation, design weight and takeoff parameters are in bold type and in a larger font size, which is not the case on the ATSU sheet.

System software protection
The computer system did not detect any anomalies. It did not propose any takeoff speeds to the crew, and did not make any correlations between takeoff weight and the associated speeds entered manually; none were made between V2 and VLS either. Moreover, VLS information is inhibited on the ground until one second before takeoff, which does not allow the crew time to check this data before takeoff.
Tailstrike type incidents, also related to data input errors, have occurred on various types of aircraft[14].
Following an incident to one of its aircraft, Boeing published technical operational bulletins for operators using aircraft equipped with FMS. The topics discussed are inadvertent input of the ZFW on the total weight line or entering wrong takeoff reference speeds.
As a solution, the bulletins propose that crews enter the ZFW and allow FMS to compute takeoff weight by adding the fuel measured by the fuel quantity indicating system[15].

[14] 12 March 2003: B747-400 in Auckland - 14 Jun 2002: A330 in Frankfurt - 11 November 1998: MD11 in Portland.

[15] The Boeing FMS automatically computes takeoff speeds (V1, VR, V2) based on entered weight values. The speeds are proposed and the crew decides whether or not to confirm them based on current flight conditions. The Airbus FMS does not feature this functionality.

NTSB has recommended that FMS manufacturers change their software so that a warning is made when a potentially dangerous speed value has been entered and, in general, that they review overall robustness for system errors.

Lessons learned

The mechanisms by which data input errors occur may have many different origins.
The manner in which parameters were presented on the weight estimate, associated with the flight-specific values, could have led the reader to confuse takeoff weight and zero fuel weight. This is all the more true knowing that it is unusual to enter any other parameter than ZFW in the FMS interface.
The difference between the parameter input masks and their presentation on the weight estimate is also conducive to errors.
All the checks performed after the error had been made were not effective in avoiding error propagation:
- The 'pre-start' check that verifies entered speeds consists simply of reading the takeoff sheet and does not provide the opportunity to detect any errors.
- The briefing before takeoff does not call for a comparison between takeoff weight and characteristic speeds.
- Aircraft systems do not systematically check the consistency of entered parameters, highlighting the importance of having several defence mechanisms against input errors:
- there is no input filter to prevent a significant error in weight when requesting the ATSU sheet printout;
- there is no filter in the FMGS to prevent input of a significant error in performance or speed.
Crews may develop a false sense of security, however, since certain incorrect parameters are rejected by the system, such as values that exceed limits or those entered with an incorrect format (for example, when an incorrect takeoff speed is entered, no error message is displayed unless the value is less than 100 kt).
Protective mechanisms intervene mainly once flight has begun.
Since this time, the operator has introduced changes in procedures to improve error detection:
- using a table to check that the calculated V2 is greater than VMU for the aircraft's weight, given the most conservative conditions;
- printing the green dot on ATSU sheets as well as on printed pre-flight sheets; comparing with the green dot (clean) computed by the FMS;
- removing the MTOW value from the takeoff sheet (it is mentioned on the weight estimate);
- changing the layout on takeoff sheets so that design weight can be read clearly;
- printing the weight from the weight estimate on the takeoff sheet, in a box next to the design weight;
- changing the operating manual so that during the briefing before takeoff, mention is made that TOGA is available and thrust adjustment conditions are recalled to correct any insufficient performance observed. Simulator tests conducted have shown that applying TOGA power during lift-off would only add to the nose-up risk, but applying TOGA power as soon as the flight phase has been entered would improve climb performance.

Other potential improvements are under study:
- feasibility of performing a consistency check between the weight used for the takeoff sheet request and the probable or true weight in the loading computer system;
- studying the structure of briefings which includes having all members of the flight crew proofread all data essential to calculations (namely true weight, weight used to calculate performance, weight on the load sheet, and FMS weight);
- if possible, install electric tail skids such as those on the A340-500/600 with a tailstrike indicator on the flight deck;
- study the need to update the takeoff sheet for a reduction of less than 5 tonnes. As a reminder, in this event, a variation of 5 tonnes would entail a variation in speed of about 1 kt.
Moreover, an emergency tailstrike procedure was introduced by Airbus requesting the following:
- limit climb to FL100 or the minimum safe altitude with a vertical speed less than or equal to 500 ft/min;
- depressurize the aircraft and land at the nearest appropriate aerodrome.

Comment: This event emphasizes the fact that propagation of an input error is difficult to stop at the level of an individual if there are no effective barriers. With automated systems, error detection is not easy either, especially if the crew has little experience with this type of aircraft and therefore few references with regards to orders of magnitude.

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