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Accident Investigation: Reactive, But Irreplaceable Lessons Learned with the JJ3054 Runway Excursion

by

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Abstract

On 17 July 2007, at 1719 local time, the model A-320 Airbus aircraft, registration PR-MBK, operating as Flight JJ3054, upon attempting to land at SBSP, did not decelerate as expected, and started to swerve to the left. The aircraft ended up departing the runway through its left side close to the runway departure end, and crossed over Washington Luís Avenue before colliding with a cargo express service facility belonging to the very operator and with a fuel service station. The number 2 engine of the aircraft was operating with a pinned reverser. The airport runway was wet and slippery, according to information provided by the TWR to the aircraft crew. The accident killed all the 187 aircraft occupants, and 12 other people on the ground. At the time preceding this accident, the Brazilian air transport system was experiencing a particular moment, with critiques being made to the adequacy of the investment policies regarding the infrastructure of the sector, and to the functioning of the civil aviation authority (CAA), generating flight delays and cancellations, overcrowding the passenger lounges of the most important Brazilian airports. Such a hostile environment generated a huge pressure on the regular aviation crews, who were working in a high tension atmosphere. Meanwhile, two investigations of the crisis affecting the sector were under way in the National Congress. Following the accident, the Federal Police and the São Paulo State Civil Police began enquiries to determine responsibilities. In a brief manner, this article presents the evolution of the investigation work relative to this accident, highlighting the importance of investigation in the context of flight safety management as an efficient tool for the detection of design flaws, as well as deficiencies of the regulatory and oversight processes.

1 INTRODUCTION

On 17 July 2007, at 1719 local time (2019 UTC), the Airbus aircraft, model A-320, registration PR-MBK, operating as flight JJ3054, departed from Porto Alegre (SBPA) destined to Congonhas Airport (SBSP) in São Paulo city, São Paulo State.

There were a total of 187 souls on board the aircraft, being six active crewmembers and 181 passengers, including 2 infants and 5 extra crew members (not on duty).

The weather prevailing along the route and at the destination was adverse, and the crew had to make a few deviations. Up to the moment of the landing, the flight occurred within the expected routine.

The aircraft was operating with the number 2 engine reverser de-activated, in accordance with the Minimum Equipment List (MEL).

According to information provided to the TWR by crews that had landed earlier, the active runway at Congonhas (35L) was wet and slippery.

During the landing, at 1854 local time (2154 UTC), the crew noticed that the ground spoilers had not deflected, and the aircraft, which was not slowing down as expected, veered to the left, overran the left edge of the runway near the departure end, crossed over the Washington Luís Avenue, and collided with a building in which the cargo express service of the very operator functioned, and with a fuel service station.

All the persons onboard perished. The accident also caused 12 fatalities on the ground among the people that were in the cargo express service building.

The aircraft was completely destroyed as a result of the impact and of the raging fire, which lasted for several hours.

The accident caused severe damage to the convenience shop area of the service station and to some vehicles that were parked there. The cargo express service building sustained structural damages that determined its demolition.

This article presents a summary of the evolution of the investigation work concerning this accident[iii], taking into account the context in which the work was done, along with its conclusions, which culminated in the issuance of 83 flight safety recommendations, stressing the importance of accident investigation for the management of flight safety, as an efficient tool for the detection of design flaws, as well as deficiencies in both regulatory and oversight processes.

2 BRAZILIAN CIVIL AVIATION SCENARIO PRIOR TO THE ACCIDENT

2.1 The Air Transport System

In the period preceding the accident, the Brazilian civil aviation was going through a particular moment after a catastrophic accident - the midair collision between two aircraft in October 2006 – which triggered an air traffic controllers' shutdown, as a protest against allegations of neglect resulting from investigations conducted by the police.

In consequence, the Brazilian air transport system was being marked by delays and cancellations of flights, with passengers crowding the departure lounges of major airports.

Through the mass media, there was criticism of the adequacy regarding the investment policies in the aviation sector, as well as criticism of the operation of the civil aviation regulatory agency. There were allegations of interference and pressure from a number of State sectors, exacerbating the passengers' dissatisfaction, which in the end was transferred to the airport administrations' and airline companies' employees.

During this period, there were even occurrences of aggression against check-in clerks and of threats against pilots, on account of passengers fed up with cancellations and delays of their flights. Such hostile climate generated enormous pressure on the crews of the regular aviation, who had to work under strong tension. In the specific case of this operator, the fact that the captain and one of the flight attendants had to wait at the door of the aircraft (a procedure adopted by the company) contributed to exacerbate the tension.

Congonhas – specifically – the busiest airport in the country, had been receiving severe criticism for some years, because of the serious problems associated with the operation in rainy weather, due to the low friction coefficients and accumulation of water on the runway as a result of the unevenness of its surface.

The first weeks of 2007 were marked by interruptions in the operations of Congonhas due to the accumulation of water on the runways, causing flight delays and, consequently, inconvenience to passengers. The need to urgently reform the runways was already known, at least since 2005, but only palliative measures were taken before the adoption of the definitive solution in 2007.

Several occurrences of aquaplaning were reported, some of them involving regular passenger transport aircraft.

2.2 The Operator

Adding to this scenario, the gradual diminution up to the cessation of the activities of another big company, which had entered a process of judicial recovery, had left a vacuum in the market that began to be occupied by the other companies, generating a disorganized moment of growth.

At the same time, a transition of equipment was in progress within the company, which began to concentrate on the Airbus line, and stopped operating the Fokker 100. Thus, the demand for A-320 pilots (captains and co-pilots), which was already high, got even higher.

Taking into account the yearbooks issued by the regulatory agency in the period 2003-2007, one can see that the operator had a growth of 110% in the volume of flight hours, 30% in its fleet, 115% in the number of pilots, and 160% in the number of flight attendants.

There was some concern about the tendency of the operator to hasten the training of the newly hired pilots, possibly on account of the need to quickly put them in the operating line to accommodate the pressing demand. However, a proper assessment of this issue was not possible, since the Commission of Investigation did not have access to all versions of the training program being used in the period prior to the accident.

The comparative analysis of the operator training program for new pilots and the one used by the Airbus revealed some important differences in the formation process.

It was observed that despite the more comprehensive theoretical instruction on the part of the operator, the practical training provided in the Airbus training program was more gradual, allowing a better assimilation by the pilots.

As for the crews, it was also observed that, at the time of the accident, the number of captains of the operator was disproportionally large in relation to the number of co-pilots. It was not rare for a second captain to be assigned the function of co-pilot (as was the case with the JJ3054).

It was also observed that the crews were worried with the interferences on the operational processes and on each pilot's individual decisions, a fact that created an unfavourable climate in relation to safety.

Still in relation to the operator: the company was physically spread through various buildings in the city of São Paulo and other locations of the state, suggesting a lack of unity, with difficulty of communication and coordination between the sectors.

This segmentation ended up leading the administrative managers to a lack of knowledge regarding the extent of their responsibilities beyond the context of their own working sectors. The Safety, for instance, would not do his job in conjunction with the Training, which would be deprived of information about occurrences and reports capable of improving the process of training of the crews. The CRM trainings were set up from scenarios not linked to the occurrences experienced by the operator. There was no feedback from the Operations sector in relation to the quality of the crew member who had been forwarded to it by the Training.

In general, the organizational climate may be seen as the working environment within the organization. Signs of the organizational climate may be found in the manner the chain of command is structured, in the delegation of authority and responsibility, in the formal communication channels, and in the form with which the employees are held liable for their own deeds.

As for the operator, the lack of integration between its sectors gave the employees the impression that the policies, on account of being decentralized, were not well defined, even contradictory or conflicting, and could be replaced with informal rules and values, thus creating confusion within the company.

During the investigation, it was observed that, in some cases, the pilots would perform a procedure thought to be the most correct, even though it could be different from the one prescribed. The case of operation with a pinned reverser was an example: some of the pilots said that, in spite of the MEL's prescription, they would opt for applying another one no longer in force, just because they considered it better (preventing the additional 55 meters in the landing distance).

2.3 The Civil Aviation Authority (CAA)

A national civil aviation agency was created in October 2005, and it started its activities as civil aviation authority in March 2006.

The posture adopted by the agency proved to be far from reality, with an overly bureaucratic operating system, acting more like an observer, requiring procedures and documents, but not acting as a safety culture facilitator.

The regulation process conducted by the CAA was slow in relation to the operation of the regular aviation in Congonhas, if one considers that the establishment of a requisite for the operator to have all the thrust reversers available for the operation with a wet runway was being studied since April 2006 at least.

A draft of the regulation, ready for approval, was released by the CAA in December 2006, and it could have prevented the accident, but was only approved in May 2008.

In relation to the inspecting activities, there was a certain distancing of the CAA relative to the renovation works of the Congonhas runway, since the Work Operational Plan was not presented to it for approval, as prescribed in the regulations.

Besides, the Agency did not execute the special airport inspection during the works for the recovery of the landing runways. As well, no inspection of the main runway was made, to formally attest its operational condition after the completion of the works, so that the runway could be opened for the operation

2.4 The Airport

The São Paulo/Congonhas International Airport is a public airport administered by the INFRAERO (Brazilian Airports Infrastructure Enterprise) and operates day and night VFR/IFR.

It has two asphalt landing-and-takeoff runways: the main runway (17R/35L) measures 1,945 x 45 meters; and the auxiliary runway (17L/35R) measures 1,435 x 45 meters.

At the time of the accident, Congonhas was the busiest Brazilian airport, although its hours of operation were usually restricted to the period from 6 am to 11 pm. It operated international flights, regular domestic air transport, and general aviation services.

It is located in the urban area of São Paulo County, in a densely populated zone surrounded by buildings.

As a consequence, part of the population in the vicinity of the airport was demanding the airport to be closed, on account of the noise level and exposure to the risk of accidents, since the visual traffic, the final approaches and the climbs after departure are conducted over residential areas.

On the other hand, its privileged location has been responsible for the high demand for flights operating to and from the airport, on account of its proximity to the business centres of the city.

With the objective of augmenting the operational capacity of the airport, a new passenger terminal was built and the aircraft apron was reformed, without previous authorization from the CAA (in discordance with the regulation).

The aerodrome did not have a Runway End Safety Area (RESA) in the extension of each end of the runways 17L/35R and 17R/35L (non-compliance with ICAO Annex 14).

As already mentioned, in the years preceding the accident, the runway had been the reason of continuous complaints on the part of the pilots, on account of problems related to operations in rainy conditions, mainly due to the risk of aquaplaning.

In November 2005, the pavement of the main runway (treated with grooving) was replaced with a rugged pavement.

According to information provided by the airport administration, the work done aimed at reestablishing the desired levels of friction along the most critical segments of the runway, thus guaranteeing its operational safety, mainly on account of the proximity of the rainy period and the constant complaints made by the users, until a definitive solution could be implemented, to renovate the whole runway pavement, including the correction of the transversal and longitudinal declivities.

This type of pavement did not keep the original qualities, and a few months later the runway started showing friction problems again. Besides, the problems of declivity continued hindering more efficient water drainage during occurrence of heavy rain.

Then, in spite of the services done months before, various NOTAMs were issued, beginning in January 2006 and continuing all along that year, alerting about the characteristics of the ruggedness and the low friction of the Congonhas main runway, as well as its condition of being slippery when wet.

In the first months of 2006, two incidents occurred which involved regular air transport aircraft, and the runway conditions were considered contributing factors.

The weekly measurement of the friction coefficient for the main runway surface pavement revealed a serious deficiency in the first third of the runways, on account of the high degree of rubber accumulation on the pavement.

Due to problems in the bid process for the runway recovery works, a re-texturization service was done as a palliative measure, in the months of October and November 2006.

After the re-texturization service, the friction coefficients of the main runway reached values above the established minimums. The runway, however, continued showing problems of water accumulation, on account of its irregular surface.

In the first semester of 2007, both landing runways of Congonhas underwent pavement repair work (first the secondary runway was repaired, and then the main runway).

The repair work of the main runway started on 14 May, and the runway was reopened for operations on 29 June, without the grooving prescribed in the respective project. No significant precipitations were observed from the reopening of the main runway for operations up to the 14 July.

Since 15 July (Sunday), abundant rain had started making operations difficult, and a number of pilots reported slippery runway conditions.

3 FIRST MOMENTS AFTER THE ACCIDENT

Three minutes after the accident, the CENIPA had already been notified. Ten minutes later, a team of the CENIPA’s regional office arrived at the crash site. The investigation group from Brasilia came in approximately three hours later on an Air Force jet.

The accident, of course, had an enormous national impact. The society immediately began pointing the runway as largely responsible for the tragedy, blaming the airport authorities for the “premature" opening of the airport for operations (still without grooving).

Teams from the Federal Police and São Paulo State Police also began their work.

At the crash site, a huge fire prevented access to the wreckage, delaying the retrieval of the flight recorders.

Other feasible actions were developed, such as recovery of the airport surveillance system video, which showed that the aircraft was rolling on the runway after landing at a speed well above the one usually observed in a normal landing (figure 1).

Figure 1: Images from the airport surveillance system.

In interviews with the TWR-SP controllers on duty at the time of the accident, they confirmed the impression of above normal speed depicted by the surveillance video.

An examination of the runway, started at night under pouring rain, allowed to identify the trajectory of the aircraft down the runway, and the point of escape to the left side (figure 2).

Figure 2: Marks of the aircraft trajectory after landing.

Important components of the aircraft, such as the engines and landing gear, underwent a preliminary assessment, and indications were found that the engines were producing power at the moment of impact, whereas there were no signs of aquaplaning marks on the tires.

Finally, with the help of firefighters, it was possible to cool the tail of the aircraft so that the flight recorders could be retrieved. Despite the violence of the impact and the raging fire, the tail of the aircraft had been reasonably preserved, allowing full recovery of the data from the recorders, although the fire exposure had exceeded the certification limits.

The readout procedures, the data validation and analysis, as well as transcription of the audio, were performed in the laboratory of the National Transportation Safety Board (NTSB), since at the time, the CENIPA laboratory[iv] was still in its early stages of implementation.

4 LINES OF INVESTIGATION

Initially, it must be noted that, besides the lines of investigation established from the available evidence, it was necessary to establish additional ones in order to rule out the contribution of aspects of airport management and aircraft condition, raised in the context of the gravity of the accident and its consequences, which resulted in an additional workload for the entire investigation team.

This required a thorough study of the conditions of administration and operation of the airport. More precisely, the commission analyzed the processes related to the planning and execution of works in passenger terminals, ramps and runways, even in the aspects of compliance with current national and international regulations.

The evolution of the problems concerning the operation of the runway in wet conditions in the period before its renovation was especially detailed, addressing issues such as diversity of the problems of the pavement over the period, the lack of RESA, and the accessory nature of the grooving, putting in evidence actions and omissions on the part of the airport administration and Civil Aviation Authority, mainly during the works.

In relation to the aircraft, a detailed study of the maintenance processes, from the records of failures entered by crew members to records of maintenance actions executed by the company, seeking to verify the adequacy of the internal regulation and its compliance, as well as conformity of the processes in view of the regulations.

On the other hand, the information obtained from the flight recorders corroborated the impressions left by the evidence found in the crash site. In fact, the engines were developing power up to the time of impact, there was no evidence of aquaplaning, and the pilots could not understand the behaviour of the aircraft after touchdown.

Thus, it was possible to restore the sequence of events that culminated in the accident, as shown below.

Flight JJ3054 was operated by the A-320 aircraft, registration PR-MBK, which had its number 2 engine thrust reverser deactivated by maintenance, in accordance with the MEL ("Minimum Equipment List").

It was the second leg of the journey for that crew. In the first leg, with a landing in Porto Alegre, the FDR shows that the crew performed with precision the procedures established in the MEL / MMEL ("Master Minimum Equipment List") for operation with one thrust reverser deactivated.

During the landing on Congonhas runway (the event of the accident), the FDR did not record any thrust lever movement of the number 2 engine (the one with the pinned reverser), from the moment it was positioned at “CL”, up to the collision of the aircraft.

As for the number 1 engine, the FDR recorded the movement of its respective thrust lever to the "IDLE" position moments before the landing, when the “RETARD” auto call-out sounded, and the airplane was at a height of about 10 feet above the runway.

At the landing, the touch of the aircraft landing gear on the runway occurred at a speed of approximately 140 kt., while the FDR recording shows that one of the thrust levers was at "IDLE" and the other at “CL”.

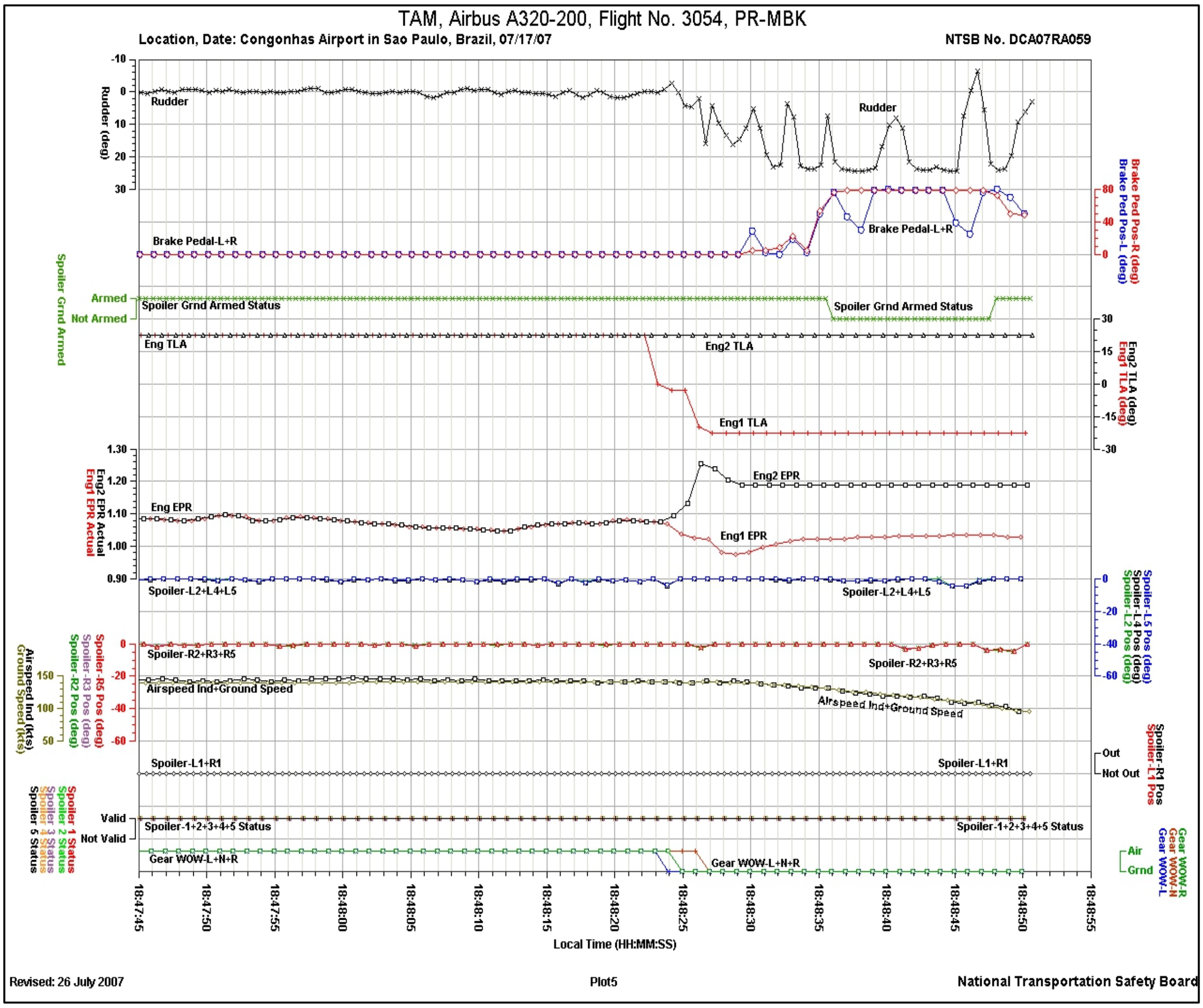

Figure 3: FDR plots.

The FDR also recorded that, after the landing, there was neither deflection of the ground spoilers, nor activation of the autobrake.

When the nose gear touched the runway, about 2.5 seconds after the left main gear, the number 1 engine thrust lever was moved to the “REV” position, according to the FDR.

About six seconds after the main gear touched the runway, there was the first activation of the brakes by means of the pedals, which reached the maximum deflection five seconds later.

The FDR also recorded the use of the rudder and the differential braking by the pedals as the aircraft veered to the left (probably in an attempt to maintain the plane on the runway and stop it).

5 HIPOTHESES

In order to explain the chain of events described above, which culminated in the accident, two hypotheses were formulated, which presuppose that there were no errors in the recording of data by the FDR, based on the lack of any indications of failure during the checks automatically made by that recording system.

First hypothesis: a failure in the system that controls the power of the engines would have provided the number 2 engine with the information that its respective thrust lever was at the "CL" position, regardless of any other setting determined by the pilot.

Second hypothesis: the pilot would have performed a procedure in discordance with the MMEL.

The evaluations of the hypotheses were developed as follows.

5.1 First Hypothesis

Relatively to the first hypothesis, the operation of the engine power control system follows a chain of commands (figure 4) which starts with the activation of the thrust lever by the pilot. The movement of the lever is mechanically transmitted through the AFU to the thrust control unit (TCU). From the TCU, an electronic signal is sent to the FADEC ("Full Authority Digital Electronics Control"), which governs the engine. The recordings made by the FDR have their origin in the data provided by the FADEC.

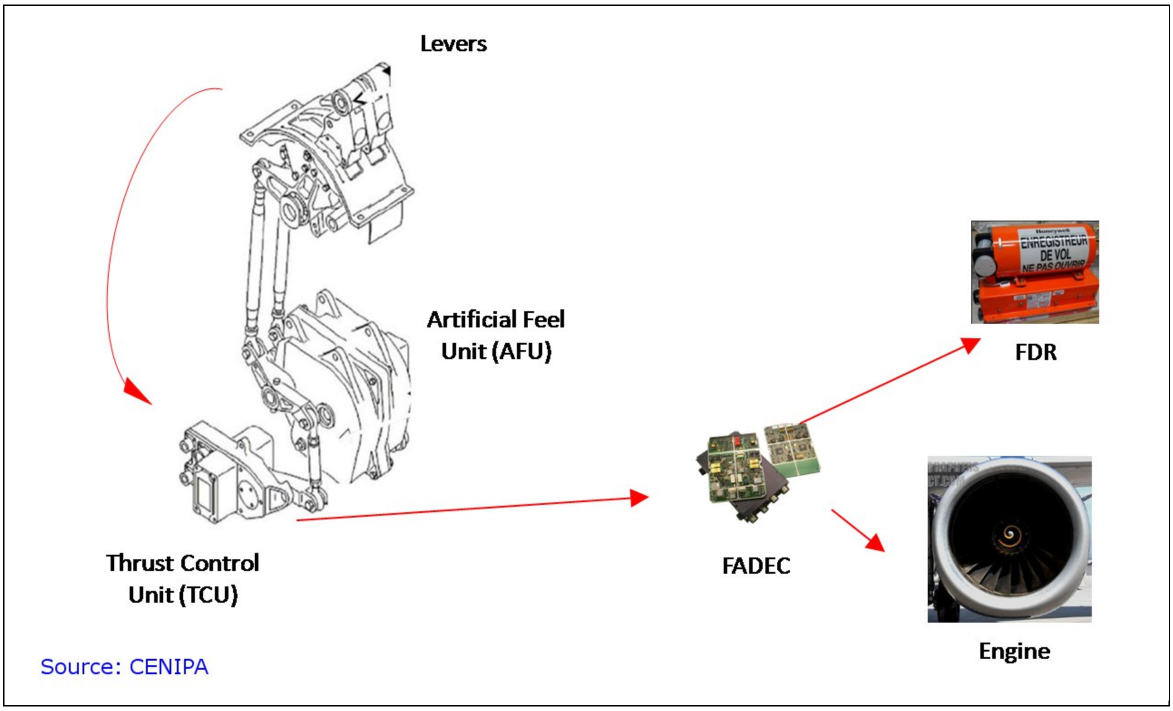

Figure 4: Power transmitting system.

When this chain of activations from the engine up to the thrust lever is analyzed, the possibility of errors occurring in the process of data recording by the FDR is discarded, as already commented.

Therefore, any recording of data incompatible with the real setting of the thrust lever would have its origin outside the FDR. As mentioned above, the power data recorded by the FDR are provided by the FADEC.

Each engine of the aircraft has its own FADEC, which possesses 2 channels that receive the signals individually, as a way to prevent the dissemination of failures. Each one of these channels has its parameters continually monitored, accommodating the power at "CL" or "IDLE", according to the flight conditions.

According to this logic, for the FADEC to direct the power of the engine to "CL" in response to a possible internal failure, it is necessary that the aircraft be considered by it in a flying condition and that the "slat/flaps" be retracted. If the FADEC interprets that the aircraft is on the ground or that the slat/flaps are extended, the FADEC will direct the power to "IDLE" in the accommodation of the failure.

So, since the PR-MBK was with the "flaps" extended for the landing, it is possible to discard the idea of a failure in the FADEC.

The next stage in the chain of events would then be a failure in the TCU. This unit is responsible for the measuring of the angle made up by the setting of the thrust lever. It has distinct processes for the measuring, and sends information both to the FADEC and to the computers responsible for the activation of the ground spoilers.

The items of information sent to the FADEC come from two rotating transformers (“resolvers”) existing in each thrust lever. Any failure or discrepancy between the measurements of the two transformers of a same lever would turn the “Master Caution” light on, and trigger a sound alarm and an alert in the ECAM (“Electronic Centralized Aircraft Monitoring”), announcing a discrepancy in the reading of the thrust lever setting.

There was not any recording either of discrepancies in the measurement of the thrust lever angle, or of an activation of the “Master Caution” light by the FDR. The CVR did not record any sound alarm either, or even a mention by the pilots relative to an alert in the ECAM indicating such failure.

As for the ground spoilers, a failure of any of the potentiometers responsible for the information of the positioning of the thrust lever to the respective spoiler elevator computer (SEC) would result in the non-commandment of the deflection of the respective spoiler, and would display a message in the ECAM with the procedure to be performed by the pilot.

If more than one spoiler had failed to deflect on account of a failure of the potentiometers, then in addition to an alert in the ECAM, there would be a sound alarm and the Master Caution light would be turned on.

The FDR did not record any activation of the Master Caution light, or any failure in the activation of the ground spoilers. In fact, the activation system of the ground spoilers worked as expected, and the deflection of the ground spoilers was inhibited on account of the information that one of the thrust levers was at “CL”.

The CVR did not record any sound alarm either, or even a mention by the pilots relative to an alert in the ECAM indicating such failure.

The lack of recordings of failures, or the fact that they are not mentioned, the lack of any aural warnings, according to the recorders, allows a failure in the TCU to be discarded.

As for the possibility of failure of the activation rod which connects the AFU to the TCU, or its connection, it can be discarded, because it would imply to move down the command of the TCU, by means of gravity, moving the thrust lever to the "REV" position. In addition, a failure like this would activate an alerting device in the ECAM.

The lack of evidence concerning this alert, plus the reading of the thrust lever at the "CL" position, allows discarding this possibility.

What remains is, therefore, the possibility of mechanical failure of the activation rod which connects the thrust lever to the AFU, or a failure of this unit. In this case, it would be possible to have an indication of the lever at “CL", no matter which the real setting was.

The AFU, recovered in the midst of the wreckage (figure 5), was subjected to several tests in an attempt to find marks of impact that could lead to the identification of the actual position of the engine no. 2 thrust lever during the final moments of flight JJ3054.

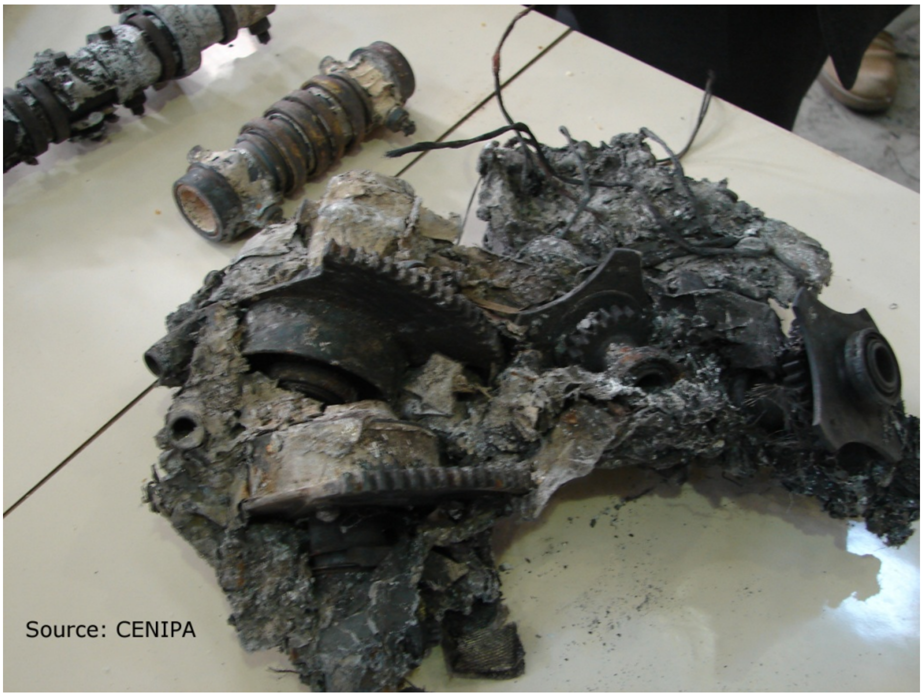

Figure 5: Artificial Feel Unit (AFU) found amidst the wreckage.

Due to the lack of success in the examinations, the possibility of an AFU failure could not be ruled out.

However, according to the data provided by the manufacturer, the possibility that a failure like this can occur exactly at the moment of landing is less than 4×10^{-11} per flight hour.

5.2 Second Hypothesis

To validate the hypothesis that the pilot failed to follow the procedure recommended in the MMEL for the landing with an inoperative thrust reverser, it was essential to find some motivation to justify the non-application of a procedure that had been applied in the previous leg, and, thus, that was known by the crew.

Among the aspects of the operation in Congonhas that differed the most from those found on the previous leg in Porto Alegre, there are the following ones: the conditions in which the flight JJ3054 was dispatched, the specific characteristics of Congonhas Airport, and the night period.

The airplane had been dispatched from Porto Alegre with its maximum capacity, with all the passenger and crew seats taken, with a total of 187 POB (of whom, two were infants). Therefore, there were enough seats for everyone, except for the infants, a condition that is in accordance with and authorized by the regulations.

In relation to the aircraft weight, despite the extra 2.4 tons of fuel (because of the economic refuelling made in Porto Alegre), the weight recorded by the FDR when landing at Congonhas was approximately 63.5 t, and, therefore, below the structural limit established for the destination aerodrome (64.5 t).

According to the calculations of the performance at the landing, the runway distance required for the flight dispatch, not considering the utilization of the reverser available and with a wet runway condition, would be approximately 1,781 meters for the aircraft with its maximum landing structural weight.

On the other hand, the estimated distance to stop the aircraft in a wet runway without the use of thrust reversers, without unexpected (ALD) events, with the weight recorded by the FDR upon landing, was of 1,332 m.

Considering these data, and the fact that the main runway in Congonhas had a declared landing distance available (LDA) of 1,880 m, it is possible to affirm that the aircraft was dispatched within the appropriate safety parameters.

However, as already commented, the operation in Congonhas represented an enormous concern for the pilots, in psychological terms.

The recording of the CVR indicates that the PIC showed anxiety in relation to the conditions of the runway for the landing, to the point of asking the SIC, on two occasions, to contact the TWR-SP and question about the conditions of the rain and runway, and specifically, whether the runway was slippery.

It is worth reminding that, two days before the accident, with the first precipitations of rain after the restart of the runway operations with the pavement recovered, several complaints were made by the pilots just after landing, and even an accident occurred, involving another big size airplane, on the day before the accident of the JJ3054.

So, it is possible to identify that the influence of the runway conditions on the pilots, from a psychological perspective, favouring the creation of a state of anxiety, had probably begun still in the approach phase, and lasted until the confirmation that something more serious was happening – something involving the aircraft systems, since the ground spoilers and the autobrake were not activated.

Besides the aspects mentioned above, there are other ones that may have somewhat influenced the performance of the crew, in the context of the hypothesis analyzed, and that need to be highlighted.

The crew consisted of two captains, with the senior of the two sitting on the left seat during all the journey and acting as the PIC during the landings at Porto Alegre and Congonhas.

As a personal characteristic, the PIC displayed an average performance in terms of piloting, and had a background marked with minor difficulties in more critical operational situations, something that was counterbalanced by a high degree of standardization and adherence to the prescribed procedures. This characteristic reinforces the evidence that the MMEL had been consulted at the beginning of that flight.

At a certain moment during the approach, the PIC reported having a mild headache, according to the CVR, which may have exerted some influence on his cognitive and psychomotor capabilities during the final moments of the flight, when the unpredictability of the situation demanded a more effective performance.

The fact that one reverser was not available to him may have influenced the pilot to some extent, from a psychological perspective, although the flight was being conducted within the operational envelope of the aircraft.

The PIC probably knew that the application of the procedure for landing with only one reverser imposed an increase of up to 55m on the runway length required, when contaminated, since this information was contained in the MMEL.

On account of the scenario encountered by the JJ3054, and considering the characteristics of the PIC, it is possible to suppose that a good motivation to not complying strictly with the procedure prescribed in the MMEL for the landing with the pinned number 2 engine reverser would be the 'loss' of the 55m, if he considered that the Congonhas runway was contaminated, something that would be plausible within that context.

If this was the case, the procedure performed was not the same that was in force before, since both thrust levers should have been set to "IDLE", according to that procedure.

However, considering that in the former procedure there was a moment at which only one thrust lever had to be activated (the one corresponding to the engine whose reverser was operative), it is possible to identify in here more room for the occurrence of an error in the execution of the procedure. After all, the change in the procedure prescribed by the manufacturer had been made precisely due to the cases in which the error of moving only one of the levers had been made, and even contributed to the occurrence of the accidents of Bacolod (Filipinas – 1988) and Taipei (Taiwan – 2004). Besides, it is important to highlight that the FWC of the PR-MBK, in the same way of the A-320s of Bacolod and Taipei, did not have the H2F3 standard, an improvement offered by the manufacturer through a service bulletin.

Another important aspect, the operations on the main runway had already been suspended for the evaluation of the water drainage conditions in the presence of rain, while the JJ3054 was still cruising. Later, the crew was informed by the TWR-SP that the runway was wet and slippery.

Therefore, it can be seen that the operation in Congonhas may have represented a source of concern, on account of the scenario within which it was being developed, and that included: the 2.4 tons of weight added in the tankering, the crowded airplane, the pressure to proceed to Congonhas, the PIC's physiological condition (headache); a SIC with little experience as co-pilot in the A-320 (and its autothrust system), the wet and slippery runway, and the occurrences on the day before. Certainly, the scenario itself did not favour a better performance by the crew.

Also, it is necessary to consider that the human being makes his/her decisions in accordance with the context perceived by him/her. The way the context is perceived, however, does not always correspond to reality.

According to this line of reasoning, one can imagine that the PIC was willing to perform the old procedure on purpose, on account of considering that the Congonhas runway might be contaminated, so as to obtain a better performance in the deceleration of the aircraft after the landing at Congonhas, avoiding the increase of 55m prescribed in the MEL.

So, on account of all the pressure brought by the circumstances, he may have had his attention focused on the need to set only the number 1 engine thrust lever to the "REV" position (preventing the increase of the landing distance required) and, due to an error of perception, he may have commanded only that thrust lever to the "IDLE" position, letting the other lever remain at "CL".

Thus, the aircraft would have behaved exactly as recorded by the FDR. The lack of understanding of that behaviour on the part of the pilots would have prevented the adoption of any corrective measures.

When both hypotheses are compared, the second one appears more likely, because a failure of the AFU activation during the landing seems highly improbable in statistical terms, in addition to the fact that human error is an expected and frequent component of any complex system, aviation included.

6 KEY FINDINGS

In the A-320 aircraft, it is possible, during landing, to position one of the thrust levers in "REV" and the other in "CL".

In this configuration, the logic of the power control system allows a condition of antagonism between the engines, and this can lead to a catastrophic situation (such as the one of this accident).

In fact, even with the aircraft on the ground ("Weight on Wheels" - WOW), with the number one engine thrust lever in the "REV" position, with the "ground spoilers" armed, with "autobrake" selected, and applying maximum pressure on the brake pedals, the power control system prioritized the information concerning the positioning of a trust lever in "CL", and such lever had no safety device to protect against a possible inadvertent positioning.

In this situation, with the information that a lever was in "CL", the "ground spoiler" did not deflect, the "autobrake" did not actuate, and the braking conditions deteriorated to the point of not permitting to stop the aircraft on the runway.

The pilots realized that the aircraft was not slowing down at the required rate only a few seconds before impact (too little time to understand what was happening).

On the other hand, the H2F3 routine proved effective in alerting the inappropriate positioning of the levers during landing and, according to simulator tests carried out by the Commission of Investigation, if installed in the aircraft, it would have allowed the crew to identify the JJ3054 problem and correct it in a timely manner.

It was found that there were several pilot error antecedents in the positioning of the levers for landing with an inoperative reverser (and these antecedents led the manufacturer to modify the landing procedure in force at the time). This fact, alone, would imply in non-compliance with the requirement of ICAO Annex 8[v], Part III, Chapter 4, section 4.1.6, letter "a":

PART III. LARGE AEROPLANES

...

CHAPTER 4. DESIGN AND CONSTRUCTION

4.1 General

...

"4.1.6 Systems design features

Special consideration shall be given to design features ***that affect the ability of the flight crew to maintain controlled flight****. This shall include at least the following:*

> *a) Controls and control systems. The design of the controls and control systems shall be such as to* ***minimize the possibility of*** *jamming,* ***inadvertent operations****, and unintentional engagement of control surface locking devices."*

Moreover, even if, at the time of the A-320 certification, the manufacturer had not glimpsed the possibility of inadvertent positioning of a thrust lever in "REV" with the other one being left in "CL", there was a history of events showing that this possibility was fully known and predictable at the time of the JJ3054 accident.

Thus, it was found that the A-320, without the implementation of the H2F3 routine, does not meet the requirements of ICAO Annex 8, Part II, Chapter 1, paragraph 1.2.2 and Chapter 3, paragraph 3.2.1, as well as of the requirement of Part III, Chapter 1, paragraph 1.4:

"PART II. PROCEDURES FOR CERTIFICATION AND CONTINUING AIRWORTHINESS
CHAPTER 1. TYPE CERTIFICATION
1.2 Design aspects of the appropriate airworthiness requirements

1.2.1 The design aspects of the appropriate airworthiness requirements, used by a Contracting State for type certification in respect of a class of aircraft or for any change to such type certification, ***shall be such that compliance with them will ensure compliance with the Standards of Part II of this Annex and, where applicable, with the Standards of Parts III****, IV, V, VI or VII of this Annex.*

1.2.2 ***The design shall not have any features or characteristics that render it unsafe under the anticipated operating conditions****.*

…

CHAPTER 3. CERTIFICATE OF AIRWORTHINESS

…

3.2 Issuance and ***continued validity*** *of a Certificate of Airworthiness*

3.2.1 A Certificate of Airworthiness shall be issued by a Contracting State on the basis of satisfactory evidence that ***the aircraft complies with the design aspects of the appropriate airworthiness requirements****.*

…

PART III. LARGE AEROPLANES

…

CHAPTER 1. GENERAL

…

1.4 Unsafe features and characteristics

Under all anticipated operating conditions, the aeroplane shall not possess any feature or characteristic that renders it unsafe."

Besides, in the case of the JJ3054, the lack of the H2F3 routine favoured the loss of situational awareness on the part of pilots, contributing to the occurrence of the accident.

This also implies saying that the A-320 aircraft that was operating as flight JJ3054, did not meet, for lack of the H2F3 routine, the requirements of the U.S. regulation (14CFR25 - § 25.1309 (c))[vi] adopted in full for the A-320 certification[vii] in Brazil.

The regulation required warning information to be provided to the crew to alert them about unsafe operating conditions, and to enable them to take the appropriate corrective actions. The regulation also provided that the systems, controls and means of warning and monitoring should be designed so as to minimize crew errors capable of creating additional hazards:

"Subpart F - Equipment
GENERAL

…

§ 25.1309 Equipment, systems, and installations.

…

(c) Warning information must be provided to alert the crew to unsafe system operating conditions, and to enable them to take appropriate corrective action. Systems, controls, and associated monitoring and warning means must be designed to minimize crew errors which could create additional hazards."

In summary, considering the lack of an efficient warning device in that operating condition, the logic of the aircraft system implies non-compliance with the applicable certification and continuing airworthiness requirements.

Thus, the H2F3 routine should have been implemented in the design by means of an Airworthiness Directive.

Another important observation refers to the fact that automation, although designed to reduce the workload and minimize the incidence of human errors in the face of the increasing complexity of the aircraft systems, ended up favouring the loss of situational awareness by the crew of the JJ3054.

This is particularly worrying, as this "side effect" has been present in other accidents involving modern aircraft, making the guarantee of efficiency and reliability in the interaction between man and machine a growing challenge for the industry.

The investigation also allowed revealing shortcomings in the processes of regulation and oversight by the CAA.

In fact, the accident could have been prevented if the procedure for the approval of a regulation had not taken more than two years. Thus, since April 2006, the CAA understood that it was necessary to require the availability of all thrust reversers for operation with a wet runway in Congonhas, but this requirement only came into effect in May 2008.

The lack of direct oversight by the CAA in relation to the renovation works in Congonhas, and uncontrolled growth of operators contributed in an indirect manner to the formation of the scenario that favoured the occurrence of the accident.

A more incisive action would probably have made the Congonhas runway renovation to take place at an earlier time, preventing a prolonged operation in degraded condition. In addition, a controlled growth of the airlines would favour a better training of the crew, besides alleviating the internal communication problems of the operator involved in this accident.

Finally, it was found that the requirements of ICAO Annex 8 on the need to consider the limitations imposed by human factors in the design and construction of aircraft are still very vague, hindering their direct application, something which is reflected in the national regulations:

PART III. LARGE AEROPLANES

...

CHAPTER 4. DESIGN AND CONSTRUCTION

4.1 General

> *Details of design and construction shall be such as to give* ***reasonable assurance that all aeroplane parts will function effectively and reliably in the anticipated operating conditions****. They shall be based upon practices that experience has proven to be satisfactory or that are substantiated by special tests or by other appropriate investigations or both.* ***They shall also consider Human Factors principles****."*

7 CONCLUSION

The investigation of the flight JJ3054 accident was extremely complex and comprehensive, and was conducted amid an atmosphere of crisis in the airline industry, which led to the development of additional lines of investigation besides those determined by evidence.

Nevertheless, the logical lines of investigation led to important findings, especially those related to design deficiencies and fragilities of the CAA posture.

These findings are especially important in the context of the implementation of a new model of accident prevention, carried out by means of the Flight Safety Management Systems[viii] (SMS).

It has been observed in some countries that there is a tendency to overestimate the role of the proactive and predictive management tools, as if they were sufficient to ensure an acceptable level of safety in aviation.

In general, this tendency is evident in CAA's that do not have either tradition or deep knowledge of the investigation activity, and ultimately minimize the importance of occurrence investigation as it is a reactive management process.

Moreover, since the regulation and oversight of the management systems falls on the CAA, any deficiencies in its internal operational processes (from which the regulation and oversight processes result) often end up not being detected, given the fact that these authorities tend to focus their efforts on other stakeholders of the system, such as airlines, manufacturers, ATS, maintenance workshops and airports.

The investigation of the JJ3054 accident came to prove that, although the SMS model represents a major evolution in relation to the traditional model of prevention, the importance of investigating accidents and incidents in this new model remains unchanged, especially with regard to the discovery of flaws in the aircraft design, as well as deficiencies in the regulatory and oversight processes.

END NOTES

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[i] Email: *fernando.camargo@cenipa.aer.mil.br*.

[ii] CENIPA: *Centro de Investigação e Prevenção de Acidentes Aeronáuticos*

[iii] Final Report: http://www.cenipa.aer.mil.br/cenipa/paginas/relatorios/advertencia2.php?pdf=3054ing.pdf

[iv] *Laboratório de Leitura e Análise de Dados de Gravadores de Voo* (LABDATA) - implemented in CENIPA in 2006, at the time of the accident it had only capability for analysis and production of animations. Currently, the LABDATA is able to perform readouts of damaged recorders from most of the models in operation in the aviation industry.

[v] INTERNATIONAL CIVIL AVIATION ORGANIZATION. **Annex 8 to the Convention on International Civil Aviation:** Airworthiness of Aircraft. 9. ed. Montreal: ICAO, 2001.

[vi] Refer to the Code of Federal Regulations – Title 14, Chapter l, Part 25 - AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES (14CFR25).

[vii] Refer to the RBHA (*Regulamento Brasileiro de Homologação Aeronáutica/* Brazilian Aeronautical Certification Regulation) 25 – Transport Category Airplanes Airworthiness Requisites, approved by the Directive nº 285/DGAC, dated 06 August 1990.

[viii] Refer to the ICAO Doc 9859, Safety Management Manual (SMM). 2 ed. . Montreal: ICAO, 2009.