Barbara Faccini

FOUR MINUTES, 23 SECONDS

Flight AF447

Volare Aviation Monthly
January 2013

INTRODUCTION

The night of the 1st of June 2009 the Airbus 330-203 F-GZCP, fight Air France 447 from Rio to Paris, disappeared in the middle of the Atlantic Ocean, with its 228 passengers. It took about two years, the 12th of May 2011, for the "black boxes" with the digital record of the flight data (DDR) and the voices and sound of the flight deck (CVR) to arrive at the BEA, the French government Entity investigating on flight accidents. Most of the people who followed the case thought that, eventually, it would have been possible to understand how this disaster could have occurred.

The black boxes were found during the fifth phase of sea search campaign at the bottom of the Atlantic Ocean, more than 3,900 meters deep. Notwithstanding, they were in good conditions and it was possible to retrieve the data they recorded. This should have made it possible to close the investigation on one of the most enigmatic cases in the history of modern civil aviation. However, as it should have been foreseen, the conclusions have been neither evident nor clear.

On the 29th of July 2011 the BEA put on line the third Interim Report, where the state of the art on the investigation was outlined. A long appendix was attached, with the DFDR graphs and the summary of the same data coupled with part of CVR dialogues. In summary, the Bureau retained that human error was the cause for the tragedy. This statement, unconceivable under many aspects, triggered a lively debate and a fight between Airbus, DGAC, and EASA from one side and the victim family association and the SNPL France ALPA Syndicate from the other, with Air France in within, shot from both sides.

The BEA changed its position on the 5th of July 2012, when the Final Report was issued. New elements, never reported before, were introduced and some answers to SNPL France ALPA questions were given. Basically, the human error hypothesis still remains. But this error has been related to some responsibilities of the certificatory entities, to the characteristics of the training, to the slow and passive behavior of the manufacturer, of Air France and of the aeronautic authorities in reacting to the numerous previous accidents, fortunately without casualties, implying the freezing of pitot probes, especially the Thales AA type mounted on A330-203 F-GZCP. Air France was on its way to substitute the probes with another, more suitable type just few days before June the 1st, 2009.

But there is more: the way certain Airbus automatic systems behave are also being accused, starting with the famous stall warning. Airbus systems interface human and machine through highly sophisticated computer programs that in some cases are difficult to understand and handle correctly. These airplanes, perfect-viewing, equipped with the best technology and capable of preventing man's mistakes when everything works as planned by the engineers, may become a death trap whenever computers go blind or if they are not receiving proper signals to elaborate.

This is the reconstruction of the last minutes of flight AF 447, obtained by cross checking every official document available to the public, that is to all of us potential passengers.

Main sources about flight AF447

This reconstruction is based primarily on the **BEA** three **Interim Reports** and the **Final Report** on F-GZCP accident (downloaded from its official site: http://www.bea.aero/en/enquetes/flight.af.447/flight.af.447.php). In these documents, some inconsistencies can be noted.

In the Third Interim Report, DFDR graphs are plotted on different scales, which makes the reading particularly difficult; their resolution is very low. For some parameters, such as altitude, the reported values are large whilst variations, in some case, are very small, preventing the proper catchment of important details. The BEA focuses mainly on few parameters, omitting the explanation of some others, which can be easily pointed out when the graphs are compared. Pilot dialogues are only partially reported, without information on the tone of the voices, and it is difficult to understand the full meaning of certain phrases: an order, a request or a simple statement? The warnings, the noises corresponding to the pressing of a button or the switching of an interrupter, the environmental and background sounds are only partially reported.

In the Final Report many of the previous unclear points are solved, but some lacunae are still present. The CVR has been enlarged, sounds and noises have been added but, still, it isn't the integral transcription. For example, only the dialogues regarding "the conduction of the flight" are included. Without the complete translation it is impossible to figure out the psychological state of the pilots, which is essential to better highlight what was going on. The investigators in charge of the human factor analysis made a good job to explain the mental mechanisms that triggered at the beginning of the accident sequence, but completely omitted to comment the last three minutes of a four minutes and a half event….and some clues from the dialogues of the uncommented minutes are illuminating…. Obviously, in an investigation involving flight security, it cannot be put forward anything based on uncertain data, or a reconstruction unsupported by evident proofs. It is however true that a theory is often build on hypothesis that can be only verified afterward. After two years of residence on the bottom of the ocean some key elements may have disappeared, but this is not enough to exclude factors that - as in a mathematical equation - can provide a solution when they are taken into consideration.

Another source was "Crash Rio-Paris", volume n° 5 of the "Erreurs de Pilotage" series by Jean Pierre Otelli (Altipresse Editions). This book appeared on the market few months after the BEA third Interim Report, when the safety investigation was still ongoing. Many elements lead to think that it was committed by Airbus, which managed to obtain the black box data notwithstanding the manufacturer was still under accuse by the French justice. Otelli must have been given the full CVR transcript, as he published a much more detailed version of the dialogues with respect to that released by the BEA. Comparing the two sources, however, it is quite evident that he cut down some phrases and skipped others that, on the contrary, are present in the BEA Report. Dialogues are also referred to the wrong person, in some cases. It is a bad debunking operation aimed at making money and hiding the manufacturer responsibilities from the eyes of the public.

The most complete document about AF447 is the **Judiciary Report** (downloaded here: http://norbert-jacquet.jacno.com/airbus-af447-rio-paris-les-rapports-dexpertise-judiciaire/). It describes the entire accident sequence in the light of DFDR and complete CVR data, comparing Air France and Airbus operative procedures, analyzing the working behavior of A330 systems and the pilot responses to what the instruments were presenting them. The only strange discrepancy is that it assigns certain dialogues to a different person with respect to the BEA Final Report. It's impossible to establish which version is correct, as the CVR audio tape is confidential. In this reconstruction, the BEA assignment has been chosen as reference. At last, outstandingly, the numerical DFDR dataset has not been released to the injured parties.

The protagonists

The human factor is always present in a plane accident, and in particular it's extremely controversial in the AF447 case. It is thus fundamental to know the psychological features of the pilots. A serious investigative team should deeply investigate this aspect, as the psychological and physical state of a person heavily affects his/her actions. As an example, it should be recalled the SilkAir 185 accident, in which the captain committed suicide causing the death of all the other passengers and crew members.

Detailed information about AF447 pilot careers can be found in BEA reports, and are only briefly summarized here. Their personality is described according to testimonies reported on the web.

Marc Dubois

The Captain, 58, is an experienced pilot with about 11000 flight hours. He started as an Air France steward, then he made all the necessary steps to become a pilot, from PPL to ATPL. He has the Type Rating for A300, A320, A330 and A340. In his long career, he flied different kinds of planes, from Cessna 172, to Boeing 737-200, passing through old-fashioned liners such as the Caravelle 12. He first worked for Air Inter and then passed under Air France (where he should have ended his career) after the merging of the two companies. He thus has a great experience also on machines much less automatized than the Airbus. Such a long path and having started as a steward indicate that the passion for flying always ran through its veins. His friends describe him as a quiet man, proud of his work and happy to end his career performing the long intercontinental routes. He takes care of the needs of his loved ones; he is thoughtful and present. From CVR dialogues this is confirmed from the gentle and calm attitude toward the co-pilots and the cabin crew. He shows particular patient with a hostess asking him repeatedly about alternate airports and transatlantic navigation fight rules. He explains everything never getting upset. Similarly he is quiet and far from losing its patience when the youngest co-pilot insists for asking the Air France OCC to change the alternate airport of Sal (Cape Verde), which is closed overnight but for emergencies.

In this journey to Rio, Marc is accompanied by Veronique Gaignard, his new girlfriend, ex hostess and now a rather successful lyric singer. Controversial sources (*Pièces à Conviction* – TV France 3; le Figaro) report that Marc, when boarding on the plane to go back to France, was particularly tired. The day before the fight Marc and Veronique went to some friends living at a hour of driving from Rio, and probably they were celebrating until late. From CVR dialogues his tiredness seems to find some evidence. He appears "absent" in several moments, at the point that he does not hear when asked and the second co-pilot answers in his place. Talking with a hostess Marc confesses that he had had just one hour of sleep the night before and that it was definitively not enough. His need for rest may be compulsory when, about two o'clock in the night, even if they were about to cross the Inter Tropical Convergence Zone and in spite of the increasing turbulence, he decides to take his scheduled rest. This physical condition probably affected his analytical capability when he came back into the cockpit, with the airplane in full emergency.

David Robert

The first co-pilot, 37, has clocked about 6500 flight hours under his belt. He has the Type Rating for A320, A330 and A340, and got all his licenses at ENAC, the most prestigious flight school of France. He worked for both Air France and Air Calédonie, often riding the route between the two hemispheres in the south east Asia and living probably on the island of Nouméa for a while. He is quite eclectic, possessing also a degree as air traffic control engineer. In addition, he has been appointed cadre at the Technical Flight Crew Division as representative of the Flight Deck Crew hub at the Air France OCC. For passion, he flies a small TB10 Socata.

Surprisingly, very little can be found about him on the web. He lived in Rosny-sous-Bois at the periphery of Paris; he was a Jew, married and father of a small baby. Few things about his personality can be deduced from the CVR, because he appears only for a quarter of time before impact. In the beginning of the accident sequence he shows a higher level of irritability with respect to the other co-pilot, as he tries many times to wake up the Captain instead of remaining concentrated on monitoring the flight path and on troubleshooting.

Pierre-Cédric Bonin

The second co-pilot, 32, was born near Bordeaux; with about 2900 flight hours he is the least experienced of the trio. He got the PPL at an Aero Club of Arcachon Basin. In 2003 he was selected as Air France "cadet" and sent by the company to the *Amaury de la Grange Training Centre* in Merville, in the northern France, where he got the ATPL before being employed. He has the Type Rating for A320, A330 and A340.

Pierre is a generous and friendly person. He is brilliant and playful, used to quickly react in every situation probably also because he is an amateur sailorman; moreover he is a glider pilot. He married young and is deeply in love with his wife Isabelle who, taking advantage of the long Whitsun weekend, decided to accompany him in this trip to Rio. Two young boys aged 4 and 8, the reason for their lives, are waiting them at home at their grandparents' house. Of the three, he is

the one who has “something more to lose” from an accident. This probably contributed to raise his level of stress through the whole accident sequence, compromising his situational awareness.

Neither of the three pilots has ever been trained in the simulator for an Unreliable IAS at high altitude cruise, and neither of them has ever been trained in recovering a liner from a full stall, but only from the approach to stall. This in fact was not included in the training programs of both Air France and Airbus, and even today no data are available to recreate such a scenario in a flight simulator. Accomplices in retaining Airbus planes impossible to stall, the two giants of French aviation had never classified the relative procedure as an “emergency procedure”, that is a sequence of maneuvers the pilots should be trained at so often to become an automatism.

To conclude, few words about the theory (often comparing in forums, blogs and journals) that the majority of liner pilots had lost their basic skills and their capability to really fly a plane, as a consequence of the use of autopilot and of the overwhelming technology. In the case of AF447 pilots:

- The Captain had a great experience also on planes devoid of automation, like the Cessna 175;
- Pierre and David regularly enjoyed flying basic airplanes: a glider for the first, a TB10 for the second.

It is thus evident that this theory is untenable in their case. If they did not recognize that their plane entered a stall, the reason should be searched elsewhere.

4 minutes, 23 seconds

Flight AF447 was quiet, up to that moment. The evening of May, the 31th, 2009, the elegant Air France Airbus A330-203 registered F-GZCP took off full-loaded from the Galeão international airport in Rio de Janeiro, destination Paris Charles de Gaulle with an estimated time of arrival at 11 a.m. the next day, June the 1st. Many passengers on a work travel would have started the week coming back to their offices with only few hours of delay.

CVR registration starts at about 00:15Z (Zulu in the ICAO code, that is UTC). In the cockpit, Marc, the Captain, and the second co-pilot Pierre-Cédric attain routine operations of flight monitoring and communications with the Brazilian ATC. And there is also time for some non-aviation discussions, as the time goes by. The first co-pilot, David, is in his scheduled rest and will have to substitute one of them later, as normally foreseen for long flights.

From 01:46Z, Pierre repeatedly drops the Captain attention over a particular parameter on their flight control displays: the REC MAX. It is the maximum altitude that the airplane can safely reach in cruise considering its actual weight and the external conditions (like outside temperature). They are at fight level (FL) 350 (35000 feet, 10670 m) and, since they are approaching a large storm, Pierre wishes to climb for other 1000 feet in order to fly outside the clouds and limit turbulence.

The bad weather is linked to the Inter-Tropical Convergence Zone (ITCZ or FIT, in French), an area where air masses coming from different hemispheres – and having different characteristics - converge at the humid equatorial latitude giving birth to MCS (*Mesoscale Convective Systems)* and large squall lines. In satellite imagery the ITCZ looks like a perpetual, mobile white belt wrapped around the Earth's hips.

It is a phenomenon well-known by all crews en route between the two hemispheres, but Pierre has only little experience of transatlantic flights. To him, the ITCZ is a source of worry hidden under his slight insistence. The Captain hesitates. He does not answer in a clear way, nor he suggests a crossing strategy. He just waits, even if the conditions would allow to climb at FL360. It seems that he doesn't really care, as if his thoughts were elsewhere and his tiredness had slowed down his attention for the work he is performing.

Three hours and a half into the flight, the A330 encounters the main storm front. It apparently passes through the upper limit of a developing Cb (Cumulus nimbus, Fig. 1) at SALPU point, but still no lightning can be envisaged. However, turbulence increases. Marc and Pierre gaze at the glowing of Saint Elmo's fires flashing over the windshield: a clear sign that the electrical activity of the storm is rising.

Pierre is surprised by this phenomenon, eerie and spectacular, that he hasn't seen before. He notices again that the REC MAX is FL375, probably hoping to obtain the permission for climbing; Marc still does not answer. The outside temperature is higher than forecast, and increasing. At 01:56Z the Captain decides to take his rest, and wakes up the first co-pilot by ringing a sort of carillon, called *high-low chime*, within the flight rest cabin.In addition he implicitly confirms Pierre

as pilot flying (PF), asking him by joke if he has got a liner pilot license. It's probably feeling the sudden weight of a big responsibility, that Pierre says yes. He will remain in the right seat, while David will get the left seat as relief Captain.

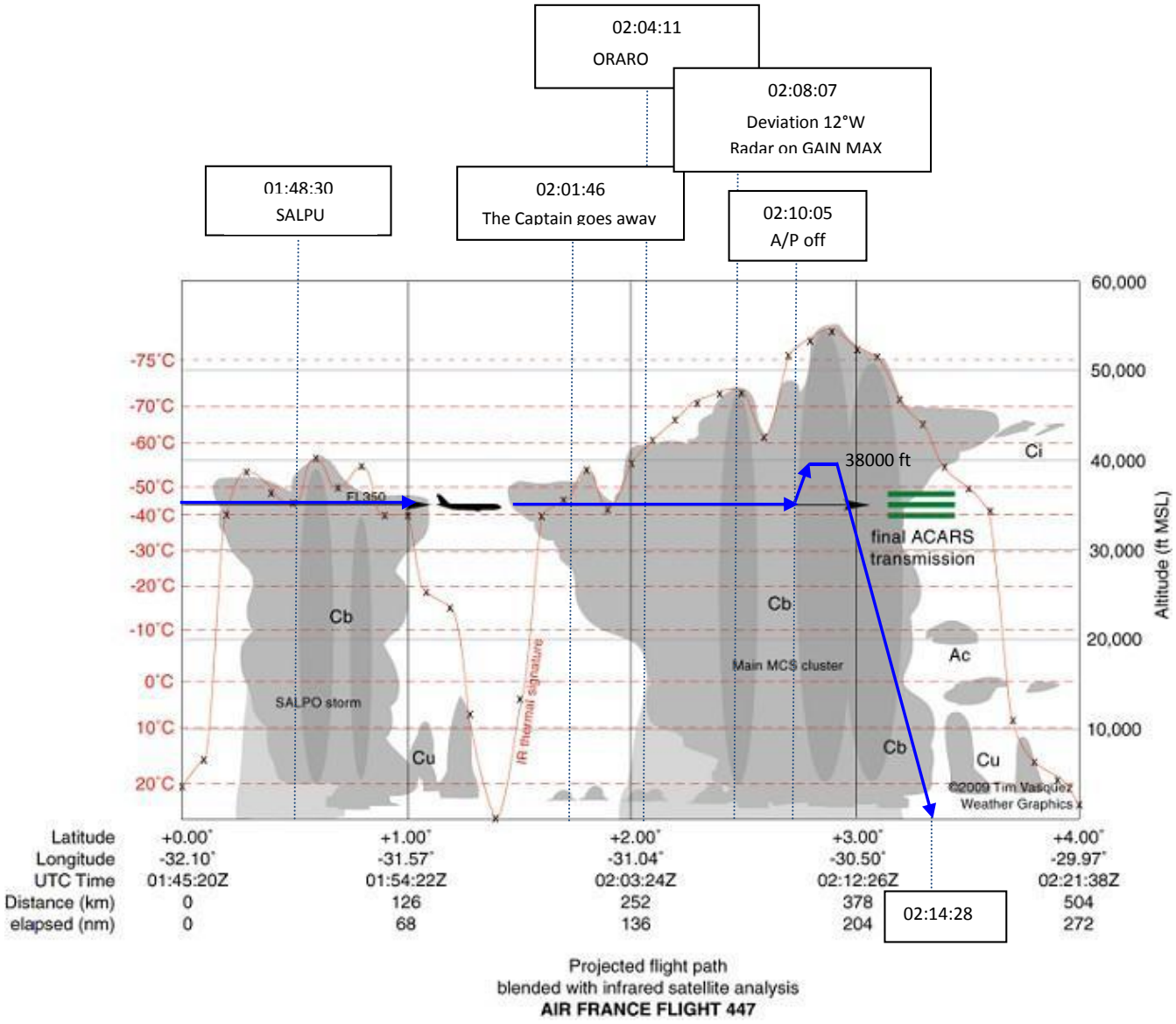

Fig. 1 - Section of flight AF447 from 01:45:20Z to 02:14:28Z (Source:www.asso-af447.fr)

The senior co-pilot arrives soon, and while they are still all together in the cockpit the PF makes a small briefing about meteorological conditions and radar contacts, pointing out that they will proceed within the clouds at that flight level and that radio contact in HF with Dakar failed. They

entered the transition zone between Brazilian and Senegalese ATC radar covering, a “dark spot” where contacts are often very difficult and scanty. They will be alone for a while, right in the middle of the Ocean…

After listening to the briefing and recalling the frequencies to contact ATLANTICO in HF, Marc stands up leaving his place to David. Then, he goes out. It’s 02:01:46Z.

The two copilots discuss about temperature and REC MAX, then about Marc’s decision to keep Sal airport (closed at night but for emergencies) as one of the alternate airports. A good feeling seems to exist among them.

At 02:03:45Z the outside temperature is ISA+10. Since the turbulence is rising again, Pierre recommends the PNC to pay attention and stay seated until they will come out of the storm. Only few minutes later (02:06:40Z) he notices that the temperature increased again at ISA+13, -42° C, warm for that altitude. It’s a clear sign they are entering in the updraft of another Cb: the hot and humid ascending currents feeding the thunderstorm are so strong to be capable to augment the temperature of 13 degrees with respect to standard foreseen for that altitude. The crossing of ITCZ seriously worries the youngest co-pilot. Why the captain did not understand it? While reaffirming that climbing at FL360 would have been sufficient to be out of the cloud mass, he probably thinks that his wife and the passengers will have to bear all the turbulences.

Few minutes later, David sets the onboard radar scale on GAIN MAX, that is at the highest resolution, in order to better observe the cloud details. It’s now, that they probably notice the conditions are not so good as they were hoping. Red echoes stand up everywhere, and they are heading exactly toward them.

They look at each other, without commenting, but probably they both think they’ve done a mistake. Should have they checked earlier? Should have they deciphered the Cb evolution with more attention? After all they knew the convergence was there waiting for them: they just had to evaluate how to pass through.

- 02:08:03. David: Tu veux pas altérer un peu à gauche éventuellement? (Do you want to divert maybe a little to the left?)

- 02:08:06. Pierre: Excuse-moi?(Pierre: Excuse me?)

- 02:08:07.David: Tu peux éventuellement prendre un peu à gauche...je suis d’accord qu’on est en manuel, hein? (You can possibly go a little to the left…I agree we are in manual eh?)

- 02:08:12. David: Ben tu vois à vingt avec les…(Well you see at twenty with the..)

David is suggesting a deviation to the left. For sure it is there that the Navigation Display (ND)screen shows a narrow passage between the storm towers. Without speaking, Pierre sets the autopilot for a heading deviation of 12 degrees to the left.

- 02:08:19. David: C’que j’appelle en manuel…ah non on est en calibré…(What I call in manual…ah no we are in calibrated…)

- 02:08:23. David: C'est… C'est moi qui viens de passer en max, hein…(It's…It's me who just changed to max, eh?)

Then, all of a sudden, the background noise augments, a pungent smell saturates the air in the cockpit and the perceived temperature increases.

- 02:08:36. Pierre: A la vache tu as touché quelque chose du conditionnement? (Holy cow, did you touch something at the conditioning?)

- 02:08:39. Pierre: Non mais au conditionnement d'air… (No but the air conditioning…)

- 02:08:40. David: J'ai pas touché. (I didn't touch anything.)

- 02:08:41. Pierre: C'est quoi cette odeur, là? (What's this smell?)

- 02:08:43. David: C'est… c'est l'ozone…c'est l'ozone. (It's…it's the ozone…it's the ozone.)

- 02:08:45. Pierre: C'est l'ozone c'est ça? On est d'accord? (Is this the ozone? Are we sure?)

- 02:08:46. David: C'est pour ça que…(This is the reason for…)

-02:08:47.Pierre: Déjà on sent que c'est vachement plus chaud. (Well I can feel that it's already incredibly hotter)

- 02:08:50. David: C'est ça qui fait chaud et ozoneux. (It's this, that is hot and ozony)

In saying this, David points the index finger towards the bright red echoes on the navigation display. Pierre is watching outside on his right, trying to read in the darkness, and he doesn't notice David's gesture. Unreal like a dream, the obscurity of a night devoid of stars leads you astray. The stroboscopic lights reflect on the water and ice particles of the clouds, with an hypnotic effect. And the tiredness is getting heavier….

Then, he turns to his colleague, asking:

- 02:09:01. Pierre: Ça c'est quoi? C'est proper au FIT? (What is it? Is it specific of the FIT?)

- 02:09:05. David: L'ozone? (The ozone?)

- 02:09:05. Pierre: Ouais. (Yes)

- 02:09:05. David: No… (No…)

- 02:09:06. Pierre: No? (No?)

- 02:09:07. David: No, non c'est..euh c'est l'air chargé en électricité. (No, no it's…euh it's the air charged with electricity)

- 02.09.10. Pierre: Ah oui d'accord, qui… (Ah, yeah, all right, who…)

Probably Pierre wasn't thinking about it. Maybe neither of the two recalls the physical phenomena giving birth to Cb. Aviators have a strange attitude toward meteorology, for many of them a boring discipline, but fundamental. However, Pierre is a sailor and a glider pilot, winds are his natural environment; the dead calms and the storms over the sea, when the cumulus clouds grow over the horizon beyond Cap Ferret lagoon, where blue touches blue.

- 02:09:11. David: Qui…? (Who…?)

They entered a very strong updraft. The warm and humid air sucked from the sea freezes at high altitude and the water starts to crystallize around small particles driven by the wind. Innumerable tiny ice grains form (the so-called "*graupel*") and collide, causing the separation of the electric charges; the top of CB acquires an opposite charge with respect to its base and the first electrostatic bridges are generated.

A sudden flash enlightens the half-darkness of the cockpit, hitting the pilots' eyes.

They keep silent a while, shut up by the lightning. The Nature is pretty much bigger than them and their wonderful plane that, acting as a Faraday cage, protects them from the electrical discharges.

- 02:09:17. Pierre: Ça y est, ça retombe. (Here we are, it goes back down.)

- 02:09:20. David: C'est étonnant comment il fait chaud d'un coup. (It's amazing how hot it is all of a sudden.)

The ice crystals are copious. Their impact starts producing a crackling and continuous sound. An army of small bullets scratches at the airplane surface attacking its most vulnerable parts, like tiny insects harassing all together the skin of an elephant.

Moments of silence, again. The BEA wrote that the change in the background noise did not give rise to any specific comment because the phenomenon was little known to pilots at that time. This is unbelievable: how could it be that pilots did not recognize it in 2009? After all, they spend most of their lives crossing the sky and the clouds!

It's highly probable that they do notice it. And this, together with the increasing turbulence, keeps them alert. They were used to, especially David that has already flown many intercontinental routes, but the conditions are degrading fast and they should pay much more attention. Pierre is the most worried of the two, at the beginning.

- 02:09:54. Pierre: Voilà, je réduis un peu…..Voilà. (There I've reduced it a little…here we go)

In the middle of a turbulence it is good to reduce the speed, in order to lower the structural strain. Without a word but with this thought surely in his mind, Pierre decides to reduce the Mach number from 0.82 to 0.80. The control panel just below the windshield, is the Flight Control Unit (FCU): in its central screen are shown the actual airplane parameters, like the speed indicated as decimals of Mach number, the heading with respect to magnetic North, the altitude, et cetera. By turning appropriate knobs, the autopilot (always active in cruise flight) is ordered to change these parameters.

But this is not enough. David guesses that the external environment is saturated with ice, so he chooses to switch on the engine anti-ice, a system preventing the formation of ice on the engines and thus avoiding dangerous incomes of ice fragments. He rises his arm to push the two buttons - one for each reactor – in the overhead panel, adding:

- 02:10:01. David: Ça coûte rien….Vas-y. (It's free!...Go on)

Pierre agrees and asks if he should keep the igniters permanently active, to avoid engine shutdown in case of particularly severe conditions.

- 02:10:03. Pierre: Tu veux qu'on mette sur *ignition start*? (Do you want it to be on *ignition start?)*

He looks at his colleague waiting for an answer before turning the system on. It's strange that he is asking the permission: he is the pilot flying, according to the Captain decision. But David is more experienced, having more flying hours over oceanic routes than Marc itself, and he is also the representative of the Technical Flight Crew Division at Air France OCC. It's somehow obvious asking his advice.

In that moment they are flying at 35000 feet. The CAS (Calibrated Air Speed, the air speed corrected for some factors affecting its measure, like Pitot probe position and pitch attitude) on the flight control screens in front of them – the Primary Flight Displays (PFD) – is 282 knots. The pitch angle is about 2 degrees and the rotation percentage of engine fans (N1) is close to 100% for both reactors. The autopilot is correcting a slight left roll due to turbulence. The radio is silent, and they are still alone within the clouds, right in the middle of the Atlantic.

Outside, however, something is happening. The unforeseen, the unpredictable event you are not expecting….and that you would never like to happen.

Something all of them, including the airplane, is not prepared for.

Inundated with ice crystals, the three Pitot probes (located laterally and slightly below the nose of the plane) get blocked, almost contemporaneously. If this was the effect of a huge amount of ice particles penetrating into the small tubes, or due to instant ice formation when the probes hit super-cooled water present within the towering cloud, it's unknown. What is sure is that, even if the Pitots are three – a redundant number to reduce the probability of a complete failure – they all froze up and stopped working properly.

Pitot probes are outstanding important devices. The air enters into a thin tube and pushes against a dynamic pressure sensor, allowing to measure the air flux speed. Since they are continuously weather-beaten and must work in the cold of high altitudes, they are equipped with an heating system (independent from those already mentioned) to avoid freezing. However, the low performances of the model equipping F-GZCP, the Thales AA, had already caused some incidents, fortunately without heavy consequences. Air France, indeed, started the substitution of this kind of Pitot on its A330/340 fleet only few days before flight 447 was airborne [(1)].

CAS and Mach number are the main speed parameters used by both the pilots and the aircraft flight control systems. They are elaborated by three computers, the ADIRU, each of them consisting of:

- An ADR module, calculating the dynamic parameters like CAS and Mach number;
- An IR module, returning data from inertial units, as ground speed and attitude.

Simplifying, the "Captain Pitot" (left side) inputs the ADR1; the "First Officer Pitot" (right side) input the ADR2, and the "Standby Pitot" (left side, under the Captain's) inputs the ADR3. They

allow total pressure calculation, that is static pressure plus dynamic pressure, from which the air speed can be derived. This last in the ADRs is further integrated with other parameters furnished by the static probes and the temperature probes, then is summed to data coming from the inertial systems (IR) allowing the calculation of vertical speed, ground speed, load factor et cetera (Fig. 2).

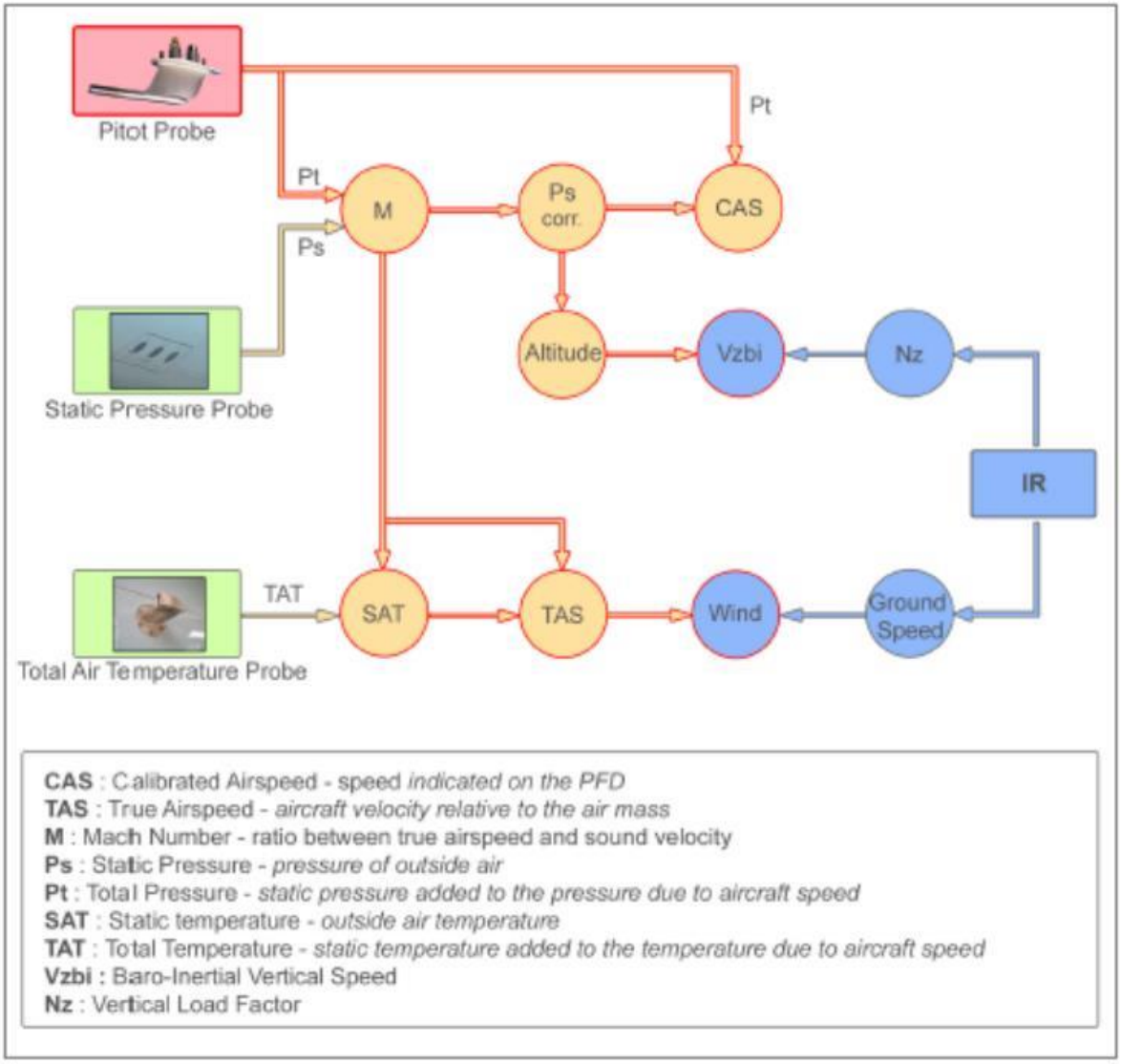

Figure 2: Processing of speed and other parameters in the A330 (BEA, Final Report on Flight 447)

It should be noted that *Pitot probes data are used also in the elaboration of altitude*. Data from ADRs are used by many fundamental A330 systems:

- The Fly-By-Wire system
- The thrust control system
- The Flight Management System (FMS)

- The Ground-Proximity Warning System (GPWS)
- The transponder
- Slat and flap control system

ADIRU data are sent to other computers, named "concentrators". An Airbus has three main concentrator (PRIM) and two secondary concentrator (SEC) computers, with different duties:

- To process the orders sent to other computers (for example those moving the ailerons and the elevators) in dependence of pilot or autopilot inputs;
- To execute orders coming from other computers, checking them iteratively (servo-looping).

One of the PRIMs is chosen as main, or "master", and it decides/checks the coherence of all the others. At the top of this electronic pyramid, two Flight Management Guidance and Envelope Computers *(*FMGEC) process all data from PRIM and SEC in order to supervise all mobile surface movements, elaborate the autopilot function and activate the protections that keep the plane within its flight envelope.

A modern liner jet is something incredibly complicated, requiring years of study to learn how to handle it. In such an highly automated aircraft, computers are fundamental for its correct functioning, even when the autopilot is disconnected and the plane is flown manually.

But computers need good input to work correctly. The loss of data from two Pitot probes is a critical problem. The loss of all three Pitots is a disaster.

Without CAS, the autopilot can no longer perform its job.

It's 02:10:05Z. In the FCU the Master Warning pushbutton lights up in front of the two pilots, and at the same time the *Cavalry Charge* calls out for autopilot disconnection. In the central Electronic Centralized Aircraft Monitoring (ECAM) screen, where all the messages on airplane system state are shown, the related red writing - AUTO FLT AP (*Auto-Pilot*) OFF – appears.

Surprise is big. Before reading any instrument Pierre reacts rapidly by pressing the pushbutton on his sidestick to gain manual control, announcing:

-02:10:06. Pierre: J'ai les commandes. (I have the controls.)

-02:10:07. David: D'accord. (Ok.)

On the PFDs the CAS varies, becoming inconsistent, senseless and in continuous fluctuation: 270 knots…95 knots….70 knots….110 knots….

In the urgency of the unexpected situation, the pilots do not notice it immediately. On the CAS stripe the indications of maximum operational and stall velocities - normally always presents – disappear, replaced by the red sign SPD LIM (Speed Limit), indicating the loss of these references. In few seconds the Mach number decreases below 0.5 and is not visualized anymore. In full turbulence and without autopilot correction, the plane banks to the right of about 7 degrees.

The tension for Pierre suddenly rises. He has to pilot by hands following only the instruments, at night and in the middle of a storm, without any visual reference, at that altitude and with the airplane in failure: something he never tried in a flight simulator…

-02:10:09. Pierre: *Ignition Start.* *(Ignition Start.)*

He orders David to activate the igniters, while engaging in flying the plane: his right hand on the sidestick, the typical Airbus lateral mini-yoke; his left hand on the thrust levers.

David do not execute his order. In the startle maybe every one is sure the other did it, and they do not cross check. Various fault messages start appearing in a sequence on the ECAM screen, indicating the lock of thrust (ENGINE THRUST LOCKED) and the progressive degradation of the automatic flight systems: each of them is accompanied by an identification "gong" and by the flashing of the Master Caution light in the lateral section of FCU.

Flight Director (FD) indications on the PFD disappear. This particular electronic function looks like a viewfinder: a green cross that should be centered in a given position on the artificial horizon to maintain the programmed flight trajectory. And it is, obviously, generated by the computers.

However, there is something on the display that should have captured Pierre's attention, making him pull the stick while contemporaneously correcting the roll, to the left then to the right.

The altimeter is descending: 34950 feet….34700…34600…The variometer indicates a negative rate. Also the altitude alert - called *C-chord* and signaling that the plane is not anymore at the altitude it was programmed for - starts horning at 02:10:09: an exasperating sound that will accompany the pilots until the end, intermixed with many other warnings.

The entire world called out for scandal on this initial maneuver apparently devoid of an explanation. On the contrary, the explanation does exist, and it's that the loss of anemometric data in the ADR caused an "apparent loss" of altitude. It's just instrumental and not real…but Pierre unfortunately does not know it. And the first reaction to the beginning of a descent is to pull slightly the nose up.

Here in the thin and less dense high altitude air every movement is amplified, and the plane just automatically entered in a deceitful flight mode. Input on the sidestick must be light. Not used to manual aircraft handling in cruise, the PF initial inputs are accentuated. The A330 starts climbing: the angle of attack (measured by three probes), previously 3.2 degrees, slightly increases as a combination of the pitch up command and the strong updraft.

Pierre did not receive any training for manual airplane handling at great altitude. Moreover, he has no reaction from the sidestick indicating the amount of force applied - as a consequence of the movements of this terminal element of the long chain of fly-by-wire commands - by the hydraulic actuators on ailerons and elevators. A questionable choice of the manufacturer…

In few seconds, at 02:10:10, the angle of attack overpasses the limit of 4.9 degrees, a threshold that is very low at high altitude. An unsettling and truncated warning silences all the others, ringing out twice in the cockpit.

Stall!... Stall!...S…

David, PNF, is concentrating on deciphering the ECAM messages, and is surprised. The Master Warning light flashes again for two seconds.

- 02:10:11. David: ...Qu'est-ce que c'est que ça?! (What is this?!)

Then, stall warning ceases. Its transient and truncated activation at the beginning of the accident sequence probably highly contributed to be judged meaningless by the pilots. This warning gets activated in dependence of the angle of attack and the Mach number. The pilots didn't notice the unreliable airspeed yet and the fact that the plane had switched to a different flight mode. Normally, an Airbus can't stall: it's written on manuals….other crews - tells the BEA – also did not take into consideration the stall warning in case of problems at cruise altitude, but were so lucky to be able to tell it.

Thanks to the short activation of the stall warning, both pilots look at the anemometer.

- 02:10:14.Pierre: On n'a pas une bonne...on n'a pas une bonne annonce de…(We don't have a good…we don't have a good display of…)

- 02:10:15.David: Mince, on a perdu les, les…les vitesses, alors…(Well, so we've lost the, the…the speeds)

- 02:10:16. Pierre: …de vitesse.(…of speed)

At this moment, David pays attention to a couple of very important ECAM messages:

- 02:10:17. David: ...Engine thrust ATHR. Engine lever thrust… (...Engine thrust ATHR. Engine lever thrust…)

The auto-thrust (ATHR) does not work anymore. The levers are locked in the position they were before autopilot disconnection, and must be unlocked and controlled manually to regulate the engine power.

Pierre, iper-concentrated on flying the aircraft, barely hears his colleague:

- 02:10:21. Pierre: Engine lever…?(Engine lever…?)

The strong turbulence, shifting between 0.8 and 1.6 g, makes the reading of instruments difficult and the piloting imprecise. The CAS on the right PFD has the absurd value of 90 knots, too low to be true. The anemometer has gone – thinks Pierre while focusing on altitude, that is rising. He keeps on countering the roll, due to the fury of the storm but also amplified by his commands, that are still too rough.

At 02:10:22 they "re-gained" 35000 feet and pitch-up inputs cease. But now the plane is climbing: the variometer indicates a very high ascending rate - 6100 feet per minute – and the *C-chord* starts horning again.

- 02:10:22. David: Alternate law...protection lost (Alternate law...protection lost)

Since autopilot disconnection, the A330 had switched to "Alternate law". Airbus computers can fly the plane according to three main modes, or laws. The first is called Normal law, and is by far the most commonly active one during a flight. When in Normal law, everything is ok and all flight and control systems are working properly to keep the plane within its flight envelope; in fact, this law furnishes protections which prevent brisk and/or too large movements on the three axes, impeding the plane to assume unusual and/or dangerous attitudes. Every input from the pilot is processed by the computer and, possibly, rectified.

However, when some data are missing, the protections cannot be generated and different flight modes get activated: the Alternate Laws, in which some protections are still functioning but others are lost, or the Direct Laws with no protections and with mobile surface displacements directly proportional to pilot inputs. Depending on the kind of failure, Alternate laws can maintain pitch protections acting on load factor, excessive speed or high angle of attack; on the contrary, roll movements are directly proportional to pilot inputs like in Direct Law, with a rate reaching 25 degrees per second.

In the worst cases, such as when air data are unavailable, also high speed and high angle of attack protections get out of order. The investigation established that F-GZCP had switched to Alternate Law 2B until the crash. Among the alternate laws this one is the most degraded, and gets activated only in the extremely unlikely occurrence of all three ADR disagreeing. Stall warning is the only indication left for a loss of lift. Airbus planes, in fact, are not equipped with a stick-shaker (the yoke vibrating at critical angle of attack) nor with a stick-pusher (the yoke pushing forward to reduce the angle of attack and counter the stall).

Now both pilots know they are in Alternate Law: it's written on the ECAM and on PFD. At the sides of the artificial horizon the small green lines indicating pitch and roll protections have disappeared, replaced by amber crosses. What is not sure is if the pilots were aware of all Alternate Law restrictions, and it's certain that they did not know which one of the Alternate Laws had come in: *no messages or instruments tell this*. It's astonishing. The existence of mixed human-computer flight modes is in itself crazy and, even if the possibility for the plane to switch into Alternate Law is remote, it's at least necessary to let the crew know which one of these modes the automatic system had to choose! We don't have predictives in the cockpit.

It's clear what Airbus share with other big plane manufacturers: the project of creating, in a near future, planes flying by themselves, totally devoid of human pilots….

A second later Pierre unlocks the thrust levers, leaving them on Climb (CLB), as previously set by the Auto-Thrust system, which automatically regulate engine power in dependence of autopilot or pilot maneuvers. His sidestick is in neutral position. On both PFD the speeds are still meaningless (Fig. 3).

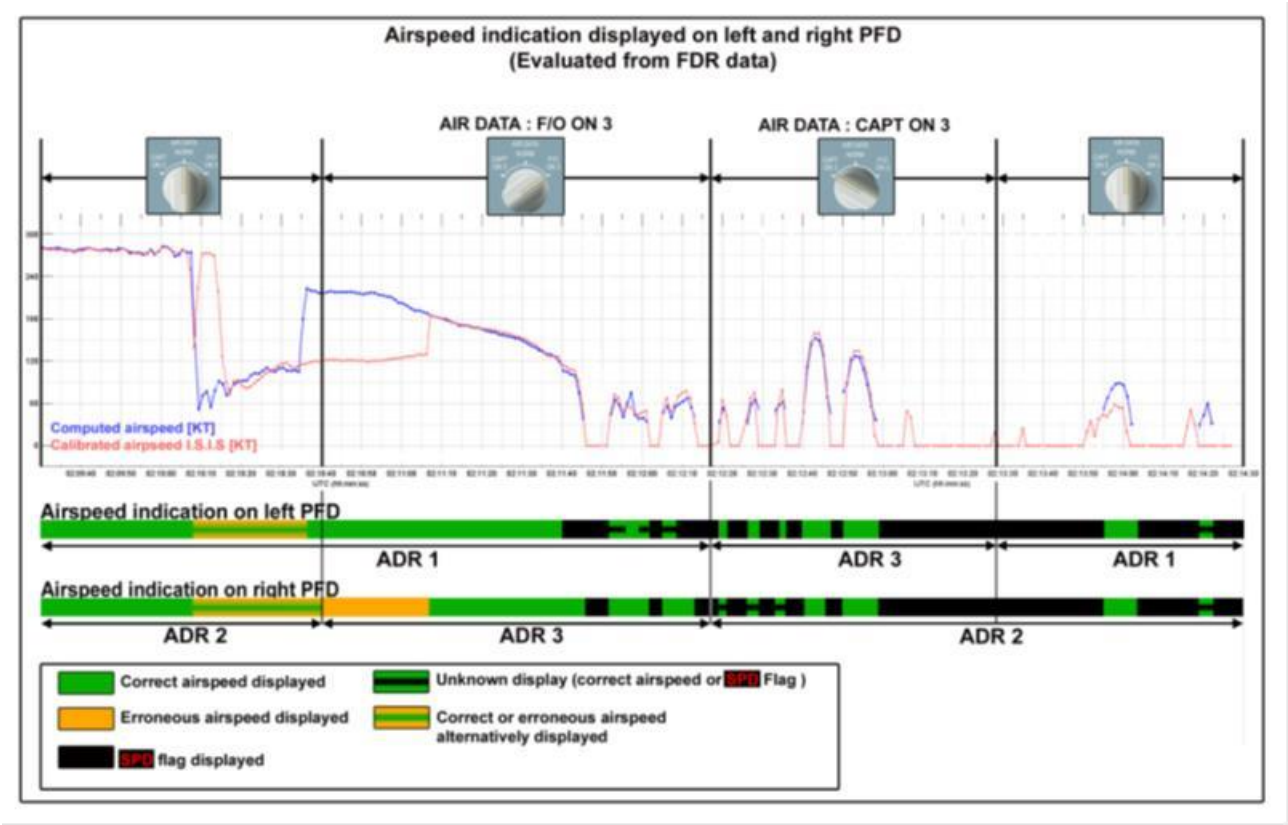

Fig. 3: Airspeed indications on PFD as reconstructed by the BEA (BEA, Final Report on Flight 447)

- 02:10:24.David: Attends on est en train de perdre…(Wait we are loosing…)

What David means here? Maybe he is noticing the decrease of engine thrust. N1 is decreasing since 02:10:08, and went down to 84% at 02:10:22 without any external intervention: the Auto-Thrust was still on and, since autopilot is lacking, it follows the FD indications, when present. However, very soon he concentrates on something else.

- 02:10:25. David: Wing anti-ice! (Wing anti-ice!)

He activates the wing de-icing system. He probably guessed that ice had something to do with the loss of airspeed indications, and fears its formation over the wings. His attention runs feverishly from one display to the other trying to figure out the origin of the problem, but he still cannot find a solution. As PNF, he should concentrate on troubleshooting but also on monitoring the flight path and its correct maintenance.

Many things all together, he is not used to. The tension for him is high, they spent so many hours on flight simulators, but no simulation comes even close to the reality they are experiencing; no training session can give the idea of the heartbreak of finding yourself in an emergency that you are not able to fully understand.

Other coded messages appear on the ECAM, indicating that nor the rudder range limiter nor the TCAS, the anti-collision system, are any more active. The sequence seems to indicate a series of multiple failures, but no information allows to determine the exact origin of the problem. Immediately after David notices what altimeter and variometer are saying. This last instrument indicates 6900 feet per minute! They are climbing at an unthinkable vertical speed, it can even be felt as a disturbing pressure at the ears.

- 02:10:27.David: Fais attention à ta vitesse...fais attention à ta vitesse! (Watch your speed…watch your speed!)

He warns Pierre, who immediately realizes what his colleague means. The airplane overpasses 36000 feet in that moment. The FD, reappeared at 02:10:26, tells to lower the nose.

- 02:10:29.Pierre: Okay, okay okay: je redescends. (Ok, ok, ok: I go back down.)

Pierre readily commands a series of pitch down inputs, always trying with difficult to counter the roll, as the A330 still roughly swings from one side to the other.

- 02:10:30. David: Tu stabilises…(Stabilize)

- 02.10.31. Pierre: Ouais.(Yeah.)

- 02:10:31. David: Tu redescends. (Go down.)

David insists, he is pressing. The CAS is 100 knots in that moment. It's still too low, and it's clearly fake….it must be fake….but all other instruments, are they trustable?

The variometer decreases to 5600 ft per minute: attitude goes down to 10 degrees at 36850 ft. Moreover, at 2:10:31, the airplane keep bending leftward, up to a maximum of 9 degree. Pierre counterbalances the roll with lateral commands in the opposite direction, event within a certain range, up to about a middle way to stop, and maintains nose down inputs. The altimeter however still indicates they are climbing, as well as the variometer, even if the vertical speed ratio is reducing: 5000… 4000… 3000 ft per minute. The airplane is still climbing up, damn it!

The cockpit is like a Christmas tree, full of intermittent lights, *C-chord* sounds continuously and saturates the environment, mixing up with the noise of the ice hitting the windshield. The turbulence makes the plain sinking and the storm gusts are so strong to make that heavy metal creature swing within the obscurity of the clouds. Passengers and cabin crew surely start feeling uncomfortable.

Now, from few seconds on, the Flight Director indications are changed and suggest nose-up commands. The system in fact has been reactivated following a modality different from the previous one. Another technological trap. The crosses of the flight director indicate as target on the horizontal plain the heading (HDG) with respect to the magnetic North, but the target on the vertical plane could be decided by the computer following different parameters: the foreseen cruise altitude (in modality ALT CRZ), or a preset vertical speed (modality V/S). In contrast to the previous condition, now FD is activated in V/S and tells to the pilot how to reach a vertical speed target of 6,000 ft per minute: an insanity.

FD modality is indicated on the Flight Mode Annunciator (FMA), located in the upper part of the PFD. In the midst of the emergency the two pilots do not think to watch it. Pierre's attention is attracted by the FD and he hesitates few seconds: he should go down to come back to FL350 (accordingly he is pushing forward the sidestick); but now the "flight director" is asking to nose up! In the uncertainty he still maintains pitch down commands.

David crosschecks continuously the two PFD and the Integrated Stand by Instrument System (ISIS).

- 02:10:32. David: On est en train de monter, selon lui…..Selon les trios tu montes, donc tu redescends. (We are climbing, according to him…. According to the three you are climbing, so go down.)

- 02:10:35. Pierre: D'accord. (Ok.)

The PF commands a nose-down input almost to the stop. The rolling is nearly under control but the nose doesn't lower too much: it remains about 8 degrees over the horizon, as consequence of the machine torque of the engines, increased after Auto-Thrust disconnection.

At 02:10:35 the altimeter touches 37000 ft. David's voice and behavior betray all his restlessness.

- 02:10:36. David: T'es à …redescends! (You are at… go down!)

- 02:10:37. Pierre: C'est parti, on redescend. (It's starting, we are going down)

- 02:10:38. David: Doucement! (Gently!)

It is not clear why David is so apparently brisk with Pierre. It may be because by the nose dive is causing an unpleasant negative g acceleration (-0,7 g) or because he doesn't see what Pierre is doing with the commands. Pierre is doing exactly what he was told, but David cannot perceive it directly: Airbus sidesticks are devoid of interconnection, and they are placed in a lateral position that prevents to see what the other pilot is doing. In the comprehensible stress, David gives unclear indications to his colleague and, perhaps, almost frightens him. Pierre should be in charge of the fight, but the awareness of the larger experience of the PNF and the heartbreak for the unforeseen has caused an inversion in their hierarchy.

Under the action of their heating system, or just because the icy cap detached at last, First Officer and Captain Pitot probes are coming back to work. At 02:10:35, the CAS on the right PFD jumps to 220 knots: it's the right value and, with respect to the initial speed of 282 knots, it's consistent with the climb the airplane is doing. But the pilots have no chance to know if this value is correct. Nothing indicates that the Pitot are now functioning correctly and that the CAS on the PFDs is trustable; moreover the Standby Pitot is still out of order and indicates 116 knots. Who can believe that he speeds recorded on PFD do make sense?

How can the airspeed be fixed? David doesn't understand the real nature of the problem, and he doesn't receive any message or indication from the onboard computer system allowing a correct diagnosis, or suggesting the right procedure to follow. He realizes that Pierre is in a tight spot and in an urgent need of trustable data. He probably has a feeling that something is wrong with some of the ADRs and thinks, wrongly, that the Standby ADR should be the reliable one.

At 02:10:38, without discussing with his colleague, David changes the source of anemometric data on the right PFD and connects it to the ADR3 by rotating the dedicated control knob just little above the engine levers. The BEA hypothesized that he has been influenced by the memory of other procedures recommended in case of ADR malfunctioning or ice formation.

- 02:10:39. David: Je te mets en, en ATT heading (I put you in, in ATT heading)

In addition, he rotates the ATT/HDG (*Attitude/Heading*) knob on F/O ON3 position, and that of FM on "BOTH on 1". The first operation changes the source of attitude and heading inertial data in the right PFD, taking them from the Standby IR3; the second operation transfers FMGEC1 parameters to the right EFIS multifunctional screen.

Unfortunately, picking up the data from the ADR3 makes the situation even worse, prolonging the inconsistency of airspeed on the first officer PFD. The Standby Pitot in fact will be the last to deice, and it is still not working properly.

Pierre watches the CAS on his PDF instantly dropping to 121 knots, increasing the misunderstanding of both pilots. The FD indications disappear again. David feel a shrinking to the stomach, looking at the result of his action:

- 02.:0:41. David: ...Qu'est-ce que c'est que ça?? (….What??)

It's probable that this further failure disorients him even more. Pierre, from his side, still doesn't understand what is going on. David didn't tell him his strategy, and did not motivate the changes in the data source; he didn't explain what's in his mind. Pierre is aware that David has more experience and hopes that his senior colleague should be able to get out of the bad situation.

Why the pilots did not choose to follow the "*IAS douteuse"* procedure (the so-called "Unreliable Airspeed Indication/ADR check procedure")? Why didn't they grab the emergency procedure handbook (*Quick Reference Handbook*) and look for the unreliable anemometric data check-list? In There is a procedure for everything in the world of aviation. The answer can be found in their incomplete training programs. *IAS doteuse* is an emergency procedure they have been trained in the flight simulators only for the takeoff, never in cruise. Their formation is incomplete, since a case like this was considered highly improbable. At the 1st of June 2009, Air France had already recorded various cases of temporary loss of airspeed in cruise but, notwithstanding, the Company had not developed specific training programs. Only a general advice had been distributed to the personnel, with vague indications and descriptions, without stressing sufficiently the gravity and the recurrence of the Pitot problem.

The mistake the pilots do, however, resides in their lack of communication: they do not discuss any hypothesis and do not share any troubleshooting strategy; they almost do not speak, and when they do, they speak in a way not comprehensible to the other. They do not join in a common effort for understanding and solving the situation. The Crew Resource Management, art and technique of working asa team, so important in aviation, seems to have been erased from their brain.

Despite the numerous pitch-down input by the PF, the plane doesn't descend. The pitch attitude is still decreasing, but only slightly. It is now 7 degrees, and the altimeter still indicates a climb: they are at about 37300 ft.

Without knowing its real speed, the PF tries to make the plane loose altitude by reducing the engine power. He loudly checks the engine setting:

- 02:10:42: Pierre: On est en… ouais on est en Climb… (We are in… We are in Climb…)

Then he pulls back the levers to two third of the range IDLE-CLB (between "minimum push" and "climb"). From neutral position, his sidestick passes to slightly nose-up. Perhaps he does this unconsciously or automatically….. or maybe something on the PFD leads him to the mistake. FD is in fact back on PFD, in V/S (*Vertical Speed)* mode, with a target of +1400 ft/min. Its indications are fluctuating: they initially suggest a slight nose-up, then they change, indicating a slight pitch-down and finally they ask to nose-up again. The N1 of the engines decreases to 85%.

At 02:10:46 David tries to shut down the *C-chord* that is drilling his ears, but pushes the wrong button. His stress overflows: he does not understand what is happening, and he is not at the commands. He raises his hand to trigger the call for the Captain in the sleeping compartment. They need help.

- 02:10:49: David: Putain il est où, euh?… (Fuck, where is he?)

Reducing the engines, a small airplane would have started to go down quickly, but the F-GZCP is a baboon of more than 200 tons and has a terrible inertia: variations in the engine power have an effect with several seconds of delay. The altimeter is still rising: 37350…. 37400… The vertical speed decreases to 1000 ft/min.

The angle of attack increases slightly, almost to 6 degrees. At 02:10:51 a new warning screams in the cockpit, totally flooring both pilots.

Stall! Stall! This time followed by a particular and nasty jingle, the *cricket*, similar to the cricket call at least in the twisted fantasy of its creator. It will go on ringing for about a minute, continuously.

David, astonished, pushes again the button to call the Captain, cursing.

- 02:10:54: David: Putain!! (Fuck!!)

Pierre starts losing clarity of thoughts, most probably for the nonsense of the situation and for the fear that is reaching him. Destabilized by the warning and confused by the FD, his inputs initially are a mixture of pitch-up and pitch-down inputs, but the firsts are more frequent, up to middle way of the *sidestick*. The angle of attack keeps increasing.

Stall! Stall!...Crrrk Crrrk Crrrk!

The volume is so high, that the alarm could be heard even outside the cockpit. Several times the hostesses call at the interphone.

The two pilots don't take notice of them. They are so focused and incredulous that they don't understand what is going on even when the plane starts shacking rhythmically. They still think it's the turbulence, but outside the fury of the storm has diminished and this shivering is due to the *buffeting*: the thin layer of laminar air that slips over the wings sustaining the plane starts detaching and sticking again, and the lift is no longer regularly generated. It's the typical phenomenon of the beginning of a stall.

Pierre struggles to stay calm. Thinking that the stall warning got activated because the engine power has been reduced (and perhaps unconsciously wishing to climb over the cumulonimbus), he announces:

- 02:10:56: Pierre: TOGA! (TOGA!)

Then he pushes forward completely the engine levers to the maximum thrust, that used for takeoff and go around (*Take Off/Go Around*).

Full power to the engines tends to further augment the pitching up of the plane. The push can be felt but it is strange: it goes in and out of phase with the buffeting, and the two phenomena mix up together providing unusual and illusory sensations. The A330 is a giant painstakingly rearing up, trying to escape the darkness of the clouds in a night devoid of stars.

In five seconds the pitch attitude passes from 7 to 15 degrees, swinging rhythmically. The roll is feeble, always counterbalance by the PF. The plane keeps on climbing, touches 37700 ft, and its vertical speed increases again up to 2400 ft/min.

Stall! Stall!...Crrrk Crrrk Crrrk!

Pierre – eyes stacked to the instruments and all senses alert –surely perceives those strange movements of the plane. The speed read on his display is about 125 knots, and increasing. He judges it unreliable (actually the Standby Pitot, still feeding his PFD, is de-icing in this very moment), but he notices that the "speed trend" indicates a strong acceleration. This other automatic function (reappearing just in these instants on the screen because ADR 1 and 2 started recording again similar and rapidly increasing speed data) provides an estimate of the plane acceleration and suggests at which speed it will fly after 10 seconds. He is confused and – most probably as a consequence of the vibrations and the sensation of sudden acceleration, together with the speed trend indications – in is mind arises a hypothesis: the plane is near to enter an *overspeed*, that is to overpass its maximum structural speed. At night, without visual references and trustable instruments, the physical feelings betray completely.

David doesn't know anymore what to do: he keeps ringing the bell in order to wake the Captain, and will do it several times in the following minutes.

- 02:11.00. David: Surtout essaye de toucher le moins possible les commandes en… en lateral, hein! (Overall try to touch the commands as less as possible in… in lateral, eh!)

Actually Pierre never reached even half of the sidestick lateral excursion, but the resulting roll oscillations should have been quite abrupt. Nose up and pitch down inputs keep alternating, but

the plane will react less to the latters, while amplifying the formers. Since tens of seconds, in fact, the trimmable horizontal stabilator (THS), previously almost flat (-2.8 degrees), started lowering progressively: in a minute it will get to -13.5 degrees, thus greatly contributing to maintain the plane in a pitched up position. It's one of "alternate law" automatisms: the computer records more nose up than pitch down inputs, and "thinks": do you want to climb? I'll help you… Unfortunately it is not signaling this. The *trim* (fine regulator of the flight commands) is manually controlled by a vertical black and white wheel located just below the engine levers. But when the computer is moving it, the movement is slow and silent, and the crew may not perceive it.

Stall! Stall!... Crrrk Crrrk Crrrk!

Stall! Stall!... Crrrk Crrrk Crrrk!

David also does not believe to the alarm screeching continuously. Neither of the pilots mention it and they will not speak for several seconds. The dismay has taken over this two young men, who do not understand the reactions of a plane considered as one of the safest worldwide. The cockpit is a visual and audial mess, the Master Warning flashes continuously, the ECAM cranks out messages in a computer undecipherable language. None of the three is able to communicate; nor Pierre, who is desperately trying to fly the plane, but on the basis of a wrong diagnosis; nor David, more expert but perhaps more fragile, overtaken by anxiety; nor the plane which however, in its own way, is screaming for help.

The PF does not understand why the warning doesn't stop. "Have I the maximum thrust?" he is thinking loudly, while checking the indication on the sleeve along the thrust levers.

- 02:11:03. Pierre: Je suis en TOGA hein? (Am I in TOGA, eh?)

David is only wishing that the Captain will arrive soon. Now the two pilots are completely disconnected one from the other.

- 02:11:06.David: Putain il vient ou pas?? (Fuck is he coming or not??)

The angle of attack passes 10 degrees; the nose is 17 degrees over the horizon, the rolling is still mild. Under the action of its powerful turbofans, the A330 climb again for few tens of meters, up to the maximum altitude of 37920 meters and then it slows down… it slows down as the engines are no longer able to push (propulsion ceiling); it still move forward thanks to its inertia, while the lift is fading completely. The last sequence of buffeting shakes the plane, its last desperate attempt to hang on the air who is no longer able to sustain it.

Then, at 02:11:14, the it starts sinking, beginning a long and inexorable fall in the void[(2)]. The variometer goes to 0, then it rapidly starts indicating negative values.

This causes a new change in the FD that, having a V/S target of 1400 ft/min, now that the variometer is negative starts indicating the needs for a strong nose-up input. From 02:11:14 to 02:11:40 the green cross on the PFD positions itself first to 10, then to 15 and at the end to 20 pitch-up degrees. Persuaded to be close to overspeed, and without noting the *Flight Director*

mode, Pierre tries to follow these indications with progressive nose-up inputs. A fatal error, totally induced by a technology that should prevent the pilots to make mistakes…

Here is the reconstruction of the FD orders, according to BEA:

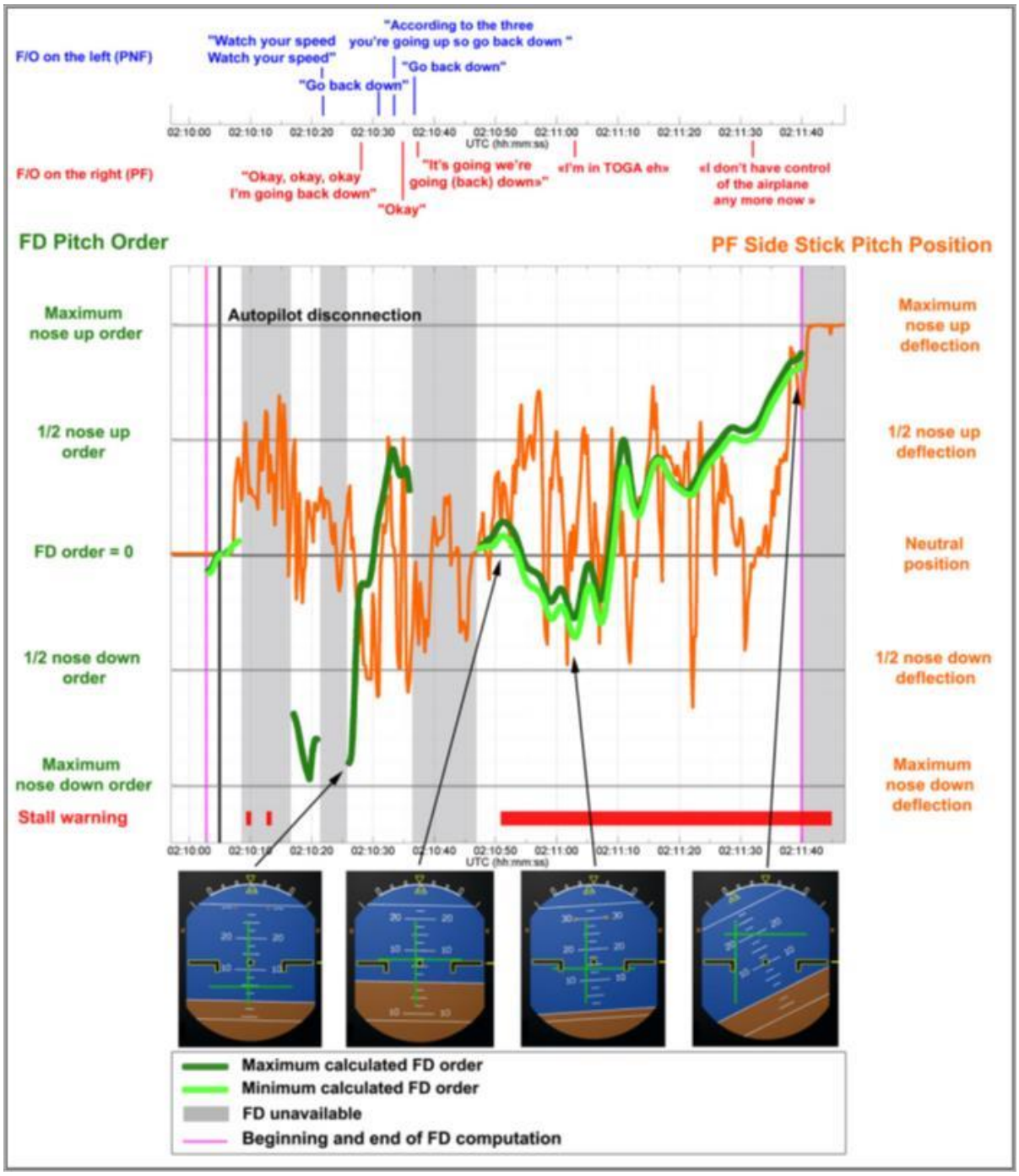

Fig. 4: Reconstruction of FD orders from 02.10.00 to 02.11.40 (BEA, Final Report on Flight 447)

Stall! Stall!... Crrrk Crrrk Crrrk!

Stall! Stall!... Crrrk Crrrk Crrrk!

-02:11:20. Pierre (?): (Trop?) vite? (Too fast?)

-02:11:21. David: On a pourtant les moteurs! Qu'est-ce qui se passe, bordel?! (But we have the engines, what the hell is going on?!)

David doesn't understand why altimeter and variometer indicate a descent with full working engines. Prey of the spatial disorientation, perhaps he doesn't trust not only the anemometer, but also all the other instruments. He notices the FD indication, but he cannot see the movements his colleague is doing on the sidestick; maybe he sees the attitude increment but he thinks it is correct. In the mess of thoughts crowding his mind, the only real thing he is practically doing is to call the Captain.

Stall! Stall!... Crrrk Crrrk Crrrk!

Stall! Stall!... Crrrk Crrrk Crrrk!

- 02:11:24. David: Tu comprends ou pas ce qui se passe??(Do you understand what is going on or not?)

He is asking while pushing again the *high-low chime* bell. Pierre doesn't answer. It's clear that he is frightened too, and that he isn't sure at all of what should be done. Most probably he does know either which instruments can be trusted. He is trying to follow the FD indications hoping that, since they re-appeared on the screen, this means that the computer is able to elaborate them and that they are correct.

In the Unreliable Speed Indication check-list one of the first points to follow is to disengaged the FD, since the wrong speed indications may lead to visualize senseless instructions. If only they could have understood they had to use that procedure!! A simple and cheap device signaling the blocking of Pitot probes on the ECAM would have been enough….

Stall! Stall!... Crrrk Crrrk Crrrk!

Stall! Stall!... Crrrk Crrrk Crrrk!

The plane is now fully stalled: it is falling down with a speed of -5200 ft/min, and the altimeter becomes a dreadful countdown. At 02.11:24 the CAS is 130 knots, equal on both on both PFD and rapidly decreasing. The standby probe is de-iced, too, but how can they know?

At 02:11:27 the A330 abruptly tilts more than 10 degrees toward the right, and Pierre decisively contrasts the rolling that is increasing. His efforts however don't give any results: now also the commands seem ineffective. The Mach number disappears again; the engines are delivering maximum power, the FD is still asking to nose-up as much as possible, while the trimmable horizontal stabilator goes on moving and surpasses 10 negative degrees.

A loud aerodynamic noise - perhaps similar to the howling of the wind – wraps up the cockpit and outside the densest darkness tightens the plane in a claustrophobic grip.

- 02:11:32. Pierre: Putain j'ai plus le contrôle de l'avion là! (Fuck, I lost control of the plane!)

- 02:11:34. Pierre: J'ai plus du tout le contrôle de l'avion!! (I completely lost the control of the plane!!)

His words are a terrible sentence.

Stall! Stall!... Crrrk Crrrk Crrrk!

Stall! Stall!... Crrrk Crrrk Crrrk!

- 02:11:38. David: Commandes à gauche!(Controls to the left!)

He says pushing the red bottom on his sidestick, to take the priority. The green light indicating the passage lights on.

David also tries to counter the roll giving an input to the left at the maximum range and nosing up slightly. But the plane answers collapsing even more to the right, more than 25 degrees. The angle of attack now exceeds 30 degrees. The FD disappears again from the display.

After few seconds, unwillingly, Pierre takes back the flight priority. It might be speculated that he does it because he looks at David and realizes that he is in an unfit position for flying the plane. As verified by the investigation, the left seat was completely pulled back, in the position used to go out.

In that moment someone is entering the cockpit, unlocking the armored door. The Captain is finally back.

The PNF doesn't notice that Pierre took over the priority and that his sidestick is deactivated. He gets the impression that the machine does not respond to his command, and exclaims incredulous and hungry:

- 02:11:41. David: Putain on est où? C'est quoi là?(Shit, where are we? What is there?)

Stall! Stall!... Crrrk Crrrk Crrrk!

Stall! Stall!... Crrrk Crrrk Crrrk!

- 02:11:41. Pierre: J'ai l'impression qu'on a une vitesse de fou… (I feel we have an incredible speed…)

Apparently the PF did not change the sidestick position from that set up seconds before in the following of FD indications, that is maximum nose-up and to the left. This input will be maintained for the next 40 seconds.

Stall! Stall!... Crrrk Crrrk Crrrk!

At this point, it is conceivable that the stress took out almost completely Pierre and David's reasoning capacity. The background noise is very loud and, together with the stall warning, it makes it difficult to even hear Marc's steps behind them. The Captain well understood that something wrong is going on and he shouts briskly:

- 02:11:42. Marc: Ehi, qu'est-ce qui se passe? Expliquez-moi ce qui se passe!! (Hey, what is going on here? Tell me what is going on!!)

- 02:11:43. David: Qu'est-ce qui se passe? Je ne sais pas…je sais pas ce qui se passe!! (What's happening? I do not know… I do not know what's happening!!)

David's voice is full of anxiety. Pierre fears the overspeed and moves slightly backward the engine levers, first on MCT (*Max Continuous Thrust*) and then on CLB.

The nose of the plane went slightly down to 12 degree of pitch, but the angle of attack has overtaken 35 degrees. The air flux is too much inclined with respect to the Pitot tubes and it doesn't enter properly; furthermore, such a high incidence causes an additional air flux entering the static probes, thus erasing the difference between the pressure measured by the static and the Pitot probes. And the Airbus computer system cannot work with such extreme data. If the airspeed is feebler than 60 knots, the FMGEC1 - that is the mainframe fed by all the other computers, including the ADIRU - assumes that the plain is not flying anymore and the CAS will no longer be displayed. If the angle of attack is greater than 35 degrees, it is discharged because the computer considers it as unreliable and, paradoxically, the stall warning will deactivate, immediately replaced by the *C-chord*.

- 02:11:45. Pierre: On perd le contrôle de l'avion là! (We are losing control of the plane!)

- 02:11:46. David: On a tout perdu le contrôle de l'avion…. (We completely lost the control of the plane …)

Under the astonished sights of Pierre and David, the CAS on both PFD suddenly disappear, and the indicator stripes become black. The analogical anemometer of the standby instrument goes to zero. From here on the airspeed will be fleetingly visualized only for few seconds, when it will accidentally exceed 60 kt.

The stall warning stops. Marc moves forward gripping on the central seat, since in that moment the plane brutally rolls even more to the right, with an angle close to 40 degrees.

- 02:11:47. David: …On comprend rien…on a tout tenté… (…We don't understand anything… We tried everything…)

This sentence is like a fist in the stomach of the Captain, who sits with difficulty and stares incredulous at the instruments. The altimeter indicates a rapid descent: 34300 ft…, 34000 ft… 33800 ft…. The variometer is at its negative maximum; CAS, Mach number and FD are lost. Less than a quarter of an hour has passed since he left the cockpit and everything was quiet. Now it's the chaos.

Pierre moves the engine levers to IDLE. The engines torque decreases, the nose quickly sinks of 25 degrees, notwithstanding the pitch-up commands, and the plane starts rolling rapidly: in seven seconds it banks 10 degrees to the left and then suddenly to the right, to stay inclined on this side of 15 degree. In ten seconds the N1 goes from 103% to 58%.

Marc watches breathless the values on the Captain's PFD, then on the First Officer's… they seem to match. Then he looks at the *standby* instruments: they are smaller and analogic; he shrink the eyes to better scan them in the half-darkness of the cockpit. Are they concordant?

- 02:11:50. David: Euh... (Euh…)

The first officers are totally confused. He must do something in a hurry, leading them, while trying to understand what's going on.

- 02:11:52. Marc: Alors tiens…prends, prends ça. (So take… take this, take this into consideration)

What is he referring to? Difficult to say. In the third Interim Report the investigators were confident he was indicating the FPV (*Flight Path Vector*),a sort of airplane sketched from the back that, plotted on the PFD, provides an indication of plane attitude and suggests the direction toward which it is moving with those parameters. Nevertheless, in the Final Report it is written that the FPV function has never been selected by the crew.

Stall! Stall!... Crrrk Crrrk Crrrk!

The stall warning re-activated for a couple of seconds, soon after the angle of attack measured by the three probes temporarily decreases below 35 degrees.

David echoes the Captain and insists with the PF:

- 02:11:55. David: Prends ça là, prends ça! (Look at that, look atthat!)

Stall! Stall!... Crrrk Crrrk Crrrk!

- 02:11:57. David: Essaye de prendre ça. (You must take that)

To whatever instrument or indication they are referring to, it seems useless to Pierre.

- 02:11:58. Pierre: Je… j'ai, le problème c'est que j'ai plus de vario là! (I…I have, the problem is that I don't have the variometer anymore!)

- 02:11:59. Marc: D'accord…(Ok…)

- 02:12:00. Pierre: J'ai plus aucune indication!! (I have no more indications!!)

- 02:12:02. David: On n'a aucune indication qui soit valable!! (We don't have any valid indications!!)

The variometer is at bottom scale: in this condition, the indicator is amber in color to sign an anomalous situation and only the small window indicating the hundreds of meters is still running. The instrument in fact hasn't been conceived to visualize values greater than $\pm$ 6900 ft/m, so once this threshold has been passes, the exact rate remains unknown to the crew. Beside the altimeter and the artificial horizon, any other indication on the PFD is lost.

The A330 keeps falling in the void and reaches a vertical speed of -13500 ft/m, swinging the nose up and down, dumb to any command.

Pierre rationality starts leaving place to the physical sensations. You should not trust your sensations if you are flying in the dark: you must trust the instruments. But when the instruments are not working, what's left to do?

-02:12:04. Pierre: J'ai l'impression qu'on a une vitesse de fou, non? Qu'est-ce que vous en pensez? (I have the impression that we have an incredibly high speed, right? What do you think about that?)

He says while putting his left hand on the airbrake lever.

- 02:12:06. David: Non! (Don't!)

- 02:12:06. David: Non surtout ne…ne les sors pas ça! (No, overall….don't extract them!!)

Hushed by the reaction of his colleague, Pierre doesn't ask an explanation and takes them back.

- 02:12:07. Pierre: Non?...Ok…(No?...Ok…)

The angle of attack returns within reasonable values, and the stall warning sounds again for other six seconds.

Stall! Stall!... Crrrk Crrrk Crrrk!

Stall! Stall!... Crrrk Crrrk Crrrk!

- 02:12:09. David: Ne les sors pas! (Don't extract them!)

- 02:12:11. Pierre: Alors on continue à descendre… (So we continue to descend…)

As an answer David pushes the engine levers forward on CLB, and the N1 of the turbofans starts increasing again. Clearly he does not share Pierre's overspeed hypothesis, but he has no alternatives.

- 02:12:12. David: On tire! (Let's pull up!)

He shouts summoning the PF to gain a stable positive attitude. In these instants of incertitude no one knows what to do; not even Marc, who is silently struggling to find an explanation, that that his co-pilots did not provide him. How did they end in such a mess?

The nose, pointing 10 degrees below the horizon despite Pierre had the sidestick all nose up and to the left, rises to flat. The plane stays banked to the right, and this position is resulting in a wide veer that will turn the heading toward Brazil.

- 02:12:14. David: Qu'est-ce que t'en penses? Qu'est-ce que t'en penses? Qu'est-ce qu'il faut faire??! (What do you think about? What do you think? What should we do?)

Asks desperately the PNF while rotating the knobs of the data source and linking the left PFD to the ADR3.

- 02:12:15. Marc: Là, je sais pas! Là ça descend... (Well I do not know! There, we are going down…)

The plain sentence of the Captain is as painful grip to the stomach.

Pierre is the first who tries to react, to do something, to find a way out although he still doesn't understand what is going on.

Maybe he didn't realize he has the priority. He pushes the red button and starts moving his sidestick again, which until few instants before seemed, strangely enough, "stacked". He tries to second the leveling of the plane and to counter again the rightward rolling. He is convinced to succeed, but soon he realizes that his efforts are useless.

- 02:12:19. Pierre: Voilà…Là c'est bon…là on serait revenu les ailes à plat, non il veut pas…(Here it is… It's ok… we are back to wing level, no, no, it doesn't work..)

At this point Marc, continuously crosschecking the instruments, finally becomes aware of a fundamental and terrible thing.

- 02:12:23. Marc: Les ailes à plat…l'horizon…l'horizon de secours!!! (Wings level…. The horizon… the standby horizon!!!)

The three stare at the small colored gyroscopic instrument, and they noticed an inconceivable thing: the pitch angle is different from that displayed on FPDs. This instrument is rudimental with respect to the others, but less prone to mistakes. It indicates a different pitch attitude and, most probably, it's the right one….

A hypothesis that could explain many aspects of this accident concerns how the pitch angle was displayed on the PFD. It is conceivable that the displayed pitch attitude was lower than the real value, maybe as a consequence of a further bug after the computers lost the airspeed data. Unfortunately, the DFDR doesn't record how this angle is displayed on the glass cockpit screens and, after two years in the depth of the Atlantic Ocean, the analysis of the avionic bay would probably not allow to retrieve this information. When could this discrepancy have begun? Impossible to know. However, if something similar occurred, three important facts could be explained: the PF accentuated inputs on the sidestick, the PNF not noticing such a high pitch angle, and a cryptic ACARS fault message indicating problems with the standby artificial horizon (as if its data, true but different from those of the two PFD, had been discarded in the servo looping). Assuming that the value shown on PFDs was about two times – two times and a half of the true value, the previous nose up input would be compatible with those of a pilot struggling to maintain the plane with a pitch attitude of 5-10 degrees. Moreover it's only after the Captain pointed out the standby horizon that everyone starts being concerned about pitch attitude (improperly called going up-going down).

- 02:12:25. David: L'horizon de secours!! (The stand-by horizon!!)

- 02:12:26. Pierre: Ok… (Ok…)

- 02:12:26. David: La vitesse? (The speed?)

- 02:12:27. David: Tu montes! (You are going up!)

- 02:12:28. David: Tu descends, descends, descends, descends!(Go down, go down, go down, go down!)

- 02:12:28. Marc: Descend!(Go down!)

Both co-pilots are astonished and anguished for not having noticed the gap on the artificial horizon before. Now they realize how much such a problem may have deceived them.

The acceleration is back to about 1g or just slightly higher. This unfortunately contributes to further disorientation, because you feel as you are climbing, but actually the airplane is falling down at an incredible speed.

Stall! Stall!…

Stall! Stall!…

The stall warning activates for other two seconds, without cricket (this occurs every time the nose swings downward. When it rises again the stall warning shuts up and the C-chord starts blaring again. It is like an acoustical bombing…)

- 02:12:30. Pierre: Je suis en train de descendre là?! (Am I going down now?!)

He asks angrily while giving a pair of pitch down inputs. Now all pilots are focused on pitch attitude.

- 02:12:31. David: Descend! (Go down!)

- 02:12:32. Marc: Non tu montes là! (No, you are going up!)

According to his seat regulations, Pierre was about 1.80 m tall. The standby instruments are located slightly toward the left. With the seat set forward it might be difficult to see them well while laying correctly the right arm for piloting. For this reason perhaps he asks.

If the standby system would have worked better, maybe the information displayed there would have been trustable.

- 02:12:33: Pierre: Là je monte, okay alors on descend…. (I am going up, ok. Thus let's go down ….)

He now starts thinking that the plane is not in overspeed, but, on the contrary it's loosing lift. The nose is too high and the stall warning rung so many times…! He pushes his sidestick forward almost to the stop, then he sets the engines to maximum thrust, on TO/GA. It is the correct maneuver the case of a stall.

- 02:12:34. Marc: Tu montes… (You are going up…)

But the plane is slow: it would need much time to react and it is out of control since almost two minutes. His nose swings again upward to 9 degree of pitch up attitude…. Then it lowers to few degrees below the horizon. All that should be done is being unflinching and keeping pushing the nose down.

Could this have been enough to recover the plane from the stall? As consequence of the pitch down input, the elevator goes from -30 to -20 degrees. The Alternate law 2B in fact is always active and it induces a load factor limitation: a full pitch down input on the sidestick wouldn't have resulted in a corresponding movement on the elevator. Moreover,a full nose-up THS would further reduce the effectiveness of the maneuver. The pitch down command should have been kept for a long time, peremptorily, to allow the THS to move and assist the elevators in pitching down but, even in this case, there would have been no more time to recover from the stall.

It is highly unlikely that the F-GZCP would have been recovered at this point….

As a consequence of pitch attitude reduction, the angle of attack goes below the 35 degree threshold. Computers re-consider it valid and the stall warning starts blaring again!

Stall! Stall!... Crrrk Crrrk Crrrk!

Stall! Stall!... Crrrk Crrrk Crrrk!

Shocked, Pierre falls back in the deepest uncertainty. He checks if thrust is really at the maximum:

- 02:12:39. Pierre: Okay on est en TOGA…(Ok, we are in TOGA…)

He doesn't understand. He maintains the pitch down input, but he is uncertain: he is at his extreme limit and he's losing hope. The maneuver to recover from the stall is giving the opposite result! Why does it activate the stall warning? Thus we are not stalled! Oh, my God, what's happening?

He does not know the paradoxical mechanism of this warning. It is unbelievable, that a similar thing was conceived. Is Airbus at that point convinced that its planes are impossible to stall, to think that a serious warning is not necessary? A stall is a continuous phenomenon. If the plane is stalled, it needs a warning sounding continuously until it is out of the stall, not one that stops shouting when the angle of attack exceeds a threshold. It's a mortal insanity.

Airbus hasn't even foreseen the display of the angle of attack measured by the probes. A visual information is better perceived by the brain than an auditory warning, especially in critical conditions. Other than all these cryptic messages, the angle of attack flashing in bold character on the ECAM would have been the only useful information to make the pilot understand the situation and save the lives of all the people on board.

- 02:12:41. Pierre: On est quoi là? En alti on a quoi là...? (What is there… what do we have in alti….?)

He leans to watch the standby instrument. The air, for few seconds, flushes back through the Pitots, and the CAS reappears: about 90 knots. It is unbelievably low. But who's going to trust it any longer?

- 02:12:43. Marc: Putain c'est pas possible!! (Fuck, it's impossible!!)

Even Marc can figure out why the stall warning reactivated.

- 02:12:44. Pierre: En alti on a quoi…? (What do we have in alti…?)

The plane is passing 20000 ft. The ocean is approaching and the space for a recovery maneuver is wearing thin.

- 02:12:46. David: Comment ça en altitude?(Do you mean in altitude?)

- 02:12:48. Pierre: Ouais ouais, j'descends là non?! (Yes, yes, I am going down, don't I?)

- 02:12:50. David: Là tu descends oui!! (Yes, you are going down!!)

They starts arguing, but it is comprehensible: they are desperate. And the plane rolls again abruptly, dreadfully of more than 40 degrees to the right.

- 02:12:52. Marc: Ehi tu…tu es en… (Hey, you are… you are in…)

- 02:12:54. Marc: Mets, mets les ailes horizontales. (Put the wings horizontal.)

- 02:12:56. Marc: Mets les ailes horizontales! (Put the wings horizontal!)

- 02:12:57. Pierre: C'est ce que je cherche à faire! (That's what I am trying to do!)

- 02:12:57. Marc: Mets les ailes horizontales!! (Put the wings horizontal!!)

Pierre reacts to this further fall of the right wing pulling the sidestick all to the left and nose up. The nose now points about 7 degree downward, but the angle of attack increases again: now the airplane moves forward as much as it goes down, and the stall warning stops again.

Neither of the three pay attention to the message that, astonishingly, appeared only in the last ten seconds on the ECAM. It says that ADR are in disagreement and suggests a possible procedure to solve the situation. It would have been too late, Airbus, anyway.

The C-chord starts sounding again, in combination with by the noise of the fall. Then the synthetic voice of the plane advises:

Dual input!

The two co-pilot are delivering simultaneous inputs.

- 02:12:58. Pierre: Je suis à fond à… avec du gauchissement! (I am at the limit with… with the roll!)

- 02:13:00. Marc: Le palonnier! (The rudder!)

The rudder is the last aerodinamic surface to lose efficacy when the plane is out of the flight envelope. The Captain is right. Pierre plunges his left feet, looking for an optimal range.

- 02:13:05. Marc: Les ailes à l'horizont…allez doucement…doucement… (Wings level… go gently…gently…..)

It not easy to understand why, in such a desperate situation, Marc didn't take direct control the plane. Perhaps the rolling and the excessive steepness of the A330 would have make too much difficult to exchange position with one of the copilots.

Initially the roll seems to smooth but, after few seconds, the plane starts rolling again on both sides of more than 15 degree, always mainly to the right, and swinging simultaneously the nose up and down of 10 degrees. Unrelenting, numb to any will.

With difficulty, from the backward position of his seat, David gives an input which is however filtered by that of the opposite sidestick, and it seems to have no effect.

- 02:13:11. David: On a tout perdu au niveau de l'aile gauche! (We lost everything at left wing level!)

- 02:13:11. Marc: Tiens…euh…? (Watch… eh…?)

The aerodynamic roar is very loud. Pierre maintains nose up inputs, between a quarter and half the sidestick excursion, and counterbalances the roll with the rudder.

- 02:13:14. David: J'ai plus rien là! (I have nothing there!)

- 02:13:14. Marc: Hein? (What?)

- 02:13:15. Marc: Tu as quoi?... Non, attends…! (What do youhave?... No, wait…!)

- 02:13:18. Pierre: On est…on y est….on passe le niveau cent!! (We are at… we are at… we are passing level one hundred!!)

- 02:13:19. David: Attends, moi j'ai des..j'ai des commandes moi, hein?! (Wait, I have…. the command, eh?!)

David gives slight nose up inputs too, but he is not assertive. The dual input warning sounds again.

Dual input!

-02:13:25. Pierre: Qu'est-ce qui…comment ça se fait qu'on continue à descendre à fond là?? (Who… how is possible that we are still going down this way??)

Rejected the overspeed thesis, discharged the stall hypothesis, what the Hell is going on? What should we do?

-02:13:28. David: Essaye de trouver ce que tu peux faire avec tes commandes là-haut…les primaires et cetera (Try to see what you can do with the commands up there… the primaries etc.etc…)

The PNF is asking Marc to reset the onboard computer, but the Captain is not convinced of the effectiveness of such a strategy and he mutters, overwhelmed by the C-chord and the aerodynamic noise:

- 02:13:29. Marc: Fera rien…On fera rien… (It won't work… It won't work….)

- 02:13:31. Pierre: On va arriver au niveau cent!! (We are arriving at level one hundred!!)

Pierre voice is almost a shout. His sidestick remains in nose up position at half range.

Despite what he said few seconds before, Marc pushes the buttons on the overhead panel to allow the substitution of the PRIM1 and SEC1 previously used as primary with those that were secondary. David makes an extreme attempt to restart the instruments, and turn the AIR DATA selector notch on the central position.

However at this point it doesn't really matter which ADR provides the data or which computer is chosen as master. The plane has an attitude so incompatible with any flight dynamic that the computers reject any reading and, shortly, both PRIM and SEC will get out of order.

- 02:13:36. Pierre: Neuf mille pieds!! (9000 feet!!)

- 02:13:38. Marc: Doucement avec le palonnier là! (Gently with the rudder!)

- 02:13:39. David: Remonte, remonte, remonte, remonte!! (Climb, climb, climb, climb!!)

David utters while pushing the sidestick forward. Simply an order or a sort of pray to the plane? Maybe both things. It is the panic: the ocean is only 2700 meters below and it is approaching faster and faster.

- 02:13:40. Pierre: Mais je suis à fond à cabrer depuis tout à l'heure...! (But I have been at maxi nose up for a while…!)

The Captain could not see the PF movements. Did he think he was pitching down? The plane kept swinging up and down and now it is barely stabilized with an attitude of 11 positive degrees. Did

Marc expect something different or maybe was he the only one to realize they were stalling, but simply and incredibly he did not tell at all? By now, it does not matter anymore.

Dual input!

- 02:13:42. Marc: Non-non-non ne remonte plus là! (No-no-no Do not climb any longer!)

Dual input!

- 02:13:43. David: Alors descends! Plus on descend (Then go down! You must go down!)

Now David is determined and pushes the sidestick completely forward. Pierre is still trying to nose up.

Dual input!

- 02:13:45. David: Alors donne moi les commandes…à moi les commandes!! (Thus give me the controls…. Controls to me!!)

Before David could end the sentence, Pierre says:

- 02:13:46. Pierre: Vas-y tu as les commandes… (Go on, you have the controls…..)

Dual input!

- 02:13:47. Pierre: …on est en TOGA toujours, hein! (…we are still at TOGA, eh!)

David pushes forward to reduce the attitude, and brings the engines levers to CLB. The CAS appears few seconds for the last time before the total switch off of the computers: it is less than 80 knots and keeps fluctuating and decreasing, as well as the altimeter: 6000 feet…. 5000 feet…..

- 02:13:53. Marc: Alors attends…AP off! (Then wait….AP off!)

The Captain is slower than the events. It is as if he thinks or wants to believe that there is still time. He orders to deactivate the auto-pilot.

But the plane doesn't even respond to the prolonged pitch down order. His nose starts swinging again as a mad whale, between few degrees below the horizon and 10-15 degrees above. The angle of attack decreases below 35 degrees, and the stall warning is mocking again the pilots.

Stall! Stall!... Crrrk Crrrk Crrrk!

Stall! Stall!... Crrrk Crrrk Crrrk!

A further banking to the right, up to 30 degrees, then it starts rolling again on both sides, like a leaf shaken by the wind.

- 02:13:59. Pierre: Messieurs…(Oh gentlemen…)

He moves his sidestick by instinct: the desperation is forcing him to act, even though it's an unintentional and unreasoned reaction.

Who knows if the passengers felt that something was wrong; who knows if they were scared as the pilots, or if they did not realize their destiny…

- 02:14:05. Marc: Attention, tu cabres là! (Pay attention, you're pitching up!)

- 02:14:06. David: Je cabre?? (Am I pitching up??)

No, he is not pitching up. But it does not matter. Nothing will matters anymore… The nose stays upwards, while that mixture of metal, electric wires and people is falling from the sky like a stone. Who could ever accept a death like this.

- 02:14:06. Marc: Tu cabres… (You're pitching up…)

- 02:14:07. David: Je cabre.. (I pitch up..)

- 02:14:07. Pierre: Mais faudrait, on est à quatre mille pieds! (But we have to, we are at 4000 feet!)

- 02:14:10. Marc: Tu cabres là! (You're pitching up!)

David doesn't want to surrender. He pulls back the engine levers to slightly more than IDLE: he must lower the nose; the stall warning is silent now: can we get out of this? Can we save ourselves?

Few seconds later the GPWS, the ground proximity warning system, screams out like an answer, a definitive sentence.

Sink rate... Pull up!

- 02:14:18. Marc: Allez, tire! (Go on, pull up!)

Pull up!

Pull up!

- 02:14:19. Pierre: Allez on tire, on tire, on tire, on tire!! (Come on, pull up, pull up, pull up, pull up!!)

He is pure survival instinct: he pushes the priority button, he pulls the nose up and sets full engine thrust.

Stall! Stall!... Crrrk Crrrk Crrrk!

- 02:14:23. Pierre: Putain on va taper…..c'est pas vrai!! (Fuck we are going to crash…it can't be true!!!)

Pull up!

Time is over. The F-GZCP is a glass-hour in the hands of the Gods, who watch it release the last grain of sand. The events queued up as an unlucky alignment of planets, calling for an enormous tribute to make someone, maybe, open his eyes and decide to finally amend what is not working.

For all of this shall not repeat again.

- 02:14:25. Pierre: Mais qu'est-ce qui se passe!!? (But what's happening!!?)

- 02:14:25. David: On est morts!!! (We are dead!!!)

Pull up!

- 02:14:26. Marc: Dix degrés d'assiette! (Ten degrees of pitch!)

Maybe this is the reason, for things like this to happen.

At 02:14:28Z the A330 slams on the water at about 200 km/h, with a pitch attitude of 16.2 degrees, inclined of 5.3 degree to the left, and a vertical speed of 55.4 m per second. The drift and the rudder tear off and are projected forward.

In few seconds most of the plane and the great majority of the occupants get swallowed by the sea and sink slowly toward the icy and silent darkness of the Atlantic Ocean floor, while the tropical rain blurs away the fuel boiling over the waves.

Notes

1) BEA Interim Report 2, page 55 and following; BEA Final Report, page 138 and following. Another French company, Air Caraibes, begun the substitution of the anemometric probes soon after a single malfunctioning event. Air France started their substitution only few days before the accident, at the end of May 2009. What's the reason for this delay?

Every kind of airplane must have an airworthiness certification ascertaining his safety. This means that the constructor must respect the rules of the certificating Entities, which in turn must stick to the Airworthiness Directives given by the International Aeronautic Entities. Within Europe this is EASA, the European Association for Aviation Safety, to certificate an airplane and check periodically the project of the plane constructor. In France, EASA is represented by the DGAC (*Direction Générale de l'Aviation Civile*). There are thus several steps that can slow down the process of signaling an accident, finding out the causes, proposing safety criteria, from one side, and issuing new safety directives to spread to the constructor and the flying company, from the other. It is a long and fragile chain. Too much. A malfunctioning is reported from the pilots to the company, which in turn reports it to Airbus. The constructor launches an investigation aimed at assessing if the plane is in an unsafe condition, that is if there are situation where the plane is not safe. This investigation obviously include supervision and direction by DGAC and EASA.

At the time of the AF447 accident the Pitot failure was classified by these entities as "major", that is a serious failure, difficult for pilots to deal with, but not capable to lead to a catastrophe. After the analysis of the accidents involving the Pitot Thales AA, in March 2009 the EASA, under the pressure of Airbus, wrote to the DGAC that it was not necessary to make the substitution of these probes compulsory for the entire fleet of A330-A340, although a more accurate monitoring of the problem was required in order to have more statistics. Thus every company was free to decide what to do. Several Air France pilots accused a slow-moving reactivity of the whole system to a serious problem. They were convinced that this kind of failure (getting more and more frequent) should have been classified as "hazardous", that is capable to prevent the crew to carry out their duty, with possible fatal consequences. A kind of failure that would have required immediate corrections.

The AF447 accident was an announced disaster: EASA, DGAC, Airbus and Air France share the responsibility for this tragedy.

2) According to an informative bulletin on Flight Security (Info SV) issued by Air France the 18th of June 2012, Airbus planes, as a consequence of their aerodynamic shape and their speeds, once stalled do not lower the nose as the great majority of the planes, especially if the engines (located under the wings) are at maximum thrust.