Situation Awareness (or lack thereof) on Air France 447

What Really Happened Aboard Air France 447? (Extract copied from Popular Mechanics)

Two years after the Airbus 330 plunged into the Atlantic Ocean, Air France 447's flight data recorders finally turned up. The revelations from the pilot transcript paint a surprising picture of chaos in the cockpit, and confusion between the pilots that led to the crash.

Here is a synopsis of what occurred during the course of the doomed airliner's final few minutes.

At 1h 36m, the flight enters the outer extremities of a tropical storm system. Unlike other planes' crews flying through the region, AF447's flight crew has not changed the route to avoid the worst of the storms. The outside temperature is much warmer than forecast, preventing the still fuel-heavy aircraft from flying higher to avoid the effects of the weather. Instead, it ploughs into a layer of clouds.

At 1h51m, the cockpit becomes illuminated by a strange electrical phenomenon. The co-pilot in the right-hand seat, an inexperienced 32-year-old named Pierre-Cedric Bonin, asks, "What's that?" The captain, Marc Dubois, a veteran with more than 11,000 hours of flight time, tells him it is St. Elmo's fire, a phenomenon often found with thunderstorms at these latitudes.

At approximately 2 am, the other co-pilot, David Robert, returns to the cockpit after a rest break. At 37, Robert is both older and more experienced than Bonin, with more than double his colleague's total flight hours. The head pilot gets up and gives him the left-hand seat. Despite the gap in seniority and experience, the captain leaves Bonin in charge of the controls.

At 2:02 am, the captain leaves the flight deck to take a nap. Within 15 minutes, everyone aboard the plane will be dead.

02:03:44 (Bonin) La convergence inter tropicale... voilÃ , lÃ on est dedans, entre 'Salpu' et 'Tasil.' Et puis, voilÃ , on est en plein dedans...The inter-tropical convergence... look, we're in it, between 'Salpu' and 'Tasil.' And then, look, we're right in it...

The intertropical convergence, or ITC, is an area of consistently severe weather near the equator. As is often the case, it has spawned a string of very large thunderstorms, some of which stretch into the stratosphere. Unlike some of the other planes's crews flying in the region this evening, the crew of AF447 has not studied the pattern of storms and requested a divergence around the area of most intense activity. (Salpu and Tasil are two air-traffic-position reporting points.)

02:05:55 (Robert) Oui, on va les appeler derriÃ¨re... pour leur dire quand mÃªme parce que...Yes, let's call them in the back, to let them know...

Robert pushes the call button.
02:05:59 (flight attendant, heard on the intercom) Oui? Marilyn. Yes? Marilyn.

02:06:04 (Bonin) Oui, Marilyn, c'est Pierre devant... Dis-moi, dans deux minutes, on devrait attaquer une zone oÃ¹ Ã§a devrait bouger un peu plus que maintenant. Il faudrait vous mÃ©fier lÃ .

Yes, Marilyn, it's Pierre up front... Listen, in 2 minutes, we're going to be getting into an area where things are going to be moving around a little bit more than now. You'll want to take care.

02:06:13 (flight attendant) D'accord, on s'assoit alors?
Okay, we should sit down then?

02:06:15 (Bonin) Bon, je pense que ce serait pas mal... tu prÃ©viens les copains!
Well, I think that's not a bad idea. Give your friends a heads-up.

02:06:18 (flight attendant) Ouais, OK, j'appelle les autres derriÃ¨re.
Merci beaucoup.
Yeah, okay, I'll tell the others in the back. Thanks a lot.

02:06:19 (Bonin) Mais je te rappelle dÃ¨s qu'on est sorti de lÃ .
I'll call you back as soon as we're out of it.

02:06:20 (flight attendant) OK.
Okay.

The two copilots discuss the unusually elevated external temperature, which has prevented them from climbing to their desired altitude, and express happiness that they are flying an Airbus 330, which has better performance at altitude than an Airbus 340.

02:06:50 (Bonin) Va pour les anti-ice. C'est toujours Ã§a de pris.
Let's go for the anti-icing system. It's better than nothing.

Because they are flying through clouds, the pilots turn on the anti-icing system to try to keep ice off the flight surfaces; ice reduces the plane's aerodynamic efficiency, weighs it down, and in extreme cases, can cause it to crash.

02:07:00 (Bonin) On est apparemment Ã la limite de la couche, Ã§a devrait aller.
We seem to be at the end of the cloud layer, it might be okay.

In the meantime Robert has been examining the radar system and has found that it has not been set up in the correct mode. Changing the settings, he scrutinizes the radar map and realizes that they are headed directly toward an area of intense activity.

02:08:03 (Robert) Tu peux Ã©ventuellement le tirer un peu Ã gauche.
You can possibly pull it a little to the left.

02:08:05 (Bonin) Excuse-moi?
Sorry, what?

02:08:07 (Robert) Tu peux Ã©ventuellement prendre un peu Ã gauche. On est d'accord qu'on est en manuel, hein?
You can possibly pull it a little to the left. We're agreed that we're in manual, yeah?

Bonin wordlessly banks the plane to the left. Suddenly, a strange aroma, like an electrical transformer, floods the cockpit, and the temperature suddenly increases.

At first, the younger pilot thinks that something is wrong with the air-conditioning system, but Robert assures him that the effect is from the severe weather in the vicinity. Bonin seems ill at ease. Then the sound of slipstream suddenly becomes louder.

This, presumably, is due to the accumulation of ice crystals on the exterior of the fuselage. Bonin

announces that he is going to reduce the speed of the aircraft, and asks Robert if he should turn on a feature that will prevent the jet engines from flaming out in the event of severe icing.

Just then an alarm sounds for 2.2 seconds, indicating that the autopilot is disconnecting. The cause is the fact that the plane's pitot tubes, externally mounted sensors that determine air speed, have iced over, so the human pilots will now have to fly the plane by hand.

Note, however, that the plane has suffered no mechanical malfunction. Aside from the loss of airspeed indication, everything is working fine. Otelli reports that many airline pilots (and, indeed, he himself) subsequently flew a simulation of the flight from this point and were able to do so without any trouble.

But neither Bonin nor Roberts has ever received training in how to deal with an unreliable airspeed indicator at cruise altitude, or in flying the airplane by hand under such conditions.

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

02:10:07 (Robert) D'accord.
Okay.

Perhaps spooked by everything that has unfolded over the past few minutes-the turbulence, the strange electrical phenomena, his colleague's failure to route around the potentially dangerous storm - Bonin reacts irrationally. He pulls back on the side stick to put the airplane into a steep climb, despite having recently discussed the fact that the plane could not safely ascend due to the unusually high external temperature.

Bonin's behavior is difficult for professional aviators to understand. "If he's going straight and level and he's got no airspeed, I don't know why he'd pull back," says Chris Nutter, an airline pilot and flight instructor. "The logical thing to do would be to cross-check"-that is, compare the pilot's airspeed indicator with the co-pilot's and with other instrument readings, such as groundspeed, altitude, engine settings, and rate of climb. In such a situation, "we go through an iterative assessment and evaluation process," Nutter explains, before engaging in any manipulation of the controls.
"Apparently that didn't happen."

Almost as soon as Bonin pulls up into a climb, the plane's computer reacts. A warning chime alerts the cockpit to the fact that they are leaving their programmed altitude. Then the stall warning sounds. This is a synthesized human voice that repeatedly calls out, "Stall!" in English, followed by a loud and intentionally annoying sound called a "cricket."

A stall is a potentially dangerous situation that can result from flying too slowly. At a critical speed, a wing suddenly becomes much less effective at generating lift, and a plane can plunge precipitously. All pilots are trained to push the controls forward when they're at risk of a stall so the plane will dive and gain speed.

The Airbus's stall alarm is designed to be impossible to ignore. Yet for the duration of the flight, none of the pilots will mention it, or acknowledge the possibility that the plane has indeed stalled-even though the word "Stall!" will blare through the cockpit 75 times.
Throughout, Bonin will keep pulling back on the stick, the exact opposite of what he must do to recover from the stall.

02:10:07 (Robert) Qu'est-ce que c'est que Ã§a?
What's this?

02:10:15 (Bonin) On n'a pas une bonne... On n'a pas une bonne annonce de vitesse.
There's no good... there's no good speed indication.

02:10:16 (Robert) On a perdu les, les, les vitesses alors?
We've lost the, the, the speeds, then?

The plane is soon climbing at a blistering rate of 7000 feet per minute. While it is gaining altitude, it is losing speed, until it is crawling along at only 93 knots, a speed more typical of a small Cessna than an airliner. Robert notices Bonin's error and tries to correct him.

02:10:27 (Robert) Faites attention Ã ta vitesse. Faites attention Ã ta vitesse.
Pay attention to your speed. Pay attention to your speed.

He is probably referring to the plane's vertical speed. They are still climbing.

02:10:28 (Bonin) OK, OK, je redescends.
Okay, okay, I'm descending.

02:10:30 (Robert) Tu stabilises...
Stabilize...

02:10:31 (Bonin) Ouais.
Yeah.

02:10:31 (Robert) Tu redescends... On est en train de monter selon lui... Selon lui, tu montes, donc tu redescends.
Descend... It says we're going up... It says we're going up, so descend.

02:10:35 (Bonin) D'accord.
Okay.

Thanks to the effects of the anti-icing system, one of the pitot tubes begins to work again. The cockpit displays once again show valid speed information.

02:10:36 (Robert) Redescends!
Descend!

02:10:37 (Bonin) C'est parti, on redescend. Here we go, we're descending.

02:10:38 (Robert) Doucement!
Gently!

Bonin eases the back pressure on the stick, and the plane gains speed as its climb becomes more shallow. It accelerates to 223 knots. The stall warning falls silent. For a moment, the co-pilots are in control of the airplane.

02:10:41(Bonin) On est en... ouais, on est en "climb."
We're... yeah, we're in a climb.

Yet, still, Bonin does not lower the nose. Recognizing the urgency of the situation, Robert pushes a button to summon the captain.

02:10:49 (Robert) Putain, il est oÃ¹... euh?
Damn it, where is he?

The plane has climbed to 2512 feet above its initial altitude, and though it is still ascending at a dangerously high rate, it is flying within its acceptable envelope. But for reasons unknown, Bonin once again increases his back pressure on the stick, raising the nose of the plane and bleeding off speed. Again, the stall alarm begins to sound.

Still, the pilots continue to ignore it, and the reason may be that they believe it is impossible for them to stall the airplane. It's not an entirely unreasonable idea:

The Airbus is a fly-by-wire plane; the control inputs are not fed directly to the control surfaces, but to a computer, which then in turn commands actuators that move the ailerons, rudder, elevator, and flaps.

The vast majority of the time, the computer operates within what's known as normal law, which means that the computer will not enact any control movements that would cause the plane to leave its flight envelope. "You can't stall the airplane in normal law," says Godfrey Camilleri, a flight instructor who teaches Airbus 330 systems to US
Airways pilots.

But once the computer lost its airspeed data, it disconnected the autopilot and switched from normal law to "alternate law," a regime with far fewer restrictions on what a pilot can do. "Once you're in alternate law, you can stall the airplane," Camilleri says.

It's quite possible that Bonin had never flown an airplane in alternate law, or understood its lack of restrictions. According to Camilleri, not one of US Airway's 17 Airbus 330s has ever been in alternate law. Therefore, Bonin may have assumed that the stall warning was spurious because he didn't realize that the plane could remove its own restrictions against stalling and, indeed, had done so.

02:10:55 (Robert) Putain!
Damn it!

Another of the pitot tubes begins to function once more. The cockpit's avionics are now all functioning normally. The flight crew has all the information that they need to fly safely, and all the systems are fully functional. The problems that occur from this point forward are entirely due to human error.

02:11:03 (Bonin) Je suis en TOGA, hein?
I'm in TOGA, huh?

Bonin's statement here offers a crucial window onto his reasoning. TOGA is an acronym for Take Off, Go Around. When a plane is taking off or aborting a landing-"going around"-it must gain both speed and altitude as efficiently as possible. At this critical phase of flight, pilots are trained to increase engine speed to the TOGA level and raise the nose to a certain pitch angle.

Clearly, here Bonin is trying to achieve the same effect: He wants to increase speed and to climb

away from danger. But he is not at sea level; he is in the far thinner air of 37,500 feet. The engines generate less thrust here, and the wings generate less lift. Raising the nose to a certain angle of pitch does not result in the same angle of climb, but far less. Indeed, it can-and will-result in a descent.

While Bonin's behavior is irrational, it is not inexplicable. Intense psychological stress tends to shut down the part of the brain responsible for innovative, creative thought. Instead, we tend to revert to the familiar and the well-rehearsed.

Though pilots are required to practice hand-flying their aircraft during all phases of flight as part of recurrent training, in their daily routine they do most of their hand-flying at low altitude-while taking off, landing, and maneuvering. It's not surprising, then, that amid the frightening disorientation of the thunderstorm, Bonin reverted to flying the plane as if it had been close to the ground, even though this response was totally ill-suited to the situation.

02:11:06 (Robert) Putain, il vient ou il vient pas?
Damn it, is he coming or not?

The plane now reaches its maximum altitude. With engines at full power, the nose pitched upward at an angle of 18 degrees, it moves horizontally for an instant and then begins to sink back toward the ocean.

02:11:21 (Robert) On a pourtant les moteurs! Qu'est-ce qui se passe
bordel? Je ne comprends pas ce que se passe.
We still have the engines! What the hell is happening? I don't understand what's happening.

Unlike the control yokes of a Boeing jetliner, the side sticks on an Airbus are "asynchronous"-that is, they move independently. "If the person in the right seat is pulling back on the joystick, the person in the left seat doesn't feel it," says Dr. David Esser, a professor of aeronautical science at Embry-Riddle Aeronautical University.
"Their stick doesn't move just because the other one does, unlike the old-fashioned mechanical systems like you find in small planes, where if you turn one, the [other] one turns the same way." Robert has no idea that, despite their conversation about descending, Bonin has continued to pull back on the side stick.

The men are utterly failing to engage in an important process known as crew resource management, or CRM. They are failing, essentially, to cooperate. It is not clear to either one of them who is responsible for what, and who is doing what.

This is a natural result of having two co-pilots flying the plane. "When you have a captain and a first officer in the cockpit, it's clear who's in charge," Nutter explains. "The captain has command authority. He's legally responsible for the safety of the flight. When you put two first officers up front, it changes things. You don't have the sort of traditional discipline imposed on the flight deck when you have a captain."

The vertical speed toward the ocean accelerates. If Bonin were to let go of the controls, the nose would fall and the plane would regain forward speed. But because he is holding the stick all the way back, the nose remains high and the plane has barely enough forward speed for the controls to be effective. As turbulence continues to buffet the plane, it is nearly impossible to keep the wings level.

02:11:32 (Bonin) Putain, j'ai plus le contrÃ´le de l'avion, lÃ ! J'ai

plus le contrÃ´le de l'avion!
Damn it, I don't have control of the plane, I don't have control of the plane at all!

02:11:37 (Robert) Commandes Ã gauche!
Left seat taking control!

At last, the more senior of the pilots (and the one who seems to have a somewhat better grasp of the situation) now takes control of the airplane. Unfortunately, he, too, seems unaware of the fact that the plane is now stalled, and pulls back on the stick as well. Although the plane's nose is pitched up, it is descending at a 40-degree angle.
The stall warning continues to sound. At any rate, Bonin soon after takes back the controls.

A minute and a half after the crisis began, the captain returns to the cockpit. The stall warning continues to blare.

02:11:43 (Captain) Eh... Qu'est-ce que vous foutez?
What the hell are you doing?

02:11:45 (Bonin) On perd le contrÃ´le de l'avion, lÃ !
We've lost control of the plane!

02:11:47 (Robert) On a totalement perdu le contrÃ´le de l'avion... On comprend rien... On a tout tentÃ©...
We've totally lost control of the plane. We don't understand at all... We've tried everything.

By now the plane has returned to its initial altitude but is falling fast. With its nose pitched 15 degrees up, and a forward speed of 100 knots, it is descending at a rate of 10,000 feet per minute, at an angle of 41.5 degrees. It will maintain this attitude with little variation all the way to the sea.

Though the pitot tubes are now fully functional, the forward airspeed is so low-below 60 knots-that the angle-of-attack inputs are no longer accepted as valid, and the stall-warning horn temporarily stops. This may give the pilots the impression that their situation is improving, when in fact it signals just the reverse.

Another of the revelations of Otelli's transcript is that the captain of the flight makes no attempt to physically take control of the airplane. Had Dubois done so, he almost certainly would have understood, as a pilot with many hours flying light airplanes, the insanity of pulling back on the controls while stalled. But instead, he takes a seat behind the other two pilots.

This, experts say, is not so hard to understand. "They were probably experiencing some pretty wild gyrations," Esser says. "In a condition like that, he might not necessarily want to make the situation worse by having one of the crew members actually disengage and stand up. He was probably in a better position to observe and give his commands from the seat behind."

But from his seat, Dubois is unable to infer from the instrument displays in front of him why the plane is behaving as it is. The critical missing piece of information: the fact that someone has been holding the controls all the way back for virtually the entire time.
No one has told Dubois, and he hasn't thought to ask.

02:12:14 (Robert) Qu'est-ce que tu en penses? Qu'est-ce que tu en penses? Qu'est-ce qu'il faut faire?
What do you think? What do you think? What should we do?

02:12:15 (Captain) Alors, lÃ , je ne sais pas!
Well, I don't know!

As the stall warning continues to blare, the three pilots discuss the situation with no hint of understanding the nature of their problem. No one mentions the word "stall." As the plane is buffeted by turbulence, the captain urges Bonin to level the wings-advice that does nothing to address their main problem. The men briefly discuss, incredibly, whether they are in fact climbing or descending, before agreeing that they are indeed descending.

As the plane approaches 10,000 feet, Robert tries to take back the controls, and pushes forward on the stick, but the plane is in "dual input" mode, and so the system averages his inputs with those of Bonin, who continues to pull back. The nose remains high.

02:13:40 (Robert) Remonte... remonte... remonte... remonte...
Climb... climb... climb... climb...

02:13:40 (Bonin) Mais je suis Ã fond Ã cabrer depuis tout Ã l'heure!
But I've had the stick back the whole time!

At last, Bonin tells the others the crucial fact whose import he has so grievously failed to understand himself.

02:13:42 (Captain) Non, non, non... Ne remonte pas... non, non.
No, no, no... Don't climb... no, no.

02:13:43 (Robert) Alors descends... Alors, donne-moi les commandes...
Ã€ moi les commandes!
Descend, then... Give me the controls... Give me the controls!

Bonin yields the controls, and Robert finally puts the nose down. The plane begins to regain speed. But it is still descending at a precipitous angle. As they near 2000 feet, the aircraft's sensors detect the fast-approaching surface and trigger a new alarm. There is no time left to build up speed by pushing the plane's nose forward into a dive. At any rate, without warning his colleagues, Bonin once again takes back the controls and pulls his side stick all the way back.

02:14:23 (Robert) Putain, on va taper... C'est pas vrai!
Damn it, we're going to crash... This can't be happening!

02:14:25 (Bonin) Mais qu'est-ce que se passe?
But what's happening?

02:14:27 (Captain) 10 degrÃ¨s d'assiette...
Ten degrees of pitch...

Exactly 1.4 seconds later, the cockpit voice recorder stops.

The Loss of Situation Awareness

After reading the transcript of "what really happened on Air France 447" it could be said that the two co-pilots were in a space that was not conducive to safely flying the plane and it is possible to infer that they had suffered a massive loss of situation awareness (SA). (Please note that the following statements are my own opinion and others will probably disagree with them. They are also not the be all and end all of the cause of the crash.)

Why do I say this?

Well you could use circular reasoning and say there was a loss of SA so they crashed and how do we know there was a loss of SA because they crashed but there is a little more to it than that and it would appear that there were breakdowns in the underlying cognitive processes of SA that led to the loss of SA and subsequent crash. These cognitive processes are very important as they allow the pilot's to maintain a certain level of capability, by allowing a reduction in attentional demand in certain areas of flying the plane, this then allows a maintenance of awareness in more important areas.

I won't bore you by going through all of the cognitive processes (there are nine) but will use three of them as examples as to where the problems could lie that led to the degradation of the pilot's SA.

1. **Attention**: The maintenance of information is one of the most basic elements of SA as what is paid attention to in the operation will give direction to what information is put into the SA model. I think it would be safe to say that there was a distinct lack of this on all counts as the pilots did not seem to know where to look.

2. **Mental Models:** These provide frames of reference and they typically include an understanding of system components, how the system works, and how to use it. A good mental model is dynamic in nature thus allowing appropriate responses in changing conditions. Again there was lack of use of a coherent mental model by all of the pilot's and if they were using a mental model then it was the wrong one.

3. **Goals:** These are central to developing SA and the seeking out of goals helps to select the correct mental model mode as well as directing attention to selecting the correct information. The goal was obviously to try and recover control of the plane but for whatever reason the pilots were not only using the wrong mental model but they were also not able determine the cause of why the plane was behaving in the way it was, in other words their attention was being directed to the wrong place.

Leading on from the above it is also possible discuss the loss of SA by using the Three Level Model of SA. This model is probably the most widely used and popular SA model in the world today.

The Three Levels of SA are:

Level 1 SA (Perception): This level deals with perception and to achieve it there is a need to perceive the relevant information through selective attention. If it is not achieved then the odds of forming an incorrect picture of the situation is almost guaranteed. Selective attention means that attention is directed to the most pertinent environmental cues based upon goals and experience in the form of mental models and it is through this selective attention that that important / essential information is given credence over non-essential information.

Level 2 SA (Comprehension): This level deals with what happens after the relevant information has been perceived and it needs to be comprehended in working memory. Comprehension of the situation not only requires recognition of the elements present but also involves an understanding of the significance of those elements in light of pertinent operator goals. It is based on a knowledge of Level 1 SA elements. This level of SA depends very much upon working memory and long term memory. It is the elements in the environment that a person perceives which activates the schemes in working memory and updates their mental model. It is mental models from long term memory that are used to enhance or clarify the situation.

Level 3 SA (Projection): This level deals with the ability to project the future actions of the elements in the environment and is achieved through knowledge of the status and dynamics of both Level 1 and 2 SA. This level of SA should allow for timely decision making but it is in reality demanding in nature, is the hardest to achieve and thus people are generally poor at it.

Using the Three Level Model it could be said that the pilot's were not able to perceive the relevant information as they did not have the requisite experience or training to direct their attention to the most pertinent cues. This may have led the wrong information being attended to and could also have been the reason why one of the co-pilots pulled back on the stick.

As there was minimal knowledge of Level 1SA it would not only have been impossible to properly comprehend the situation that was developing but there was also a lack of understanding of the significance of what was happening. Working (short term) memory would have been working at capacity (this may have been a reason why the stall alarm was ignored) and as this situation had not happened to the pilot's before they would not have had the requisite knowledge stored away in long term memory to call upon to help keep their mental model up to date and thus help regain control the plane. Again this may be a reason why one of the co-pilots pulled back the stick as according to his mental model it was a perfectly reasonable thing to do.

In regards to level 3 SA, I think that it can safely be said that there was none . The pilots were unable to make informed decisions and if they had have been able to then control of the plane would probably have been regained.

I hope that the above explanation goes some way to explaining why it is so important to have good SA at all times, especially when piloting. SA really comes into its own in emergency situations and thus needs to be up to date in view of the state of the ship; it's systems and environment. This will enable us to make decisions, revise plans and manage the ship effectively. In other words we will be better prepared to deal with upcoming events and stay ahead of the game.