HindSight20

The ability or opportunity to understand and judge an event or experience after it has occured

EUROCONTROL

Safety and Automation

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Winter 2014

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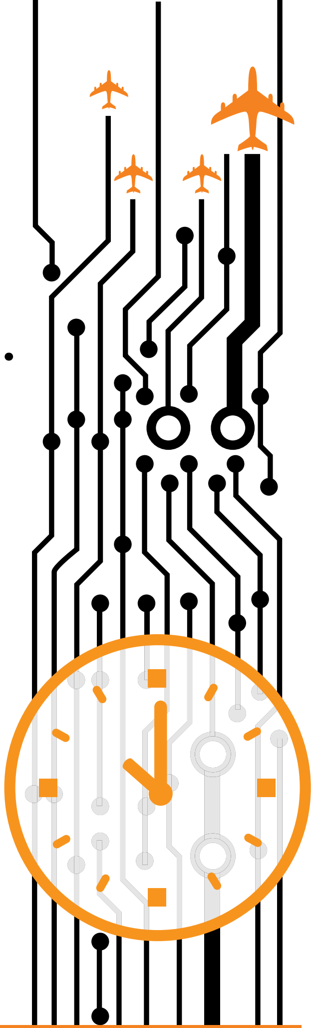

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EDITORIAL TEAM

Frank Brenner has worked in Air Traffic Management for his entire career. He has been Director General of EUROCONTROL since 1 January 2013.

Since taking up his functions at EUROCONTROL, he has initiated the development of a Vision and Strategy, including the development of Centralised Services as part of the SESAR deployment concentrating on how to support controllers with new technology which increases safety.

Before joining EUROCONTROL, Frank Brenner was General Manager Operations for FABEC, Vice Chairman of EUROCONTROL's Performance Review Commission and a member of the Performance Review Body. Trained as an air traffic controller, he has held a number of posts at DFS including Head of ATM Operations, Director of Operations at the Business Unit for Aeronautical Data Management and Director of DFS's Control Centre Business Unit.

Dear Reader,

This edition of Hindsight is on "Safety and Automation" – a subject which I find particularly fascinating as it combines the advance of technology with progress in understanding the human factors that affect our work, whether it is in the air or on the ground.

There is a developing discussion at present on the need for pilots, from time to time, to reduce the level of automation in the cockpit and to practise their flying skills. Of course, this does mean more work for the pilots but, in the long run, safety is enhanced. Some of the very interesting articles in this edition refer to the fact that some airlines encourage their pilots to use automation as much as possible. Yet the same pilots need to be able to take over manually if the need arises.

In the air traffic control centre, the situation is similar but yet different. The extent of automation is clearly less than in the cockpit and controllers still play a very active role in handling traffic. However, this may not always be the case – the vision for the future is for aircraft to fly pre-planned 4D trajectories accurate to just a few seconds. Conflicts will be avoided well in advance; on approach, the aircraft will automatically maintain an optimal separation with the aircraft in front. The controllers, like pilots today, will have much more of a monitoring role. I had the chance to experience all the automation support systems we offer to our controllers recently at a simulator run at the Maastricht Upper Area Control Centre.

What happens when something goes wrong? Only this year we have seen control centres affected by both fire and flood. We as an industry have to be ready to cope with the unexpected. That means being able to shift to manual control and separation smoothly and safely. We have to have clear procedures and, crucially, we have to practise the underlying skills that are central to ATC safety.

I firmly believe that the human being, whether he/she is a pilot or a controller, will be at the heart of safety in aviation for many years to come. That is because people provide the resilience required; they can cope with the unexpected.

Automation is an incredibly valuable tool and it is indispensable to handle today's traffic volumes. It can range from providing information, through analysis all the way to making and executing decisions. The challenge is to use it in such a way that it improves efficiency and safety but not so much that we lose sight of the human being – who is not the weak link in the chain but is rather the most effective form of safety net we know.

Frank Brenner

Local warming

Tzvetomir Blajev
Editor in Chief of Hindsight

On a summer afternoon, many years ago and just a few weeks after I had received my ACC endorsement, I was working on a busy ACC Sector. It was an especially hot summer. Everything was melting, the tree leaves did not dare to move, not the tiniest wind around... We had also an unusually 'hot' traffic scene – a specific geopolitical situation had brought a growing number of aircraft to our airspace. Flow control was something unheard by our management at the time and we were accommodating everything that was coming our way. You came in hot from the outside burning hell to the air conditioned operations room and suddenly you felt like you were somewhere in the Arctic! You took over and sat in front of the screen and immediately forgot the freezing air blowing directly on your back. The heat of the traffic situation took over. When your colleague came to relieve you, he would take another – cold – chair rather than use yours. I am not joking!

The sectors we could open were limited by the number of available consoles with the old Airborne Instrument Laboratory (AIL) radar we were using at the time. The primary part of the radar could not "see" the high seas, and the high seas of my sector bothered me a lot with traffic coming from and, from time to time, omitting to set the transponder to the ICAO system and operating it on a friend/foe mode that was rendering the secondary part of the radar also useless.

And when trouble comes, it never comes alone.

First some magnificent convective activity was reported by flight crews in the west part of my airspace, with tops penetrating to the tropopause. The crews began avoiding this, leaving my sector for adjacent airspace on anything but the flight-planned route. This massively increased the time required for telephone coordination. My watch supervisor send a colleague, a third pair of eyes, just to sit behind and look out for missed conflicts.

Then, if that wasn't enough, the Air Force – we used to call them "sunny aviators" since they rarely wanted to fly on days with marked convective activity – was taking advantage of a heat wave in the east part of the airspace a large restricted area was activated for their exercises. This made the picture of the traffic flow a rather interesting pattern of winding lines. Finally, danger areas were activated up to FL 390 so that rockets could be launched to deliver some chemicals to the clouds which would, we were told, prevent the formation of hail and so save crops below. I was losing the picture and felt that everything was turning into chaos. I heard the voice of, my watch supervisor "restrict vertical movements to a minimum". I obliged – and although it made some inbound and outbound traffic from a major airport a little bit unhappy, confident control was gradually regained and the problems left one by one on their way to my nightmares.

This story made me realise that there is more to being a controller than just applying the Air Traffic Control tasks. I had been studying in the training school, at the simulator or in position with an Instructor.

Even if you perfected them, they were not enough – there were other tasks for you, your team and your supervisor – tasks to predict, monitor and manage the workload. We can automate Air Traffic Control tasks to a certain extent and this can help us to accept even more traffic, but our human brain remains the same, with the same capabilities and limitations. How can we predict and monitor the workload of the brain of controllers? Can we automate this monitoring?

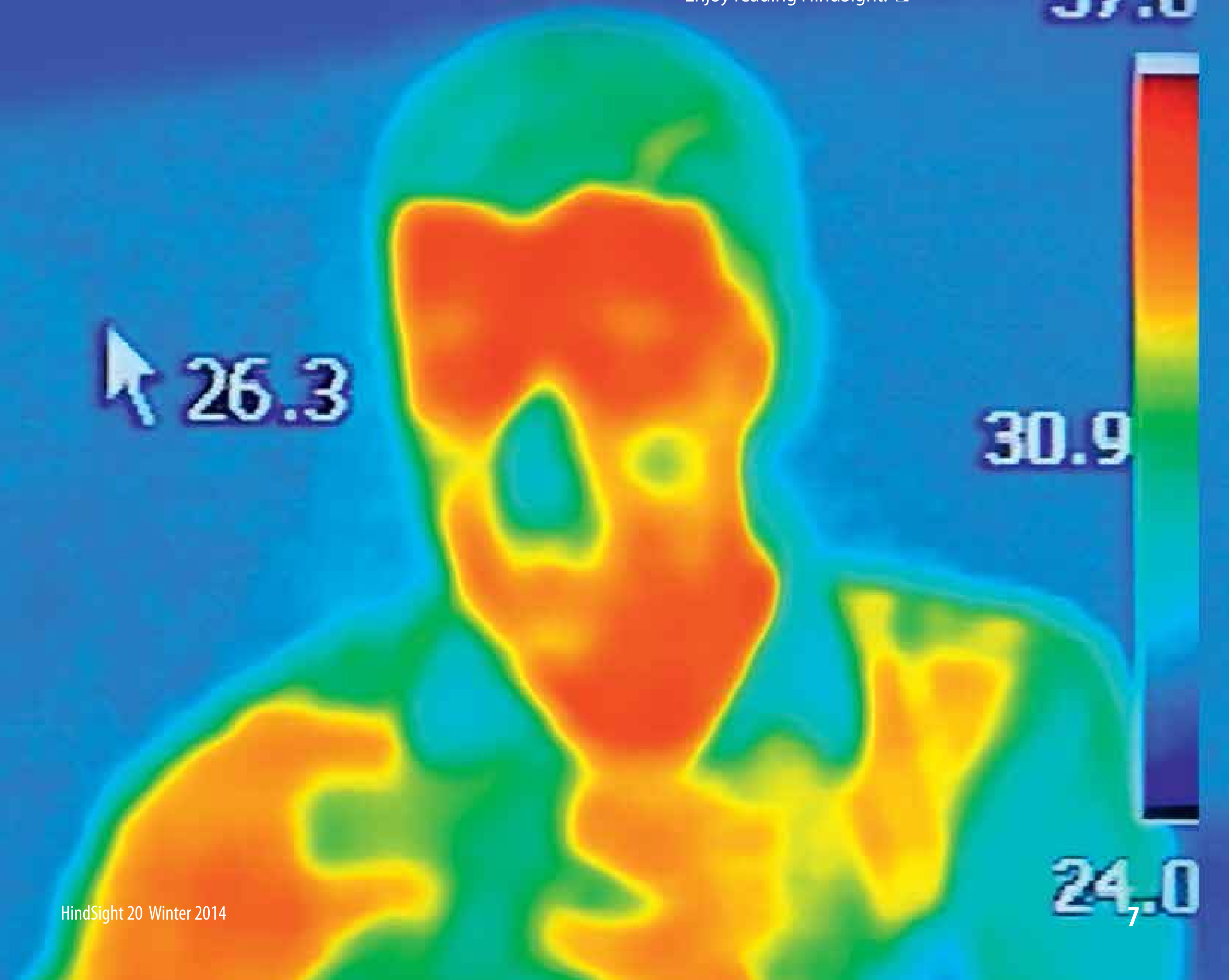
A simple proxy might be to automate the prediction of the number of aircraft entering a sector in an hour – then you set a capacity figure and try not to exceed it. But the sectors are getting smaller and the traffic over a complete hour does not tell you much about the traffic distribution within the hour. So instead of traffic load, many ANSPs are now using 'sector occupancy' – the number of aircraft in the sector at a given time. You can set limit to this as well. But hey – remember my story – who has not experienced something similar? Traffic may be below the limit, yet the complexity of the situation may be 'overheating' you.

There are few ANSPs that are studying automated systems to predict complexity – traffic complexity and situation complexity. This is a scientific approach to factor-in as many of the indicators of complexity as possible e.g. the number of vertical movements, of heading changes, of conflicts, of weather deviations and of entries and exits not at designated points. All these together are supposed to help anticipate the 'heat'. It is never precise and it is complicated to do. But it is our responsibility to manage the workload and we need automation to monitor it and help us see problems coming before they occur..

But don't misunderstand me. Automation of a task should not necessarily come in the form of complex machinery. I know at least one ANSP that fitted a simple warning light system for the controllers to display their subjective feeling of workload. And the subjective feeling of workload is what really matters since it reflects all the factors involved – not just numbers of aircraft. You press a button and your colleagues and supervisor can see you are 'red' – you are 'overheating'. The team and supervisor can then help out. Managing your own workload – and that of your colleague(s) if you have a supervisory role is, like it or not, your responsibility and you'd better do something about it – a sophisticated system or a simple one or both.

But make sure you can feel the heat around the corner!

Enjoy reading HindSight!



Human-centred automation for ATM

by Professor Sidney Dekker

When NextGen was not yet a word, Charlie Billings had just retired from NASA (the National Aeronautics and Space Administration in the US) and taken up a position as professor at The Ohio State University. Dr. Billings, who had been one of the main people behind the confidential Aviation Safety Reporting System (ASRS), employed me as his Graduate Research Assistant to help in the development of a book about human-centred aviation automation. The book came out in 1996.

Professor Sidney Dekker

is Professor and Director of the Key Centre for Ethics, Law, Justice and Governance at Griffith University, Brisbane, Australia.
Author of best-selling books on human factors and safety, he has had experience as an airline pilot on the Boeing 737.

In it, from the credibility and perspective of an insider and well-known figure in the field, Charlie was one of the first to 'lay down the law' of human-centred aviation automation systems. I say 'lay down the law' because that is pretty much what he did—unabashedly so. He put down the standard. 'Look,' he said, 'if the human remains responsible for safety, then the human must retain the authority with which to exercise that responsibility, by whatever means. Automation must be a tool over which the human must have full authority.' There was already sufficient cause for concern over this very principle at the time - in their enthusiastic embrace of what was then known as Free Flight, researchers and policy makers were willing to acknowledge that human controllers were not going to be able to detect all conflicts in random routes and that they would thus have to rely on automation to do that for them. 'But how could that be?' Charlie asked. 'Ultimately, we will hold the human controller responsible. And you cannot hold someone responsible for something over which they don't have full authority.' The argument made pretty good sense to me.

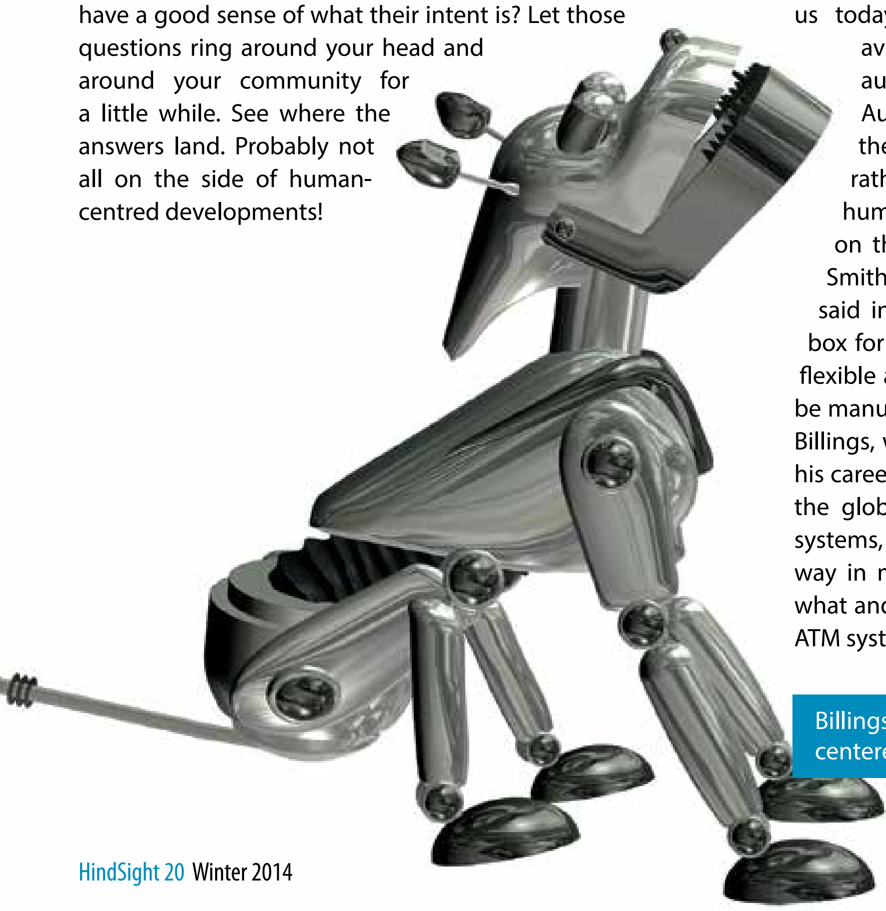
In a field with as much technical competence and prowess as air traffic management, there is always the risk that developments will not be driven by human-centred principles. The risk is that they are technology-driven, and that the result is technology-centred systems. These are the kinds of systems that can generate the kinds of wacky error messages that implicitly accuse humans of not thinking and behaving like machines. You probably know what I mean. But these are also systems that take an increasing amount of cognitive, planning and decision-making work away from the humans who remain ultimately responsible for the outcome. That is not just a practical or technical dilemma, it is an ethical one. As we are in the midst of another wave of technology-driven developments in creating next-generation air traffic management systems, it is probably a very good idea to go back to some first principles. What would Charlie have said, have warned, have reminded us of? Here are some of the most important points (called premise, axiom and corollaries, but don't worry about that too much):

Premise:
- Controllers bear the responsibility for traffic separation and safe traffic flow.

Axiom:
- Controllers must remain in command of air traffic.

Corollaries:
- The controller must be actively involved in the process.
- The controller must be adequately informed of what is going on in the process.
- The controller must be able to monitor the automation assisting them.
- The automated systems must therefore be predictable.
- The automated systems must also be able to monitor its human operators.
- Every intelligent system, whether automated or human, must know the intent of other intelligent systems involved in running the process.

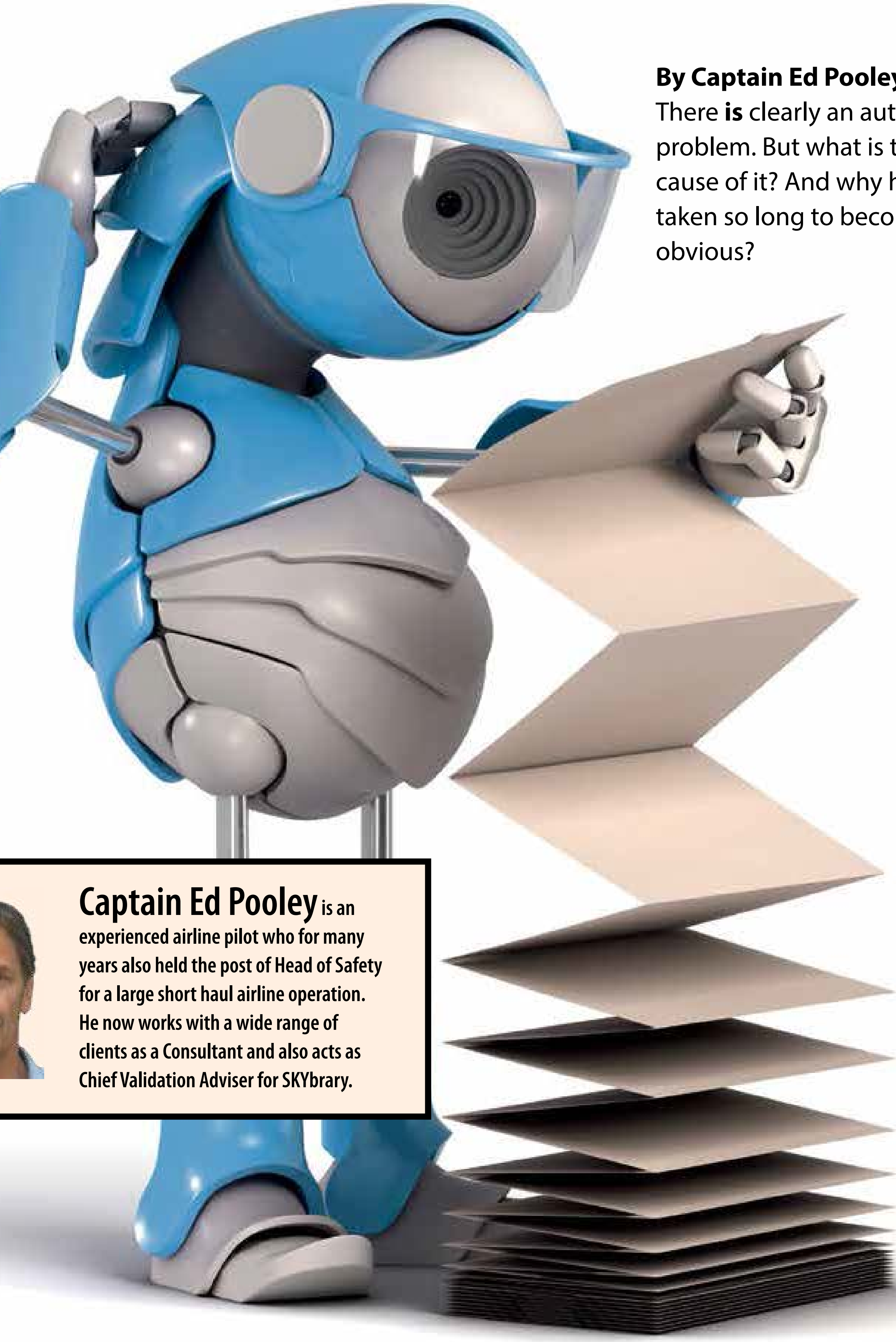
Charlie had good reasons to lay down the law the way he did. He had already come across automated systems that limited the controller's authority, without it even being obvious to the human operator that this had occurred. To him, this was not only unsafe and unethical, it was also an expression of a lack of trust between the developers and managers of a system on the one hand, and its human controllers on the other. If human controllers were not given full authority, and were not fully informed of what their automated systems were doing or why they were doing it, were the controllers actually trusted to do the right thing, to be the professionals they were? What did this say about our confidence in our fellow human beings? This concerned Charlie greatly. And indeed, a lack of involvement in process control, and not being adequately informed of what the automation has been doing, has led to inevitable 'automation surprises.' These would be avoidable if we followed the human-centred principles above. Are controllers still fully 'in command of air traffic'? Are they actively involved and adequately informed? Are the automated systems we are developing today sufficiently predictable, so that human controllers have a good sense of what their intent is? Let those questions ring around your head and around your community for a little while. See where the answers land. Probably not all on the side of human-centred developments!



Relying on automation research giants like Earl Wiener, Charlie reminded his readers (as he reminds us today) that 'the experience from commercial aviation shows that it is unwise to dream of automating human fallibility out of a system. Automation essentially relocates and changes the nature and consequences of human error, rather than removing it, and, on balance, the human operator provides an irreplaceable check on the system.' Charlie liked to quote Dr Ruffell Smith, an aviation human factors pioneer, who said in 1949 that 'Man is not as good as a black box for certain specific things. However, he is more flexible and reliable. He is easily maintained and can be manufactured by relatively unskilled labor.' Charlie Billings, who was born in 1929 in Boston and started his career as a flight surgeon, passed away in 2010. In the global enthusiasm for more technology-driven systems, reminders of his first principles can go a long way in moderating and enriching the discussion of what and how we should automate and advance our ATM systems even today. S

Billings, C. E. (1996). Aviation automation: The search for a human-centered approach. Mahwah, N.J., Lawrence Erlbaum Associates.

The 'automation problem'



By Captain Ed Pooley

There **is** clearly an automation problem. But what is the **real** cause of it? And why has it taken so long to become obvious?

Captain Ed Pooley is an experienced airline pilot who for many years also held the post of Head of Safety for a large short haul airline operation. He now works with a wide range of clients as a Consultant and also acts as Chief Validation Adviser for SKYbrary.

The rapid rise in the extent to which the pilot of a modern transport aeroplane manages and controls their aircraft with the aid of automated systems is well known. During this change, the accident rate has stayed low despite a continuing rise in aircraft movements. It seems to me that the extent to which a lack of competence[1] of pilots as the direct cause of accidents has not diminished and, relative to other such causes, has probably increased.

It is possible to see that the effects of high levels of aircraft automation appear to have been two-fold:

- Pilots' **Knowledge** of both their automated systems and the way they interact with how aircraft fly however they are controlled is often insufficient to cope with abnormal events unless these are resolved by straightforward checklist compliance.

- The extent and nature of the **Decision Making** which is required to operate a highly automated aeroplane today is quite different from that required to fly most similar-sized aeroplanes thirty years ago.

The relationship between these two components of pilot competence is important. Decision making in the event of abnormal occurrences which are not covered by a 'scripted' procedural response often requires 'background' knowledge. Before automation became so dominant, such knowledge was usually available on account of more frequent use. But now it is rarely required and has either never been acquired at all or since forgotten due to lack of use either on the line or in training.

We should also remember that flying transport aeroplanes no longer involves much actual flying – and when it does, it is rarely undertaken without the benefit of at least some 'automation support'. The majority of the generation of pilots now in the vicinity of retirement had the benefit of much more opportunity to fly manually because automation was less extensive. This provided them the context for the overall task of flight management rather than it nowadays being, on almost every flight, the central task. Only in the case of the take off have the means to automatically control the aircraft through automatic system management not yet been found. Interestingly, that is the one flight phase where the key to aircraft flight safety – appropriate pilot decision making based on readily recalled knowledge – is still crucial if an unexpected situation occurs, although of course it rarely does.

Much has been made of the importance of cross-monitoring in a two pilot flight deck as a defence against inevitable human error. Much emphasis has also been placed on compliance with the comprehensive set of rules and procedures which aim to cover all the situations which it is anticipated that pilots will 'normally' encounter. But in the context of automation, both these contributions to safety are, whilst unquestionably important, simply attempts to treat the symptom not the cause. The focus needs to be placed firmly on **effective knowledge-based decision making.**

Perhaps you are not convinced? Let me illustrate my point by looking at a couple of superficially well known accidents where all did not go well:

First, the Air France Airbus A330 (AF447) which crashed in mid Atlantic in 2009[2]. The two co pilots were (jointly[3]) in charge of the aircraft whilst the Captain took his planned rest in the cruise. It was a night flight and the aircraft had been in level fight in IMC for some time with the autopilot engaged. Then, unexpectedly, they were faced with a sudden successive but ultimately very brief[4] loss of all air speed indications and an uncommanded disconnection of the autopilot. Although there was no strictly applicable checklist for such an occurrence given that it was not considered sufficiently likely at the time, the immediate pilot action in such cases was – and remains – 'do nothing'. But one of the pilots almost immediately initiated and sustained a climb, something that was inevitably going to lead rapidly to a stall[5], which it did. Despite the stall warning – for which there is an effective mandatory response – the pitch up was continued. And the other pilot failed to intervene verbally or by taking control. By the time the Captain hurriedly returned to the flight deck, the aircraft was fully stalled and descending at 10,000 fpm leaving him insufficient time to assimilate what was happening and regain control.

1- ICAO, in Doc 9995, a recently issued Manual describing a new approach to pilot training based on the demonstration of a number of defined competencies, defines competency as "a combination of knowledge, skills and attitudes required to perform a task to the prescribed standard". The eight competencies which are defined include "aircraft flight path management, automation" and "aircraft flight path management, manual control".
2- For more detail on this see:
http://www.skybrary.aero/index.php/A332,_en-route,_Atlantic_Ocean,_2009_(LOC_HF_AW)
And to see what the public are being 'told' in a surprisingly coherent and fairly accurate account published recently general media, see http://www.vanityfair.com/business/2014/10/air-france-flight-447-crash
3- The Captain did not explicitly designate one of them as the senior pilot and Air France procedure on the matter was arguably ambiguous.
4- All three airspeed indications were lost for around 30 seconds and two for around a minute.
5- The angle of attack which corresponds to normal high altitude cruise is usually relatively close to that at which a stall warning would be triggered.

The 'automation problem' (cont'd)

The aircraft had been crossing the zone of convective weather known as the ITCZ[6]. This region was already well known as a potential environment for ice crystal icing at temperatures below -40°[7] and the potential for this to cause temporary loss of the dynamic air pressure necessary for airspeed to be computed and displayed. No other flight instruments failed[8] and all that was required was to continue in level flight with the same engine thrust and at the same aircraft pitch attitude. The latter is the basic way aircraft are controlled and an indication of pitch attitude would have been enough to continue the cruise temporarily even if altitude and engine thrust indications had also failed, which they had not. The investigation was not able to account for the actions of one co pilot or the inactions of the other. But, on the evidence presented, you may recognise that perhaps a 'startle' phase degenerated very quickly into confusion and uncertainty. This replaced the rational response that is usually founded in any professional by an underlying grasp of how their 'machine' works. What happened to two pilots 'working together' seems to me to have been impossible if there had been not just knowledge about the state of the automated systems but at a very fundamental level about how all aircraft fly. Of course prompt compliance with the mandatory stall warning drill could have saved the day but the investigation was also unable to explain the absence of that. I should mention that the flight envelope protection function on this aircraft type which prevents pilots 'accidently' losing control of their aeroplanes by taking them into a stall despite stall warning activation became inoperative because the applicable control law changed from 'Normal' to 'Alternate' when all three air data computers registered a lack of valid input for airspeed calculation.

Release control or I press CTRL-ALT-DEL !

Second, the Asiana Boeing 777 (OZ214) which crashed at San Francisco in 2013[9]. On a VMC day, ATC gave the crew a visual approach at San Francisco because the ILS Glideslope was out of service and the weather conditions did not warrant the issue of clearances to fly the available Localiser-only procedure. The Pilot Flying (PF), a trainee Captain being supervised by a Training Captain and with the relief First Officer occupying the Observer seat, decided that rather than fly a visual approach, he would use the automatics to capture the Localiser and set the Vertical Speed mode so as to follow the standard vertical profile as detailed on the Localiser-only plate. Localiser capture went as intended but right from the start, the PF had difficulty in properly controlling the vertical speed. About 1500 feet and about 3.5 miles out, somewhat higher than the correct vertical profile required, he made inappropriate mode selections and, when they caused the autopilot to begin to climb the aircraft, he decided to resolve the situation by disconnecting the Autopilot and manually selecting flight idle thrust. But he was unaware that having left the Autothrottle engaged, it would no longer track the selected speed, the mode providing this function having been overridden by manually setting idle. As the Asiana-designated stabilised approach 'gate' at a height of 500 feet was passed, the aircraft was not stabilised in accordance with the specified criteria[10] but nothing was said. With the thrust remaining at idle, the aircraft began to progressively descend below the correct vertical profile. It seems that none of the pilots were able to comprehend the reason why the view out of the window of the runway perspective then steadily became more and more abnormal as also confirmed by the visual descent path guidance provided by the PAPI[11] as the latter progressively changed from white/white/white/red (just above profile) at 500 feet agl through the two intermediate stages to reach red/red/red/red (significantly below profile – stop descent until profile regained) at 219 feet agl. It appears that once below 500 feet, none of the pilots had noticed that the

6- Inter Tropical Convergence Zone
7- Such icing results from ice crystals which encounter heated parts of an aircraft such as engines and pitot tubes being heated to melting point and then temporarily re-freezing.
8- Although there was intermittent loss of Fight Director guidance on both pilots' Primary Flight Displays.
9- For more detail on this see:
http://www.skybrary.aero/index.php/B772,_San_Francisco_CA_USA,_2013_(LOC_HF_FIRE_AW)
10- Because the rate of descent was 1200 fpm when around 700 fpm would have been expected, because the thrust setting was not appropriate to the aircraft configuration and because more than 'small changes in heading and pitch' would have been required to maintain the correct flight path.
11- Precision Approach Path Indicator - see:
http://www.skybrary.aero/index.php/Visual_Approach_Slope_Indicator_Systems for a description

the passive willingness of some aircraft operators to permit pilots who have not been adequately prepared to fly the line in all the situations they might find themselves in is not new. Indeed, the history of accidents and incidents appears to indicate that there was proportionately far more of this 'passive willingness' in the past than there is today.

airspeed was dropping, the thrust was at idle, the rate of descent was increasing far in excess of that which would be expected for a descent on the correct profile and the progressive increase in pitch in an attempt to 'reach' the runway was rapidly creating a pitch attitude which was completely at odds with that which would normally be seen. All these are fundamental requirements for the collective situational awareness of the crew. Recognition of any one of these would have constituted a requirement for an immediate go around. But in the end, a very late recognition that the aircraft was – to put it mildly – not going to make the runway only led to the initiation of a go around at 90 feet agl. Whilst this would not have been too late on a normal approach, it was at the prevailing low energy state of the aircraft. The tail hit the low sea wall just before the runway threshold and broke off after which fuselage was no longer controllable and a crash was inevitable.

The complete lack of situational awareness of the newly appointed Training Captain who watched this scenario unfold is particularly difficult to understand. This is the very strand of competence that underpins the essential performance of a senior Captain appointed to this role and, as such, it must be assured rather than assumed before the appointment is confirmed. The management decision that the Trainee Captain was ready to begin the final phase of his command upgrade also seems, in my opinion, to be at the very least questionable. The capabilities of modern flight simulators, provided they are combined with competent management decision making about whether trainee commanders have reached the 'almost-ready' stage, mean that line training has become a confirmation of competence not an exploration of it. I think the evidence of this Investigation shows that the competence of the trainee was still being explored. He had insufficient confidence in his ability to fly the aircraft without using the automatics to the maximum extent possible and having decided to rely on the automatics, he was unable to use them properly. Then, when it all began to go wrong, he did not understand how they worked. As with AF447, the day could have been saved in the early stages, and indeed in this case much later, by the simple expedient of compliance. The Asiana stabilised approach SOP was cleared stated and clearly breached both at the specified 500 feet 'gate' and then continuously once below it.

I take the view that the passive willingness of some aircraft operators to permit pilots who have not been adequately prepared to fly the line in all the situations they might find themselves in is not new. Indeed, the history of accidents and incidents appears to indicate that there was proportionately far more of this 'passive willingness' in the past than there is today. But what has actually kept the accident rate[12] low? Automation of course! It's grown rapidly in both its capability and in its reliability. Its effect has been to change the role of the pilot into one which requires – most of the time – a different set of skills underpinned by additional knowledge. But these new skills do not replace pilots' need to have the ability to manually manage and fly the aircraft during infrequent and unexpected departures from the automated normality. There will always be some situations that do not lend themselves to a prescribed SOP response even with the number of these that now exist. Compliance culture can certainly help avoid accidents but alone it is not enough. A deeper background appreciation of the big picture – both how aeroplanes actually fly and how the automated interface between the pilot and his particular machine functions – is a fundamental part of competence[13].

Think back to the Qantas A380 which suffered an uncontained engine failure in 2010[14]. The consequences of the collateral damage which followed this caused the (fortunately) augmented crew to abandon the ECAM-directed response in favour of action informed by their knowledge-based ad-hoc decisions. Yet just like all the others, this crew usually had a routine automated flight focused primarily on diligent system management. Think, too, of the Cathay Pacific A330 crew who, also in 2010, got their aircraft safely on the ground in Hong Kong when both engines began to malfunction after they had unknowingly loaded ▸▸

12- Recorded incidents attributed to 'pilot error' (as opposed to accidents) have by contrast increased because of a combination of better reporting and better investigation processes, especially the widespread use of recorded flight data to put alongside the narratives submitted by pilots.
13- Knowledge is at the core of the recent competency-based ICAO pilot training guidance referenced earlier and in the Airbus adaptation of it for A350 type rating training is explicitly, rather then implicitly defined as a 'competency' - see 'Learning from the evidence' pps 24-32 in Safety First (the Airbus Safety Magazine) Issue 18, July 2014
14- For more detail on this see:
http://www.skybrary.aero/index.php/A388,_en-route_Batam_Island_Indonesia,_2010_(LOC_AW)

The 'automation problem' (cont'd)

contaminated fuel for their flight[15]. Again the crew demonstrated their ability to deal with a situation for which existing prescribed responses alone were not enough to secure a safe outcome. I see these responses as a clear indication that the crews involved must have been both selected and trained by their employers in a way that enabled these impressive performances.

So I conclude that, whilst the way automation is delivered in aircraft design can always be improved, the root of the automation problem we are seeing today does not lie primarily – as many human factors experts will tell you – in system design. Rather, it lies in ensuring that people with the right aptitude and ability are trained as pilots in the first place. And that they are thereafter provided with type and recurrent training which is compatible with a job which now typically has very long periods of automated routine punctured only very rarely by the challenge of something (completely) unexpected. Even with the very best selection processes, a successful outcome to any path through training is not a guaranteed one. There is a very heavy responsibility on all aircraft operators to ensure that they do not release pilots to line flying duties until there is solid evidence that all aspects of their professional competence have been clearly demonstrated to be compatible with their role.

A similar training challenge can be found in other jobs where the role of automation has rapidly increased and has also delivered greater overall safety by this very fact. So whilst in aviation, we certainly need an operating culture underpinned by procedures and compliance, the real foundation is, as in other comparable risk bearing occupations, the right people in the right jobs who are trained in the right way. Then we will be able to reduce the prevalence of occasions when the performance of pilots leads to the crash of an essentially or even a fully serviceable aircraft. And we will see more instances of recovery from potential disasters such as the Qantas and Cathay Pacific examples quoted.

It is perhaps worth reflecting that, on the evidence available, the industry as a whole and the regulatory system in particular can reasonably be characterised as having been sleepwalking towards the situation we are now in. There has been a failure to realise that the undoubted safety benefits of automation needed a lot more attention to pilot qualification and pilot training than we have seen in all but a relatively few enlightened operators.

Finally, can we expect the 'automation problem' to get worse if there continues to be no 'structural' response to the underlying cause I have identified? Unfortunately, the answer is a resounding 'yes'. We are rapidly moving towards the time when both pilots on the flight deck will have gained all their experience in the 'automation age'. The consequences of the transition to automation have so far been masked by the broader experience which older pilots, especially those in command, have had. In some cases, their personal conversion to automation may have been incomplete but their reversion skills were ingrained through early-career use and have been readily accessible when suddenly needed[16]. But we are now rapidly leaving that comfort zone with only best practice at leading operators showing the way for the rest….

Now what if anything does all this mean in terms of the automation and safety in ATC? In principle, automation for both controllers and pilots has a similar cost/benefit balance. In both cases, as well as being more efficient than humans, it is also more reliable - until that is, it fails. Which is when the licence holder in ether case has to pick up the pieces rather like they used to do as a full time job before automation. When this happens, the response expected of controllers, as with pilots, is likely to be time-sensitive and require recovery from a situation in which:

- automation may have been managing a situation which is more complex than the human would have been.
- the human may well be 'startled' and their initial response less than optimal.
- there may be no pre-trained response which fits the scenario.
- the realism of prior training for "the unexpected" may have been poor and / or the frequency of exposure to it may have been insufficient.
- the automation abnormality may have been unintentionally precipitated by one's own action (or inaction).

And there is another rather important similarity linking pilots' and controllers response to the challenges of automation – their licence holding status. In my view this brings with it a personal professional responsibility which is just as much a part of the solution to automation issues as the obvious responsibilities of employers to ensure they recruit people with the right aptitude and then ensure that they provide them with the training they need to manage both the normal and the abnormal. The latter may require ad hoc decisions based on rarely-recalled knowledge and the responsibility to possess and be able to apply it is very much in the interests of both the individual and their employer. Now there's some more complexity... and a need for ANSPs and their Regulators to take a lead from best practice and not be content with achievement of safety management at the threshold of audited compliance.

15- For more detail on this see:
http://www.skybrary.aero/index.php/A333,_Hong_Kong_China,_2010_(LOC_RE_GND_FIRE)
16- Think of the A320 successfully ditched in the Hudson River off Manhattan in 2009 after a multiple bird strike - details at: http://www.skybrary.aero/index.php/A320,_vicinity_LaGuardia_New_York_USA,_2009_(BS_LOC_AW) .

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EUROCONTROL

I  AUTOMATION

by Eileen Runge

In Maastricht UAC, together with our external partners and the airlines we have developed several automation projects. The main goal is to save time but as there is less room for misunderstandings when communication takes place via information displayed on the radar screen instead of via telephone or R/T, safety benefits as well!

Auto Revision is great! Auto Revision can be a pain!

Auto Revision, the OLDI[17] revision message, is an electronic revision with external partners. Unless the aircraft concerned is too close to the transfer-of-control point, the system sends the revision details automatically as soon as the controller makes the input that the aircraft wants, say, a different flight level. A colored chevron next to the callsign indicates whether the Auto Revision worked or if the controller has to pick up the phone and coordinate the revision the old fashioned way. For the sending party, Auto Revision is a great thing. It literally takes a second! For the receiving party, things can be less straightforward. There is no "accept" function in Auto Revision. Once the data is sent the revision is considered coordinated. There is only a subtle visual alert next to the callsign of that aircraft. It is up to the receiving party to (a) detect that an Auto Revision has been sent for an aircraft, and (b) conduct a new conflict search including the new flight level. If there is a conflict, the only solution is to quickly pick up the phone and try to reach the sending sector before they actually change the vertical profile of that flight. Usually, you are too late. On the other hand I would estimate that only one out of ten flights with Auto Revision used results in a crossing problem and there is enough time to solve things with appropriate headings.

17- On-Line Data Interchange - a means to send information to a neighbouring centre electronically instead of making a telephone call

AMA is handy! AMA is creating more workload!

AMA is an electronic Arrival Management Message sent from Amsterdam ACC to Maastricht UAC. To the controllers concerned, it shows what indicated airspeed they should issue to Schiphol inbound traffic when converting from Mach Number to indicated airspeed. By controlling the speed and thereby the sequence from such an early stage, traffic flows are optimised and become more efficient which saves fuel for the customers. AMA sounds great in theory and it is in practice - as long as the controllers from the sending and the receiving sectors have the same idea about the traffic sequence in their mind. If they have different ideas it can result in chaos! The sending sector has already worked on a sequence for up to ten minutes, speeding up some aircraft whilst slowing others down. #Then, about five minutes before the transfer-of-control point is reached, the AMA comes in. Included in the label for each aircraft is a three-digit number in orange which shows the IAS Amsterdam would like these aircraft to be flying on transfer. In the worst case it shows "MIN" = minimum clean airspeed. Sometimes it shows the complete opposite on what you have been working on over the past few minutes. Sometimes you have three aircraft on top of each other and you have the same IAS displayed for all of them. At the same flight level this is not going to work! That is the moment when the coordinating controller has to pick up the phone and negotiate things the old fashioned way. We have had situations where this has led to a high workload. But the system is improving and both sides are learning as they go along. And one of our projects under development is to create an AMA with Langen ACC for Frankfurt arrivals, so we should be able to take our 'lessons learned' into that.

Big Brother is watching: the use of Mode S-downlinked parameters

We are able to see downlinked parameters for aircraft that are Enhanced Mode S equipped displayed in a window on the radar screen. To me, this is the biggest improvement we have seen in recent years. The link between the selected flight level and our label input of the cleared flight level has made the skies a lot safer. In the case ▸▸

Eileen Runge

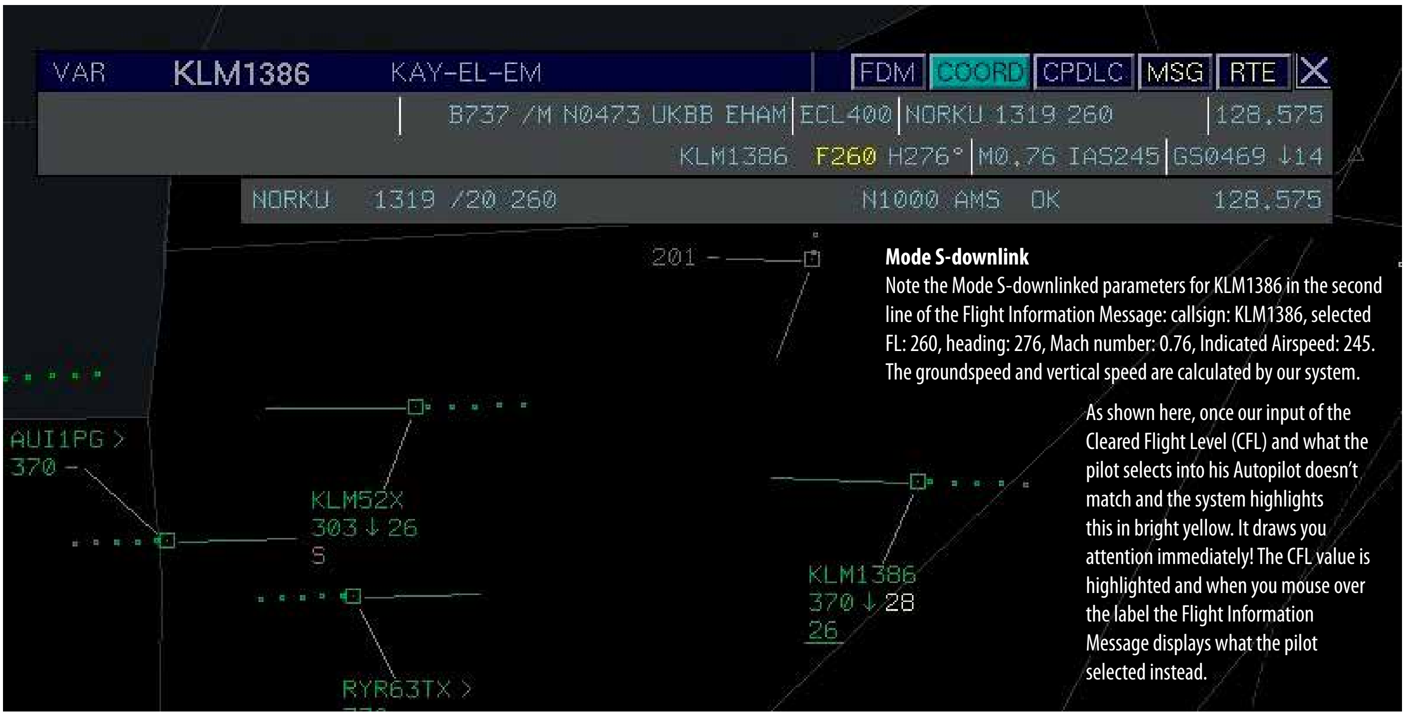
is an Air Traffic Controller at EUROCONTROL's Upper Area Control Centre in Maastricht. She works in the Hannover Sectors which cover north-western Germany and is an OJTI.

I ♥ automation (cont'd)

Once you mouse over the label the orange "S" turns into the IAS requested, e.g. "275" (KLM52X). The coordination window shows all information. Note as well the frequency of the next receiving sector being displayed at the far right of the coordination window (128.575).

AMA / next frequency

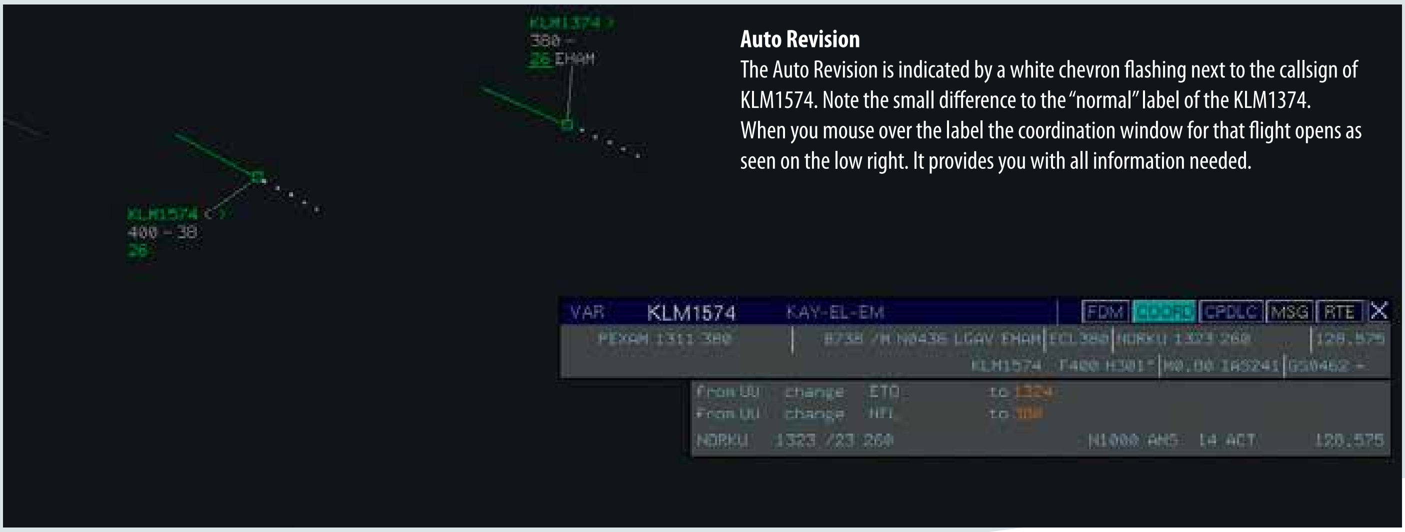
That a speed request has been sent by Amsterdam ACC is indicated by an orange "S" in the label of the aircraft concerned (KLM52X).



Mode S-downlink

Note the Mode S-downlinked parameters for KLM1386 in the second line of the Flight Information Message: callsign: KLM1386, selected FL: 260, heading: 276, Mach number: 0.76, Indicated Airspeed: 245. The groundspeed and vertical speed are calculated by our system.

As shown here, once our input of the Cleared Flight Level (CFL) and what the pilot selects into his Autopilot doesn't match and the system highlights this in bright yellow. It draws you attention immediately! The CFL value is highlighted and when you mouse over the label the Flight Information Message displays what the pilot selected instead.



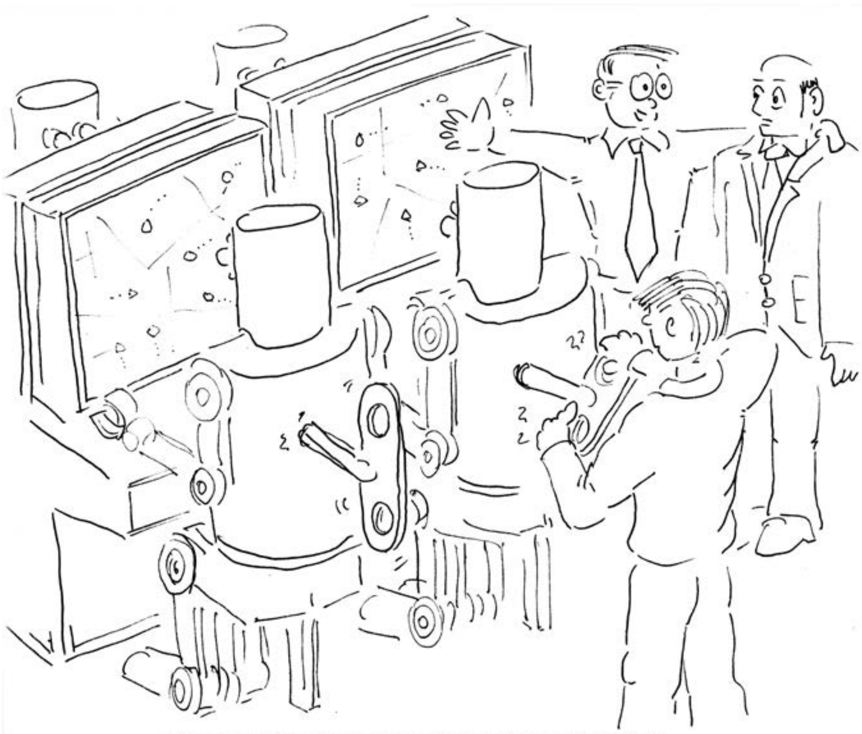
Auto Revision
The Auto Revision is indicated by a white chevron flashing next to the callsign of KLM1574. Note the small difference to the "normal" label of the KLM1374. When you mouse over the label the coordination window for that flight opens as seen on the low right. It provides you with all information needed.

of a detected discrepancy, a bright yellow visual alert is displayed and things can usually be corrected in time. The downside of this is that controllers are not listening that carefully any more to Flight Level readbacks. If there you doubt that the attitude has changed for the worse, try "let's see what they tune in the machine. If it's the wrong level I can always get back to them via voice and confirm." However, there is no question that in general, Mode S-downlink is reducing transmissions "Report heading" or "Report speed" have become obsolete as we can read such values by a simple mouse-over the aircraft label. It has also become much easier to check if pilots are really doing what they were said they would, e.g. a speed during sequencing. The times where a sequence did not work out and you knew one of the pilots was lying but did not know which one are over, thanks to Big Brother!

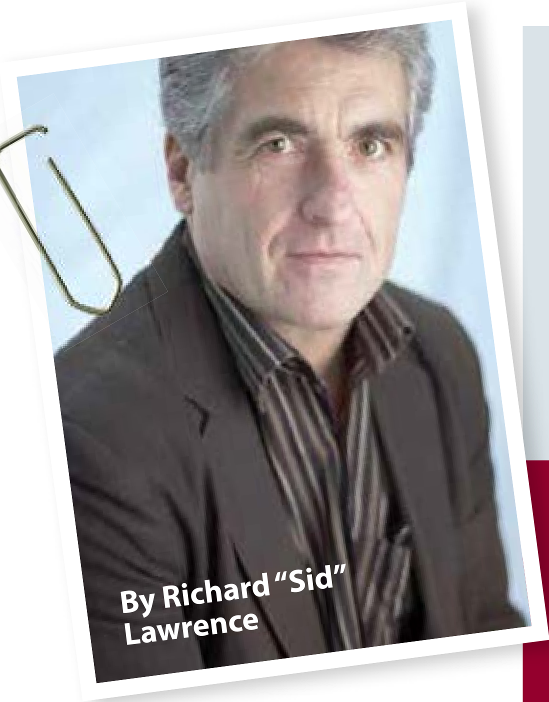
What's the frequency again?

All controllers know that question… In Maastricht the frequency of the next sector is displayed in the label once you open the transfer menu. Very handy but it has led controllers to rely on simply reading the frequency off the screen. One can argue that as a result there is more free mental capacity to deal with the real ATC challenges. But what happens when one of these colleagues is working a busy sector and we have to switch to the backup system? In the old days all of us knew more than 60 frequencies by heart, so there was no issue. Now this could easily lead to an overload of that controller. Automation can make the brain lazy and we have to be very aware of what the consequences are for every single one of us when automation fails and we are on our own again.

These are just a few examples from our many little helpers. As with all automation and assistance systems, the difficulty is to keep a healthy balance between letting them make your life a little easier and not slowly losing the skill you had before they arrived. Compare it to the parking assistant fitted to your car. And the lane keeping support and the rain sensor and the cruise control or nowadays the adaptive cruise control which keeps the distance to the car in front of you constant. You still want to be able to drive and to park your car safely without them. In ATC you don't want to depend too much on such systems - never forget that the backup system does not feature them!



As you can see the system is not fully automated, the human still has an important role to play.



Dear Readers,

In the pages that follow we will look at two EUROCONTROL Safety Alerts covering two completely different aspects of ATC: what happens to controllers when they are involved in an ATC reportable incident and phraseology associated with climb/descent.

As previously, my intention is to try and bring new information to the table. As such, I will present the feedback and responses received and provide comment and analysis. The aim is to get you thinking about the issues exposed and how they might affect your operations. The Alerts might also provoke further responses from you and I would welcome additional inputs that might fuel further debate and consideration.

The first Safety Alert for this edition of HindSight is Request for Support Message, Post-incident withdrawal of air traffic controllers from control positions.

REQUEST FOR SUPPORT MESSAGE

Post-incident withdrawal of air traffic controllers from control positions

Synopsis

Released on 26 March 2014

An Air Navigation Service Provider (ANSP) had asked for information concerning the policies and resultant practices and procedures in use related to the withdrawal of air traffic controllers from control positions following safety related incidents such as runway incursions and losses of separation.

Existing provisions and guidelines

There are no prescriptive international regulations that specify when a controller should be withdrawn from a control position after an incident; however, the practice is reflected in a number of industry guidelines:

EUROCONTROL Guidelines for Investigation of Safety Occurrences in ATM (2003)
"The supervisor should, obviously, safeguard continued service provision. The controllers involved in an occurrence should be removed from their control position. The sense of guilt that can follow from an occurrence may impair the controller's ability to continue safe operation."

EUROCONTROL SAF REP ATM Incident Reporting Culture: Impediments and Practices, (2005) states at 2.2.2.8. *"the practice of withdrawing ATCOs from operational positions when they are involved in safety occurrences, with the only aim of preserving the individual and the organisation was found to be a sound and recommendable practice. ATCOs retain their full right of reinstatement subject to further clarifications from the investigation but without prejudice of any administrative sanctions."*

Analysis

Not all incidents are of the controller's making. Nevertheless, it has been common (even standard) practice for the ATC supervisor to withdraw the controller from position immediately following their involvement in a serious incident in order to safeguard continued service provision and to provide relief to the controller(s) – who may have been adversely affected by the experience. However, some ANSPs now allow the supervisor to exercise 'judgement' and to leave the controller in position for 'less serious' incidents. The intention is to remove any perceived stigma of being withdrawn for minor separation minima infringements etc.

Support requested

Air Navigation Service Providers and National Aviation Authorities were invited to submit details of any national/ local level written policies related to post-incident withdrawal of controllers:

- What are there criteria (if any), in terms of 'seriousness' of the incident, that might trigger withdrawal?
- Is post-incident removal an automatic process or can some form of judgement be exercised?
- If judgement is used, who can exercise it, the controller, supervisor, watch manager?
- What is the policy (if any) regarding the suspension of ATCOs following removal e.g. automatic suspension, case-by-case basis?
- Describe other post-incident administrative actions, e.g. licensing/rating action, remedial training, e-instatement procedures.
- What controller support processes etc are in place e.g. CISM, counselling?

Feedback received

Responses were received from 13 ANSPs (including one military) and 1 CAA.

Incident seriousness
What are the criteria (if any), in terms of 'seriousness' of the incident, that might trigger withdrawal?

The matter of withdrawal is generally a subjective matter; however, ANSPs decide/consider using:

- Severity Cat A, B, C (as per RAT)
- Risk tolerability matrix
- ICAO Annex 13 definition
- Likelihood of national AAIB involvement
- Accident
- Effect of the incident on the controller (physical/ mental condition)

There is also general recognition that many events are not of the controller's making and they may have had no direct or indirect attribution. Nevertheless it is usually still considered prudent to relieve the controller(s) for their own benefit.

Initial Withdrawal
Is post-incident removal an automatic process or can some form of judgment be exercised?

Initial withdrawal may, again, depend on the effects on the ATCO. In nearly all cases the ATCO is withdrawn automatically – or can withdraw him/herself – pending preliminary investigation. The reasons cited for this policy include:

- Protective measure/welfare of individual.
- Without prejudice,
- No blame/culpability,
- No implication of incompetence.

Withdrawal may be for up to 3 days – pending investigation. At 'small' units or when a relief controller is not available, ATCOs may be left in position (provided they are 'fit') for short periods until a relief controller arrives. However, in one ANSP this is not the case; the ATCO is always withdrawn and traffic curtailed/ suspended if no other ATCO is available to provide relief.

Judgment (to withdraw)
If judgment is used, who exercises it, the controller, supervisor, watch manager?

REQUEST FOR SUPPORT MESSAGE (cont'd)

In the majority of ANSPs, withdrawal is often left to judgment of the Supervisor. However, the ATCO can always withdraw him/herself. Operations manager, Heads ATC etc are also involved in some cases.

Post withdrawal Suspension
What is the policy (if any) regarding the suspension of ATCOs following withdrawal e.g. automatic suspension, case-by-case basis?

Suspension of licence privileges is not always automatic and is done on a case-by-case basis according to preliminary investigation and assessment of ATC contribution.

One state does not have a suspension policy. In others ANSPs can decide but in some states cases are referred to the CAA/Regulator to make a formal decision/action.

In one state the ATCO is initially withdrawn and then not permitted to exercise the privileges of their licence even though no licence action taken. Where privileges are withdrawn it usually covers all ratings/endorsements not just those in use at the time of the incident. Checks of ATCO licence/training records may also be used to assess whether competency is in doubt.

Further administrative/re-instatement processes
Describe other post-incident administrative actions, e.g. licensing/rating action, remedial training, re-instatement procedures.

Where remedial training is undertaken, there is usually some form of proficiency check performed before controllers are released back to operational duties. ANSPs employ various panels, boards, committees etc to assess each incident and decide what, if any, further admin, licence remedial actions are necessary.

The main aim in the vast majority of ANSPs is to reintegrate the ATCO back into operations rather than to seek punishment.

CISM
What controller support processes etc are in place e.g. CISM, counselling?

CISM or some other form of formal counselling is available in most organisations. Sometimes CISM is part of the formal investigation process and CISM personnel are informed. In other cases, it is up to ATCO to approach CISM if they want assistance. Other informal means (such as a 'chat' with colleagues etc) are also used as part of the support network. In some instances the local ATCO association may also be involved.

EUROCONTROL Comment

All ANSPs have processes and procedures in place to facilitate the withdrawal of ATCOs from operations following their involvement in safety related incidents. However, whilst there are many commonalities there are also subtle differences in approach.

The overriding sentiment to emerge from the feedback is that withdrawal is, in the large majority of ANSPs, done with the best of intentions i.e. to exercise the organisation's duty of care responsibilities towards the individual and to safeguard ongoing operations. There is recognition that in many cases the ATCO may have played no active part in the development of an incident but having borne witness to it may have been adversely affected (emotionally or even physically). There is no shame in this – we're not all the same. Some people can cope with the stress of being involved in a close loss of separation incident better than others but the right thing to do is to arrange for the controller(s) to be relieved. There should be no stigma attached to this process; furthermore, withdrawal should not be seen as the organisation apportioning any blame on the controller. Instead, most ANSPs clearly state that the action is without prejudice to the investigation. This understanding and treatment is testimony to the emergence of 'Just Culture' within ANSPs. Indeed, the clear intention of most ANSPs is, where ever practicable, to return the ATCO to operational duties as quickly as possible. This doesn't amount to writing a 'blank cheque' of immunity for controllers but does points towards more enlightened thinking and attitudes within a growing number of ANSPs.

SAFETY REMINDER MESSAGE

Use of 'at pilots discretion' and 'when ready' – verbal climb and descent clearances

Synopsis

Released on 28 July 2014

An Air Navigation Service Provider (ANSP) had asked for information concerning the policies and resultant practices and procedures in use related to the withdrawal of air traffic controllers from control positions following safety related incidents such as runway incursions and losses of separation.

ICAO provisions

ICAO Doc 4444, PANS ATM, Chapter 12, Phraseologies:

- The verbal use of the word 'discretion' is referred to in several places mainly in association with 'push' and 'start' clearances,
- The phrase 'WHEN READY' is included, variously, in the context of departure, changing frequency and climb/descent, meaning that these actions may take place at a time when convenient to the pilot.

Notes:

1. The phrases 'AT PILOTS DISCRETION' and 'WHEN READY' are also included in PANS ATM Appendix 5 – Controller-Pilot Datalink Communications (CPDLC) message set. The meanings in CPDLC are synonymous in that they are both used to indicate execution when the pilot is prepared to do so.
2. ICAO Doc 9931 (Continuous Descent Operations (CDO) Manual) includes the use of either 'DESCEND AT PILOT DISCRETION' or 'DESCEND WHEN READY' for some CDO clearances. Both of these phrases mean that the pilot may adjust the rate of descent as required although by their very nature these types of operation imply that pilots would not execute a level off.

Analysis

The meaning and use of 'AT PILOTS DISCRETION', in voice communications, including the option for intermediate level offs, applies only in US airspace where it provides some operational flexibility. However, outside the US, cases have been reported where the understanding of 'AT PILOTS DISCRETION' in the operational context described is not the same; controllers expect pilots to make a continuous climb/descent to the level cleared. The unsuspecting use of 'AT PILOTS DISCRETION' by non US-based controllers in response to US-based pilot verbal requests could therefore lead to a situation where they approve the request for 'own discretion' (to climb/descend) without recognising the potential of an unexpected outcome i.e. a possible intermediate level off.

The use of the voice message, 'WHEN READY' as per PANS ATM Chapter 12.3.1.2g, namely "WHEN READY CLIMB (or DESCEND) TO (level)" prevents any possible misunderstanding outside the US and does not imply any intermediate level off.

▸▸

SAFETY REMINDER MESSAGE (cont'd)

Your attention is required

- Aircraft operators were reminded that the option for an intermediate level off following an 'AT PILOTS DISCRETION' request to climb/descend applies only in US airspace and were invited to review SOPs and note the subject for consideration and awareness.
- Non-US air navigation service providers were also invited to:
- Note the subject and share any relevant operational experiences concerning the issues described.
- Note the availability of both 'AT PILOTS DISCRETION' and/or 'WHEN READY' type phrases for specific CPDLC messages and CDO operations.
- Consider using the voice phrase 'WHEN READY', as per PANS ATM Chapter 12 Phraseologies, rather than 'AT PILOTS DISCRETION' when it is appropriate to do so.
- Exercise caution in approving verbal requests from pilots to climb/descend 'AT OWN DISCRETION'.

Further information

- ICAO PANS ATM, Chapter 12.
- IFALPA Briefing Note, 15ATSBL01, "When Ready" vs "At Pilot's Discretion", 15 April 2014.

Feedback & Follow-up action

It is understood that there is no intention to change the meaning of 'AT PILOT DISCRETION' in the US. Whilst this is a matter for the US authorities, it reinforces the need for non-US controllers to be aware of the potential for US-based carriers/pilots to have a different understanding of the meaning of this phrase and what it permits them to do.

The availability of two phrases with seemingly very similar meanings provides flexibility for pilots and controllers but also introduces potential divisions about which is the correct phrase to use in any given circumstance. Indeed, opening up the topic for debate exposes differences as exemplified below in the responses I received from 2 very experienced, practising European ATCOs during the course of developing the SRM.

ATCO 1: *"I only use the 'WHEN READY' phrase as a controller – I never use 'AT YOUR OWN DISCRETION'. For me, the 'OWN DISCRETION' clearance is to be used when a controller cannot issue a clearance (e.g. a deviation request due to CB into an active military TSA) and/or gives an instruction for a part of airspace or airport where he/she has no authority (no control)."*

ATCO 2: *"Personally, I often use the phraseology 'DESCEND AT OWN DISCRETION'. Nevertheless, whenever I use it, I always start with giving the distance to touch-down, then I continue in the same call 'DESCEND AT OWN DISCRETION TO ALTITUDE...'. In my 25 years' experience as a controller I have never had a flight that intermediately levelled off…"*

SO WHO'S RIGHT?

Well, it was agreed that the thrust of the SRM should fall firmly on the side of ATCO 1 i.e. to promote the use of 'WHEN READY' whilst acknowledging that the 'OWN DISCRETION' type of phraseology adopted by ATCO 2 is currently available for use in CDO/CPDLC operations.

It is considered that 'WHEN READY' provides sufficient flexibility for pilots (and controllers) to achieve their aims, whilst avoiding any possible misinterpretations of 'AT PILOT DISCRETION' outside the US, in particular involving US carriers/pilots.

To simplify matters, it is understood that active consideration is being given to the removal of 'AT OWN DISCRETION' from the CPDLC message set in PANS ATM and also in the CDO Manual. Any updates along these lines will be reported in these pages in future editions of HindSight.

Discretion assured!

About EUROCONTROL Safety Alerts

Although we are responsible for publishing the Alerts, the subjects and issues that surround them arise from formal and informal meetings and discussions with various groups of stakeholders. As such the Alerts are a means for us to provide a warning, issue a reminder or ask for support on behalf of the aviation industry. As well as featuring here in Hindsight, the Alerts are sent out to nearly 6000 aviation professionals (world wide) who subscribe to the EUROCONTROL Safety Alerts service. They are also hosted on SKYbrary which provides and even greater exposure of the topics to the global aviation safety community.

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http://www.skybrary.aero/index.php/Portal:EUROCONTROL_Safety_Alerts
where you can access the Safety Alerts featured here and previous Alerts.

On tour with Brent & Sid

by Bengt Collin

In the cabin of X-Line 123

"I don't like sitting this far back in the cabin", Brent complained. He and his best mate Sid were returning home after a week in Spain. "But everything worked out well, it's been a fantastic week Sid", he continued with a loud optimistic-sounding voice while he carefully studied the cabin safety instructions. "I Agree, it's been a jolly good time Brent", Sid replied. "In your opinion Brent, what was the highlight of the week", Sid asked. "Me dancing Flamenco", Brent replied instantly with a big smile on his face. Sid remembered far too vividly how Brent, under the influence of a jug of Sangria, the last evening dancing and singing at their local bar. "Viva España"!

Bengt Collin

worked at EUROCONTROL HQ as a Senior Expert involved in operational ATC safety activities. Bengt has a long background as Tower and Approach controller at Stockholm-Arlanda Airport, Sweden

"I'm dying for some more orange juice", Brent moaned. "Press the button over your head", Sid replied. "Really?", Brent didn't sound too convinced. "Sure, just press the button". Brent lifted the plastic cup to the panel above his head. "I mean press the button to call the cabin crew"; Sid was looking straight ahead, another two hours to arrival.

In a meeting room at the Centre

The representatives from the company in charge of the software update arrived 15 minutes late. Bert escorted them to the meeting room located at the ground floor. It was a standard sized room with a large table in the middle. At the far end of the table, together with the usual dry biscuits, coffee and tea was served. Bert remembered the taste of the biscuits only too well.

"We have just installed the new automatic back-up system for the upper airspace radar positions", one of the visiting software engineers named Anthony stated. "We were late so this time we did not involve any operational people in the process" he continued. "We believe it's more important to get the system up and running" another of the visitors, Ton, added. "Besides, the controllers are not interested in technical systems anyhow", he continued, smiling.

"Can you please describe the update", Bert asked. Anthony explained "it's relatively simple; if for any reason the radar data disappears, this system will automatically continue to show the position of the aircraft based on their flight plan data". "So the symbols for the aircraft will continue moving even if the radar data is gone?" Bert asked, sounding a bit surprised. "No problem, this is only installed to assist the controllers, an alert on what happened will immediately be shown at the supervisor's position" Ton responded. "The supervisor should take action as soon as it happens".

On the flight deck of X-line 123

"What are your plans for this weekend" Dirk, the Captain asked his First Officer Paul. "I take the Vespa out to the stables and do some horse riding, later I'll take a ride on my BMW motor cycle, finally I plan to play some golf" Paul answered. And you? "My wife hasn't decided yet, we'll probably continue renovating our new house". "Why not ask for a direct route to BABLA?" Dirk asked Paul in a quiet respectful way.

At the centre

"X-line one two three, fly direct BABLA", Ann looked at her radar screen while replying to X-line's request. Almost two hours in position, she was tired. She was just about to coordinate the direct routing with the next sector when Alexander arrived to release her. From experience she knew it would be no problem even if she should formally have asked first before giving the direct route to the pilots. "I have the full picture Ann, very little traffic" Alexander said, plugging in his headset to the right of her. Ann unplugged hers and headed for a coffee and a cigarette outside the building. "X-line one two three contact control on one one eight decimal two" Alexander instructed. "One one eight decimal two, X-line one two three".

In the cabin of X-line 123

"They don't serve Sangria Sid, I ordered a double whisky with Campari for each of us instead" Brent explained when Sid returned from the toilet. "Thanks Brent, but you can have mine too". "Okay Sid and whilst finishing my drinks I'll look out of the window to see if I can see any other aircraft".

At the centre

Stan was reading the morning paper as he normally did before lunch time. The only problem was that he did it while actively working at the centre. "X-line one two three on your frequency"…"X-line one two three radar contact", he returned to his paper.

The supervisor was sitting in the sun together with Ann, also smoking a cigarette and drinking a black coffee. "It's terrible that I can't smoke in position anymore, I spend more time outside the operations room than in position these days" he continued. Ann just lit her second fag; the sun was shining and the birds where singing. "It will be a nice summer!" she said.

On the flight deck of X-line 123

"OK, direct BABLA is set, it'll save three minutes". "Time for the 'Descent' check list". Both Dirk and Paul looked at their checklists although they knew them by heart.

At the centre

Alexander was looking at the radar screen, he got the impression that the picture froze for a second, then started moving again. Nothing to worry about, it was off peak traffic flows. Stan had just started reading the football results. At this time of the day his work was really boring. They should try some training on how to avoid being bored, he thought to himself and smiled. "X-line one two three TCAS descent". Stan was fully alert in fragments of a second; his newspaper fell to the floor. "X-line one two three copied, there should be no other aircraft near you". He had only two aircraft on the radar screen, X-line just passing PUTTE turning west for BABLA plus another aircraft eight miles south of X-line, heading east. At the supervisor position a red light was flashing. According to information the investigators later received from the software company, the aural warning should be available later during the year.

In the cabin of X-line 123

"Sid, I just saw another aircraft passing over us rather close" Brent was excited, he was in a good mood, having just finished his second drink. "Please don't have any more Brent, or suddenly you'll start dancing Flamenco again"; Sid looked straight ahead and closed his eyes, he needed another holiday.

Case Study Comment 1
by Dragan Milanovski

This story offers a little ambiguity about what happened and how the loss of separation could have been prevented...

At the first glance it seems obvious that if the controllers at the centre (Ann and Alexander) were a bit more vigilant during the handover/takeover, if the supervisor was in position or if Stan was not distracted by reading a newspaper this incident would have probably been prevented in time. After a while, you realise although they all contributed to the event, they have not done anything terribly wrong. One would argue that errors like these are part of the job and most of the time nothing happens before the system "catches" and corrects them. So, what made it different this time?

I am sure the idea behind the new automatic back-up system for the upper airspace radar positions was good, but I am even more convinced that getting the system up and running at any cost without involving the controllers as the final users of the system was not the best option. Little did Brent and Sid know that the highlight of the week is still ahead of them!

ATC systems are continuously evolving and they become more and more complex with time. A lot of automatic features are designed to help us do our job and continue to provide a safer service with ever increasing capacity. System changes are now taking place more often. Some of these changes are more visible to controllers, but many go unnoticed as they do not make a huge difference to the "front end". We all understand that drawing a line between the two is not always easy especially when under pressure to perform, but we also know that just adding automation without changing the way we as humans operate the system does not always bring benefits. Being humans, usually we are very quick to get used to the new features that make our life easier. After a while we even start to wonder how we used to do the job without them. Where we usually fail is in the speed at which we integrate the less "exciting" changes to the routines that automation brings. Unfortunately, sometimes it takes an incident to learn that.

In this story we cannot be sure if the controller on duty could have done something different to prevent the incident had he known about the automatic back-up system which had been installed and that the symbols for the aircraft would continue moving even when the feed of radar data has stopped. Maybe there was no time for an action to take an effect. It is not a surprise that Stan did not react at all when the screen froze for a short period of time and he also never considered the possible reasons and/or system limitations at that time. Not only that he did not know about the new feature, but he also was not competent to handle its "down side" i.e. misleading the controller in case the radar data failure is not immediately identified.

A RECOMMENDATION

The correct application of complex automated features is not always as obvious as it usually seems. The service provider from the story needs to review how system changes are implemented in the future. Early involvement of the controllers and a detailed analysis of changes of operational competencies induced by automation followed by appropriate training are likely to prevent incidents like this in the future.

Dragan Milanovski

is an ATC training expert at the EUROCONTROL Institute of Air Navigation Services in Luxembourg.

Most of his operational experience comes from Skopje ACC where he worked for a number of years in different operational posts.

Now, his day-to-day work involves ATC training design as well as Initial Training delivery for Maastricht UAC.

Case Study Comment 2
by Alexander Krastev

This story supports the conclusion based on the findings of many safety investigations that several factors link together in a sequence that ultimately leads to the unwanted safety outcome. Each of these "latent" issues used to be common in the ATC environment in the past and some still exist today. On their own, such latent problems cannot cause a safety event due to the inherent design of the ATC system – no single failure should cause an accident.

I will address these factors in the sequence they appear in the story.

The first factor is the inappropriate change management by the organisation. Two issues become obvious: (1) lack of involvement of the operational staff, i.e. the users, in the design and implementation of changes to the operational system that have direct impact on the safety of ATC and (2) the failed communication process – controllers were unaware of the implemented system change, notably of the flight plan track capability. Although I must admit here that I have never heard of an HMI design that provides identical symbols for both radar tracks and flight plan tracks.

The second factor is the flawed position handover/takeover. The outgoing controller did not inform the next sector controller and the controller taking over of the direct route she had given to X-line 123. Neither did she notify the controller taking over of the fact that coordination was pending. Both the outgoing controller and the controller taking over contributed to the rushed position handover. The latter effectively prevented notification of the changed route to the next sector controller.

The third factor is the supervisor's complacency which led to him not noting the alert about the loss of radar data. "I spend more time outside the operations room than in position these days" admitted he while smoking outside. The supervisor is supposed to be in the ops room during their duty hours. Of course, there are cases, where he/she needs to leave for a certain period of time, but there should be someone taking over the supervisor role. This might also be an organisational issue if appropriate provisions do not exist and/or back-up staff (e.g. a deputy OPS supervisor) are not made available.

The fourth factor is the controller's (Stan's) distraction. This is a well-known issue for an under-occupied controller.

Alexander Krastev
works at EUROCONTROL as an operational safety expert. He has more than 15 years' experience as a licensed TWR/ACC controller and ATM expert. Alexander is the content manager of SKYbrary.

In low workload periods, boredom becomes an issue and controller may easily lose concentration by reading a paper, chatting with other colleagues or even leaving the position for a short period of time. As Stan was reading the paper he did not notice the intermittent "loss" of the radar picture and the probable track "jump" that might have alerted him to some sort of technical problem. Such a sudden change of track position may have occurred if the system flight plan route for X-line 123 had not been updated by the upstream sector upon issuing the direct route clearance.

A RECOMMENDATION

The change management process in an ANSP should require the involvement of operational staff (controllers) at all phases of an ATC system change – from design to operational implementation.

Case Study Comment 3
by Captain Ed Pooley

I was struck by the fact that when a supplier delivers a service or a product – or in this case both – to a customer, the interests of the customer and the supplier might, on first sight, appear to be the same – a satisfied customer.
But who exactly is the customer?

Captain Ed Pooley

is an experienced airline pilot who for many years also held the post of Head of Safety for a large short haul airline operation.

He now works as an independent air safety adviser for a range of clients and is currently acting as Validation Manager for SKYbrary.

In a large organisation, the procurement process will begin once there is a defined and approved operational requirement. A minimum specification will be determined, a supplier identified and a contract set up. The delivery will be carefully monitored to see that it meets the contract specification in every way. The changes which new equipment might bring will have been foreseen when the project was approved and any training and familiarisation for the affected personnel which is not included in the contract will have been scoped and dovetailed with it. Somebody in middle management will have picked up the job of monitoring the project.

But it appears that the above did not happen in this case. Lacklustre management failed to ensure that the changes would be understood by the controllers or that they satisfied the basic requirements of an SMS in the first place. They also failed to properly control the way the contractor was permitted to work with the system. They apparently delegated 'controller training' to the contractor - they only heard about the failure to inform controllers of the changes after the fact - and they passively accepted the after-the-fact 'judgement' of the contractor that 'it's more important to get the system up and running than 'involve any operational people in the process''. So the interests of the supplier were not the same as those of the customer.

The other part of the story which caught my attention was the portrayal of a supervisor who was clearly taking a 'hands off approach' to his responsibilities. When traffic is light, any supervisor needs to ensure that complacency doesn't take over. The best way to start is by not "spending more time outside the operations room than in position" just in case it sends the wrong message to those being 'supervised'. Of course, he also was responsible for the way he routinely did his job to somebody in management who was either aware and did nothing about it or unaware and should have been.

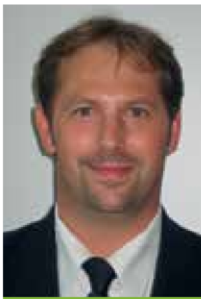
And as for the matter of smoking, there is no reason why management needed to allow smoking during a duty period, even outside the operations room, to continue. On the evidence here it was a factor not only in the behaviour of the supervisor but probably also in the quick handover of position in order to allow time for more than one cigarette to be smoked in the break. Most pilots' shifts are at least as long as those worked by controllers and often longer and, in many airlines, they haven't been able to smoke for years. The smokers amongst them at the time the rules changed all coped.

A RECOMMENDATION

The 'management' of this Unit is incompetent at some level. We don't know whether the rot actively starts at the top or just passively. But on the evidence we have, a new boss is required at the top who will make it their business to see that those who report directly to them are doing their jobs properly. And of course that effect will cascade down to the level of the shift supervisor.

Case Study Comment 4
by Tom Becker

"Errors can be prevented by designing systems that make it easy for people to do the right thing and hard for people to do the wrong thing." (Kohn, et al., 1999)



Captain Tom Becker is an active airline captain on B737 aircraft. He holds an MSc in Air Safety Management and is actually doing research on decision-making and intervention behaviour in high-risk-environments. He has been a member of the Flight Safety Committee of the German ALPA for several years.

Obviously, the automatic back-up system software in the sample story was not designed and implemented well enough to cope for real world scenarios like direct routings or other than expected human behaviour. However, the above quote, which was taken from the book "To err is human: building a safer health system" does not only refer to technical systems but its meaning extends even wider as it includes our work systems with their norms (SOP), behavioural guidelines and last, but not least our (safety) cultures. System design is crucial as it influences how we are trained and how we work at the sharp end. In this sense the sample story highlights a key area of preventive behaviour we can use in practice especially when dealing with (sometimes imperfect) automation – it is how we deal with our intuition or "gut feeling".

Already in the beginning of the story "Bert" was surprised when he heard that the symbols for the aircrafts continue moving even if the radar data was gone. Later in the text "Alexander" was irritated for a moment when he got the impression that the picture froze for a second, then started moving again. Both had the feeling that something is different or not as expected.

What is your experience? Did you ever experience such situations in which your intuition or your gut told you that something is wrong or worth a second thought or even worth a deeper analysis, but for some reason you did not follow that track? Which were the reasons not to stay sceptical?

Again system design plays a significant role by implementing communication SOP for scepticism and creating a culture where, even in practice, doubt and questioning is supported and not suppressed or put aside. In the story the gut feeling was there, but not used by the characters to question either the software-design or its actual behaviour. Considering the possibility that there would have been no complacency by the other characters or even no direct request from the sample flight the weak software design would have probably gone undetected until the next "window of opportunity" for an incident would have been opened – maybe with a different outcome then.

If we ask ourselves: How do we deal with our own doubts and, even more important, how do we handle the doubts and concerns of our team- ▸▸

Case Study Comment 4
by Captain Tom Becker (cont'd)

members in daily practice? Do we appear as open as we would like to do? Sometimes our self- and public image might differ. How often do we use interpersonal feedback to align those images? How do our superiors and our management deal with our concerns? Are they open for scepticism and feedback? Sometimes already a short question or remark on being sceptically can serve as a nudge for others to join our thoughts.

However, automation and technical systems will never be able to substitute our human intuition as a safety tool. So, why not fostering that in practice by implementing specific communication SOP or by installing a kind of "remember button" at our workstations to keep such "trigger thoughts" alive and to make our doubts and concerns visible thereby involving team-members in the thought process? We have warning lights and symbols for many technical systems. Why none for our human "non-technical" system? Here again a systems approach is required to develop practical solutions – in order to make it always easy for us at the sharp end to do the right thing.

A RECOMMENDATION:
Although automation assists us in accomplishing our main duty – the prevention of accidents and incidents – a sound scepticism on what it does or shows could be helpful sometimes. Even if it might turn out at the end that our doubts or concerns were not reasonable – "always on the safe side" is still the basic principle in aviation.

Case Study Comment 5 by Mike Edwards

What happened next…

At the centre
Stan could not understand what had happened, there was no aircraft near X-line 123. It must be a spurious TCAS Alert, or maybe one of those new Stealth fighters that they were not supposed to know about, he thought. He had calmed down and was now just annoyed that he would now probably have to waste his break time, trying to enter a Safety Report into the new electronic safety database. To complete his increasingly bad morning, when the aircraft called the TCAS, he had been reading about how his team, Tottenham, had been beaten 0-3 at home yesterday. So much for that new manager!

On the flight deck of X-line 123
After they had followed the RA and returned to their cleared level, Paul turned to Dirk and asked "What the xxxx was that?". "I don't know, but it was big" said Dirk. "Do you think we should ask ATC about it?" asked Paul. "No, best not, he seemed a bit shocked. We'll leave them alone" replied Dirk.

In the cabin of X-line 123
The pilot came on the PA and apologised for the sudden descent and climb. Apparently they were avoiding turbulence or something. Brent was snoring and Sid was drifting in and out of sleep, dreaming about eating herring and marmalade sandwiches.

At the centre
An assistant alerted the Supervisor that he was wanted back in the operations room. "Now what?" he sighed as he heaved his considerable bulk out of his comfy chair. Three people were standing around the Supervisor's position looking at a flashing red light. "What's that?" asked one. " Ah.. that's….. new" said the Supervisor, painfully aware of how inadequate that sounded and dreading the next question about what it was for, and knowing that he did not have the answer. There had been a briefing sheet lying on the desk when he came on duty this morning, but he had not got round to reading it yet.

Stan rescued him by calling him over. He quickly explained about the TCAS alert, trying to keep it low key. "Okay, not to worry, just fill in a safety report on your break" said the Supervisor, failing to see Stan's whole body language drop.

The Supervisor went back to the desk and read the briefing sheet about the red light. "Ye Gods, which idiot approved this?" and then immediately knew which idiot it would be. He went upstairs and knocked on the door of the idiot. The idiot smiled in the vacant way that idiots do. The Supervisor put the briefing sheet on the desk and asked when had it been approved. "At the usual Project Board meeting a couple of weeks ago" said the idiot. The Supervisor just stared at him, so the idiot went on "Bert was involved.. oh no..he was on leave, but Sven from Ops was there…ah…well no actually he had called in sick that day…anyway it can only be a help to the controllers in the unlikely event of a radar failure, so it has to be a good thing, doesn't it". "Was a Hazard Analysis done?" asked the Supervisor. "It's in hand, now that Sven is back, I am going to ask him to

do one today" grinned the idiot, satisfied with another job well done.

Conclusions

The new software build had been introduced into the live environment without any operational expert advice, hazard analysis or pre-operational briefing material for supervisors and controllers. It was fundamentally flawed in design, functionality and implementation. Its operation was based on the Supervisor's desk being manned 24/7, which was clearly not the mode of operation, whether officially or not. The controllers, who were the ones that needed to know first and immediately were not to be given any information. The way that this unit or ANSP runs projects needs a complete overhaul.

The incident itself was initiated by Ann, who cleared X-line 123 to route direct to BABLA, which is in an adjacent sector, without the prior approval of the controller responsible for that sector. This type of non-conformance has been identified as one of the principal contributing factors in the current EUROCONTROL's study of Top 5 Operational Safety Issues, one of which is 'Conflict involving adjacent sectors'.

The second factor in the causality chain was that Ann did intend to co-ordinate the direct routing with Stan on the adjacent sector, but forgot to carry out the planned action, after being distracted by the arrival of Alexander for a handover.

The next factor in the chain was that there was no actual handover, other than Alexander declaring that he had the picture. If a properly-structured handover had taken place, the position of X-line 123 and the direct routing that still needed to be co-ordinated, would have been included and the potential conflict removed.

A RECOMMENDATION

A large number of incidents occur either during a handover or within 10 minutes after a handover. It is recommended that Controllers should always carry out a formal and structured handover. Depending on the type of unit, this can include weather, equipment, information on non-standard stuff (e.g. Danger Area activity, para Drops, active gliding sites, military exercises), flow restrictions, runways in use, pressure settings and finally the traffic. There are various mnemonics available that can assist controllers and ANSPs.

Mike Edwards

was until recently Head of Safety Investigation at NATS (the UK Air Navigation Service Provider). He held this role for 7 years and prior to that he was Head of Investigation at London ACC. He had been an ATCO at Edinburgh and Heathrow before becoming the manager of all student controllers and then a Supervisor at London Terminal Control. He holds a PPL with Group B rating.

Automation as alien: challenges for human factors

by Professor Thomas B. Sheridan

In 1951, in an article about designing a better air traffic control system, psychologist Paul Fitts explicitly laid out what "men are batter at" and what "machines are better at", which came to be called the MABA-MABA list. That list is now well out of date, as modern sensors and computers have now clearly exceeded human capabilities in many of the attributes Fitts awarded to humans. And over these sixty plus years automation and decision support tools have become standard fare for aiding and abetting human operators in aircraft navigation and landing, collision avoidance, weather prediction and avoidance, and other complex tasks.

However, while automation is touted by its hard core engineering designers as a friend or even saviour to controllers and pilots, it has made the task of human factors professionals responsible for making it work with real people ever more challenging. In a 1980 article in MIT Technology Review titled "Computer Control and Human Alienation" I pointed to a number of ways computer automation has alienated its users, who often do not understand how it functions, why it is doing what is doing, and in essence do not quite trust it. They admit it can do marvellous things, but sometimes expect it to know more than it really knows, and consequently develop unrealistic expectations that can get them in trouble, especially in off-nominal situations. "Father of cybernetics Norbert Wiener" made the point in his prize-winning book God and Golem Inc, the theme of which is that the computer, like the Golem monster of Hebraic tradition, does what it is programmed to do, not necessarily what its human users want and expect.

The 2013 crash of Asiana 214 in SFO provides an example. According to the accident report: "In an attempt to

By pressing this button I will get the attention of everybody on the board... which is pretty awesome... since that is as far as our responsibilities go...

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A SCALE OF "LEVELS OF AUTOMATION"

1. **Computer offers no assistance: human must do it all**
2. **Computer suggests many alternative ways to do the task**
3. **Computer prioritizes alternative ways to do the task**
4. **Computer recommends one way to do the task**
5. **Computer executes that recommendation when and if the human approves**
6. **Computer allows a restricted time for human veto prior to automatic execution**
7. **Computer chooses a method, executes and necessarily informs the human**
8. **Computer chooses a method, executes and informs the human only if requested**
9. **Computer chooses a method, executes and ignores the human**

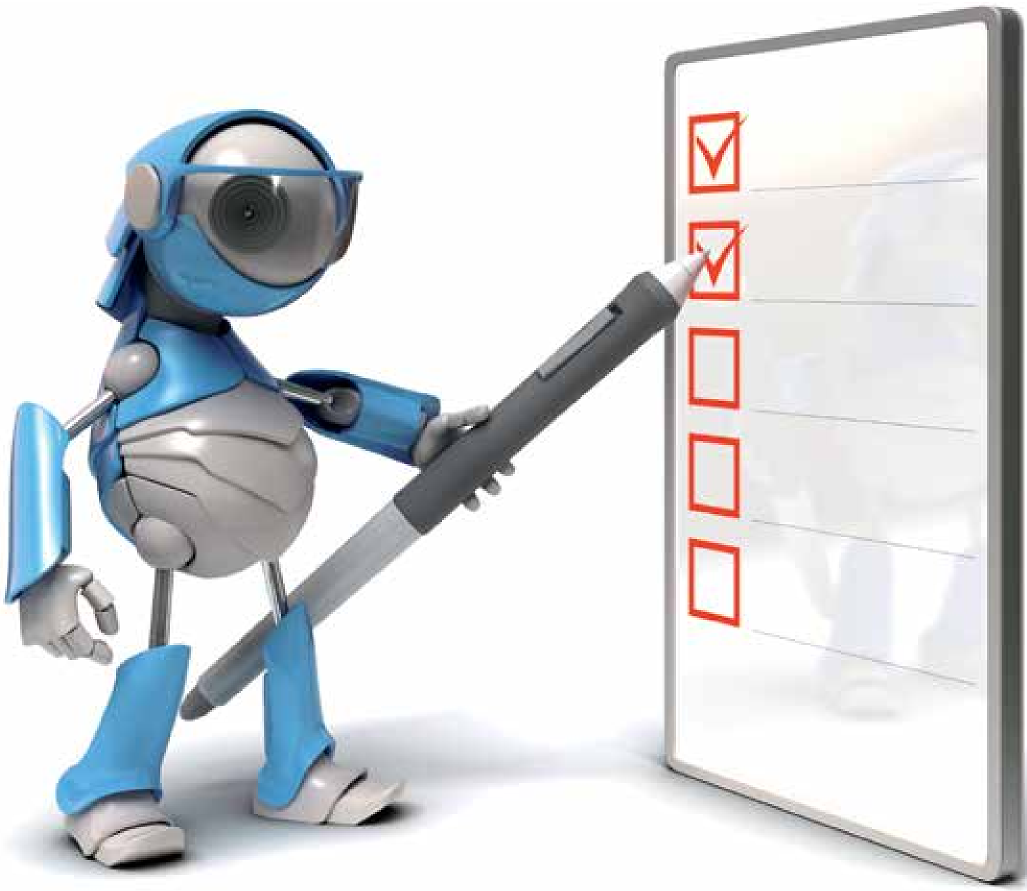
increase the airplane's descent rate and capture the desired glidepath, the pilot flying selected an autopilot mode (flight level change speed) that instead resulted in the autoflight system initiating a climb because the airplane was below the selected altitude. The pilot disconnected the autopilot and moved the thrust levers to idle, which caused the autothrottle to change to the HOLD mode, a mode in which the autothrottle does not control airspeed. The pilot then pitched the airplane down and increased the descent rate. Neither the pilot flying, the pilot monitoring, nor the observer noted the change in A/T mode to HOLD." Altitude, and then airspeed decreased, and at 100 feet an effort to initiate a go-around failed and the main landing gear and aft fuselage struck the SFO seawall.

"Expectancy, workload, fatigue and automation reliance" were blamed in the report. Those factors are all inter-connected, and it is also well established experimentally that some people just take much longer than the average to acquire sufficient situation awareness, make correct decisions and act properly, especially under stress. One answer to the Asiana 214 accident is more training to understand autothrottle modes and system activation logic, and adhere better to standard operating procedure. But there are also serious automation design issues—whether there is a level of complexity that is just too much for busy operators to comprehend and confidently use when the need arises (which may be rare!). Too many automation modes to accommodate and too many contingencies makes operators' mode awareness more difficult to maintain.

Stay in the loop or not?

Controllers, pilots and human factors professionals for years have debated under what circumstances operators should stay "in the loop" and whether there are inherent perils in making the human a supervisor of automation, a "flight manager". But this is not a binary choice. It is really a debate concerning what "level of automation" to invoke (see Table).

While it has been many years since autopilots and flight management systems were first introduced to aircraft, that level of automation has not yet come to air traffic controller workstations. Decision support tools at the 2-5 levels however, are appearing.



Automation as alien: challenges for human factors (cont'd)

For example, while continuous monitoring and vectoring are proven techniques, there are pressures to move controllers to a higher level of responsibility in coordinating with flight plans and traffic flow, allowing automation to spot incipient collision potential and alert the controller to attend to the screen and impose remedial action when the need arises. But then will there be sufficient time for the controller to drop some unrelated task, observe and understand the situation, make a decision and effect communications with the aircraft involved?

Computer-adaptive automation versus automation adaptable by human

There has also been much discussion within human factors circles recently about adaptive automation versus adaptable automation. In adaptive automation, the automatic control or information processing/display works differently depending on aircraft speed, altitude, attitude, traffic density, deviation from course, or some other measured parameter, independent of the operator. On the other hand, in adaptable automation the parameters must be changed by the human. The pressure from the computer community is always to make automation "smarter" (in the adaptive direction), but much research in human factors has shown that removing the human from the decision loop can produce reduced situation awareness, complacency, over-reliance on the automation, and unbalanced workload. When operator workload is too high there might be a situation where it would be desirable for automation to automatically take over control, but one problem is: how to measure workload quickly and reliably. If there were a well defined time window during which the human must perform a certain function, that is a situation where automation had better take control, hopefully to at least "buy time" for the human to recover. But again, can such situations be well defined, and if so how long should the automation wait before seizing control?

Authority and responsibility

The implication from much research is that some intermediate level between full automation (what is possible) and full human control is best. However, as more automation creeps into aircraft and air traffic control systems, and complexity necessarily increases, what is the degree to which human pilots and controllers are responsible if events go awry? If the automation hardware fails that is usually detectable, and the automation (or its designer, installer, maintainer, etc.) can be blamed. More often the situation is murky: an unusual weather or traffic situation, software that may not have been designed for exactly what occurred, a slight misunderstanding by the humans involved as to what the automation knew, was doing, was capable of, or how to manage it. Making provision for just shutting off the automation and assuming direct manual control might seem like an easy solution, but it takes time for humans to figure out what has gone wrong and to recover control, in some cases much longer than the system designers expect. It seems to me that system developers need some automation policy with clear guidelines allocating authority and responsibility.

LESSONS

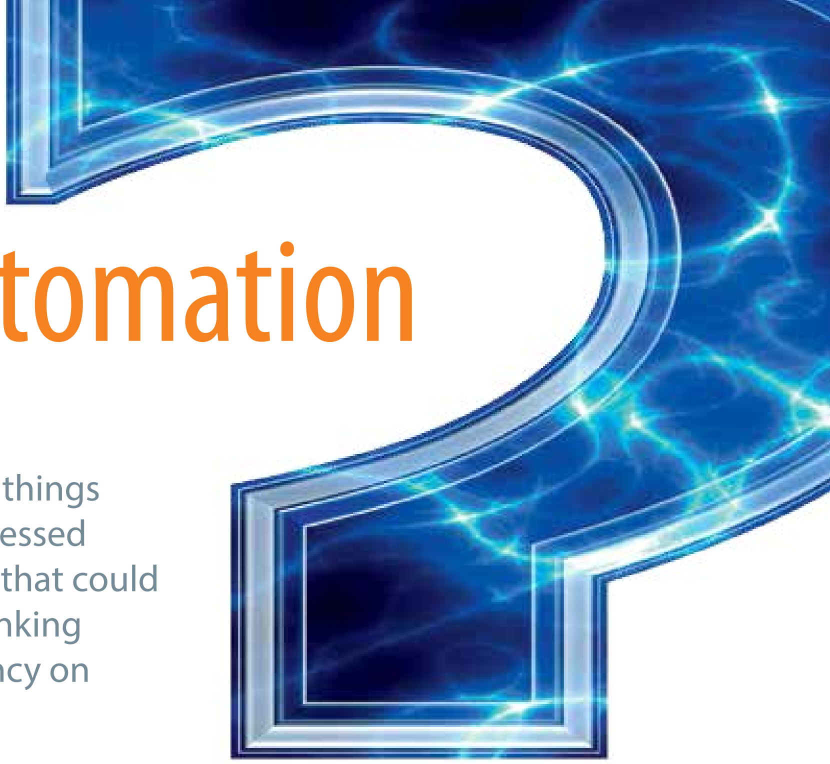
1. Knowledge of automation activation logic. Try your best to understand the logic of how the automation works. If it is not understandable at an operational level, or if documentation/training is missing or inadequate, complain.

2. How much to trust. Developing appropriate trust in an alien being like automation requires training, time and interaction. Be conscious of what you can reasonably expect from the automation and what its limits are.

3. Getting back into the loop. Use of the automation often requires your being "out of the loop." So be sure you know how, if the need arises, to reinsert yourself in the loop to re-establish direct manual control, and how much time is necessary to do this.

4. Adaptive vs adaptable control. Currently very little adaptive control (as described above) operates within aviation automation; it is essentially all adaptable, meaning the pilot/controller is responsible for setting what mode the automation is in. For multi-model automation be conscious of what mode has been set in.

5. Be kind to your friendly human factors colleague. These folks work at the intersection between the pilot/controller user and the technical automation engineer. They are advocates for the user, and are pleased to get your feedback. But they necessarily do so with awareness of the realistic limitations of automation capability, operator training and cost.



Who Needs Automation

by Jim Krieger

Okay, that might be stretching things a bit but I have personally witnessed events over the last few weeks that could understandably sway one's thinking about our perceived dependency on automation.

On September 26, 2014, Chicago Air Route Traffic Control Center (Chicago Center or ZAU ARTCC), suffered a devastating fire that affected operations not only at that facility but numerous other air traffic control facilities as well. For all intents and purposes, ZAU was rendered mostly ineffective, having lost nearly all connectivities to their long-range radar sites and much of their flight data automation resources. Indeed, the "machine" portion of our interconnected human-machine system, was down for the count!

This affected operations at Chicago O'Hare Tower in a variety of ways, especially the lack of automated flight plan information part. For O'Hare arrivals, this meant that every flight that would normally fly through Chicago Center airspace, now had to transition through outlying approach control facility airspaces like Rockford, Illinois and South Bend, Indiana, to name a few. Despite not being accustomed to such large volumes of traffic, the controllers in these facilities did amazingly well, bringing the O'Hare arrival rate up to near normal levels within days.

The lack of automated flight data information also required O'Hare Tower controllers to find new ways to get the job done for departing flights. For example, during the first days following the fire, controllers had air carriers faxing and emailing their flight plans to the tower. Each route then had to be validated before takeoff, which meant full readbacks for each departing aircraft, a monumentally laborious task. Because of this, the ATC team took action to split the clearance delivery position into two, and eventually three separate positions to minimize delays. To facilitate the process even more, they requested that we reassign some of the now idle Chicago Center controllers to O'Hare Tower (3 per shift), to coordinate flight plan information. The ZAU controllers immediately became an invaluable resource to us and the newfound camaraderie between them and the O'Hare controllers was truly a priceless collateral benefit.

Each day brought more innovation from our people as they learned and adjusted to the situation, and increased our operating capabilities along the way. We were soon landing and departing on three runways simultaneously just like the days when our machine friends were doing their part. Total traffic counts rose accordingly from about 1200 on the first day, to well over 2600 (approximately 99% of normal) just days later. And to think that all of this was happening with very limited automation resources! The humans were obviously very much up to the task even when the machines were not.

This whole scenario provides a good example of the ability and willingness of people to be flexible, to constantly learn, to make adjustments as needed, to easily fill in gaps not ever seen in the past, and to pull together during trying times. When the automation machine is reintroduced into our system and everything has returned to "normal", I think it will serve us well to remember what happened during this event, how the people adapted, and how whether we know it or not, they are doing that every single day in their mission to keep the flying public safe. This time it was just a lot more obvious.

Jim Krieger is an experienced Air Traffic professional who recently served as the FAA's Group Manager for Runway Safety in the United States. He has held numerous air traffic control and leadership positions at Chicago-O'Hare International Airport and he currently works as the Air Traffic Manager at O'Hare Tower.

Some lessons learned about pilots and flight deck automated systems

by Dr Kathy Abbott

There has been a lot of recent press about various opinions, studies, and views on automated systems. This article talks about lessons learned, including positive lessons and vulnerability areas, with respect to automated systems and pilot interaction.[18] Although the focus is on pilots, many of the lessons also apply to air traffic personnel.

Kathy Abbott, PhD, FRAeS, serves as the Chief Scientific and Technical Advisor for Flight Deck Human Factors to the Federal Aviation Administration (FAA) on human performance and human error, systems design and analysis, flight crew training/qualification, and flight crew operations and procedures.

LESSON 1: Automated systems have contributed significantly to improvements in safety, operational efficiency, and precise management of the aircraft flight path. However, vulnerabilities exist in pilot interaction with automated systems. These include:

- Pilots sometimes rely too much on automated systems and may be reluctant to intervene. In effect, they delegate authority to those systems, which sometimes results in deviating from the desired flight path under automated system control.
- Autoflight mode confusion errors continue to occur: autoflight mode selection, awareness and understanding continue to be common vulnerabilities.
- We continue to see FMS programming and usage errors, such as mis-programming, data entry errors.

LESSON 2: Automated systems, not "automation.

"Many times, we refer to "automation," as in flight deck automation or air traffic automation. However, that implies that "automation" is a single system, when the reality is that there are many different automated systems on an aircraft (or in an air traffic management system), and those systems represent automation of different types of tasks. Billings[19] described three categories of aircraft automation. The first was "control automation" or automation whose functions are the control and direction of an airplane (a system such as the autopilot is an example of control automation). The second category was "information automation" or automation devoted to the calculation, management and presentation of relevant information to flight crew members (for example, moving map displays or alerting systems). The third category was "management automation," or automation of the management tasks.

There is significant growth in the use of Electronic Flight Bags (EFBs) as a mechanism to introduce applications of information automation (e.g., electronic navigation charts) into the flight deck. The number of EFBs is growing. The number and types of applications implemented on these devices are also increasing, many of which affect flight path management.

EFBs (and other future "information automation" systems) have the potential to be beneficial in many ways, and enable applications in the flight deck that would be difficult to provide in other ways. However, EFBs may have negative side effects if not implemented appropriately. They could

18- This article is based on lessons learned from the work of the Flight Deck Automation Working Group (see http://www.faa.gov/about/office_org/headquarters_offices/avs/offices/afs/afs400/parc/parc_reco/media/2013/130908_PARC_FltDAWG_Final_Report_Recommendations.pdf). However, the lessons and views stated are those of the author.

19- Billings, C. E. (1997). Aviation automation: The search for a human-centered approach (Human Factors in Transportation). Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

increase pilot work load, increase head-down time, distract the flightcrew from higher priority tasks, and contribute to crew communication and coordination issues. These potential impacts of EFBs and other "information automation" systems need to be addressed during both design and evaluation[20].

Note that automated systems for air traffic are all "information automation." Similar concerns arise with respect to potential issues with workload, distraction, and communication and coordination.

LESSON 3: Lack of practice can result in degradation of basic knowledge and skills.

There has been concern expressed about degradation of basic flying skills because of automated systems in the flight deck. The data show that pilot knowledge and skills for manual flight operations (including both "stick and rudder" and cognitive skills), are a vulnerability area in some cases. However, automated systems do not directly cause degradation in knowledge and skills for manual flight operations – but lack of practice does. The presence of automated systems in an aircraft does not prevent the pilot from flying manually, and the FAA has published a Safety Alert for Operators (SAFO) 13002 that encourages airlines to find opportunities for pilots to practice and refine those skills.

LESSON 4: "Levels of automation" is a useful concept for communicating ideas about automated systems, but can be hard to put into practice.

Many operators define levels of automation described as a simple hierarchy in a rigid and prescribed fashion. After gaining operational experience with training and operational use of these rigid definitions, several operators concluded that such a description assumed a linear hierarchy that does not exist. The various features of the autoflight system (autopilot, flight director, autothrottle/autothrust, FMS, etc.), can be, and are, selected independently and in different combinations that do not lend themselves to simple hierarchical description. As a result of this experience, those operators revised their policies to allow the pilot to use the appropriate combination of automated system features for the situation, without rigidly defining them in terms of levels, except for the highest (everything is on) or the lowest (everything is off).

LESSON 5: Use a flight path management policy, instead of automation policy.

Many operators have an automation policy, and they vary significantly. The policies range from allowing the pilots to use whatever they consider appropriate, to policies that require use of the highest level of automation possible for the circumstances. Even operators of the same airplane type, which are supported by common, manufacturer-based philosophy and procedures, differed markedly from each other. These differences are because of a variety of valid reasons that include the operators' unique history, culture and operational environment.

However, the focus on management of automated systems was not always well integrated with the focus on managing the flight path of the aircraft, and may distract from the tasks associated with flight path management.

Operators should have a clearly stated flight path management policy that includes (but is not limited to) the following:

- The policy should highlight and stress that the responsibility for flight path management remains with the pilots at all times. Focus the policy on flight path management, rather than automated systems.
- Identify appropriate opportunities for manual flight operations.
- Recognise the importance of automated systems as a tool (among other tools) to support the flight path management task, and provide operational policy for the use of automated systems.

For air traffic personnel, a similar idea applies - focus the policy on the aviation task, with the automated systems as tools for the human to use.

20- See http://www.volpe.dot.gov/coi/hfrsa/work/aviation/efb/vreppub.html for references that discuss EFB considerations.

One more upgrade and I will be the Captain...

LESSON 6: Use of automated systems can reduce workload during normal operations but may add complexity and workload during demanding situations.
Pilots often described long periods of time in modern, highly automated aircraft where workload was very low. It appears that use of automated systems may reduce workload during much of normal operations, but during demanding situations (e.g., certain phases of flight when the pre-planned flight path is changed, such as being vectored off a complex procedure, then vectored back on to resume the procedures, or programming and verifying an RNAV approach, change of runway assignment during taxi, or during non-normal or emergency procedures), use of the automated systems may add complexity and workload to the pilots tasks.[21 22 23] In normal operations a highly automated airliner may be easier to fly than previous generations of aircraft but, in a non-normal situation, it sometimes is comparatively harder.

LESSON 7: Sometimes we attribute vulnerabilities to automated systems when we should look at complexity.
Some of the vulnerabilities we identify with automated systems can be attributed (at least partially) to the fact that these systems and their operations are inherently complex

Some lessons learned about pilots and flight deck automated systems (cont'd)

from the pilots' perspective, rather than simply because the systems are "automated." Areas of complexity include pilot tasks related to use of the systems, the pilot-machine interface and interaction with the system, and operating with certain airspace procedures. Future airspace operations are expected to be more complex and are expected to use more automated systems to support Performance-Based Navigation operations.

LESSON 8: Be cautious about referring to automated systems as another crewmember.
We hear talk about "pilot's associate," "electronic copilots" and other such phrases. While automated systems are becoming increasingly capable, they are not humans. When we attribute human characteristics to automated systems, there is some risk of creating false expectations about strengths and limitations, and encouraging reliance that leads to operational vulnerabilities (see Lesson 1).

Last but not least, **LESSON 9: Pilots (and controllers) mitigate safety and operational risk on a regular and ongoing basis.** Pilots fly thousands of flights every day that are conducted safely and effectively. They provide the ability to adapt to operational circumstances, deal with operational threats, detect and mitigate errors by others in the system, mitigate equipment limitations and malfunctions, and provide flexibility and adaptability to address non-routine and unanticipated situations.

I hope these lessons will stimulate some discussion about the practical aspects of automated systems. Automated systems have contributed significantly to safety and efficiency of the aviation system, and we expect them to do so increasingly in the future. However, we hold the pilots, controllers, and other humans in the aviation system responsible for its safe operation. We should never forget that the safety and effectiveness of the civil aviation system rely on the risk mitigation done by professional, well trained and qualified pilots (and controllers) on a regular basis.

21- E. L. Wiener, "Cockpit automation," in Human Factors in Aviation, E. L. Wiener and D. C. Nagel, Eds. New York: Academic Press, 1988, pp. 433-461.
22- R. Parasuraman and V. A. Riley, "Humans and automation: Use, misuse, disuse, abuse," Human Factors, vol. 39, June 1997 pp. 230 - 253.
23- Parasuraman, Sheridan, and Wickens, "A Model for Types and Levels of Human Interaction with Automation," IEEE Transactions on Systems, Man, and Cybernetics – Part A: Systems And Humans, Vol. 30, No. 3, May 2000 pp. 286 - 297.

Safety and automation

by Adrian Bednarek

I can remember perfectly my first steps in air traffic control. And no, it is not ancient history... in fact, it is only nine years since I was cleared to use the microphone on my own and talk to pilots for the first time...

Every morning we used to print a new set of strips on A4-sized sheets and then divide them with a paper cutter. The first radar console I ever worked at was made of thick navy blue plastic and filled with tiny red and yellow buttons which glowed in the dark. There wasn't much to look at on the screen - the borders of our sector, final approach tracks, aircraft radar tracks, their mode 3/A codes and mode C altitude readouts. That was all we had and all we needed at that time.

Less than ten years have passed and everything has changed. Today, I sit in front of a high resolution radar screen, capable of displaying so much information that I am unable to read it all at once: Active areas and zones, meteorological data, main roads, rivers, cities, SIDs and STARs, flight plan tables, taxiing queues, mode S data, planned trajectories, velocity vectors etc. All clearances given to pilots are immediately visible on adjacent sectors' screens. Safety net servers monitor all available data to alert me before separation violations or airspace infringements occur. I can honestly say that my job has become more pleasant and less stressful.

The technology which has already stormed into aircraft flight decks has finally knocked on our ops room doors! And it has completely changed the way our work is done. Which makes me wonder if we are aware of the risk automation is introducing to our everyday routine? Are we able to recognise the threats and avoid the traps which computerised ATM systems set? Do we understand what is going on inside those systems?

On the evening of 29 September 2006 a Boeing 737 on a scheduled flight from Manaus to Rio via Brasilia collided with an opposite-direction Embraer Legacy 600 which was on the first leg of a delivery flight to the USA ▸▸

Tell him to go around and hold! I have to initialize the ASMGCS, RIMCAS, alerts and all...
But George, the RWY is clear and it's the last flight of the day...

flying from São José dos Campos to Manaus. The accident occurred in VMC with both aircraft in level flight at FL370 over the Brasilian rainforest and took the lives of all 154 people on board of the 737. It occurred half an hour after ACC controllers had lost both radio contact with the Embraer and its transponder readouts. As the investigation revealed, the latter was probably the result of inadvertent selection of the transponder to standby by the pilots. Their aircraft then continued its flight at the initially assigned level of FL370 in the absence of an ATC instruction to descend to FL360 at the point specified in the filed Flight Plan. And what was clearly not appreciated by the military air traffic controllers involved once the mode C replies from the Embraer had ceased was that their ATC system had reverted to flight plan data. As a result, successive ACC sectors were provided with information that the Embraer (only intermittently visible as an unstable primary track) was actually flying at FL360. As always, it was not the sole cause of this tragedy but it was certainly a crucial factor.

I would risk making the statement that this accident could have then – and still can today – happen anywhere else in the world.

How many surprises is your ATM system hiding from you? Do we fully understand the equipment we work with? I suspect that no one knows the full extent of all the algorithms which together create the logic of computer systems we use. Even their creators are unable to foresee all the scenarios which their systems could face in the future. Am I exaggerating?

Maybe. But I suggest that you try to honestly answer these questions:

- How well do you know the computer system you use?
- How often are you surprised by its behaviour?
- Are you able to convince yourself that you fully understand its logic?
- Can you always use all of its functions in a timely manner?

I remember one day few years ago, shortly after a new ATM system had been introduced at our unit, when it turned out that even the simplest situations might cause us trouble. In this case, two controllers were dealing with the aeroplane which was flying without a transponder. Thanks to our new software, the controllers' assistant had been able to correlate the aircraft primary track with its flight plan, which was supposed to be a great help in such scenario. But in reality it quickly became obvious that the effects of this rarely used function were not clear to everyone involved - it was very hard to distinguish a pseudo-track created in this way from a real-time track based on transponder information. You can imagine what the crew members were thinking when two ATCOs kept asking them to double-check their transponder settings when they didn't have one on board!

Of course, as long as my state-of-the-art computer system is working the way I want it to, I need no longer worry about loads of simple things. It is more relaxed, my actions are more efficient and the system as a whole is safer for sure. Problems arise only when the computer itself becomes the object I am focussing on. Unsuccessful flight plan update, unusual route modification, setting the required ATC sector sequence, displaying or hiding another layer of information, moving an electronic flight strip to a place it doesn't want to be moved to... All those actions require our attention and they very often make us forget about what is really important - the aircraft tracks on the screen or the aircraft themselves outside the Tower windows. Many incidents and accidents have taken place when the pilots forgot that their priority was actually to fly the aeroplane. Now air traffic controllers are facing a similar challenge.

Focusing on the tool instead of the job being done is not the only problem with automated systems. Many researchers have pointed out that we ought to expect a number of others, for example:

- **Breakdowns in mode awareness and the resulting automation surprises.** We have already seen in the examples above that our automated ATC systems, with their continuously increasing autonomy, are capable of putting us in a difficult position. The number of functions and available automation modes is getting bigger all the time. It is clear to everybody that we will continue to find ourselves surprised by their behaviour.

- **Knowledge demands and the need for new approaches to training.** Most of our current training programs don't cover the complexity of the whole system and instead provide us with just a simple set of tips and tricks to make the system work under routine conditions. But to fully anticipate effects of our actions, we need to understand the complex input-output relationships going on 'inside the box'.

- **Complacency and trust in automation.** Our computer systems work fine for most of the time and we have learnt to trust them. But are we really prepared for what is going to happen after a total or even partial failure of the automated system we use?

About two years ago my colleagues and I were ourselves faced with a failure. It was a summer afternoon and it was busy when we received a phone call that our ACC flight plan database had failed. We were still able to get all the aircraft safely to their destinations but it was not possible to assign any new SSR codes and ACC management decided that new flights could not be accepted into the airspace.

We were determined to find a way to get the aircraft waiting to take off in our TMA safely airborne as soon as possible. It took us nearly half an hour to come up with arrangements which could be substituted for the usual procedures. All departing traffic would be kept at lower flight levels to stay clear of our FIR's ACC sectors and was rerouted to adjacent FIRs and TMAs. All coordination was done verbally and was necessary on an individual aircraft basis since the routing on their filed flight plans had become irrelevant.. We were also given a few transponder codes which we could use but there were not really enough and we had to make sure that none of them were used more than once every 30 minutes. Again, a piece of paper, a pen and a clock played a vital part in air traffic control! It was completely safe but very far from being efficient.

That day made me aware of how many actions are required just to make a simple flight from A to B happen. It reminded me how many phone calls would have to be made simply to get the proper transponder code and coordinate a higher level for a departing aeroplane without automation. Many, many actions including a lot of phone calls which would together represent multiple reasons why my attention might easily be drawn away from the blips on my radar screen.

Looking back at that afternoon I also realised that someday a similar failure may affect the safety of aircraft in the air. Just imagine the potential effects of losing a flight plan database in a split second. Do your local procedures clearly state what should you do under such circumstances? How many times in your career have you had an opportunity to practice how to deal with such a failure? Does your refresher training address this issue?

All of those problems are inherent elements of such complicated systems where thousands of gigabytes of data is being pushed through countless servers and where several people make decisions based on the presentation of that data. No technological advancement, nor even the most generous investment, will set us free from those threats – continuous development will quickly introduce new challenges.

The only thing we can do is to prepare ourselves by learning how the automated systems work as a whole, what logic they are following and by practicing what to do when they stop working. By making such preparations we should be ready with the proper response and, if necessary, be able to start working the way which nine years ago was considered an everyday routine.

Adrian Bednarek
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Ergonomic system design in air traffic control – Incorporating a user-centred approach

"The road to technology-centred systems is paved with user-centred intentions." **David D. Woods**

by André Perrott

User-centred design has been one of the central factors for success in the design of consumer products. The importance of concepts such as usability, intuitive design and simplicity continue to increase in importance alongside the core need for functionality. Instead of technology being the only focus, it is now enlarged by a focus on the users – who can choose the product they prefer.

In Air Traffic Control we have historically seen less of this balanced perspective. But of course the world of aviation differs from the consumer goods market. Air Navigation Services require a highly professionalised use of operational facilities as well as redundant and highly-interlinked systems. This has sometimes resulted in the technology-centred design of conservative systems, which are exceptionally robust (they rarely fail) but which take insufficient account of the context of use (e.g. goals, tasks and other support systems).

Technology-centred approaches to system design are based on the idea that complexity can be broken into chunks that are easy to engineer. The overall solution is thus the sum of various sub-solutions. Each component works perfectly on its own but in connection with other components may show weaknesses such as inconsistent modes of operation, unanticipated system behaviour (automation surprises) or unhelpful display of information in relation to tasks.

User-centred design is not a completely new idea; in fact it is firmly established in various innovative industries. ISO 9241-210 set down and standardised the basic process. The most important characteristics are:

- A significant analytical phase to understand the context in which the technology will be used
- Many iterations with many prototypes, the complexity of the prototypes keeps increasing (from paper prototypes to wireframes to functional beta versions).
- Users included in all phases of the process

A number of advantages accrue from a user-centred perspective. The ergonomic quality of the final product can be increased significantly because the expert knowledge of the user is taken into account. Things that may have gone unnoticed can be recognised and corrected in good time. Another advantage is a higher level of user acceptance. Users identify with the solution they helped bring about and are more likely to accept technical compromises. At the same time, developers and users increase their knowledge base during the course of the development. In addition, development costs can be reduced by early user involvement. When users are in-

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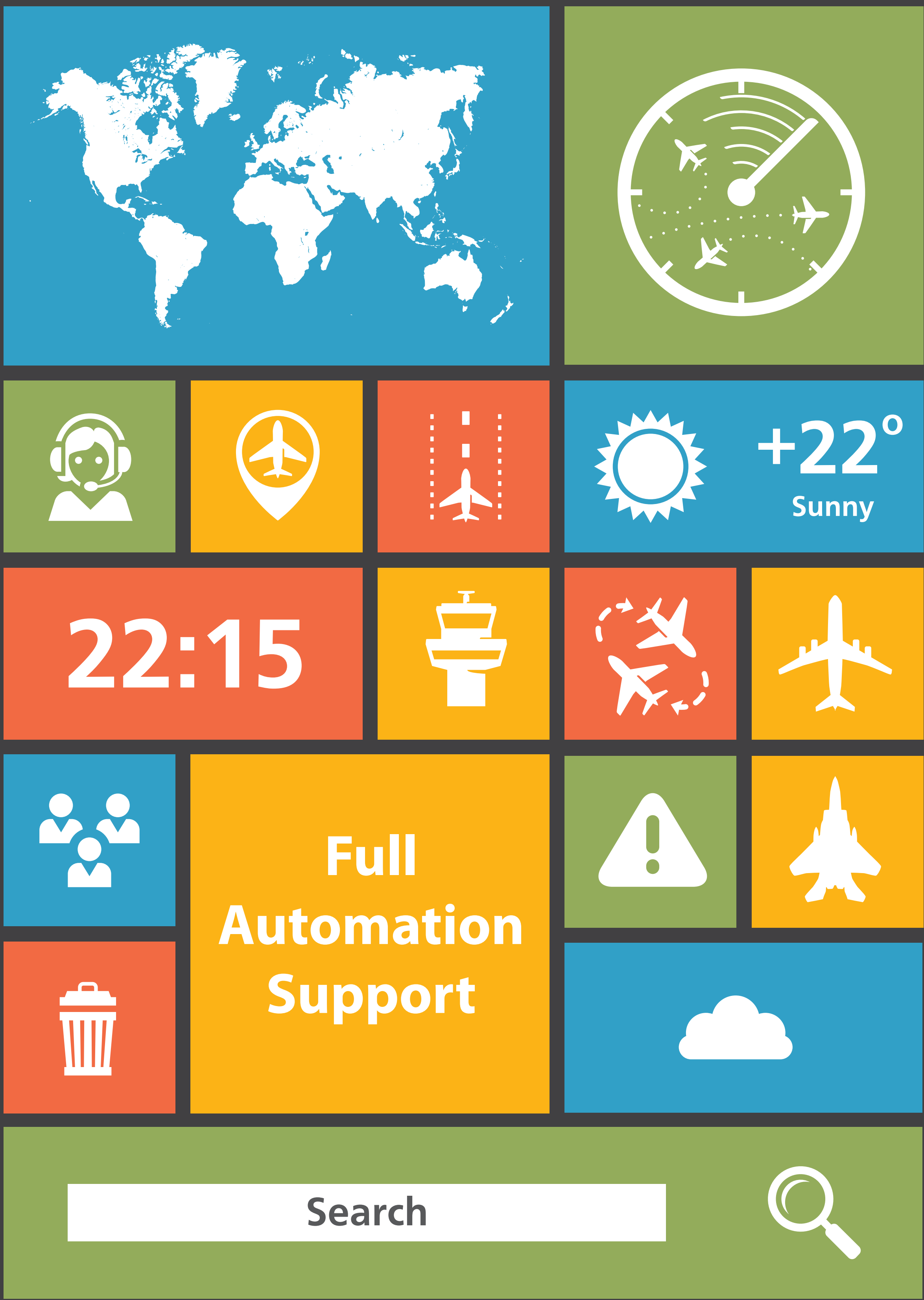
MY MENU



Ergonomic system design in air traffic control – Incorporating a user-centred approach (cont'd)

volved early on in a project, generally 1-2.5 % of the total budget is sufficient for ergonomics. If the system has already been in operation prior to corrective action, costs can multiply from double to ten times depending on the extent of the changes that have to be made.

User-centred design also involves certain hazards. These result from the ambivalent perspective on user participation, which can range anywhere on a spectrum between pseudo-participation (all decisions have been carried out in advanced and the user just give their blessing) to democratic design (the option with the most votes is implemented). Both of these extremes should be avoided and the design objective ought to be somewhere in the middle.

This is why it is important to have a clear understanding of the roles of system developers and users. If we compare the complimentary roles of users and technical system developers, it is suggested that:

Users should:

- be experts in their field
- explain their approaches to work and the objectives of their work
- communicate their needs, requirements and interests
- evaluate the appropriateness of various solutions
- point out problems with various solutions

Developers should:

- establish explicit requirements
- identify implicit requirements
- understand typical working methods at the working position
- use appropriate methods to transform subjective statements made by users into objective ones
- use a range of future scenarios to ensure that a design is resilient to likely change
- be able to convert user insights into design concepts and solutions
- facilitate user evaluation of a prospective design solution in a structured and methodical way

The DFS experience of incorporating users in system design

The focus on users and ergonomics is often understood as an addition to the normal design process, which also generates additional costs. But this assumption neglects the reality of complex design project where a large number of sub-systems are closely linked to the user and place high demands either directly on the user or on the tasks they must perform. A system design that is both lean and ergonomic is not a contradiction in such a context. Rather, the two can complement each other. Looking for quick solutions under complex conditions leads to exactly what one was trying to avoid – long development times and weak ergonomic system design.

To illustrate the user-centred process, we can look at an example at DFS in which user involvement was extremely beneficial.

The starting point was the change from a negative screen polarity (bright symbols on a dark background) to a positive one (dark symbols on bright background). The first phase of this project examined the priority of the objects displayed in colour from the ATCO perspective. Controllers were not asked which colour they preferred the most (democratic design) but were instead engaged in a discussion about their task. One important subject was matching the perceived priorities to the physical colour differences between foreground elements and the background. In this way, the participants discussed about their task instead of the possible colour combinations. Human factors experts were then able to convert their feedback into ergonomic requirements based on objective physical colour parameters.

In addition, the various existing systems at all DFS units were recorded. One finding was that colours were being used differently across units even though they shared the same system with the same functionality. The topic of discussion was whether differences between the units were actually necessary for operations or had just historically evolved. It was concluded that none of the colour sets being used followed any overall rationale, they had just been selected and then subsequently optimised based on trial-and-error.

This initial phase was followed by five iterations. After each iteration, the colour proposals were refined. Over time, the complexity of the prototypes increased steadily. The first evaluation was carried out in a laboratory whereas the final one was made under realistic conditions in the new control room in Langen. The evaluations involved users from all the units. The result was the introduction of a uniform colour concept that provided a basis for all colours displayed on the radar screen.

Regardless of whether the design task includes the implementation of a completely new ATM system, the exchange of old hardware or just the adjustment of colours, the same principles apply. Changes are likely to mean that the complexity of the whole ANS system increases. Numerous interdependencies can lead to a solution that seems adequate in isolation but does not necessarily blend effectively into the overall system 'landscape'. The result is a patchwork of sub-systems which do work together as required but the behaviour of which is no longer understandable to the users. Typical symptoms are unplanned system behaviour, inconsistent use of colours, variation in fonts and variation in the structure of tables and other visualised objects which do not mesh with each other.

User-centred principles and concepts are needed to integrate several system philosophies and to work against undesirable developments. They must to reflect the fundamental working methods of the entire system.

User-centred principles and concepts are needed to integrate several system philosophies and to work against undesirable developments. They must to reflect the fundamental working methods of the entire system. They can provide a clear direction for development, be used as benchmarks and show whether a development is on track or not.

For this, the following questions need to be addressed from a user perspective:

- Why is a new development even needed?
- Who are the users?
- Which tasks are to be conducted by using the technology?
- Which current problems can be solved?
- How would new technology change the current working methods?

Answering these questions provides the opportunity to take a step back and observe the overall situation. Are we actually working on the real problem or are we just fighting the symptoms? For example, in the example described above, there were clear indications that labels in certain colours were being overlooked. One idea was just to change this colour (fighting the symptom). But a careful analysis showed that the individual colour was not the problem after all, rather the overall colour concept was not in line with the priorities of operations.

Some Conclusions

ANS system developments take too long and frequently have high expenditures that often arise long after the system has been introduced. The question how usable systems can be developed and introduced in an acceptable amount of time remains unanswered. However, user-centred design provides a crucial basis for a solution to this problem.

A paradigm shift has already started at DFS. Positive experiences from previous projects are being adopted and negative developments are being questioned and analysed systematically so that lessons are learned. Projects now employ a user-centred approach from the very beginning as planning and analysis progress.

An important factor in the successful establishment of a user-centred perspective has been the commitment by DFS management. This led to the establishment of the Ergonomics Board which was given responsibility for steering and coordinating central ergonomic issues, including the development of integrated ergonomic concepts that involve automation, information display and user interaction.

Safety nets vs controller's risk perception and risk management

by Jean-Marc Flon

Automation is taking more and more hold in everyday life. This is so to say an understatement but what does that mean exactly in the ATC world and especially in the field of safety? For sure one of the obvious primary answers is the introduction of safety nets and the automatic detection of safety events.

Jean-Marc Flon is General Manager Air Traffic Services at Paris CDG where his responsibilities include oversight of Approach and Tower Control as well as Apron Management. Earlier in his career, he was a controller at Chambery, Paris Orly and Nice, during which time he was active in the French Air Traffic Controllers' Association including serving as President.

They are nowadays important tools and act as a supplementary safety barrier when, in the handling of traffic, something has gone wrong and especially so when detection and management of a conflict has failed. But how are these tools perceived and used by the controllers with due regard to the notion of risk management?

One first thing I have to say before entering into the matter, as this can sometimes be a criticism about the development of these tools, is that in over thirty years in ATC, I've never seen a controller taking the risk of handling traffic to the margins and waiting for a safety net alert to pop up before acting on a detected conflict. Controllers, as far as I know from experience, do not control by using safety nets and moreover these tools are not considered as an ATC tool.

So now what safety nets are we talking about? Paris CDG has been A-SMGCS Level II compliant since 2002, which means that potential conflicts on the runway are detected by the Runway Incursion Monitoring and Conflict Alert System (RIMCAS). On approach, the controllers' radar suite is equipped with a Short Term Conflict Alert (STCA) system specific to the approach. Given a situation in which triple simultaneous approaches are operated at CDG[24] as well as a high traffic density, STCA is particularly valuable. Finally, a tool specifically aimed at detecting intrusion into a defined area, the Area Proximity Warning System (APW), which was initially defined for detecting airspace infringement by VFR traffic, was implemented in 2011.

Two years ago, with the definition of a local safety action plan, CDG management decided it was time to share safety issues and the overall safety performance at CDG with those on the front line and especially watch managers. So that we have a comprehensive view of CDG's safety events and safety performance, we not only rely on submitted Safety Reports but on a thorough analysis of all events which are automatically detected by the various safety nets. After beginning this process with STCA data in 2008, RIMCAS events were added in 2012 and the local safety unit now analyses around 2500 events every year. The output from this analysis enables a better understanding of how the system works and ensures that its strengths as well as its weaknesses are more precisely identified.

2012 saw a dramatic increase in the number of Runway Incursions (RI,) which rose to 59 compared to the 46 recorded the previous year. Did that mean that suddenly there was a safety problem at CDG? Of course not. The obvious explanation was that a discrepancy existed between safety events detected through reporting and through automatic detection. It was thus demonstrated that a number of events were not being reported and suggested that there might be a dif-

24- CDG has two pairs of runways operated single mode which means 2 dedicated arrival runways for CDG plus, for westerly approaches, a similarly aligned runway at nearby Le Bourget airport, the whole in less than 3.3 NM spacing between the outer runways extended centrelines

image A

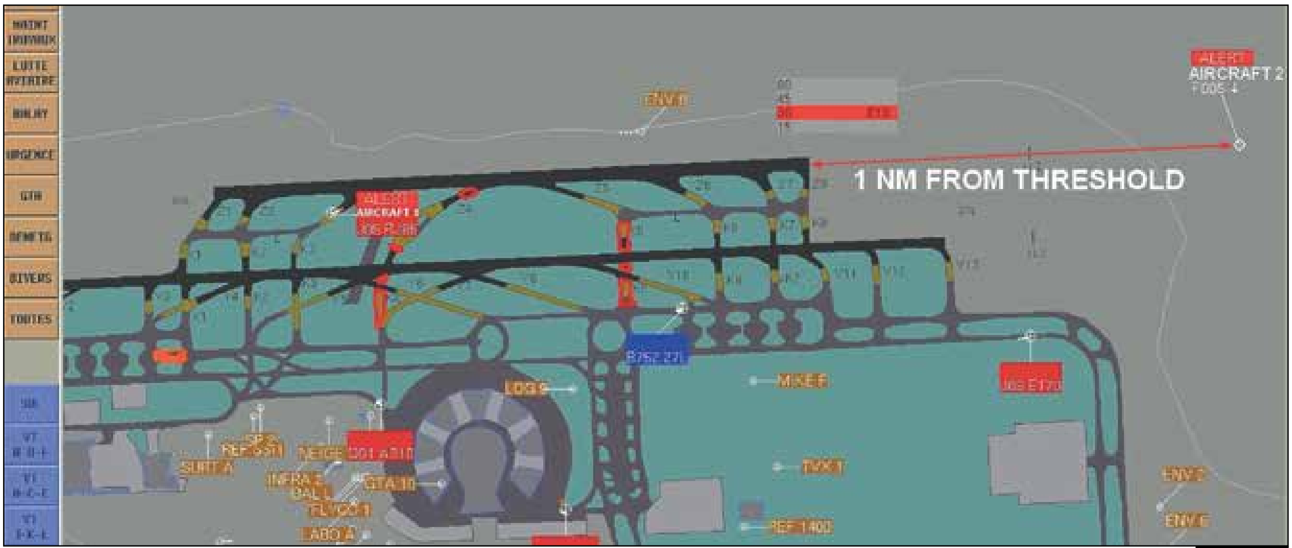


image B

ferent perception by operational controllers of what really was an RI safety event than that of the local safety unit.

To establish the underlying trends and reasons for this "performance" we had to delve more deeply into the data and refine the analysis. To support this, a management dialogue with watch supervisors was essential.

The initial discussions on what constituted safety-relevant events and how safety performance should be measured gave the clear impression of a deep rift between the views of the safety unit and those of front line operators. The use of safety nets data was seen as management "spying" on operational controllers and communicating only negative feedback on their performance no carrots, only sticks as the saying goes! The gap had to be bridged.

It was decided to differentiate categories of RI and to analyse safety performance by category. One category used was RI caused by the delivery of conflicting clearances, which was the one that saw a dramatic increase when RIMCAS event analysis began. A difference was then made between the non-intentional delivered clearances (errors) and the intentionally delivered. For this last category it was necessary to define three typologies:

- **Type 1** – landing clearance given before the previous landing aircraft has completely vacated the same runway[25] in VMC – (see image A)
- **Type 2** – take-off clearance given before a previously landed aircraft has completely vacated the same runway (either crossing or landing)
- **Type 3** – landing clearance given when LVO are in place and a previous landed aircraft has not vacated the runway actives (see image B)

We were thus able to better understand the risk perception and risk management behaviour of individuals or groups of controllers. The findings could then be shared with watch managers and examine the trade-offs being made during everyday operations.

In examining these issues, a Type 1 RI could be an acceptable trade-off if instructing a go around might lead to other risks[26] such as an immediate conflict with a departing aircraft on the adjacent inner parallel runway which would have the effect of generating more pressure on the system as a whole. A similar trade off could be acceptable in the Type 2 case with mixed mode operations, in the Type 3 case with LVO in place a landing clearance ▸▸

25- i.e. the landed aircraft is still in the defined runway protected area which for the RIMCAS settings are defined at 90 m from RWY centre line in normal operating conditions and 150 m in low visibility operations (LVO)
26- See EUROCONTROL & FSF Go-around Safety Forum 2013 on SKYbrary at: http://www.skybrary.aero/index.php/Portal:Go-Around_Safety and an article in FI "Second Chances" dated July 29th-August 4th 2014

Safety nets vs controller's risk perception and risk management (cont'd)

delivered before a previously landed aircraft has completely vacated the defined runway is another matter in terms of risk management (possible localiser deviation) and would indicate a distorted risk perception by the controller.

By means of this thorough analysis and management dialogue, it was possible to adopt a common view on what constituted an "acceptable" level of event risk management by a controller and take a zero tolerance position on the remainder.

One other issue is Separation Minima Infringement (SMI). Considering the simultaneous approaches operated at CDG, these are monitored very carefully and the trend of continuous improvement has considerably gained strength over the last couple of years. But are we sure that in focusing on SMI, we are not generating other risks? What if a controller keeps an aircraft too high on final approach so as to ensure separation with an aircraft and thereby creates a non-compliant approach[27] and possibly an unstable one? What are the risks and what level of safety is achieved then? As you can imagine, this issue is being carefully looked at and actions have been taken to minimise the safety risks.

An example of the consequences which can follow if an aircraft is kept high on the approach occurred at CDG on 13 March 2012[28]. Fortunately, the end result was eventually a go around but because of the lack of situational awareness on both sides on realising that the crew would not be able to land off the approach and the lack of corrective actions, the consequences were potentially serious. The aircraft, an A340, was being radar vectored for a Cat III ILS approach with LVP in force. It was given a step down descent due to other traffic and was thus maintained higher than the normal 3° descent. The crew allowed their aircraft to get so far above the ILS GS that the aircraft was still at 3700 feet when 4 nm from the landing runway - over 2000 feet above the ILS glide slope. Then and with only 2 nm to go and the autopilot engaged, the aircraft suddenly pitched up with an angle of 26° and with an airspeed down to about 130 kts. Fortunately the crew then immediately disconnected the autopilot with a pitch down input before going around (see image C).

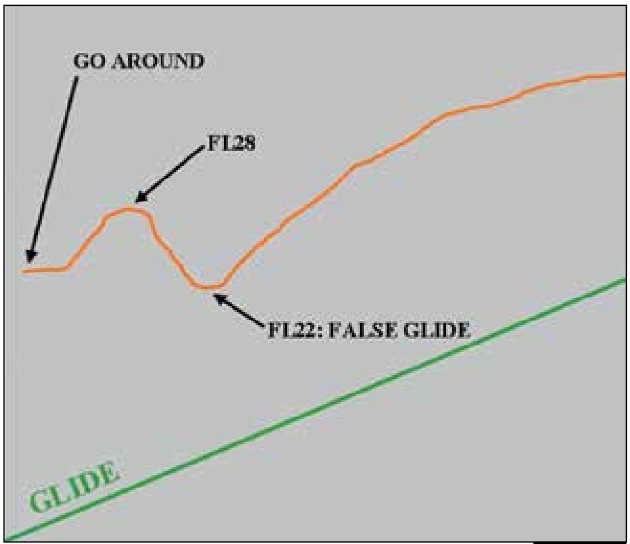


image C

The BEA (French AAIB) thoroughly analysed this serious event which, due to the high altitude on approach, was caused by the capture of a false Glide Slope signal which can occur when an aircraft is flying in an area above the 5.25° glide path. The same typology of safety event occurred at Eindhoven airport on May 31st 2013 which led to a thorough investigation on the matter by the Dutch Safety Board[29].

Despite the rarity of a scenario such as this, an action plan has been locally developed to prevent these occurrences and uses automatic detection of the most critical non-compliant and potentially unstabilised approaches. This is achieved by using the APW system to notify controllers of any non-compliant approach. Boxes are defined for each ILS approach so that the controller is notified on his radar screen as soon as an aircraft enters the defined area (see image D). This system was introduced experimentally this spring and early results, although they still have to be consolidated, appear promising.

The implementation of this tool and controllers' response to its alerts have been carefully coordinated with operators as we need to tread very carefully on this issue given that ensuring a stabilised approach is the responsibility of the pilot not ATC, we can only do our best to help the crew achieve it. But it was necessary to act also from the ATC perspective as first of all the rapid detection of such a situation is

27- A compliant approach, as defined at CDG, requires closing track to final approach of < 45° (or <30° on parallel active approaches), level flight for at least 30 seconds before the FAP, glide path interception from below and the required airspeed until the FAP that shall permit the aircraft configuration.
28- see a summary and access the Official BEA Report at:
http://www.skybrary.aero/index.php/A343,_vicinity_Paris_CDG_France,_2012_(LOC_HF)
29- see report Dutch Safety Board "Pitch-up Upsets due to ILS False Glide Slope" and articles FI "Pilots Unready for false Glide Slopes" dated July 8th-14th 2014 and AW&ST "False Promises" dated July 21st 2014.

decisive in ensuring a satisfactory level of safety allowing to enhance the situational awareness of all actors. Secondly, and as pointed out by the Dutch Safety Board, with the introduction of complex and automated on-board systems, that have dramatically improved the level of safety by adding support to the crew in dealing with difficult situations, could lead them to be too reliant on the automation provided and under certain circumstances degrade the level of safety[30], so ATC can in such circumstances be a remedial loop.

Overall, we at CDG are convinced that the introduction of safety nets in ATC and the analysis of all safety events detected through them facilitates a more comprehensive view of our safety performance and is an essential element for a performance based environment which is a concrete challenge in the aviation industry for the years to come. It enables us to identify both trends and any underlying safety issues and can be used to enable a productive dialogue with those on the operational front line which helps everyone to come to a consensus on safety and performance. Monitoring of safety net alerts is then no longer seen as an intrusion into the controllers' work but as a tool which helps to introduce objectivity into a controller's notion of risk and risk management so as to ensure that they issue clearances fully aware of the relative risks that they continually have to deal with and assess. Moreover, far from being a tool creating reliance on automation, it is a tool that leaves the operator at the forefront of decision and alerts him when need to be, issuing a final warning that helps the controller to reassess a situation, maintain a high level of situational awareness and act accordingly using his core skills in order to maintain or restore an acceptable level of safety. **S**

30- Dutch Safety Board Report page 61 : "In that respect the Dutch Safety Board is concerned that the use of advanced automation can lead to situations where the flight crew's flight path management degrades".

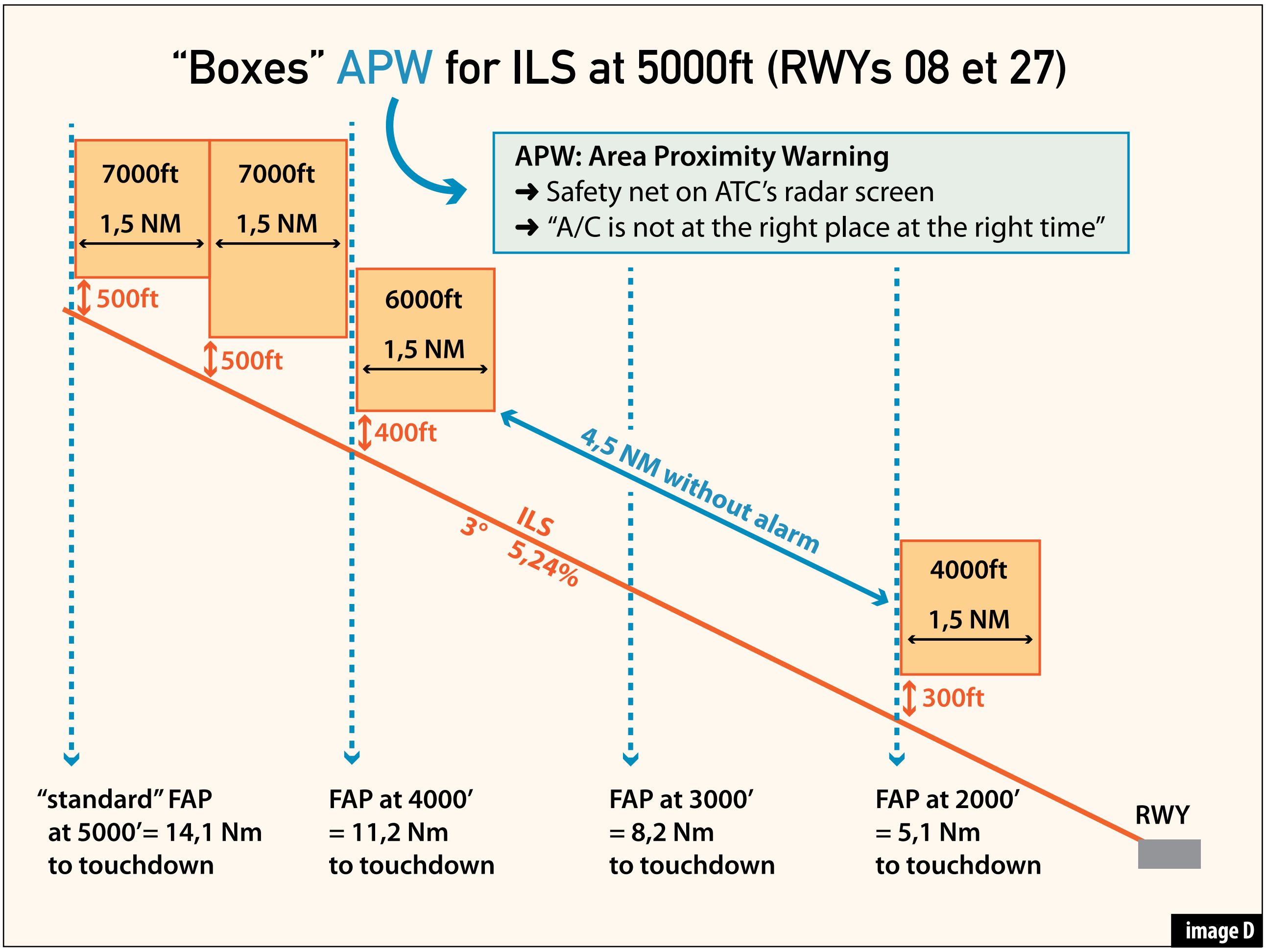


image D

How to sharpen your automated tools

by Dr Kim Cardosi

Save fuel and the environment with fewer emissions! Fly more flexible routes! Get better altitudes! Programmes that claim to make flying more efficient have several things in common – new tasks for pilots, new flight deck displays, automated decision support tools, changes to ground automation and to displays for air traffic control (ATC) and changes to air traffic procedures...

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Cost-benefit assessments determine the initial investment for air carriers and estimate the magnitude of the return on their investment. Safety assessments identify potential hazards and determine if the inherent risks of aircraft flying closer together are sufficiently mitigated. Mechanical components and software are tested to ensure that they perform as intended. But not even in the small print is the underlying assumption that the advertised benefits can only be realised if the equipment is user-friendly, the automation is 'trustworthy' and pilots and/or controllers are motivated to use it. This means that the benefits to the front-end users—pilots and controllers—have to outweigh the costs of additional workload.

One piece of automation which is beginning to arrive in the flight deck that should bring advantages is Automatic Dependent Surveillance – Broadcast (ADS-B)[31] which displays appropriately-equipped traffic[32] in the vicinity of an appropriately-equipped aeroplane[33] to the pilots. Automation like this sound intuitively like a good idea, but it has to be implemented effectively. This means getting the Human Factors of the design right so that it is straightforward for the pilot to use. What follows is based on some initial experience with ADS-B –based flight deck traffic displays in the USA and its use by pilots. One of the key lessons already learned is that just applying Human Factors design guidelines for new automation is never going to suffice – we need to do this in conjunction with pilots in order to optimise its use. Some of this is done before the system reaches the flight deck, but it's often afterwards, in the first weeks or months of implementation, that some of the real learning takes place, as operational experience is gained. So, how do we get this crucial feedback from pilots? I'll come back to this point at the end. But first, a bit more on getting it as right as we can from the start.

There is a wealth of human factors guidance for good equipment design as it relates to displays and controls. But assuming we have a well-designed system with an intuitive display, easy to operate controls and an operating procedure with no mental gymnastics required, there are several aspects that still need to be addressed on the checklist for success.

So, how do I use it?

Training is one of the tools needed for an automated system to succeed. Without proper training, there is no return on investment in automated tools. Training should involve much more than learning a series of opera-

31- See http://www.skybrary.aero/index.php/Automatic_Dependent_Surveillance_Broadcast_(ADS-B)
32- Aeroplanes which are equipped with ADS-B In
33- Aeroplanes which are equipped with ADS-B Out

tional steps. Before introducing the mechanics of an operation, the benefits from a system perspective should be explained and ideally work down to 'what's in it for me?' This includes not only the current equipment and procedures, but also scheduled updates. An understanding of the big picture that includes what occurs on the other side of the microphone is an important part of training that is often overlooked, but becoming increasingly important.

What you see is what you get. However…

Training for both pilots and controllers on ADS-B applications should include the capabilities and limitations of the technology. ADS-B In equipage allows flight crews to have more accurate real-time information than controllers – but only with respect to the distance between their aircraft and other aircraft equipped with ADS-B Out. Controllers have the advantage of the more complete picture. Limitations to the flight crews' view are namely:

- ADS-B In systems can't detect aircraft without ADS-B equipment (ADS-B Out).

- ADS-B In systems have range limitations (150-250 nm), so traffic beyond this range is not likely to be displayed.

What you see depends on which window you're looking through…
Flight deck displays of traffic may have different pages or views. It's important for pilots to understand which views/pages (if any) interact with information in the Flight Management Computer (FMC) and what actions can be taken without affecting information in the FMC. Training should include the intended use of each page or view and best practices for use of the different features, including an explanation of what traffic is displayed/excluded in each view. For example, if only ADS-B traffic is displayed, it may surprise pilots when some nearby traffic is not on the display!

Lost in Translation?

Flight deck displays of traffic can display the call signs of ADS-B Out aircraft. In order for pilots to call the other aircraft or to refer to the other aircraft in voiced communications with air traffic, pilots will need to 'translate' the displayed aircraft call sign. Some call signs are likely to be familiar to pilots (such as 'UAL' for United and 'AAL' for American). Others, such as 'AZA' for Alitalia, 'DLH' for Lufthansa, 'AAR' for Asiana, and 'QFA' for Qantas are less familiar in the US, for example. It would be helpful for pilots to have a way to match the three letter identifier in the aircraft call sign to the call sign prefix used in voiced communications. This could be as simple as a list of carriers that they are likely to encounter during their flight.

How to sharpen your automated tools (cont'd)

What's in it for me?

It's important for pilots and controllers to know that the value of ADS-B displays on the flight deck extends beyond any individual procedure. For example, pilots can use the display to call other aircraft and ask them for ride reports. This negates the need for 1) the crew to ask the controller for similar information, and 2) the controller to solicit the information from other aircraft. Similarly, flight crews can use the traffic display to observe aircraft deviations around en-route convective weather and to make more informed requests of ATC (such as standard altitude requests), thus reducing the number of nuisance requests (i.e., ones that cannot be granted due to traffic). Most pilots, however, do not know what the separation standards are (and those pilots who are familiar with the standards in general have no way to know which standard the controller is applying). The monetary value of these advantages is difficult to quantify, but airlines are not likely to buy an optional system that can't be demonstrated to pay for itself.

There's no substitute for 'hands-on' training.

The mode of the training will not only affect how and what the user learns, but also how the user feels about it. Training is costly, but it is an investment and shouldn't be considered a luxury. Airlines and Air Traffic Service Providers may need to be reminded that pilots and controllers will be more likely to accept new technology – and hence, realise the operational benefits – when they have the benefit of learning it in an operational context. Ideally, this means incorporating use of the new tool in a simulator. While training in the airplane simulator for all ADS-B applications is not likely to be viewed as cost-effective by the airlines, even an interactive desktop simulator with access to a line check airman for questions helps to build confidence in the equipment and procedure. A briefing sheet or computer-based training (CBT) alone is not likely to be regarded by pilots or controllers as sufficient for a reduced-separation procedure, nor should it be.

> You can help to shape the tools you are given and the training you receive by making your voice be heard. With any new tool, the results of initial operating experience are likely to be carefully monitored to identify effects on safety and efficiency.

'Flight crew' extends beyond the cockpit…

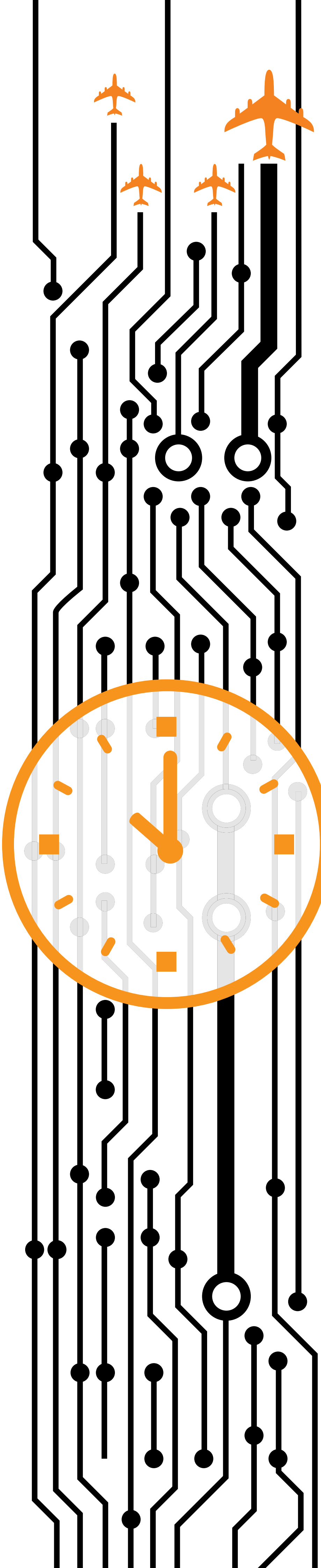
All involved parties – pilots, controllers, and dispatchers (where applicable) should have a working understanding of the information and tools being used in the air and on the ground. Knowing which information is used by the pilot, controller, and the automation will help to manage expectations. This was seen in the implementation of Traffic Alert and Collision Avoidance System (TCAS). While pilots understood that TCAS could only 'see' aircraft with Mode C transponders, pilots and controllers alike were frustrated when situations would resulted in a TCAS Resolution Advisory (RA) for the pilot, but not a conflict alert for the controller. Once it was understood that TCAS didn't have flight plan information (and so, did not know 'intent'), and that it used very different algorithms than the controller's automation, the system was seen as being more 'predictable' (a.k.a. 'trustworthy').

You're in charge.

You can help to shape the tools you are given and the training you receive by making your voice be heard. With any new tool, the results of initial operating experience are likely to be carefully monitored to identify effects on safety and efficiency. This should include soliciting feedback from users, often in the form of questionnaires. While it will be tempting to rush off to your next task or well-deserved break, USE YOUR VOICE to identify any relevant area (training, procedures, tools) that need to change to make the tool work for you. There is likely to be some information that must be manually entered (also known as the care and feeding of the computer) – your feedback can help to maximize the return on your investment.

Share your knowledge. Have you discovered an off-label advantage or 'unintended benefit' of the new tool (like pilots using the ADS-B display of traffic to see who may be ahead of them in customs cues and planning accordingly)? If so, pass it along.

It's in everyone's best interests to realise the operational benefits associated with new technology—ride quality, fuel savings, and other efficiencies. Most controllers and pilots are driven to provide the best possible service with the highest level of safety. You need, and deserve, the organizational support in place before, during, and after initial implementation of any tool that changes your job. Use your voice – you'll be glad you did.



Flying
digital or analogue?

by Captain Pradeep Deshpande

In our increasingly digitised world there is sometimes apprehensiveness and even a little bit of suspicion towards what is not digitally processed and presented. Often we are pleased to see data merely presented in digital form even if it was actually processed by analogue means. Analysts over the years have therefore tried to convert art into science and fed it to the new breed of digitally hungry minds. In my opinion flying has met the same fate too.

Many of today's older pilots have grown up in the analogue world before transitioning to the digital one. I must admit that I owe the inspiration to write this piece to a short video 'Children of the Magenta'[34]. It's not new and many of you may have seen it but if you haven't - , it's a 'must view'!

The skill set required for a professional pilot includes good CRM, technical knowledge, weather awareness and adequate psychomotor or hand-flying skills among others. In this article I will focus only on the hand-flying skill part and within that, flying the approach and landing.

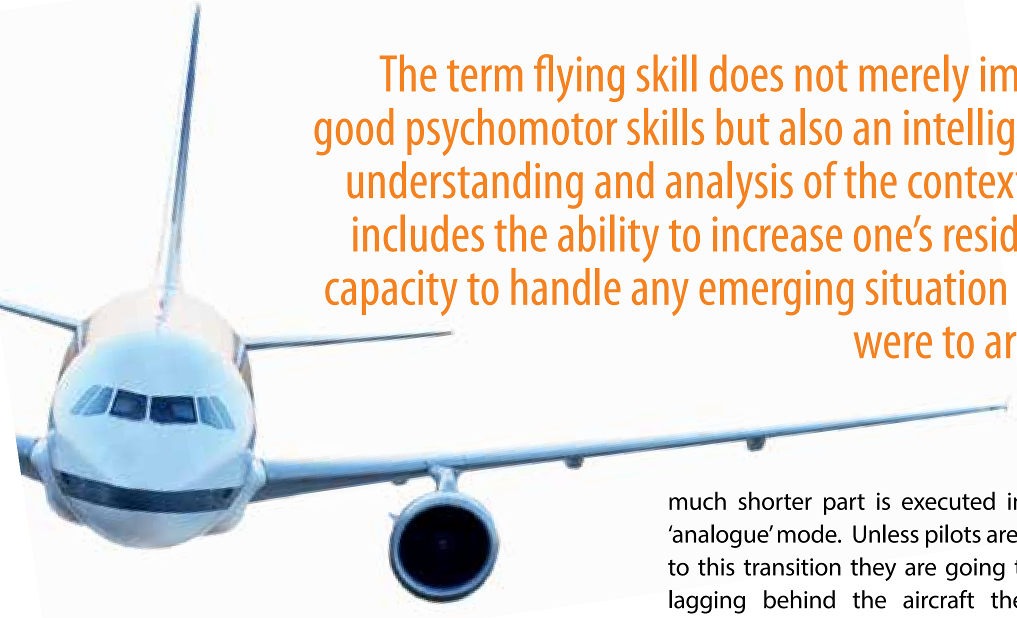
Since the spread of commercial aviation as means of travel, accidents related to approaches and landings have been in sharp focus due to the higher vulnerabilities during this phase of flight. This has resulted in the attention being given in two distinct areas – the provision of hardware and the procedures and training of pilots. Hardware improvements have been seen in the landing aids, runway lighting systems, weather prediction and in aircraft systems. Pilot training has seen the ALAR[35] approach which has included the establishment of and strict adherence to defined stabilised approach criteria, the rise of the practice of routine flight data monitoring, the concept of non-punitive go around policies and adjustments to the authority gradient in the flight deck in respect of calls for a go around.

While all the above improvements have shown excellent results, the one area that has been neglected is the maintenance of manual flying skills. One may argue that if the initiatives proposed by the ALAR project and what followed it had been applied, the chances of unsafe landings would have been minimised. I agree. However, there is more to it than that. With stabilised approach criteria, really bad approaches are easy to recognise and deal with; it is the not-so-bad approaches that are more problematic. Those where the crew feel they can

▸▸

34- View a copy of this video on SKYbrary at: http://www.skybrary.aero/index.php/Automation_Dependency
35- The acronym Approach and Landing Accident Reduction was introduced in work on the subject by the Flight Safety Foundation which began in 1996

Flying – digital or analogue? (cont'd)



The term flying skill does not merely imply good psychomotor skills but also an intelligent understanding and analysis of the context. It includes the ability to increase one's residual capacity to handle any emerging situation if it were to arise.

legitimately continue the approach to a landing merely because the aircraft passed the designated stabilised approach gate(s) in compliance with the criteria. What often happens is that they are then unable to execute it because they failed to appreciate the dynamics of a rapidly changing external situation and/or the prevailing energy state of the aircraft.

The term flying skill does not merely imply good psychomotor skills but also an intelligent understanding and analysis of the context. It includes the ability to increase one's residual capacity to handle any emerging situation if it were to arise. It also means the ability to distinguish a good approach from a bad one particularly when it is (or is perceived to be) nominally within the applicable stabilised approach criteria.

Whilst a large part of this would form a part of the innate cognitive skills of an individual, the good news is that a considerable part of the necessary awareness can be developed from that foundation given sufficient focus on the task. This ability to make good – and timely – tactical judgments becomes very important because while most of a typical approach is flown in what I call 'digital' mode, the final and much shorter part is executed in the 'analogue' mode. Unless pilots are alive to this transition they are going to be lagging behind the aircraft thereby increasing the odds of a poor landing or even worse, an unsafe one.

The basis of good transition from digital mode to the analogue mode starts during the preparation for the descent and continues all the way through until the aircraft vacates the active runway. If it is one of those days where the wind velocity is of significance to aircraft control near the ground in terms of its effect on the tail/headwind component during flare, then the ATIS wind may become something of more dynamic concern as the runway gets closer. If ATC provide a sequence of spot winds then it must be recognized that their value is as a context rather than as the wind which will actually prevail in the flare to touchdown. The fact that the distance of the anemometer(s) which ATC are using from the runway TDZ[36] can vary tremendously from airport to airport must also be recognised – although any sequence and the variation in wind speed and direction it shows is valuable. For example if the mean wind reported equates to a headwind component of 10 knots, the pilot must plan to arrive at the runway threshold at the applicable V_{app}[37] plus 5 knots and then set the engine thrust gradually to flight idle as or soon after the flare is commenced. To arrive at this point however, the pilot has to often negotiate a large segment of the approach where the winds may be rather different to the reported airport wind. They may need to adjust the thrust in response to the changes in the Indicated Air Speed in order to maintain the target Vapp which is of course what the auto throttle usually does. During an approach in unstable air, the auto throttle-commanded thrust setting can vary from as much as 69 % to as little as 49 % to adjust for a speed that may be less than 10 knots from the Vapp. This is a digital response and because the auto throttle has the auto pilot to assist in the large trim changes that ensue, the changes involved are not that obvious. But if a pilot was to make such large adjustments during while in manual flying, clearly it will not work. Instead they must use their judgement and anticipation to makes more modest changes in the thrust setting, whilst tolerating some variation about the Vapp in such a way as to progressively reduce the variation from target N1 so as to arrive at the threshold with the aircraft within the acceptable tolerance limits for the applicable landing reference speed.

Pilots need to understand that such tolerances are provided so that they can make coarse corrections when conditions are less than ideal. When landing in strong and gusty winds, the pilot must retain the residual capacity to respond to the unexpected - say a sudden wing drop or unexpected drift in the flare. They must be permitted to accept a speed which is not exactly the prescribed one as they cross the

36- Touch Down Zone
37- The indicated air speed which should be flown on the approach based on the Estimated Landing Weight (ELW) of the aircraft

EDITORS NOTE

Those readers who are more familiar with the 'digital' area control centre than the 'digital' flight deck may be wondering how much of the piloting talk above is transferable to their environment.

Suggesting that the supervisor occasionally switches off all the aids that make it possible to handle busy traffic periods at a busy time is hardly sensible. But maybe there is an opportunity to provide safe and expeditious ATC service with less than full automation at quieter times as a means to retaining controller 'reversion skills'.

After all, automation is not yet infallible and opportunities to remind oneself how to handle loss of full automation in a training simulator are either not sufficiently frequent or not yet available at all.

threshold. The tolerances are there to allow pilots to slightly reduce their attention on airspeed so as to give more of their attention to controlling the aircraft to achieve a safe touch down within the TDZ. They need to realize that the impact of an additional 5 or 7 knots will in most circumstances make little difference to the landing whereas the consequences of not appreciating drift after flaring or allowing the rate of descent to suddenly increase or decrease can be significant.

So if it is appreciated early on that some superior controlling may be required on an approach due to prevailing weather conditions, the crew must brief and be prepared for greater speed variations. Emphasis must be placed on the mean engine thrust and all variations should be within a couple of percent of this. When what may be quite large changes in indicated airspeed occur, they must be countered with small changes in thrust. What matters is to be patient and watch the changes taking place gradually. Unless one encounters wind-shear (which may well be a go around situation) these changes would be quite adequate to get you on the threshold within the tolerance limits. But the monitoring pilot must beware of inappropriate calls of 'check speed' and the handling pilot of mechanically reacting to speed variation without taking any account of the prevailing wind conditions.

The message illustrated here is that it does not pay to be strictly digital in your thinking. The objective is to execute a good landing and not merely flying the approach at precisely the required speed. Another aspect of 'digital flying' is following the command bars of the Flight Director (FD). In some types of FD, just ensuring that the target is always met does not necessarily mean that the aircraft is on the correct approach path. In this 'V bar' type, the command bars may just be guiding the aircraft towards the correct path after it has drifted from, say, the ILS the glideslope or localizer. In this case, a quick glance at the raw ILS data would reveal where the aircraft actually is and thus indicate what kind of a change is likely to occur once the aircraft arrives back on the correct path. Seemingly minor deviations from the correct path at large distances from the runway very quickly increase as one comes closer to it so that larger control inputs are needed. And in aircraft that use roll spoilers to assist in roll control, an excessive roll command may lead to a significant increase in drag on the down-going wing which causes the airspeed to fall at a potentially critical stage of the approach. Anticipating the implications of flying manually but still using the FD allows the pilot to foresee the control input that is about to become necessary in respect of both the thrust setting and the flight controls as the aircraft regains the correct path. The operative words here are 'about to' and it is this analogue response that the pilot must appreciate. Correcting after the aircraft achieves the correct path would be the 'digital' response and would be 'too little too late'.

The transition from digital (automated) to analogue (manual) flying is relevant to the approach. Subject to aircraft type, 'coming on the controls' just prior to disengagement of automation can represent a lost opportunity to determine, by lightly but firmly holding the controls for a period beforehand, to get the 'feel' of the aircraft. Without the Autothrottle engaged, small changes in thrust are best achieved by 'walking' the thrust lever knobs i.e. making a small movement of one lever and then using that as a reference for movement of the other(s).

The replacement of analogue systems is a huge technical achievement that has made flying simpler in more ways than one. But however capable and reliable it is, it cannot entirely replace what has traditionally been called 'seat of the pants' flying. Appreciating all the implications of operating our digital aeroplanes has the potential to make flying safe and even more enjoyable. But we all must strive to become the 'fathers' rather than the 'children' of the magenta!

Capt. Pradeep Deshpande

served as a combat pilot in the military for 22 years.
He was a flying instructor and examiner in the military before joining commercial aviation. Commercially he has flown the Airbus A 310 and is currently flying the B 737 800 NG at Air India.
He has approximately 9000 hours from 32 years in aviation.

38- An optional but almost always displayed overlay on the Aircraft Attitude Display – once known as the Attitude Indicator – which provides a target pitch and roll and provides cues to 'fly' the aircraft to comply with the target. With the AP engaged, the set target will always be met.

New ATC procedures - unintended effects on the flight deck?

by Colin Gill

Unforeseen effects

Enhancements in ATC and airspace procedures that make best use of the aircraft Flight Management System (FMS) can significantly reduce pilot workload and enhance flight efficiency and this is clearly a good thing. However, it is essential that any consequential safety effects on the flight deck are identified and addressed collaboratively between ATC and aircraft operators. A good example of this need is in the fuel management issues related to RNAV arrival routes that use linear holding procedures such as 'Point Merge'.

What is linear holding?

Linear holding can be designed into an RNAV STAR. It allows ATC to delay, sequence, and integrate aircraft arrivals by giving routings along predefined variable legs to specific points, instead of providing radar headings. It can also entirely replace or significantly reduce the need for traditional holding stacks. 'Point Merge', shown below, is a particular type of linear hold that is already in operational use at some airports. ATC arrival clearance is given for the complete longest linear hold route. As the correct spacing is achieved, the aircraft is instructed to route to the 'merge point' from where a single arrival path is resumed.

Colin started his aviation career as a military air traffic controller, subsequently specialising in safety management systems. Since 2007 he has worked for the UK CAA in a variety of posts including Head of ATM Policy.
He is currently the UK CAA Safety Strategy lead for future systems and equipment and Chairman of the ICAO ATM Operations Panel.

So what is the problem?

In simple terms, when in a traditional vertical holding stack, or when being provided with headings from ATC, the aircraft FMS is 'reactive' in its fuel calculations, as it does not know how many holds will be flown or where the controller will vector the aircraft. But when ATC instruct an aircraft to fly the complete RNAV linear hold, the FMS 'sees' this route as a 'closed loop' and provides landing fuel predictions based on the assumption that this will be flown in its entirety. The FMS of course does not know when ATC will provide an instruction to fly to the merge point. As a result, in advance of a clearance to the merge point, in certain circumstances the FMS would generate a fuel-warning message with consequent flight crew uncertainty in their fuel situation despite carrying appropriate fuel loads. This led to some aircraft operators carrying more fuel than was actually needed, a situation that results in extra fuel burnt to carry the extra load. There was also concern that this situation could lead to fuel emergencies being declared when not necessary.

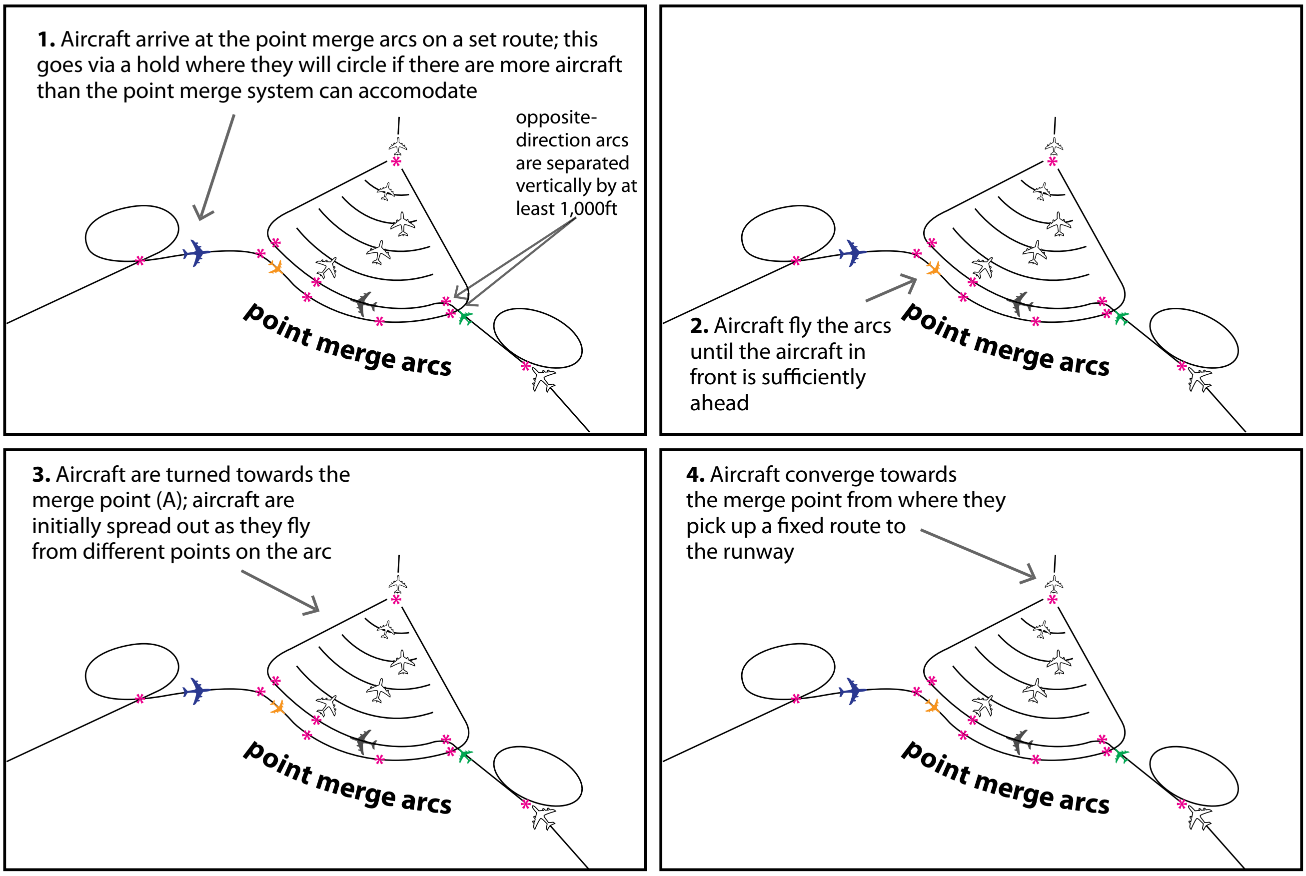
How was the problem resolved?

As part of planning for implementation of RNAV linear holding within the UK Future Airspace Strategy, UK CAA facilitated a working group of controllers and pilots to gain full understanding of the problems and issues identified from linear holding deployment in other states. This focused on fuel planning; FMS operation; and ATC techniques and procedures. The outcome was ATC and pilot understanding and agreement on the varying flight deck and ATC demands and safety risks, a set of consistent flight crew and ATC procedures and processes, and identification of next steps.

What is the solution?

In addition to the complete 'long' STAR that shows all of the linear hold legs and points, ATC should also promulgate a 'short' STAR that purely depicts the shortest arrival route via the merge point. Aircraft operators would use the short STAR to plan the trip fuel; the linear hold element of the long STAR would be addressed within statistical contingency fuel planning as per conventional holding.

After weighing up the effects of varying potential techniques, it was agreed that (unless there was no delay or sequencing required) ATC would normally provide a clearance for the long STAR. This would ensure that the linear hold legs and points were populated in the FMS and avoided flight crew needing to re-programme the FMS at short notice if ATC required any part of the linear hold to be flown. This proce-



dure also was found to be the fail-safe way to integrate and sequence the aircraft from an aircraft separation perspective.

Aircraft operators accepted that based on current FMS design and coding, there was no way to entirely eradicate the potential for some FMS fuel warning messages, but it was agreed that these were not fuel warnings that required a fuel emergency to be declared. Therefore, there was a need for flight crew to understand and manage these FMS messages appropriately.

In support of flight crew management of potential FMS fuel messages, it was considered essential that ATC provide flight crew with a prediction of the amount of linear holding expected.

What next?

UK CAA will be working with ATC providers and aircraft operators to agree on the exact UK RT phraseology used to provide warning of the amount of linear holding to be expected. It has also been found that radio communication failure procedures for linear holding in current use across Europe are at variance and further work is needed to identify the most appropriate SOP.

A UK communications and education programme is being developed, including the production of an AIC to ensure that the linear holding design, ATC procedures, and fuel management processes are fully understood.

Aircraft operators need to be able to apply consistent procedures regardless of location. Therefore, it is recognised that regional and then global standardisation is needed. Through the ICAO Flight Operations Panel, activity is already underway to ensure that aircraft operator fuel planning guidance is further developed to reflect linear holding. UK has also briefed ICAO at regional level and further European activity is being initiated to ensure a standardised solution that can be implemented globally.

Wider Issues?

As we move into SESAR and NextGen deployment, ATC procedures and airspace design procedures become more integrated and reliant with the flight deck and features of aircraft automation. So that the efficiency and safety benefits are realised, such concepts must be collectively considered using all stakeholders across the domains. It is highly likely that the technical aspects of major ATM developments and interactions with the flight deck are covered in depth, but maybe more proactive attention is needed to consider the human factors aspects and consequences on operating procedures and processes?

Looking back with hindsight is wonderful, and it is good that due to good safety relationships the unforeseen effects are quickly identified, thus enabling actions to be taken. But ideally, we need to identify safety effects such as fuel management issues before implementation. Current EASA rules specify that air traffic service provider hazard and risk assessment shall address the airborne components of the ATM functional system through cooperation. Current EASA proposals develop this concept further through the application of a 'total system approach' to safety. Having the right operational staff in the same room to work through these issues by thinking about the wider consequences is a key to success.

If it weren't for the people...

by Dr Steven Shorrock

In Kurt Vonnegut's dystopian novel 'Player Piano', automation has replaced most human labour. Anything that can be automated, is automated...

Ordinary people have been robbed of their work, and with it purpose, meaning and satisfaction, leaving the managers, scientists and engineers to run the show. Dr Paul Proteus is a top manager-engineer at the head of the Ilium Works. But Proteus, aware of the unfairness of the situation for the people on the other side of the river, becomes disillusioned with society and has a moral awakening. In the penultimate chapter, Paul and his best friend Finnerty, a brilliant young engineer turned rogue-rebel, reminisce sardonically: *"If only it weren't for the people, the goddamned people,"* said Finnerty,*"always getting tangled up in the machinery. If it weren't for them, earth would be an engineer's paradise."*

While the quote may seem to caricature the technophile engineer, it does contain a certain truth about our collective mindsets when it comes to people and systems. Our view is often that the system is basically safe, so long as the human works as imagined. When things go wrong, we have a seemingly innate human tendency to blame the person at the sharp end. We don't seem to think of that someone – pilot, controller, train driver or surgeon – as a human being who goes to work to ensure things go right in a messy, complex, demanding and uncertain environment.

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Our mindset seems to inform our attitude to automation, but it is one that – if it ever were valid – will be less so in the future.

Human as Hazard and Human as Resource

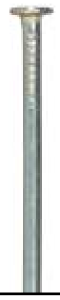
The view of 'human as hazard' seems to be embedded in our traditional approach to safety management (see EUROCONTROL, 2013; Hollnagel, 2014), which Erik Hollnagel has characterised as Safety-I. It is not that this is a necessarily a (conscious) mindset of those of us in safety management. Rather, it is how the human contribution is predominantly treated in our language and methods – as a source of failure (and, in fairness, as a source of recovery from failures, though this is much less prominent). Most of our safety vocabulary with regard to people is negative. In our narratives and methods, we talk of human error, violations, non-compliance and human hazard, among other terms. We routinely investigate things that go wrong, but almost never investigate things that go right.

This situation has emerged from a paradigm that defines safety in terms of avoiding that things go wrong. It is also partly a by-product of the translation of hard engineering methods to sociotechnical systems and situations. As the American humanistic psychologist Abraham Maslow famously remarked in his book Psychology of Science, *"I suppose it is tempting, if the only tool you have is a hammer, to treat everything as is it were a nail."* If we only have words and tools to describe and analyse human failures, then human failures are all we will see. Yet this way of seeing is also a way of not seeing. What we do not see so clearly is when and how things go right.

It is not just the safety profession. It is, to an extent, management and all of society. At a societal level, we seem to accept a narrative that systems are basically safe as designed, but that people don't use them as designed, and these blunders cause accidents. Hence the ubiquitous "Human error blamed for…" in newspaper headlines. From a human as hazard perspective, it seems logical to automate humans out wherever possible. Where this is not possible, hard constraints would seem to make sense, limiting the degrees of freedom as much as possible and supressing opportunity to vary from work-as-designed.

An alternative view is that humans are a resource (or, for those who object to the term's connotations, are resourceful). In this view, people are the only flexible part of the system and a source of system resilience. People give the system purpose and form interconnections to allow this purpose to be achieved. They have unique strengths, including creativity, a capacity to innovate, and an ability to adapt. As it is impossible to completely specify a

"I suppose it is tempting, if the only tool you have is a hammer, to treat everything as is it were a nail."



sociotechnical system, it is humans – not automation – who must make the system work, anticipating, recognising and responding to developments.

This view of the human in a safety management context seems to resonate with a more fundamental view of the human in management thinking more generally. Over 50 years ago, Douglas McGregor identified two mindsets regarding human motivation that shape management thinking: Theory X and Theory Y. Theory X dictates that employees are inherently lazy, selfish and dislike work. The logical response to this mindset is command-and-control management, requiring conformity and obedience with processes designed by management, and a desire to automate whatever can be motivated, because this removes a source of trouble.

The Theory Y mindset is that people need and want to work; they are ambitious and actively seek out responsibility. Given the right conditions, there is joy in work, and so work and play are not two distinct things. Rather than needing to be 'motivated' by managers, people are motivated by the work itself and the meaning, satisfaction and joy they get out of it. Importantly, humans are creative problem solvers.

Toward a humanistic and systems perspective

Two things seem to be certain for the future. The first is obvious: we will see more automation. The second is less obvious, but equally certain: Whatever mindset motivates the decision to automate, it will be necessary to move toward a more humanistic view of people that incorporates Hollnagel's Human as Resource and McGregor's Theory Y. For this view to prevail, we will need to reform our ideas about work away from command-and-control and towards a more humanistic and systems perspective.

It is inevitable that work with automation will not always be as designed or imagined. While part of the design philosophy may have sought to suppress human performance variability, humans must remain variable in operation. As well as the rare high-risk scenarios, there will be disturbances and surprises, and even routine situations will require human flexibility, creativity and adaptation. This does not call for technophobia, but humanistic and systems thinking. People will be key to making the system as a whole work.

We, the people

Finnerty's exclamation raises an important question: who are the people? It seems that he was talking about people on the front-line. But they are not the only people. We might think of four roles for the people in the system: system actors (e.g. front line employees, customers), system experts/designers (e.g. engineers, human factors, human resources), system decision makers (e.g. managers and purchasers), and system influencers (e.g. the public, regulators) (Dul et al, 2012). When automation goes wrong, it tangles up people in all roles. The system actors (front-line staff and customers) just pay the highest price. The responsibility for automation in the context of the system must therefore be shared among all of us, because automation does not exist just within the boundary of a 'human-automation interaction' between the controller/pilot and the machinery. Automation exists within a wider system. So how can we make sense of this?

Making sense of human work with automation

Our experiences with automation present us with some puzzling situations, and we often struggle to make sense of these from our different perspectives. For example, we might wonder why someone 'ignored' an alarm that seemed quite clear to us, or why they did not respond in the way that (we think) we would have responded. We might also wonder why someone would have purchased a particular system, or made a particular design decision, or trained users in a certain way. To make sense of these sorts of situations, and to ensure that things go right, we need to consider the overall system and all of our interactions and influences with automation, not isolated individuals, parts, events or outcomes.

▸▸

If it weren't for the people... (cont'd)

There are a variety of systems methods that can help to do this (see bit.ly/1s6mgcv). But following are some tips from a EUROCONTROL White Paper just published, *Systems Thinking for Safety: Ten Principles* (see bit.ly/1uTeQ9g).

1. **Involve the right people.** The people who do the work are the specialists in their work and are critical for system improvement. *When trying to make sense of situations and systems, who do we need to involve as co-investigators, co-designers, co-decision makers and co-learners?*

2. **Listen to people's stories and experiences.** People do things that make sense to them given their goals, understanding of the situation and focus of attention at that time. *How will we understand other's (multiple) experiences with automation from their local perspectives?*

3. **Reflect on your mindset, assumptions and language.** People usually set out to do their best and achieve a good outcome. *How can we move toward a mindset of openness, trust and fairness, understanding actions in context using non-judgmental and non-blaming language?*

4. **Consider the demand on the system and the pressure this imposes.** Demands and pressures relating to efficiency and capacity have a fundamental effect on performance. *How can we understand demand and pressure over time from the perspectives of the relevant field experts, and how this affects their expectations and the system's ability to respond?*

5. **Investigate the adequacy of resources and the appropriateness of constraints.** Success depends on adequate resources and appropriate constraints. *How can we make sense of the effects of resources and constraints, on people and the system, including the ability to meet demand, the flow of work and system performance as a whole?*

6. **Look at the flows of work, not isolated snapshots.** Work progresses in flows of inter-related and interacting activities. *How can we map the flows of work from end to end through the system, and the interactions between the human, technical, information, social, political, economic and organisational elements?*

7. **Understand trade-offs.** People have to apply trade-offs in order to resolve goal conflicts and to cope with the complexity of the system and the uncertainty of the environment. *How can we best understand the trade-offs that we all system stakeholders make when it comes to automation with changes in demands, pressure, resources and constraints – during design, development, operation and maintenance?*

8. **Understand necessary adjustments and variability.** Continual adjustments are necessary to cope with variability in demands and conditions, and performance of the same task or activity will vary. *How can we get and understanding of performance adjustments and variability in normal operations as well as in unusual situations, over the short or longer term?*

9. **Consider cascades and surprises.** System behaviour in complex systems is often emergent; it cannot be reduced to the behaviour of components and is often not as expected. *How can we get a picture of how our systems operate and interact in ways not expected or planned for during design and implementation, including surprises related to automation in use and how disturbances cascade through the system?*

10. **Understand everyday work.** Success and failure come from the same source – ordinary work. *How can best observe and discuss how ordinary work is actually done?*

Conclusion

If it weren't for *the people*, it is true that there would be noone to get tangled up in the machinery. But if it weren't for the people, there would be no system at all: no purpose, no demand, no performance. We need to reflect, then, on our mindsets about us, *the people*, about the systems we work with and within, and about how we will ensure that things go right.

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The Automation & ATM website

ON THE BASIS THAT "THE PATH TO INCREASED EFFICIENCY (AND SAFETY) IS PAVED BY AUTOMATION", RESEARCH BEING JOINTLY CARRIED OUT BY EUROCONTROL AND THE FAA WORKING GROUP ON SAFETY RESEARCH IS ESPECIALLY FOCUSED ON THE SUBJECT.

Overall though, The Group has three main aims:

- understanding system safety
- developing new approaches to assess and improve safety
- disseminating its results to the industry

On the automation front, they have developed the 'Automation & ATM website' as a central resource for the ATM community. The impact of automation systems starts long before a controller ever sees the new system. Decisions made during the initial concept development can have far-reaching consequences as automation systems are deployed. A summary of key automation lifecycles and a relevant theme for each are identified below:

- AUTOMATION DESIGN – Automation Design typically begins with the evaluation of existing system operational shortfalls, issues, constraints and metrics in order to identify new automation system needs. During this phase, it is important to consider high-level functionality issues such as the distribution of Authority & Responsibility between controllers and automation.

- TESTING, VALIDATION & ASSURANCE – As the automation system design matures, it proceeds through validation and verification (V&V) of design documents and specifications, operational test and evaluation, operational suitability evaluation, and the correction and closure of issues identified during testing. Safety Assurance testing during this phase is essential to ensure that controllers will be able to operate the system safely when it is deployed.

- CHANGE MANAGEMENT – As a newly developed automation system is integrated into current operations, controllers should understand why the change is being made, what the benefits of the change will be and how it will affect the tasks that they do. Automation systems should be actively monitored during this time to identify any unanticipated results of using the automation, for example determining if controllers are using the automated system in ways that are different from the way in which it was designed to be used. Developing and applying the proper Training & Skills will ensure that the implementation of an effective automation system is not hindered by operators being unable to understand and apply the automation.

- OPERATIONAL USE – As automation is entered into daily use, the responsible and accountable organisation will maintain and sustain the implemented automation system. Activities typically conducted in this phase include daily monitoring of the automation system to ensure that it is working as intended, evaluation of the system's safety, efficiency and effectiveness, and the execution of a formal post implementation review. Organizations should actively monitor the Methods of Operations of automation systems to ensure that the operational use of the system does not introduce hazards that were unanticipated during system development.

Further detail on each lifecycle phase and stories representing each phase are provided on the website which is at http://Automation.FortHillGroup.com

Please take a look! There is something for everybody involved with ATM – and you can help our work at the same time…..

The work has been led primarily through a collaboration between UK NATS and the FAA Human Factors Research and Engineering Division with support from Fort Hill Group LLC.

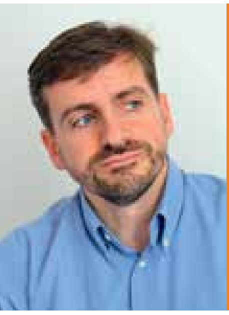
Not all or nothing, not all the same: classifying automation in practice

by Dr Luca Save

Different Levels of Automation

Since the seminal work of Sheridan & Verplanck[39] it has become apparent that automation is not 'all or nothing', that is, automation is not only a matter of either automating a task entirely or not, but to decide on the extent it should be automated. The well-known 10-points scale proposed by these authors was successful in representing a continuum of levels between low automation, in which the human performs the task manually, and full automation in which the computer is fully autonomous. But the practical experience of classifying automation shows that the two extremes of this scale are somewhat rare in complex transportation systems, at least as we know them nowadays. A fully manual task is difficult to find as much as a fully automated one. Keeping away from science fiction, functions with no human intervention at all are difficult to design, especially in 'open' systems like ATM. Even when considering examples of advanced automation, such as the modern driverless metro lines, it is interesting to note the tendency to protect or isolate the infrastructure to reduce the risk of external interferences which may put at risk the safety and efficiency of operations (the images below show an example of the platform doors adopted in most of the modern metro stations and a well isolated track of the same metro, in a section which is not underground). When these or similar solutions are more difficult to adopt, like for a tram running on street traffic or in a traditional railway network with several junctions and intersections, the presence of a driver is normally required. In addition, removing the driver does not imply a complete elimination of human monitoring, which remains necessary even if operated in a remote and centralised form and with the support of sophisticated technologies

Hence the range of options between 'automation' and 'no automation' is a wide one and it is worth considering the advantages and disadvantages of each of them.



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Two images of a 'driverless' metro line in Toulouse (France)

Qualitative differences in the automation

Over the years, research on automation has also highlighted an important aspect of the changes delivered by automation. Introducing automation means bringing qualitative shifts in the way people practice and not just delegating a set of pre-existing tasks to a machine[40]. No matter how much emphasis is put on this transformation e.g. modifying existing tasks or introducing radically

39- Sheridan, T. B., & Verplank, W. (1978). Human and Computer Control of Undersea Teleoperators. Cambridge, MA: Man-Machine Systems Laboratory, Department of Mechanical Engineering, MIT.
40- Dekker, S.W.A. & Woods, D.D. (2002). MABA-MABA or Abracadabra? Progress on Human -Automation Co-ordination. Cognition, Technology & Work, 4(4), 240-244.

new ones, it should be clear that different tasks involve the use of different psychomotor and cognitive functions, which in turn implies the adoption of different automation solutions. For example, expanding human capabilities to monitor a certain process (e.g. a Remote Tower) is not the same as replacing the human in the execution of a certain action (e.g. the aircraft auto-braking system). Similarly supporting the analysis of a complex dataset, such as that involved in predicting the risk of a traffic conflict, is not the same as identifying the best solution to resolve the conflict.

Some of these differences have been captured in the 'Model for Types and Levels of Automation' by Parasuraman, Sheridan and Wickens[41], which was probably the most significant evolution of the famous 10-point scale. Their model introduced the idea of associating levels of automation to 4 generic functions, derived from a four-stage model of human information processing:

1. Information Acquisition,
2. Information Analysis,
3. Decision and Action Selection
4. Action Implementation.

A consequence of having four functions – different in nature – is that each function can be automated at different levels.

41- Parasuraman, R., Sheridan, T. B., & Wickens, C. D. (2000). A model for types and levels of human interaction with automation. IEEE Transactions on Systems, Man, and Cybernetics – Part A: Systems and Humans, 30, 286–297.

Not all or nothing, not all the same classifying automation in practice (cont'd)

The experience of classifying automation in SESAR

In the context of a SESAR project named 'Good Practices for HP Automation Support', we took the lesson of Parasuraman et. al. seriously. We decided to consider different automation levels inside each function as a means to derive guidelines for the identification of effective automation solutions[42]. One of the main challenge we were facing from the beginning was the lack of a specific taxonomy to distinguish different levels for the different functions. As also explained by the authors, the original 10-point scale was essentially focused on "Decision and Action Selection" and the concept required significant adaptation in order to also work for the other three generic functions, including the need to consider a different number of levels within each of them. We therefore opted for the development of a new **Level of Automation Taxonomy (LOAT)** which was presented as a matrix[43].

In its final version the taxonomy uses 4 columns, corresponding to the 4 generic functions. Each one has a different number of automation levels – 5 for "Information Acquisition" and "Information Analysis", 6 for "Decision and Action Selection" and 8 for "Action Implementation". The development resulted from a combination of theoretical work investigating the different ways of sustaining human practices and the analysis of 26 examples of automated functionalities, from both ground and aircraft-related systems.

From INFORMATION to ACTION →

INCREASING AUTOMATION ↓

A INFORMATION ACQUISITION	B INFORMATION ANALYSIS	C DECISION AND ACTION SELECTION	D ACTION IMPLEMENTATION
A0 Manual Information Acquisition	**B0** Working memory based Information Analysis	**C0** Human Decsion Making	**D0** Manual Action and Control
A1 Artefact-Supported Information Acquisition	**B1** Artefact-Supported Information Analysis	**C1** Artefact-Supported Decsion Making	**D1** Artefact-Supported Action Implementation
A2 Low-Level Automation Support of Information Acquisition	**B2** Low-Level Automation Support of Information Analysis	**C2** Automated **Decsion Support**	**D2** Step-by-Step Action Support
A3 Medium-Level Automation Support of Information Acquisition	**B3** Medium-Level Automation Support of Information Analysis	**C3** Rigid Automated **Decsion Support**	**D3** Slow-Level **Support** of Action Sequence Execution
A4 High-Level Automation Support of Information Acquisition	**B4** High-Level Automation Support of Information Analysis	**C4** Low-Level Automatic **Decision Making**	**D4** High-Level **Support** of Action Sequence Execution
A5 Full Automation Support of Information Acquisition	**B5** Full Automation Support of Information Analysis	**C5** High-Level Automatic **Decision Making**	**D5** Low-Level **Automation** of Action Sequence Execution
		C6 Fulll Automatic **Decision Making**	**D6** Medium-Level **Automation** of Action Sequence Execution
			D7 High-Level **Automation** of Action Sequence Execution
			D8 Full **Automation** of Action Sequence Execution

A condensed version of the LOAT matrix

42- SESAR Joint Undertaking (2013). Guidelines for Addressing HP Automation Issues. P16.5.1 Deliverable 04.

43- For a detailed version of the matrix including the definitions of individual automation levels refer to Save, L. Feuerberg, B. (2012) Designing Human-Automation Interaction: a new level of Automation Taxonomy. In De Waard, D. et al (Eds.) (2012), Human Factors: a view from an integrative perspective. http://www.hfes-europe.org/human-factors-view-integrative-perspective/

SOME CLASSIFICATION EXAMPLES

A few examples of the findings derived from the study are briefly described, each one associated with an illustrative scenario.

1 Automation is not just substitution.

Only in very few cases automation is about completely replacing the human. As already noted, this is unlikely in 'open' and complex systems like ATM. We reflected on this aspect when analysing the example of the AP/FD (autopilot/Flight Director) TCAS mode developed by Airbus. This innovation has consisted in enhancing the current TCAS RA (Traffic Collision Avoidance System Resolution Advisory) functionality in the case of corrective RAs by directly connecting it to the autopilot. Provided the autopilot is already engaged, once a TCAS RA is annunciated, it is then flown by the autopilot. It is interesting to observe how this may have led to misconceptions by those not actually in the flight deck in relation to its actual nature. Examples of these misconceptions are apparent in statements such as: "the pilot is no longer in the loop" or "the risk of pilot error has been eliminated, as the aircraft is now flown by reliable automation".

A more careful consideration revealed that the role of the crew remains a central one, even if pilots are not actively involved in the execution of the manoeuvre. Annunciation of a corrective TCAS RA normally requires the pilot to disconnect the autopilot and follow the RA based on visual indications whereas, with the new arrangement, the manoeuvre is performed by the autopilot. The crew must still monitor the manoeuvre and, as always, can disconnect the autopilot and fly the aircraft manually if deemed necessary. So in practice the new situation does not relieve the crew from remaining in the loop just as before since the crew needs to monitor the situation and be ready to communicate with the ATC and carry out the necessary actions once 'Clear of Conflict" is activated by the TCAS. In terms of the LOAT taxonomy, both the manual and automatic TCAS RA response represent "Decision and Action Selection" support at a level C4 ("Low-Level Automatic Decision Making). While a difference is more obvious in the case of "Action Implementation" support, which passes from a level D2 ("Step-by-step Action Support) to a level D6 ("Medium Level Automation of Action Sequence Execution). It is a higher level of automation, but it is important to note that it is not yet the highest one.

2 The highest possible level is not always the best level.

This was observed when comparing the automated functionalities of different MTCD (Medium Term Conflict Detection) tools. In some cases these are designed to activate only on controller's request as with the what-if function used to detect potential conflicts before issuing a clearance). In other cases the functionalities automatically trigger an alert as soon as the alerting logic of the tool detects a conflict. Both processes are "Information Analysis" functions. However the functions in the first group correspond to a lower level than those in the second group.

Analysis of different validation reports highlighted the fact that a higher level of automation offered a better support when the operational environment and the airspace concerned were of limited complexity. On the other hand, a lower level of automation represented the best compromise in the case of traffic flows characterised by an elevated number of vertical evolutions, which also implied a limited accuracy of the trajectory prediction. In such cases the lower level of automation was still offering a useful support to the conflict detection task, but minimised the number of nuisance alerts which, by contrast, tended to jeopardize the usefulness of the higher level functions.

3 A lower level of automation might be better than no automation.

Failing to identify the best level of automation may also imply renouncing the benefit of an automation. In line with the previous example, this emerged when comparing two different configurations of an AMAN (Arrival Manager) tool, which were both "Decision and Action Selection" functions. The first configuration provided advisories to the controller at a lower level of automation. For example a "G" advisory on the track label indicated the need to gain 2 minutes or more with respect to the predicted arrival of the concerned aircraft. While an "LL" advisory ("lose lose") corresponded to the request to lose 6 minutes or more. The other configuration was ▸▸

Not all or nothing, not all the same classifying automation in practice (cont'd)

based instead on more directive advisories. These included a precise indication on the track label of the desired ground speed (e.g. "286") and of the time to start the "Top of Descent" (e.g. "9.30").

In principle, the second configuration ensured the creation of a more orderly and stable sequence of aircraft, provided that controllers strictly followed the advisories when communicating with each aircraft. However, in the specific environment in which the functionality was tested, the characteristics of the ATS geography, as well as the terrain in the terminal area, imposed a number of different operational constraints on controllers. For example it was not possible to systematically apply the continuous descent approach, which in principle would have been the most efficient and cost effective profile. The controllers therefore preferred the first configuration, since the lower level advisories left them with a choice between different ways of achieving the same goal. For example, a delay of a few minutes could have been created by either reducing the speed and remaining at the same level until the top of descent or by anticipating the descent and issuing clearances for a staged or non-continuous descent. The selection of a different course of action from the one indicated by the AMAN advisories was of course also possible with the higher level configuration of automation. However, if controllers then failed to follow the indications precisely, there was no alternative to just bypassing / ignoring the automation.

4 Pilot and Controller tasks are not automated in the same way.

Aircraft automation is sometimes considered to be more advanced than ATC automation. This perception is only partially true, as it seems to disregard the different nature of pilot and controller activities, at least to the extent that non-pilots sometimes understand them. Pilot tasks are much more "Action Implementation" oriented than controller tasks, for which the emphasis is more on monitoring, planning and communicating. Therefore, the replacement or support of a human action – which is normally perceived as "real" automation – is inevitably more successful when pilot tasks are concerned.

In the limited number of automated functionalities we examined in our SESAR study, there was a prevalence of "Information acquisition" and "Information Analysis" functions in ATC-related automations. Examples of this were the Multi-Radar Tracking system display, the STCA (Short Term Conflict Alert) system, the MTCD (Medium Term Conflict Detection) system and the TCT (Tactical Controller Tool). On the other hand there was a clear prevalence of "Action Implementation" functionalities among aircraft automations. For instance, in addition to the above mentioned automated TCAS RA response, we looked at the Autopilot following an FMS trajectory, the Autobrake system and the ASAS-ASPA (Airborne Separation Assistance – Airborne Spacing system) capability.

Finally a more balanced distribution between ground and aircraft was observed for the "Decision and Action Selection" automations, although the ATC functionalities were generally less mature and were providing a lower level of support. AMAN, which is a good example of ATC "Decision and Action Selection" functionality, is increasingly prevalent but in most of the cases it provides just a useful reference that the controller may decide to follow or not, depending on operational circumstances. This kind of support is at a considerably lower level than that offered, for example, by a TCAS RA which indicates to the pilot one single and directed action to avoid possible collision with conflicting traffic.

It is interesting to note that some of the aircraft functionalities we analysed also included "Information Acquisition" and "Information Analysis" components. However these were generally acknowledged to be less sophisticated than the ATC-related ones (consider the example of the TCAS Traffic Display which is known to be of limited functionality relative to controllers' radar displays and well known to be unusable by pilots as a means of self-separation).

Much more sophisticated "Information Acquisition" functionalities are beginning to be introduced for the flight deck and we looked at ATSAW-SURF (Air Traffic Situation Awareness for Surface Operations) – which uses ADS-B IN capability. More than just a simple technological improvement, this will, subject to the development of operator procedures, make possible a partial delegation to pilots of tasks which have previously been an exclusive prerogative of ATC.

Maintaining basic skills while managing change

by Captain David McKenney

We have all experienced the feeling of being "rusty" on knowledge and skills that we have not used recently or maybe were never properly developed in the first place. When I read stories that pilots and controllers are losing their skills because of over reliance on automated systems, I smile and reflect on how easy it is to concentrate on writing a good story, but in doing so, make assumptions and forget the facts.

Our Navigation System failed so I had to revert to the old manual methods and being a little "rusty" we drifted slightly to the North...

So ask yourself, "Are pilots and controllers losing their skills because of automated systems, or is it really a lack of practice?" I believe a major reason for skill degradation occurs because of the emphasis and often-times required use of automated systems that prevents the pilot from practicing manual handling operations. In some cases, the lack of practice is critical because the knowledge and skills may not have been properly developed initially due to many reasons. Some reasons may include inadequate training methods, inadequate training devices, inexperienced instructors, or not providing the required repetitions to fully develop the skill.

While knowledge and skills are developed by repetition over time, it is important to remember that knowledge and skills are perishable. Manual handling skills, both motor and cognitive, must be fully developed during initial training so they become ingrained and allow for skill degradation that normally occurs between practice opportunities. Degradation of knowledge and skills can and do occur over time due to lack of practice. If humans don't routinely practice knowledge and skills, they can become rusty and lose expertise.

Evolving flight deck equipment, operations, and airspace design requires a corresponding evolution in pilot and controller knowledge and skills. Over time, the scope of operations, together with the complexity of airspace, procedures, and automated tools on the flight decks has evolved. This has resulted in a corresponding increase in the set of required skills and knowledge that pilots need for flight path and energy management for today's complex aircraft and airspace. Just because we automate something does not relieve the pilot of the requirement to maintain the knowledge and skills of how to accomplish a task when the automated systems are not available.

The same is true for air traffic control functions. A controller is expected to be able to provide traffic guidance ▸▸

Maintaining basic skills while managing change (cont'd)

and separation with and without the use of automated systems in a constantly changing airspace system with new procedures. Like pilots, controllers also need to maintain recency of experience and have the knowledge and skills for the evolving technology as well as maintain the knowledge and skills for basic and reversionary operations.

Complexity in airspace operations is increasing. As the need for flexibility increases, as enabled by future changes, so does the complexity and potential for unexpected events. Air traffic controllers and pilots must be prepared for dealing with unexpected events, and the equipment design, training, and procedures and operations must enable them to do so.

So how can we maintain required skills while managing change? Some important considerations for achieving this goal can be found in the 2013 report from the international Flight Deck Automation Working Group (FltDAWG)[44] titled: The Operational Use of Flight Path Management Systems. This report addresses safety and efficiency of modern flight deck systems for flight path management, including energy-state management, in both modern and future airspace. This report includes 28 findings and 18 recommendations regarding the use of flight path management systems for flight path and energy management, including manual flight operations, autoflight mode confusion, task/workload management, and monitoring of autoflight systems. A few items related to maintaining basic skills are discussed below.

The report's first finding states, "Pilots mitigate safety and operational risks on a frequent basis, and the aviation system is designed to rely on that mitigation." While controllers were not the main focus of this particular study, a similar study for controllers would undoubtedly include a similar finding. In fact, the aviation system relies on humans in many roles working individually and together for mitigating risk.

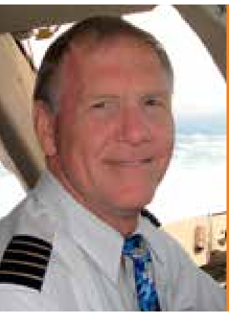
Since the aviation system relies on humans as a mitigation strategy, we need to ensure that human capabilities are taken into account for the design, implementation, and operation of the system. Before such technology is designed and implemented, industry and government must consider and incorporate measures to ensure that a human-centered design approach is used to develop the future aviation system and provide the necessary training. Such an approach takes into account human, aircraft, and airspace capabilities and limitations that allow the human operators to have the knowledge, skills, recency of experience through practice, and flexibility to manage the operation or intervene when required.

Since the aviation system relies on humans as a mitigation strategy, we need to ensure that human capabilities are taken into account for the design, implementation, and operation of the system.

The FltDAWG report findings show that in managing this change, the system still has vulnerabilities in such things as:

- Pilot knowledge and skills for manual flight operations,
- Pilot use of, and interaction with, automated systems,
- Pilot skills to most efficiently and effectively accomplish the desired flight path management related task, and
- Communication and coordination between pilots and controllers.

As pointed out in the FltDAWG report, because of the changes in aircraft equipment and in flight operations, there has been a corresponding change (and increase) in needed pilot knowledge and skills. It also became apparent that the definition of "normal" pilot skills is changing over time, and pilot skills that were once thought of as "typical" are now thought of as "basic or reversionary". Figure 1 shows this in a notional manner.



Capt. David McKenney flies for United Airlines and has over 40 years experience on many aircraft types including the Boeing 727, 747, 757, 767 and 777. He is currently IFALPA Human Factors Chairman and Director of Pilot Training Programs for the Airline Pilots Association (ALPA). He was a co-chair of the PARC / CAST Flight Deck Automation Working Group and co-authored their report "Operational Use of Flight Path Management Systems".

44- http://www.faa.gov/about/office_org/headquarters_offices/avs/offices/afs/afs400/parc/parc_reco/media/2013/130908_PARC_FltDAWG_Final_Report_Recommendations.pdf

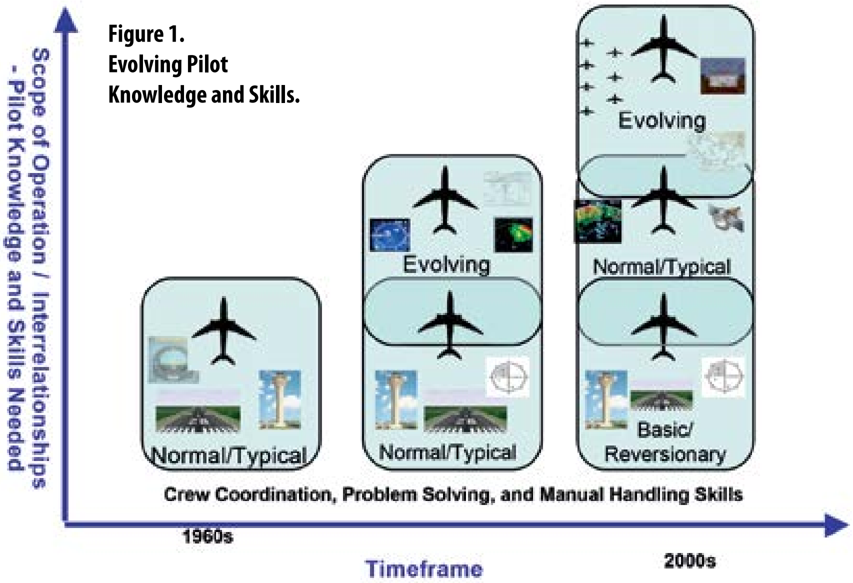


Figure 1. Evolving Pilot Knowledge and Skills.

Figure 1 is equally applicable to controllers, as the role and requirements for air traffic controller knowledge and skills, like the pilot, has also not diminished as a result of automated systems and the evolving airspace and procedure design for airspace modernization. Several of the FltDAWG findings and recommendations address pilot skills as well as air traffic and airspace considerations. Successful flight path management is done within the context of the airspace system, so airspace and air traffic integration is an important consideration.

Continued evolution of the airline industry and international/national airspace systems incorporates new technology and procedures. **Changing technology requires us to change the way we train and maintain skills.** One of the human challenges while managing change is maintaining skills that are critical, but seldom used. The operator is challenged by providing the necessary training and opportunities for pilots to develop and practice required skills, while controlling costs.

The FltDAWG report suggests that an operator's initial and recurrent training program cannot be the sole means for pilots to maintain manual flying skills. Training programs must be supplemented by encouraging pilots to manually fly the aircraft during line operations and reinforced through the airlines developing policies and cultures that encourage manual flying while providing appropriate opportunities to exercise manual flying during normal flight operations. The report describes this as "Manual Handling Operations" and makes the following recommendation:

FltDAWG Recommendation 1 – Manual Flight Operations.

Develop and implement standards and guidance for maintaining and improving knowledge and skills for manual flight operations that include the following:

- Pilots must be provided with opportunities to refine this knowledge and practice the skills;
- Training and checking should directly address this topic; and
- Operators' policies for flight path management must support and be consistent with the training and practice in the aircraft type.

As part of achieving the list of items above, the term "manual flying skills" and the associated knowledge and skills should be agreed upon. It involves more than "stick and rudder" skills. It also involves cognitive skills and knowledge on how to handle situations that arise and how to keep the pilot engaged with the flight path management operation and ready to take over manually. It also includes basic airmanship qualities including decision making, situation awareness, and good judgment.

Based on the FltDAWG results, the FAA issued Safety Alert for Operators (SAFO) 13002 on Manual Handling Operations in January 2013. In SAFO 13002, the FAA recognized that manual flying skills should be exercised to maintain pilot proficiency and recommended that carriers adopt an integrated approach by incorporating emphasis of manual flight operations into both line operations and training. This includes incorporating manual flying into initial, upgrade, and recurrent training as well as encouraging pilots to take opportunities to manually fly the aircraft when automated flight is not required by safety considerations, regulations, operations specifications, or company standard operating procedures (SOPs).

EASA also issued Safety Information Bulletin (SIB) 2013-05 on 23 April 2013 on Manual Flight Training and Operations. This SIB similarly encourages operator's to incorporate emphasis of manual flight operations as a means of maintaining basic flying skills into training and line operations.

Similarly, air traffic controllers should have opportunities outside of required annual recurrent training to exercise and maintain proficiency in all required skills for all operations, both manually and using automated systems. Successful flight path management is a joint responsibility of the pilot and air traffic controller, done within the context of the airspace system, and requires all parties to be well trained and ready to handle routine, non-normal, and unexpected events with or without the use of automated systems.

Working on the edge of performance: the implications of automation

by Dr Tamsyn Edwards and Dr Barry Kirwan

"It starts off by just falling behind a bit. So you might just be a few steps behind what you're supposed to be doing and if that builds up too much then you will get to the point where you start to lose the picture"

"You realise you're late on the situation. 'Why am I late on that situation?'"

Dr. Tamsyn Edwards is a Senior Human Factors specialist working for NATS. She is currently undertaking work to determine ways to identify and mitigate the causes of controller fatigue and how to maximise human performance through the design of new systems. Tamsyn is also a trained Human Factors investigator of air traffic control incidents. Prior to joining NATS in 2013, Tamsyn completed a PhD from the University of Nottingham in collaboration with EUROCONTROL, which investigated interactions between multiple, co-occurring factors (such as workload, fatigue, situation awareness) and the associated impact on controller performance.

Within ATC, automation has already had a big effect on air traffic control systems and working practices. And all signs point to the amount of automation increasing – we're all aware of the predicted increases in traffic by 2020, and with the addition of the deployment phase of SESAR initiatives, it seems likely that controllers will be working with progressively more automated systems. However, to take a look on the negative side, automation that has not been designed specifically with impact on the human in mind can drive workload upwards, create fatigue, and negatively affect the controller's mental 'picture' by reducing situational awareness, potentially leading into a myriad of problems and, ultimately, losses of separation.

These external pressures can push controllers to the edge of their performance. Stories shared between air traffic controllers highlight the subjective experience of reaching performance 'limits': *"If you have aircraft that isn't listening and you're busy…it may be the extra thing that sends you over".* The control situation is not comfortable, but performance is still maintained. But what's it like to work on this edge, and what are the indications that a controller is working to their limits? Is it possible to use this information to support the introduction and use of control systems with increased automation? We were fortunate enough to be able to talk with 23 controllers at the Maastricht UAC (MUAC) about their experiences of working at the edge of performance and here are some of their stories. It must be noted that these interviews were conducted a while ago, and the current automation tools in MUAC are greatly improved and seen as an asset by the controllers. Nevertheless, such comments and experiences give us pause for thought in the race to automate.

Getting close to the edge – the use of 'indicators'

Controllers told us of different experiences depending on where they were in the human performance 'envelope'. On a day-to-day basis, performance can be comfortably maintained at an exceptional standard. However, if demand (due to task or external factors) increases, there may be some discomfort, but accompanied by a sense of *"it's just part of the job, it's what you get paid for".* However, if demand increases further, a negative effect on performance may set in. The controller may begin to fall behind the traffic: *"It's something that will build up and you miss one…and then okay maybe you miss another one or two or you're confused as to who called you. Sometimes that happens and it'll go back down again and there's no problem and sometimes it will keep rising and you start to lose the picture."* According to the human performance envelope

theory, this point represents the performance limit, the edge of safe performance, after which there is the danger of a performance precipice, e.g. the controller 'losing the picture', with the heightened risk of a loss of separation, depending on traffic circumstances.

Controllers say that they can identify when they, or their colleagues, are nearing their performance limits through identifying specific 'indicators': *"The indicators occur en route to losing control or moving towards or even crossing the limits [of performance]. So it's not like the limit is here and you see the indicators and then, suddenly, bang, you run over. The indicators are part of it on the way down to losing control."*

Controllers automatically took notice of these indicators *"you don't think about…I just do it like it's a brain process that isn't conscious,"* and monitored their own personal indicators as well as indicators they observed in their colleagues: *"…We work closely together, we monitor each other, whether they're on the ball or whether they're tired, whether they're distracted, it's part of the job and you make allowances."*

But what exactly are these indicators? They can be internal (a feeling) or external (observable). Internal indicators may alert the controller to specific state or negative influence on performance: *"I know that when I start thinking, 'Oh it's going fine' I've learned that I force myself to tighten the bolts and to really pay extra attention".* On the other hand, external indicators are observable in others. They can be:

- **Changes in personal performance:** *"If you are a coordinator controller, you follow what the executive is doing and if it's an easy situation and the obvious solution is not applied straight away, it can trigger a little alarm in your head."*
- **Behavioural and physical changes:** *"You see it coming, you see them getting nervous, you see them talking faster."*
- **Compensation strategies – change of control strategy to maintain performance:** *"When somebody is being extra careful, I suppose that it's because they feel that they need to be extra careful."*

Specific indicators for Specific Factors

Although all controllers were familiar with the use of indicators, for some it was difficult to specify those they used on a daily basis because the process is usually automatic: *"It's in you and you just have to listen" "I think for yourself it's most probably more difficult, you see it much more easily for other people than for yourself."* However, after discussion all controllers were able to identify the indicators they used to recognise when they or a colleague were reaching the edge of performance. Indicators were associated with factors such as low and high workload, fatigue, and reduction in situational awareness (SA), all areas which automation can influence. They included observable indicators seen following changes in control strategy which had occurred as a response to the approach of performance limits. The ones listed below are not meant to constitute an exhaustive inventory, but rather to serve as examples.

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Dr. Barry Kirwan is a Human Factors and Safety specialist working for EUROCONTROL since 2000 and was formerly Head of Human Factors in NATS. He has also worked in the nuclear power, oil and gas, chemical and marine sectors of industry. For the last ten years he has run the EUROCONTROL Safety Culture Programme, but has recently moved back into Safety R&D where he is involved in two large EC-funded projects, OPTICS and Future Sky, evaluating all aviation safety research, and exploring next generation safety culture and safety intelligence across the entire air transport system. He also co-chairs FAA-EUROCONTROL Action Plan 15 on Safety R&D.

Working on the edge of performance: he implications of automation (cont'd)

High workload

"It's almost excited because there is more traffic coming. It's a different situation if someone is already in a complex situation, you realise he is falling behind"

Table 1: Internal indicators of high workload

Category	Indicators
Cognitive changes	Don't know the next steps Increased focus Calls are a surprise
Changes to control	More reactive No back-up plan Future plan reduces in minutes ahead

Table 2: Observable indicators of high workload

Category	Indicators
Perception changes	Can't talk to executive/ executive doesn't hear you
Performance changes	Miss actions Can't see simple solutions Overlook aircraft
Verbal cues	Speaks louder Speaks faster
Compensation strategy: Control strategy changes	Less prioritisation on efficiency and more on safety Back to basics Defensive controlling Continuous talking so as not to be interrupted

Low workload

"In low workload, there's nothing to do so you start doing other things, boredom becomes an issue and then you start talking or having a chat or doing whatever and it's, yeah, you can miss things." One indicator mentioned was leaving a problem to develop for longer or creating complex situations to reduce boredom. If subsequently distracted or suddenly busy, this can create an unfavourable situation.

Table 3: Indicators of low workload internal to the controller

Category	Indicators
Cognitive changes	Pays less attention Easily distracted Reduced awareness
Changes to control	Leaves situations to develop for longer Tries to create more complex situations Less safety margin
Subjective feeling	Bored Relaxed

Table 4: Observed indicators of low workload

Category	Indicators
Visible cues	Sitting back in the chair Talking to colleagues
Performance changes	Overlooking an aircraft Forgetting an aircraft Falling behind traffic due to distraction

Fatigue

"Controllers tend to be more relaxed when they're fatigued, giving clearances without giving a rate of descent, but assuming that the aircraft will descend or the aircraft will pass."

"If I'm tired my concentration levels are low and I might miss a few things, maybe I don't hear the pilots or I don't monitor my own readback."

Table 5: Internal Indicators of fatigue

Category	Indicators
Cognitive changes	Slow Increased assumptions Not as sharp
Changes to control	Less flexible Slower to solve problems Don't see, or take longer to see, a solution
Subjective feeling	More effort to control Don't want to work busy traffic Not comfortable

Table 6: Observed indicators of fatigue

Category	Indicators
Verbal	Slower speech
Teamwork	More discussions with coordinator
Performance changes	Multiple, small mistakes, 'sloppy' Overlooking aircraft, Mixing up call signs Forgetting / surprise
Compensation strategy: Executive Controller (EC) changes control strategy in response to feeling fatigued	Conservative control Simple controlling, easy solutions Increased safety buffer in use
Compensation strategy: Coordinating Controller (CC) changes control strategy in response to noticing EC is fatigued	More proactive – solve issues prior to reaching EC Double-checking of clearances

Situational Awareness

Under high demand, the reduction of SA was reported to be progressive: *"It starts off by just falling behind a bit. So you might just be a few steps behind what you're supposed to be doing and if that builds up too much then you will get to the point where you start to lose the picture."* With low traffic levels, the loss of SA was more rapid: *"We sort of relaxed, 'Oh, it's done now', both of us had forgotten about it [the aircraft]."*

Compensation strategies from the EC attempt to make the situation safe when awareness is degraded. Conversely, compensation strategies by the CC are tactical and appear to facilitate the EC in rebuilding the picture.

Table 7: Internal Indicators of reduced SA

Category	Indicators internal to the controller of losing the picture	Indicators internal to the controller having lost the picture
Cognitive changes	Difficulty prioritising Thinking whilst giving the clearance Tunnel vision/hearing	Lost awareness Everything a surprise No plan Can't see a solution
Changes to control	Reduction of the scope of future planning	Reactive control
Subjective feeling	Under-confidence	Panic

Table 8: Observed indicators of reduced SA

Category	Observable indicators of losing the picture	Observable indicators of having lost the picture
Visible cues	Slow at task	Zig-zagging head movement of where to look 'Blacked out' / silent
Performance changes	Running behind Time of planning ahead degrades Missing calls	Unsafe clearance Unexpected decisions Jumping from one aircraft to another Don't know who's calling

Each of the 23 controllers interviewed described all the indicators in Tables 1-8 as ones they used, so these appear to be representative. Some other indicators were used only by one or two controllers. However, these differences provided a valuable learning opportunity: *"I've got my own indicators, but if everyone else has too, it would be interesting to know what they were".*

Working on the edge of performance:
he implications of automation (cont'd)

The importance of self-awareness of indicators

It was apparent that indicators can play an important role in maintaining safety in air traffic control. They were also a source of feedback about oneself and one's colleagues so that awareness of them is likely to result in modified control strategies: *"…it's that point [of recognising something is wrong] where you have to, well in my opinion you have to change the way that you're controlling the traffic."* However, a key point that was raised was about individual awareness of markers: *"I'd say 300%, if you know that you're not on top form today then that's fine, just adapt your working style and you'll get through the day…if you don't recognise it and you're still trying to work as you usually do, then it might end in tears."*

Automation and performance indicators

But what effect does automation have on these indicators and awareness of them? With the growth of automation, some indicators learned through previous experience may be lost. One example of this was a controller who was occasionally reminded about excessively rapid speech: *"It's getting busy… you start speaking fast and then somebody says "Say again" and then that's it, you have a hint. 'Okay good, I have to slow down because I was not aware that I was speeding up my transmissions because of the amount of traffic'.* You slow down and everything's fine again." However, with the introduction of CPDLC / data link, the relevance of this indicator as a trigger for a change in control strategy could be lost.

New working methods may need new indicators, but these need to evolve and emerge, so there may be a vulnerable period in the early stages of change without any available 'warning signs'. But awareness of this risk helps. By gaining a greater understanding of what indicators may be lost, controllers can be ready to identify and share new ones and new coping strategies. By integrating these activities with the process of introducing automated systems, we can mitigate an issue which has plagued many deployments of automated systems and achieve a more successful implementation of automated systems in ATC.

POST-SCRIPT - around the time of writing this article, an international workshop convened seventy Human Factors professionals from across the entire Air Transport industry at EUROCONTROL in Brussels in order to identify the top Human Factors issues for aviation safety. The top three included Automation and the Human Performance Envelope. More information can be found at: **http://www.optics-project.eu/?p=776**

Automation in the flight deck, blessing or curse?

by Captain Dirk De Winter

One thing is certain, there are definitely new challenges ahead.

Back in the mid 1980s, the arrival of the B737-300 at my airline brought a new level of automation on the flight deck. New functionalities such as Auto Thrust (A/T), a digital version of the autopilot (AP), a flight management computer (FMC) and electronic flight instrument displays (EFIS) significantly reduced pilot workload. This was favoured by many pilots, especially those who had previously been flying the B737-200.

B737-200 Auto Pilot control panel

B737-300 Navigation Display

B737-300 Auto Pilot control panel

No more reading of the thrust setting placards and manually adjusting the thrust setting every couple of thousand feet in the climb. Just dial in the desired speed and the auto thrust system will command the thrust required to maintain it. No more unfolding of en-route charts and calculating an approximate heading when given a direct routing to a navigation aid, which was still out of reception range. Just select the aid in the FMC and through the AP the aircraft is guided to the navigation aid. Searching for a diversion airport? Increase the scale of your Navigation display, select 'airports' on the EFIS control panel "et voila".

Of course, this advance in flight deck technology required a change in skills. The focus on basic flying skills shifted to system operation and monitoring skills. Initial and recurrent training evolved accordingly.

And cooperation with ATC also improved. Even before the pilot monitoring had made the read back of an ATC instruction, the pilot flying had dialled in the required speed, heading or altitude changes on the AP control panel, selected the appropriate AP modes and the aircraft followed them. Or to be more precise, tried to follow them. Unlike today's version of the digital AP, the aircraft still had to obey aerodynamic and inertial laws. When a small speed increase was requested, the A/T system would not command full thrust to achieve the change but used basic ▸▸

Automation in the flight deck, blessing or curse? (cont'd)

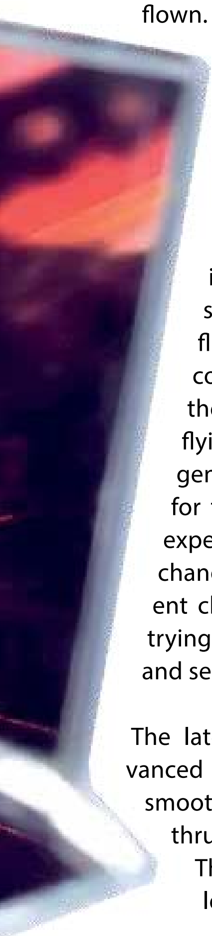
algorithms which ensured that only a gentle increase in thrust followed a requirement for a small speed increase and reduced it gently to the required new thrust setting once the new speed had been reached.

However it was also the case that when a large speed change was requested, the A/T might increase the thrust more quickly and so disturb passenger comfort. Descents could be performed using various modes. The most common mode was a descent in which the A/T commands idle thrust and the AP adjusts the pitch to follow the speed commanded by the pilot or set by the FMC. Any large change in speed then meant a large change in pitch and rate of descent. To soften the level off, pilots would often reduce the speed to reduce the rate of descent or change the AP mode to command a reduced rate of descent, typically 1000 ft/minute. But this meant that the A/T which had previously set idle needed to increase the thrust to that required to maintain the selected speed and this change might not be very smooth.

While monitoring of automation modes is essential, some recent accidents have indicated that when automation capability is degraded or its use in less familiar ways attempted, the pilot has not necessarily appeared to have had sufficient knowledge to achieve the desired flight path.

Whilst such adjustments might occasionally disturb passenger comfort it's a blessing for TMA controllers. The high climb performance of twinjets has often caused nuisance TCAS alerts because the normal altitude capture mode of the AP allows high rates of climb when approaching the selected altitude. This high closure rate can cause a nuisance alert to an aircraft flying 1000ft above. The flight crew can anticipate this and select a reduced climb rate of maximum 1500 ft/minute for the last 1000ft instead of the normal altitude capture mode. This increases the flight crew workload but when well managed avoids nuisance alerts and stabilises the traffic in the TMA.

A350 FMA on the top of the Primary Flight Display



Another surprise generator is the use of the cost index (CI). This parameter represents the ratio between the time and fuel cost for the airline or for the specific flight. When entered in the FMC, it determines the climb, cruise and descent speeds which should be flown. Whilst before aircraft of a particular type could be expected to fly the same speeds for the same flight phase, now there is considerable variation. High fuel cost will result in a low cost index and slower speeds. Changing flight level for the same cost index will also change the cruise speed. So whilst flying optimised cost index generates fuel efficiency for the airlines, slower than expected or unpredictable changes in speeds can present challenges for controllers trying to maintain traffic flow and separation.

The latest APs have more advanced algorithms, which try to smooth out the effects of both thrust and pitch changes. This allows the pilot to select any speed, heading or altitude and AP mode without having to monitor the pitch and thrust. But they still have to monitor the Flight Mode Annunciator (FMA) in order to verify the correct engagement of the A/T and the lateral and vertical AP modes.

While monitoring of automation modes is essential, some recent accidents have indicated that when automation capability is degraded or its use in less familiar ways attempted, the pilot has not necessarily appeared to have had sufficient knowledge to achieve the desired flight path. And the situation has been made worse by failure to adequately monitor the 'basic parameters' of pitch and thrust which would have ensured that the flight path could have been stabilised. That would have left more time for troubleshooting and even recovery of the desired level of automation. In some accidents, full automation was available to the pilots but unfortunately the A/T modes used were not appropriate for the flight phase and this was neither observed nor properly understood by the pilots. Monitoring of the thrust setting would have shown that it was not aligned with the speed requested by the AP and the position of the aircraft.

Proficiency requirements for licensed professional pilots in Europe currently include an annual demonstration of manual flying skills and a demonstration of manual flying without the A/T at 3 yearly intervals. Modern flight operations make extensive use of automation and rarely require or even allow extended manual flying especially with manual thrust setting. To counteract any degradation in manual flying skills, many airlines include additional manual flying in their recurrent training.

This should be promoted, as improved manual flying skills will improve the knowledge of the basic pitch and thrust settings. It will also encourage cross checking of basic pitch and thrust settings as part of normal monitoring of the flight instruments and the FMA. In the rare case of a complete loss of automation, this will enable the stabilisation of the flight path and buy time to diagnose what has gone wrong and recover.

Captain Dirk de Winter

has over 11,000 hours flying time gained over the last 22 years. He started as a cadet pilot with SABENA in 1987 flying Boeing and Airbus aircraft. Before starting his flying career Dirk obtained a Masters degree in Electronic Engineering from the University of Brussels. Since January 2009 Dirk has been working part-time at EUROCONTROL.

To follow or not follow...

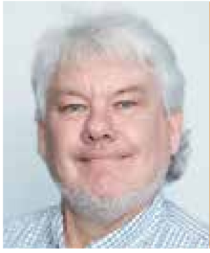
is that really a question?

on TCAS operations during emergency descents

by Stan Drozdowski and Harry Hutchinson

You are cruising at FL370. And then the pressurisation fails or a large crack appears in the windshield. You want to get lower as soon as possible in case a decompression occurs. Before the crack appeared, TCAS II had been in the TA/RA-mode. Now should you switch it to TA-ONLY-mode to supress any RA while descending? Operational practices vary between operators and aircraft types and pilots must always observe the applicable procedure. While it is quite difficult to provide the definitive answer, in this article we will look into various scenarios and analyse a number of examples. We hope it will be food for thought and perhaps trigger discussions on the subject!

Stanislaw Drozdowski is an ATM Expert at EUROCONTROL HQ in Brussels, working in the area of ground and airborne safety nets. Previously, he worked as a system engineer with Northrop Grumman and as an Air Traffic Controller in Poland and New Zealand.



Harry Hutchinson is an ACAS expert at QinetiQ in Great Malvern, UK. Harry trained as a physicist at the University of Bristol and moved to RSRE (the predecessor to QinetiQ) to work on semiconductor physics, before moving into the field of ATM research.

There is no automation in place to switch between TCAS operating modes – this action will always require the pilot's manual input. However, on an everyday basis, most pilots will change from STAND-BY to TA/RA before a flight and back again afterward. Below we outline a scenario which may have severe safety consequences if no action is taken (i.e. changing the TCAS mode) and for which there is no automation available to support the crew[45].

TCAS MODES OF OPERATION

Most TCAS II installations will have the following modes of operation available: STAND-BY, TA-ONLY, and TA/RA.

When STAND-BY mode is selected, the TCAS equipment does not transmit interrogations. Normally, this mode is used when the aircraft is on the ground or when there is a system malfunction.

In TA-ONLY mode, the TCAS equipment performs the surveillance function. However, only TAs will be generated and RAs are suppressed. A TA-ONLY aircraft will be 'seen' by other TCAS II aircraft as if it has no TCAS fitted. Thus, an aircraft operating in the TA-only mode is denied the full benefit of collision avoidance capability if another aircraft comes into conflict – it will be a passive target and resolving the conflict will be left to the other aircraft.

Circumstances in which TCAS II should be operated in the TA-ONLY mode may be detailed in the pilot's Operations Manual and are usually limited to specific in-flight failures and operational conditions.

The full TCAS II functionality provided by the TA/RA-mode will be what is almost always selected when airborne. However, this selection indicates to other TCAS II-equipped aircraft that the crew is likely to follow any RA generated. Not to do so would not only deny one's own aircraft the safety benefit provided by the RA, but would also compromise the effectiveness of a coordinated RA generated in conjunction with the other aircraft. In other words, if it is intended that any RA will not be followed due to a particular circumstance or procedure, then TCAS should be set immediately to TA-ONLY mode.

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45- Some aircraft types may have built-in system protections that will inhibit Climb RAs if an engine fails.

TCAS (ACAS) II – an aircraft system based on Secondary Surveillance Radar (SSR) transponder signals. TCAS II interrogates the Mode C and Mode S transponders of nearby aircraft ('intruders') and from the replies tracks their altitude, range, and bearing, and issues alerts to the pilots, as appropriate.

TRAFFIC ADVISORY (TA) – An indication given to the flight crew that a certain intruder is a potential threat.

RESOLUTION ADVISORY (RA) – An indication given to the flight crew recommending: a manoeuvre intended to provide separation from all threats; or a manoeuvre restriction intended to maintain existing separation. RAs are coordinated between equipped aircraft.

To follow or not follow – is that really a question?
on TCAS operations during emergency descents (cont'd)

TA-ONLY-MODE vs. TA/RA-MODE

As recommended by ICAO ACAS Manual (Doc. 9863), TCAS II should be operated in the TA-ONLY mode "in the event of particular in-flight failures or performance limiting conditions". In these circumstances the pilot's ability or willingness to respond to an RA will be limited, either due to impaired aircraft performance or a concern that a response to an RA may aggravate the original problem (e.g. stall while responding to an RA, due to insufficient power to perform a Climb RA, or prolonging the time period when the aircraft stays at higher altitudes following a decompression).

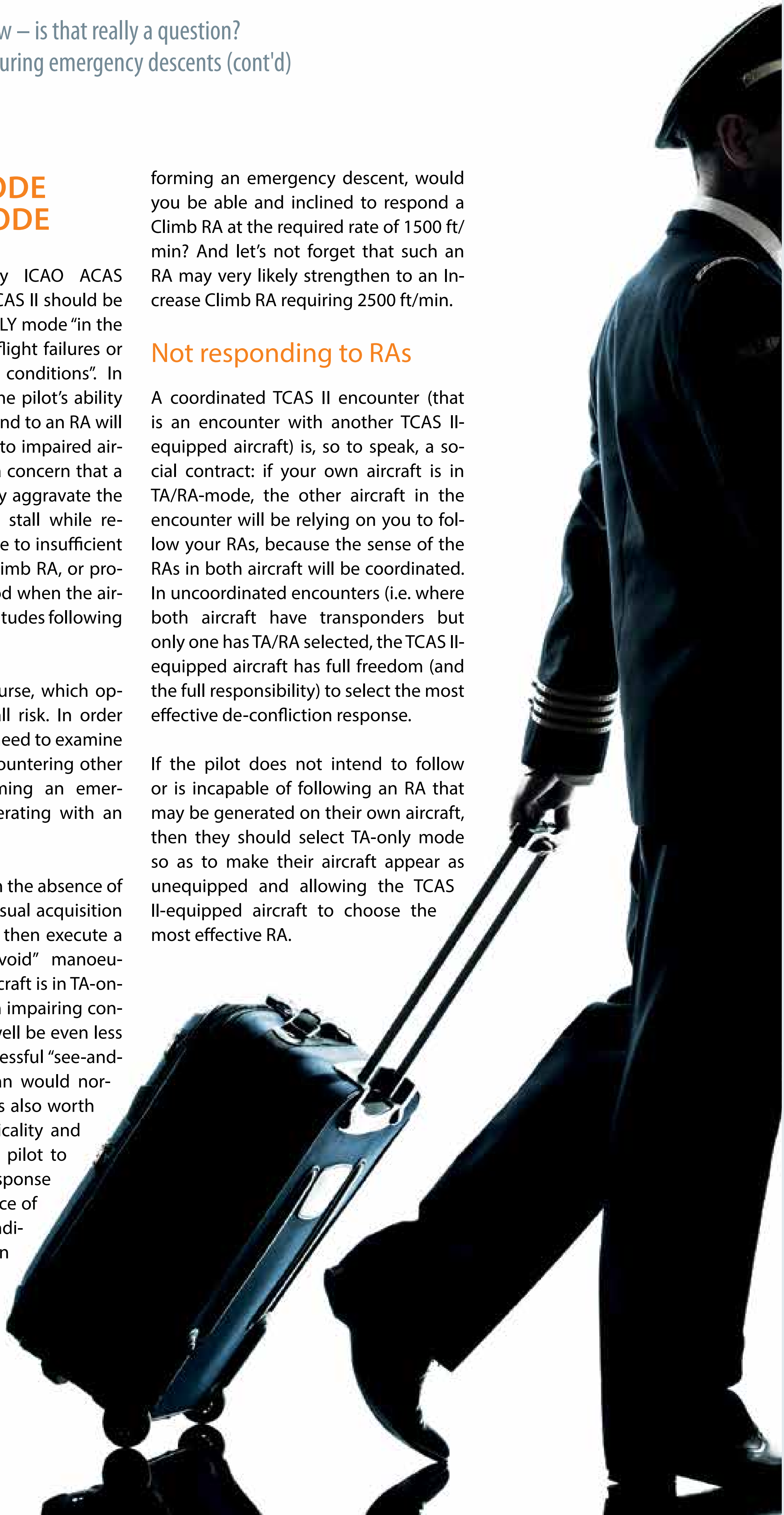
The question is, of course, which option offers least overall risk. In order to give an answer we need to examine the probability of encountering other aircraft while performing an emergency descent or operating with an engine out.

Some will argue that in the absence of an RA, a TA may aid visual acquisition and that the pilot can then execute a successful "see-and-avoid" manoeuvre. However, if the aircraft is in TA-only mode because of an impairing condition, the pilot may well be even less able to execute a successful "see-and-avoid" manoeuvre than would normally be the case. It is also worth considering the practicality and the willingness of the pilot to achieve a correct response to an RA in the presence of such an impairing condition. If you are flying on one engine or performing an emergency descent, would you be able and inclined to respond a Climb RA at the required rate of 1500 ft/min? And let's not forget that such an RA may very likely strengthen to an Increase Climb RA requiring 2500 ft/min.

Not responding to RAs

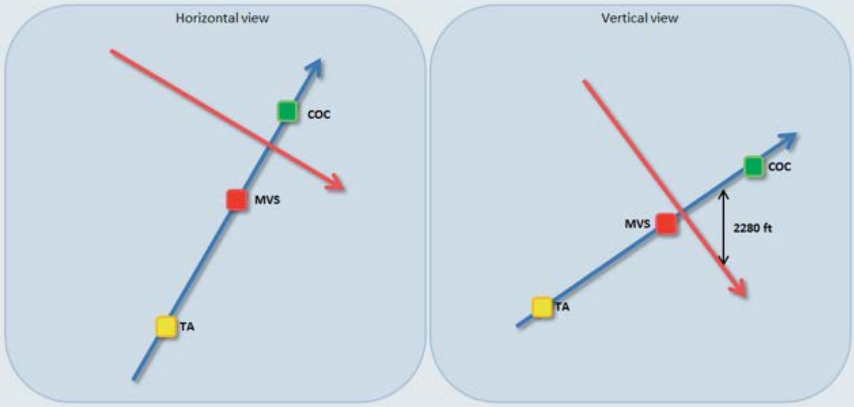
A coordinated TCAS II encounter (that is an encounter with another TCAS II-equipped aircraft) is, so to speak, a social contract: if your own aircraft is in TA/RA-mode, the other aircraft in the encounter will be relying on you to follow your RAs, because the sense of the RAs in both aircraft will be coordinated. In uncoordinated encounters (i.e. where both aircraft have transponders but only one has TA/RA selected, the TCAS II-equipped aircraft has full freedom (and the full responsibility) to select the most effective de-confliction response.

If the pilot does not intend to follow or is incapable of following an RA that may be generated on their own aircraft, then they should select TA-only mode so as to make their aircraft appear as unequipped and allowing the TCAS II-equipped aircraft to choose the most effective RA.



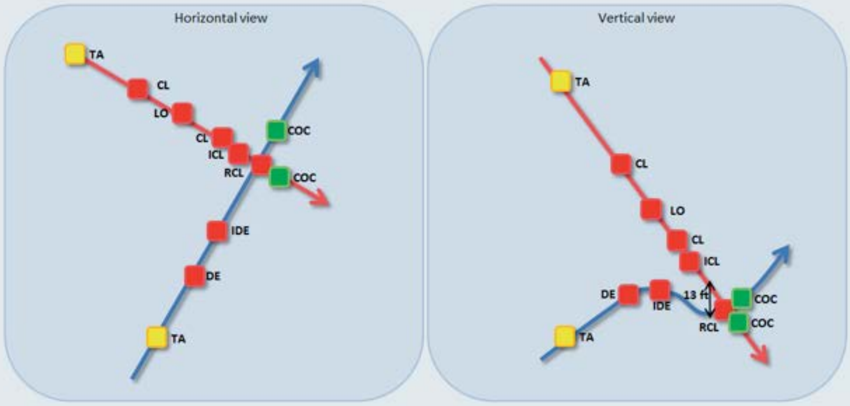
EXAMPLES

We will now look at the emergency descent case in two scenarios. At the beginning of our event, the Red aircraft is making an emergency descent through FL200 at 6000 ft/min. The Blue aircraft is climbing through FL140 at 3000 ft/min. The predicted horizontal miss distance is 0.1 NM.



SCENARIO 1

In **SCENARIO 1** the Red aircraft is in TA-only mode while carrying out its emergency descent. Blue receives a Traffic Advisory (TA), followed by a preventive Monitor Vertical Speed (MVS) RA[46] and at the Closest Point of Approach (CPA) is already 2280 feet above Red. A Clear of Conflict (COC) message is posted soon afterwards.



SCENARIO 2

In **SCENARIO 2** the Red aircraft is in TA/RA mode carrying out its emergency descent. It receives a TA and then a Climb (CL) RA, to which it does not respond and subsequently also ignores a Level Off (LO) and subsequently Climb (CL) and Increase Climb (ICL) RAs. The Blue aircraft gets a Descend (DE) RA, to which it responds. This strengthens to an Increase Descent (IDE). Just after the CPA, the RA for the Blue aircraft reverses to a Climb RA (RCL) before a Clear of Conflict (COC) is announced. Although the Blue aircraft is following its RAs as required – and in reality such RA sequences are a challenge to fly and rarely performed 'by the book' – at the CPA the vertical miss distance is only, 13 feet. To put this number in perspective, the height of a Boeing 737-800 is 42 feet.

Although, it is not applicable in the scenario described above, swapping the Mode S addresses[47] in lots of similar geometries may produce totally different outcomes.

46- Monitor Vertical Speed does not require any manoeuvre; it just requires 'no change' in the current vertical speed.
47- In coordinated encounters only the aircraft with the higher Mode S address is permitted to declare a reversal.

Conclusion

The Scenario above has been intentionally constructed to show why remaining in full TA/RA-mode during in an emergency descent might increase any risk of collision. Of course, an almost unlimited number of scenarios of this type can be invented which will cover a wide range of horizontal and vertical geometries. Types of RAs and their timing will be different, but many other cases are also likely to produce challenging RA sequences.

The risk of receiving an RA and not following it cannot be overstated. It puts both aircraft at increased risk and is likely to generate difficult-to-follow RA sequences on the other aircraft. It is fully recognised that the risk of collision is only one of many factors that needs to be considered while developing operational procedures for emergency descents but, undoubtedly, it is an important factor. S

Will we ever automate the tasks of the ATCO?

by Job Brüggen

Let's face it, everyone believes that future automation will take over the role of the Air Traffic Controller sooner or later...

Elevators were the first means of transportation to lose the driver/operator. Nowadays, we send spacecraft around the universe, we step into metros and trains in Paris or Toulouse that do not have a driver in the front anymore. Aircraft are flying across the globe on autopilot 99% of the time. The world's best chess player is a computer program. Robots will take over home care duties and many more tasks. Ha ha! Surely we must be able to automate the tasks of the ATCO! The ATCO is talking half-duplex to aircraft over a VHF line. If someone is transmitting, everyone else has to shut up or a message is lost. How silly is that in the modern world? Have we all been fast asleep for the last 50 years?

Do you remember the research efforts at the EUROCONTROL Brétigny centre with a project called 'ARC2000' (sending automated clearances to aircraft without a controller)? The PHARE Demonstrations (automated 4D trajectory negotiation over datalink)? Free flight self-separation trials? It would be only a matter of time. The future was coming and it was coming rapidly (I am talking 90's stuff here). In March this year, I read about an A320 that had undertaken the second "initial 4D" (i4D) trajectory flight trial as part of a SESAR project. Come on, we did that twenty years ago. What has taken us so long?

At the lowest level, we automate things that need processing, transformation or other treatment. Flight plans, radar tracks, label assignment, presentation screens, input methods, weather updates, information status pages, and so on. Basically it is all information (pre-) processing and assists all the mental gymnastics the controller still has to perform. Tasks are performed faster, more reliable, cheaper. A big help.

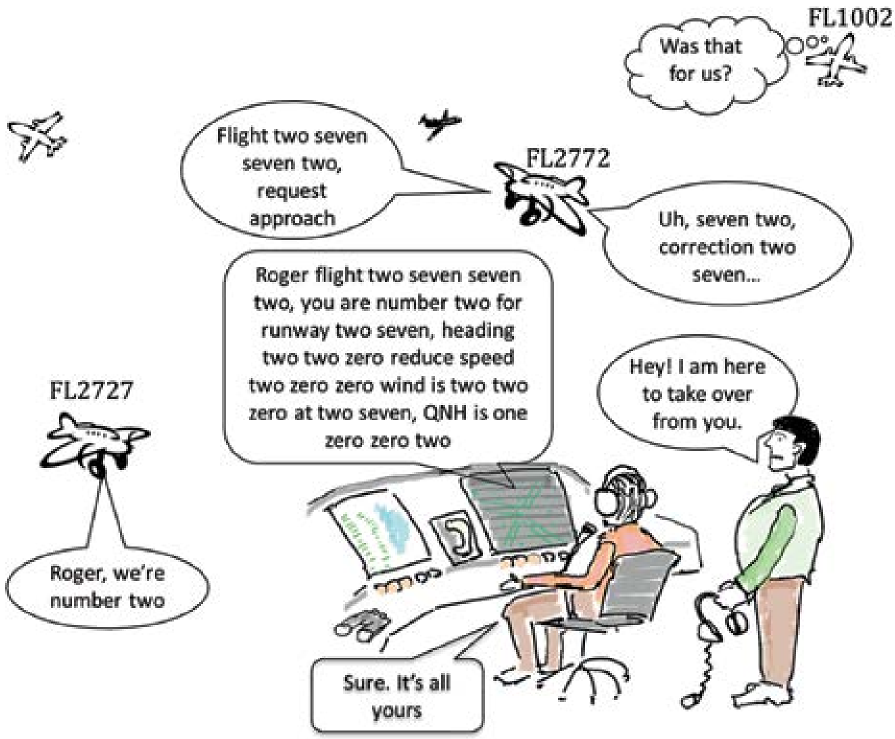
At the intermediate level, we can see algorithms that begin to assist the controller in exactly that mental process. Predictions, arrival management tools, conflict alerts, flow management tools: also known as decision support tools. They provide advice to the controller, who then can decide what to do with them. Again a great help to humans who are notoriously

> The human sustains the all-important safety level by responding skilfully to changing circumstances by relying on good coping strategies. They provide the resilience that machines simply do not currently deliver.

bad monitors. A machine continuously checking the separation between aircraft (which is, after all, our core business) can provide tremendous value.

Still, humans are the centrepiece of the intellectual part of the job. Sure enough, we have 'cornered' the controller with enough automation to take the final leap. How difficult can it be to take over that part as well? The rules and procedures are clear and relatively simple. The manoeuvring space is big. The number of instructions that can be issued to an aircraft is very limited. Phraseology is standardised. A machine separating the aircraft will not get tired – or bored – when working night shifts. There is no union of machines to ask for a pay rise. So at the final level of automation, could machines take over the task of the controller? Take the decisions as well as execute them?

Job Brüggen is the safety manager of ATC The Netherlands (LVNL) and is particularly known for his activities in Just Culture developments. He was one of the first to demonstrate the detrimental effect of prosecution of air traffic controllers on incident reporting. In 2003 he re-created the CANSO Safety Standing Committee and chaired it for six years. He is currently leading the effort for the FAB Europe Central safety management activities. He also advises in the health care industry on safety matters with a particular focus on Just Culture and safety leadership.



Air - ground datalink could free us from elementary errors. How long have we been waiting?

In 2001 there was an inspiring presentation by Heinz Erzberger from NASA called 'The Automated Airspace Concept'. He had developed the CTAS platform (Center Tracon Automation System) at NASA, and having thus proved that generating conflict free aircraft trajectories is quite achievable, he cleverly began with the question 'okay, but what if the automated system fails?' He defined a backup system (called TSAFE) that would independently monitor the automated clearances and the aircraft trajectories that would follow and would be able to send out alerts directly to the pilot. That backup system would also monitor the separation between manually-handled aircraft that would still not have the advanced systems on board – so yeah, still a controller around.

It would be an engineer's dream. Controllers would be system managers doing the really tough intellectual part, machines would ensure smooth flow and deal with the hassle of communicating clearances to aircraft. This is where a win-win situation would be created – significantly more capacity in the airspace and more safety! How's that for a paradigm shift? Nothing short of a revolution!

Alas, the matter proved to be more difficult. We can automate tasks that are highly deterministic; when you do this, then precisely that will happen. Flying an airplane for example. But controlling a bunch of aircraft, as simple as it may seem, is of much more dynamically unpredictable nature. The Paper accompanying the presentation I mentioned above cautioned against setting one's hopes too high by "…. the boundary between the set of solvable and unsolvable problems is unknowable. While the envelope of problems controllers can solve is also limited, it is much larger than the CTAS solvable set. Moreover, human controllers excel at adapting their control strategies to completely new situations, a capability that is beyond existing software design." It was 2001, so we could say this is a 'blast from the past', but I sense we have not really solved this puzzle yet.

So we are back at the human in the loop. The human excels in adapting control strategies to unexpected situations. Clearly that is their best asset in this game and it remains undisputed so far. The human sustains the all-important safety level by responding skilfully to changing circumstances by relying on good coping strategies. They provide the resilience that machines simply do not currently deliver. Is that, then, the main barrier to further automation? Please allow me to point out a conceptual flaw I see lying at the heart of the ATC industry. States are responsible for ensuring that air traffic service in their airspace is provided. And historically, states do not enjoy a great reputation for successful innovation. Sure, the European SESAR programme is burning money, but sovereignty of airspace remains a fundamental obstacle to further innovation. Moreover, the fact that many air navigation service providers currently enjoy a monopoly is a further disincentive to innovation.

We can, though, see signs of SESAR programme elements that are taking cautious steps to further automate the intellectual gymnastics of the controller. If you take the current 100-page European ATM Master plan, you will count 13 hits on the word 'automation', mostly associated with 'Conflict management and automation'. A shining star? Equally, the plan describes a significant change in the way the ATCO of the future will control traffic. Exactly what that role will be is not yet revealed and maybe this is for the better. - it will be part of an evolution rather than a revolution. It's amusing in a way how aerospace can be innovative on one side and so utterly conservative at the same time.

Quite recently, I read an article that claimed that office workers (so people like myself, ahem) were more likely to get automated out of the way than frontline personnel. That is of course ridiculous, unthinkable and will never happen…! S

Automation exceptions and flight path management

by Roger Cox

Discussions about automation over-reliance often focus on what happens when an automatic feature fails. In the Asiana 214 accident in San Francisco last year, the automation worked exactly as designed but the crew misunderstood it and failed to take over manually in time to prevent the accident. I was the NTSB's operational factors investigator in the investigation of the Asiana 214 accident in San Francisco last year, and I am writing this short article to discuss the crew's misunderstandings and mindset in managing the automation.

The flight was high on a visual approach to runway 28L and the pilot flying (PF) put the airplane into an idle power descent on final approach. The thrust levers remained in idle for one minute ten seconds as the airplane descended from 1,500 ft. to 86 ft. and as the airspeed dropped from 169 knots to 109 knots. Coincidentally, the flight passed through the 500 foot stabilised approach window very close to on speed and on path, but it was descending too fast and the crew made no adjustments. The pilot monitoring (PM) finally advanced the throttles to attempt a go-around, but he was too late. The airplane struck the seawall, bounced and pirouetted down the runway, and caught fire shortly after it stopped.

The three pilots in the cockpit were shaken up but survived. Shortly after the accident they each told investigators they believed the autothrottle should have engaged automatically and maintained the selected approach speed. None of the pilots could remember where the thrust levers were positioned or what the engine power settings were during the last minutes of the approach as they sank lower and lower below the proper approach path. They made an incorrect assumption about how the autothrottle worked and they didn't have a plan for what to do if their assumption was wrong.

The Boeing 777, which was the type involved in the accident, has a full time autothrottle (A/T). It is designed to be used either paired with the autopilot or when the airplane is being flown manually by the pilot. The A/T has an automatic engagement feature commonly referred to as "A/T wakeup." The feature will engage the A/T automatically if the airspeed is detected to be below a minimum threshold for one second. According to Boeing, at flaps 30, the minimum threshold is 8 knots below Vref. If it had engaged on the accident flight it would have returned the airspeed to 137, the selected approach speed. However, the feature does not function in all circumstances. There is an automation exception.

When the autothrottle is in a mode known as "hold," its servos are disengaged and engine thrust is controlled by where the pilot positions the throttles. Boeing created this exception to the full time autothrottle to give the pilot added control and flexibility. In older models when the pilot wanted to make a temporary adjustment to engine thrust he had to disengage the autothrottle. With the advent of hold mode, the autothrottle senses when the pilot adjusts the throttles and relinquishes

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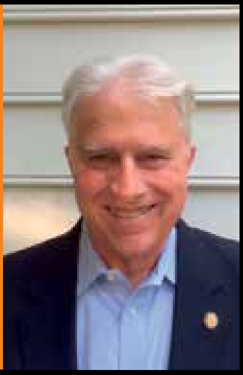

control; it notifies the pilot it is doing so by announcing HOLD in green on a coloured electronic display[49] located in front of each pilot. Unfortunately, when the PF put the airplane in hold mode, he didn't see the annunciation and didn't realise he was telling the autothrottle to relinquish control. Even though he had completed most of his training on the 777 he didn't understand the built-in automation exception.

The PF wasn't alone in his misunderstanding. Many of the 777 pilots investigators spoke with did not realise the autothrottle could effectively become dormant. There were several reasons for this. First, the Boeing flight crew operations manual (FCOM) was less than clear about the exception. Second, the presentation slides used in training did not mention the exception. Finally, the simulator training demonstrating the wakeup feature did not show how the exception could prevent wakeup from taking place. Ironically, one company instructor who had experienced the exception during approaches several times himself taught his students, including the accident PF, about it, but his message was never incorporated in company manuals or passed back to Boeing for clarification.

Given that the three pilots in the cockpit did not understand the automation exception, what is hard to understand is why none of them took timely action to prevent the accident. The day was sunny and clear, the runway was in full view, and there were multiple cues, including a PAPI[50] and a VDI[51] in the cockpit to show them they were getting low and slow. From the time the airspeed first dropped below the selected approach speed of 137 knots until the throttles were advanced, 28 seconds elapsed. It would seem there was ample time to act. Had the crew simply intervened at 500 feet and pushed the thrust up to the normal setting for an approach they would have landed safely.

An examination of the company's policies and actual practices with regard to use of automation showed they wanted pilots to use the highest level of automation available. The company 777 chief pilot confirmed this, saying the airline recommended using as much automation as possible. Pilots were expected to turn the A/P and A/T on as soon as possible on departure and leave it on until at or near the completion of the flight. The accident pilots had good records and clearly had complied with the company's policy throughout their careers. They trusted the automation and relied on it, as they were taught.

In a study[52] published in 2013, the PARC/CAST Flight Deck Automation Working Group found that although automated systems had contributed significantly to safety for many years, pilots sometimes relied too much on automated systems and might be reluctant to intervene. The first point made under the report's recommendation 9 was "the policy should highlight and stress that the responsibility for flight path management remains with the pilots at all times. Focus the policy on flight path management, rather than automated systems."

In order for pilots to be able to focus on flight path management, they need the flexibility to move between different levels of automation, from fully engaged to semi-automatic to manual flight. Excessively rigid automation policies inhibit that flexibility. The FAA recognised this in 2013 when it issued SAFO 13002, "Manual Flight Operations" and when it revised air carrier rules to increase manually flown manoeuvres in training.

The accident crew encountered an automation exception they did not understand. Regardless of why the autothrottle stopped functioning, the crew's first priority should have been correcting the flight path and energy state. In its accident report, the NTSB made 16 findings and 13 recommendations related to operations and human performance. One of those recommendations, A-14-55, made to the airline, says "modify your automation policy to provide for manual flight, both in training and line operations, to improve pilot proficiency." Implicit in this recommendation is the need for pilots to better recognise when the automation is not working as they expect and to have a plan for taking over and using semi-automatic or manual methods to control the flight path and energy state of the airplane when necessary.

49- The display is called flight management annunciator , or FMA.
50- Precision approach path indicator
51- Vertical deviation indicator
52- 'Operational use of Flight Path Management systems," Final Report of the Performance-based operations Aviation Rulemaking Committee/ Commercial Aviation Safety Team Flight Deck Automation Working Group, September 5, 2013

Switching off automation: we know why, but not when

by Captain Wolfgang Starke

Just as is the case for Air Traffic Controllers, pilots need a very unique set of skills, competencies, abilities and personality traits as a prerequisite...

Some of these can be trained but others will simply have to be developed over the years. What is clear is that pilot training is not a one-off exercise but rather a continuous effort to train skills and develop competencies so as to remain proficient throughout an entire career. All this is possible thanks to and – at the same time – despite increasing automation and the proliferation of technology. Many pilots feel the very tangible threat to the erosion of basic flying skills, pressure to strike the right balance between automated and manual flying and the multiple challenges of on-the-job training.

Despite sophisticated technology, the laws of physics have remained the same and the good "old-fashioned" stick-and-rudder was not only crucial in the past but remains essential. This is why, as is widely known, pilots do need to do some of their training on the job. Some airlines mandate regular manual flying without the assistance of supporting aircraft systems whereas others do not. This necessary requirement can turn out in practice to be a real challenge. We seem to know why to switch off the automation but finding the right moment to do so seems to be a much more difficult task. Due to our busy and sometimes tiring rosters or jet lag on long haul crews may be less and less willing to risk going "back to basics".

It was the first day after a roughly three weeks' vacation. On my first day back to work the alarm went off at 4am. The duty scheduled was a set of five domestic and European flights with a domestic deadhead flight afterwards, a total duty time of 12:30 hours in the company of a First Officer with low experience.

We decided to use as much automation as we could to reduce workload on this long and exhausting day. The clearly-communicated objective was to "keep it simple, keep it standard". It all went well and eventually we ended up in a hotel at Stuttgart Airport tired but content with a job well done.

With the benefit of hindsight, our decision to use automation that day was correct. But it only feels correct until you stumble upon a phrase in your manual that tells you to regularly disengage automation for training purposes. This on-the-job training should only be done when workload, weather, traffic density and other factors which may affect the safety of flight, are suitable. But now we can ask ourselves, how often does this happen? When is the right moment to do so?

Any airline which wants to survive needs to be efficient. It is self-evident that crews and aircraft must be scheduled in view of efficiency and return on investment. This results in rosters in which the above-mentioned long day is not an exception but rather the norm. Sometimes, such long days are made more complicated by technical issues which do not directly affect flight safety as well. Such issues can be for example an inoperative auxiliary power unit so that air conditioning on the ground does not work.

If we now decide to train, or not to train our manual flying skills, one major factor during decision making is fatigue. When tired, we are all inclined to reduce workload as much as possible. Looking at our work around Europe, we see that the weather, a factor for flight safety, is sometimes good, sometimes not. Sometimes we fly to and from major hubs, sometimes remote airports. It can be a challenge to find a flight where traffic density is low and weather is good.

This all affects fatigue and alertness levels and ultimately has an impact on our capacity to deal with the tasks we have to perform.

Of course, there are other factors affecting fatigue, not just the operational ones that have been mentioned. High temperatures during summer time, poor sleep, issues brought from home, uncomfortable clothing or out-of-favour colleagues, or physical work / exercise can all make a difference.

Therefore, occasions where on-the-job training can safely be done can quickly become very rare. And sometimes, crews must say "no".

Recently, I was scheduled on a line training flight with a newly employed First Officer. The duty started with a domestic flight of roughly 50 minutes and back to my home base. After the first flight we were scheduled to change aircraft and on the second one, the autopilot was inoperative.

Hand flying is excellent training, so why not accept this aircraft? Well, it is a training flight where supervision of the new colleague means extra workload. The impossibility of workload relief due to the unserviceable autopilot imposes even more workload. This can easily exceed the capacity available of the crew. Eventually I agreed to fly as the First Officer involved had relevant previous experience. Weather and traffic density were also acceptable.

On another occasion – few years ago – I was expected to fly without an autopilot and without a flight director into the London TMA at a peak time accompanied by an inexperienced colleague. Even though the weather was relatively good, I refused this opportunity for training because I considered that the traffic density in the London TMA was simply too high.

All this shows that there are occasions where on-the-job training can and should be done. But these occasions, depending on the operation you are flying, can sometimes occur infrequently.

Worthwhile on-the-job training needs proper planning from the airline but to the same extent it needs appropriate pre-planning of private, off-duty time by the crews. Attention and alertness can be managed and should be managed on both sides in order to allow training to be performed safely.

No doubt, on-the-job training is needed in times where automation takes a bigger and bigger part in modern aviation. Automation and technology clearly set new requirements for training. Eroding basic flying skills is a reality today among the pilot community and the looming threat of over-reliance on automation systems is already manifesting itself. This is why ECA, the European Cockpit Association, has identified pilot training and airmanship as a key priority for the coming years.

Coming back to the best practice of on-the-job training, the question is if we can safely do this training without compromising safety. In theory, the answer is "Yes. Let's switch off the automation." But looking into the potential challenges – and this may sound familiar to all operational staff -the answer is rather: "Yes. But when?" And the ultimate answer is that each time a training opportunity is sought, it is up to us – pilots and controllers – to take a responsible decision on whether it is feasible taking the operational reality into account.

Captain Wolfgang Starke is a Bombardier Dash 8-Q400 line training Captain with the Air Berlin Group. He chairs the Air Traffic Management and Aerodromes Working Group of European Cockpit Association (ECA) and serves on committees for the Vereinigung Cockpit (German Air Line Pilots' Association) and for IFALPA. He is an IFALPA representative member ICAO's Airborne Surveillance Task Force (ASTAF).

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An article taken from **SKYbrary** is reprinted in each **HINDSIGHT**. For this issue, we have chosen **"Automation Dependency"**

Description

Automation Dependency has commonly been described as a situation in which pilots who routinely fly aircraft with automated systems are only fully confident in their ability to control the trajectory of their aircraft when using the full functionality of such systems. Such a lack of confidence usually stems from a combination of inadequate knowledge of the automated systems themselves unless all are employed and a lack of manual flying and aircraft management competence.

The Safety Issues

Two problems arise directly from automation dependency. Firstly, affected pilots are reluctant to voluntarily reduce the extent to which they use full automation capability to deal with any situation - routine or abnormal – which arises. Secondly, if the full automation capability is for some reason no longer available or it is considered that it is no longer capable of delivering the required aircraft control, then the tendency is to seek to partially retain the use of automated systems rather than revert to wholly manual aircraft trajectory control. The effect of both is often a loss of situational awareness triggered by task saturation for both pilots. The consequence of this is frequently a reduction in the extent to which the PM is able to effectively monitor the actions of the PF.

Solutions

- Standard Operating Procedures (SOPs) are understandably oriented towards maximum use of automation in the interests of efficiency as well as safety. However, they must be flexible enough to allow pilots to elect to fly without automation or with partial automation in order to maintain their competence between recurrent simulator training sessions. This is particularly important if AOC holders with ATQP Approval are permitted to extend the normal six month interval between such sessions. OFDM programmes which capture close to 100% of flights can be used to track the extent to which full automation is used. SOPs should also make it clear when it is expected that pilots' response will include reducing the level of automation beyond any un-commanded reduction which may have already occurred.

- Pilot Training must:
  - ensure that a sufficient understanding of both the basis for automated system functionality and its partial as well as full use is fully understood.
  - ensure that pilots are able to understand the importance of monitoring the expected function of automation so that in the event their incorrect inputs or malfunction have unexpected consequences, timely corrective action can be taken
- The Autothrottle (A/T) must be seen as part of the overall automation system. Pilots must be able to competently fly the aircraft with or without it engaged just as they would be expected to be able to fly the aircraft with or without the Autopilot (AP).

Related Articles

- Loss of Control

Further Reading

- Optimum Use of Automation, Airbus Flight Operations Briefing Note (2006)
- Crew Reliance on Automation, UK CAA Paper (2004)

Video

Capt. Warren VanderBurgh of American Airlines' Flight Academy presentation titled: "Children of the magenta line", 1997

Accident and Serious Incident Examples

Automation Confusion: The following are just a few examples of confusion arising from mismanagement of automation which had serious or potentially serious consequences for a serviceable aeroplane:

- **B777-200 San Francisco (2013)** - The crew failed to notice that mismanagement of the aircraft during an approach, using an unfamiliar level of automation in preference to the visual approach for which they had been cleared, had resulted in the A/T setting thrust to idle. They then delayed a decision to initiate a go around until it was no longer possible.
- **A340-300 Paris CDG (2012)** - Crew confusion and near loss of control when the automatics were allowed to capture an a false ILS GS lobe during a Cat 3 approach at Paris CDG in IMC.
- **A320 Tel Aviv (2012)** - The crew comprehensively mismanaged the automation both during the approach and during the go around which, subsequently, became necessary. The Investigation identified significant issues with the crew understanding of automation.
- **B737-800 Amsterdam (2009)** - The crew failed to notice that they were attempting to fly the approach with thrust at idle and their attempt at a last minute recovery was mismanaged.

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In the next issue of HindSight: **Workload**

EUROCONTROL

Putting Safety First in Air Traffic Management

This publication has been prepared under the auspices of Safety Improvement Sub-Group (SISG) of EUROCONTROL. The Editor in Chief acknowledges the assistance given by many sources in its preparation.