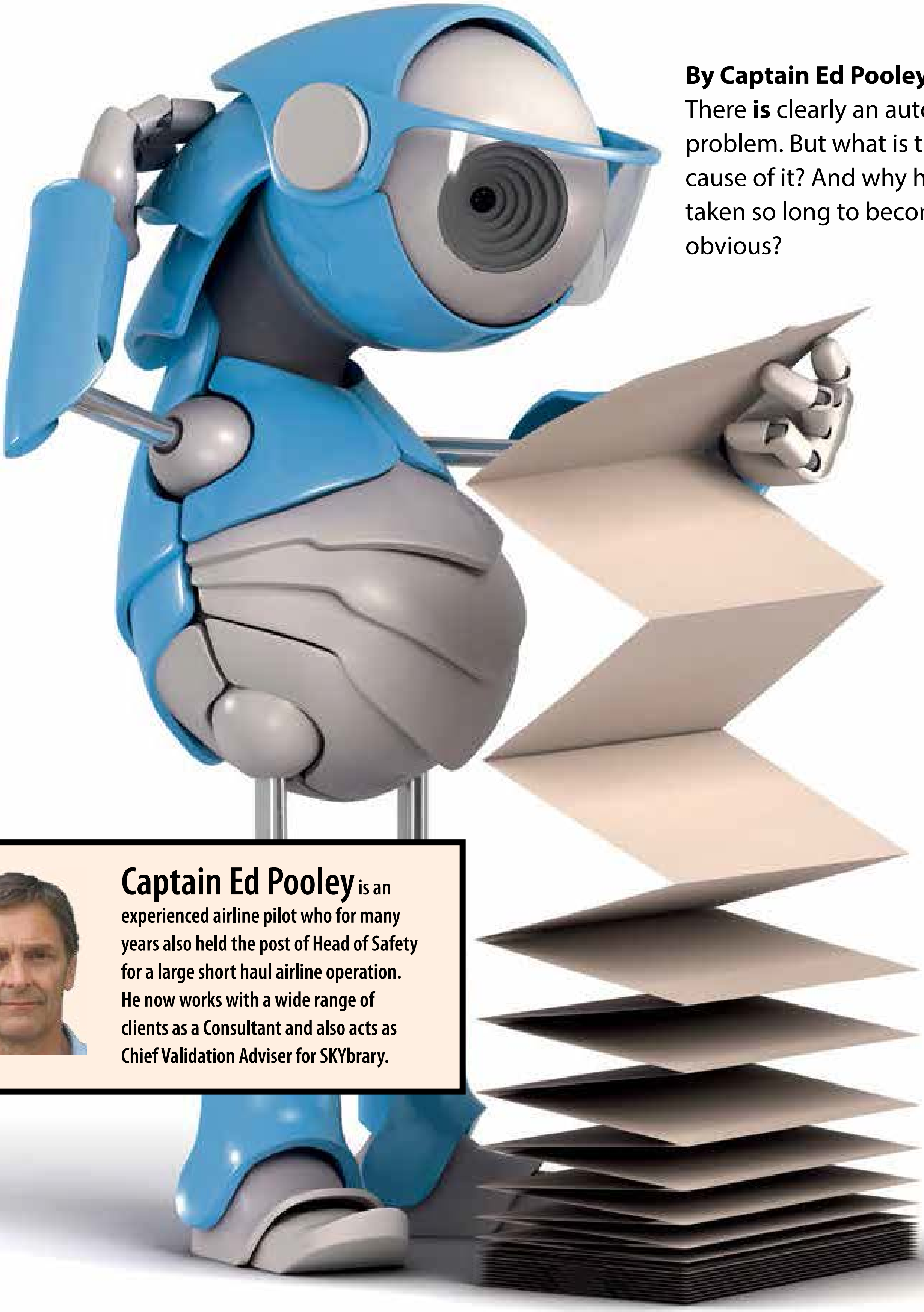
The 'automation problem'

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?



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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.

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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)

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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) .