

## Shall we cut off the lizard's tail?

by Tzvetomir Blajev

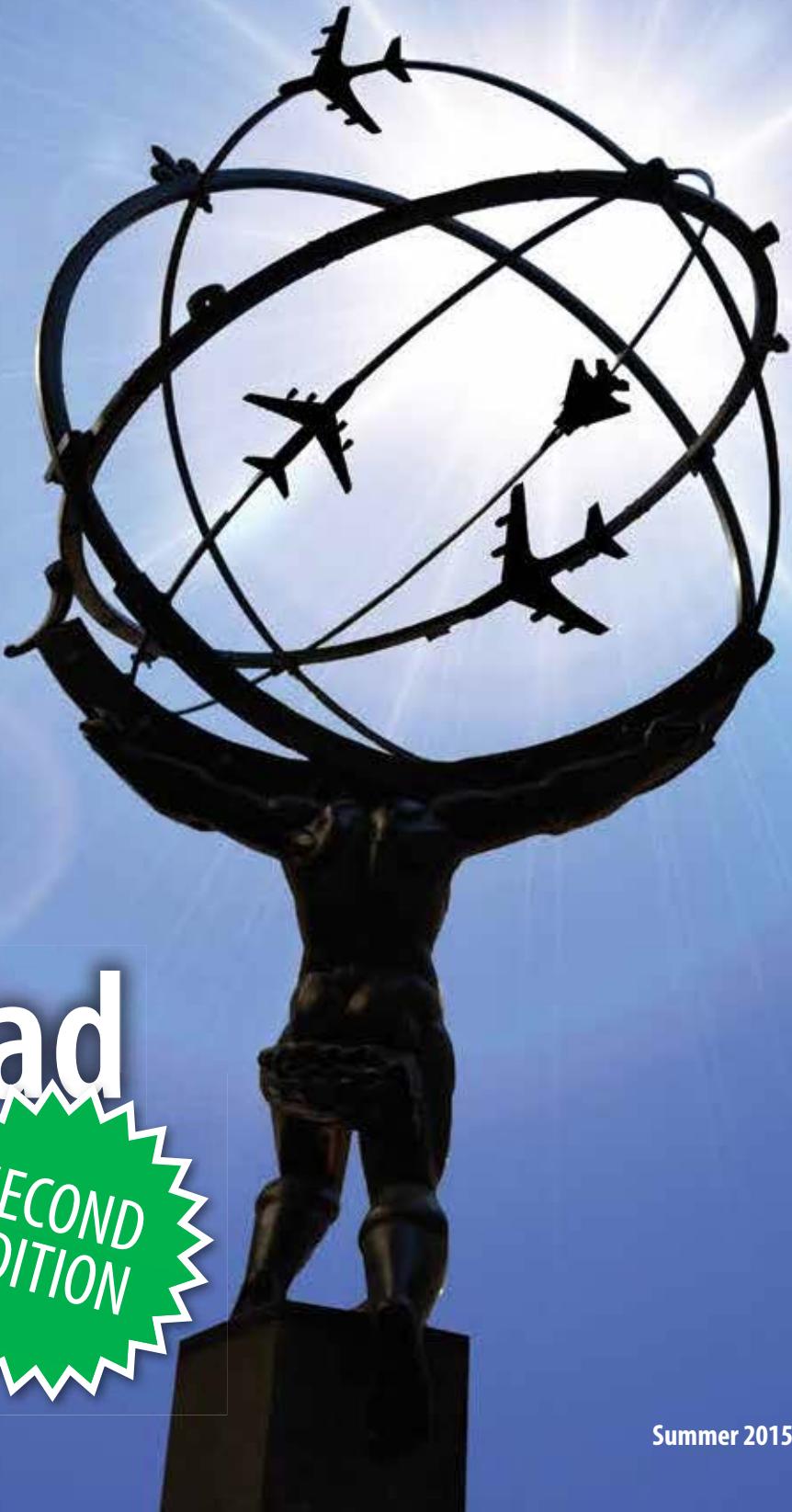
## What is your maximum workload?

by Professor Sidney Dekker

## Workload and the surprise factor

by Captain Ed Pooley

# Workload



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Summer 2015

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

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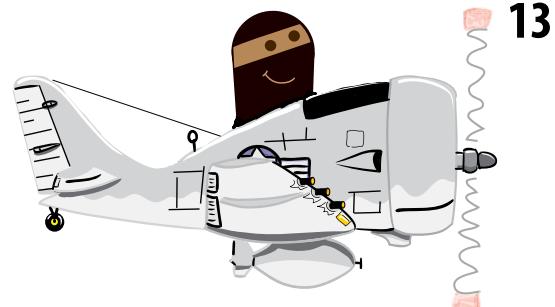
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Please send your message – rude or polite – to:  
**[tzvetomir.blajev@eurocontrol.int](mailto:tzvetomir.blajev@eurocontrol.int)**

Or to the postal address:

Rue de la Fusée, 96  
B-1130 Brussels

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## EDITORIAL TEAM

**Editor in Chief:** Tzvetomir Blajev

**Editorial Adviser:** Captain Ed Pooley

**Graphic Designer:** Frédérique Fyon



**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,

Workload affects us all and, as this edition highlights, many factors affect the workload of controllers and could potentially have an impact upon performance – most importantly, upon safety. So it is useful to step back a little, to see how European ATM is changing and to consider what impact this might have for controllers.

Some of the changes are very clear. For example, traffic is starting to grow again and this growth is expected to continue, with our latest medium term forecast predicting an average annual growth rate of 2.1% over the next seven years; this means that by 2021 we will see an extra 2.5 million flights a year, with particularly rapid growth in south east Europe.

We are also seeing more aircraft flying at higher flight levels, even for short/medium haul flights. This will change the distribution of aircraft in Europe's airspace and will also mean more climbing and descending. Another big change is the adoption of Free Routes Airspace (FRA), which is being progressively introduced, both geographically and also time-wise, with FRA being made available not just at night and/or at weekends but more generally throughout the week.

The tools available to controllers are changing. For example, although datalink has had a slow start, we can expect to see it being used much more widely as we overcome some of the problems initially encountered. We will need it in order to cope with higher traffic levels and also in order to achieve some of the performance enhancements envisaged. The SESAR operational concept is very clearly one which is based on the extensive sharing of real time data and datalink is a significant first step.

This concept will also bring much greater predictability. We are already seeing much better information from airports on exactly when aircraft will depart, both as part of the Airport Collaborative Decision Making programme and also as a result of the rollout of the Advanced Tower concept for other airports. This will be very important to our efforts to enhance the capacity and efficiency of the network as a whole.

The structure of ATM is also changing, with a greater realisation that the traditional model of each individual ANSP doing everything itself is outdated and is not the most efficient or cost-effective approach. So we will see more services being performed centrally, being jointly operated or being jointly procured. Not everything needs to be housed in the same building and we are even seeing the concepts of remote towers or virtual centres being explored.

All this change means that it is particularly important to review constantly the human part of ATM and, in particular, the role of the controllers, who are at the heart of ensuring safety in Europe's skies. How will the way they work be affected? Will the resulting workload be sustainable and safe? What can be done to help? I am sure that this edition of Hindsight will be valuable to all of us faced with these questions.

**Frank Brenner**

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# Shall we cut off the lizard's tail?



**Tzvetomir Blajev**

Editor in Chief of Hindsight

passengers at the airport waiting for their passports to be checked. How is it possible that following all the laid-down procedures prevent you from getting the job done in the normally-expected time?

Comparing strictly-followed procedures and normal ones can often illustrate the difference between a 'job as imagined' and a 'job as really done'. The procedures in place are often static and do not properly reflect the complexities of the real world. In reality, professionals like pilots, controllers, doctors and border control officers strategically prioritise their tasks. They treat some of them like elastic springs and reduce them to the bare minimum and completely omit others that they do not consider mission-critical. The nature of decisions about cutting their task load when under pressure is not dissimilar to a lizard under threat which 'elects' to lose its tail for safety reasons. Tails for lizards and non-critical tasks for professionals are not unnecessary, but one can sacrifice them as a self-defence mechanism to escape from critical situations. This allows the professionals to get the job done when the task load suddenly shoots up and allows lizards to save their lives when under attack by a predator. This flexibility is one of the features that make professionals what they are and they are proud of being able to accomplish tasks when under pressure.

*"You cannot guess what long queue for border control I am in. There is no end to it! Unless I find a way to jump the queue I will probably miss my flight".*

The specific pattern of frequency spectrum in the voice of my wife has always the potential to wake me up but this time it sounded even more alarming. A nationwide strike in Belgium had brought the public sector to a standstill. Border control officers were 'working to rule' and following all their procedures to the letter. The result was a long queue of

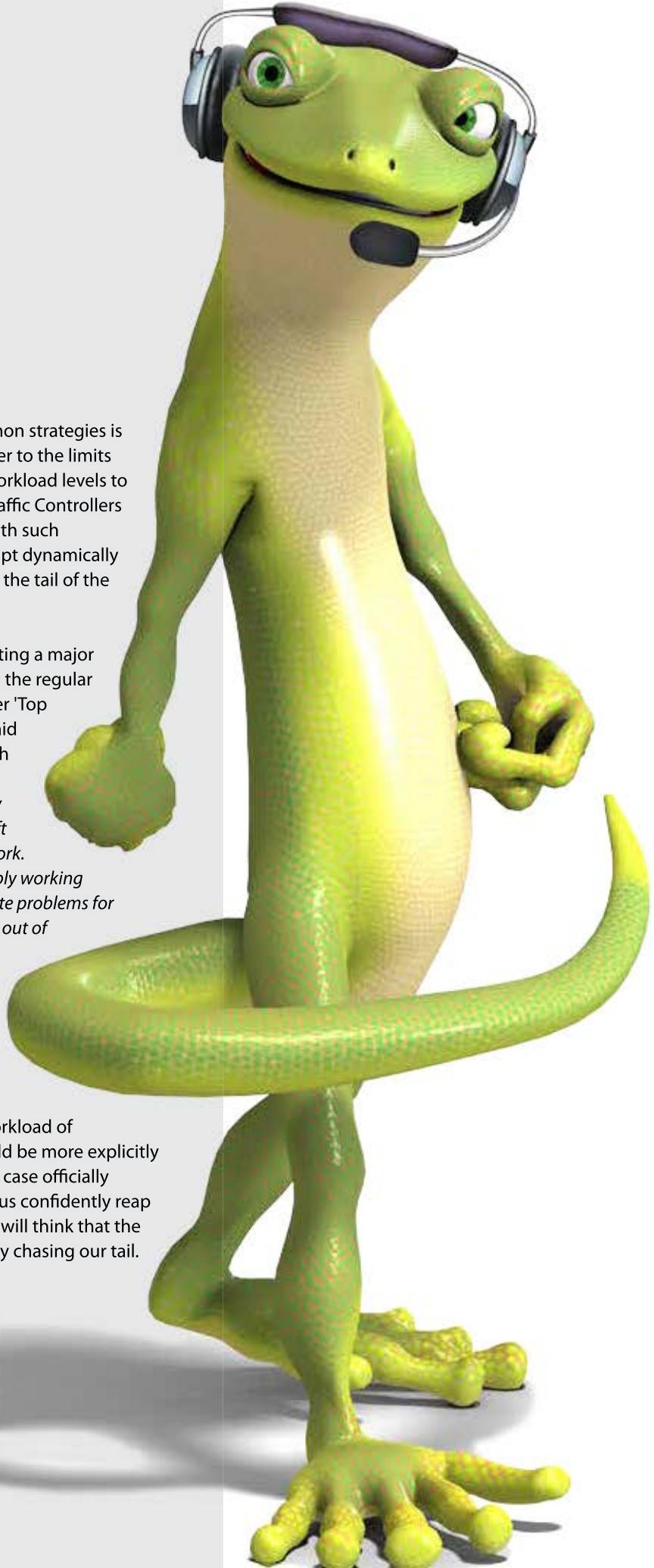
But how much flexibility can be safely accommodated?

With performance schemes in place, Air Navigation Service Providers are under pressure to do more with less, to accommodate more traffic demand whilst maintaining current levels of safety, to be more efficient and at the same time not allow the workload to reach unsafe levels. Let us examine two commonly-used strategies to manage more traffic demand that are often used together.

One strategy is to know the traffic well in advance and, when necessary, to pre-arrange it. This means giving up some flexibility in order to gain some predictability. If all flights arrive in a sector randomly without any pre-ordering, then a safety buffer will be needed for sector capacity in order to prevent sudden excessive bunching. Arranging the traffic non-randomly (by flight planning, flow control and working with more precise indicators like sector loads) increases the predictability of the task demand. The more predictable the demand the less uncertainty we will need to provide for in our estimations and the safety buffer on the capacity is often reduced. Instead of 12 aircraft in the sector and a buffer of 4 we can now have 15 and a buffer of 1. Increasing predictability not only allows us to work with more traffic, it also results in us working closer to our limits.

The other strategy is to accommodate more traffic demand by increasing the productivity of the controllers. Invariably this means a redistribution of tasks between the controllers in the team. For example re-allocating some non safety-critical coordination tasks so as to increase efficiency in the performance of primary controlling tasks and training controllers to be faster and leaner in their controlling. The gain in productivity "pays" for the acceptance of some additional traffic demand.

Both strategies allow us to work with higher traffic demand. However, when you work with higher traffic demand, each additional aircraft arriving in the sector typically leads to an increase in workload which is a little more than the increase which the previous aircraft brought. The reason that workload increases in this non-linear way is that every new aircraft will potentially have to be de-conflicted against a higher number of aircraft already present in the sector.



In summary, the result of applying the two common strategies is to make it possible to work with more traffic closer to the limits where small perturbations can suddenly bring workload levels to a critical high. Nowadays, professionals like Air Traffic Controllers are more often finding themselves confronted with such situations. And as they are professionals they adapt dynamically in order to get the job done and cope by "cutting the tail of the lizard".

Let me give you an example. Last week, I was visiting a major European Air Navigation Service Provider. During the regular workshop we had as part of the Network Manager 'Top 5' risk prioritisation process, the Safety Manager said "You know that we have increasing problems with 'intruders'. These are flights that enter the sector not as originally planned by their flight plan. I know the word 'intruder' may be too strong for the aircraft operators but these flights intrude on our plan of work. And the plans these days are very tight. We are simply working at the edge of what is possible. These intruders create problems for us because we have squeezed all possible efficiency out of the way we work and one flight more in the sector becomes the straw to break the camel's back".

As the pressure of society to get cheaper air travel increases, we will see ANSPs in a continual search for strategies to accommodate more traffic with the same number of controllers or less. I believe that in ATC, the effects on the workload of controllers of any new strategy or a change should be more explicitly assessed, protection measures identified and the case officially approved. This will protect us but will also allow us confidently reap the benefits of our improvements. Otherwise we will think that the workload is properly managed but we will be only chasing our tail.

**Enjoy reading HindSight! ☺**

# What is your maximum workload?

by Professor Sidney Dekker

Workload makes intuitive sense to most people. They can typically tell when their workload is "high." But what is too high?

In Hindsight 8 of 2009, I told of a trial at some European airport that wanted to go up to a throughput of 55 aircraft an hour in some sectors. A group of controllers volunteered to try this and I predicted that the trial would be successful. It probably was, depending on who you ask. I also predicted that the airport would probably soon go up to sixty aircraft per hour or more. They have.

So how do we know what your maximum workload is? In an even earlier 2007 Hindsight column, I quipped that to determine your maximum workload, you should talk to your union, not a human factors specialist. I apparently did not have much confidence in the science of my own field.

It hasn't grown a lot. At least not in respect of the question raised in the title of this column. My colleague Jim Nyce and I recently wrote about the measurement of workload in a scientific journal as "psychological alchemy." Alchemy, of course, was the medieval forerunner of chemistry. It was particularly concerned with turning base metals into gold. As far as we know, it never succeeded (notwithstanding, even Isaac Newton was an alchemist – and his were hardly medieval times anymore).

Psychological alchemy is concerned with turning its own base data into numerical gold. Wilhelm Wundt, working in his 19th century Leipzig psychology laboratory, once declared that he wanted to develop a "chronometry of the mind." He later abandoned the idea as too ambitious a research goal.



## Professor Sidney Dekker

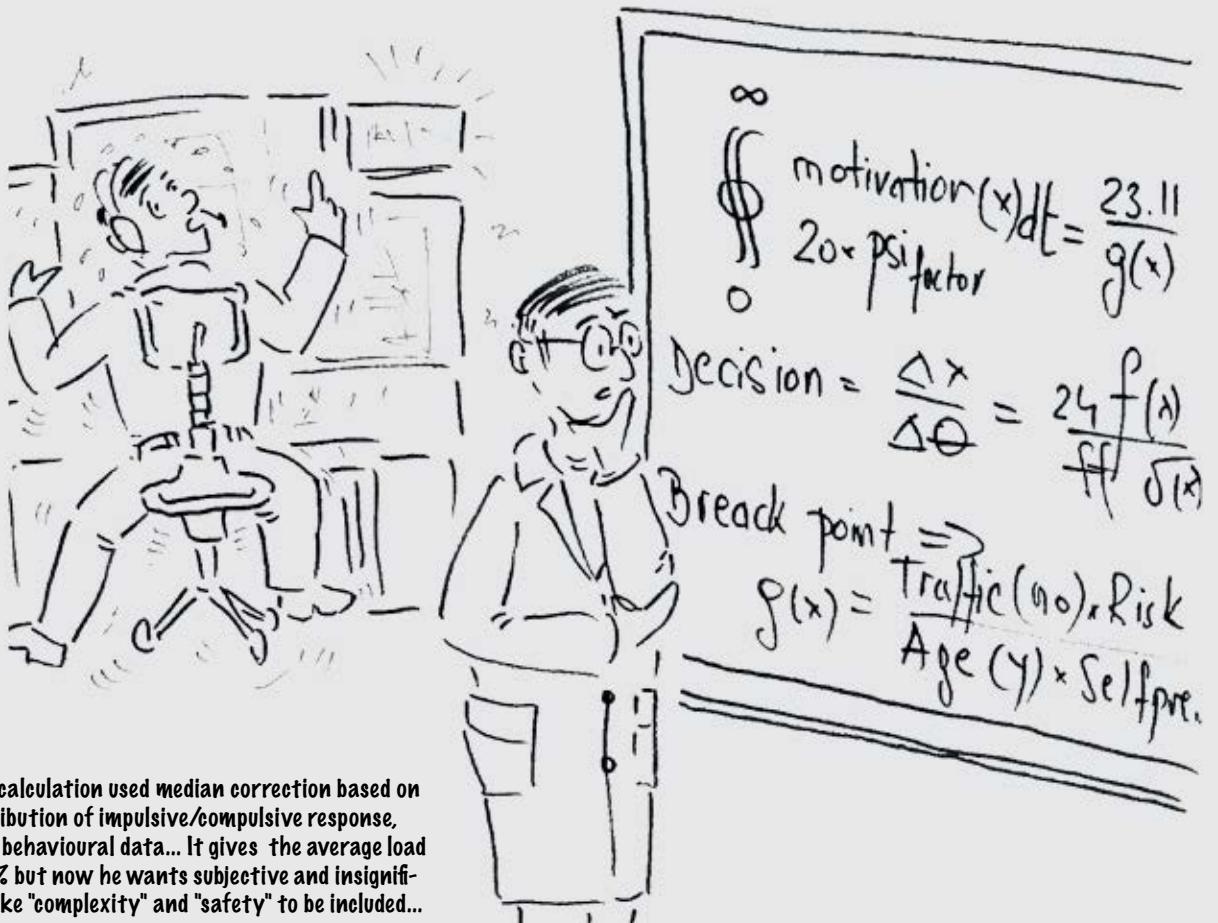
is Professor and Director of the Key Centre for Ethics, Law, Justice and Governance at Griffith University, Brisbane, Australia.

Author of best-selling books on human factors and safety, he has had experience as an airline pilot on the Boeing 737.

But today's workload measurement has picked up where he left off. Take a workload rating scale (like the NASA-TLX). It deploys a bunch of psychological terms (mental demand, physical demand, temporal demand, performance, effort, and frustration) and gives people scales to mark how much they experienced of each. People are asked to "introspect" or "look inside" and reflect on their own subjective experience. How was your mental demand? Well, uh, just reflecting, I'd say this much: tick. How was your performance? Uhhh, I dunno, what about... here, tick. How frustrated were you? Aaaargh, now that you ask, here, this much: tick.

As soon as your tick is on the scale, then the psychologist has her or his number. Because the scale has numbers, and your tick falls on or somewhere between them it produces a non-zero number (typically up to seven or nine or some other arbitrary figure). The point for the psychologist is that numbers are good; they make the whole exercise look like science. Because numbers are no longer subjective. They are no longer just your opinion. They are objective data. Objective psychological data.

Huh? Yes, psychologists can even do statistics on these data! For the nerds among you, a team in Oklahoma once proudly conducted an analysis of variance (yes, ANOVA) on the data derived from such scales. The data came from an air traffic control experiment aimed at demonstrating that paper flight strips were unnecessary. But the workload scales are, in technical parlance, ordinal. That is, they just order things (this is less than that, or more than that). It is not a ratio scale. If you have measured "mental load" with an ordinal scale, you can never claim that the difference between 1 and 2 is as large as the difference between 4 and 5. Or that the difference between 2 and 4 is twice as large as the difference between 3 and 4. The problem is, you can only do fancy statistical analyses on ratio scales. Never mind, the Oklahoma team set to work, pulling out a ruler to measure the distance between the left side of the scale and where controllers had put their tick.



A question about some unproven psychological category (...mental load? What in the world is mental load?) became a tick, a tick became a distance from the left side of the scale as measured in whatever units the ruler offered, the distance from the left side of the scale became a number, the number became a data point in a statistical analysis and finally, the statistical analysis became proof that your paper flight strips were a waste of everybody's time.

Right. That is called alchemy: psychological alchemy. What is worse, it performs what my colleague Jim Nyce called a strategic retreat. A retreat from you, the operator, the controller. It produces numbers, and statistical "proof" so that your managers or engineers feel more confident to take action based on it. Like removing paper flight strips. Or re-sectorising so that you can now do it all alone, all by yourself! Or that you now get 55 airplanes to talk to. Or 60! But where are you, the controller, in this? What happened to your actual experience of workload? Well, you were asked about it. And your answers to those questions became a tick, and the tick became...

OK, I think you get the drift.

Fortunately, researchers today are actually not just interested in figuring out maximum workload anymore. What matters more to them is workload transitions – and particularly going from low workload (also known as "underload") to high workload. This has been shown to be related to all kinds

or problems: too many task demands and things competing for visual attention, severe time constraints, the difficulty of ramping up psychologically and physiologically. In air traffic control, the opposite has also generated concern: coming off a traffic peak, or going from high to low(er) workload, has been shown to have negative effects on controller vigilance and directed attention in some cases.

This kind of research is more interesting and perhaps even more genuine. What it shows is not numbers (55 per hour – or 60!), but patterns. It shows how things interrelate, interconnect and interact (this traffic low after this traffic peak at this time of day in those sectors, given this roster and this manning). Those patterns hide possibilities for action and intervention. Different ways to schedule you. To build rosters in other ways. To re-sectorise at different times or in different ways. Nobody needs to be shown right or wrong with such results either. Instead, this kind of research gives us things to think about, talk about and try out. So what do you do now? Have a healthy distrust of numbers produced by the psychologists and human factors people who swirl around your workplace. Ask them, and yourself, and your manager, questions about patterns and interrelationships that together make up the workload as you experience it. Don't worry too much about maximum or minimum numbers.

If you don't mind, I will stop writing now. Even though I don't have a union to help me determine it, I think I have exceeded my maximum workload for the day. S

# Workload and the surprise factor

By Captain Ed Pooley



**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.

I don't know how many HindSight Readers are familiar with the story of Goldilocks (a little girl) and the Three Bears – a baby bear and her mother and father. It includes a scene where, whilst wandering in a forest early one morning and rather hungry, Goldilocks comes across the Bear Family's cottage and looks through the window. With no bears in sight, she goes in and sees three bowls of porridge. She tries a little of each. Then she tries out each of the three chairs and finally, having found the bears' three beds and falls asleep. But not before she has decided

that in each case, two of the choices are always too much in the direction of an extreme – too hot/cold, too hard/soft or too large/small and one is "just right". For the majority of both controllers and pilots, the everyday exposure to workload is rather like that. There is an optimum, at each end of which are the extremes of 'too low' and 'too high'!

Workload on the flight deck is, on a normal day, predictably cyclical for every flight. Unless the flight which follows is a short haul turnaround flown

by the same crew, it is also necessary to consider the hour or so before the aircraft pushes back from the gate for which there is also some predictability. For any crew there is rather a lot to do during a period of time which is invariably a fixed number of minutes before STD – typically 60, 75 or 90 minutes<sup>1</sup>. This interval often has less to do with what is required than the need to keep the Flight Duty Period<sup>2</sup> to a minimum. Even before 'signing on' for a flying duty, if the aircraft commander is new to command, new to the aircraft

1- Long haul flights in larger aircraft are likely to be preceded by more generous reporting times.

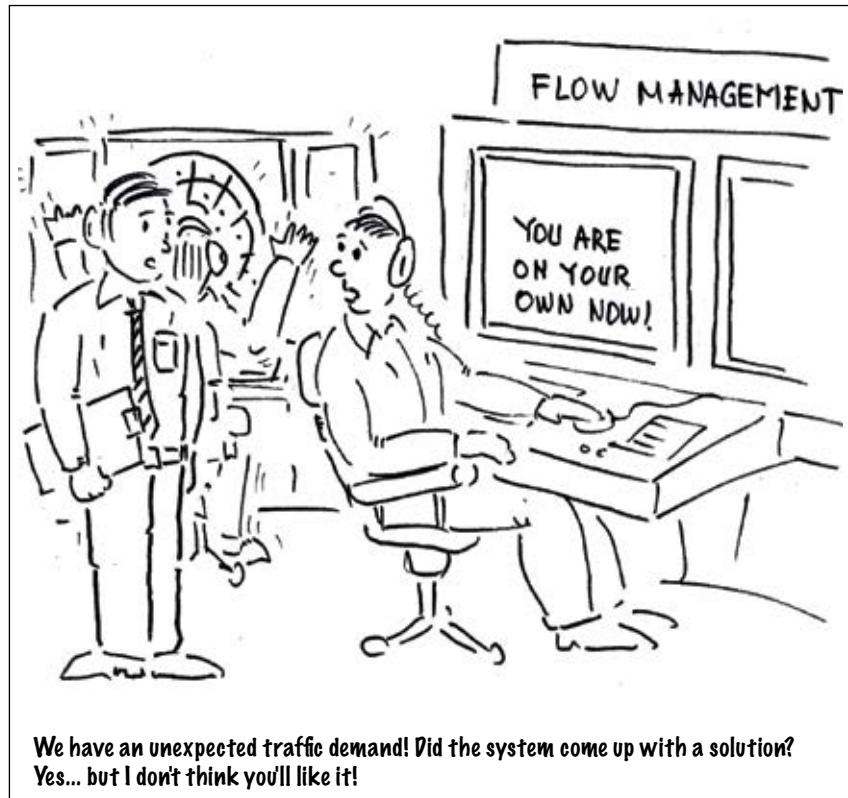
2- This begins at the time that a crew member is required to report for duty and ends at engine shutdown after the final flight. It is often scheduled quite close to the maximum permitted. This is different to a Duty Period which can and does continue after this time as required – including positioning after flying duty.



type or variant, about to operate a variant within a common type rating which they have not recently flown or is unfamiliar with the route and/or destination and alternates, then they will almost certainly have undertaken some pre-flight preparation in their own time. Probably not too many controllers feel the need to do that unless OJT beckons!

So pre-flight is routinely high workload and can become very high workload if operational normality does not prevail with the overriding pressure being that these days, every late departure has to have a reason, the determination of which is a subject on its own. Needless to say, most Captains want to minimise the number of times they are the 'cause'!

Engine start to 10,000 feet is accompanied by a different but equally high workload. Then, almost always, comes the low workload period beginning above 10,000 feet and lasting until about the top of descent. Usually only the direct or indirect effects of adverse weather or the occurrence of an aircraft malfunction



will interfere with this. Once descent has started, the routine workload slowly builds up to a maximum until after completion of the landing when it reduces to a intermediate level until engines off.

Of course this broad predictability is not guaranteed but this repetitive cycle is probably more constant than the variation in a shift as a controller. Nevertheless, normality for most

controllers will have some 'baseline' variations in workload which can be anticipated at the beginning of a particular shift – although I'm sure that these baselines are rarely the same unless it's the same shift in the same position.

For both pilots and controllers, these routine expectations of workload variation will (for pilots) or may well (for controllers) encompass the full range of acceptable workload. But this at least represents a familiar 'normality', and whilst the challenges in the vicinity of these two extremes are rather different, they at least happen more or less when expected. Where to 'draw the line' when faced with overload can be dealt with procedurally by making reasonable assumptions about the point just before that where the performance of individuals may no longer be consistently safe and devising a reliable solution.

But there is an extra dimension to workload in respect of the high end of the spectrum and with it a heightened risk of overload. This is the fact that 'the

►►





## Workload and the surprise factor (cont'd)

system' in both the flight deck and in the control room must be able to cope with the particular case of a (very) sudden and (entirely) unexpected transition to high workload which demolishes in seconds the previous expectation that fluctuations in workload would continue along the anticipated path. Recovery – or at least containment – before overload is reached becomes the aim.

From the perspective of the party on the receiving end of a surprise, the trigger for this sudden change could be either 'internal' or 'external'. In either case the origin of the change could be 'technical/environmental' or 'human' – although inevitably, as in any endeavour with a human in charge, the latter tends to dominate. A sudden unexpected increase in workload on the flight deck or in the control room may fairly quickly result in the same condition for the other too. But of course both pilots and controllers can initiate an unexpected and sudden increase in their workload by their own inappropriate or unintended actions without any help from anyone else!

Some of the most common scenarios for sudden and 'out of the blue' high workload are as follows:

The first of these stands out as the one where ATC is unlikely to be involved – although in respect of risk-mitigation, it has a lot in common with the last two. For the next three, there are procedures for both pilots and controllers to follow and in these situations, the response is at least similar in principle every time and the responses are procedurally prescribed, are covered in training and for real fairly often. The last two, however, typically demand rather more ad hoc decision making and there is much more chance that every situation will be different. Here, (and in the first case) the normal training system may have provided the least benefit.

Coping with any operational issue needs two approaches – prevention and recovery. Since prevention procedures will often have failed, the ability to recover is important and supportive training to increase the chances of this is therefore crucial. But in the case of a 'sudden' and 'unexpected' rapid transition to high workload, not every scenario can be anticipated. Training must therefore employ representative scenarios and assess the competence demonstrated in coping with them. I admit that it will be difficult if not impossible to directly include the self-caused high workload

case but this should not prevent the development of overall resilience sufficient to stay out of more than momentary overload altogether.

To be effective, this training must be based on two guiding principles:

- A way must be found to 'hide' these 'representative scenarios' within a whole training exercise so as to introduce at least a little of the unexpected onset which would accompany the real thing.
- We all know how quickly news of each new training exercise gets passed round. To avoid this loss of surprise, a huge library of representative training scenarios must be developed so that the surprise they provide is as near to real as possible.

Of course the best place to practice this is in a simulator which replicates a real aeroplane or work station and for most pilots at least, this is possible. But I suspect that many controllers will not be exposed to quite such realistic training opportunities so that in itself will be an additional challenge.

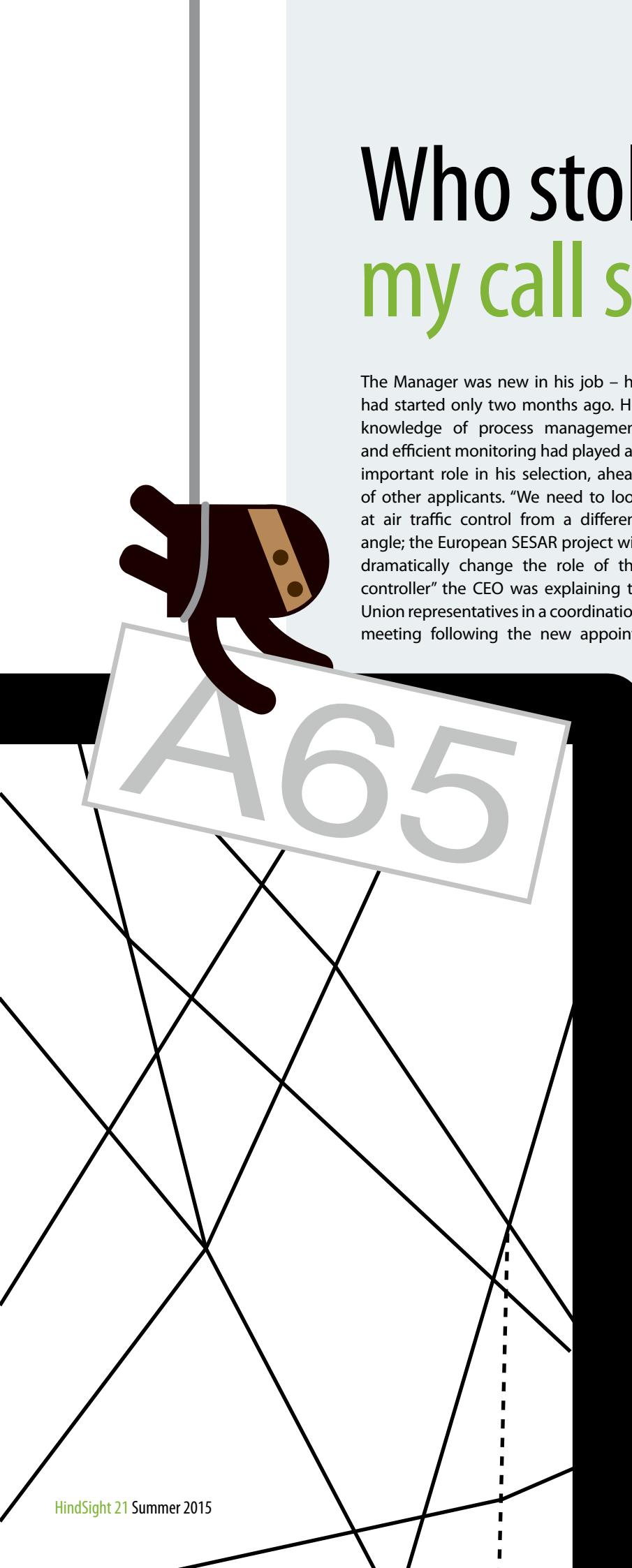
And one final thought. Is the predictable consistency of a 'goldilocks' workload really what we want? Even if we define 'normality' as including the predictable and anticipated variation in workload, do we really want to stop there? Why did we become pilots or controllers? I suggest that most of us did so because there was also the prospect of an occasional unexpected challenge to rise to and meet successfully without needing a completely memorised or scripted solution.

Trigger In	Condition	Cause	Workload effect for
Flight deck	Aeroplane control	Pilot	Pilot
Flight deck	Low fuel	External/Pilot	Both
Flight deck	Aeroplane malfunction	External	Both
Flight deck	Medical emergency	External	Both
Control room	ATC system malfunction	External	Both
Either	Traffic separation	Either	Both



# Who stole my call sign?

by Bengt Collin



The Manager was new in his job – he had started only two months ago. His knowledge of process management and efficient monitoring had played an important role in his selection, ahead of other applicants. “We need to look at air traffic control from a different angle; the European SESAR project will dramatically change the role of the controller” the CEO was explaining to Union representatives in a coordination meeting following the new appoint-

ment. “This organisation is like a fat cat lying in the sun, waiting to be fed. We have to change that”, he continued. One of those at the meeting, a senior controller, looked out of the window. It had started to rain and he had no umbrella.

One pair of fighters had already departed from the local air force base bound for one of the exercise areas some ten minutes east of the base. Sylvester led a second pair as they taxied out to the runway for departure. It was a sunny day. During an earlier training flight before lunch, he had been flying under callsign A32 but for this second sortie, he had been assigned callsign A65. He had really enjoyed lunch – fried herring and mashed potato with lingon berry jam. Immediately after take-off he contacted the controller responsible for clearing air force flights crossing the terminal area of the international airport nearby; “Control, Alpha six five airborne”. Bert, the controller, replied “Alpha six, five fly heading one zero zero, climb to flight level one one zero, call you back for further climb”. “Heading one zero zero, climbing to flight level one one zero, Alpha six five”. The landscape he was passing over was so beautiful, small lakes, attractive green forest. Perhaps there would be time for a trip on his Harley later. ►►



**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



## Who stole my call sign? (cont'd)

Bert began to coordinate A65 with the two controllers responsible for traffic north and east of the international airport just south of the intended flight path. He had to coordinate all crossing traffic as he did not control the airspace himself. The first controller, Greg, replied immediately. You could tell he was bored to death and had virtually nothing to do by the way he replied. "Send them wherever you like, it doesn't matter to me" Greg responded in a tired but not unfriendly way.

The second coordination was not as simple. He didn't expect it to be given that there was a trainee in position. By turning around to his left, he could see that the trainee, Yvonne, had been left alone, her instructor was nowhere in sight. As always, once he had made contact he proposed a solution. It was much quicker and efficient to do it that way. "Please stop ABC123 at level one two zero, I stay below with Alpha six five". "OK", Yvonne replied. He could overhear other aircraft calling on her frequency, she was obviously busy. He thought about asking the supervisor to call Yvonne's instructor back, but decided not to. After all, it was the

supervisor's duty to support his team by following the operational environment, not his.

Frederic and Kevin, two representatives from a consulting company, had arrived to the centre at lunch time. "We will be measuring the work load of the controllers" Frederic explained to the supervisor, Tony. "It's part of the new efficiency program initiated by the new manager" he continued. "For example, what is that controller over there busy with", Frederic asked the supervisor, nodding towards Greg, now lying across his desk half asleep? "Greg, wake up! We have visitors". The supervisor felt rather embarrassed to say the least. "Well this is what happens when we are required to keep all the sectors open whatever the work load" Greg answered in his typical, obstructive way.

"Why not start your study at another sector, perhaps...", the supervisor tried to change focus away from Greg. But he stopped mid-sentence when his phone began to ring and he saw that it was his wife, i.e. absolutely top priority. "Please just go ahead, I'll get back to

you as soon as I've dealt with this important phone call". Frederic and Kevin walked slowly over towards Yvonne.

Bert instructed the first pair of fighters to contact the air force controller in charge of the exercise area located east of the civil terminal area. The second pair of fighters, A65, passed just north of the international airport maintaining flight level one one zero. The conflicting traffic for A65, ABC123, was descending through flight level 170 westbound so they should be clear of conflict in around two minutes.

Whilst he waited for a third and final pair of fighters, operating as A32, to depart, to follow the same eastbound route as the previous ones, Bert tried to coordinate a military transport aircraft heading southwest but the line was busy. The airspace south of the civil terminal area was controlled from a different and rather small approach centre. There was not really any need to keep it open, it had remained just for political reasons.

In this small centre, there were four controllers on duty but only one working – the other three were playing cards. This was their usual routine – work very hard for an hour then have three hours free. Even better, one or two of them could leave early which was very useful – you

## MAKE YOUR CHOICE...



**Low workload**

could do all your shopping before you officially stopped for the day. The controller in position, Marie, was very experienced; she had full control of all the aircraft, although she was responsible for traffic to and from four different airports. The only minor stress factor was the necessary coordination with the towers, but she could handle that too without any problem.

Bert again tried to coordinate his southbound transport aircraft. The interphone at the other centre was busy all the time which was very irritating. They must be extremely busy. He focused on the transport aircraft; it would leave his area in a minute or so and he really needed to coordinate.

Frederic introduced Kevin and himself to Yvonne. "Hi, we are going to measure your working conditions in line with a request from your new manager". "What do you estimate your current work load to be?" Frederic asked without waiting for a reply to his introduction. "We have a scale from one to six, one is a very light workload and six is very high". Yvonne turned round, "sorry what did you say?". "One is light, six is very high workload", Kevin suddenly came to life, repeating Frederic's words but louder. Yvonne looked at them, appearing rather puzzled and opened her mouth to say something but didn't.

"What is your opinion? I will fill in this and your other replies to our questions on my printed form, you just need to answer". "For obvious reasons we can't do this survey outside the operational environment, I'm sure you understand". Kevin had a serious tone in his voice.

Bert, still unable to coordinate his southbound aircraft, noticed the A32 pair had got airborne. "Control Alpha three two airborne". Just as he was going to reply, the controller at the centre south replied on her interphone, "yes, what do you want?" He recognised Marie's voice, he knew her well. "Hi, I have Echo one six zero for you, just wait a sec", Bert answered the A32 before it reached four thousand feet, the standard climb limit after departure. "Alpha tree two fly heading one two zero, climb without height restrictions", "Where was I" he said as he returned to the coordination, "ah yes, Echo one six zero, south west of...." "Radar contact, send him to me", Marie interrupted. "Thanks, climbing without restrictions, Alpha three two" the pilot replied. "OK, I'll send him to you". Marie had already hung up.

After taking down the shopping list for today's evening meal from his wife, the supervisor Tony walked over to Kevin and Frederic. He tried unsuccessful to talk to them but they were argu-

ing with Yvonne. Her body language was unmistakable, she was obviously annoyed with them. She had turned away from her radar screen and was pointing a finger at Kevin. "Don't you dare tell me what I should do", she shouted. It could have been worse, I could have been married to her, Tony thought, returning to his working position. She will make an excellent controller!

"Control, Alfa three two, I did not reply to your clearance". What did he say; he did just that, he did read back the clearance to climb? Bert was confused. "Someone else read back the clearance", the pilot from A32 clarified. "But we are climbing now, Alfa three two", he continued. Bert suddenly went cold as ice. He scanned his HMI. Which pilot had picked up the clearance and was climbing? How could this happen? In a few seconds he saw A65 climbing, passing through the same level as ABC123 just half a mile behind it.

Yvonne turned back to her radar screen; ABC123 had just met the fighters. "ABC123 descend to flight level six zero".

"That looked really scary Bert", Greg laughed while calling up Bert to verify that the last pair of fighters had left his area. "Did they have visual contact"? 





# Case Study Comment 1

## by Richard (Sid) Lawrence

Where to start with this one? There are clearly a 'multitude of sins' to consider – over eager/inappropriate management, poor supervision, an absent OJTI, high workload, endemic call sign allocation issues, inadequate hearback, distraction...the list goes on.

However, with my EUROCONTROL Call Sign Similarity Project Manager's hat on, I'll stick with the call sign related issues as these are at the heart of the problem. Clearly nobody in the military set up realised that by re-using the same call sign, albeit with a different crew/pilot, this might induce human factor-related misunderstandings. Comparison with civil ops is, in some respects, inappropriate. Civil flight schedules and associated commercial flight numbers and ATC call signs are generally allocated before the start of each IATA summer and winter season. In the military, whilst some air transport type operations may involve an element of scheduling, the planning of operational training sorties is a much more dynamic affair. A typical flying programme is probably published the day before at the earliest. In some air forces, 'training' (instructor and student) pilots are allocated an individual call sign which they use on every training flight – this lets ATC and aircraft operating authorities know who exactly is flying which aircraft. But whilst on 'training' squadrons this makes life a bit easier, operational training sorties tend to use different call signs every day.

Short call signs such as A65 are easy to pronounce but they are easy to mix up too. As an aside, in the civil world ICAO Doc 8585 recommends that call signs ending in 5 or 0 should be avoided to lessen the possibility that they may be mistaken for headings and flight levels. It would be fair to say that adherence to this practice is, shall we say, at best 'patchy' and at worst ignored. So if civil operators don't do it, we can hardly expect the military to consider doing this either.

We also can't expect the military operators to conform to the EUROCONTROL Call Sign Similarity "Rules" that we use as the basis for detecting and de-conflicting similarities embedded within civil aircraft operators' flight schedules using the EUROCONTROL Call Sign Similarity Tool (CSST). These "Rules" – although it's best to consider them as conventions rather than "rules" per se – describe the main types of 'similarity' that can lead to call sign confusion; they also describe the various recommended call sign suffix formats – numbers and letter – that can be adopted, e.g. nn, na, nnn, nna, naa, nnnn, nnna, nnaa.

The question you might ask is why did the squadron have to use the same call sign numbers again for a different flight a few hours later? After all there are plenty of other combinations available that could have removed any potential confusion in the pilot's mind at a stroke. Now I'm not a human factors specialist and I won't pretend to know the inner most workings of the human brain (least of all my own so I'm sometimes told!!) but, intuitively, it just doesn't seem sensible to re-use a call sign when there are plenty of other number combinations to choose from!

As in the civil world where an aircraft operator has a specific R/T designators, e.g. British Airways' use of 'SPEEDBIRD', the addition of a call sign designator prefix for military flights, e.g. "SAXON" might help to better differentiate call signs. So instead of A65 and A32, we could have SAXON 65 or SABRE 32. Of course the same principle of not re-using the same call sign within a matter of hours can still apply but the addition of a call sign prefix might just help to break previous mental connections.

### A RECOMMENDATION

Just as in civil operations, it is important that military authorities try to avoid/reduce the risk of call sign similarity/confusion not only in their own operating environment but also within the mixed civil/military environment that is commonplace. Accordingly, I would recommend that the military aviation authority reviews its call sign allocation policy, perhaps coming up with a version of its own call sign similarity "rules" that could be applied service-wide. 

**Richard "Sid" Lawrence** served in the UK Royal Air Force for 29 years across a wide range of ATM and related safety disciplines. Richard joined EUROCONTROL in January 2006 and is currently working in the Network Manager Directorate Safety Unit covering a broad spectrum of ATM safety related topics including management of the EUROCONTROL Call Sign Similarity/Confusion project.



# Case Study Comment 2

## by Captain Ed Pooley

Well, my first impression is what a dysfunctional ATM setup exists in this region! No surprise that the need to start some sort of improvement is overdue. However, we only hear of some change planned for the main ACC in the story when a regional solution is obviously required.

Anyway, the new manager has failed to realise that his initial priority should have been not to begin workload measurement or any other part of the change process but to first spend some time gaining an understanding of the status quo. Such insight would have allowed his vision of modernisation can be turned into reality through a change management programme based on the starting point – the people, their approach to their job and everything else about their working environment. And in particular he needed, at an early stage following his appointment, to get to know his management team down to the supervisor level so as to be able to judge their fitness for purpose in their existing roles and their suitability for implementing significant change. An address about a vision should have been merely a prelude not the starting gun on change. Clearly, the wrong person got the new manager's job....

On a more specific failure, the delegation of the premature workload measurement exercise to a contractor appears to have been inappropriately tasked and/or inappropriately briefed. Oversight of the two idiots supplied for the survey work in the control room was non-existent thanks to a completely inadequate supervisor. It seems that the same supervisor also failed to ensure that an OJTI did their job properly and, on the evidence available, commanded little

or no respect amongst his controllers. Again, the wrong man got the job – or perhaps in this case, his performance had just deteriorated once in post...

But the near miss which represented the immediate threat to safety was nothing to do with workload or efficiency or the civil ATM service generally. It was the consequence of a flight crew error which was made more likely by a frankly stupid system of allocating R/T call signs to military training flights. Whilst there can be no justification for the call sign allocation made, the solution needs to be formulated by the military authorities – for all bases. However, it is obvious that after its first use of the day, a call sign must not be used again that day be a different crew – and unless individual pilots are allocated personal call signs, it should really not be re-used at all that day.

I did wonder about the availability of STCA which wasn't mentioned. Not installed, not operating or not set up in such a way that would detect such a potential conflict?

Of course, Mode 'S' DAPs from the military aircraft could have triggered a quicker warning to the civil controller which may well have provided him with sufficient time to intervene. But then, if the military had fitted a mode S transponder to their fast jets (or even a mode C one), the civil aircraft would have received a TCAS RA if the time-to-proximity threshold had been breached....

**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.

Finally, as a observation, I would suggest that it is poor practice to separate a military fast jet (or a pair) by only 1000 feet from crossing or opposite direction traffic. The performance of such aircraft means that by the time the potential conflict has been picked up by STCA or radar observation, there may be insufficient time to pass avoiding action instructions or insufficient time to act on them.

### A RECOMMENDATION

The military authority HQ needs to undertake a risk assessment on their operation of fast jets in controlled airspace where the civil authorities provide ATS. In the near term, this might lead to a sensible service-wide policy on R/T call sign allocation and in the longer term, it might result in the fitting of altitude encoding transponders to all their aircraft accompanied by a requirement to switch them on whenever in controlled airspace. ↴



# Case Study Comment 3

## by Captain Pradeep Deshpande

The subject which I would like to focus on is the control of military fighter aircraft through civil airspace.

Routing of military aircraft through civilian airspace, particularly in the proximity of international airports, is fraught with potential difficulty from both the pilot and controller point of view. Military fighter planes often fly in formation with a single aircraft taking responsibility for ATC communications on behalf of two or more aircraft. Situations may arise where, should the visual contact which is often a necessity when maintaining a compact formation be lost due to weather or any other reason, the attention of the formation leader may get divided between maintaining safety within the formation as well as coordinating the transit through the civil airspace. The formation may even be using two separate radio frequencies at the same time, one within the formation and the other for transit. The workload in the cockpit even during a seemingly routine climb out could be higher in the fighter cockpit as compared to a multi-crew flight deck. This is fully appreciated by the air traffic controllers and therefore, as in this case, the fighter formation was given a heading and a restriction on the altitude to climb to without giving details of the conflicting traffic.



In hindsight, giving some information on the opposite direction traffic may have been a prudent move, however, the controller's decision not to do so cannot be faulted since he had made the required effort to establish the vertical separation.

Not paying attention to ones call sign is a serious yet oft-repeated error. Military fighter missions are generally allotted a 'block' of mission numbers, and these are used in sequence during the course of an exercise. On a day such as this where one pilot flies multiple missions using call signs that are distinguished only by another number, the chances of committing such an error are pretty high. Arguably, on a multi-crew flight deck this error would have been caught in time by the second crew member, but on a single seat fighter the backup does not exist. The safety net for this could have been provided by Yvonne or her supervisor – that however, is another aspect of this case.

### A RECOMMENDATION

Procedural control could be used to mitigate the risk of a conflict such as this. A simple solution would be the creation of a transit corridor to the south of the international airport which is relatively free of civilian traffic and also has an adequate number of controllers. This would allow the military jets to transit to and from their exercise area with minimal exposure to the traffic coming in and out of the international airport. Also, restrictions on flight level/altitude could be established to ensure that the military aircraft stay below a certain level whilst the civilian aircraft do not descend until they are within a prescribed distance of the international airport. Clearly, radar control provides more efficiency for air traffic control but in a scenario that has an area being coordinated by one agency and controlled by another, procedural control must form the basis for air traffic management. This will not only allow a built-in safety to cater for any delays in coordination but will also give the military fighters some room to manoeuvre should the situation so demand. ☺

### 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.





# The quantified self in a complex system: a systems perspective on mental workload

by Dr Steve Shorrock

In the last few years, many of us have started to quantify ourselves. We have purchased activity trackers to monitor and track health and fitness metrics such as distance walked and run, calorie consumption, heart rate and sleep quality. By quantifying inputs, outputs and what goes on in between, it is possible to set a desired goal, adjust, and track progress toward it... ▶▶





### The quantified self in a complex system: a systems perspective on mental workload (cont'd)

This occurs within a complex system (a person), but one where it is usually possible to control the inputs and outputs fairly well. Sometimes, we like to think of socio-technical systems in the same sort of way. We measure concrete things like traffic and RT load, less concrete things like traffic complexity, and sometimes rather abstract intermediary things like 'mental workload'. Yet many remain sceptical of the quantification of aspects of human experience in complex systems.

From a systems perspective, human performance exists in the context of a dynamic (and often messy) system. For complex systems such as aviation, everything connects with something. When there are changes in one part, there are adjustments elsewhere. So 'human performance' is only relevant in the context of the system: other humans, a variety of equipment, procedural constraints, working environments, demands, and so on. All of these aspects of the system interact in variable ways, over time and in different situations. From a humanistic perspective, human beings supersede the sum of their parts. We cannot be reduced to components or concepts, nor can we be dislocated from our human and environmental context. The trouble with many measures in socio-technical systems is that they can dislocate, mask and distort the human, system and environmental context.

Quantitative data about humans and systems look scientific because they take on a certain (often spurious) accuracy in black and white, with all their decimal places. But such data are as political as they are scientific, or at least they become so because the search is sometimes not for an answer to a question but the desired answer to a question (e.g. that a change is safe or acceptable). Unrav-

**"the most important things cannot be measured".**



elling the history of the numbers can reveal some inconvenient truths. And once something is measured, it can be tempting to prescribe a maximum, minimum, or target. All of these can create problems in socio-technical systems, which do not have hard physical parameters, and which can change their behaviour in response to being measured, and in response to arbitrary quantified targets. Numbers can take on a life of their own.

But it is naïve to think that we can or should completely avoid numbers. Unfortunately, there remains an attitude among some that "If you can't measure it you can't manage it." This is despite everyday evidence to the contrary, and despite the thinking of management and quality guru and statistical professor, W. Edwards Deming who remarked that "the most important things cannot be measured". And qualitative data – of the sort that I tend to prefer – don't always penetrate the management-by-numbers or hard engineering mindsets. Qualitative data are messy and might not reduce uncertainty in the same way as numbers, and uncertainty is a key source of anxiety for decision makers. It's also worth remembering that quantitative measures can also suggest that workload is too high, and this might carry more weight for some than a story or controller comments. Numbers may also be the only thing that some have any time or inclination to digest when it comes to decision making. The quantification of performance is really a trade-off in data collection. Such data can often be gathered from more people, more efficiently.

For these reasons, most numerical measures concerning human experience and system parameters should be treated as social objects. Any data on mental workload, sector capacity

values, traffic numbers, or whatever, are a reason for a conversation, the start of a conversation – not an end point. We can't measure workload like we can measure our heart rates, calorific intake or physical activity, but we can do what we can to try to make sense of our experience, accepting that any data collection is a compromise, and there are nearly always social and political implications.

In practice, how we human factors specialists measure, assess or understand your workload – or anything else – is secondary. This is because only a small minority of European ANSPs employ human factors specialists in the first place, and those ANSPs who do any kind of 'mental workload assessment' could be counted on one hand (with fingers to spare). Decisions about changes to technology and procedures are, in the majority of cases, made with no input from human factors specialists in ANSPs. Decisions are made on the basis of a perceived business or operational need and an available technological or procedural solution (which sometimes creates a 'need'), and the solution undergoes some form of design process and safety assessment. Technological solutions are increasingly commercial-off-the-shelf, with little room for adaptation.

After over one thousand hours talking with operational staff (and managers) all over Europe, and hundreds of hours

observing controllers, my questions on workload rarely concern numbers, even though so much research on workload is aimed at measurement. To you controllers, some of these are worth asking prior to the introduction of changes. For instance:

- Ask the proposer about the purpose(s) of the change – the answers may change over time.
- Ask designers and engineers about the requirements, engineering process, user needs analysis, prototyping, interaction design, testing and simulation.
- Ask training specialists about the training needs analysis, the length and timing of training and familiarisation, its design, method and platform.
- Ask HR and planning about the staffing, stress management and fatigue implications, including shift work and breaks from operational duty.
- Ask operational management about how demand can be reduced or varied when needed (e.g. high-workload training flights in small airports).

And finally, ask yourself, your colleagues and all of the above about your involvement in all aspects of the change. You are the experts in your work, and you will inherit the result of any changes...and have to adapt to them. ■



**Dr Steven Shorrock** is Project Leader, Safety Development at EUROCONTROL and the European Safety Culture Programme Leader. He is a Registered Ergonomist and a Chartered Psychologist with a background in practice and research in safety-critical industries. Steve is also Adjunct Senior Lecturer at the University of New South Wales, School of Aviation.



# Are you a competent workload manager?

**Dragan Milanovski**

A controller's ability to manage workload is a subjective and individual response to a given task load situation. It enables him/her to continue to provide a safe and efficient ATC service. Personal factors (e.g. skill, experience, stress) or external factors (e.g. time pressure, noise, stressors, distraction, organisational change issues etc.) can all influence workload. There seems to be a general consensus that ability to manage workload is one of the key ATC competencies. How does a controller develop this competence?

There are currently two conceptually different approaches to addressing workload management in ATC training.

Traditionally, workload management is introduced towards the end of a training course, allowing students to initially focus more on carrying out individual tasks and mastering some of the skills such as applying separation standards correctly, vectoring, speed control etc. Then as the traffic loading is made busier and more complex, the associated workload inevitably increases and the skill of workload management is introduced in training. This requires students to consolidate what they have learnt up to this point and to continue to apply the "individual task-based skills" along with some new tips and techniques from the instructors for use when the workload is high. Many discover important new aspects of the skills which they thought they had mastered by this point in training, such as building in safety buffers, or at times opting for less efficient solutions. Many others, however, find it very difficult to adjust to the new conditions and to understand why some of their skills are no longer working as they were before. A typical instructor assessment would in this case blame the student's lack of ability (simultaneous capacity) required for the job. Whilst

such a remark might be true in a small proportion of cases, more often than not, we fail to understand the real reasons for the insufficient performance.

Competency-based training offers an alternative to the traditional way of teaching workload management. Within this concept, the workload management is addressed from the very beginning of the training as a core ATC competency. Regardless of the traffic level or the individual training objective, the ability to manage personal workload is treated as a part of the job. The emphasis throughout training under this system is on what the final performance should be, integrating the knowledge, skills and attitudes required to perform the task (the provision of an ATC service) to the prescribed standard.

Usually, a competency-based assessment is made on the basis of the different levels/standards of performance reached progressively during training, which allows students to build up their competence until the finally-required level of performance is achieved. But how do we know that a student has reached the desired performance level in terms of workload management? Typical performance criteria (in terms of observable behaviour) which are associated with work-

load management are listed below:

- manages personal efficiency and work tempo by proactively adapting solutions
- limits the number of simultaneous actions and ensures their timely completion
- prioritises and schedules tasks;
- manages interruptions and distractions effectively;
- builds in appropriate safety buffers into control actions;
- organises traffic flow according to traffic complexity by using direct routings, initiating actions early and avoiding excessive vectoring;
- asks for and accepts assistance when appropriate;
- delegates tasks as necessary in order to reduce workload;
- selects appropriate tools, equipment and resources to ensure the efficient accomplishment of tasks.

Although the above list is only provided for illustrative purposes, we can already see a number of benefits which it offers over the traditional approach. For example, the prioritisation of tasks and work tempo and the proactive approach are questions of attitude which need to be trained from the start. Although at the beginning of training, low traffic volume and complex-



**What you need right now is a hot bath, an hour of relaxation yoga, a good meal and a glass of wine, but you know that's impossible... So a 5 minute cigarette break should do...**

ity mean that the method might not make a huge difference to the overall outcome, it is important to insist on the execution of tasks according to an appropriate priority and with a pro-active focus. As traffic levels and complexity increase, the desired observable behaviour remains the same.

For the same reason, selecting the most appropriate tools and equipment for the task is another aspect which might be considered for early introduction in training. It could be argued that students must learn how to use all the tools at their disposal, and that allowing them time to experiment has no impact on the overall outcome of a simple exercise or during periods of low traffic volume and complexity. This is probably true, but it is also a fact that in this case we will be missing out the attitude element of the competence, i.e. considering the use of different tools then always picking the one most appropriate for the task.

Another good example is how students deal with interruptions and distractions. Apart from teaching students the knowledge and skills needed to resolve situations in the event of interruptions, we also need them to develop a conscientious attitude towards routine and effective resolution of interruptions and distractions. This is possible only if they can manage interruptions and distractions consistently and using the same techniques, even during periods in which there is plenty of time available and no real pressure to carry out other tasks. To put it simply, if the time is available, it is not acceptable to waste it.

How do we teach future controllers to ask for help when they need it and/or accept such help when it is offered, and how do we teach them to recognise a situation in which it is appropriate to delegate tasks? If we wait until students are overloaded and there is no solution other than delegation or seeking assistance and by then it is probably too late. If a student has never delegated a task before, it is highly unlikely that he/she will do it at times when the workload and the complexity become too high. However, if such judgements are integrated into training right from the beginning, students can opt for these actions a lot earlier and learn to appreciate both the potential benefits and likely consequences, there is a lot better chance of success.

Teaching all aspects of vectoring at all times is also a better option. Admittedly, vectoring is not a simple technique and it requires the development of a number of individual sub-tasks (usually on a part-task trainer) at an early stage of the training, but once these sub-tasks are well established, the aim should always be for the control-

ler to achieve a desired outcome using the least possible number of control actions while also minimising any additional track miles which the aircraft must fly as a consequence. If this approach is applied consistently, it is not a problem to avoid excessive vectoring and to limit the number of simultaneous solutions during busy periods.

I am sure you can think of many other examples in your own environment in which it makes more sense to approach workload management training in an integrated manner even though this might seem difficult at first sight.

Looking at these examples, it is easy to see that workload management is quite complex and that a controller probably needs more time to develop this core ATC competence. However, despite its complexity, we can focus on these aspects of behaviour from the very beginning of training. Addressing workload management in a practical and integrated manner gives us a lot more time to teach and then consolidate the required skills and attitudes. In addition, this method provides an early opportunity to identify weak performance in workload management and gives us enough time to address any difficulties with personalised remedial action. ■



## 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.



# Your team is likely to be the key

by Adrian Bednarek

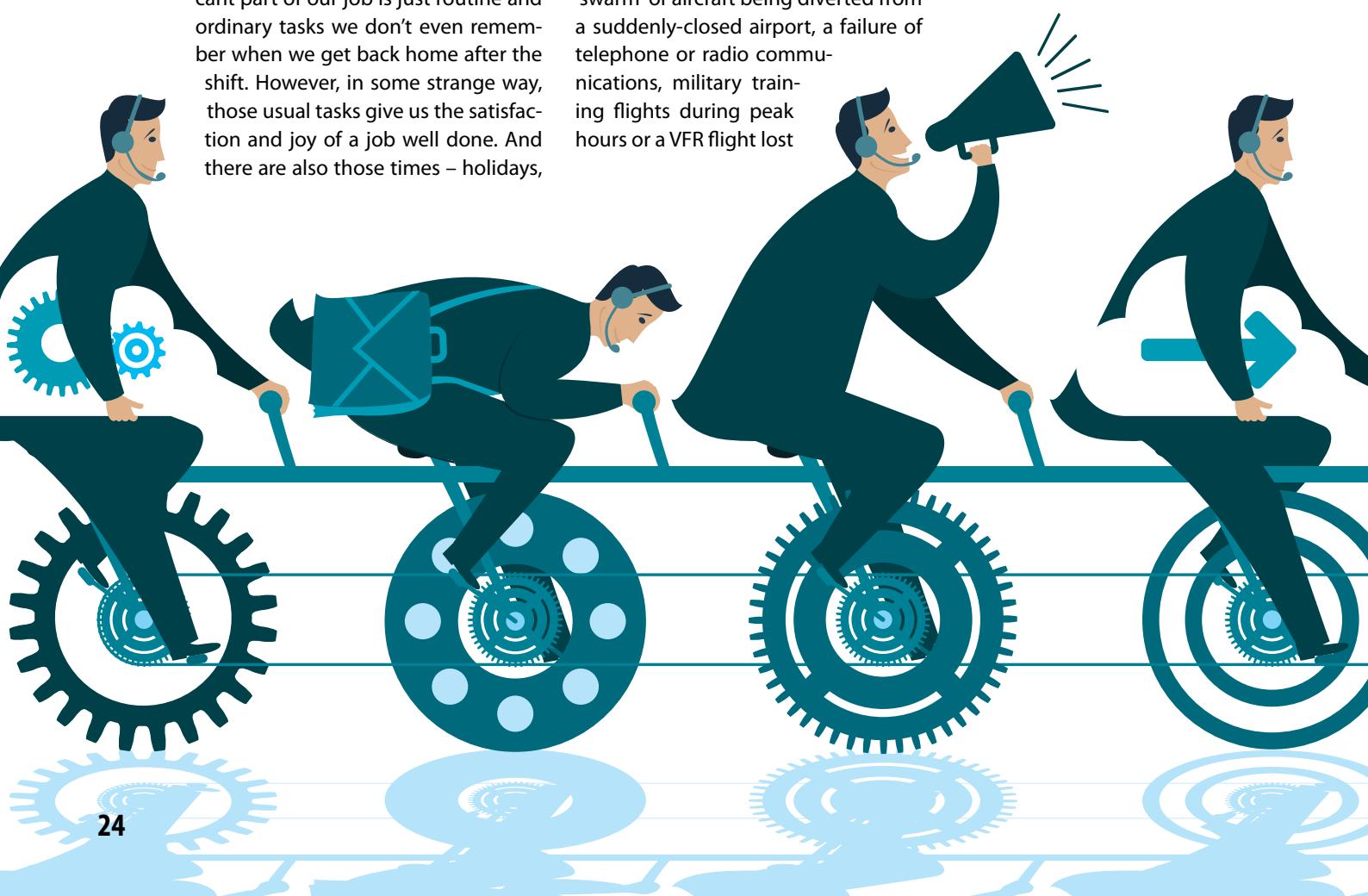
It is a common belief that an air traffic controller's profession is one of the most stressful jobs in the world. But actually, I am more inclined to agree with another opinion common in the controller community – that our job is 90 percent daily routine and 10 percent of rapid heartbeat.

If we took a closer look at those figures, we would quickly discover times of unwelcome boredom and monotony interspersed with short intervals of total panic and bewilderment. Clearly, the balance between these would differ if we took some additional factors into account – controller experience and age, type of service being provided, level of traffic, available equipment. But what we would see is that significant part of our job is just routine and ordinary tasks we don't even remember when we get back home after the shift. However, in some strange way, those usual tasks give us the satisfaction and joy of a job well done. And there are also those times – holidays,

night shifts on Saturdays or days when some Icelandic volcano with an unpronounceable name erupts – when I wonder if my presence in the ops room was even noticed. These are the times when minutes become hours and hours become infinity. At the other end of the scale are those short seconds and minutes which passed in the blink of an eye and turned some of my hair grey. Maybe an unexpected 'swarm' of aircraft being diverted from a suddenly-closed airport, a failure of telephone or radio communications, military training flights during peak hours or a VFR flight lost

in cloud and not visible on a screen.. I'm sure every controller can easily recall moments like those and will remember them for a long time.

Workload which has been identified as 'too high' or 'too low' is something not desirable in any human activity, especially in high risk activities. Both of these situations have specific hazards associated with them, which are direct consequences of the fact that people don't like to be bored and neither do they like to face situations which require extraordinary effort. That can raise several questions, starting with the most obvious one: how do you measure workload? Are there any reliable data available? Who would set the limits of an acceptable workload and how?



**Usually, he or she is a part of a bigger group of individuals – a team of controllers, assistants, unit or shift supervisors as well as various other people who are physically in the same room...**

**This is the environment where complex interpersonal relations grow, where friendship and hostility emerge and, finally, where our job gets done every day.**

One could perhaps use a simulator to help answer those questions but even that wouldn't be a perfect tool yielding a clear picture. There are too many variables and interactions which cannot be readily simulated – at least not at a cost proportional to the benefit. What would happen to workload if one particular phone line went dead? What if our airspace becomes a favourite destination for the training flights of nearby flight schools? What if it turns out that Tower windows fog up or there are so many reflections in them it's not possible to see anything outside at night? And what about low workload? It's almost impossible to test such conditions in a simulator.

As a result, even if you assume optimistically that all resources are being used efficiently and everyone else is doing everything correctly, there is no guarantee that your working environment will perfectly match the needs of your

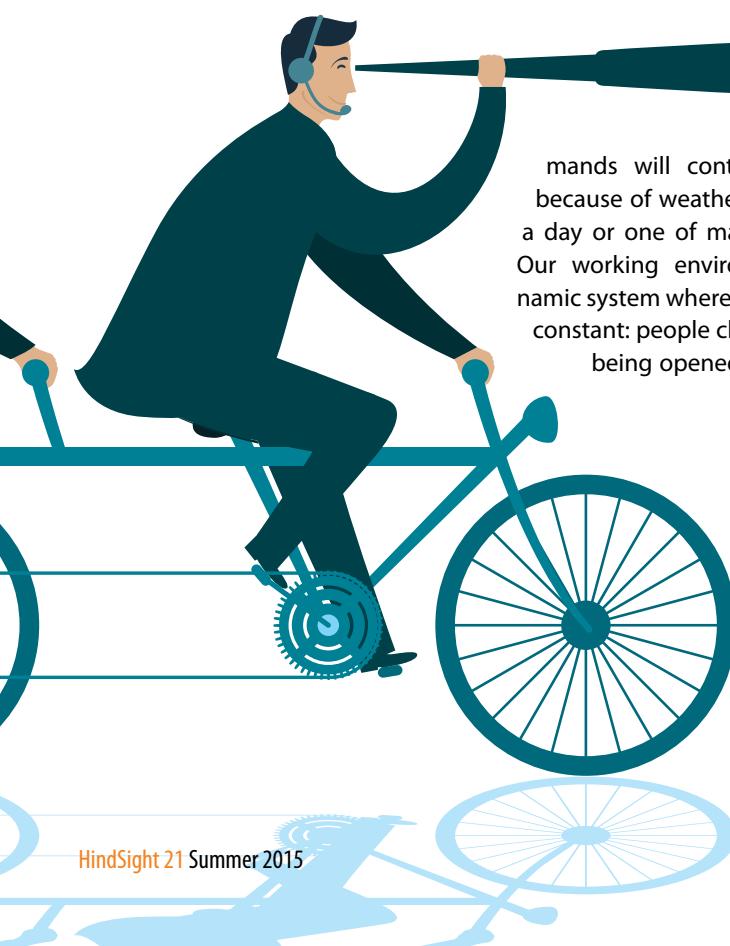
fluctuating workload. But you can be sure that those demands will continuously change because of weather, season, time of a day or one of many other factors.

Our working environment is a dynamic system where almost nothing is constant: people change, sectors are being opened and closed, traf-

fic flows in unpredictable ways, equipment fails and weather doesn't want to follow forecasts. It is not possible to respond to those changes merely with regulations and procedures. In the end, there is always a human operator – the air traffic controller sitting there in the ops room – who has no other option but to find a way to cope with those issues in real time.

Usually, he or she is a part of a bigger group of individuals – a team of controllers, assistants, unit or shift supervisors as well as various other people who are physically in the same room. These are the people we interact with for several hours a day, several times per week. This is the environment where complex interpersonal relations grow, where friendship and hostility emerge and, finally, where our job gets done every day. This is also the place where mechanisms for coping with workload problems are being created. Those formal and informal methods can differ from place to place but I am sure that every person in your ATS unit makes use of them, maybe even without being aware of it. We have known each other in our teams for several months, quite often for years. Unlike the pilots in big airlines, it is unusual for most controllers to work with somebody whom they don't already know. We've been seeing our colleagues doing their jobs for a very

►►



**Adrian Bednarek**  
works in Krakow, Poland as an air traffic controller and a safety manager, focusing on safety culture and practical drift in organisations. He has university degrees in safety engineering and aviation.

Your team is likely to be the key  
(cont'd)

long time and we know what their usual way of working looks like. We're also the first people to notice how the workload (both high and low) changes their behaviour...

When things become more complicated than usual, we may see them moving closer to the screen; they stop talking to us and – quite often – they stop listening. We may see them overlooking an aircraft, momentarily missing some actions which are obvious to us. Perhaps their faces blush or they start to fidget or stamp their feet! Being an incidental observer gives us an opportunity to focus on the situation while being released from the burden of decision making, listening and talking. At the same time, a controller doing his or her own job can be tempted to ignore all of the symptoms of 'overload' in order to get the job done and to protect their feelings of personal pride and professionalism. Plus, if the workload level increases gradually, controllers directly involved may not even notice the change at its early stage.

I remember one afternoon when I was just a rookie being trained for my radar rating. Traffic was low so there was only one sector open with me working as an assistant and an experienced colleague as an executive controller. The rest of the team were on their break, waiting for a phone call in case we needed any assistance. Suddenly, our flight strip printer woke up and started to spit out new arrivals, one after another, until they formed an impressive pile at the controller's strip bay. There were a lot of aircraft heading our way and I began to worry we wouldn't be able to deal with all this on our own. But when I asked if we should call for help, the controller answered with a simple "no". Before long, I was able to see all the symptoms of high workload appearing: lack of plan, chaotic actions, overlapping transmissions, ask-



If he doesn't blink in the next 5 minutes it means that we have to split the sector...

ing for repetition, giving impossible-to-follow instructions etc. It took me a while to get the courage to ignore the controller's refusal and call for help myself.

If I had done it earlier, we would have avoided the embarrassment and confusion but, as always, it was only easy to say so with hindsight... At the time, the situation was not so clear and alongside me was a much more experienced controller saying 'no'. He was also well-known for having unconventional working methods and I was pretty sure that he knew what he was doing. He was also an OJTI and I was afraid that not following his instructions would have a counter-productive effect on my future training progress. But even taking situations such as that into consideration, I am still convinced that our closest co-workers are the place we should look for help. In most cases this method will rely on interpersonal interactions and social connections within the team.

Getting help from other people is the easiest and the most effective way of dealing with high workload. Additional staff can open a new sector (as long as such a possibility was foreseen by the management) or take care of

additional coordination (as long as someone had thought about having an extra phone line available) or provide you with an extra pair of eyes which will warn you about the risk before the short term conflict alert does. But the challenge is to know when to call for help and who should make that call. Unfortunately, formal procedures quite often leave that to the controller himself yet he or she might be the last person to notice the symptoms of their high workload. We also have to recognise that making that decision very early is crucial, as some of the possible responses like opening new sectors and briefing an additional controller will themselves briefly add to the workload.

What does it look like in your unit? Who makes the call to get some extra staff? How can you reach those people? Are there specific steps to follow when opening new sectors? Do you need to switch your voice communication system? Do you have a checklist for it? How long will it take to action?

When working as a pair, one planning controller and one executive controller, it may also be a good idea to think how those controllers can support each other during high and low

workload periods. For example, when the majority of the traffic is already in the sector, a planning controller can provide an extra pair of eyes. He or she can simply point out a developing conflict on the screen when the executive controller is focused on problem-solving somewhere else. The problem is we usually don't have clear rules on how to provide such help or how to accept it. This also applies to situations when a planning controller needs extra support from another person in your team. It would help a lot if you had your support action plan sorted out before it is actually needed. Setting clear, but very often informal, rules can greatly improve your team's performance in such situations. If you don't have such rules you're risking an avoidable additional increase in workload caused by the need to assign and clarify individual parts of your job to your colleagues.

## When working as a pair, one planning controller and one executive controller, it may also be a good idea to think how those controllers can support each other during high and low workload periods.

Low workload situations, on the other hand, can be more tricky to detect. Yawning or closing of the eyes are obvious symptoms for others to watch out for. But before that, we should be able to hear controllers starting to talk about things not related to their work, or maybe not talking at all. We may also notice that people move their chairs further away from the screen

and sit in more relaxed ways than they would usually do. Sometimes an aircraft is forgotten, especially when it has already flown off the screen. Sometimes, we may also see some of those symptoms affecting ourselves. And we might feel bored and count every minute for that aircraft to leave our sector. At times like this, everything and everyone in the ops room easily gets our attention. Quite often, we also use these moments to perform experiments, like applying minimum separation even when it's not necessary. Or just leaving the situation on its own just to see if it's going to 'resolve itself' instead of applying simple pre-tactical resolution. Our vigilance is effectively relegated to stand-by mode and we need extra time to adapt to any new and more demanding situation.

The problem of low workload can be defined in a very simple way – people don't like to be bored and when they are, they tend to do something silly. Once, I heard a story about one European ANSP experiencing a mysterious series of trackball malfunctions at one of their ACCs. Their technical staff couldn't figure out why those fairly reliable devices kept failing on a regular basis. It took them some time before they found an answer. Controllers working night shifts at that centre had been so bored that they had invented a game in which they were using their trackballs. The goal of the game was to move a cursor to a chosen position on the other side of the screen with one powerful punch. It's hard not to agree that idle brain is the devil's workshop, isn't it?

So, how can we cope with the effects of low workload? As always, it's all "common sense". Consider scheduling all non-routine activities (military training, calibration flights, navaids maintenance) for specific periods of a day or a

week. If your airspace and equipment allow you can try to collapse sectors and close supporting services to keep yourself busy enough. If you're terribly bored, you can try to invent a kind of mind game which will keep you looking at the screen such as estimating distances between aircraft or navaids. That might be especially helpful for students during their OJT when the traffic level is low. Another possibility is trying to set up a kind of routine in your mind which involves a specific timeframe for making a cyclic scan of your radar screen, even if it's empty at that time. The same can be done in the TWR environment by periodically scanning the runways, taxiways, or the ground surveillance screen, verifying that you know which vehicle is going where. Think of this as though you are preparing for position handover all the time and you need to be current on every detail of current the situation in order to determine what would merit inclusion in a handover brief. And on the subject of handover, it also might be a good idea to shorten low workload shifts and rotate team members more often thus leaving less time for boredom.

Of course, it is up to you and your colleagues to decide what solutions will work best for variable workload in your local environment. Our job, whether we like it or not, is based on teamwork in complicated socio-technical system. Workload measurement in such systems is neither easily measureable nor predictable and the perception of it is highly subjective both in respect of self-perception and in the observation of others, since both depend on individual character and approach to task. Crucially, it is this that means that controlling workload from a high managerial level may be very difficult, or even impossible. The place where it can be really dealt with is at the sharp end – in your ops room. 

# Self-induced workload caused by poor communication

by Peter Hudec

Workload is very wide term and there are a lot of factors that can affect it. Such as aural/ visual (static and dynamic) information processing, the balance between traffic load and its movements and airspace complexity, the man-made environment (e.g. route structure and working position design and the way a position facilitates actions, for example interacting with radar by means of a keyboard and mouse), relevant change in the natural environment in the form of adverse meteorological conditions such as thunderstorms, fog, icing), co-ordination methods, overall availability of support equipment and many more. But workload can also be influenced by personal variables, such as performance instability arising from age, experience, skill, etc. In this article I am going to address the potential for avoidable increase in communication workload which is sometimes caused by controllers and how this may interact with efficiency and safety.



## Peter Hudec

became an ATCO in 1983 and an executive supervisor in 2005. He finished his TWR/APP and supervisor operational post at Bratislava, Slovakia at the end of March 2015. Since 1995 he has been working in various positions related to safety investigation and supervision and currently works for the ANSP Safety Division as a Safety Specialist.



Generally, every time we have to repeat something – "say again" – our communication workload is increased. What we could say in a single transmission, now needs repeating once, sometimes twice, sometimes three times, until we achieve an understanding of the transmitted message by the recipient.

This kind of communication workload increase may occur for a variety of reasons:



**In ATC, we often speak more quickly (between 140 and 160 words per minute) than is recommended in ICAO ANNEX 10 Volume II<sup>1</sup>.** The Recommendation that "controllers should be encouraged to speak slowly and distinctly", is still valid, but the volume of traffic, efficiency and capacity sometimes encourages us to speak faster, so that work as imagined (WAI) is different from work as done (WAD). This is an increasing problem. In a busy sector, communication blocks recorded by a logging system might look like this:

Busy in this context means that those white gaps between transmissions on the frequency are very narrow (just a few seconds), so that the only way you can accommodate more communication without eliminating these gaps altogether is to speak more quickly when you transmit. If you try to accommodate more transmissions by narrowing the gaps between them, you have to be careful not to 'step on' and thus block someone else's message which you are not necessarily expecting.

## Speed of Speech

As we speak faster, we may not be able to pronounce words, letters and numbers with sufficient clarity and thus the recipient does not correctly understand the message. This problem can be aggravated when it is combined with the effects of a local accent unfamiliar to the recipient. The result will be a higher probability

that we will hear requests for repeat or get a wrong readbacks from pilots that will have to be corrected. We may even not detect such wrong readbacks – but that is another story.

## Phraseology

From time to time some controllers use non-standard phraseology "to save words and time" so as to be more efficient, which can have the opposite



Action	Date	Time from	Time to	Duration
	2015-02-24	08:43:15	08:44:37	00:01:22
	2015-02-24	08:45:04	08:47:59	00:02:55

00:10 00:30 00:30 00:40 00:50 01:00 01:10 01:20 01:30 01:40 01:50 02:00 02:10 02:20 02:30 02:40

**1 - Paragraph 5.2.1.5: "Transmitting technique", Paragraph 5.2.1.5.2: "Transmissions shall be conducted concisely in a normal conversational tone, a) enunciate each word clearly and distinctly; b) maintain an even rate of speech not exceeding 100 words per minute. A slight pause preceding and following numerals makes them easier to understand; c) maintain the speaking volume at a constant level"; etc.**



## Self-induced workload caused by poor communication (cont'd)

effect when they subsequently have to repeat a transmission that was not understood due to an incorrect or unexpected format such as leaving out the word "decimal" in a frequency change. Some examples of time lost merely by the latter are shown in EXAMPLES A,B, C.



### Some ATCOs use numbers within a single message for more than one purpose

- clearances to climb or descend together with frequency changes<sup>2</sup>. This increases clearance complexity and may lead to wrong readbacks or requests to repeat. This is mostly

because of the need to get the job done very quickly doing two things together saves transmission time by avoiding the need to address the same flight twice in quick succession. The Recommendation: "Controllers should be encouraged to keep their instructions short" also supports the separation of such instructions.

#### EXAMPLE A

**Controller:** XYZ6KH resume own navigation, contact Bugen 13289, good bye

**Pilot:** 132 decimal 9, good bye, XYZ6KH.

**Controller:** Decimal 89 and resume own navigation.

**Pilot:** 128 decimal 9 and resume navigation XYZ6KH.

**Controller:** 132 decimal 890.

**Pilot:** 132 decimal 890 XYZ6KH.

*Note that saving the one word 'decimal' led to the use of 37 additional ones.*

The more complex a message is, especially if it contains a lot of numbers, the higher the probability that a wrong readback will occur. Sometimes such a readback error may not be picked up and a loss of separation may follow. Examples of this creating additional workload shown on D and E.

#### EXAMPLE B

**Controller:** XYZ7343 12037 good bye.

**Controller:** XYZ7343?

**Pilot:** XYZ7343, go ahead sir.

**Controller:** 12037 good bye.

**Pilot:** Say again the frequency, XYZ7343.

**Controller:** 12037.

After 40 seconds:

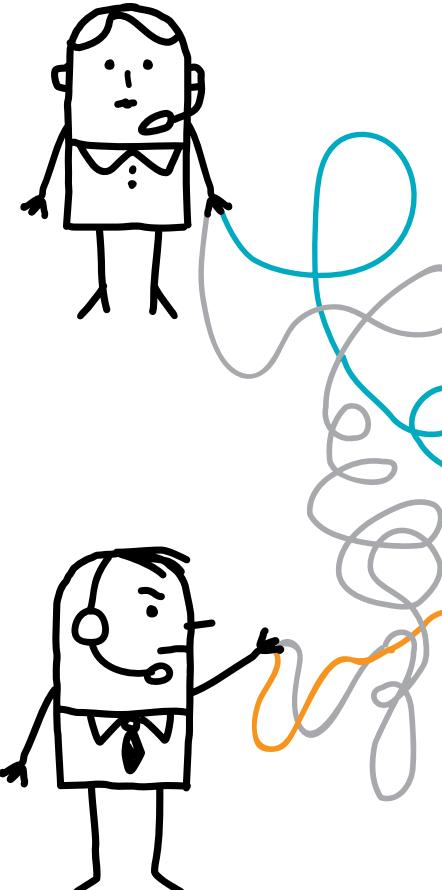
**Pilot:** Sorry sir, you have confused us, XYZ7343.

Can you say slowly the frequency?

**Controller:** 120 decimal 375.

**Pilot:** 120375 thank you, XYZ7343.

*Note that saving the one word 'decimal' led to the use of 58 additional ones.*



#### EXAMPLE C

**Controller:** XYZ361 contact Bugen Radar 132890 good bye.

**Pilot:** Say the frequency again for XYZ361.

**Controller:** Frequency 132890, ahoj.

**Pilot:** 13890, XYZ361.

**Controller:** Negative sir, 132 decimal 890.

**Pilot:** 132 decimal 890 for XYZ361.

*Note that saving the one word 'decimal' led to the use of 35 additional ones.*

2 - This is not consistent with the Recommendation in the "European Action Plan for Air Ground Communications Safety" Part 5.2 "Best practice for ATCOs", Paragraph 5.2.1.1 which says "Do not pass RTF frequency changes as part of a multi-part clearance".

## EXAMPLE D

**Pilot:** XYZ829, request descent.

**Controller:** XYZ829 descent to FL290, change Radar 134 decimal 475, good bye.

**Pilot:** Descending FL270, change frequency 134 decimal 475.

**Controller:** 290 flight level and 134 decimal 475.

**Pilot:** Descending FL29 and 134 decimal 475, XYZ829.

*Note that saving the one word 'decimal' led to the use of 28 additional ones.*



Some controller transmissions are not easily readable because of their improper use of the microphone/headset – yet another reason for having to repeat the message.

## EXAMPLE E

**Controller:** XYZ2347, Bugen?

**Pilot:** XYZ2347, go ahead.

**Controller:** Contact Willy 120 decimal 550 and descend to FL120.

**Pilot:** 120550, descending level 100, XYZ2347.

**Controller:** Descend to FL120.

**Pilot:** Say again?

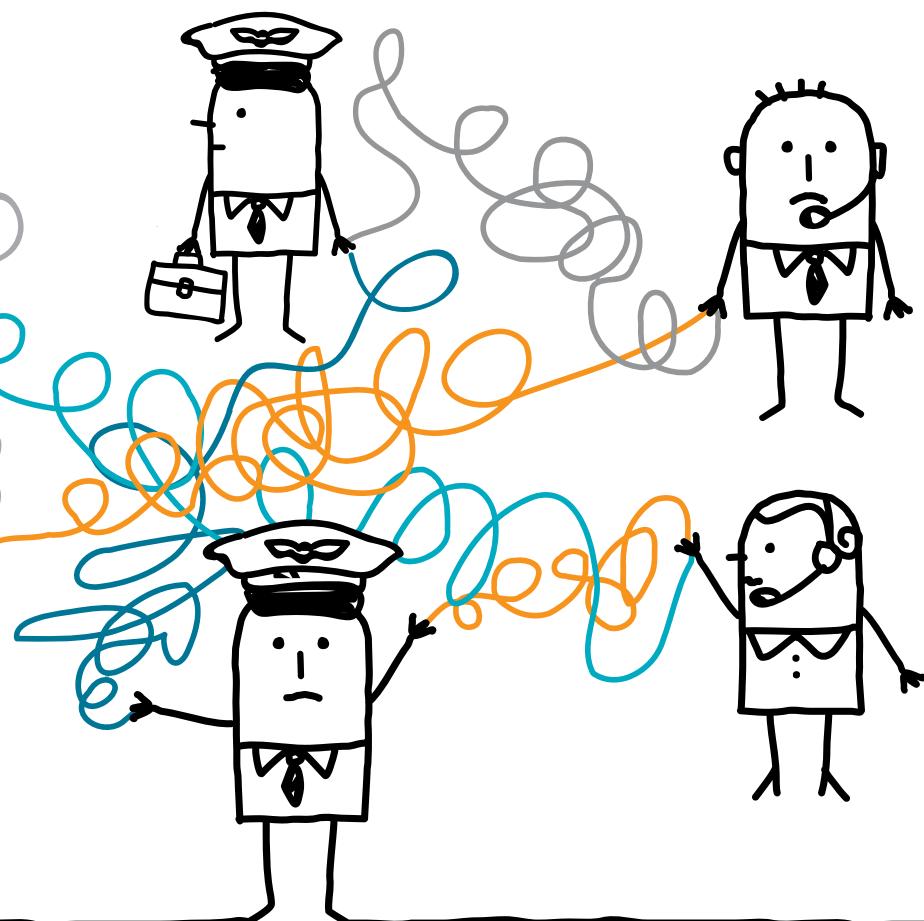
**Controller:** Descend only to FL120.

**Pilot:** Sorry, descending FL120, XYZ2347.

*Note that saving the one word 'decimal' led to the use of 33 additional ones.*

So you can see that any communication that is not understood by the recipient can needlessly increase workload both directly (more time used for a task) and indirectly (less time for other tasks). It can even create work itself – more time spent focusing on pilot readback – your hearback) means more active listening. And effective active listening always requires effort and energy.

At the beginning, we saw that saving words could be seen as saving time so as to be more efficient but I hope that now we appreciate that the result of such action can have the opposite effect. Time is our friend – it can work for us – but it is also our enemy – it can work against us when things are not going as planned. And it is not only just a matter of increased workload because the delivery of operational safety can be affected too. It seems there is a relationship between **workload** (in this case communication workload), **efficiency** and **safety**. Therefore communication has to be used very wisely to keep these three factors in balance as time passes and circumstances change. 



# See who is talking!

by Tom Goossenaerts

Several ATC occurrences find their origin in the gap between the situation as perceived by the Controller and the real air traffic situation picture. The causes leading to this misinterpretation are various in nature. The consequences however are usually the same: a lot of precious time is lost before the ATCO has a correct view on the situation...



## Tom Goossenaerts

has a MSc in telecommunications technology and has worked on various – mainly military – avionics systems and on ground-based communications equipment for several years. He joined EUROCONTROL in 2005 as team leader of the Voice Communications Team at MUAC. In 2010 he moved to the project management unit where he became responsible for leading the NVCS project, the joint DSNA-MUAC EUROCONTROL procurement initiative.



I know that this is a stop gap solution to reduce misunderstandings, but I'm looking forward to the day when we'll have CPDLC...

Not rarely drastic measures are needed to ensure adequate separation. The effects here are both safety risk and impact on the workload of Controller. Additionally one can argue that this creates an impact on the workload for Pilots as they are at the end of the separation assurance chain.

## But what are the typical scenarios we are talking about?

A typical case in which such incorrect image is mistakenly taken for the correct one is 'callsign confusion'. A Controller issues a clearance to an aircraft yet a different aircraft replies, assuming the clearance was intended for him. The pilot of the first A/C may not react since both the ATCO and the pilot of the second (replying) A/C are under the assumption that they were communicating to the correct party. Neither of them is correct however. Alternately, both aircraft pilots reply simultaneously and the incorrect reply is masked on the frequency and not noticed by the Controller. The situation initially passes unnoticed, still often results in a single or even a double conflict (the instruction is followed by the not intended aircraft and not followed by the intended one). In a number of cases a second conflict kicks in as the second A/C is following an unintended trajectory.

Another case, irrespective of similar callsigns, is a mental confusion by the ATCO of the aircraft addressed. The ATCO looks at an aircraft, gives instructions to it and manipulates the flight data of it seeing its callsign but always considering it as another one. It may seem like an impossible scenario since all information is correctly displayed; still it happens. Moreover it is one of the most dangerous ones as the read-

## Presentation on CWP:

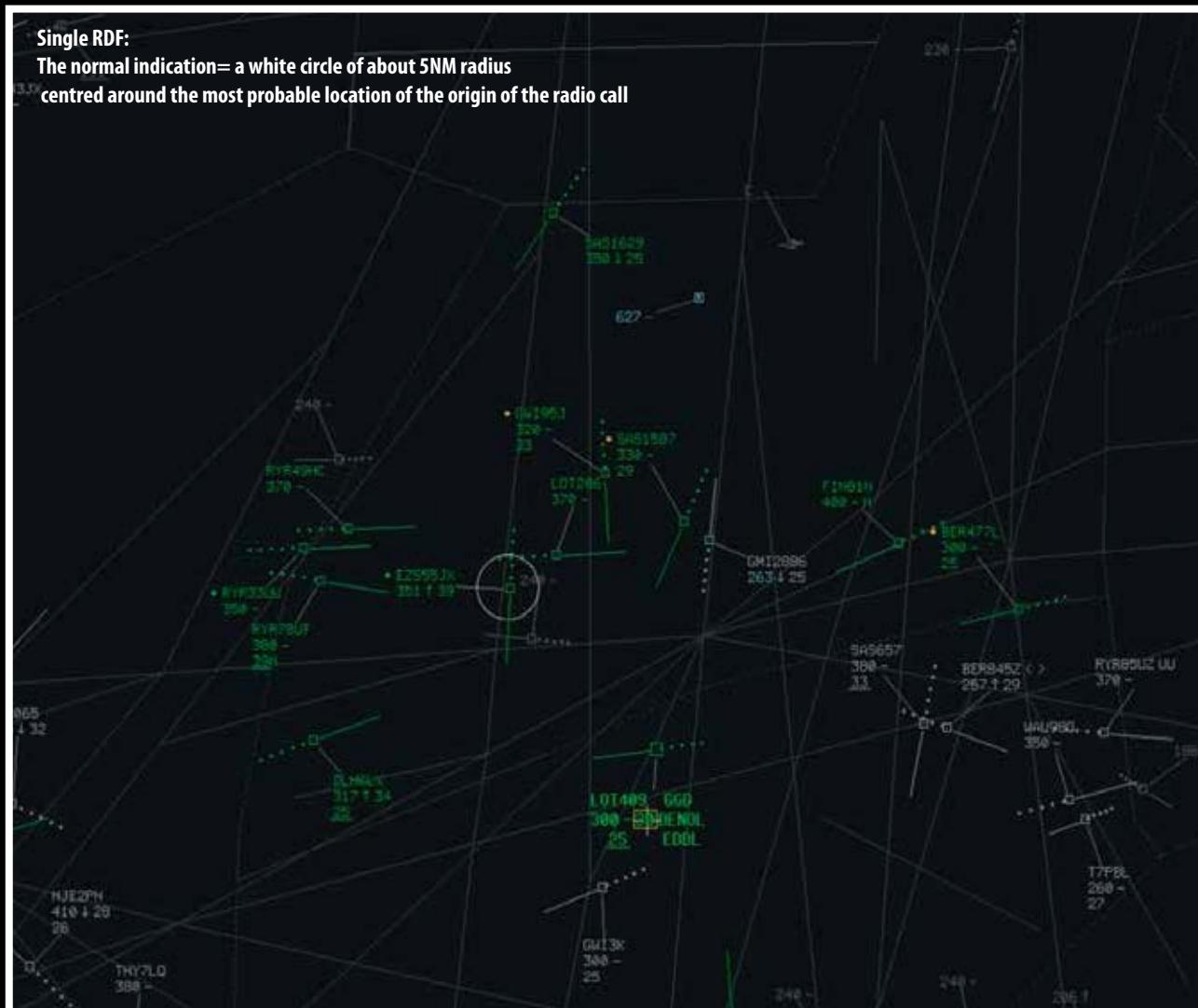
All possible RDF indications:  
overview of the possibilities we plan to foresee in the HMI

- Upon a successful triangulation the following symbols will be displayed around the calculated position

- Single calculated RDF transmission
- Multiple calculated RDF transmissions at the same time
- RDF calculated – OFF screen
- Last calculated RDF transmission
- RDF transmission on an Emergency Frequency
- RDF not able to calculate position
- RDF able to calculate position only from one radio site

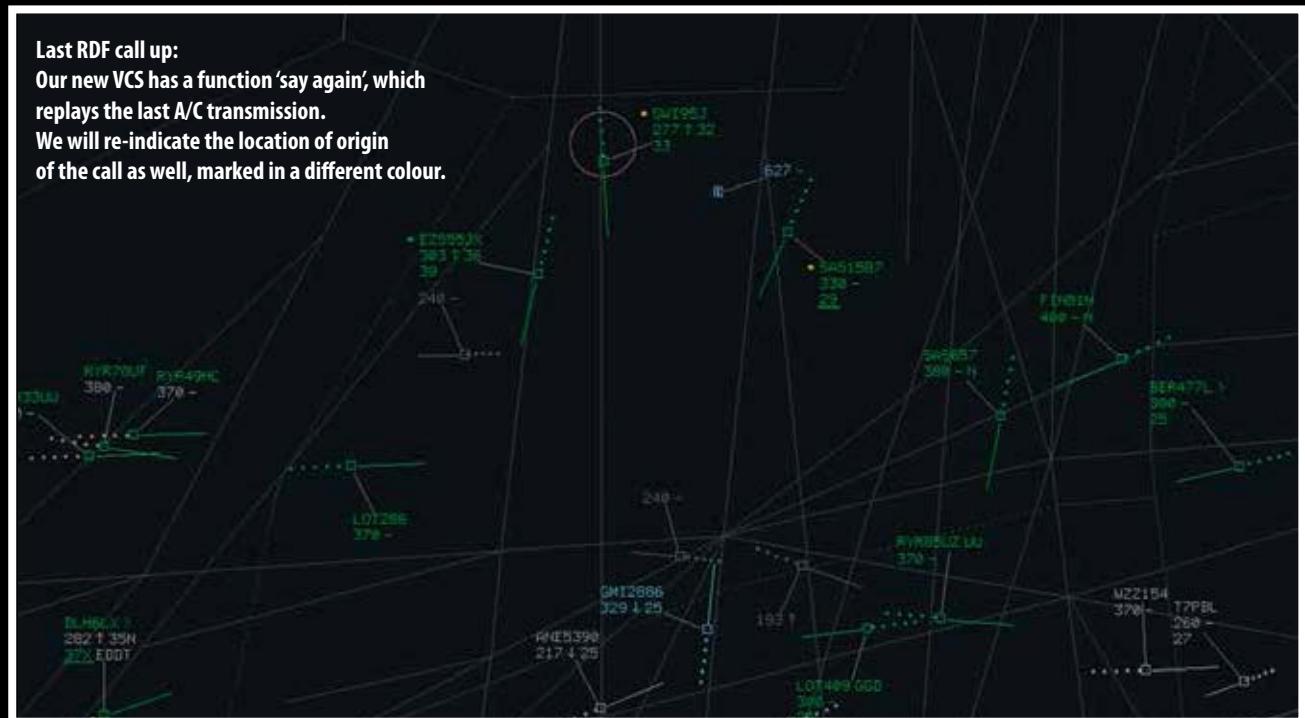
back is correct from the correctly addressed aircraft but not the from the intended surveillance target the ATCO was focusing his attention at.

As demonstrated, a major drawback of ATC communications is the fact that voice communications are still the ATCO's primary tool for providing clearance instructions. Whereas the radar screen displays a very accurate air traffic picture, the ATCO has absolutely no visual feedback with respect to the originator of a pilot-to-ATCO voice call.





See who is talking! (cont'd)



We all know the drawbacks of air-ground communications, but is there any reliable solution on the horizon, apart from telling the Controllers to be more careful when they speak and listen?

One way to increase the awareness of the ATCO in the area of voice communications, and hence to prevent conflicting situations rather than to resolve them, is to provide the ATCO with fast, clear and accurate information on the area where a radio call has been initiated from. In other words – to help the controller to see who is talking and to increase the reliability of the detection by combining audio and visual perception information streams.

ATC radio calls transport no other information than the RF carrier and the 2 amplitude-modulated sidebands containing the voice signals. As a result it is impossible to extract any geographical information directly from the signal. This information will therefore have to be produced in an indirect way.

One means to bring forward this information consists of an array of Radio Direction Finders (RDFs) working together. The technology behind Radio

Direction Finders is nearly as old as radio itself: radio beam tracking devices have been available on the market for many years.

Nevertheless, only few implementations are known in which the information of multiple individual radio direction finders is combined to provide a continuous flow of triangulated positions.

MUAC launched a dedicated project to implement Radio Direction Finders of the current generation, capable to provide a fast and accurate calculated fix of a transmitting aircraft and as such to deliver the operational benefits.

MUAC has executed some tests with RDF devices installed on 2 sites and this on limited as well as full capacity. Having a good system may be totally jeopardised by a dysfunctional HMI. Ultimately, the already overloaded surveillance screen of the Controller

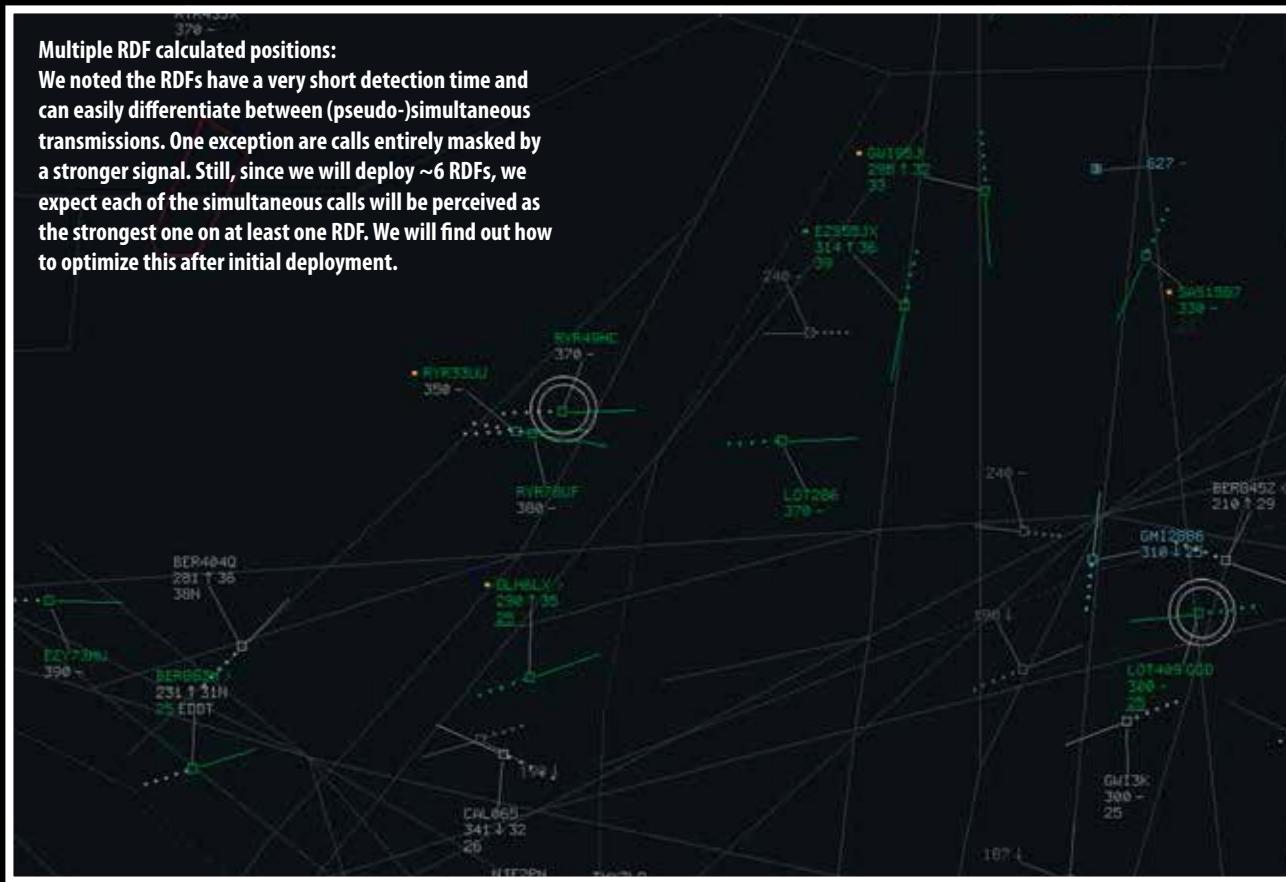
should also integrate the new information. Here after are some screen shots to demonstrate how the concept of RDF would appear in the "real world".

We often tend to think that if you do something it is for a single reason, that there are single causes explaining the events and actions. This way of thinking can be also sometimes deduced from conversations and discussions about investments in ATM system. We either invest in system functionality to improve efficiency and reduce flight delays or in safety nets and safety-supporting features. But sometimes we can "hit" both objectives. Having RDF functionality is one of these examples. It clearly supports safety and it helps at least one routine and frequent task of the Controller – to identify where the communication originates. Reducing the cognitive effort for this task and decreasing the time required for sure helps the controller to be more efficient with all the other circumstances being the same.

**And, yes, I am talking to you Decision Makers – help the Controller to see who is talking. This is not a small talk. S**

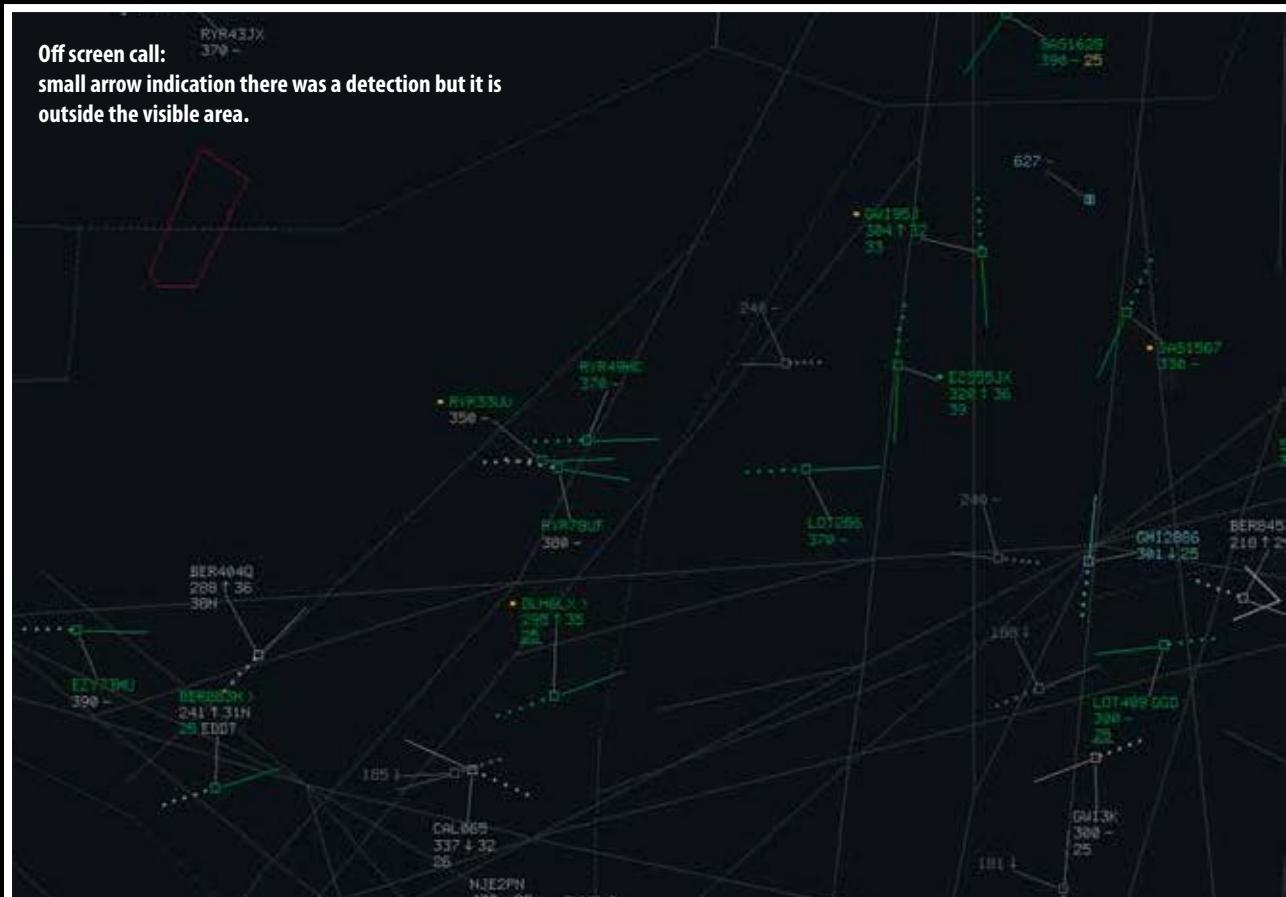
**Multiple RDF calculated positions:**

We noted the RDFs have a very short detection time and can easily differentiate between (pseudo-)simultaneous transmissions. One exception are calls entirely masked by a stronger signal. Still, since we will deploy ~6 RDFs, we expect each of the simultaneous calls will be perceived as the strongest one on at least one RDF. We will find out how to optimize this after initial deployment.



**Off screen call:**

small arrow indication there was a detection but it is outside the visible area.



# Workload: getting it to work

by Yoram Obbens and Rob Bezemer

On 16 March 2015, a system for predicting controller workload was introduced for Amsterdam ACC operations. Now, ACC supervisors have the ability to use workload data to:

- manage ACC operations;
- make decisions on sector configurations;
- consider staffing options;
- intervene timely to prevent controller overload;
- consider traffic regulations

This is a significant step in modelling and predicting of controller workload for Amsterdam ACC operations. It is part of a larger project that started within Luchtverkeersleiding Nederland (LVNL) almost a decade ago.

How did LVNL develop a prediction model and implement it on a daily operational basis? What is the impact on operational safety and performance? And for what other purposes is this model used? Let us share our experience.





## Workload: from past to present

Until 2005 LVNL relied mostly on the judgement of controllers to assess the impact on controller workload of major airspace changes and projects. Understanding of this impact is important for assessing the effect on sector capacities and assuring safe operations with adequate performance for the airlines. Although the use of expert judgement can be very valuable, it is subjective and can be inconsistent. Subsequently, the need has arisen to assess effects on controller workload for major airspace changes using a quantitative method.

### Strategic use first

The development of a Workload Model (WLM) for Amsterdam ACC operations began in 2006 as a research project. In the early years, the model was developed and validated with operational data – various data sources were used for this purpose. Results showed that WLM performed better when predicting executive controller workload compared to other traffic count metrics like sector entries or occupancy.

Based on these results, WLM development accelerated in 2008 and 2009 and was used in major strategic airspace projects, for example the AM-RUFRa project. Since then WLM has also been used in numerous airspace changes to assess the effects of temporary changes or special events like the 2012 London Olympic Games and the 2014 Nuclear Security Summit in the Netherlands.

### WLM for operations

Traditionally, supervisors and FMP controllers use traffic counts to predict controller workload. However, during WLM development, the opportunity for operational use of the model was identified. To determine the usefulness of WLM in daily ACC operations, a separate project began in 2012. From non-operational trials conducted in that same year, it was concluded that

the model could add value as a support tool for ACC supervisors and FMP controllers. Benefits identified include:

■ **Sector management:** managing sectors, their configurations and staffing. With workload information readily available, situational awareness of ACC supervisors is improved. This information can further assist decision making regarding sector staffing, the opening of additional sectors or ad-hoc coordination of unexpected overload with adjacent centres. The result? Improved safety for ACC operations.

■ **Flow management:** managing traffic flows within sectors by regulating traffic. Again, with workload information readily available, FMP controllers can make more accurate decisions on regulating traffic. The result? Achieving more efficient operations with less delay.

In 2014, efforts were made to develop the model as an operational system, developing standard procedures and training personnel and WLM for Amsterdam ACC was commissioned on March 16 2015. ►►



**Yoram Obbens**  
has been a senior performance analyst for the Dutch ANSP LVNL since 2005. He holds a Master's degree in aerospace engineering from the Technical University of Delft and has been involved in the development of LVNL's workload model from the beginning.



**Rob Bezemer**  
is a supervisor and executive controller at the LVNL Amsterdam Area Control Centre. He has over 25 years of operational experience and has been involved in the development of LVNL's workload model from the beginning.



## Workload: getting it to work (cont'd)

### The principles of WLM

A fully detailed description of LVNL's workload model would be too comprehensive for this article so here are the key principles of WLM:

#### 1. ATS route structure

The ATS network and its relevant traffic flows within a specific ACC sector is one of the fundamentals of the WLM. Also, sector boundaries, available airspace and specific characteristics (e.g. sector balconies and delegated areas) are incorporated. This means that for each ACC sector, a list of relevant routes or traffic flows is defined. Traffic entering the sector is then allocated appropriately.

#### 2. Controller workload breakdown

The workload of a controller is the result of:

- routine actions (e.g. standard handovers, check-ins or standard issued clearances), and
- actions required to manage potential conflicts (detection and resolution). For WLM these potential conflicts are called traffic interactions.

For each specific route or traffic flow it is established how demanding these routine tasks are. Routes with no specific procedures are less demanding whereas routes that require specific controller action to ensure adherence to procedures, are considered more complex. In addition, for each specific route and for each pair of routes, the intensity of the interactions is established by considering:

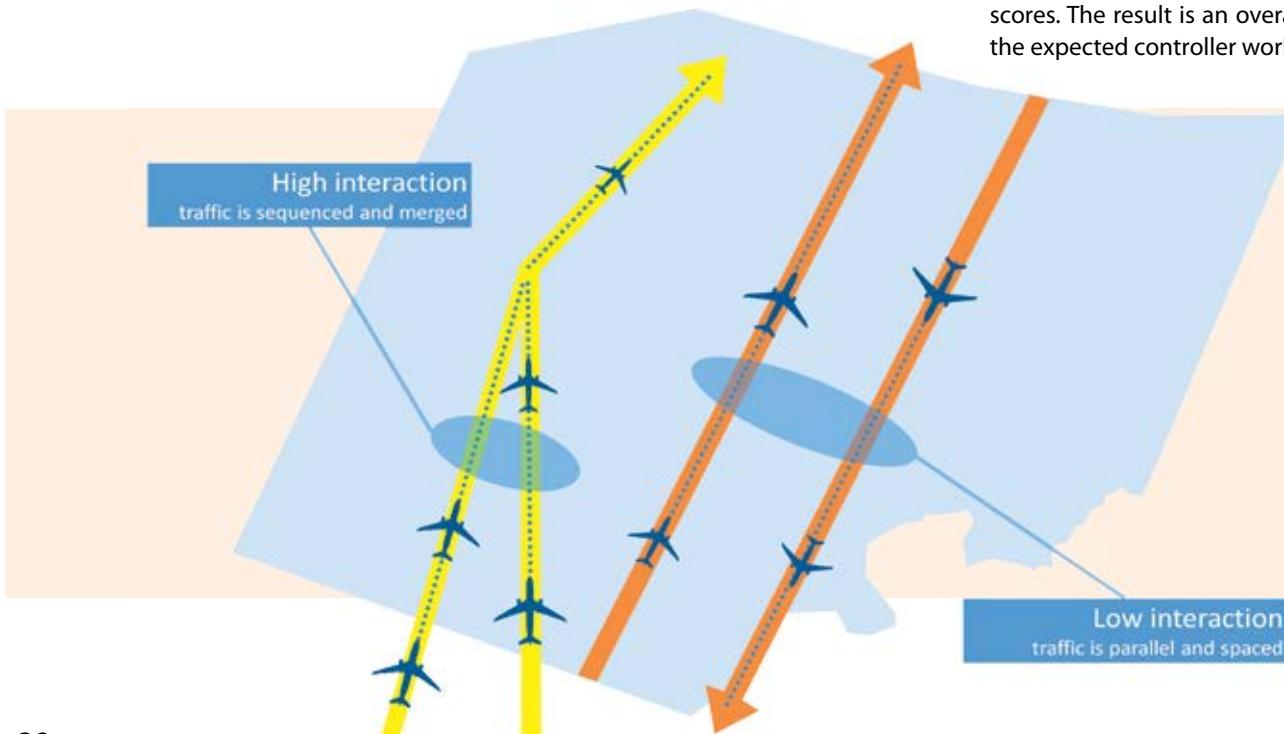
- the airspace available for manoeuvring;
- the geometry of routes and crossing points;
- the time available for conflict resolution.

For example, the interaction of traffic on two widely-spaced parallel routes is considered to be minimal and the potential for conflict is low. On the other hand, two traffic flows that have to merge at a certain defined point means increased interaction, given that the traffic is moving in the same direction and has similar flight profiles.

The level of intensity of traffic interactions and routine tasks is established by using weighted scores. These scores are fed into the WLM algorithm for calculating workload. A five-point scale is used ranging from zero (lowest weight) to four (maximum weight). Scores are determined by operational expertise. Guidelines describe the scoring criteria and provide examples to ensure consistency. An extract from these guidelines is shown below as an example.

#### 3. Time Blocks

Traditionally, sector capacities are defined as the maximum allowable number of flights passing through a sector per hour. However, workload is not experienced per hour by controllers. Periods of high workload tend to occur in much smaller time frames. As a compromise between the two, 20 minute-time blocks are used in WLM. This means that the model takes into account all traffic that enters each sector during a period of 20 minutes. Each flight within this period is allocated to one of the predefined routes and the expected controller workload for the period is then calculated using the traffic distributed on routes and the previously-discussed weighted scores. The result is an overall figure for the expected controller workload.



Traffic interaction within a route	Route limitations
0 (minimum score)	<ul style="list-style-type: none"> <li>■ No significant lateral, vertical or time limitations</li> </ul>
1	<ul style="list-style-type: none"> <li>■ Lateral limitation along the route;</li> <li>■ Vertical limitation along route (temporary);</li> <li>■ Ample time (flight distance) along a route to adhere to procedures and to manage conflicts.</li> </ul>
2	<ul style="list-style-type: none"> <li>■ Lateral limitations along a part of the route;</li> <li>■ Vertical limitations along route (available flight levels limited, &lt;9);</li> <li>■ Available time sufficient (flight distance) along a route to adhere to procedures and to manage conflicts.</li> </ul>
3	<ul style="list-style-type: none"> <li>■ Lateral limitations along one side (distance &lt; 10NM);</li> <li>■ Vertical limitations along route (available flight levels limited, &lt;6);</li> <li>■ Available time limited (flight distance) along a route to adhere to procedures and to manage conflicts.</li> </ul>
4 (maximum score)	<ul style="list-style-type: none"> <li>■ Lateral limitations on both sides of route;</li> <li>■ Vertical limitations along route (available flight levels very limited, &lt;3);</li> <li>■ Available time very limited (flight distance) along a route to adhere to procedures and to manage conflicts.</li> </ul>

#### 4. Workload threshold

Defining a threshold for maximum controller workload is essential for obvious reasons. During the development of WLM, it was calibrated to establish threshold values for acceptable workload. R/T calls, instructions issued

to aircraft and workload measurements with Instantaneous Self-Assessment (ISA) scores were used for this purpose. The result was the determination of an universal WLM threshold value for all sectors.

#### Analysing changes: AMRUFRA

The AMRUFRA project implemented in 2009 provides a good illustration of the use of WLM in assessing the changes which will result from strategic airspace projects.

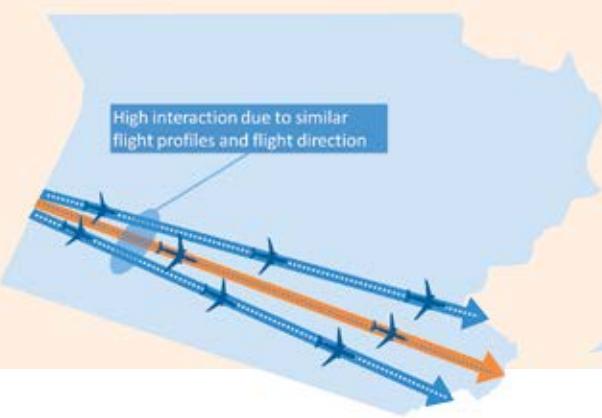
The most important changes in the AMRUFRA project (the parties involved being AM=Amsterdam, RU=Ruhr, FRA=Frankfurt) from the point of view of Amsterdam ACC were:

- the expansion of ACC Sector 2 (southern boundary displacement with military TMA-D);
- the introduction of a new out-bound route via waypoints LUNIX-NAPRO-AMOSU to the (U) Z738 airway.

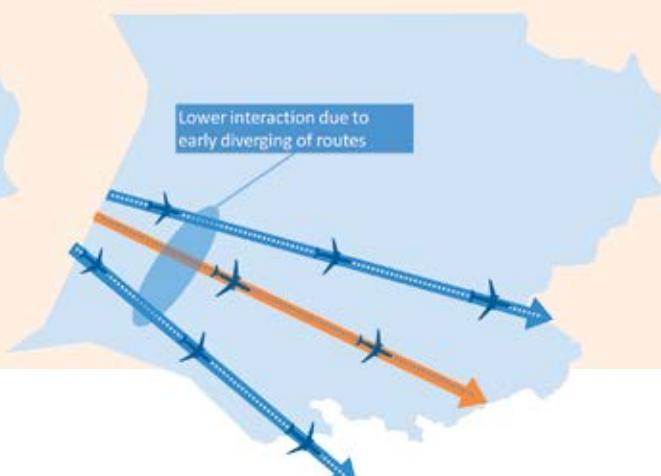
The implications for controller workload and sector capacity were analysed using WLM. Versions of the planned changes were input to the model – new routes were added, existing routes were re-evaluated, old routes were deleted and all weighted scores for routine tasks and traffic interaction were assessed. The next



Before AMRUFRA



After AMRUFRA





## Workload: getting it to work (cont'd)

step was to benchmark the workload results of the finalised new sector design with the old sector design as a reference. The early divergence of Amsterdam departure routes and the increase in available airspace decreased the traffic interaction. Analysis showed that controller workload for handling Amsterdam departures and en-route traffic to EDDL/EDDK would decrease significantly. Based on these results it was decided to increase the capacity of ACC sector 2: the declared capacity of movements per hour for weekdays was increased from 36 to 38.

### Daily operations using WLM

As noted earlier, WLM is now being used to actively assist ACC supervisors and FMP controllers in making daily operational decisions. Centrally-placed at the ACC supervisor's working position, the WLM display provides relevant and timely access to controller workload information.

## System Overview

The WLM platform gives users different views of the expected controller workload and provides insight into traffic characteristics. It calculates and displays expected controller workload based on traffic information from Network Management by using flight plan data available via ETMFS.

The platform interface provides the following information:

- The expected workload for all elementary sectors and combinations of Amsterdam ACC is shown clearly on the *workload dashboard*. Supervisors can manage the activation of sectors in WLM and are alerted as soon as the calculated controller workload exceeds a pre-determined threshold.





- A specific sector can be selected and viewed in the *workload view*. This screen shows the projected workload for each 20 minute period. Colour indicators are used to represent the main traffic flows within Amsterdam ACC. Anticipated controller workload can be viewed up to 20 hours in advance, although the projection up to 4 hours ahead is more practical and accurate.
- Traffic counts for a sector can be viewed in the *traffic view*. This screen shows the number of flights entering the selected sector every 20 minutes.
- Detailed flight information can be shown in the *flightlist*. When selecting a specific 20-minute period in

the *workload view* or *traffic view*, the corresponding flights are shown with detailed flight information and the individual contribution to the overall calculated controller workload.

#### One small step for WLM...

To familiarise operational users of WLM with the system and its use in their decision-making, a gradual introduction into daily operations was considered most appropriate.

As a first step, WLM information is being used for sector management at Amsterdam ACC. With this information, ACC supervisors have a better overview of expected controller workload. This provides them with key information for their decision-making on how to manage the ACC

sectors which normally takes place between 10 and 60 minutes in advance. When managing sectors, the ACC supervisors first consider WLM information and they then combine this with other relevant information to make their decisions on sector opening schemes, staffing or coordination with adjacent centres in specific conditions.

The next step for operational use of WLM will be the introduction of capacity management which is scheduled for the second half of 2015. During this stage of implementation, FMP controllers will use WLM information for regulating traffic. With the availability of this information, it is expected that less traffic regulation will be necessary and that regulation will be more precise. This should lead to less delays and increased network performance.

#### The future looks good

Plans for future development of WLM at Amsterdam ACC includes enhanced features for detailed analysis, the development and incorporation into WLM of Short Term ATF Measures (or STAM) and the integration of the WLM-system with other operational systems so as to enable data-exchange (e.g. provision of WLM information at controller working positions).

Alongside this, the development of a workload model for Schiphol Approach and Ground Control has begun. Only the future will tell if a WLM will be useful for all Schiphol operations, but based on Amsterdam ACC experience alone, the prospects appear good! 

# Faster is not always better

by Katarzyna Żmudzińska

*It was a cold Sunday morning and, unusually for the route, we had only 26 passengers. We took off on schedule and were quite surprised when the departures controllers cleared us direct to XXXX [destination] and to FL230.*

*The First Officer [pilot flying] observed that there were not too many aircraft around as the frequency was remarkably quiet. When we were passing through FL215 we got a TA and noticed a target on the TCAS traffic display, above us, moving from left to right. The FO started to reduce the vertical rate which at this point was 5300 [ft/min]. At the same time, the controller reminded us that our cleared level is 230. While I was in the process of responding to her, I heard a TCAS RA command to "Level off". The FO disconnected the autopilot and performed a smooth level off at FL225. Suddenly, we got very busy: the FO flying the aircraft and me looking outside to see the intruder, talking to ATC and monitoring FO's actions. We never saw the other aircraft above due to haze. We told the controller we had an RA and would be filing a company report.*

*She said she has to do the same...*

[A story from a Boeing B737 Captain]

As the story told by a Boeing 737 pilot indicates, TCAS RAs (Resolution Advisories) can be generated due to high vertical rates before an aircraft reaches its cleared level, against another aircraft at the adjacent level. Operationally, these RAs are unnecessary and cause additional workload and paperwork for all involved. They can also introduce new risks as pilots do not always correctly follow their RAs. Monitoring data indicates that approximately 40% of all RAs are generated due high vertical rates, regardless of TCAS version fitted on the aircraft. In line with ICAO recommendation some airlines published their own Standard Operating Procedures (SOP) to prevent these types of RAs. In this article we examine their effectiveness through simulations. Following these recommendations would help not only to prevent unwanted RAs but also to prevent the associated increase of the workload. That being said, these recommendations also involve additional workload.



## Katarzyna Żmudzińska

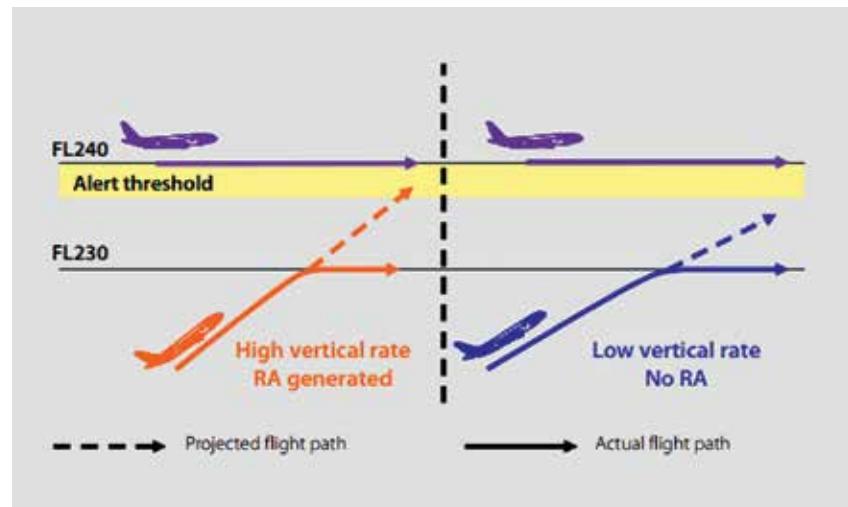
is a graduate of the Poznan University of Technology. In 2014 she was a trainee at EUROCONTROL's Air Traffic Services Unit, working mainly on ACAS issues.

She is a glider and light aeroplane pilot.



## Unnecessary RAs due to high vertical rates before level-off

The performance of modern aircraft allows pilots to climb and descend with high vertical rates. While this can provide operational benefits (i.e. fuel or time savings), it can become problematic when aircraft continue to climb/descend with a high vertical rate close to their cleared level. TCAS will issue an RA when it calculates a risk of collision based on the closing speed and vertical rates. A high vertical rate before level-off may cause the TCAS logic to predict a conflict with another aircraft even when appropriate ATC instructions are being correctly followed by each crew. This is because TCAS does not know aircraft intentions – autopilot or flight management system inputs are not taken into account because TCAS must remain an independent safety net. If, simultaneously, another aircraft is approaching an adjacent level, the combined vertical rates make RAs even more likely.



Once an RA has been issued it must be followed without delay and it takes precedence over any ATC instructions. Any deviation from the intended flight path, resulting from the RA, causes additional workload to all involved and can be disruptive to ATC traffic flow and planning and in congested airspace there is a risk for follow up conflicts. Moreover, several cases have been observed where pilots did not correctly follow their RAs and instead increase their vertical rate following an "Adjust vertical speed, adjust" RA.

When a TCAS-equipped aircraft is approaching its cleared level with a high vertical rate, TCAS will generate an RA advising the reduction of vertical rate (e.g. "Adjust vertical speed, adjust" or "Level off, level off" RA, depending on the TCAS software version). It might even change the vertical direction (i.e. "Climb" when descending or "Descend" when climbing). If both aircraft are TCAS-equipped and one aircraft is climbing or descending while the other one is in level flight, an RA will typically be issued first to the climbing/descend-

ing aircraft and only to the aircraft in level flight if a response to the initial RA is not satisfactory. However, in cases of very high rates or when both aircraft are climbing and descending, RAs will be issued to both aircraft. The precise sequence of RAs may be different if one of the aircraft is not TCAS-equipped.

In order to reduce the number of RAs caused by high vertical rates before level-off, ICAO recommends under certain conditions a reduction of vertical rate while approaching the cleared level.

A major European airline has introduced a Standard Operational Procedure (SOP) requiring their crews to approach the cleared level with a specified maximum vertical rate in all cases (see the adjacent text box for details). The workload implications of the two approaches are different: the ICAO recommendation requires routine monitoring for

**ICAO Annex 6:**  
Max. 1500 ft/min. in the last 1000 ft (when the pilot is aware of another aircraft at or approaching an adjacent altitude or flight level).

**Major European airline SOP:**  
Always max. 1000 ft/min. in the last 1000 ft.



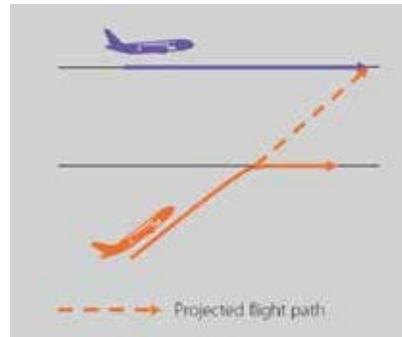


## Faster is not always better (cont'd)

potential conflicts and occasional vertical rate reduction whilst the airline SOP only requires routine vertical rate reduction. This airline experienced a reduction of nuisance level-off RAs by a factor of 10 (the effectiveness of the ICAO recommendation is unknown). Additionally, some States have introduced specific vertical rate reduction requirements or recommendations applicable in their airspace. "While these provisions prescribe the vertical speed during the last 1000 ft before the level off, the vertical speed of the aircraft may dictate that these reductions start to take place earlier." In this article, for simplicity, only the ICAO recommendation and the above mentioned airline SOP are examined.

### Effectiveness of vertical rate reduction if correctly applied

The number of possible conflict geometries is infinite; therefore it is impossible to examine the effectiveness of these recommendations in all cases. Therefore, a small number of encounters were created to test simplified level-off geometries in computer-based simulations. These scenarios assumed perfect surveillance and virtually the same speed for both aircraft in all cases. Heading, as well as altitude of either aircraft were not subject to normal variations (due to wind etc.). Analyses were conducted at various altitude bands, based on TCAS sensitivity levels<sup>1</sup>, varying the initial vertical rate of the climbing aircraft.



To determine their effectiveness, these scenarios were compared to a baseline scenario where the aircraft only reduces its vertical rate in order to level-off 1000 ft below the other aircraft.

If no vertical rate reductions are applied at all (i.e. the aircraft starts reducing its vertical rate only in order to level off), it is likely that an RA will be triggered, especially at the higher levels, with relatively low vertical rate. The maximum vertical rates (ft/min) at which no RA will occur for different load factors are shown in Table 1 below. For example, an aircraft climbing at 1,800 ft/min will not generate an RA if it just reduces its rate for level-off (e.g. ignores the ICAO recommendation), with deceleration of 0.20 g in the altitude band between FL200 and FL420.

In each scenario one aircraft was always in level flight, while the other was climbing towards it, either head-on or on a crossing track. These scenarios assumed a projected track with no horizontal or vertical miss-distance at the Closest Point of Approach<sup>2</sup>, i.e. a collision; however, the climbing aircraft would start to reduce its vertical rate to achieve the required vertical rate 2000 ft before the other, to level off, subsequently, 1000 ft below. The vertical rate in the last 1000 ft before level off will be either 1500 (ICAO recommendation) or 1000 ft/min (major European airline SOP) and, subsequently, the climbing aircraft will level-off 1000 ft below the aircraft in level flight. The vertical rate reduction deceleration was set to varying values from 0.1 g to 0.3 g (in 0.05 g increments).

1 - The TCAS sensitivity level is a function of the altitude and defines the level of protection. The warning time is greater at higher altitude.  
2 - The Closest Point of Approach is the instant at which the slant range between own TCAS II equipped aircraft and the intruder is at a minimum.



**Table 1:** RA triggering thresholds if **no vertical rate reductions** are applied

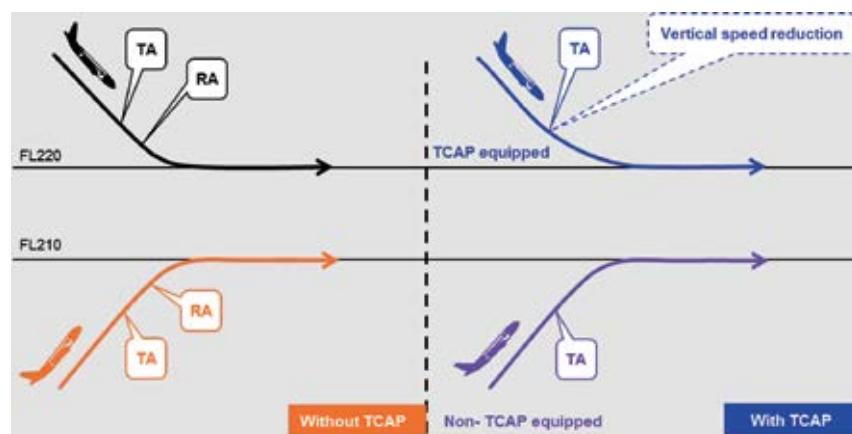
Altitude band	0.10 g	0.15 g	0.20 g	0.25 g	0.3 g
FL200 – FL420	2,000	1,850	1,800	1,850	1,750
FL100 – FL200	2,550	2,300	2,200	2,150	2,100
FL50 – FL100		3,000	2,800	2,700	2,600
2350 ft AGL – FL50			4,050	3,700	3,500
1000 ft – 2350 ft AGL					6,250

However, if the ICAO recommendation or airline SOP is applied, unwanted RAs in level-off geometries will be prevented with much higher vertical rates until 2000 ft below the other aircraft. These maximum vertical rates (ft/min) at which no RA will occur are shown respectively in Tables 2 and 3 below. For example, an aircraft climbing at 3,900 ft/min will not generate an RA if it just reduces its rate for level-off in line with the ICAO recommendation (Table 2), with deceleration of 0.20 g in the altitude band between FL200 and FL420.

Not surprisingly, more aggressive vertical rates deceleration (higher g-load) will make the ICAO recommendation and airline SOP less effective. However, higher decelerations are less likely to be used in normal operations due to passenger comfort.

## TCAP

Aircraft manufacturers recognise that unwanted RAs are an operational problem and try to supplement procedures with technology which would prevent unwanted RAs. An example of a technological solution to the problem is the TCAS Alert Prevention

**Table 2:** RA triggering thresholds when **ICAO-recommended** vertical rate reductions are applied

Altitude band	0.10 g	0.15 g	0.20 g	0.25 g	0.3 g
FL200 – FL420	5,500	4,150	3,900	3,750	3,700
FL100 – FL200		5,800	4,950	4,650	4,500
FL50 – FL100			8,000	6,450	5,950
2350 ft AGL – FL50					
1000 ft – 2350 ft AGL					

**Table 3:** RA triggering thresholds when **airline SOP-recommended** vertical rate reductions are applied

Altitude band	0.10 g	0.15 g	0.20 g	0.25 g	0.3 g
FL200 – FL420	6,200	4,250	3,950	3,800	3,750
FL100 – FL200		6,050	5,050	4,700	4,550
FL50 – FL100			8,450	6,500	6,000
2350 ft AGL – FL50					
1000 ft – 2350 ft AGL					

(TCAP) functionality which has been introduced by Airbus to prevent the generation of RAs in 1000-foot level-off geometries (see Hindsight 12). The functionality uses a new altitude capture law for flight guidance computers, which decreases the aircraft's vertical rate towards the selected altitude, once a TA has been generated and the auto-pilot and/or flight director are engaged, and when another aircraft is known to be in the vicinity.

## Summary

TCAS II will generate RAs in 1000-ft level-off encounters if aircraft approach their cleared levels with high vertical rates as autopilot inputs or pilot intentions are not known to TCAS. RAs

caused by high vertical rates result in unnecessary workload to flight crews and can be disruptive for ATC. Any unexpected departure from ATC clearance carries a risk of a follow up conflict. Monitoring data indicates that as much as 40% RAs are generated due high vertical rates and 75% of the aircraft getting an RA in the level-off geometry approach their cleared level with a rate above 1500 ft/min. These RAs are not operationally needed and can be avoided in many cases if vertical rate reductions are applied.

Although the simulations conducted assume a perfect environment, they indicate that reductions in vertical rates in the last 1000 feet before level-off are effective in preventing RAs due to high vertical rates before level off. ■

# Know your limits



by Maciej Szczukowski

Air traffic controllers' work is surrounded by definitions, theories and values. Safety, efficiency, delay, capacity, workload – these are every day notions in ATC.



**Maciej Szczukowski**

has been an Air Traffic Controller for almost 15 years at Warsaw Okęcie Airport, Warsaw, Poland. He has also been an aviation consultant and ground school instructor, working with pilots and cabin crew. He has experience as a private pilot.

Some of them may be calculated and are ideally kept constant while others are variable and change throughout a shift. Most of the figures are a function of others and it is therefore more important to establish their limits rather than keep them at any particular level.

Workload is one of them.

For decades specialists have tried to find a formula to measure workload. Mathematical equations, quantitative and qualitative research or experiments as sophisticated as utilising functional spectroscopy to monitor the concentration of hemoglobin at the cortex<sup>1</sup> have been used. The most general formula science has come up with is "task" x "time" x "frequency". However, this ignores the complexity of ATC and workload remains a subjective concept, shifting among or trying to fit the statistics of task demands and the assumptions<sup>2</sup> about available technology. Consequently the most precise definition of ATCO workload we get today is the capacity of team's mind and body.

It is obvious that from a controller's point of view, each aircraft operation does not require the same amount of work. The concept of complexity is introduced to assess the level of difficulty perceived by controllers during traffic handling – based on the volume and nature of the required controller interventions. In parallel, ATC mental complexity describes the level of required mental response as determined by a controller's ability, knowledge and experience. It "reflects the relationship between the demands of a specific environment on the operator and the capability of the operator to meet those demands". The most well-known measure here is the "declared capacity". However, its limitation is that such a "declaration" is based only on ideal conditions and does not include any of the unpredictability which characterises most ATC environments. Adverse weather conditions which alter the traffic flow and restrict available airspace, equipment or communication problems and sudden and unplanned closures of taxiways or runways can both decrease capacity and significantly increase workload.

These are the times when managers and supervisors have to respond by reducing the demand. An example where the lack of such a reaction led to an overload for

controllers occurred in Barcelona in December 2012. With low visibility procedures in force because of thick fog, only one runway was available for approaches. This led to a mean delay of around 40 minutes and approach control frequency was overburdened. "Break, break" was the most often-heard phraseology and very soon the approach controller was not able to coordinate relay the effects of delays or estimates. He was soon faced with many increasingly urgent crews' requests for approach clearances. Because aircraft were continuously being handed off from surrounding ACC sectors and supervisors did not support the controller in any way, the situation soon became even more urgent with crews beginning to report "fuel emergencies". This 'pushing tin' eventually reached its limit when the airport stated that there were no more parking spaces available. That is when one of the pilots was supposed to have said "let the aircraft land and put them on taxiway, car park, roof ... but on the ground!"<sup>3</sup>.

To find the dynamic capacity of a sector, allowing to equate its effectiveness with actual demands and preferably to minimise the odds of a situation similar the one mentioned above, workload simulations are usually used. They calculate the sum of tasks required in different circumstances, although the relative simplicity of such calculations limits their versatility. One response to this is the idea of a peak traffic count based on practical experience. Such a threshold can be helpful in decision-making processes<sup>4</sup>. Another idea has been proposed by SESAR

according to which, instead of regulating large volumes of traffic, the entry of complex, but local, airspace by too many aircraft in short periods of time should be prevented. The obvious problem, as in any approach, is that the prediction has to be made well in advance<sup>5</sup>.

**The expression 'excessive workload' suggests that the acceptable upper limit of demand has been exceeded. However, a low workload level has its own problems.**

In 1999, Heil presented an inductive model of enquiry based on knowledge of the relationship between air traffic controllers' ages and their performance. By referring to previous research<sup>6</sup> and by creating a series of tests for over 800 active controllers, he was able to confirm the theory that ATCO performance only increases until the mid 40s. The hypothesis was advanced that the relationship between age and performance is not necessarily linear and that although there is a negative correlation between age and performance on tasks requiring cognitive abilities, it is not so in case of tasks requiring experience and knowledge. Unfortunately the quantitative approach to the research missed participants' subjective feelings about their qualifications, environment and the influence of these on their ability to main-



1 - Ayaz, H., Willems, B., Bunce, S., Shewokis, P. A., Izzetoğlu, K., Hah, S., Deshmukh, A., Onaral, B. (2010). Cognitive Workload Assessment of Air Traffic Controllers Using Optical Brain Imaging Sensors. *Advances in Understanding Human Performance: Neuroergonomics, Human Factors Design, and Special Populations*, pp.21-32.

2 - Lee, P.U., Prevot T. (nd.) Prediction of Traffic Complexity and Controller Workload in Mixed Equipeage NextGen Environments. Retrieved from: <http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20120016433.pdf>

3 - <http://avherald.com/h?article=45b4bc8&opt=0>

4 - Welch J.D., Andrews J.W., Martin B.D. (n.d.) Macroscopic Workload Model For Estimating En Route Sector Capacity. Retrieved from [https://www.ll.mit.edu/mission/aviation/publications/publication-files/ms-papers/Welch\\_2007\\_ATM\\_MS-28122\\_WW-18698.pdf](https://www.ll.mit.edu/mission/aviation/publications/publication-files/ms-papers/Welch_2007_ATM_MS-28122_WW-18698.pdf)

5 - Suárez N., López P., Puntero E., Rodriguez S. Quantifying Air Traffic Controller Mental Workload. Fourth SESAR Innovation Days, 25th–27th November 2014. Retrieved from <http://www.sesarinnovationdays.eu/sites/default/files/media/SIDs/SID%202014-03.pdf>

6 - Salthouse (1991), Hardy & Parasuraman (1997), Tsang & Shaner (1998).

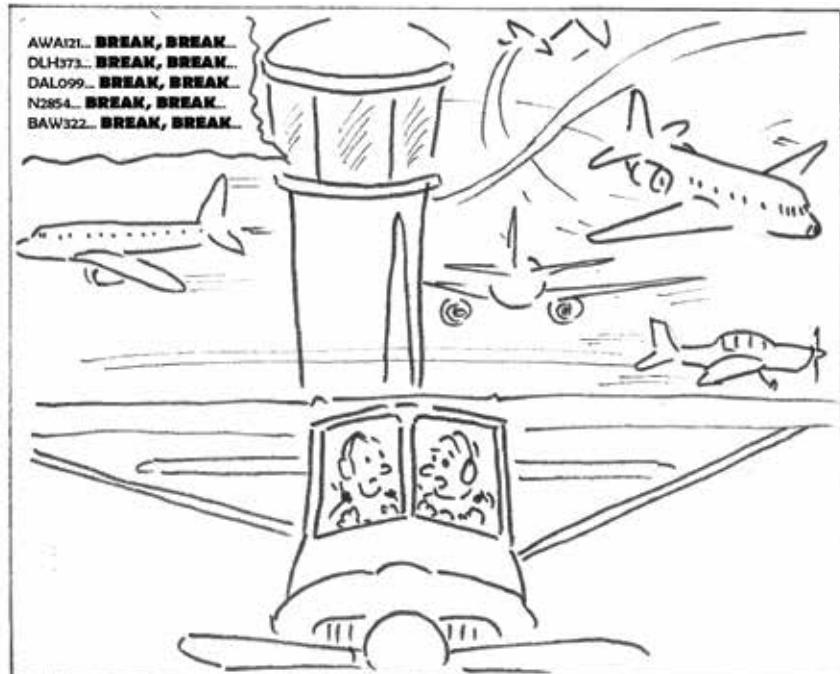


## Know your limits (cont'd)

tain adequate competence with increasing age. And the researchers did not take into account the level of fatigue of controllers taking part either<sup>7</sup>. The reasonable conclusion from such work is that workload is actually not a function of the number of tasks but rather a consequence of the division of duties. Another challenge for senior controllers and supervisors in effective task allocations hence, for example, correct sector configuration<sup>8</sup>.

The expression 'excessive workload' suggests that the acceptable upper limit of demand has been exceeded. However, a low workload level has its own problems. In July 2010, a Boeing 737 was cleared to cross a runway on which another aircraft had already been cleared for takeoff, though it was still taxiing to the departure runway. The safety net for the 737 crew – asking about a stop bar still turned on – did not work (the trainee controller switched it off). The investigation concluded that there had been ATCO overconfidence and inattention because of the "undemanding environment as seen by the workload at the time". In this case, division of duties as mentioned above was involved – On-the-Job Training was in progress during the occurrence<sup>9</sup>.

But workload is not only about tasks and duties. It is also affected by personal variables like skills and experience in an encountered type and structure of traffic or one's proneness to apprehension. It expresses itself in ATCO behaviour and fatigue. The latter in turn includes drowsiness, decreased concentration



So you can hear it for yourself... They said that the controllers are overworked, but the only thing they do is to ask for BREAKS...

and reaction time. Research conducted by Repetti showed that there is a relationship between daily workload (traffic volume and visibility at the airport) and a controller's behaviour after work (the degree of social withdrawal and the extent of expression of anger)<sup>10</sup>. On days of high workload and distressing interactions with co-workers or supervisors, ATCOs reported more health complaints and more negative moods<sup>11</sup>. It seems however that although social withdrawal „may help an aroused individual to return to a baseline emotional and physiological state”, supportive spouses are also able to diminish the effects of workload related stressors.

There is no single standard which can anticipate all elements increasing workload<sup>12</sup>. New models are being created, including the EUROCONTROL Capacity Analyser tool (CAPAN), which uses RAMS (Reorganised ATC Mathematical Simulator) to "translate" quantitative

values from simulated control positions into qualitative categories of traffic load<sup>13</sup>. We now need to focus more on mental workload models rather than dispassionate mathematical formulae. Creating dynamic thresholds, based on situational awareness, decision-making processes, matched with local procedures and demands but taking into account the psychological factors inherent in ATC profession, is the way to go. Otherwise, everything we will gain from controller effectiveness in a high demand environment, will be lost later due to the negative effects of overwork.

I believe that it is an obligation of each controller to establish their own workload limits, keep to such limits and communicate them to their team. It is essential to be open to changing them and to remain open for discussion about them throughout one's career. And after changes in equipment, procedures, airspace or airport structure, it is important to tell those who are responsible about any significant effects of changes, including how their decisions affect controller workload. If controllers' views are not heard, any feeling that one's own workload limit is approaching is actually the last moment to stop, let something go or accept the delay. There is only one little step between such a limit and no safety at all. Don't take that step. S

7 - Heil, M.C. (1999). Air Traffic Control Specialist Age and Cognitive Test Performance. Retrieved from [http://www.faa.gov/data\\_research/research/med\\_humanfacs/oamtechreports/1990s/media/am99-23.pdf](http://www.faa.gov/data_research/research/med_humanfacs/oamtechreports/1990s/media/am99-23.pdf)

8 - <http://www.skybrary.aero/index.php/Sectorisation>

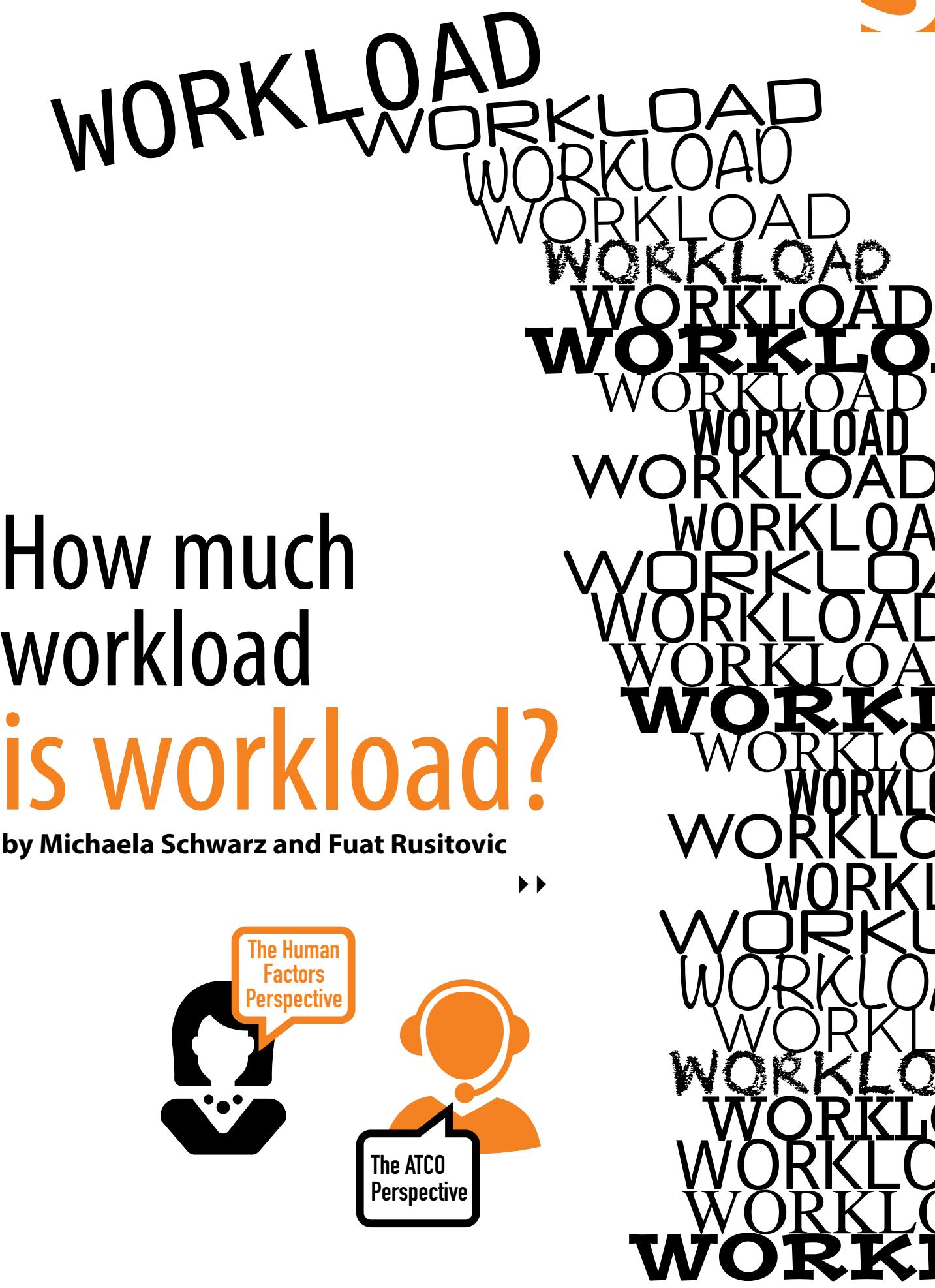
9 - <http://www.skybrary.aero/bookshelf/books/1971.pdf>

10 - Repetti R.L. (1989). Effects of daily workload on subsequent behavior during marital interaction: The roles of social withdrawal and spouse support. *Journal of Personality and Social Psychology*, Vol 57(4), pp.651-659.

11 - Repetti, R.L. (1993). Short-term effects of occupational stressors on daily mood and health complaints. *Health Psychology*, Vol 12(2), pp.125-131.

12 - Welch J.D., et al., op. cit.

13 - [http://www.eurocontrol.int/sites/default/files/library/026\\_Pessimistic\\_Sector\\_Capacity.pdf](http://www.eurocontrol.int/sites/default/files/library/026_Pessimistic_Sector_Capacity.pdf)



by Michaela Schwarz and Fuat Rusitovic



## How much workload is workload? (cont'd)



## The ATCO Perspective

Being an ATCO, workload is an omnipresent factor in my daily business. Questions like; 'What is an optimal workload for an ATCO?' 'Can we define thresholds?' 'How can we measure workload?' are with me every day.

Before I continue, I want to give you some examples of how I personally perceive workload during parts of a typical shift.

10:00 UTC. I start my first run in position as executive controller on a sector which is known for having a high volume of vertical movements. The traffic load is pretty low, only a couple of aircraft on the frequency and with a not very complex traffic distribution. After about 15 minutes, traffic increases and reaches its peak after another 20 minutes. 90% of the flights have to perform vertical movements as they are inbound and outbound from aerodromes in the area. The frequency is very busy and there is not much time between transmissions. I am feeling good, very good. I am still ahead of the situation and everything is working out as planned. After this peak, the traffic level reduces to a moderate level for the rest of my run. Break.

12:00 UTC: For the second run, I am working as a planning controller on a different sector which is usually combined with another sector most of the day as there is not a lot of traffic in it. However, this time the sector is not combined because there is a rush of inbounds to a major aerodrome and another wave is expect-

ed soon. There's almost nothing for me to do and after about 20 minutes, the challenge is to stay focused and alert. A short chat now and then with my sector partner helps, but I wonder for how long. I ask myself "is there something I can do?", "have I missed something?" over and over again. Fortunately, an anticipated increase in traffic begins but I get released from position before it gets really busy. Break.

Let's jump to the last run of the day. 17:00 UTC: It's in the same position as my first run. I take over during a busy period. There are no ongoing conflicts, but still plenty to do and I feel fine. Traffic load is high but absolutely doable. My planner is busy too and time flies. After about 40 minutes traffic reduces, but it's only a brief respite and traffic increases again until we are at the same peak as earlier. It gets really busy but we are doing fine. A lot of vertical movements, moderate traffic complexity but nothing special. I am feeling fine but I catch myself missing initial aircraft calls from time to time. "Station calling, say again?" I am fine. Am I? Am I really? There is nothing different than on my first run but my situational awareness is not quite as good as it was. Then, my shift is over and I am released.

Obviously the workload that was perfect for my first run wasn't so perfect for my last run, although according flow management measures it should have been the same. And what about my second run? How do we define under load? Couldn't that lead to equally

or even more potentially dangerous situations than overload?

There are plenty of factors that contribute to workload. But often only one is measured and taken into account by flow management and/or operational management. This factor is related to occupancy counts (the number of aircraft within a certain sector per minute) or sector capacity (the number of aircraft there are in a certain sector per hour). Both factors are based on a generic definition of sector complexity, number of vertical movements and traffic flow, but do not consider overall traffic complexity.

But, what about other factors like:

- How many hours have I already been on duty?
- How many shifts did I work in a row without a day off?
- What time of day is it (circadian rhythm)?
- Who is my sector partner? (if we understand each other instinctively, it's easier to handle more traffic)
- What is the complexity of individual traffic situations?

For me, the last one is the most important one: traffic complexity.

But how can we measure that? It's easy to calculate frequency occupancy values and to create figures about how many aircraft a sector is able to deal with. And with sectors that are not very complex, frequency occupation is the bottleneck. No doubt about it. With Controller Pilot Data Link Communication (CPDLC) we have a technology which can expand that bottleneck to a certain degree but what about the resultant complexity? How many vertical movements do I have to oversee? How many turns due to conflicting traffic do I have to give? Do we have a tool to measure that? I think we do.

## Fuat Rusitovic

works as an ATCO and on-job-training instructor at the ACC Vienna.  
He is involved in the planning and development of pre-on-job simulator training and the coordination of the Team Resource Management program at Austro Control.





## The Human Factors Perspective

Workload for Air Traffic Controllers is a well-known and well-researched concept. Human

Factors experts generally refer to Hilburn & Jorna (2001) who distinguish task load (i.e. the demand imposed by the ATC task) from workload (i.e. the ATCO's subjective experience of that demand). Hilburn & Jorna (2001) also provide an excellent summary on research related to task load factors including but not limited to:

- Traffic load / number-of-aircraft-under-control (Hurst & Rose, 1978; Stein; 1985)
- Number of traffic problems/ conflicts (Kalsbeek, 1976)
- Number of flight altitude transitions (Cardosi & Murphy, 1995)
- Mean airspeed (Hurst & Rose, 1978)
- Aircraft mix and variations in directions of flight (Wyndemere, 1996)
- Proximity of aircraft and potential conflicts to sector boundaries (Wyndemere, 1996)
- Weather (Scott, Dargue & Goka, 1991; Mogford et al., 1994)

- Mean aircraft separation, sector area, mean airspeed, sector flow coefficient (Arad, 1964)
- ATC position (oceanic versus terminal) (Wickens, Mavor & McGee, 1997)
- ATCO interface (visual displays, data entry systems) (Jorna, 1991)

**tors** include the ATCO being well rested and fit for work, leading a healthy lifestyle, taking regular restorative breaks and being aware of his own capabilities and limitations.

**Team factors** include team quality and climate, adequate leadership and supervision, appropriate communication and assertiveness etc.



## Michaela Schwarz

works as a Safety Management and Human Factors Expert at Austro Control in Vienna. She is a registered Aviation Psychologist with more than ten years of practical experience in the aviation industry including assignments at EUROCONTROL and Qantas Airways.

Workload for ATCOs can be assessed through subjective, behavioural and psycho-physiological measures (adopted from Hilburn & Jorna (2001). See table.

Whether or not and if so to what extent a person can manage task load depends on personal, team and organisational factors. **Personal fac-**

Finally **organisational factors** include duty roster, break plans, sector opening/collapsing, flow control/management and a pleasant work environment aiming for optimal task and workload conditions. So knowing all the task load and workload factors and how they can be managed, why are we restricting ourselves to occupancy counts? ▶▶

Subjective	Behavioural	Psychophysiological
<ul style="list-style-type: none"> <li>■ NASA Task Load Index (TLX) (Hart and Staveland, 1988),</li> <li>■ The Air Traffic Workload Input Technique (ATWIT) (Stein, 1985)</li> <li>■ Subjective Workload Assessment Technique (SWAT) (Reid and Nygren, 1988)</li> <li>■ The Instantaneous Self-Assessment of Workload (ISA) (Jordan &amp; Brennan, 1992)</li> <li>■ Mobile ISA available at <a href="http://www.think.aero/isa/">http://www.think.aero/isa/</a></li> </ul>	<ul style="list-style-type: none"> <li>■ Communication efficiency</li> <li>■ Communication times, message length, content</li> <li>■ Flight data management</li> <li>■ Inter-sector coordination</li> <li>■ Number of control actions</li> </ul> <p>Summarised by Hilburn &amp; Jorna (2001)</p>	<ul style="list-style-type: none"> <li>■ Heart Rate Measures (ECG)</li> <li>■ Eye blink rates (EOG)</li> <li>■ Eye movements, pupil diameter, fixations (Eyetracking)</li> <li>■ Brain activity (EEG)</li> <li>■ Electrodermal activity (EDA)</li> <li>■ Biochemical Activity (cortisol, adrenalin)</li> <li>■ Muscle activity (EMG)</li> <li>■ Body temperature</li> <li>■ Respiration</li> </ul> <p>Summarised by Schandry (1998)</p>



## How much workload is workload? (cont'd)



The ATCO  
Perspective

Modern air traffic management (ATM) systems provide pre-calculated conflict predictions up to 30 minutes before aircraft enter a sector based on their flight plans, actual radar-derived position, aircraft performance and local Air Traffic Services (ATS) procedures such as exit conditions. For example, in the case of an aircraft entering the sector at FL300 that has to exit the sector at FL220, such a system will predict potential risks taking into account the best estimates of complete aircraft trajectories. Wouldn't using such conflict predictions be more accurate as a means to measure workload than only referring to occupancy counts?

ANSPs and ATCOs would benefit from a tool that provides a complexity value for the expected traffic in addition to occupancy counts. The benefit for the ATCO would be the avoidance of potential overload situations attributable to traffic complexity. And the ANSP would profit from a more efficient use of human resources. So called 'Dynamic Density and Complexity' Models (Masalonis, Callaham & Wanke, 2003) already take various complexity metrics into account (e.g. sector aircraft count, sector volume, aircraft speeds and distribution of aircraft relative to sector structure). This could be a good start for developing a tool that considered actual traffic complexity and which could proactively increase safety performance.

*Monotony 'is indicated by reduced physiological activation, subjective sleepiness and behavioural impairments'*  
- Straussberger, 2006





A tool to calculate actual traffic complexity should also be able to take human capabilities and performance variability into account. ATCOs perceive workload differently depending on their individual condition, personal experience and workload management strategies. Both overload (excessive workload) and underload (monotony/boredom) should be part of the assessment. Monotony 'is indicated by reduced physiological activation, subjective sleepiness and behavioural impairments' (Straussberger, 2006). Both traffic repetitiveness and dynamic traffic density have been found to contribute to monotony. Workload measures (subjective, behavioural and psychophysiological) can help to identify optimum levels of task load to support ATCO performance and avoid overload and monotony.



### The ATCO Perspective

I agree.

As well as defining a limit for the maximum safe traffic complexity there should be a limit for the minimum as well. The situation of an ATCO in under load is hard to describe. It's a feeling of uncertainty as to whether everything is OK, which is as bad as being in overload. Additionally you have to cope with staying focused and alert on the task when you have almost nothing to do. In these cases it would be good practice to ask the supervisor to collapse sectors to distribute the workload better. However, often this is not possible because it may create an overload in another sector so developing a tool that considers traffic complexity in all sectors taken together is important.

## So what is the optimal workload for an ATCO?

To be honest, we don't know. We doubt that it is possible to set a value for optimal workload but we can get as close as possible to a value for good workload. Putting occupancy counts and traffic complexity together and calculating a number which would keep an ATCO at a steady and fairly busy level would be a major step in the right direction. Human Factors experts can help with measuring workload of ATCOs during live operations in order to evaluate such new tools and establish the maximum and minimum desirable values on the new workload scale.

Until then we can only suggest that you call for help if you need it, like asking for another ATCO to supervise. Or ask the supervisor to open a new sector in case of overload or collapse sectors if in underload. S

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# The chronology of workload

by Capt Shah Alam

When I started learning to fly in the military back in early 1980's in a Chinese-built PT6 aerobatic trainer, powered by a small radial piston engine, I didn't have any idea about workload...

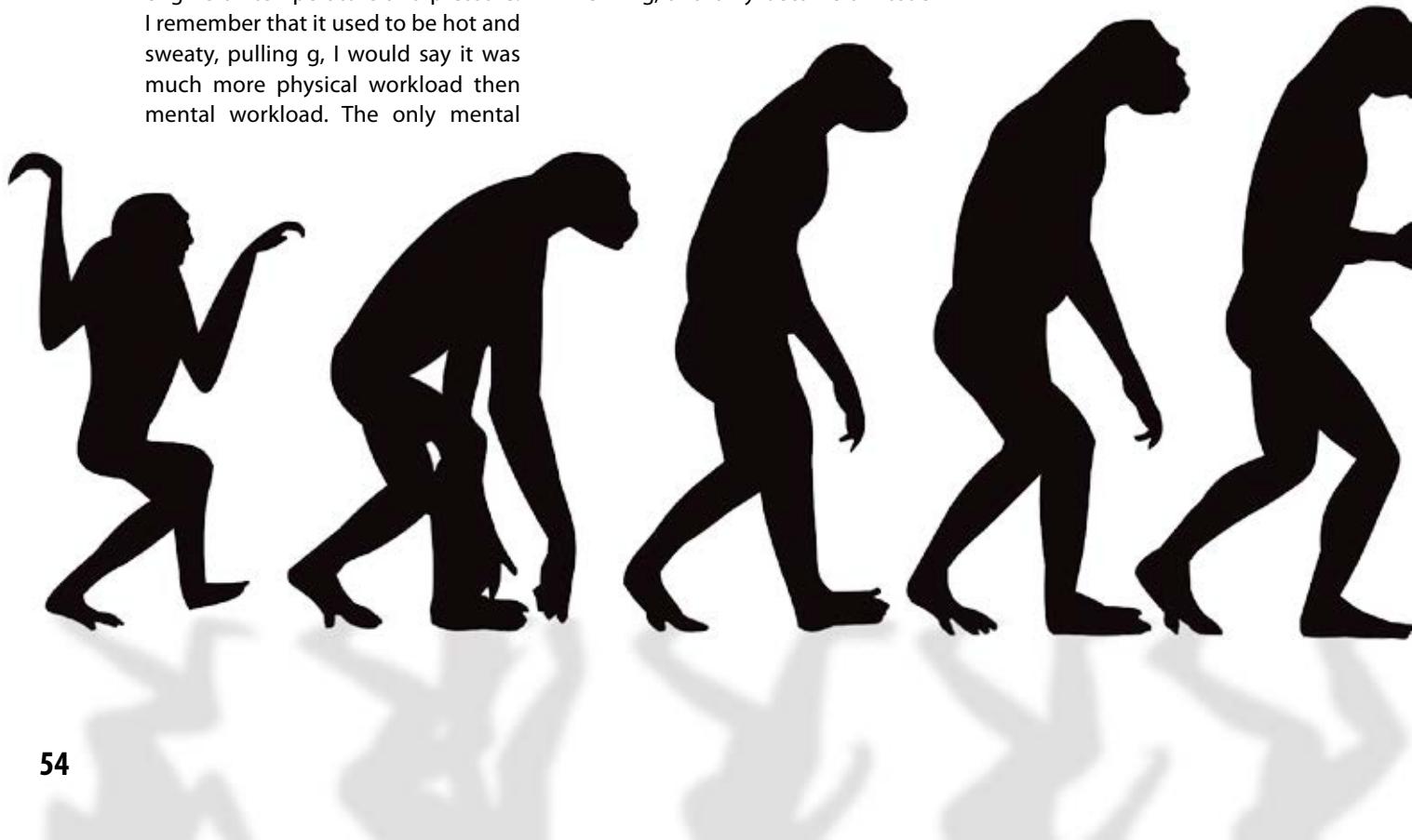
We just had a short ATC and Met briefing in the morning, followed by a short briefing by the instructor and off we went for the sortie. We had to remember our checklist and the limitations by heart. I do not remember ever being told about workload as a threat as such. It was all stick and throttle action from start up onwards. Of course, there was no automation, no FMS, no EFB, no MCP to manage the flight. Flying was simply fun and 'success' was down to skill in handling and aerobatics. We didn't have much to do heads-down in the cockpit and I would not call it a flight deck! Flying was just looking out, doing your manoeuvres looking out with just an occasional glance inside to check your engine oil temperature and pressure. I remember that it used to be hot and sweaty, pulling g, I would say it was much more physical workload than mental workload. The only mental

workload that I faintly remember was in navigation and instrument flying sorties. But I would not dare to call it workload compared to what I now have after flying for 34 years in military and in commercial aviation.

In fact we had a subject in the Air Force academy known as Airmanship, which is basically equivalent of present day aviation law and aviation physiology which mainly covered the medical and physiological aspects of flying. But we were never made aware that something called workload existed as such, our activity was just part of our human instinct like a normal day of any work. I presume it never came up as a factor because it was never normally overwhelming, and only became an issue

if you had an emergency or a major failure.

My first real workload came when I started flying military transport in Russian built Antonov-26 aircraft. Before departure, we had to check the NOTAMS, Met Forecasts and Jeppesen navigation and approach charts. But the flying itself was still simple. No autopilots, manual selection of frequencies and courses to fly and straightforward ILS, VOR or NDB approaches. Hardly any airports had a SID for the departure and even if they did, it was invariably a pretty simple turn after takeoff to follow a outbound radial or course. We only needed to select the VOR or NDB frequency and the desired



course and it was then a simple matter of intercepting the course or radial by following the memory aids TDC (tail-desired-correction) or DHC (desired-head-correction).

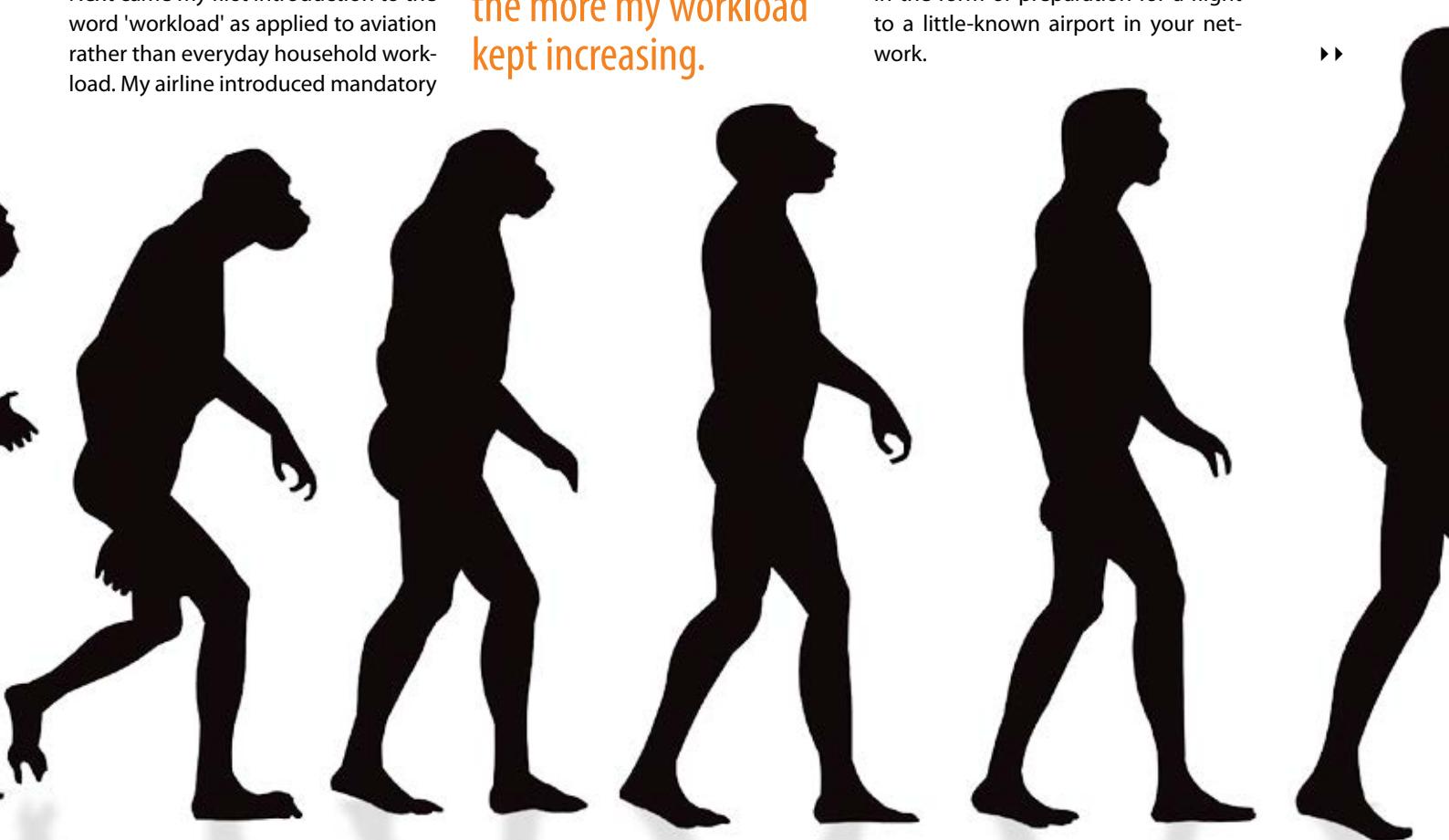
When I started flying as a commercial airline pilot in the early 1990s, I was first introduced to automation in the form of autopilot and an EFIS control panel, we loved to proudly call them our 'glass cockpit'. Now we had fancy flat-screen panels called the PFD and the ND which replaced the age-old ADI and HSI. The flying itself became easier but the work to manage the flight started to increase. We now had to learn how to interpret the EFIS display and so on.

Next came my first introduction to the word 'workload' as applied to aviation rather than everyday household workload. My airline introduced mandatory

CRM courses for pilots. We started seeing case studies on how some of the major fatal accidents had happened where workload had been a contributory factor. I began to get the impression that the more advanced and

I began to get the impression that the more advanced and modern aircraft I flew, the more ATC was also using increasingly advanced technology to monitor the skies and the more my workload kept increasing.

modern aircraft I flew, the more ATC was also using increasingly advanced technology to monitor the skies and the more my workload kept increasing. The skies all over the world became busier, airspace became more complex, rules more stringent and the rate at which new concepts and technologies were being introduced increased resulting in more to learn and learn and again learn. The age-old cockpit had now become today's flight deck with all the modern gadgets like TCAS, EGPWS, RAAS, FMS, ACARS, EFB. New procedures are being introduced to match with these state of the art cutting edge technologies. Next we started learning about RNAV, RNP, and now RNP-AR, all of this meant more learning and more pre-flight workload in the form of preparation for a flight to a little-known airport in your network.





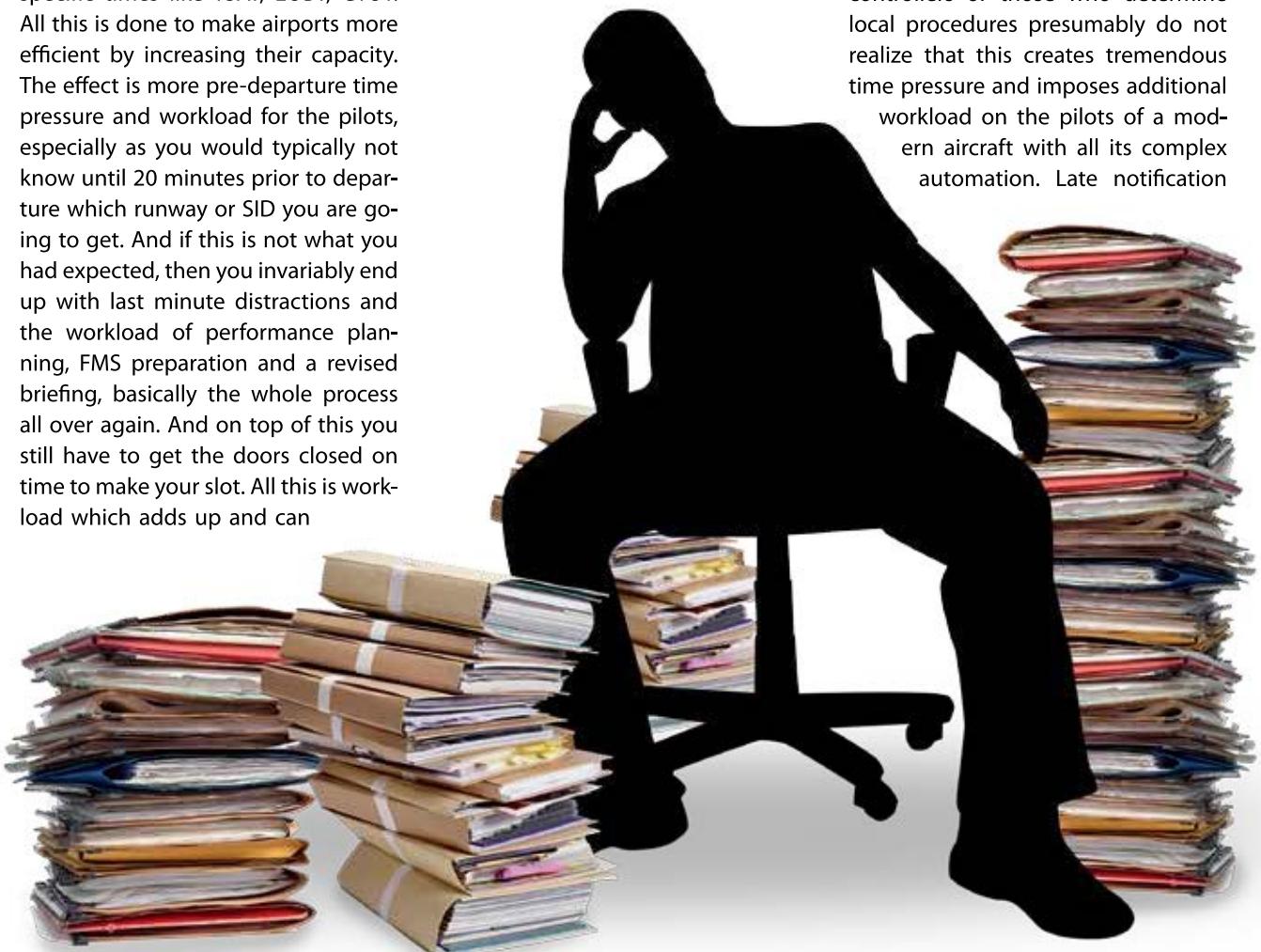
## The chronology of workload (cont'd)

Now let me share what the present day workload of a typical transcontinental flight looks like. Nowadays, some of the major airports have page after page of charts and masses of airport briefing pages with technical information, much of which is not related to the operational needs of pilots. Sometimes there can be close to a hundred pages of SIDs and STARs each with a different name and chart number but really many are the same ILS approach with a small bullet note of procedure to make it a different chart as ILS X,Y or Z approach. There now seems to be a competition by the chart makers, in the skies by ATC and in the company to increase pilot workload. At major EU airports, you would now need to understand not only 'Slot time', but more specific times like TSAT, EOBT, CTOT. All this is done to make airports more efficient by increasing their capacity. The effect is more pre-departure time pressure and workload for the pilots, especially as you would typically not know until 20 minutes prior to departure which runway or SID you are going to get. And if this is not what you had expected, then you invariably end up with last minute distractions and the workload of performance planning, FMS preparation and a revised briefing, basically the whole process all over again. And on top of this you still have to get the doors closed on time to make your slot. All this is workload which adds up and can

fray the pilots' nerves. They will now be at more risk of making mistakes in performance planning with the wrong flap setting for the changed Runway or the wrong V speeds. Situational awareness can degrade and this can increase the chances of taxiway or runway incursions. Now if you then add the cold weather deicing procedure at major airports you would have the real threat of workload. On the other extreme, some of the Asian airports will still not give you the departure clearance until you are taxying out and handed over to the tower controller. They will often not appreciate that the departure procedure needs to be inserted in the FMS, the MCP needs to be setup and the EFB needs to be organised for the departure procedure. All these

are head-down actions during taxiing which add to workload.

Even with all these complications, the departure workload is much simpler these days than the arrival workload. Let us look at what happens in a major airport in Europe, Asia or the USA. The ATIS will typically give you two or sometimes three runways for arrival. If you do not have datalink and D-ATIS then you have to wait until within VHF range to plan your arrival and to brief the crew. You may well not know which arrival and runway you are going to get until after you have started your descent. For some US airports, you do not get confirmation of the landing runway until you are handed over to the approach controller. The controllers or those who determine local procedures presumably do not realize that this creates tremendous time pressure and imposes additional workload on the pilots of a modern aircraft with all its complex automation. Late notification



or change to a landing runway needs last minute FMS, EFIS, MCP and EFB setup followed by a briefing in a busy R/T situation when you are constantly being called by ATC for speed change, level change, frequency change and or heading change. This means high workload and the risk of degraded situational awareness due to head-down time of at least one pilot and chances of getting 'out of the loop' because temporarily, it is no longer possible for both pilots to monitor ATC. Then add to this the ATC-imposed speed control and maybe a high speed arrival until late followed by the stringent Company requirement for a stabilised final approach. Most controllers do not tell you the track miles while they are vectoring you so you do not know your profile till late which might lead to interception of the glidepath from above. Acceptance of an ATC request to maintain high speed for too long can result directly in an un-stabilised approach. Worst of all is when the last minute change of runway is during a visual or a non precision approach as occurs at some of the major US airports. Controllers there do not appear to realise that if pilots are not used to flying visual or non-precision approaches, thus the work load on the flight deck for both pilots increases significantly. The monitoring pilot's ability to cross check for errors by the handling pilot degrades in situations like this. Controllers also do not always seem to understand the energy management difficulty for pilots of large passenger jets in situations like these.

For some airport controllers, a different approach to their task is an appreciation of when and why pilot work load increases. Controllers need to recognise that pilots are mostly pretty well prepared and procedurally responsive to things which go as planned or if a change of plan is known early enough. The contrast be-



## Capt Shah Alam

is an experienced pilot who flew in the Bangladesh Air Force and with Biman Bangladesh Airlines for over 30 years. His airline roles included being a TRE and a CRM trainer and holding management positions as Chief of Technical and as General Manager Corporate Planning. He now works as a Captain on the Boeing 777 aircraft with Qatar Airways.

tween en route and terminal area pilot workload is marked. The former is generally low because management of the airspace is pretty much the same the world over whereas each individual major airports has its own unique pre-departure procedure, arrival procedure, taxi procedure or taxi routes presented in an abbreviated form which itself creates extra workload for a pilot who is not familiar with it. He needs to look at the briefing pages to check the standard taxi routing and any last minute runway change increases workload to the extent that positional awareness may be lost, and errors ranging from taking the wrong runway exit or subsequently taking a wrong taxiway or even a taxiway incursion at a hot spot may follow. Some might argue that hotspots are depicted on the chart, but checking that means reading the airport reference pages and their notes and explanations when you are still flying the aircraft and responding to ATC re-clearances for every 1000 feet of descent and to frequent changes of heading and speed, not to mention the workload created by the diverse use of aviation English around the world. Without being prejudiced we see the full range of possibilities from 'all American English' to 'Chinese or East Asian English'. So why can't we have an arrival procedure and a landing runway given to the pilot early enough to allow them to prepare well, when the flight deck workload is low instead of giving the

changes in the terminal area. And if ATC is providing radar vectors, give the track miles to go automatically so that pilots can plan the energy management and the descent profile. Such practices add to safety by reducing workload and better situational awareness.

ATC must remember that pilots often do not operate to the same airport often. Having served almost four years in a major airline, I have not yet operated to all the airports served by my B777 fleet. So if I'm rostered to operate to a completely new airport in the US or in China then the preparation has to start days ahead to read the airport pages, taxi routes, special ATC procedures, expected arrival and departure procedure, Jeppesen charts, state procedures, the Operations Manual Part C and so on. Now add to this around 70-80 pages in the briefing package on the day consisting of page after page of NOTAMs which will mainly tell you where one taxi light is missing, or some of the markings are missing or some crane operating near the airport. This is real workload.

My hope that the regulators and airport authorities will some day harmonise the procedures at major airports and thus reduce the number of superfluous charts and briefing pages. ATC would always pass the expected departure and arrival routes and the runway early enough, maybe via datalink, for automation insertion and planning to reduce the workload and achieve safer skies. 

# Where is my workload? Identifying hot spots



**by Patricia Lopez de Frutos and Nicolas Suarez**

Today is a normal day in Europe, with normal traffic flows and no incidents.

Aircraft are flying through European skies efficiently, following user-preferred routes and keeping to their target times. In this normal situation, nothing seems to go wrong. Nevertheless, the Local Network Position of ACC WXY has detected a possible non-normal situation.



**Patricia López de Frutos**  
holds a M.S. in aeronautical engineering and has a working experience of over 15 years in the ATM business sector. Her area of expertise is focused on validation of future concepts and their impact on performance. Currently, she is a principal research engineer at CRIDA (ATM R&D and innovation Reference Centre). She coordinates CRIDA participation in SESAR Development Phase.



**Nicolas Suarez**  
holds a B.S. in aerospace engineering and has a working experience of over 25 years in the Air Traffic Management (ATM) domain. His area of expertise is focused on the development, assessment and validation of ATM operational concepts and logical architectures. Currently, he is a technical manager in CRIDA (ATM R&D and innovation Reference Centre).

Due to an unexpected weather disturbance, a number of aircraft trajectories have been modified. This situation, combined with a small set of departure delays in airport ABCD will result in a hotspot in sector EFGH in 45 minutes from now. Having identified the hotspot, the Local Network Manager in cooperation with the Regional Network Manager proposes to level cap the flow of aircraft coming into the sector. This solution is also coordinated with the operations control centres of the airlines involved which results in minimum all-round disturbance to the system. This action allows all the aircraft involved to maintain their target times.

As seen from this hypothetical example, the key to identifying and addressing small system disturbances is to correctly identify and deal with hotspots. However this seemingly easy process has a number of challenges. The first one is to identify what is a hotspot.

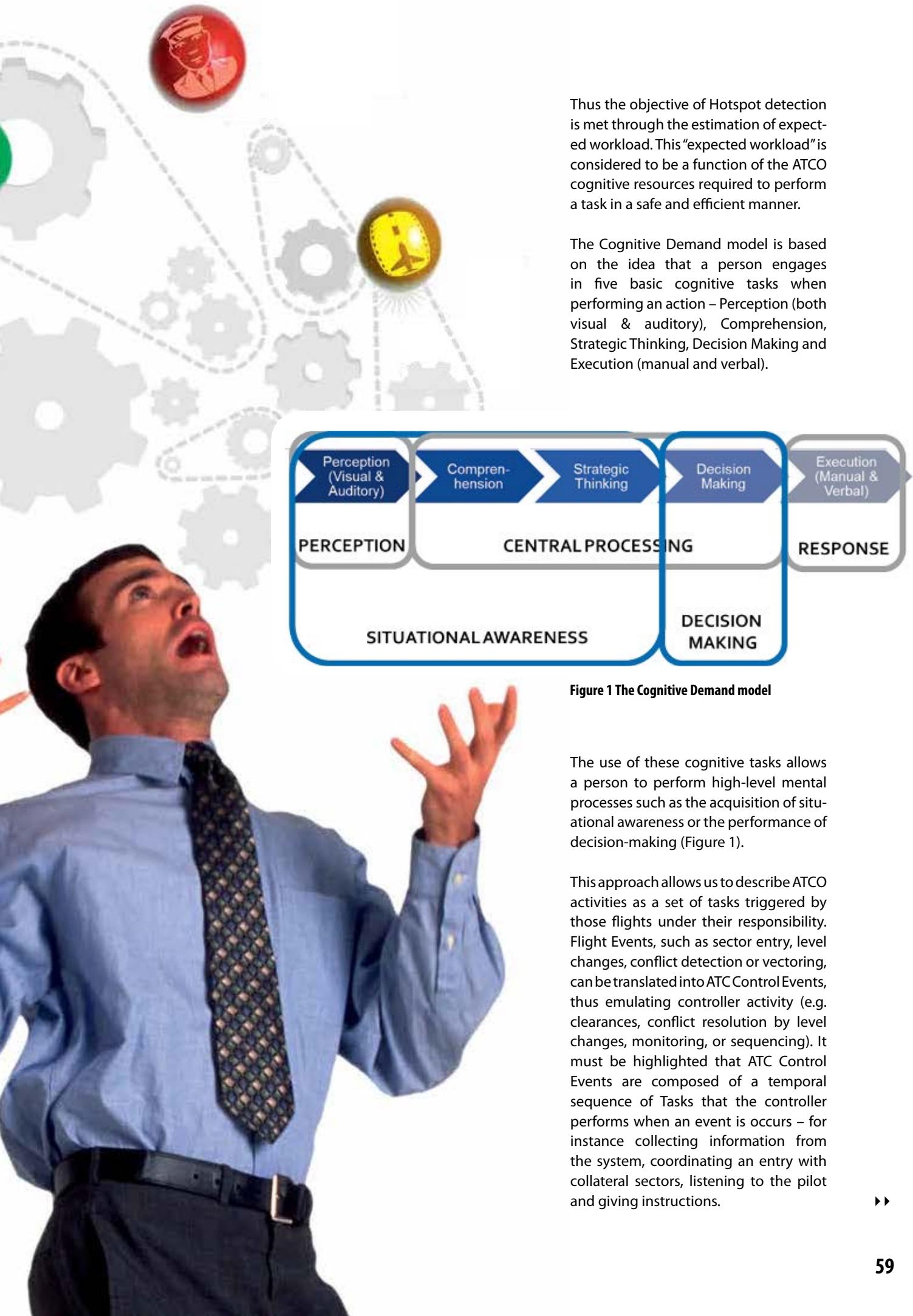
Hotspots can be defined in a number of ways, but the most useful method is to assess the prospective hotspot in terms of complexity. A hotspot is defined as a location of high complexity where one or more controllers will need to pay extra attention to ensure the safe flow of aircraft. So far so good but, what exactly is complexity? In this context, ATM complexity is understood to be a multi-dimensional construct that includes static sector characteristics and dynamic traffic factors. These factors can, for example, be physical aspects of the sector, or factors relating to the movement of air traffic through the airspace.

This last paragraph has introduced a key aspect of ATM complexity, its direct relationship with workload, so we are able now to refine our understanding of a hotspot. A hotspot is an area of high controller workload where one or more ATCOs will experience undue pressure if they are to ensure the safe flow of aircraft. Thus, if we are able to determine those areas where ATCO workload is above a certain threshold, we will be able to identify potential hotspots.

Generally speaking, the workload experienced by an ATCO has a range of different components, but from an operational point of view, the most significant feature of workload is the "mental workload".

Mental Workload is defined as a function of the resources required by the cognitive processes that a task demands (cognitive demand) and the mental resources available. In this context, mental overload occurs when there is an excess of task load (cognitive demand) compared to the psychologically available resources that the controller is able to supply. It is assumed that tasks are always performed without reducing safety levels.





Thus the objective of Hotspot detection is met through the estimation of expected workload. This "expected workload" is considered to be a function of the ATCO cognitive resources required to perform a task in a safe and efficient manner.

The Cognitive Demand model is based on the idea that a person engages in five basic cognitive tasks when performing an action – Perception (both visual & auditory), Comprehension, Strategic Thinking, Decision Making and Execution (manual and verbal).

**Figure 1 The Cognitive Demand model**

The use of these cognitive tasks allows a person to perform high-level mental processes such as the acquisition of situational awareness or the performance of decision-making (Figure 1).

This approach allows us to describe ATCO activities as a set of tasks triggered by those flights under their responsibility. Flight Events, such as sector entry, level changes, conflict detection or vectoring, can be translated into ATC Control Events, thus emulating controller activity (e.g. clearances, conflict resolution by level changes, monitoring, or sequencing). It must be highlighted that ATC Control Events are composed of a temporal sequence of Tasks that the controller performs when an event occurs – for instance collecting information from the system, coordinating an entry with collateral sectors, listening to the pilot and giving instructions.





## Where is my workload? Identifying hot spots (cont'd)

Tasks are performed through elementary actions called Primitive Operator Actions. Each one of these involves different parts of the Cognitive Process such as reach flight strip, fixate object, search with pattern, listen, recall, recognise, select, compare, compute, decide, say a message and type. Primitive Operator Actions are triggered according to the cognitive processes implied in the controller task and result in the use of different cognitive resources with different loads.

The relationship between ATC Control Events, Tasks, Primitive Operator Actions and cognitive resources is determined by the way in which controllers perform their control actions and constitutes the operating concept used by the Cognitive Model to estimate the required cognitive resource needed to manage a specific traffic situation (Figure 2).

We can now model ATCO activities in terms of the tasks associated with the operating concept used to provide the control service over an area, but we

still need to translate the model into "something" that can be used to obtain a number. To accomplish this, we must determine how the performance of tasks affects cognitive demand.

Cognitive Demand is calculated using Wickens' algorithm. When Tasks overlap in time, the Total Cognitive Resource Demand depends on two factors, the resources demanded per task and a "conflict" component when two tasks compete for the same pool of resources. The Multiple Resource Model postulates separate resource pools in terms of three dimensions of information processing so that when two tasks use the same pool of resources there is a conflict and a higher cognitive demand results.

Wickens' algorithm allows us to estimate cognitive demand using a set of flight events and control events. Furthermore, this algorithm permits us to use different operating concepts depending on traffic features and environmental context.

There are three basic concepts that we need to implement (figure 3):

**Cognitive Demand (Task Load):** the physical and mental activity required to deliver perceptual actions, cognitive actions and motor skills. To model this concept it is assumed that Flight Events result in ATC Control Events that are driven by an underlying Operating Concept and that their implementation requires a specific set of cognitive resources.

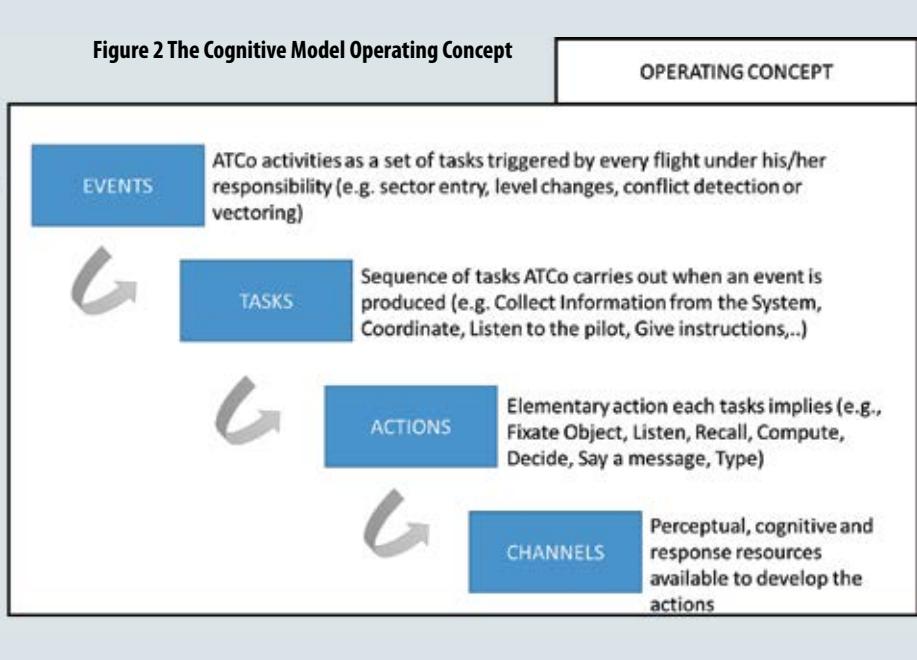
**Available Mental Resources:** the mental resources that an ATCO has available to provide the control service, considering only a fixed amount of base resources. The psychological factors experienced during a controller's shift such as fatigue, stress and satisfaction with work done shape the available resources.

**Threshold:** the value beyond which Cognitive Resource Demand (Task Load) exceeds the Available Mental Resources. This is where a direct impact on safety begins and the ATCO will need to be trained to cope with these situations or be supported by technology. Currently the Cognitive Model assumes a fixed amount of available resources.

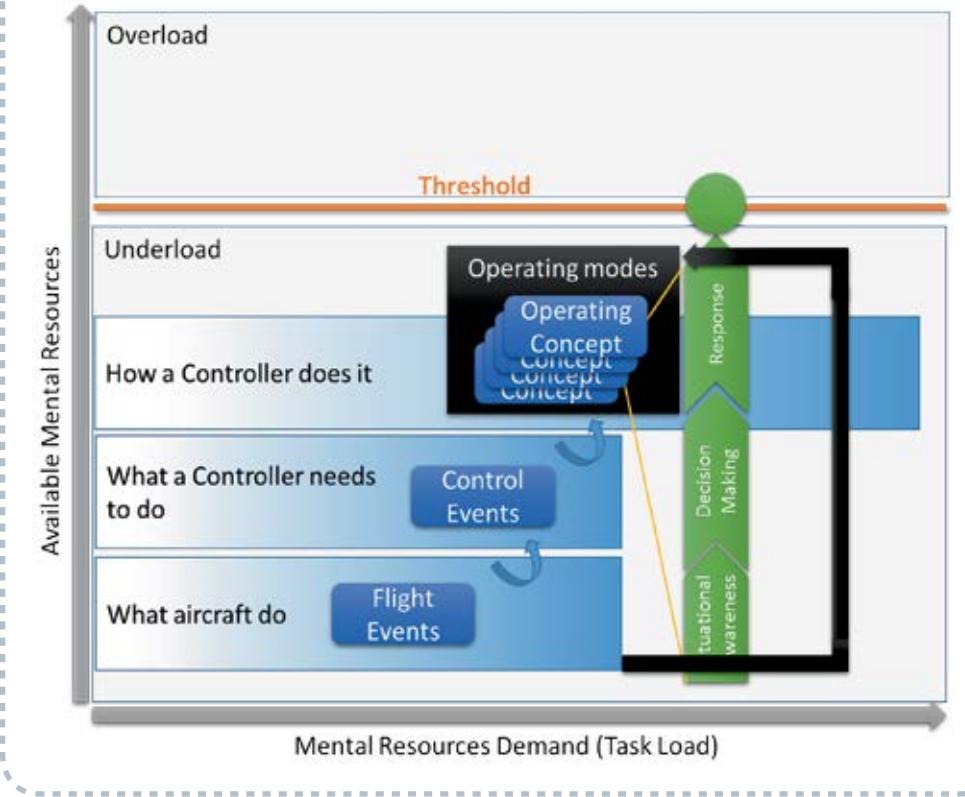
The implementation of these three components results in a system that is able to estimate the workload using commonly available information such as flight events and operational inputs.

Up to this point, the reader will have noticed that there is a strong theoretical emphasis in this approach. So the question that we now need to pose is can we build an experimental sys-

Figure 2 The Cognitive Model Operating Concept



**Figure 3 The Mental Workload Model System Framework**



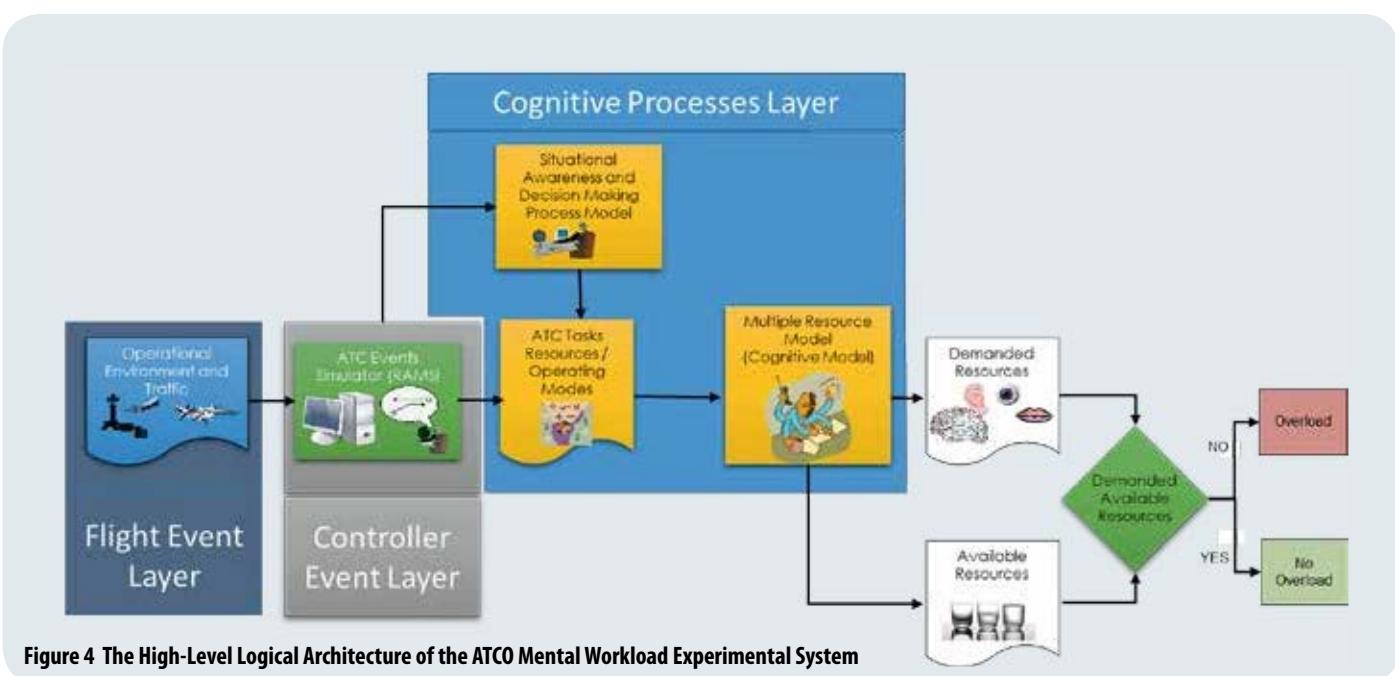
plement this approach already exist and are being used by ENAIRE and CRIDA and are under evaluation as part of the SESAR programme.

Additionally, analysis of validation data from the mental workload model indicates that there is a need to upgrade the mental workload model to take into account the variability of human behaviour under the different traffic patterns and dynamic environments that are the Operating Modes. This will

tem that implements this approach? The answer to this question lies in our ability to develop an appropriate logical architecture and an associated set of operational requirements. This architecture defines the principles that support the estimation of the workload (Figure 4).

We believe that the use of Cognitive Demand to assess the workload is a viable approach for the identification of hotspots. This approach has a distinct advantage presenting the hotspot in terms of high workload areas that require special effort from ATCOs. The models and systems required to im-

be achieved by introducing dynamic thresholds, enhancing the definition of operating modes and developing situational awareness and decision-making process models. Psychological factors such as fatigue, stress and emotion will be integrated to complete the model as part of future projects. S



**Figure 4 The High-Level Logical Architecture of the ATCO Mental Workload Experimental System**

# Workload levels and their impact

by Dr. Beth Lyall

Workload has been described as an indicator of the level of total mental and/or physical effort required to carry out one or more tasks at a specific performance level.<sup>1</sup> The reason we pay attention to workload is because of the effects it can have on performance as it changes. When workload is too high or too low, it can significantly increase the probability of all types of errors.

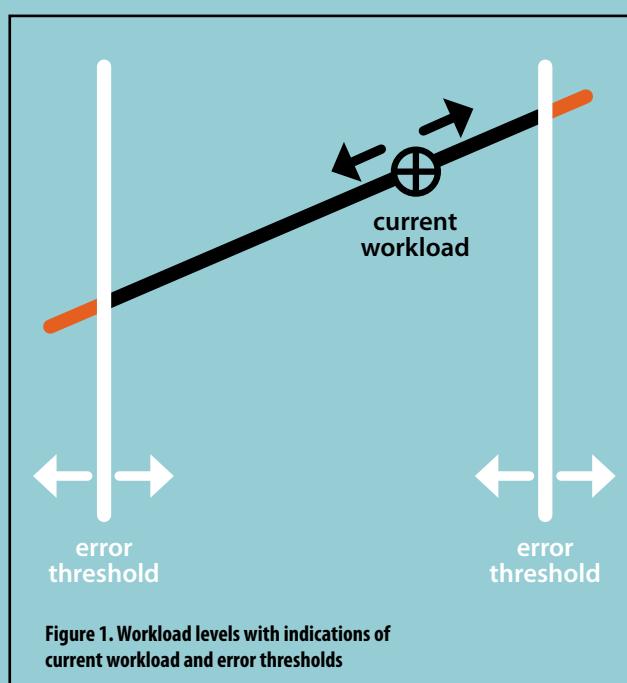


1- Stramler, J. H., Jr. (1993). *The Dictionary for Human Factors/Ergonomics*. Boca Raton, FL: CRC Press, Inc.

The challenge in addressing workload is that it needs to be broken down into its components in order to understand what actions can effect an improvement in performance. In this article I will give one way of breaking down the concept of workload and how it can be addressed in design, training, and operations.

Workload is one element in a situation that impacts performance and the potential for making errors. In a safety-related situation we are interested in minimising errors and ensuring that errors that do occur can be recognized and managed.

**Figure 1** presents a notional workload description that will allow a discussion of all the different components and their impact. The line depicts how workload moves from low to high. Many factors define the point along this line that workload will reside at for one point in time. That point will change as the tasks and situations change. The two threshold lines on the graphic indicate the level of workload at which the probability of errors increases. There is an error threshold when workload goes too low and one where workload goes too high. When the current workload level goes beyond either threshold, the occurrence of errors is much more likely. The challenge is that all of these are moving parts. Workload goes up and down, and the thresholds move based on certain factors. In the remainder of this article, I will address each of these components and how they are influenced.



## Current Workload Level

The current workload point is determined by a combination of many factors including:

- Tasks being accomplished
- Design of systems and equipment
- Processes and procedures
- Situation and environment

**Tasks:** Some tasks are more difficult to accomplish than others. They require more mental or physical resources, making workload higher at the times they are being accomplished. However, tasks do not stand-alone.

**Design of Systems and Equipment:** The design of the systems and equipment used to accomplish the tasks will also impact the workload at that time. If the design is poor and requires a lot of effort to understand and use the system, then workload will be higher. Workload is impacted by the design of all systems, displays, controls, and equipment being used. If workload is significantly impacted, it can lead to critical performance errors. Human factors considerations in design have been developed<sup>2</sup> to reduce the potential for these design-induced errors.

**Processes and Procedures:** The availability and design of any required processes or procedures also impact workload. For example, performance in an emergency situation is easier if an appropriate checklist is available for that situation. And when that checklist is needed, the effort required to find the right checklist, understand it, and use it will impact the workload at the time of doing the tasks to deal with the emergency.

**Situation and Environment:** Finally, the situation in which the tasks need to be performed will impact the workload experienced. Attributes of the situation that affect the level of workload include urgency, competing tasks, time of day, ambient lighting, noise, and the availability of other team members to help.

Each of these four factors vary throughout a work session, causing the current level of workload to go up and down as the four factors come together at any one point in time.



<sup>2</sup> - Lyall, B. and Harron, G. (2005). A Systematic Approach To Addressing Human Factors Considerations In The Design Of Flight Deck Components. Proceedings of the Thirteenth International Symposium on Aviation Psychology, April 18-21, 2005, Oklahoma City, Oklahoma.

## Workload levels and their impact (cont'd)

# Error Thresholds



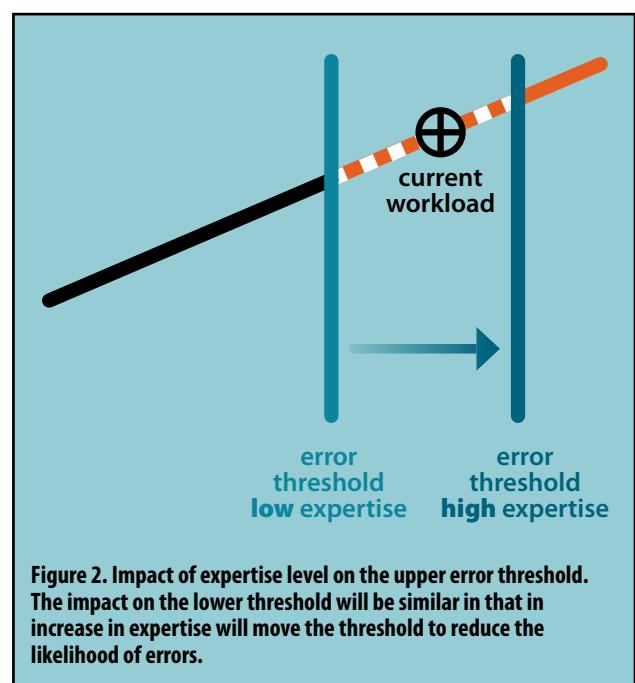
The big reason we care about the level of workload is that it can lead to performance errors. Workload levels can contribute to many types of errors including physical errors of data entry or manual handling; perceptual errors of not recognizing a change in display label, not identifying a system failure, or not hearing an aural alert; and cognitive errors related to planning, decision-making, problem-solving, troubleshooting, communicating, task management, and many more. It is the relation between the current level of workload and the error threshold that determines the likelihood of these errors. If the current level of workload is at or beyond the error threshold – either at the high or low end of the workload range – errors become more likely.

Along with the four factors (tasks, design of systems and equipment, processes and procedures, and situation and environment) that impact where the current level of workload will be along the range of workload, there are factors that are associated with the error thresholds. The workload threshold for error is determined by a combination of several attributes related to the person performing the tasks at a particular point in time. Four of these attributes are:

- Level of expertise
- Fatigue
- Distraction
- Stress

## Level of Expertise:

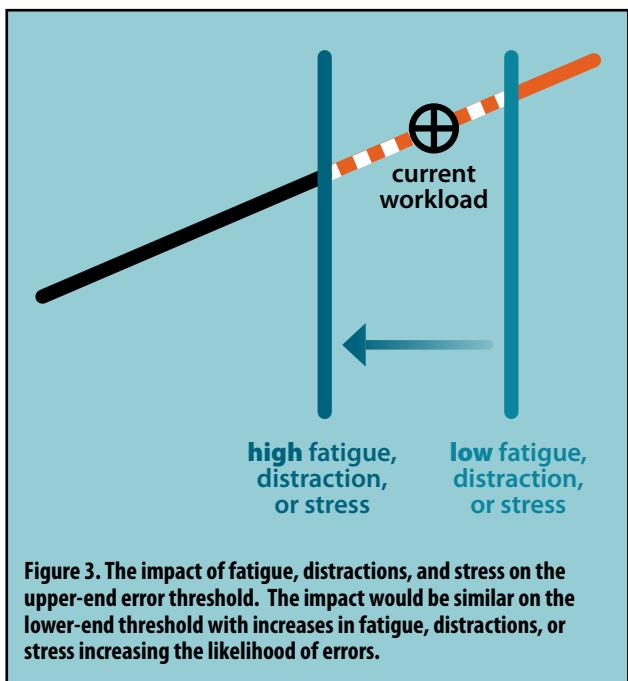
We usually think of a person's expertise as encompassing their knowledge, experience, and training for accomplishing tasks. That is important here too with the knowledge, experience, and training someone brings having a big impact on their performance and the likelihood that they will make an error in general. I want to expand expertise for this discussion to also include the knowledge, experience, and training for using the systems, equipment, processes, and procedures – and in facing the situations and environments. So all of the factors that contribute to the existing level of workload are important when considering how prepared a person is for dealing with those tasks and situations. This combination sets the threshold for error. If expertise is high, the threshold is higher, and, considering the threshold at the high end of the workload range, a person can handle increasing levels of workload before significantly impacting the probability for error. But the threshold for error for novices will be lower, more likely leading to errors when facing lower levels of workload. **Figure 2** illustrates this difference in error thresholds for people with lower and higher levels of expertise for the current tasks and situation at the high end of the workload range. The impact would be similar at the low end with more expertise resulting in less likelihood of errors.



**Figure 2. Impact of expertise level on the upper error threshold.**  
The impact on the lower threshold will be similar in that an increase in expertise will move the threshold to reduce the likelihood of errors.

## Fatigue:

The impact of fatigue, whether physical or mental, is to reduce the threshold for error and make it more likely that errors will occur for particular workload task and situation combinations. One of the challenges with fatigue is that it usually increases as a work session progresses. It also changes with levels of alertness and changes in the circadian rhythms. We all know that we feel more tired or fatigued in the middle of the night than we do during the day. The error thresholds change with these changes in fatigue throughout a work session, resulting in errors being more likely with less workload at the high end and less tolerance for lulls in workload at the low end. This means that the same challenging tasks that are accomplished easily with no errors early in a work session will be more prone to error occurrences later in the session if fatigue increases. **Figure 3** shows this effect along with the similar impact of distraction and stress.



## Distraction:

Distractions can come from many sources including competing tasks, voices of others nearby, noise, and lights and reflections. When we are distracted, many areas of performance are affected. For workload, distraction moves the error threshold (either high or low), making it more likely that errors will occur.

## Stress:

Our level of stress impacts the error threshold by moving the high-end threshold to the left – or moving the low-end threshold to the right – and making it more likely to commit errors for a given current level of workload. Stress can also increase the levels of fatigue and distraction enhancing their associated impacts as well.

## What Can You Do?

### 1. Understand the impact of the different factors related to workload

Everyone is different. Review and continue to try to understand how the current workload levels change for you in your work situations, which factors have more impact for you, and what you can do to recognise the current levels of workload and when you are getting close to the error thresholds.

### 2. Be prepared

- Stay current on your training and engage in getting new knowledge about incidents and situations you may not have yet encountered.
- Reduce your stress by having a regular exercise and relaxation routine.
- Manage your level of alertness by getting enough sleep, eating a well-balanced diet, staying hydrated and limiting your use of caffeine as an alertness strategy.

### 3. Develop strategies to use while at work

- Review and brief about the expectations for changes in workload situations – at the beginning of a shift and as expectations change.
- Recognise changes in workload and take steps to address their impact.
- Develop routines to keep yourself alert and reduce the risk of fatigue.
- Try to avoid the impact of distractions by coming to work prepared and ready to focus by employing the fatigue avoidance strategies mentioned earlier and taking a professional attitude to each work session. S



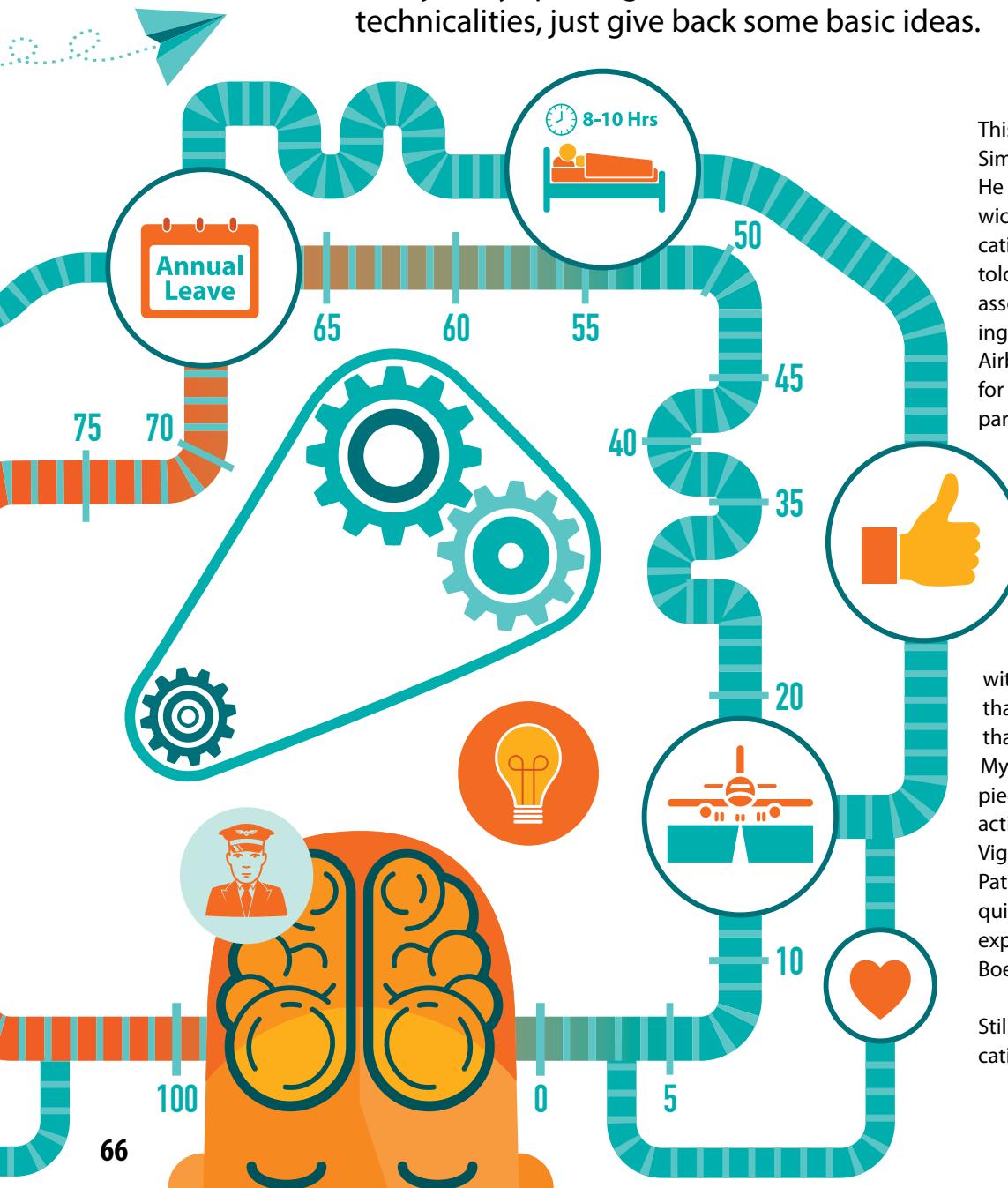
## Dr Beth Lyall

is founder and president of Research Integrations, Inc. For over 25 years she has been improving safety through the enhancement of human performance in design, certification, training, and operations in aviation and other safety critical domains by conducting and applying human factors research. She has served on a number of international aviation industry committees including the Flight Deck Automation Working Group.

# Can ATM learn from the experience of pilot workload measurement?

by Jean-Jacques Speyer

Hard-won experience from 35 years of experience with airline pilot workload measurement methods can perhaps shape the future of Air Traffic Controller workload measurement in the context of SESAR & ATM just by sparking some ideas...We don't want to bore you with any technicalities, just give back some basic ideas.



This all started with Professor Bob Simpson, my thesis supervisor at MIT. He used to meet his guys over a sandwich lunch and was pretty communicative about his own work. One day he told us about his review of workload assessment methods for the impending MD80 certification. Years later at Airbus, as I was being interviewed for a job in the Flight Operations department, I was asked "have you ever heard of pilot workload?" "No... oh, yes, now wait a minute, yes, now I remember..." Within days I was working on the design of the flight deck of the world's first two-crew wide-body aircraft, the Airbus A300FF, with a "carte blanche" to go and meet up with NASA's HF gurus who were more than happy to show headquarters that they were popular in Toulouse. My starting point was a landmark piece "A Simulator Study on the Interaction of Pilot Workload with Errors, Vigilance and Decisions", by the late Dr Patrick Ruffell Smith. His work coupled quite well with my personal practical experience of workload from time as a Boeing 707 Flight Engineer.

Still to this day minimum crew certification under FAR 25 and its Appendix

D stipulates both workload functions and factors that need to be assessed and documented but do not suggest any means of compliance. After proposing a simple framework to my management, which the airworthiness authorities readily accepted, we could start work in earnest to develop our own evaluation methods.

The overall idea was to compare a new aircraft to be certified for two-crew operation with existing ones – at the time already well – proven in actual airline service – to assess whether the new aircraft footprint would be within the envelope of the older design. Methods were developed just by “doing it” – by intuition.

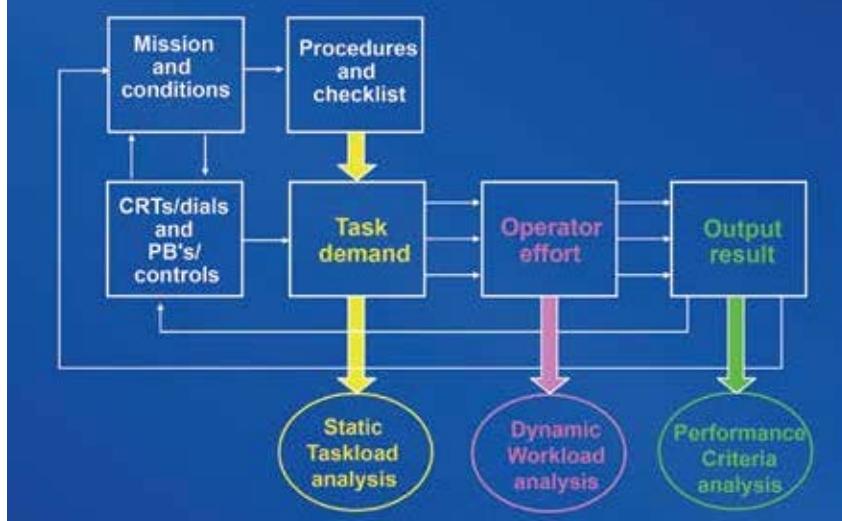
evaluations in mockups with early sets of procedures not yet subject to flight experience. The avionics smoke procedure analysis even triggered a redesign of the A300 electrical system.

**Dynamic Workload Analyses** compared the timelines of workload variations under demanding scenarios with subjective ratings from each pilot using an 8-point scale derived from Cooper-Harper's scheme to evaluate *Aircraft Handling Qualities*<sup>1</sup> with concurrent subject pilot and observer ratings from Airworthiness Authority pilots. These demonstrated that workload ratings measured for both the A300 and for the smaller A310 were within those recorded for B737/DC-

Certification reports – already as early as then – emphasized the need for pilot training to include full use of ECAM messages and FMS modes, specifically predicting the need to focus on conventional aircraft handling without resorting to automation so as to maintain pilot flying skills and avoid loss of situational awareness, years ahead of issues that would become top industry concerns,

**Performance Criteria Analyses** compared electronic flight instruments and flight management systems respectively to electromechanical instruments and conventional navigation systems (HSI, ADI), measuring pilot performance when executing a specified and demanding circuit on the flight test A300. Another experiment compared side-stick/Fly-By-Wire (FBW) versus conventional controls by removing the conventional controls at the left side of the test aircraft and replacing those with a side-stick. Experience was gained in assessing basic measures derived from dozens of aircraft performance parameters such as for example pitch, speed, elevator position and engine power lever angle. For the FBW experiments, smoothness, stability measures and rates of reversals showed a marked improvement over conventional control. When using the side-stick, pilot control inputs were reduced by 50% or more, releasing time for other flight management duties.

## Conceptual framework and tools for HMI-Analysis



**Static Taskload Analyses** considered the Normal, Abnormal & Emergency system procedural tasks that had in the past been carried out by a Flight Engineer. These indicated that task-load of the aircraft under evaluation for certification would be within the envelope defined by the reference aircraft (B737/DC-9), an early indication of acceptable two-person crew operations on the new aircraft. This work also enabled first hand task-sharing

9's. Overall, workload profiles were in the moderate range and crews never experienced workload levels becoming extreme and unacceptable to the point that errors became inevitable. Good convergence emerged between subject pilot and observer ratings, with about 75% of ratings being identical. Calibrated and validated, the proposed rating scale was deemed usable.

Following the positive outcome of these methods, a mathematical model, the **Airbus Workload Model**, was developed in the wake of the A310 certification and fitted the subjective rating data well. This model was a statistical combination of aircraft flight parameter data such as airspeed and roll rate with heart rate variability data on both pilots and flight status measures such as phase of flight. The model predicted the rating a pilot would have given on the workload rating scale. The overall experimental methodology was sufficiently original for a joint patent to be obtained in France,

1 - G. Cooper and R. Harper. The use of pilot rating in the evaluation of aircraft handling qualities. Technical Report TN D-5153, NASA, April 1969.



## Can ATM learn from the experience of pilot workload measurement? (cont'd)

the USA and Europe on behalf of three parties concerned<sup>2,3</sup>.

The model gave the "subjective" nature of ratings a solid foothold as subjective measures often sounded unusual and weird, eventually strengthening acceptance of the two crew certification process. The availability of continuous modeled graphs provided a unique opportunity to examine some issues such as possible associations between workload, automation and errors; there was an indication that severe errors may occur during periods of high and increasing workload; as well as the suggestion that these take place near surges and peaks of workload. Workload decreases noted thereafter appeared as pilots procrastinating, taking tactical postures, at times even shedding tasks. We also found that just as for errors, plotting workload graphs and automation levels pointed towards a classical inverse relationship between the two.

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Step-by-step, the version of this model that had been developed for the A310 was used for the A320 and was expanded for airline applications on A310, A320, B767 and B747-400 aircraft and validated for the

A340 certification. It was also able to help investigate the impact of automation on crew underload in long-range operations in parallel with dedicated **crew alertness measurements** to help formulate recommendations to cope with crew fatigue.

Although there had been much research on pilot workload, virtually all of this had been focused on overload. Hence we progressed to measuring crew alertness in actual airline operations to complement workload plots calculated from the model using DFDR data and pilot ECGs.

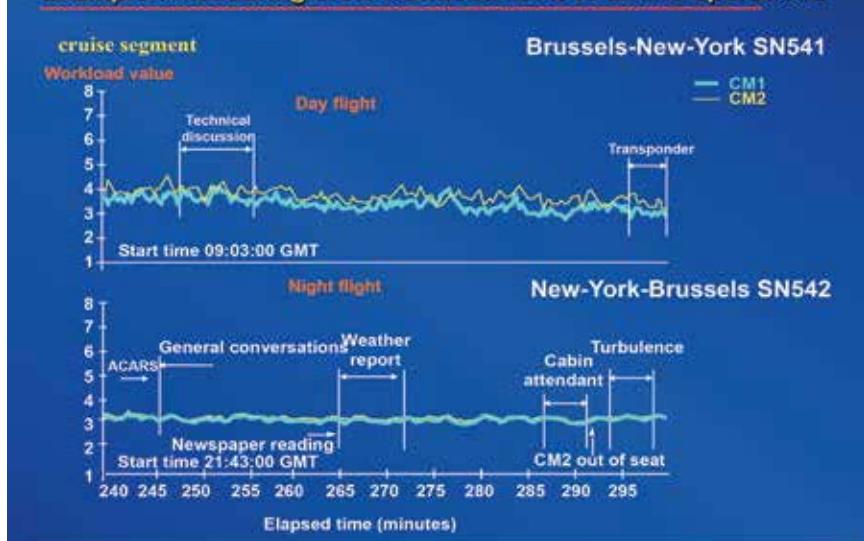
It was found that for short periods, both pilots would cooperate in shared tasks and that these would be separated by longer periods where pilots were effectively disconnected from one another. To preserve crew vigilance, the concept of pilot alternation emerged, crewmembers taking turns to enable napping "in the seat" to reduce sleep pressure. Pilot ECGs showed that low activity with relatively flat workload curves were typical of night flights whereas a saw-tooth pattern characterised daytime flights. This suggests that lower workload variability could act as a predictor of low vigilance or under-alertness. Unsurprisingly, high pilot workload was calculated when arriving at busy and unfamiliar airports after long overnight flights. One night we even recorded a precautionary engine shutdown after erratic oil pressure fluctuations just after a near miss coupled with ATC coordination problems – the activity ratings surged. This was seen as "proof of the pudding" as far as the model's reliability was concerned given that it had been formulated during certification testing where pilots knew in advance there would be problems to be faced.

WORKLOAD ASSESSMENT	CRITERIA			APPRECIATION
	Reserve Capacity	Interruptions	Effort or stress	
LIGHT 2	AMPLE			VERY ACCEPTABLE
MODERATE 3	ADEQUATE	SOME		WELL ACCEPTABLE
FAIR 4	SUFFICIENT	RECURRING	NOT UNDUE	ACCEPTABLE
HIGH 5	REDUCED	REPETITIVE	MARKED	HIGH BUT ACCEPTABLE
HEAVY 6	LITTLE	FREQUENT	SIGNIFICANT	JUST ACCEPTABLE
EXTREME 7	NONE	CONTINUOUS	ACUTE	NOT ACCEPTABLE CONTINUOUSLY
SUPREME 8	IMPAIRMENT	IMPAIRMENT	IMPAIRMENT	NOT ACCEPTABLE INSTANTANEOUSLY

2 - Dunlap & Associates, the Cochin Laboratory of Adaptation Philosophy and Airbus.

3 - Speyer JJ, Fort A, Blomberg R.D , Fouillot JP,"Assessing Workload for Minimum Crew Certification", in AGARD AG-282, "The practical Assessment of Pilot Workload, Ed. By Dr A.Roscoe,, June 1987

### Example : measuring crew workload in A310 airline operations



Work on active/passive pilot alternation also informed a means to monitor the awake pilot during the other pilot's in-seat napping on long haul flights and warn him/her, if necessary, of his/her own impending sleepiness. This concept of electronic pilot activity and alertness monitoring depended on two inputs:

- pilot activity monitoring by detection of their interaction with different aircraft systems such as the FMS, ECAM, EFIS FCU and RMP ,
- pilot eye-tracking because of the possibility that pilots would still manipulate systems when in a low alertness state,

The concept also goes along with present philosophy on pilot flying/pilot monitoring.

Evaluation on selected flights showed that:

- Cameras could be used to obtain some measure of the cognitive part of pilot workload since filmed eyelid closures correlated with alertness measures as it would clearly be impracticable to 'wire-up' line pilots to EEG recorders in routine airline operations,
- Cameras could be used to record what instruments pilots were actually looking at – although this was and remains taboo for normal line flying purposes,

- EEG recordings confirmed that decreased alertness would get back to higher levels if a pilot took on a cognitive workload coupled with physical interface activity, within a limited time and sufficiently vigorously that situational awareness could be regained. A finding we could verify for the cruise parts.

Finally, we undertook Minimum Crew Certification for the A380. This was quietly and smartly performed by means of NASA's TLX index. Its 6 dimensions – mental, physical and temporal demand, frustration, effort and performance, were measured using hand held devices to capture pilot ratings. After calibration these could assess multi-attribute tasks involving tracking work, systems monitoring and scheduling work, communications, systems status work and resource management, so as to assess all elements of workload acceptability using just a handful of scenarios.

This process led to the finding that on all long-haul flights without augmented

crews, taskload tended to rate higher since longer time on task would deplete more of their physical and mental reserves. It was also found that in the case of the A380, as with all the other types, CRM breaks down under extreme workload. When cognitive bias overpowers the PF, the other pilot has to take over. But what if both pilots are under pressure that narrows their workload capacity? How then can we avoid situational awareness sliding further away?

So, what does all this say for the world of the ATC Controller? Perhaps some ideas are that:

- Their work could be monitored; just as we had observer-pilots rating workload and describing flight scenarios, can we imagine a similar procedure for future ATM operational evaluation and certification using an equivalent of the **Aircrew Data Logging** software.
- Eye tracking could be used to see what the controller looks at and record eye movement sequences eyelid or eye-pupil devices to assess alertness & workload
- ATC strategies & tactics could be mapped, workload models would soon emerge and discriminations like taskload, workload & performance could be made! ↗



**Jean-Jacques Speyer**

Jean-Jacques, MS EI & Mech Eng, VUB, Brussels, Belgium, MS Aero & Astro, MIT, USA, DU HF's & Ergonomics, Univ René Descartes, Paris, France. After an airline start as B707 Flight Engineer, JJ Speyer moved on to Flight Operations Engineering & Certification at Airbus from where he retired as Senior Director Airline Consulting, Fuel & Flight Efficiency at the end of 2009. He is currently Professor in Aircraft Specification & Certification at the Vrije Universiteit Brussel.



# Workload management in a 2-man flight deck: when automation increases the workload...

**by Captain Dirk De Winter**

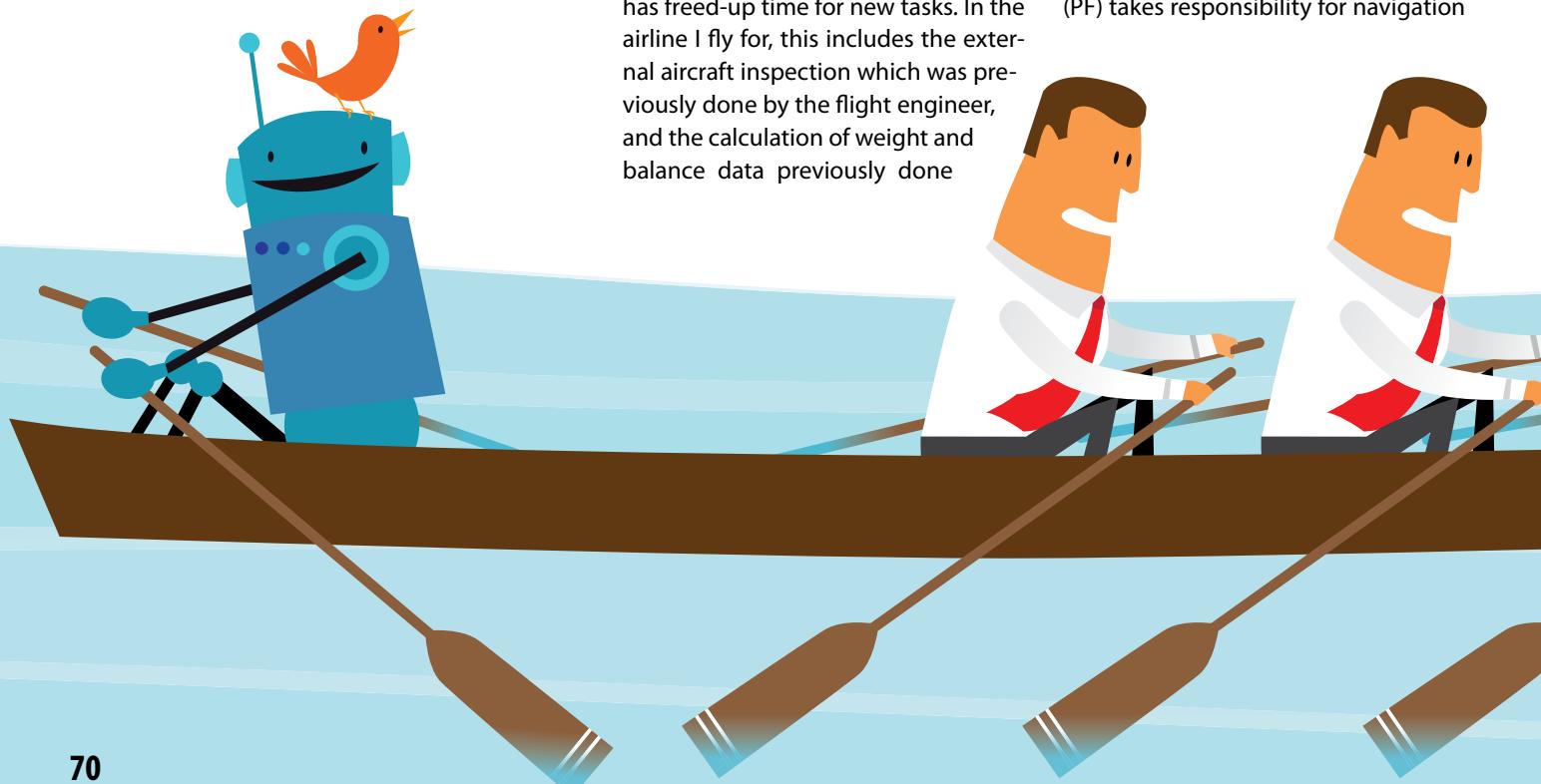
While the flight deck of first generation passenger jet aircraft hosted a 3 to 5 man crew, modern versions need only a 2 man crew and transport many more passengers. The knowledge and skills of the navigator are replaced by a few keystrokes on the keypad of a Flight Management System (FMS)...

The now digital VHF radios are easily operated by the pilots and aircraft systems have become extremely reliable, digitally controlled and much more automated. Navigating, communicating and system operation have become so "easy" that these tasks can now be combined with the primary aircraft control tasks of the two pilots without any other flight deck occupant. However these two pilots are not working in the same way as the larger crews used to.

During the pre-flight cockpit preparation, new technologies such as datalink allow the uploading of the flight plan straight into the FMS, thus avoiding the time consuming and error-prone process of manual entry. The use of computer programs on the electronic flight bag (EFB) to calculate the take-off performance data instead of the old manual process relying on a paper "weight book" has certainly made this process more efficient. However the time saved by these new technologies has freed-up time for new tasks. In the airline I fly for, this includes the external aircraft inspection which was previously done by the flight engineer, and the calculation of weight and balance data previously done

by the despatcher who also sent various flight data such as the fuel uplift, passenger numbers and delay codes to the Company. In the flight preparation phase, the type of tasks undertaken may have changed, but the time required to complete them all has remained very similar and this is reflected in the flight and duty time limitations.

Once in the air, in addition to their aircraft control tasks, the Pilot Flying (PF) takes responsibility for navigation



and the Pilot Monitoring (PM) takes responsibility for communication and systems operation. During normal operations, the procedures and tasks for the PF and PM in the various flight phases are well described and evenly distributed. With good use of the available automation, the level of workload is such that spare capacity to maintain situational awareness is available.

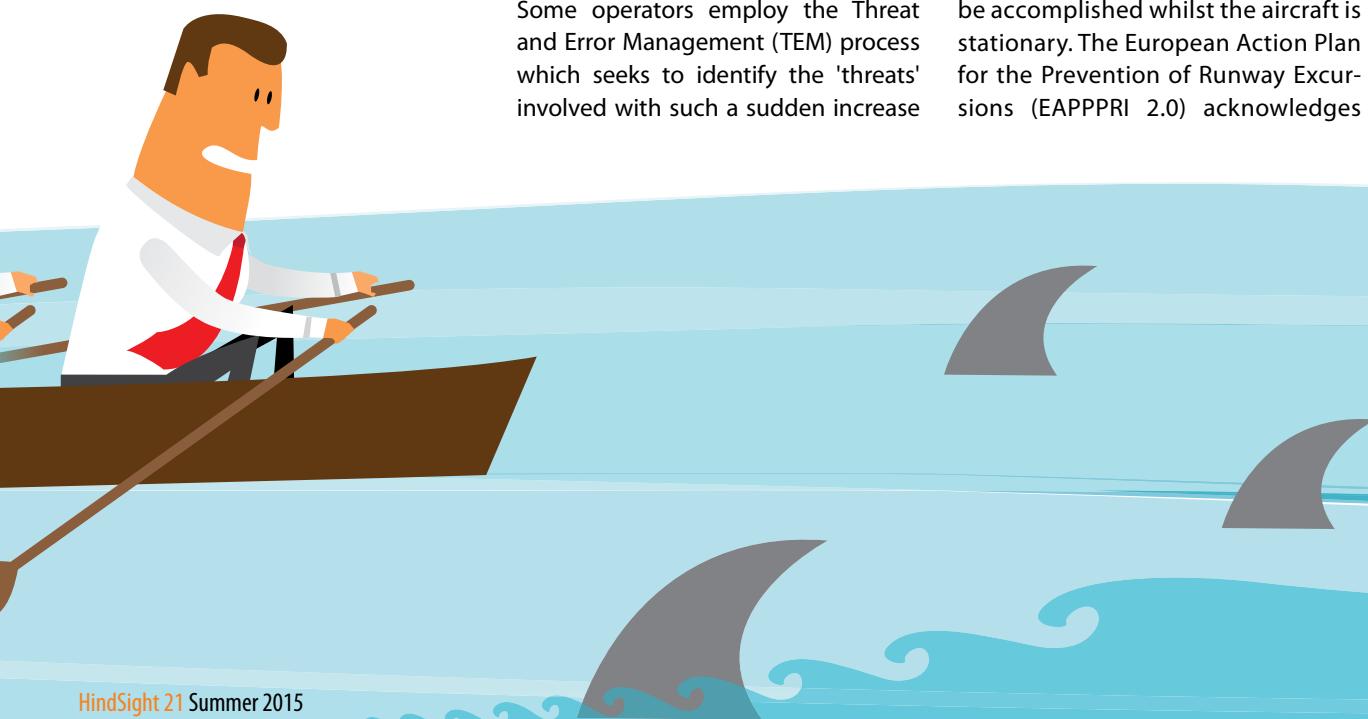
However if an unexpected situation occurs which requires extra attention, the workload can increase considerably. A good example is a runway change during the taxi-out phase. Many airlines perform single engine taxi on their twin-jets and these are slightly more complex and change the order of set-ups and checklists because these aircraft were originally designed to taxi on two engines. Adding a taxi out runway change to this significantly increases the flight crew

workload. After the PM has verified the new taxi routing and confirmed this with the PF, he needs to stop his primary task – guiding and monitoring the PF – to make the changes to the departure routing in the FMS, select the corresponding chart from the EFB and then cross-check the routing in the FMS against the routing on the chart. Next, the PM needs to go to the take-off performance module in the EFB to recalculate the performance data for the new runway and enter these into the FMS. Afterwards the PF must cross-check these entries and re-brief the changes to the departure routing. An initially normal taxi phase suddenly turns into a high workload phase where errors such as an incorrect taxi routing could lead to a runway incursion or errors in the performance calculation or FMS data entry could lead to a tail strike or even a runway excursion.

Some operators employ the Threat and Error Management (TEM) process which seeks to identify the 'threats' involved with such a sudden increase

in workload and offer mitigation measures such as bringing the aircraft to a full stop and remaining stationary so the PF can more effectively monitor the PM as they complete every step of the change process.

Controllers have a "big picture" view of the airport and are trying to optimise the aircraft movements both on the ground and in the air which is one reason why they sometimes change departure runways or departure routings. Changing weather conditions are another. Whilst this is likely to also be beneficial for the flight involved, controllers should consider the time needed by the flight crew to make the necessary changes in the FMS and re-brief the new runway or departure routing. Additionally they might offer an opportunity to stop the aircraft en route to the new runway so that all consequences on the flight deck can be accomplished whilst the aircraft is stationary. The European Action Plan for the Prevention of Runway Excursions (EAPPR 2.0) acknowledges ►►





### Workload management in a 2-man flight deck: when automation increases the workload... (cont'd)

this issue and proposes recommendations for flight crew (REC 1.4.10) and air traffic controllers (REC 1.5.17).

go-around procedure. Some aircraft have a FMS functionality called "secondary flight plan" to store the rout-

1.4.10

**During taxi departure or during approach, Pilots should not accept a runway change proposal if time to re-programme the FMS / re-brief is not sufficient. This includes a change of departures intersection.**

Figure 1: EAPPRI 2.0 – Recommendations for Aircraft Operators

1.5.17

**When planning a runway change for departing or arriving traffic, consider the time a pilot will require to prepare / re-brief.**

Figure 2: EAPPRI 2.0 – Recommendations for Air Traffic Controllers

The same principle applies to approaches. Paris Charles-de-Gaulle airport; one of the busiest airports in Europe, has two pairs of parallel runways with the terminal buildings in between the Northern and Southern runway pairs. The two inner runways are usually used for takeoff and the two outer runways are usually used for landing. This means that once landed, aircraft often have to hold short of the inner (departure) runway to await crossing clearance from the tower controller. To optimise the arrival sequence, controllers sometimes change the approach from the Northern to the Southern runway or vice versa. Like a change in departure runway, this generates a high workload for the flight crew with the major difference that the aircraft position can't be frozen to allow for a change of the landing runway in the FMS and a review of the approach and

ing for the approach and go-around procedure for an alternate runway. This "secondary flight plan" can be set up and briefed during the cruise and if required activated with just a few keystrokes making it easier for the crew to accept a runway change. Unfortunately crews often choose to enter the inner (normally the take off) runway into the "secondary flight plan" because in low traffic situations they could request a 'side step' to land on the inner runway and thereby reduce taxi-in time. Also, in anticipation of a short turnaround, the next sector might have already been loaded into the "secondary flight plan". So even if the aircraft is equipped with this secondary flight plan functionality, it's far from sure that it will contain the amended approach and landing runway which the controller has in mind. So the

sooner the flight crew is advised of this runway change, the more chance there is that the flight crew will be able to complete a successful stabilised approach and landing. In my view, practical guidance for a straight-in approach is that the landing runway should not be changed once the aircraft is within 20 track miles of the threshold or beyond a late downwind position abeam the landing threshold. This case shows that automation assists in reducing pilot workload but that when there is a change to the original plan; automation creates extra workload that requires careful mitigation.

In recurrent training, workload management is analysed and trained as part of the crew resource management (CRM). Traditionally, the focus is on how the two pilots cooperate. However the way they cooperate with the cabin crew and ATC should also be part of the training process. Here a Training Captain would simulate normal cabin manager or air traffic controller behaviour and not facilitate the flight crew to complete the exercise. A few weeks ago, I had a flight crew under training who requested a hold on a 10 mile final to a major airport in order to investigate a minor technical problem. Whilst this makes the navigation task of the flight crew easier and places the aircraft in an ideal position to start the approach if the situation deteriorates, it is not necessarily an optimal position for the controller who has to manage his arrival sequence. Consequently, there's little chance a controller would authorise such a request without the prior declaration of a PAN or MAYDAY. In lesser situations, controllers are trained to assist flight crew and facilitate the navigation by offering suitable holding fixes or radar vectoring so that the flight crew can swiftly begin the failure management process.

### 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.



# Using workload data to manage the deployment of change:



## defining the limits of safe workload

by Nic Turley and Brian Janes

The world is full of good advice: derive user requirements; involve operational controllers in the design process; conduct formal human error analyses; provide high fidelity simulations under varying workload conditions and so on – but what happens when this is not enough?

In 2012, NATS successfully introduced Electronic Flight Data (EFD) into the Prestwick Area Control room. EFD represented a significant change from previous paper operations and was another step on NATS' journey towards fully electronic operations.

The deployment of EFD at Prestwick posed significant challenges due to the nature of the system (paper to glass), changes to working practices and the limitations of simulations in the validation of complex socio-technical systems for live operations.

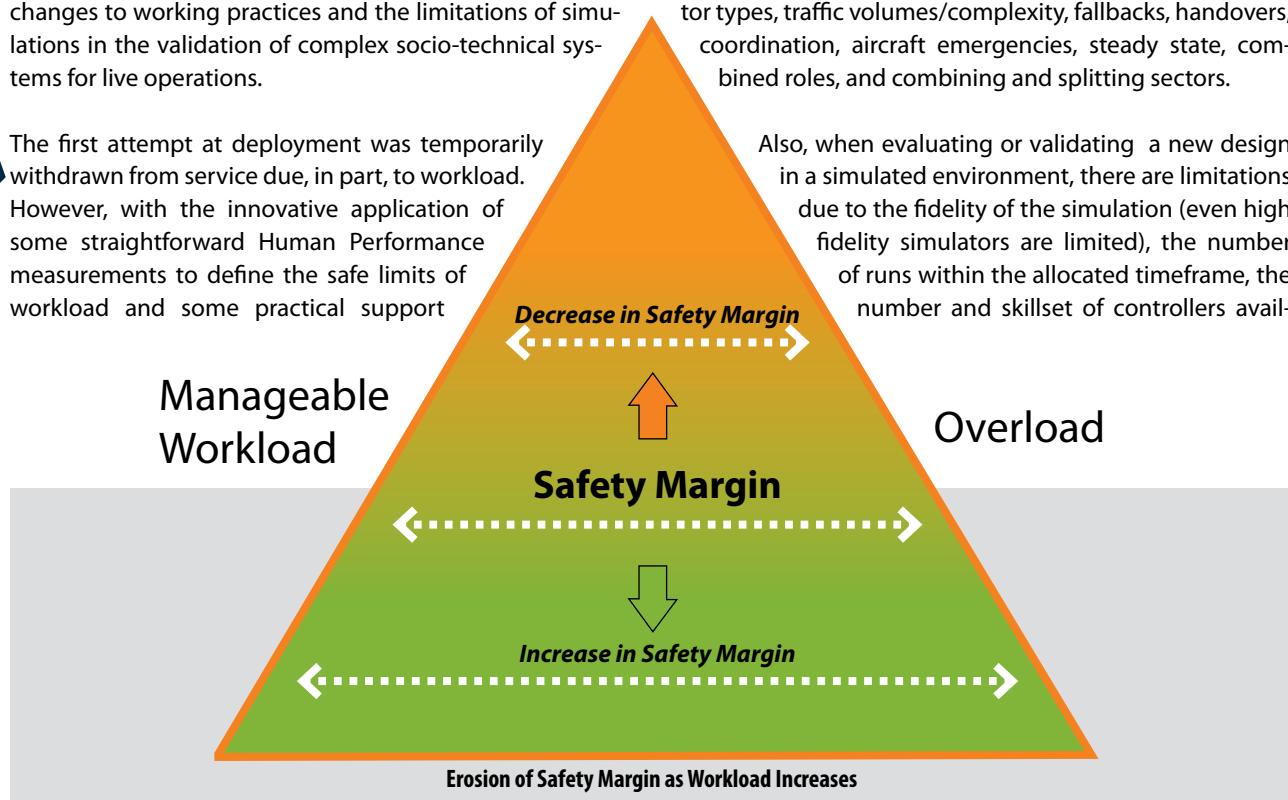
The first attempt at deployment was temporarily withdrawn from service due, in part, to workload. However, with the innovative application of some straightforward Human Performance measurements to define the safe limits of workload and some practical support

from controllers and front line supervisory staff, EFD was successfully introduced into full operational service.

### Safety Margins of Workload

There are many different aspects of a system that need to be considered when implementing new technology into live operations safely and efficiently such as the different roles involved (e.g. Planner/Executive/Assistant/Supervisor), sector types, traffic volumes/complexity, fallbacks, handovers, coordination, aircraft emergencies, steady state, combined roles, and combining and splitting sectors.

Also, when evaluating or validating a new design in a simulated environment, there are limitations due to the fidelity of the simulation (even high fidelity simulators are limited), the number of runs within the allocated timeframe, the number and skillset of controllers avail-





### Using workload data to manage the deployment of change: defining the limits of safe workload (cont'd)

able, critical roles that cannot be replicated (e.g. supervisor roles not replicated due to limitations of some simulators), interconnection between systems (e.g. operating as stand-alone), replication of real life traffic/pilot interaction, weather, the experience of the controllers and their experience/training with the new system. The list goes on.

Because of these limitations, when new systems are being introduced into service it is important to understand that the safety margins for workload observed in the simulated environment may be different to those observed in the real world. It is therefore critical to identify the size of the buffer between manageable workload and overload in the real world system as quickly and as reliably as possible.

The change in workload safety margins when implementing new systems has been likened to 'Q' corner of a fixed wing aircraft (the margin between stall speed and over speed reduces with increasing altitude). If the system is new and the changes are significant, it is much more difficult to identify the triggers for overload. Therefore the margin between manageable workload and overload may be reduced and become a 'cliff edge' which is much more difficult to anticipate and respond to.

Identifying and defining the changes in the safety margins of workload during implementation is extremely difficult to achieve. However, NATS has been working on innovative methods to do just that, making it possible for any erosion of safety margins due to an increase in workload to be restored quickly.

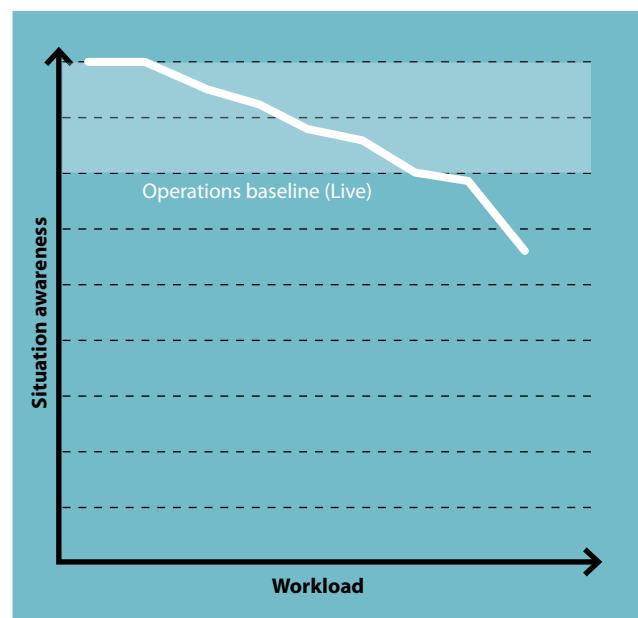


**Nic Turley** is a Human Factors Specialist with over 20 years' experience in applying HF to the procurement, development and use of complex safety critical systems. Prior to joining NATS Nic worked for large IT consultancies working on the development of Royal Navy warships, attack submarines and reconnaissance systems as well as other major defence and rail procurement. Nic is currently the Deputy Head of HF in NATS and is responsible for NATS Safety Culture Strategy as well as Assessor of Technical Standards for the HF team.

### Development

The EFD work began with the development of an in-house workload scale; more than 18,000 data points were collected from air traffic controllers in live operations across NATS centres (Terminal Control and En-Route) at Prestwick and Swanwick over an 18 month period.

A second measurement relating to controller situation awareness was introduced alongside the workload measure and further data points were collected from live operations. Together, the workload and situation awareness scores for the same period provided an insight into the workload levels under which situation awareness remained above what was considered to be a safe level. This then provided a means for comparing the relative tolerance of different systems to varying levels of workload.



The observed link between high workload scores and situation awareness scores appeared to be related to the point at which the controllers found it difficult to maintain the 'picture' (a term used within NATS to describe the capacity of the individual to maintain sufficient situation awareness to manage current and future anticipated traffic scenarios). If this was the case then this would provide a means for protecting safety margins during the introduction of a new system: **keeping workload levels below a known critical level would (theoretically) ensure that situation awareness would remain above a desired critical level and thus enable continued safe operation of the system.**



## Application to EFD

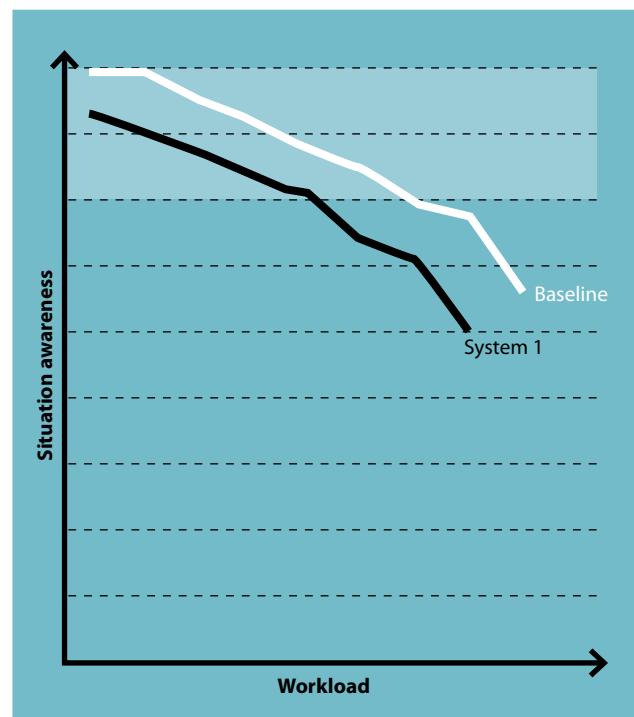
The temporary withdrawal of EFD from service provided an opportunity. We had data from a number of sources: simulations; live operations; pre implementation simulations; live operations during implementation and live operations post-reversion to paper. These data sets provided a clear insight into the events which took place following the initial introduction of EFD and the subsequent reversion to paper operations.

This now meant we had a clear 'picture' of the current operational profile (baseline) to compare against and were no longer implementing 'blind'. Data showed that the percentage of time that controllers were experiencing non-satisfactory situation awareness scores was higher for EFD than the current operating system at similar levels of workload.

One very clear finding related to the limitations of using workload data alone from simulations in the absence of situation awareness indicators. A clear limitation of the simulations related to key workload factors not being replicated (e.g. phone calls interrupting planner actions). Live traffic scenarios, which would be classed as high workload in live operations, did not invoke the same workload experience for controllers in the simulator.



**Brian Janes** is currently Head of Independent Human Factors Assurance at NATS reporting to the Operations Director, Safety. Brian joined NATS 10 years ago and has held a number of technical and people leadership positions including Acting Deputy Head of the Human Factors Group. His technical skills include User Interface and Interaction Design, Safety Analysis and Validation.



## Introducing EFD back into live service

In order to facilitate the introduction of EFD back into live service, efficiencies and improvements were identified in order to reduce task demand. These included:

- Electronic (Forward) coordination
- Auto population of initial levels
- Carry forward of previous sector heading and speed data
- Data entry
  - Heading, level and speed
  - Co-ordinations
  - Oceanic clearance times
- Strip interactions

The changes were identified and implemented through working closely with a core team of controllers to ensure they would be effective.



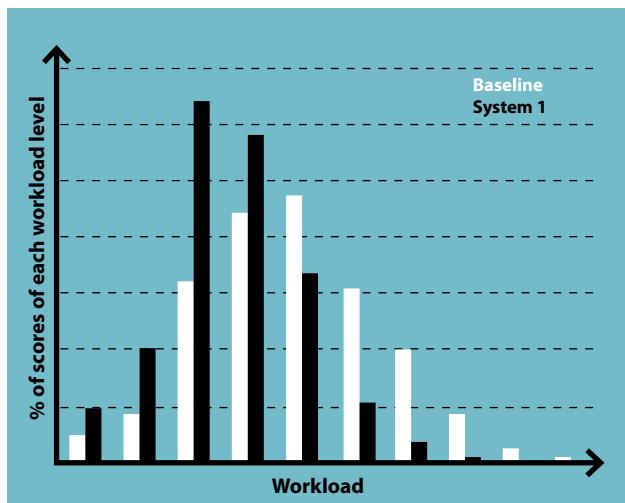
## Live Ops Validation

EFD was reintroduced during a period of Limited Operational Service. The supervisors were tasked with maintaining the workload of the controllers at or below LOW-MODERATE levels as defined by the in-house workload measurement tool (data showed that this was the level at which the controllers could maintain good situation awareness).

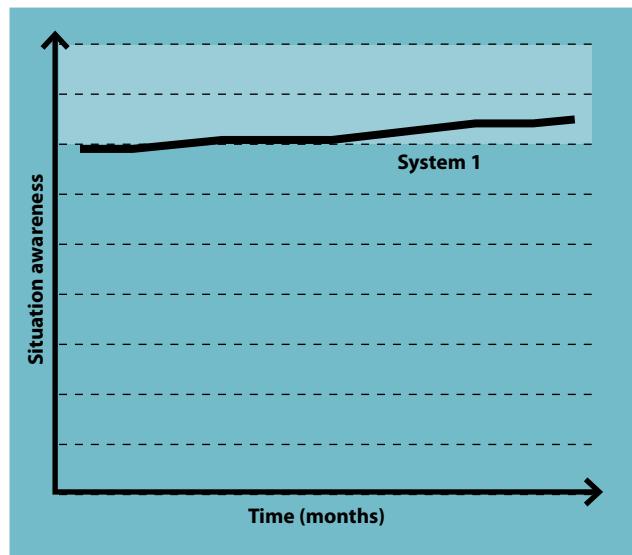
Supervisors have expertise in controlling workload (as part of their day job) and use a large amount of information to support this task (e.g. traffic information; number of controllers present; sector configurations; specific sector issues etc.). At the end of each controlling session, controllers reported the actual level of workload and situation awareness they experienced and this was fed back to operational managers and supervisors to ensure that workload and situation awareness had remained within acceptable limits.

To provide complete safety assurance, a paper back-up team was utilised during each period of operating with EFD. This allowed reversion at any point (either prompted by the supervisor or the controllers).

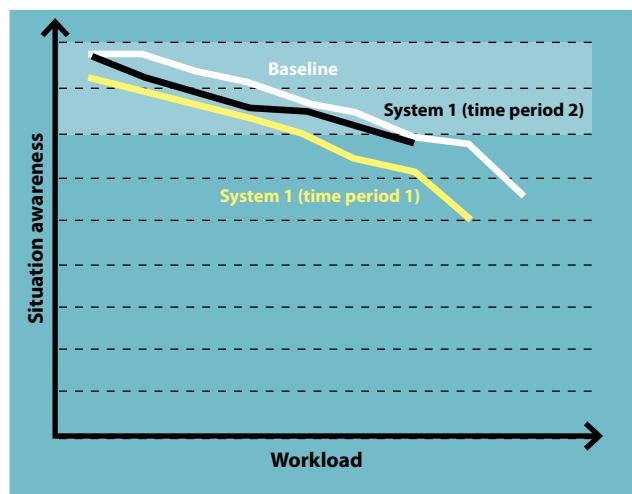
From the data it became clear that the supervisors were able to maintain the workload of the controllers within the desired range. A buffer had been built in and during this period there were no overload reports.



90% of the situation awareness scores during this period were 'Good' or above (very similar to baseline scores of 91% 'Good' or above). Over time, as workload was maintained at a low to moderate level, an increase in situation awareness scores was observed. This was taken to indicate a gradual increase in the buffer relating to workload, possibly resulting from increased familiarity with the new system.



Being able to 'see' the progress taking place allowed for increases in the defined workload level at a gradual rate, with constant feedback that situation awareness wasn't being eroded. The improvements could be seen when looking at the workload/situation awareness profiles at different points in time.



After a few months, the paper back-up was removed and the utilisation of EFD in live operations continued to increase until all controllers were using EFD on a full time basis and traffic was able to be managed at the same levels as when the previous systems were in use.

Due to this success, this process was repeated on further projects (e.g. iFACTS, the London 2012 Olympic Games, air-space changes). Previous issues encountered during project implementation (e.g. overloads) were not experienced. We now have baseline data from live operations (how the current system performs), more accurate data from simulations, and limited operational service applied sooner (as we know the levels of controller workload to maintain safety and clear indicators when these levels need to be adjusted). The approach also allows significant amounts of data to be collected (e.g. in the 1000s, with 100+ participants). Investigation to broaden the use of this technique for live operations monitoring is currently being explored.

# Sterile radio procedures



**by Captain Wolfgang Starke**

Basically there are four phases of flight where workload is high and errors of flight crews are likely to occur. These four phases are the taxi-phase, the take-off and initial departure phase, approach and landing as well as emergency situations.

While high workload during emergency situations seems pretty clear to understand, stress during approach, landing and take-off is self-explanatory, the issue of high workload during taxi-phase of flight might be unexpected to certain stakeholders. However, sticking to some basic principles most of these phases can be rather relaxed as huge amount of tasks is generated somewhere between ATC and pilots.

Workload has been a recurrent topic in the aviation community over the last few years, especially as flight crew workload varies a lot, even during routine flights, from low to high and vice versa. These two situations represent specific risks. But it is very personal how to quantify workload. The effects of workload are very individual as well. Problems resulting from high or low workload are normally a product of different factors like personal experience, emotional state, cooperation within the flight deck etc. Beginning from this point of view, I asked myself what have been the events from my personal experience when workload definitely became an issue.

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## Sterile radio procedures (cont'd)

### Taxi

During taxi-phase the workload can increase pretty fast, especially during taxi-out. Of course, the possibility of stopping always exists while taxiing an aircraft, however this opportunity is hardly ever used. Normally pilots try to expedite taxi whenever they can as a favour to ATC as well as to stay within their schedules.

As long as everything happens as predicted and the airport is known to the crews the taxi-phase should not be a problem. But if things change, an unusual re-routing is received, technical problems arise or there is an issue within the cabin workload does increase rapidly. This effect is greater during taxi-phase as there is no autopilot allowing the pilot flying to divide his attention. The ideal solution would be to stop the aircraft but no one wants to disturb a major airport operation because of a 'possibly small problem'. Proper communication can ease this issue. On the flight deck side, pilots should clearly state their problem to ATC while Controllers should try not asking pilots to move, depart or expedite when they obviously have a problem. Even soft pressure from controllers' side on pilots to move, depart or expedite could work counterproductive. It would be better to proactively offer the chance to stop somewhere in the vicinity as soon as the controller becomes aware of any 'possibly problem' on board the aircraft. Hints for this can be various, typically I would say very slow taxi speed, incorrect or very short communication or uncertainty about the route to follow.

The same goes for re-routings. As the Captain normally steers the aircraft (s) he is not able to make notes or study charts while handling the aircraft. The First Officer might be busy with cabin-calls, checklists or other actions. Solu-

tions to this dilemma might be progressive taxi-clearances or a chance to stop for a couple of minutes. It might be disturbing for a controller to have a taxiway blocked due to an aircraft holding there. But the possible effects on safety if an aircraft is blind flying in vicinity of runways might rapidly become dramatic.

### Departure

If you look at the departure-phase of a flight, there is much and more on the "to do" list and it has to be done within a short period of time. Also the engine power is high while airspeed is low, a combination which does not leave too much room for mistakes and little time to correct. During the take-off roll the lack of time leaves only two options, STOP or CONTINUE. A possible exchange of information is therefore limited to really essential information. The same should be true for ATC, deliver important information / instructions or keep quiet.

About a year ago the Tower-Controller on a major hub in Europe asked a departing Airbus A-321 if he was still able to abort the take-off. The crew just filtered out the words "abort take-off" and did so. At a speed close to V1, the maximum speed at which a take-off abort can be done, this was a risky manoeuvre in reaction to a question.

Once airborne there are a lot of limitations to obey and time to react is very short. While levelling off for example the time from level off to an exceedance of the maximum flap speed can be as little as a few seconds and climb rates can be very high.

A common practice amongst pilots is to brief themselves before departure about what to expect and how to handle the different steps during initial part of a flight. A solution to possible



problems between controllers and pilots lies in communicating every request to pilots as soon as possible. This should be done at the latest combined with the take-off clearance, allowing pilots to properly prepare themselves for this high workload phase.

As soon as gear and flaps are retracted, the after take-off checklist has been read and no immediate level-offs are to be expected, pilot workload reduces rapidly and once past 10,000 feet altitude (FL100) any non-essential request by ATC can be dealt with.

To illustrating the problem of very short notice of important restrictions, the following is an incident that happened to me shortly after my upgrade to become a Captain. The whole story ended up in a massive exceedance of the maximum flap speed and a rapid high-G manoeuvre. When on take off and only about 10 knots below V1, we were informed by ATC about a light aircraft flying through our departure route at an altitude of 1,500 feet. The suggestion was to level off at 1,000 feet. Given the fact that our load was only about 30% of the maximum this request meant rotating for lift-off and literally starting the level-off manoeuvre at the same time. When levelling off, power had to be reduced by about 70%, flaps had to be retracted and the



gear needed to be raised. At the same time TCAS was starting to provide Traffic Advisories (TAs) and the controller gave us new clearances and instructions. This was a really dangerous situation and if I had had the knowledge earlier, I would have preferred to delay take-off until the VFR traffic had gone.

## Approach and Landing

As flight efficiency becomes more and more important, a high priority is assigned to an optimum, continuous descent. For most jet aircraft this means a continuous descent with the engines at idle thrust. While prolonging the descent and approach as well as requests for high speed are taking aircraft to the non-optimum but safe side of the descent planning, reducing track miles to go or advising a required speed reduction takes aircraft above their idle-descent profile, effectively facing pilots with additional problems. Due to the limited effectiveness of speed brakes, especially in low speed regime, workload increases quite massively when pilots try to fix this problem in the absence of proper tools for this task.

If such a shortened flight path is accompanied by a change of runway or approach, workload of flight crew might exceed a safe value. To understand this, we need to see what needs

to be done in order to prepare for an approach. First, the new approach needs to be selected and properly programmed into the Flight Management System (FMS). The route from present position to landing must be checked and closed if needed. Then the approach aids need to be tuned, inbound courses and minima set and, in most aircraft, the approach aids need to be identified.

After this is done, the approach must be briefed between the pilots including go-around procedures and missed approach route. The landing performance must be calculated and reference speeds must be set to complete the approach briefing. At complex airports the runway turn-offs as well as initially expected taxi-in routes should be reviewed.

The whole process of re-planning an approach can take up to ten minutes. As the descent phase of a flight is not free of any additional tasks, this can end up in high levels of stress for the flight crew. Not to mention that additional communication with cabin crew might become necessary if the remaining flight time is shortened significantly. This issue can also be found within the European Action Plan on the Prevention of Runway Excursions (EAP-PRE 3.3.2, Appendix C).

Of course, getting closer to the landing runway, it becomes more and more important to maintain the intended flight path accurately and monitor the aircraft position and energy state. It is obvious that these tasks do increase workload.

During the normal operations of taxi, departure and landing, there is one important thing to reduce flight crews' workload. As flight crews are instructed to maintain sterile flight deck procedures that demand the omission of any non-essential task while taxiing and in flight below Flight level 100, "sterile radio procedures" should be clearly understood by controllers as well. This means refraining from any non-essential communication to an aircraft whilst it is in a high-workload phase. Any instruction, plan or information such as track-miles to go etc. should be given to flight crews on earliest convenience allowing them to pre-plan their actions in good time. Once an aircraft is below 10,000 feet altitude, ATC communication with that aircraft should be limited to important instructions or information only.

However, some situations are simply not foreseeable. Unexpected missed approaches or abnormal emergency conditions can normally not be planned.

## Abnormal and Emergency Situations

On the day before Christmas in 2011 my aircraft was approaching a German Airport round about midday. The weather was a little windy with moderate icing conditions above 2,500 feet altitude but good visibilities below. Due to the reported winds, the First Officer as pilot flying decided to configure the aircraft a bit earlier than usual for landing. Passing approximately 2,000 feet on approach we recognised



## Sterile radio procedures (cont'd)

that the No. 1 engine was malfunctioning. Our first intent was to notify ATC, perform the required emergency drills and go on landing the aircraft.

However, the approach became unstable requiring us to go around and as an immediate consequence we received quite a few radio calls, a frequency-change to departure and another bunch of questions from the controller. Remember! we were flying a single-engine go-around into moderate icing conditions on a turbo-prop aircraft. It took a couple of "stand-by's" and "we'll call you back's until we were able to sort ourselves out, work through the checklists, get the cabin prepared and all the required tasks.

As a comparison, only about two months ago my aircraft was approaching Vienna runway 34 with the First Officer again acting as pilot flying but this time also on initial line training. From what I judged a completely uneventful approach, he produced a rather hard landing and bounced the aircraft. After I took control and initiated a go around, the controller did exactly nothing at all, He just let us fly the aircraft. After we were through about 1,500/2,000 feet, he queried whether we needed any assistance to which I replied "negative, bounced landing, call you back". His response was "roger, follow standard missed approach" which left us free to sorting out all the

**In any abnormal or unexpected situation, the best ATC response is to let the flight crew fly their aircraft until a safe flight path is assured.**

problems. Only after we had cleaned up the aircraft, engaged the autopilot and called the controller back did he instructed us to contact departure for a second approach.

Comparing these two situations, I have to say, that the handling of the latter was excellent! He must have guessed correctly that workload in this moment was simply too high to allow any radio communication. This empathy from the controller let us continue undisturbed, delaying non-essential things like information sharing to a later moment when a safe flight-path was assured. More than just this, his first call was questioning our needs; at no time he pressed us or disturbed us, although it was rush-hour in Vienna.

In any abnormal or unexpected situation, the best ATC response is to let the flight crew fly their aircraft until a safe flight path is assured.

A second important piece of advice is not to press or guide a flight crew in any direction. Under possibly extreme workload, the easiest solutions sometimes do not turn up. If flight crews are instructed to do something they do not want, an easy response is simply to say "NO". However, it is a mistake to rely on the ability of a flight crew to say "NO" at any time. It is better is to ask open questions and at same time separate all other traffic to the maximum possible from this aircraft in distress.

### Conclusion

It is self explanatory that a controller cannot appreciate all the pressing factors that are building up a high flight crew workload. The same goes with pilots, sometimes there is no workaround a certain request although knowing the controller is being stressed. But whenever one side is recognising the other side suffering from high workload, it is generally true that less is better than more. Empathy with and knowledge about the other side of the ether helps to understand situations without asking and by that supports overall safety.

As a rule of thumb the following time-frames should be kept free of any non-essential radio calls i.e. remain sterile.

- During take-off from the moment the take-off clearance is issued until passing transition altitude or even better until passing FL100.
- While aircraft are approaching an airport, information about the approach to be expected, remaining distance, possible delay, weather, etc. should be given at earliest convenience but no later than passing FL100.
- After landing, every radio call should be delayed until the crew is no longer using reverse thrust/reverse pitch. ■

**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 of ICAO's Airborne Surveillance Task Force (ASTAF).



# Rhythm of the night

by Anthony Seychell

Oh, What a night! It hadn't been particularly busy for a Friday. The usual flights on their well-established routes, the adjacent ACC constantly ringing to request direct routings, the strip-printer nosily clattering away printing strips for the re-routing which nobody uses because we are working in a radar environment. All routine and soon time to go home but before that there was still the dreaded band-boxing. Already my colleague was preparing to close her sector as her shift ended at 0600. I wasn't looking forward to her sector being combined with mine. It contained the XYZ TMA, which included the major XYZ airport and the smaller ABC aerodrome. The shift roster was not in tune with the band-boxing because as soon as the sectors were combined, the XYZ night-time curfew ended. By the time my relief came at around 06.25, there would already be several departures climbing out of the TMA while I would also be doing the pre-sequencing of the arrivals descending into the TMA. Management had decided that there was no need to man the second sector 0600 – 0630; it had something to do with productivity.

Ten minutes into the combined sector, I was already feeling that I was at my limit and close to losing the picture. The sector was extremely busy so I told the Coordinator Assistant to answer all calls from the adjacent ACC and refuse all direct routings. Also I told him to find a way to silence the noisy strip-printer; it was becoming really annoying and a disturbance. Finally my relieving colleague arrived and took over and I could go home.

I never had rings on the screen but I was sure that at the end I came quite

close to seeing them and hearing the aural STCA alarm. I thought that before leaving, I should have a word with the supervisor about this overload situation and I considered writing a report about it. Too many of us were ending up feeling overloaded and close to losing the picture after the implementation of the new roster and, soon afterwards, an airspace reorganisation. I wasn't quite sure that I could have handled the rhythm of the night at the end if I had had encountered a contingency situation.

strips showed that someone had not done a proper study of our changed working methods. Work-as-imagined was totally different to Work-as-done.

People at the sharp end, like ATCOs and ATSEPs, often have to handle situations where better planning and risk appreciation by management could have led to improvements in service delivery without significantly increasing workload. Management should adopt a 'human-centred' approach when designing, implementing or operating a system, or managing a



**Anthony Seychell** is an experienced ATM safety expert who has both an ATC operational and an ATC engineering background. He worked previously at Malta Air Traffic Services in a variety of posts, the last being that of Safety Manager. He joined EUROCONTROL in 2007 and currently works for the ESP where he is coordinator of the Programme to support ANSPs in SMS Implementation (SASI) and provides support to other ESP activities.

The Ops Room of our XYZ ACC seems to have been designed to ensure the maximum possible discomfort to the staff and to increase the task/work load as much as possible. Besides the poorly-planned collapsing of sectors and decreased staffing, it was also a noisy place. The single-person operation meant that the ATCO was often distracted from his watch over the traffic. The constant requests from the adjacent ACC for direct routings meant that the telephone was ringing (or buzzing) all the time. The strip printer was a noisy machine and the fact that it was printing unnecessary

change, i.e. those responsible should consider the people in the system. Such a 'human-centred' approach should follow established human factors and ergonomic principles. Shaver and Braun<sup>1</sup> have defined human factors and ergonomics as "*a scientific discipline whose goal is to optimize the interaction between people and the systems they use to enhance safety, performance, and satisfaction. In simpler terms, it focuses on designing the world to better accommodate the needs of people*". The Human Factors and Ergonomics Society<sup>2</sup> tells us that human factors and ergonomics are

1 - Human Factors and Ergonomics initiatives make good business sense, Eric F. Shaver and Curt C. Braun, Idaho Business Review, January 5, 2009

2 - <https://www.hfes.org//Web/Default.aspx>



### Rhythm of the night (cont'd)

the study to help ensure that people's interactions with technology will be productive, comfortable and effective. Is the interaction of humans with systems always productive, comfortable and effective?

These descriptions of human factors and ergonomics indicate that the 'human-centred' approach is not just about pleasing the people in the system. It also provides an opportunity to optimise the system, the performance of the human and the tasks that they have to undertake. The 'human-centred' approach ensures that the procedural and technical consid-

erations match human capabilities and this maximises the likelihood of a successful outcome. It also leads to a better understanding of people's activities, e.g. the tasks that they perform, the demands, pressures and limitations that people face and what motivates them.

Another important aspect of the human-centred approach is that it gives people ownership, by involving them in changes and initiatives. A system will be more effective if the people in the system have some say in how it is

created, organised and run. The staff members are often the only people that truly know the intricacies (details, complexities) of their task, so involving them in the generation and operation of a system will help to increase support for, trust in and adherence to it.

Many of us are nowadays familiar with 'safety assessments', often perceived as some sort of a mysterious rite performed by the safety juju man which leads to the pronouncement that our new system as safe and acceptable for our use. But how often is a safety assessment done for a soft change



such as a roster change, a change in the remuneration/reward structure or even changes in the staff selection processes? As we saw in our initial scenario, the band-boxing occurred when traffic was actually increasing. Was a proper safety assessment of the task load performed? It is obvious that reducing staff and collapsing sectors while the traffic is increasing may not be a very good idea. Often changes are considered individually and no assessment is performed at a system level. But this is critical because the risks affecting task performance can only be understood if the change in the task(s) is considered in context and thereby fully understood.

Going back to our original scenario in the ACC, we have already seen that the Ops Room was a noisy place. Often we contribute a lot to noise ourselves without even noticing. There have been cases where the incoming/outgoing controllers do their briefing handover at the supervisors' desk, the vicinity of which then becomes a sort of a chat-club with each participant contributing that little bit more to the noise level. This might naturally induce the ATCOs, especially those choosing to work without headsets and relying solely on the console speakers, to increase the speaker volume. This then sets off a vicious circle where the others also raise the volume, people speak louder and...

What about the physical design of the room itself? How user-friendly is the equipment? How difficult is it to interact with the console's computer-driven system? Lighting, ventilation, heating, humidity? Traffic and its complexity are actually only a component of an ATCO's workload. It is well known that a badly designed system significantly increases the

work and task load. A good human impact analysis can materially contribute to the effective reduction of the work and task load. The human-centred approach to change management brings a number of benefits:

- Proactive identification of the people affected by the change, particularly those in roles that have the potential to impact safety;
- Proactive identification and prevention of human error associated with a change;
- Reduced resistance to change.

Despite all the advances in technology and the introduction of more and more automation, the humans are still the main means of mitigation when our system somehow fails because they act as key defences to help in controlling the risk. Our centre was a busy ACC but the amount of traffic was not the cause for the ATCOs' feeling of overload. A study would have indicated 'classic' system failures – the contribution of staffing as the biggest contributor to the overload situation with the working environment and practices also playing an important part. These human factors problems severely impacted the human performance, significantly reducing the ACC's resilience to failure. Of course, a strong reporting culture is an essential element of safety culture and greatly assists in identifying problems, reducing their effects and seeking long-lasting solutions. In a positive safety culture environment, staff will be encouraged to come forward with not only their concerns but also suggestions/recommendations for their resolution.

Back in my days as an ATCO I felt that there was a song that described our work very well: The Rhythm Of The Night by the Italian group Corona<sup>3</sup>. The first part of its lyrics went:

*Rhythm is a dancer,  
It's a soul's companion,  
People feel it everywhere,  
Lift your hands and voices,  
Free your mind and join us,  
You can feel it in the air,*

Although I didn't dance the aircraft, I felt that that there was a certain rhythm in the work and people felt it, especially the ones in the air.

The ATC/ATM world has changed considerably since my ATCO days because ATC is a dynamic business and traffic is almost always increasing. We are making use of more and more automation to handle traffic but traffic is only one factor affecting workload. We need to look more at the humans in the system and adopt a human-centred approach so that we can better understand human abilities and limitations. That will enable us to design systems which optimise the interaction between people and other system elements to enhance safety, performance, and job satisfaction.

I'm convinced that ATCOs all over the world still feel the Rhythm but the task of managers and 'safety practitioners' is to ensure that the ever-increasing number of flights and complexity of traffic do not negatively impact ATCO workload. S

3 - <http://www.metrolyrics.com/the-rhythm-of-the-night-lyrics-corona.html>

# A-B-C... it should be easy as 1-2-3!

## How to design a simple, safe and efficient taxiway designation system

by Gaël le Bris and Magali Kintzler

### Introduction

An airside where all users can find their way easily is a key issue to help improve the safety of the manoeuvring area and to reduce mental workload for pilots and controllers. The European Action Plan for the Prevention of Runway Incursions (EAPPRI) states that the inherent difficulties of communicating on the manoeuvring area mean that aerodrome design, visual aids and infrastructure naming conventions play an important part in reinforcing the intended instructions passed by the air traffic controller.<sup>1</sup>

The designation of the taxiways plays a major role in the airside safety. Taxiway naming should be simple, logical and intuitive as far as practicable. However, many existing airports have only grown through incremental development in recent decades and they do not always have a fully harmonised designation system.

Paris-CDG celebrated its 40th anniversary last year. From the opening of the airport in 1974 to the entry into service of RWY08R/26L in 1999, all the runway entrance and exit taxiways were designated by a single number: from 10 to

19 for RWY09/27 (the Northern runway now called RWY09R/27L) and from 20 to 28 for RWY08/26 (the Southern runway now called RWY08L/26R). The connecting and parallel taxiways were designated by adding a suffix to these numbers. For instance, "10" was rapid exit taxiway (RET) Y3. "10.1" and "10.2" were the name of the two segments of taxiway DA1 used just after "10" for joining Terminal 1. All the major taxiways not directly related to the runways were divided into portions – for example N1 to N13 were defined for each portions of the taxiways now called UNIFORM and CHARLIE.

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1 - European Action Plan for the Prevention of Runway Incursions (EAPPRI), Appendix B – Guidelines for Local Runway Safety Teams, edition 2.0, ERSI, April 2011, page B5, <http://www.skybrary.aero/bookshelf/books/1862.pdf>

**Gaël le Bris** holds two MSc degrees and is Airside Development Manager for Aéroports de Paris at Paris-Charles de Gaulle airport. His work includes managing and coordinating airside development projects. He is also responsible for their Safety Risk Management. He leads aircraft/airport compatibility studies and economic and technical benchmarking for his department.

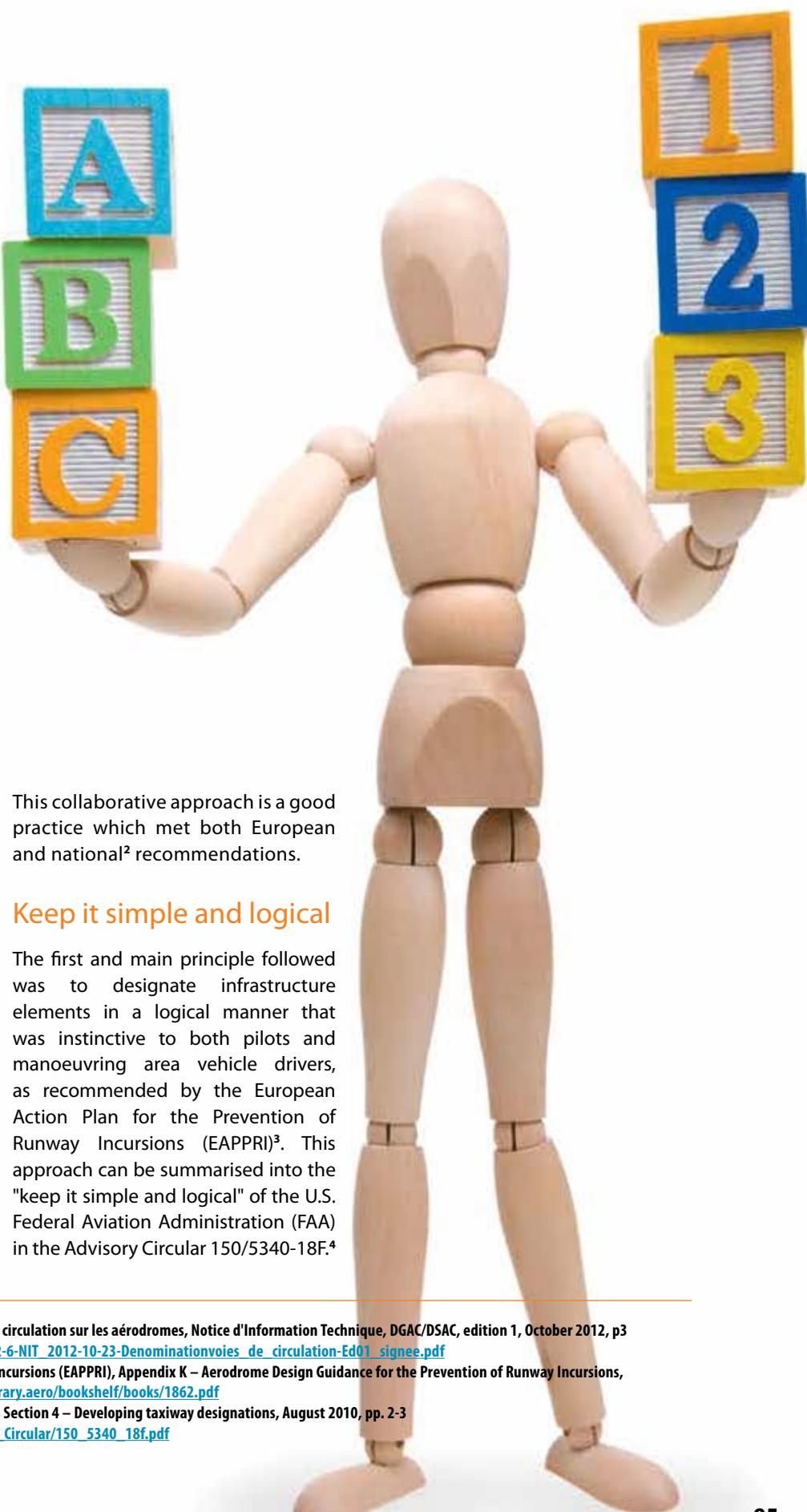


**Magali Kintzler** is an air traffic controller and ATC manager at Paris-Charles de Gaulle airport. Her work includes coordinating airside projects with Aéroports de Paris and informing controllers of changes. She is also responsible for runway safety and wake turbulence projects.



These designations changed to letters and numbers on the South side when a second parallel runway was built along RWY08/26 in 1999. The taxiways on the North side changed in a similar way when a fourth parallel runway was built close to the former RWY09/27.

With subsequent developments of the airside and the expansion of Terminal 2, other particularities and exceptions appeared. We lost the simplicity of the initial plan. Many of the mnemonics to help controllers, pilots and the drivers of the movement area to precisely and easily locate themselves ceased to be valid. Consequently, it was time to change the entire designation system to a more coherent and simple format.



## Working together

A dedicated workgroup of representatives from the airport operator (Aeroports de Paris) and the ANSP (DSNA) was created to oversee the project. In parallel, meetings were held by each of these entities with their respective acting staff in order to involve all airside operations' stakeholders. In particular the airport operator included movement area drivers in these meetings. They are – a workforce which has a different perception and perspective of ground movements to that of pilots and controllers, and they must be taken into account in taxiway naming projects, especially at airports subject to winter conditions.

Pilots were involved in the project through their representatives on the Local Runway Safety Team (LRST). The general principles and then the modification of the runway exit taxiway naming were presented and discussed at LRST meetings. Details of the planned re-designation were then sent to the pilots and airline representatives participating in the LRST and the airport Safety Risk Management (SRM) processes for their comments and validation.

This collaborative approach is a good practice which met both European and national<sup>2</sup> recommendations.

## Keep it simple and logical

The first and main principle followed was to designate infrastructure elements in a logical manner that was instinctive to both pilots and manoeuvring area vehicle drivers, as recommended by the European Action Plan for the Prevention of Runway Incursions (EAPPRI)<sup>3</sup>. This approach can be summarised into the "keep it simple and logical" of the U.S. Federal Aviation Administration (FAA) in the Advisory Circular 150/5340-18F.<sup>4</sup>

2 - Dispositions relatives à la dénomination des voies de circulation sur les aérodromes, Notice d'Information Technique, DGAC/DSAC, édition 1, October 2012, p3  
[http://www.developpement-durable.gouv.fr/IMG/pdf/2-6-NIT\\_2012-10-23-Denominationvoies\\_de\\_circulation-Ed01\\_signee.pdf](http://www.developpement-durable.gouv.fr/IMG/pdf/2-6-NIT_2012-10-23-Denominationvoies_de_circulation-Ed01_signee.pdf)

3 - European Action Plan for the Prevention of Runway Incursions (EAPPRI), Appendix K – Aerodrome Design Guidance for the Prevention of Runway Incursions, édition 2.0, ERSI, April 2011, page K3, <http://www.skybrary.aero/bookshelf/books/1862.pdf>

4 - Standards for Airport Sign Systems, AC 150/5340-18F, Section 4 – Developing taxiway designations, August 2010, pp. 2-3  
[http://www.faa.gov/documentLibrary/media/Advisory\\_Circular/150\\_5340\\_18f.pdf](http://www.faa.gov/documentLibrary/media/Advisory_Circular/150_5340_18f.pdf)



A-B-C... it should be easy as 1-2-3!

How to design a simple, safe and efficient taxiway designation system (cont'd)

The other basics were the following:

- The numbering grows from the West to the East, and then from the North to the South.
- The letters I, O and X are not used for taxiway designation in order to avoid confusions with 1, 0 and crossing or closure symbols. This is an ICAO recommendation<sup>5</sup>, confirmed by the European Certification Specifications for Aerodrome Design (CS ADR-DSN)<sup>6</sup>.
- Two different taxiways cannot have the same name<sup>7</sup>.
- A same infrastructure element cannot have two names, except when it is a de-icing pad.
- An active runway entry taxiway cannot have the same number as that of the runway it connects with<sup>8</sup>.

These rules were applied on the movement area for naming the taxiways and apron taxiways:

- All major taxiways are designated by a single letter e.g.: A, B, Q, S.
- Subsidiary taxiways are designated by two letters and a number e.g. GE1.
- Links between two major taxiways are designated using the combined letters of the two taxiways plus a number. For instance, links between taxiways BRAVO and QUEBEC are designated BQ1, BQ2, etc.
- The taxilanes (taxiways serving an apron and only used for this purpose) are designated by letters and a number e.g. GE1. The main taxilanes are called by a single letter and a number e.g. E1.

Specific provisions were made for taxiways at the runway complexes due to the criticality of the vicinity of the take-offs and landings. These taxiways must be clearly identified for preventing runway incursions, but also runway excursions by differentiating the straight and rapid exit taxiways:

- The runway entry taxiways of the outer runway use a specific letter followed by a unique number for each one e.g. all the entry taxiways of RWY08R/26L are designated V + a number like – V1, V2, V3, etc.
- The same rule applies for the inner runways, but straight (entry) and rapid exit taxiways are designated with a different letter so as to distinguish them. e.g. the straight taxiways of RWY08L/26R are designated T1 to T12, and the rapid exit taxiways (RET) are named W1 to W6.
- In the case of straight (entry) taxiways, their designation begins with a letter which is the same as that of the first parallel taxiway they connect with e.g. the taxiways between SIERRA and RWY08L/26R are taxiways S1 to S9).
- The letters and the numbers used for the designation of the two continuous taxiways on each side of a runway are different.

Finally, this project provided an opportunity to remove unusual designations and deviations from extant standards and the best practices:

- The prefixes "Outer" and "Inner" were removed from taxiway ALPHA ("Inner ALPHA" became A3 in 2011). Coincidentally, this good practice became a European standard in February 2014 when the EASA issued the CS ADR-DSN6.
- Two non-continuous adjacent but different taxiways cannot have the same name<sup>7</sup>.
- All taxiways and taxilanes must have a designated name.

East-West oriented taxilanes are designated GOLF + a number when they lead northward to Terminals 2A to 2G, but designated PAPA + a number when they lead southward.

North-South taxilanes are designated using FOXTROT + a number.

Intermediate holding points (IHP) are designated as TANGO (like "Terminal" or "Traffic area") + the letter of the apron in their vicinity + a number e.g. TA1 and TA2 when entering and exiting apron ALPHA.

When an intermediate holding point is located on a short taxiway, this taxiway takes the name of the IHP.

A de-icing area has the name of the cardinal point of the airport where it is located (NW, NE, SW, SE) or the apron where it is collocated (ROMEO or JULI-

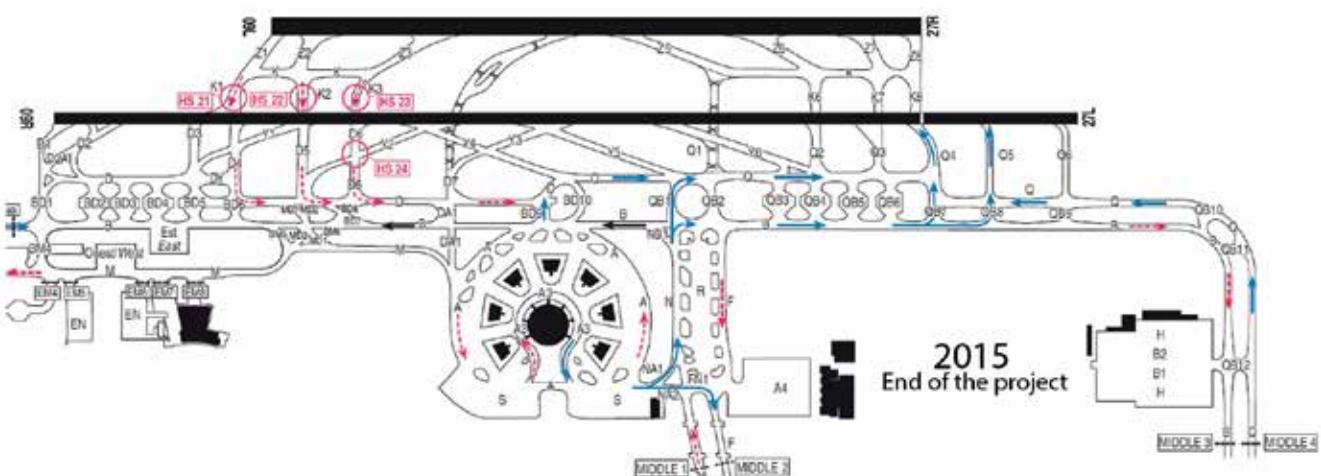
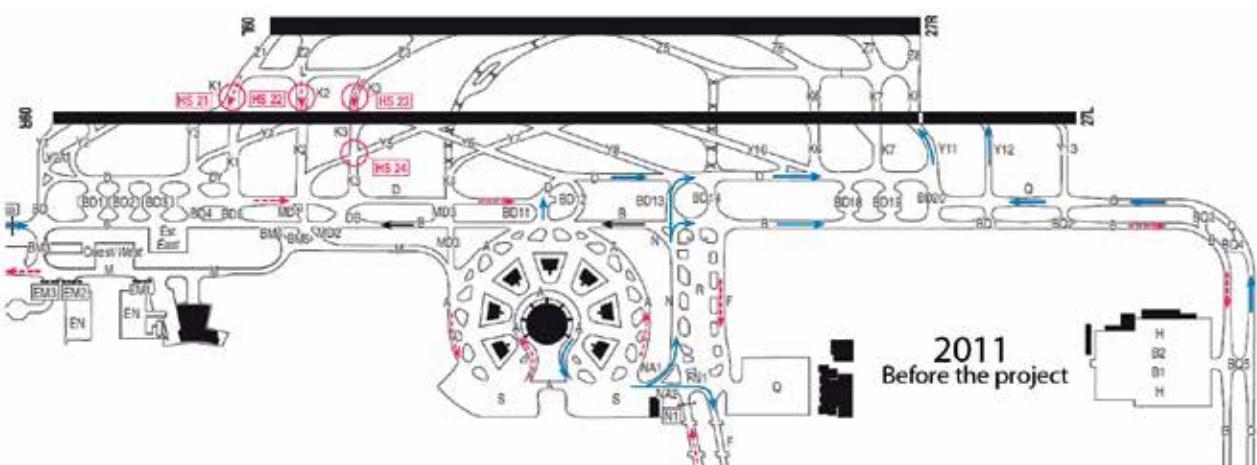
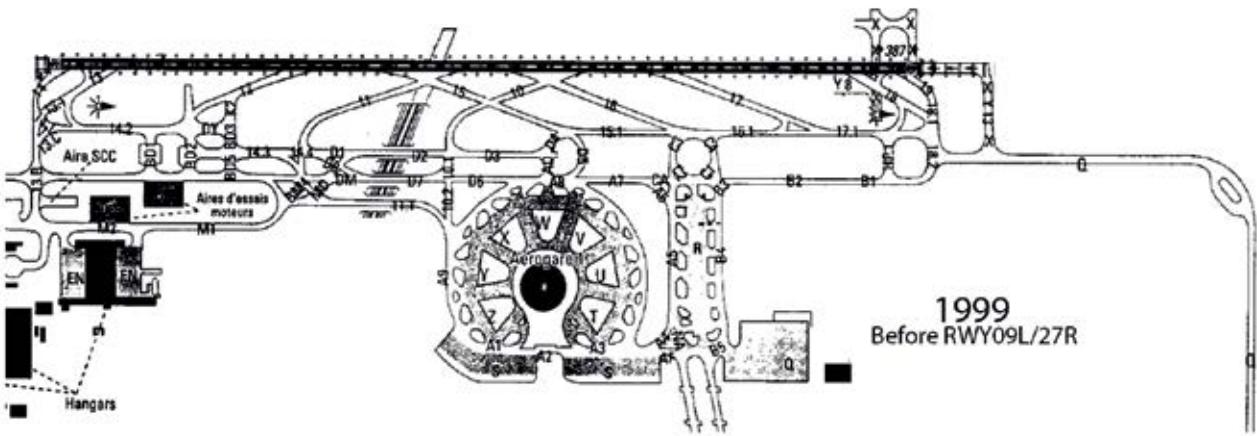
5 - Annex 14 Volume I – Aerodromes, chapter 5 Visual aids for navigation, section 5.4.3 Information Signs, article 5.4.3.36, 6th edition, ICAO, July 2013

6 - CS.ADR-DSN, Chapter N – Visual Aids for Navigation (Signs), CS ADR-DSN.N.785, Issue 2, EASA, January 2015, p137-138

<http://easa.europa.eu/certification-specifications/cs-adr-dsn-aerodromes-design>

7 - These rules follow or are inspired by the propositions of the IFALPA to the ICAO for taxiways naming convention.

8 - French law "arrêté du 28 août 2003 (modifié le 15 mai 2007) relatif aux conditions d'homologation et aux procédures d'exploitation des aérodromes" so-called CHEA, Appendix A, article I.5.2.3.1, [https://www.sia.aviation-civile.gouv.fr/dossier/texteregle/CHEA\\_A\\_01\\_V2.pdf](https://www.sia.aviation-civile.gouv.fr/dossier/texteregle/CHEA_A_01_V2.pdf)



**Figure 1: Evolution of the taxiway designations (Northern part of the airport)**

A-B-C... it should be easy as 1-2-3!

How to design a simple, safe and efficient taxiway designation system (cont'd)

ETT). A de-icing pad within a de-icing area has the name of the de-icing area + a number e.g. NW1 to NW4. Because of their particular function and the re-categorisation as part of the non-movement (or traffic) area when activated, the de-icing pads have a specific name even when they are co-located with a taxiway. But the two names are not used at the same time. For instance, taxiway BD2 is only called NW1 when it is operated as a de-icing pad.

### Phasing the change

To limit the initial mental workload just after changes to names and to have a practicable plan for the modification, we phased-in the changes over 4 years. Each phase are performed in a single night to coincide with an AIRAC cycle date.

In September 2011, the Southern runway complex was modified. September 2013 was the turn of the Northern runway complex and the taxiways around BRAVO, DELTA and QUEBEC. On the same night in September 2014, the taxiways serving aprons ECHO, NOVEMBER and INDIA were re-designated. Also, the taxilanes serving apron PAPA, previously without a name, became C1 and C2. Finally, September 2015 will see the completion of this multi-year project with the modification designations in the vicinity of Terminals 2A to 2G.

### Preventing the incidents and learning from the recent events

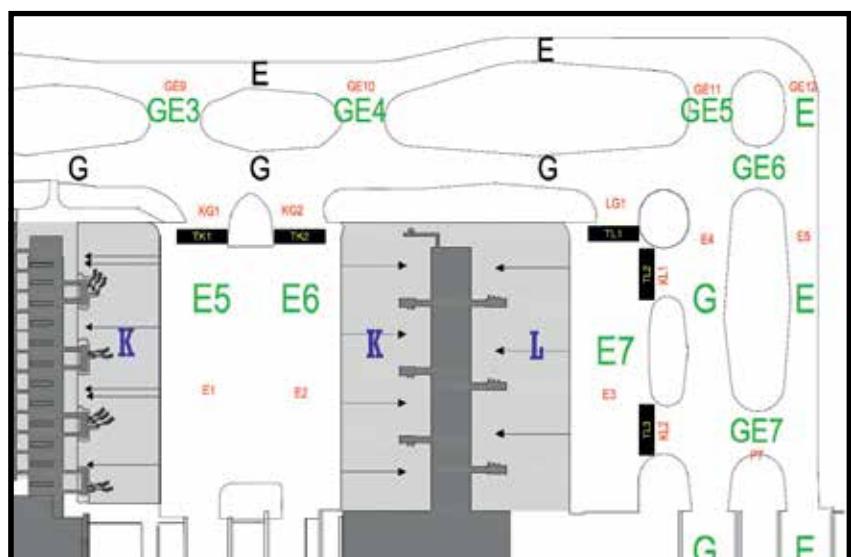
The best practices applied to the taxiway naming were selected following a risk-based approach with strong safety assurance roots. For example, this is why the letters and the numbers of a taxiway crossing a runway are different on each side of this runway. Indeed, clearance misunderstanding due to the continuity of a taxiway name on both sides was identified by the ATC as a possible cause of some runway incursions.

### Maintenance of the designation system

In addition of complying with the standards and the best practices, the project followed a risk-based approach. In order to correct any unexpected "side effects" of the changes, we put in place a safety assurance program to monitor their efficiency. This proved to be particularly helpful in identifying a need for improvement just after the changes to Northern taxiways naming. Here, it appeared that the phraseology at the end of the ground routings to Threshold 27L could be a source of confusion with the name of taxiways used for alignment. For instance, for taxiing to Q4 from BRAVO, the controllers typically gave the following clearance: "taxi N, B taxiway to holding point Q4". But safety reports showed verbal and mental shortcuts which were conducive to understand that taxiing was through "BQ4". Because taxiways BQ3 to BQ6 can be activated as de-icing pads, it was decided that

this could generate a serious hazard if an unexpected aircraft passed through without clearance. These issues were addressed in September 2014 when all the links between taxiways BRAVO and QUEBEC were re-designated QB + a number instead of BQ + a number.

This is an example of how the user feedback and the safety assurance can help to improve a naming system even after the completion of the programme. When designing the project, the airside operations community wanted something simple and logical for pilots, controllers and drivers. But we also envisaged the creation of a robust and stable system in which minor changes could be easily performed to correct short-term local safety issues. Also, this system should be capable of taking into account the long term infrastructure development with limited further modification. The first years of operational feedback are positive about the completion of these objectives. ■



**Figure 2: Taxiway naming around Terminals 2 from Sept. 2015 (extract)**  
 Blue: aprons / Black: unchanged / Red: old names / Green: new names / Yellow on black: new designations of the IHP

# A lack of workload resilience in a non-radar environment

by HindSight Editorial Staff

The SKYbrary Accident and Incident Library contains over 750 articles summarising selected accidents and serious incidents which have been independently investigated, each one of which is linked to a copy of the full Official Investigation Report. Some involve controller workload issues, especially high workload relative to the capacity of an individual controller. Here is a short summary of one of these based on the findings of the Investigation. The finding relating to workload and the ability of the controller involved to cope with it based on their experience level and training was accepted as a formal 'Safety Issue' and dealt with by the ANSP involved.

In January 2012, ATC error resulted in two aircraft on procedural clearances in oceanic airspace, an A320 and an A340, crossing the same waypoint in the Eastern Indian Ocean within an estimated 2 minutes of each other without the prescribed 1000 feet vertical separation required when there was less than 15 minutes between them. By the time ATC identified the loss of separation and sent a CPDLC message to the A340 to descend in order to restore separation, the crew advised that such action was already being taken.

The Investigation identified various organisational deficiencies relating to the provision of procedural service by the ANSP concerned. one of which

was that "processes for monitoring and managing controller workloads did not ensure that newly-endorsed controllers had sufficient skills and techniques to manage the high workload situations to which they were exposed".



Flight Plan Tracking of the two aircraft involved (reproduced from the Official Report)

**The full article is at:**

[http://www.skybrary.aero/index.php/A320 / A346, en-route, Eastern Indian Ocean, 2012 \(LOS HF\)](http://www.skybrary.aero/index.php/A320 / A346, en-route, Eastern Indian Ocean, 2012 (LOS HF))

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

## Definition

Working in aviation requires operatives (pilots, controllers, airside safety, etc.) to take in information from a multitude of sources, assess this information, prioritise it, and use it to make decisions and take actions. This complete process from sensing information (whether it is aural, visual, mental, kinaesthetic, gustative or olfactory) through to taking action is referred to as "human information processing", or information processing for short. So, information processing refers to the ability of the operator to process the type and amount of information within the required timeframe, and to do so in an effective manner that leads to suitable responses.

## Need to Know

Information processing capabilities vary from person to person, day to day, place to place and task to task. It is particularly affected by age, health, stress, different environments, workplace cultures, experience levels, interpersonal relationships, distractions, and in particular, by its own limitations. These limitations can be substantial and will be explained later in this Article.

Knowing how our information processing capabilities can be limited is important in designing and delegating tasks to ensure that the informa-

tion processing requirements fall within the capabilities of employees and colleagues (i.e. within their memory, attention and decision-making capabilities) such that the following are minimised:

- Failure to see information
- Misunderstanding information
- Handling the information incorrectly
- Forgetting the information.
- reacting inappropriately

Perhaps more importantly, we should understand our own limitations, especially during periods of high workload and/or when particular illusions may go unnoticed.

## Situational Awareness and Information Processing

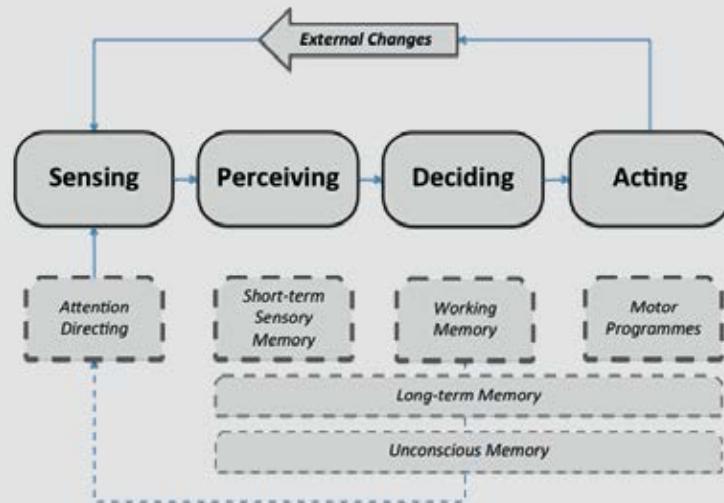
Our situational awareness is built upon our perception of the world that relies on information attained through our senses. The information available to us includes: flight, navigation and engine instruments, primary flight displays, radar, TCAS, radio voice communications, data-link, direct vision, crewmember communication, vibrations, noises and smells, and more. It also includes our mental model of our "plan" of how things are expected to occur, and our prediction of what others' plans are, and how they may prog-

# SKYbrary

## Information Processing

ress. Our perception of the world will be a four-dimensional model. Four dimensions because we retain memory of what has occurred already and we are also able to project forward in time to predict what the situation will be. At any given moment, in three-dimensions, the accuracy of our situational awareness depends on how accurate our perception is compared to reality. It is possible to be highly accurate, especially in simple and familiar situations. However, our predictions for the future will be, on the whole, less accurate, as will our perception in complex and busy environments. We may have a good idea of what will happen when we ourselves make changes, corrections and decisions, and this will be based on our experience; however, it is less easy to judge what others will do. Therefore, maintaining situational awareness is a continuous process requiring mental effort and it will become vulnerable during periods of high workload where our information processing capacity is exceeded. And, usually, it is these high workload situations when we need to ensure that our situational awareness is as accurate as possible.

### Building Blocks of Human Information Processing



It is accepted that there are at least four stages in information processing:

- sensing
- perceiving
- decision-making
- motor action, or performing

Supporting these key steps in information processing are various elements of memory, referred to as sensory memory, working and short-term memory, long-term memory and motor memory. These are not distinct sections of the brain, but it is useful to refer to the functions that each provide as distinct from the others. Another important building block is the "attention directing" mechanism.

One major feedback loop exists, where we sense changes that occur due to our own actions – in this way we are able to measure and correct our progress in achieving a task i.e. digitally and analogue, e.g. by shooting more and more accurately towards a bull's-eye, or by correcting continuously to maintain straight-and-level flight, respectively.

Another key feedback loop is when our mental model of the world, influenced by past experiences, drives our attention: we are looking for evidence that supports our model – even if it is wrong.

## SKYbrary download (cont'd)

### Vigilance and Attention

Vigilance refers to our state of awareness to external stimuli; this state can range from low to high levels of vigilance. Vigilance might best be described as a positively motivated intention to be ready to react to a range of inputs. It is an energetic state that we can turn-up and turn down at will, but also one which can drop off during periods of low stimulus, boredom, fatigue and stress. Our situational awareness will determine how vigilant we become and to what external data we include in our scan of awareness. For example, on a typical flight deck, pilots need to remain vigilant of a whole range of possible data, from engine, navigation, communication and other aircraft systems, as well as events occurring outside of the flight deck. It is just too much for our sensory and perception mechanisms to recognise and make sense of all this information. Which is why we need to "pay attention" to the most important stimulus in the moment, and divide our attention between various stimuli when there are several important factors that require our observation and response.

Attention is a necessary function if we are to focus on the things that matter at the right time. Various theories exist which explain the mechanism that permits multi-tasking, and also the degree to which we can or cannot multi-task. One determinant of whether we can multi-task or not is the capacity we have for dividing attention between stimuli. For the most intricate, or unfamiliar, tasks we usually require full attention and this will result in us being unable to perceive anything else that is occurring. E.g. whilst being occupied in a hobby such as delicate sculpture, we can become so engrossed that we

fail to hear the phone ring, or notice someone entering the room. In the workplace this may also occur when we are fully occupied in dealing with many different inputs e.g. flying an unfamiliar non-precision approach in poor weather at night, we can fail to re-tune the navigation aids at the appropriate point. This is why some systems utilise visual and aural alarms to break our focus and "grab our attention"; it helps that we are particularly sensitive to hearing our own name and call-sign. It is also why pilots and air traffic controllers need to be persistent in maintaining scans, in which attention is temporarily broadened such that other critical information can be sensed. Having other team, and crew, members also allows attention to be divided between people which can greatly enhance the information processing capacity available; this requires effective planning and briefing. As well as external events of relevance vying for our attention, our attention will always be tempted by loud, bright, moving and proximate events and objects; i.e. we are easily distracted by irrelevance, especially from tasks requiring applied thought – as anyone who has ever procrastinated will recognise. Also, distraction can be internally generated. Internal thoughts about current, past and future events will arise, and often these thoughts are totally unconnected with the task at hand. Internal distractions are more likely to occur when fatigued, stressed or ill.

### Sensing

Whether the input is sound, light, pressure, taste or smell, unless we can place our attention onto these inputs there is only a short period of time before the sensation disappears; e.g. visual memory lasts for less than 1 second, audible (echoic) memory lasts

for up to 8 seconds. It is these "sensory memories" that allow us to immediately read-back a frequency, or recall a telephone number long enough to dial it once, but 30 seconds later be unable to recall accurately. Paying attention to any of these inputs will involve forming a perception and the transfer of data into more robust memory. This takes effort and involves the decision-making mechanism; in these examples this may be either continuously repeating the numbers (during which we can process no other information – at all) or writing down the information as a record.

Of course at this sensing stage we can be at a disadvantage if our sight and hearing are attenuated (naturally or not), and also if our inner ear is affected in any way. This means that our perception of the outside world will be incomplete, or distorted.

### Perception

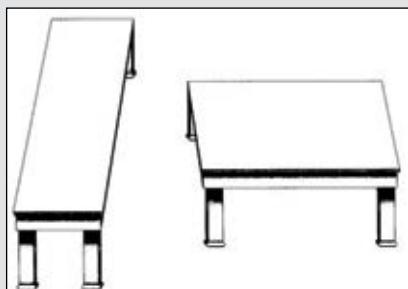
Perception is the process of converting sensory information into something that makes sense – i.e. creating an internal mental model of the outside world. Because we are unable to "collect" 100% of external data (as already mentioned above) our internal model will be incomplete. However, based on our previous experiences, we are often able to make sense of the little data we receive and create a realistic model based on our expectations. Much like the fact that we can easily recognise someone's face from a badly pixelated picture; if it's someone we know, then our brain literally fills in the gaps and joins the dots. It is this mechanism that helps us to divide attention and sometimes multi-task.

However, the same mechanism can lead us to "misperceive" the world –

# Information Processing (cont'd)

the more we rely on past experiences the more our expectations will distort our perception. For example, a helicopter pilot who regularly flies along snow-covered valleys in Norway will have a mental model of fir trees being 150ft tall. If he enters a valley which is full of newly planted fir trees he may fly much closer to the ground than intended as he has misperceived the scale of the outside world. Hence the importance of cross-checking our perceptions with other data; in this example – the radar!

Another source of misperception concerns how juxtaposed objects within an environmental setting can influence each other to create a visual illusion.



**Fig 1. Shepard's illusion of equal table top dimensions**

perceive anything but different tables. Similarly in figure 2, although we can measure each horizontal line and recognise that they are the same length, it is impossible to shake off the perception that they are different. Both these illusions have relevance for pilots judging the height, distance and slope of runways on approach.

## Working Memory

Working Memory is the aspect of our memory that we use all the time when conducting any task. It holds small amounts of data for a very short time, which is to be used immediately. Therefore, we can read-back an Air Traffic Control instruction to descend and change Transponder Code and maintain these numbers long enough to enter them into the appropriate systems. Mental repetition may be required to achieve the task, but once completed the information is lost within 30 seconds and replaced with the next set of data we need e.g. setting-up the displays to facilitate an instrument approach.

Typically the capacity of our working memory is 7 digits +/- 2. We can extend this by "chunking" digits together into meaningful blocks such as a long telephone number with 12 digits (e.g. 49 123 747 8989) can be chunked as shown into just 4 memorable blocks. Chunking can also be usefully employed to access long-term memory through the use of mnemonics and other tricks, e.g. I always remember the downwind checks for the De Havilland Chipmunk, even though I haven't flown one for over 30 years – My Friend Fred Has Hairy Balls – Mixture, Fuel, Flaps, Harness, Hood, Brakes!

The more times that data is used in our working memory, then the more likely it is to enter our long-term memory.

## Long-term Memory

Similarly, the more times data is accessed in our long-term memory, then the more likely we are to be able to recall it when needed. This fact gives support to the method of training called "over learning", where we repeat a procedure or task many more times than is necessary just to perform to a satisfactory level. This is a positive counter-measure to guard against long periods between training and actual performance during live operations; and gives support to the concept of practicing elements of operating that have not been performed for a long time, or at least mentally rehearsing or discussing them.

Long-term memory can be said to consist of three sections, each defined by the manner in which data is stored – Semantic, Episodic and Unconsciously.

### Semantic Memory

Semantic Memory is our database of facts about things, which is built through repetition and familiarity. We use the semantic memory to understand words, to "do" mathematics and to follow checklists and instructions. This does not mean that everything stored in the semantic memory is correct. If we learn an incorrect fact e.g. Chiang Mai is the capital of Thailand, then this is what we will answer, instead of Bangkok, if someone asks us what is the capital of Thailand? Similarly if we incorrectly learnt and therefore "remember" that we turn the APU on before retracting Flaps after landing, then unless we follow the Checklist we are liable to make an error.

Just because we have meaning and facts stored in our semantic memory does not necessarily mean we can always recall them, when required. Rare-

**Fig 2. Muller-Lyer Illusion**

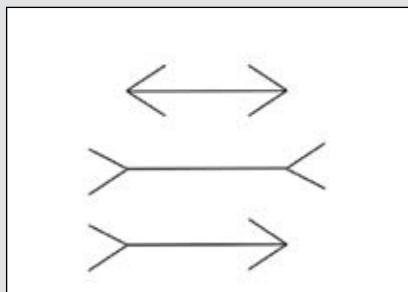


Figure 1 above displays the exact same table but from different perspectives – even after measuring each table top and realising they are the same, it seems impossible for our brain to

## SKYbrary download (cont'd)

ly used data can become inaccessible unless we happen to be reminded by some context i.e. a mnemonic (as already mentioned) or something else familiar, like a sequence of events, or a familiar experience. This is why when remembering facts it is useful to engage the imagination, other senses and even the emotions<sup>[1]</sup>.

### Episodic Memory

Episodic Memory contains experiences, including knowledge of specific events; the more vivid, or emotional, then the more likely it is we will remember. And, as for all memory, the more we access and recall certain memories, then the easier they will be to access and recall again in the future. A bit like joke-telling! Unlike factual semantic memory, information (stories, if you like) held in episodic memory can change with each telling, especially with time. This is because we interpret events differently depending on many factors, one of which is our expectations of how things were, or should have been. Inconsistencies between witness reports, for the same event, are mainly due to witnesses experiencing the same event differently and then layering different interpretations on top of what they experienced.

### Motor-skills Memory

When we are highly-skilled at a task then we can perform seemingly without too much conscious effort. Peculiarly though, the more we think about "how we are doing it" the less skilful we suddenly become! E.g. a golfer suddenly losing the ability to putt, a maestro playing a difficult piano solo getting stuck, or a pilot landing in a strong crosswind suddenly over controlling.

The stages of skill learning can be broken down into four steps<sup>[2]</sup>:

- unconscious incompetence
- conscious incompetence
- conscious competence
- unconscious competence

It is in this last stage when the skill becomes "second nature" and we are able to conduct another task at the same time such as instruct another pilot to fly. This is because the demand on our information processing ability for automatic tasks is much reduced. Whereas if we slip back into the third stage we become aware, once more, of what we are doing, and this uses up processing capacity.

In effect we all run different dedicated motor programmes and motor sub-programmes for a variety of different skills that "kick-in" when the situation demands. Whilst we may rarely make an error in performing these skills, we sometimes initiate an inappropriate skill, at the wrong time e.g. when intending to fly an approach to overshoot (go around) we may find ourselves landing and taxiing back to the terminal. These are referred to as "action slips".

### Deciding and Acting

In the early stages of flying training, focus is on learning and developing motor skills to the point that they become automatic. However, as training progresses focus broadens to include a wider range of skills that require judgement, such as, communication, problem-solving, procedures, decision-making, planning; and also skills that require knowledge, such as performance, software and systems

management. Decision-making in itself is an acquired skill, which will not be covered in depth here. However, in the context of information processing, the deciding stage is concerned with selecting the type of action that best fits the current task.

The actions we choose can be:

- skill-based
- rule-based, and
- knowledge-based

The information processing model shows that selected actions are concerned with correcting the "outside" world so that we can perceive progress being made in the desired direction – it is an error-correcting closed feedback loop. However, if we are sensing incomplete or false data, then our selected actions can be error-generating<sup>[3]</sup> (open-feedback loop).

Apart from automatic motor-skills responses, our responses will be sequences of conscious actions and communications. It is common in aviation for decisions and actions to be made quickly under-pressure and therefore it is likely that accuracy will suffer in place of speed. Therefore, it is extremely important in such pressure situations to be as vigilant as possible and to purposefully put effort into raising our situational awareness. This will allow speedy anticipation of likely events but also keep our awareness broad to react appropriately to unanticipated events. As Maslow calls it<sup>[4]</sup> flow, or as we know it from the sports-field being in the zone.

# Information Processing (cont'd)

## Multi-task or Manage Resources?

Can we or can't we multi-task?

There is no doubt that humans can drive a car and hold a conversation at the same time (we all do it routinely). However, in most circumstances we are driving a familiar car along a familiar route, and the conversation is unimportant (we can stop it anytime we need to). In these situations our mental model can rely a lot on schemata of previous experiences stored in our memory, allowing us to divide our attention, and perhaps re-tune the radio, drink coffee, chat to our passenger and drive all at the same time (not recommended!).

However, we all have a point where we quickly reach capacity and have to "dump" certain tasks. When taking a detour that requires a bit of map reading, the conversation stops, the radio is turned off (to help us concentrate) and we ask our passenger to hold the coffee. We don't even have the capacity to think about delegating the map reading to our passenger; or, is this our ego talking – **I've got it!**

Therefore utilising the other available human resources (crew/team) when the workload increases is a skill that needs to be practised and implemented. Sometimes this decision is already made and a standard procedure exists i.e. flying monitored approaches. Similarly, when a member of your team/crew is fully engrossed in a critical task they can be helped by picking up other tasks, and should probably not be distracted. 

## Related Articles

- Attention
- Decision Making
- Human Error Types
- Lessening the Effects of Visual Illusions
- Managing Somatogravic Illusions Presentation
- Memory
- Memory in ATC
- Somatogravic and Somatogyral Illusions
- Vigilance in ATM
- Spatial Disorientation
- Visual Illusions

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- [2] Noel Burch. "Learning a New Skill is Easier Said than Done." Gordon Training International
- [3] Rasmussen, J. 1986. Information Processing and Human-machine Interaction: an approach to cognitive engineering. New York. Elsevier Science Ltd.
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## In the next issue of HindSight: Safety nets



### Putting Safety First in Air Traffic Management

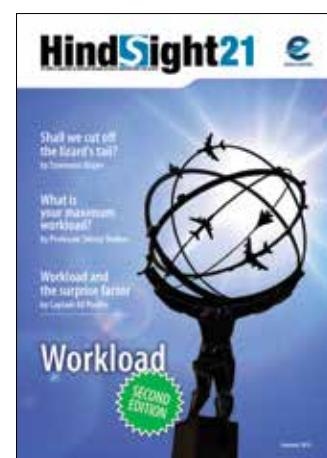
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