

# Human Performance in Complex Systems

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## A little about me

- » 22 years in aviation
- » Air Traffic Controller
- » Helicopter Pilot
- » CEO ANSP & Safety Regulator
- » PhD research into Air Traffic Management Systems



# Agenda

In no particular order but we will touch upon.....

- » Where my research came from.
- » The European context.
- » The Irish ATM system.
- » Audio alerts in ATM – and recent developments elsewhere.





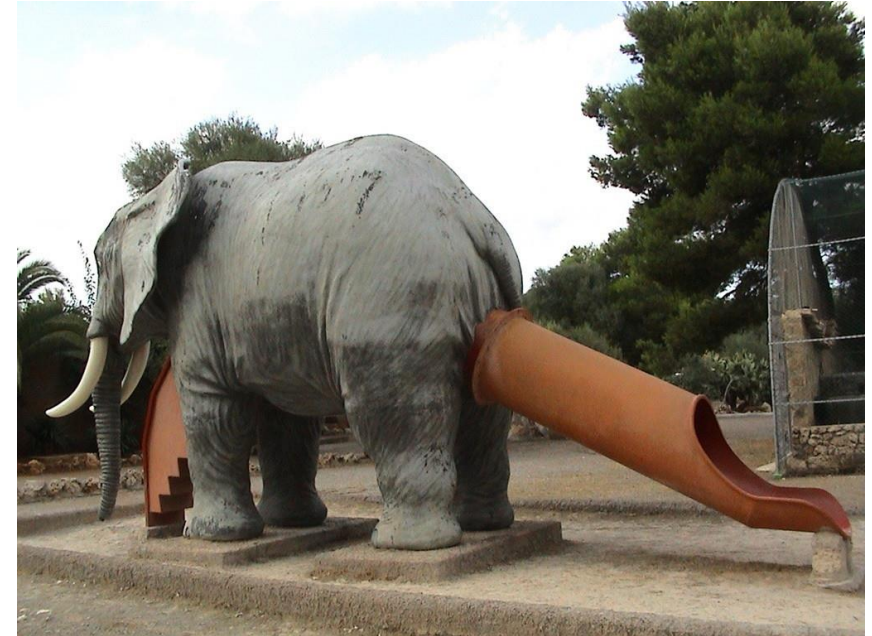
## How it started.....

Personal experience  
as an air traffic  
controller ...



# Made me think about how we imagine things.....

- » Technology can achieve the desired functions
- » Operators have competence to use the technology as intended
- » Policy and Procedures dictate systems and human behaviour
- » Correlation between those specifying systems and those designing systems



# Made me think ...

## In reality...

- » *Technology does not always function as predicted*
- » *Operator's behaviours deviate from baseline*
- » *Procedures may not be executed as planned*
- » *Systems change through additional components & tasks*
- » *Complexity of interactions with other systems/agents*



# Political Context is Important



Cost

Safety  
Capacity  
Efficiency





# Political Context is Important





# Is it all about Cost and Profit?

» Cheaper, Agile, Adaptable

» Technology – Buy off the Shelf

» Limited design authority

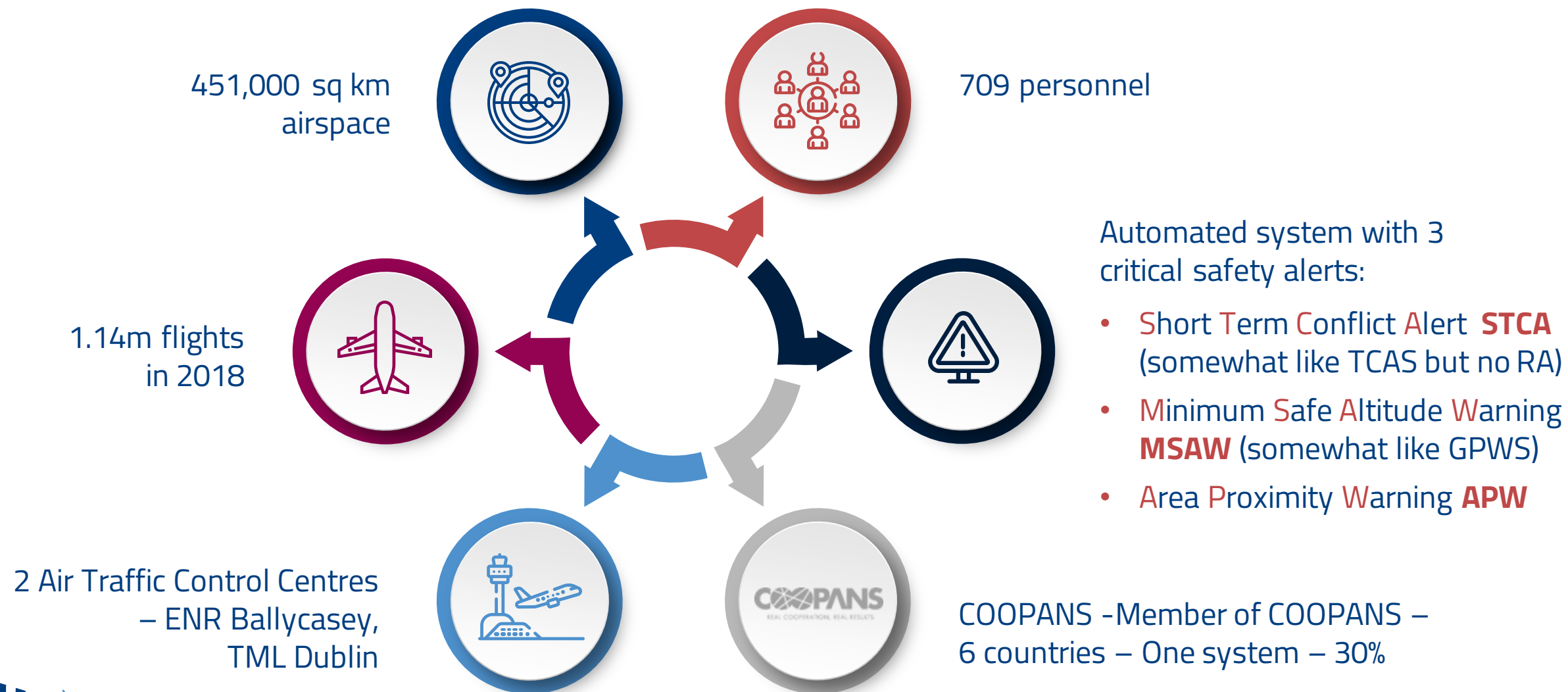


# Irish ATM System

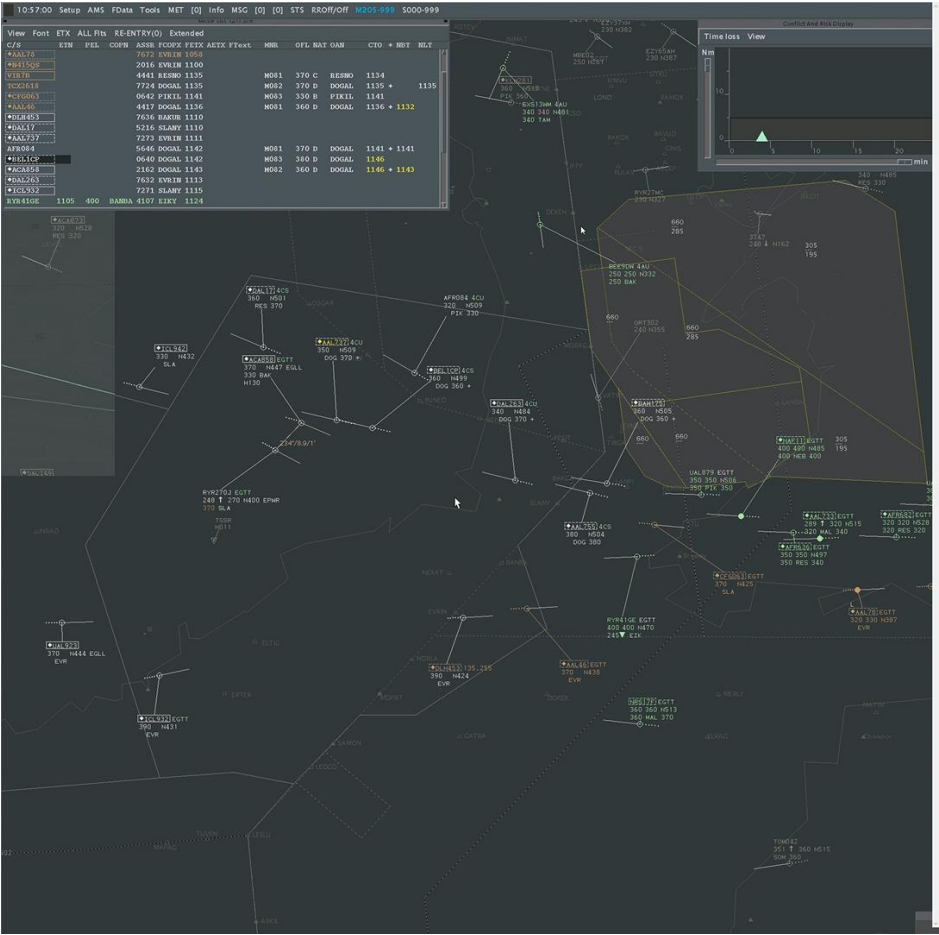
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# ATM System Framework



# Typical Sector Operation





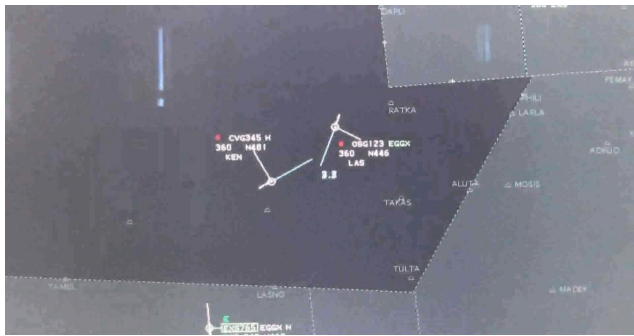
# Summary of Video

In the clip there was:

- » circa 60% Frequency Occupancy
- » 22 Frequency Controller-Pilot exchanges
- » 53 ATCO inputs (not including label management)
- » circa 5,000 passengers in the aircraft involved
- » circa €10,000 in revenue from the flights in the clip



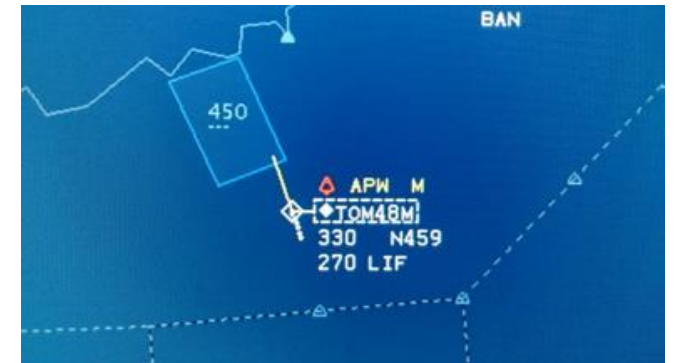
# So what's the issue?



**Short Term Conflict Alert**



**Minimum Safe Altitude  
Warning**



**Area Proximity Warning**

## So what's the issue?



**Short Term Conflict Alert**

# Not a new story.....

- » Inappropriate design can lead to loss of SA and push the human outside the system control loop (Durso et al, 1998; Endsley, 1995).
- » Decision errors may be contributing to up to 60% of all aviation accidents (Jensen & Benel, 1977; Buch & Diehl, 1984; Diehl, 1991; Li & Harris, 2008)
- » ATM system Alerts
  - lack of uniqueness of alarms, multiple false alarms
  - alarms being counter intuitive
  - alarms annoying
  - alarms increase ATCO workload (Ahlstrom, 2003; Newman & Allendofer, 2000).





# Not a new story.....

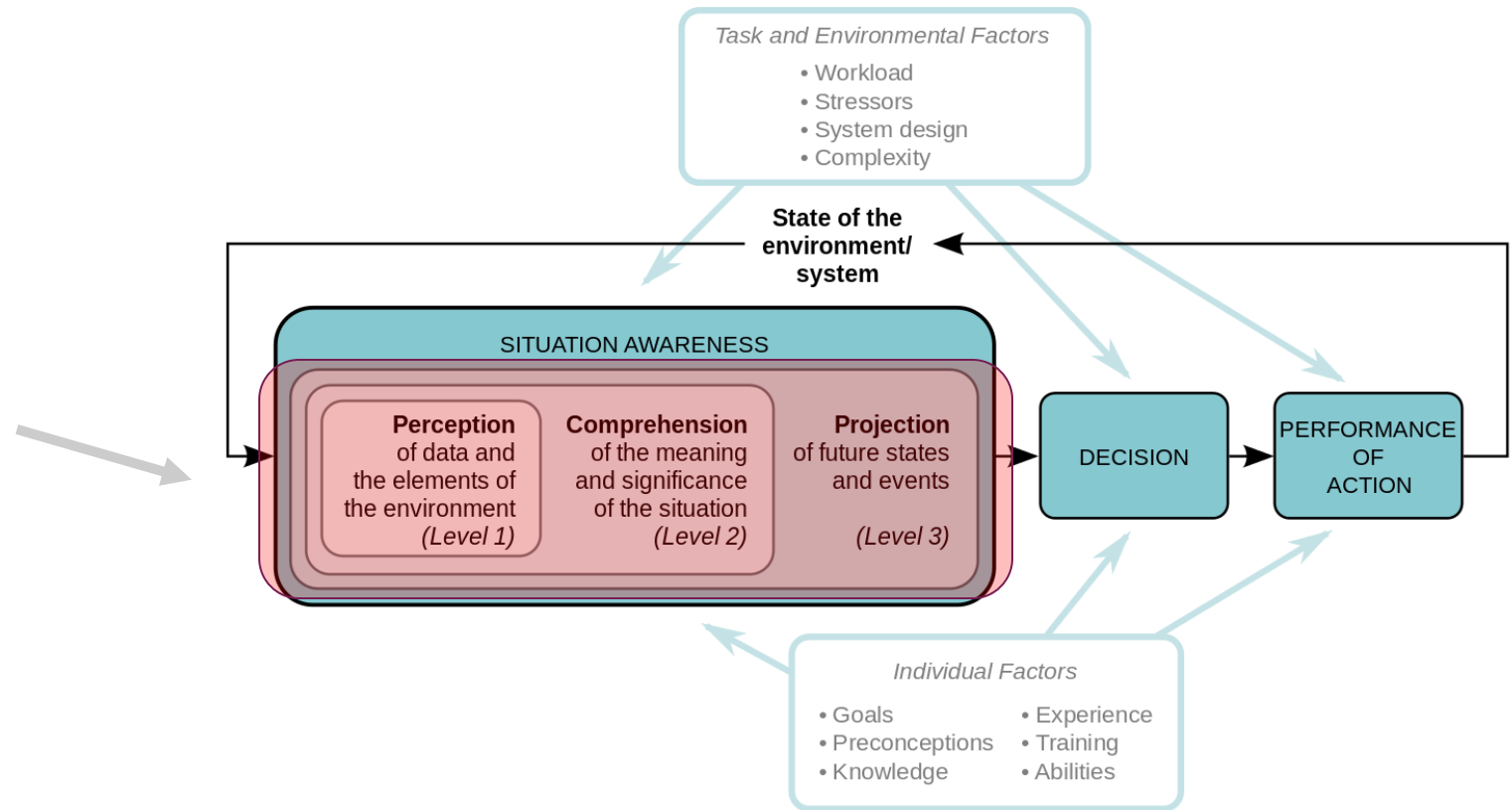
## Poorly designed alerts:

- » Annoy, Distract, Disrupt, induce Startle and prolong information processing, delaying Decision making and reducing SA (Baile, Konstan, and Carlis, 2001; Imbert et al, 2014)



# What pitch are we on?

Can we provide tools which support L1, L2, L3 and promote faster responses, better decisions and a swifter return to normal operations?



Endsley's model of SA. This is a synthesis of versions she has given in several sources, notably Endsley (1995a) and Endsley et al (2000). Drawn by Dr. Peter Lankton, May 2007.



## Margins...



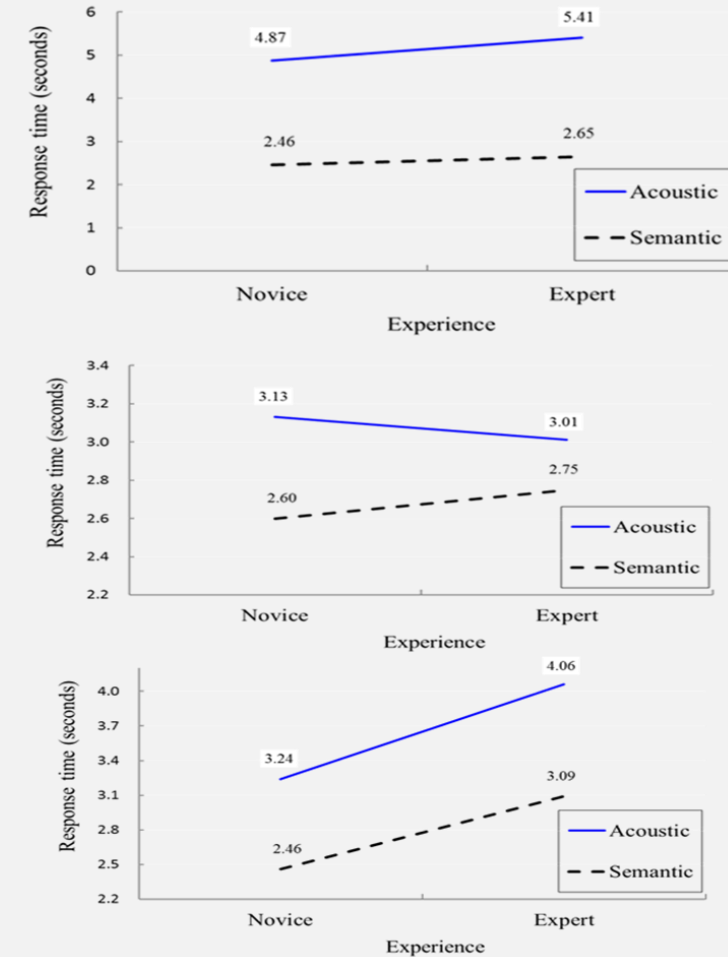
***RONAN O'GARA: The smallest of margins can make the biggest difference***

- » Critical safety alerts
- » Time is of the essence
- » Inherent pressure
- » Potentially significant outcomes from misjudgements



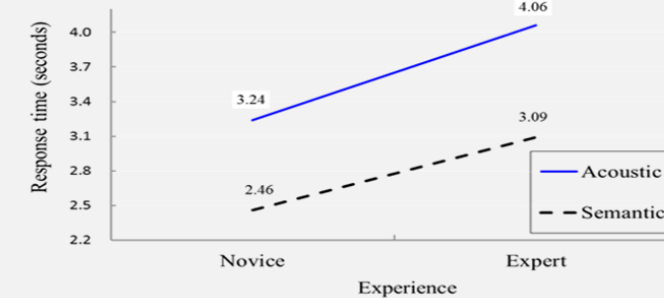
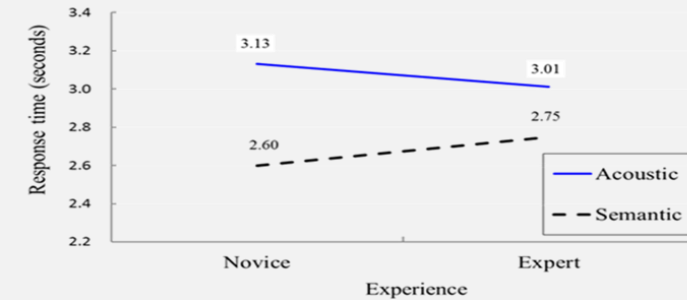
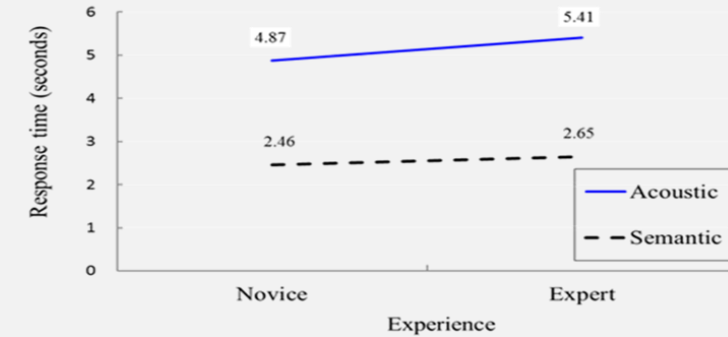
# Could we design a better alert?

- » 77 Air traffic controllers participated
- » Two groups
  - » Normal system sound (38 ATCOs)
  - » **Semantic alert** using a free text to speech internet programme (39 ATCOs)



# Could we design a better alert?

- » Response time to alert and accuracy of response noted
- » -10yrs = novice; 10yrs+ = expert
- » Results –
  - Faster response to semantic alert
  - Improved response regardless of experience level (N35,Exp42)
  - Semantic alert provides perception and comprehension
  - Faster return to normal sector ops



## Can I prove it?

- » Eye movements closely linked to visual attention (Kowler 2011)
- » Visual attention is a precursor to initiating the cognitive process involved in attention distribution, situation awareness and real-time decision-making (Lavine et al., 2002).
- » Fixation duration comes from deliberate consideration and induces more fixation counts for more detailed information (Schulte-Mecklenbeck, Kuhberger, & Ranyard, 2011)
- » Saccade is fast eye movements and it declines with increased workload (Ahlstrom & Friedman-Berg, 2006)
- » Pupil diameter increases as a function of cognitive demand (Ahlstrom & Friedman-Berg, 2006)

## Windows to the soul..... study 2



26 ATCOs



2 groups –  
Acoustic V  
Semantic



Head mounted  
Eye Tracking  
device



Conflict Alert  
scenario – 50  
mins



COOPANS  
Simulator  
system for  
fidelity



## Semantic Design Findings

- » ATCO shifts attention in shorter spans to search for critical information (Saccade Velocity, Saccade Duration) – important in a time limited event.
- » Collection of Information (Fixation Counts) and Deliberate Cognitive thinking & Problem Solving (Fixation Duration) increased significantly (Kotval & Goldberg 1998).

## Semantic Design Findings

And again in English.....

- » Semantic design cues the ATCO that there is an important message (**avoids startle**), specifies the nature of the critical event (**improves SA and expands working memory**) permitting more time for an effective resolution strategy (**as you know the critical event, you know the resolution strategies**)
- » L1 Perception → L2 Comprehension → L3 Projection

## In the cockpit...

- » Emergency situations increase workload and require additional effort to manage.
- » Multiple competing alerts may exceed available mental resources and narrow attentional focus leading to delayed or inadequately prioritised responses.
- » In some aircraft complexity and variety of ancillary warnings and alerts can make it difficult for crew to discern the primary failure.
- » NTSB recommends FAA develop design standards for aircraft system diagnostic tools that improve the timeliness and effectiveness of their response.



# Summary

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# Summary

1. The good news! - This is not Rocket science
2. Human/Automation Team is crucial for High Reliability environments.
3. Inappropriate design leads to accidents/incidents, including startle, loss of SA and pushing the operator outside the system control loop.
4. Appropriate design of decision support tools can assist in moderating workload, improving SA and ensuring a better match between task demand and cognitive resource.



# Summary

5. Human-centred design should be based on a strategic, collaborative and automated concept of operations. (Schuster & Ochieng, 2014).
6. A good design can eradicate expertise issues
7. Human evolution precludes any significant change in Human Performance ..... much easier to design our systems than change our operators.
8. Human Performance safety assessment - you or the manufacturer - consequences?

# Let me take you back to 1936





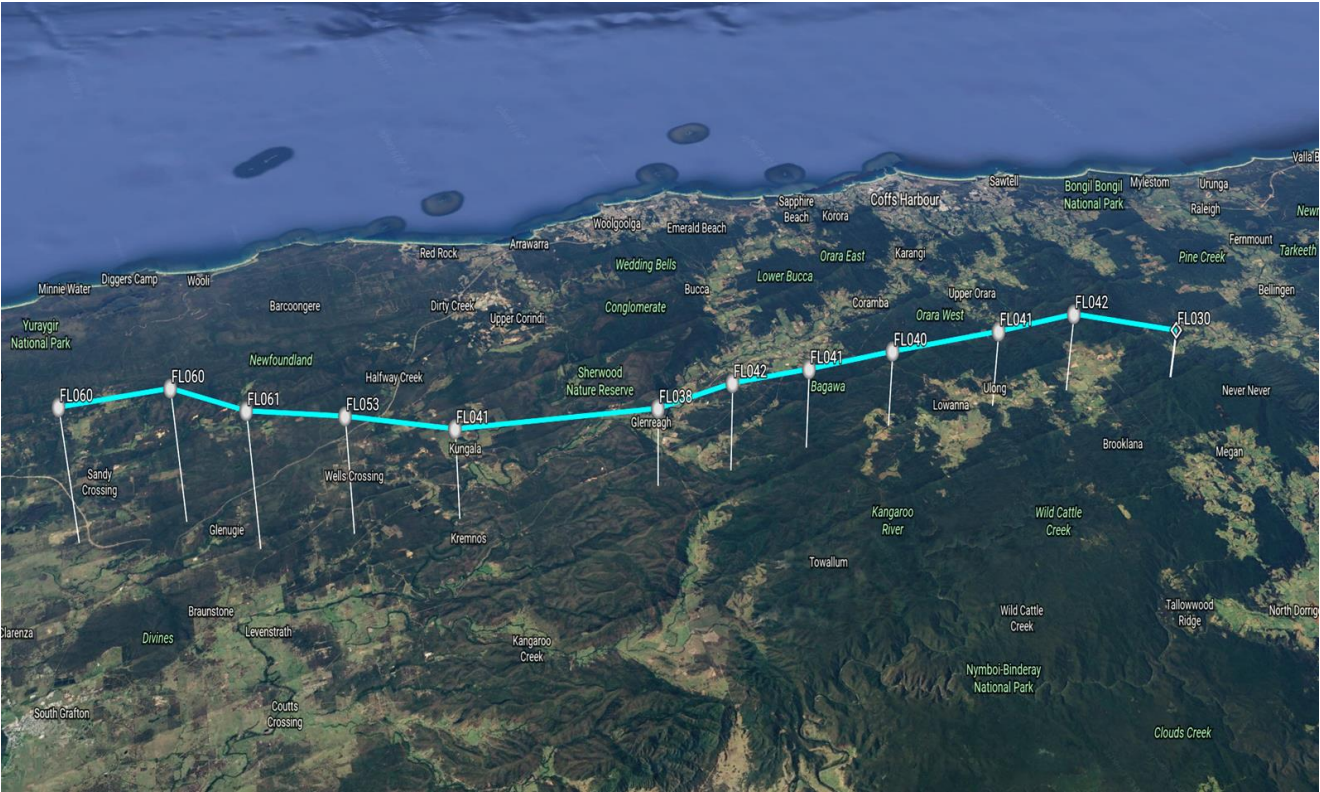
Shannon  
Aer Radio –  
now  
Ballygirreen

- Launched on the 9th of July 2019
- 24/7/365 Support for Aircraft in any of the three emergency phases globally
- Free Service for pre-registered users
- 300 Users signed up to date
- Detailed interaction with user on queries supplying graphical depiction of aircraft movement, overlaid on terrain mapping
- <https://aireonalert.com/>





# Light Aircraft Crash Australia Coffs Harbour September 2019 MOONEY M20 4 Seater





## Feedback from Search and Rescue Australia

- The file - extremely invaluable, easy to import, reduced the potential for a human error converting any positions formats.
- Having the time in UTC down to the seconds is also great to confirm timings, speed and descent profiles.
- Analysing the Aireon locations allowed us to have an expected next updated position from Aireon to be within approximately 1.5 minutes based on the previous satellite tracking detections.
- Helped reduce the size of the primary search area to a radius of approximately 5nm based on the speed of the aircraft.

**Aireon Alert system greatly assists with the Search for missing aircraft.**

**In this instance we also had coverage from Flightradar24, but a large area of the Australian Search and Rescue Region has no such coverage from ground based ADSB receivers.**

**So Aireon with it's Global satellite coverage is going to be extremely useful in searches for missing aircraft.**

# Thank You

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“Any intelligent fool can make things bigger, more complex, and more violent. It takes a touch of genius — and a lot of courage — to move in the opposite direction.” — Albert Einstein