# AI and Aviation: Building Ethical, Predictive Human Performance Management Systems

## *Re-defining 'Demand' for the future*


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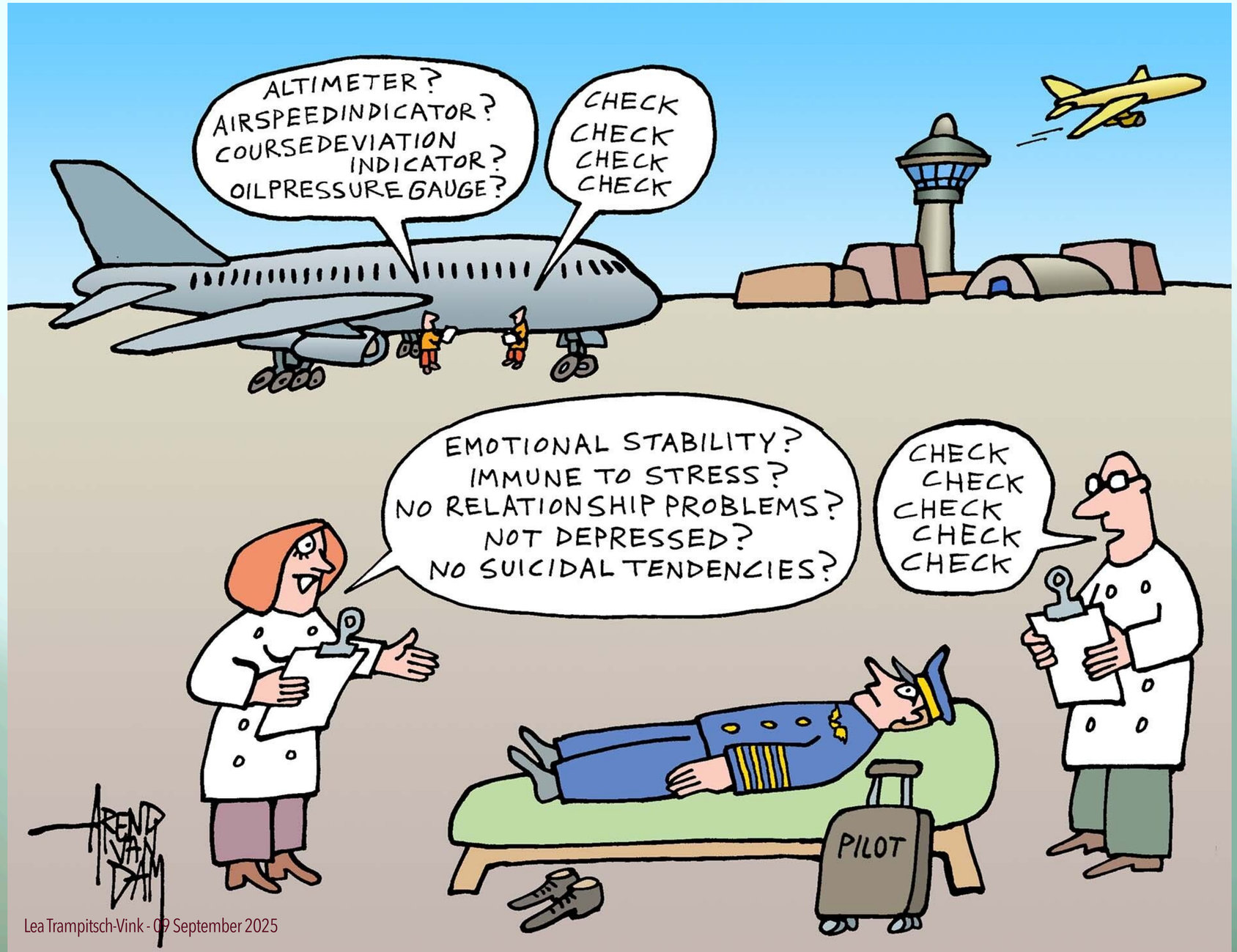
Co-Chair European Commission Expert Group on Human Dimension
Director, Just Minds AT


# What Are Humans Good for?

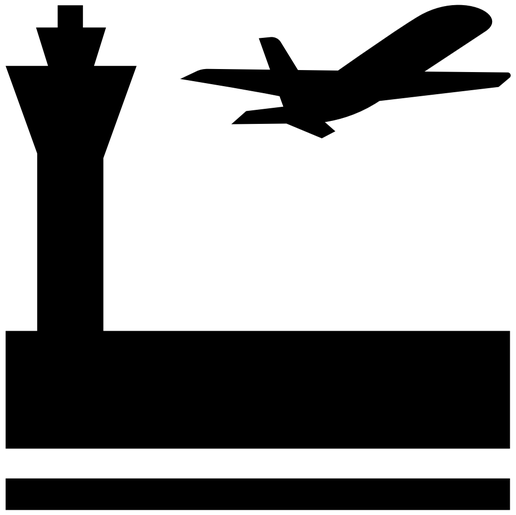
# Humans will remain…for now…

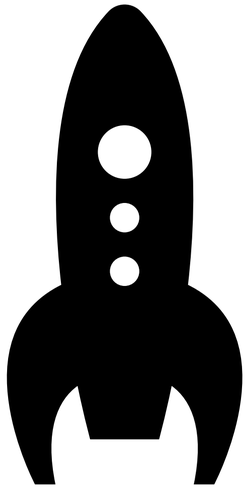
Over 50 years of research have concluded that when compared to machines we excel in the following:

1. We are good at Complex Decision Making (of a certain type… when Ethics meets Safety meets Demand…)
2. Adaptable and Flexible
3. We have Ethics and Moral Responsibility (mostly!)
4. We have excellent intuition… but why? (Error detection(
5. We are great communicators, able to convey great depth, sometimes with a single look…
6. We can push through when we should have long ago stopped…
7. Our diversity makes us superhuman when we work together!

Our question is… So what?!?!?! Why does it matter so much?

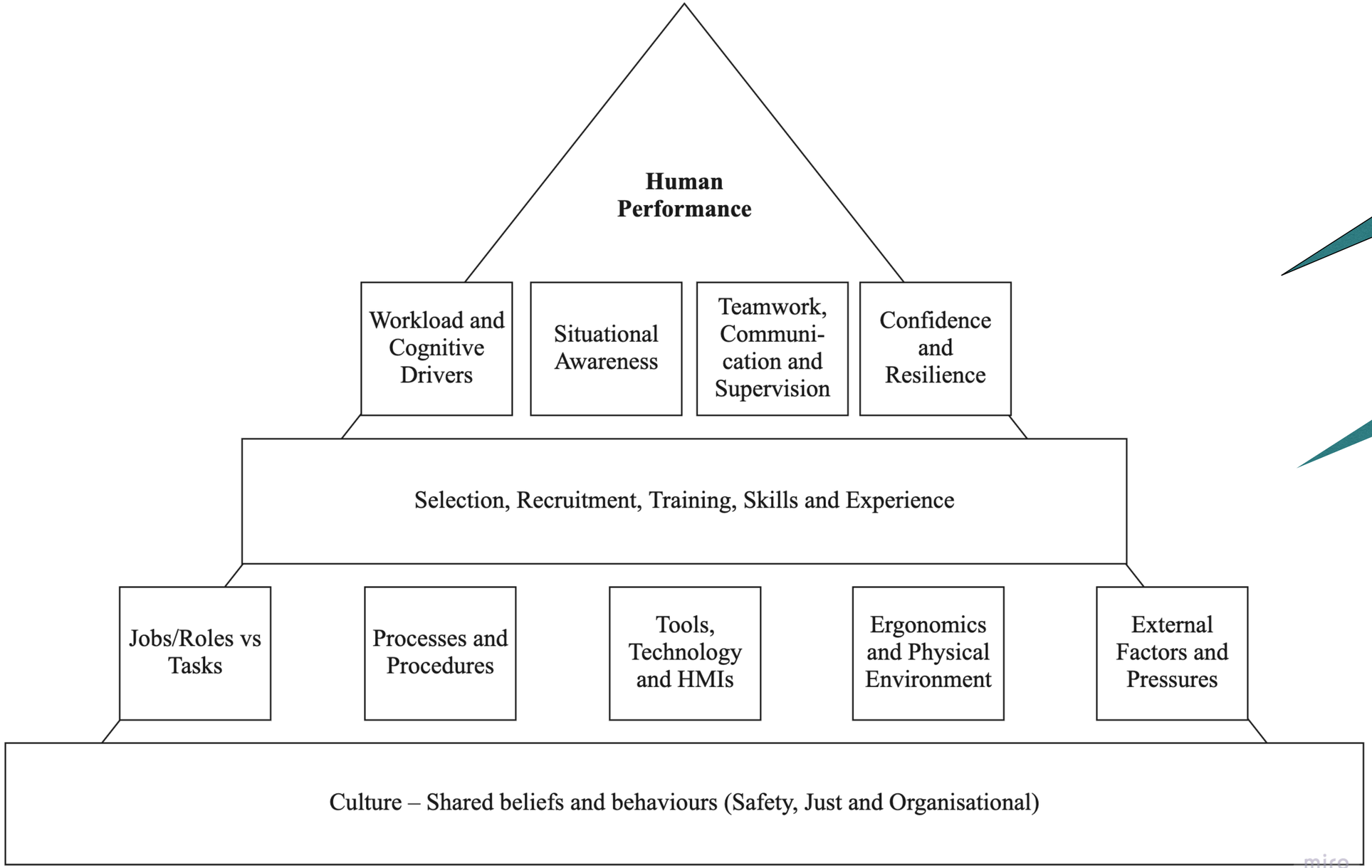
# ATM IN NEED OF MORE HUMAN PERFORMANCE…





- Soaring Demand, retiring workforce…
- New Airspace Users, increasing task unpredictability
- Traditional performance metrics no longer fit for purpose
- Regulations designed to limit loss of service and performance

# What does pirate hunting have to do with designing a cockpit?




Individual day-day Variability

Talent Management or Non-individual criterion

Infrastructure and Ergonomics

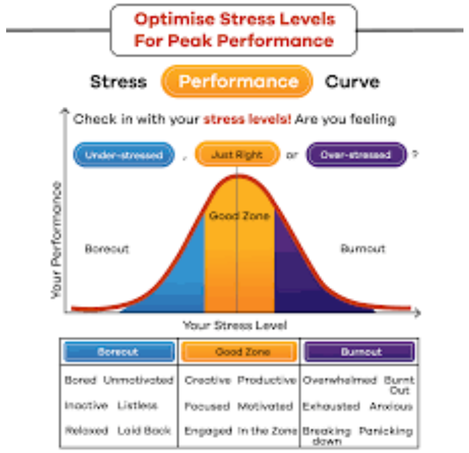
Culture

Vink, L. S., & Walzl, B (2025)

# Whenever humans and systems interact…

## Human Performance

- Achieve tasks
- Concentrate for long periods
- Attention and perception
- Sustainable




## Human Error

- Slips
- Lapses
- Mistakes
- Fatigue

*„Our goal as practitioners and managers must always be to maximise Human Performance and reduce human error" to a minimum*

# Definitions

## ICAO:

"the study of the interaction between humans, the machines they use and the environment in which they work, with the goal of optimizing performance, safety, and well-being."

(Source: ICAO Doc 9683, Human Factors Training Manual, 2019, Chapter 1)

## CANSO

"the science of understanding human behavior, capabilities, and limitations and applying that understanding to improve safety, performance, and well-being in operational environments."

(Source: CANSO Human Performance Framework, 2017, page 9)

## NASA

"the study of how humans perform in operational environments and applies that knowledge to the design, development, and evaluation of systems, tools, machines, environments, and work processes to optimize human performance and minimize error."

(Source: NASA-STD-3001, NASA Human System Integration Standard, Revision A, 2007, Chapter 1, page 1)

## Eurocontrol

"the application of knowledge about human capabilities and limitations to the design and operation of technical systems and processes to optimize human well-being and overall system performance."

Eurocontrol Specification for the Application of Human Factors Requirements in CNS/ATM Systems, Edition 3.0, 2015, page 13

## FAA

"the field of study that focuses on how humans perform in operational environments and how to optimize human performance in those environments to enhance safety and effectiveness."

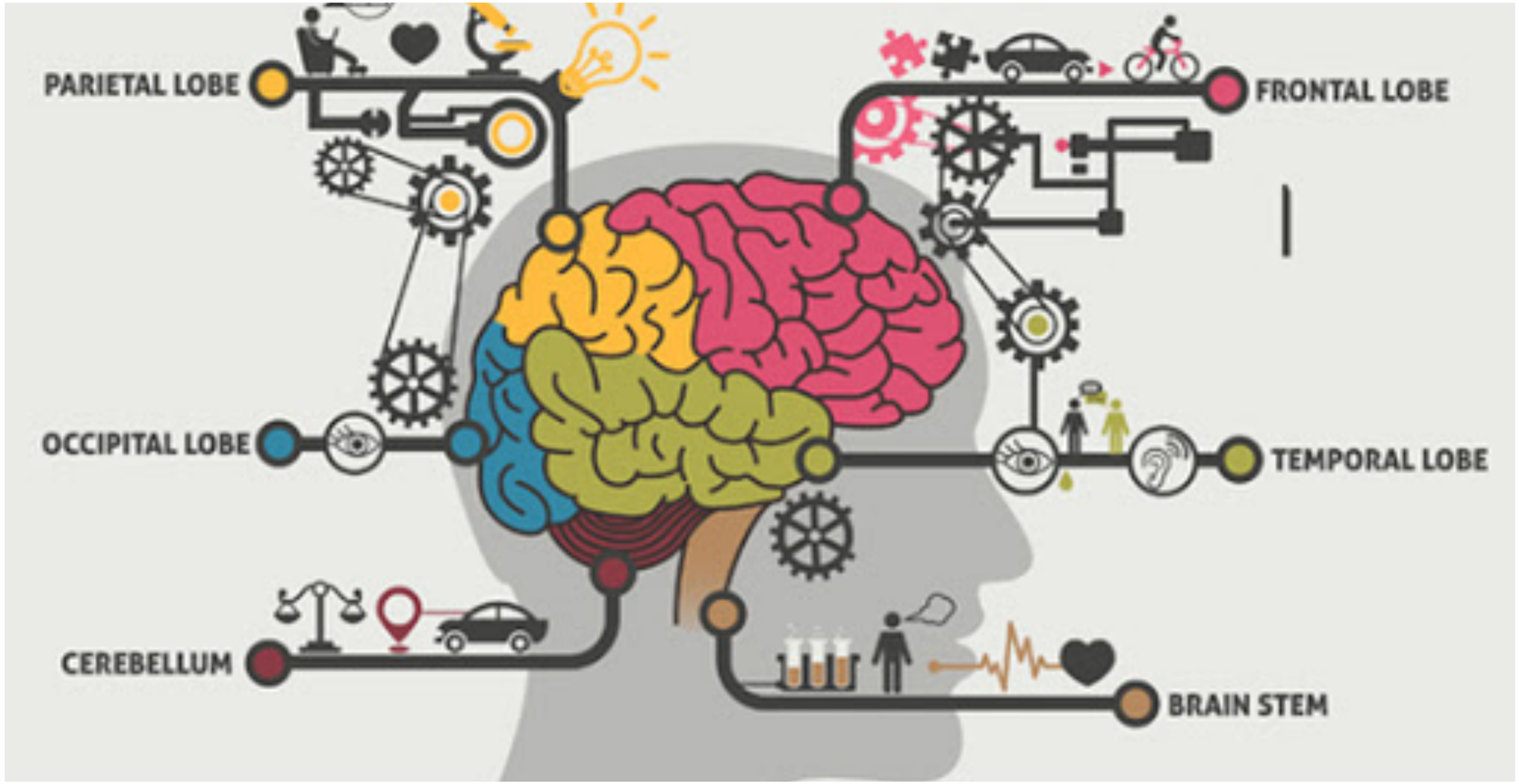
(Source: FAA Order 9550.8, Human Factors Program, 2015, Chapter 1, page 1)

## ISO

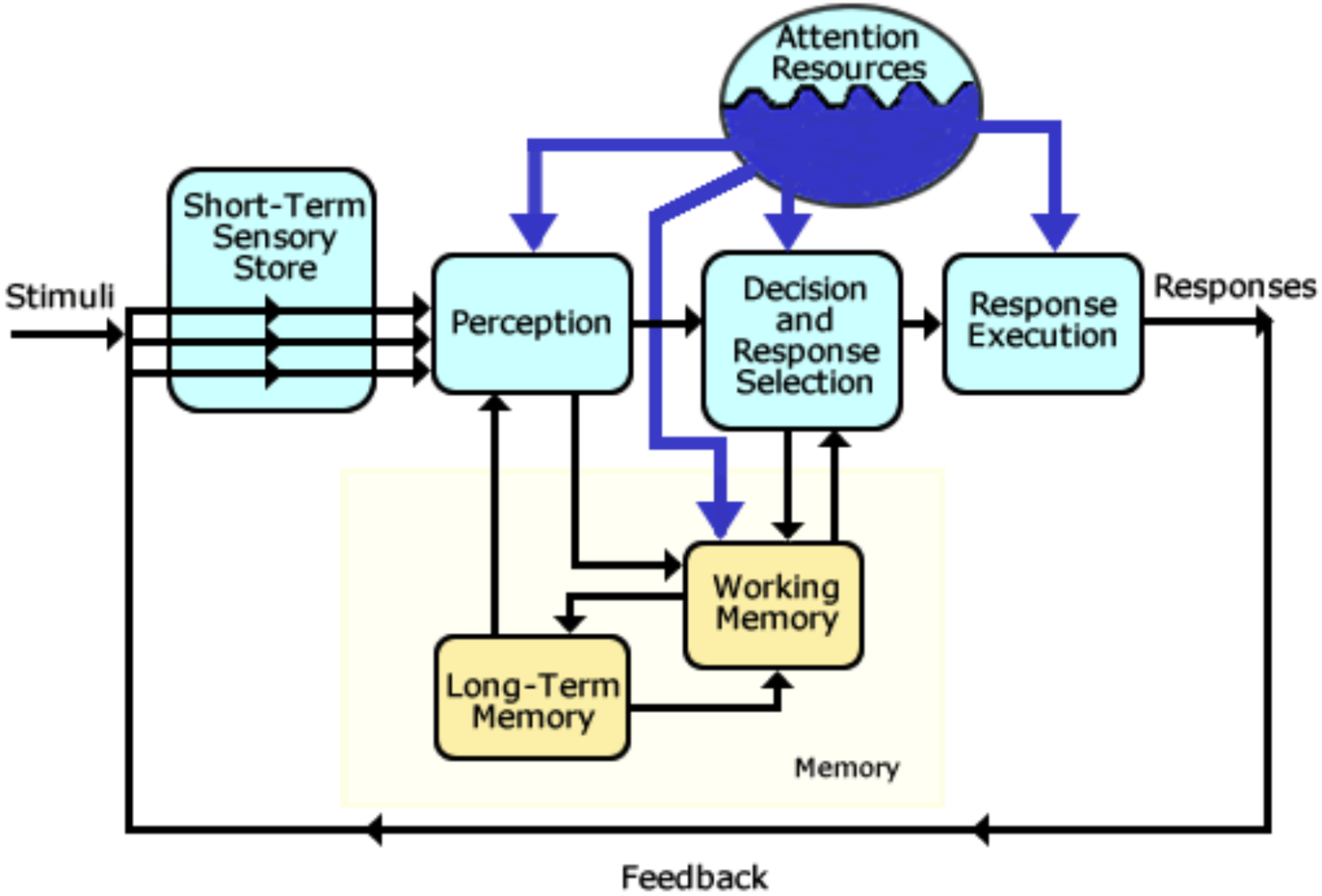
"the scientific discipline concerned with understanding interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and other methods to design in order to optimize human well-being and overall system performance."

(ISO 9241-210:2019, Ergonomics of Human-System Interaction - Part 210: Human-Centred Design for Interactive Systems)

# A quick tour of the brain



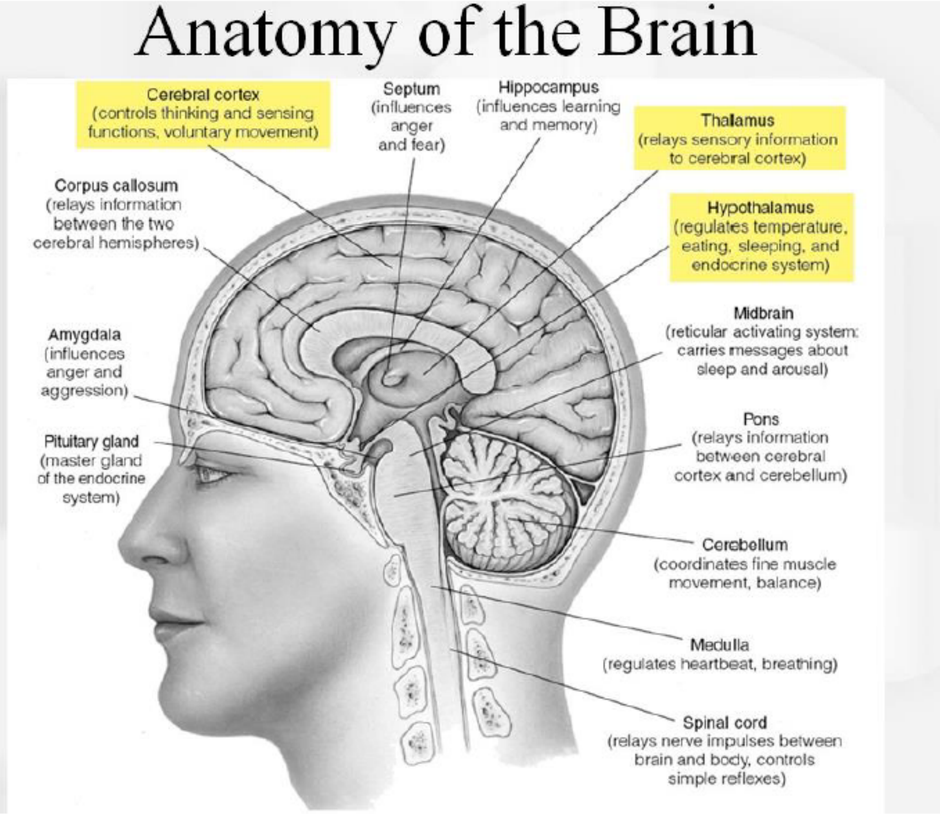
# Dr. Wickens and the Theory of Resource Depletion




Key take away:

- The brain uses the most energy of the entire body! Weighing only 2% of bodyweight, it uses up to 40% of the energy each day…
- It costs a lot to think! Your brain prefers to use automated functions and not think much
- Wickens proposed the idea that our brains must focus limited resources on key elements

# So how does it all work?



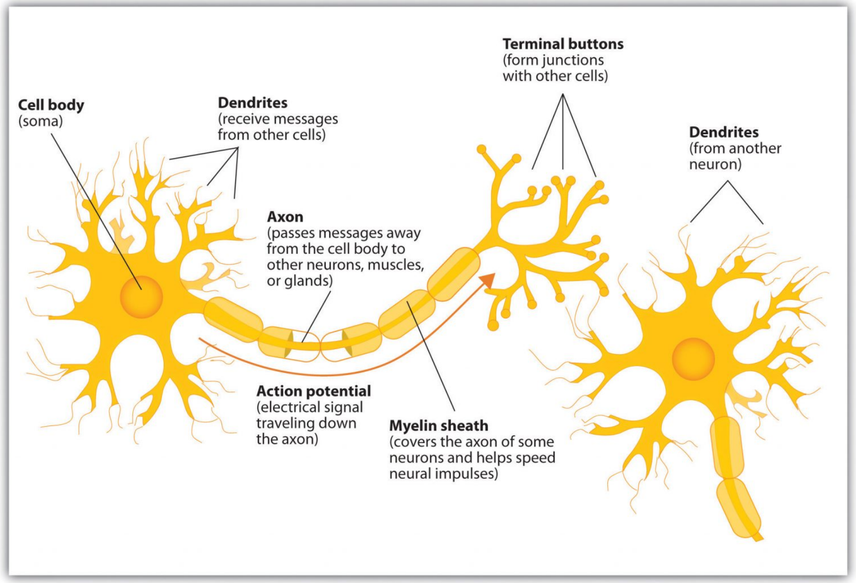

1. The brain works like this…the 'Hind Brain' is responsible for keeping us alive. It is the oldest part of our brain and known as the monkey brain. It sends signals down our spine to control heart rate, muscles, hormones etc..
2. Fight or flight is the central question of the brain.. everything else in the brain exists to assist your brain in making the decision whether to fight or flight
3. Memory works in cohesion with Emotions to make this decision: have I seen this before, if yes then what do I do? If no, then what is the closest other experience to it and what did I do for that?
4. Emotions help code our memories and provide weighting. In other words, the memory which has the best weighting will be that selected by the brain for decision making
5. Senses and Consciousness provide confirmation and check and balances to the 'mental model' that our memories and emotions hold
6. So the further away from the hind brain you go, the less important the function.. but… each of those functions improves the 'mental model' of the world

Skill, rules, knowledge framework (Rassmussen 1982), GEMS (Reason, 1990) + Multiple resource theory (Wickens 1986) + SA (Endsley, 1995) + Systems thinking (Kahneman, 2011) + Dennett (2018) + BHPC (Rao & Ballard, 1999)

# Three rules of being human - key take aways!

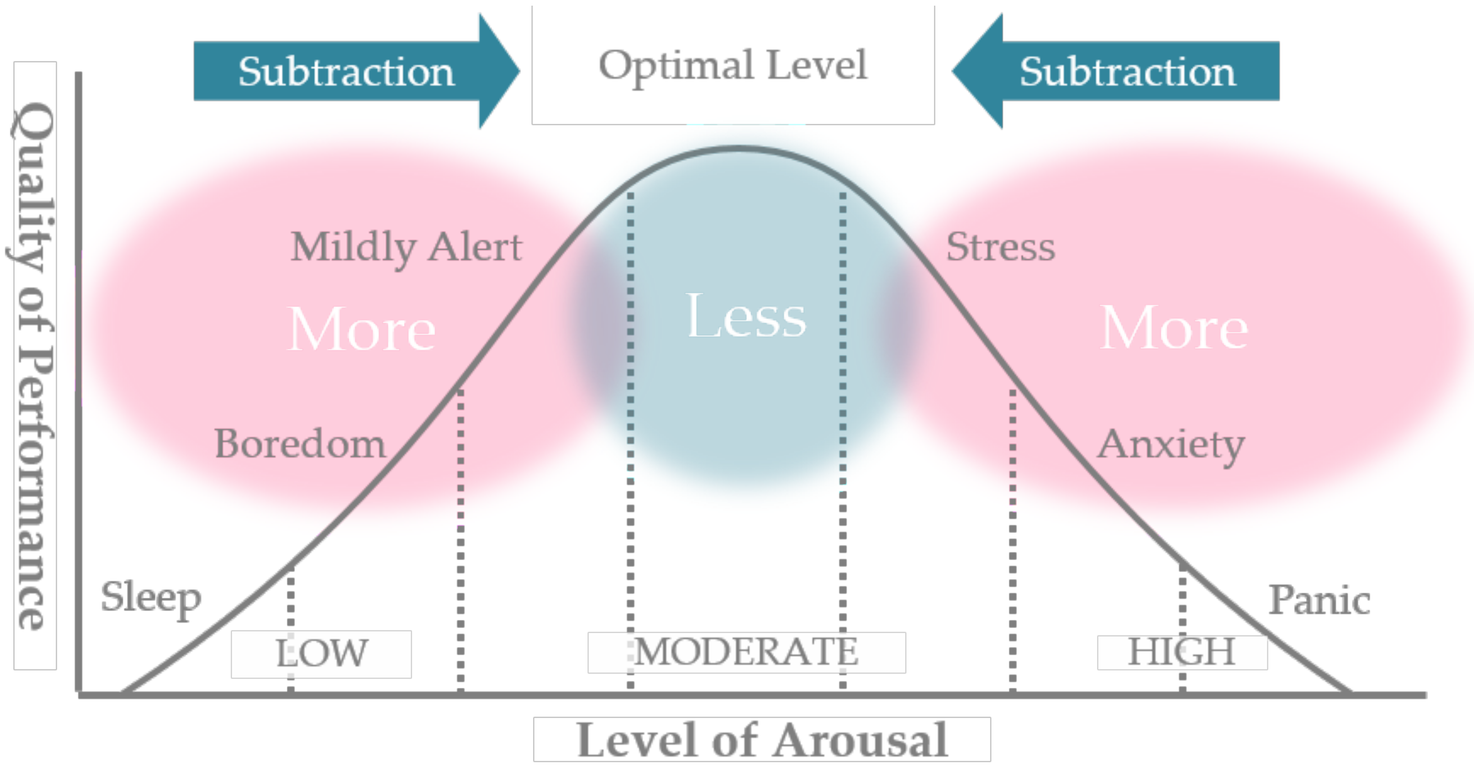
**If you know three things about us.. know this…**

1. We are primed to always be on the negative side
2. We are inherently lazy! - our brains want to conserve energy
3. We will always prioritise reinforcing our view over updating our ways



# Rethinking Stress

This is the Yerkes-Dodson curve…Our performance corresponds to the arousal (or 'threat' ) levels…




As we have learned now… deep inside the brain, our hindbrain regulates our entire body by asking itself a key question:

- Is the body state appropriate for the threat level?

We should start to think of the hindbrain is being like the accelerator of a car. As threats increase, the accelerator is sped up to respond. As threats turn down, then we take the gas off.

- So stress is not just vital for us, it IS how our body works. Stress is a normal state of being. What can cause us problems is when the accelerator is down for too long…

What this means, is that Stress is a medical or physiological term about how the brain regulates itself…

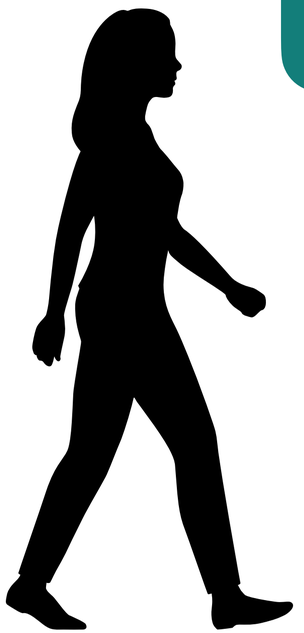
The kind of 'stress' we usually think of is a Social construction refer generally to the right hand side of this graph…

# Human Performance and Fatigue

Fatigue Control System

Stress Response Cycle

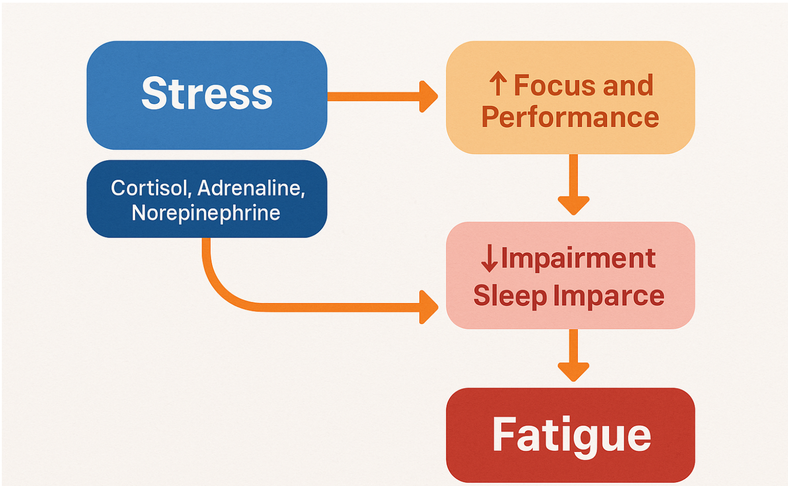
Arousal / Attention Systems



Workload and Resource Management System

Emotional Regulation

Error Management



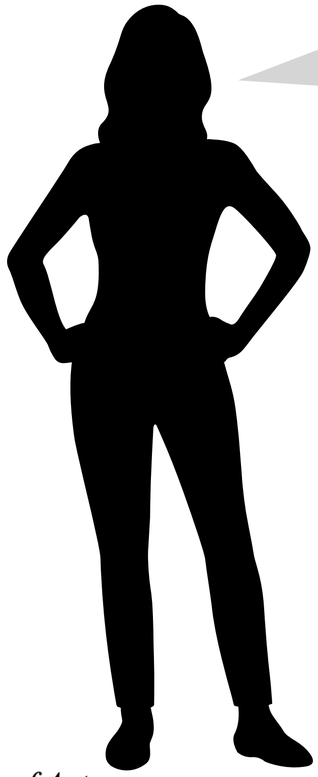
# What does 'Automation' mean to Humans?

From information to action →

Increasing automation ↓

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

*Figure 3*. SESAR Levels of Automation Taxonomy Scale. Reprinted from: *"Levels of Automation: an Introduction"* by Hecker, P. (2017), presented at the World ATM Congress 2017, p.11.

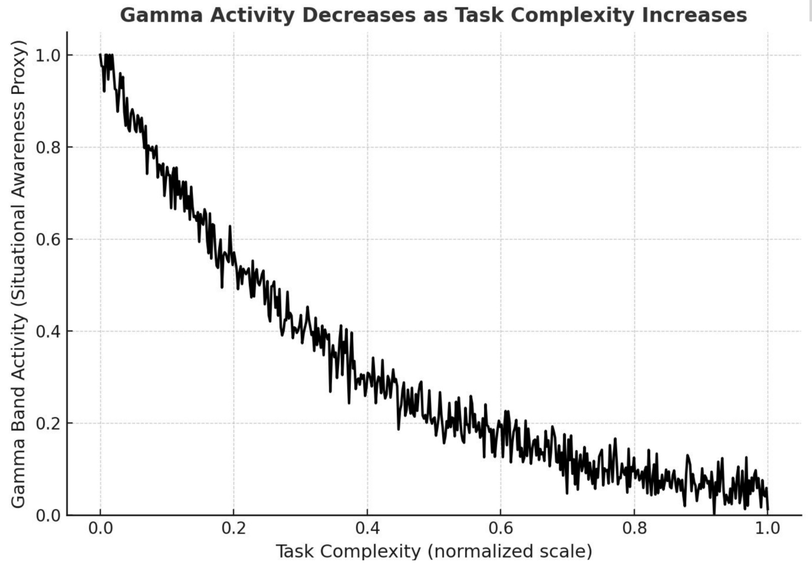


We a limited to "getting info in," "analysing that info," "making decisions with that info" and "doing something with it"

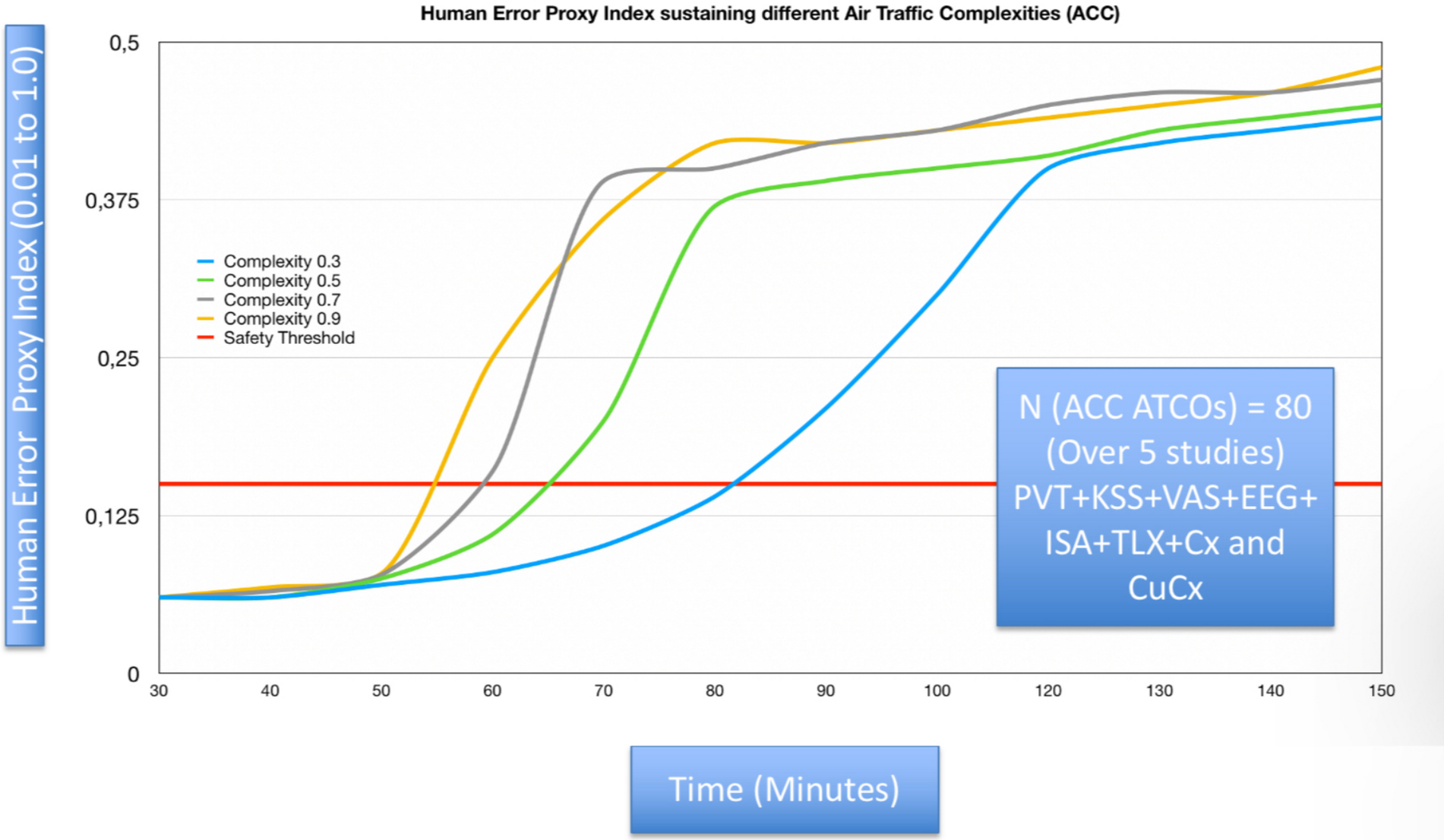
Increasing automation often decreases human performance…

Bainbridge (1983) - On the Ironies of Automation

Endsley (2023) - On the Ironies of AI



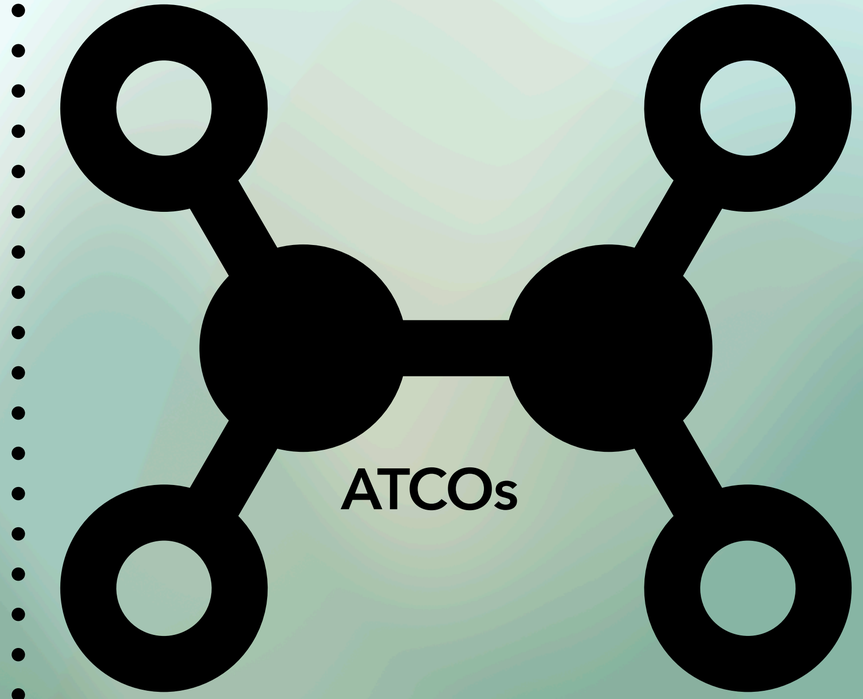
4th Run of Day



# There Are Many More People Than Just the ATCOs…

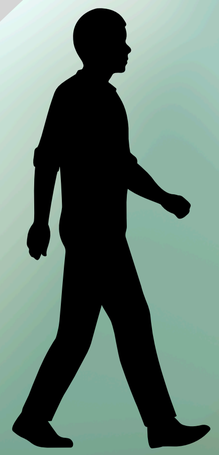
Pilots

Systems Control Engineers




AIS, FISO, Flow Management…

How can we increase Human Performance from these roles and therefore distribute HP across our Teams better – leading to increase in overall HP?



Supervisors

# The missed opportunity

## AI can help - but only if we reimagine the concept of operations and system around it

Ziakkas, D. & Vink, L.S. (2023) *The Handbook of Implementing AI in Aviation*. Purdue University Press

- AI isn't just Automation: **it is an *amplifier* of what we measure…**
- If we continue to optimise based on how we do things today, there is limited
further.
- The qu
*measur*


**AI is an amplifier of what we measure!!**

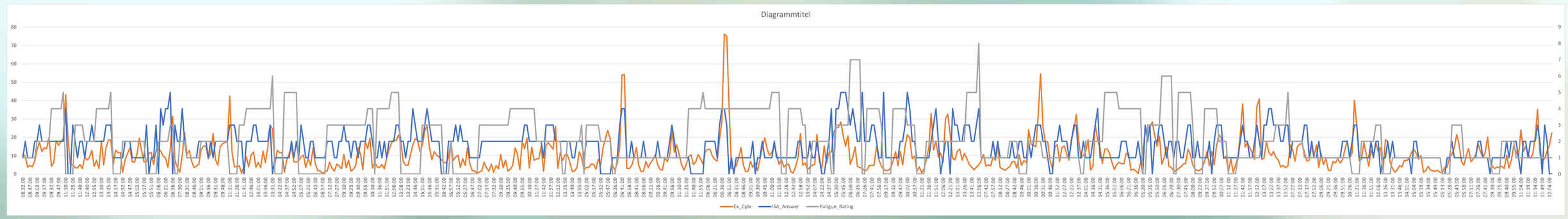
# Redefining ATM Performance

**From throughput to thinking - measuring what really matters!**

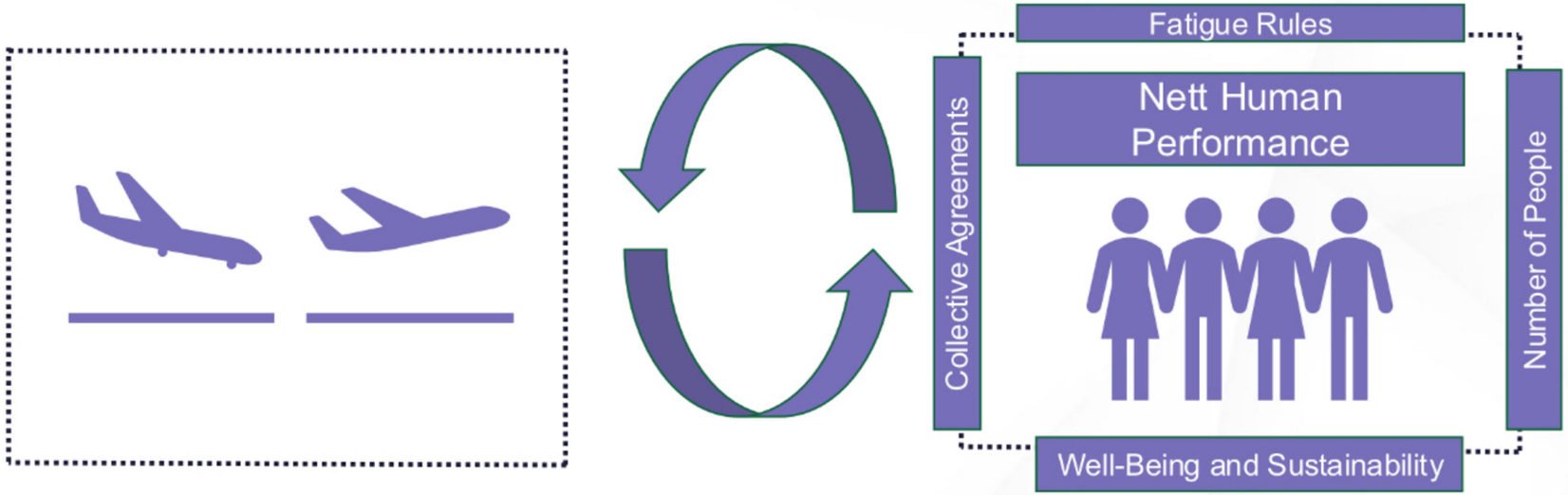
Old KPI: **“number of aircraft per hour”**

**12 hours of Human Performance based on system data and predictive algorithms…**

New KPI: **“cumulative complexity”**




**Workload, Fatigue, Complexity…**
**Up next: Effort, boredom and human error…**




ATM Demand = ATM Complexity Capacity

Predictive

"Cost"

Human Performance Index = "Cumulative Complexity"

(ATM Complexity = Weather + Trajectory (Vert/Hor) + Volume)

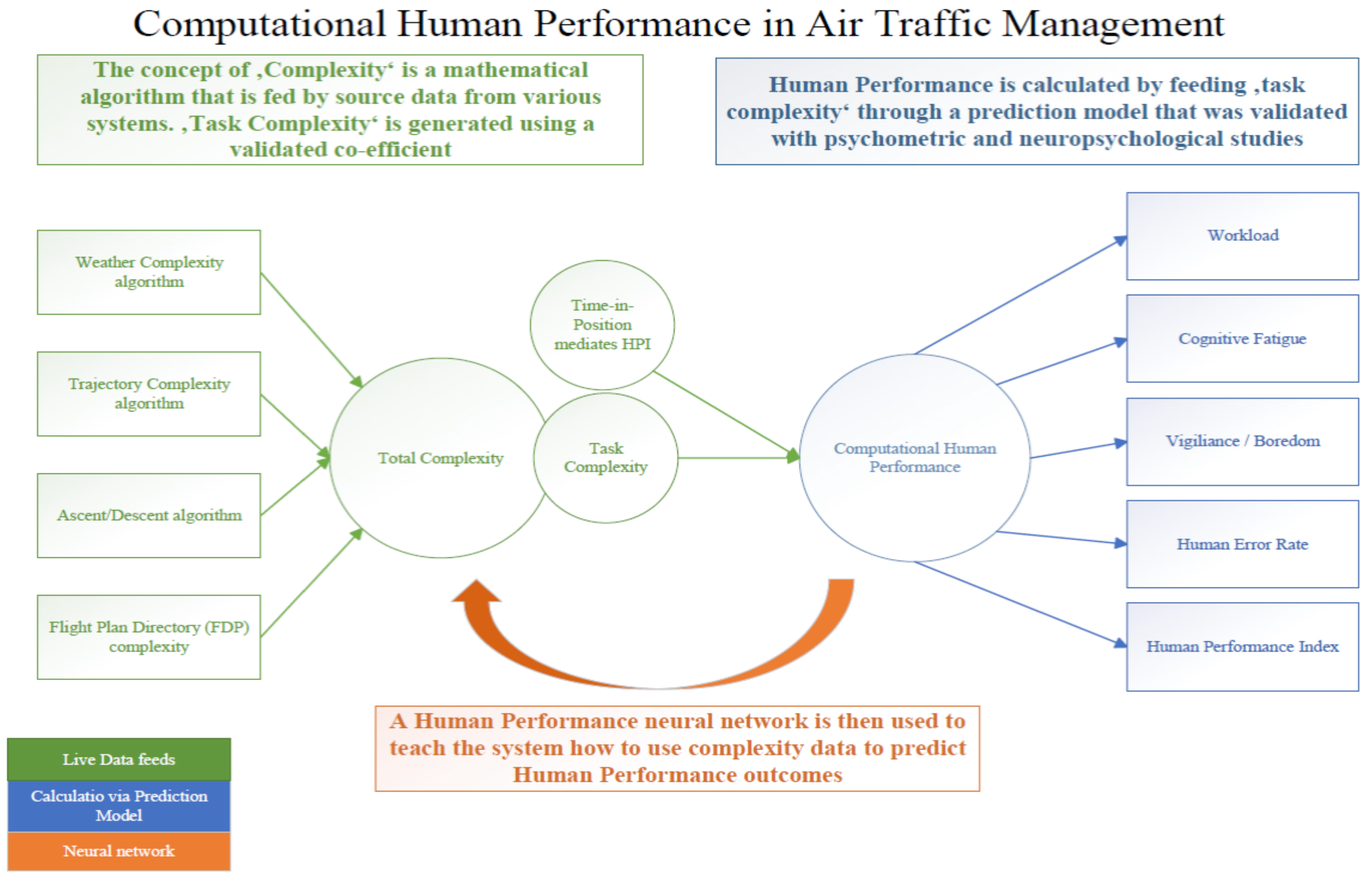
(Complexity moved over time by the number of available sectors)

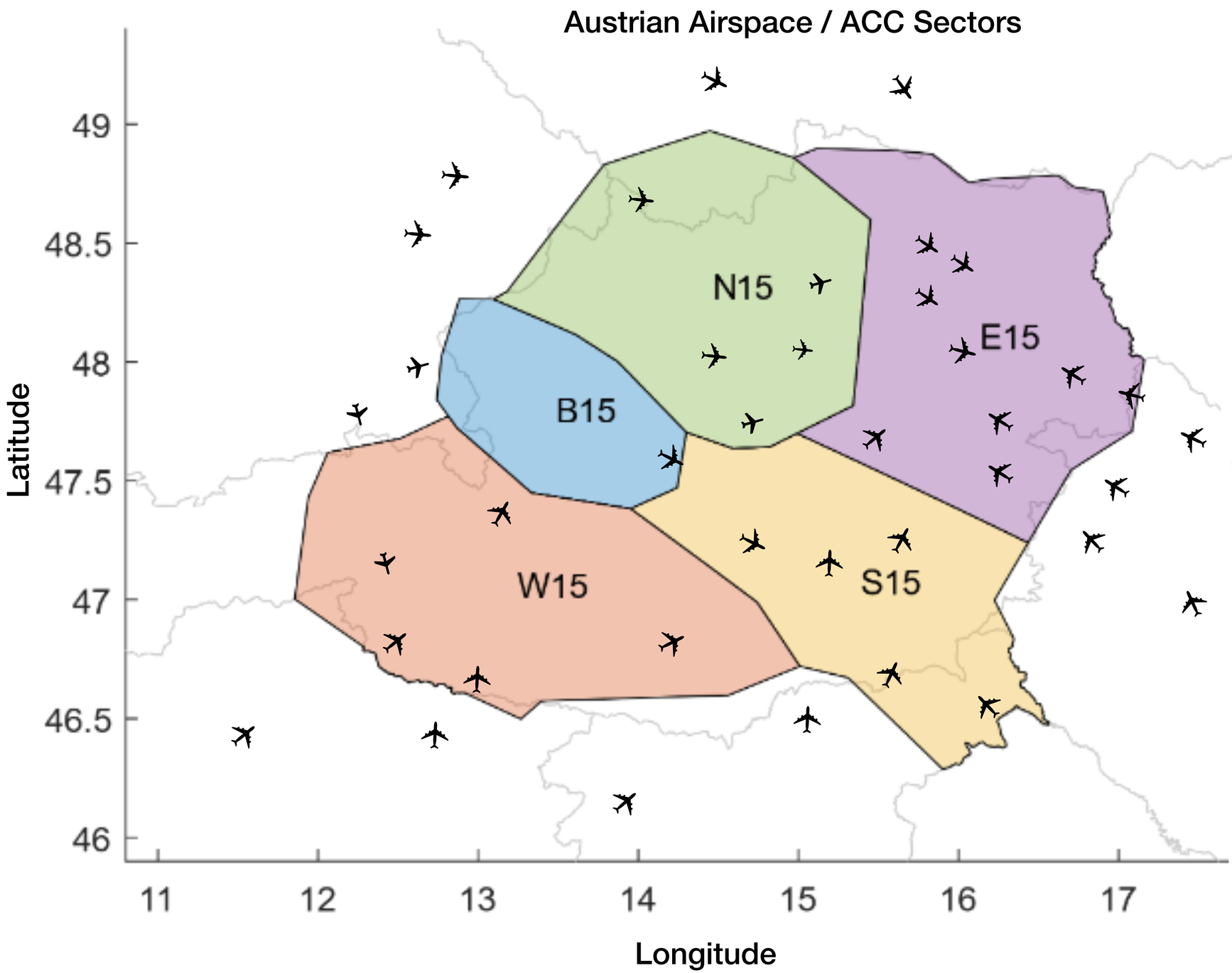
HPI = CCx (Cx + TIP controlled for Length of Break and normalised for length of shift)

# Introducing the STORMS

## The Socio-Technical Operational Resource Management System

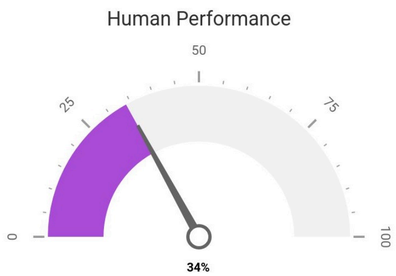
- A new tool designed to transition ATM into a new age of Complexity
- Powered by the SYNAPSES engine
- Can predict performance, fatigue, error and warn of overloads
- Dynamically open and close sectors based on demand
- Real-time demand shaping based on available human capacity

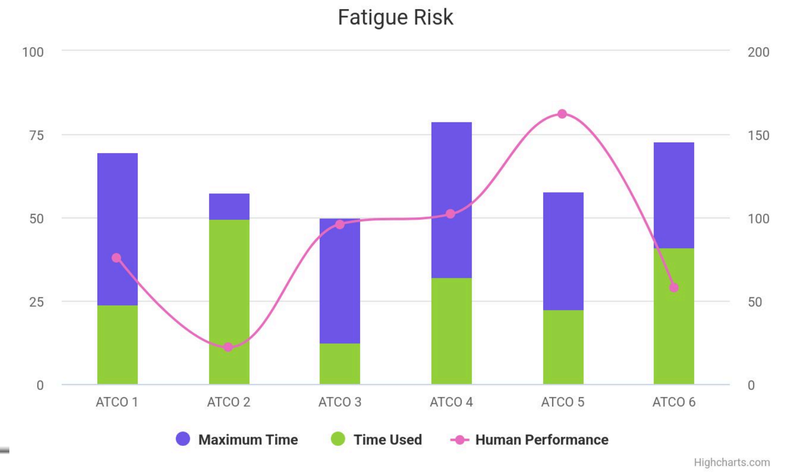





To show how complicated it can be:

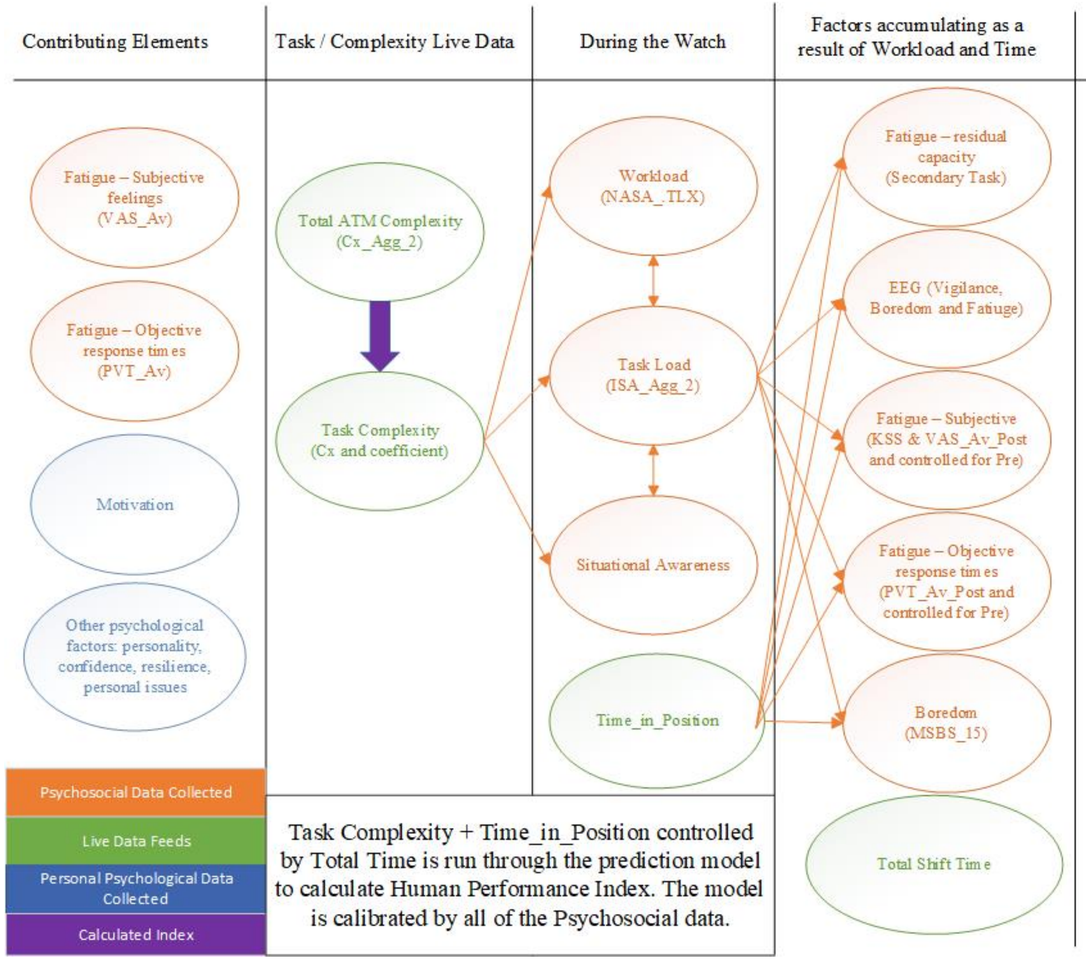
1. Air Traffic Complexity
2. Weather and Environmental
3. System Performance Variables
4. Human Performance
5. Compliance and Safety Outcomes
6. Performance outcomes
7. External Factors

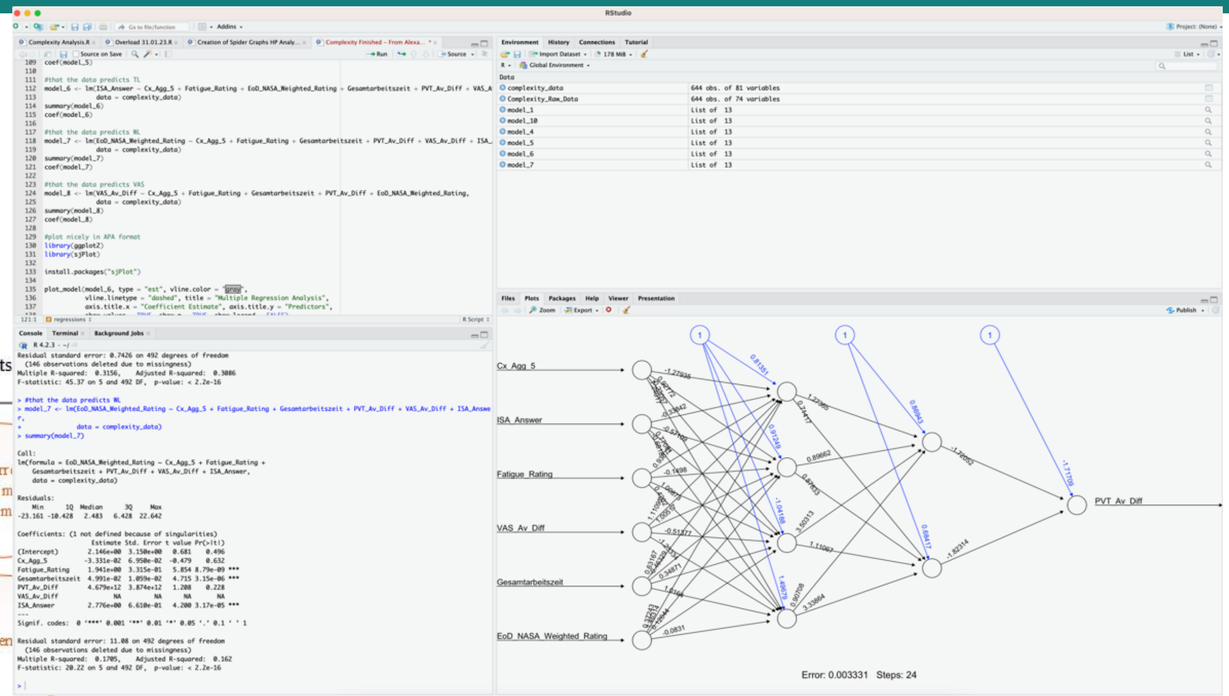



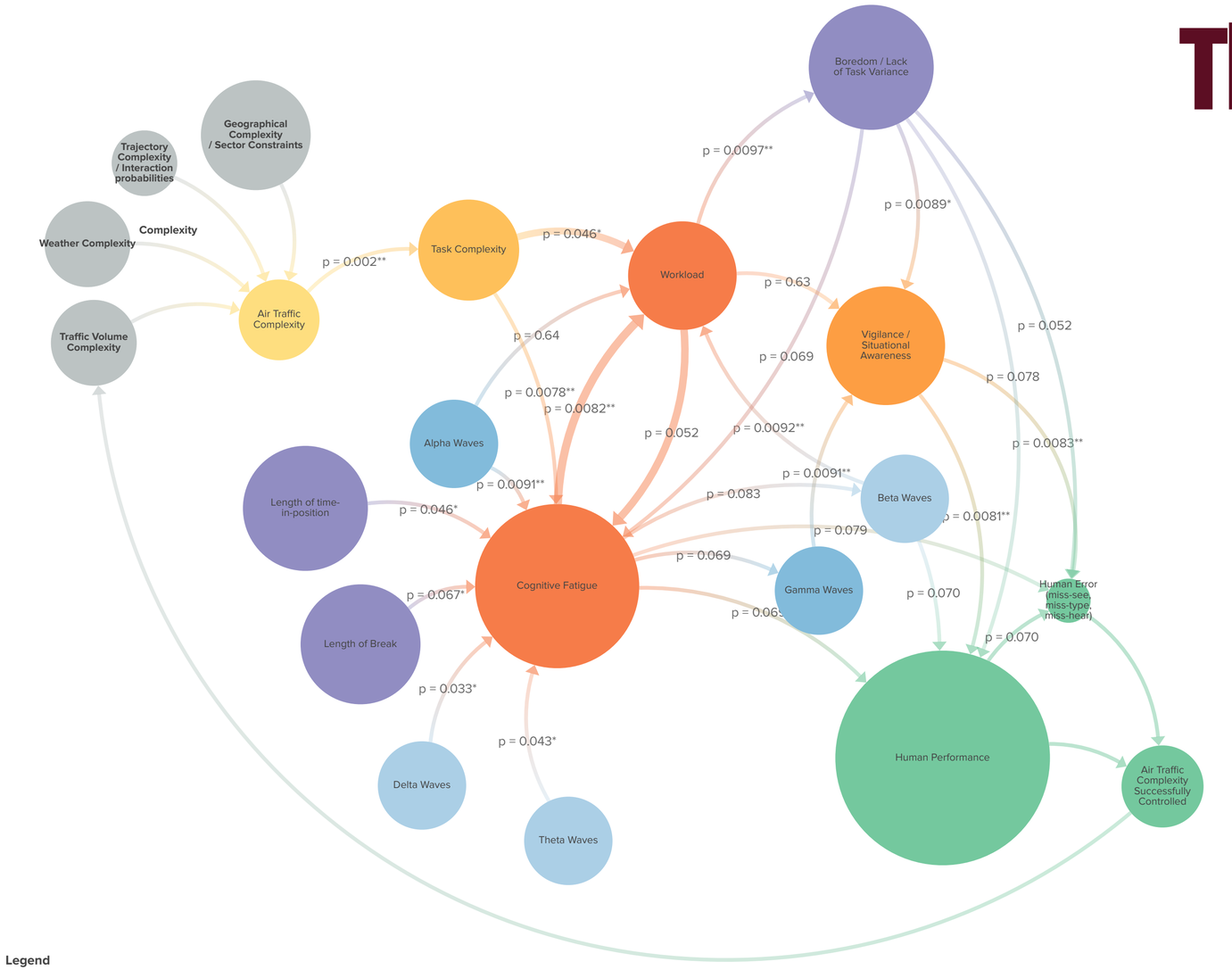
# The research behind it

## Five years, real operations, real operators and real humans




- 85 ATCOS over five main studies
- 12 hours of Shift time
- Batteries of psychometric tests
- Result: a calculator based on average distributed performance and ***not individual monitoring***




# The Synapses Model

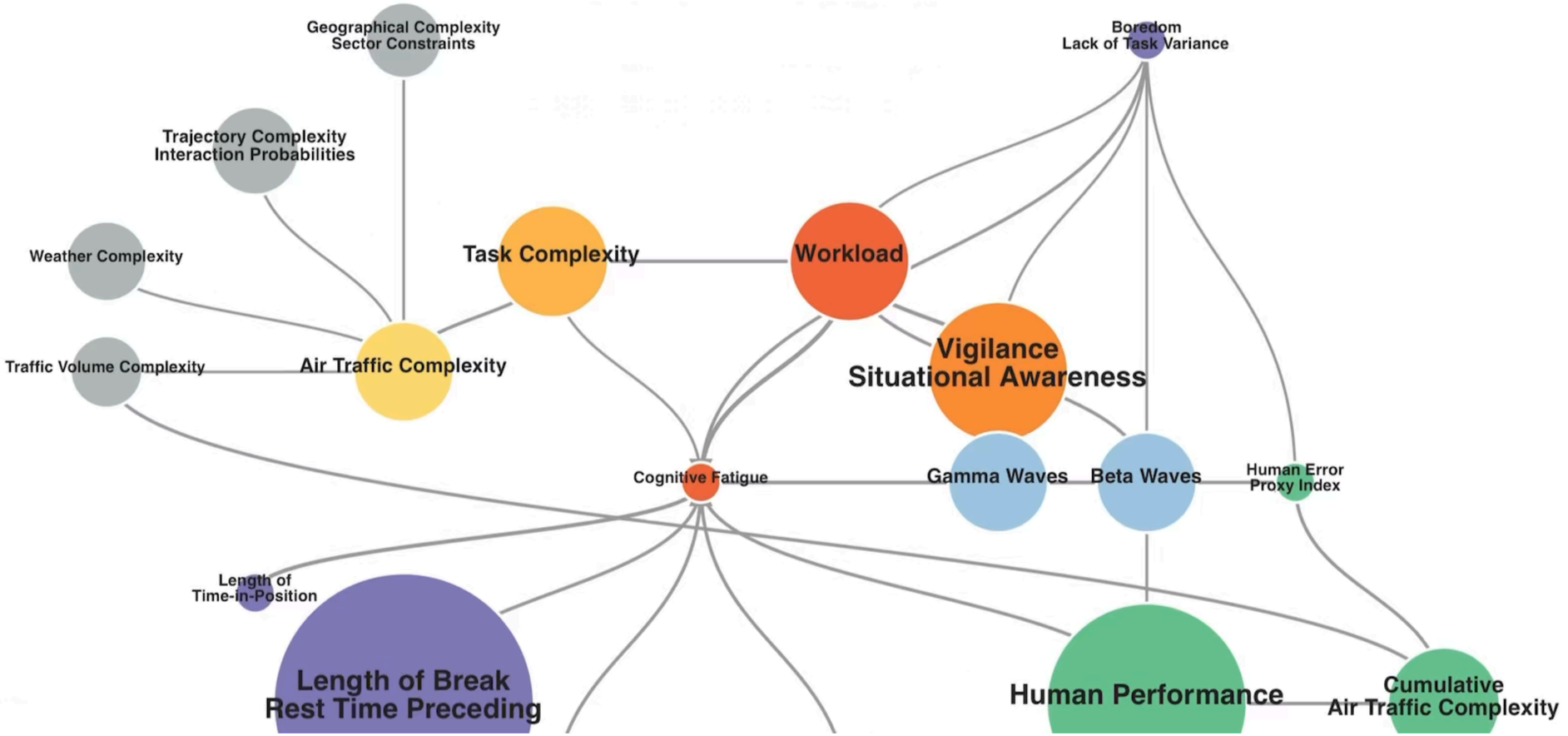
Our studies involving over 85 ATCOs (Roughly 45% of ACC ATCOs) over five studies found the following:

1. Air Traffic Complexity = Task Complexity
2. Task Complexity accurately predicts Workload
3. Workload + time-in-position accurately predicts Cognitive Fatigue and Risk of Human Error
4. Situational Awareness degrades regardless of compensation measures taken against fatigue or Workload
5. Time-in-position, Length of Breaks and Boredom as well as Task Complexity itself all moderate Workload and Fatigue… this is the ultimate finding!!
6. 18 different Psychometric measures including EEG were used to validate this model
7. We can accurately predict fatigue and human error probability based on Complexity
8. Cumulative Complexity = Human Performance Index

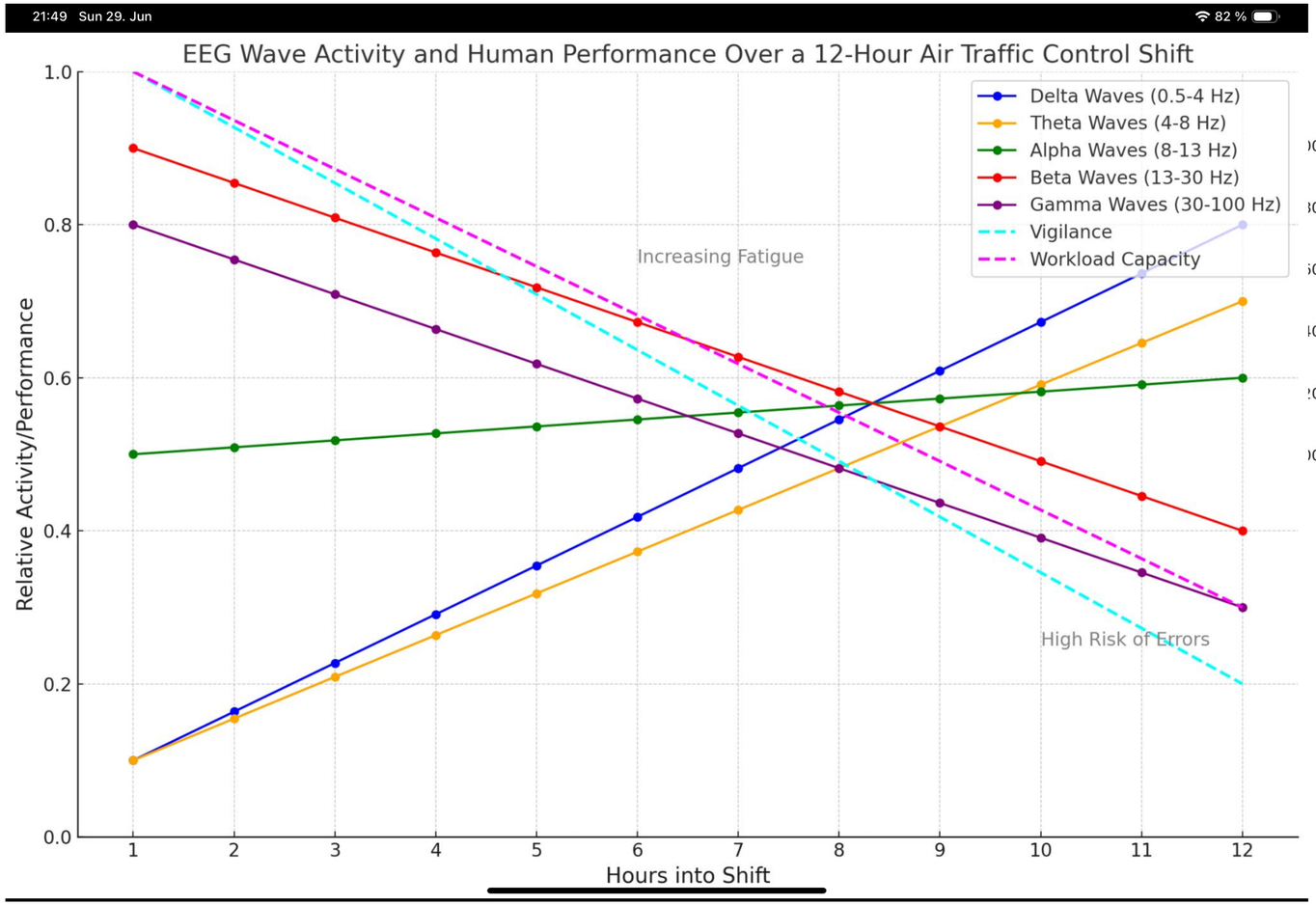
Local Remote Synapses-Vis/index.html Done

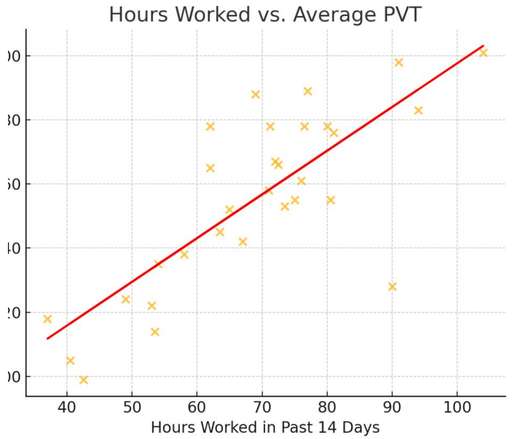
Synapses – Human Performance Model

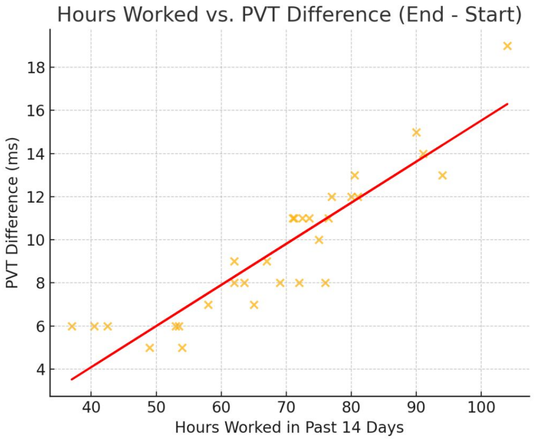
Synapses – Human Performance Model



# Why measuring is crucial at all? - Three studies



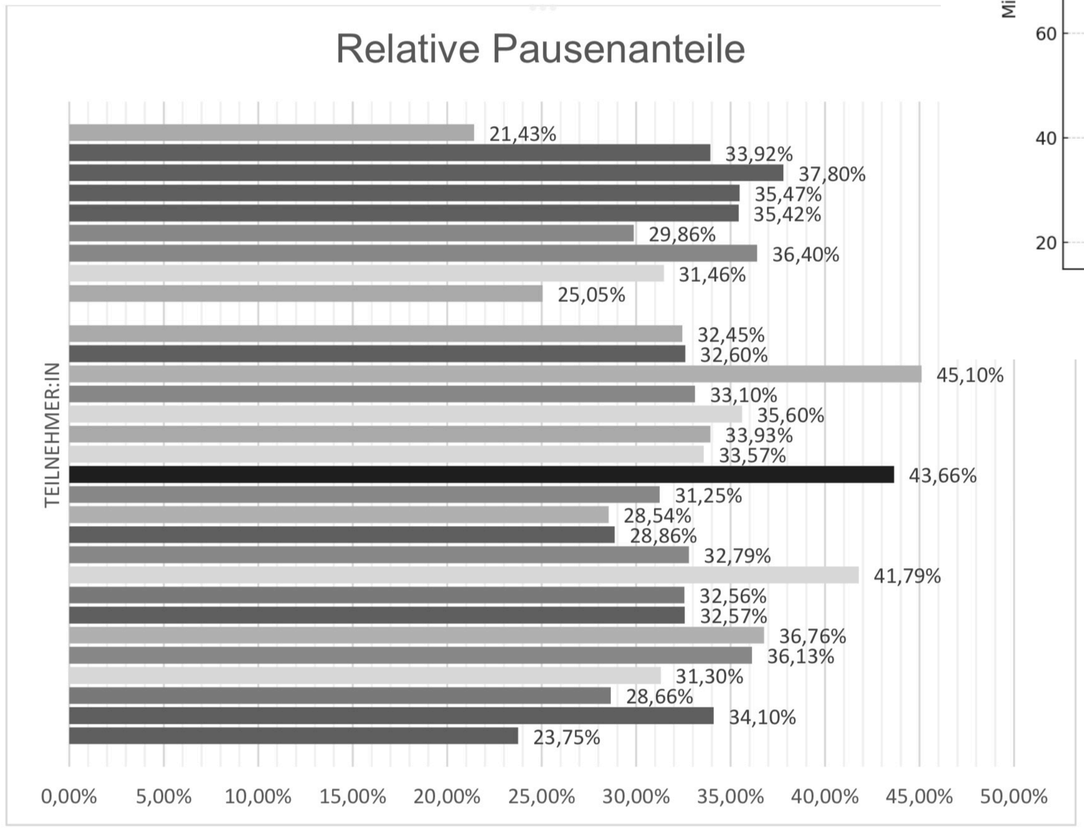



*Abbildung 8: Relative Pausenanteile*

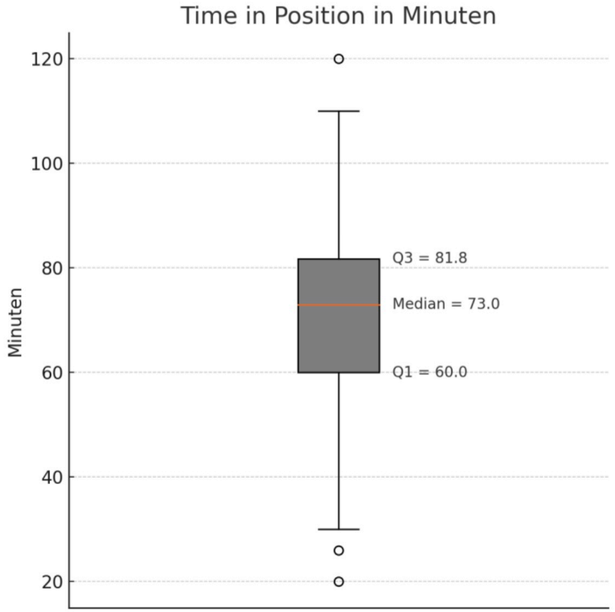
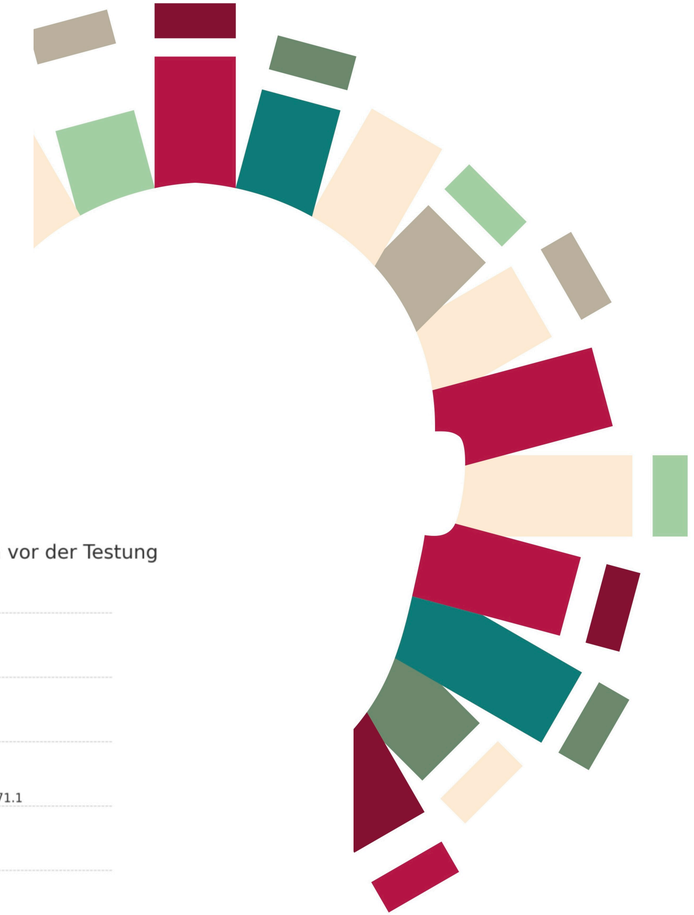



*Abbildung 9: Time in Position pro Run*


*Abbildung 11: Arbeitsstunden innerhalb von 14 Tagen vor Testung*



# Study 2

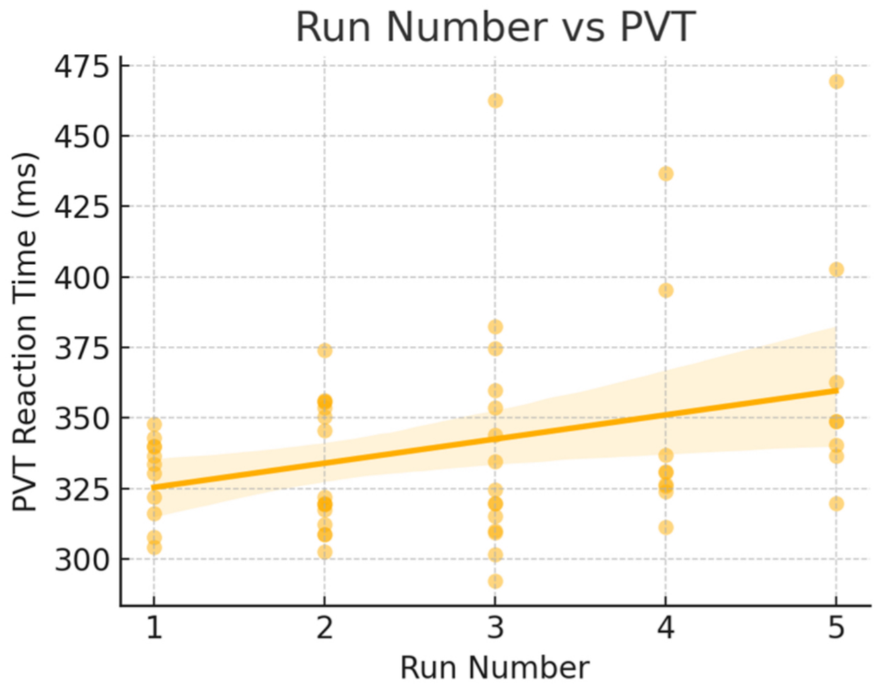



*Abbildung 12: Run Number vs PVT*

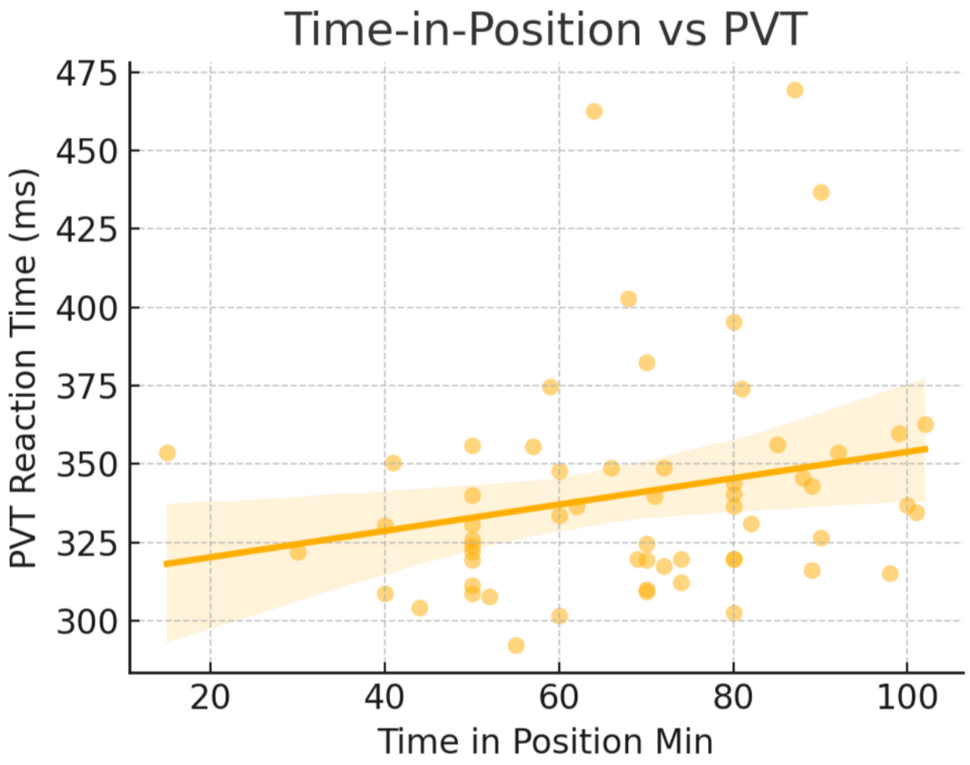


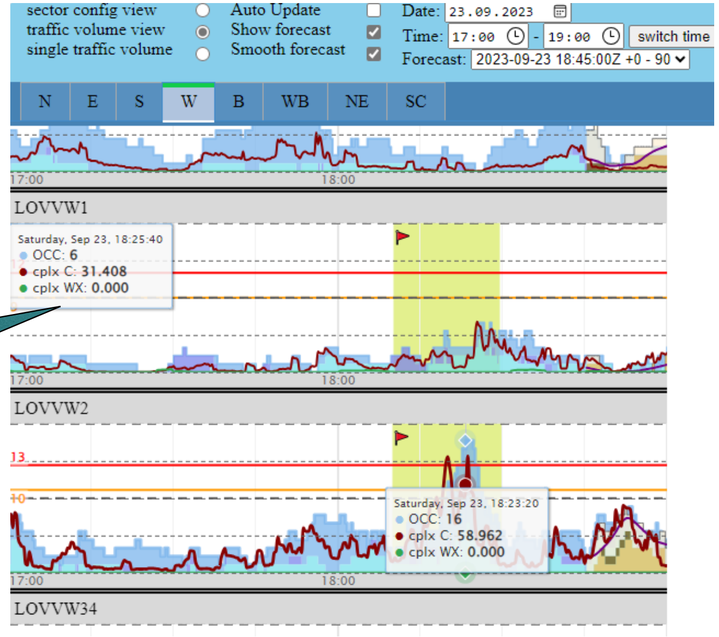

*Abbildung 13: Time-in-Position vs PVT*

# From ‘Complexity’ to ‘Cumulative Complexity’

**Your sector might be safe – but the shift is not…**

1. At the individual level, tasks a manageable… ***however cumulative exposure is not***
2. STORMS calculates the rolling burden of cognitive demand and splits it more evenly
3. Enables recovery and redistribution before loss of peformance
4. Dynamic sectorisation and shared situational awarness

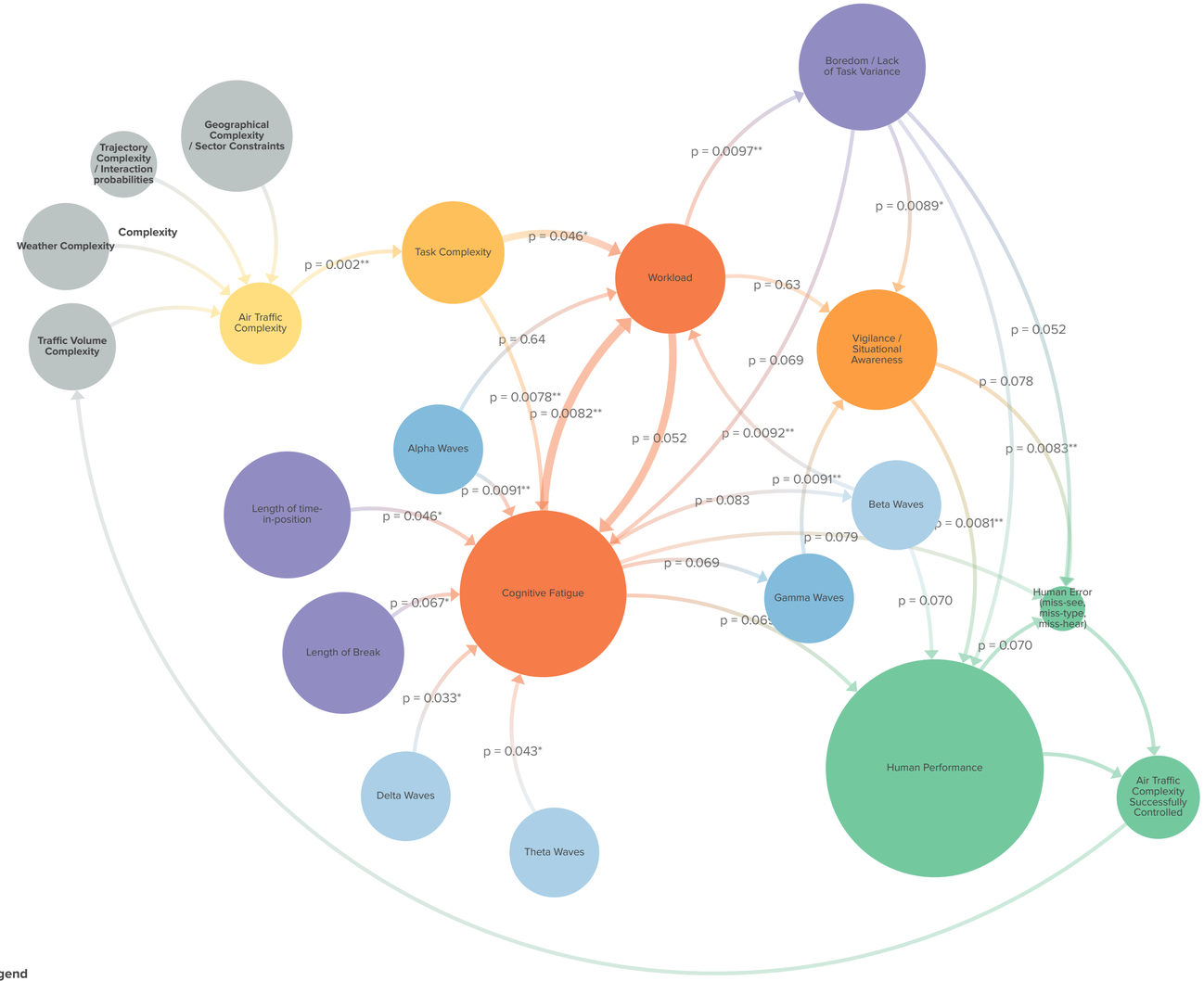
Imagine if every cockpit knew this! Autopilots could assist pilots better….

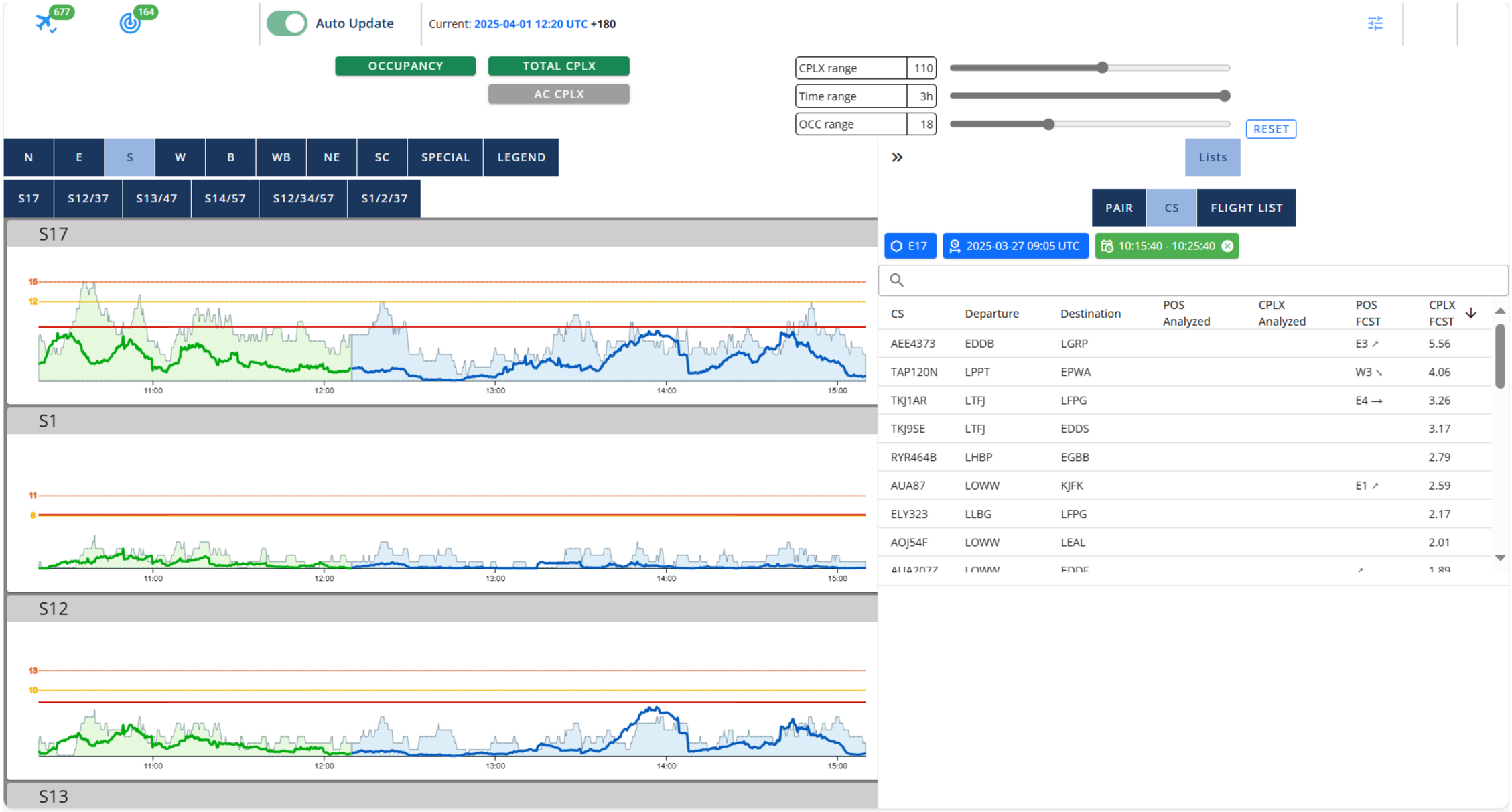


# Real-time Ethical Automation

## Machine learning that supports – not surveils

- SYNAPSES doesn't measure individuals
- Real-time alerts
- Humans remain in loop, main ATCO role doesn't change
- We are hunting for more performance from other roles: Supervisors, network management etc
- Tooling and automation as co-pilots and assistants

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CPLX range 110
Time range 3h
OCC range 18
RESET
N E S W B WB NE SC SPECIAL LEGEND
S17 S12/37 S13/47 S14/57 S12/34/57 S1/2/37
Lists
PAIR CS FLIGHT LIST
E17
2025-03-27 09:05 UTC
10:15:40 - 10:25:40
S17
15
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S1
11
8
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S13
CS Departure Destination POS Analyzed CPLX Analyzed POS FCST CPLX FCST
AEE4373 EDDB LGRP E3 ↗ 5.56
TAP120N LPPT EPWA W3 ↘ 4.06
TKJ1AR LTFJ LFPG E4 → 3.26
TKJ9SE LTFJ EDDS 3.17
RYR464B LHBP EGBB 2.79
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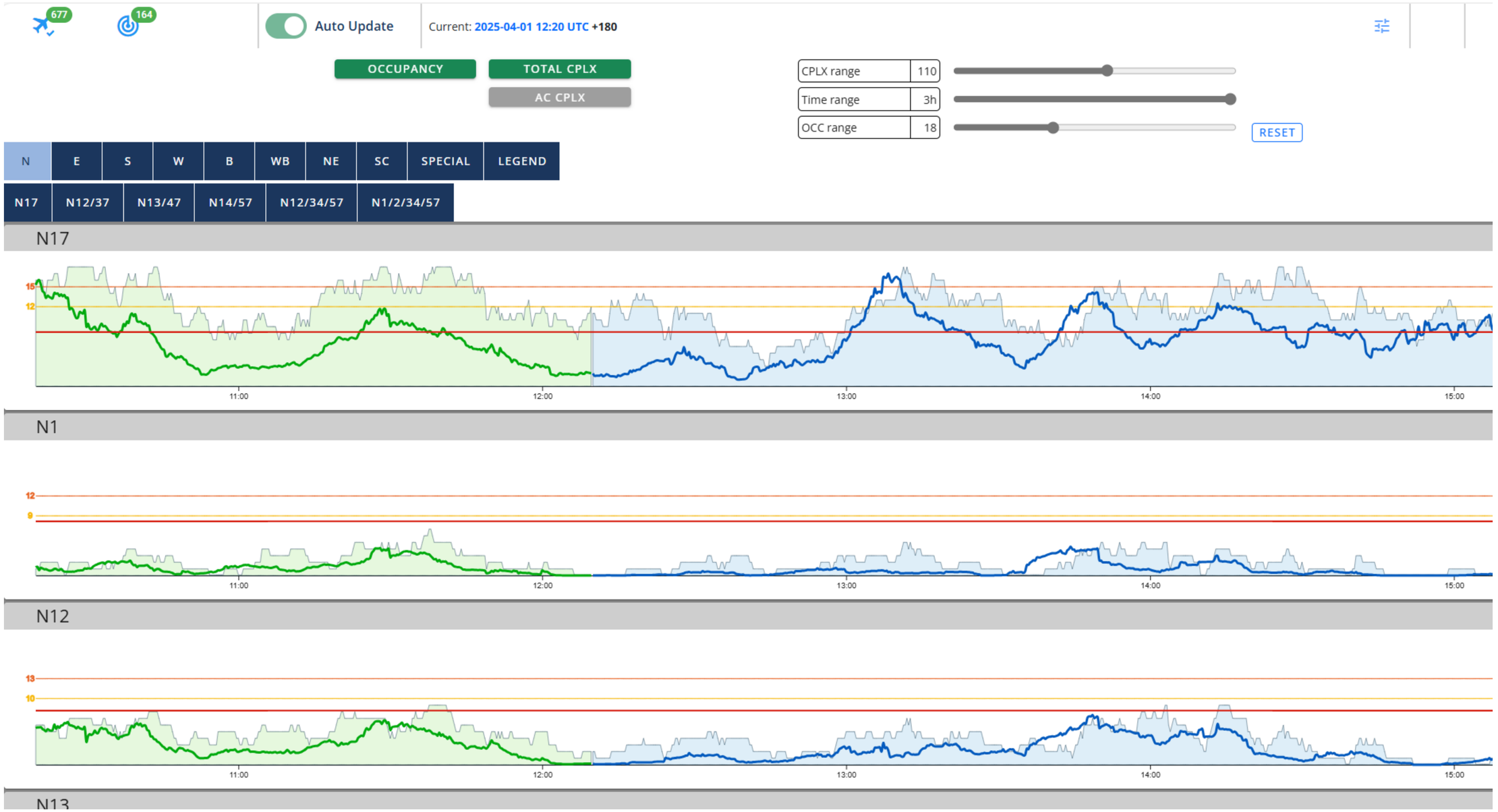
ELY323 LLBG LFPG 2.17
AOJ54F LOWW LEAL 2.01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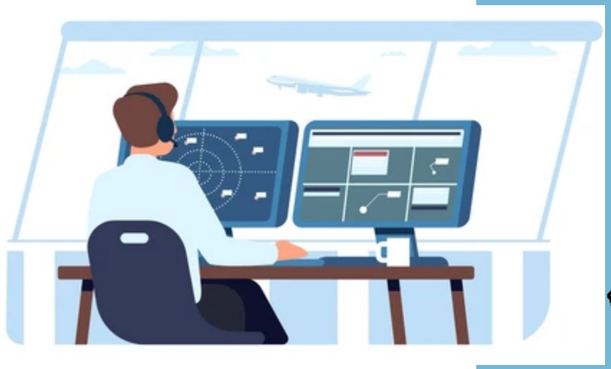
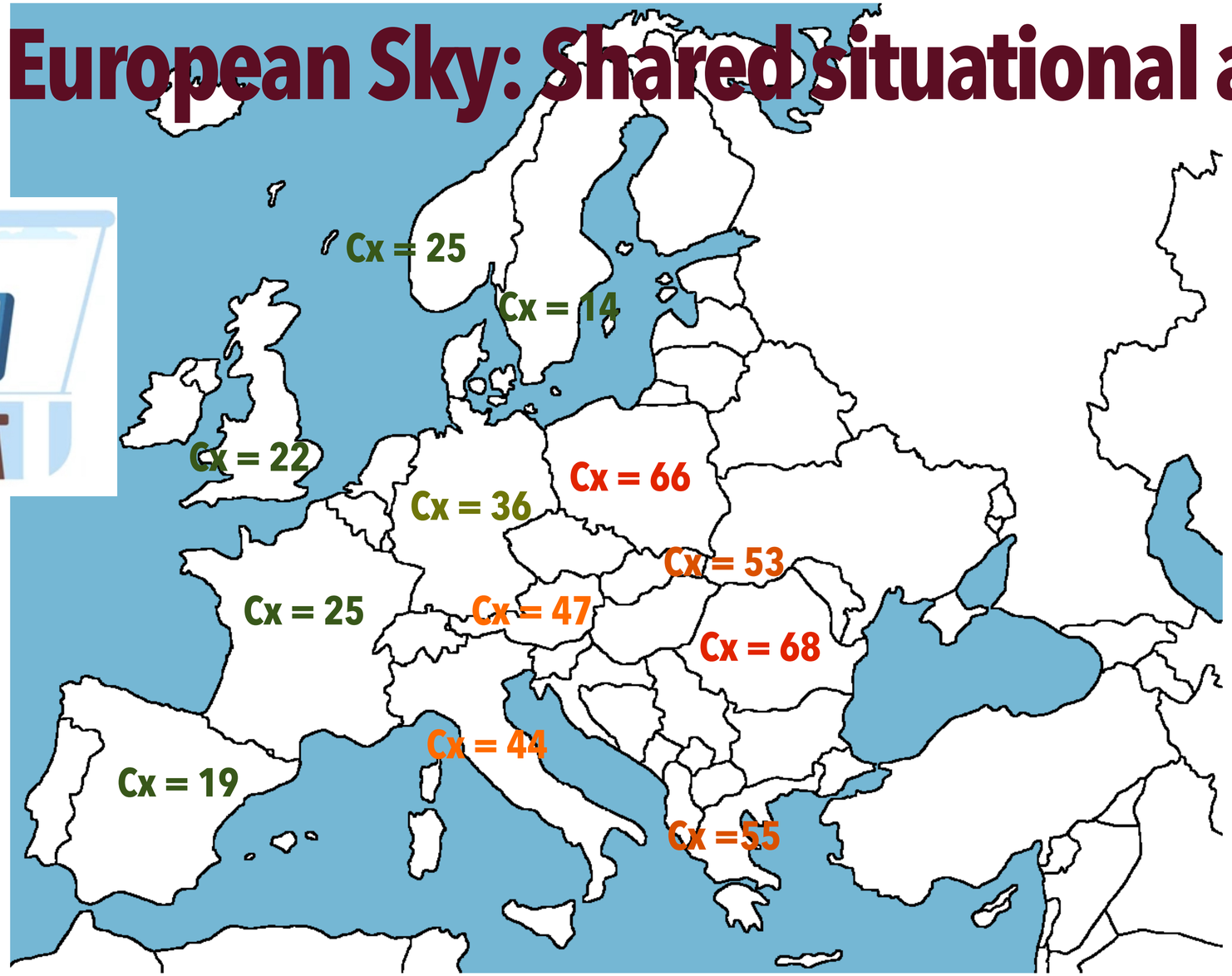
# Benefits of using AI and Automation with a “Complexity” driver

1. Dynamic sector control - open and close sectors based on predicted complexity and available Human Resources (accounting for Fatigue rules)
2. Post-operations analytics based on true cost of human performance
3. Occurrence analysis based on abnormal detection (increases Just Culture and bypasses need for Human Error analysis)
4. Machine learning of complexity factors leading to better route optimisation
5. Opportunity to increase new airspace users (in un-controlled airspace) allowing controlled airspace to be fixed
6. Increase in System Monitoring potential - maintenance scheduling and stress testing
7. Increased resilience and crisis planning / management
8. True-country to country shared situational awareness
9. Feeding ‘Airspace Complexity” to Pilots could increase situational awareness
10. AI decision making opportunity massively increased including at Corporate and business levels
11. True Fatigue Risk Analysis based on human performance “achieved” vs use of people and human error analysis

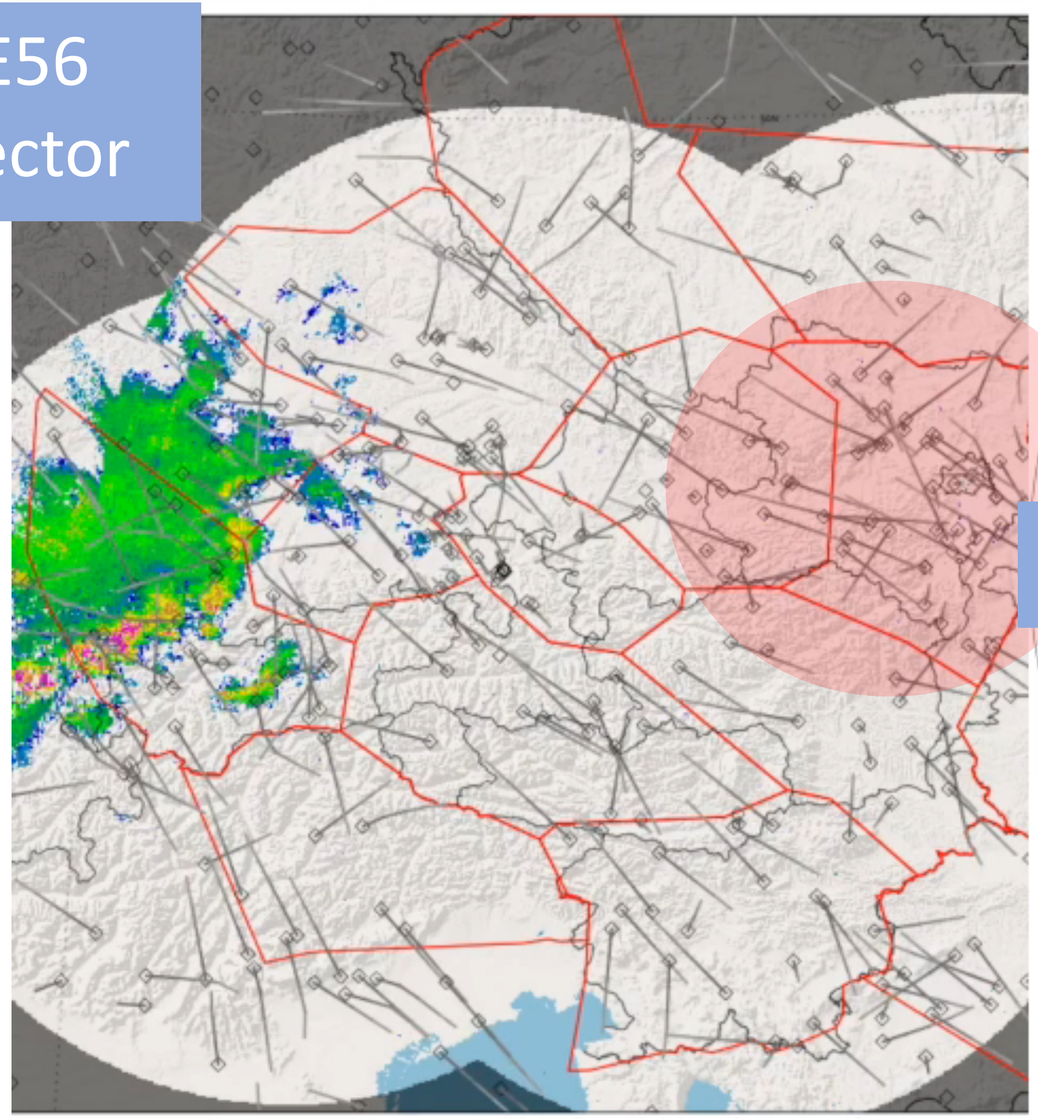
# A Single European Sky: Shared situational awareness

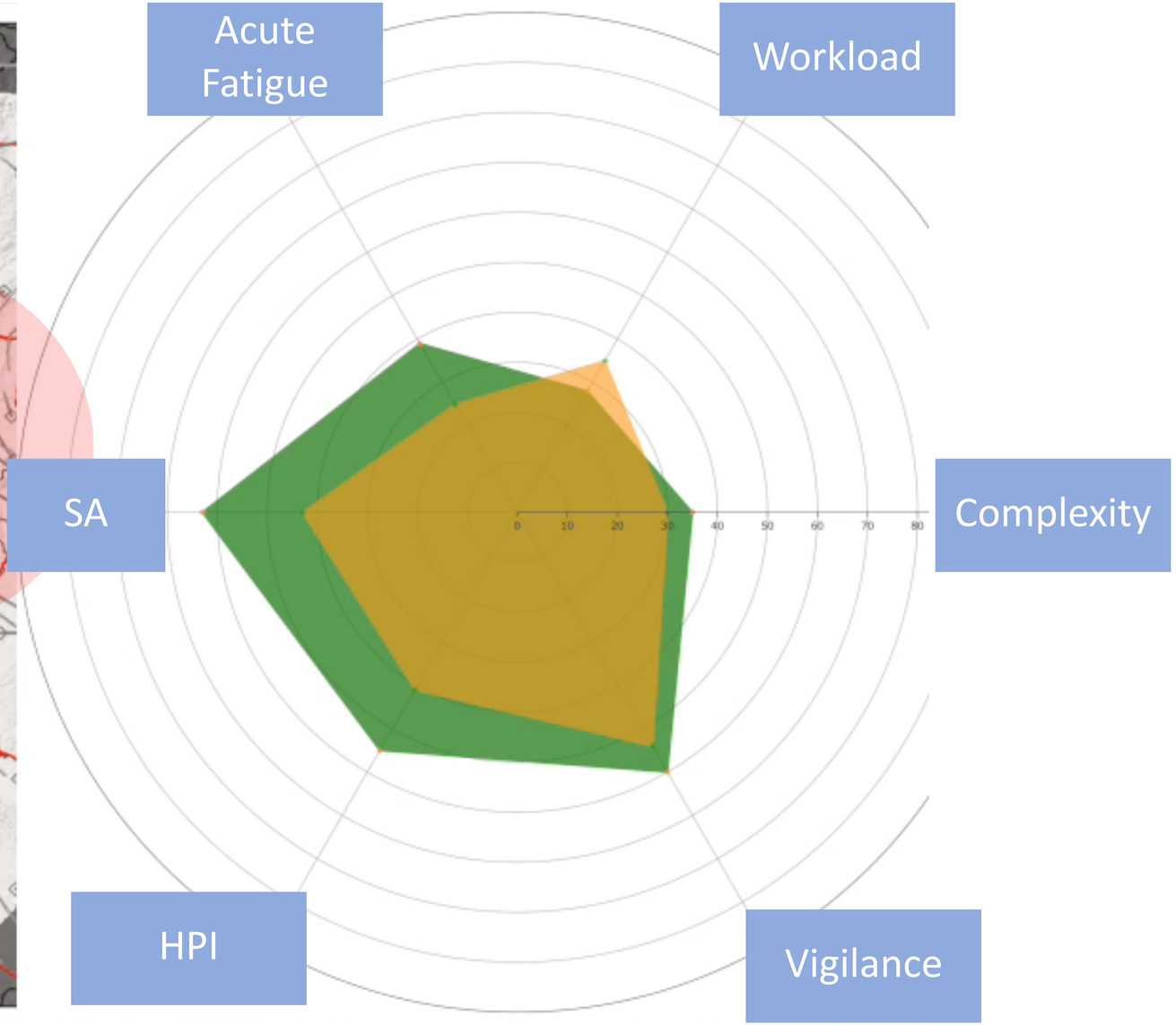




# Tracking Cognitive Overloads

E56 Sector

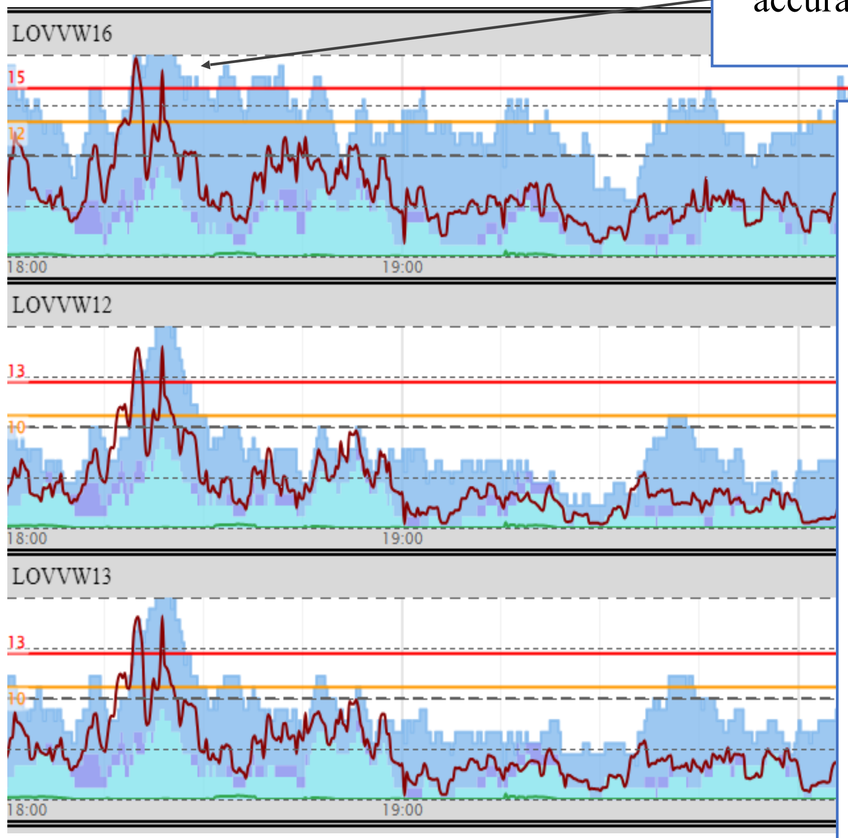




# 2023_09_23 W2 Sector @ 1820 UTC

Predicting potential human error occurrences before they happening

Overload predicted accurately at 1820 UTC




ACC supervisors have access to this view.

The can see peaks and troughs in Total Complexity as well as to look into what is driving it.

It predicts using machine learning with relative accuracy.

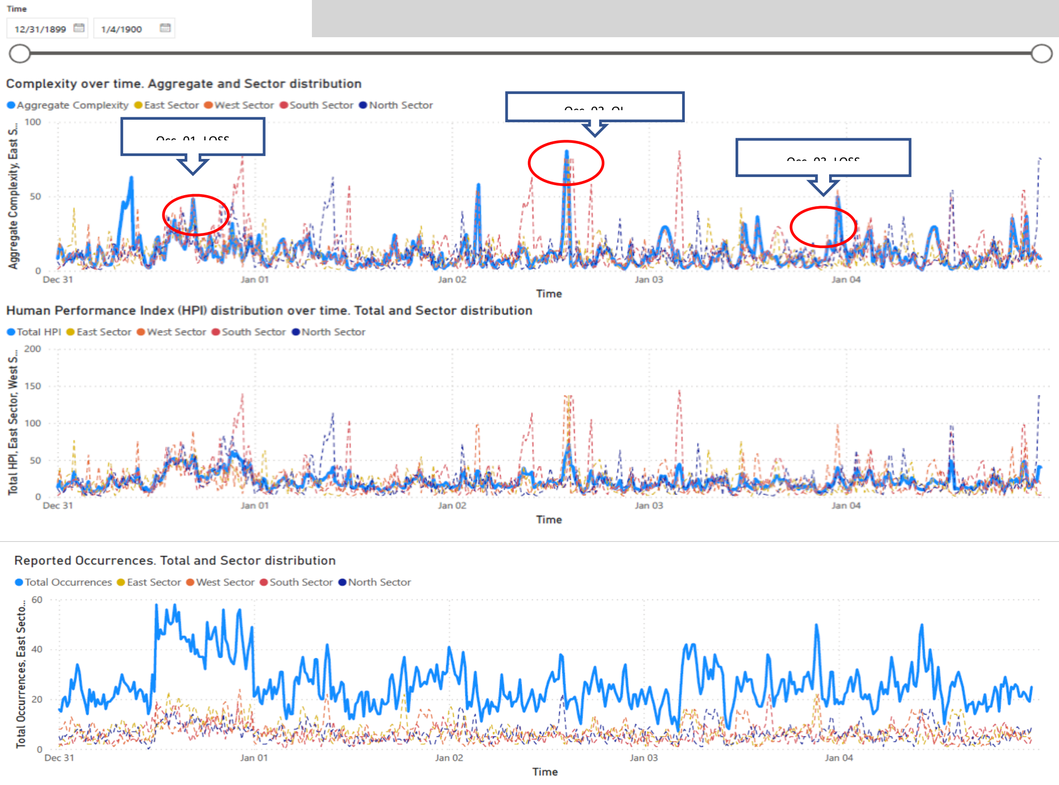
Using the Human Performance Spider Diagrams, we can recreate analysis of occurences and see them before they happen.

# AI is the opportunity, Complexity is the key

To implement AI ethically, we must rethink how we define performance

- STORMS reframes demand, enables safety, and sustains the human
- Let's stop managing airspace throughput–and start managing complexity

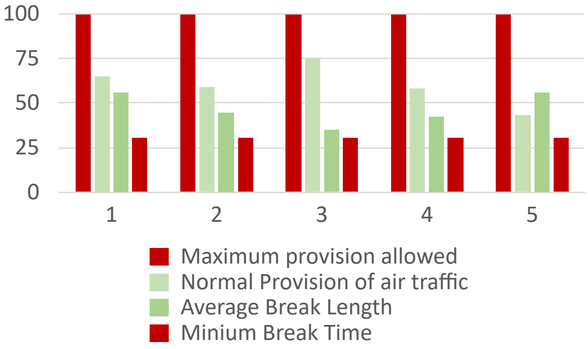
*We can tell better stories with Complexity*




Fatigue Risk

| Day | Allocated Overtime | Broken Soft Rules | Broken Hard Rules | SkyRoster Score |
|---|---|---|---|---|
| 1 | 5 | 25 | 2 | -1800000 |
| 2 | 3 | 30 | 1 | -1775000 |
| 3 | 6 | 40 | 10 | -4750000 |
| 4 | 1 | 27 | 3 | -2175000 |
| 5 | 2 | 10 | 0 | -500000 |

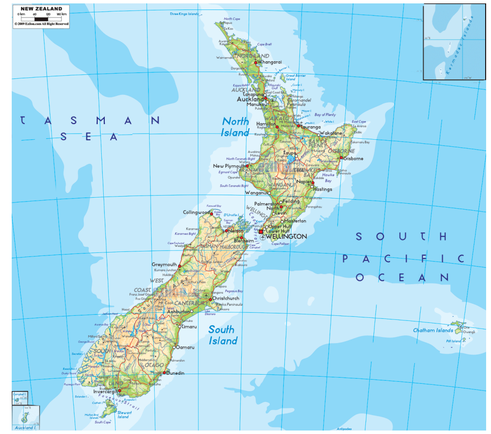
Maximum Provison time vs minimum Breaks



# Who am I?

- Born in New Zealand to Dutch Parents. Grew up in Singapore until aged 17. Moved back to NZ for almost 10 years then 2 in Maastricht, 4 in UK and now 5 in Vienna.
- BSc (ClinPsyc), MSc (OccPsych), MA Music and History
- PhD in Intellectual History and Psychology
- 2006-2015: Navigator and Command positions RNZN (pirate hunting, Antartica, search and rescue, military medicine / Master Mariner Certificate
- 2015-2016: Psychology lecturer at Maastricht University
- 2016-2019: Human Performance Specialist / HF R&D lead NATS
- 2019- Head of Human Performance Austro Control
- 2022 – Chair CANSO Human Performance Management Workgroup
- 2022 – Founder ‚JustMinds' Research and Practice/Consultancy
- 2024 - Vice-Chair European Expert Group on the Human Dimension in Transportation

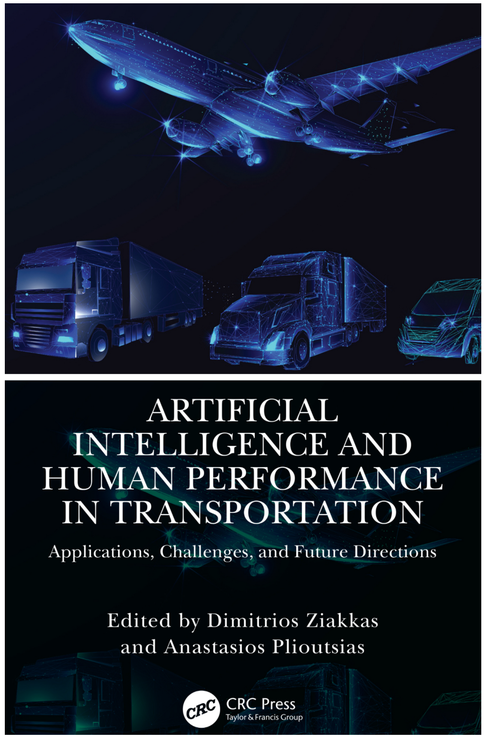
- Chartered Clinical and IO Psychologist (Austria) / Chartered Aviation Psychologist (EU)
- Volunteer clinical work with young LGBTQ people
- Adjunct professor of Cognitive Neuroscience and Psychology (Graz, Maastricht, Vienna)
- Author European Fatigue Risk Management Guidelines
- Author several books on implementing Artificial Intelligence in Aviation
- 2024: Cognitive Neuropsychology PhD: new research into Neural Networks of Psychological Performance and Human Error




# Resources and Further Reading

## Selected Readings


1. Vink, L. S. (2022). A new methodology for assessing human contributions to occurrences (MAHCO) in Air Traffic Management utilising a Bayesian hierarchical predictive coding approach to the brain, and the benefits for just culture. *Transportation research procedia*, *66*, 201-213.
2. Rudin-Brown, C. M., & Filtness, A. J. (Eds.). (2023). The handbook of fatigue management in transportation: waking up to the challenge. CRC Press.
3. Ziakkas, D., & Vink, L-S., (Eds). (2023). *Implementation Guide For Artificial Intelligence in Aviation: A Human-Centric Guide for Practitioners and Organisations.* Purdue University Press.
4. Ziakkas, D., & Piloutsias, A. (2024). *Artificial Intelligence and Human Performance in Transportation*. CRC Press.
5. Vink, L-S., & Walzl, B., (2025). Redefining Human Performance in complex socio-technical systems: Human Performance as Key Performance Indicator. *Transportation research procedia, 88, submitted for publication.*
6. *Vink, L. S. (2024a). The development and deployment of future integrated neuropsychological support for operations: The case for and definitionof real-time computational human performance. [Manuscript submitted for publication]. In R. Bor, C. Eriksen, R. J. Georgemiller, & A. L. Gray (Eds.), Handbook of aviation neuropsychology: A practical guide for the clinician. hogrefe.*
7. *Vink, L. S. (2024b). A history of the techniques, methodologies, and practices of neuropsychology for operational support in airline operations and air traffic management. [Manuscript submitted for publication]. In R. Bor, C. Eriksen, R. J. Georgemiller, & A. L. Gray (Eds.), Handbook of aviation neuropsychology: A practical guide for the clinician. hogrefe.*

# Thank you + Contact

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Cognitive Neuroscientist

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