Human Performance in Aviation and the balance of Ethics, Workforce planning and Just Culture

European Rail Safety Days

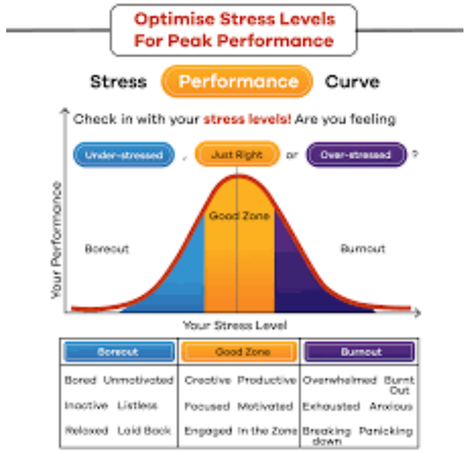
Dr. Lea Sophie Trampistsch-Vink, PhD

Head of Human Performance, Austro Control
Chairwoman, CANSO HPM Workgroup
Director, Just Minds AT
Co-Chair Commission Expert Group Human Dimension

Whenever humans and systems interact…

Human Performance

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



Human Error

- Slips
- Lapses
- Mistakes
- Fatigue

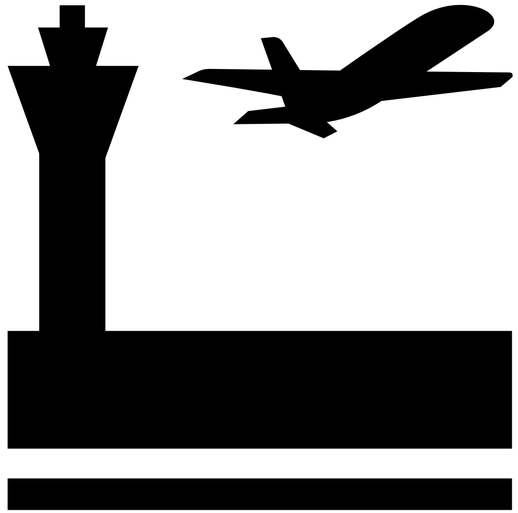
„Our goal as practitioners and managers must always be to maximise Human Performance and reduce human error" to a minimum

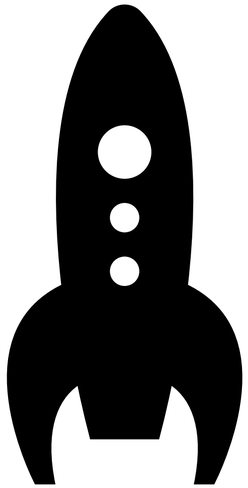
Our story today…

Come with me on a long journey towards building trust through ethical data modelling and predictive Human Performance metrics..

1. ATM is under pressure to increase throughput with less people
2. But we have ethical issues with increasing automation, liability issues with responsibility and we cannot monitor individual performance
3. The opportunity to increase in the short term is to automate around regulated positions
4. But the data is not being captured correctly at the moment
5. Therefore we have a new solution developed to consider HP as a socio-technical demand driven and dynamically controlled system
6. But this can also put pressure on people to perform more - or be sustained for longer
7. Our Just Culture policy is not just about having an open and honest system for learning, it is also a mechanisms to protect the organisation from a lack of due diligence and design of HP - to put our people in the best position possible
8. But the new tooling helps us to convince people that our Just Culture policy is working to protect them
9. Therefore redefining the demand metric, modelling the predicted and dynamic control of people, and then learning what is ab-normal conditions a benefit to improving Just Culture…

ATM IN NEED OF MORE HUMAN PERFORMANCE…



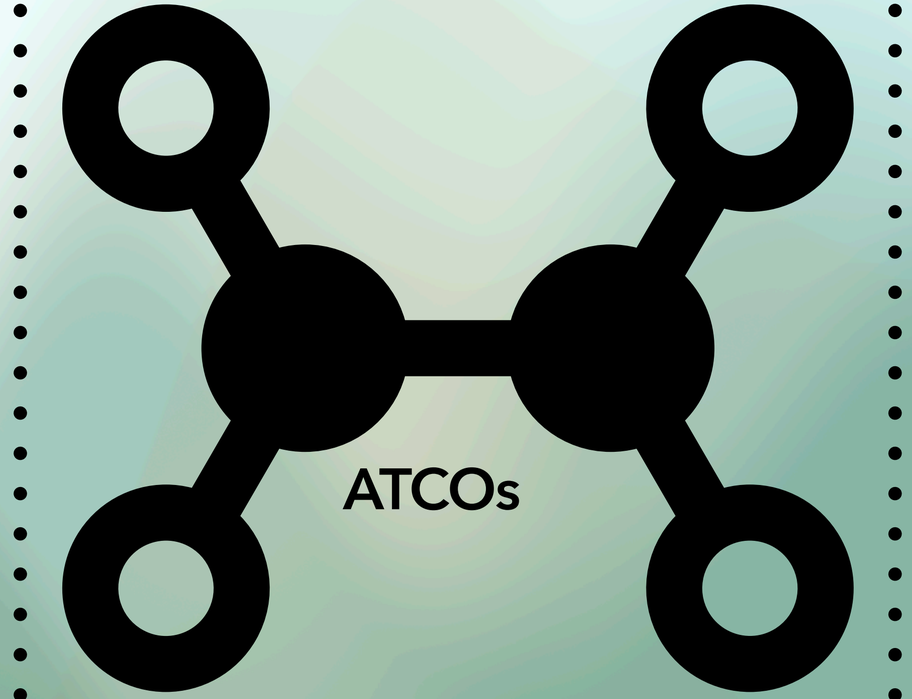


- Soaring Demand, retiring workforce…
- New Airspace Users, increasing task unpredictability
- Traditional performance metrics no longer fit for purpose
- Regulations designed to limit loss of service and performance

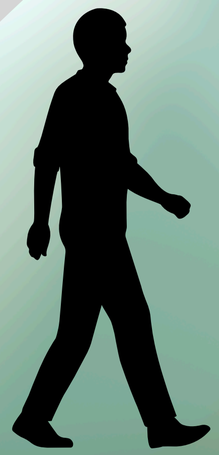
There Are Many More People Than Just the ATCOs…

Pilots

Systems Control Engineers



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



Supervisors

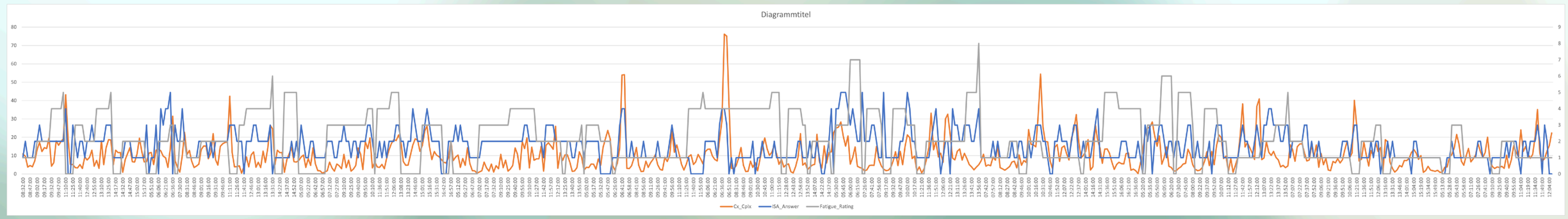
Redefining ATM Performance

From throughput to thinking - measuring what really matters!

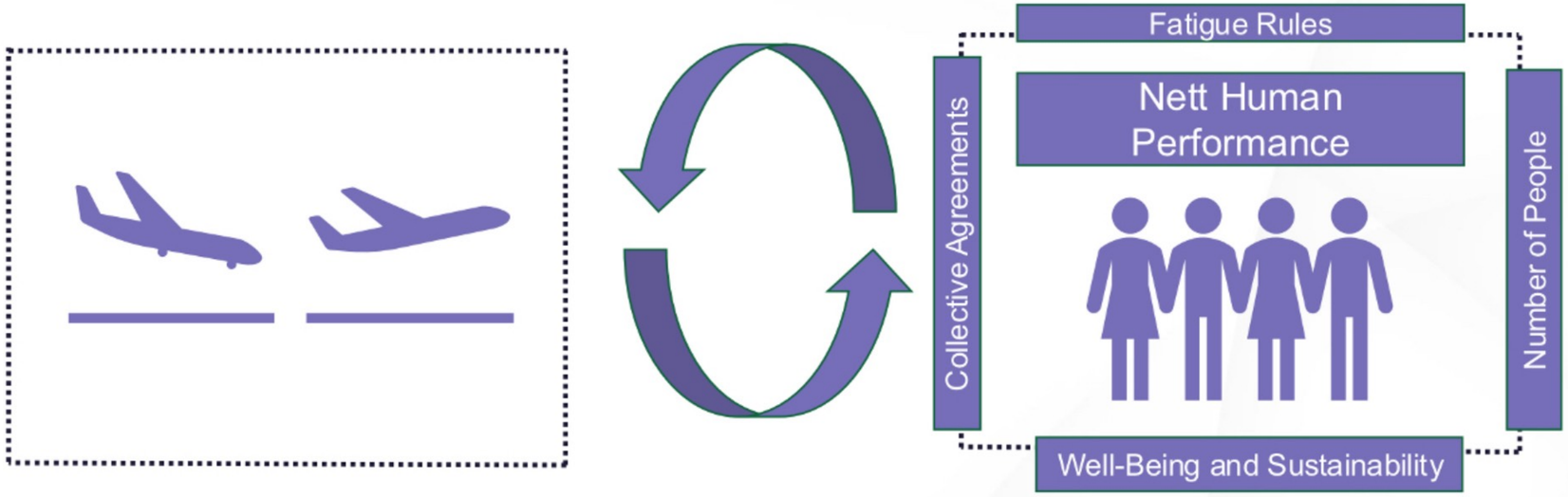
Old KPI: **“number of aircraft per hour”**

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)

Cumulative Complexity and Dynamic Human Performance in Aviation: How to Make Use of AI and Higher Automation Today

Lea Sophie Trampitsch-Vink

[a]*Safety and Quality, Austro Control, GmbH, Schnirchgasse 17, Vienna, 1030, , Austria*

Abstract

Air traffic management is approaching the limits of human capacity under current automation paradigms. While air traffic controllers and pilots operate at near-maximum workload, opportunities exist to extend automation and AI support across the broader socio-technical network of aviation roles. This paper introduces a conceptual framework for dynamic human performance management built on the novel construct of cumulative complexity. Drawing on foundational theories of task complexity, Multiple Resource Theory, and dual-process models of decision-making, the framework positions cumulative complexity as a predictive variable for workload, fatigue, vigilance, and error risk. Empirical validation through the Synapses model and EEG measures (N = 85) demonstrates that cumulative complexity can reliably forecast human performance trajectories in real time. Unlike static readiness assessments, the proposed approach enables proactive allocation of human and technological resources, sustaining cognitive resilience across entire air traffic management networks. The paper argues that adopting cumulative complexity as a systemic measure provides a pathway for aviation to leverage AI and higher automation today, not as a distant vision, but as an immediate strategy for enhancing safety, efficiency, and workforce sustainability.

Keywords: Human Performance, Air Traffic Management, Cumulative Complexity, AI, Automation, Aviation

1. Introduction

Cognitive Complexity Load: Capturing the Temporal Effects of Task Complexity on Human Performance

Lea Sophie Trampitsch-Vink[1] and Sjir Uitdewilligen[2]

[1]Austro Control, Vienna, Austria

[2]Faculty of Psychology and Neuroscience, Maastricht University, The Netherlands

Alternative : Proposed Construct: Cognitive Complexity Load (CCL)

Rationale

We introduce the construct of *Cognitive Complexity Load* (CCL), a dynamic index that quantifies how multidimensional task complexity imposes cumulative cognitive demand on operators. CCL builds directly on Wood's foundational theory of task complexity Wood, 1986, operationalizes Wickens' multiple resource competition **Wickens2008**; Wickens, 1984, and integrates curvilinear demand–performance relations (e.g., Yerkes–Dodson; Cummings et al., 2015) into a single temporal measure.

By modeling how task complexity accumulates over time, dissipates during breaks, and interacts with time-in-position and recent duty history, CCL captures both immediate workload and the fatigue that emerges from sustained exposure. It is therefore a bridge construct: a single dynamic index that unites two of the most studied yet often separately modeled outcomes in human performance—workload and fatigue.

Formalization

Momentary complexity is modeled as:

$$C_t = \boldsymbol{\alpha}^\top \mathbf{x}_t, \tag{4}$$

where $\mathbf{x}_t$ are complexity components and $\boldsymbol{\alpha}$ are their context-sensitive weights.

Accumulated demand follows:

$$A_t = \begin{cases} \rho_{\text{on}}\, A_{t-1} + C_t, & \text{on-position,} \\ \rho_{\text{off}}\, A_{t-1}, & \text{on-break,} \end{cases} \qquad 0 < \rho_{\text{off}} < \rho_{\text{on}} < 1. \tag{5}$$

The normalized index is:

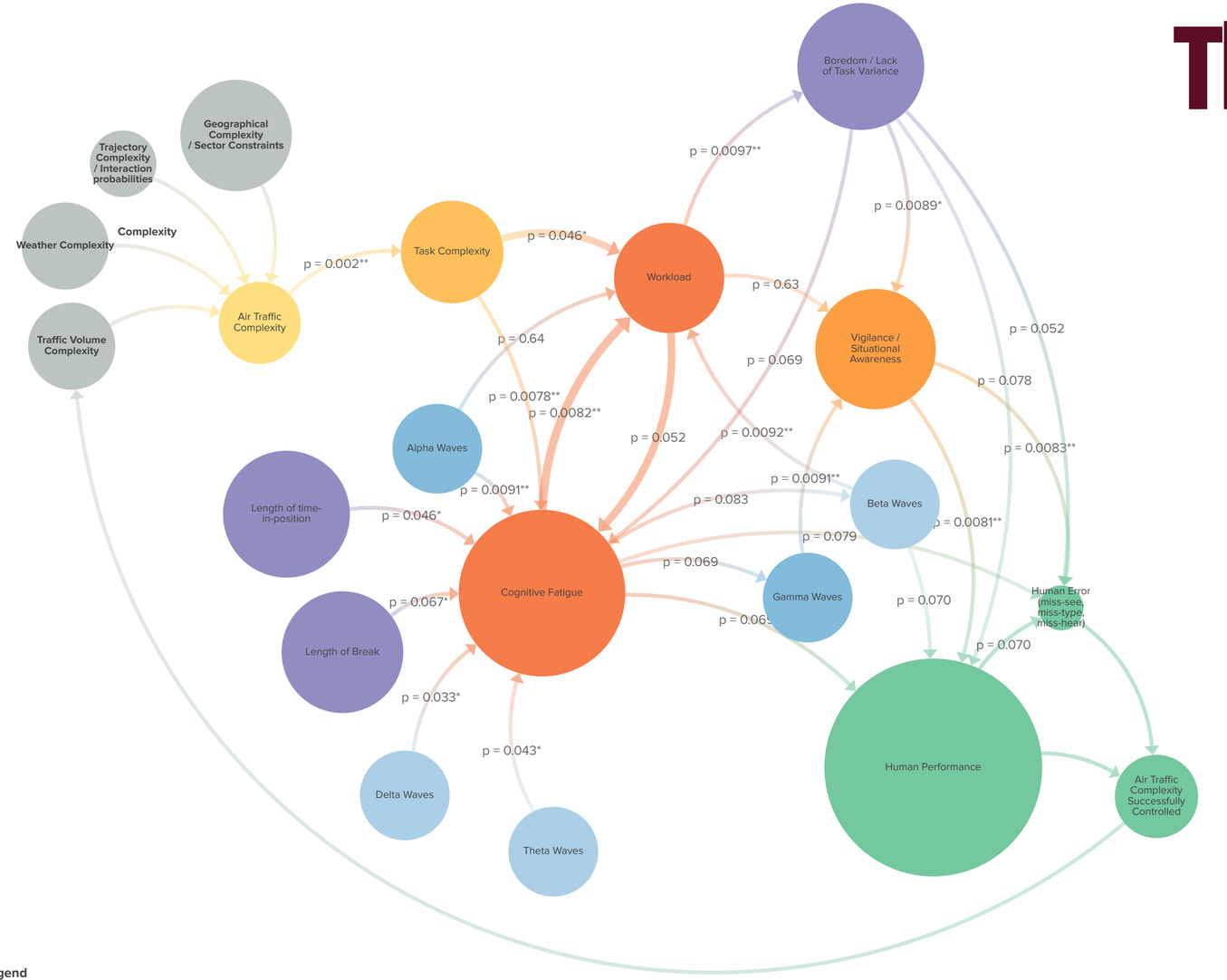
$$\text{CCL}_t = \frac{A_t}{\max_{j \in \mathcal{W}} A_j}, \qquad \text{CCL}_t \in [0, 1]. \tag{6}$$

Interpretation

CCL is interpretable (each parameter maps to operational levers), streamable (computable from real-time data feeds), and generalizable (normalized across sectors and shifts). We propose CCL as the candidate for a standardized *Human Performance Index* (HPI) in ATC, unifying workload and fatigue under a single, mathematically rigorous construct.

CANSO

The Synapses Model



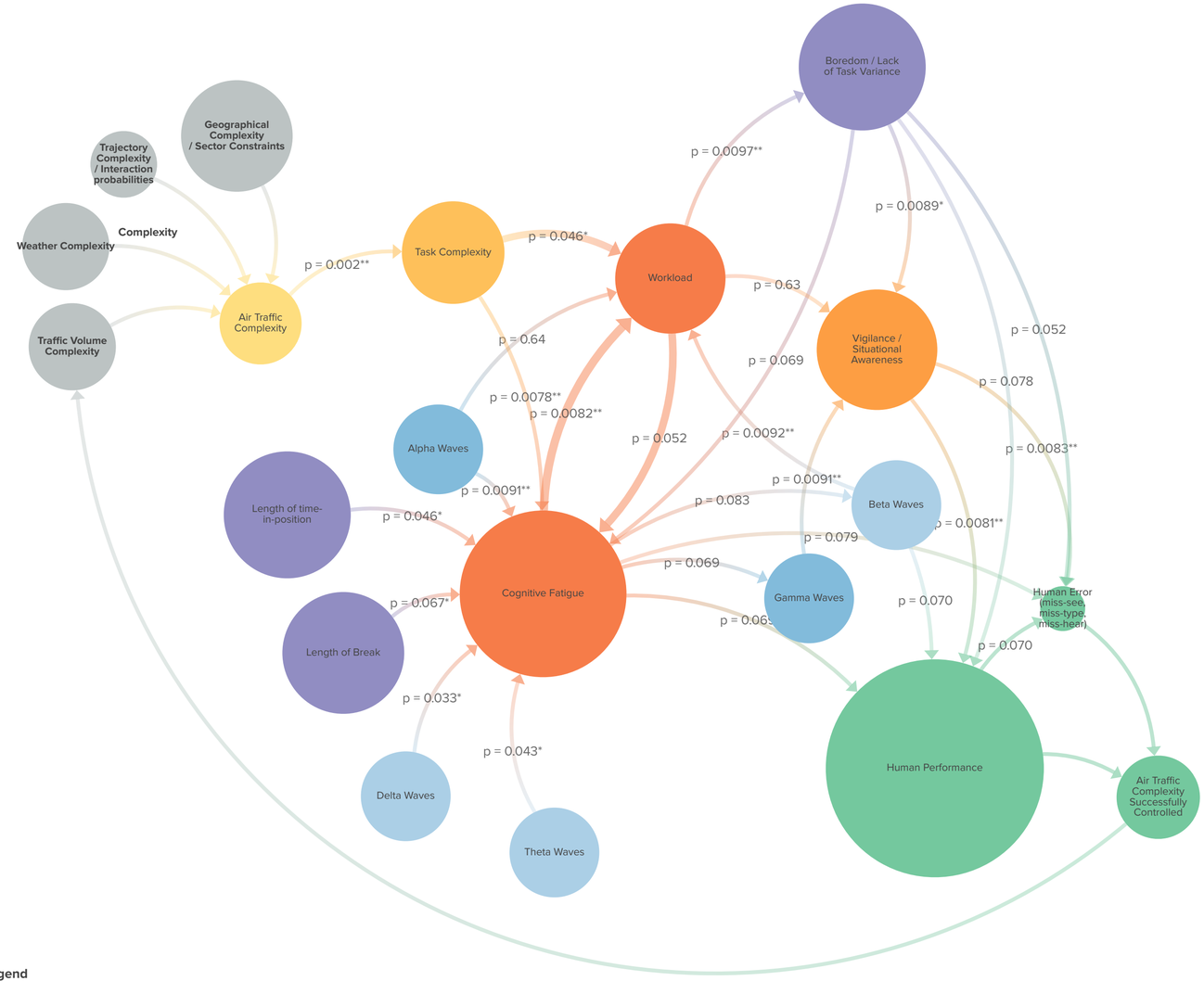
Our studies involving over 85 ATCOs (Roughly 45% of ACC ATCOs) over five studies found the following:

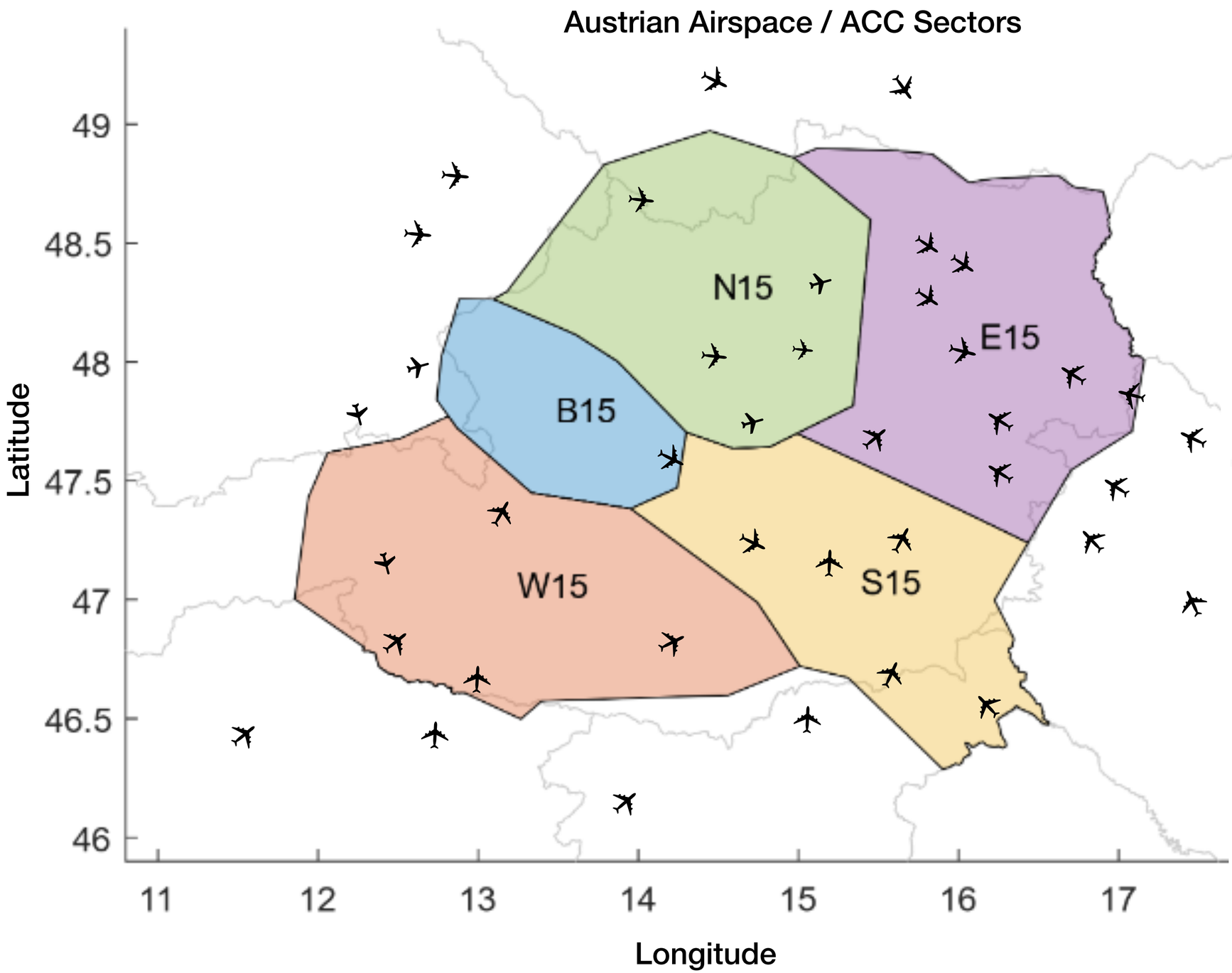
1. Air Traffic Complexity = Task Complexity
2. Task Complexity accurately predicts Workload
3. Workload + time-in-position accurately predicts Cognitive Fatigue and Risk of Human Error
4. Situational Awareness degrades regardless of compensation measures taken against fatigue or Workload
5. Time-in-position, 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

Real-time Ethical Automation

Machine learning that supports – not surveils

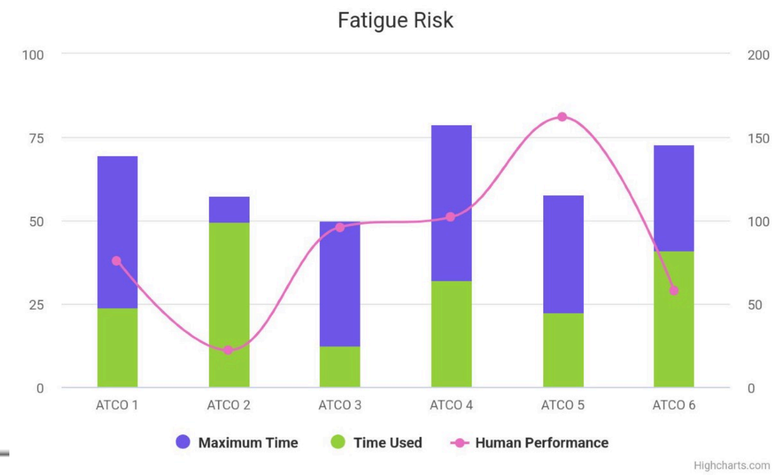
- SYNAPSES doesn't measure individuals
- Real-time alerts
- Humans remain in loop, main ATCO role doesn't change
- We are hunting for more performance from other roles: Supervisors, network management etc
- Tooling and automation as co-pilots and assistants





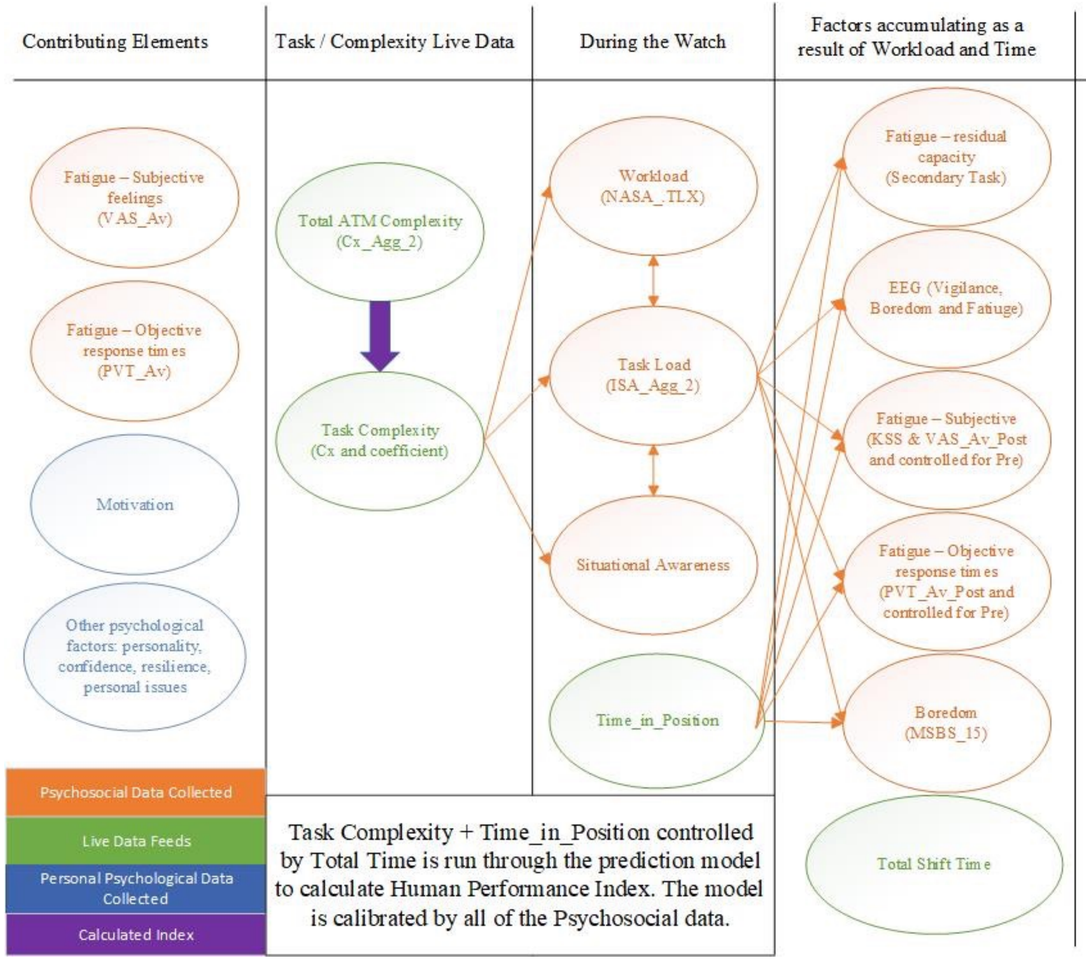
To show how complicated it can be:

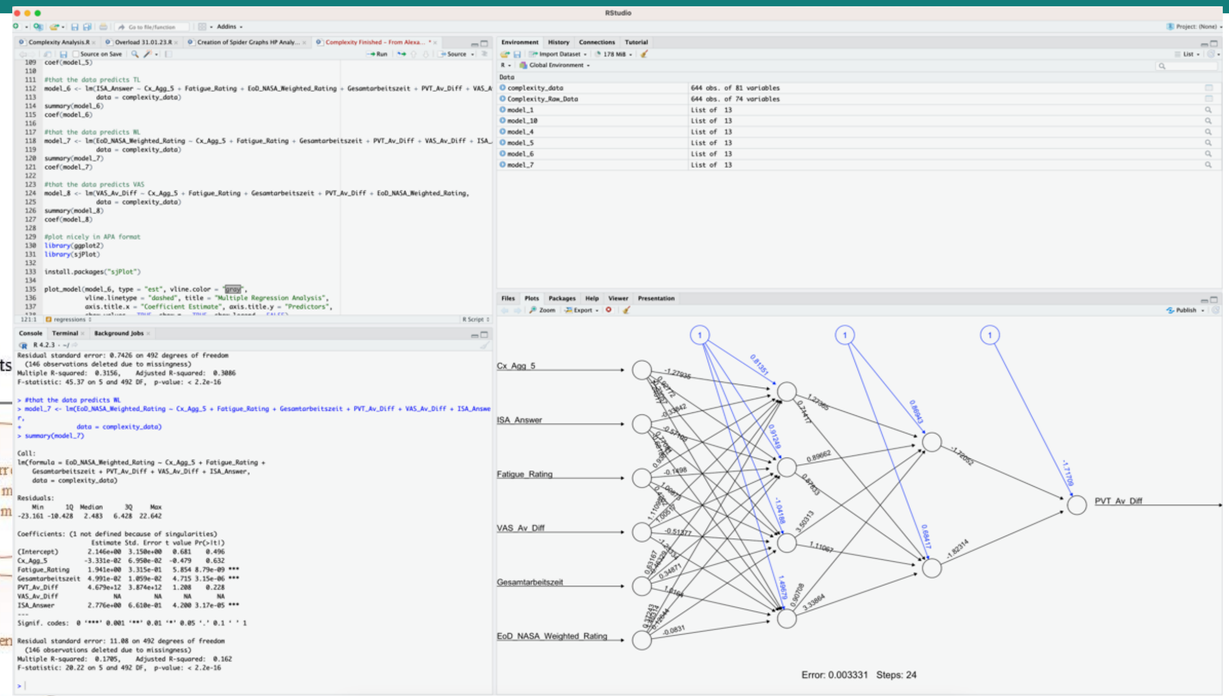
1. Air Traffic Complexity
2. Weather and Environmental
3. System Performance Variables
4. Human Performance
5. Compliance and Safety Outcomes
6. Performance outcomes
7. External Factors



The research behind it

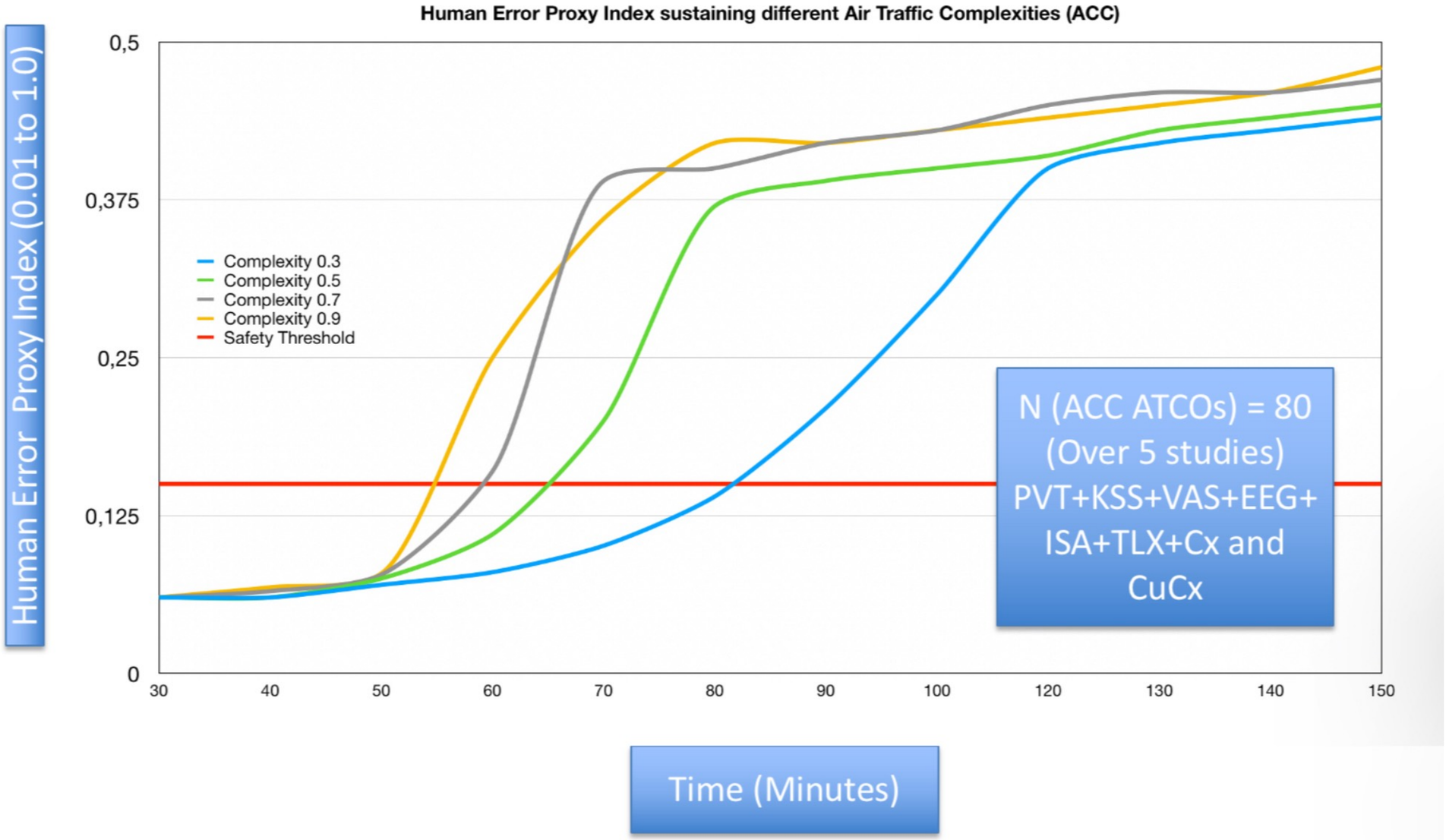
Five years, real operations, real operators and real humans





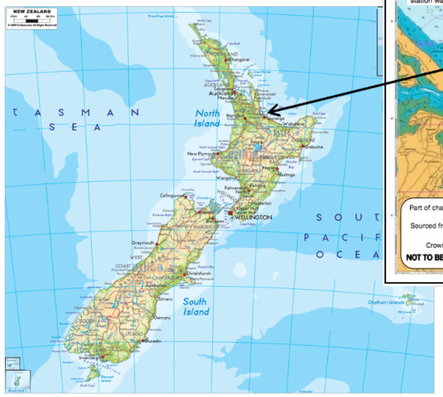
- 85 ATCOS over five main studies
- 12 hours of Shift time
- Batteries of psychometric tests
- Result: a calculator based on average distributed performance and ***not individual monitoring***

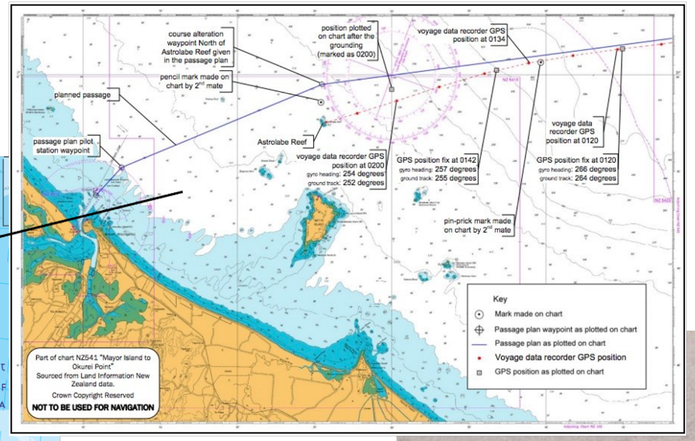
4th Run of Day

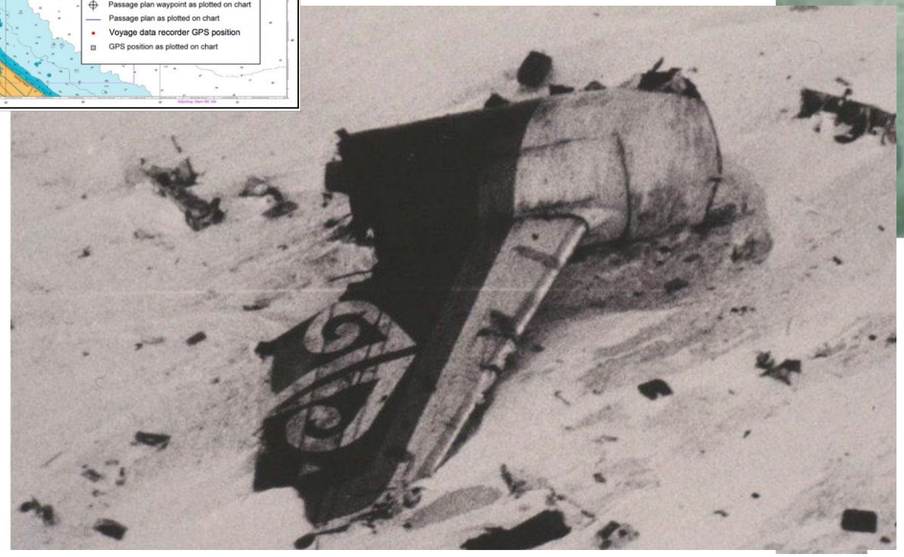


What do these three stories have in common?

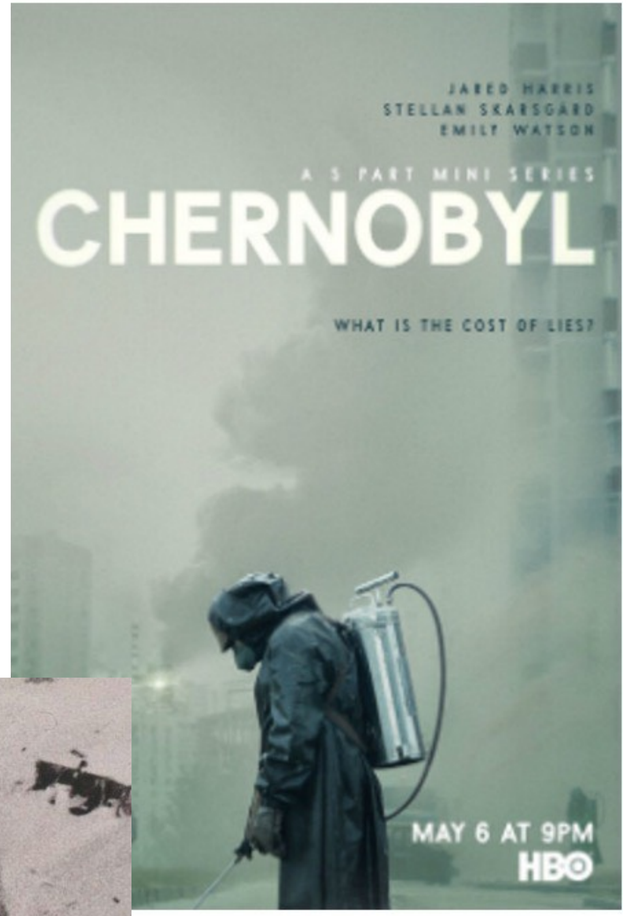
MV Rena - October 2011



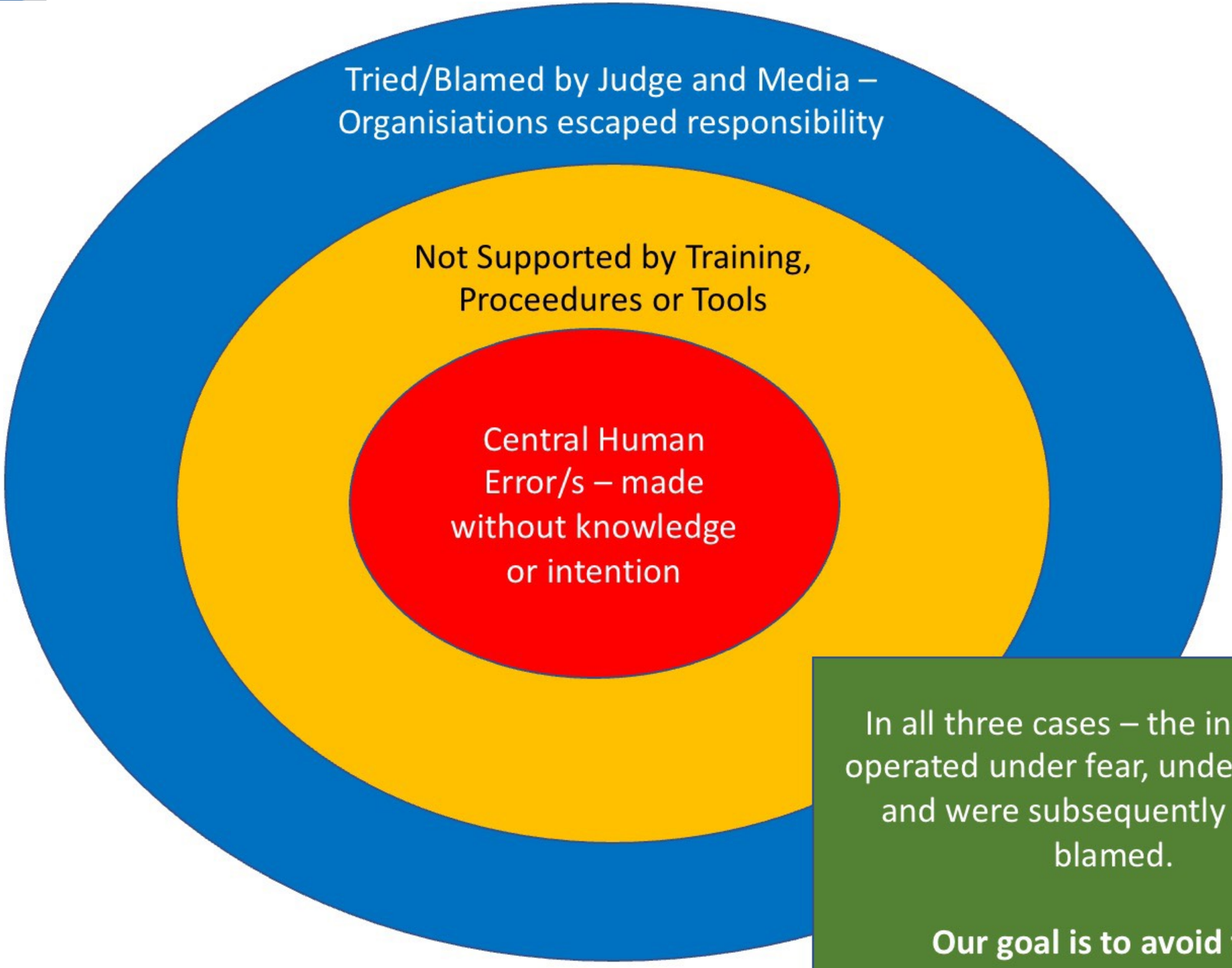




Air NZ – TE901
November 1979



Chernobyl –
April 1986

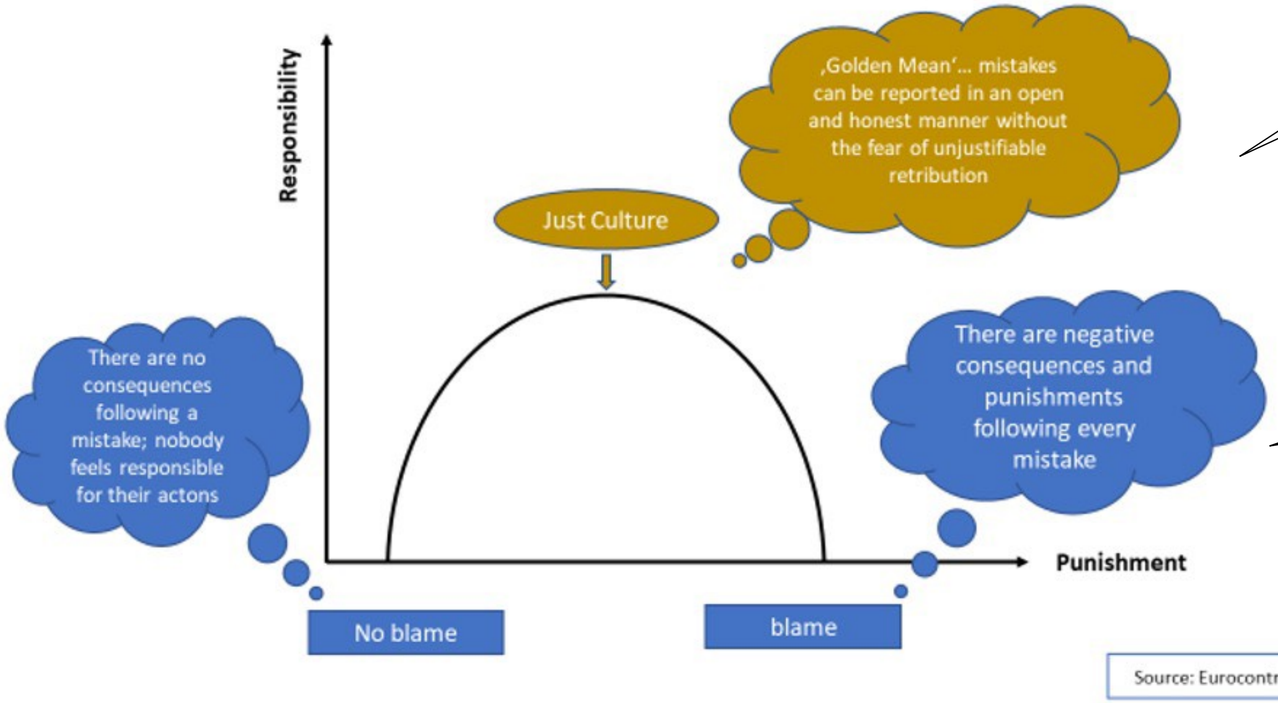


In all three cases – the individuals operated under fear, under pressure and were subsequently entirely blamed.

Our goal is to avoid this.

Just culture is:

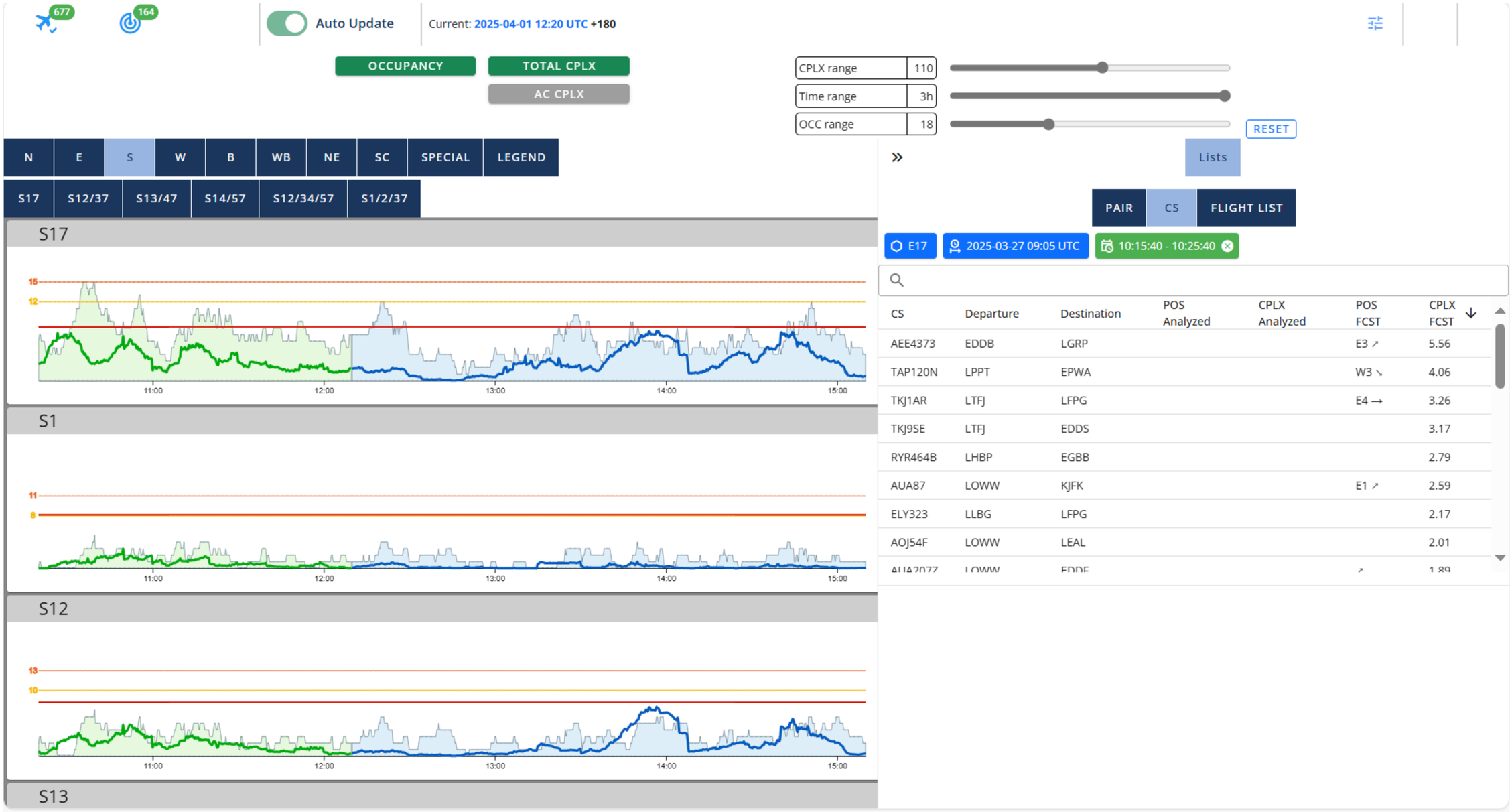
"A culture in which operators or other staff are not punished for acts, omissions or mistakes commensurate with their experience, but where negligence, violations (sabotage) and destructive acts are not tolerated"



The key is to build trust between all staff and the management and systems that investigate and protect them

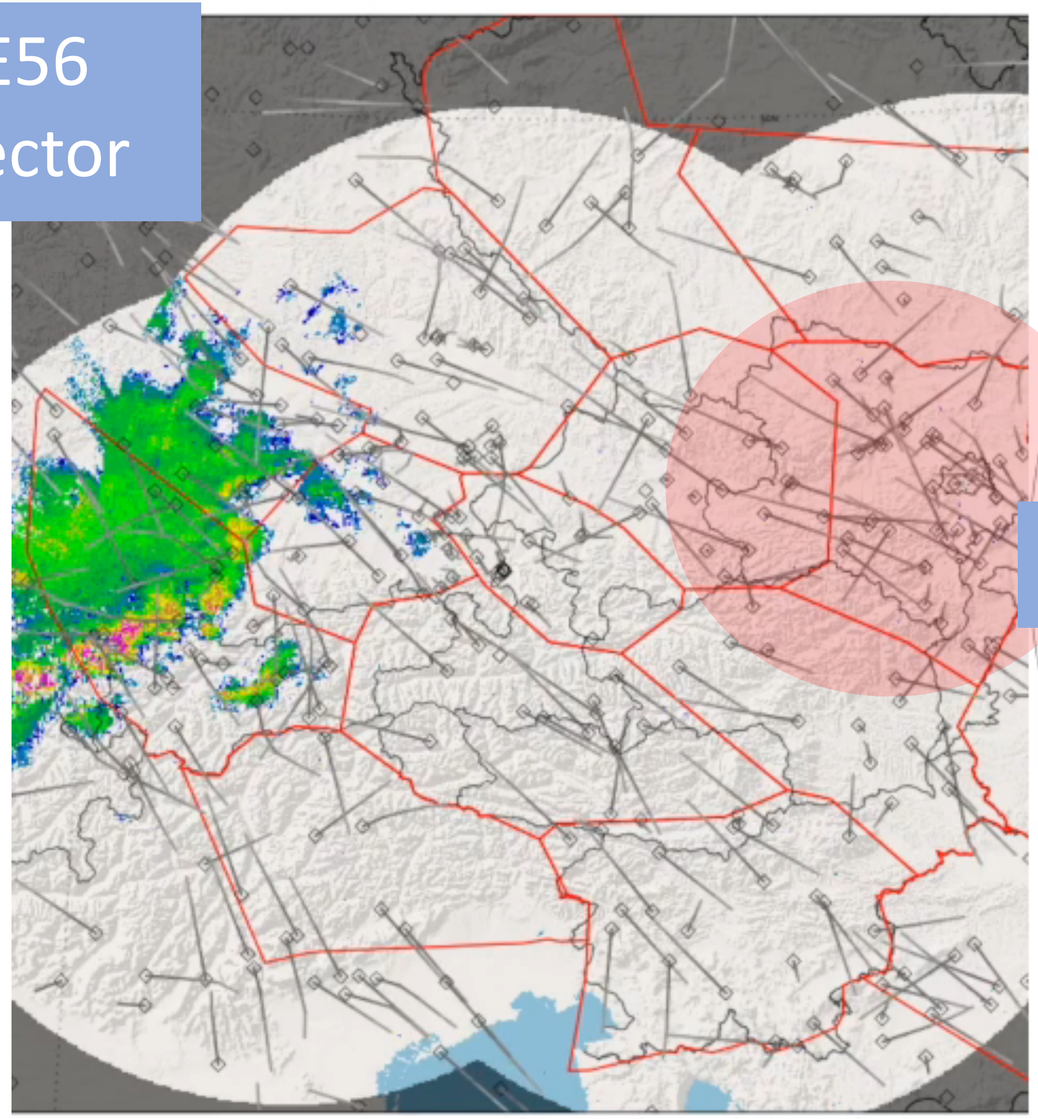
But for us.. this gives us so much more than individual trust..

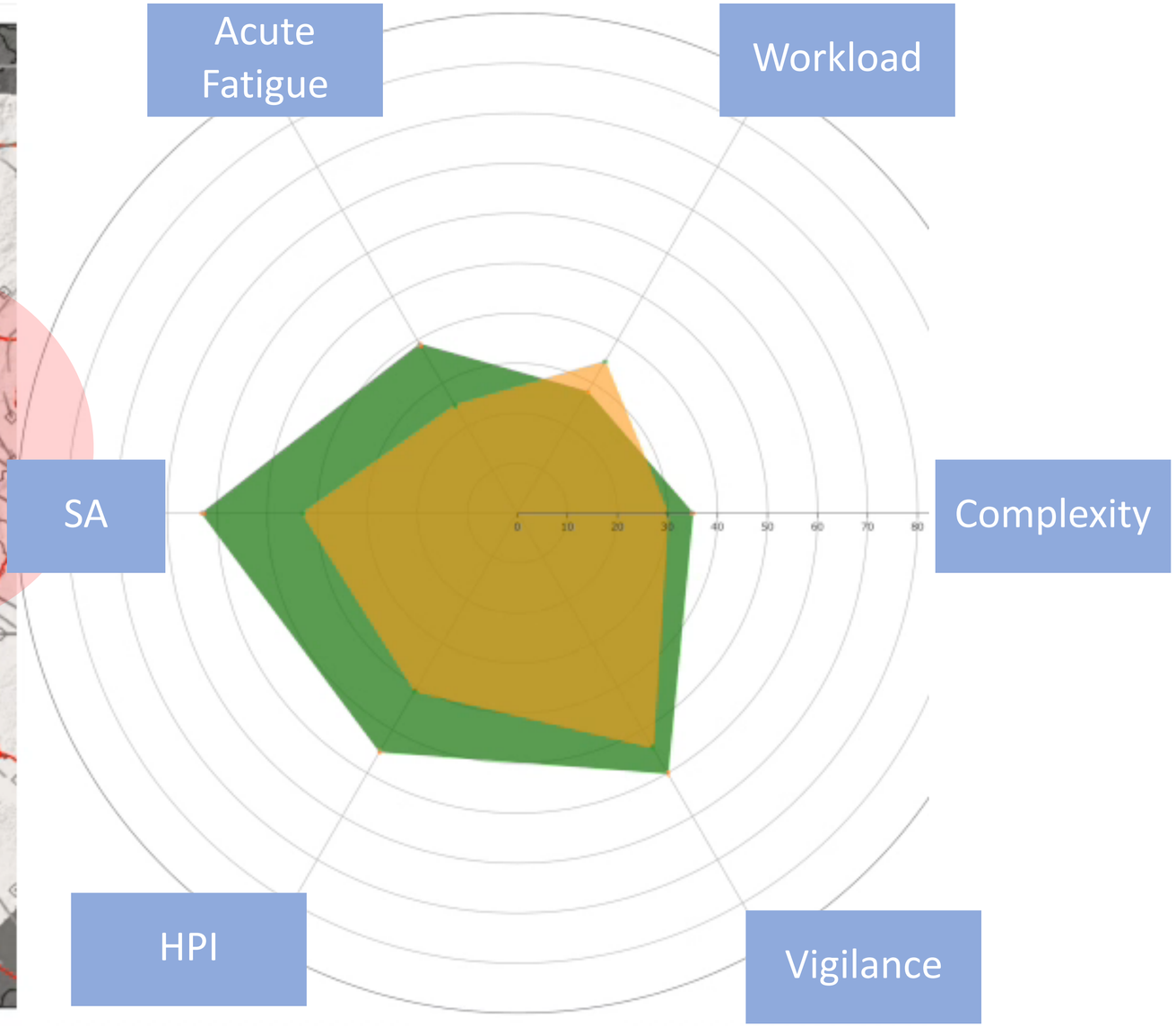
It is a balance of pressures vs human performance cost


677
164
Auto Update
Current: 2025-04-01 12:20 UTC +180
OCCUPANCY
TOTAL CPLX
AC CPLX
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
12
11:00 12:00 13:00 14:00 15:00
S1
11
8
11:00 12:00 13:00 14:00 15:00
S12
13
10
11:00 12:00 13:00 14:00 15:00
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
AUA87 LOWW KJFK E1 ↗ 2.59
ELY323 LLBG LFPG 2.17
AOJ54F LOWW LEAL 2.01

Tracking Cognitive Overloads

E56 Sector

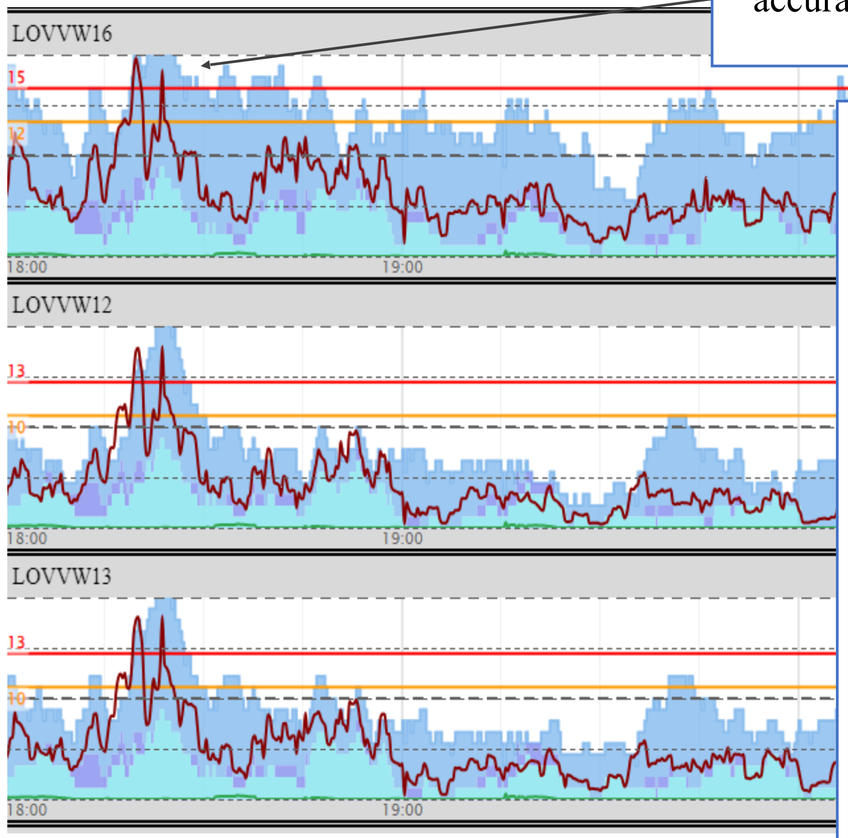




2023_09_23 W2 Sector @ 1820 UTC

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.

Our story today…

Lets wrap up the story.

No one comes to work with the intention to do a bad job.. It is statistically insignificant.

Our goal is to maintain the balance of normal operating conditions, and when things are ab-normal, to understand why in a way that is tolerant of statistically likely risks…

If we ever detect at-risk behaviour, our staff can be sure that we have been through every possible set of sub-conscious, tolerated human error and other causal factors.

The numbers speak for themselves: in 2023, we had 2186 occurrences…

And only 3 Just Culture committees.

Resources

Relevant Resources from today

1. Rudin-Brown, C. M., & Filtness, A. J. (Eds.). (2023). The handbook of fatigue management in transportation: waking up to the challenge. CRC Press.
2. Bor, R., Eriksen, C., Georgemiller, R. J., & Gray, A. L. (Eds.). (2024). *Handbook of Aviation Neuropsychology: A Practical Guide for the Clinician*. Hogrefe Publishing.
3. Vink, L. S. (2024). A History of the Techniques, Methodologies, and Practices of Neuropsychology for Operational Support in Airline Operations and. *Handbook of Aviation Neuropsychology: A Practical Guide for the Clinician*, 20.
4. 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.
6. Ziakkas, D., & Plioutsias, A. (2024). Artificial Intelligence and Human Performance in Transportation: Applications, Challenges, and Future Directions.
7. Walker, M. (2017). Why we sleep: Unlocking the power of sleep and dreams. Simon and Schuster.
8. Vink, L. S., & Walzl, B. (2025). Redefining Human Performance in complex socio-technical systems Human Performance as key-performance indicator. *Transportation Research Procedia*, *88*, 31-39.
9. Wickens, C. D., Helton, W. S., Hollands, J. G., & Banbury, S. (2021). *Engineering psychology and human performance*. Routledge.

ICAO Doc 10151, ICAO Doc 9966, CANSO HPM SoE, Eurocontrol Guidelines on Rostering Best Practices

Thank you + Contact

Lea Sophie Vink (LinkedIn)
Clinical Neuropsychologist & Human Performance Specialist

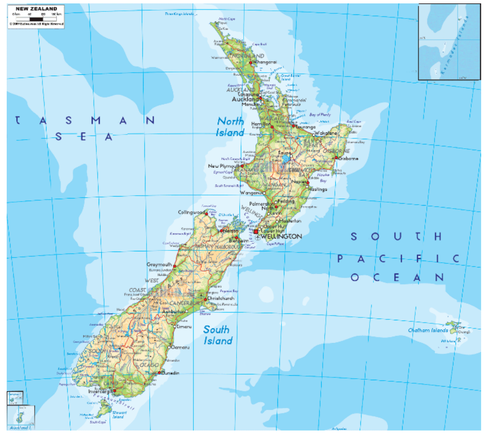
lea.trampitsch-vink@austrocontrol.at (for Austro Control)

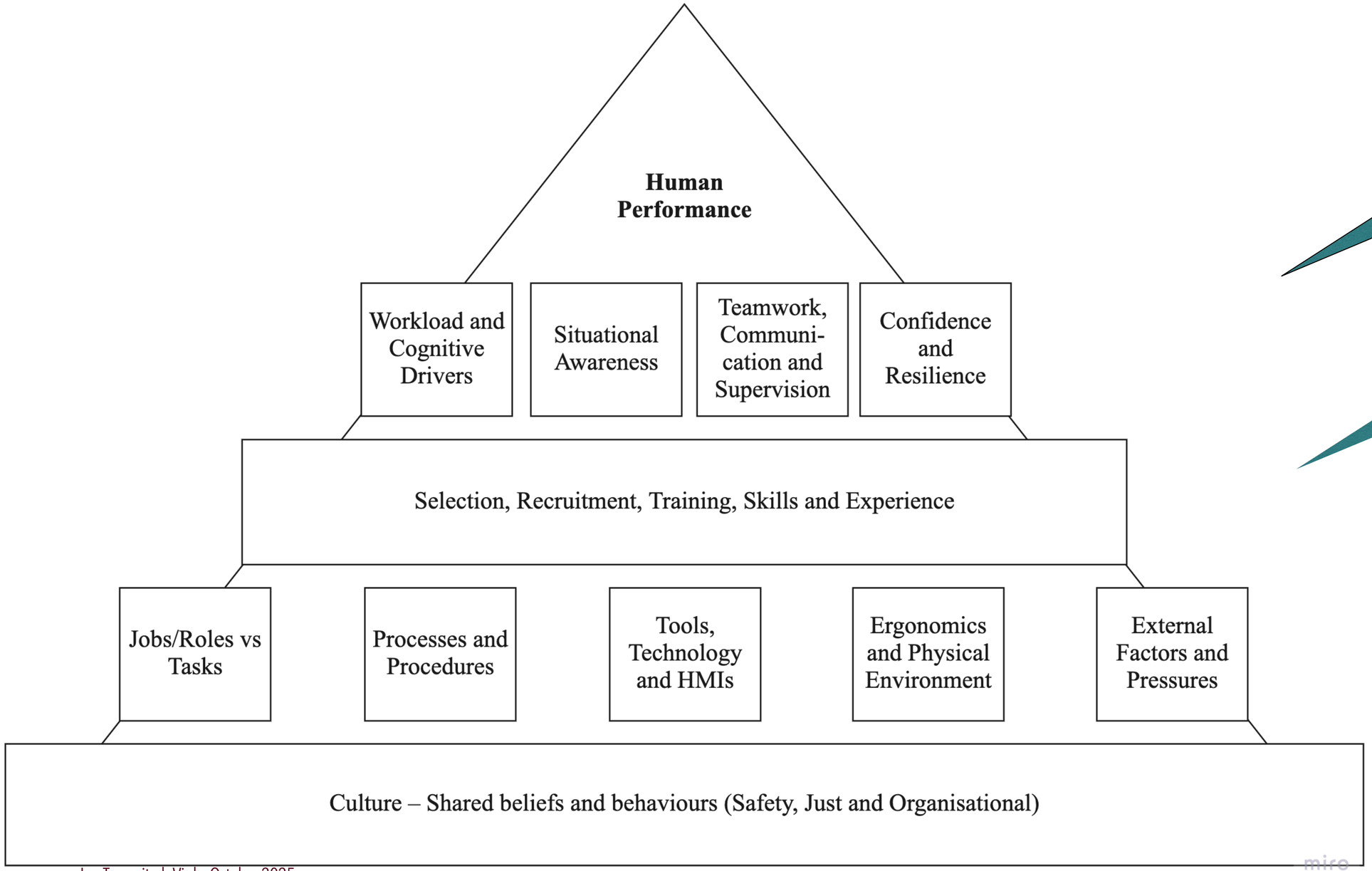
frontdesk@justminds.at (for Consulting Business Inquiries)

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





Individual day-day Variability

Talent Management or Non-individual criterion

Infrastructure and Ergonomics

Culture

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