

The Moving Ladders Problem

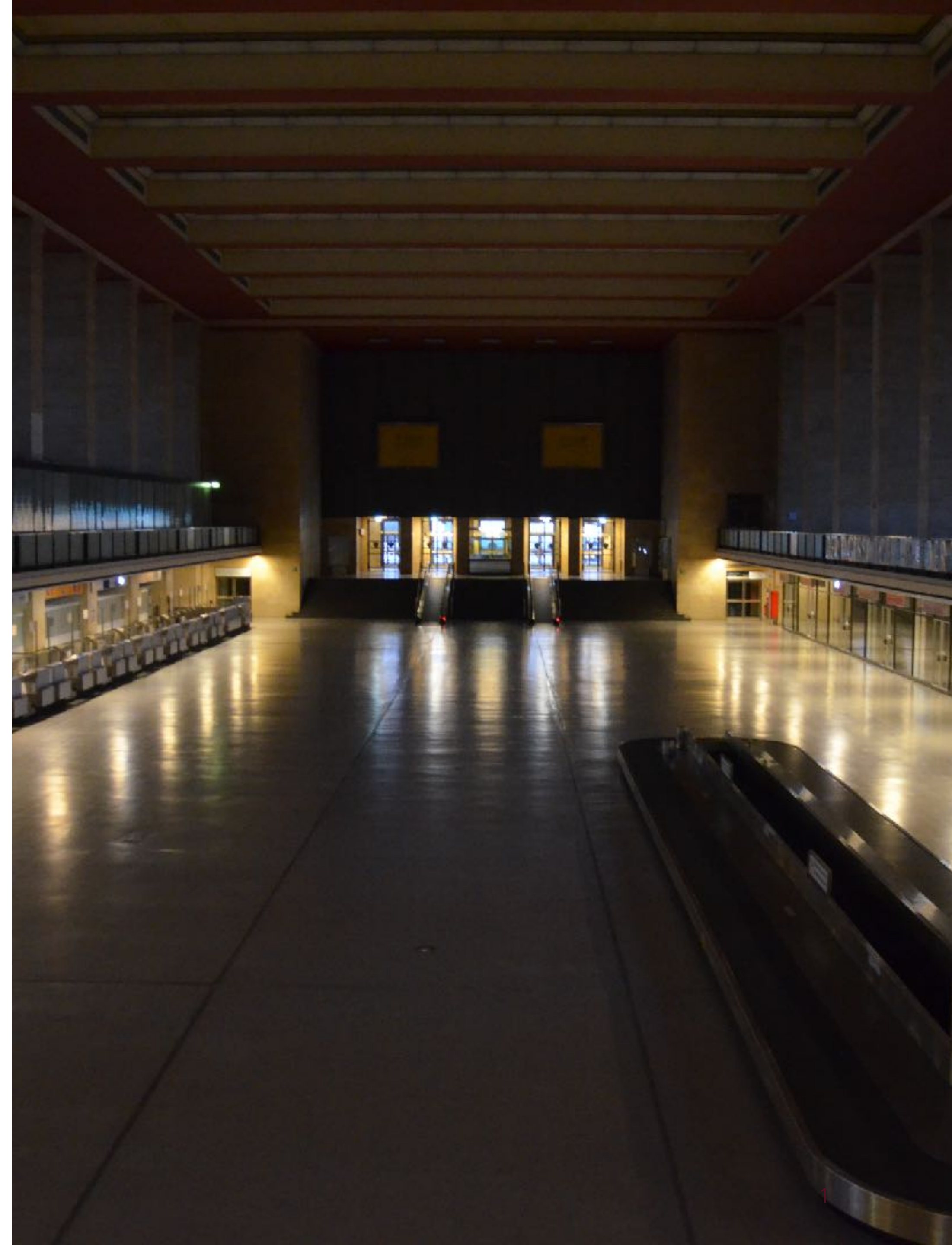
What Automation Takes Away from the Human, and Why Nobody Has Measured the Gap.

Stories from Europe and beyond...

Dr. Lea Sophie Trampitsch-Vink, PhD

Founder & Director, Just Minds Institute

Co-Chair European Commission Expert Group on Human Dimension



Have You Ever Asked...

**What Can Your Operators No Longer Do Because
of the Automation You Have Given Them?**

**Why Are They Still the Ones Held Responsible
When the System Fails?**



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 (ClinPsych), MSc (I-O Psych)
- PhD Clinical Psychology + Phd Cognitive Neuroscience
- 2006-2015: Navigator and Command positions RNZN (pirate hunting, Antarctica, 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)
- Adjunct professor of Cognitive Neuroscience and Psychology (Graz, Maastricht, Vienna)
- Safety & Assurance Specialist + Fatigue Risk Management and Human Performance Management System Consultant
- Predictive Human Performance Systems
- 2025: Cognitive Neuropsychology PhD: new research into Neural Networks of Psychological Performance and Human Error



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European Association for Aviation Psychology Conference EAAP 35

Redefining Human Performance in complex socio-technical systems
Human Performance as key-performance indicator

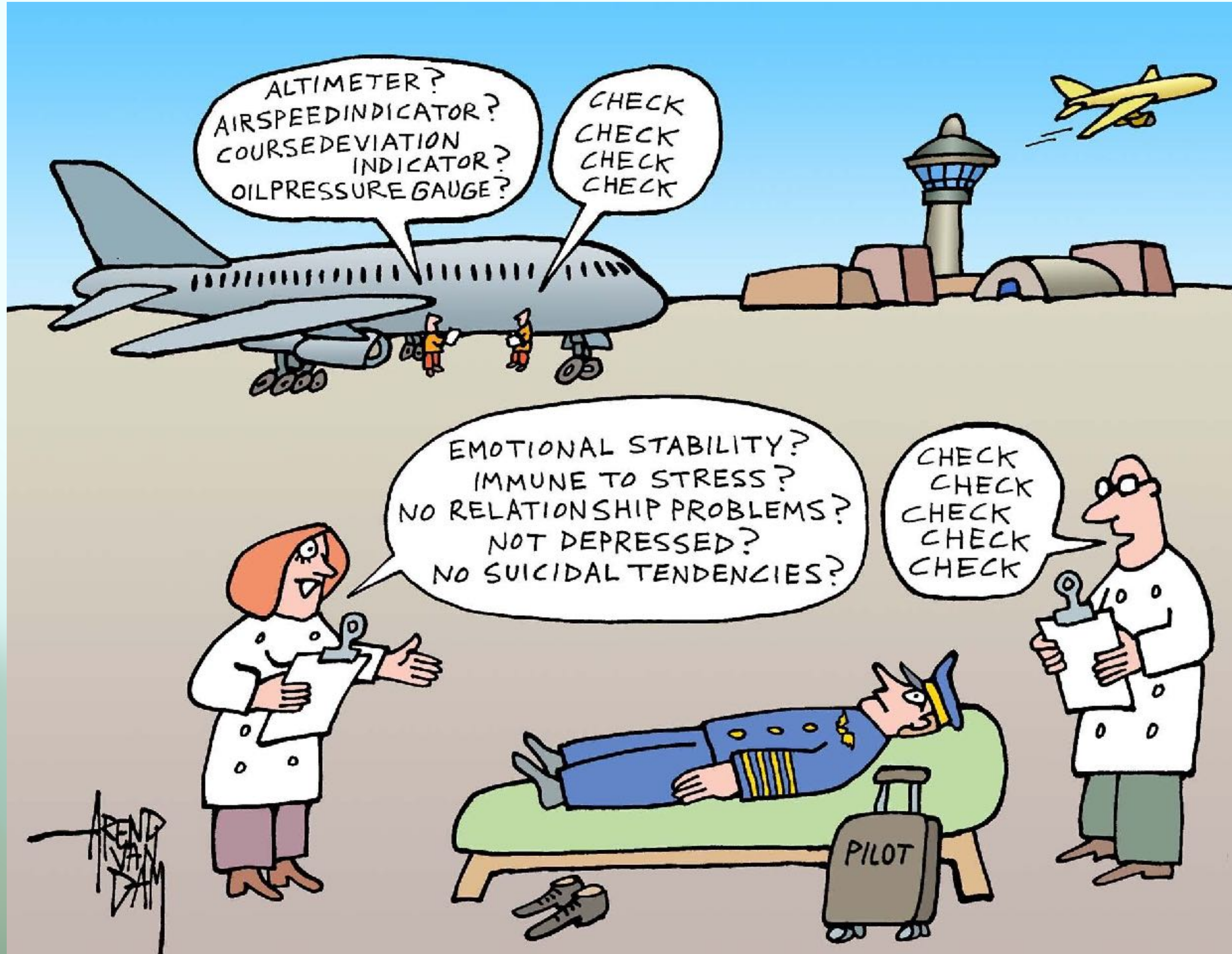
Lea-Sophie Vink^{a,*}, Beatrix Walzl^b

^aAustroControl, Vienna, Austria
^bVienna, Austria

Abstract

Over the past decade, high-reliability organizations such as aviation, maritime, and the energy sector have transitioned from a narrow focus on individual human factors to a broader understanding of human performance (HP) as a critical component within socio-technical systems. This paper introduces a novel framework for identifying and measuring HP, using safety assurance techniques to link individual factors with organizational outcomes. The framework incorporates layers of influence, including individual variability, talent management, infrastructure, and cultural dynamics, connected to key metrics such as workload, stress, and fatigue. A case study involving a European air navigation service provider demonstrates how this framework elevates HP to a key performance indicator (KPI), integrating a 'human performance index' with a 'fatigue risk index' and operational data like traffic complexity and rostering. The study illustrates the framework's utility in creating actionable KPIs that support growth management, variance identification, and proactive system design, thereby enhancing overall safety and performance.





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!

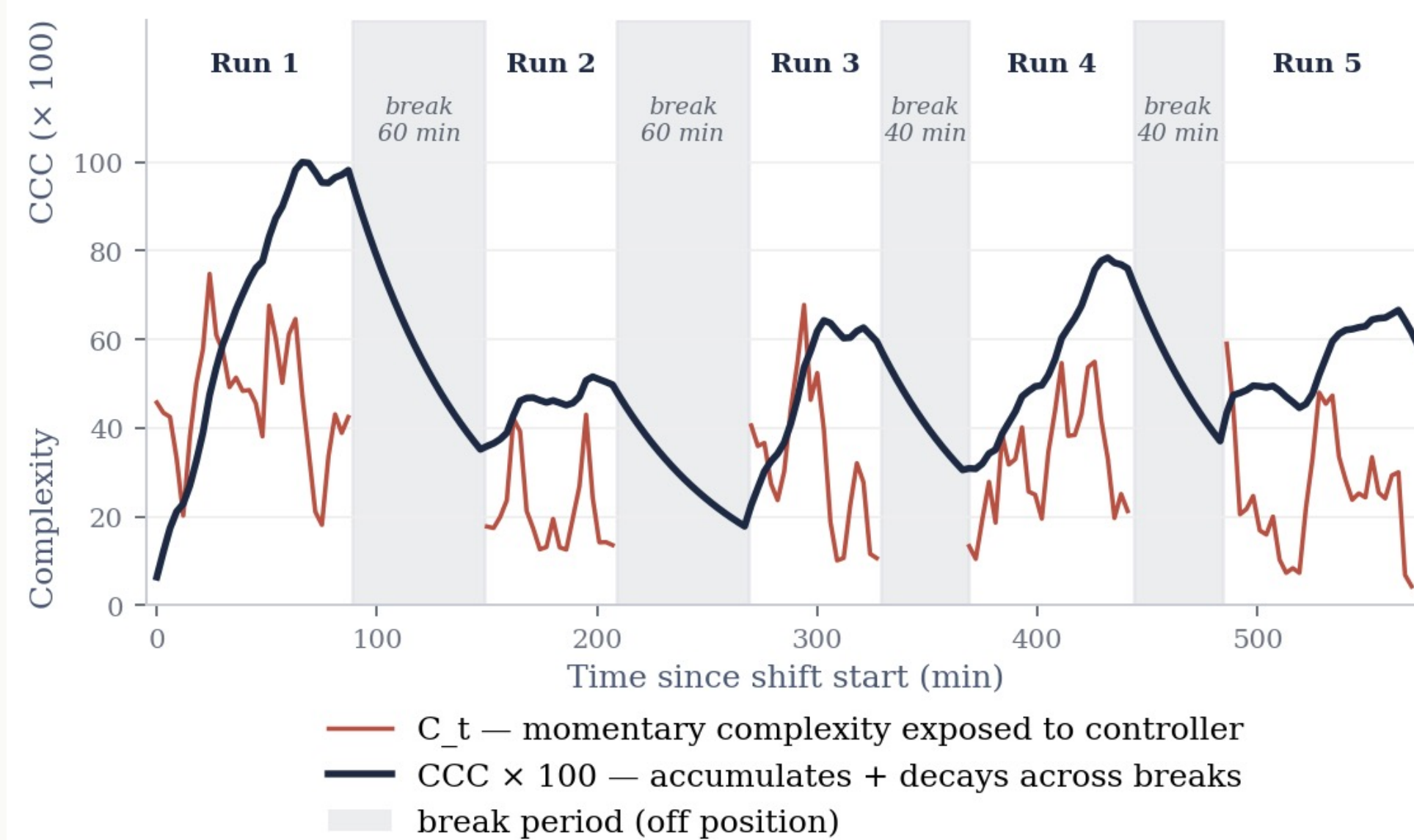


Our question is... So what?!?!? Why does it matter so much?

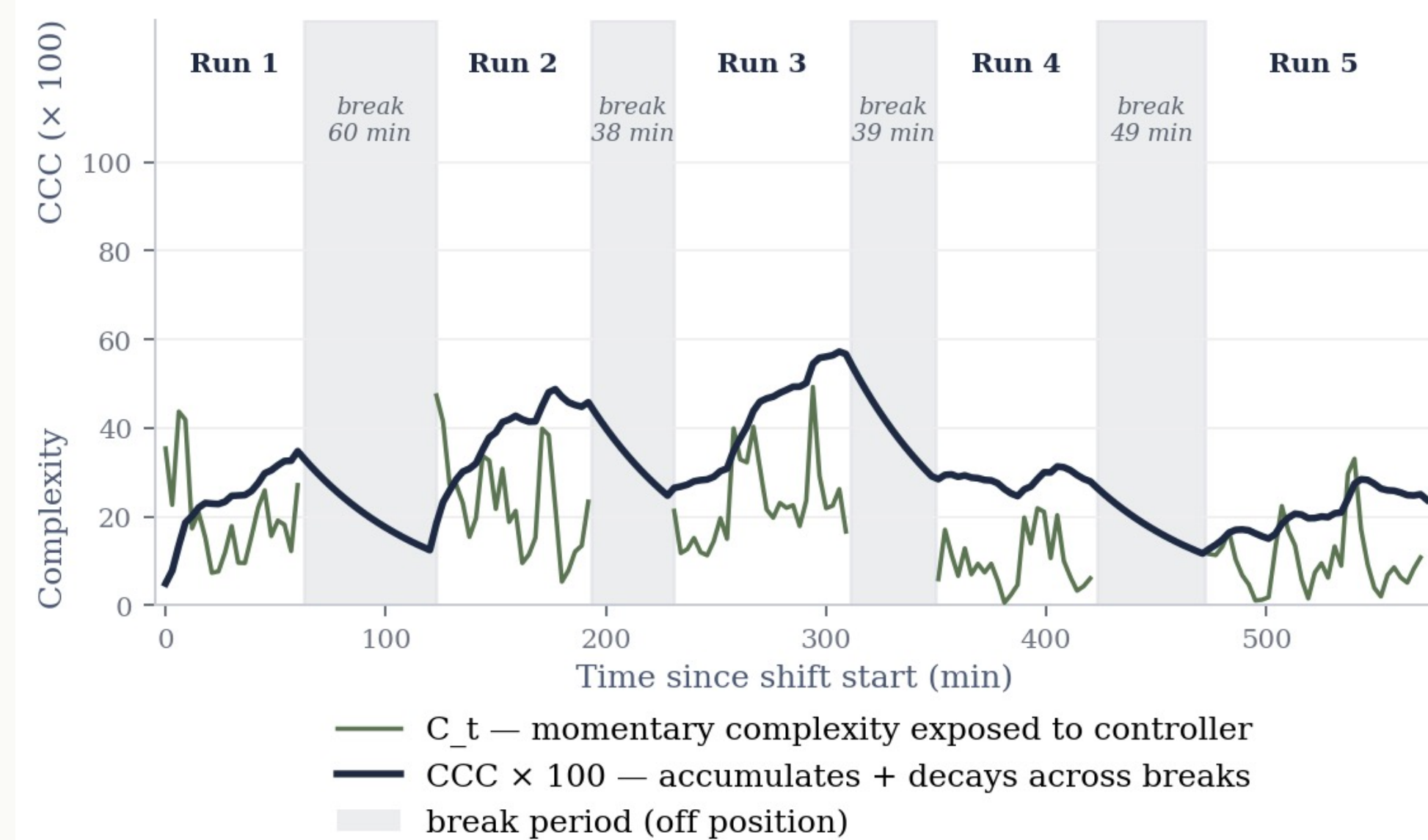
Figure 2. Two contrasting shifts, side by side

Two real shifts of equal length and run count. Different complexity profiles, different cumulative exposure. Breaks are visible as grey bands.

Shift A — high intensity, high variability (0909-04)



Shift B — low intensity, lower variability (1408-01)



Mean Cx (shift)	Variability (SD)	Cumulative (A_max)	Mean break
32.3	15.8	719	50 min

Mean Cx (shift)	Variability (SD)	Cumulative (A_max)	Mean break
16.9	10.8	412	47 min

How to read the curves. Red line drops to zero in grey bands = *controller off position*. Navy line decays but does not collapse = *CCC carries prior exposure forward across breaks*. Run peaks and slope visible within each on-position segment.

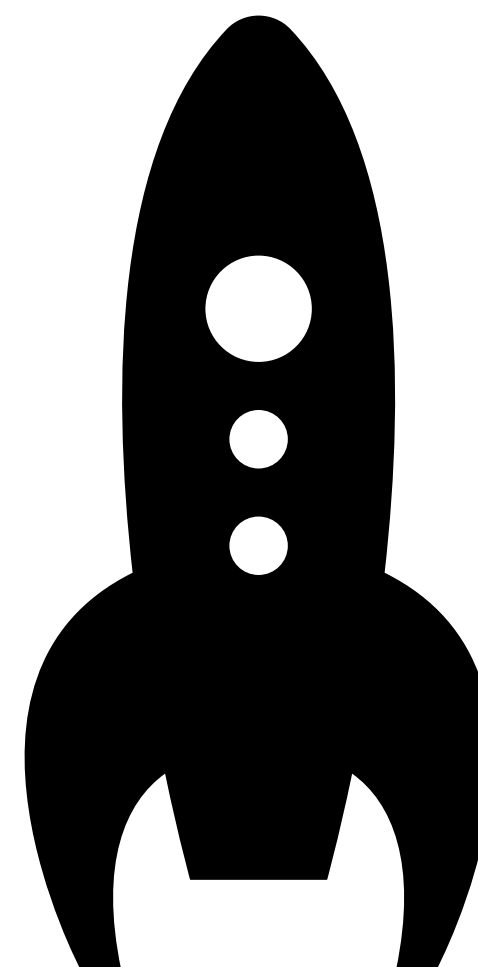
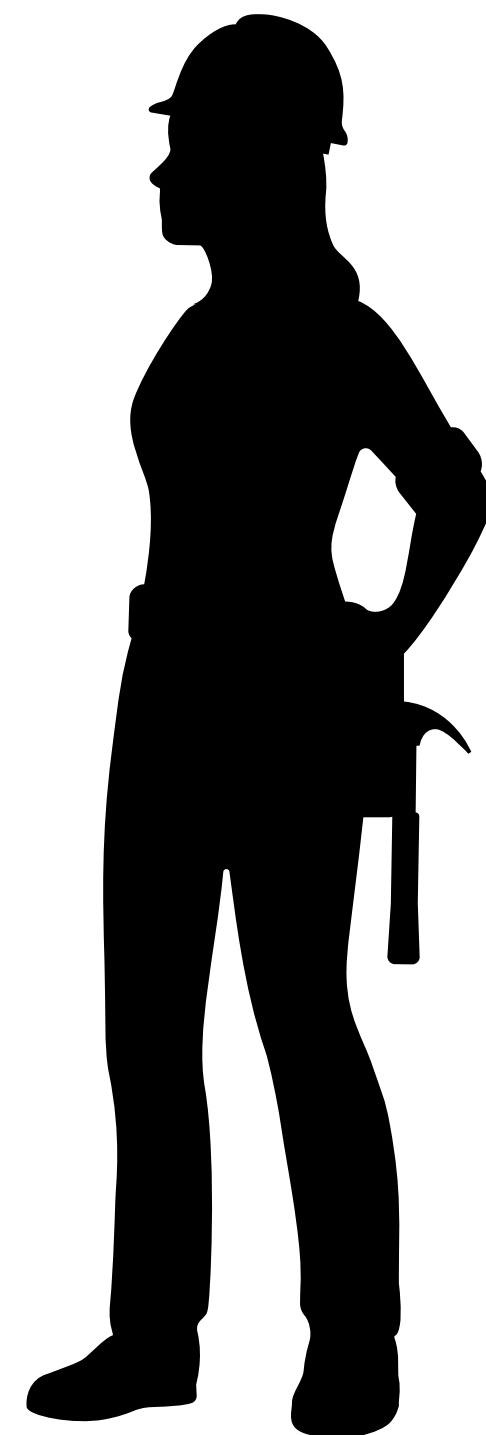
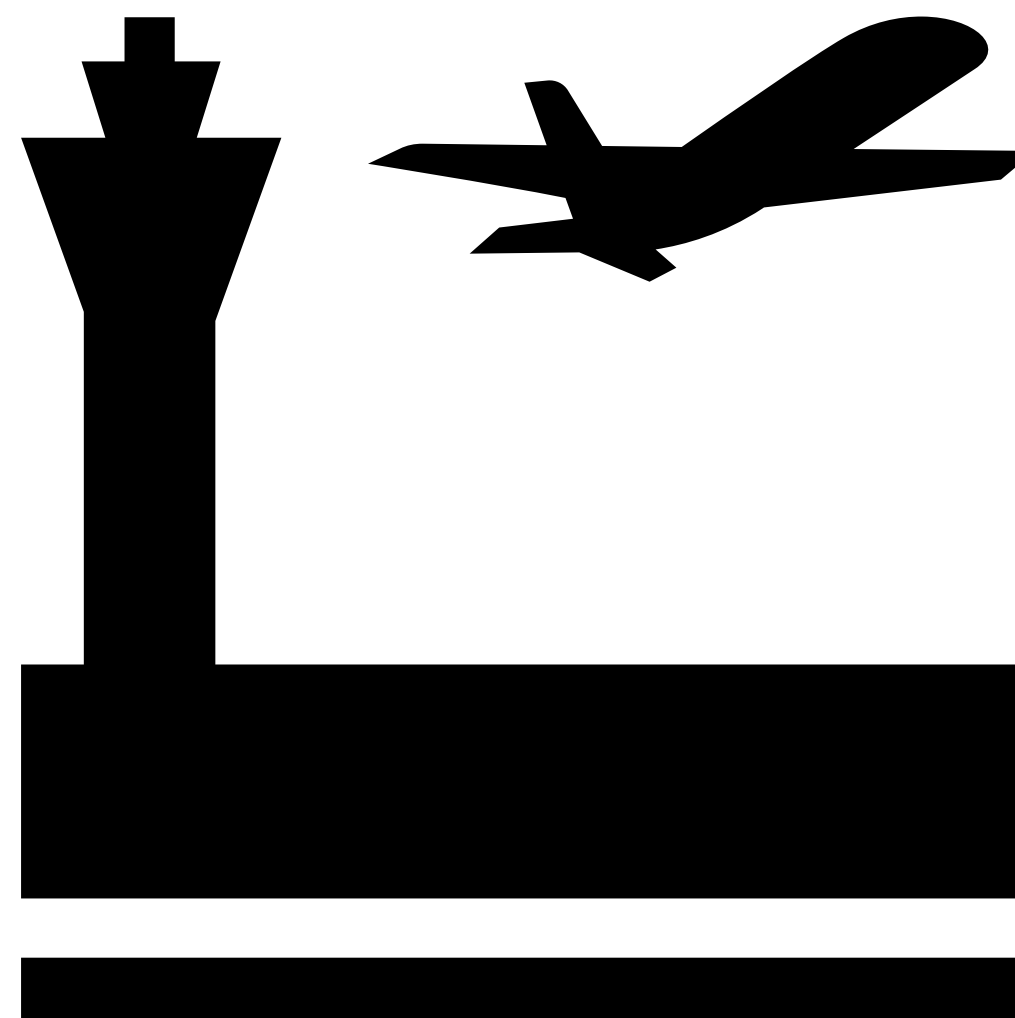
Note. Both shifts span 571 minutes and comprise five runs. C_t = momentary complexity as exposed to the controller (zero on break). CCC = recursive accumulation with $\rho_{on} = 0.95$ on position and $\rho_{off} = 0.95$ off position. To make the two shifts visually comparable, both CCC curves are normalised against the larger of the two shifts' maxima (A_{max} = 719 from Shift A) and scaled $\times 100$. Raw A_{max} for each shift is reported in the annotation cards.

AVIATION IN NEED OF MORE HUMAN PERFORMANCE...



Approved by and published under the authority of the Secretary General

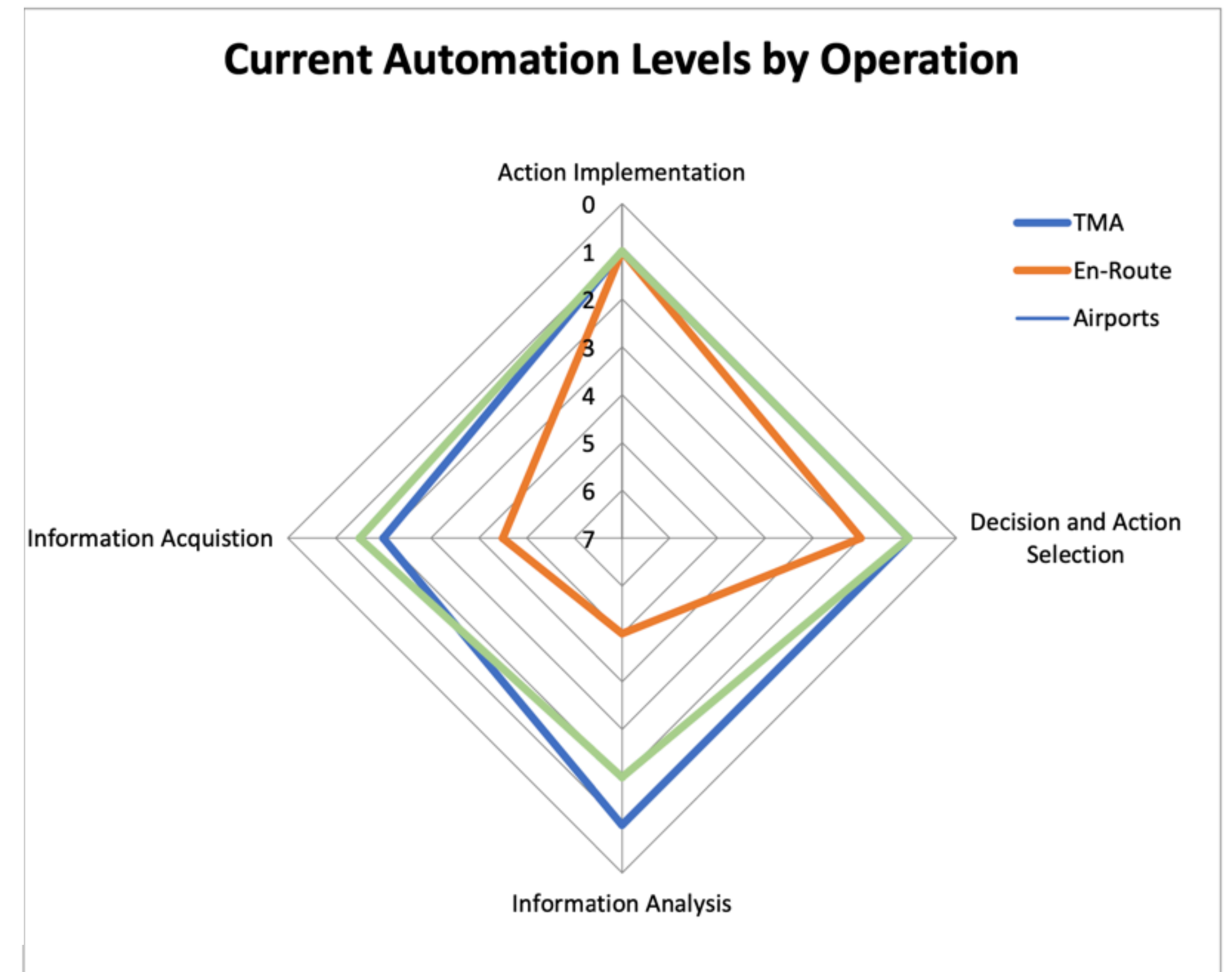
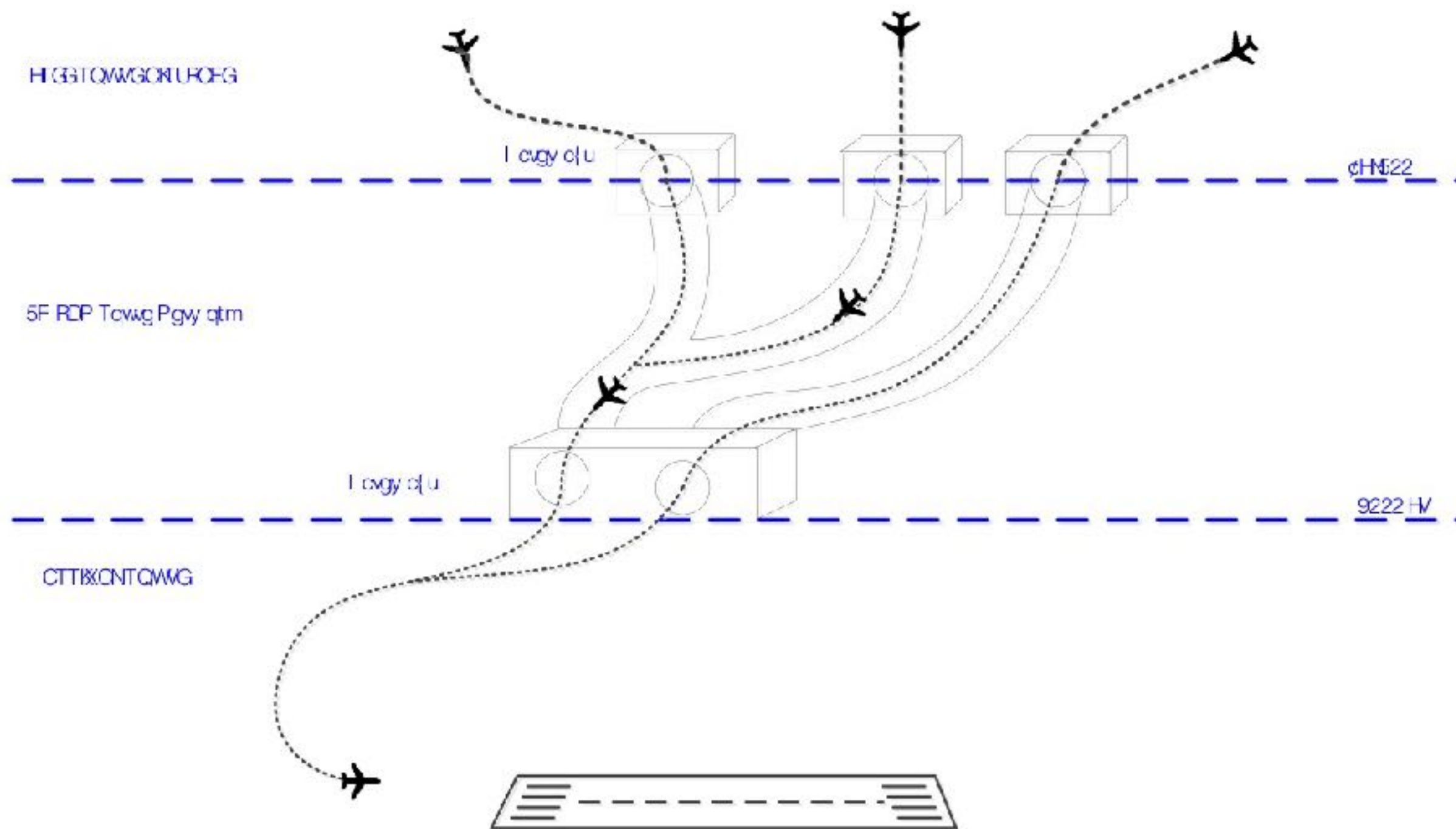
INTERNATIONAL CIVIL AVIATION ORGANIZATION



- 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

The moving ladders problem...

More Automation may make things worse
 - Transition could be more dangerous!

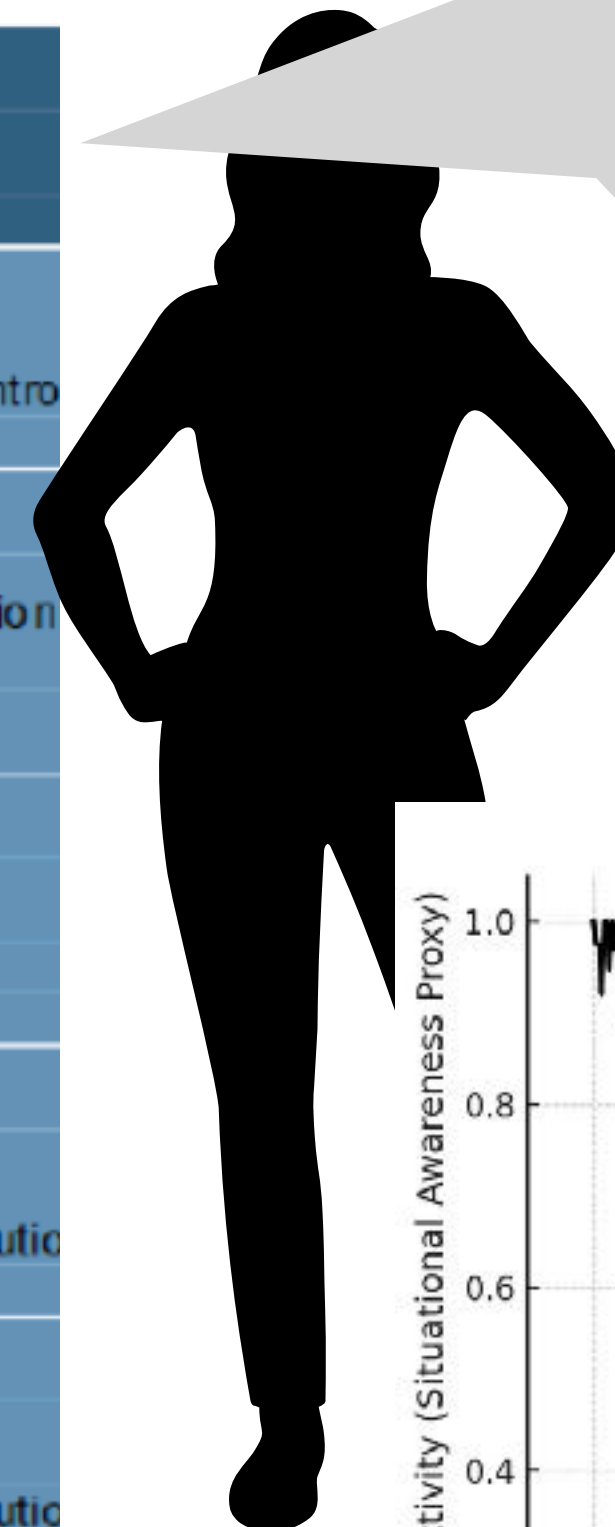


What does 'Automation' mean to Humans?

From information to action

Increasing automation

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

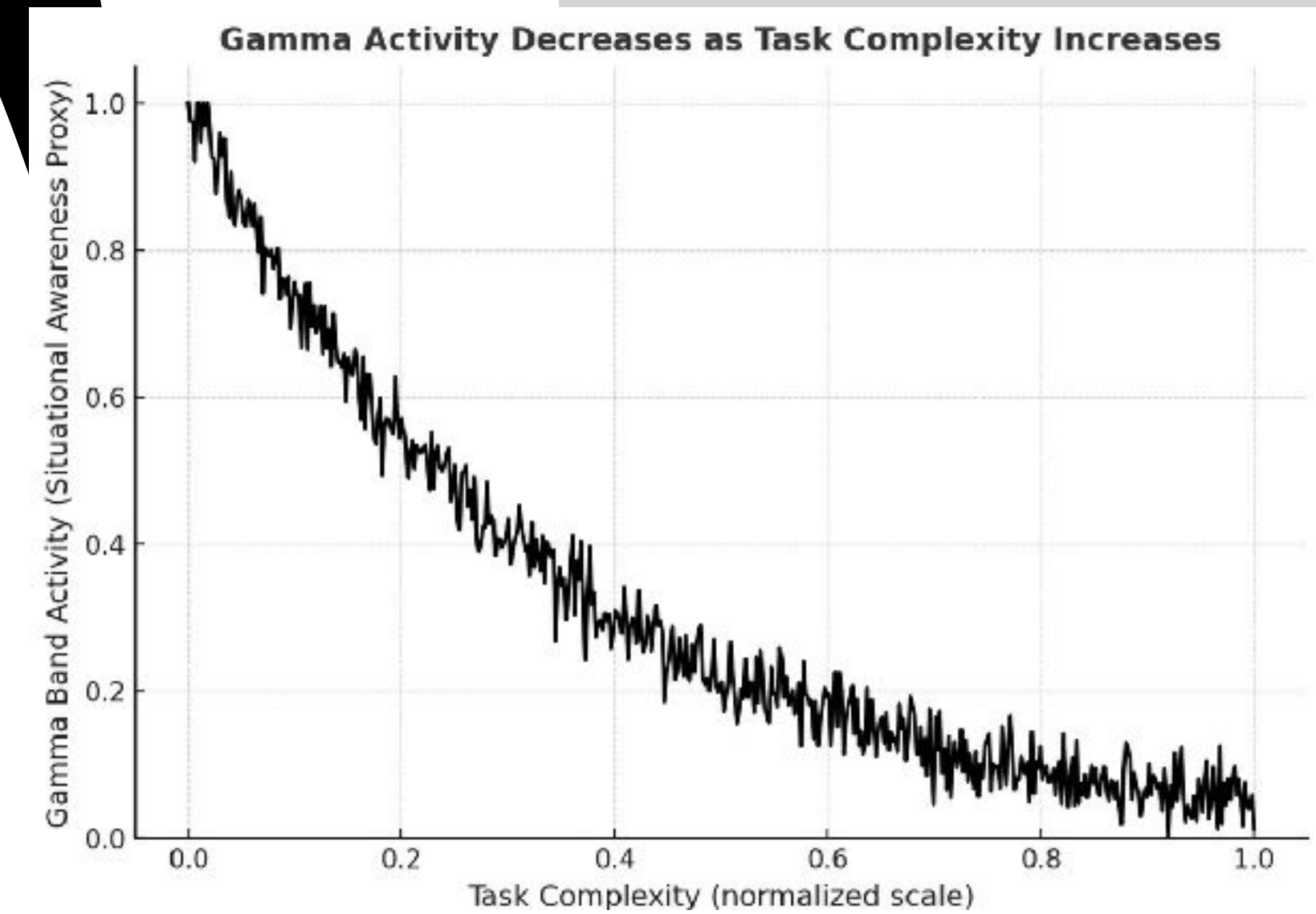


We are limited to "getting info in," "analysing that info," "making decisions with that info" and "doing something with it"

Increasing automation often decreases human performance...

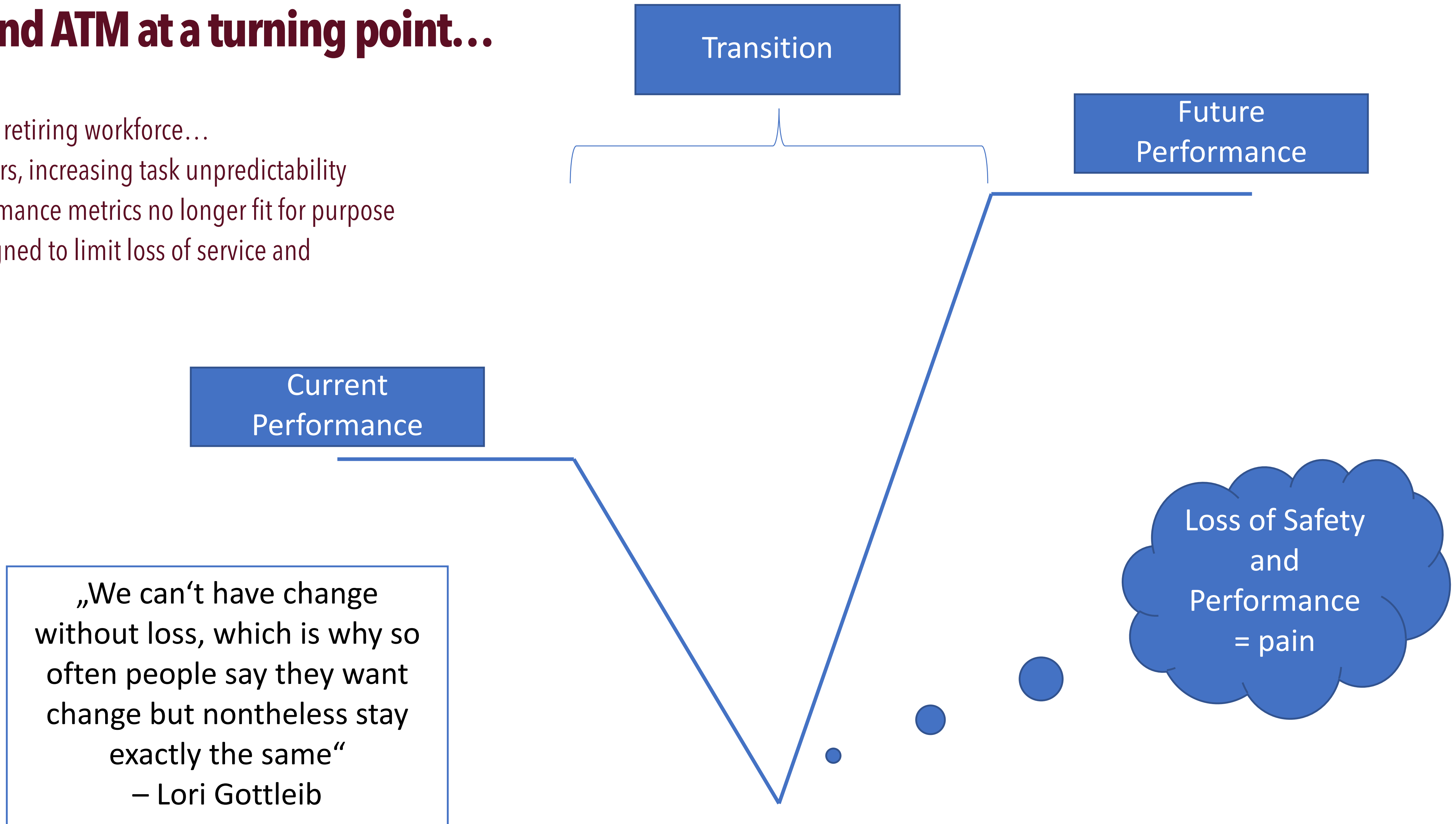
Bainbridge (1983) - On the Ironies of Automation

Endsley (2023) - On the Ironies of AI



Aviation and ATM at a turning point...

- 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



„We can't have change without loss, which is why so often people say they want change but nonetheless stay exactly the same“
 – Lori Gottlieb

Loss of Safety and Performance = pain

The trouble with licences..

Automation can remove capability while leaving liability behind.

- Safety-critical law requires a responsible agent.
- AI cannot be summoned, punished, or licensed.
- Growing mismatch between capability and accountability.

Machine cannot meaningfully bear responsibility.

- Manufacturers cannot absorb all operational liability.
- Operator organisations face residual risk.
- Licensed operators increasingly lack genuine control.



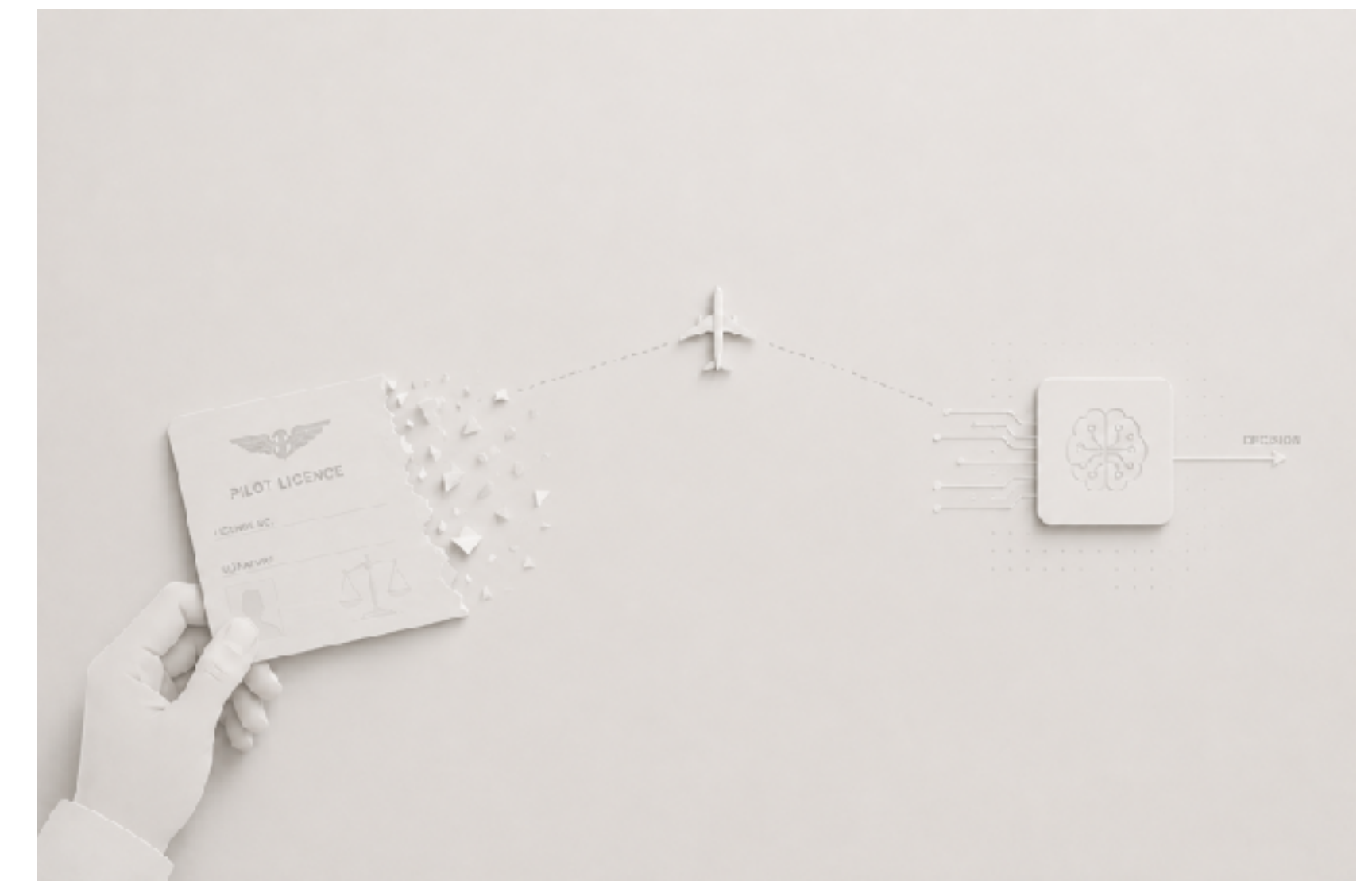
The Licence Fiction

Why artificial intelligence cannot lawfully replace the licensed operator



THE MOVING LADDERS
MAY 25, 2026

The law has no place to put the consequences of an act committed by a thing that cannot be summoned, that cannot be punished, that cannot stand in a courtroom, and that cannot, in any meaningful sense, have done otherwise.

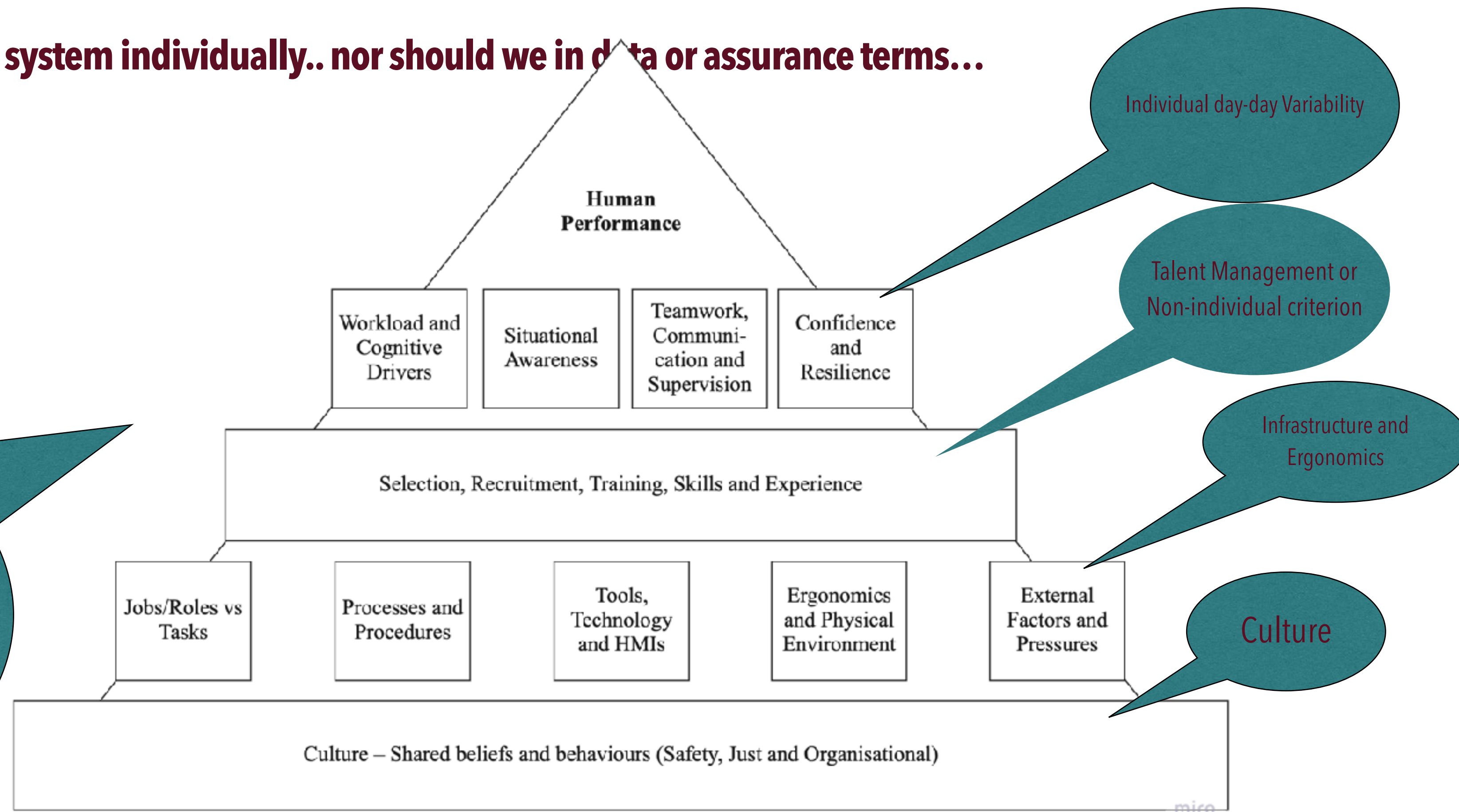


Re-imagining the concept of operations and assurance

ATCOs do not conceive of all the parts of their system individually.. nor should we in data or assurance terms...

- The concept of operations must evolve
- from a static network model to a dynamic, complexity based world

from task assignment to **'cognitive load orchestration'**



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

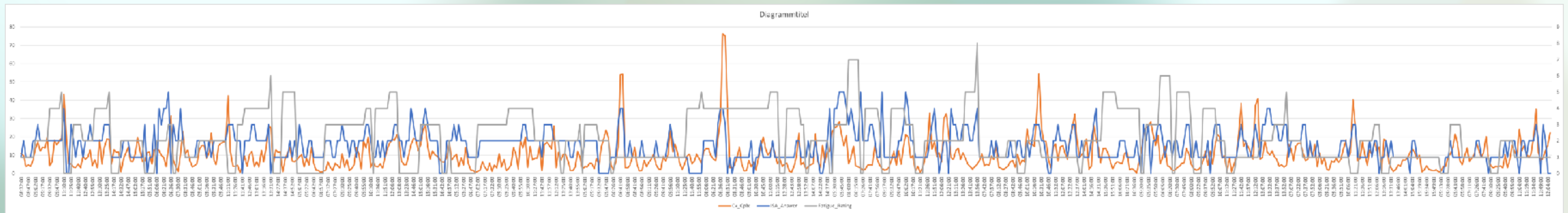
Redefining ATM Performance

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...



Developing Cumulative Cognitive Complexity

This new construct paves the way for understanding cognition in 4-dimensions with resultant, predictable outcomes...

What is CCC?

ACCUMULATION

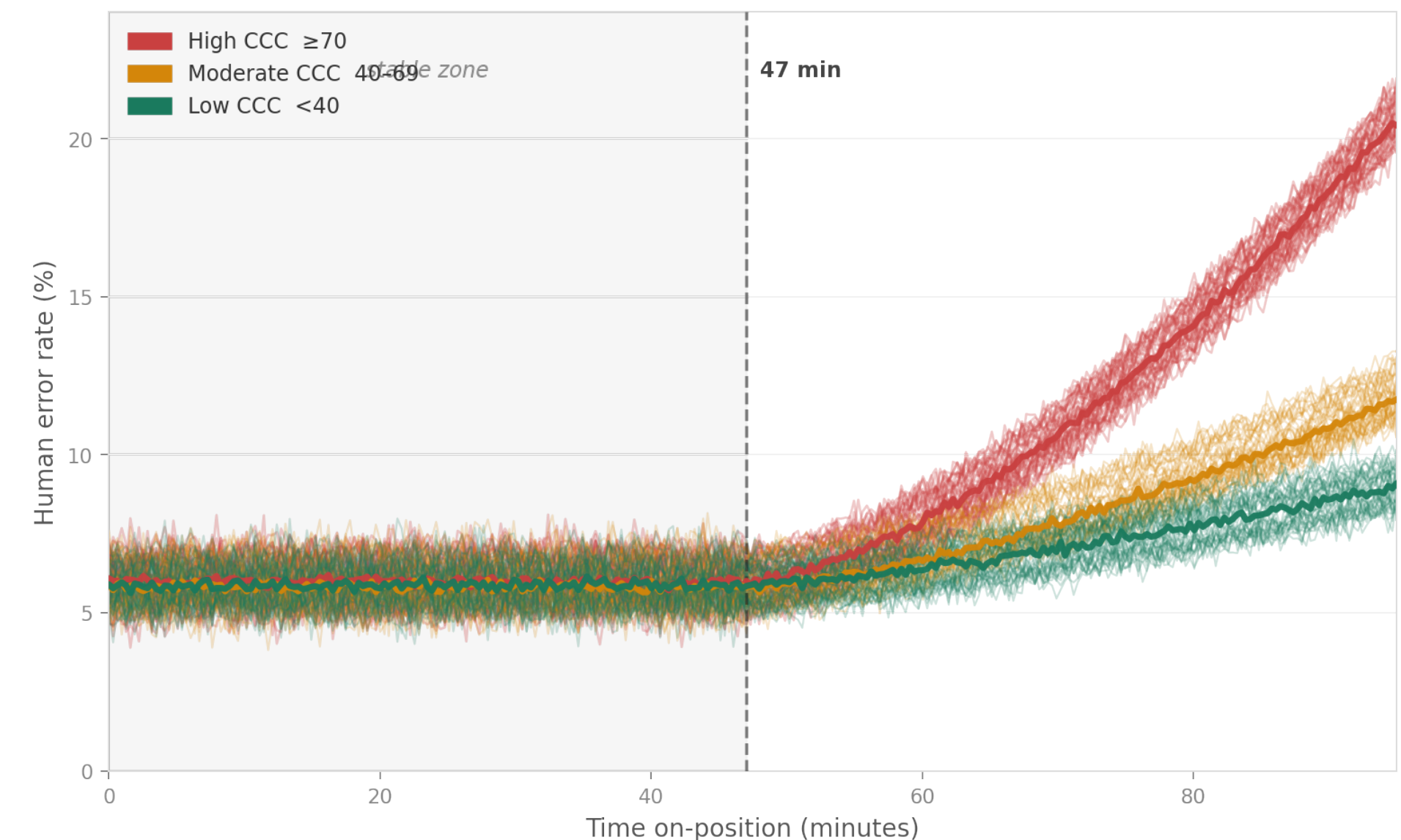
Task demand doesn't just hit you now — it builds. CCC tracks how complexity stacks up across your entire time on-position.

PARTIAL RECOVERY

Breaks help, but they don't fully reset the clock. CCC decays during breaks — slowly — reflecting real cognitive recovery.

TEMPORAL VULNERABILITY

The same airspace complexity hits differently at minute 10 vs minute 80. CCC captures that difference. Momentary workload cannot.



125 controllers · 3 CCC bands · bold lines show band medians

Cumulative Cognitive Complexity

Data-driven Human Performance prediction using real-time Task Complexity

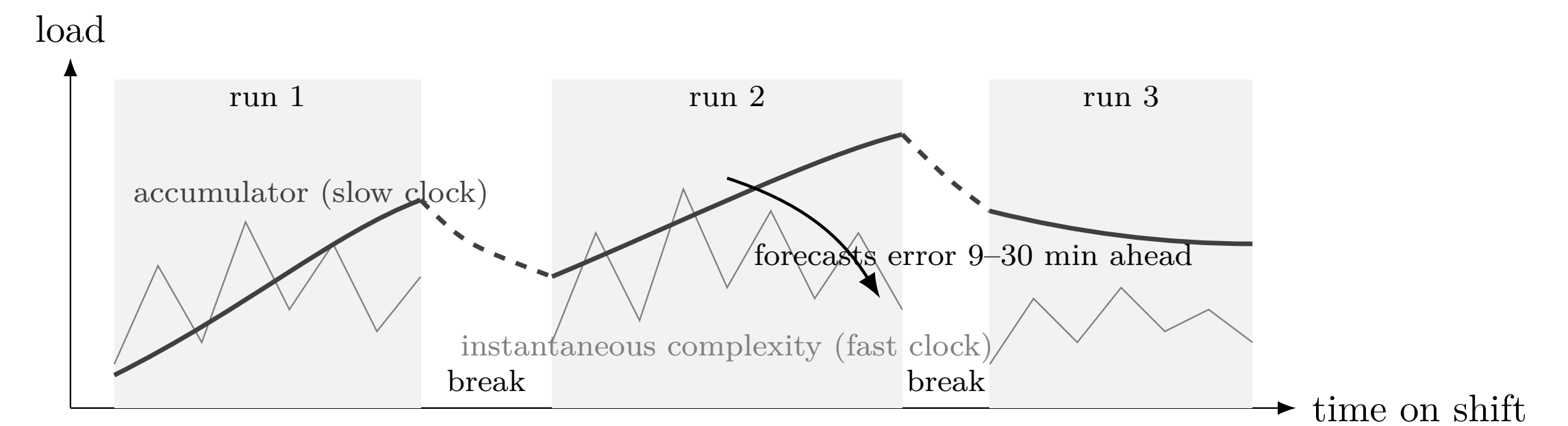
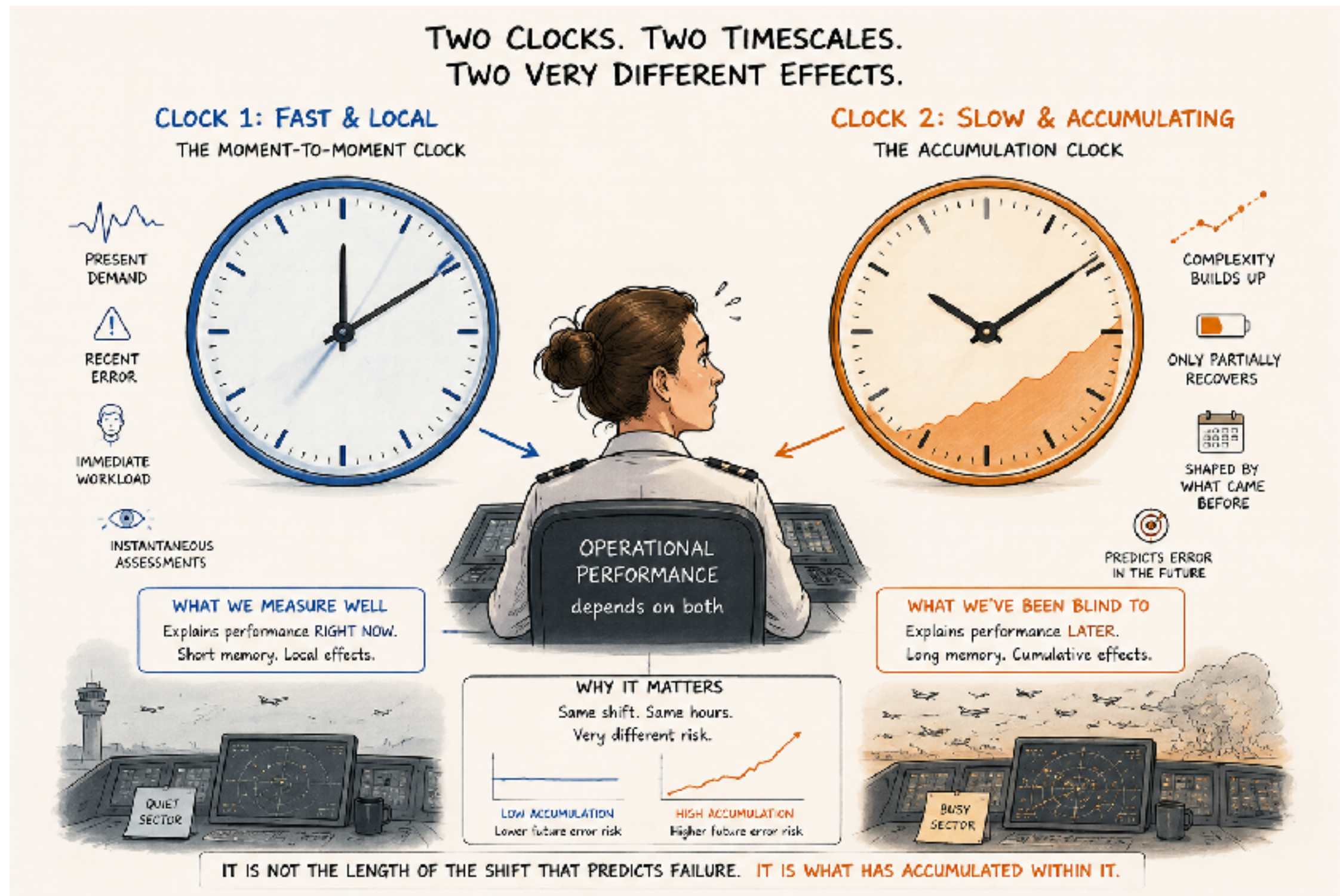
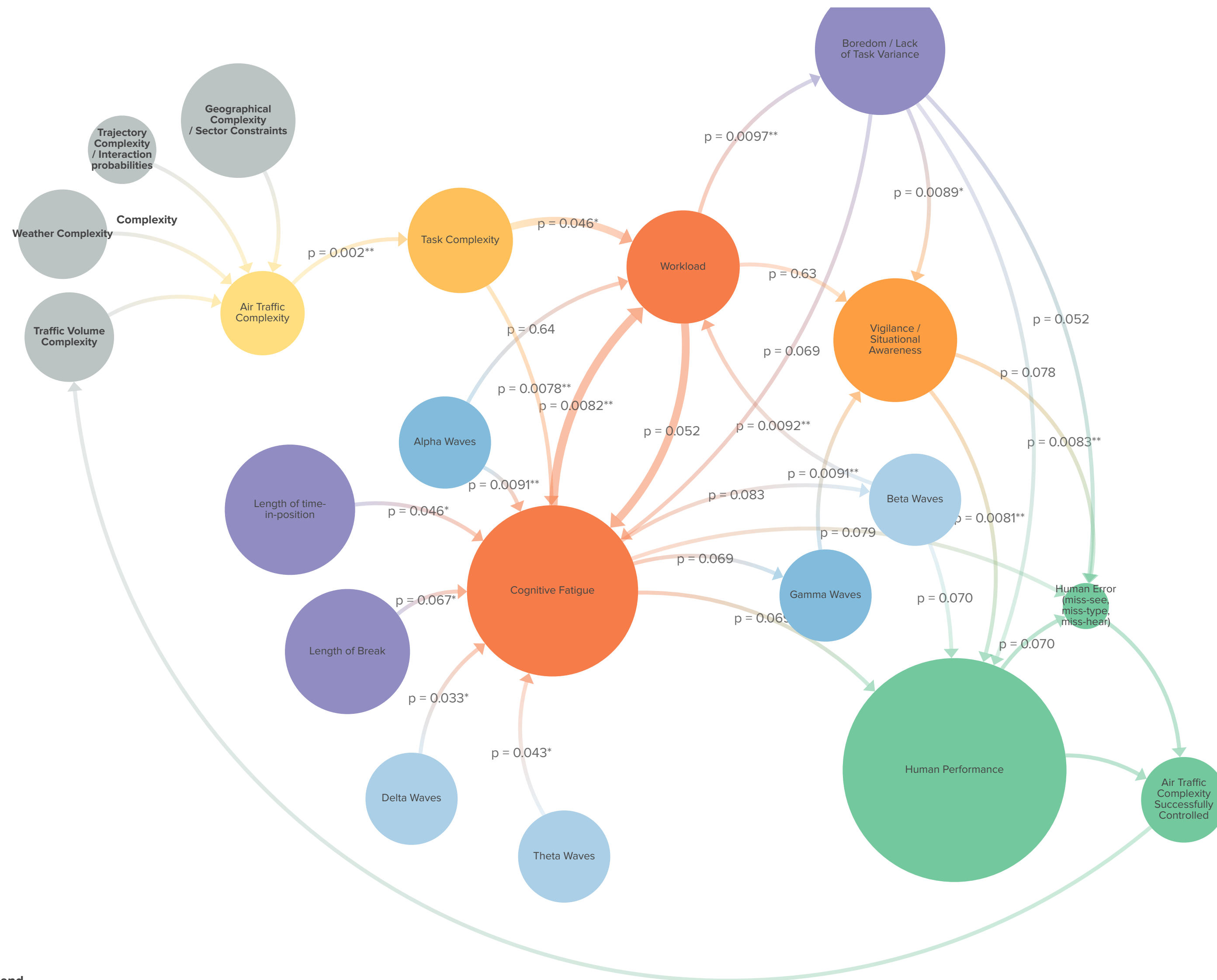


Figure 2

The two clocks. Instantaneous complexity (grey) is spiky and local; it is absorbed moment to moment. Cumulative Cognitive Complexity (navy) integrates that input with finite retention, building within a run and decaying only partially across a break, and it is this slow, accumulated quantity that forecasts operational error 9 to 30 minutes ahead (red). The partial, duration-dependent decay across breaks is the dashed segment.

The Synapses Model



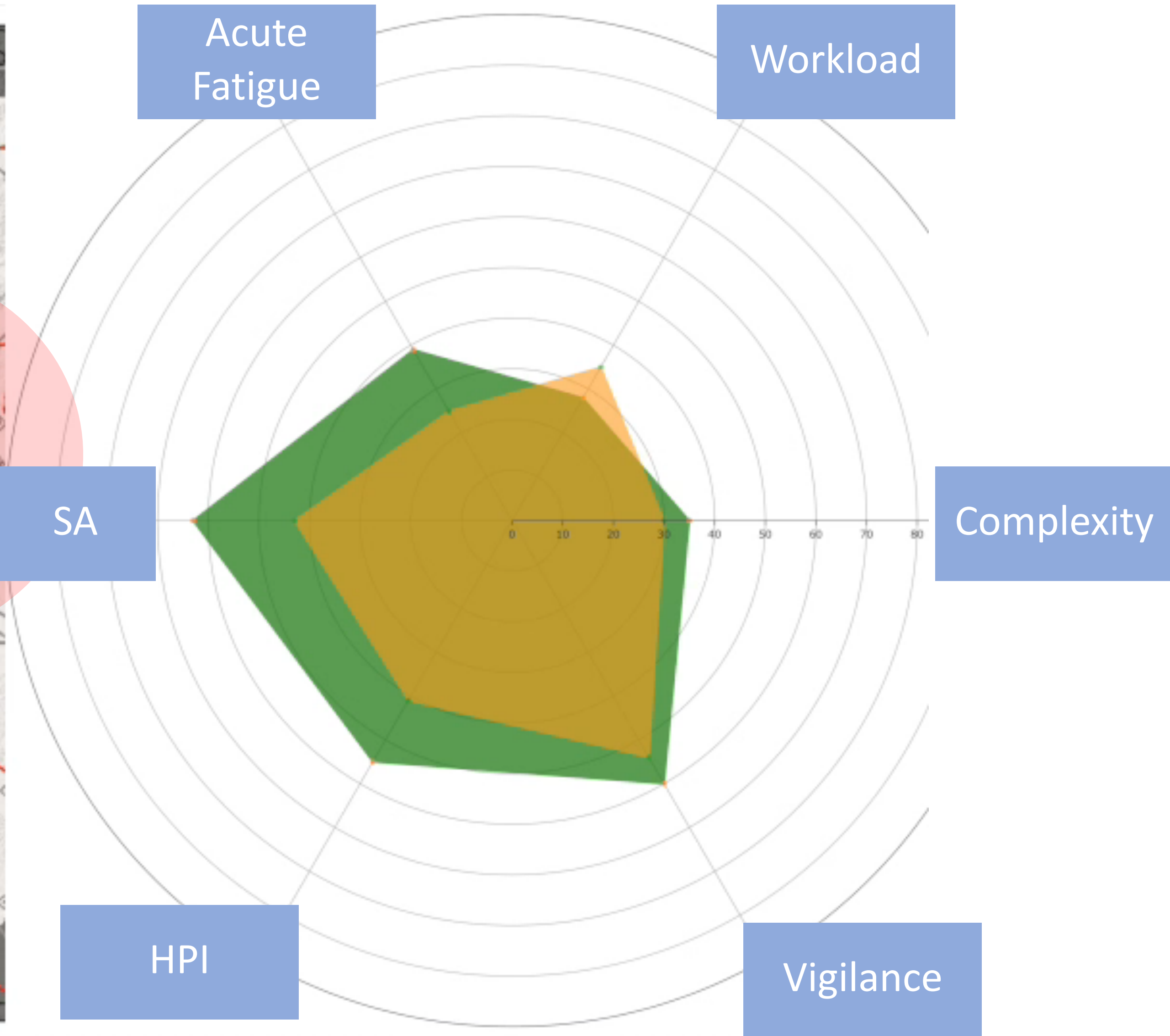
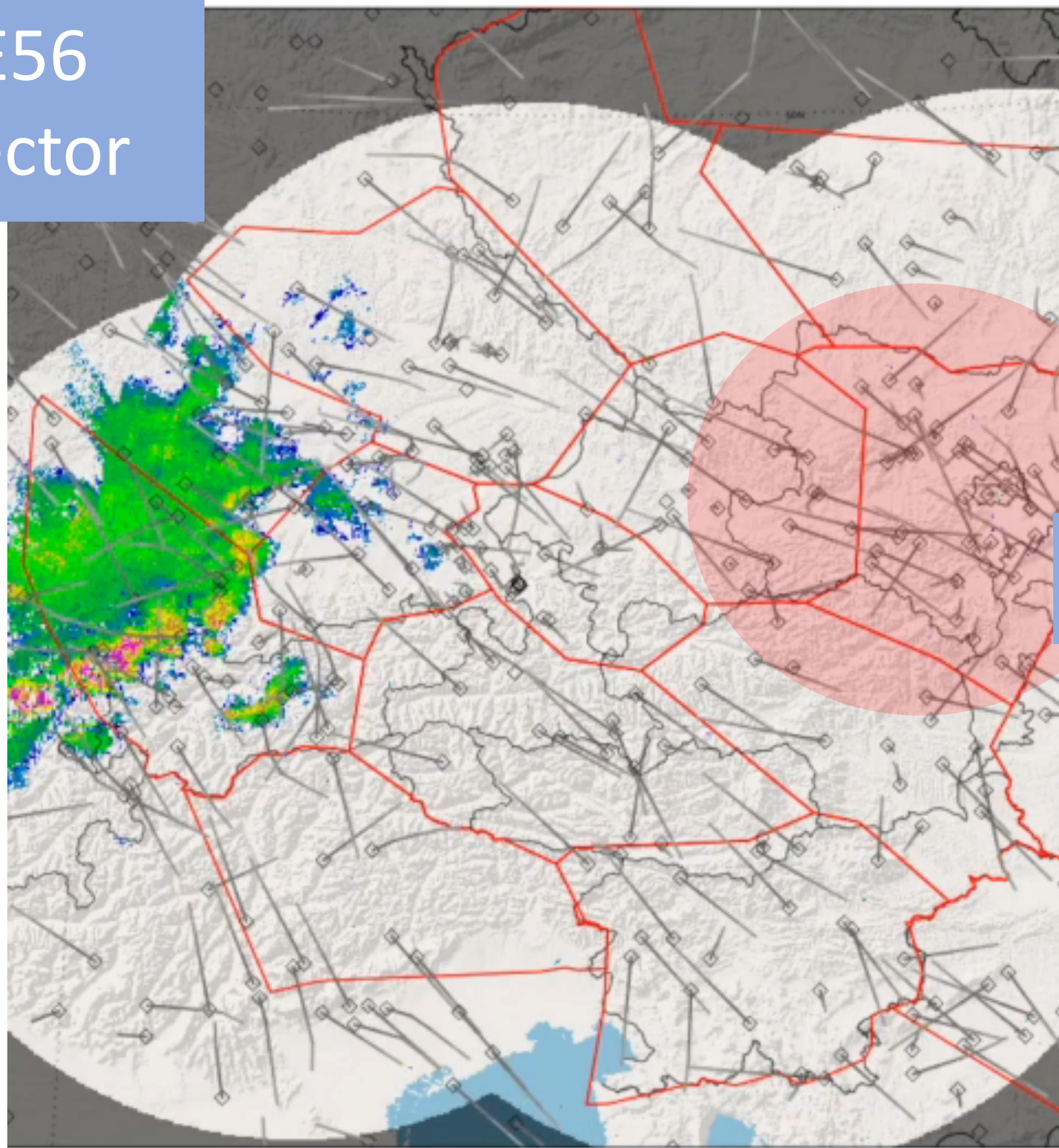
Our studies involving over 85 ATCOs (Roughly 45% of ACC ATCOs) over five studies found the following:

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

end
- Opposite

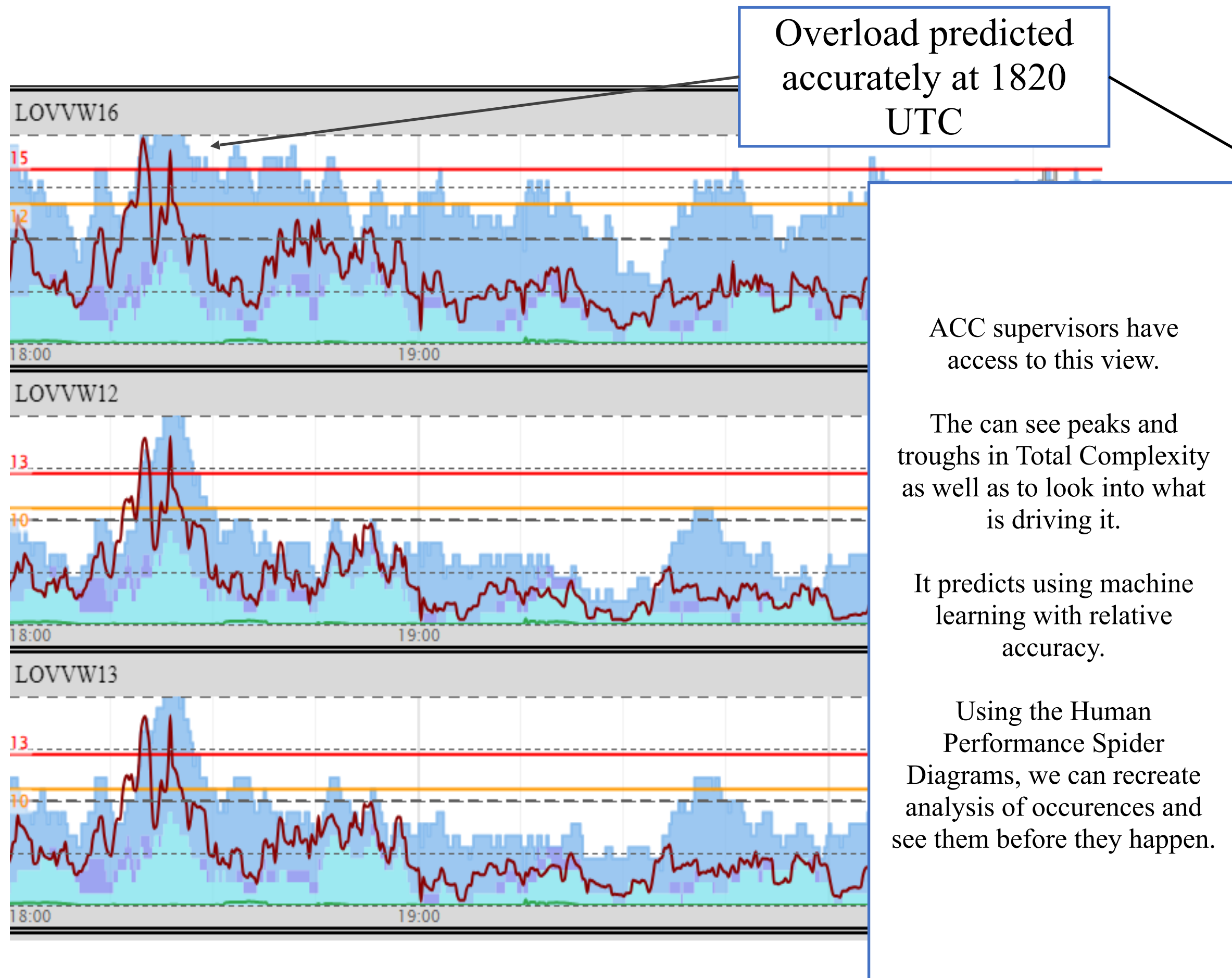
Tracking Cognitive Overloads

E56 Sector



2023_09_23 W2 Sector @ 1820 UTC

Predicting potential human error occurrences before they happening

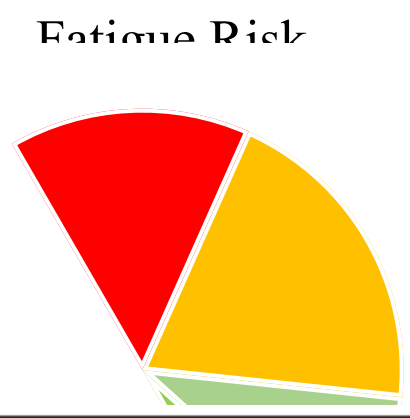
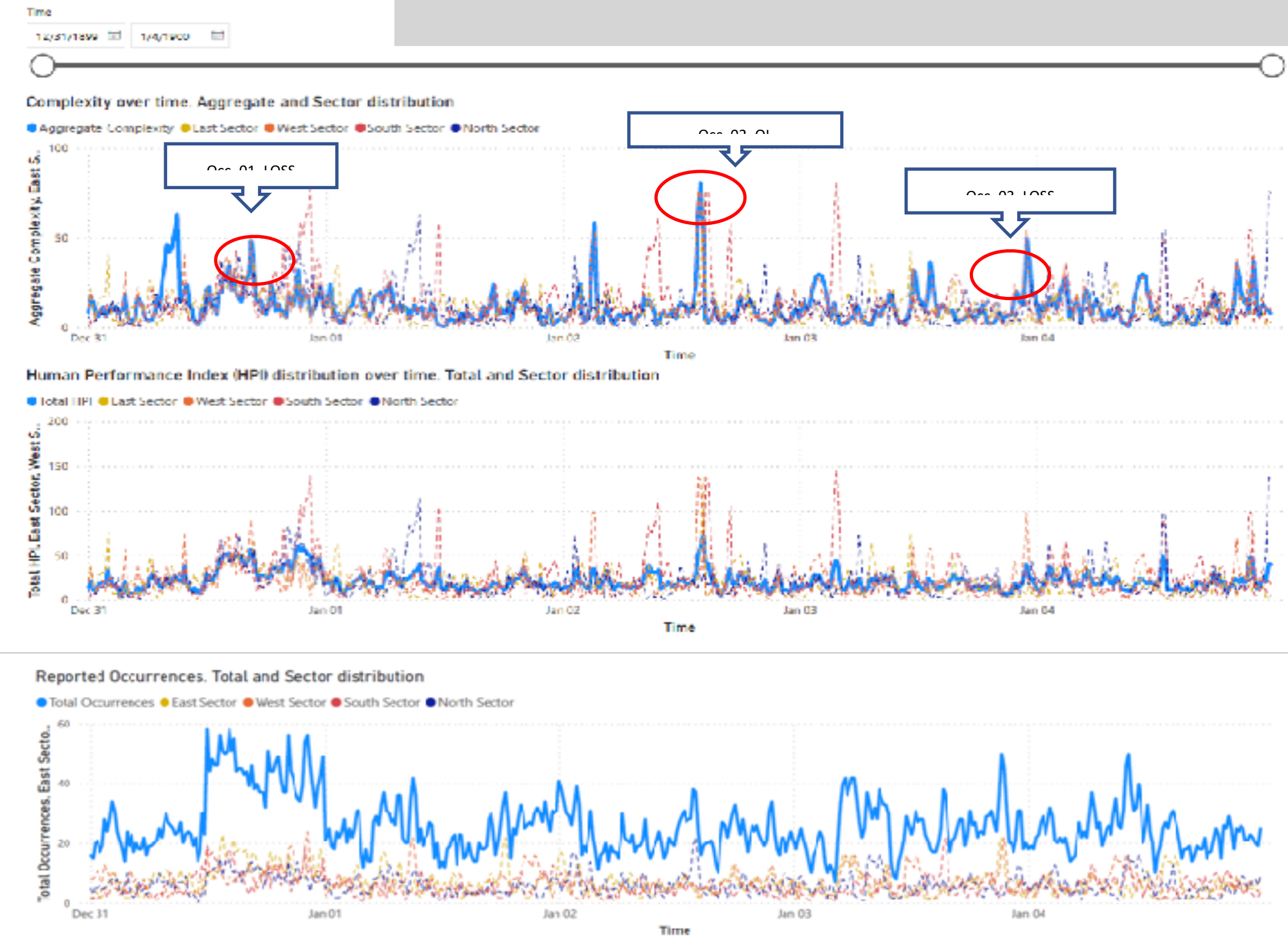


AI is the opportunity, Complexity is the key

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



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 Provision time vs minimum Breaks

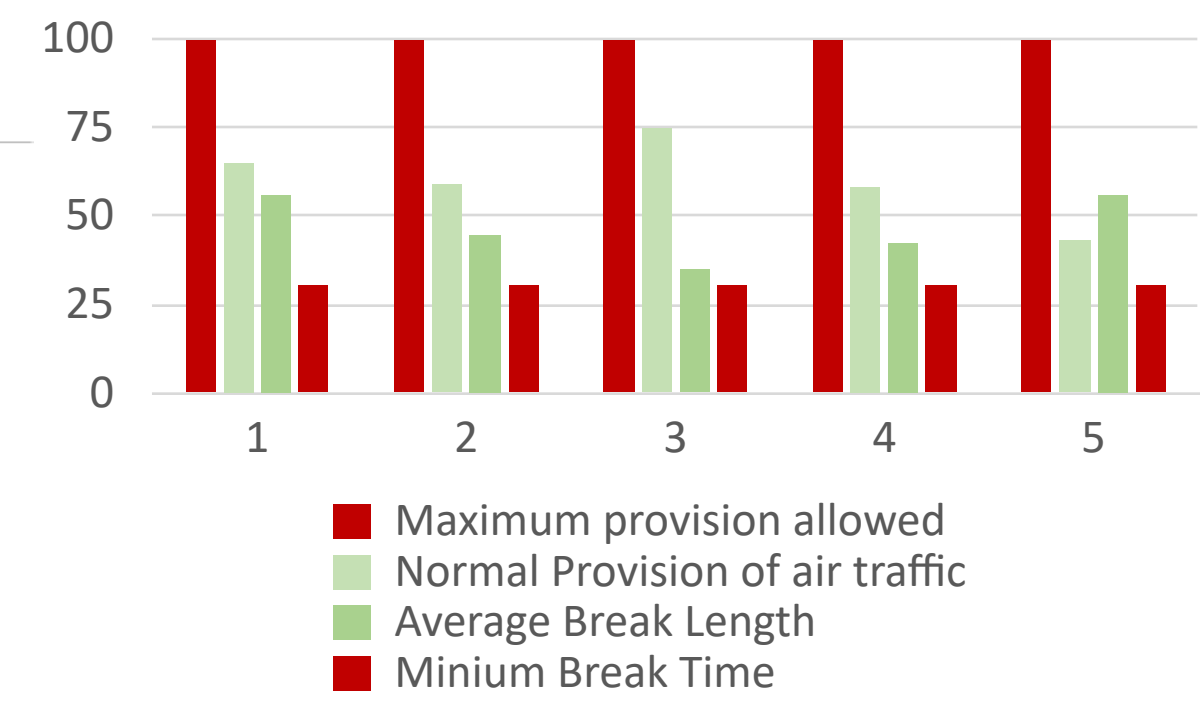
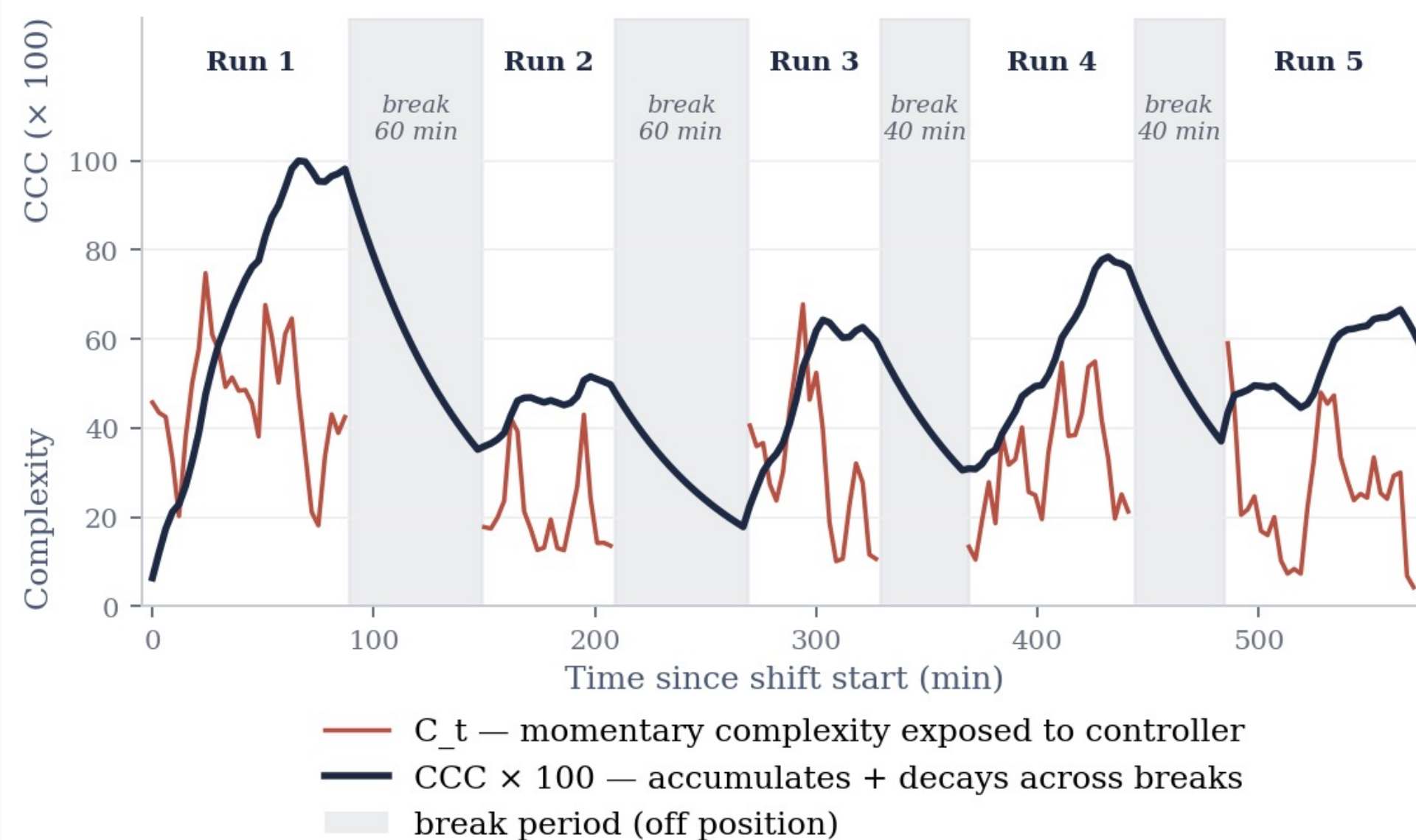


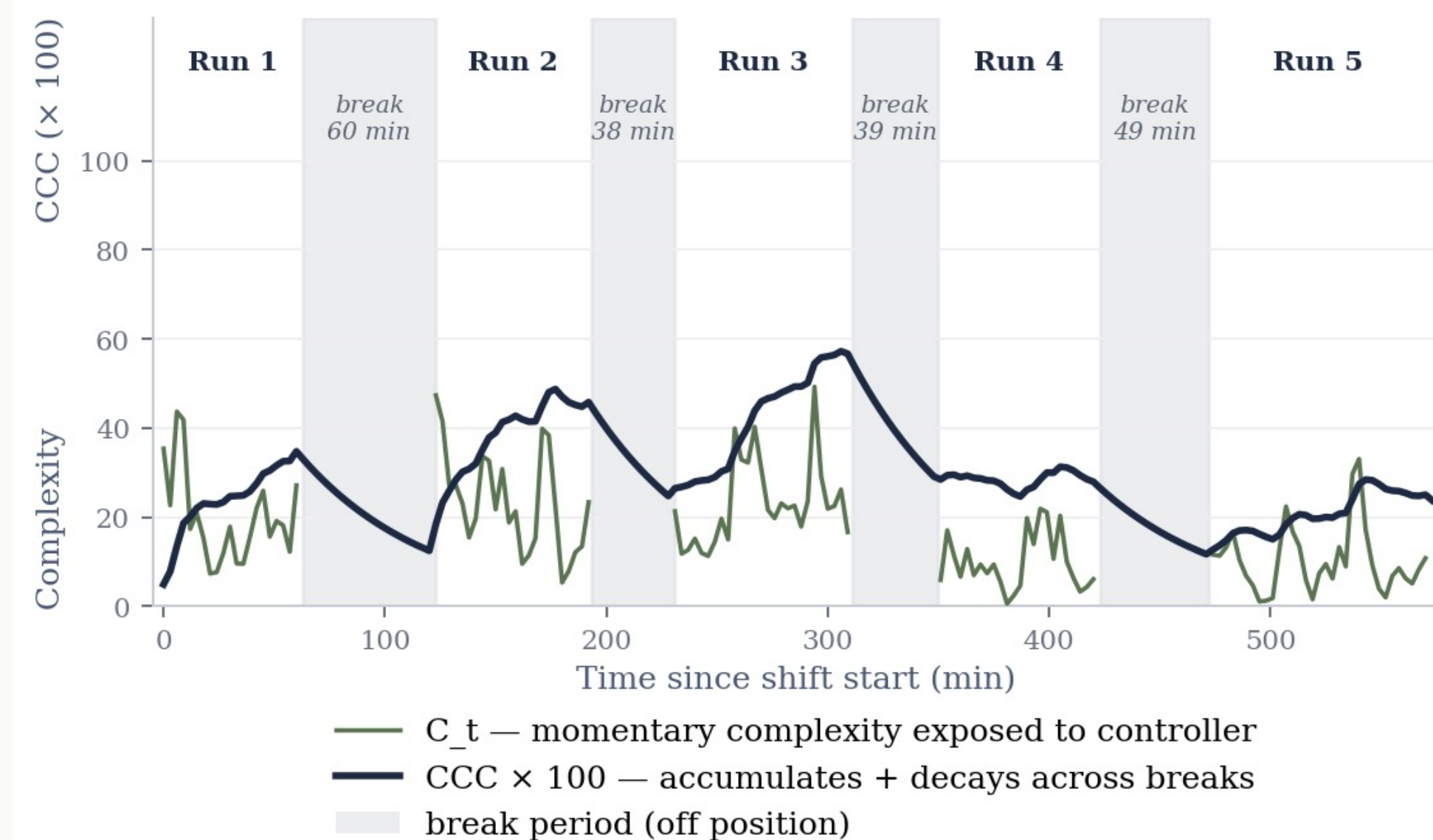
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Open html - visualise the data

[file:///Users/leavink/Desktop/Presentations/CCC research/LGA_risk_radar_v2_dynamic_boundary-2.html](file:///Users/leavink/Desktop/Presentations/CCC%20research/LGA_risk_radar_v2_dynamic_boundary-2.html)

Components:

1. Task (Air Traffic) Complexity Algorithm
2. Synapses Human Performance (CCC) Algorithm
3. Fatigue Risk Management Algorithm (and Rostering)
4. Post-Ops analysis link and algorithms (linked to outcomes)

Allowing us to look into other effects

This new construct paves the way for understanding cognition in 4-dimensions with resultant, predictable outcomes...



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Transportation Research Procedia 88 (2025) 81–88



ORIGINAL ARTICLE

Reaching for Distraction: Navigating Boredom and Monotony in High-Reliability Organisations

Lea Sophie Trampitsch-Vink^{a,b}, Sjir Uitdewilligen^c, Maximilian Peukert^d, and Florian Ott^e

^aAustro Control, Vienna, Austria; ^bJustMinds Institute, Vienna, Austria; ^cFaculty of Psychology and Neuroscience, Maastricht University, The Netherlands; ^dAir Navigation Services of Sweden (LFV), Malmö, Sweden; ^eTechnical University of Dresden, Dresden, Germany

ARTICLE HISTORY

Compiled May 11, 2026

ABSTRACT

High-reliability organisations depend on operators who remain cognitively prepared for rare, high-stakes events during long stretches of low demand, a paradox automation and artificial intelligence are sharpening across every safety-critical domain. This study examines how aviation professionals cope with boredom during operational tasks, and whether their chosen strategies carry consequences for safety. Mixed-methods analysis of 270 qualitative responses from a multinational survey of aviation professionals yielded an eight-category taxonomy of boredom experiences. Operators with the highest state boredom scores were significantly more likely to report digital distraction strategies (DUBS $M = 2.86$ vs. 2.54 , $p < .001$), consistent with distraction being recruited reactively rather than proactively. Coping strategies were consistent with distraction being recruited reactively rather than proactively, and one strengthened by the absence of any parallel trait-level coping strategies. Pilots reported social coping more often than Air Traffic Controllers (63% vs. 34%, $\chi^2 = 12.76$, $p < .001$), a difference explained by access to collegial interaction rather than disposition. Ninety-one per cent of respondents reported no formal organisational policy on boredom management, and 95.9% had received no dedicated training. The data reframe digital distraction as a probable safety signal of a high-risk boredom state, rather than a discipline failure, and provide significantly strengthened evidence that single-pilot and remote-tower configurations, by removing the colleague from the operational environment, simultaneously intensify the boredom condition and remove its most effective countermeasure.

KEYWORDS

aviation; air traffic control; boredom; monotony; coping strategies; high-reliability organisations; automation; underload; safety



Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 66 (2022) 201–213



34th Conference of the European Association for Aviation Psychology

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

Lea Sophie Vink^{a**}

^a Human Performance Lead, Austro Control, Schnirchgasse 17, 1030 Vienna

Abstract

The traditional approaches to classifying Human Error have provided a strong and beneficial approach to understanding the roles of humans in safety occurrences. However, as the demand for human performance has increased and with the rise of more automation, the line between man and machine continues to become increasingly blurred. Traditional Human Error analysis techniques are no longer sufficient for extracting the most valuable learning data from occurrences. Furthermore, there is a continuing need to strengthen Safety and Just culture. One means to achieving this is through developing ever greater trust in the ability of organisations to accurately investigate and report occurrences. This paper outlines a new 10 step approach to investigating human contribution to occurrences which is based on a version of predictive situational awareness in the brain that is derived from hierarchical predictive coding approaches. Utilising statistically based induction, the steps allow investigators to make an objective assessment of human error analysis and integrate it with traditional subjective feedback on conscious decisions. This approach that can provide further evidence to support the reconstructions is also discussed. This approach to human factors related occurrences in Air Traffic Control in 2021/2022 and the results are discussed. Using a refined approach and educating operators on the approach can significantly benefit Just Culture. The cost and frequency of reporting because it will allow for the removal of biases by individual operators. Focus on validating the approach against current methods and testing it for occurrences further to non-safety related decision making.

Investigations

Boredom

Abstract

In aviation, routine and quiet days often lead to boredom for operators, whose roles typically involve repetitive tasks despite training for high-pressure situations. This study explored the prevalence of job boredom and boredom proneness through an online survey of $N = 318$ aviation professionals, primarily Air Traffic Controllers and civil pilots, from over 25 countries. The survey consisted of quantitative and qualitative methods. Results indicate widespread boredom across all aviation professions. Male operators were significantly more likely to experience boredom than female colleagues. Operators working as on the job training instructor had less boredom proneness than colleagues not having this role. No significant differences for age, cultural background and job tenure were found. Most participants evaluated boredom as an unpleasant and negative state, impacting work. Moreover, participants linked boredom primarily to work environment and task characteristics. Boredom in aviation conditions and lack of human interaction were consistently rated as major factors for boredom.

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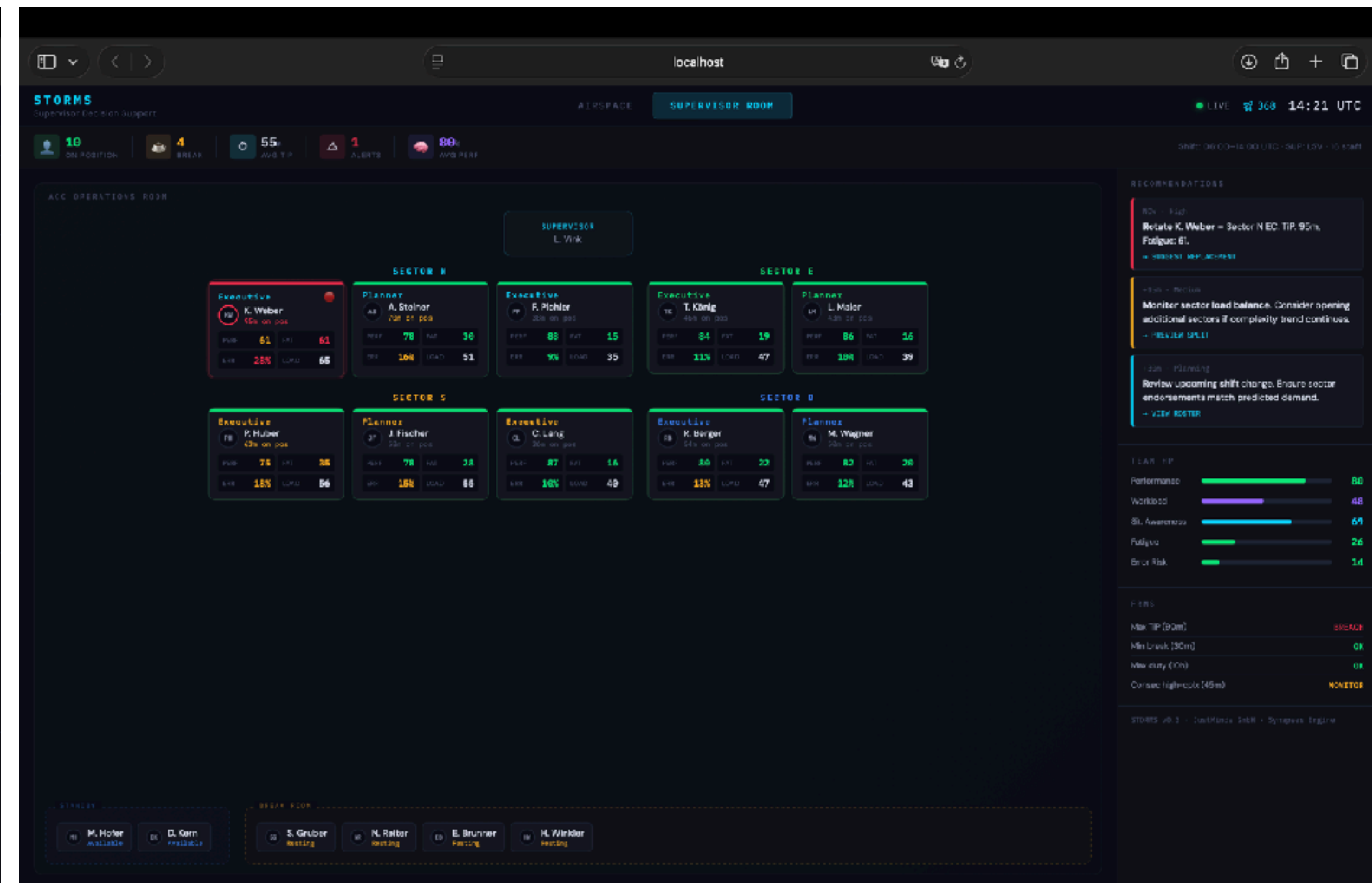
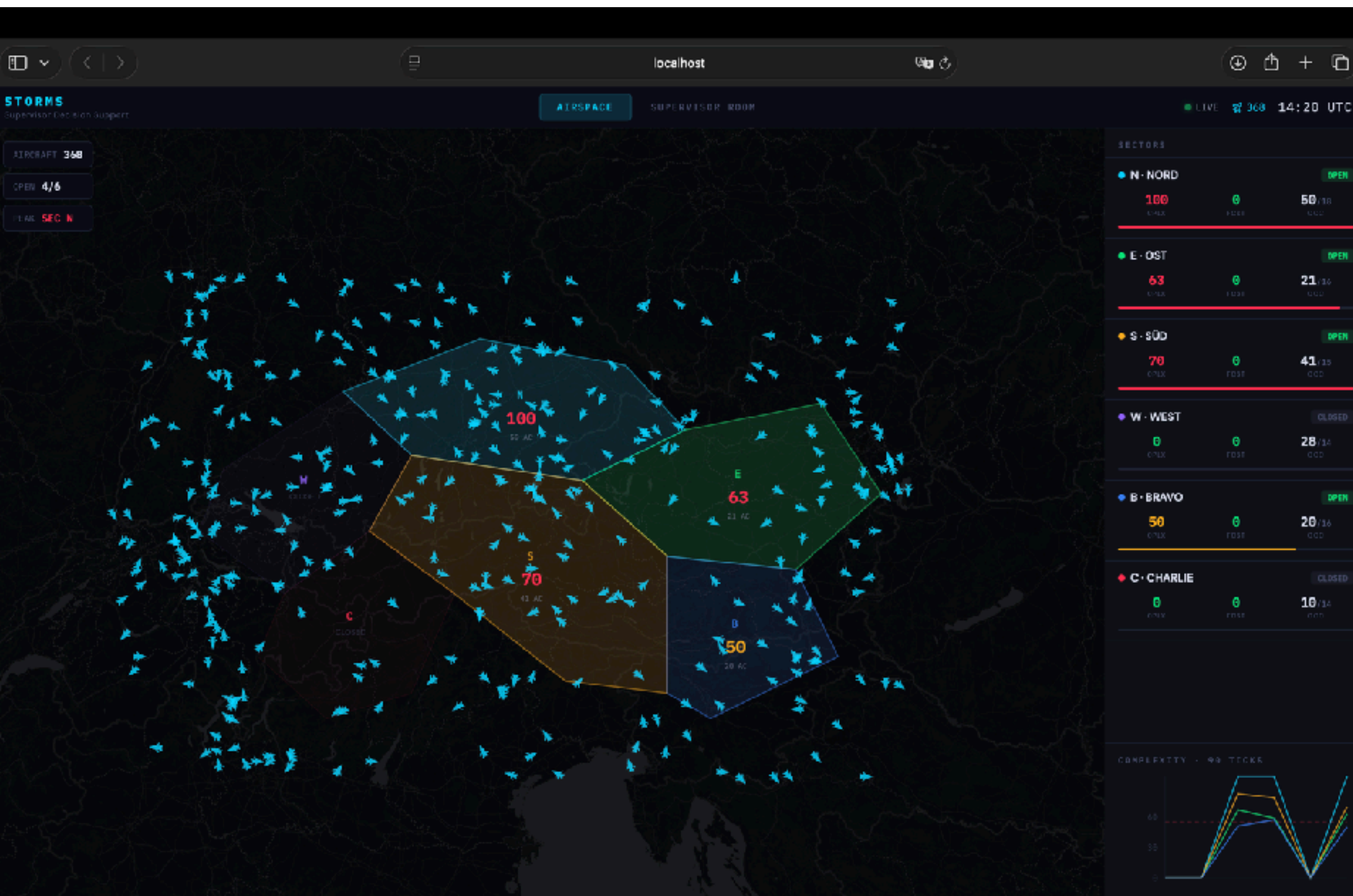
This is an open access article under the CC BY-NC-ND license (<https://creativecommons.org/licenses/by-nc-nd/4.0/>) Peer-review under responsibility of the scientific committee of the European Association for Aviation Psychology (EAAP) 35

Keywords: Aviation; Air Traffic Control; Pilot; Boredom; Monotony

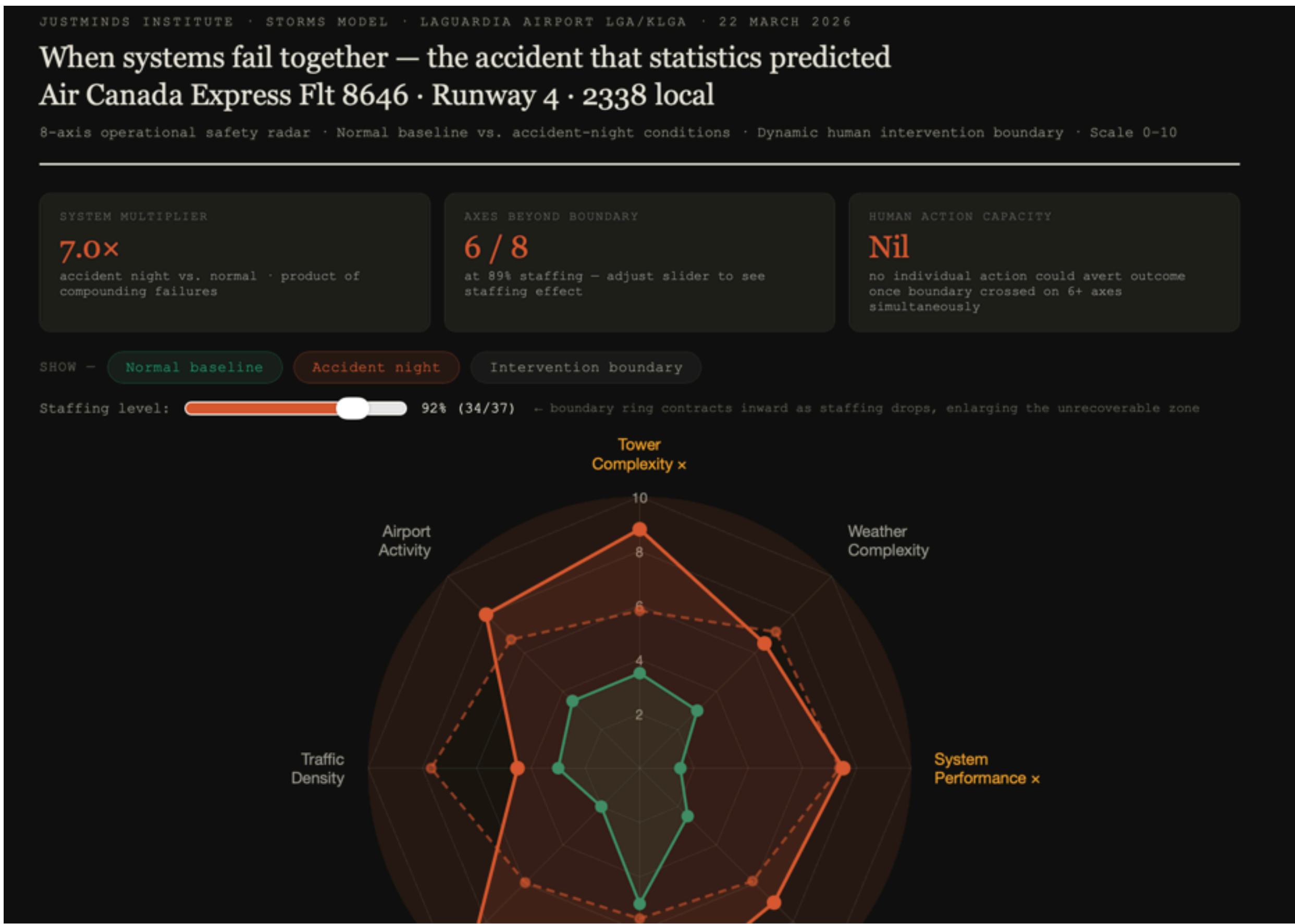
1. Introduction

Aviation professionals are trained to handle critical situations under high workload, but an often-overlooked hazard in routine situations is boredom. The prevalence and triggers of boredom in aviation are largely unknown.

What can we do with this? - STORMS



What can we do with this?



EN

DE

FR

ES

PT

just  minds

JustMinds Human Factors Field Toolkit

Measure what matters in the field.

Single Test

Run once and see your results immediately.

My Study

Track your performance across multiple sessions on this device.

Research Study

Configure a study for multiple participants with QR code access.

Build Your Battery

Available now

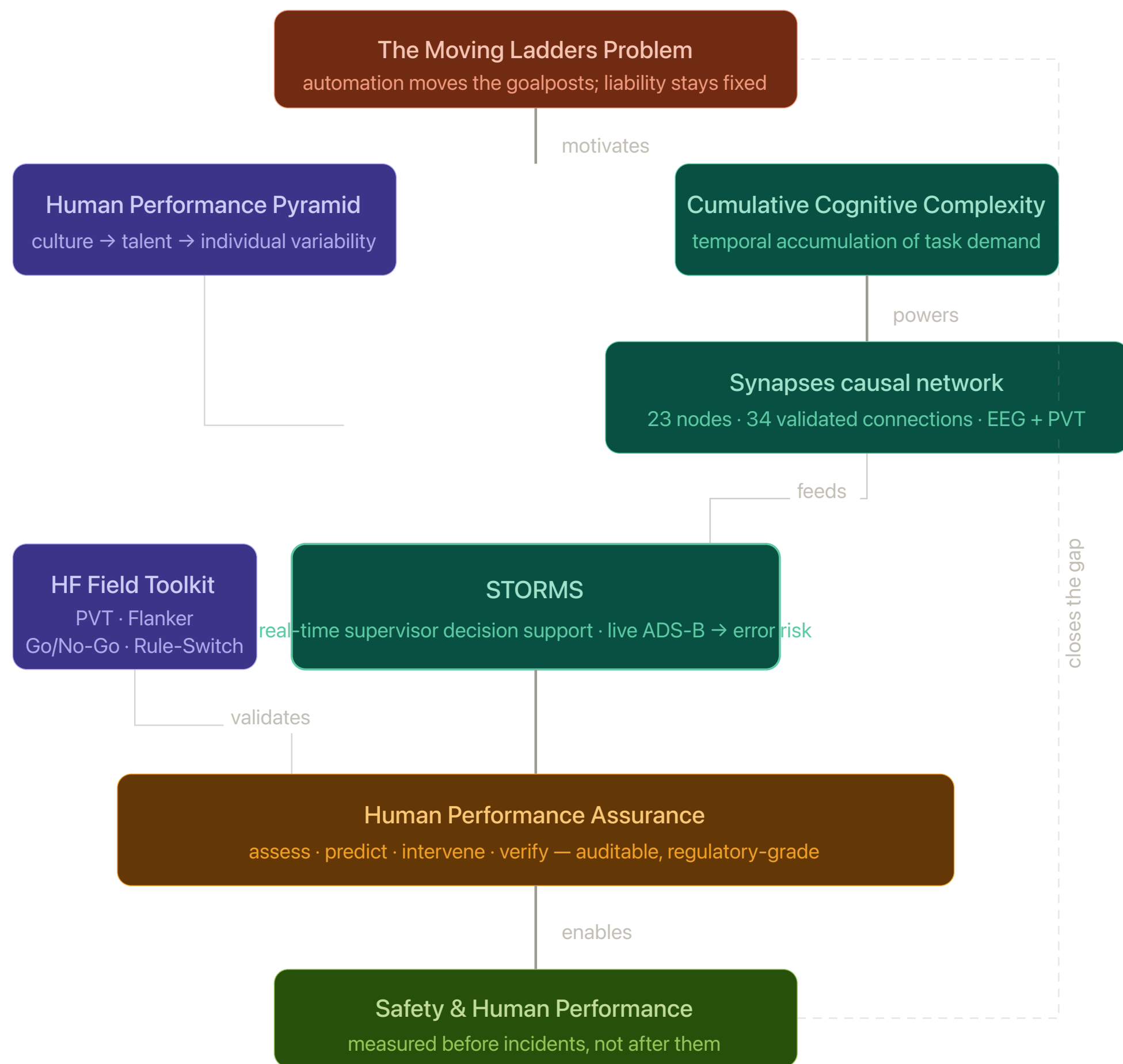
Fatigue Risk Battery

Five validated tasks — PVT, Flanker, Go/No-Go, Rule Switch, and subjective ratings — producing a two-dimensional Fatigue Risk Score and visual risk map across Speed & Alertness and Control & Stability. 10 min

Sustained Attention & Context Tracking

Two validated tasks — a context monitoring paradigm and the SART sustained attention test — producing an Attention & Context Index as a behavioural proxy for situational awareness components. 8 min

New approaches for HF Assurance



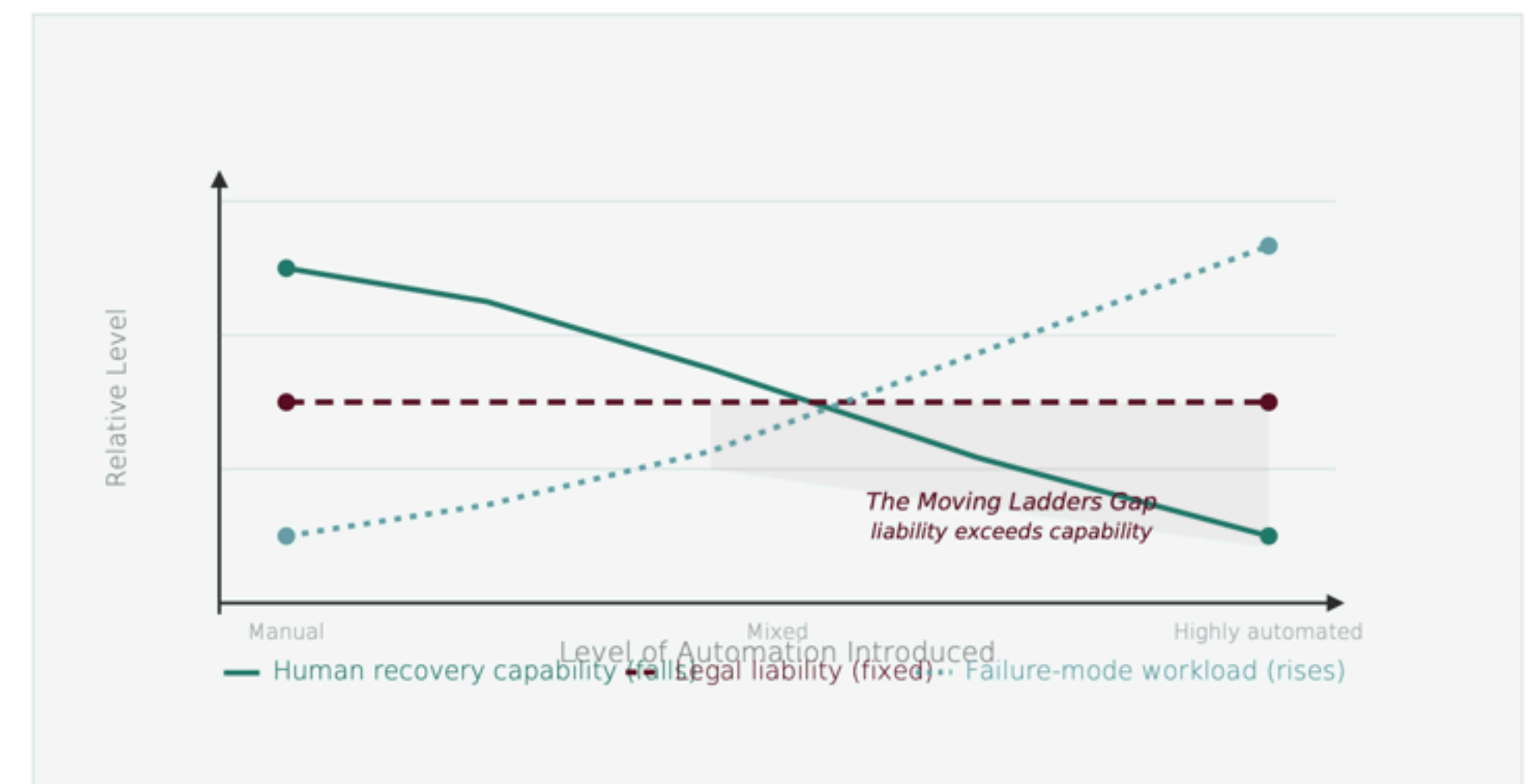
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The Moving Ladders Problem

Lea Trampitsch-Vink · JustMinds Institute, Vienna · July 2025 · Deputy Chair, EC Expert Group · Human Dimension in Aviation

*“The ladders of life that we scale merrily
Move mysteriously around
So that when you think you’re climbing up, man
In fact you’re climbing down.”*
— NICK CAVE

The Paradox Visualised



The Moving Ladders Paradox — as automation increases, human capability to recover from failure falls and failure-mode workload rises, while legal liability remains anchored to the human operator. © JustMinds 2025

Conclusions

The question is not "how much automation should we add?" It is "what are we taking away from the human, and have we measured the gap?"

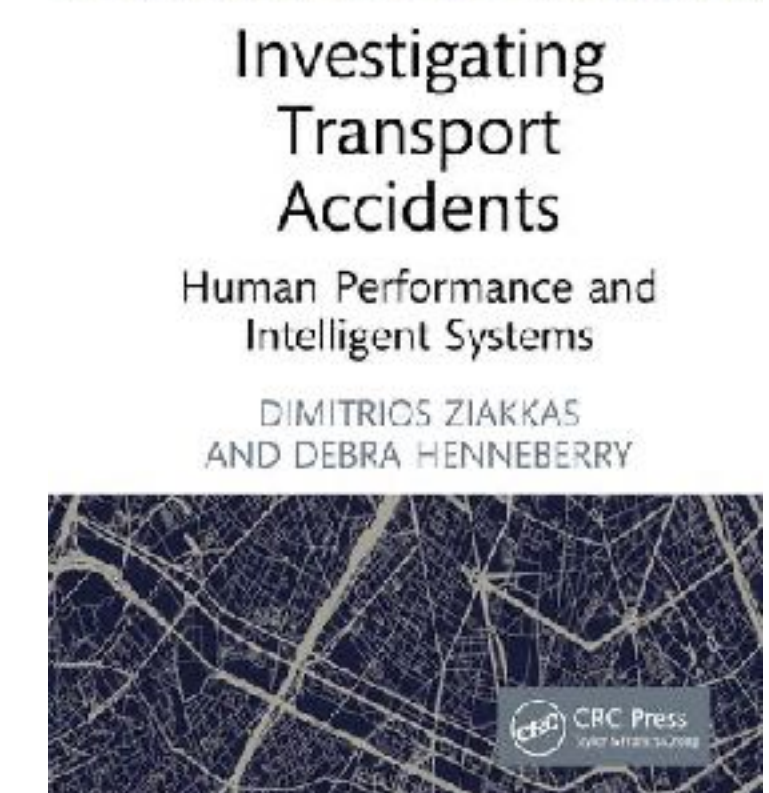
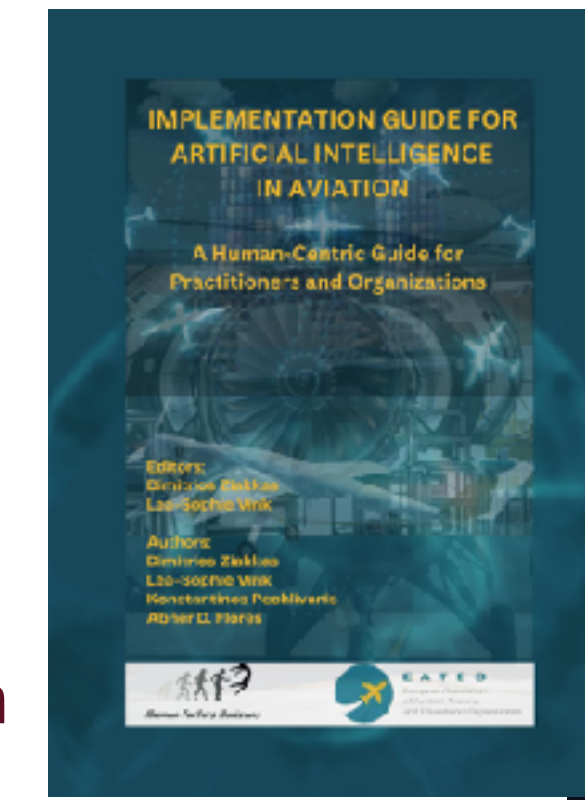
1. Every automation and design decision is simultaneously a human performance decision. Embraer makes both, whether it intends to or not.
2. The Moving Ladders Problem is not a training issue. It is a design issue, a certification issue, and under EU Regulation 2024/2853, increasingly a liability issue.
3. Human performance is measurable, predictable, and manageable in real time. We have proven this with 85 controllers across five studies. The same logic applies to every cockpit you build.
4. CCC and STORMS exist because we stopped asking "how tired is this operator?" and started asking "how much cognitive demand has this system imposed on this human, and what happens next?" That question belongs in your design process.
5. The organisations that will lead the next decade of aviation are not the ones that automate the most. They are the ones that automate with the clearest understanding of what the human can still do, and must still do, when the automation reaches its limit.

“THE MOST DANGEROUS MOMENT IN ANY AUTOMATED SYSTEM IS NOT WHEN IT FAILS. IT IS WHEN IT HAS BEEN WORKING SO WELL, FOR SO LONG, THAT NOBODY IN THE COCKPIT REMEMBERS HOW TO TAKE OVER.”

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.
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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.
6. Vink, L. S. (2024a). *The development and deployment of future integrated neuropsychological support for operations: The case for and definition of 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.
8. *EASA AI Roadmap Version 3.0 (2025)*
9. Vink, L.S. & Uitdewiligen, S. (2026). Validating a Dynamic Task Complexity Tool: Predicting Human Performance in High-reliability Organisations. *Journal of Experimental Psychology: Applied*. (Submitted manuscript)



Thank you + Contact

Dr. Lea Sophie Trampitsch-Vink ([LinkedIn](#))
Clinical and IO Psychologist & Human Factors Specialist
Cognitive Neuroscientist

Substack: <https://substack.com/@themovingladders> (Moving
Ladders Problem + Licence Fiction)

lea.trampitsch-vink@justminds.at (for business inquiries)

Website: www.justminds.at

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