Supporting European Aviation

Safety Management at EUROCONTROL

Stories of AI and BI

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FOUNDING MEMBER SESAR JOINT UNDERTAKING

NETWORK MANAGER

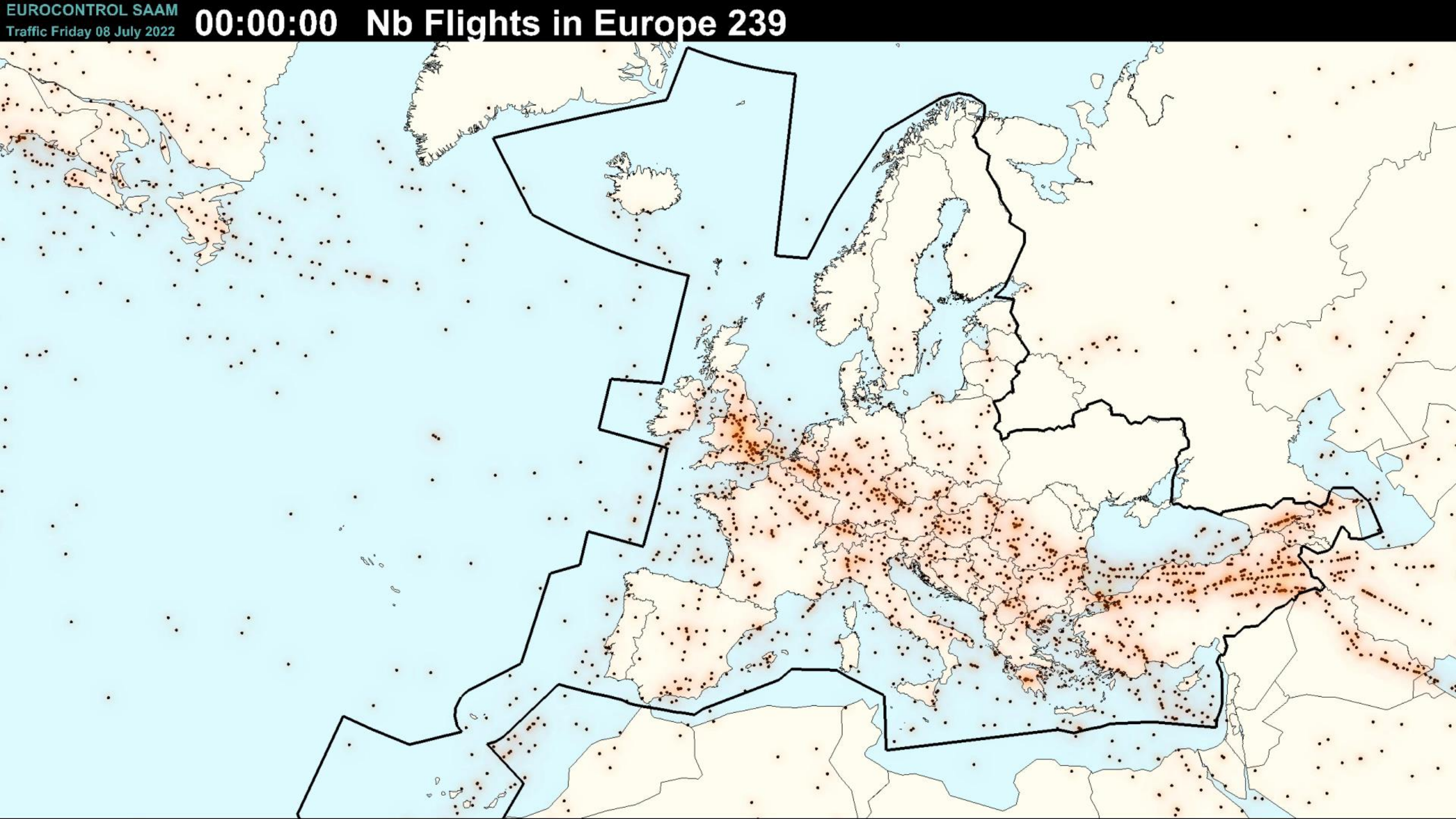
AGENDA

- Who we are
- Why AI and BI
- Toolkit for ATM investigation **(eTOKAI)**
- Structured Exploration of Complex Adaptations **(SECA)**
- Final Thoughts

ABOUT EUROCONTROL

Since 1963, EUROCONTROL is the **pan-European Organization for the safety of air navigation**

- 41 + 2 Member States, including 26 of EU
- 90+ Air Navigation Service Providers
- 5000+ users for B2B services
- 6600+ airlines
- 525 airports
- 4 sites in Belgium, France, Luxembourg, the Netherlands
- 865€ million budget


EUROCONTROL SAAM
Traffic Friday 08 July 2022
00:00:00 Nb Flights in Europe 239

ABOUT SAPIENZA UNIVERSITY

Sapienza was established in 1303 and it currently accounts for over 100.000 students.

The Sapienza **Department of Mechanical and Aerospace Engineering** provides:

- 2 BSc programmes
- 3 MSc programmes
- 5 Post-graduate courses
- 3 PhD programmes

The division of **Industrial Systems Engineering** has experience on:

- socio-technical systems modelling
- AI/BI engineering applications
- operations management
- tech dev through dept spinoff **aiComply**

EUROCONTROL SAFETY MANAGEMENT TOOLS

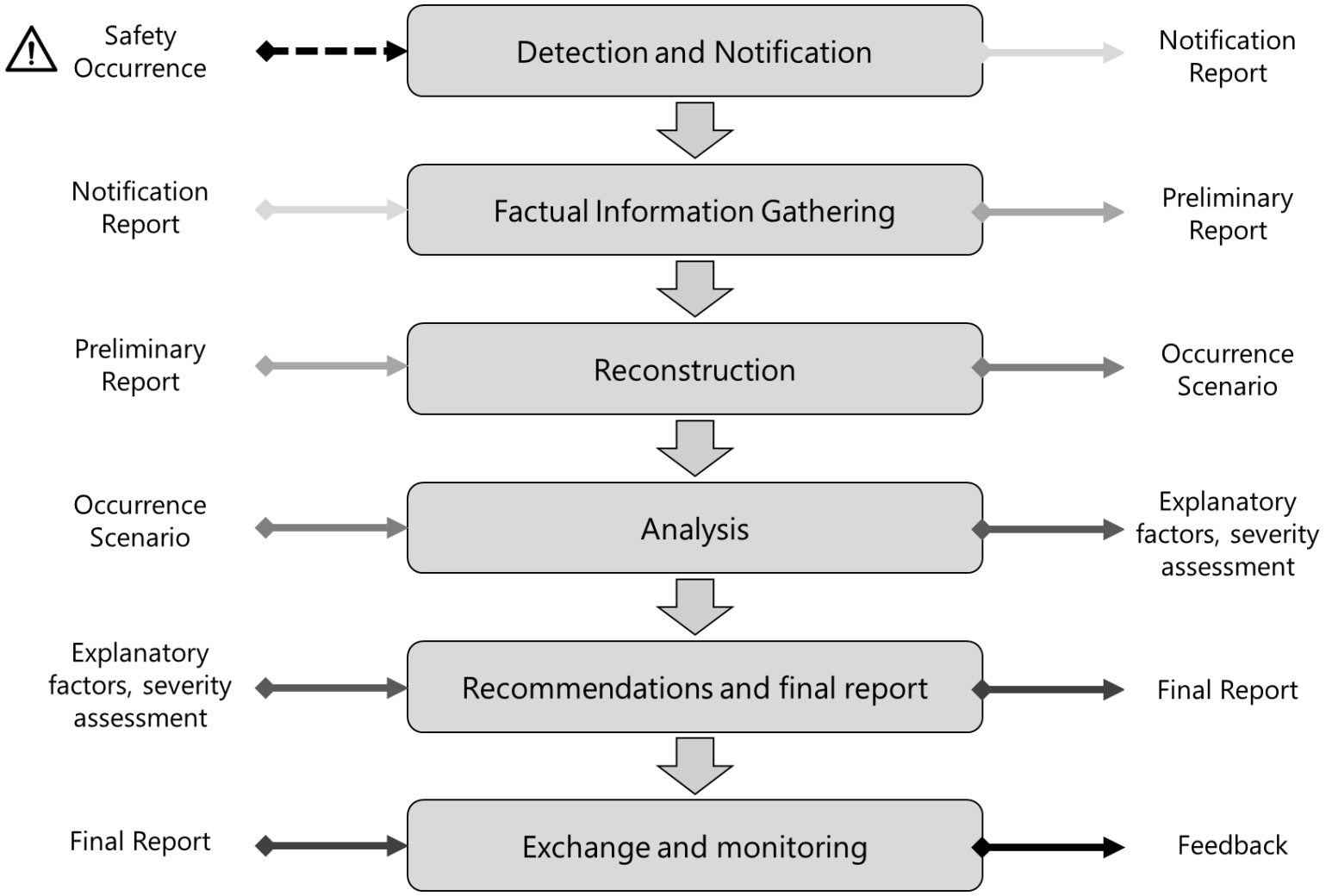
- **eTOKAI (e-Toolkit for ATM Investigation)**
- ASMT (Automatic Safety Monitoring Tool)
- FATIGUE assessment tool
- SAFETY CULTURE tool
- STANDARDS of EXCELLENCE in SMS, joint initiative with CANSO
- CARMA (regulations)
- **SECA (Structured Exploration of Complex Adaptations)**
- et al.

*Ultimate purpose: **foster safety intelligence**, as the interpretation of safety data to enhance decision-makers' capability to act proactively*

FOCUS ON SAFETY REPORTING

eTOKAI toolkit for ATM Investigation

FOCUS ON SAFETY REPORTING and eTOKAI

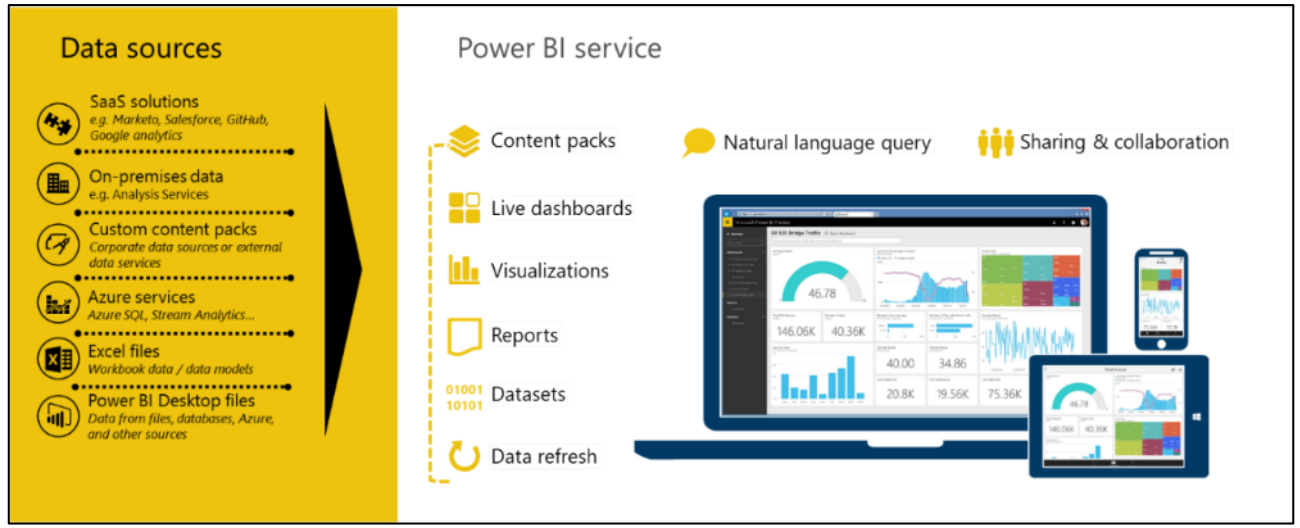


eTOKAI features:

- Compliant with EU Reg. 376/2014
- Initially developed in 1998, continuously updated
- Harmonized taxonomy
- eTOKAI is currently used by over 60 ANSPs

eTOKAI BUSINESS INTELLIGENCE

TOKAI dashboard

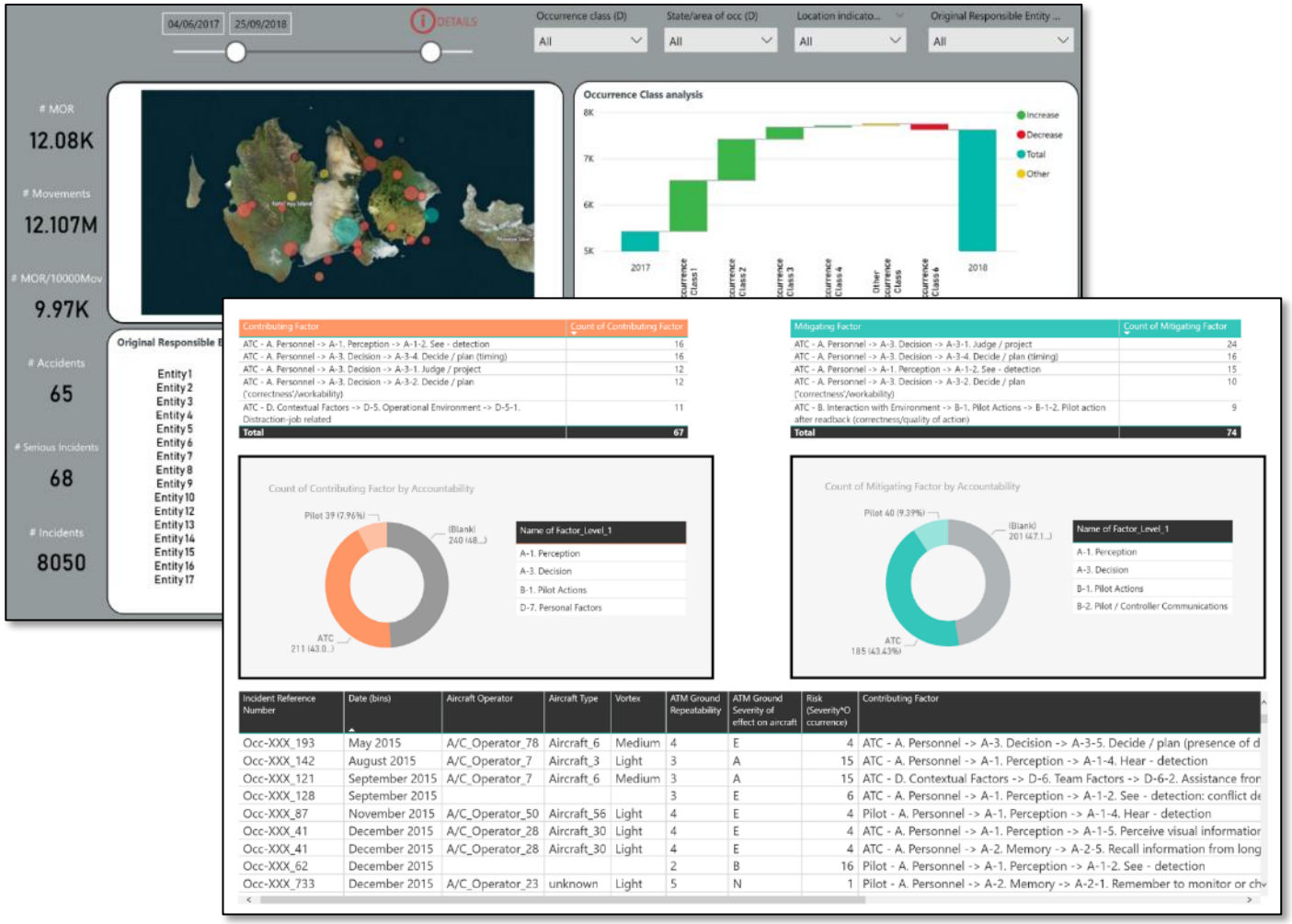


Microsoft | Power BI

ETL, Data Analysis and Data Visualization

EXAMPLES OF eTOKAI DASHBOARDS

50+ report pages, over 250 variables
in four reporting categories
BASIC; ADVANCED;
QUALITY CHECK; RISK DETAILS



ML TO GO BEYOND SINGLE POINTS OF FAILURES

TOKAI dashboard

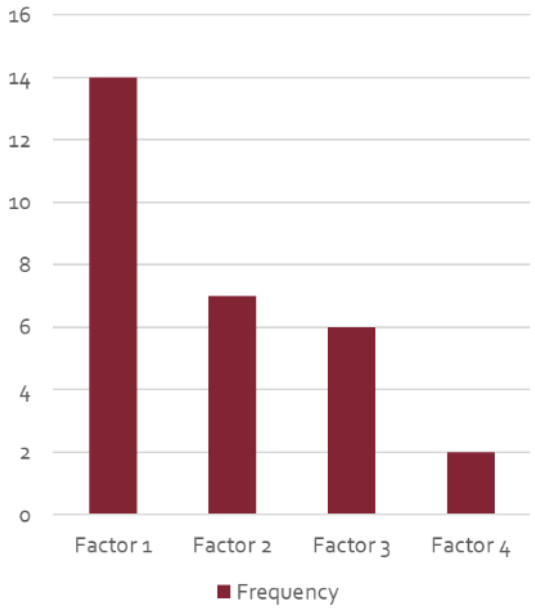
Explanatory Factors

A neutralized taxonomy describing actions as performed without blaming apportioning

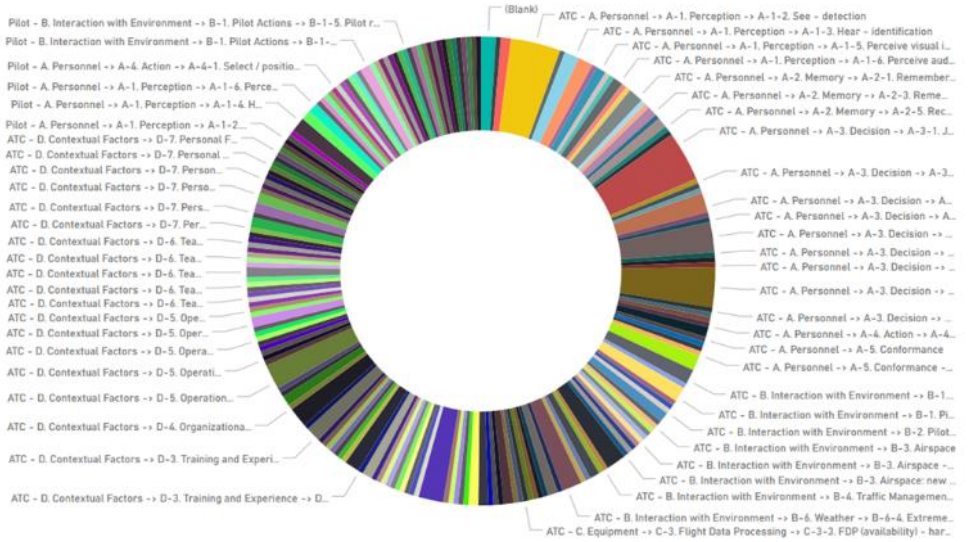
- Personnel
- Interaction with the Environment
- Equipment
- Contextual Factors

600+ FACTORS

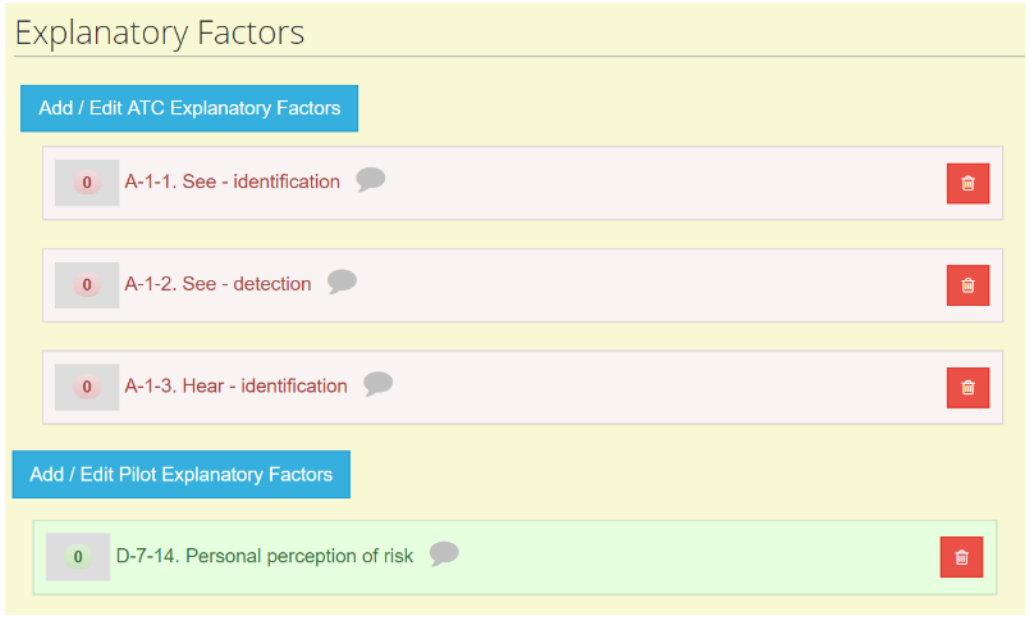
The expected scenario



The messy reality



EXPLANATORY CLUSTERS

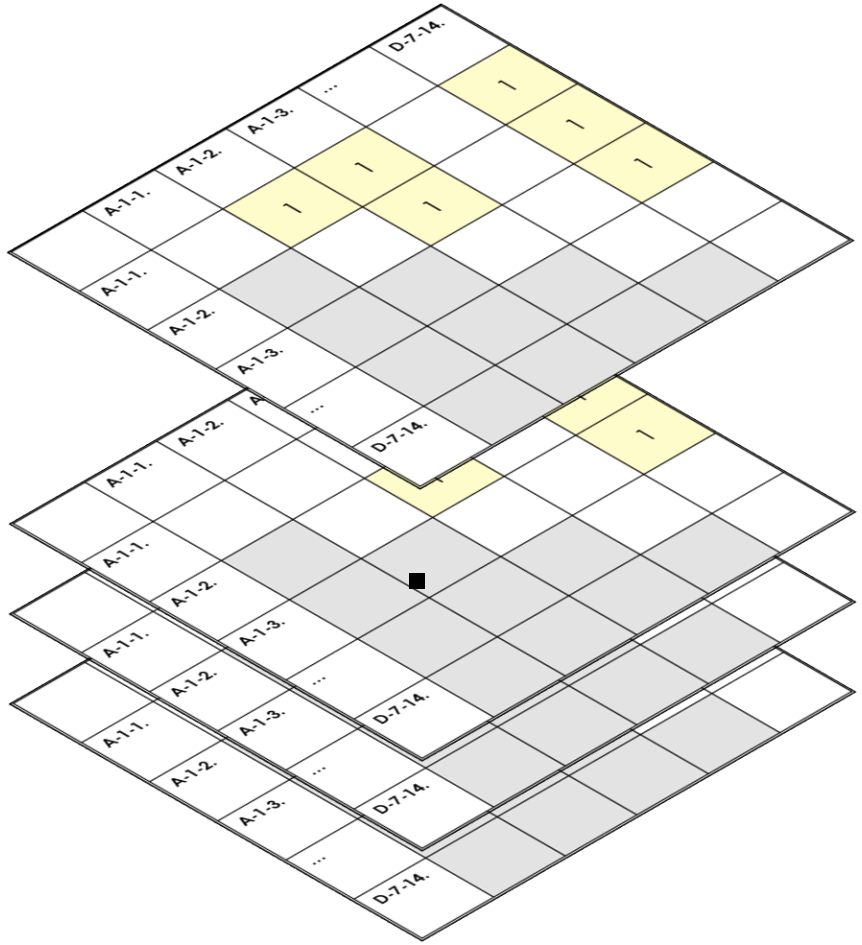


	A-1-1.	A-1-2.	A-1-3.	...	D-7-14.
A-1-1.		1	1		1
A-1-2.			1		1
A-1-3.					1
...					
D-7-14.					

R. Patriarca, G. Di Gravio, R. Cioponea, A. Licu (2019). Safety intelligence: Incremental proactive risk management for holistic aviation safety performance, Safety Science, Volume 118, 2019.

EXPLANATORY CLUSTERS

Number of reports



	A-1-1.	A-1-2.	A-1-3.	...	D-7-14.
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A-1-2.			3		12
A-1-3.					5
...					
D-7-14.					

R. Patriarca, G. Di Gravio, R. Cioponea, A. Licu (2019). Safety intelligence: Incremental proactive risk management for holistic aviation safety performance, Safety Science, Volume 118, 2019.

ML IN ACTION: PCA AND MDS

Principal Component Analysis (PCA) is a statistical method used to describe variability among observed variables in terms of a potentially lower number of unobserved variables.

Multi-Dimensional Scaling allows presenting those results into relative terms.

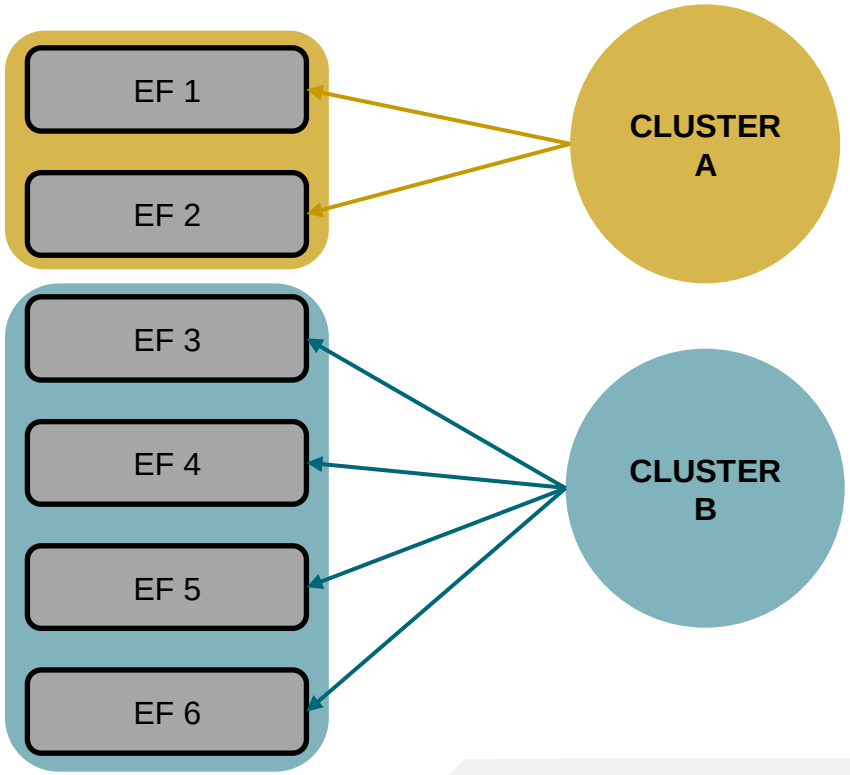
PROBLEM

Reduce a set of ***N*** variables into a set of ***M*** variables (M<N) so that:

$$z_i = \sum_{p=1}^{M} L_p F_p + \varepsilon_i \qquad i = 1, \ldots, N$$

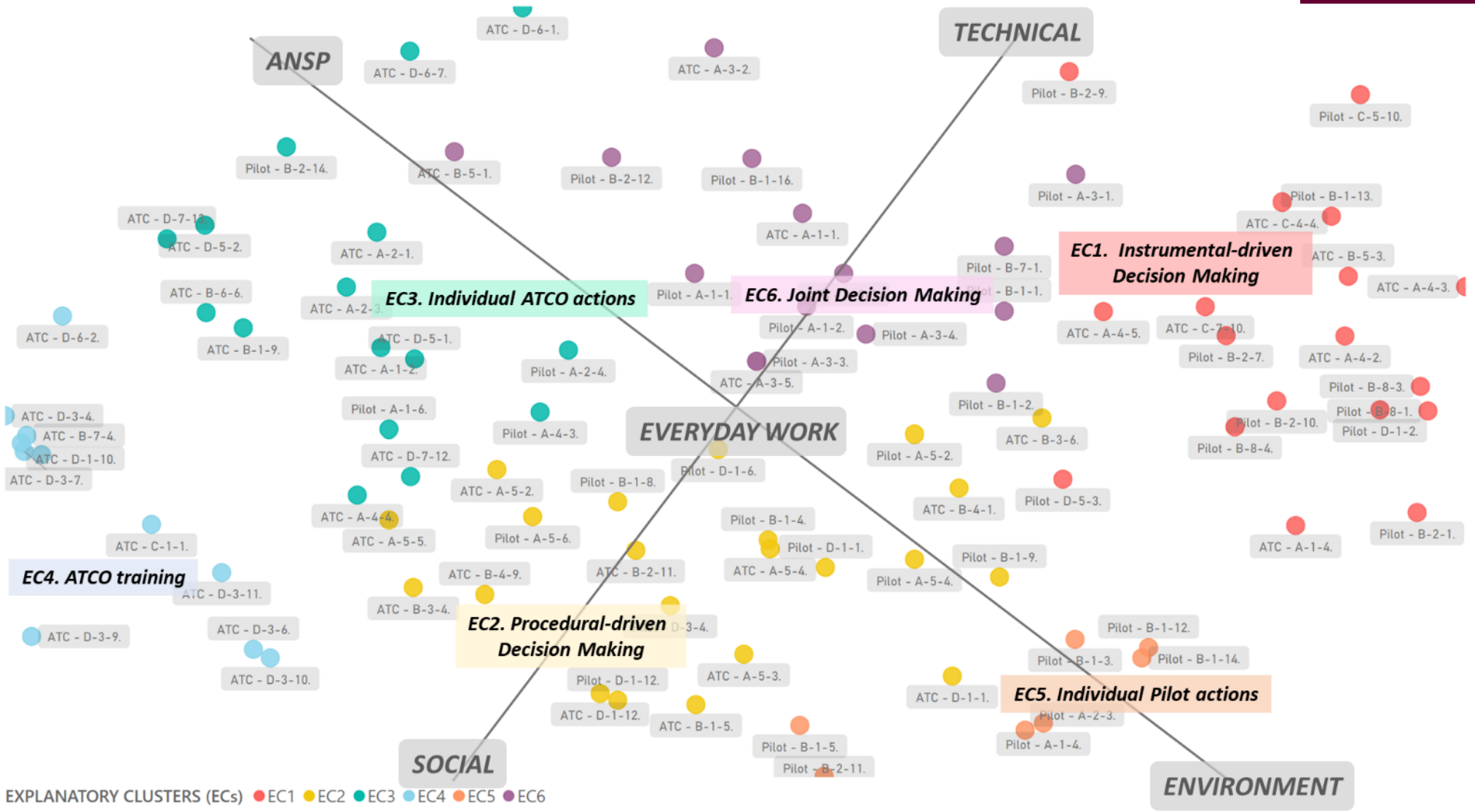
TARGET

The eTOKAI EFs (N) **can be used to detect underlying functional relationships** (M)



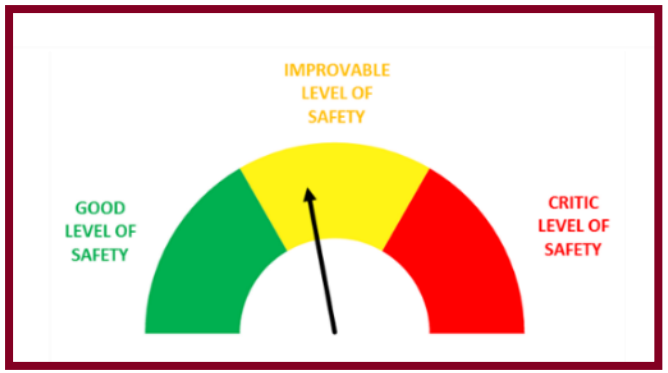
R. Patriarca, G. Di Gravio, R. Cioponea, A. Licu (2019). Safety intelligence: Incremental proactive risk management for holistic aviation safety performance, Safety Science, Volume 118, 2019.

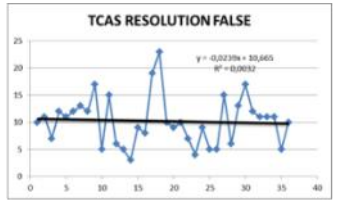
EXPLANATORY CLUSTERS

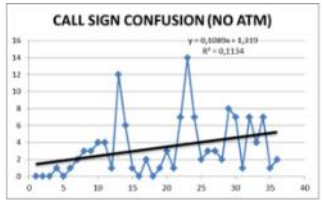


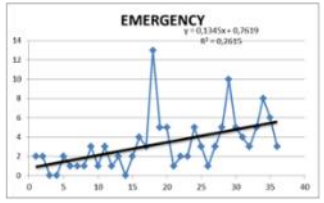
R. Patriarca, G. Di Gravio, R. Cioponea, A. Licu (2019). Safety intelligence: Incremental proactive risk management for holistic aviation safety performance, Safety Science, Volume 118, 2019.

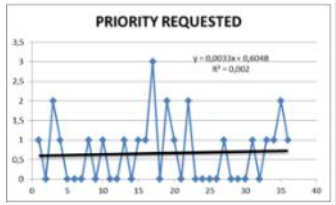
OVERALL PERFORMANCE:
THE AEROSPACE PERFORMANCE FACTOR

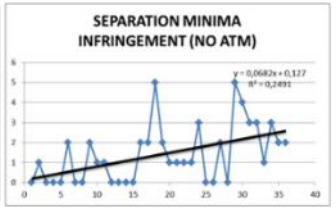


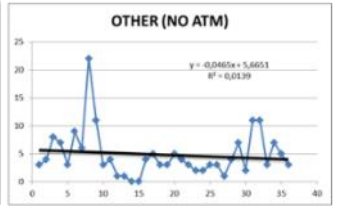


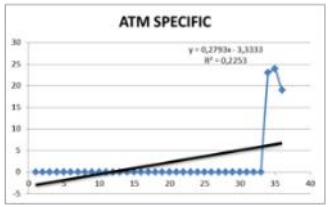


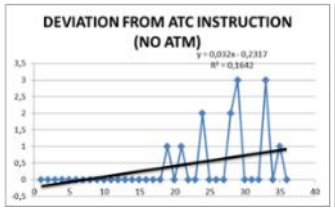


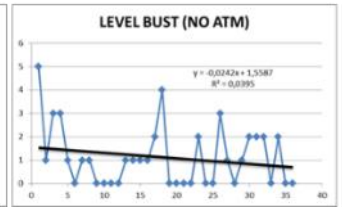


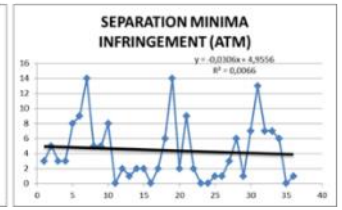


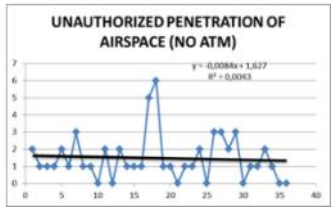








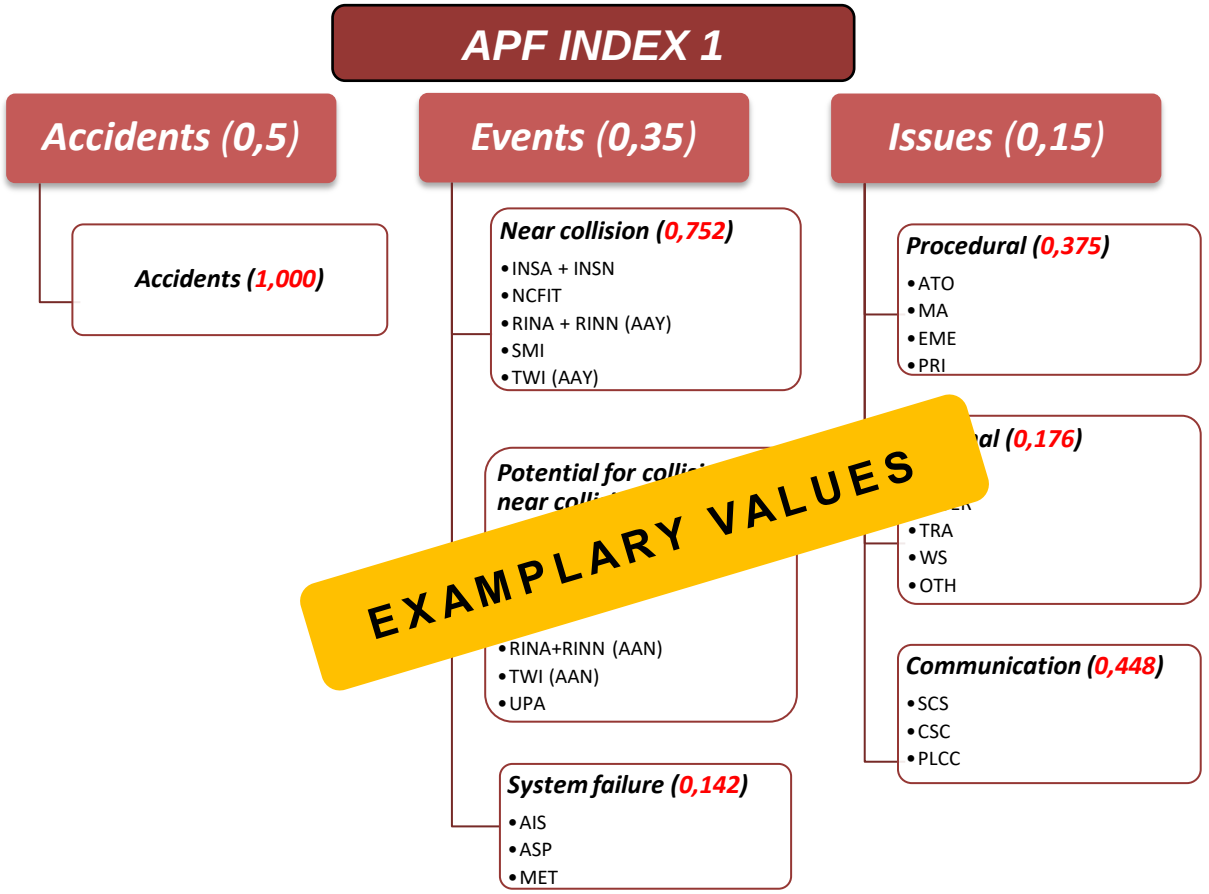


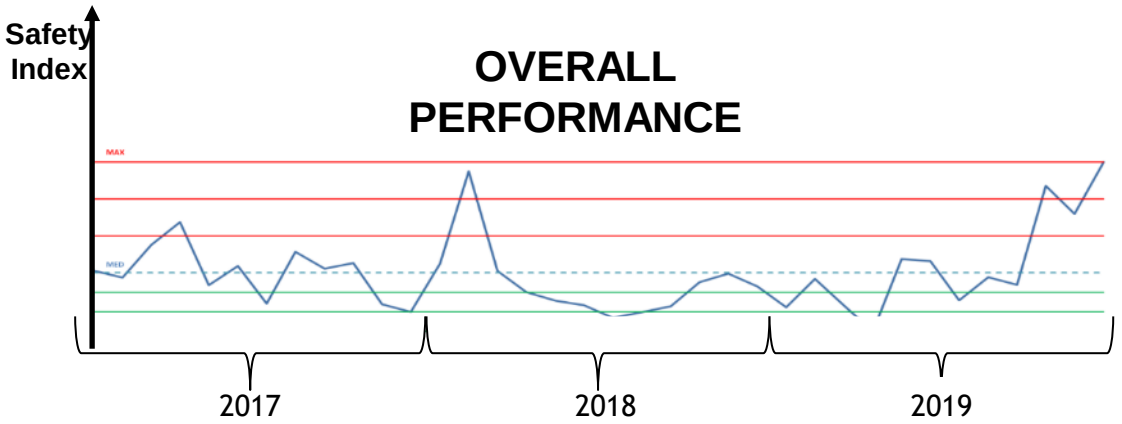


$$Event_{ij}\ APF\ Index = \frac{Event_{ij}\ count}{Traffic_j}\ Event_i\ AHP\ weight$$

$$APF\ Safety\ Index_{\ k} = \sum_{j=1}^{J}\sum_{i=1}^{I} Event_{ij}\ APF\ Index$$

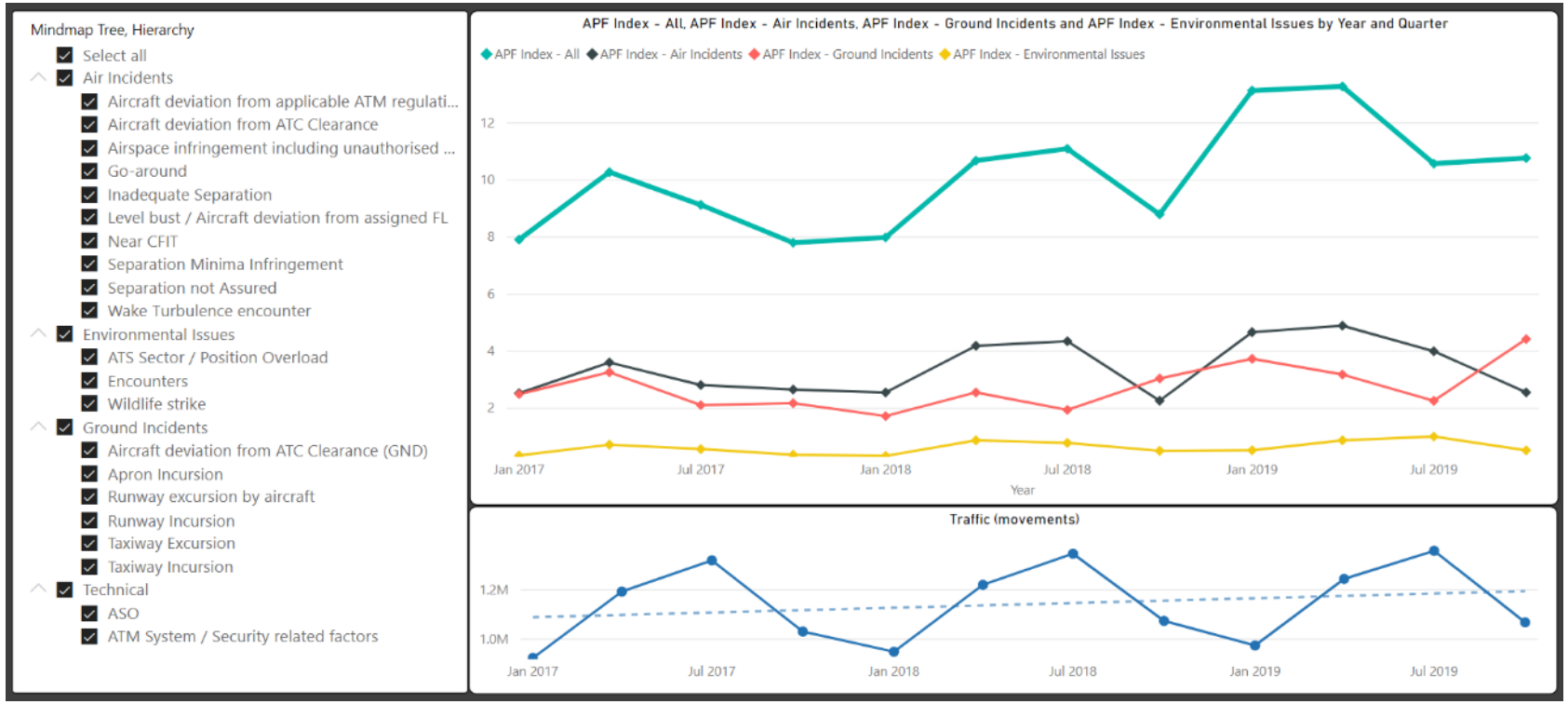
OVERALL PERFORMANCE:
THE AEROSPACE PERFORMANCE FACTOR





More info: *https://skybrary.aero/bookshelf/books/5134.pdf*

ANOMALOUS SAFETY PERFORMANCE



PROBLEM

Find anomalous safety performance

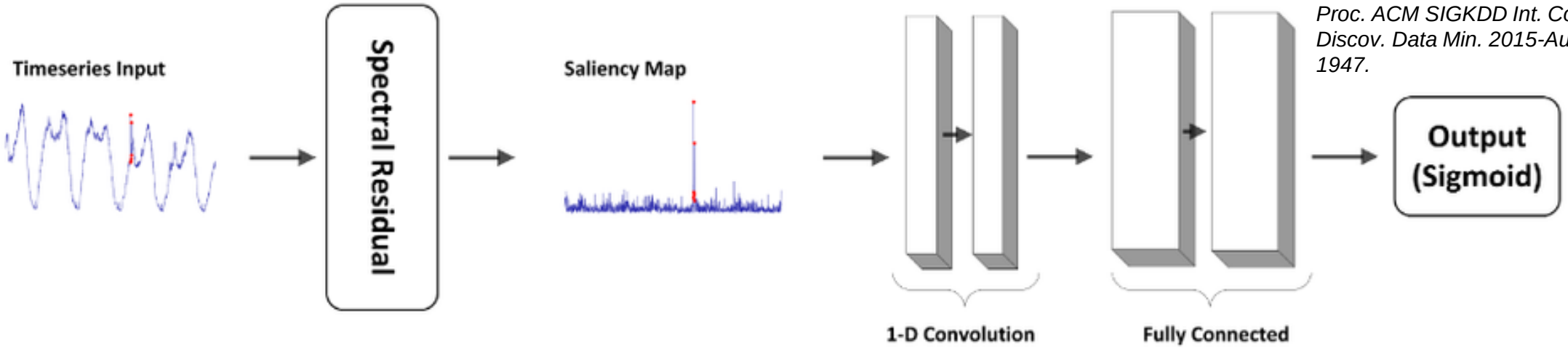
TARGET

Using an anomaly detection algorithm

R. Patriarca, et al. (2022). Democratizing business intelligence and machine learning for air traffic management safety, Safety Science, Volume 146, 2022, 105530,

ANOMALOUS SAFETY PERFORMANCE

SR-CNN



Laptev, N., Amizadeh, S., Flint, I., 2015. Generic and scalable framework for automated time-series anomaly detection. Proc. ACM SIGKDD Int. Conf. Knowl. Discov. Data Min. 2015-Augus, 1939–1947.

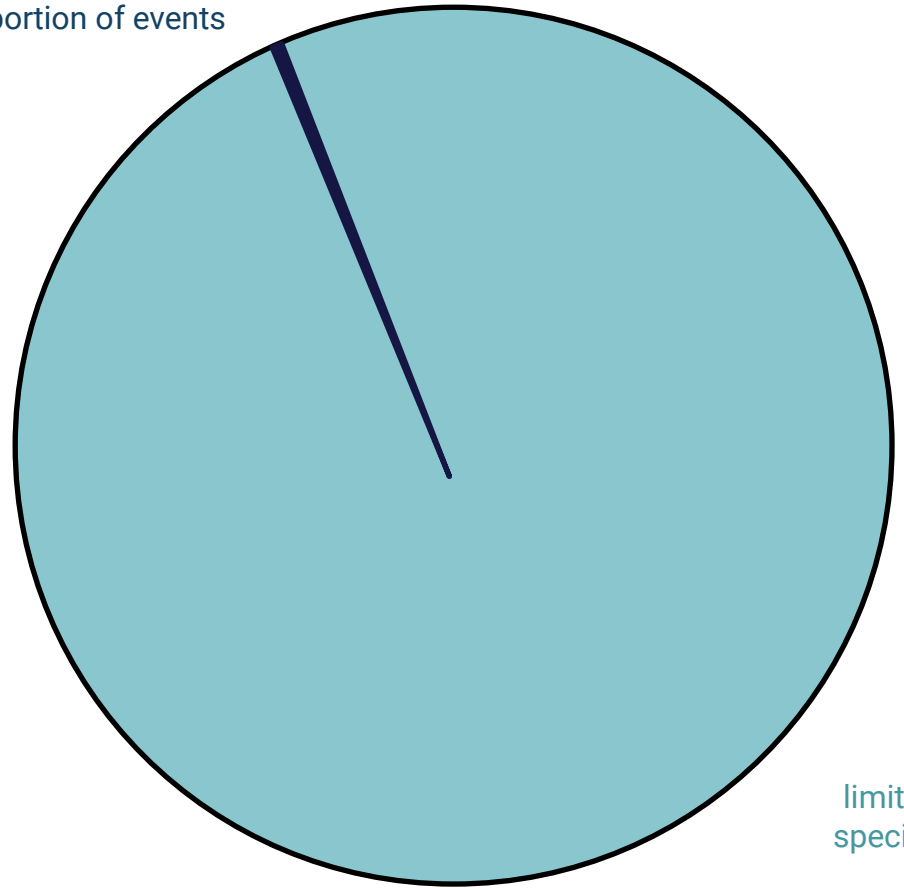
SR-CNN algorithm: Spectral Residual (SR) based on Fast Fourier Transform, + Convolutional Neural Network (CNN) to enhance the naïve single threshold traditionally suggested by SR.

$$T^* = \{t^* \mid y_{t*} = 1\}$$

$$\mathcal{A} = \{ TAF_u : u = u_{t*}, t^* \mid V_u^e \leq t^* \leq V_u^s \}$$

MODERN SAFETY MANAGEMENT in ATM

adverse events
many support tools exist
to study this portion of events



everyday work
limited methodological resources
specifically designed to investigate
this portion of events

PROBLEM
Studying accidents is important but not enough

TARGET
Knowledge on everyday work needs to be elicited

MODERN SAFETY MANAGEMENT in ATM

Vectoring an aircraft,
prioritizing taxiway movements,
coordinating upper space traffic…

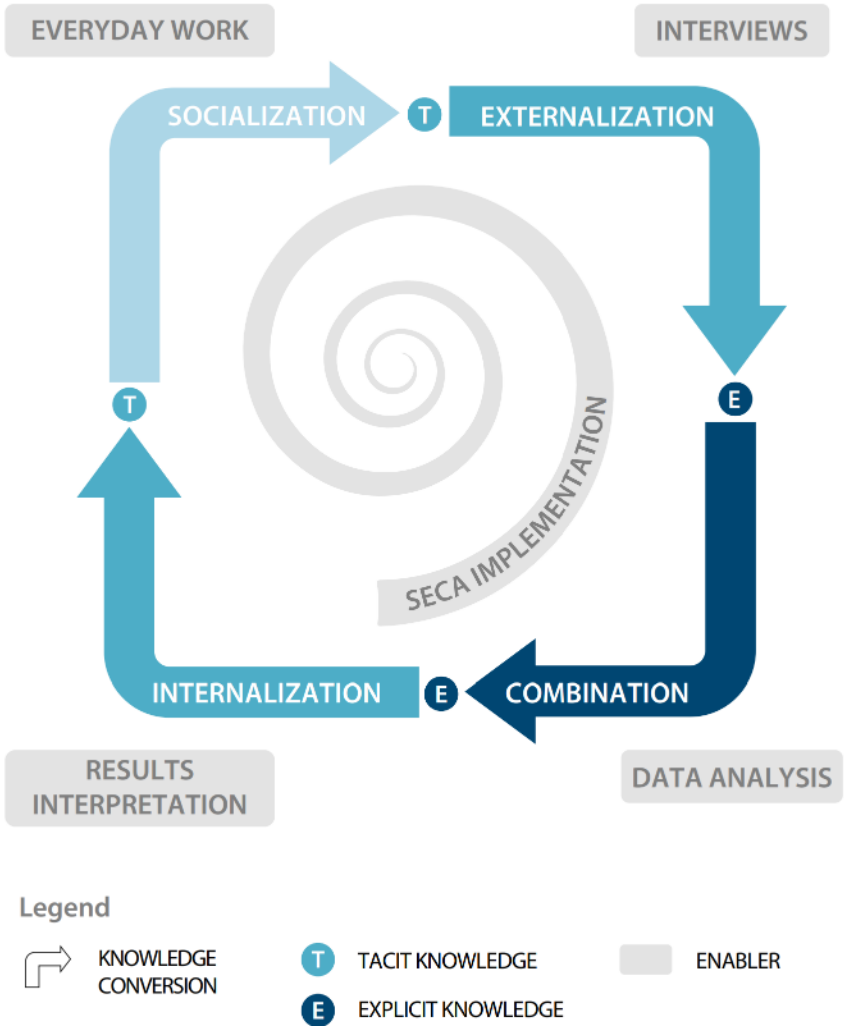
it is more than just rule-following

Work-As-Prescribed

Work-As-Done

Hollnagel, E., Leonhardt, J., Shorrock. S. and Licu, T. (2013). From Safety-I to Safety-II. A White Paper. Brussels: EUROCONTROL Network Manager.

A KNOWLEDGE MANAGEMENT PROBLEM



PROBLEM 1:
how to **externalize data**?

PROBLEM 2:
how to **combine** the externalized data?

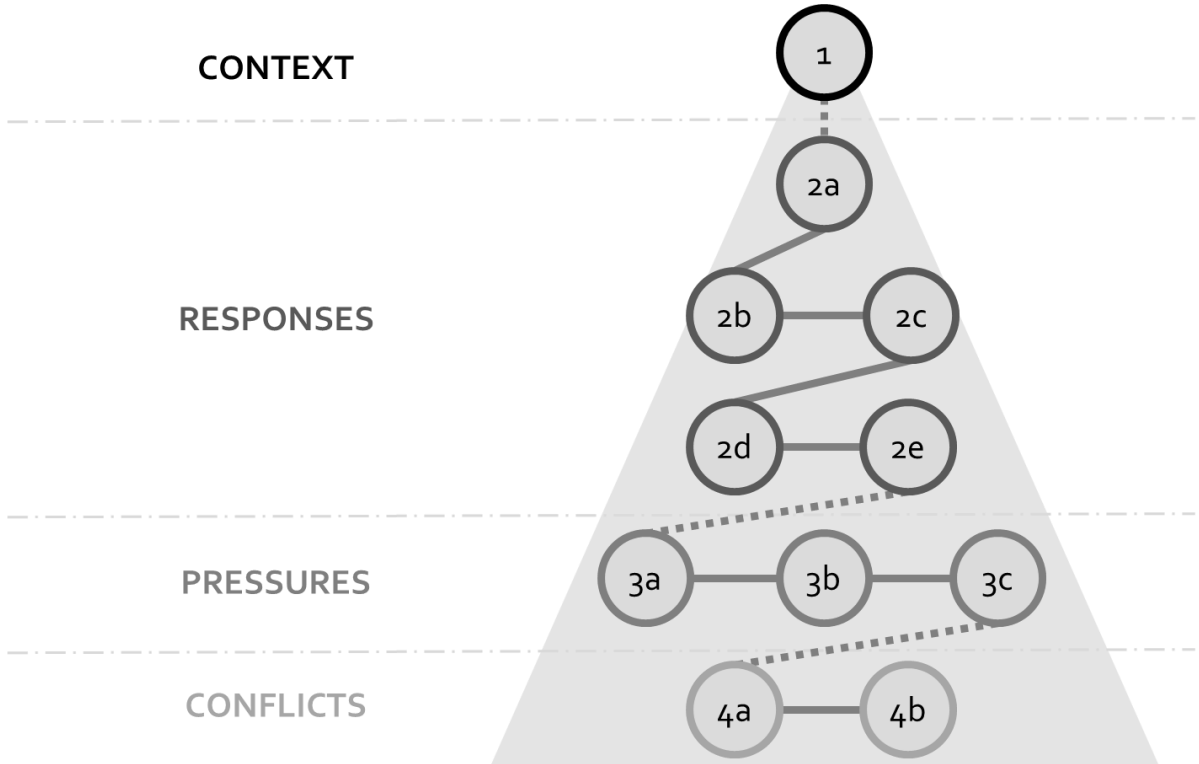
Inspired by: *Nonaka, I., Toyama, R., Konno, N., 2000. SECI, Ba and Leadership: A Unified Model of Dynamic Knowledge Creation. Long Range Planning 33, 5–34.*

R. Patriarca, et al. (2022). Unearthing weak signals Engineering for safer and more efficient socio-technical systems – The Structured Exploration of Complex Adaptations (SECA) method.

SECA DESIGN

PROBLEM 1: how to **externalize data**?

Structured Exploration of Complex Adaptations (SECA)



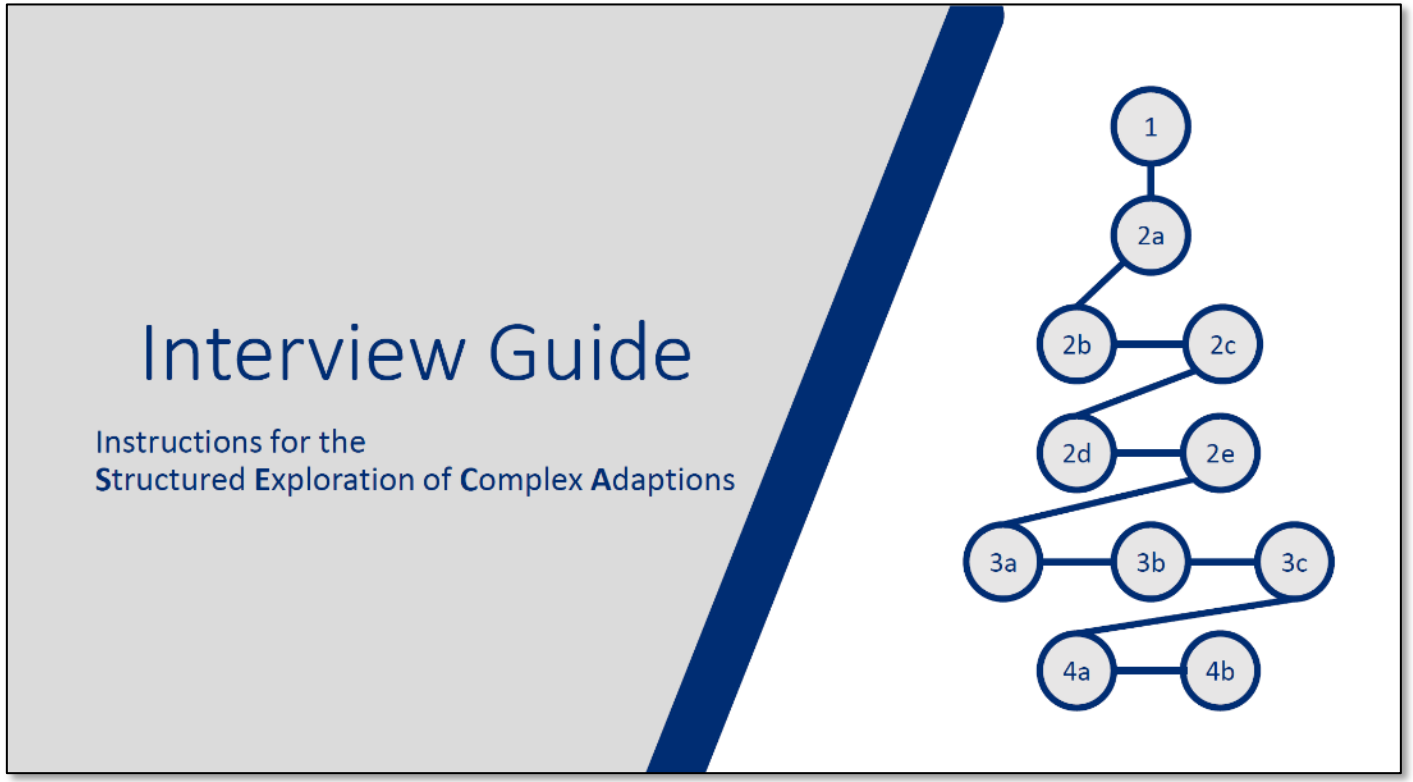
CODE	DIMENSION	ELEMENT
1	Context	Description of the situation
2a	Responses	Personal response
2b	Responses	Procedures (written rules)
2c	Responses	Units' normal way of working
2d	Responses	Less experienced colleagues' response
2e	Responses	Experienced colleagues' response
3a	Pressures	Pressures from Management in the organization (blunt end)
3b	Pressures	Pressures from the outside the unit (work related environment)
3c	Pressures	Pressures from colleagues
4a	Conflicts	Goal conflicts
4b	Conflicts	Trade-offs

SECA DESIGN

PROBLEM 1: how to **externalize data**?

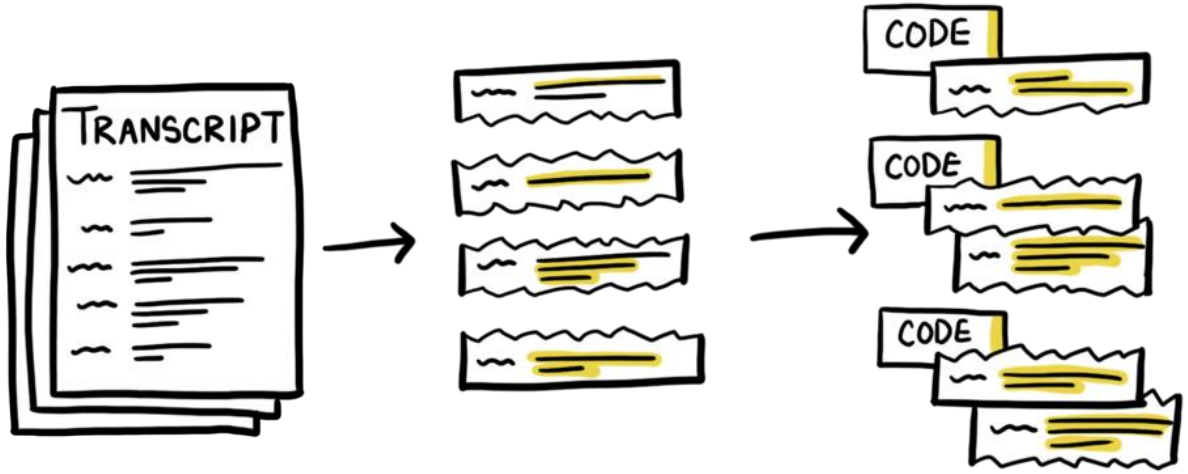
After several iterations and field experiences over a 2-years project, the project team defined a SECA Interview Guide:

- List of questions
- Exemplary answers
- Best practices for interviews

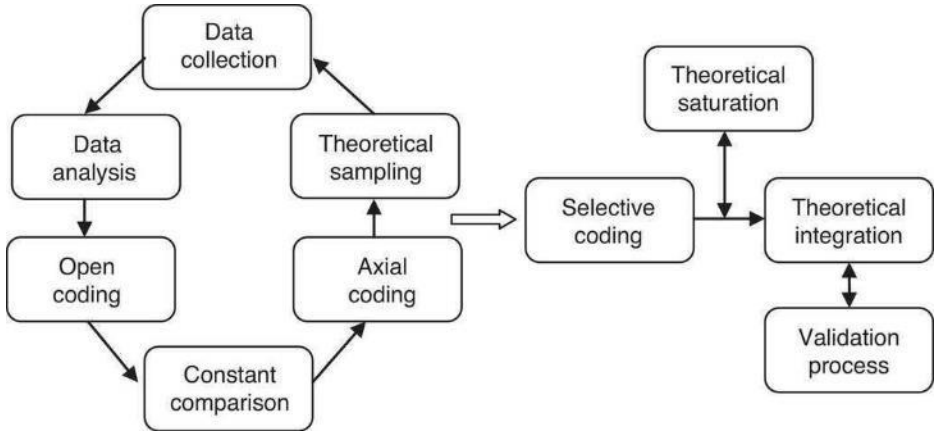


SECA NATURAL LANGUAGE PROCESSING

PROBLEM 2: how to **combine** data?



SECA INTERVIEWS



GROUNDED THEORY

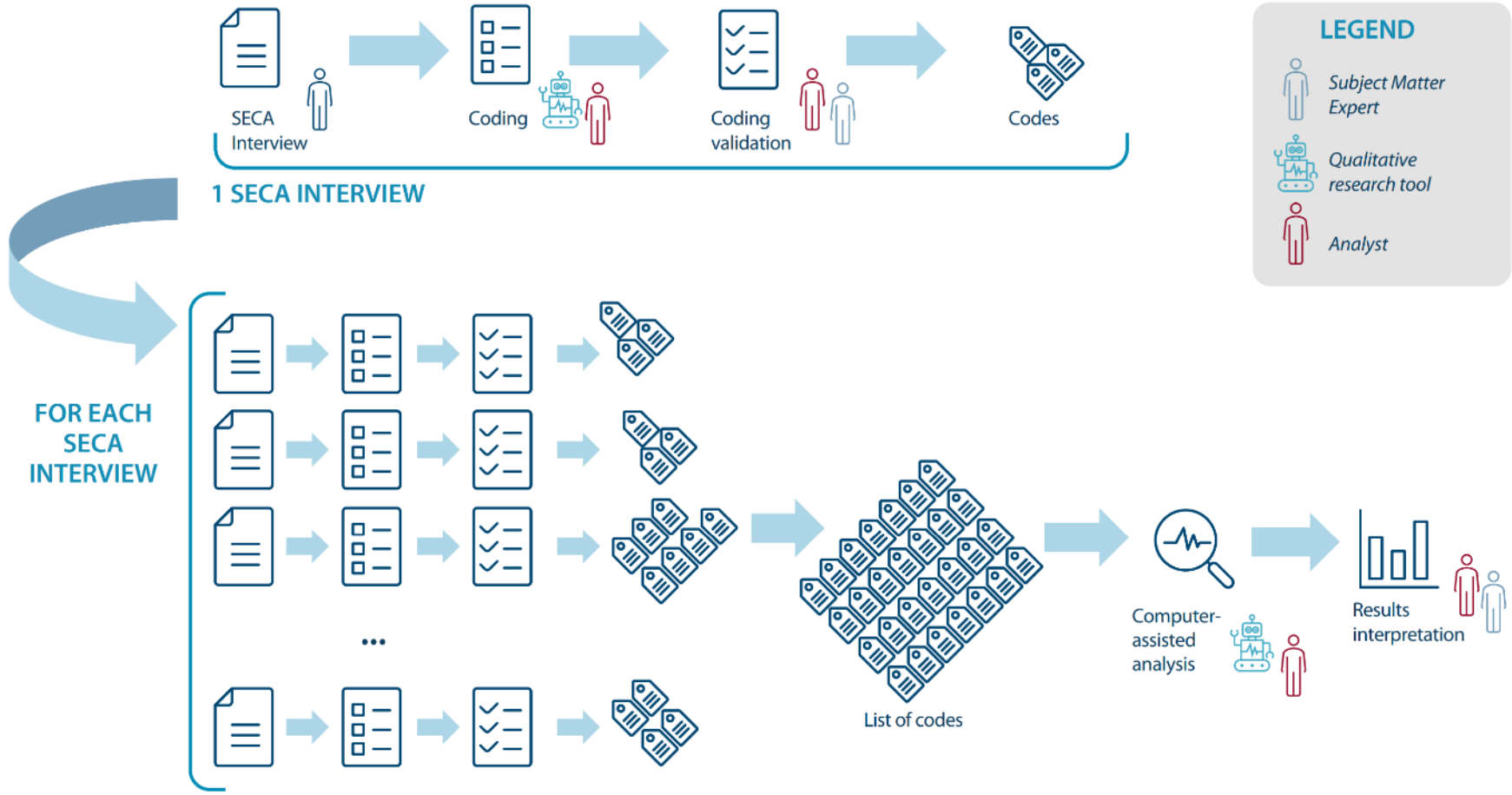
Operational PATTERNS are dependent from local practices, no universal theory

NATURAL LANGUAGE PROCESSING

TECHNICALITIES
Normalization
Custom stopwords
Tokenization (Regexp)
Stemming (WordNet)

NATURAL LANGUAGE PROCESSING

PROBLEM 2: how to **combine** data?

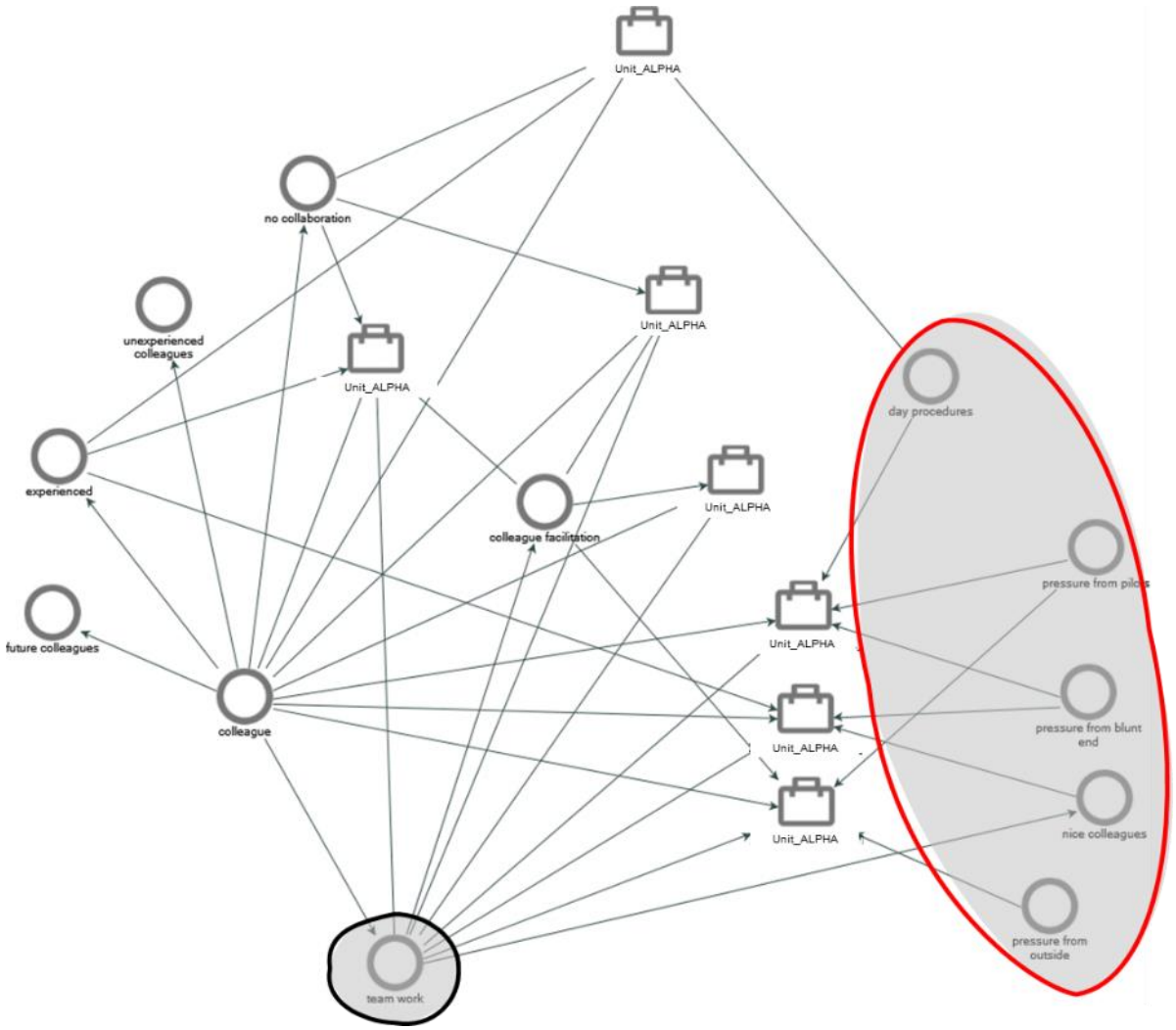


SECA EXEMPLARY FINDINGS

UNIT **ALPHA**

UNIT **BRAVO**

SECA EXEMPLARY FINDINGS



- Next to me on the PLC position sat a trainee with their coach. They got a direct for a flight but couldn't put it in because it was unknown to the system. I suggested they make an entry in the daily log, but they refused and saw no need for that even though the trainee had never done an entry in the daily log before and the direct in the system would be useful for the future. I wrote the entry myself.
- No procedure. No entries in the daily log because it has to be done during the break.
- Might be afraid to write an entry in the daily log because they are not used to it and don`t want to expose themselves with what they might think "unimportand stuff".
- Some would write an entry in the daily log like me, but most don't want to sacrifice their break.
- No pressure from blunt end/outside. Passive pressure: I felt I needed to write the entry because otherwise nobody would.
- If I just do my job, there is no obligation for me to make the entry in the daily log, but If I don't enter the waypoint into the daily log, the waypoint will stay unknown to the system, which I don't want. Otherwise I could spend the time convincing them to do it themselves, but that could end in an argument.

WEAK SIGNALS TEAM

TEAM COORDINATION AND GUIDANCE

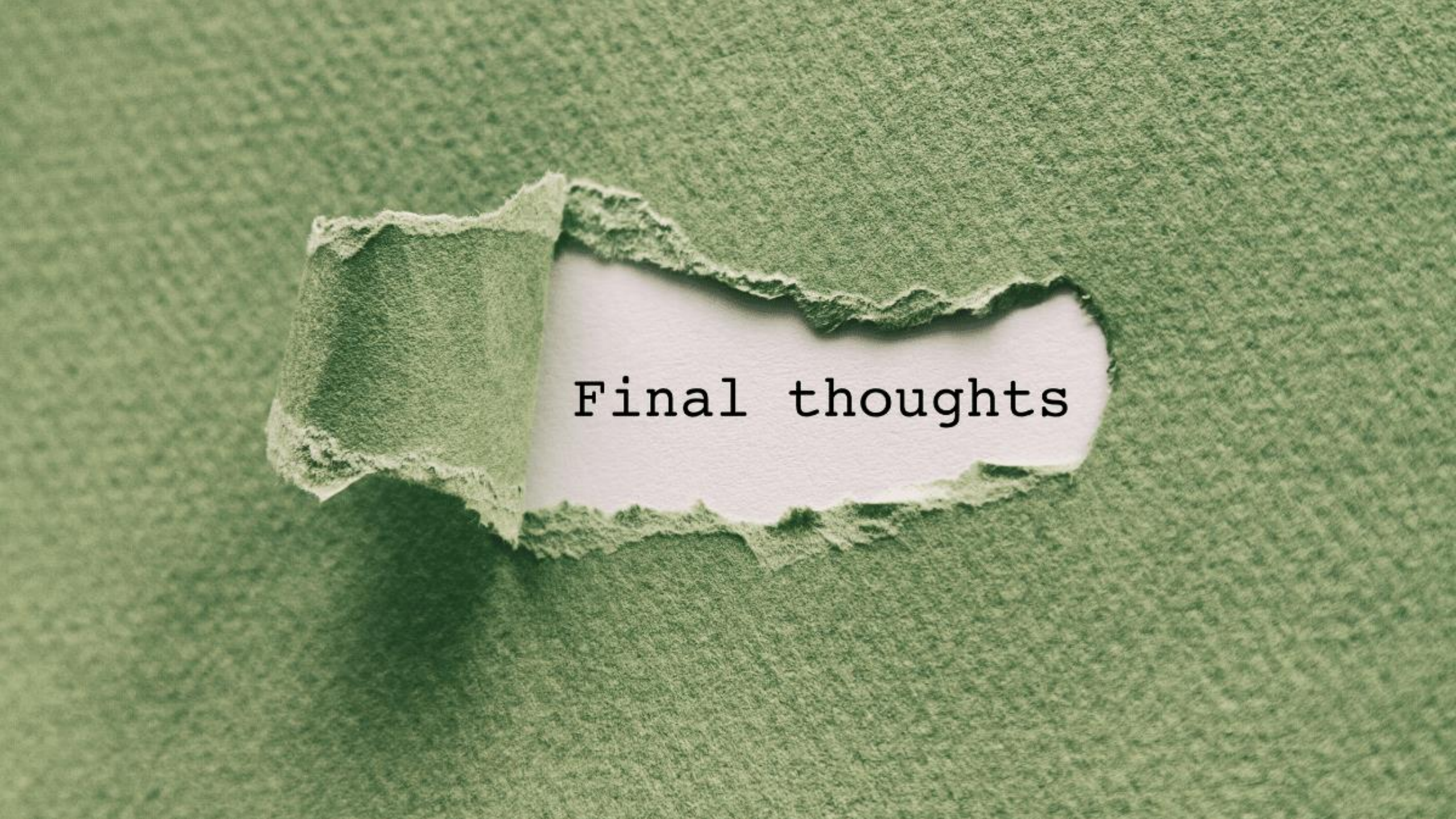
- Mareike Baumann, DFS

CONTRIBUTORS

- Kenneth Bechmann Funch, Naviair
- Radu Cioponea, EUROCONTROL
- Janna Daugaard, NAVIAIR
- Sara Dietrich, DFS
- Lisa Günther, DFS
- Christiane Heuerding, DFS
- Thorsten Luedtke, DFS
- Anne Juul Maaløe, Naviair
- Andre Perott, DFS
- Nils Tavares Schader, DFS
- Malene Winther-Larsen, Naviair

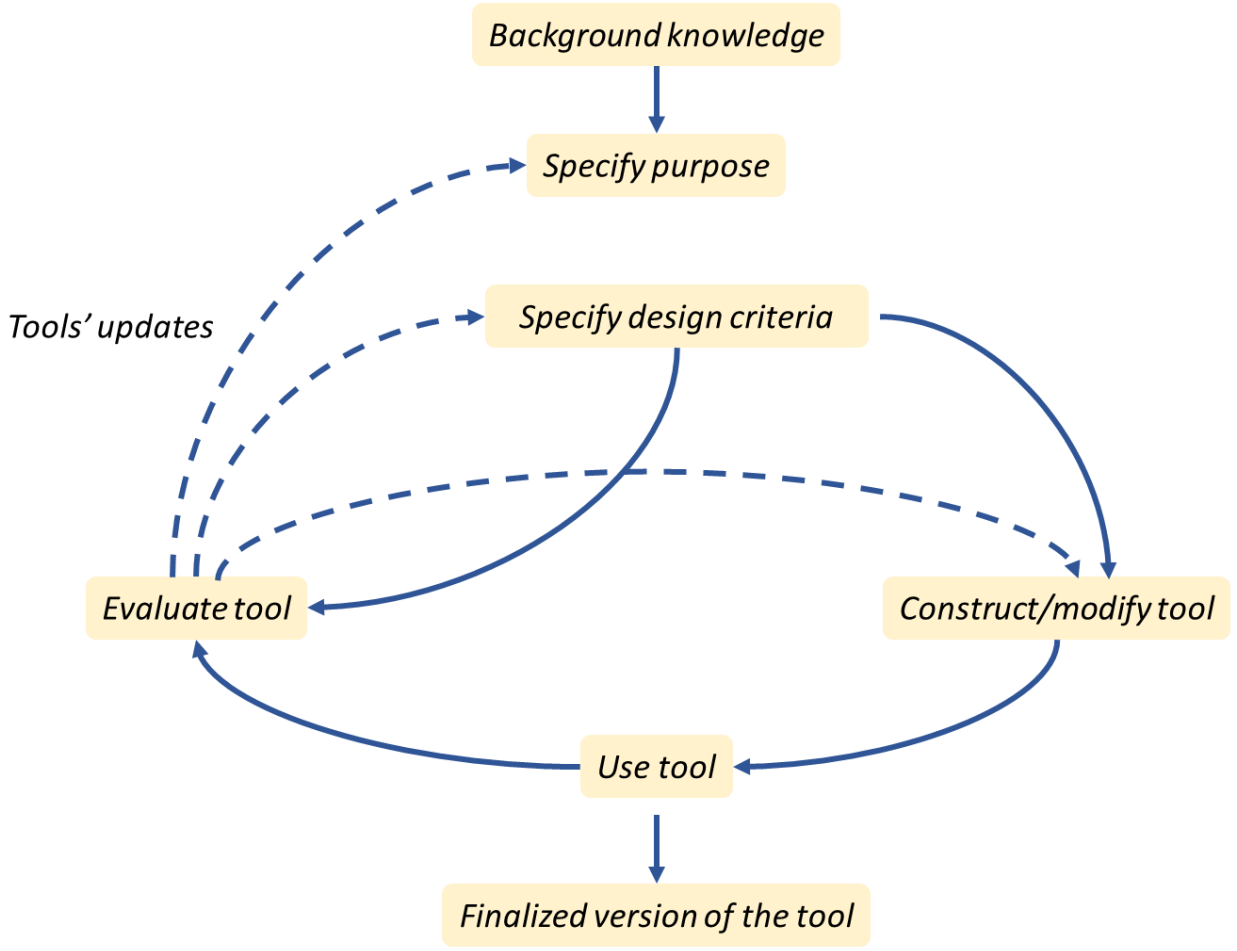
ACKNOWLEDGMENTS

A project of this kind, which extends over several years and involves the development of initially theoretical approaches, their communication and implementation in practical applications through suitable methods and tools, needs a lot of staying power. On this path, we have continuously and committedly Diana Alexandra Stefan, Sebastian Däunert, Thomas “Snoopy” Jäckel, Dr. Alice Müller Leonhardt and Christoph Peters. They deserve our special thanks.

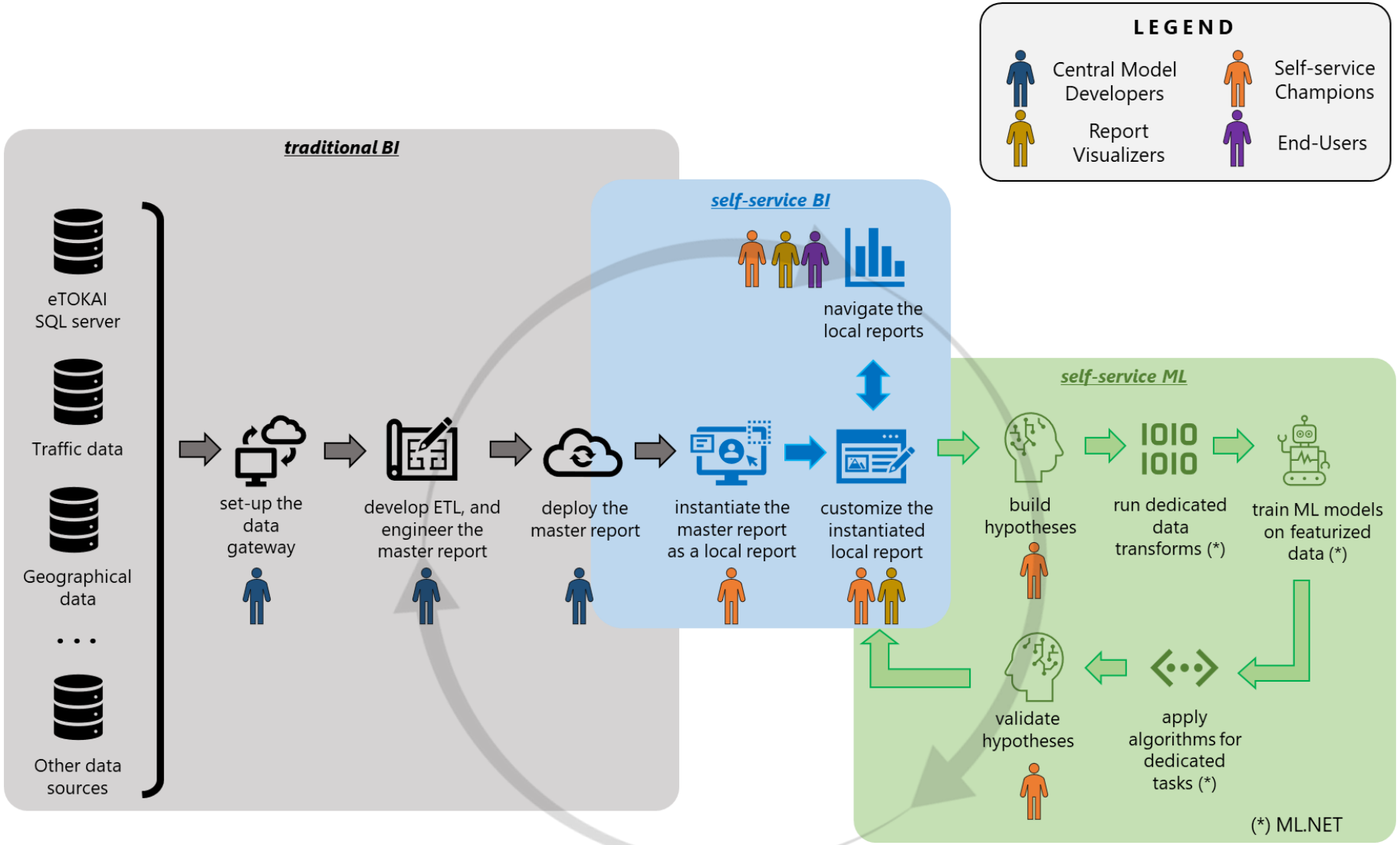

Final thoughts

DASHBOARD DESIGN

- Relying on **design science** research principles (Simon, 1993)
- Development and Deployment based on **Agile** thinking
- Continuous **feedback** monitoring by end-users (safety analysts, safety managers)
- Formalized **quality assurance**

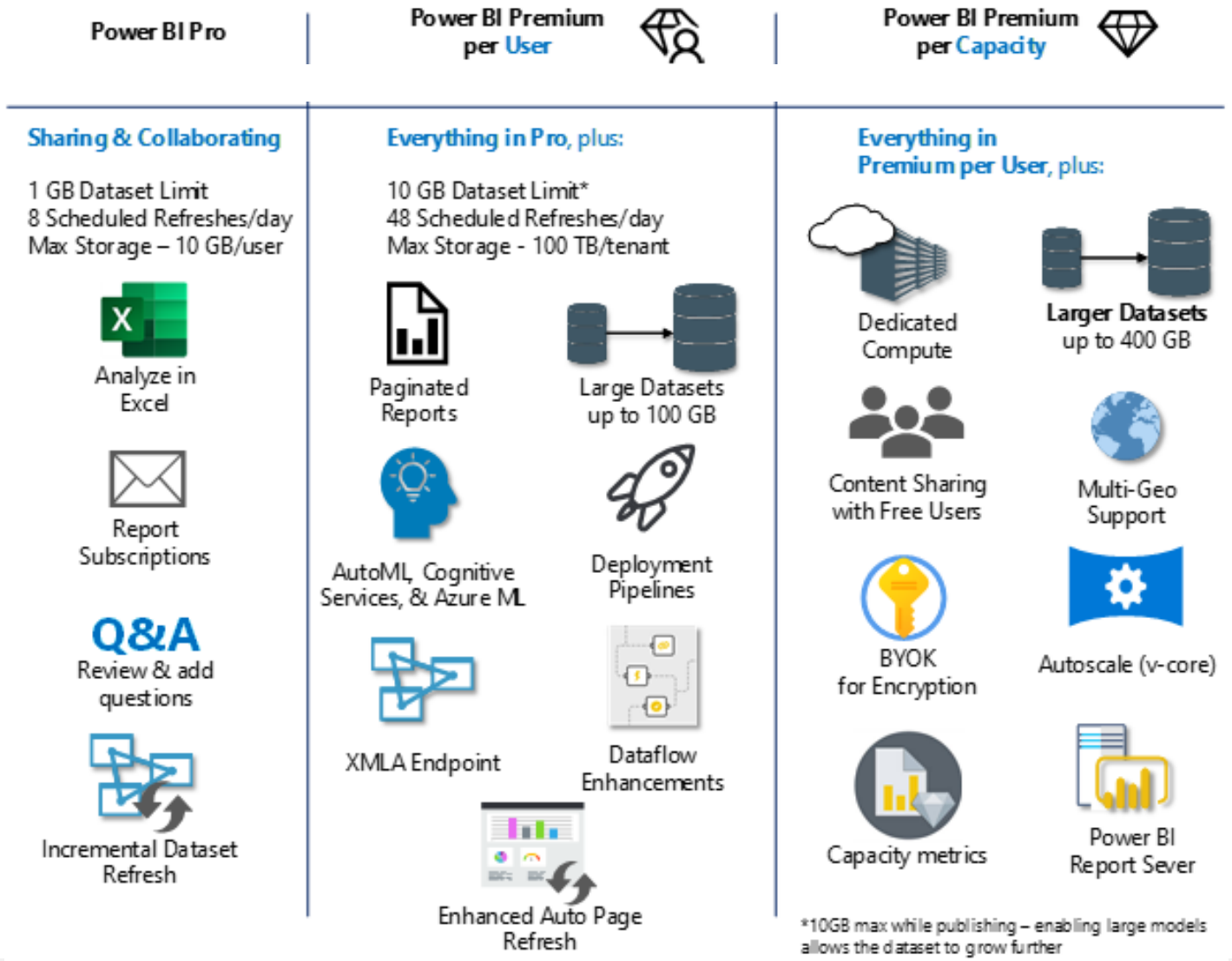


SELF-SERVICE BI & ML



R. Patriarca, et al. (2022). Democratizing business intelligence and machine learning for air traffic management safety, Safety Science, Volume 146, 2022, 105530,

DASHBOARD DESIGN



No need to extract data, dashboard **directly connected** to eTOKAI

Row-level security for each data field

Users can be entitled to do **self-service reporting**

SUMMARY

Fostering safety intelligence:

- Democratize BI and AI for usage at ANSPs
- Data-driven safety management
- AI to support – not substitute – analysts for time-consuming tasks
- Training on the tools is necessary, organizational support provided by EUROCONTROL (e.g., EUROCONTROL course on SECA in early 2023)

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