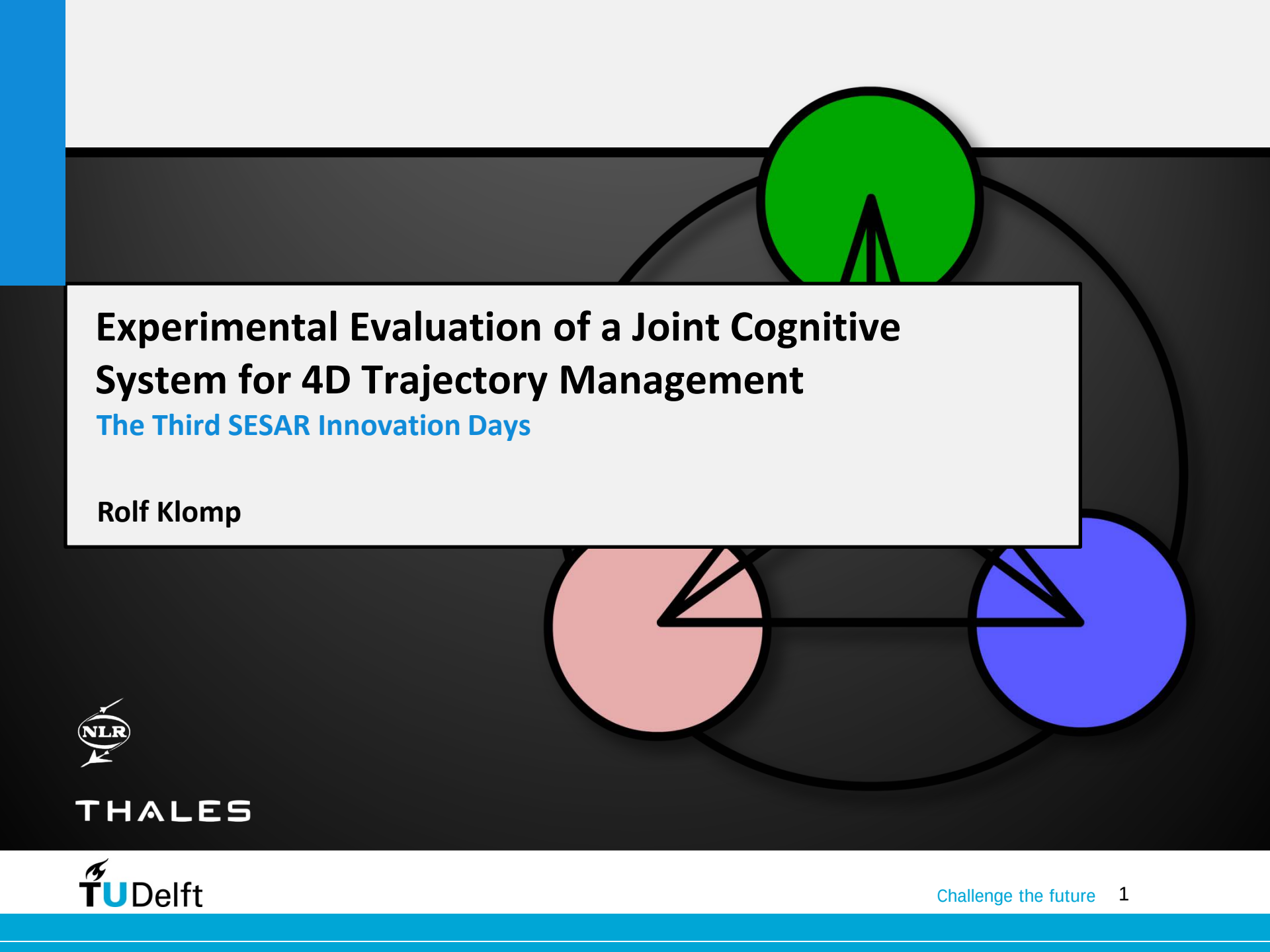




Experimental Evaluation of a Joint Cognitive System for 4D Trajectory Management

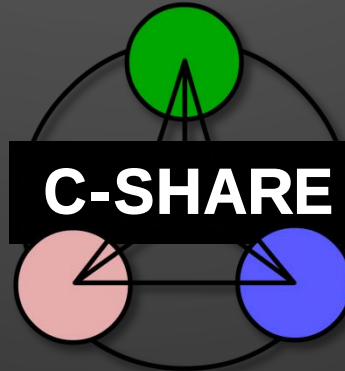
The Third SESAR Innovation Days

Rolf Klomp



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C-SHARE consortium



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Max Mulder (coordinator)
René van Paassen
Rolf Klomp
Gesa Praetorius

Martijn Mooij
Annemiek van Drunen
Sorin Iacob
Vincent Clot

Dennis Nieuwenhuisen
Pim van Leeuwen
Tanja Bos
Anneloes Maij

Towards higher levels of automation

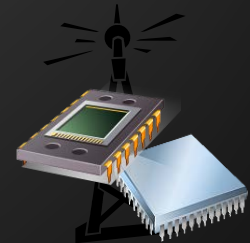
A key pillar of the SESAR Master Plan:

Allocate a central role for the human, but supported by a high degree of automation

However, the role of the human is not well defined yet

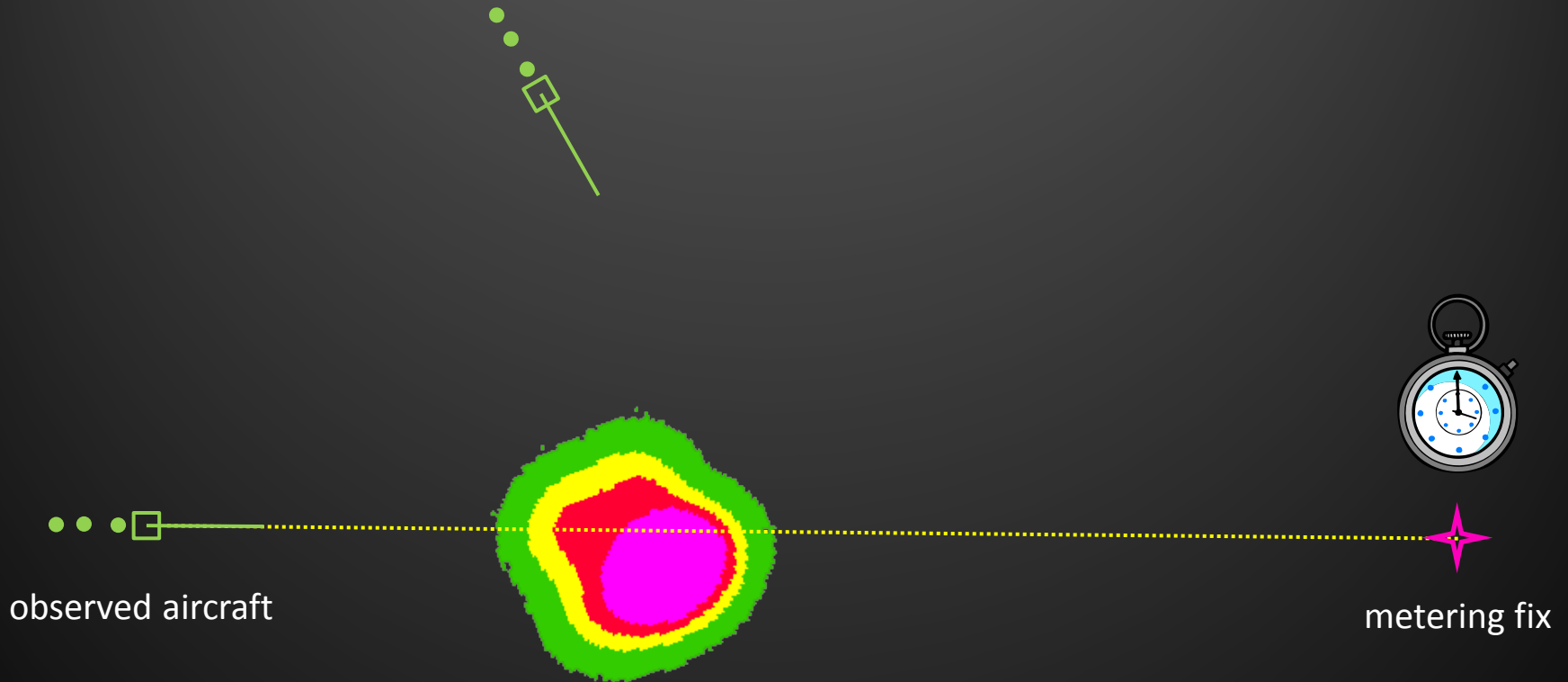


ATM network demand

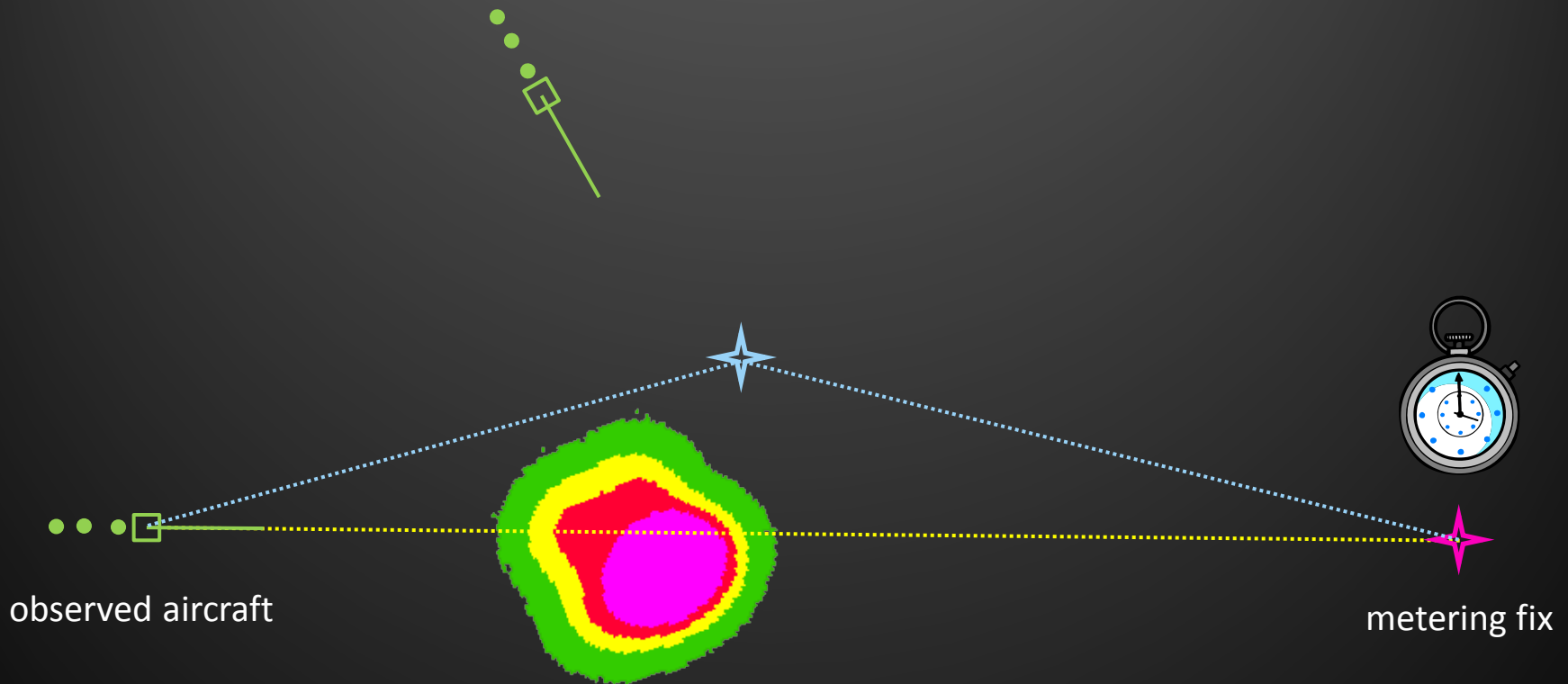


Technological advances

How can we effectively cope with complex situations in 4D trajectory planning?

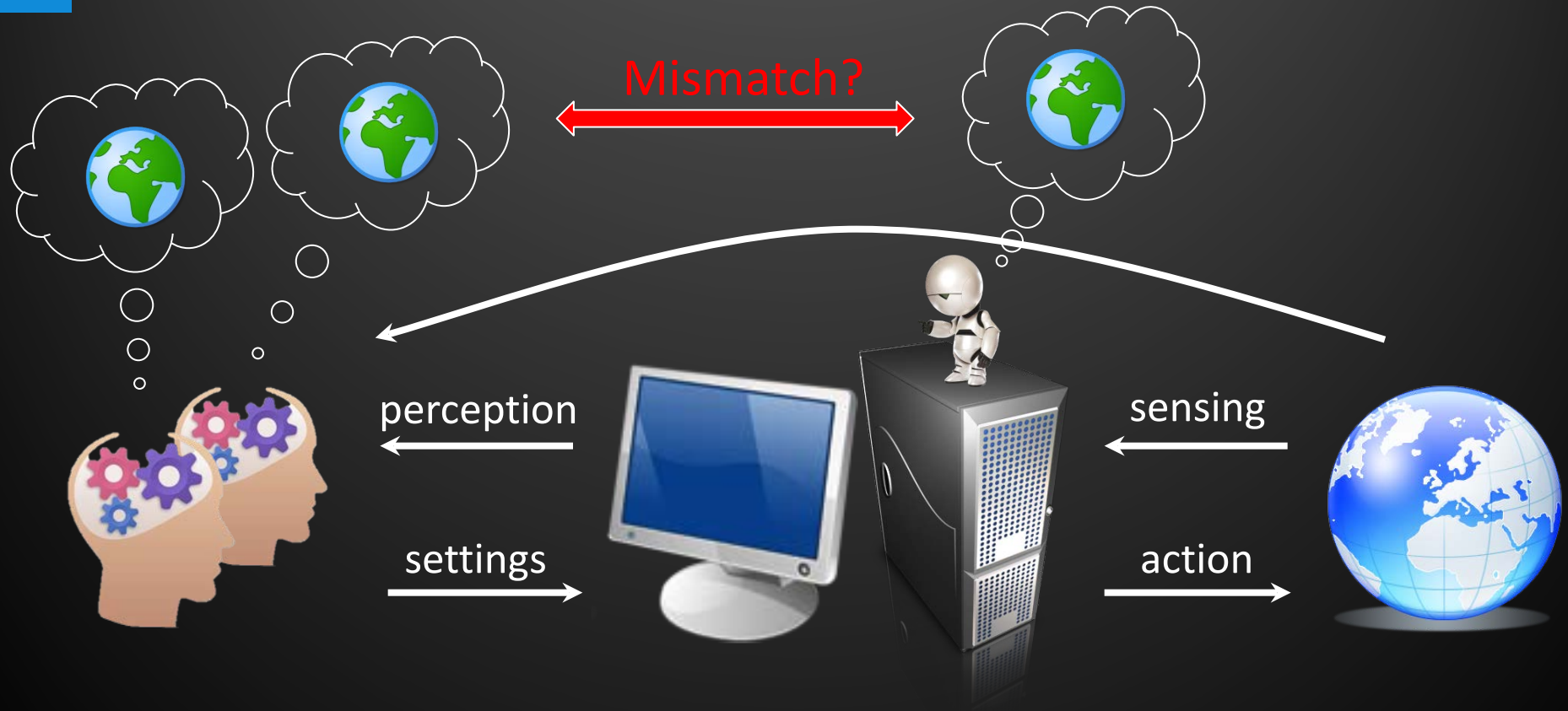


By taking a 'leap of faith' and always trusting automation?

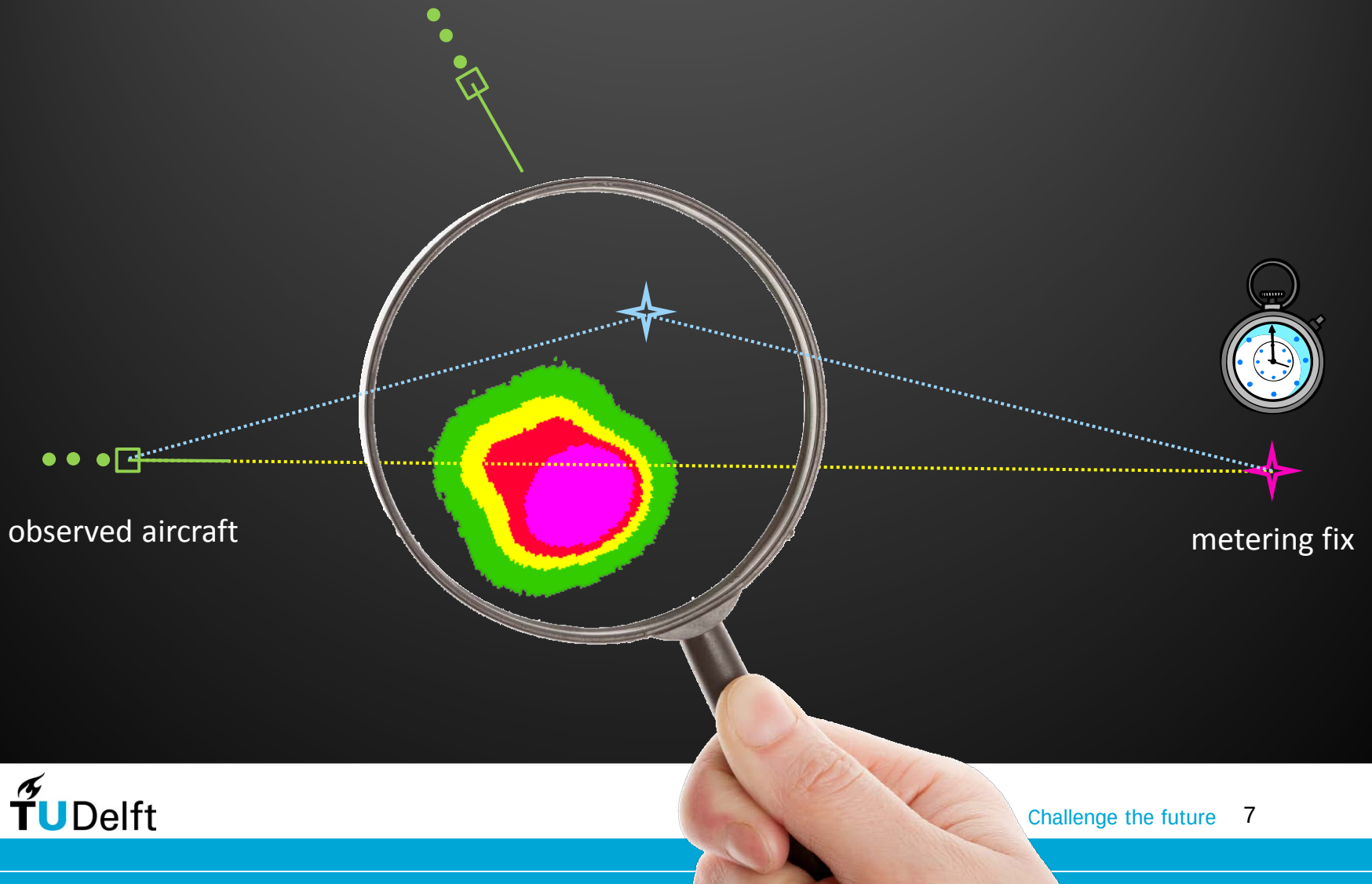


The challenge of human-systems integration

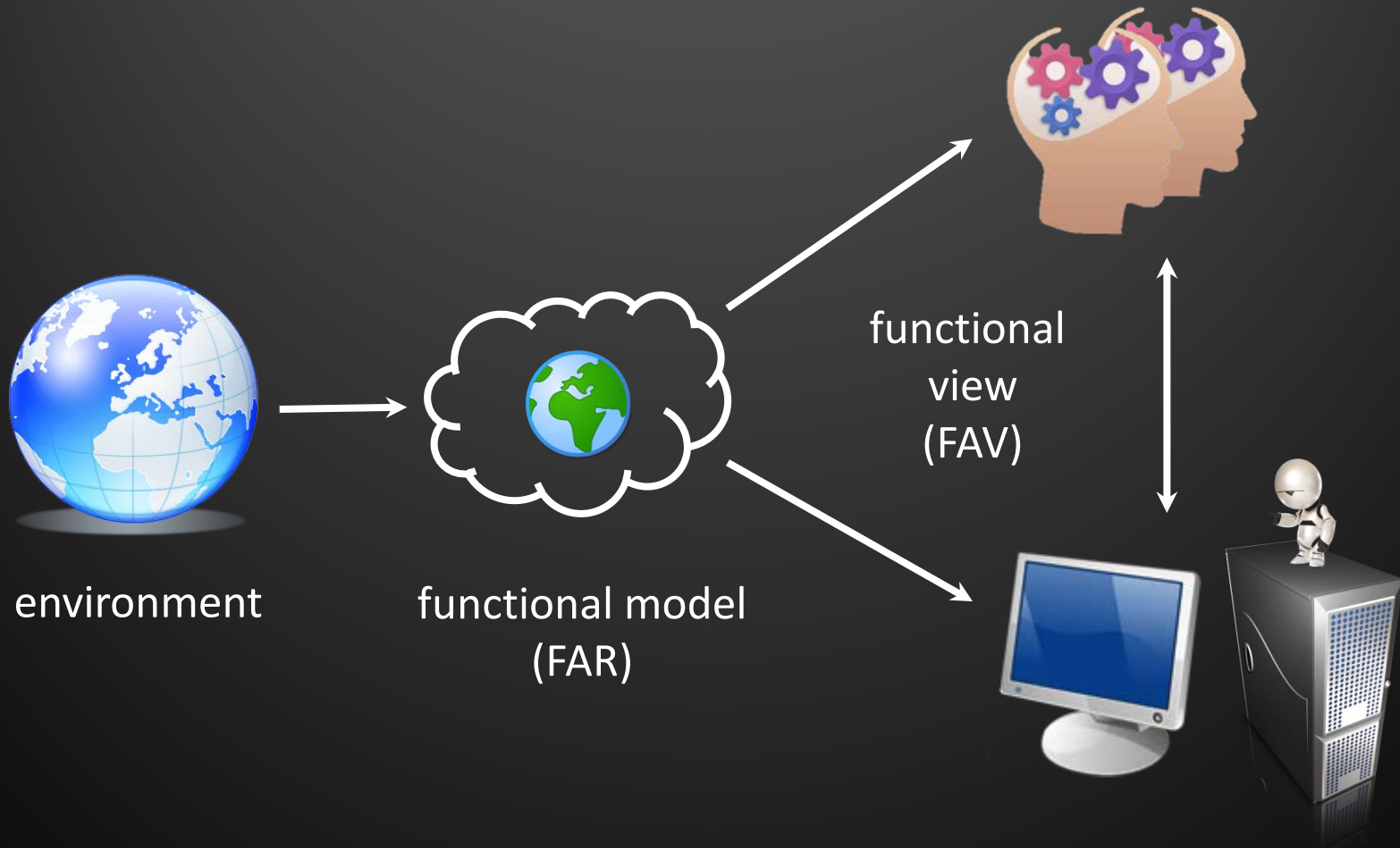
Human-machine interaction



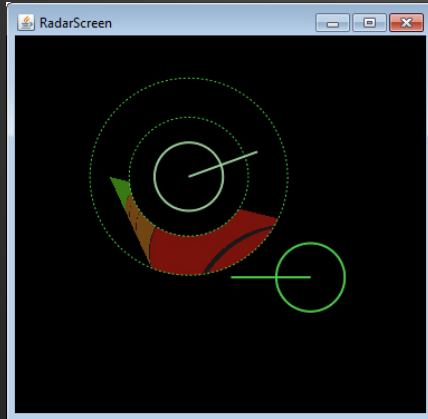
C-SHARE aims to make automation more transparent



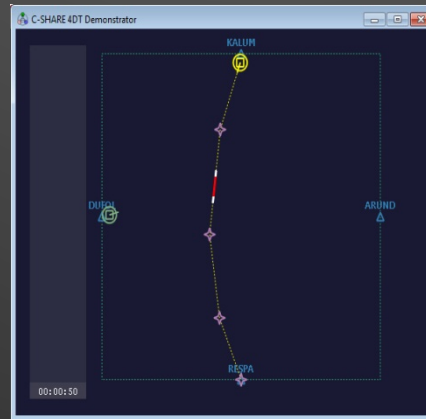
The foundation for effective human-machine coordination is based on a common ground of the problem to solve



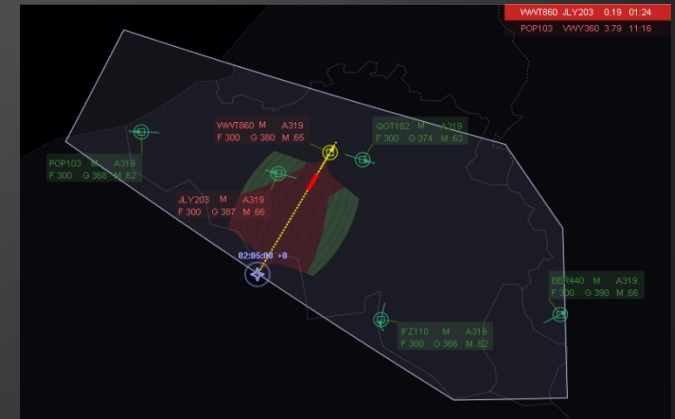
Applying the multi-disciplinary CSE and EID paradigms is an iterative process



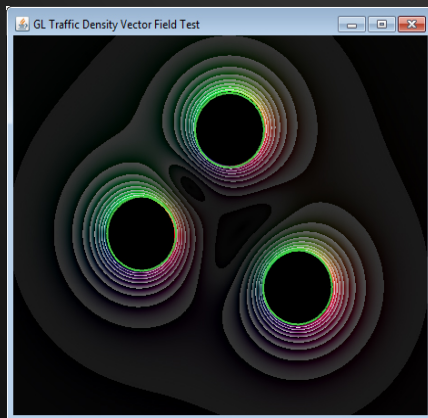
Solution Space Diagram



Discrete route-based info



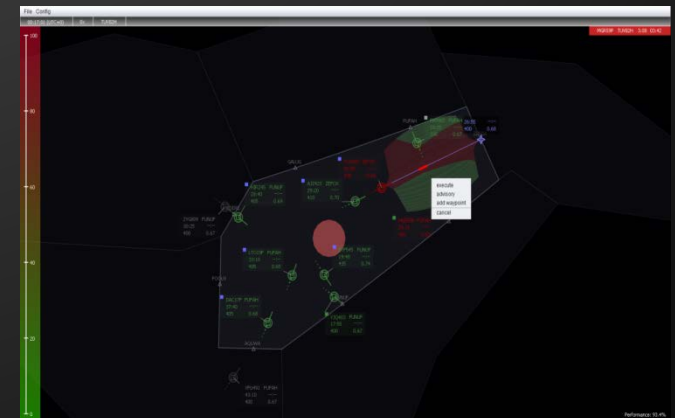
Initial Travel Space implementation



Vector field method

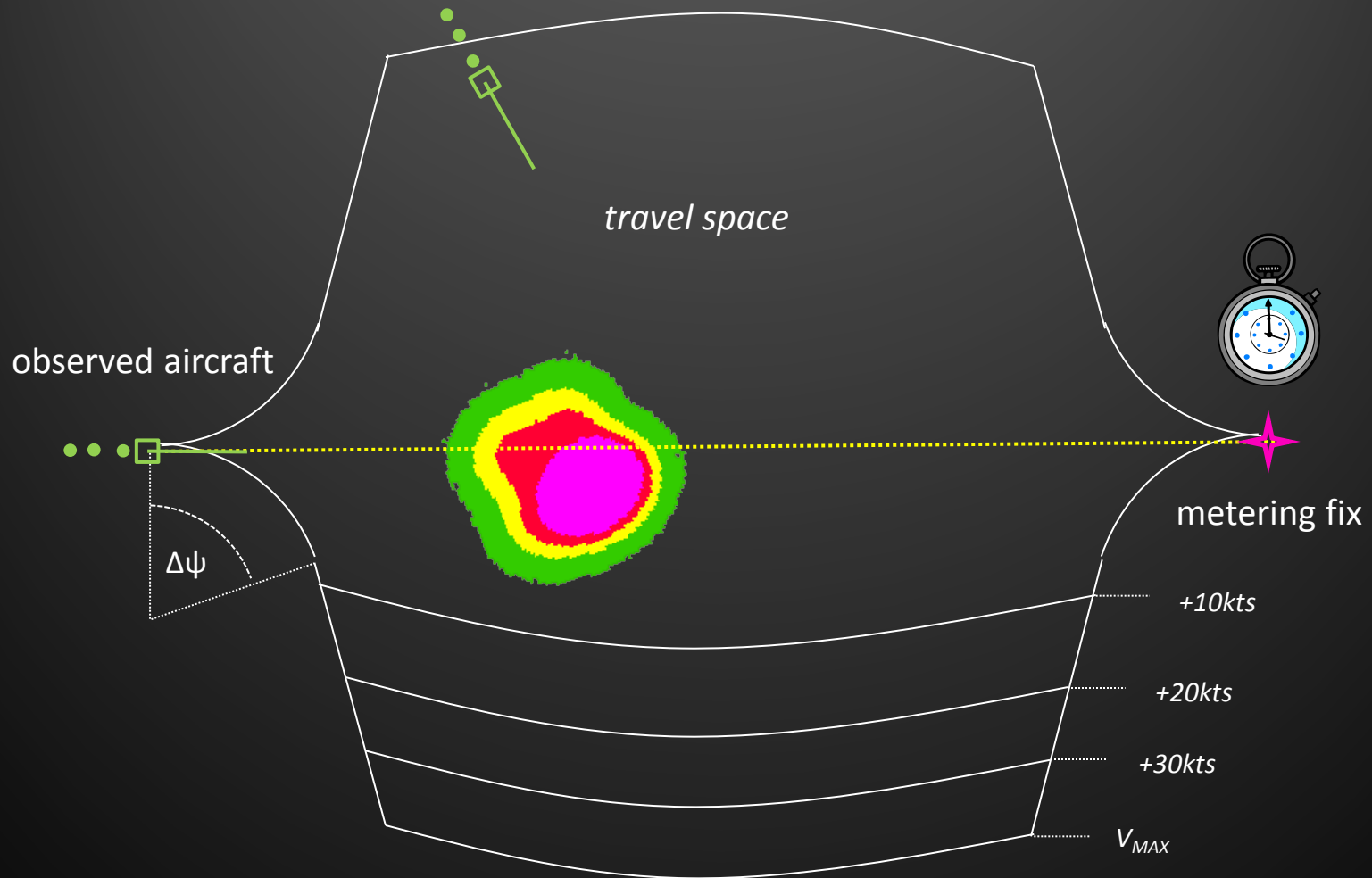


HMI designs

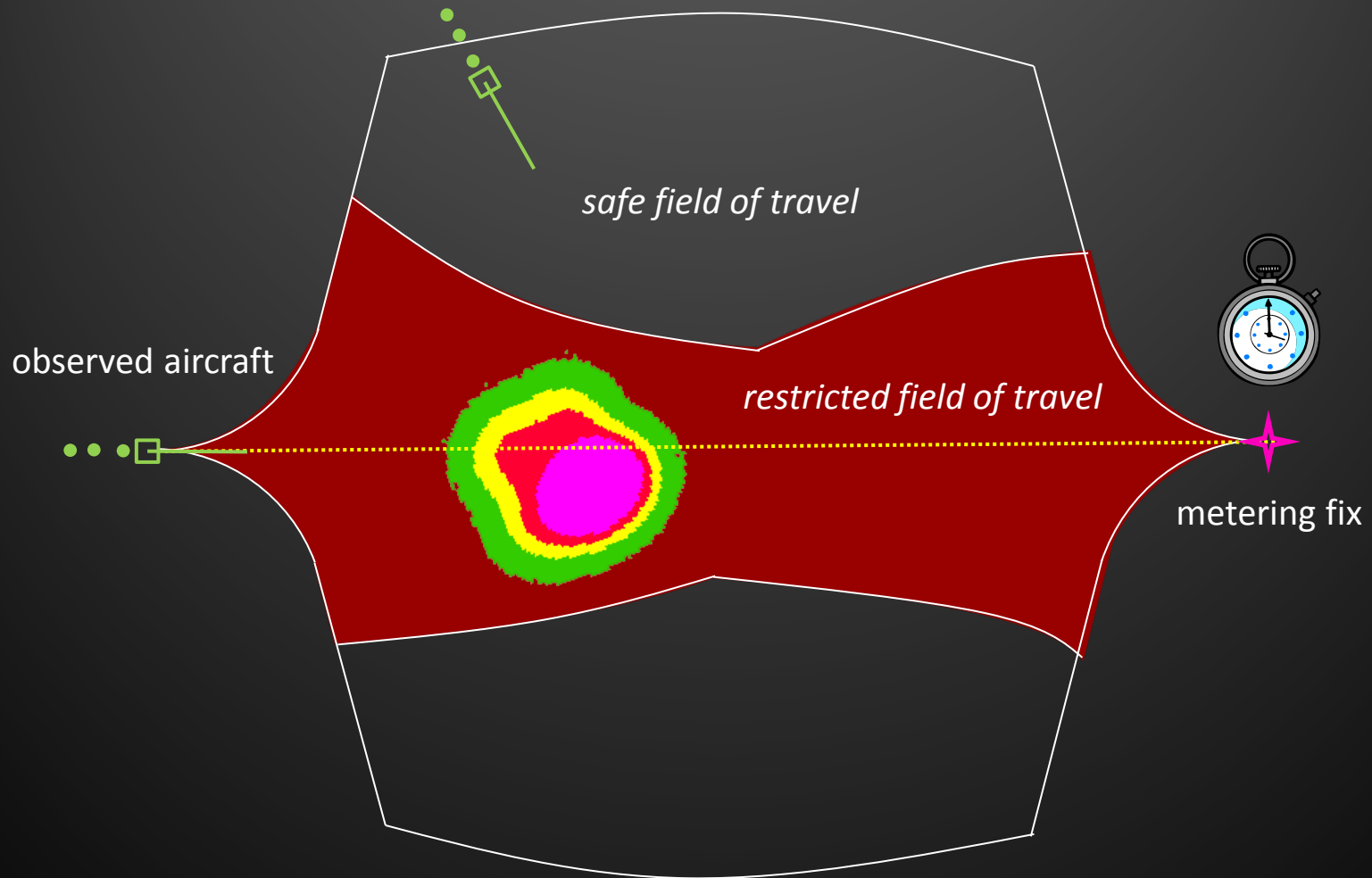


Final JCS experiment version

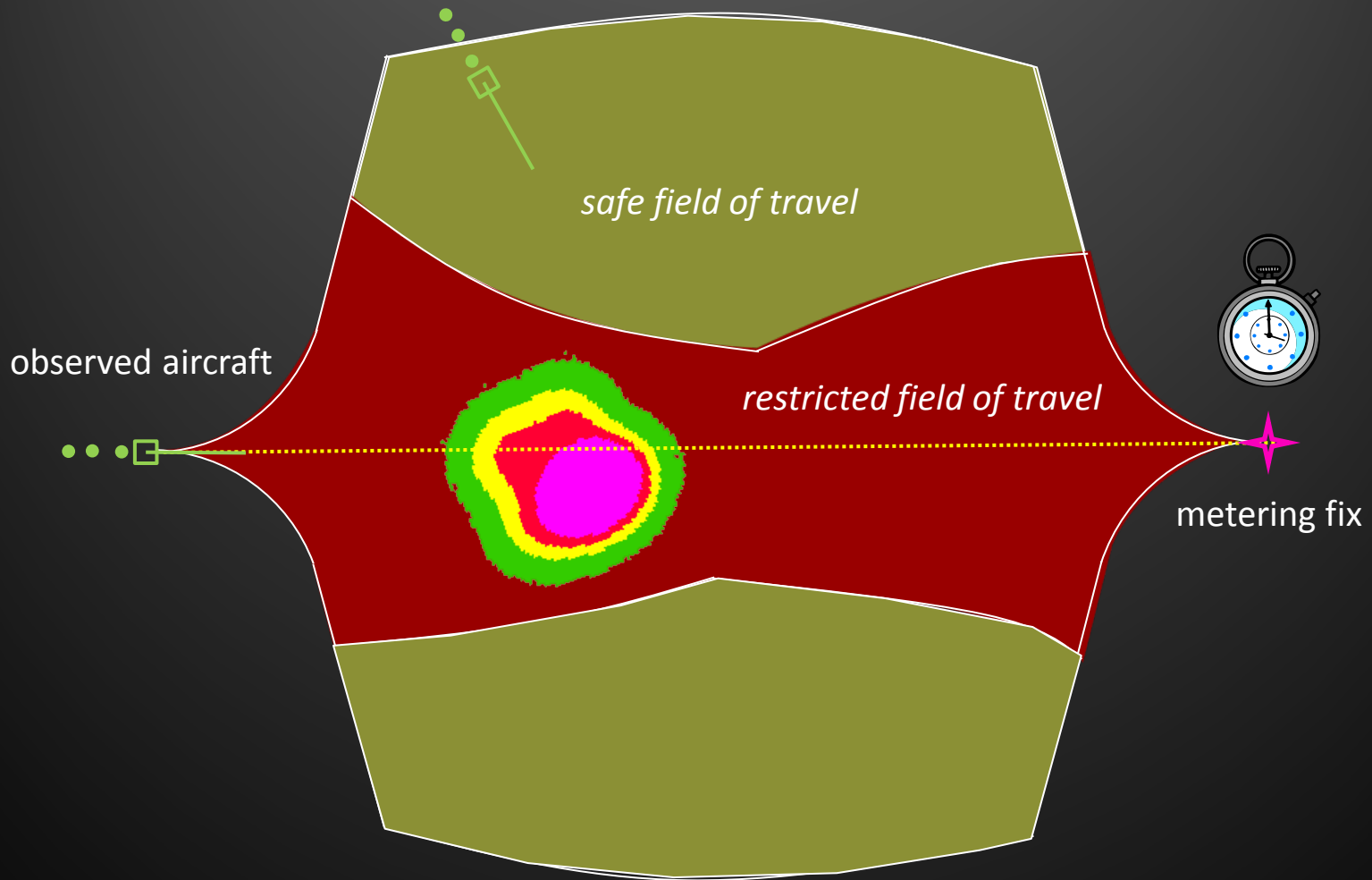
Breakdown of the Travel Space Representation



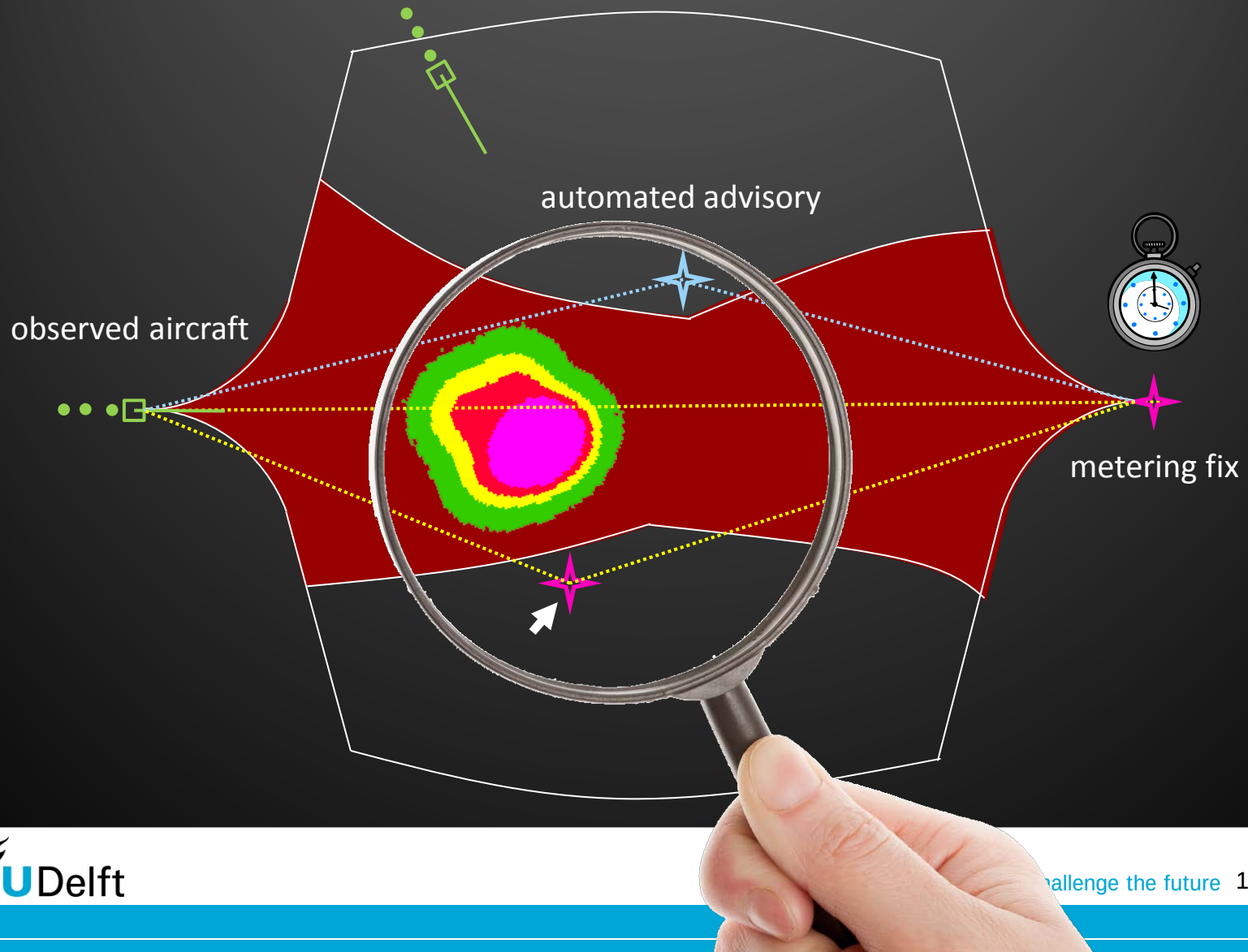
Breakdown of the Travel Space Representation



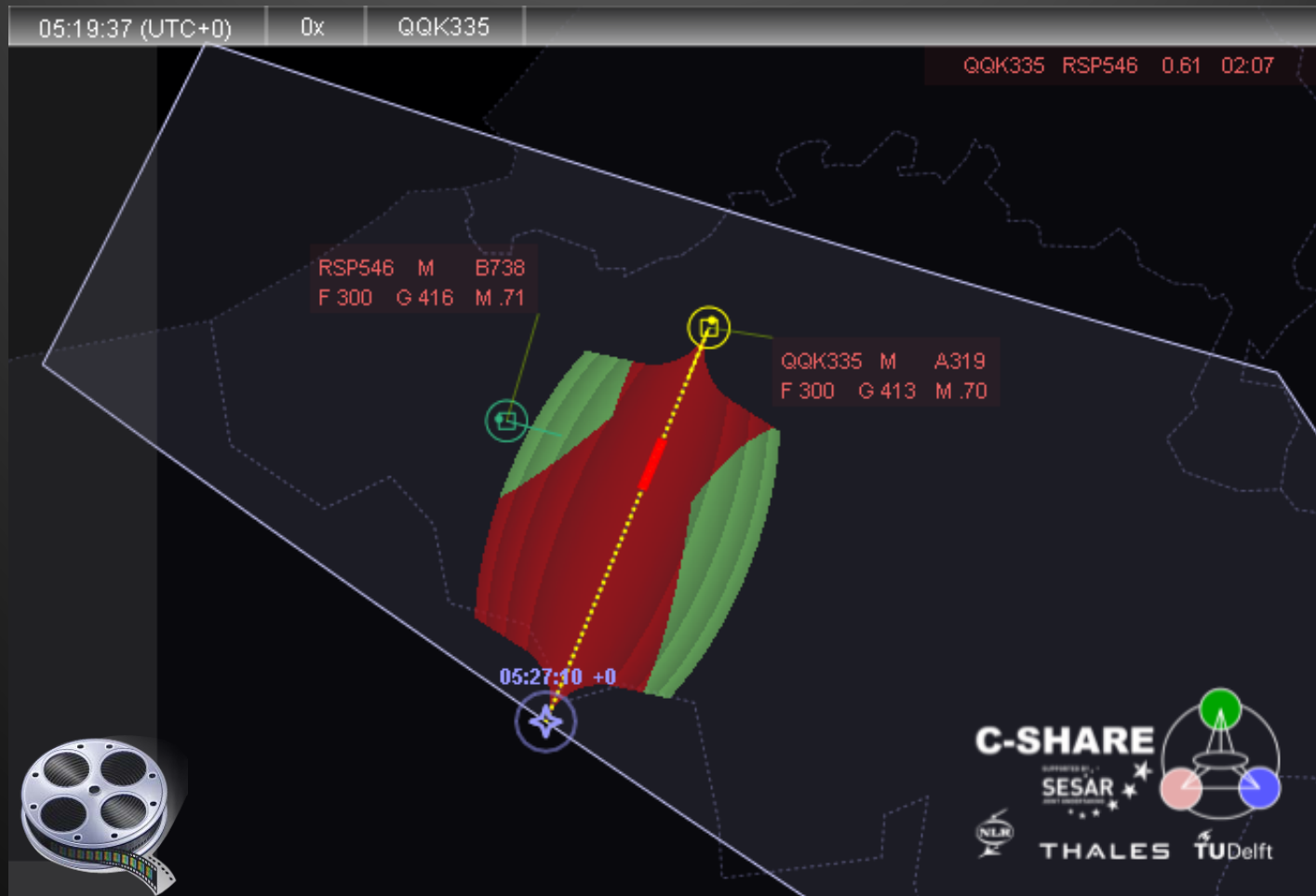
The travel space describes the constraints for problem solving rather than a single optimised solution



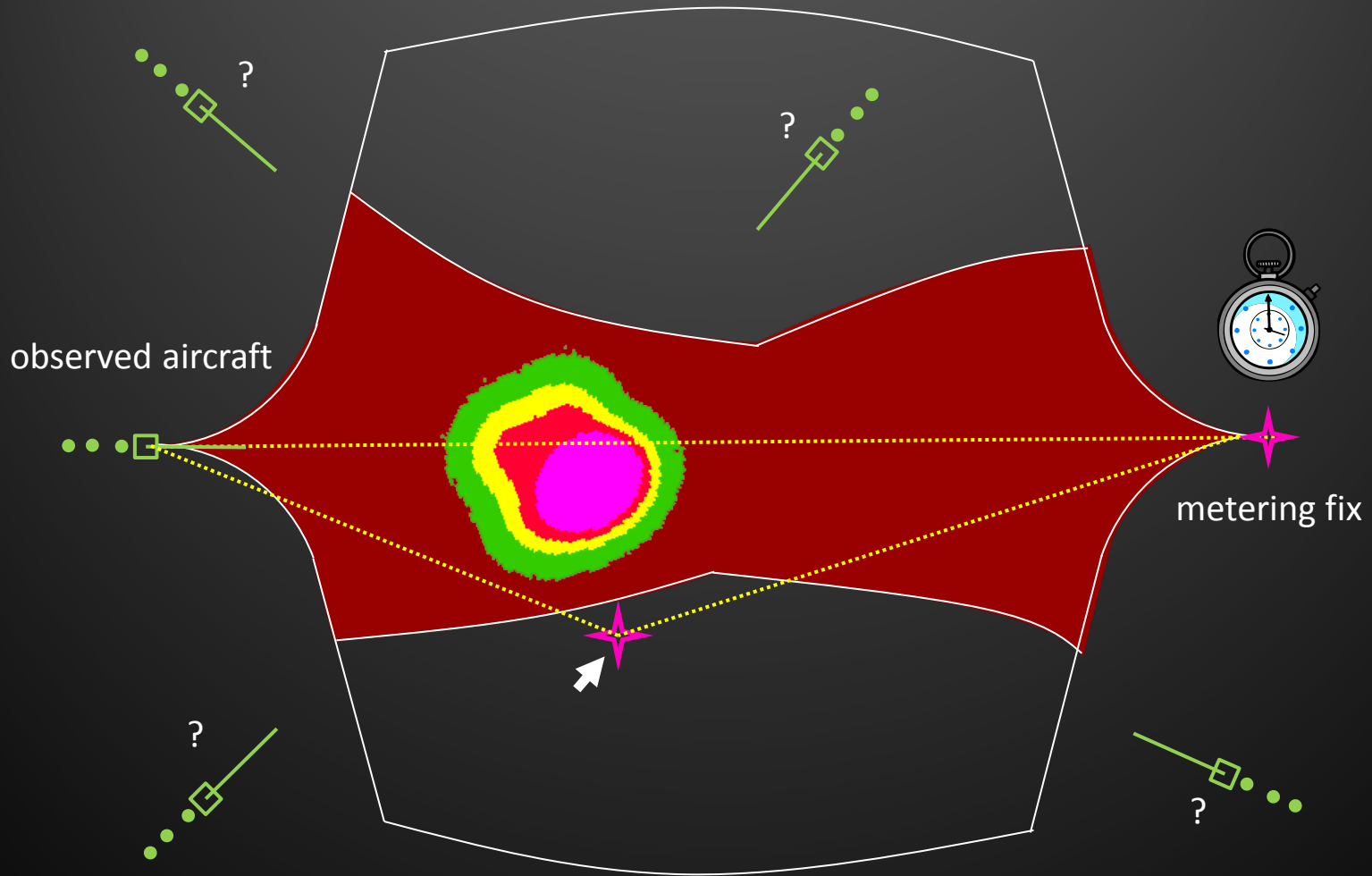
Allowing for automation and the human operator to work together as team players



Example use of the Travel Space Representation



The Travel Space is an egocentric representation



[illegible]

C-SHARE second human-in-the-loop experiment

Aim of the study:

- To investigate the **effectiveness** of the Travel Space Representation under **varying** airspace and traffic conditions

Independent variables:

- Traffic orderliness: structured, unstructured
- Scale of perturbations: small, medium, large

Dependent Measures:

- Loss of separation and overall performance
- Workload and acceptance
- Use of automated advisories

Experiment set-up

Two sub-experiments:

- Manual Control task
- Automated advisories

Participants:

- (2x) 12 Participants
- 3 groups: ATCos, domain experts, students

Procedure:

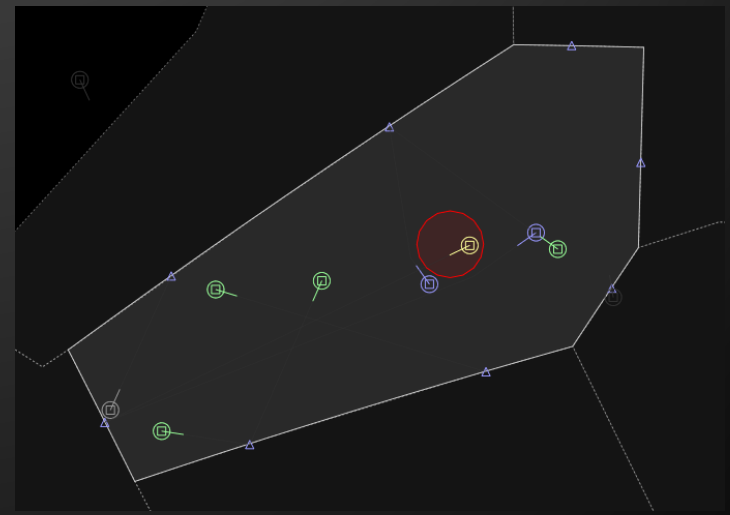
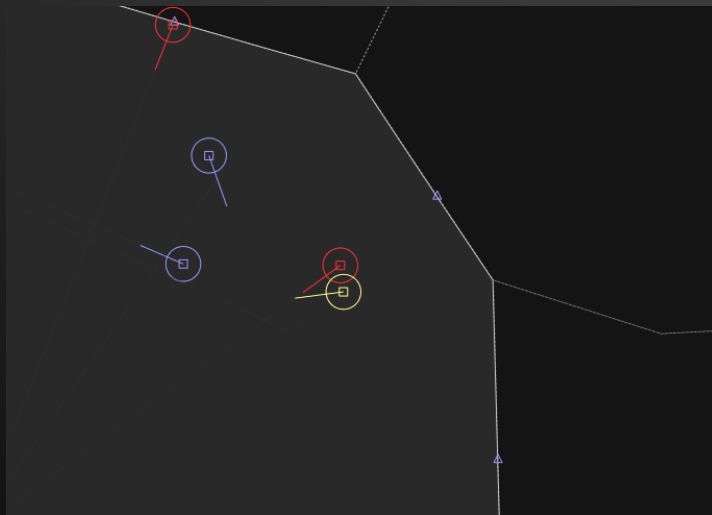
- 45 minute briefing and training
- 6 experiment runs of 6 minutes (4x speed)
- 2 hours total



Results

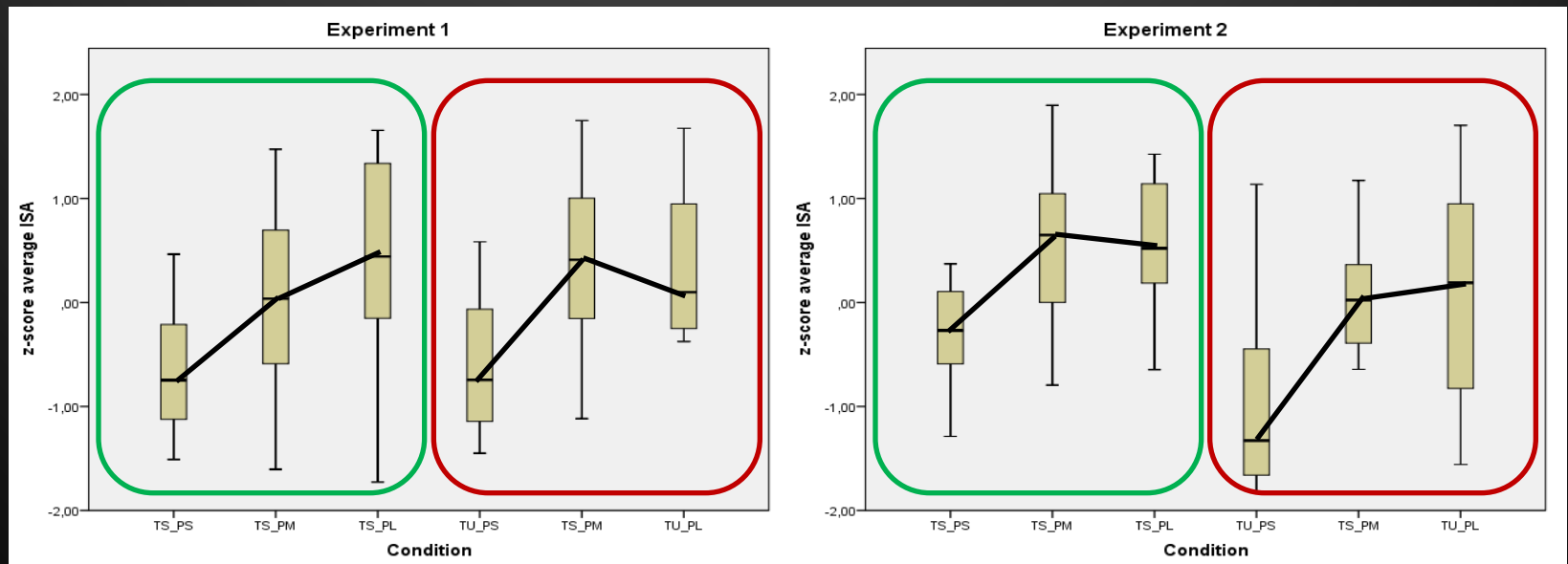
Loss of separation and overall performance:

- An expected breakdown in human-automation coordination during the more complex scenarios did not occur during either sub-experiment
- In both experiments 2 loss of separation events occurred over of 2232 controlled flights
- Similarly 2 Restricted Area intrusions occurred



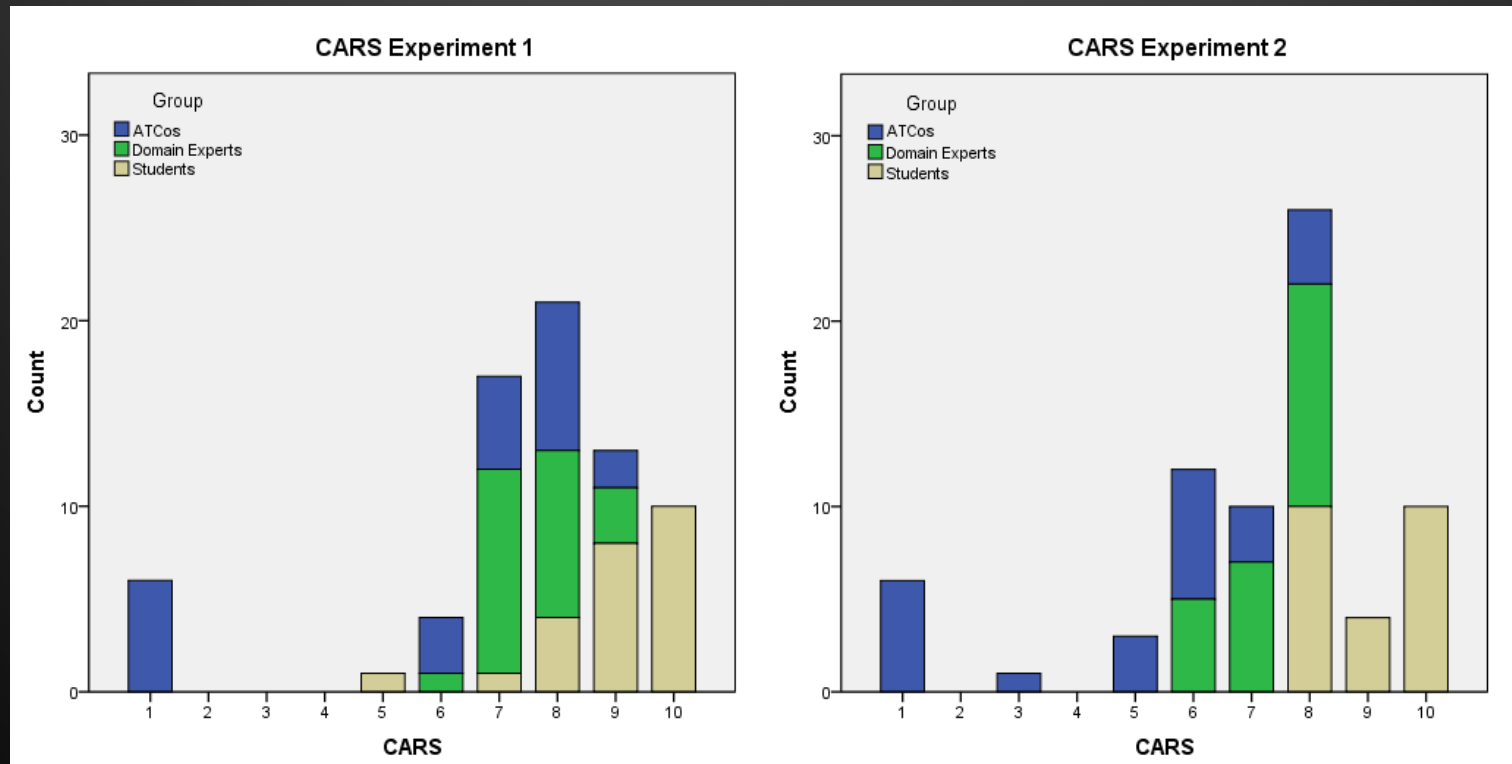
ISA workload self-assessment

- In both experiments the relative workload increased significantly with perturbation scale, however, never became unmanageable
- In sub-experiment 2 workload significantly decreased for unstructured traffic, likely due to the availability of automated advisories



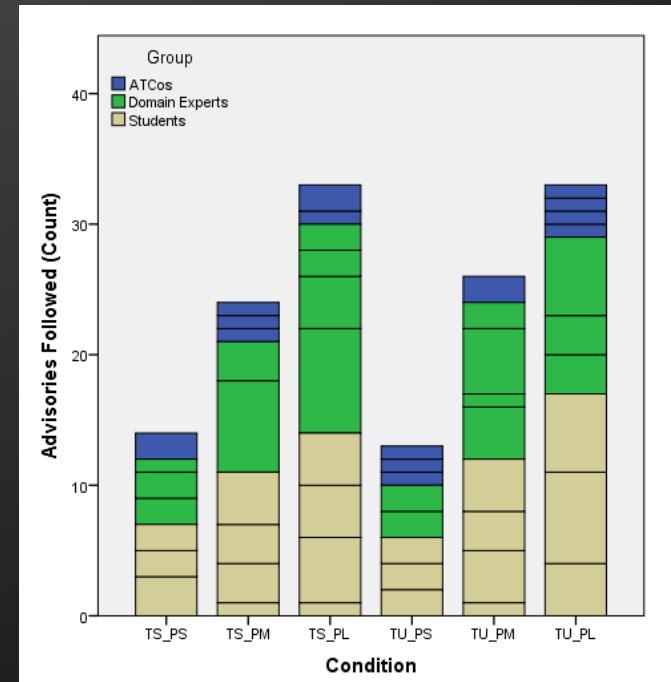
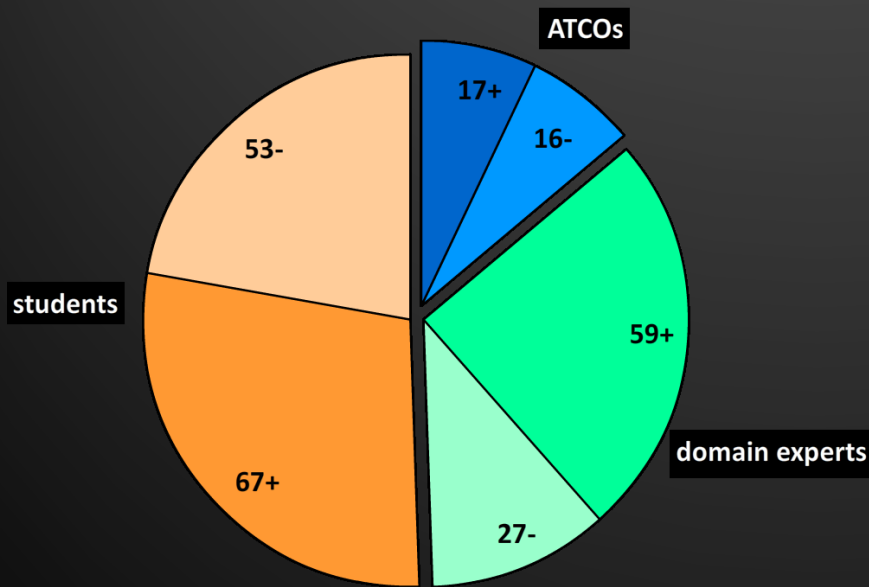
CARS acceptance rating

- Acceptance was highest for students, followed by domain experts and finally ATCos
- Acceptance did not significantly decrease in more complex scenarios



Automated advisories

- Use of advisories was highest for students, followed by domain experts and finally ATCOs
- More advisories were used in complex scenarios
- The number of advisory rejections shows that the Travel Space enables the operator to understand, veto, and re-direct automation



Issues in human factors and system performance measurements

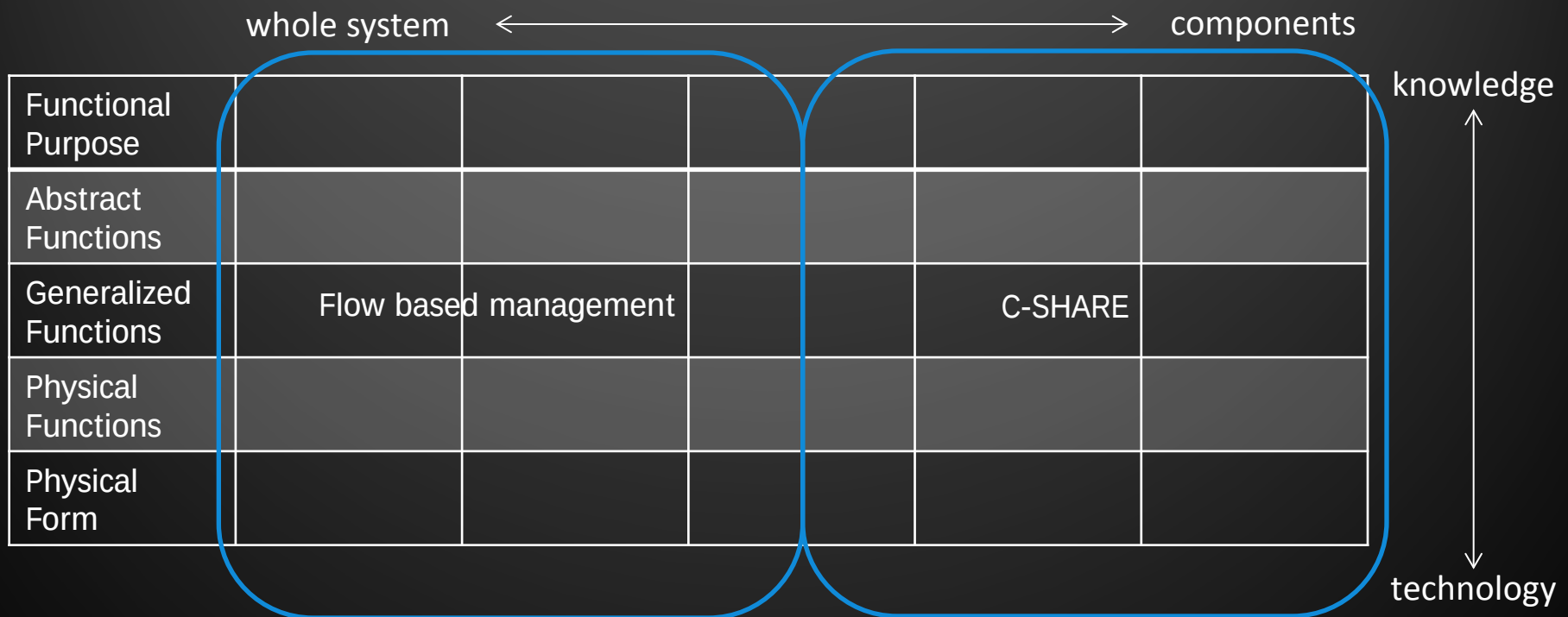
- Currently no methods to evaluate joint human-automation systems
- Methodologies focus heavily on the distinction between the **human** and the **system** parts
- Results are biased by experience and are highly dependent of individual strategies
- There is no clear baseline of a future operational ATM concept

Overall project outcome

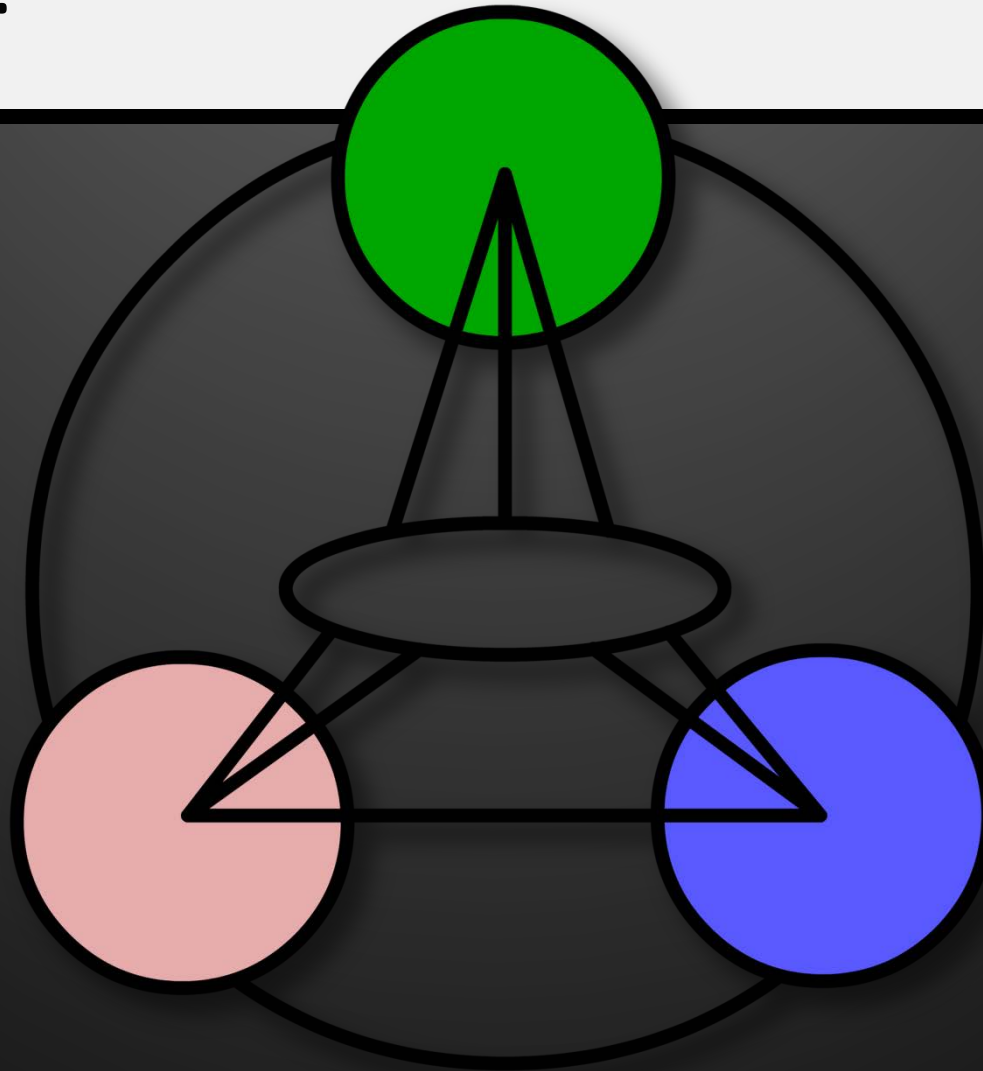
- Proven that C-SHARE **approach to the design** of decision support tools can greatly benefit human-automation coordination
- One of the first working (scalable, multi-platform) joint human-automation prototypes for trajectory-based operations
- Opportunities for further research have been identified

Future research

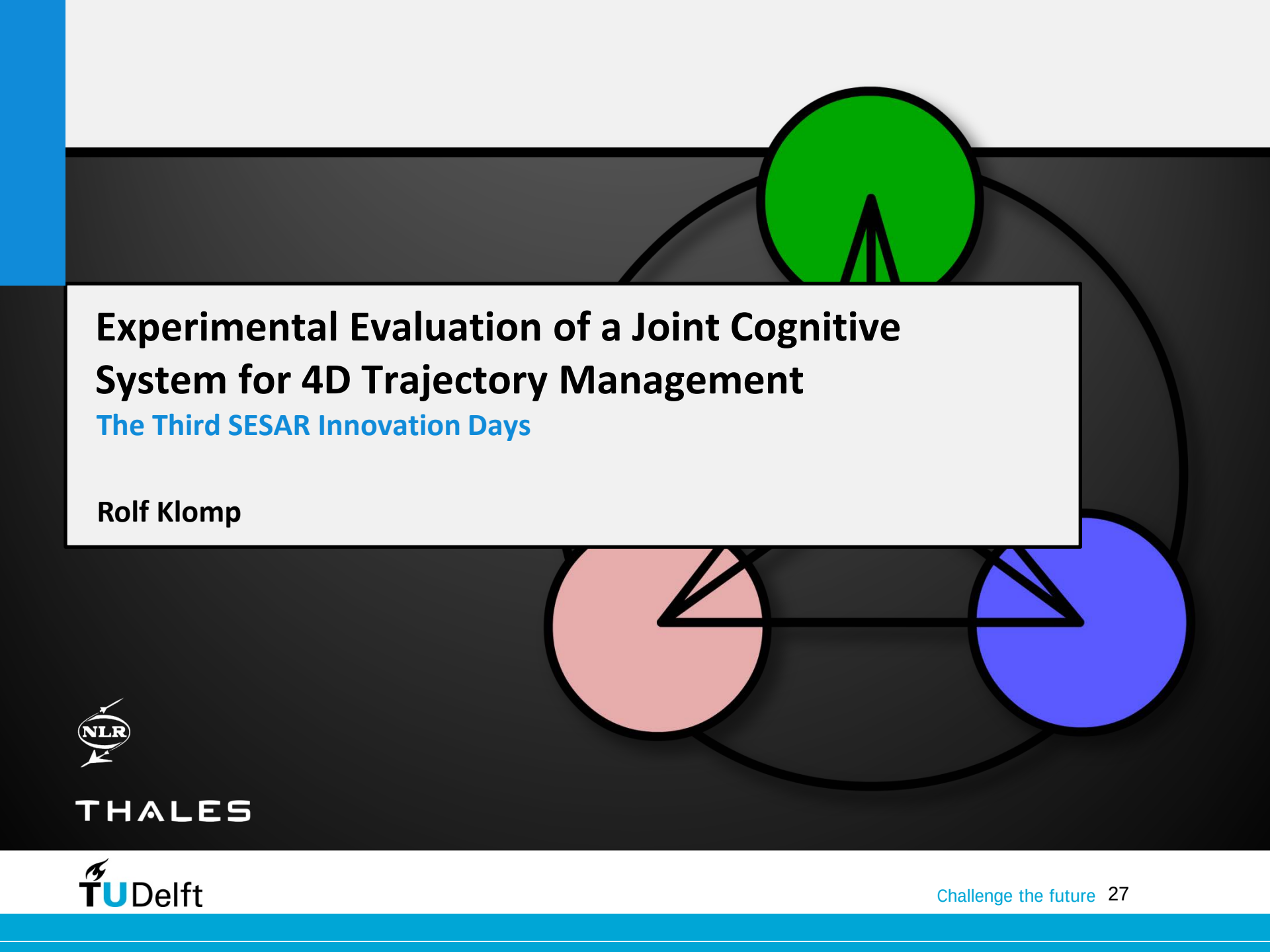
Bridging the gap in the Abstraction Decomposition Space



Questions?



Contact: R.E.Klomp@TUDelft.nl



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Rolf Klomp



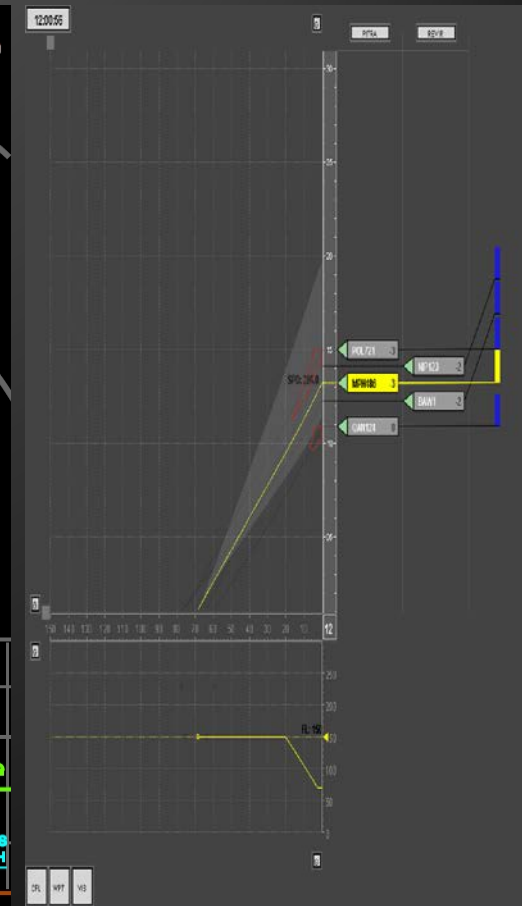
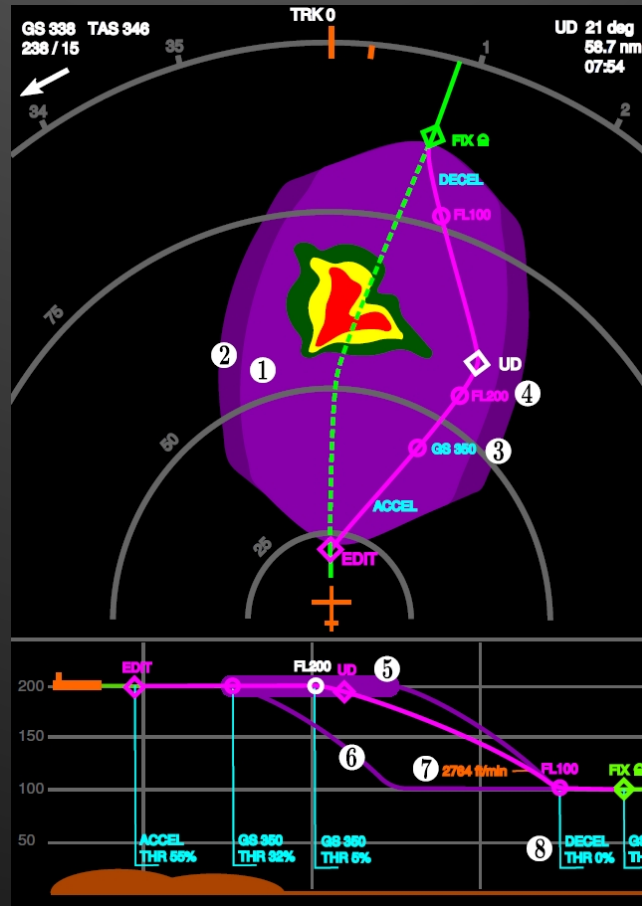
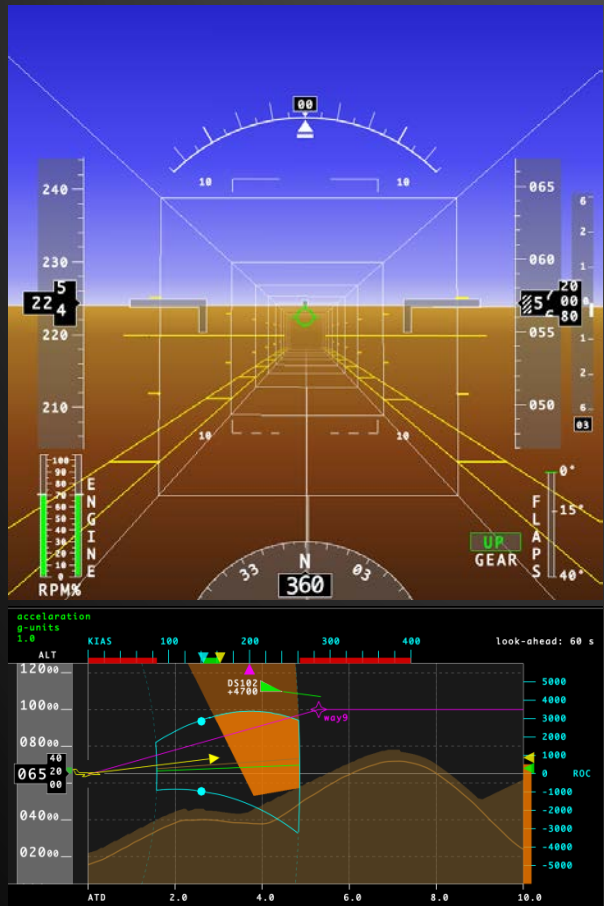
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There is a risk of introducing breakdowns in human-automation coordination

- “Out-of-the-loop” situation awareness
- Vigilance problems
- Transient workload peaks
- Skill degradation
- Overreliance
- Lack of trust
- ...



Example displays using the ecological approach

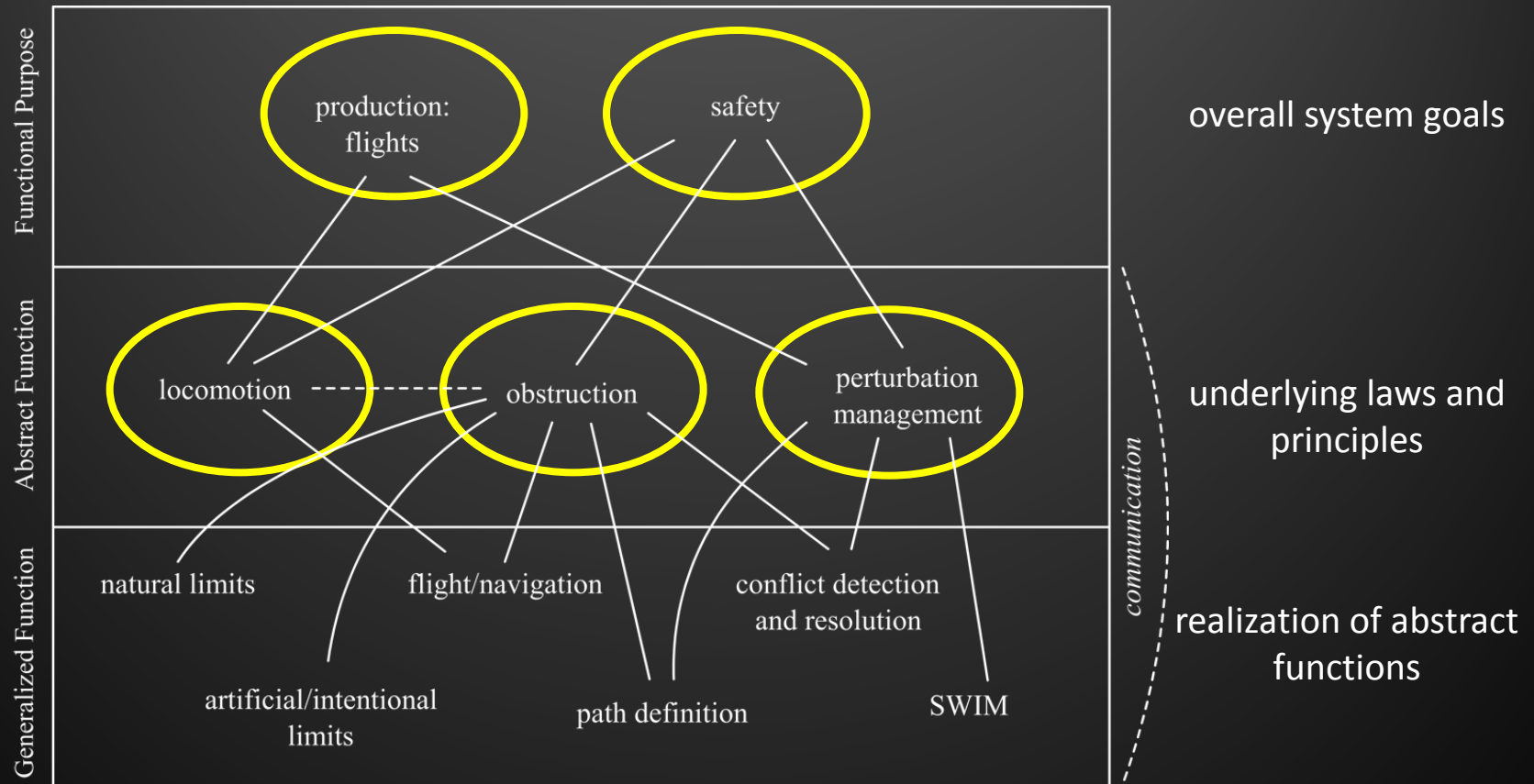


The multidisciplinary approach is based upon the proven CSE and EID frameworks

The five steps of CSE:

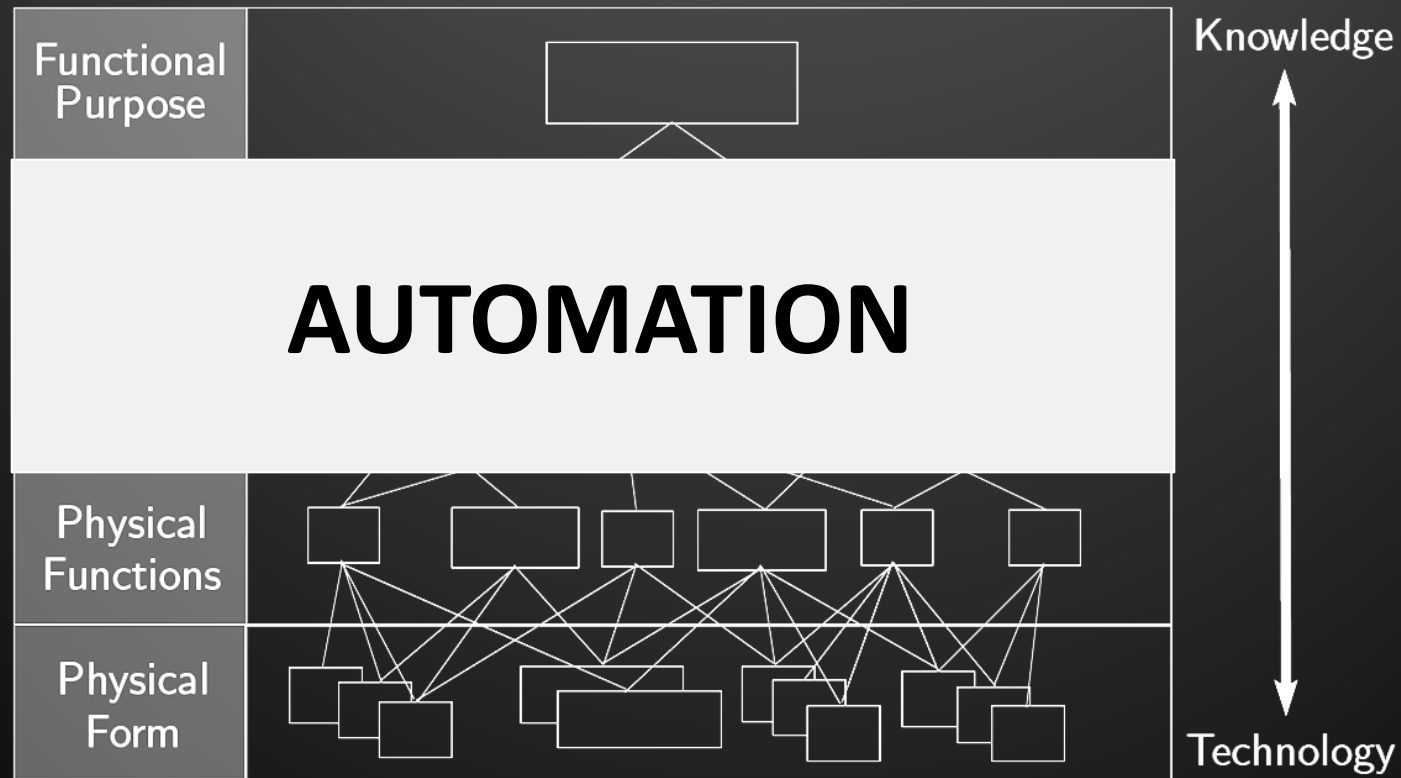
- Work Domain Analysis *what is the purpose of the system?*
- Control Task Analysis *what must be done?*
- Strategies Analysis *how can it be done?*
- Cooperation Analysis *how can work be shared?*
- Worker Competencies *how can operators best be supported?*

The Abstraction Hierarchy shows the opportunities, constraints and relationships of the problem domain

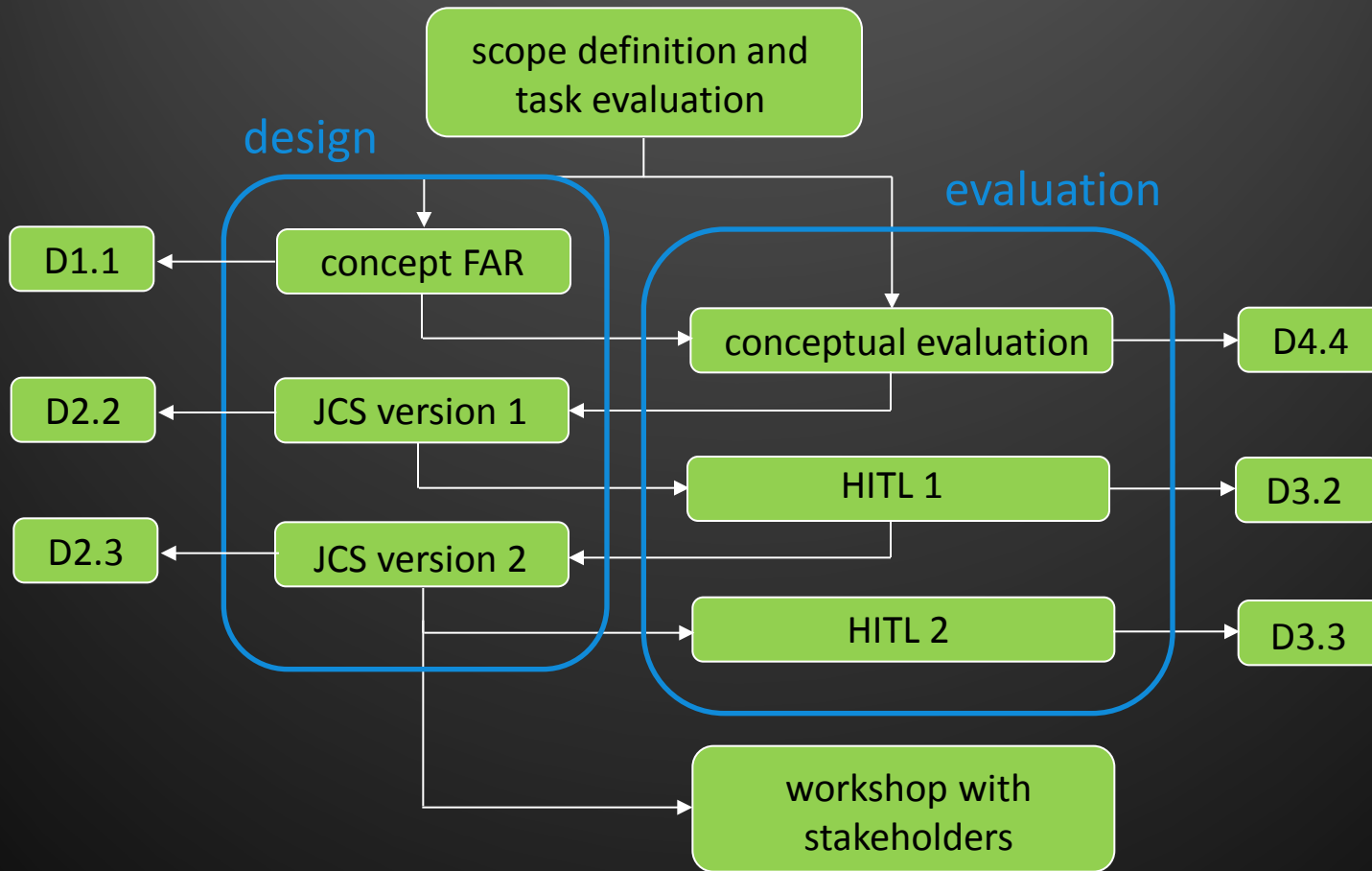


The multidisciplinary approach is based upon the proven CSE and EID frameworks

EID: making visible the invisible



Iterative approach



C-SHARE first human-in-the-loop experiment

Aim of the study:

- To validate the Travel Space concept and obtain expert feedback in an early design stage
- Held with 3 former ATCOs involved in SESAR activities at the EEC in Brétigny



C-SHARE final workshop

- 16 international domain experts and future end-users with a broad range of expertise
- Hands-on demonstration of the JCS
- SWOT analysis to identify strengths, weaknesses, opportunities and threats to guide future research activities



demonstration cubicle



Interactive SWOT