Australian Government
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# Designing for Adaptation in Workers' Individual Behaviours and Collective Structures with Cognitive Work Analysis: Case Study of the Diagram of Work Organisation Possibilities

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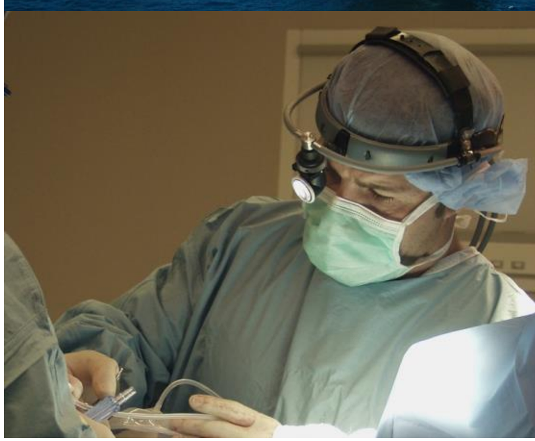
# Complex Sociotechnical Systems



# Need for Adaptation in the Workplace

- Workers adapt their individual behaviours and organisational structures to the evolving task demands

  (e.g., Bigley & Roberts, 2001; Bogdanovic et al., 2015; Hutchins & Klausen, 1998; Luff & Heath, 2000; Lundberg & Rankin, 2014; Rochlin et al., 1987; Ziegert et al., 2006)

# Behavioural Adaptation

- e.g., Emergency management (Bigley & Roberts, 2001)

# Structural Adaptation

- e.g., Naval operations (Rochlin et al., 1987)

# Existing Design Frameworks

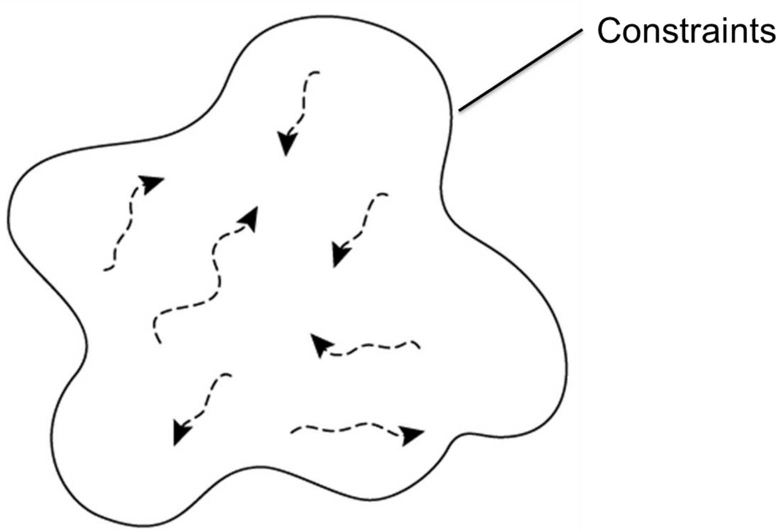
- Resilience engineering (e.g., Hollnagel et al., 2006)
- Sociotechnical systems theory (e.g., Clegg, 2000)
- Cognitive systems engineering (e.g., Hollnagel & Woods, 1983)
- Computer-supported cooperative work (e.g., Schmidt & Bannon, 1992)

# Work Analysis Approaches

- Normative approaches:
  - e.g., sequential flow or timeline task analysis (Meister, 1985)
- Descriptive approaches:
  - e.g., naturalistic (Zsambok & Klein, 1997) or ethnographic (Suchman, 1987) studies

# Cognitive Work Analysis (CWA)

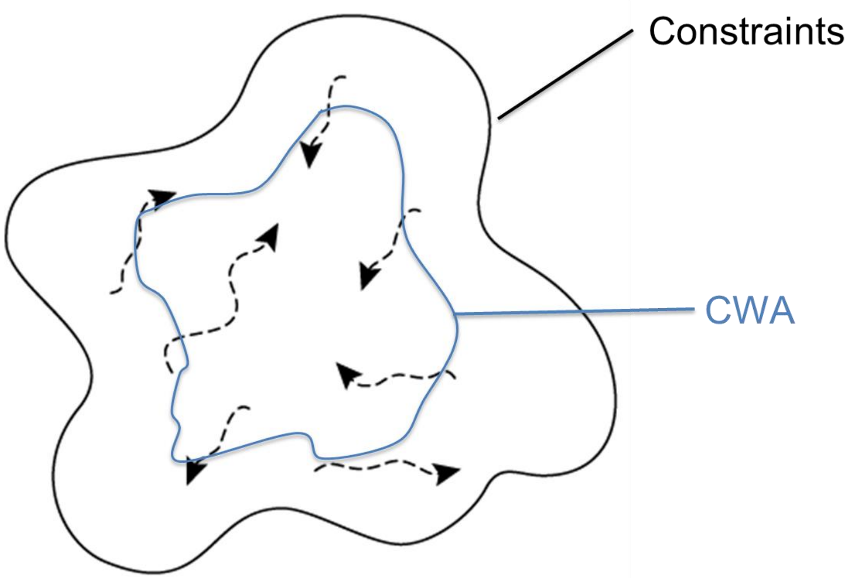
- Formative approach (Rasmussen et al., 1994; Vicente, 1999)




| CWA Dimensions | Constraints |
|---|---|
| Work domain analysis | Work domain |
| Activity Analysis | Activity |
| Strategies analysis | Strategies |
| Social organisation and cooperation analysis | Work organisation |
| Worker competencies analysis | Workers |

# Cognitive Work Analysis (CWA)

- Experimental studies (e.g., review by Vicente, 2002)

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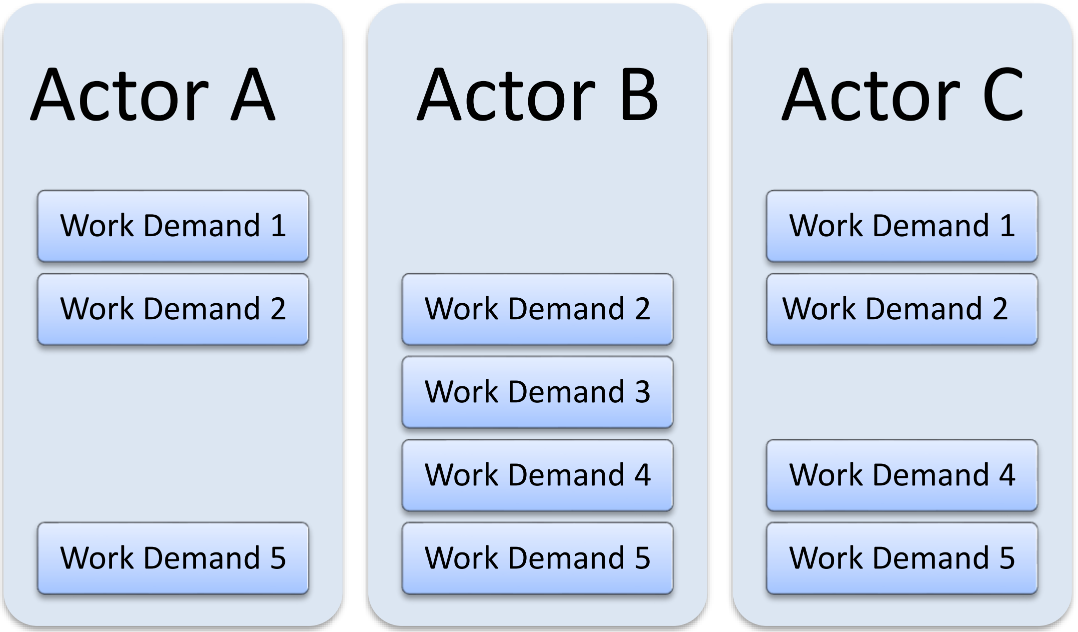
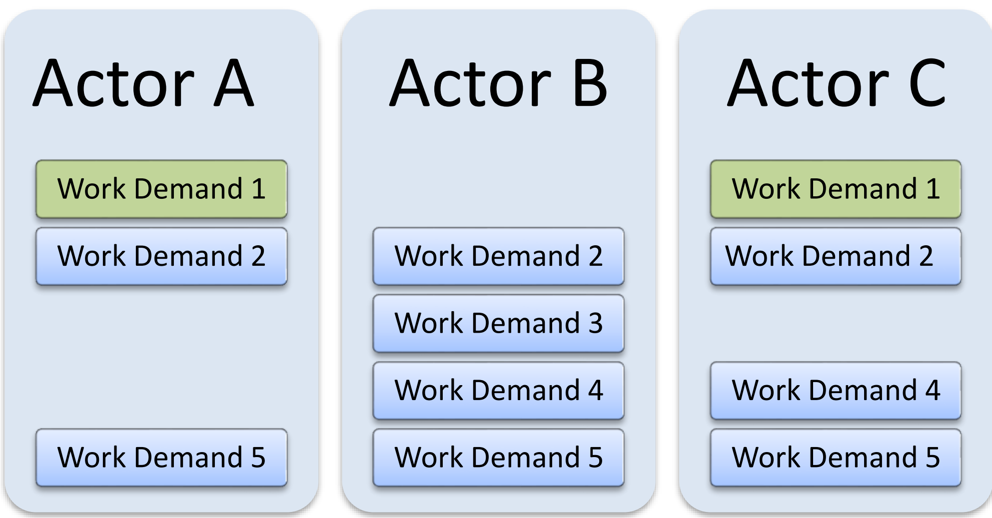
# Diagram of Work Organisation Possibilities

(Naikar & Elix, 2016)



# Constraints, not Possibilities

## Constraints




## Possibilities

Actor A

Actor C

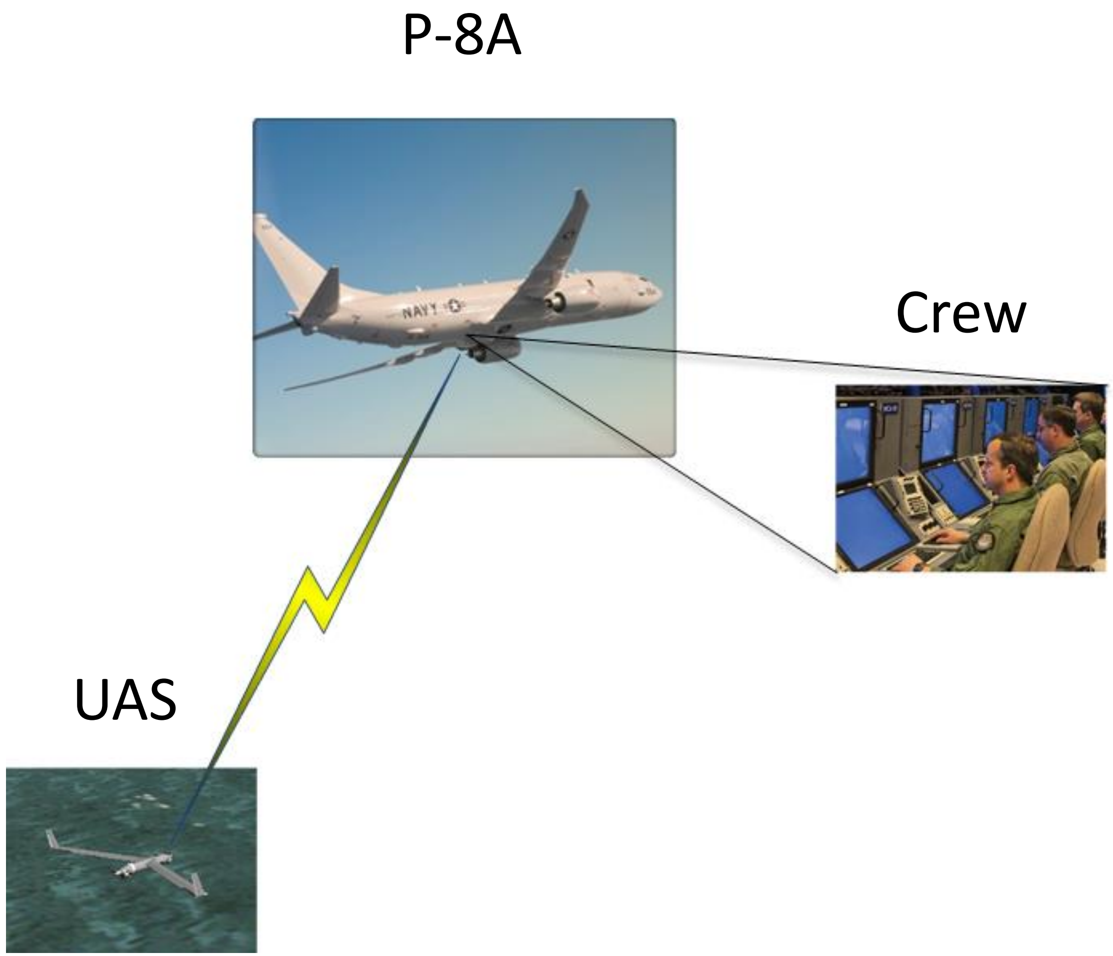
Actors A and C

# Work Organisation Criteria

(Rasmussen et al., 1994; Vicente, 1999)

- Compliance
- Safety and reliability
- Access to information/controls
- Coordination
- Competency
- Workload

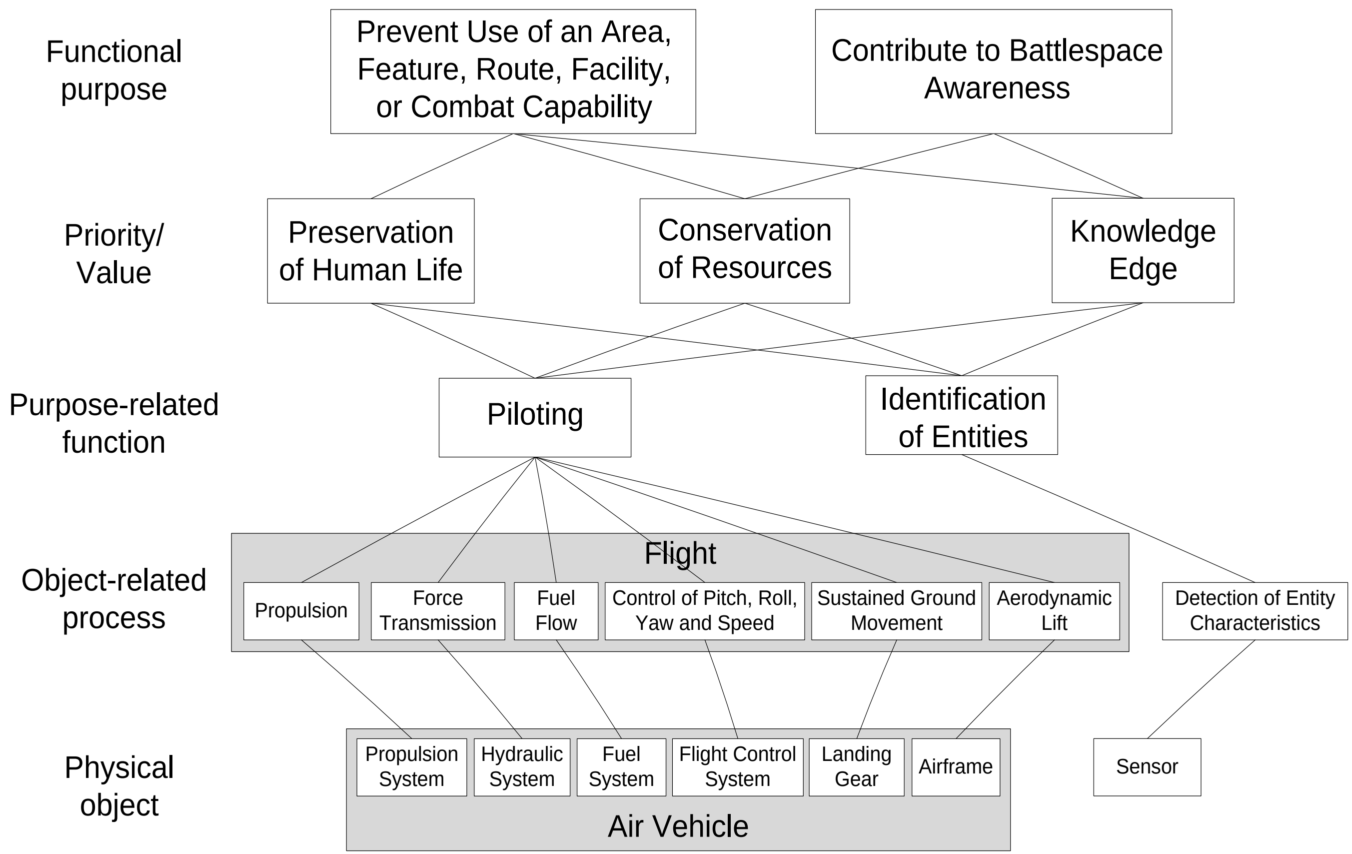
# Case Study



# Work Demands

- First two CWA dimensions:
  - Work domain analysis
  - Activity analysis

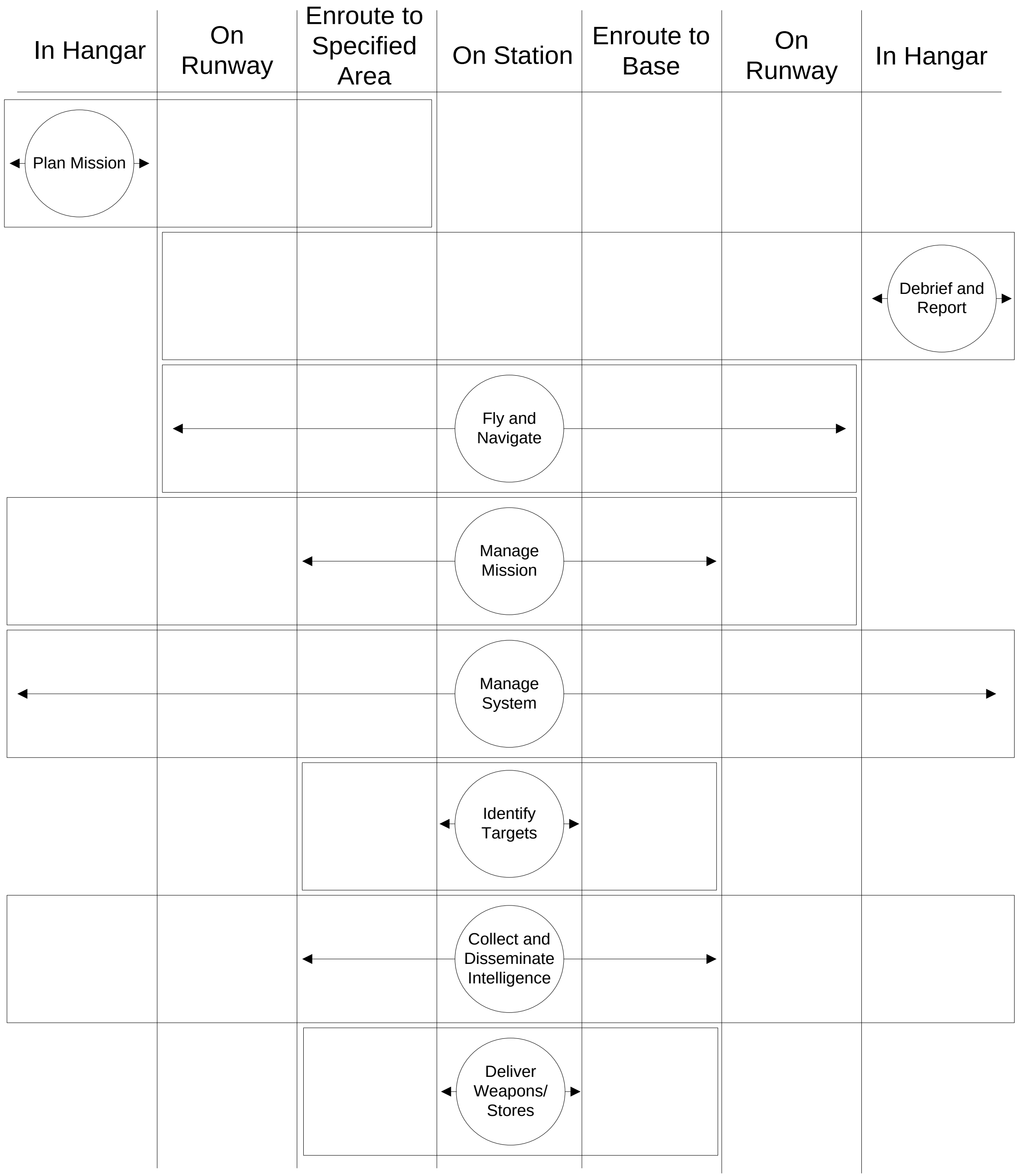
# Work Domain Analysis



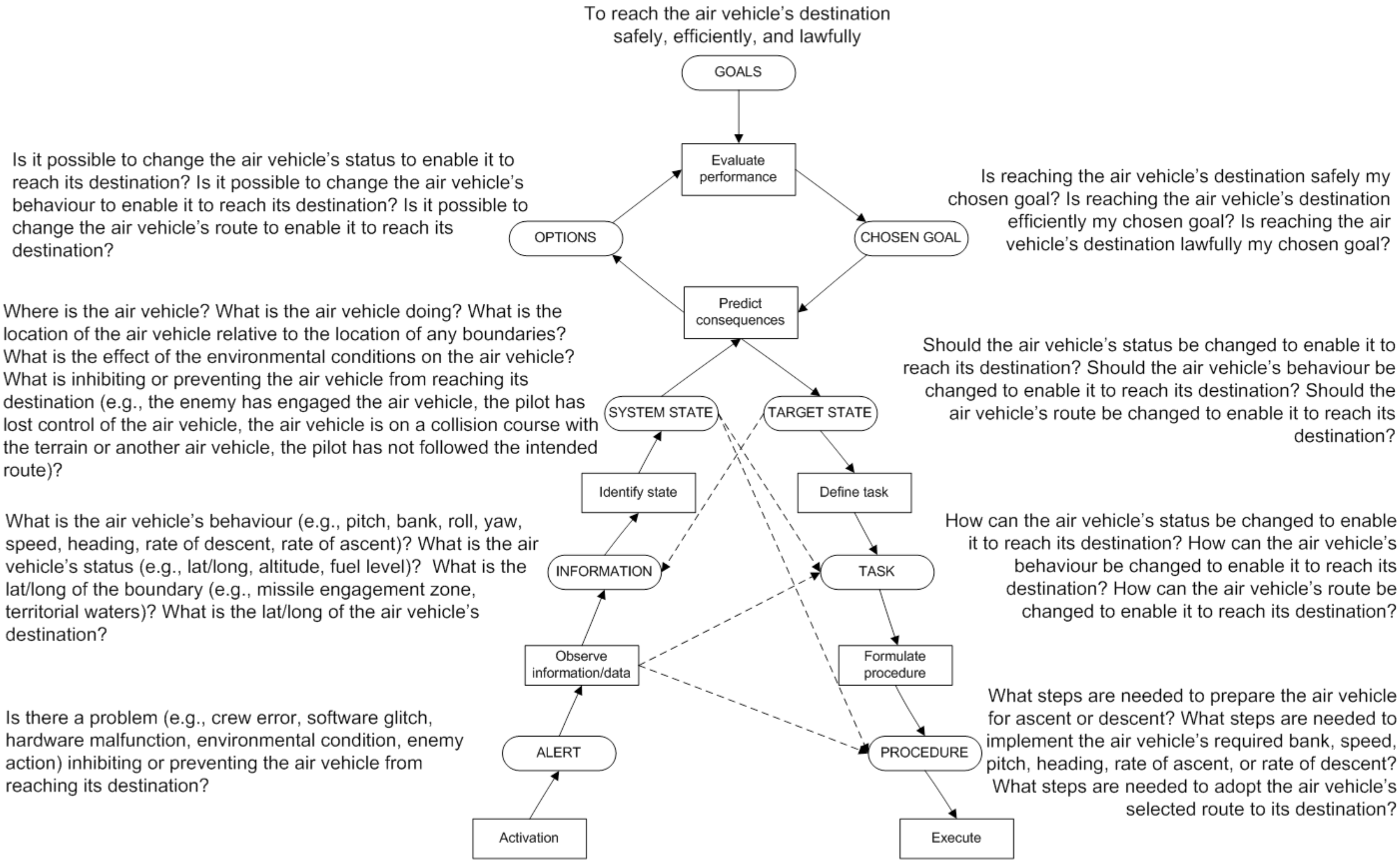

Abstraction hierarchy

# Activity Analysis

## Contextual Activity Template



# Activity Analysis

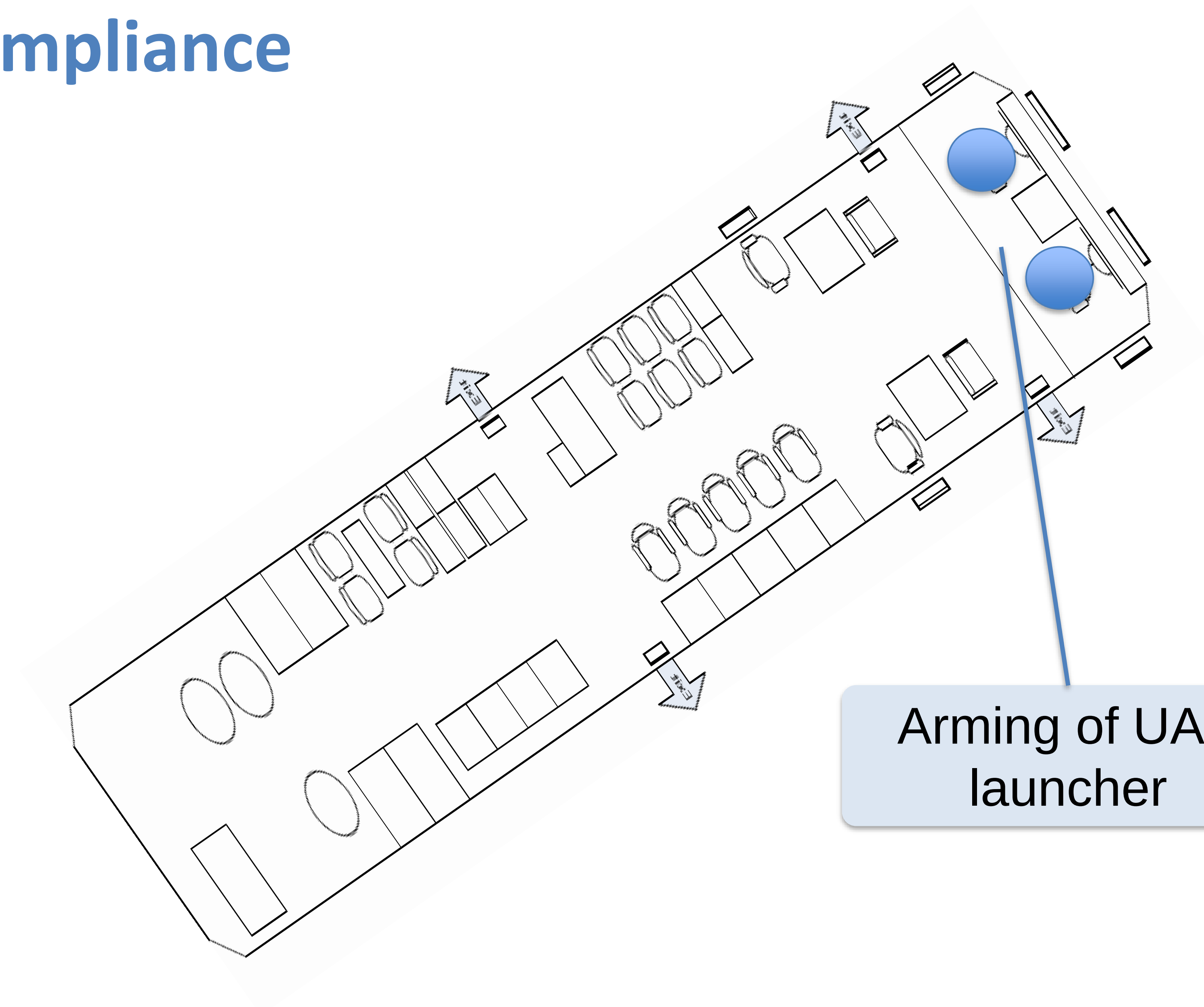



Decision Ladder for *Fly and Navigate*

# Limits on Distribution of Work Demands

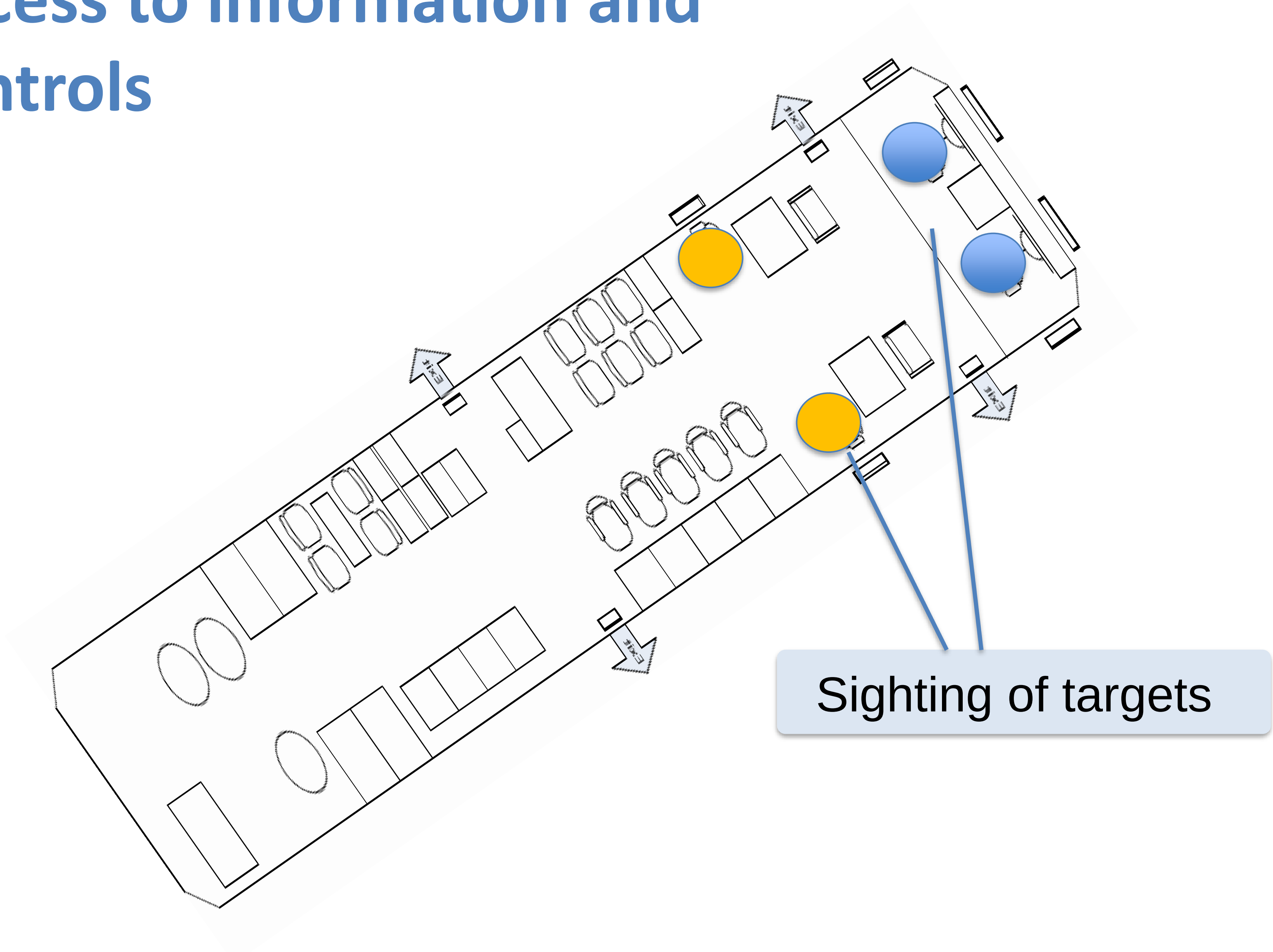
- Work organisation criteria:
  - Compliance
  - Safety and reliability
  - Access to information/controls
  - Coordination
  - Competency
  - Workload

# Compliance

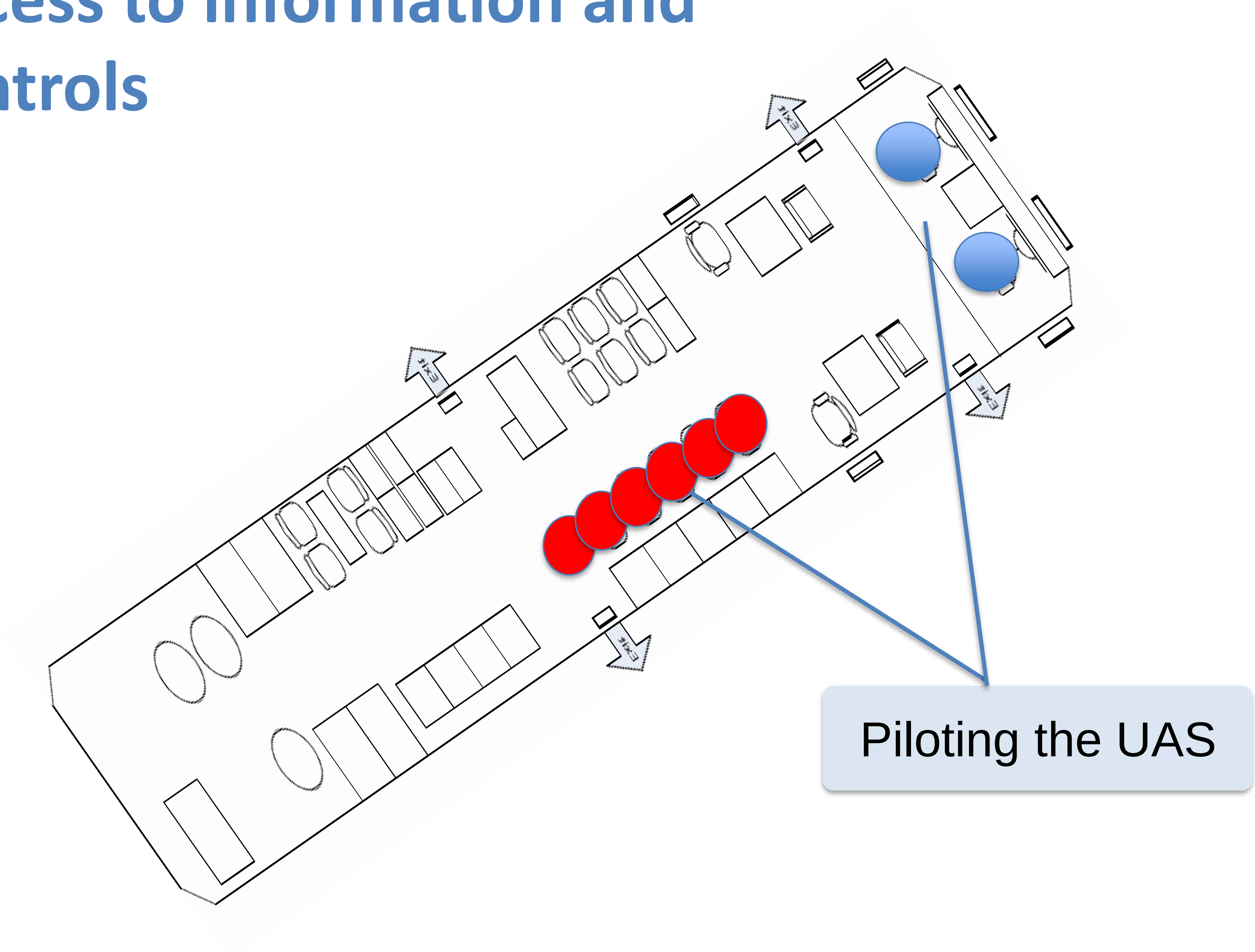


Arming of UAS launcher

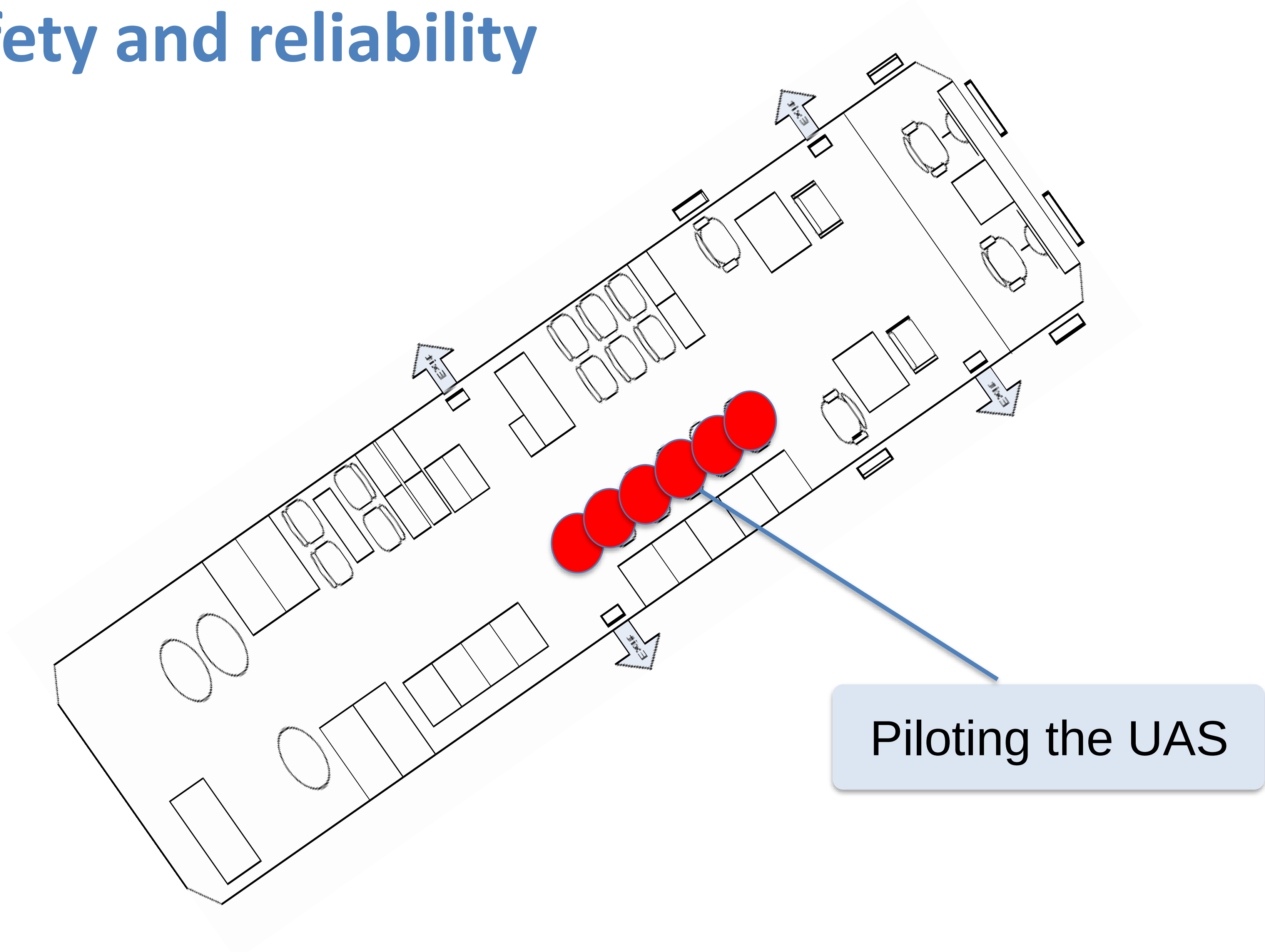
# Access to information and controls



# Access to information and controls



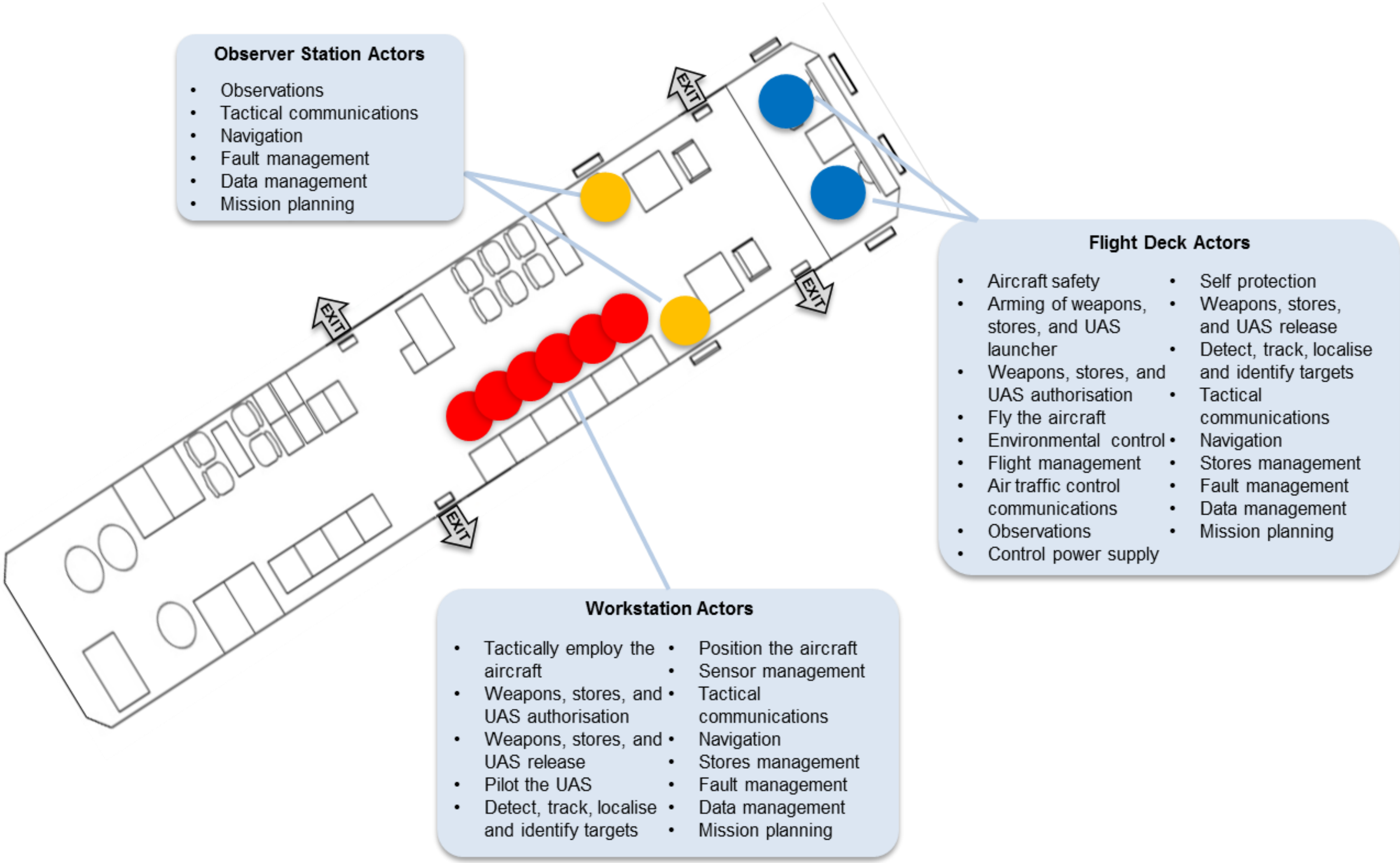
# Safety and reliability



# Coordination, Competency, Workload

- e.g., Workload

# Work Organisation Possibilities Diagram of Future Maritime Surveillance System



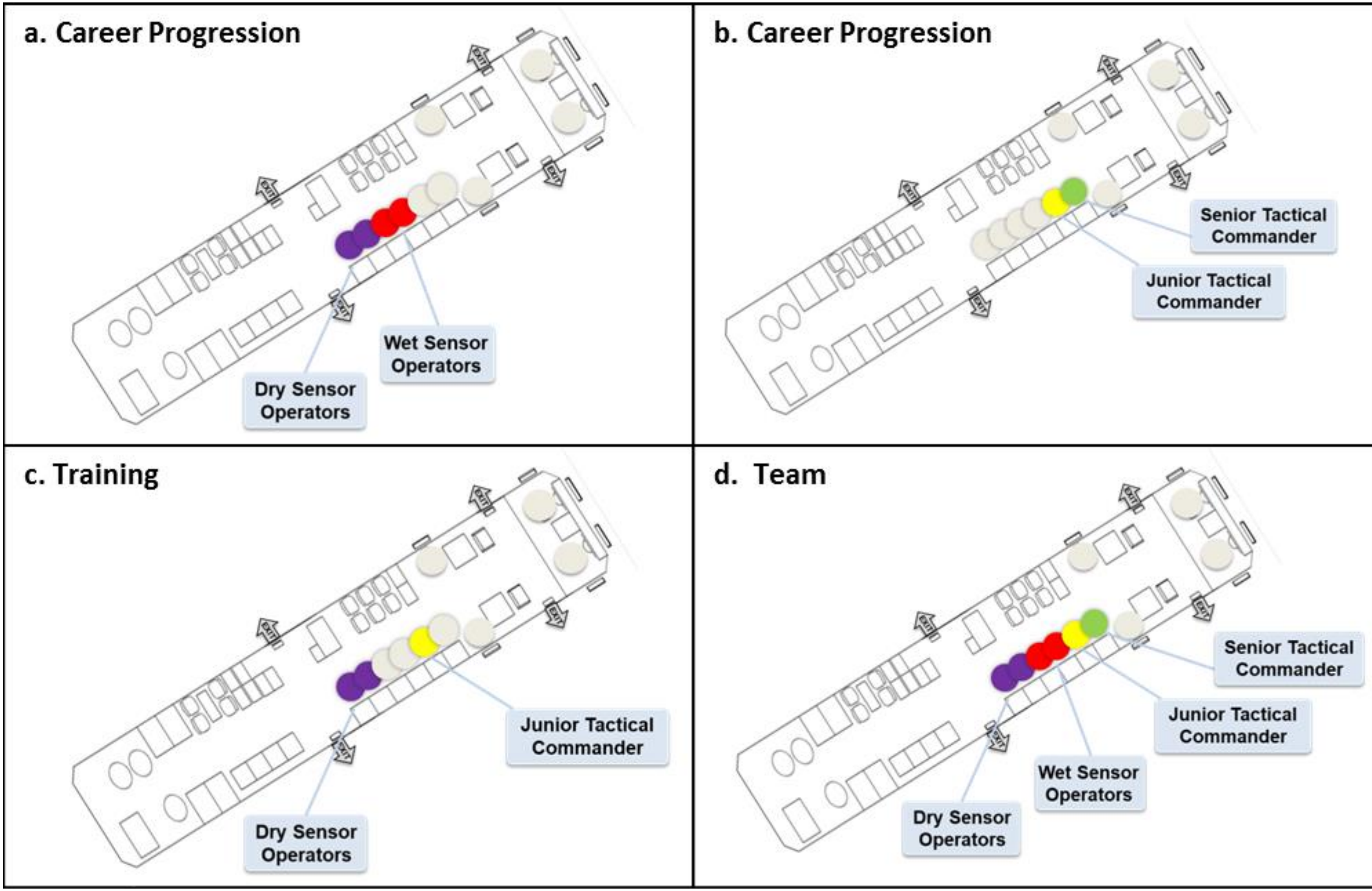
# Design Problem

- 6 workstation actors: pilot the UAS; detect and localise targets with UAS sensor
- 2 flight deck actors: detect and localise targets with UAS sensor
- 2 observer station actors: only if tactical interfaces provided at these stations

# Potential Design Solutions

- Most obvious solution: Enable all crew members to operate the UAS
- Most obvious alternative: Enable only one or two crew members to operate the UAS

# Proposed Design Solution



# Integration of Team, Training, and Career Progression

- "The progress of various team members through the career cycle of navigation practitioners [on naval vessels] produces an overlapping distribution of expertise that makes it possible for the team to achieve training and job performance in a single activity"

(Hutchins, 1990, p. 191).

| Criteria | Senior Tactical Commander | Junior Tactical Commander | Wet Sensor Operators | Dry Sensor Operators |
|---|---|---|---|---|
| Compliance | | | | |
| Safety and Reliability | • Big picture perspective (Beneficial If the UTAS leaves the area of operations)<br>• Big picture perspective (Problematic if having to focus in on the UTAS) | • Less of a requirement to have a big picture perspective of operations (as compared to the Captain, Co-pilot, and TACCO) | • No requirement to have a big picture perspective of operations<br>• The risk of the track being lost (on acoustics) because the Sensor Operator (acoustics) is distracted by operating the UTAS may not be acceptable | • Less of a requirement to have a big picture perspective of operations (as compared to the Captain, Co-pilot, and TACCO) |
| Access to Information/ Control | • Has some ability to control the P-8A to the UTAS release point | | | |
| Coordination | • Best suited to formulate the UTAS release point<br>• Coordinates with the Sensor Operator (acoustics)<br>• Already involved with the release of the UTAS<br>• Added communications (e.g., ATC) | • Could be involved with the release of the UTAS<br>• Monitors the surrounding air traffic<br>• Added communications (e.g., ATC)<br>• Added coordination with the Sensor Operator (acoustics)<br>• Added coordination with the TACCO (and potentially Captain/Co-pilot) | • High coordination between the two Sensor Operator (acoustics)<br>• Comprehensive understanding of the target status and behaviour<br>• Required to monitor surrounding air traffic<br>• Not involved in releasing the UTAS<br>• Added coordination with the TACCO (and potentially Captain/Co-pilot) | • High coordination between the UTAS operator and the radar operator<br>• Comprehensive understanding of the terrain and/or surface traffic<br>• Not involved in releasing the UTAS<br>• Added coordination with the TACCO (and potentially Captain/ Co-pilot) |
| Competencies | • Competent to tactically employ an aircraft<br>• Competent to navigate an aircraft<br>• Competent to perform communications<br>• Competent to release the UTAS<br>• Not competent to fly an aircraft<br>• Not competent to operate any sensors | • Some competencies associated with tactically employ an aircraft<br>• Competent to navigate an aircraft<br>• Competent to perform communications<br>• Competent to release the UTAS<br>• Not as experienced as the TACCO tactically employing an aircraft<br>• Not competent to fly an aircraft<br>• Not competent to operate any sensors | • Experience operating sensors and may be competent in sensor management<br>• Not competent to tactically employ an aircraft<br>• Not competent to fly or navigate an aircraft<br>• Not competent to perform communications<br>• Not competent to release stores | • Competent to operate other sensors<br>• Competent in collision avoidance<br>• Least experienced crew member<br>• Not competent to tactically employ an aircraft<br>• Not competent to fly or navigate an aircraft<br>• Not competent to perform communications<br>• Not competent to release stores |
| Workload | • May reduce during recovery<br>• Workload may be high at times | • May reduce during recovery<br>• Workload may be high at times | • May reduce during recovery<br>• Able to share workload<br>• Workload may be high at times | • Lowest of any crew member<br>• May reduce during recovery<br>• May need to rotate through different sensors |

# Industrial Criteria

(e.g., Whitefield et al., 1991)

- Impact:
  - Design accepted by the RAAF for further development
- Uniqueness:
  - Formative versus normative and descriptive approaches
- Feasibility:
  - Achieved within schedule, financial, and personnel constraints

# Conclusion

- Future Research

# Final Points

- Elix and Naikar (2019). Accepted for publication in *Human Factors*.

- Extension to workforces or teams with human and artificial agents:
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