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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

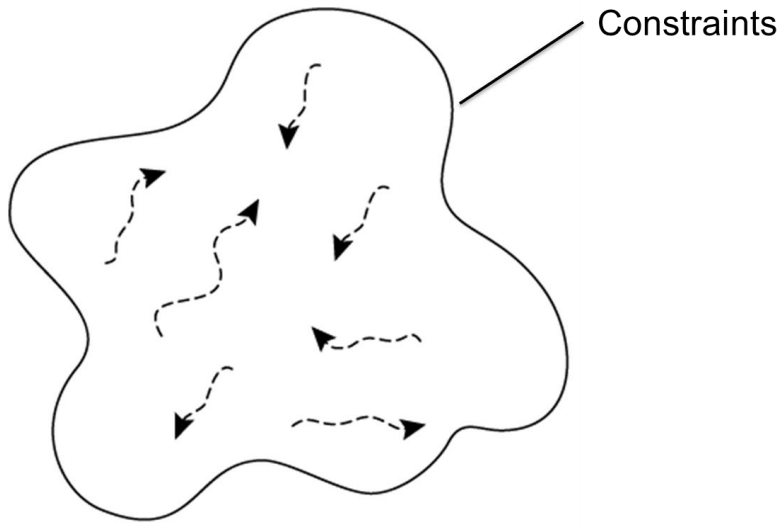
- Resilience engineering (e.g., Hollnagel et al., 2006)
- Sociotechnical systems theory (e.g., Clegg, 2000)
- Cognitive systems engineering (e.g., Hollnagel & Woods, 1983)
- Computer-supported cooperative work (e.g., Schmidt & Bannon, 1992)

# Work Analysis Approaches

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

# Cognitive Work Analysis (CWA)

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

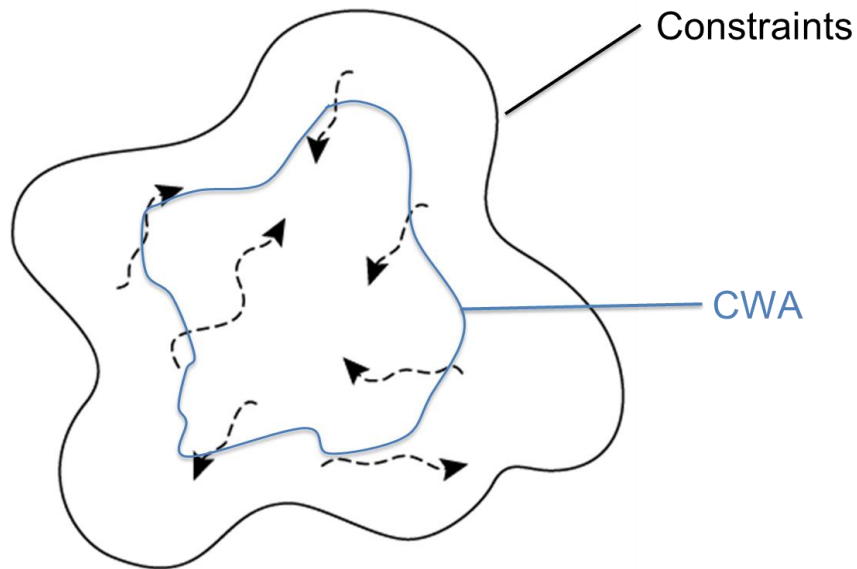


CWA Dimensions	Constraints
Work domain analysis	Work domain
Activity Analysis	Activity
Strategies analysis	Strategies
Social organisation and cooperation analysis	Work organisation
Worker competencies analysis	Workers



# Cognitive Work Analysis (CWA)

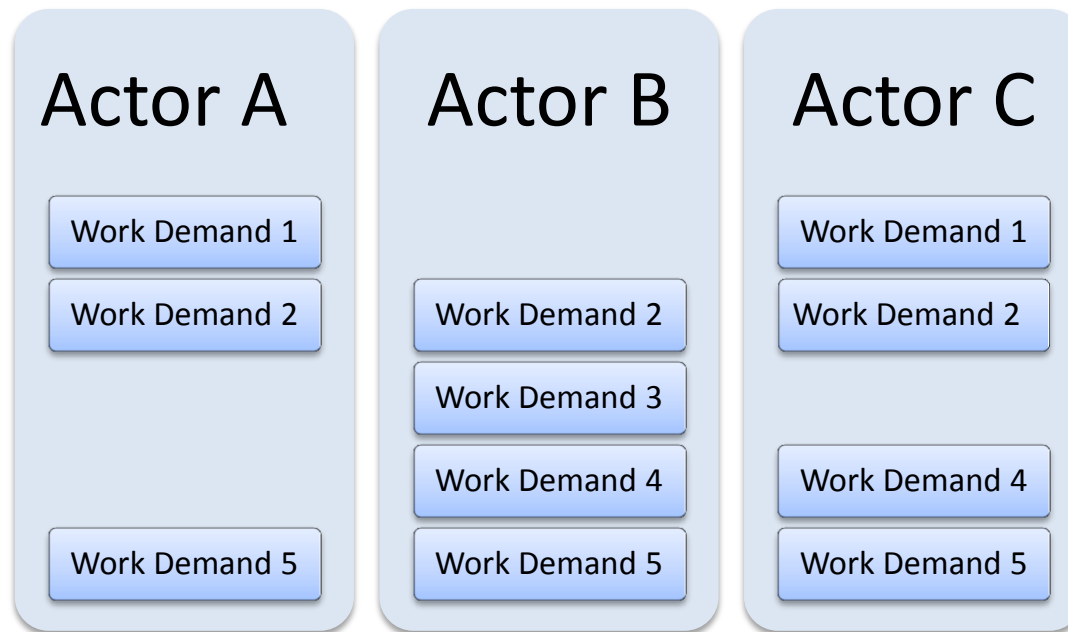
- Experimental studies (e.g., review by Vicente, 2002)



CWA Dimensions	Constraints
Work domain analysis	Work domain
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Social organisation and cooperation analysis	Work organisation
Worker competencies analysis	Workers

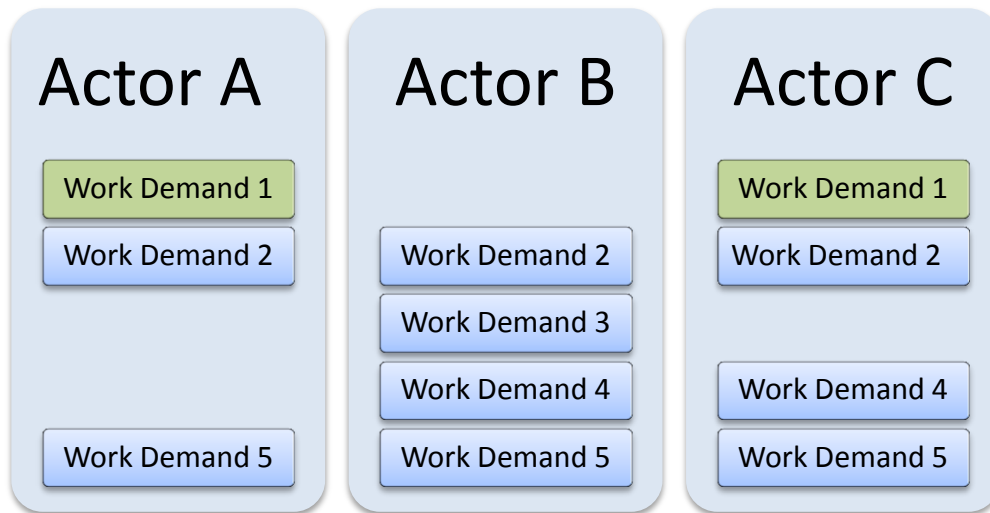
# Diagram of Work Organisation Possibilities

(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

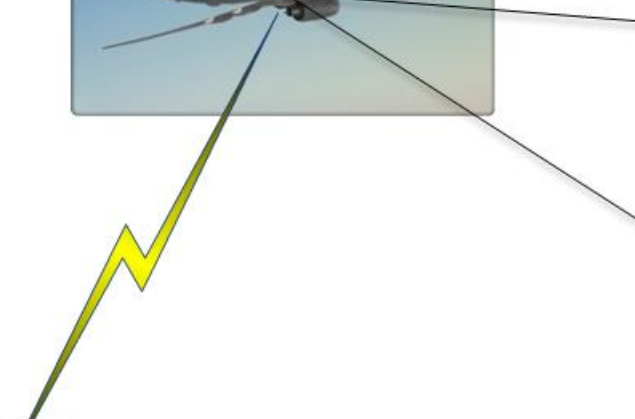
P-8A



Crew



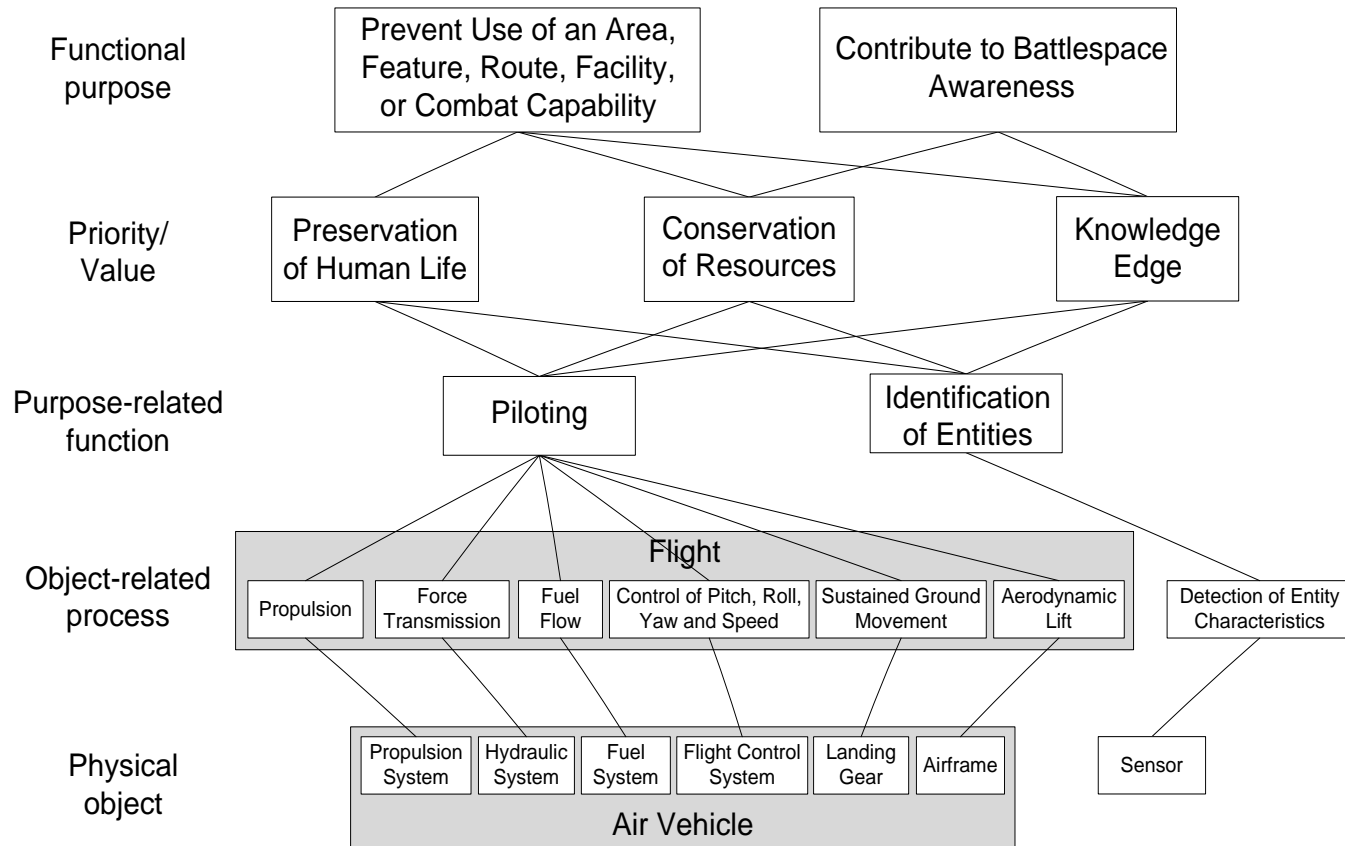
UAS



# Work Demands

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

# Work Domain Analysis



Abstraction hierarchy

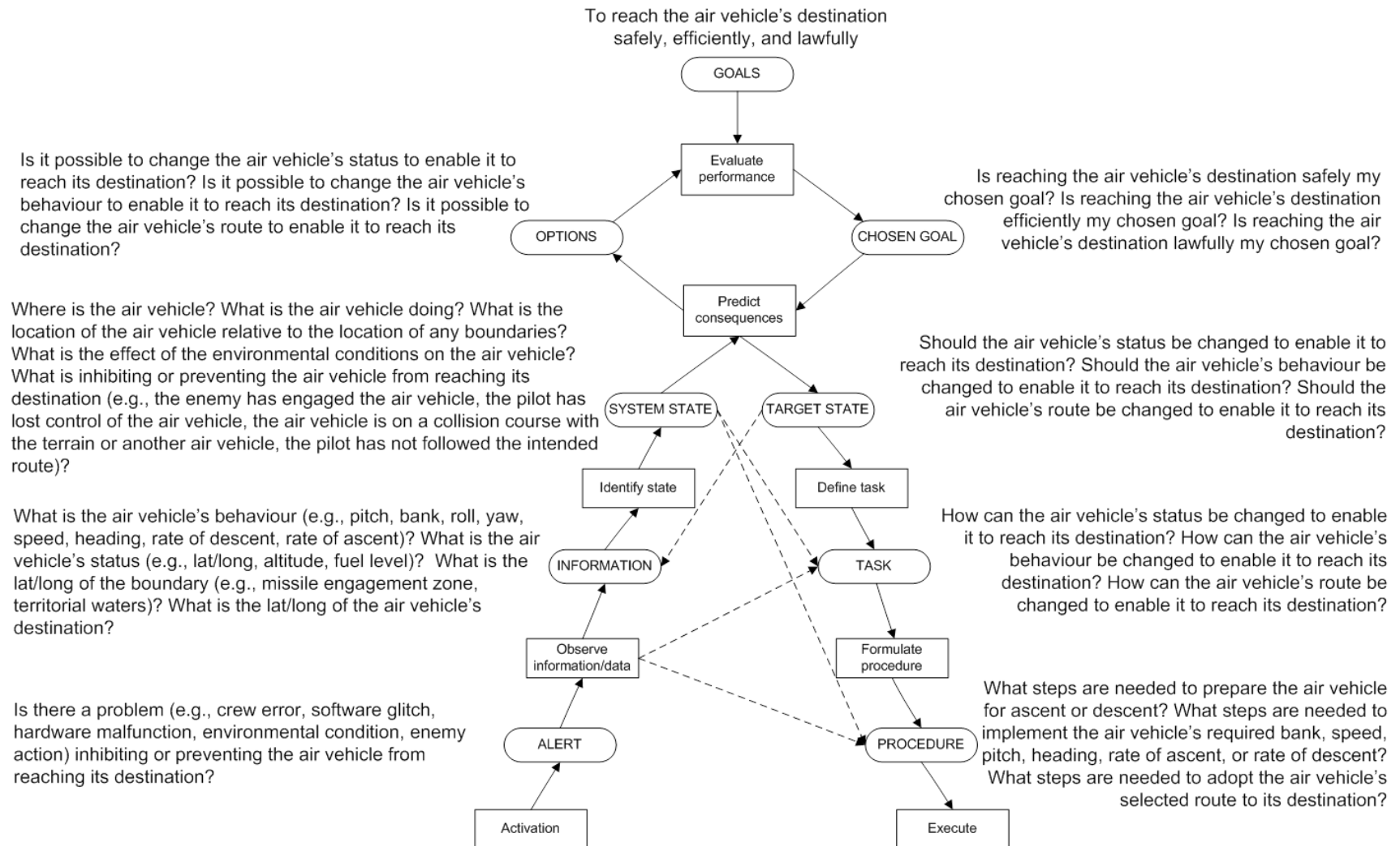
# Activity Analysis

## Contextual Activity Template

In Hangar	On Runway	Enroute to Specified Area	On Station	Enroute to Base	On Runway	In Hangar
<div>← Plan Mission →</div>						
						<div>← Debrief and Report →</div>
	←		<div>Fly and Navigate</div>		→	
		←	<div>Manage Mission</div>	→		
←			<div>Manage System</div>			→
			<div>← Identify Targets →</div>			
		←	<div>Collect and Disseminate Intelligence</div>	→		
			<div>← Deliver Weapons/ Stores →</div>			



# Activity Analysis

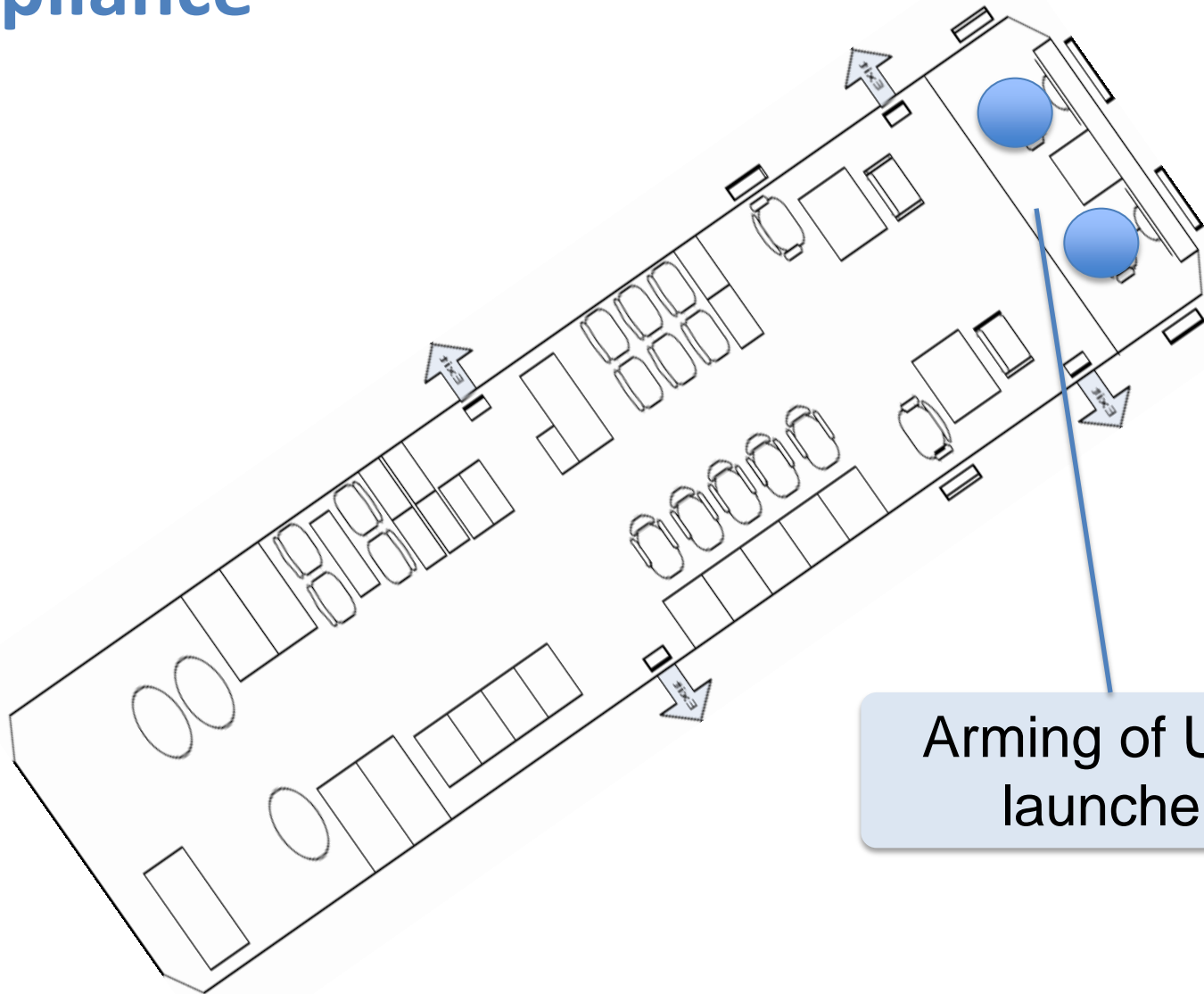


## Decision Ladder for *Fly and Navigate*

# Limits on Distribution of Work Demands

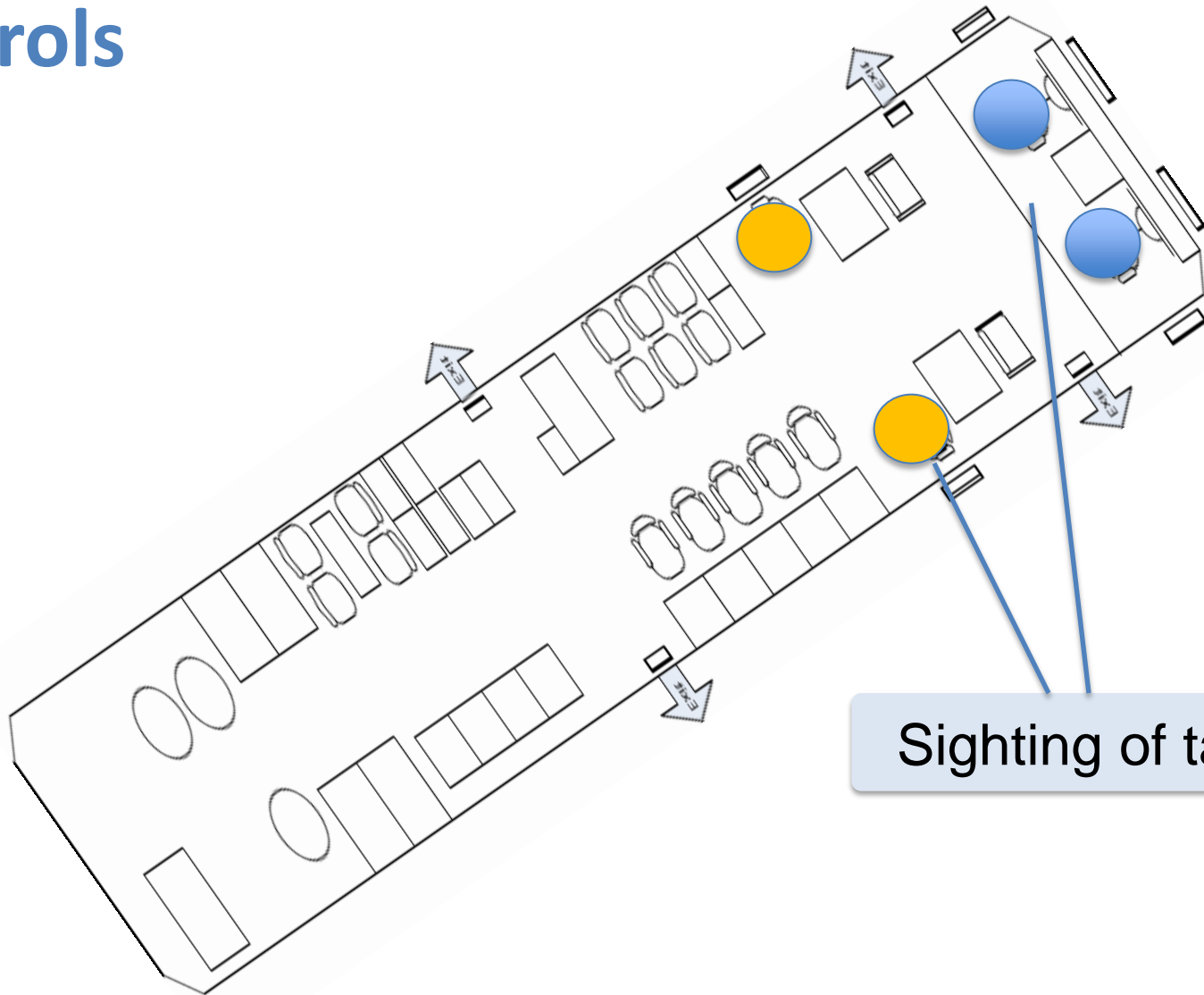
- Work organisation criteria:
  - Compliance
  - Safety and reliability
  - Access to information/controls
  - Coordination
  - Competency
  - Workload

# Compliance



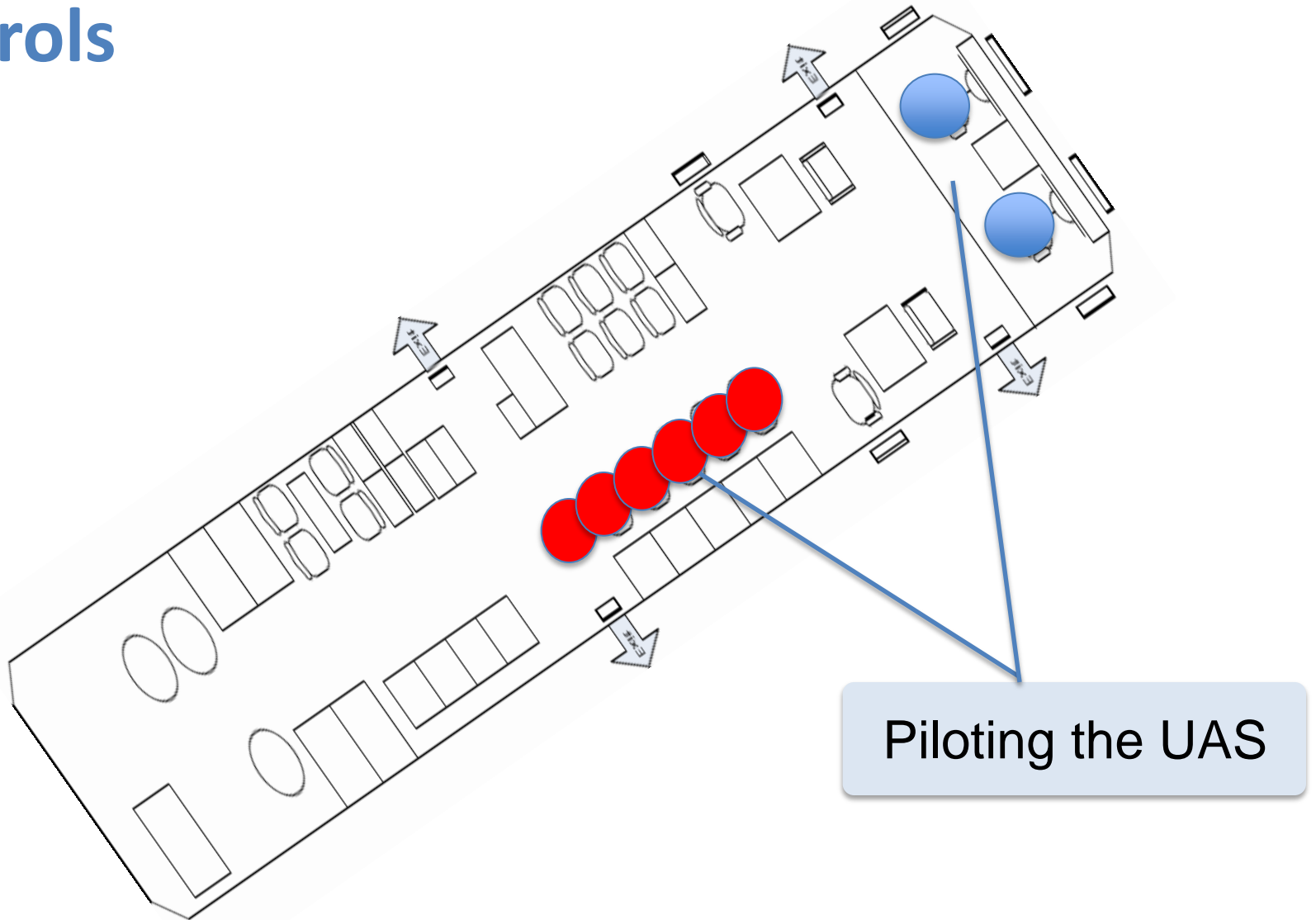
Arming of UAS  
launcher

# Access to information and controls

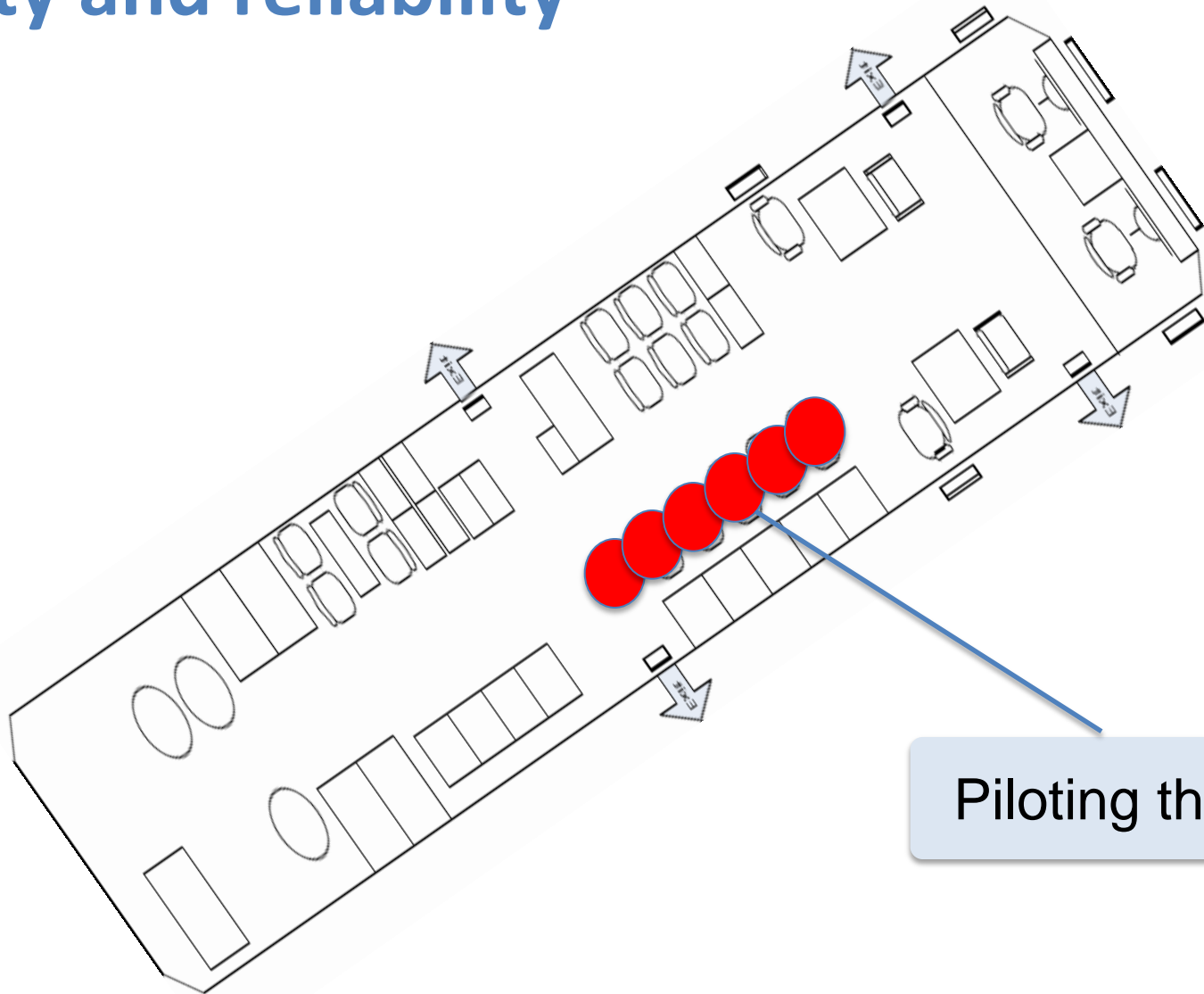


Sighting of targets

# Access to information and controls



# Safety and reliability

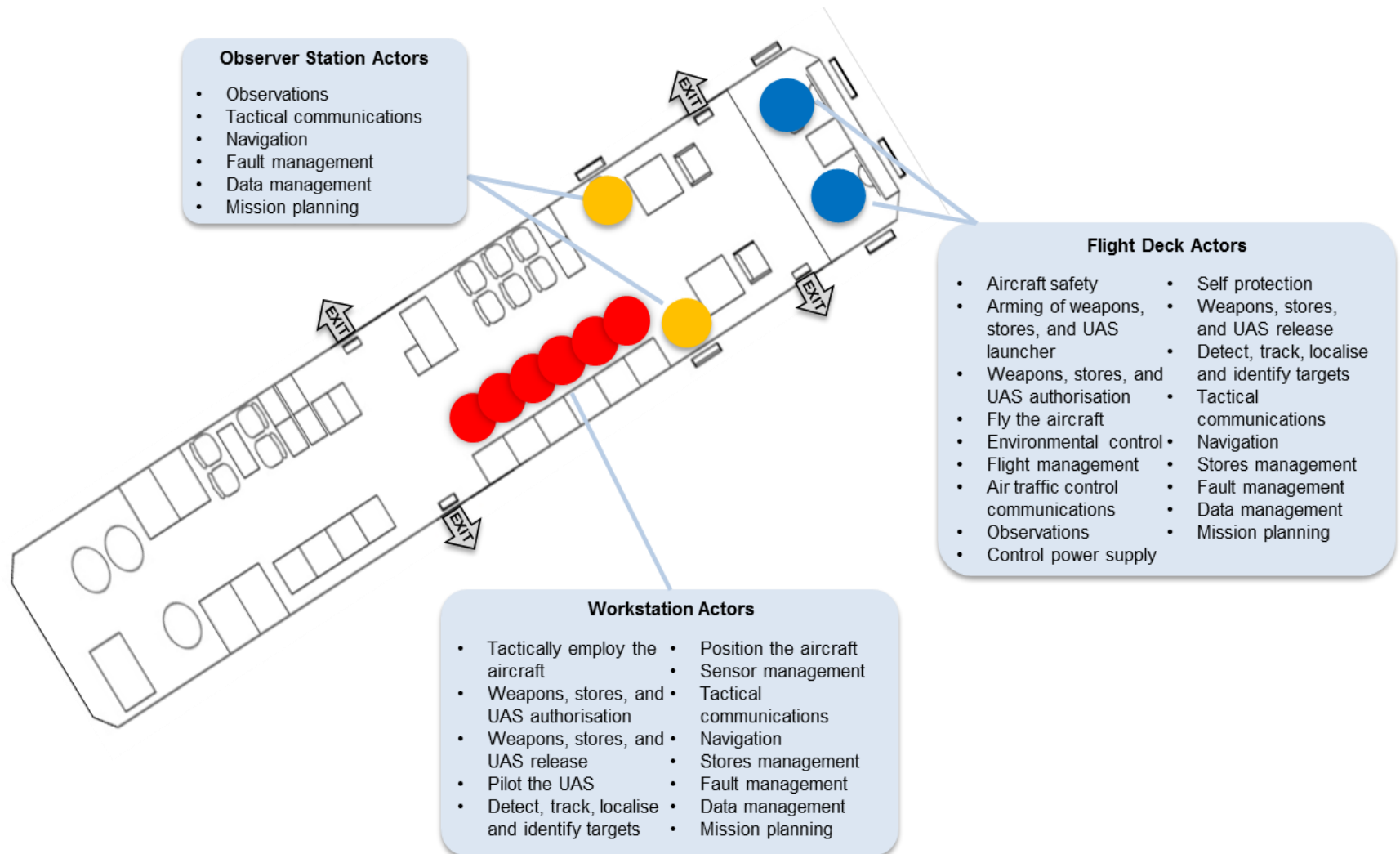


Piloting the UAS

# Coordination, Competency, Workload

- e.g., Workload

# Work Organisation Possibilities Diagram of Future Maritime Surveillance System





# Design Problem

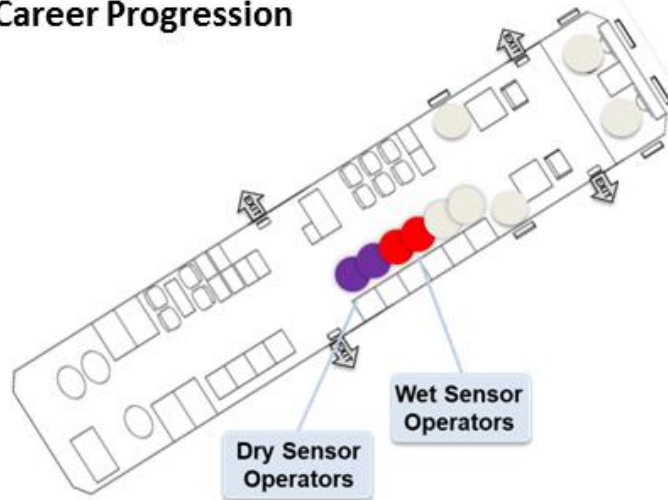
- 6 workstation actors: pilot the UAS; detect and localise targets with UAS sensor
- 2 flight deck actors: detect and localise targets with UAS sensor
- 2 observer station actors: only if tactical interfaces provided at these stations

# Potential Design Solutions

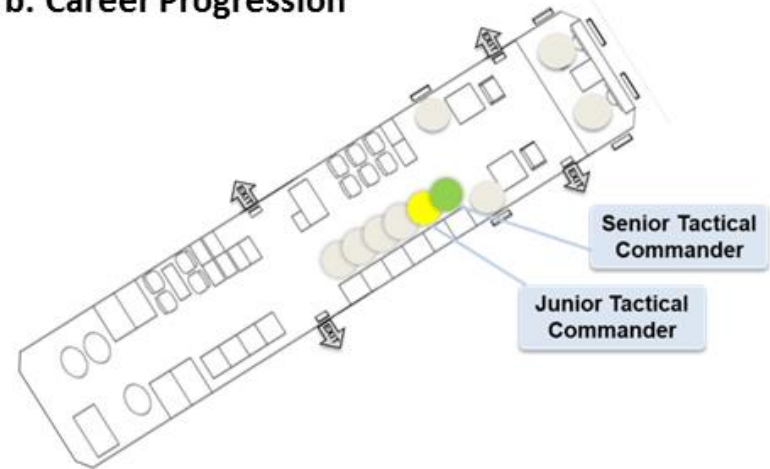
- Most obvious solution: Enable all crew members to operate the UAS
- Most obvious alternative: Enable only one or two crew members to operate the UAS

# Proposed Design Solution

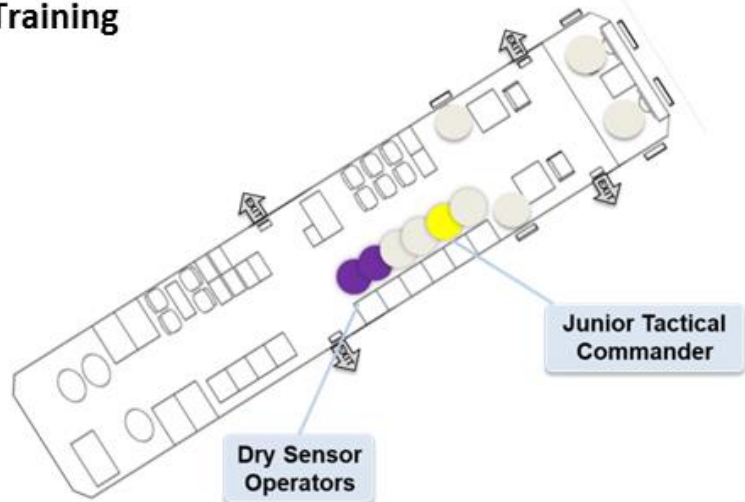
a. Career Progression



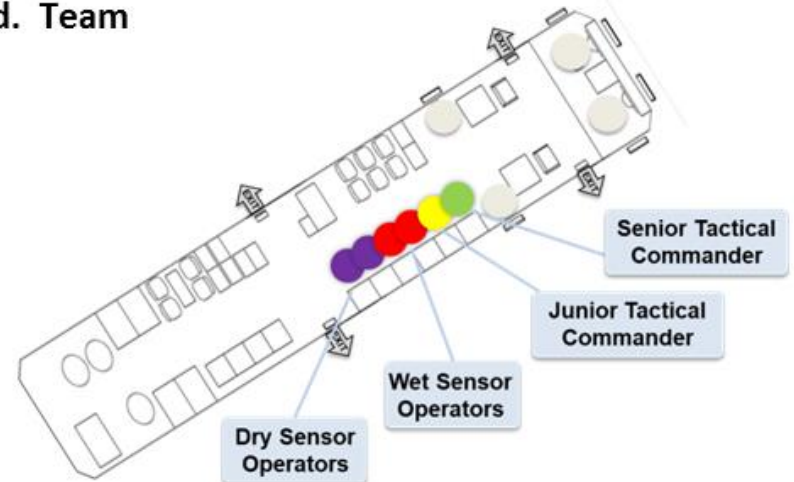
b. Career Progression



c. Training



d. Team



# 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	<ul style="list-style-type: none"> <li>Big picture perspective (Beneficial If the UTAS leaves the area of operations)</li> <li>Big picture perspective (Problematic if having to focus in on the UTAS)</li> </ul>	<ul style="list-style-type: none"> <li>Less of a requirement to have a big picture perspective of operations (as compared to the Captain, Co-pilot, and TACCO)</li> </ul>	<ul style="list-style-type: none"> <li>No requirement to have a big picture perspective of operations</li> <li>The risk of the track being lost (on acoustics) because the Sensor Operator (acoustics) is distracted by operating the UTAS may not be acceptable</li> </ul>	<ul style="list-style-type: none"> <li>Less of a requirement to have a big picture perspective of operations (as compared to the Captain, Co-pilot, and TACCO)</li> </ul>
Access to Information/ Control	<ul style="list-style-type: none"> <li>Has some ability to control the P-8A to the UTAS release point</li> </ul>			
Coordination	<ul style="list-style-type: none"> <li>Best suited to formulate the UTAS release point</li> <li>Coordinates with the Sensor Operator (acoustics)</li> <li>Already involved with the release of the UTAS</li> <li>Added communications (e.g., ATC)</li> </ul>	<ul style="list-style-type: none"> <li>Could be involved with the release of the UTAS</li> <li>Monitors the surrounding air traffic</li> <li>Added communications (e.g., ATC)</li> <li>Added coordination with the Sensor Operator (acoustics)</li> <li>Added coordination with the TACCO (and potentially Captain/Co-pilot)</li> </ul>	<ul style="list-style-type: none"> <li>High coordination between the two Sensor Operator (acoustics)</li> <li>Comprehensive understanding of the target status and behaviour</li> <li>Required to monitor surrounding air traffic</li> <li>Not involved in releasing the UTAS</li> <li>Added coordination with the TACCO (and potentially Captain/Co-pilot)</li> </ul>	<ul style="list-style-type: none"> <li>High coordination between the UTAS operator and the radar operator</li> <li>Comprehensive understanding of the terrain and/or surface traffic</li> <li>Not involved in releasing the UTAS</li> <li>Added coordination with the TACCO (and potentially Captain/Co-pilot)</li> </ul>
Competencies	<ul style="list-style-type: none"> <li>Competent to tactically employ an aircraft</li> <li>Competent to navigate an aircraft</li> <li>Competent to perform communications</li> <li>Competent to release the UTAS</li> <li>Not competent to fly an aircraft</li> <li>Not competent to operate any sensors</li> </ul>	<ul style="list-style-type: none"> <li>Some competencies associated with tactically employ an aircraft</li> <li>Competent to navigate an aircraft</li> <li>Competent to perform communications</li> <li>Competent to release the UTAS</li> <li>Not as experienced as the TACCO tactically employing an aircraft</li> <li>Not competent to fly an aircraft</li> <li>Not competent to operate any sensors</li> </ul>	<ul style="list-style-type: none"> <li>Experience operating sensors and may be competent in sensor management</li> <li>Not competent to tactically employ an aircraft</li> <li>Not competent to fly or navigate an aircraft</li> <li>Not competent to perform communications</li> <li>Not competent to release stores</li> </ul>	<ul style="list-style-type: none"> <li>Competent to operate other sensors</li> <li>Competent in collision avoidance</li> <li>Least experienced crew member</li> <li>Not competent to tactically employ an aircraft</li> <li>Not competent to fly or navigate an aircraft</li> <li>Not competent to perform communications</li> <li>Not competent to release stores</li> </ul>
Workload	<ul style="list-style-type: none"> <li>May reduce during recovery</li> <li>Workload may be high at times</li> </ul>	<ul style="list-style-type: none"> <li>May reduce during recovery</li> <li>Workload may be high at times</li> </ul>	<ul style="list-style-type: none"> <li>May reduce during recovery</li> <li>Able to share workload</li> <li>Workload may be high at times</li> </ul>	<ul style="list-style-type: none"> <li>Lowest of any crew member</li> <li>May reduce during recovery</li> <li>May need to rotate through different sensors</li> </ul>

# 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:
  - Ashleigh Brady ([ashleigh.brady2@dst.defence.gov.au](mailto:ashleigh.brady2@dst.defence.gov.au))
  - Neelam Naikar ([neelam.naikar@dst.defence.gov.au](mailto:neelam.naikar@dst.defence.gov.au))