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Systematic Mapping of Modeling and Simulation for Operational Analysis of Future Naval Mine Countermeasure Systems

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Survey:
Future Naval Mine Warfare
and Underwater Warfare



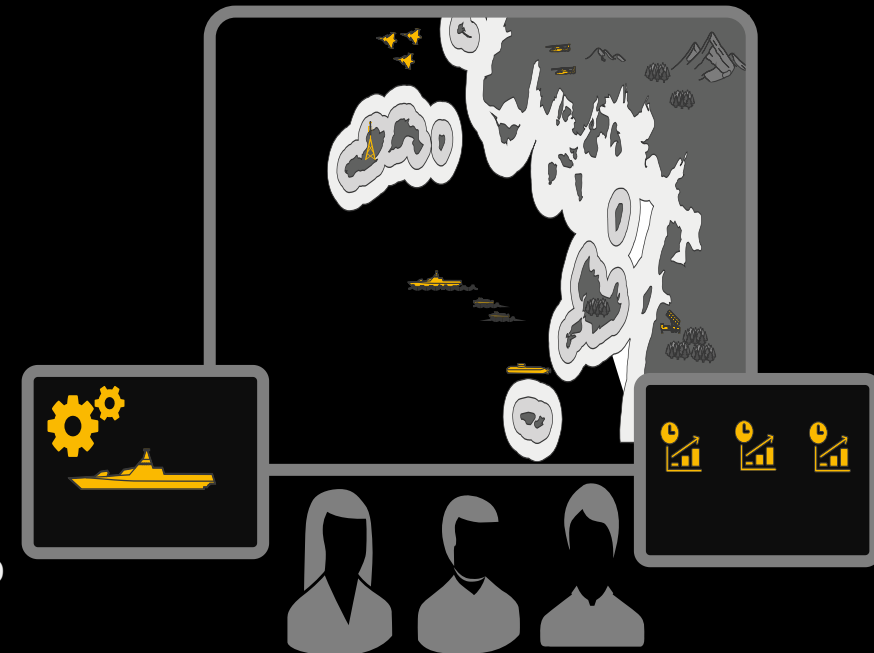
Background



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Formalize a decision support for concept development and evaluation of future naval mine countermeasures systems (NMCM)

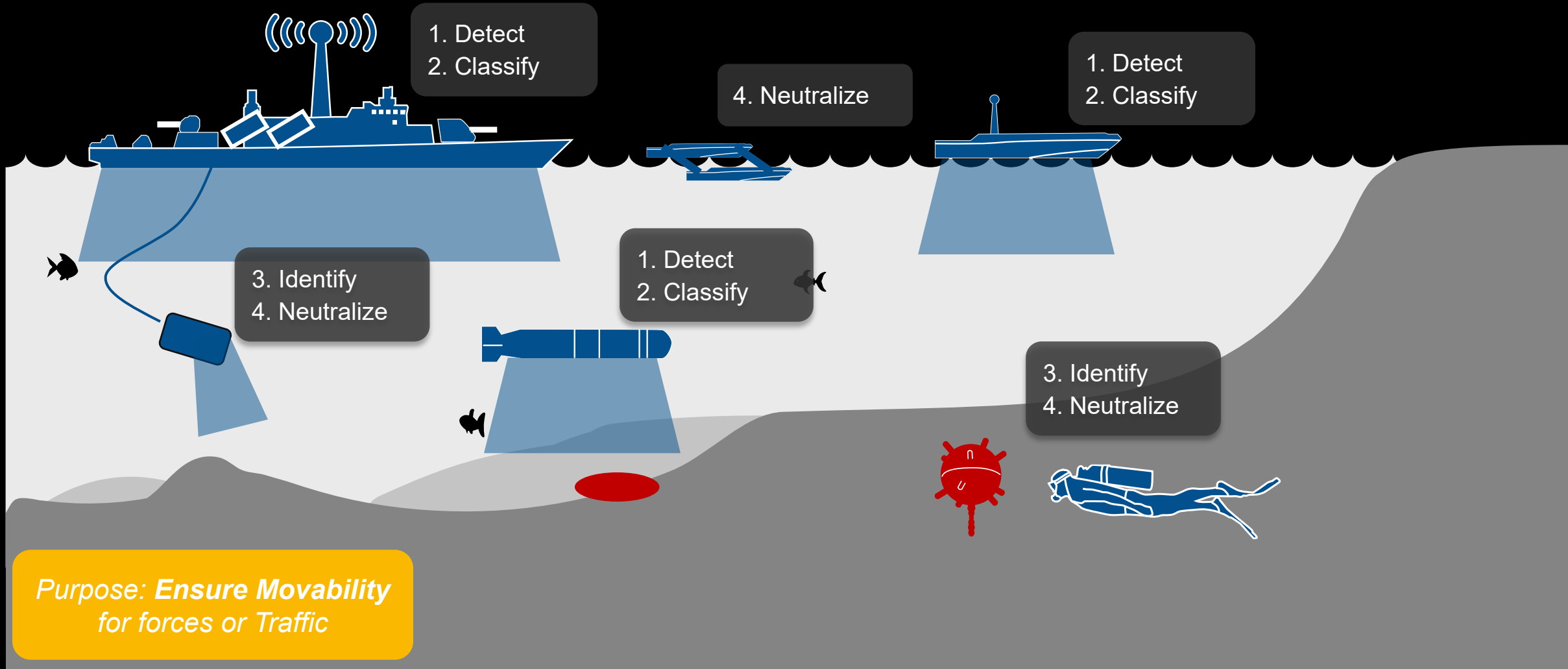
- *Decision Support* – Quantitative support, emphasis on exploration rather than optimal solution
- *For concept evaluation* – how to compare SoS designs containing both new and legacy systems. Operating in different environments
- *Naval mine countermeasure systems* – includes both surface, and underwater systems; MCMV, AUV, ROV, USV cooperating..
- *Future* – what if analysis regarding both design concept and scenario



Example: Minehunting



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Purpose of Mapping Study



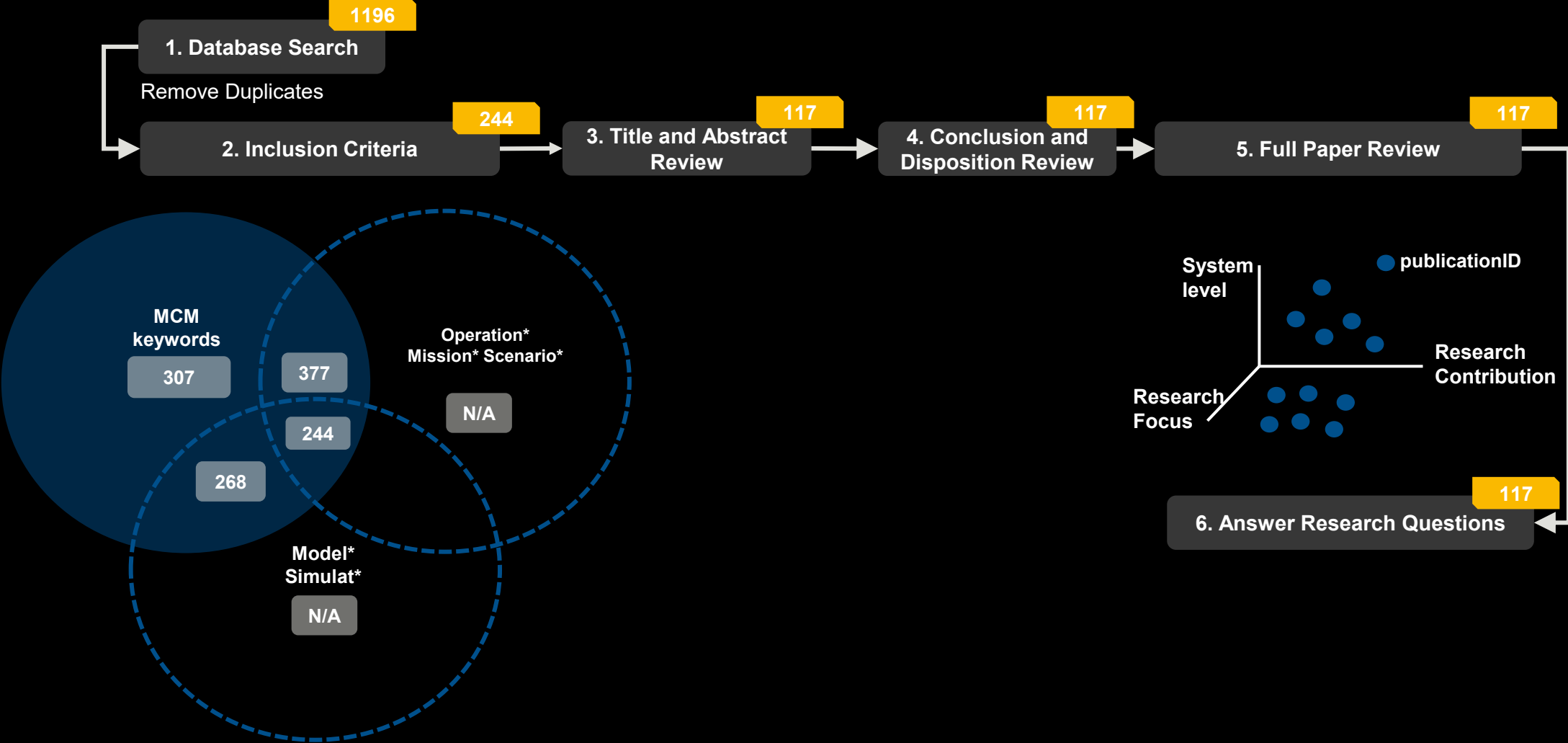
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***RQ1:** What is the current state of the naval mine countermeasures field with respect to operational analysis through modeling and simulation?*

***RQ2:** What modeling and simulation methods are most commonly used to support operational analysis of future naval mine countermeasure systems in terms of measures of effectiveness, risk analysis, and cost analysis?*

***RQ3:** What are the key challenges in applying modeling and simulation for operational analysis of naval mine countermeasure systems during conceptual design?*

Mapping Methodology



RQ1: What is the current state of the naval mine countermeasures field with respect to operational analysis through modeling and simulation?

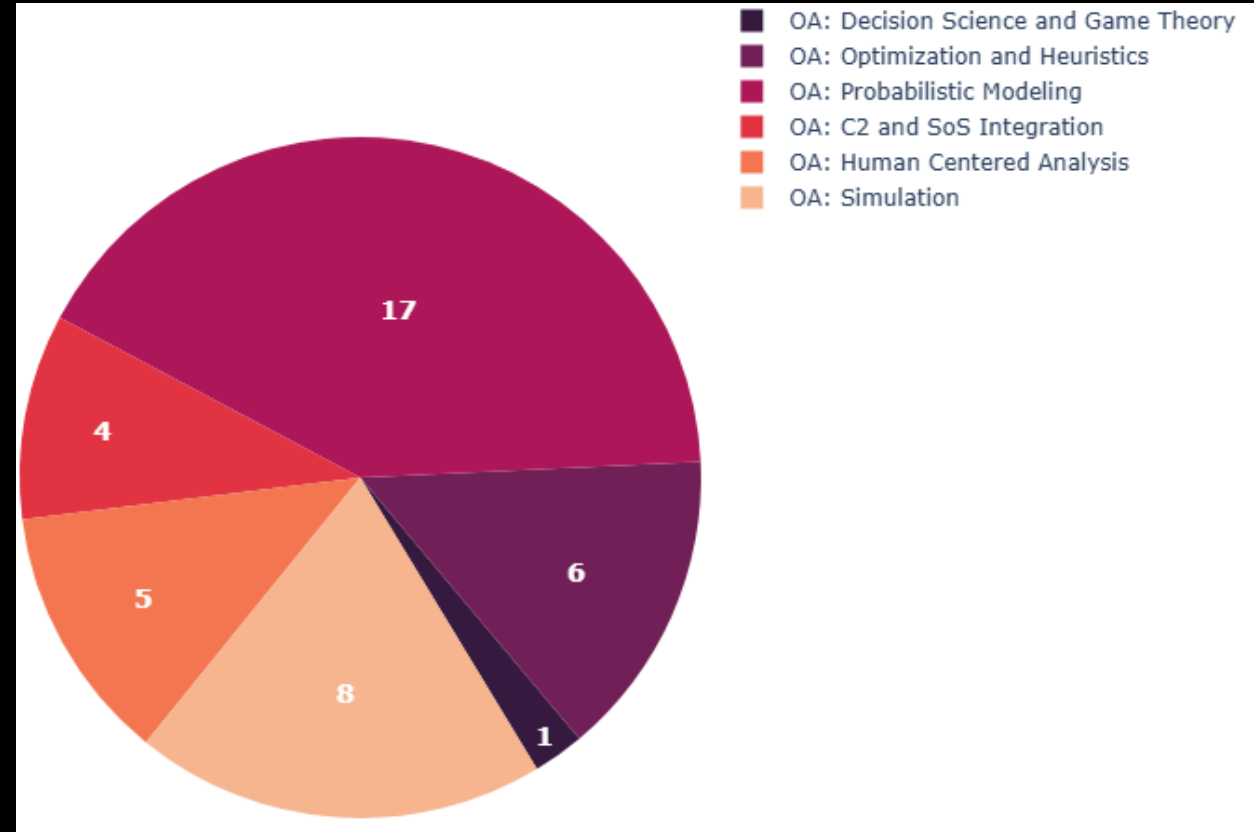
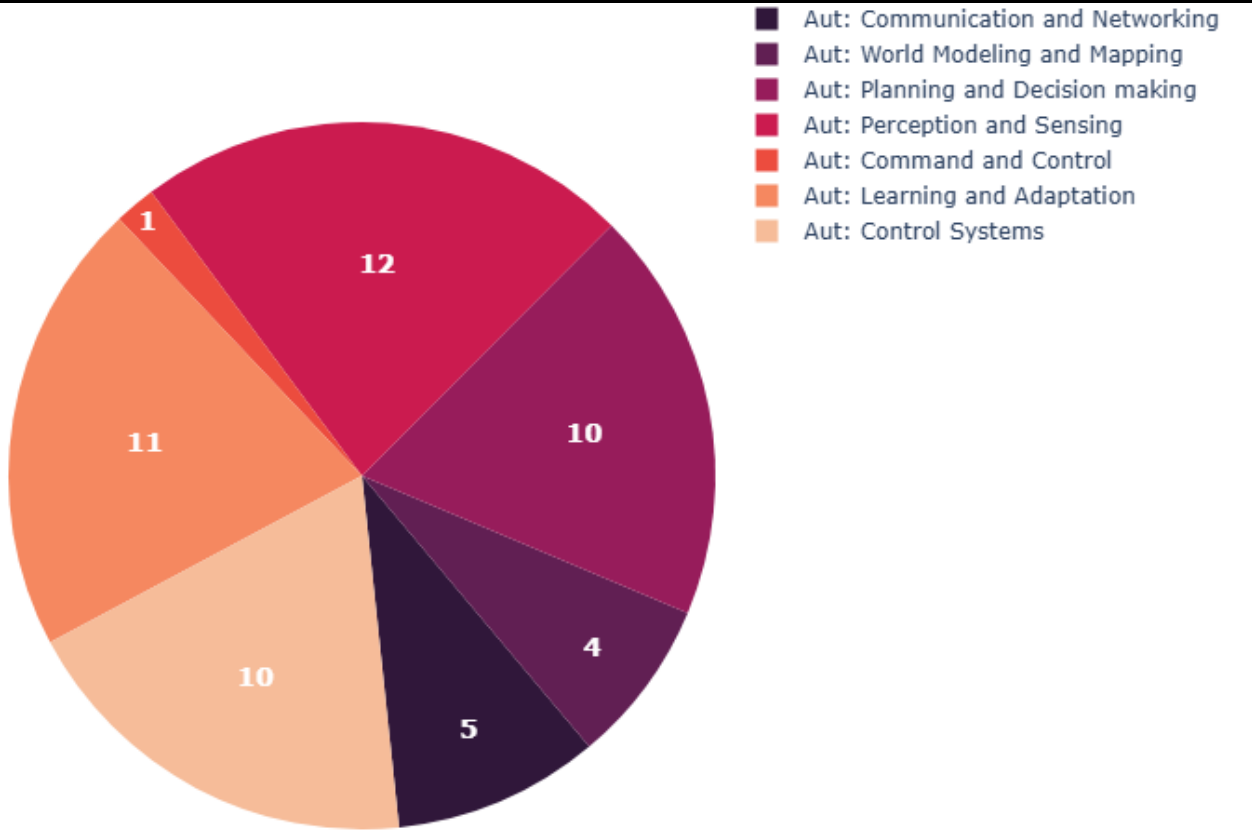


Naval Warfare system	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1
Mine Warfare system	1	0	0	0	0	0	0	0	0	0	0	4	1	1	0	0	1
MCM system	1	1	1	0	7	0	1	1	1	1	4	7	3	2	4	0	1
MCMV	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Space system	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Aerial system	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface system	3	0	0	0	0	0	0	1	4	0	1	2	0	1	0	0	0
Subsurface system	3	2	4	3	3	11	0	9	5	0	1	2	0	0	3	0	0
Subsystem	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Mine system	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Design concept																	
Conceptual design																	
Aut: Communication and Networking																	
Aut: World Modeling and Mapping																	
Aut: Planning and Decision making																	
Aut: Perception and Sensing																	
Aut: Command and Control																	
Aut: Learning and Adaptation																	
Aut: Control Systems																	
OA: Decision Science and Game Theory																	
OA: Optimization and Heuristics																	
OA: Probabilistic Modeling																	
OA: C2 and SoS Integration																	
OA: Human Centered Analysis																	
OA: Simulation																	
system simulation																	
Historical or Status Report																	

Autonomy is about engineering functions that enable a system to be more or less autonomous, generally it focuses on real-time simulation and modeling in order to be used in a real-world application.

The purpose of OA is to evaluate and study the performances of a system used in an operation. It often favors low fidelity models and fast computing.

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RQ2: What modeling and simulation methods are most commonly used to support operational analysis of future naval mine countermeasure systems in terms of measures of effectiveness, risk analysis, and cost analysis?

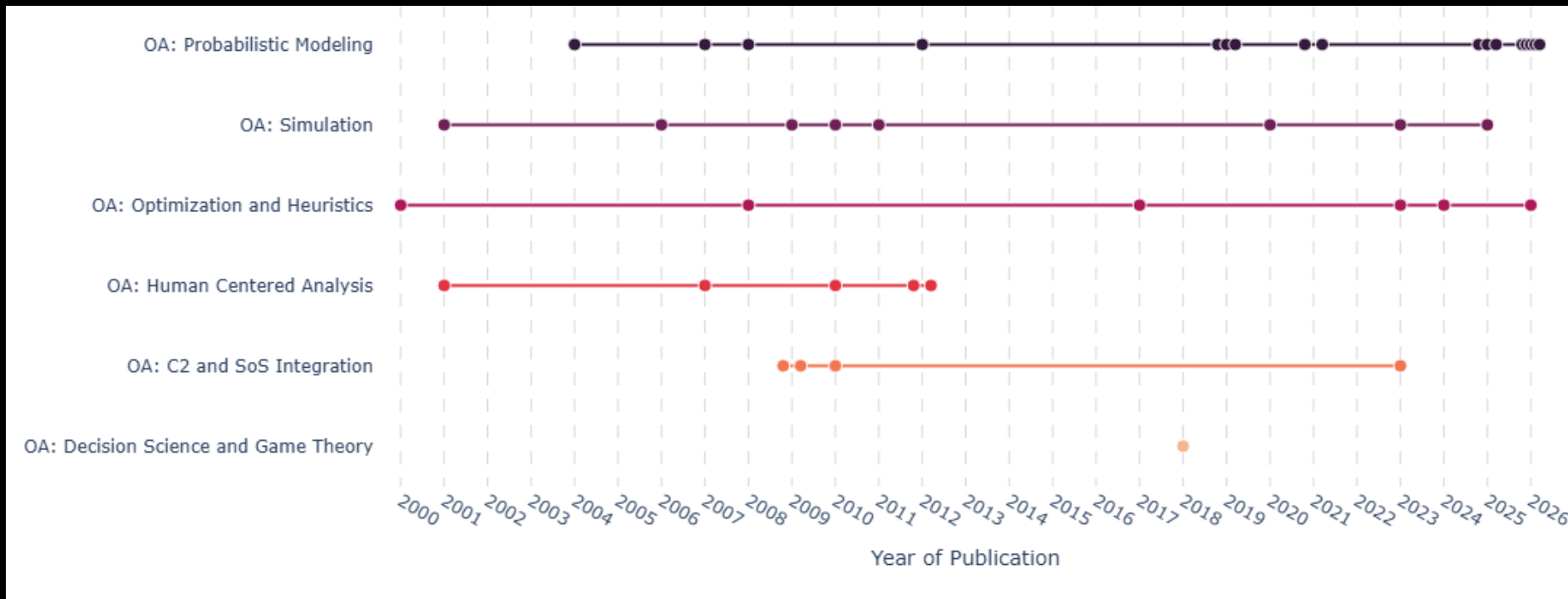


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MoE:
Percentage Clearance
Percentage Prosecuted
Area Coverage Rate

Cost:
Acquisition Cost
COTS
Operational Cost

Risk:
Number of Remaining Mines
Probability of Mine in cell



Limitations

- Absence of Research
 - Only Scopus Database
 - No snowballing step
 - No Technical Reports published at local Research agencies and Institutes
- Selection Bias
- Judgment Bias

Future Strengths



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- Absence of Research
 - Established workflow to include more papers
 - Visualization in Dashboard - github
- Selection Bias
 - Possibility to let different LLM select
 - Involve more Authors
- Judgment Bias
 - Possibility to let different LLM categorize
 - Involve more authors

RQ3: What are the key challenges in applying modeling and simulation for operational analysis of naval mine countermeasure systems during conceptual design?



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- Absence of Diverse mine threat analysis
- Scarcity of Design Space Exploration studies on SoS level
- Scarcity of Cost and effectiveness trade-off studies on SoS level
- Holistic view of future NMCM capabilities



Research Gap

Future Work



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1. Overall view of future diverse mine threat
 - Evidently exists a lot of research within subsurface autonomy
 - Already exists planning and evaluation support for static mine counter
2. Outline Archetype Scenarios for NMW
 - Span Static to Dynamic mine threat
3. Compile Modelling techniques for OA
 - Design Space Analysis
 - Trade-space Analysis
 - Comparison of Alternatives in different scenarios

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Please, do reach out to us if you think NMW and UWW is important for our future capabilities

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