

Airspace Research and Development Portfolio Assessment of Urban Air Mobility using Knowledge Graph Data Science

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Outline

- Introduction
- Portfolio Analysis Process, Methodology, and Results
 - Knowledge Graph Ontology
 - Critical nodes identification
 - Node performance metric through Requirement Maturity Level (RML)
 - Research gap identification
- Conclusion and Future Work

Introduction

- *National Aeronautics and Space Administration (NASA) is spearheading an innovative digital engineering approach to integrate, communicate, and facilitate the research of Urban Air Mobility (UAM) operations.*
- *To safely support UAM operations at scale in the National Airspace System (NAS), NASA's Air Traffic Management-Exploration (ATM-X) project have been conducting research that evolves the UAM air traffic management system towards a highly automated and operationally flexible system of the future.*
- *Derived from diverse sources, the airspace research roadmap implemented through Model-Based Systems Engineering is used to manage the complexity of UAM airspace evolution accommodating the increasing tempo of UAM operations over time.*

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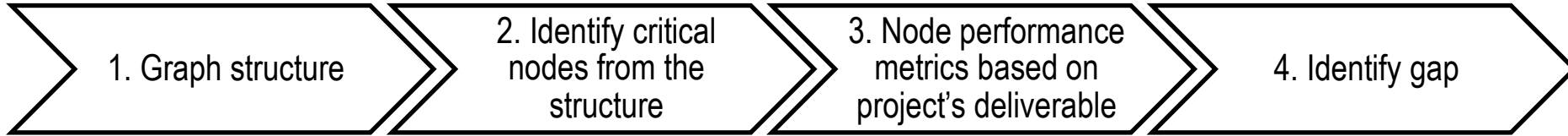
Introduction (Cont.)

- *The roadmap model captures a highly complex interdependencies among individual elements far beyond the subject-matter-expert's ability to extract insights for project's portfolio assessment.*

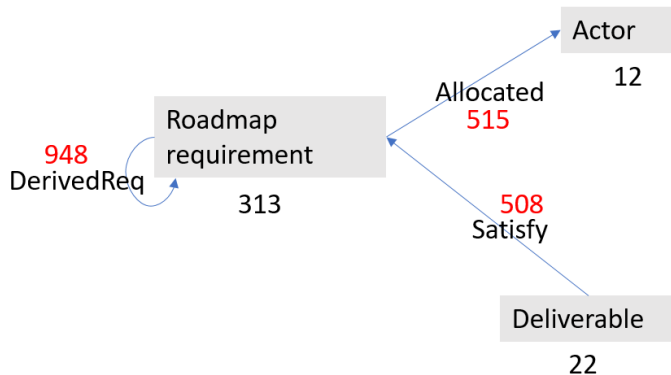


Fig. 1 Partial UAM Knowledge Graph Structure relevant to this study where purple nodes are requirements, blue nodes are system actors, and yellow nodes are project's deliverables (the left figure for the bird-eye view and the right for the zoom-in view)

Portfolio Analysis Process and Methodology



Portfolio Analysis Process, Methodology, and Results



- Roadmap requirement (system requirement) is **allocated** to system actor(s).
- Project's deliverable **satisfies** the roadmap requirement(s).
- Roadmap requirement can be **derived** from another requirement.

Portfolio Analysis Process, Methodology, and Results

1. Graph structure

2. Identify critical nodes from the structure

3. Node performance metrics based on project's deliverable

4. Identify gap

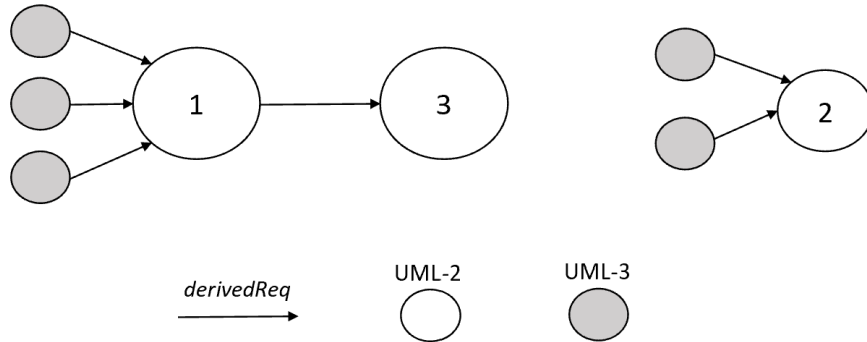


Fig. 3 Notional PageRank Score.

- PageRank (PR) is a Centrality algorithm used by Google Search to rank web pages in their search engine results.
 - Intuitively, pages that are well cited from many places around the web are worth looking at (high score). Also, pages that have only one citation from a respected and quality source are also generally worth looking at.
- **Requirement** node 1 has more incoming links than those of node 2, therefore, the PageRank score of node 1 (representing by its size) is larger than that of node 2.
- Node 3 has only one incoming link but the source of this incoming link has a high score, therefore, node 3 will also have a high score.

Portfolio Analysis Process, Methodology, and Results

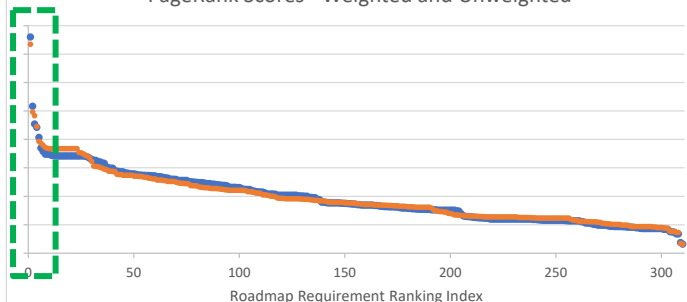
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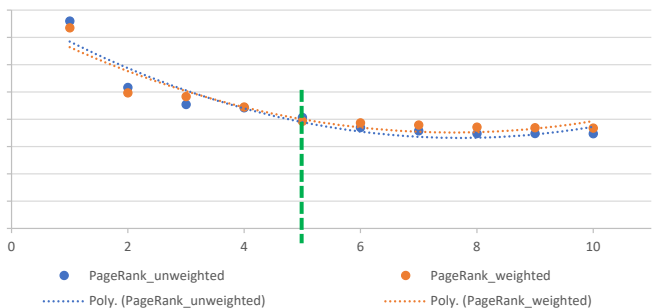
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PageRank Scores - Weighted and Unweighted



PageRank Scores - Top 10 Ordered by Unweighted



- **Weighted edges** to guard against bias
 - twice as many *derivedReq* edges as *allocated*, the *derivedReq* edges may trump the *allocated* edges, likely producing biased results. For this reason, normalization of these edges is implemented through the weighting.
- A finite set of important requirements.
- **Top 5 requirements** are considered.
- Number of critical nodes is not sensitive to the weighted edges.

Portfolio Analysis Process, Methodology, and Results

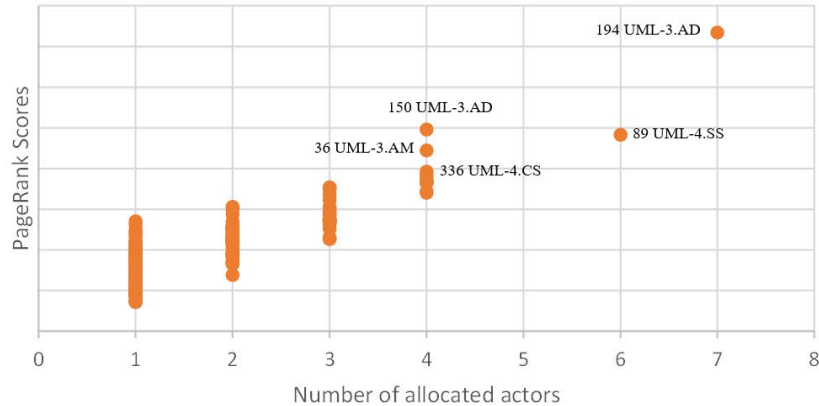
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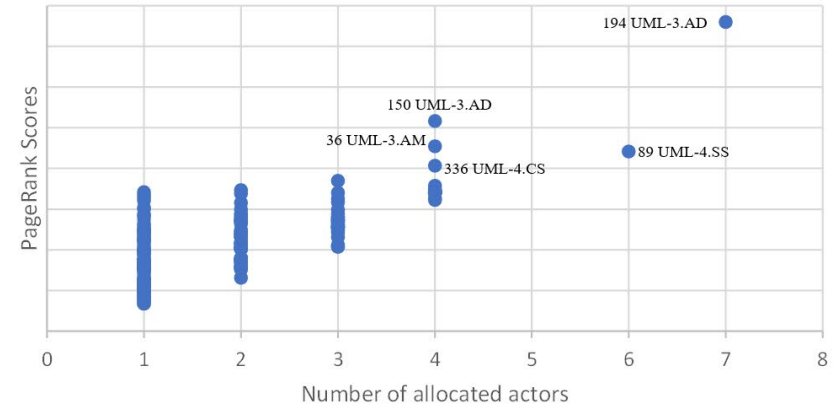
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Weighted Case

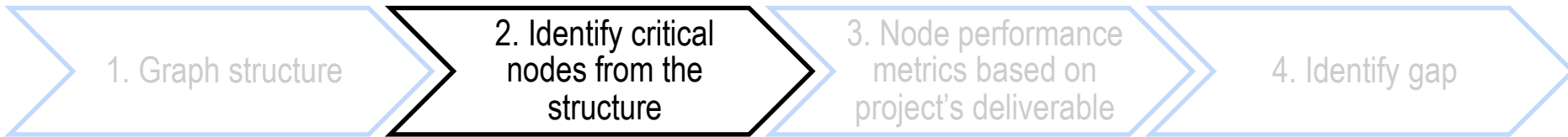


Unweighted Case



PageRank score is very sensitive to the number of allocated actors.

Portfolio Analysis Process, Methodology, and Results



Requirement ID	Weighted – Placement	Unweighted – Placement	Full Requirement Text
194 UML-3.AD	1 st	1 st	The FAA will provide a means to authorize contingency procedures that include the UAM Operator, Vertiport Operator, Fleet Manager, Vertiport Manager, PIC, or ATC.
150 UML-3.AD	2 nd	2 nd	The UAM Operator shall establish a plan to resolve off-nominal conditions with the PIC, Fleet Manager, or Vertiport Manager, without ATC involvement.
89 UML-4.SS	3 rd	4 th	The FAA will approve flight rules that allow ATC to delegate separation responsibility to the PIC, Fleet Manager, or Vertiport Manager, or PSU under appropriate conditions.
36 UML-3.AM	4 th	3 rd	The PSU, UAM Operator, Vertiport Operator shall discover the information needed to build a Common Operating Picture.
336 UML-4.CS	5 th	5 th	The RPIC should communicate with the Fleet Manager, Vertiport Manager, or ATC to resolve contingency and emergency operations.

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$$RML(\mathcal{R}) = m + \sum_{i=1}^m \frac{2^{i-1}}{2^m - 1} \cdot \left(1 - \frac{1}{2^{n_i-1}}\right)$$

The highest TRL of all deliverables

The **Requirement Maturity Level (RML)** of a requirement is a measure of the level of validation of that requirement, based on the set of deliverables that trace to it and their TRL values.

Accounted for:

- More deliverables mean higher RML
- Deliverables at lower TRLs count less toward the RML than deliverables at higher TRLs

m = the highest TRL of all deliverables' TRLs

TRL = Technology Readiness Level which can range from 1 to 9

n_i = the number of deliverables of TRL i that are traced to the requirement R

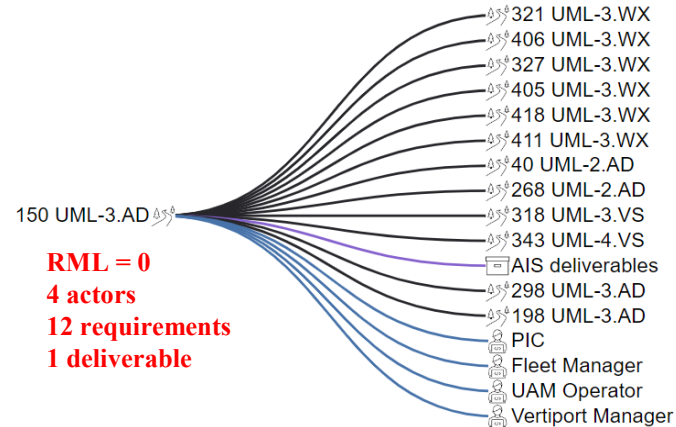
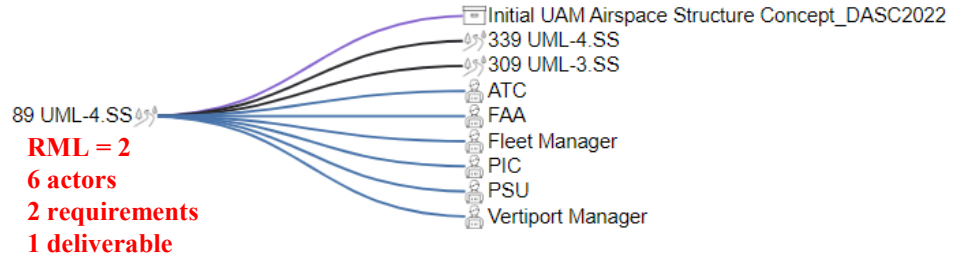
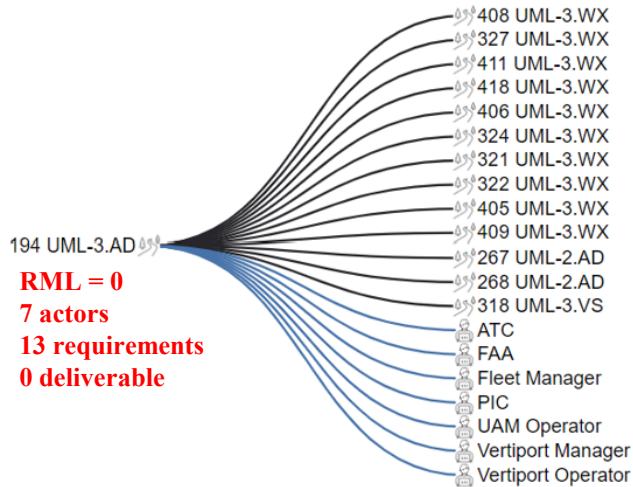
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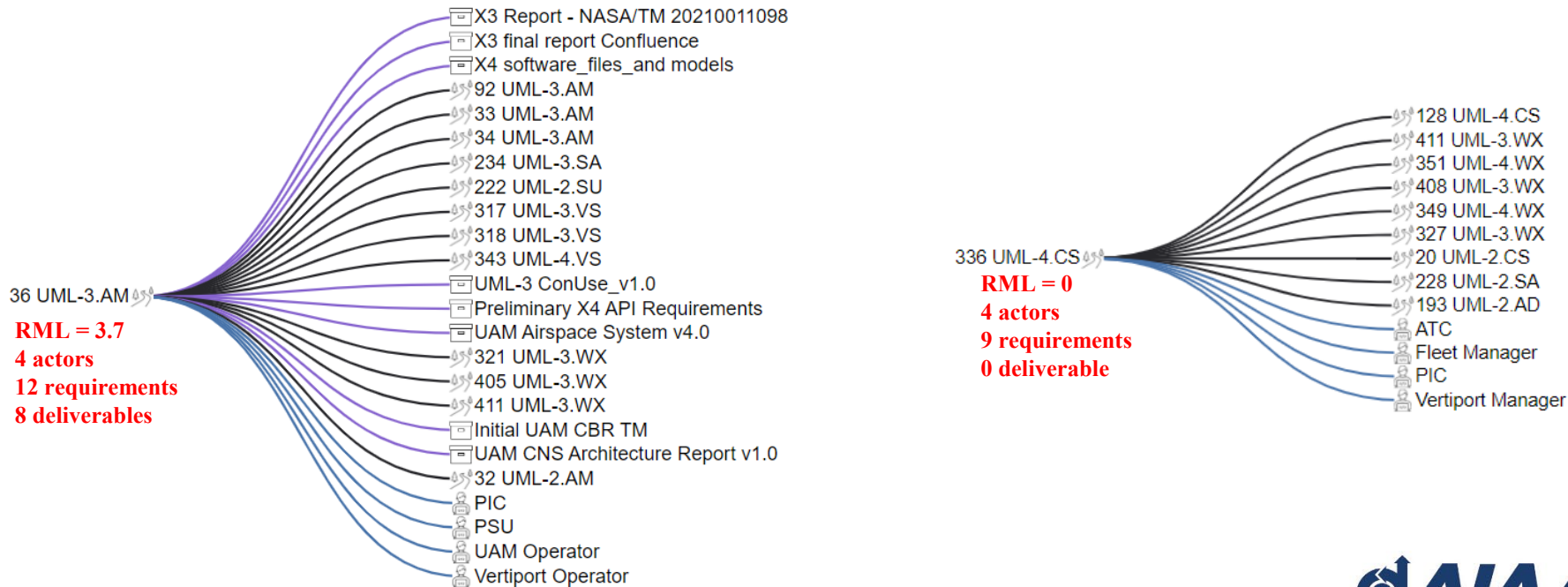
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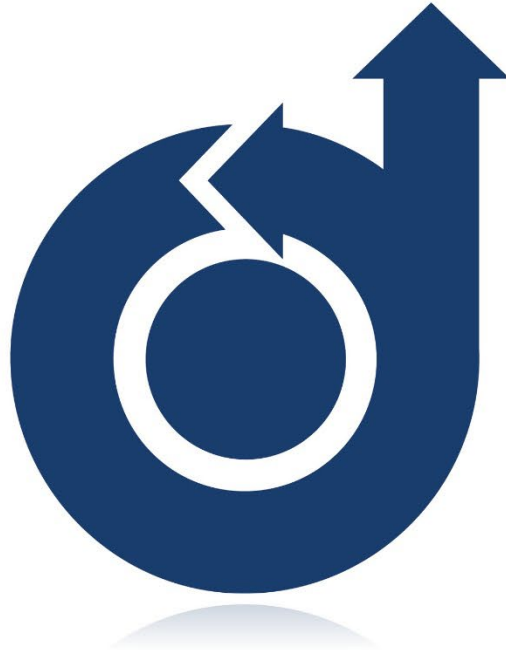
Conclusion and Future Works

Conclusion

- Advanced knowledge graph data analytics was applied to the subset of UAM knowledge database to perform research gap analysis, which will assist project managers for future portfolio planning.

Future Work

- Rich database, with highly complex interrelationships
- Opportunity to try and mature this methodology for the full data set.



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