Research Roadmap and the UML-3 Operational Integration Assessment

Theory and Practice for Evolving Complex Enterprise Systems

September 2022

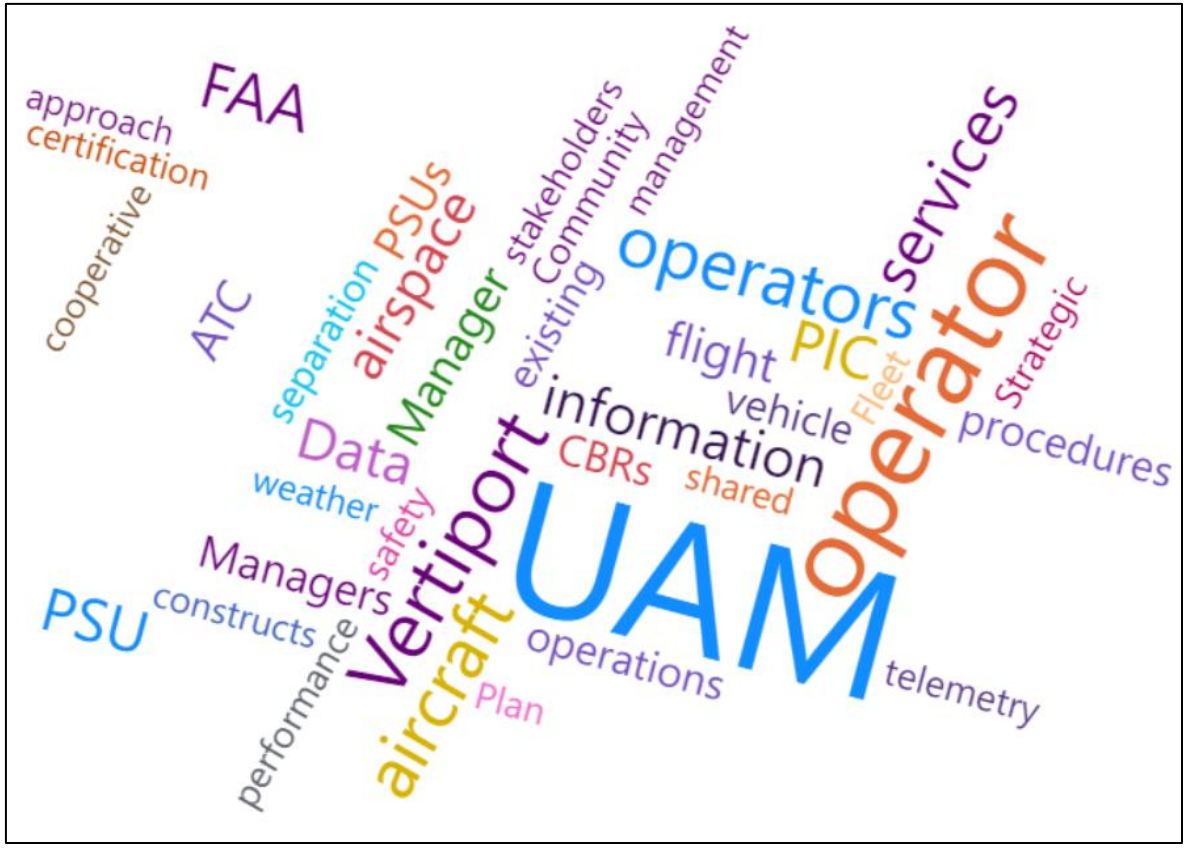
Dr. Ian Levitt, NASA

Research Roadmap and Digital Engineering

THEORY

What is a Research Roadmap?

A **living document** that describes how research informs the **progression** of complex system **capabilities**



Context

By way of **high-level…**

→ Requirements

→ Assumptions

→ Constraints

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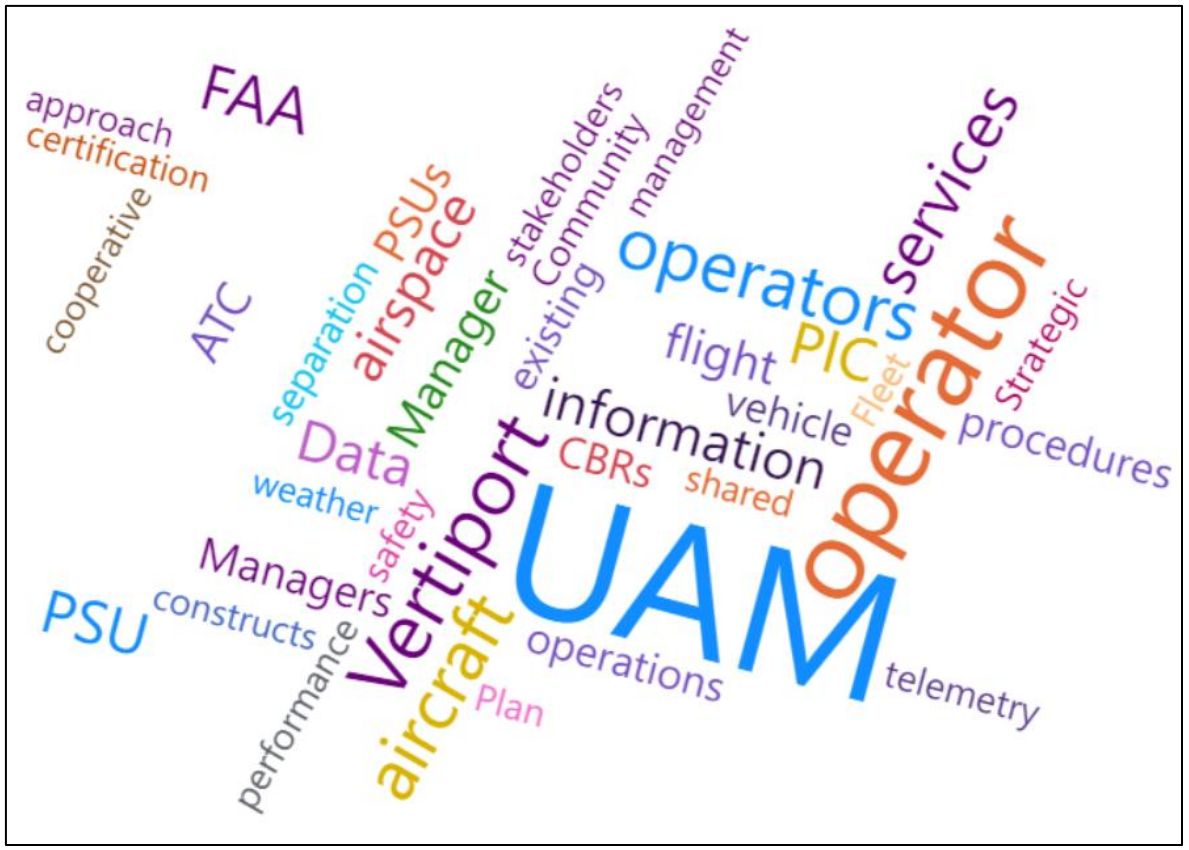


By way of **high-level…**

→ Requirements

→ Assumptions

→ Constraints

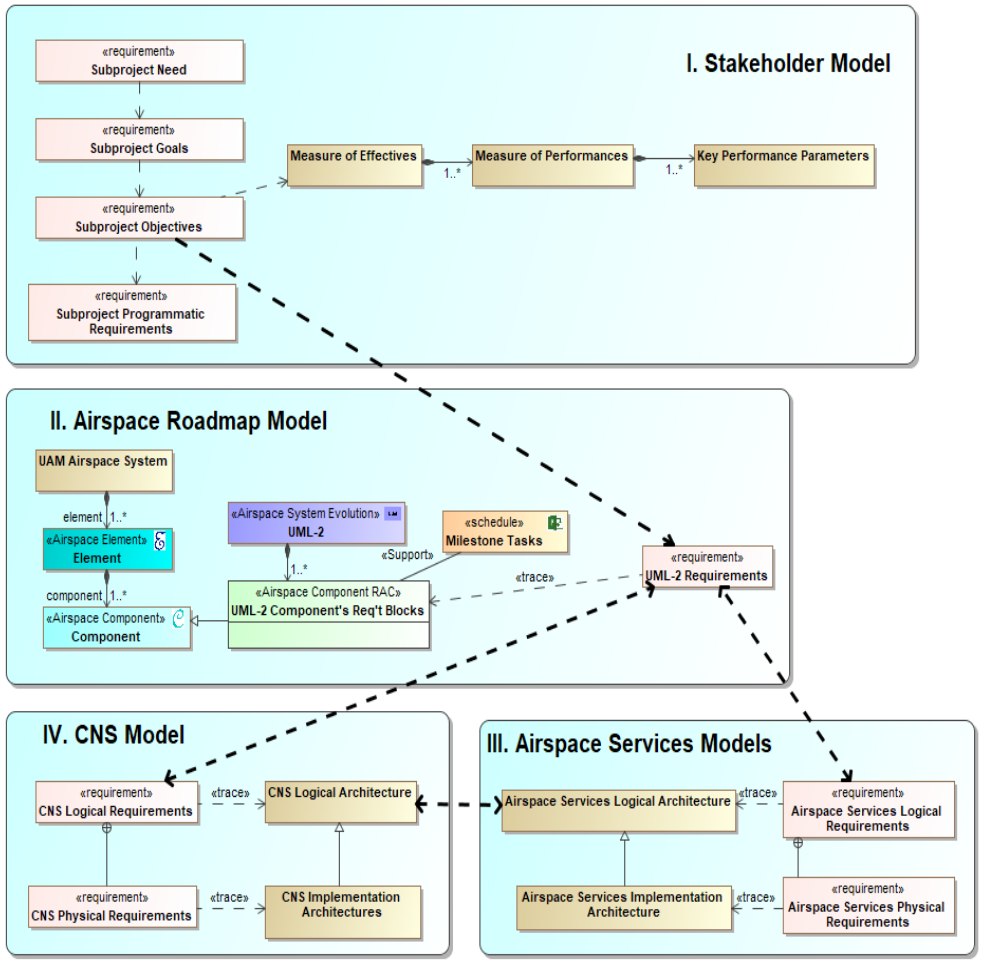
Not really a Roadmap!

Does not use timeframes

Includes contradictions found in research

Roadmaps can be extracted

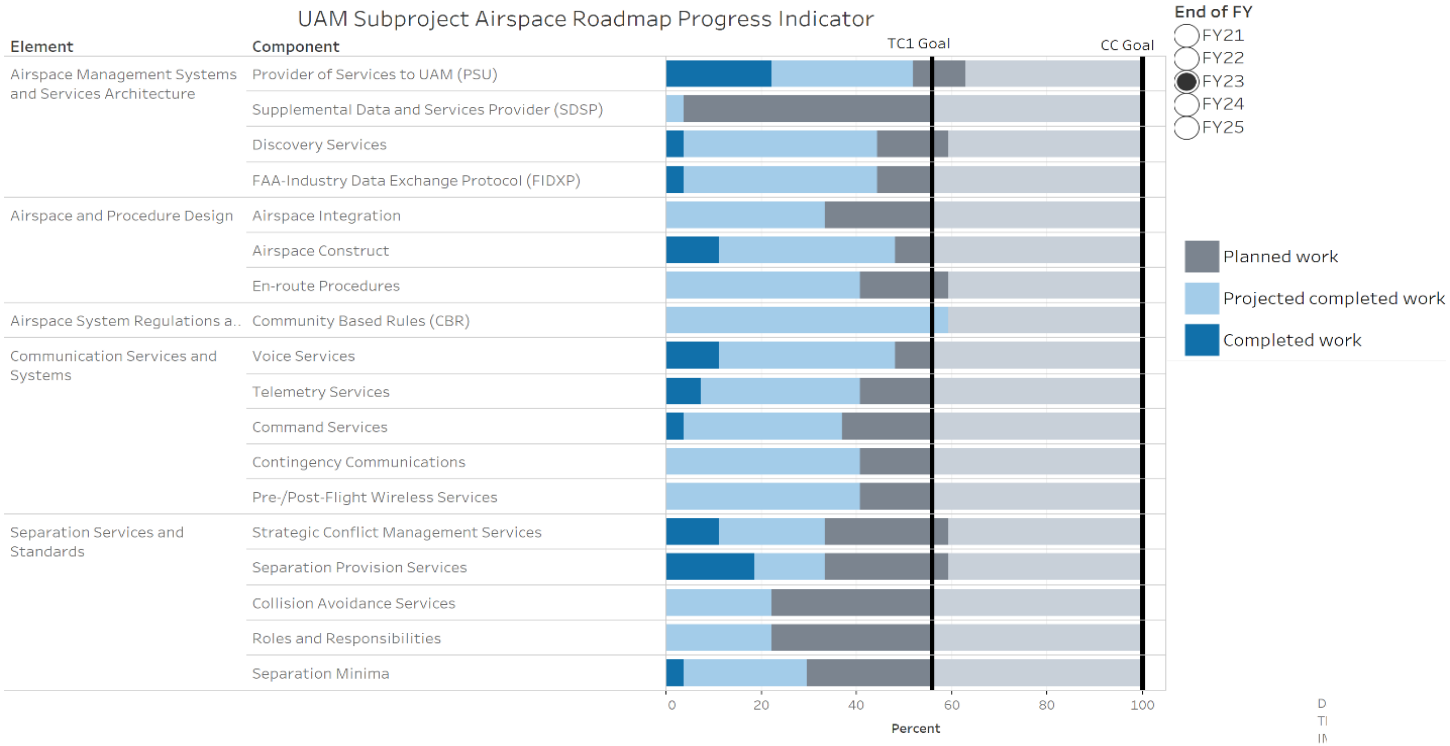
Under-the-hood System Engineering



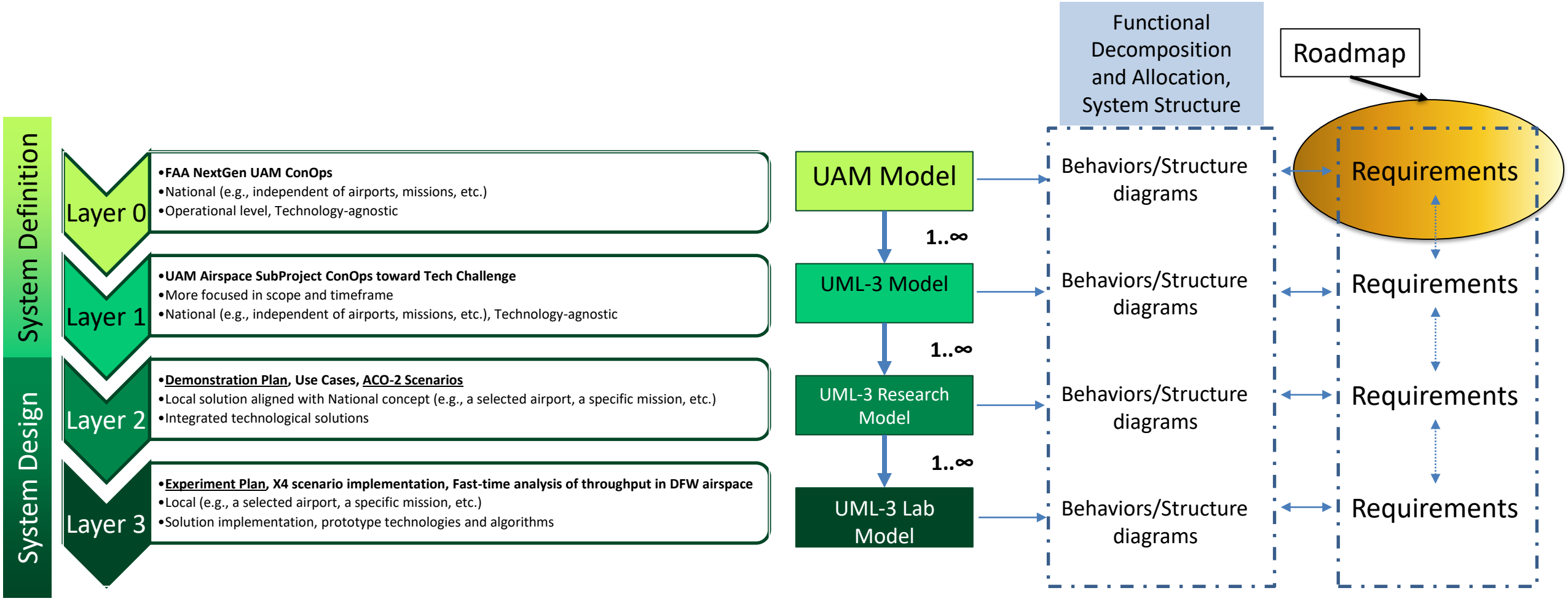
CNS = Communication, Navigation, and Surveillance
UML = UAM Maturity Level

Digital Engineering methodology

- Traces to research through requirements hierarchy
- Analyzes requirements for research insights
- Provides dashboard reports for program management



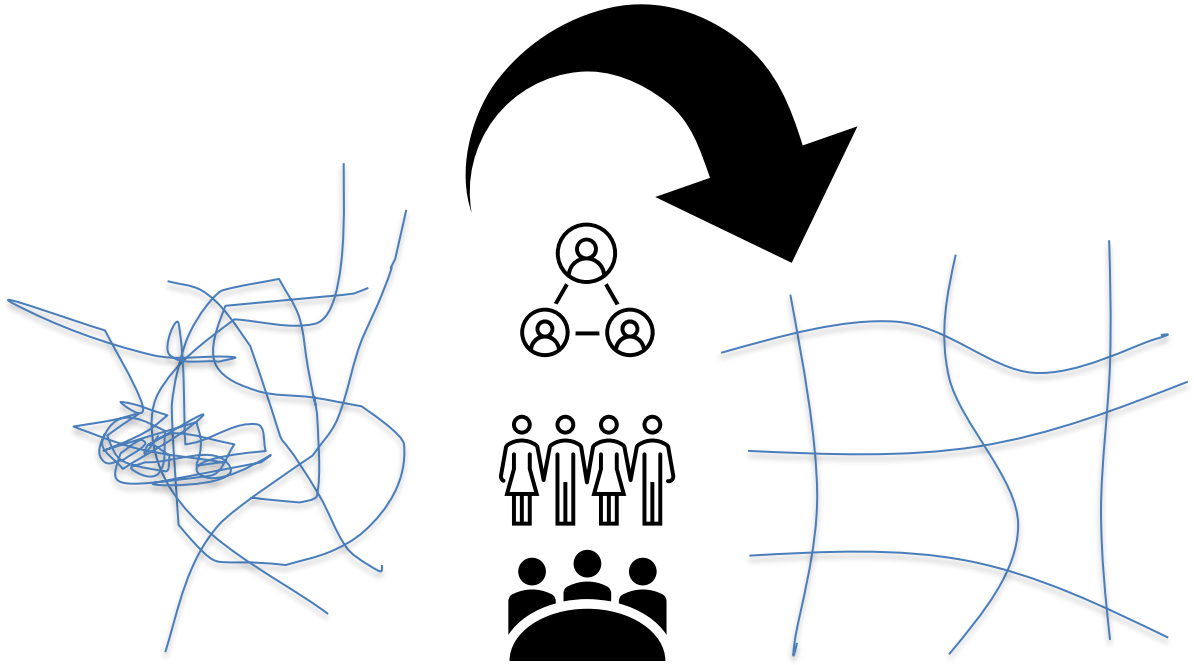
Notional Hierarchy of System Models



UAM Airspace Research Roadmap v1.2

PRACTICE

UAM Airspace Research Roadmap Development



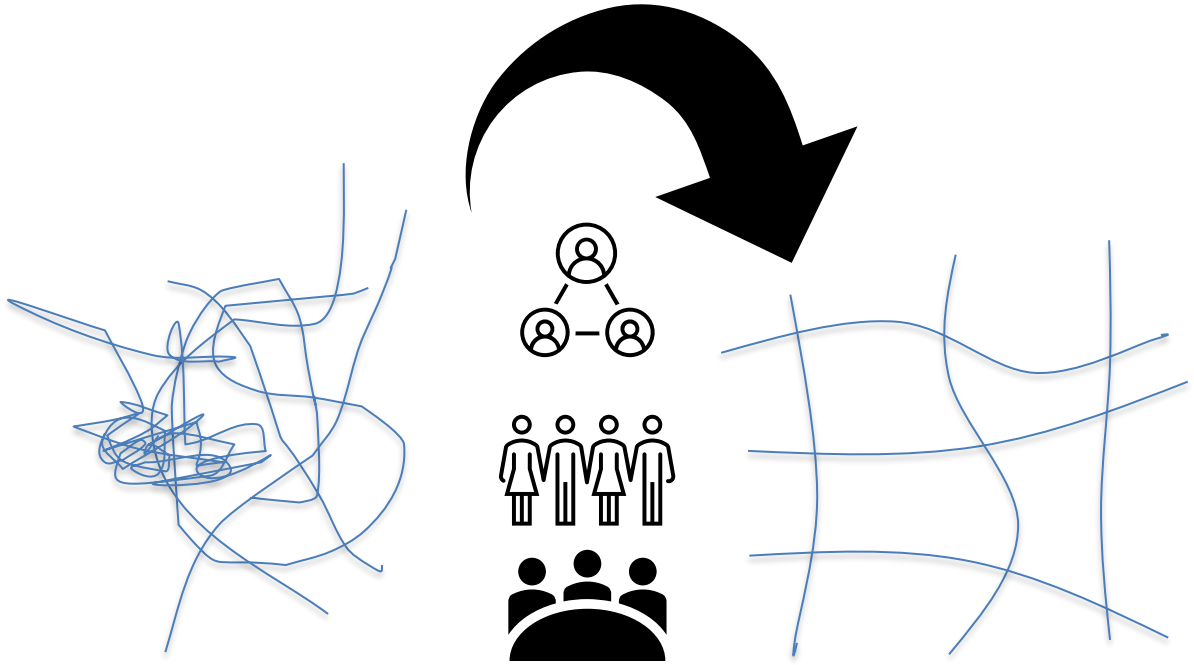
Oct 2020	Jan 2021	Apr 2021	June 2021	Oct 2021	Jan 2022	Apr 2022	June 2022	Oct 2022	Jan 2023+

Started

Rev 1.0
NASA Technical Memo

NASA-Informed

UAM Airspace Research Roadmap Development



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NASA-Informed

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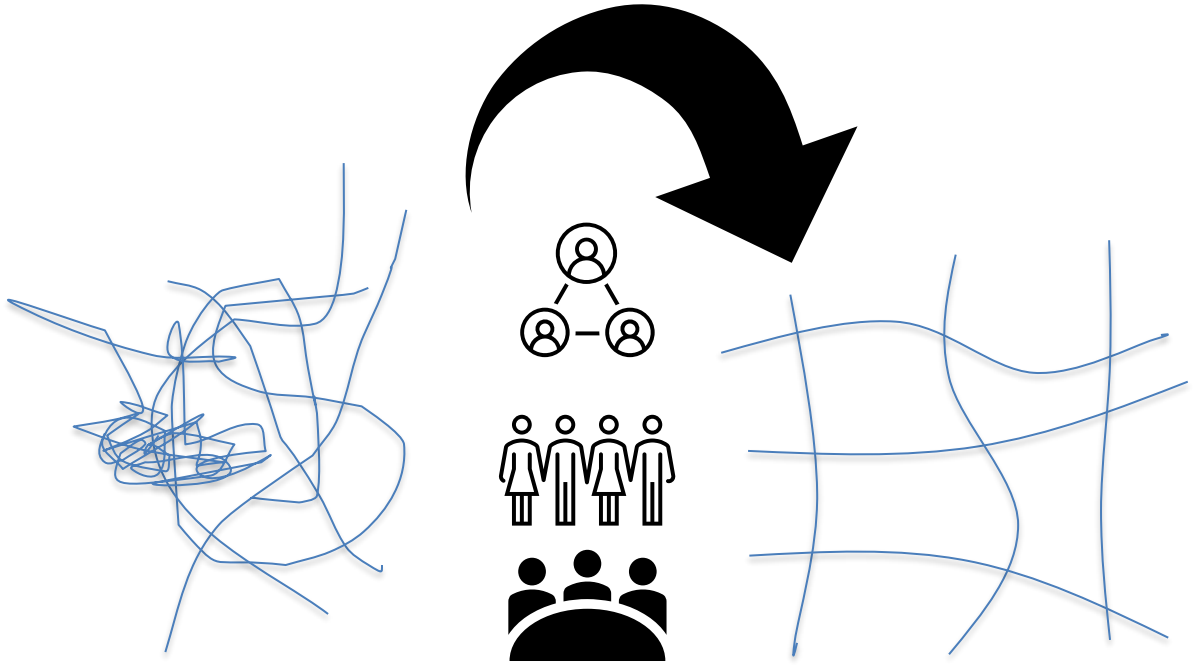

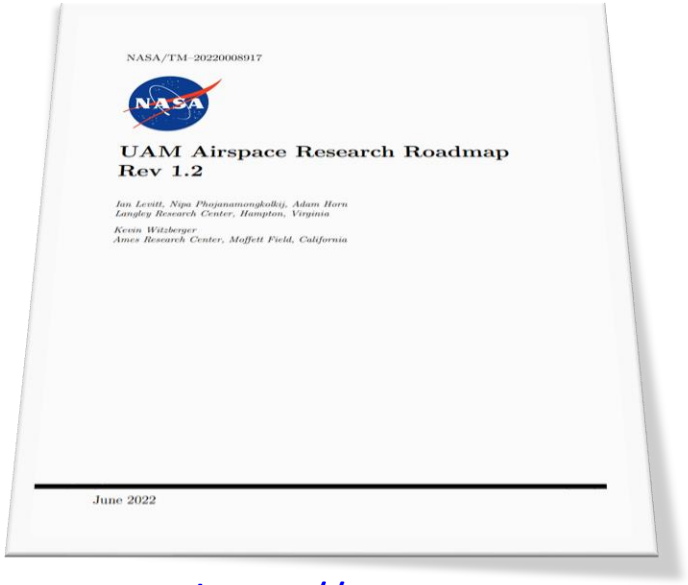

https://nari.arc.nasa.gov/uam-research-roadmap

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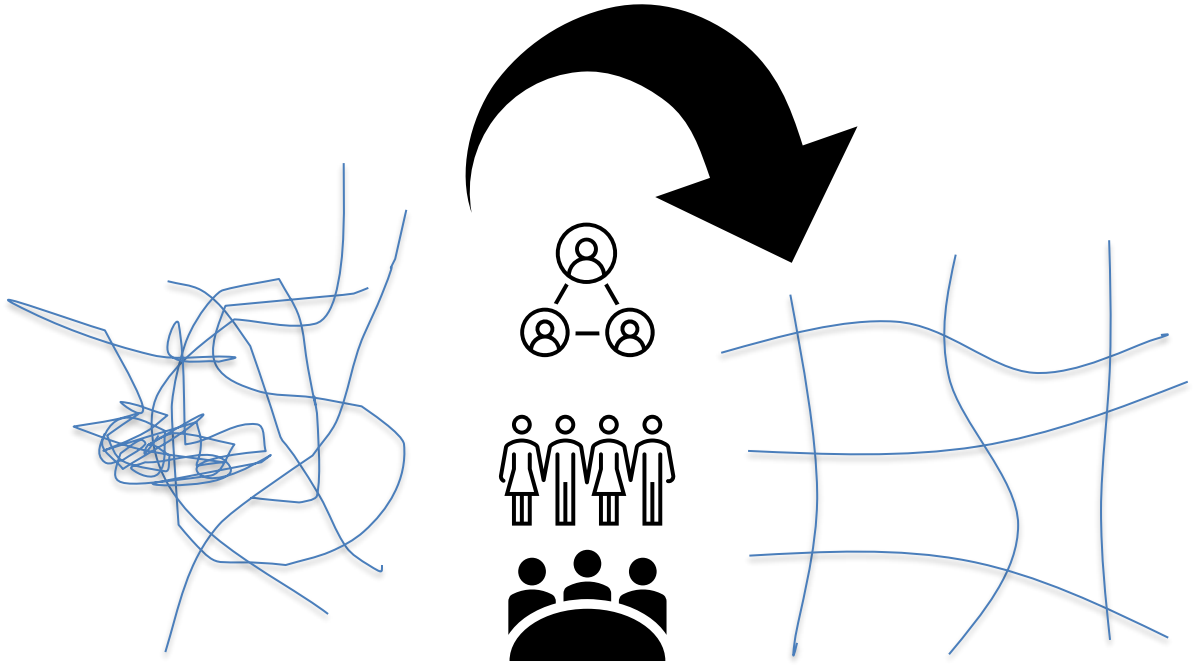

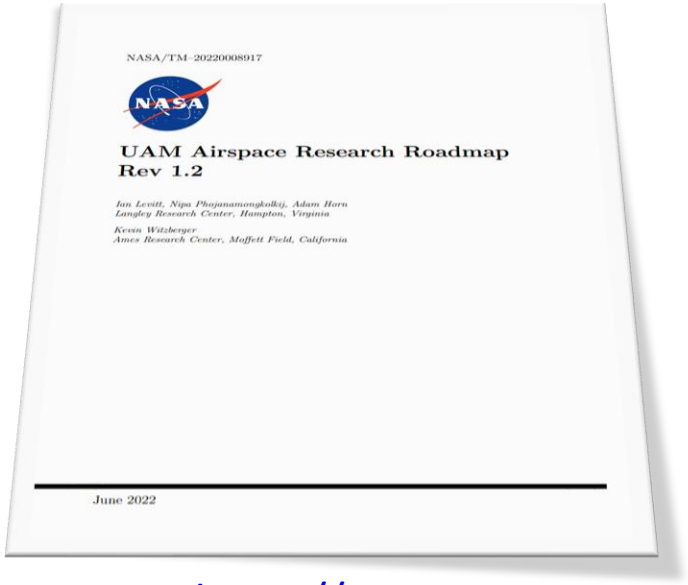

§1 Introduction

§2 UAM Airspace System Definition

§3 UAM Airspace System Progression

§4 System Engineering Methodology

§5 Roadmap Requirements Tables

§6 Conclusions and Next Steps

References

Appendix A: Acronyms

Appendix B: Glossary

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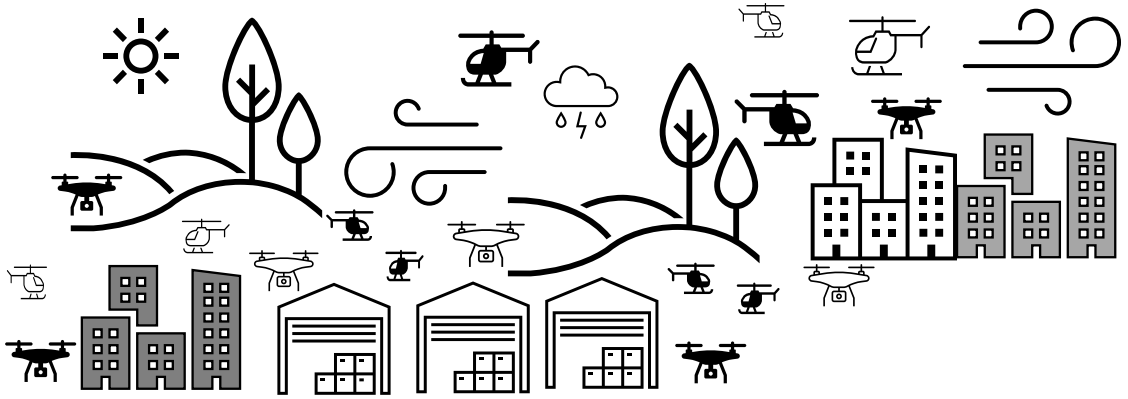
NASA-Informed

FAA-Informed

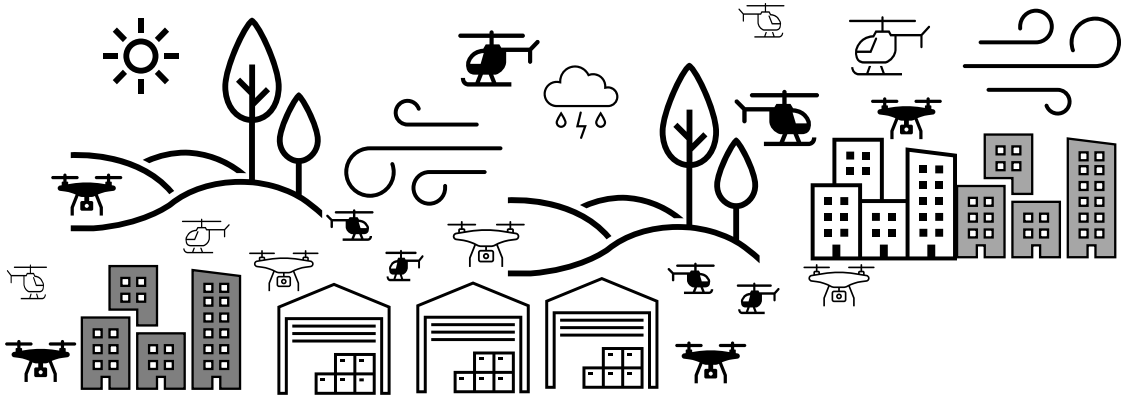
Community-Informed

System Engineering Methodology



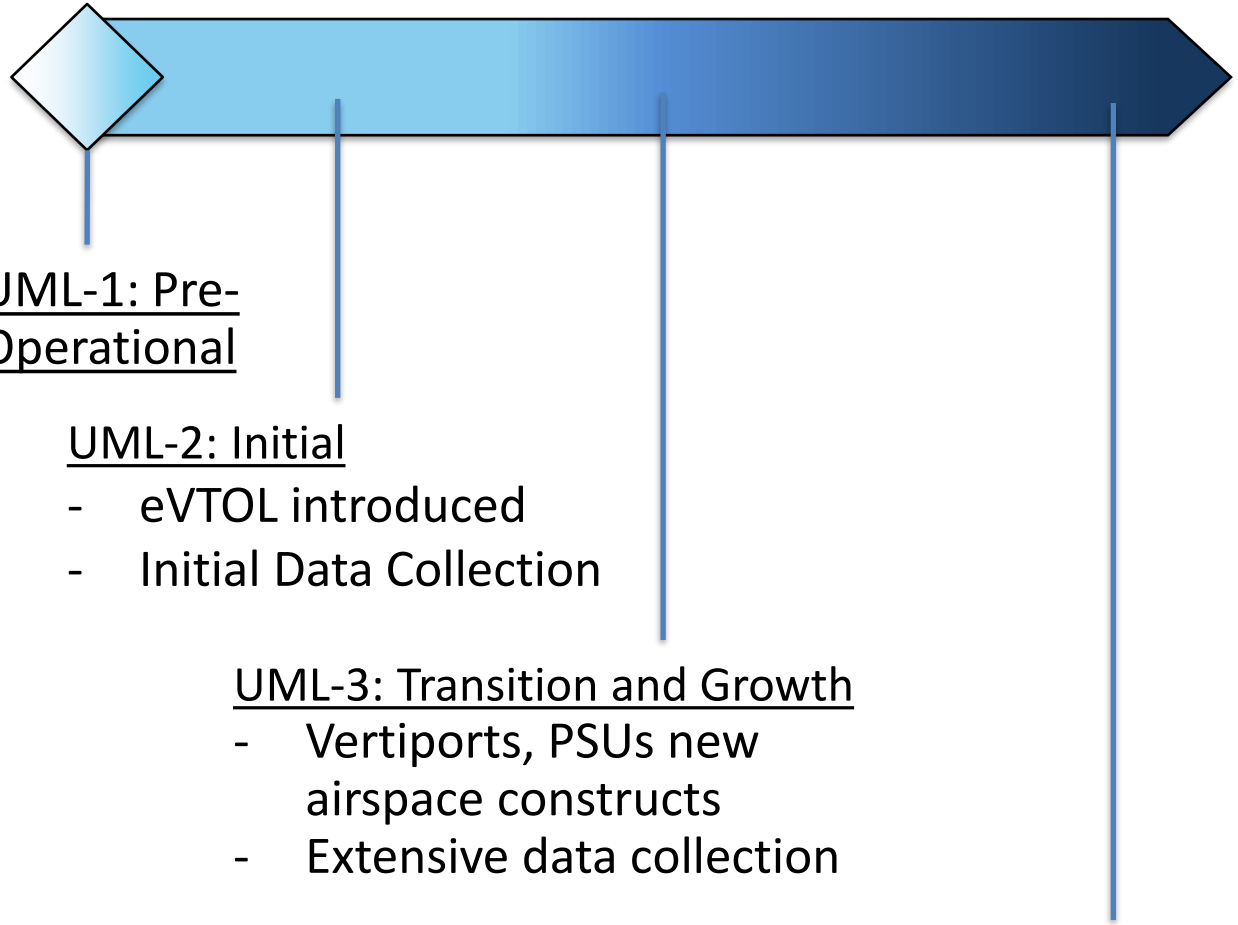
UAM System of Systems

System Engineering Methodology



UAM System of Systems

Capabilities evolve over time



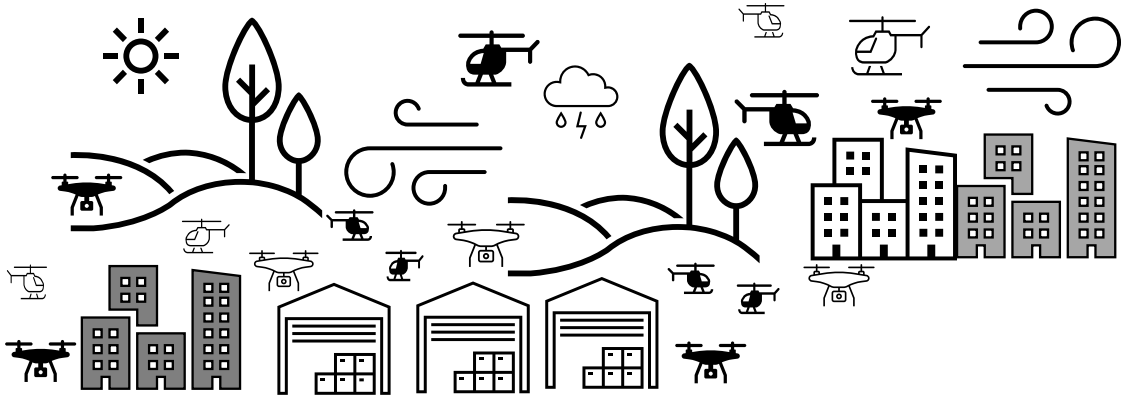
UML-1: Pre-Operational

UML-2: Initial
- eVTOL introduced
- Initial Data Collection

UML-3: Transition and Growth
- Vertiports, PSUs new airspace constructs
- Extensive data collection

UML-4: New Predetermined Separator
- New mode of operation
- ATC is not the separator

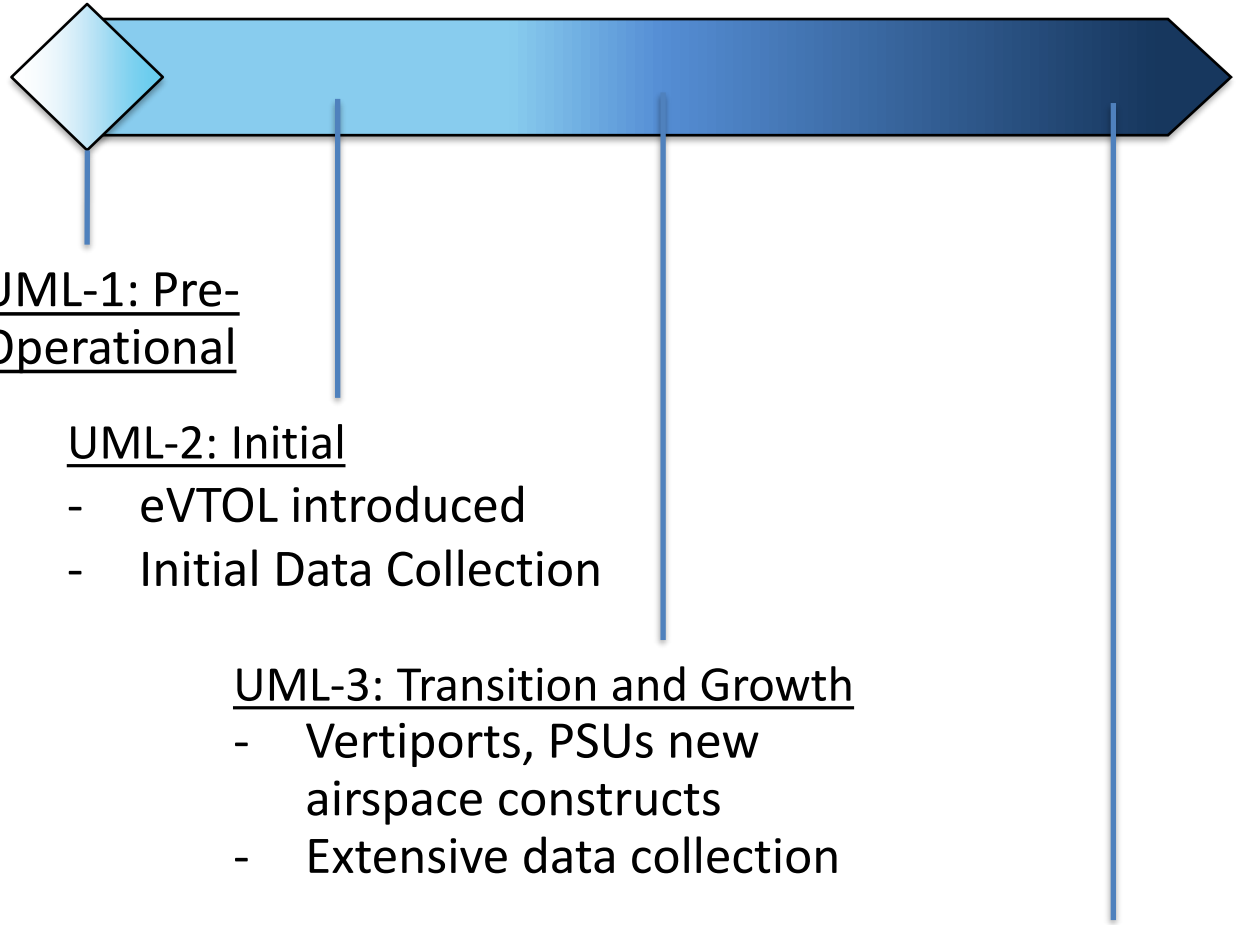
System Engineering Methodology



UAM System of Systems

Capabilities evolve over time

What is research telling us about the future system?



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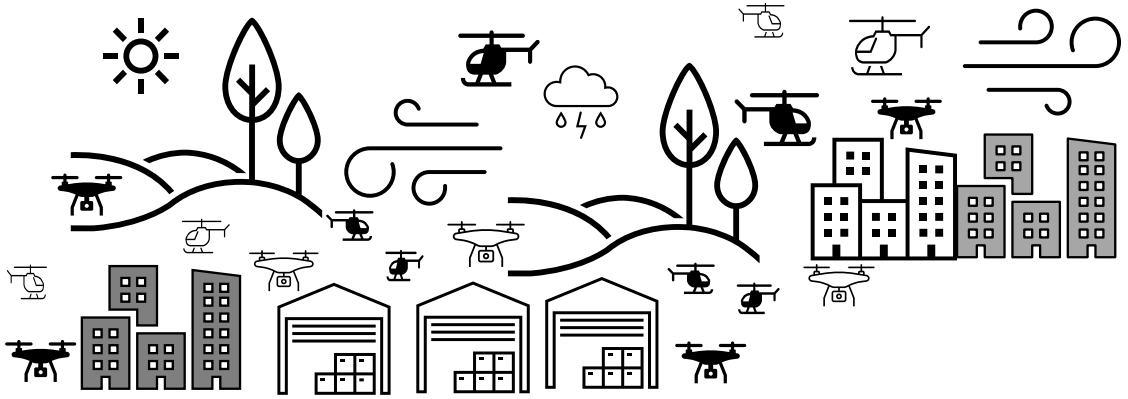
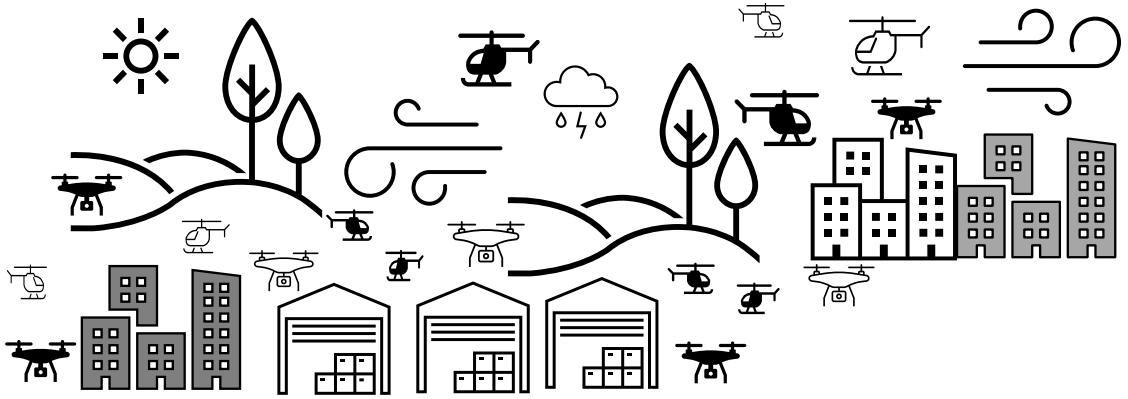


UAM System of Systems

Enterprise decomposed into capabilities that cover the airspace system

- Airspace Mgmt
- Airspace Design
- Regulations & Policies
- Communications
- Navigation
- Secured Airspace
- Separation Services
- Surveillance
- Vertiport Operations
- Weather

System Engineering Methodology



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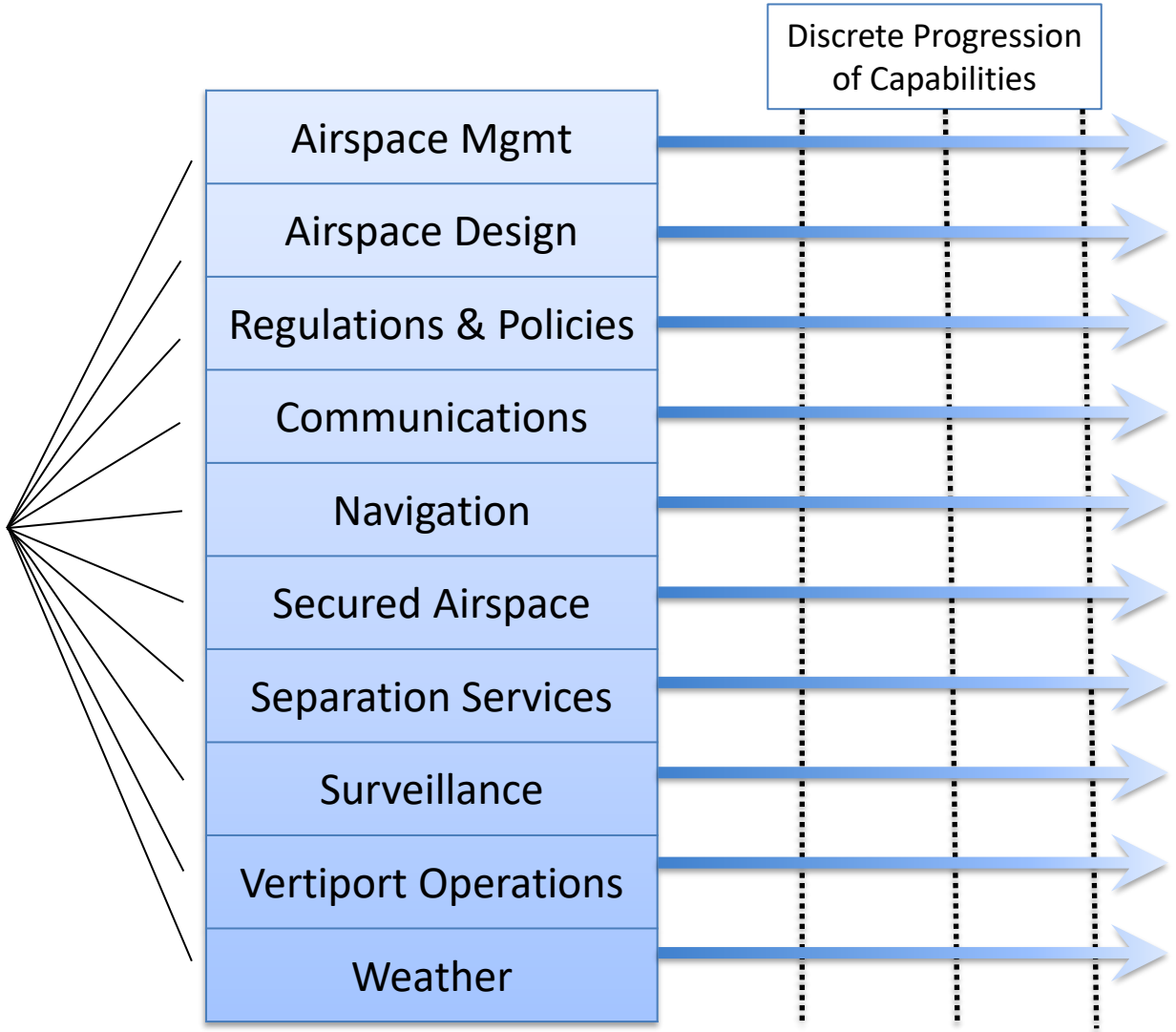
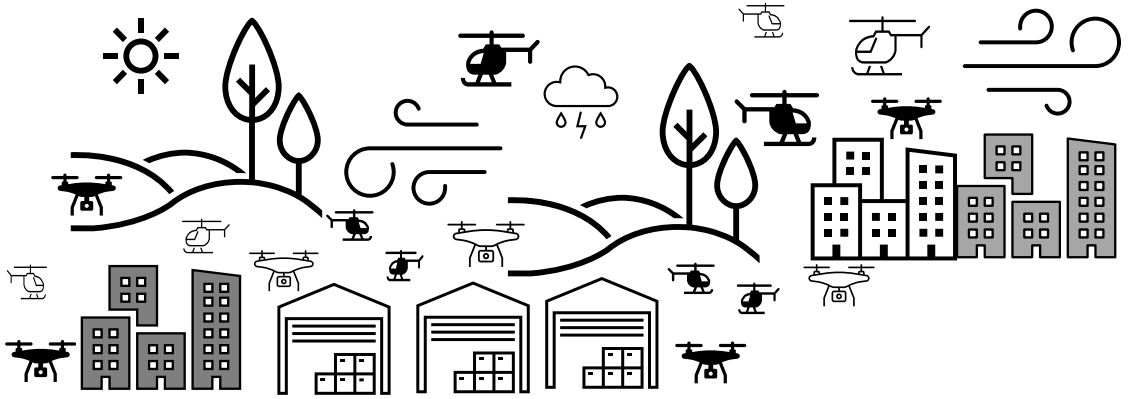


System Engineering Methodology



UAM System of Systems

Enterprise decomposed into capabilities that cover the airspace system

- Research Assumptions **will**
- Research Requirements **shall/should**
- Research Gaps **TBR**

Discrete Progression of Capabilities

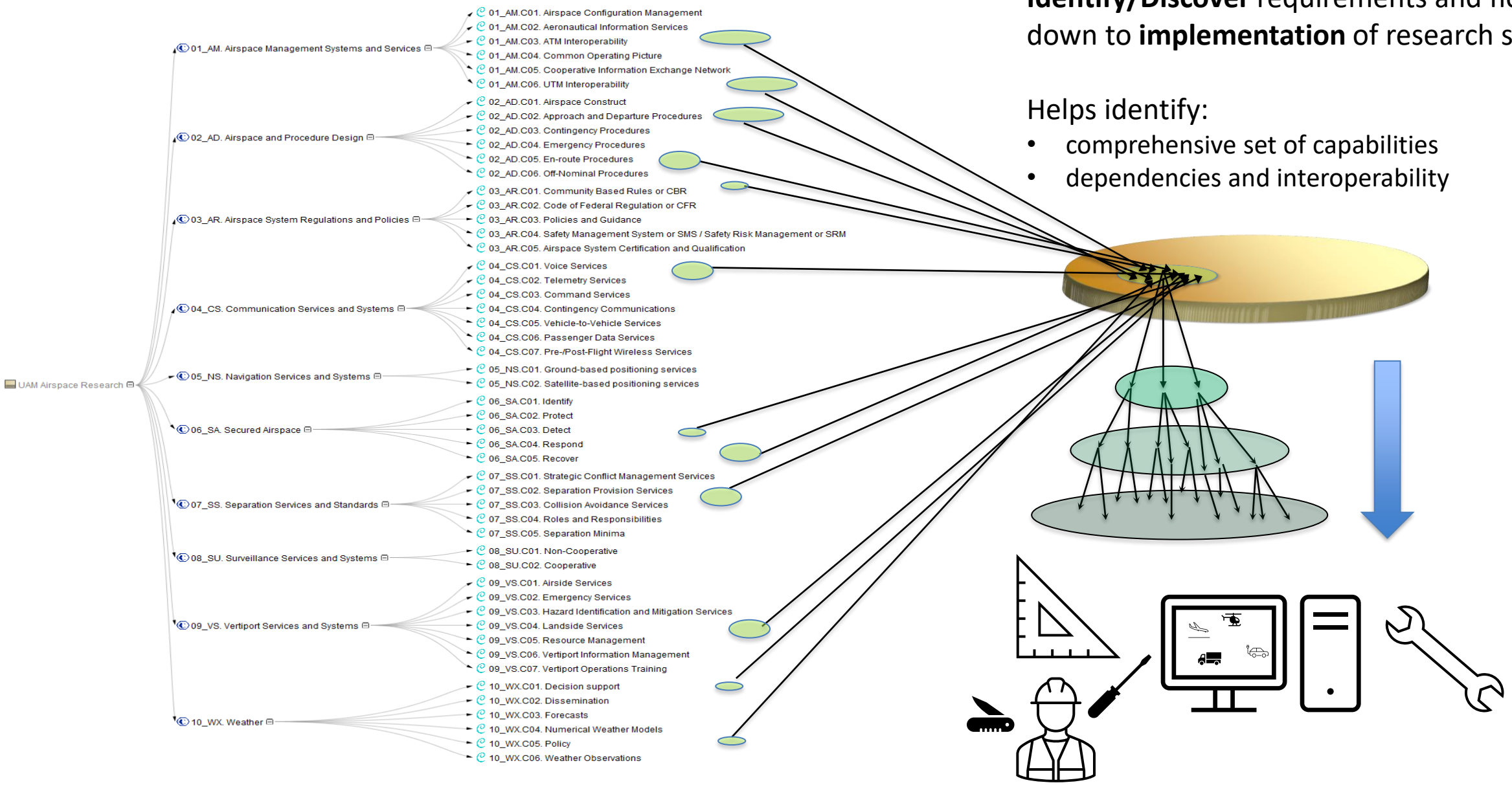
- Airspace Mgmt
- Airspace Design
- Regulations & Policies
- Communications
- Navigation
- Secured Airspace
- Separation Services
- Surveillance
- Vertiport Operations
- Weather

Expressed as…

Digital Engineering for Research

THEORY

Development of a Research System

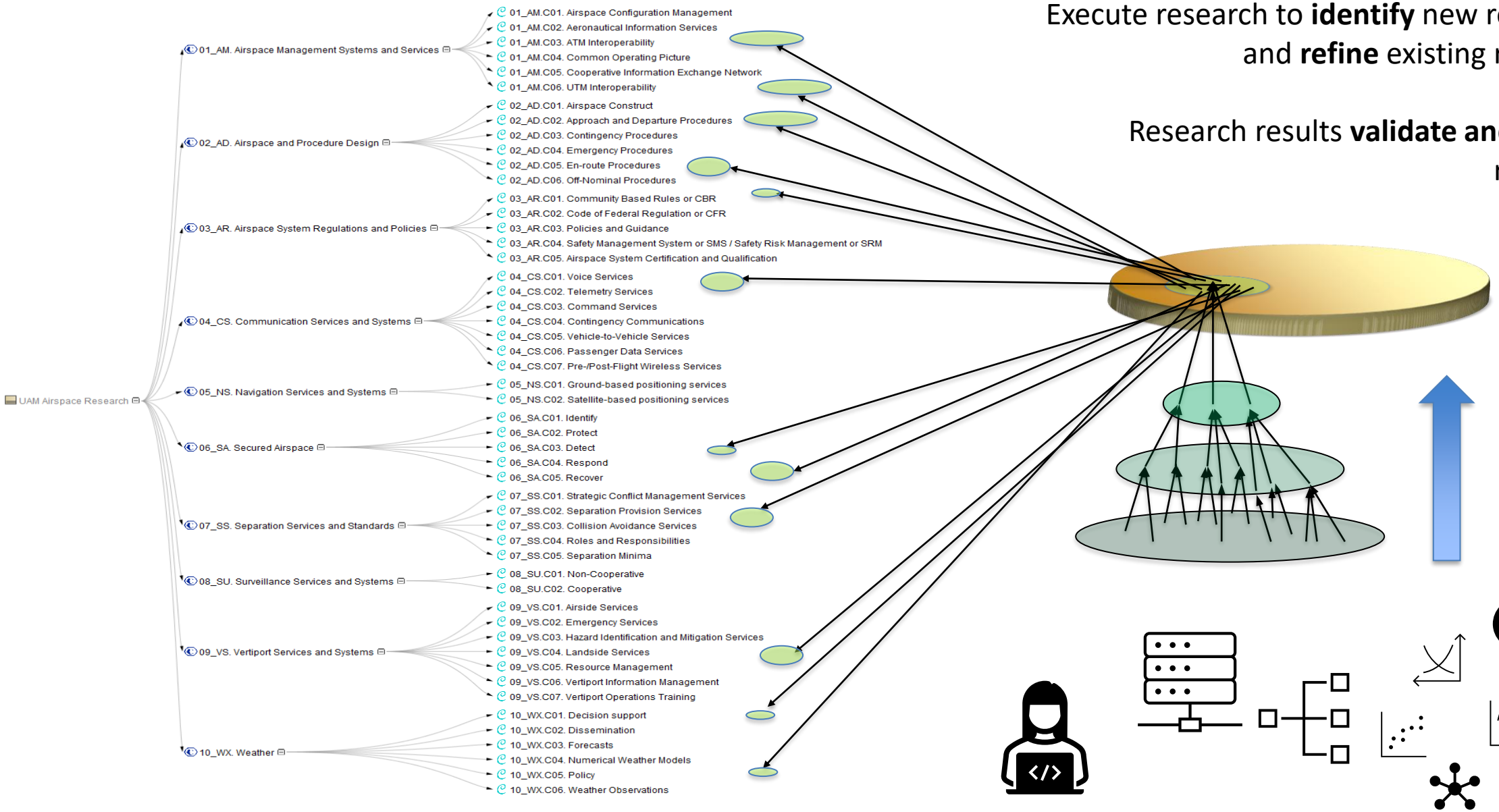


Identify/Discover requirements and flow-down to **implementation** of research system

Helps identify:

- comprehensive set of capabilities
- dependencies and interoperability

Integration of Research Results



Execute research to **identify** new requirements, and **refine** existing requirements

Research results **validate and mature** the requirements

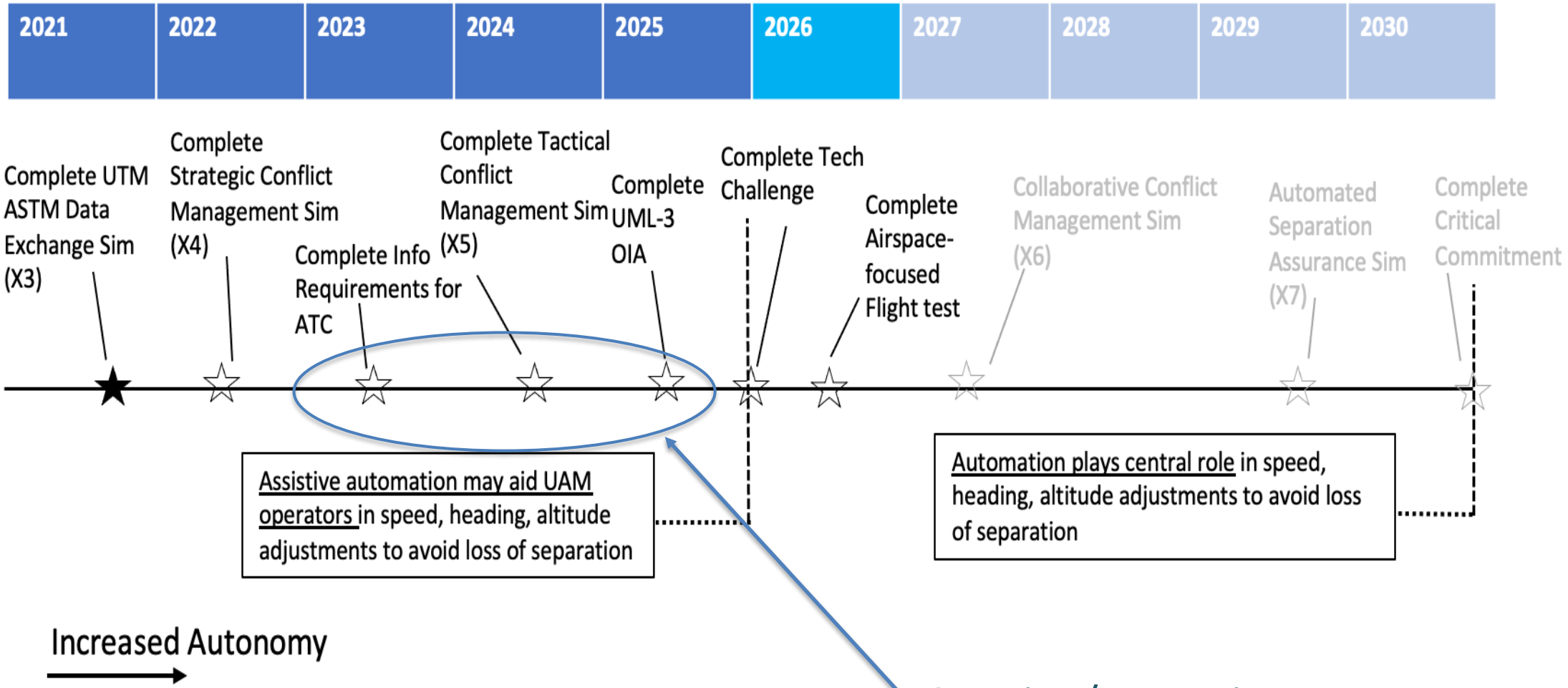
X5 & UML-3 Operational Integration Assessment (OIA)

PRACTICE

ATM-X's Urban Air Mobility (UAM) Subproject

Evolving the Airspace Towards UML-4

UAM Airspace Subproject's Future Efforts

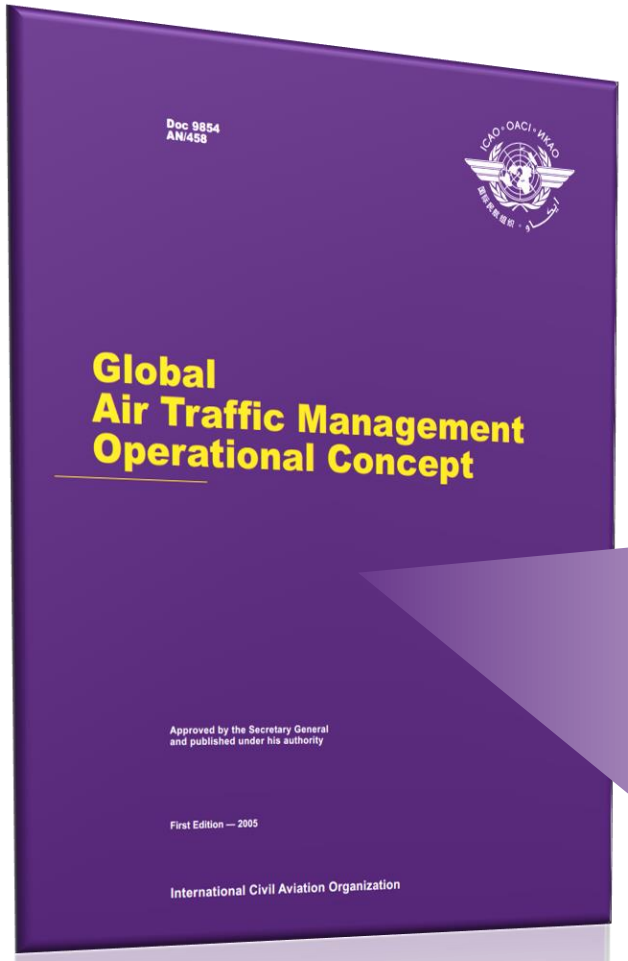


- On Demand Airport Transfer
- Cargo Delivery
- Cross Metro Transfer
- Regional Network
- Air Ambulance
- Fleet Operations

UML-3 Operational Integration Assessment Use Cases

Image Credit: National Aeronautics and Space Administration (NASA)

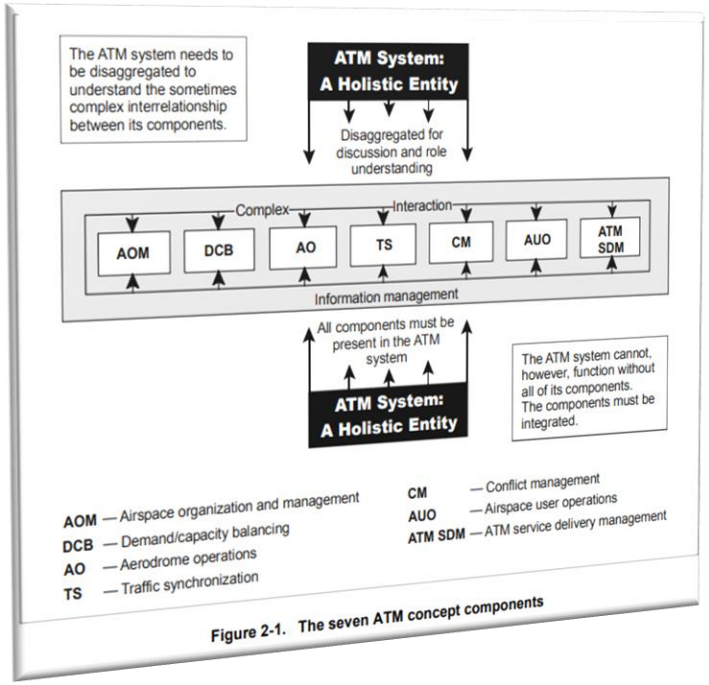
UML-3 Cooperative Conflict Management (CCM) Concept



Cooperative Conflict Management (CCM) addresses **scalability** through new ATM paradigms that distribute the responsibility for Conflict Management amongst cooperative actors

Relies on system actors having access to a Common Operating Picture

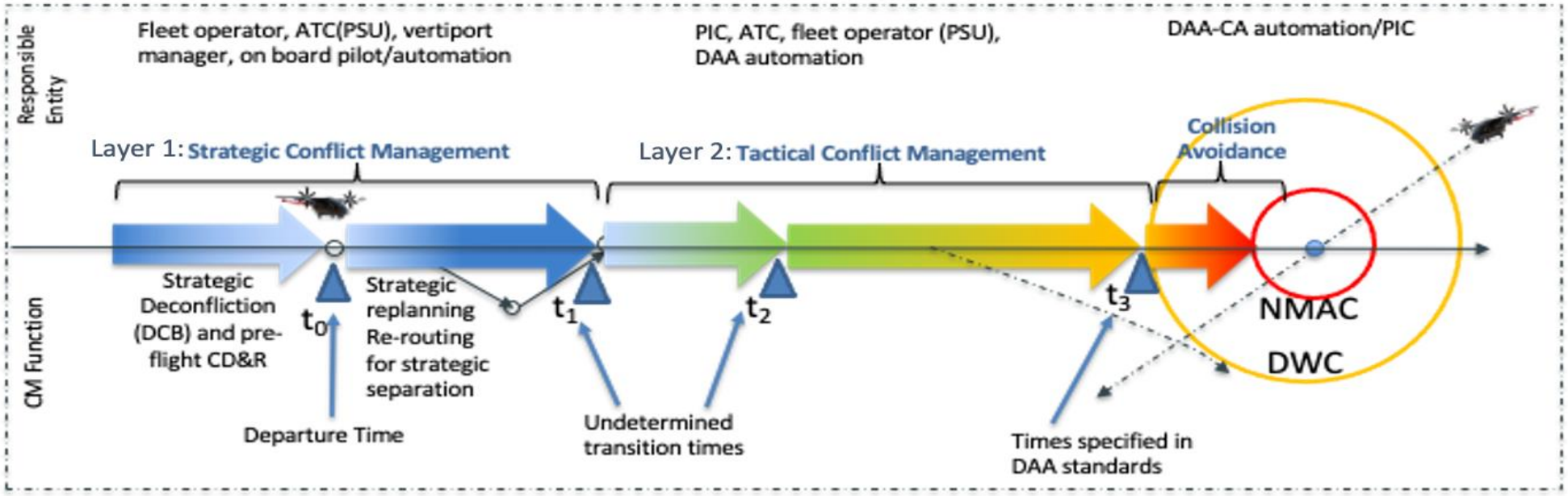
CCM for UML-3 means IFR or VFR, but with novel procedures enabling increased tempo



UML-3 CCM Goals

VFR: managed flow of UAM traffic for increased throughput, extending below VMC, with acceptable pilot workload

IFR: efficient and predictable flow of UAM operations, with acceptable ATC workload at sustained tempos



Notional Conflict Management Diagram
Developed by NASA/Maria Consiglio

UML-3 Technical and Operational R&D

Tactical Conflict Management (X5)

- Implement automation to support Cooperative Conflict Management
  - Strategic and Tactical for UML-3
  - Interoperability tested through simulation and analysis
- Assess the effectiveness of the total system

UML-3 Technical and Operational R&D

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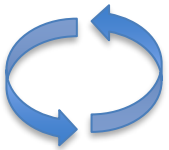

UML-3 Operational Integration Assessment (OIA)

- Integrate X5 capabilities into a higher-TRL operational environment
  - Joint NASA/FAA integrated LVC
  - Most system actors represented
- Integrate UAM and non-UAM traffic
  - Novel airspace constructs
  - Off-nominal scenarios
- Key objectives
  - Accelerate UML-3 Operationalization
  - Evaluate innovative solutions for operational integration
  - Evaluate and explore ATM, Flight Crew, and Operator functions
  - Identify barriers associated with progressing operations from VMC to IMC

UML-3 Technical and Operational R&D

Tactical Conflict Management (X5)

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Traces to broad set of research requirements and assumptions

UML-3 Operational Integration Assessment (OIA)

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Requirements Development

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    - 01_AM.C02. Aeronautical Information Services
    - 01_AM.C03. ATM Interoperability
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    - 01_AM.C05. Cooperative Information Exchange Network
    - 01_AM.C06. UTM Interoperability
  - 02_AD. Airspace and Procedure Design
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    - 03_AR.C04. Safety Management System or SMS / Safety Risk Management or SRM
    - 03_AR.C05. Airspace System Certification and Qualification
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    - 04_CS.C01. Voice Services
    - 04_CS.C02. Telemetry Services
    - 04_CS.C03. Command Services
    - 04_CS.C04. Contingency Communications
    - 04_CS.C05. Vehicle-to-Vehicle Services
    - 04_CS.C06. Passenger Data Services
    - 04_CS.C07. Pre-/Post-Flight Wireless Services
  - 05_NS. Navigation Services and Systems
    - 05_NS.C01. Ground-based positioning services
    - 05_NS.C02. Satellite-based positioning services
  - 06_SA. Secured Airspace
    - 06_SA.C01. Identify
    - 06_SA.C02. Protect
    - 06_SA.C03. Detect
    - 06_SA.C04. Respond
    - 06_SA.C05. Recover
  - 07_SS. Separation Services and Standards
    - 07_SS.C01. Strategic Conflict Management Services
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    - 09_VS.C05. Resource Management
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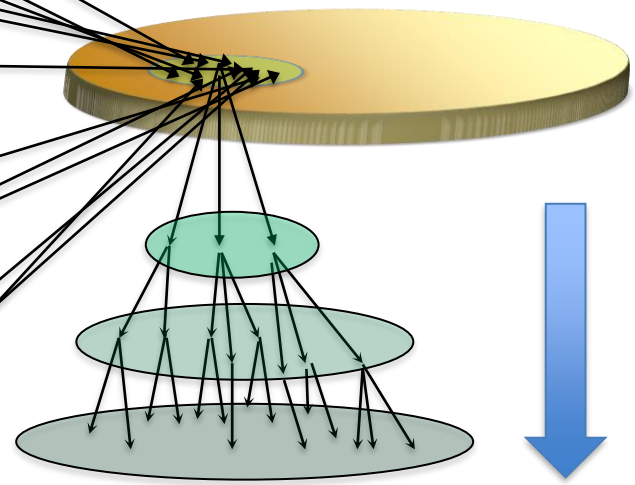
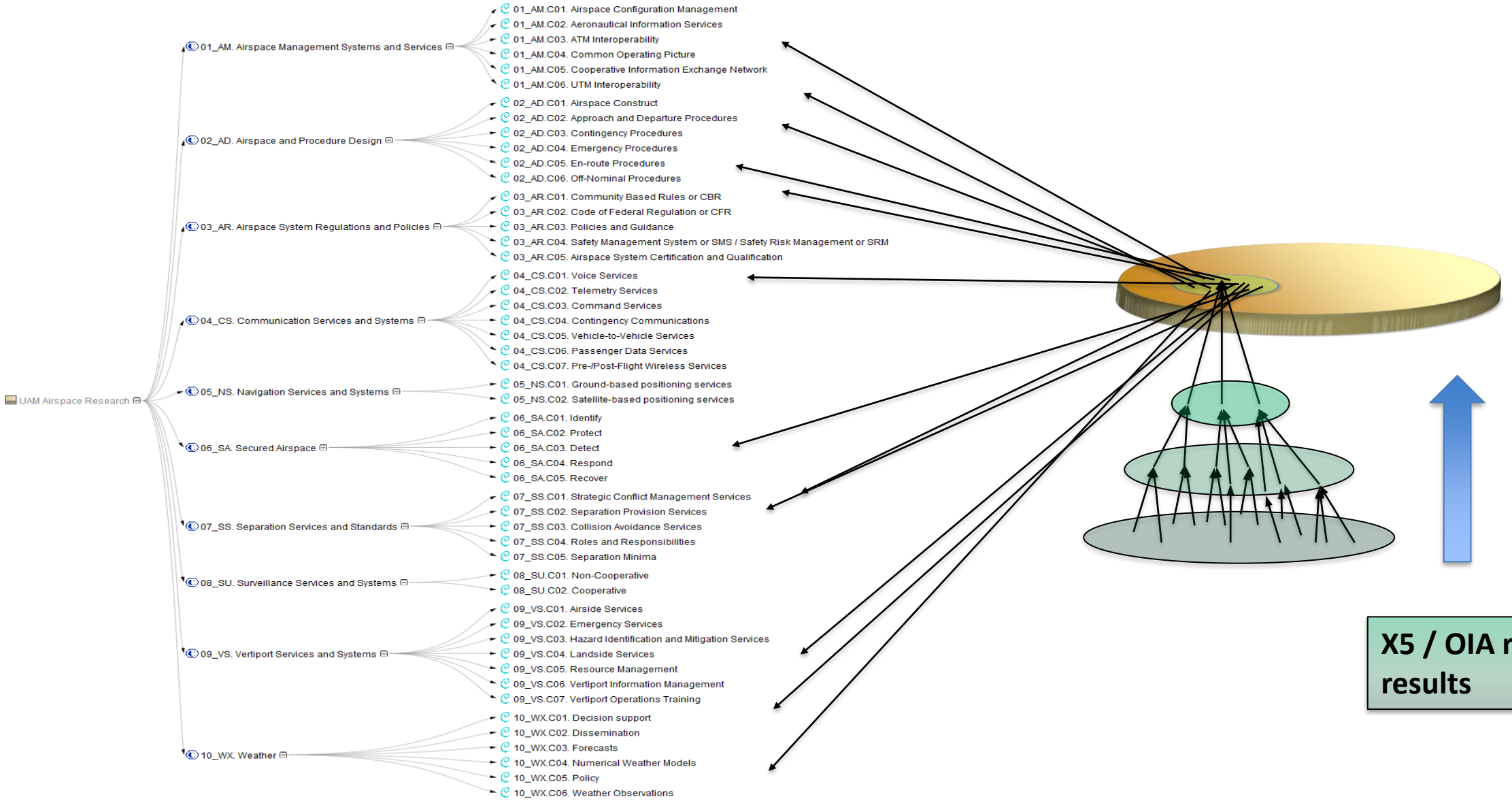
    - 09_VS.C07. Vertiport Operations Training
  - 10_WX. Weather
    - 10_WX.C01. Decision support
    - 10_WX.C02. Dissemination
    - 10_WX.C03. Forecasts
    - 10_WX.C04. Numerical Weather Models
    - 10_WX.C05. Policy
    - 10_WX.C06. Weather Observations

X5 / OIA research requirements



Integration of Research Results



X5 / OIA research results

Agile Requirements Development

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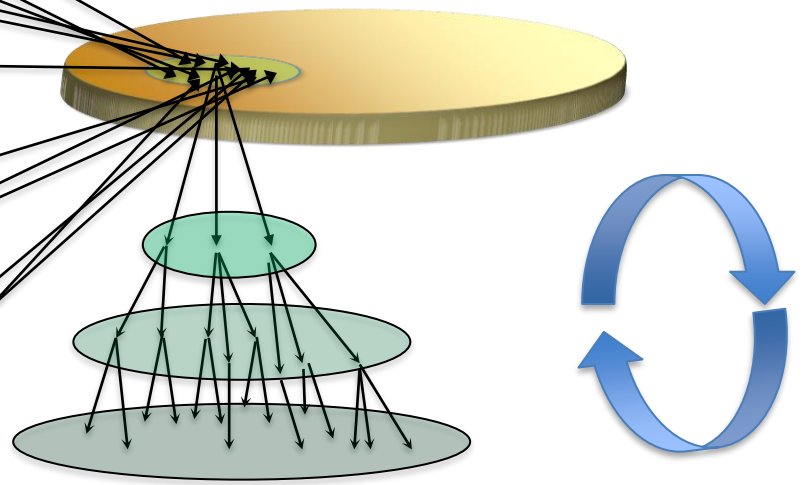
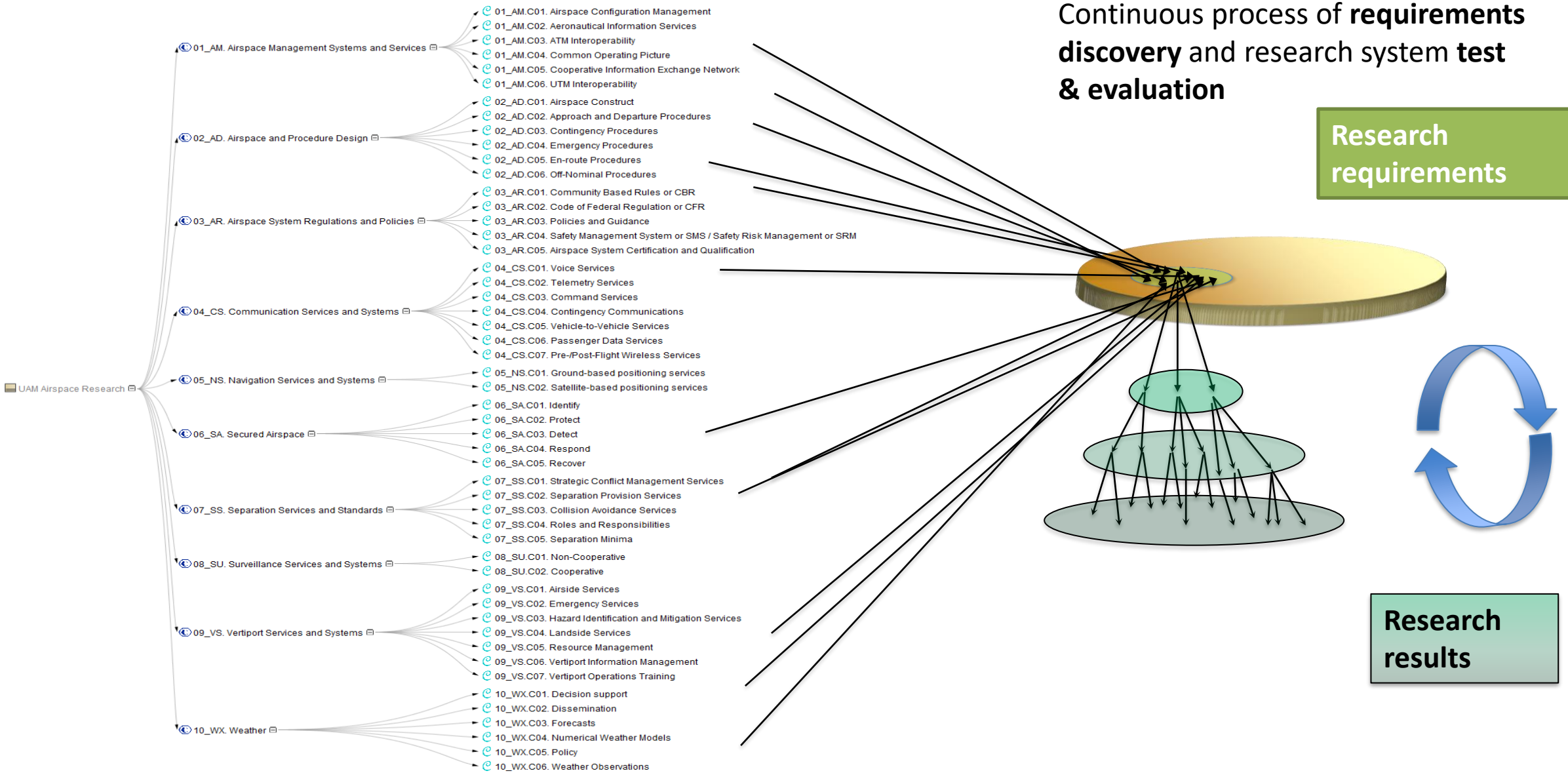
Continuous process of **requirements discovery** and research system **test & evaluation**

X5 / OIA research requirements



X5 / OIA research results

Agile Requirements Development



Continuous process of **requirements discovery** and research system **test & evaluation**

Research requirements

Research results

Next Steps

Practice

- Baseline UAM Airspace Research Roadmap Rev 2.0 in Jan 2023
- Build out database of research results
- Apply AI/ML techniques to increase efficiency of the researcher, program manager, and system engineer
- Apply process to next 5-8 years of ATM-X UAM Subproject research

Theory

- Develop concept of operations for Knowledge-based Digital Platform
- Study transportation system enterprise and its sectors