

SCITECH 
FORUM

6-10 JANUARY 2025 | ORLANDO, FL

***ENERGIZE
THE FUTURE***

AIAA SCITECH 2025

Systems Engineering Processes and Methods:

Tracing NASA Contributions Toward Aviation Safety Stakeholder Guidance



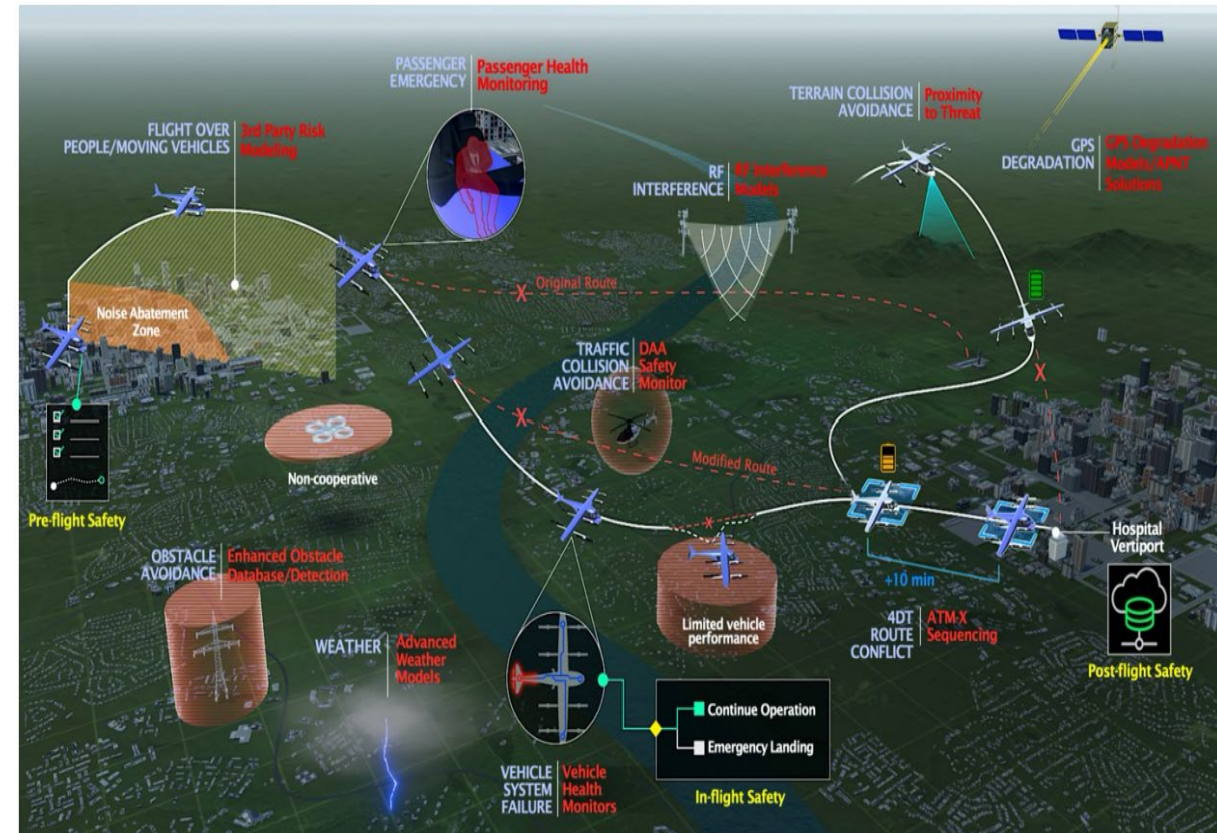
Darisha Vidrine, MS, Samantha Infeld, PhD, Doug Agyemang, Michael Vincent, Kyle Ellis, PhD, Summer Brandt, PhD, Wendy Okolo, PhD
National Aeronautics and Space Administration

NASA's System-Wide Safety Project

SWS Goals

Developing and maturing

- IASMS Services, Functions, and Capabilities (SFCs)
- Validated assurance methods
- Functional requirements for IASMS applications





SWS Sub-Project Teams

The SWS project addresses these goals through sub-project teams that focus on:

- The research and testing of software to implement IASMS capabilities and assurance of autonomous functions for traditional and emerging operations
- The testing and evaluation of integrated IASMS services, functions, and capabilities.
- Developing the overarching concept of operations and architecture that clearly address stakeholder needs



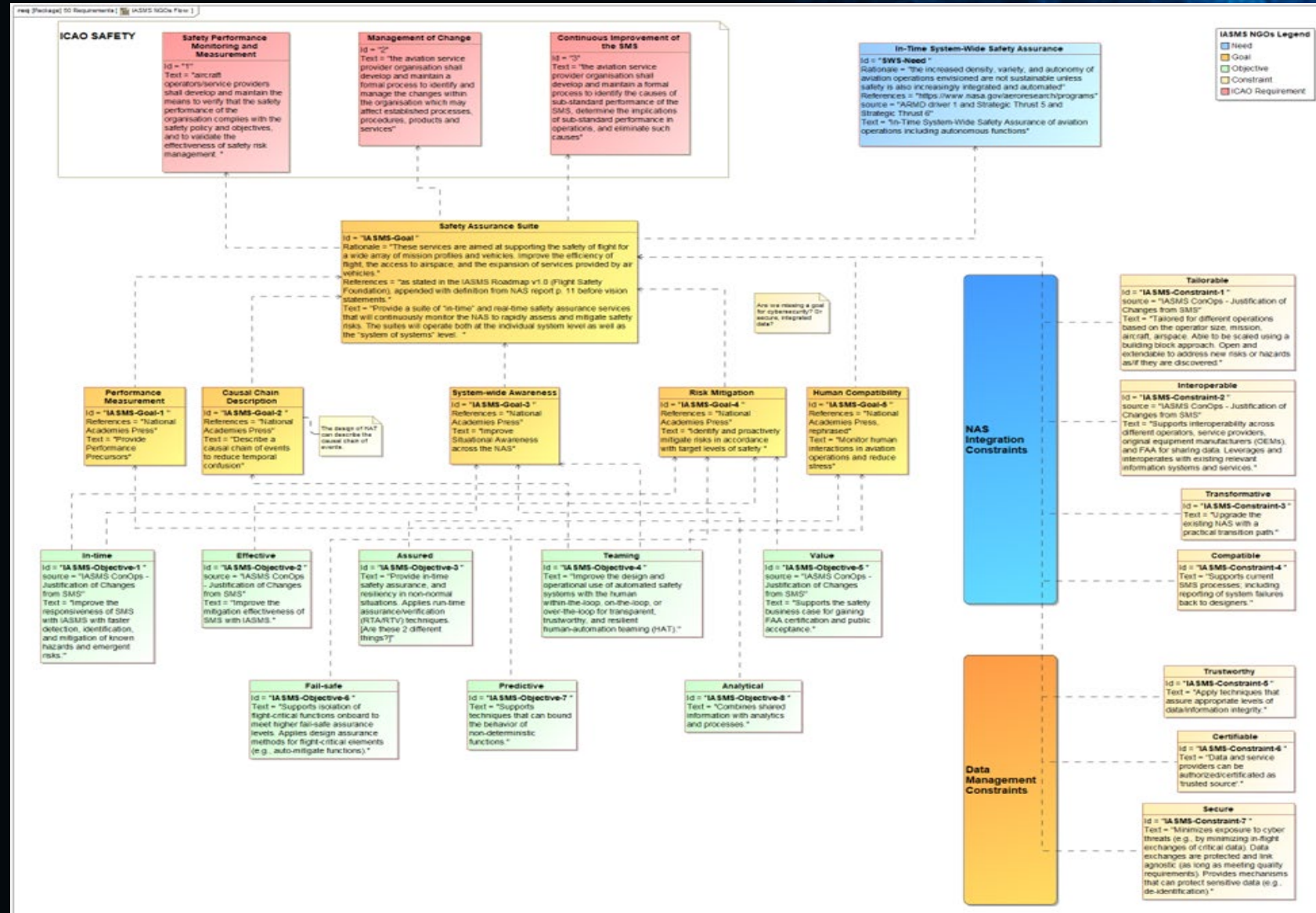
System Design Process



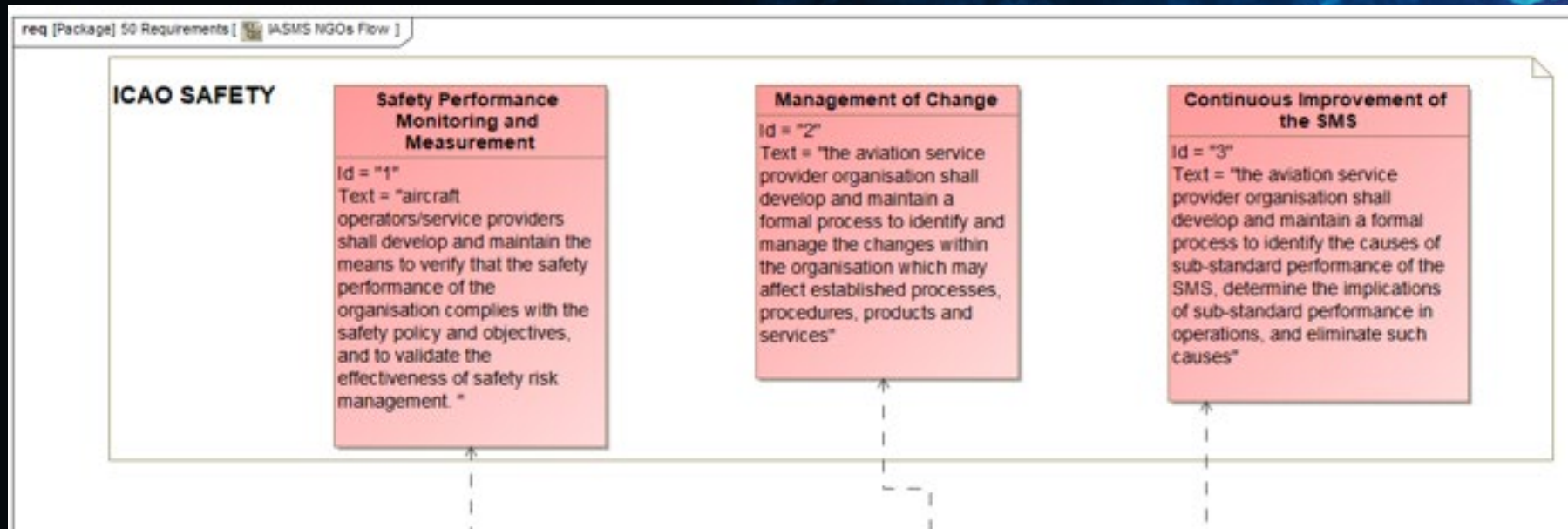
System Design Process

- Needs, Goals, and Objectives Flow
- IASMS System Functions
- Decomposing System Functions into Potential Behaviors
- Validating architecture through traceability:
 - FAA Unmanned Aerial System Safety Risk Management Guidance
 - National Academies Safety Assurance Recommendations
 - IASMS Research and Autonomy Verification & Validation Roadmaps

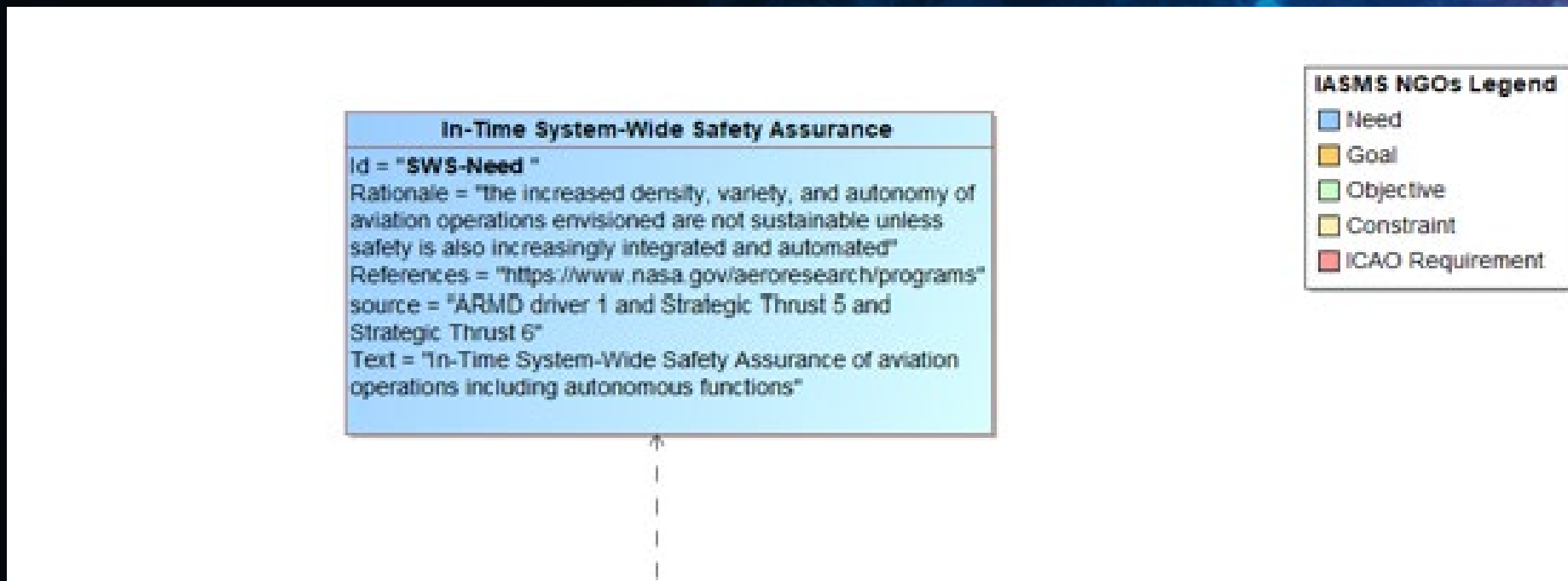
Needs, Goals, & Objectives (NGO)



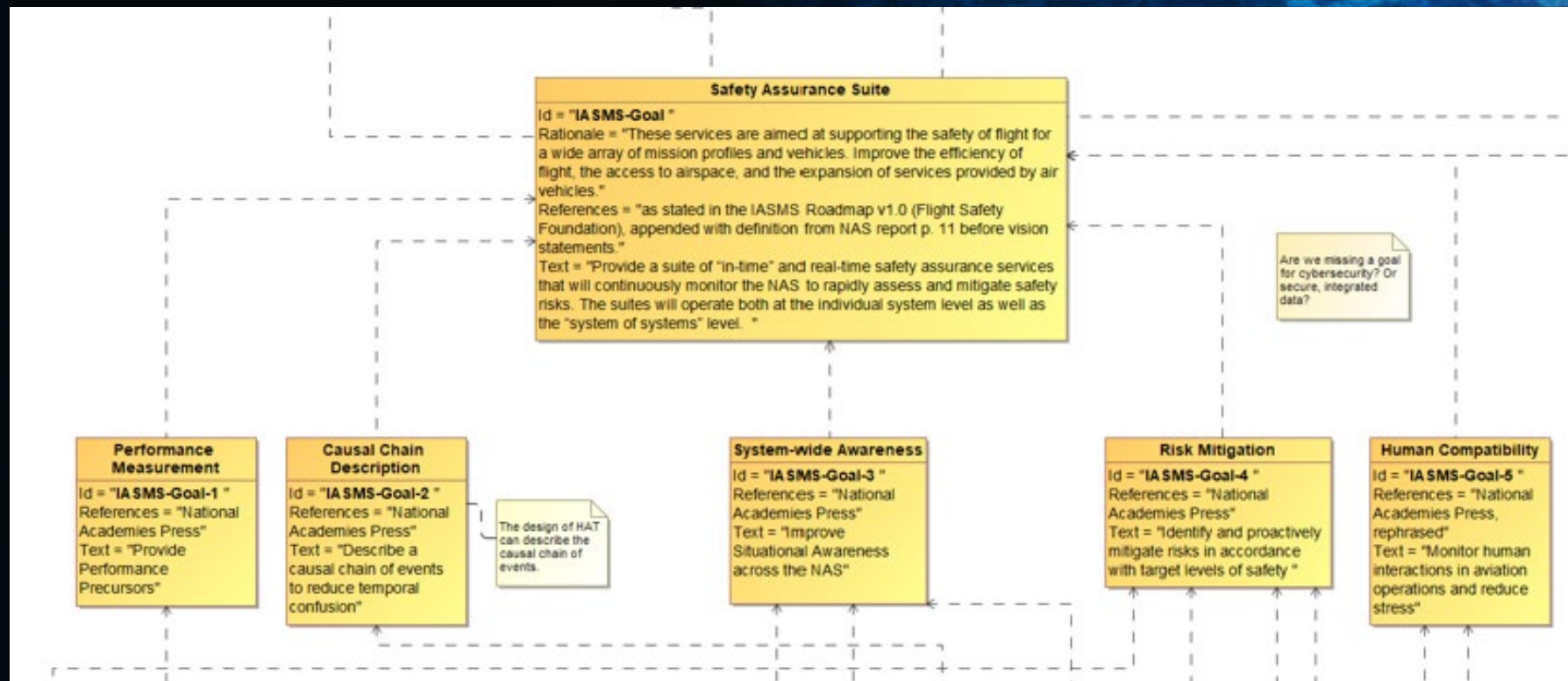
Frame 1: International Civil Aviation Organization



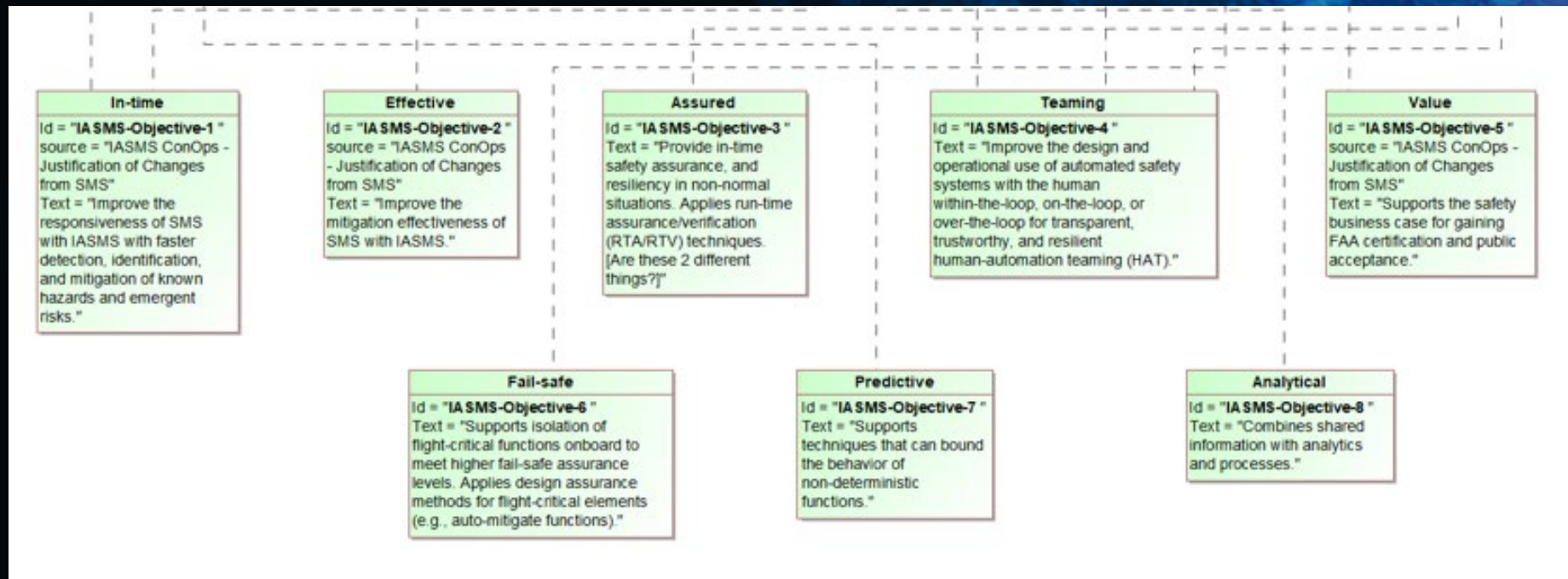
Frame 2: In-Time SWS Assurance



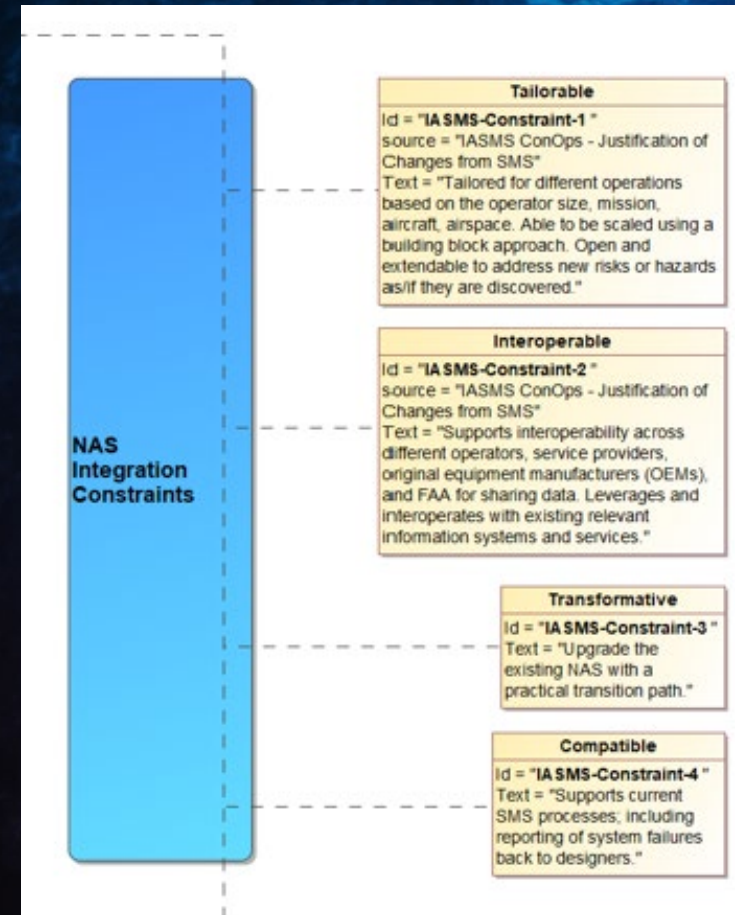
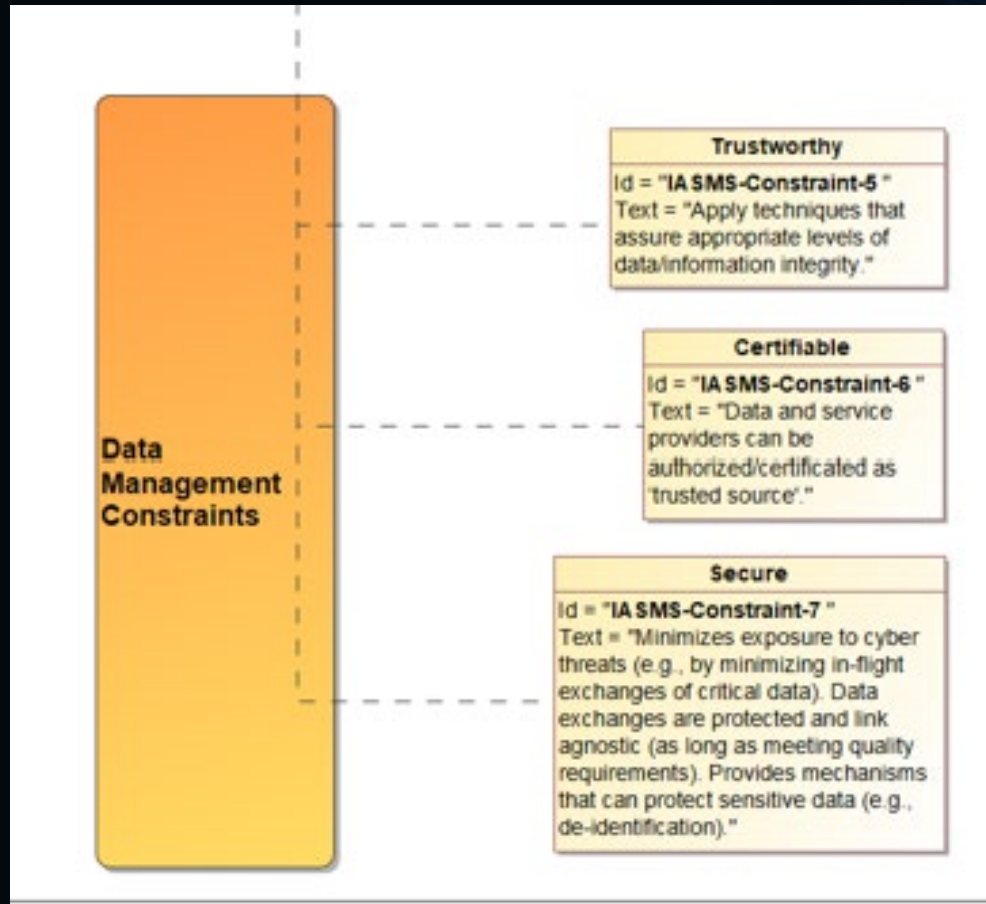
Frame 3: IASMS Goals



Frame 4: IASMS Objectives



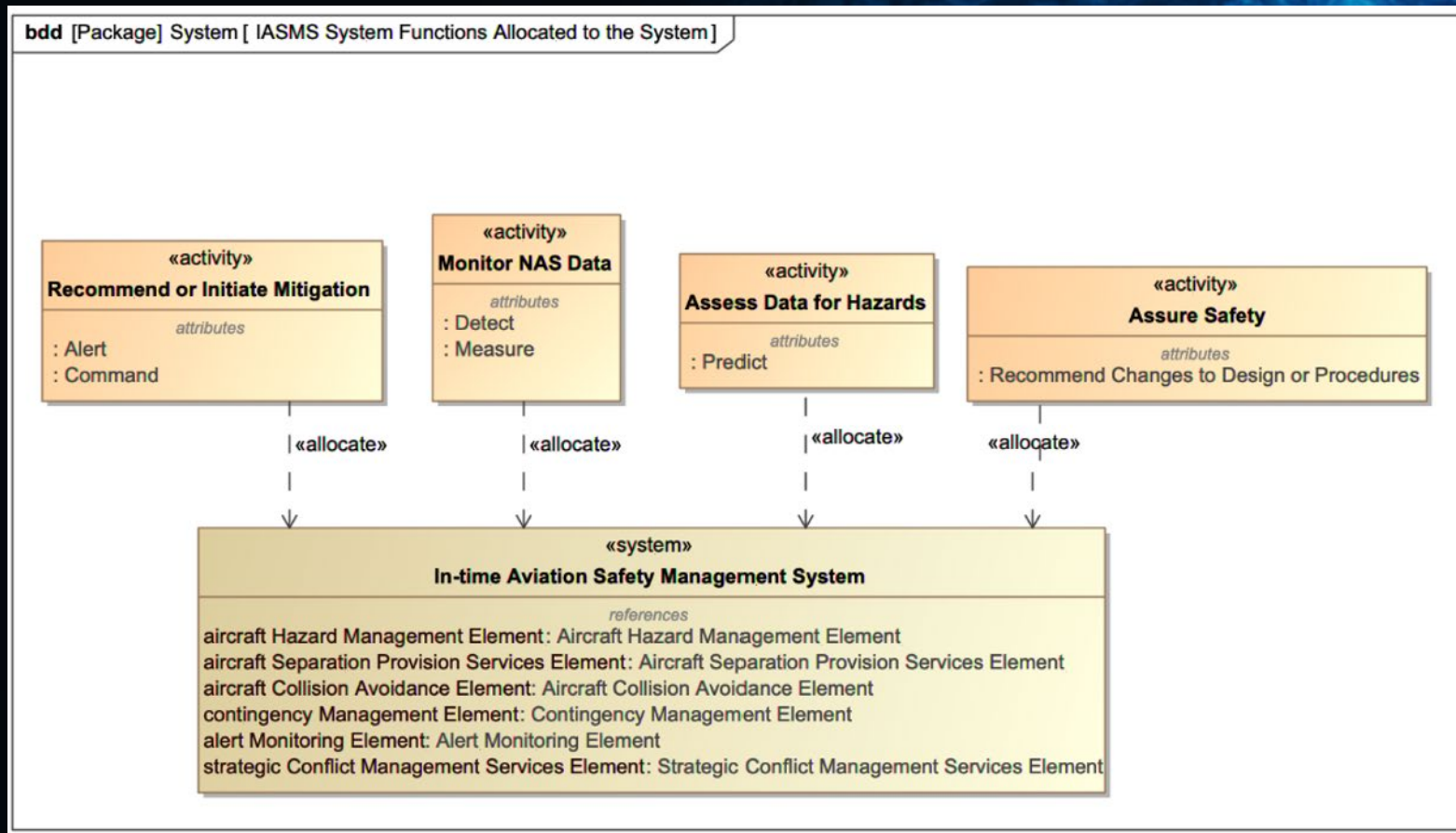
Frame 5: Constraints





Conceptual Architecture

IASMS Functions Allocated to System

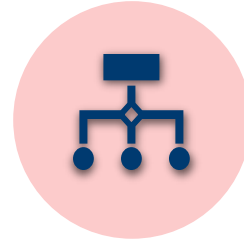




Conceptual Architecture



ORGANIZED BY HAZARD TYPE THEY MAY MANAGE

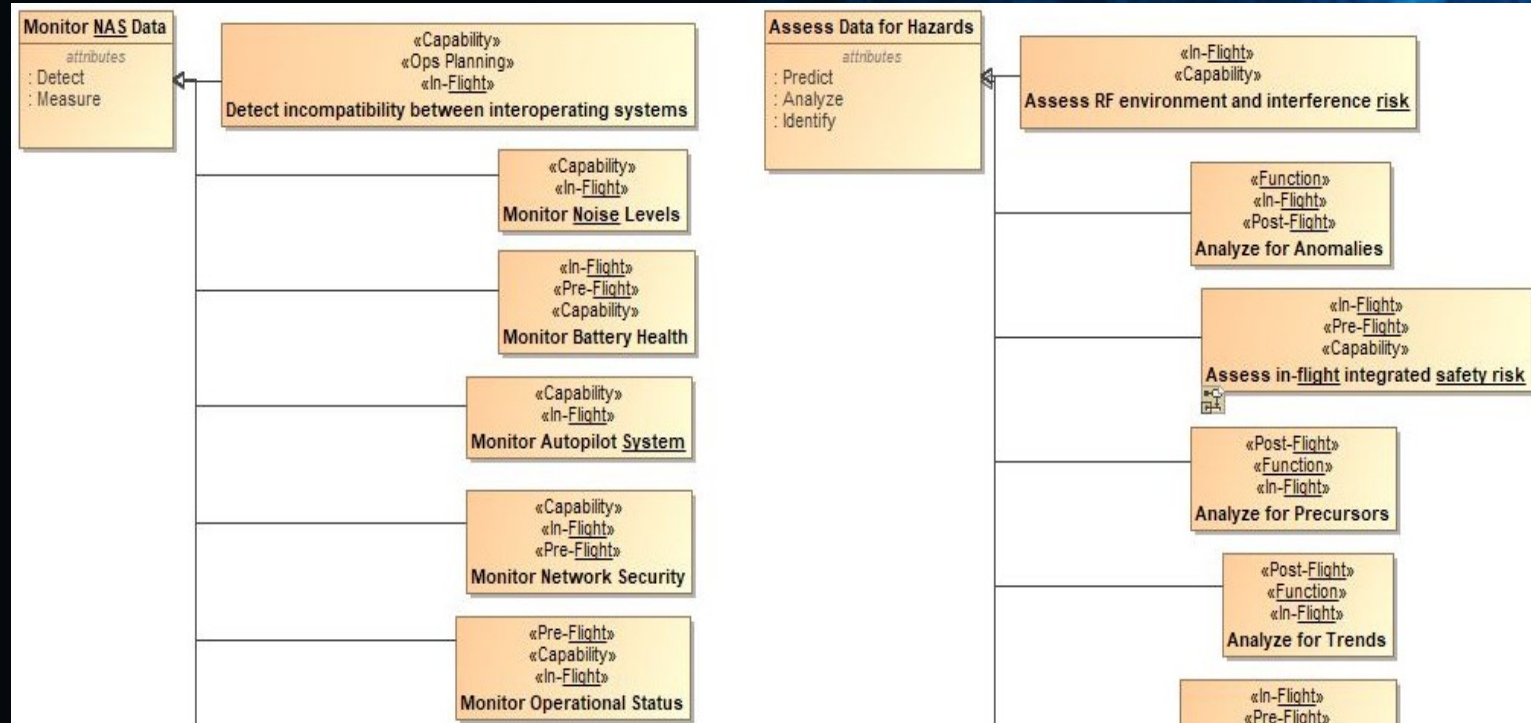


COMPOSED OF SETS OF SERVICES AND FUNCTIONS (SFCS) AND DATA INTERFACES FOR THE INPUTS AND OUTPUTS OF THOSE SERVICES



THE SFCS HOSTED AND ACCESSED BY ANY AGENT WILL DEPEND ON THE OPERATION, OPERATOR, OR AUTONOMY INVOLVED

IASMS Functions with Potential Behaviors



Descriptive Modeling of Roadmaps and Agency Guidance

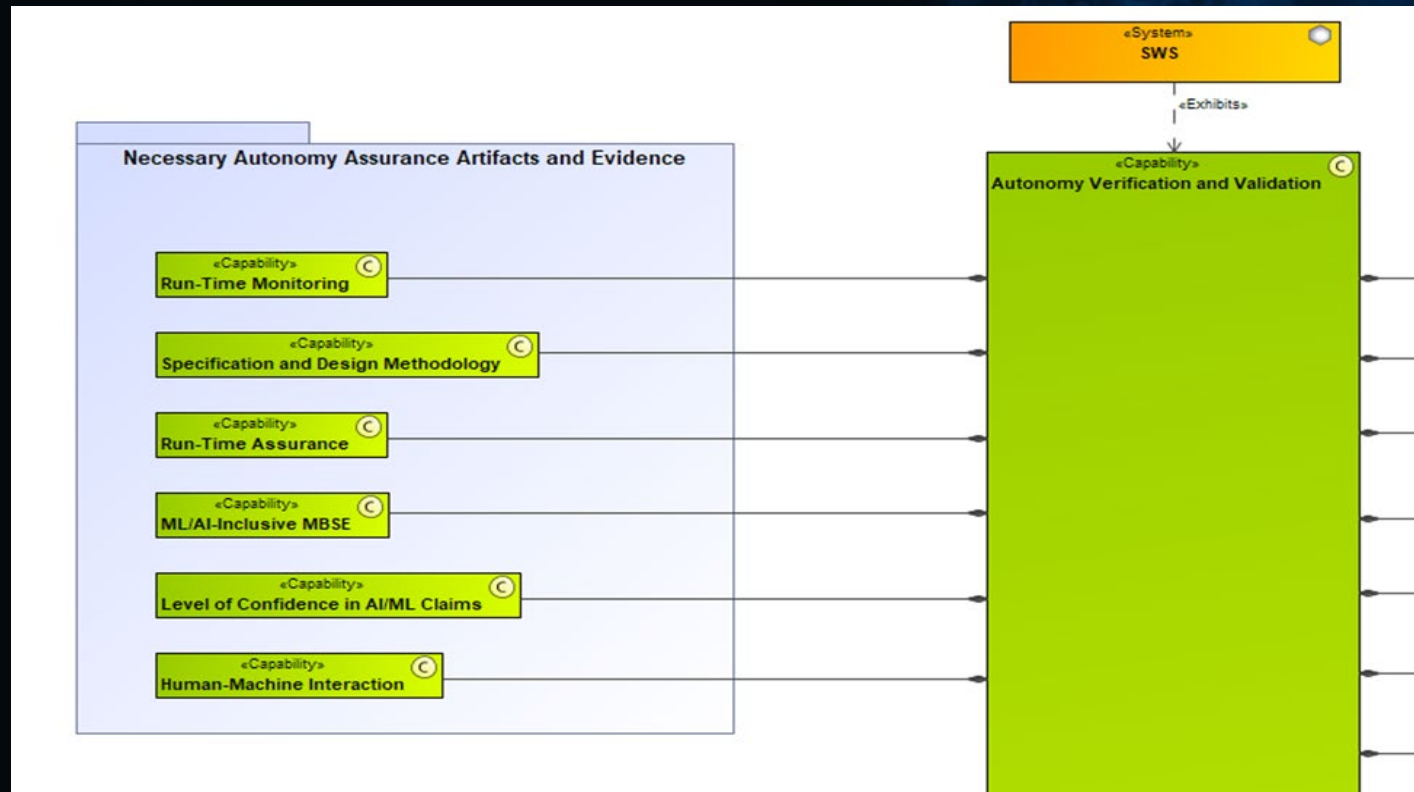
IASMS Research Roadmap in Strategic Model

Legend		Enterprise Phases				
Phases		2020-2025	2025-2030	2030-2035	2035-2040	2040-2045
Roadmap Version 1.0		7	13	15	7	5
Aviation Weather						
Qualified Microclimate Forecasting 2030-2035		1	2	2		
Qualified Microclimate Nowcasting for Urban Weather 2025-2030		1				
Qualified Weather Service for New Entrants 2025-2030		1	↙			
Upper Atmosphere Weather Forecast 2030-2035		1				
Cross-Cutting Research and Development						
Certification Processes for Architectures with Design Assurance 2035-2040		1		1	2	1
Computing and Cross-Model Communications Infrastructure 2025-2030		1				
Coordination and Separation of Autonomous and Human-Managed Traffic 2030-2035		1	↙			
Validate Safety of Human-Managed Airspace and Autonomous Vehicles 2030-2035		1				
Individual Vehicle Flight Management						
BVLOS Ground Risk Assessment 2025-2030		2	4	5	2	1
Common Operating Picture and Deconfliction 2025-2030		1				
Expanded Terrain and Obstacle Info for BVLOS 2025-2030		1	↙			
Flight Planning 2020-2025		1				
IVFM Single Pilot Ops for Large Cargo Transport Mission 2035-2040		1	↙			
Large Cargo Operations End-to-End 2040-2045		1				
Limited Cargo Operations for Individual Vehicle Flight 2030-2035		1				
Limited Cargo Operations for Tactical Separation 2030-2035		1				
Limited Remotely Piloted Commercial Operations 2035-2040		1				
National Strategy DAA Capability for cUAS 2030-2035		1				
Population Mapping Tools 2020-2025		1	↙			
Remotely Piloted AAM-Like Operations 2030-2035		1				
Self-Monitoring and Healing 2030-2035		1				
Vehicle Risk Assessment 2025-2030		1				
Safety Data and Resilience Analysis						
ANSP Adoption 2020-2025		3	3	2	1	1
Identification of Emerging Risks 2040-2045		1				
In-Time Safety Data Collection 2030-2035		1				
Risk and Resilience 2020-2025		1	↙			
Safety Data Sharing 2025-2030		1				
Safety Database 2025-2030		1	↙			
Safety Hazards Identification 2035-2040		1				
Safety Performance 2020-2025		1	↙			
State Safety Program Expansion 2030-2035		1				
State Safety Programs 2025-2030		1	↙			
Strategic Conflict Management						
Airspace Volume Complexity Management 2030-2035		1				
Flexible Airspace for Volume Segregation 2035-2040		1				
Flexible Airspace Volumes and Operations 2040-2045		1				
Integrated Airspace Support 2035-2040		1				
Reduced Airspace Volume Protection 2030-2035		1				
Strategic Conflict and Separation Management 2040-2045		1				
Strategic Management for Low-Altitude 2020-2025		1	↙			
Tactical Separation Management						
Adaptive Buffer Zone 2035-2040		1	3	2	1	1
Conflict Advisory Alert and Routing Guidance 2030-2035		1				
DAA Implementation for Tactical Separation 2025-2030		1				
Larger UAS DAA Implementation for Tactical Separation 2030-2035		1	↙			
Low Altitude Static Obstacle Avoidance 2020-2025		1				
Semi-Autonomous Delivery with Human Oversight (Small Package) 2025-2030		1	↙			
Surveillance Info for BVLOS Operators 2025-2030		1	↙			
UAV Tactical Separation Management for Large and Medium Transport 2040-2045		1				

IASMS Research Roadmap Traceability

	IASMS Roadmap Strategic Connectivity																				
	Aviation Weather	Cross-Cutting Research and Development	Individual Vehicle Flight Management	Safety Data and Resilience Analysis	Strategic Conflict Management	Airspace Volume Complexity Management 2030-2035	Flexible Airspace for Volume Segregation 2035-2040	Flexible Airspace Volumes and Operations 2040-2045	Integrated Airspace Support 2035-2040	Reduced Airspace Volume Protection 2030-2035	Strategic Conflict and Separation Management 2040-2045	Strategic Management for Low-Altitude 2020-2025	Tactical Separation Management	Adaptive Buffer Zone 2035-2040	Conflict Advisory Alert and Routing Guidance 2030-2035	DAA Implementation for Tactical Separation 2025-2030	Larger UAS DAA Implementation for Tactical Separation	Low Altitude Static Obstacle Avoidance 2020-2025	Semi-Autonomous Delivery with Human Oversight (Sma)	Surveillance Info for BVLOS Operators 2025-2030	UAV Tactical Separation Management for Large and Med
TC2-03-02 Complete Design Reviews For Systems-Under-Test by Partners	11	3	5	1	1								2								
TC2-03-13 AOSP Integration (FY23)	11	3	5	1	1								2								
TC2-03-14 AAM Integration (FY23)	11	3	5	1	1								2								
TC2-03-15 Assess Usability of Candidate SFC Interfaces (completed)	11	3	5	1	1								2								

Autonomy V&V: Support Capabilities

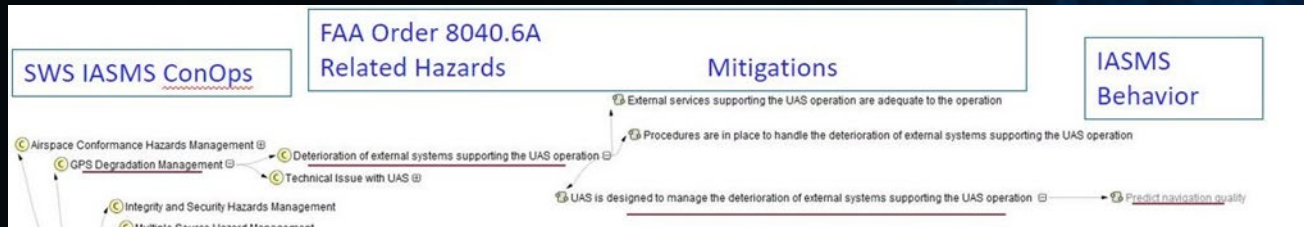


Autonomy V&V: Roadmap Traceability

The screenshot shows a software interface with a tree view on the right and a table below it. The tree view is titled "V&V Strategic Connectivity" and contains a folder "Addressing Gaps in Path to Certification". The table below the tree view has columns for a description, a status indicator (a yellow circle with a 'C'), and a numerical value (2 or 2).

Description	Status	Value
Autonomy standards, guidance, and regulations	C	2
Case studies to document assurance expectations	C	2
Complete and sound means of compliance	C	
Convincing safety proofs and arguments	C	
Demonstration of absence of unintended behavior	C	
Industry standards for autonomy, AAM, and AI	C	
New test metrics for completeness	C	
Online learning and updates	C	
Safety assurance and benchmark datasets	C	
Scale-up analysis model methods to larger systemes (unintended)	C	
Vision/perception systems for sensing	C	

FAA Order 8040.6A UAS SRM Policy Guidance

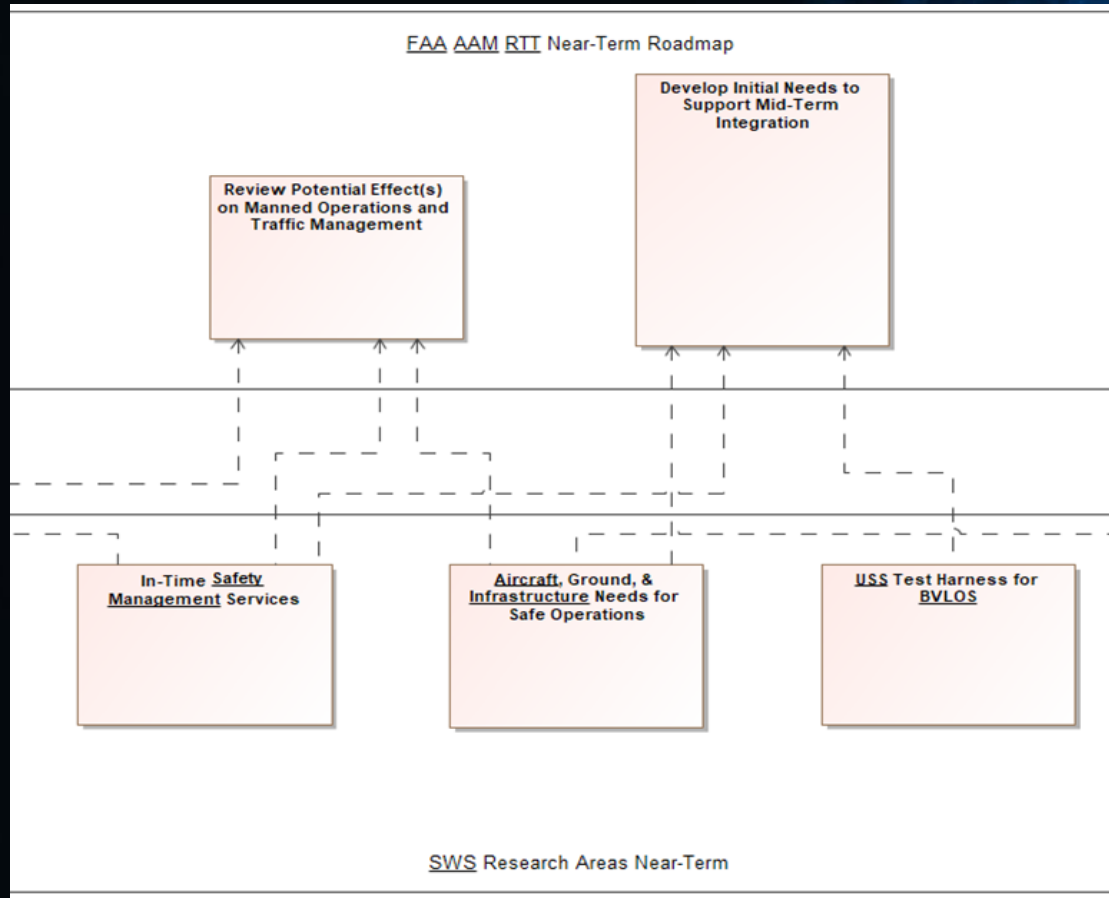


Appendix B Relation Map

△ Name	UAS Mitigations	IASMS Functions
	<ul style="list-style-type: none"> Procedures are in place to handle the deterioration of external systems supporting the UAS operation UAS is designed to manage the deterioration of external systems supporting the UAS operation External services supporting the UAS operation are adequate to the operation 	<ul style="list-style-type: none"> Predict navigation quality(context AAM System of Systems) Predict Wind and Weather Effects(context AAM System of Systems) Access Assured Positioning Navigation and Timing(context AAM System of Systems) Facilitate Human-Automation Teaming in Pre-Flight Planning(context AAM System of Systems) Apply Contingency Select Logic(context AAM System of Systems) Plan Contingencies(context AAM System of Systems) Select and execute contingency for flight plan(context AAM System of Systems) Select and execute contingency maneuver(context AAM System of Systems) Switch to alternate frequency(context AAM System of Systems) Switch to back-up system/support/procedure(context AAM System of Systems) Monitor Navigation Systems Conditions(context AAM System of Systems) Monitor Radio Communication Conditions(context AAM System of Systems) Assess flight plan risks across all monitored hazards(context AAM System of Systems) Predict Airspace Density(context AAM System of Systems) Deliver Analysis to Decision-Makers for Procedure and Priority Changes(context AAM System of Systems) Modify flight plan(context AAM System of Systems) Protect Flight Data(context AAM System of Systems) Provide Trend Analysis Results and Recommendations for Design and Procedures(context AAM System of Systems) Deliver Flight Data To Trend Analysis Location(context AAM System of Systems)
ADS-B signal degradation		

NASA-FAA Advanced Air Mobility Research Transition Team

FAA AAM Research Transition Team



Conclusion



In Conclusion

Traceability methods were implemented to link the research work and system architecture elements developed at NASA with community-created roadmaps and FAA aviation guidance.

The process encountered challenges because project milestones did not decompose problem-solving along the same dimensions as the roadmaps.

Despite these obstacles, the traceability activities prompted a reassessment of project activity planning.

The traces established in the SysML model of the IASMS facilitate the recording and presentation of traceability information in various visual formats.

This visualization was instrumental in demonstrating the project's impact and its alignment with societal needs to NASA management and our industry and organizational partners.

Acknowledgements

The SWS ConOps team developed the vision for the IASMS concept of operations, including the statements used as IASMS objectives. This includes especially **Kyle Ellis, Lance Prinzel, Paul Krois, Jim Ackerson, Michael Vincent, Misty Davies, Nikunj Oza, Robert Mah, Chad Stephens, Wendy Okolo, and Joe Coughlan.**

The main authors of the IASMS Roadmap developed in coordination with the System-Wide Safety project at NASA, include Flight Safety Foundation Contributors **Deborah Kirkman, Jan de Regt, Kaleb Gould, Debra Moch-Mooney, and Jessie Mooberry.**

The authors of the Autonomy Verification and Validation Roadmap include SWS team member **Guillaume Brat**, who assisted in developing the framework of autonomy V&V capabilities and areas relevant to use for SWS research and IASMS architecture validation.

SFCs developed and tested by NASA are described in multiple publications by the research group under SWS team member **Steve Young**, including most recently a Technical Memo describing the software and test results. Steve contributed to the functional architecture with his foundational knowledge of the IASMS concept, consulting on generalizations of SWS software to capabilities terms, and approving additions to the needed IASMS behaviors identified by the systems engineering team.

References

- [1] National Academies of Sciences, Engineering, and Medicine. 2018. In-time Aviation Safety Management: Challenges and Research for an Evolving Aviation System. Washington, DC: The National Academies Press. <https://doi.org/10.17226/24962>
- [2] Ellis, K., Krois, P., Koelling, J., Prinzel, L., Davies, M., Mah, R., and Infeld, S. 2021. Defining Services, Functions, and Capabilities for an Advanced Air Mobility (AAM) In-time Aviation Safety Management System (IASMS). 2021 AIAA Aviation. <https://doi.org/10.2514/6.2021-2396>
- [3] Section 2.2 An Overview of the SE Engine by Project Phase, NASA Systems Engineering Handbook, February 6, 2019. <https://www.nasa.gov/reference/systems-engineering-handbook/>
- [4] International Civil Aviation Organization, “Safety Management Manual,” ICAO Doc 9859, Fourth Edition, 2018. <https://www.icao.int/safety/safetymanagement/pages/guidancematerial.aspx>
- [5] National Aeronautics and Space Administration, “NASA Aeronautics Strategic Implementation Plan,” 2023. <https://www.nasa.gov/directorates/armd/armd-strategic-implementation-plan/>
- [6] Flight Safety Foundation, “IASMS Research Roadmap Version 1 2025-2045”. 2023. Under NASA Grant 80NSSC21M0187.
- [7] Section 4.1 Stakeholder Expectations Definition, NASA Systems Engineering Handbook, February 6, 2019. <https://www.nasa.gov/reference/systems-engineering-handbook/>

References

[8] Ellis, K., Krois, P., Koelling, J., Prinzl, L., Davies, M., & Mah, R. 2021. A Concept of Operations and Design Considerations for an In-time Aviation Safety Management System (IASMS) for Advanced Air Mobility (AAM). 2021 AIAA Sci Tech Virtual Event. Reston, VA: AIAA.

[9] International Council on Systems Engineering (INCOSE). 2023. Model-based systems engineering (MBSE). Guide to the Systems Engineering Body of Knowledge (SEBoK). [https://sebokwiki.org/wiki/Model-Based_Systems_Engineering_\(MBSE\)](https://sebokwiki.org/wiki/Model-Based_Systems_Engineering_(MBSE))

[10] The Object Management Group (OMG). 2023. Unified Architecture Framework. Object Management Group. <https://www.omg.org/uaf/index.htm>

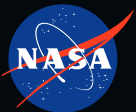
[11] Brat, G., Yu, H., Atkins, E., Sharma, P., Cofer, D., Durling, M., Meng, B., Alexander, C., Borgyos, S., Fan, C., Garg, K., Topcu, U., and Bakirtzis, G., “Autonomy Verification & Validation Roadmap and Vision 2045,” NASA/TM-20230003734, 2023. <https://ntrs.nasa.gov/citations/20230003734>.

[12] Federal Aviation Administration Order 8040.6A, “Unmanned Aircraft Systems Safety Risk Management Policy”, 2023. https://www.faa.gov/regulations_policies/orders_notices/index.cfm/go/document.information/documentID/1042092

SCITECH 
FORUM

6-10 JANUARY 2025 | ORLANDO, FL

ENERGIZE THE FUTURE



Tracing NASA Contributions Toward Aviation Safety Stakeholder Guidance

Copyright © [Darisha Vidrine/National Aeronautics and Space Administration]. Published by the American Institute of Aeronautics and Astronautics, Inc. with permission.