ICAO ANC
Workshop on Safety Intelligence and Safety Performance Management

FLIGHT SAFETY FOUNDATION
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IASMS Overview

presented by
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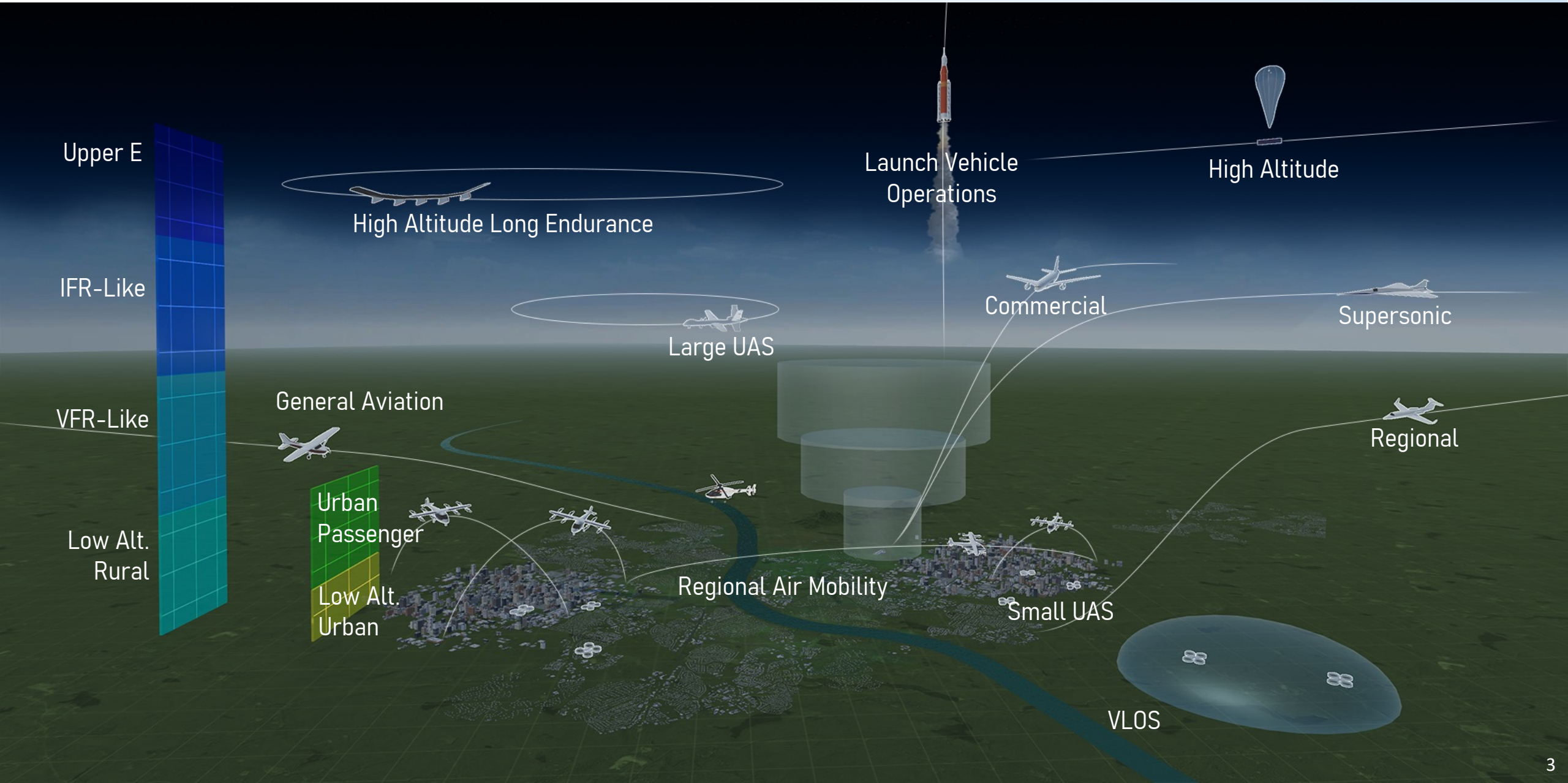
and
Dr. Kyle Ellis, System-Wide Safety Project, NASA

March 22, 2023

Innovating the Future of Aviation

Evolution of Airspace Operations and Safety

Operational Domains in the Future Airspace



Transformed Airspace
A Great Opportunity

Increased number of traditional commercial operations

Accessible to all with new aviation missions

Environmentally sustainable

Enablers

- **Digital Transformation –> InfoCentric Airspace**
- **AAM – New vehicle types and new operations**
- **Automation and Autonomy – Improve existing and enable new, scalable aviation missions**

System-Wide Safety

Transformed Airspace
A Complex Challenge

More Operations = Increased risk potential

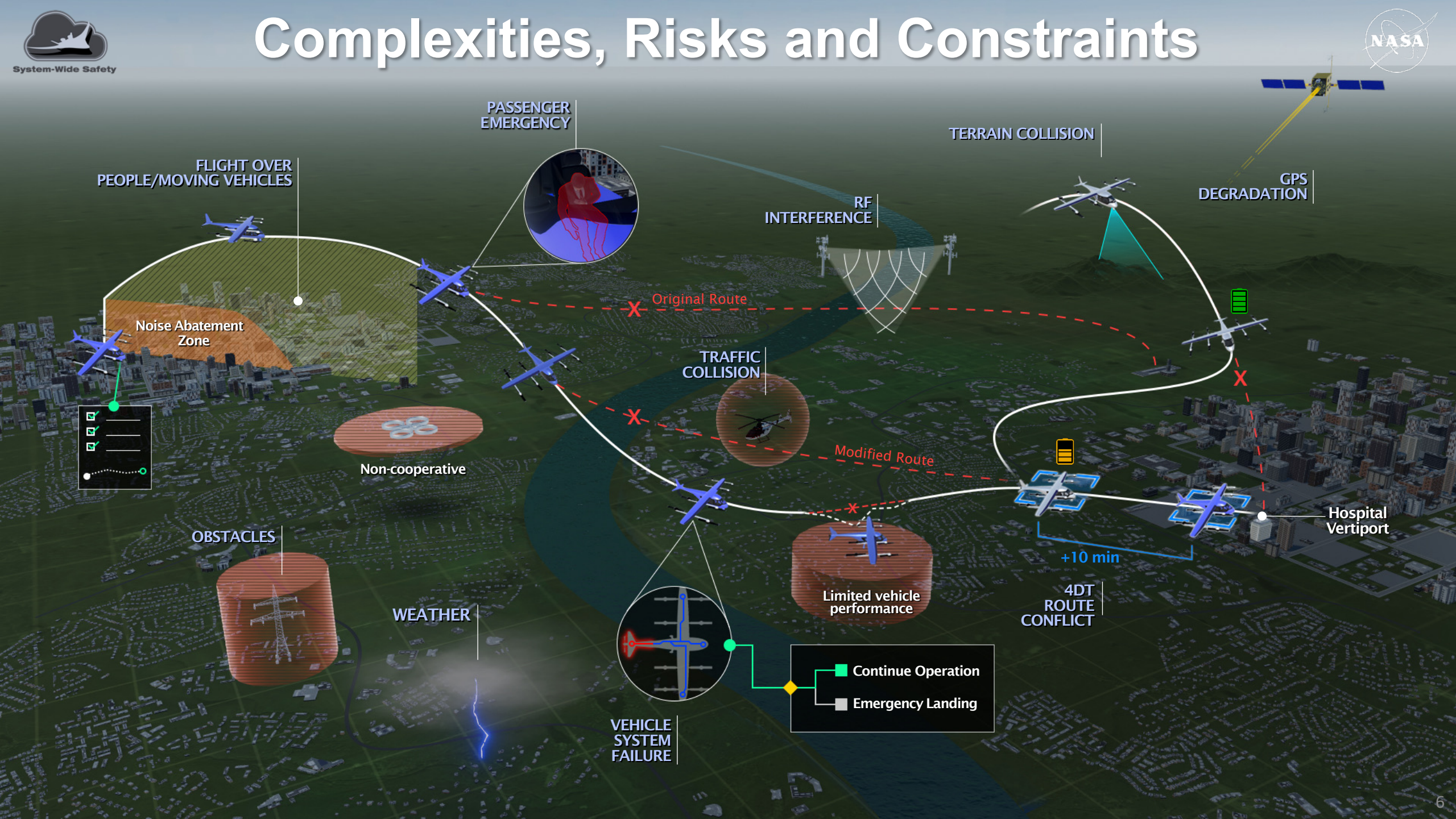
New Missions = Increased Integration Complexity

Sustainability = New Constraints

Notable Barriers

- **Digital Transformation – Changes to Existing Systems and Integration of New Systems A Known Challenge**
- **AAM – Certification Paths Needed for both Airworthiness and Operations**
- **Automation and Autonomy – Means of Assuring Automated/Autonomous Systems Needed**

Complexities, Risks and Constraints

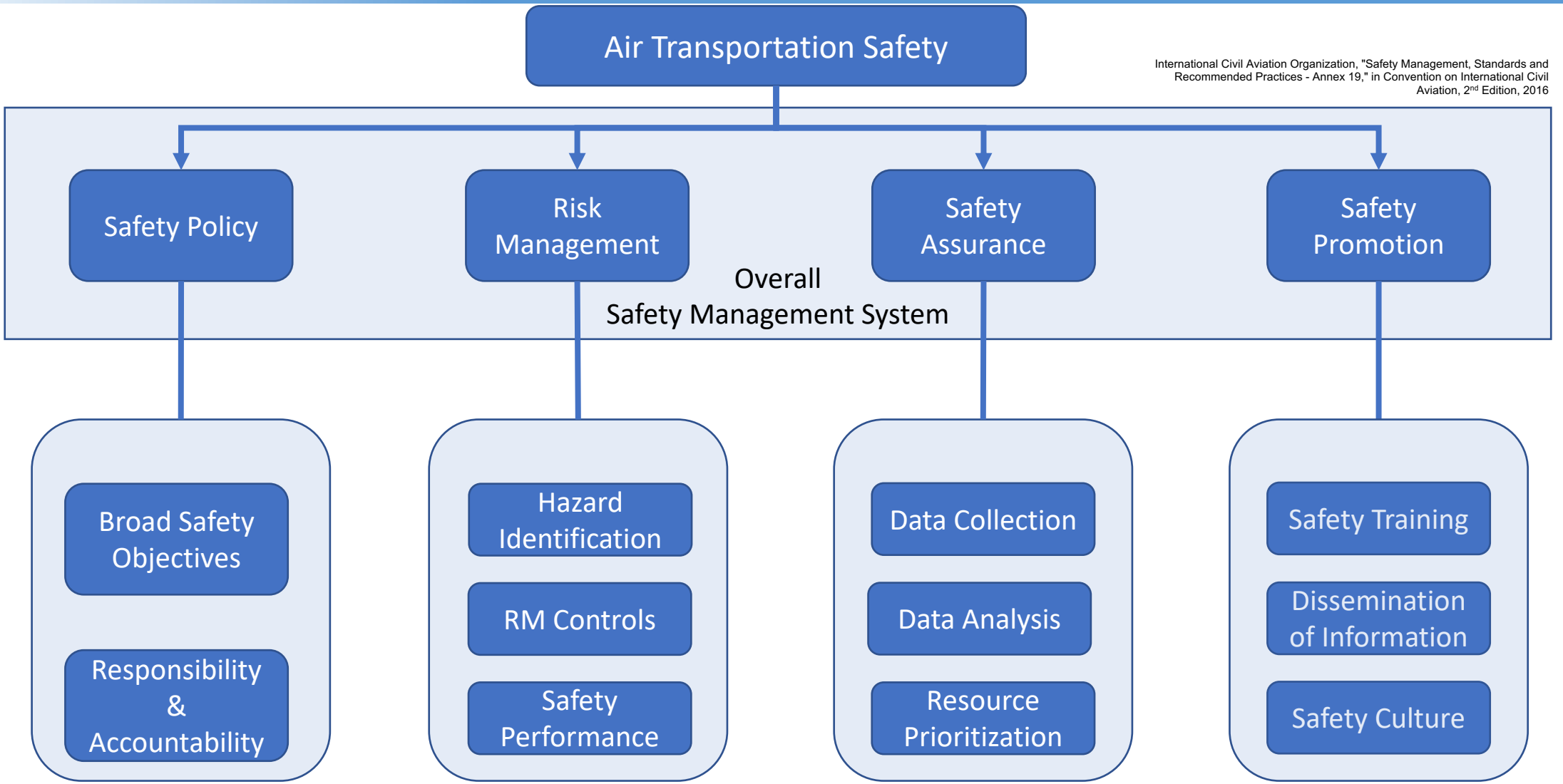


System-Wide Safety Project Goals

*To **explore, discover, and understand** the **impact** on **safety** of **growing complexity** introduced by modernization aimed at improving the **efficiency of flight**, the **access to airspace**, and/or the **expansion of services provided by air vehicles**.*

*To **develop** and **demonstrate innovative solutions** that **enable** this **modernization and the aviation transformation** envisioned for the **global airspace system** through **proactive mitigation of risks** in accordance with **target levels of safety.***

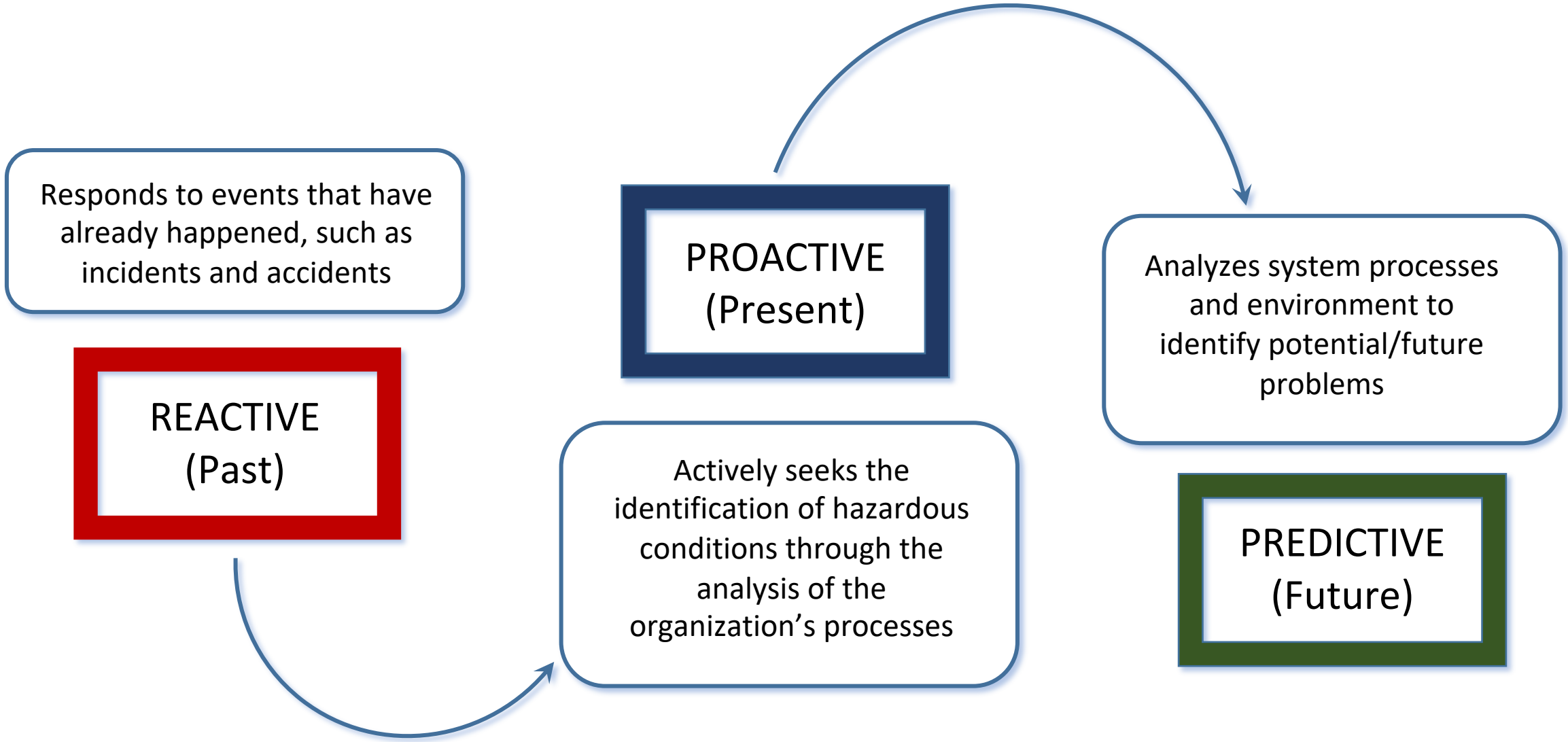
Achieving Aviation Safety Today



International Civil Aviation Organization, "Safety Management, Standards and Recommended Practices - Annex 19," in Convention on International Civil Aviation, 2nd Edition, 2016

Labor intensive
Limited ability to scale
Not fast enough

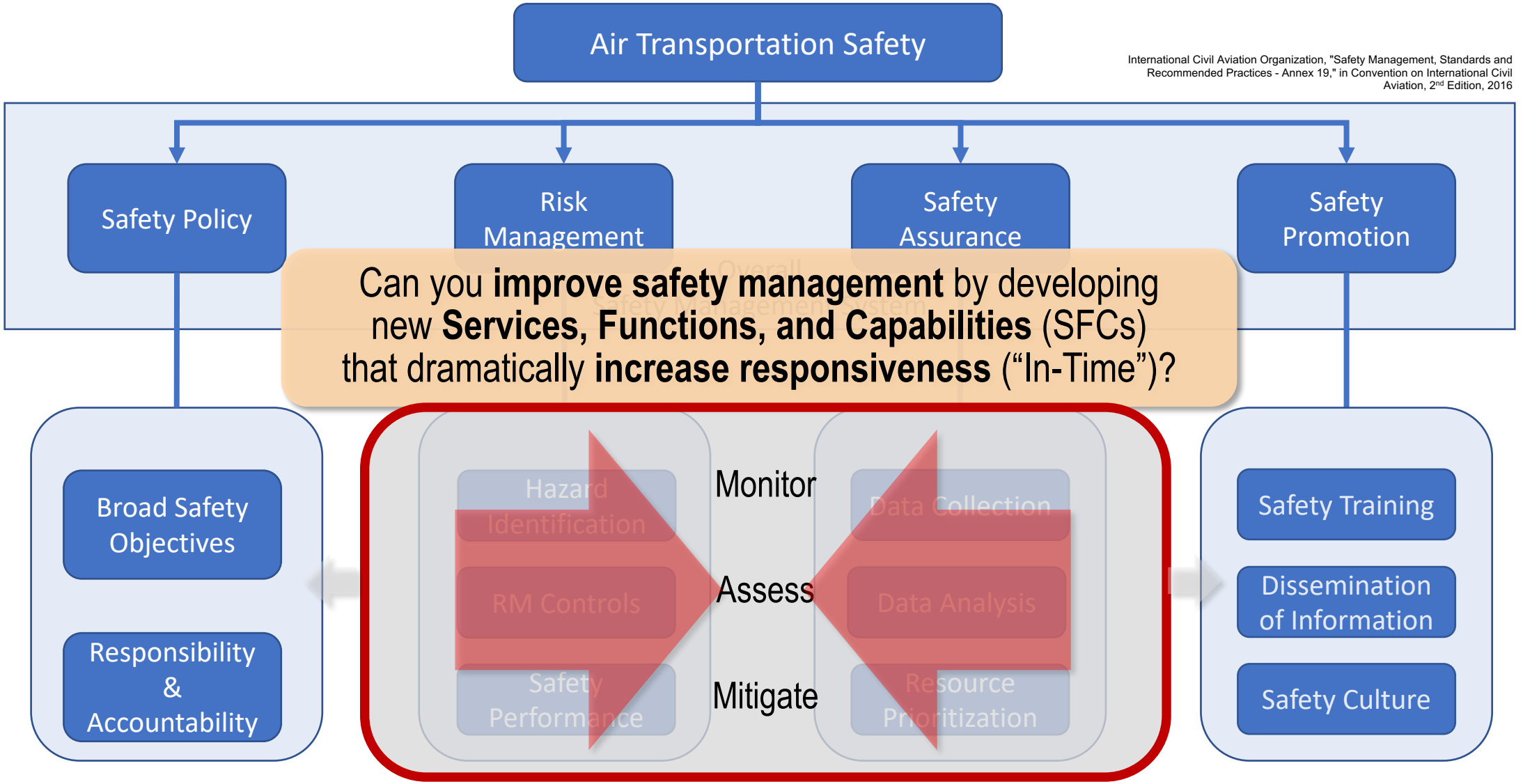
Safety Management & Safety Intelligence



[1] https://www.faa.gov/about/initiatives/sms/explained/basis/

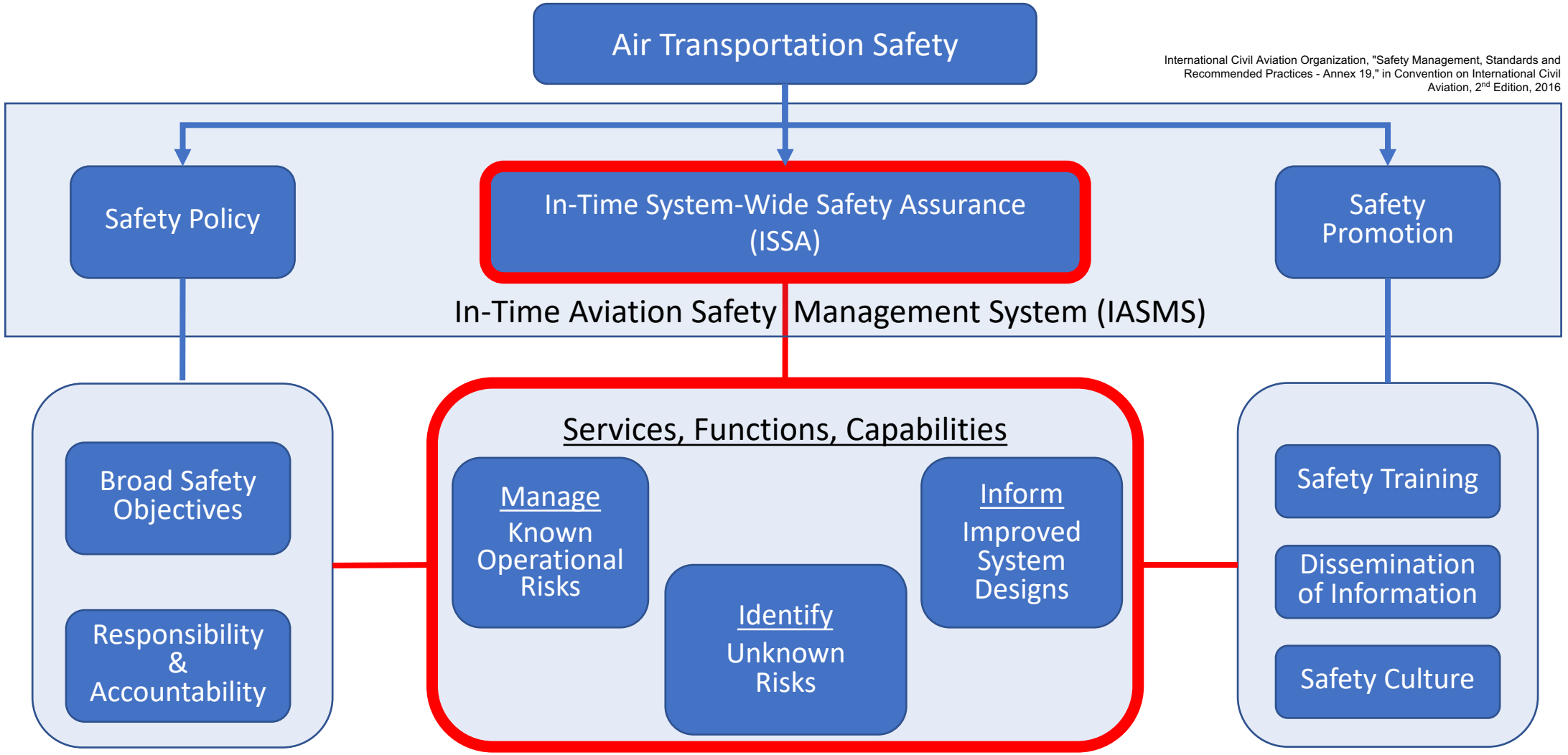
Adapted FAA Graphic[1]

Safety Management System Evolution



Ref: National Academies, In-Time Aviation Safety Management: Challenges and Research for an Evolving Aviation System, 2018.

How We Achieve Aviation Safety Tomorrow



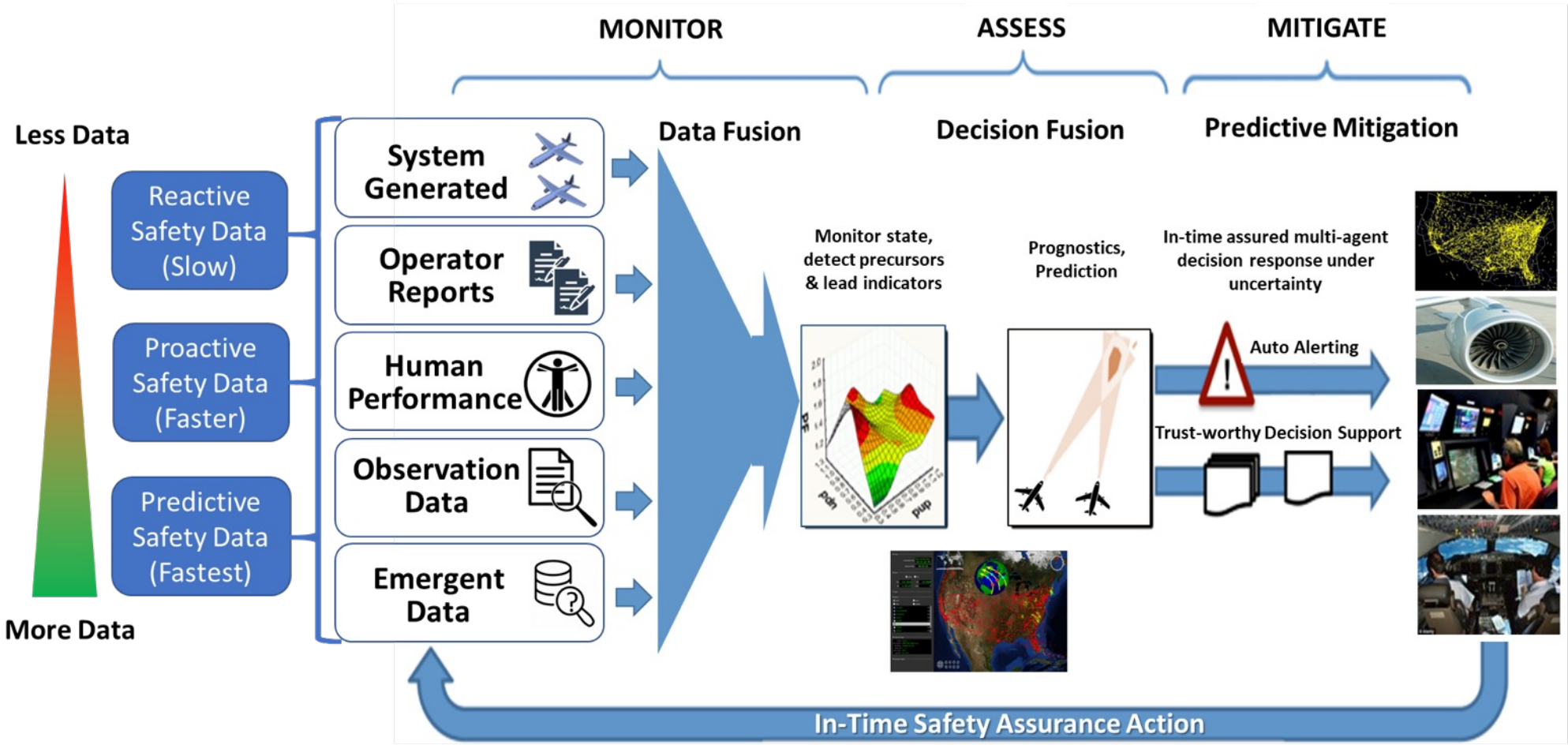
Quickly manage known operational risks at scale

Quickly identify unknown risks

Quickly inform design

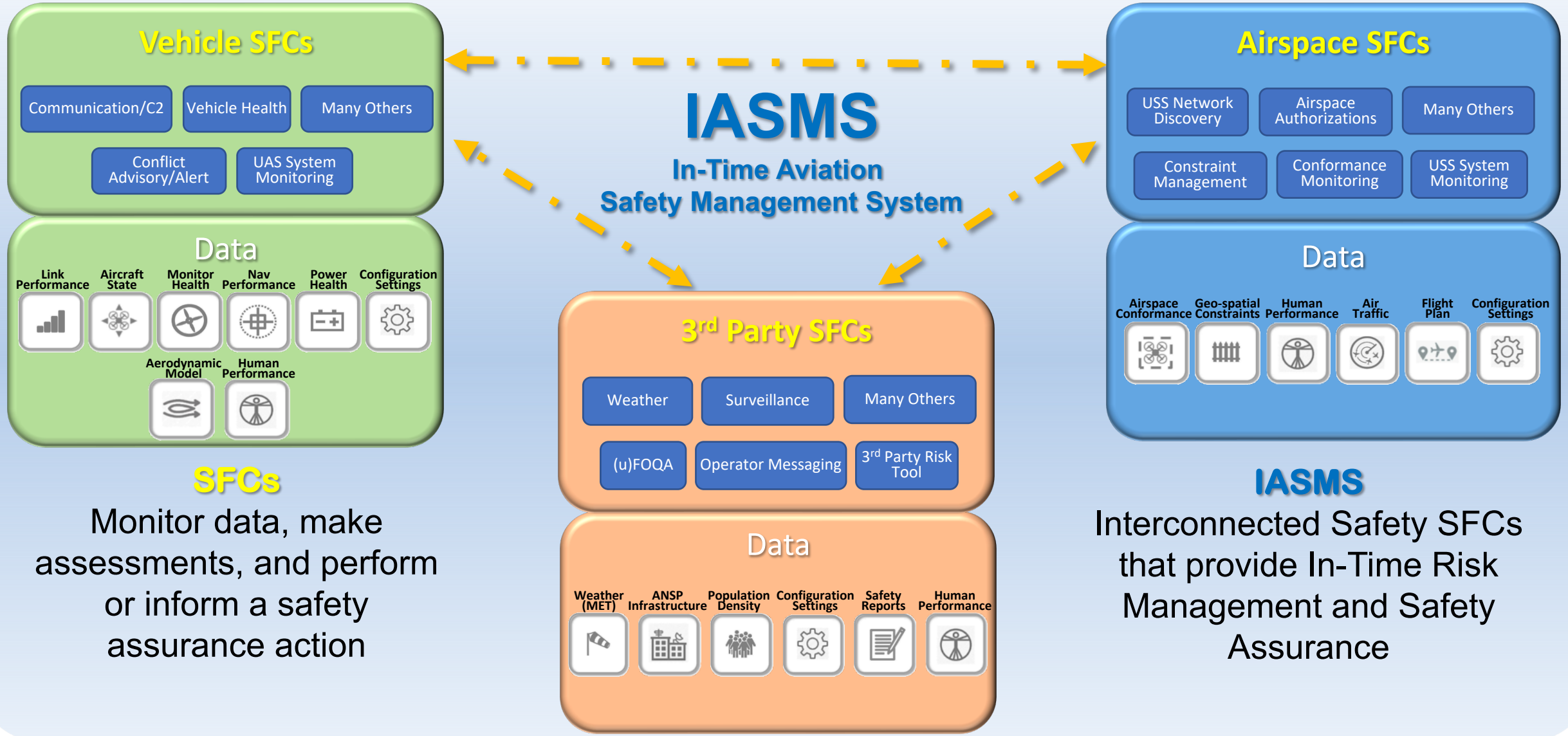
Increasingly In-Time Safety Assurance

Operational Needs	Improve in-time safety	Improve scalability	Improve accessibility	Increase participation
Info-Centric NAS Goals	In-time Safety Assurance	Tailored Safety	Interoperability	



Credit: NASA

Distributed Digital Systems Architecture



SFCs

Monitor data, make assessments, and perform or inform a safety assurance action

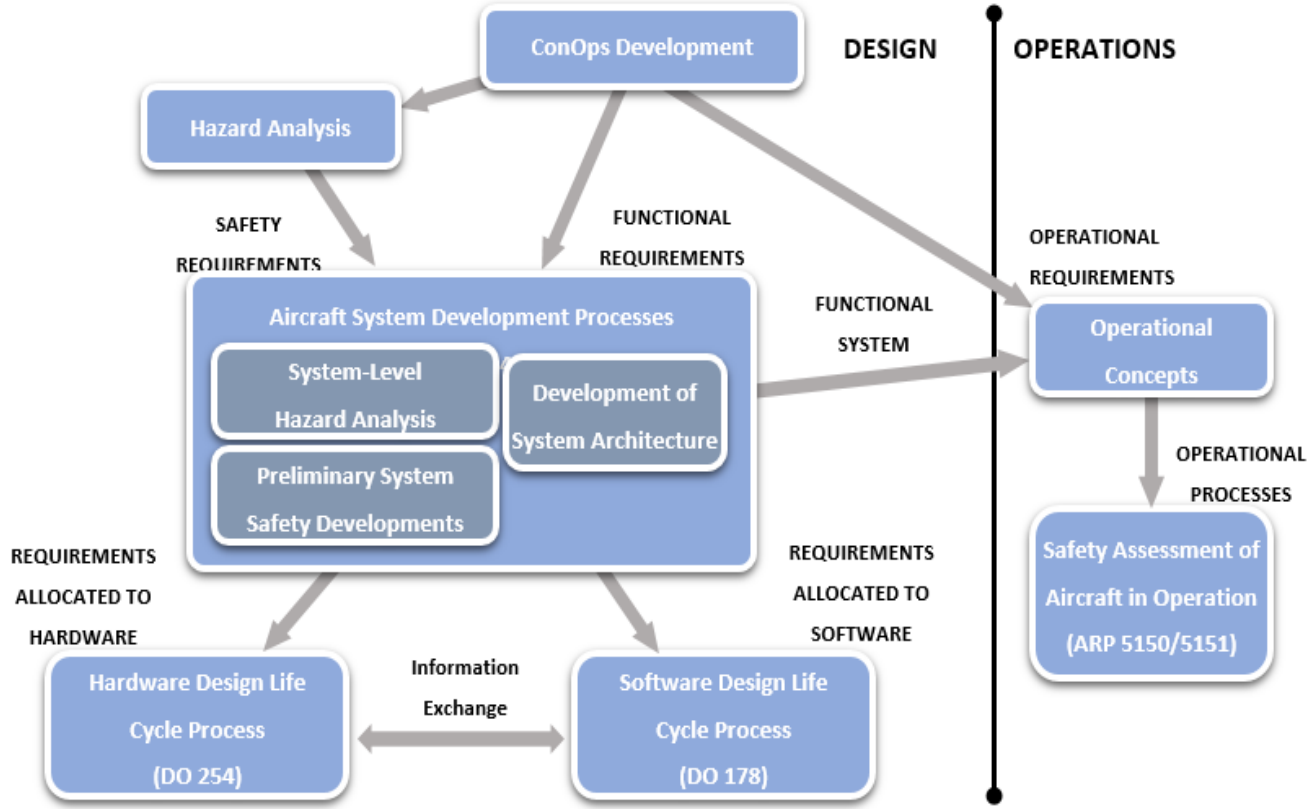
IASMS

Interconnected Safety SFCs that provide In-Time Risk Management and Safety Assurance

SFC Assurance of Functionality

Assure Design

- **Assurance requirements are specific to flight rules, operation complexity and risk criticality**
- **SFCs must be assured to an appropriate level via an acceptable process**



Building Confidence

SFCs that

Manage Operational Risks:

Must mitigate risks with an acceptable level of certainty

SFCs that

Identify Unknown Risks:

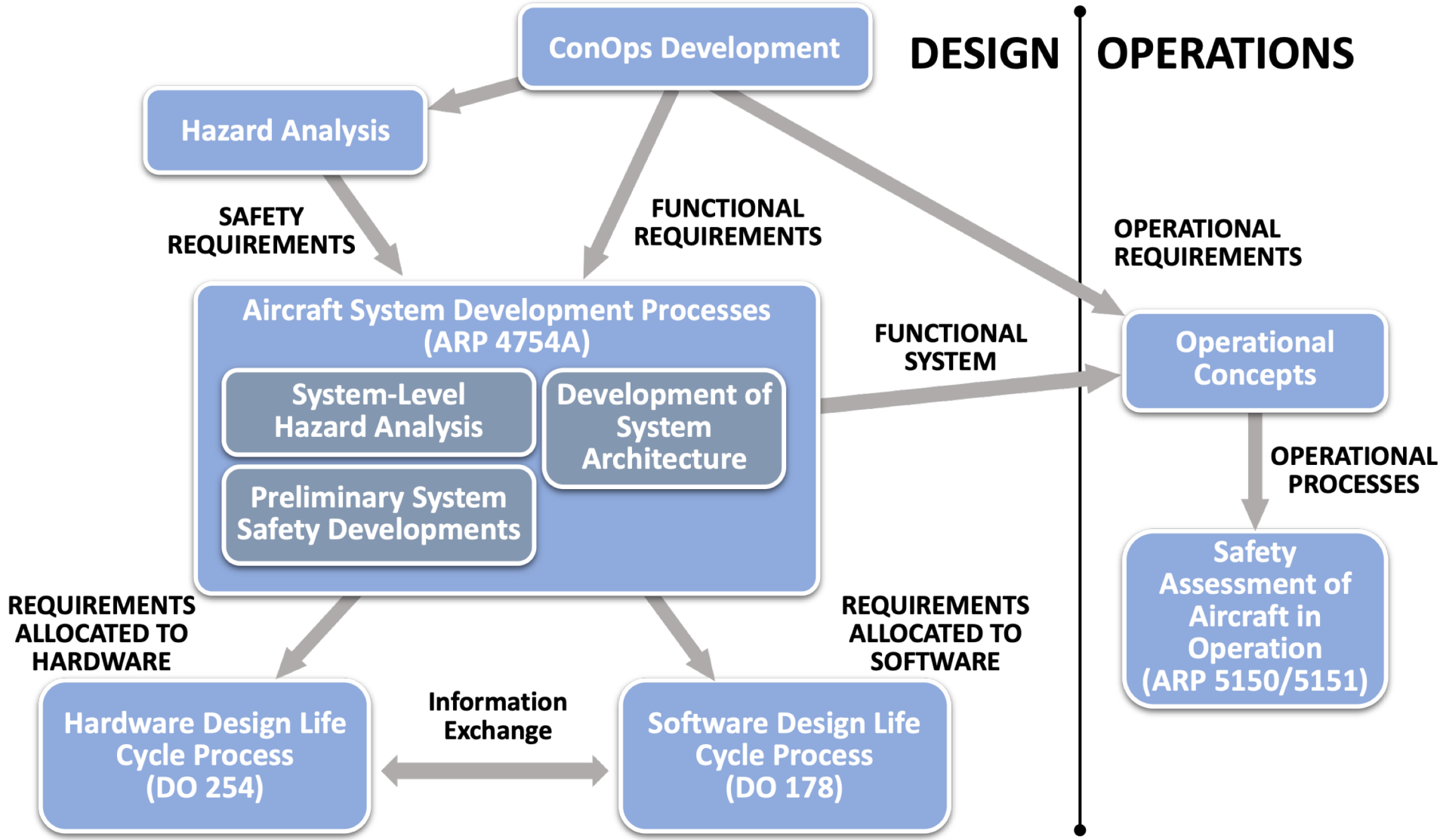
Must correctly identify unknown anomalies and hazards in the system

SFCs that

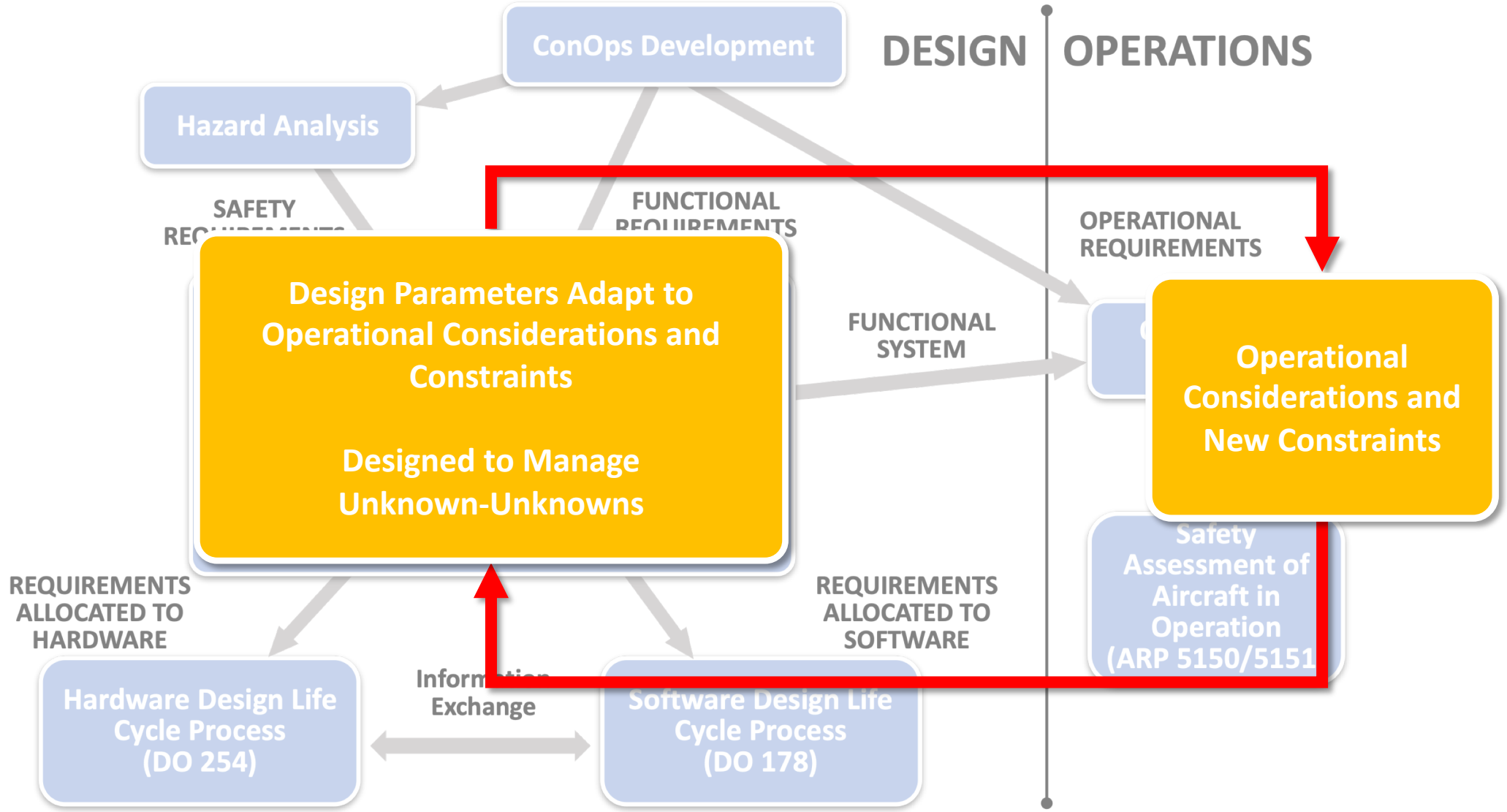
Inform System Designs:

Must correctly assess performance and deficiencies of the existing design

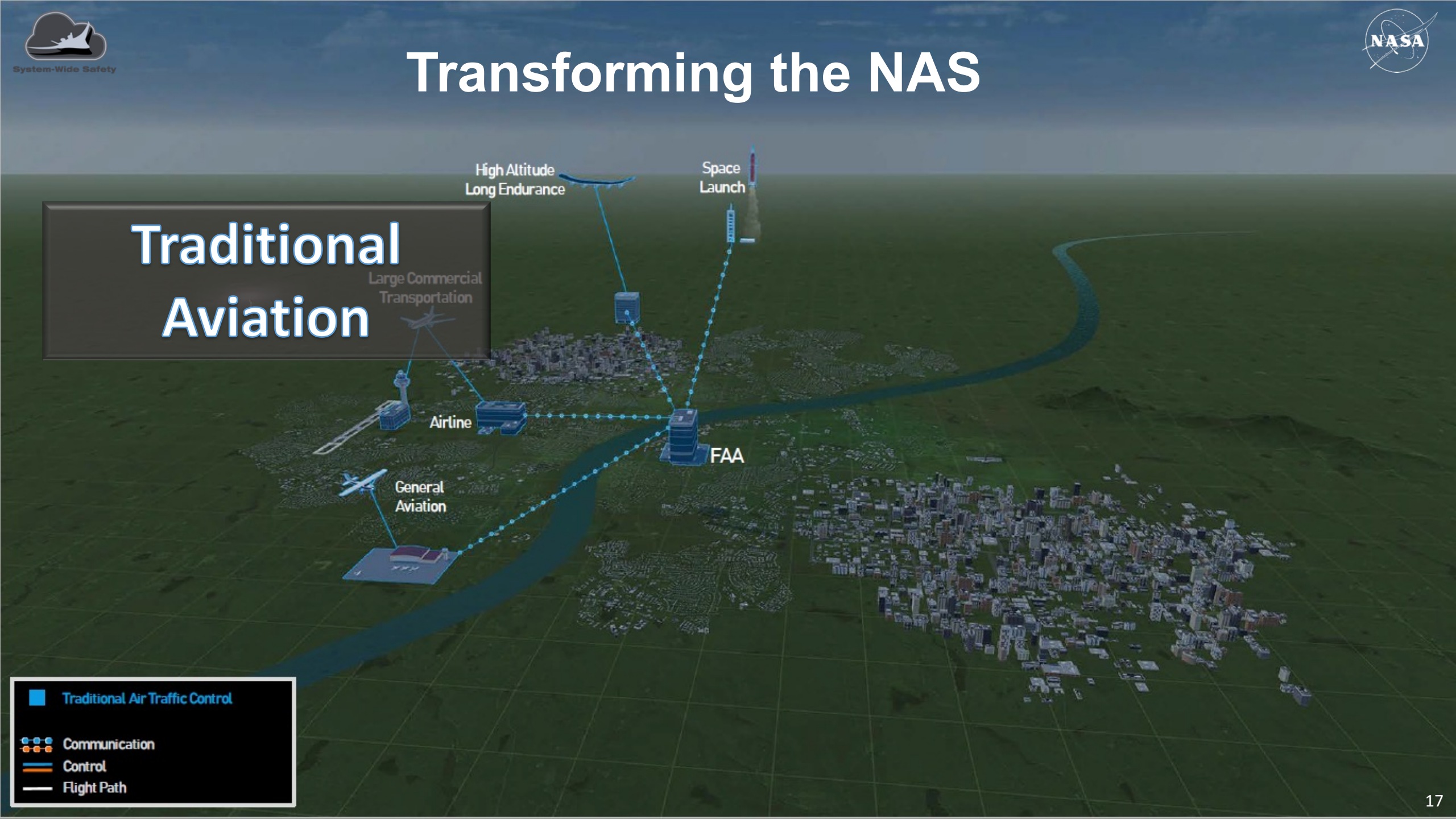
Design Safety vs. Operational Safety



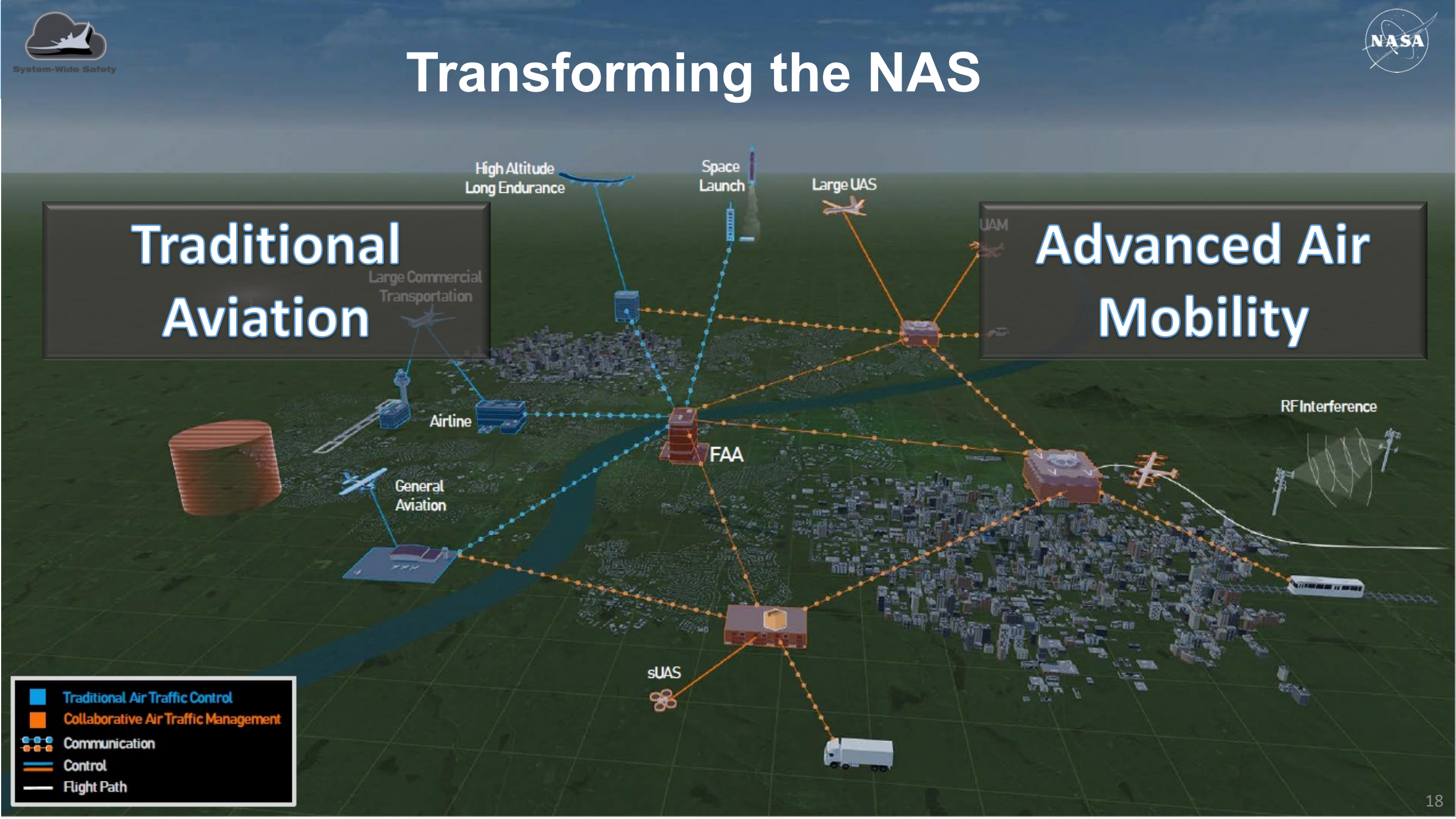
Design Safety vs. Operational Safety



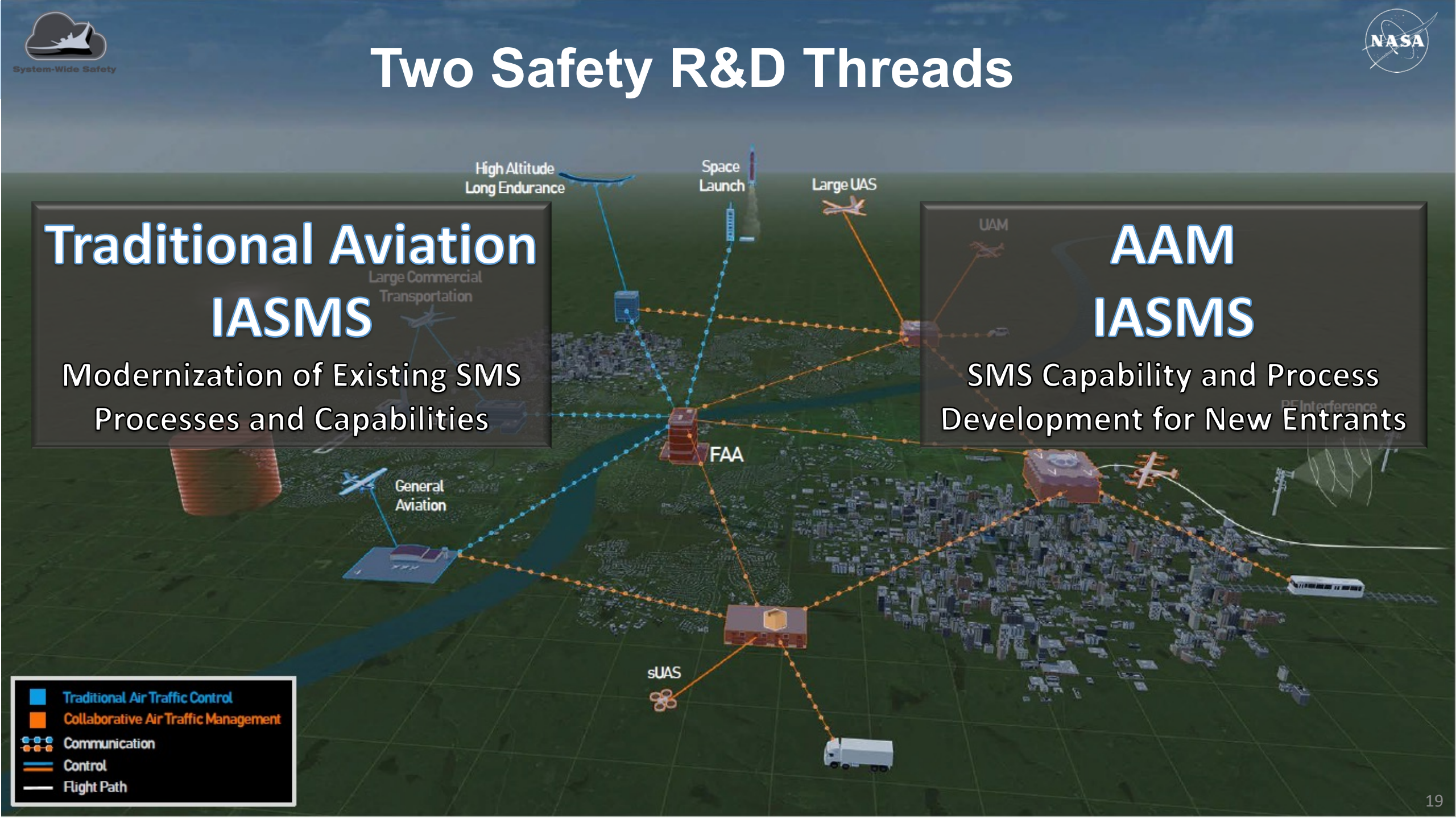
Transforming the NAS



Transforming the NAS



Two Safety R&D Threads



Traditional Aviation IASMS

Modernization of Existing SMS Processes and Capabilities

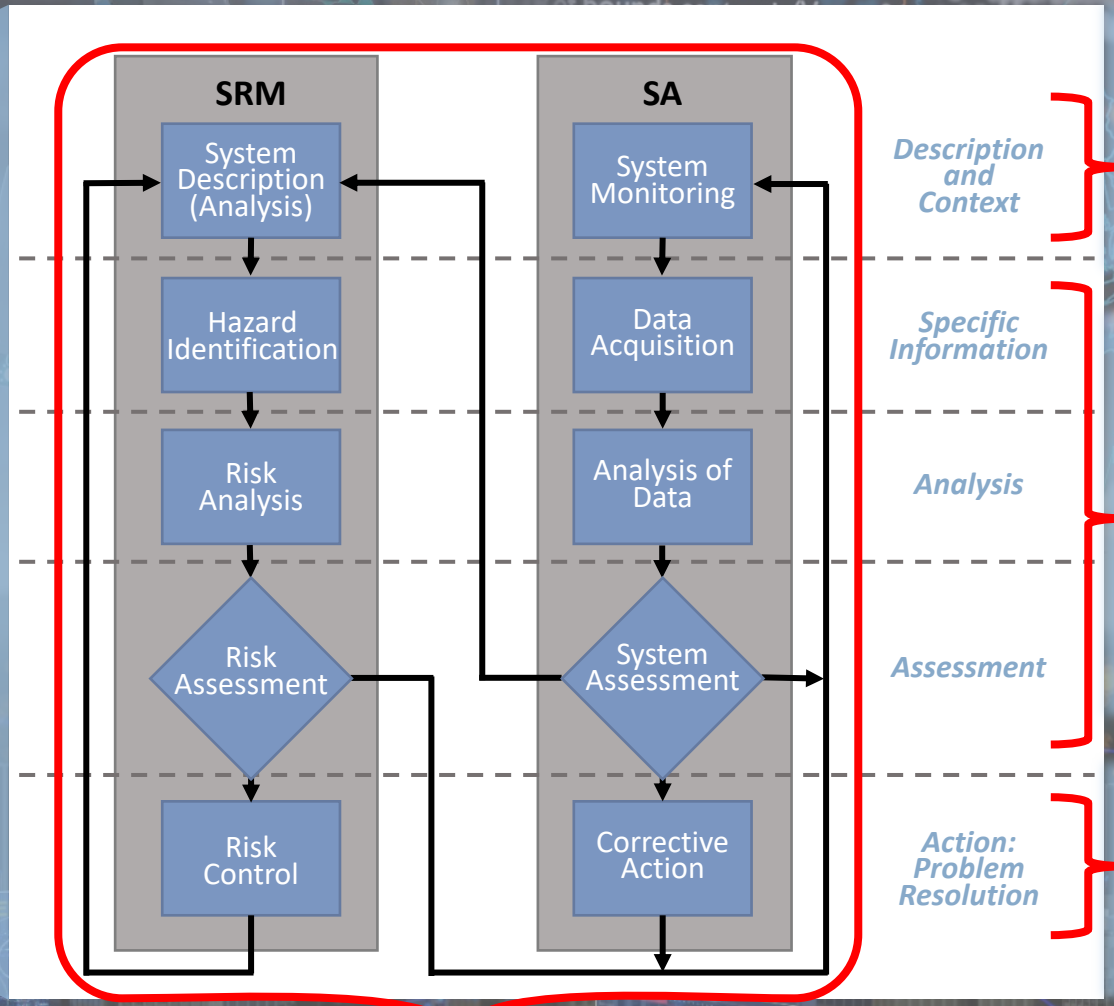
AAM IASMS

SMS Capability and Process Development for New Entrants

In-Time Aviation Safety Management Systems

Needs

- In-Time Safety Risk Mitigation
- Proactive -> Predictive Safety Management Systems
- Adopt ML/AI for predictive analysis and advanced data mining
- Build upon existing IT architectures for increased access to data and tools
- Improve system agility and responsiveness



R&D Required:

- New Safety Databases
- Non-traditional data
- Data Fusion w/existing services
- Required vs. Voluntary Data
- Synthetic Data Generation

- ML/AI Anomaly Detection
- Predictive Risk Assessment
- Multi-Risk Safety Prognostics
- Integrated Risk Assessments
- Digital Twin Assessments
- Data Exchange Architecture
- Digital Information Service Integration

- Pre-Flight Mitigation
- In-Flight Mitigation
- Post-Flight Mitigation
- Re-Design Consideration

Figure from FAA AC No: 120-92B, Safety Management Systems for Aviation Service Providers

In-Time Aviation Safety Management Systems


NASA
EXPLORE FLIGHT
WE'RE WITH YOU WHEN YOU FLY

In-Time Aviation Safety Management System (IASMS) Research Roadmap

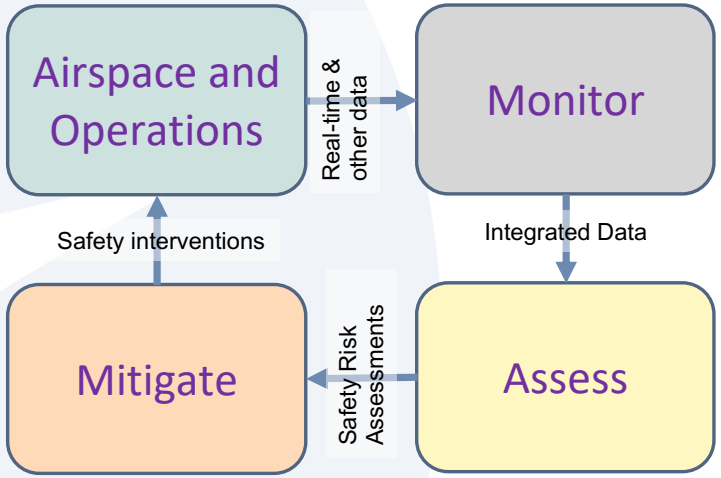
Background / Timeline

- FSF grant awarded in 2021, by NASA's System-Wide Safety project, to inform decisions on NASA safety research priorities, timing, and partnerships
- Work over the past two years has included extensive interviews with over 200 stakeholders including regulators, traditional aviation, new entrants, and other perspectives
- Draft roadmap (November 2022) captures overall evolution through 2045
  - Not specific to US environment
  - Postulates efforts with respect to research, technology/standards, and policy to enable capabilities to be fielded
- In-person workshop held at NASA LARC facility Jan 10-12 to gather aviation community feedback from a broad range of thought-leaders Initial Roadmap to be published by Flight Safety Foundation later this Spring

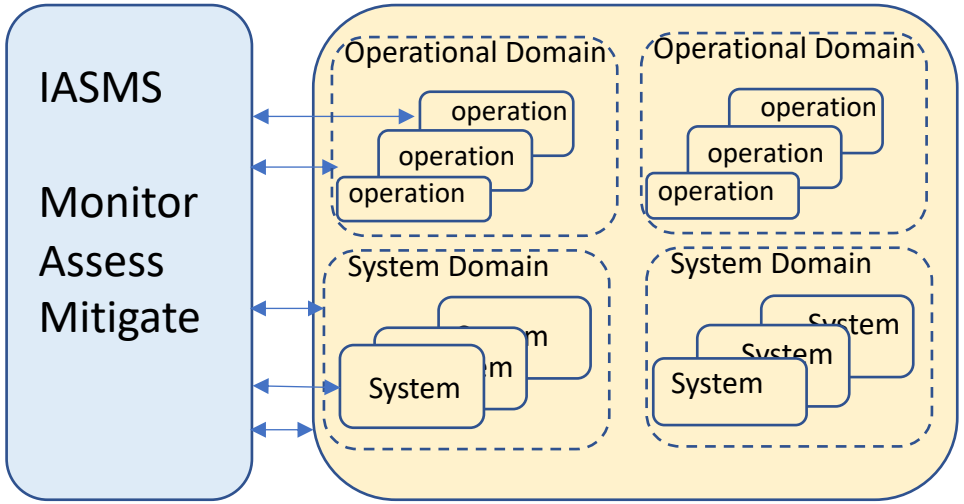
In-Time Aviation Safety Management System

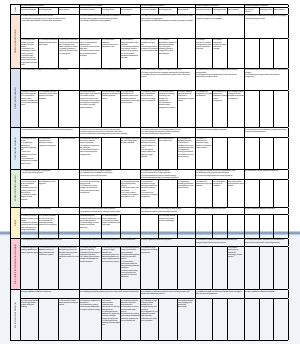
National Academies Report, 2018

Conops for IASMS



IASMS is envisioned to be a federated suite of capabilities that evaluates safety trends and identifies appropriate interventions





IASMS Research Roadmap

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Operational Environment

Human-centric Capabilities

- Emerging non-traditional users
- Mature air transport and airport operations
- Limited safety data sharing
- Non-scalable Infrastructure & safety assurance processes

Digitally Transformed Infrastructure

- System-wide digital, machine-interpretable data
- Highly automated operations segregated from traditional operations
- Trajectory-based operations
- CNS infrastructure transformation

Automation-Enabled Diversity

- Highly automated management of flights
- Integrated airspace with diverse ops
- Adaptive management of airspace risk levels
- Federated data and governance enables proactive safety & resilience
- Human role transformation

IASMS Evolution

Domain-Specific Safety Monitoring & Alerting Tools

Integrated Predictive Technologies with Domain-Level Application

Adaptive Real-time Safety Threat Management

IASMS Research thrusts

- Safety data analysis for new entrants
- Predictive analytics
- Resilience and human contributions to safety
- Effective expansion of SMS to new stakeholders

- Cross-domain analytics to identify emerging safety hazards
- Digital twins for safety assurance & real-time evaluation of options
- “Meta” analysis of safety trends
- Architecture & investment tradeoffs

- Automated safety risk mitigation
- Data integrity, suitability, and decision-making under ambiguity
- Autonomy instrumentation & trust
- Graceful failure modes
- Effective human oversight

IASMS Roadmap Structure and Scope

- Roadmap Scope: Lays out research needs supporting air traffic management safety through 2045
  - High-level view in five-year buckets
  - Has “swim-lanes” for safety & resilience analysis, tactical & strategic management, vehicle evolution, and cross-cutting drivers
  - Postulates research, technology, and policies needed in one time frame to be in place to enable a capability in a later time frame

<table>
<tr><th colspan="3">20XX - 20XX+5</th><th>20XX+5 - 20XX+10</th></tr>
<tr><td colspan="3">New capabilities introduced by, or during, this time period
• X.m.1 Capability 1</td><td rowspan="2">New capabilities introduced by, or during, this time period
• X.n.1 Capability 1
• X.n.2 Capability 2</td></tr>
<tr><td>Research Completed</td><td>Technology & Standards</td><td>Policy Initiative</td></tr>
<tr><td>X.m.2 Research 1
X.m.3 Research 2</td><td>X.m.4 Standard for XY</td><td>X.m.5 Policy 1</td><td></td></tr>
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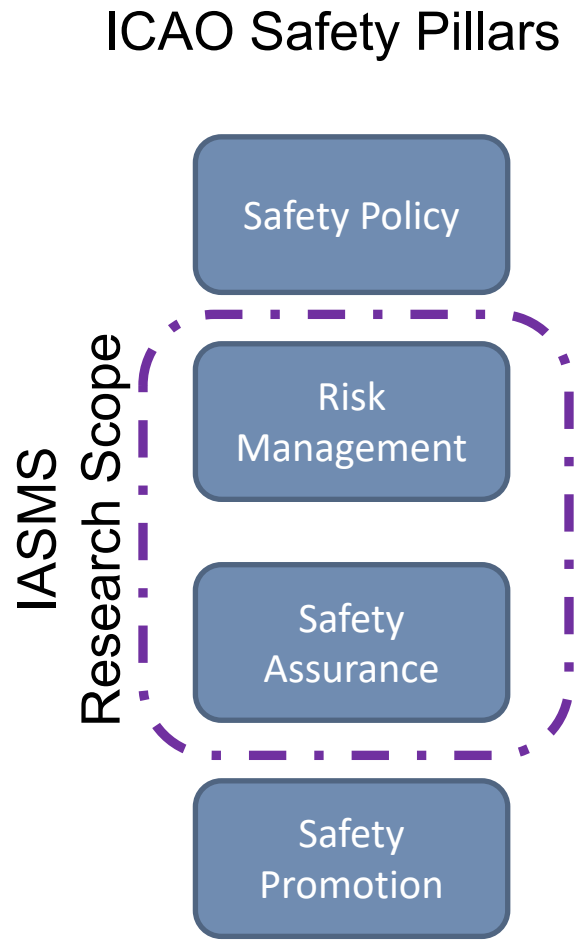

Example progression of Safety Analysis Swim-lane

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Key safety capabilities introduced by 2025:			Key safety capabilities introduced by 2030:			Key safety capabilities introduced by 2035:		
Key research initiatives	Technology & Stds	Policy initiatives	Key research initiatives	Technology & Stds	Policy initiatives	Key research initiatives	Technology & Stds	Policy initiatives
2.1.1 Initial safety performance metrics for UAS 2.1.2 Integrated methodology to assess system risk and resilience 2.1.3 Broader ANSP adoption of internal safety data analysis			2.2.1 Safety database and funded post-analysis capability for new entrants 2.2.2 State safety programs expand monitoring of SMSs 2.2.3 Sharing of safety data among regulators			2.3.1 AAM, new entrants and traditional operations real-time critical safety data collection and aggregation 2.3.2 Expansion of State Safety Programs to include monitoring of UAS SMS		
2.1.4 Prototype safety database & analysis capability with new entrants 2.1.5 Develop LFAO methodology to assess resilience practices 2.1.6 Explore policy mechanisms that can mitigate safety impacts of significantly disruptive events	2.1.7 Develop international standards for ANSP safety data analysis	2.1.8 Determine mechanism to ensure new entrant safety data is available and an analysis capability is funded 2.1.9 Identify pathway to expand and harmonize SMS for UAS programs	2.2.4 Post-operational in-time analysis of safety data for traditional ops 2.2.5 Analysis of new entrant safety data 2.2.6 Explore historical safety data to identify predictive techniques	2.2.7 LFAO metrics established 2.2.8 Initial common SPI definitions for UAS	2.2.9 Guidance on integrating business COO with SMS 2.2.10 Broader adoption non-punitive safety reporting 2.2.11 International standards established for UAS SMS	2.3.3 Refine algorithms to identify emerging risks 2.3.4 Existing prediction methods are researched to create predictive SMS	2.3.5 Establish international standard for information exchange 2.3.6 Testing and validating predictive management system methodologies	

Key Feedback from Aviation Stakeholders in recent Workshop

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- Regulators urged to develop more timely, scalable means to address safety assurance requirements
- Better alignment needed across all stakeholders to prioritize the introduction of early AAM capabilities (e.g., BVLOS package delivery, piloted AAM vehicles)
  - Call for a “marshall plan”
  - Infrastructure requirements in line with introduction of capabilities (e.g., vertiport needs)
- Need for a compelling executive level story to support further investments in safety advancements
- New safety assurance capabilities needed (design & operational) for enabling new operations
- Emphasis on the safety continuum and recognizing need for expectations to be different based on environment /mission
- Expansion of safety practices to broader set of stakeholders, including those in the supply chain

Next Steps for the IASMS Roadmap

- Updated roadmap to be published by Flight Safety Foundation in April
- Continue to engage with stakeholders to reflect evolving priorities
  - Expand outreach to broader set of stakeholders
  - Further develop key IASMS safety research steps
  - Expand content related to to nearer-term research that support priority needs
  - Expand international engagement on harmonization opportunities

Deborah Kirkman Bio

Currently a director at the Flight Safety Foundation (FSF), Deborah Kirkman has worked to enable innovation in aviation for nearly four decades. She is leading FSF's efforts to develop a research roadmap for future safety innovations including those supporting advanced air mobility (AAM), facilitates FSF's Autonomous and Remotely Piloted Aviation Capabilities (ARPAC) advisory committee, and recently served on the FAA's aviation rulemaking committee for Beyond Visual Line of Sight (BVLOS) operations.

Deborah began her career at Bell Laboratories. Much of her professional career was spent at the MITRE corporation, where she most recently managed MITRE's portfolio of work in UAS integration. Her other systems engineering work in air traffic management includes digital pilot-controller communications, National Airspace System performance metrics, the Free Flight program, and NextGen. She has held several leadership roles in RTCA as well, including co-chairing the Business Case and Performance Metrics working group of RTCA's NextGen Advisory Committee.

An instrument-rated private pilot, Deborah's original studies were in Electrical Engineering, including a BS from the University of Virginia and an MS degree from Stanford University.

Backup

IASMS Capability Development Goal

Through a series of operationally challenging new entrant and airline partner use cases, develop and demonstrate an assured system-wide safety framework and capability set that enables increasingly complex airspace operations.

- ***Safety framework*** is the set of requirements and their substantiations needed to enable safe, repeatable and efficient access to the NAS

- Such a safety framework may be highly valuable in supporting the FAA's rule-making process for operations across many domains including UAM, traditional aviation and space launch.

IASMS R&D with Industry

Concept of Operations

Hazard Analysis: Identify Safety Critical Risks

Determine Acceptable Safety Assurance Requirements

IASMS Services and Capabilities Framework of SFCs to Assure Safety

Data and Architecture Requirements for IASMS SFCs

Development of Functional & Assured IASMS

Flight Demonstration with Functional & Assured IASMS

Operational IASMS Data Generation to Inform Recommendations for Safety Framework Standards

Recommendations Document published by Standards Committees to Inform Safety Framework Requirements

New Safety Framework Requirements Established by Regulators (FAA)