In-Time Aviation Safety Management Systems (IASMS)

NASA-FAA SWS RTT
Technical Interchange Meeting
April 11, 2023

System-Wide Safety

System-Wide Safety (SWS) Project
Airspace Operations and Safety Program (AOSP)
Aeronautics Research Mission Directorate (ARMD)

Innovating the Future of Aviation

Human-Centric Capabilities

Safety + Density

Human centered traffic &
Safety management

Digitally Transformed Infrastructure

Collaborative Environment

Service oriented architecture
for tailored mission services
+ ML
+ IoT

Automation-Enabled Diversity

Highly Automated

Complexity, scalability,
And dynamic adaptation
+ digital mesh
+ AI
+ IoT

Evolution of Airspace Operations and Safety

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

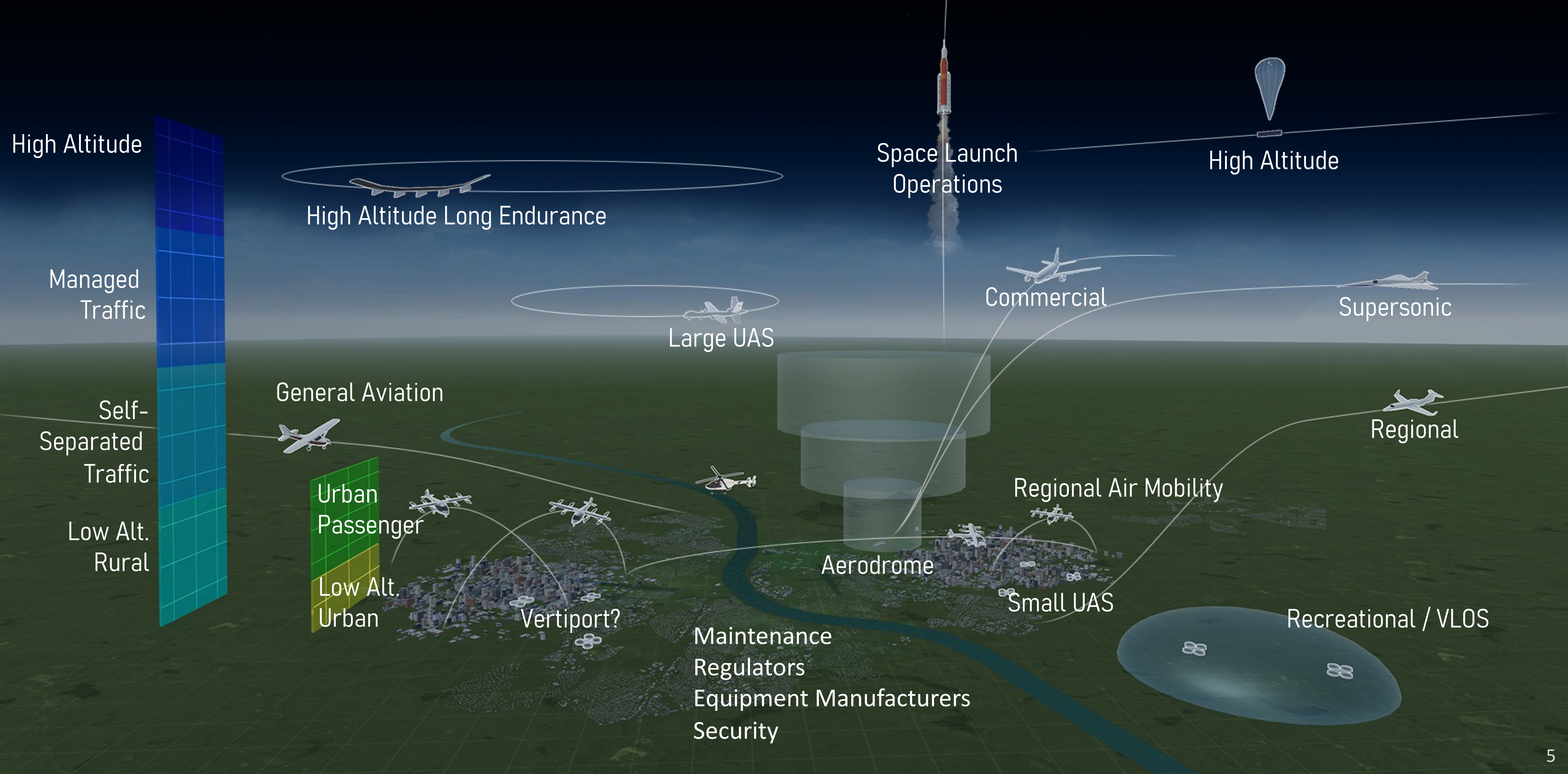
New Missions = Increased Integration Complexity

Sustainability = New Constraints

Notable Barriers

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

Variety of Aviation Participants



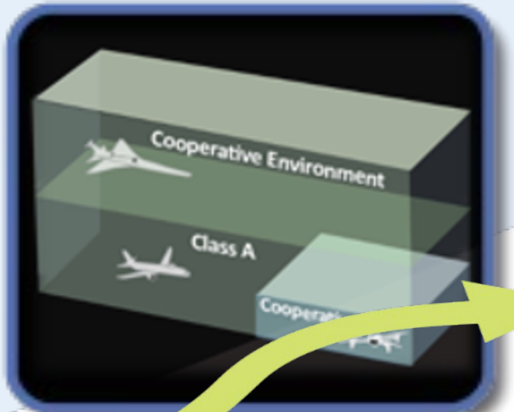
Evolution of Airspace Operations and Safety

+ Efficiency and proactive planning

Trajectory

Know and **exchange** current and planned aircaft positions

+ Service-oriented architecture for tailored mission-oriented services



Collaborative

Connected, performance-based, collaborative ATM

Introduces 3rd-party service providers

+ Complexity, scalability, and dynamic adaptation

Highly-Automated

Machine Learning/Artificial Intelligence – based dynamic, robust performance and safety

Machine-to-machine interactions and humans collaborate

Digital Transformation of ATM

Automated in-time safety monitoring and alerting services

Integrated predictive risk mitigation across domains

Automatically-assured adaptive in-time safety threat management

Today

~2035+

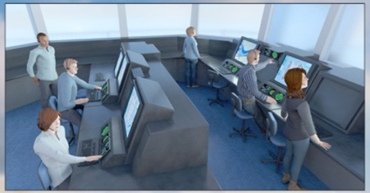
~2045+

Innovating the Future of Aviation

Class A

Radar Based

Safety + Density
Human centered traffic & safety management



Info-centric NAS

Collaborative Environment
Service oriented architecture for tailored mission services
+ ML
+ IoT

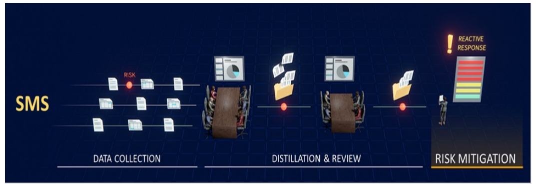
Sky for ALL

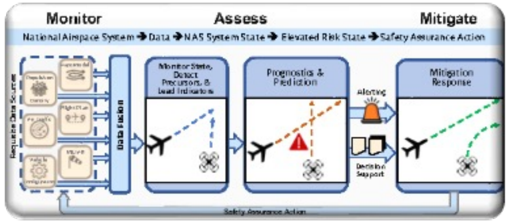
Highly Automated
Complexity, scalability, and dynamic adaptation
+ digital mesh
+ AI
+ IoT

Evolution of Airspace Operations and Safety

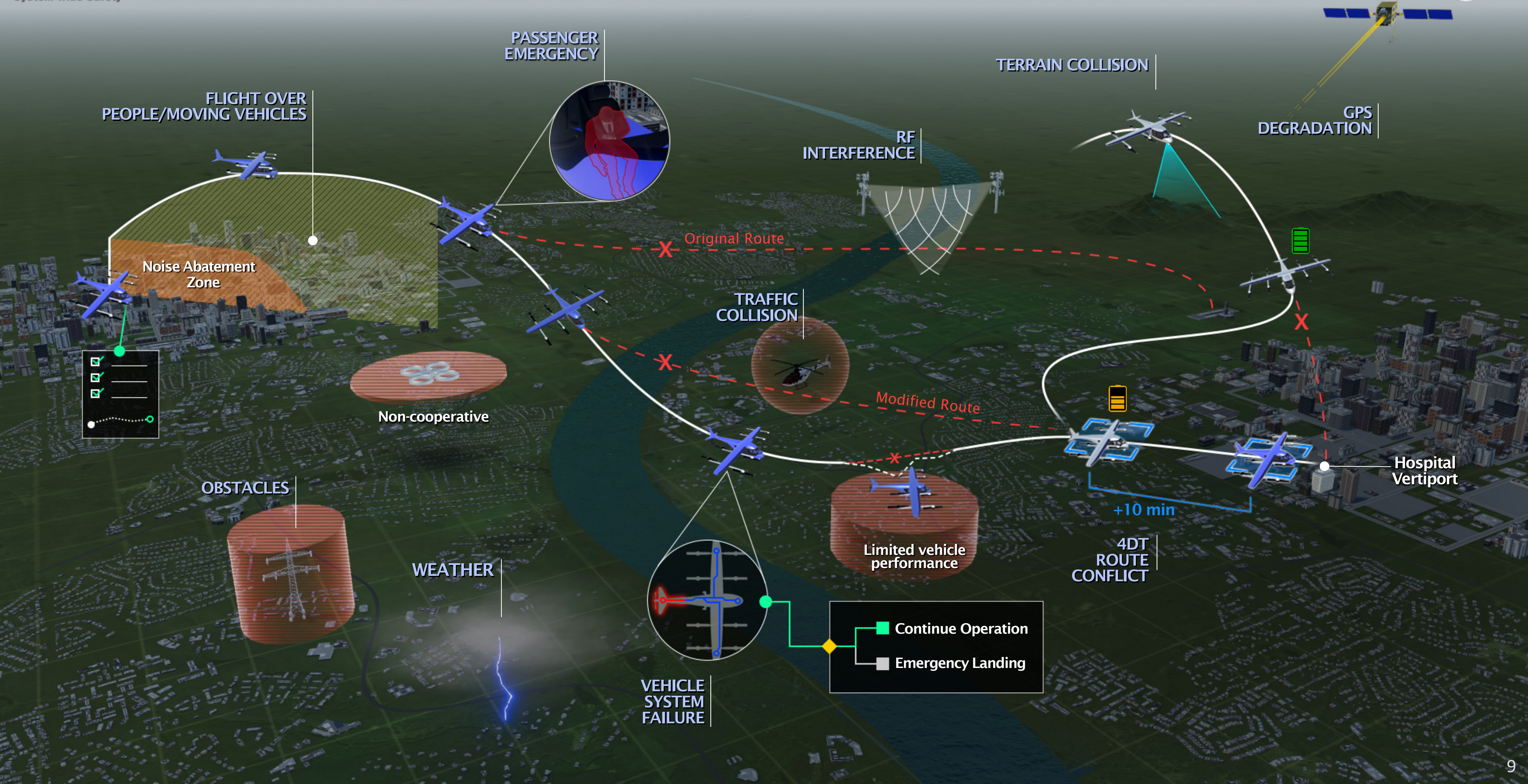
To Help Achieve Aviation Safety Tomorrow

	Today	2035 Info-Centric NAS	2045 Sky for All
NASA Strategic Capabilities			Domain Specific (In-time) Safety Monitoring and Alerting Tools Adaptive In-time Safety Threat Management Integrated Predictive Technologies with Domain Level Application
FAA ICN Keys to Safety		Tailored Safety Interoperability In-time Safety Assurance In-time Safety Management	Tailored Safety Interoperability In-time Safety Assurance In-time Safety Management
ICAO SMS Pillars	Air Transportation Safety Safety Policy: Broad Safety Objectives; Responsibility & Accountability Risk Management: Hazard Identification; RM Controls; Safety Performance Safety Assurance: Data Collection; Data Analysis; Resource Prioritization Safety Promotion: Safety Training; Dissemination of Information; Safety Culture	Air Transportation Safety Safety Policy: Broad Safety Objectives; Responsibility & Accountability Risk Management: Hazard Identification; RM Controls; Safety Performance Safety Assurance: Data Collection; Data Analysis; Resource Prioritization Safety Promotion: Safety Training; Dissemination of Information; Safety Culture	Air Transportation Safety Safety Policy; Risk Management; Safety Assurance; Safety Promotion Overall Safety Management System National Academies IASMS ISSA Monitor Assess Mitigate Broad Safety Objectives; Responsibility & Accountability Hazard Identification; RM Controls; Safety Performance Data Collection; Data Analysis; Resource Prioritization Safety Training; Dissemination of Information; Safety Culture



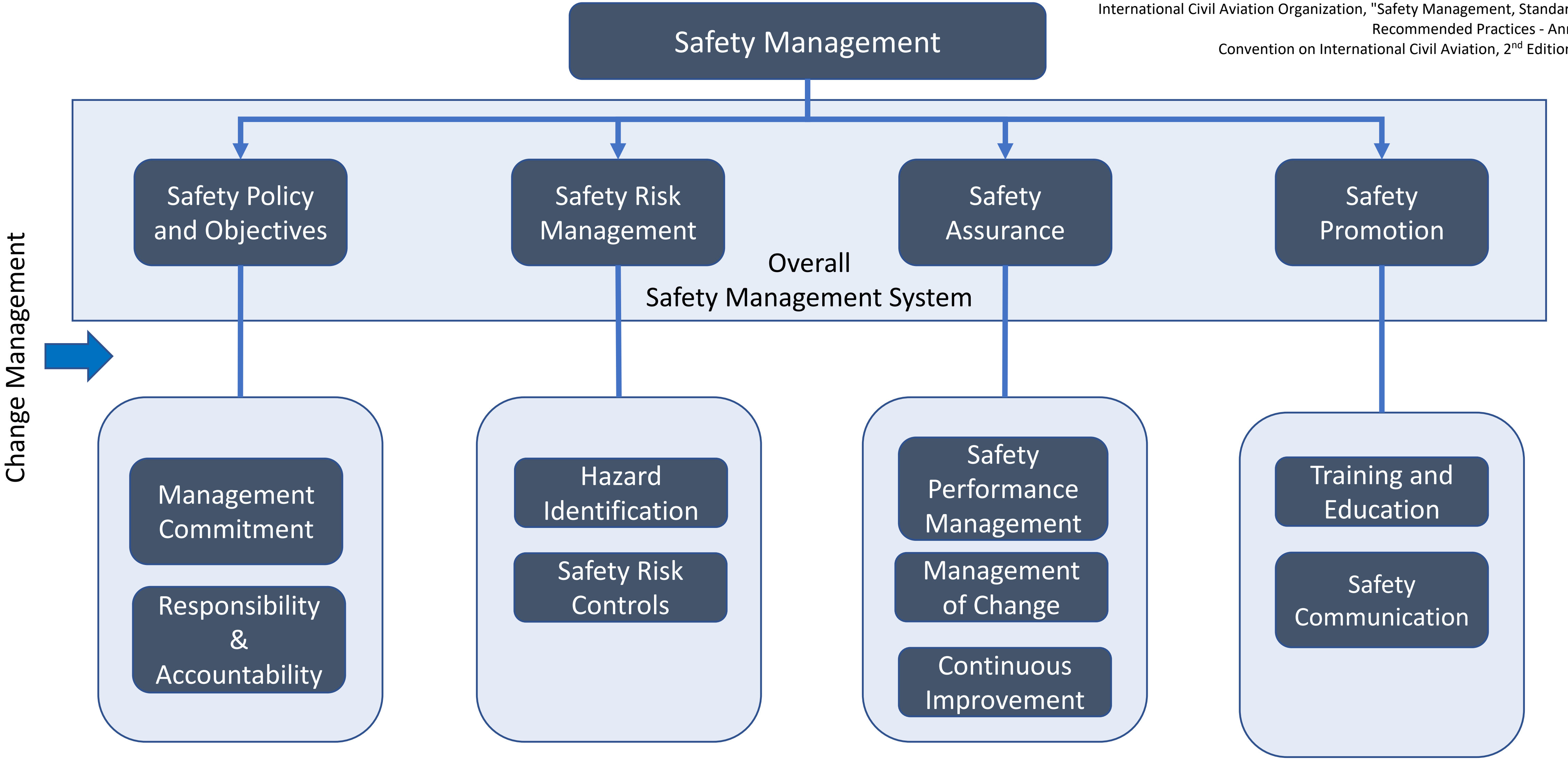


Complexities, Risks and Constraints



How We Achieve Aviation Safety Today

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



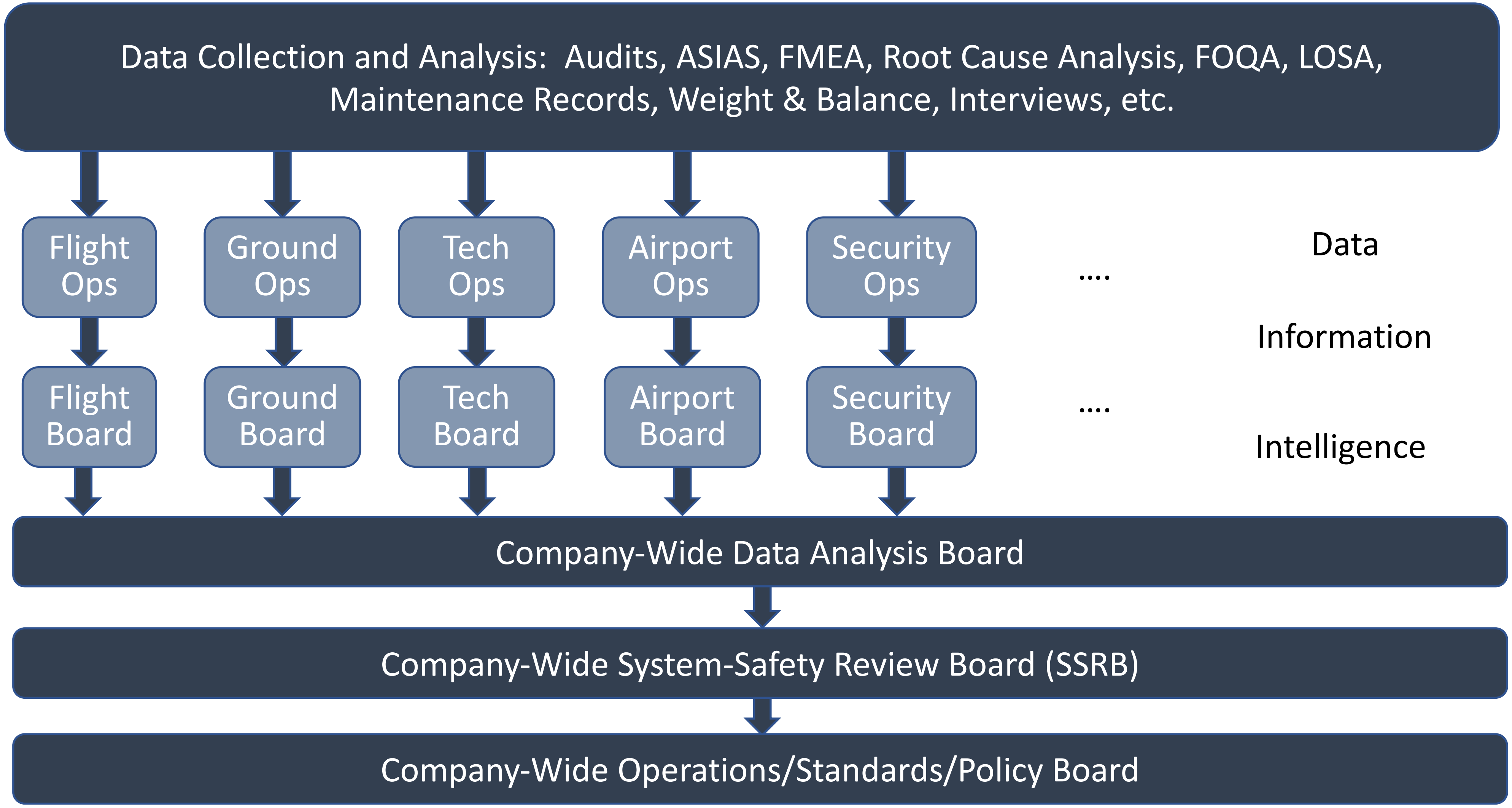
Current-Day Safety Management Systems

Current-day SMSs are primarily reactive—analysis based on data collected over a period of time

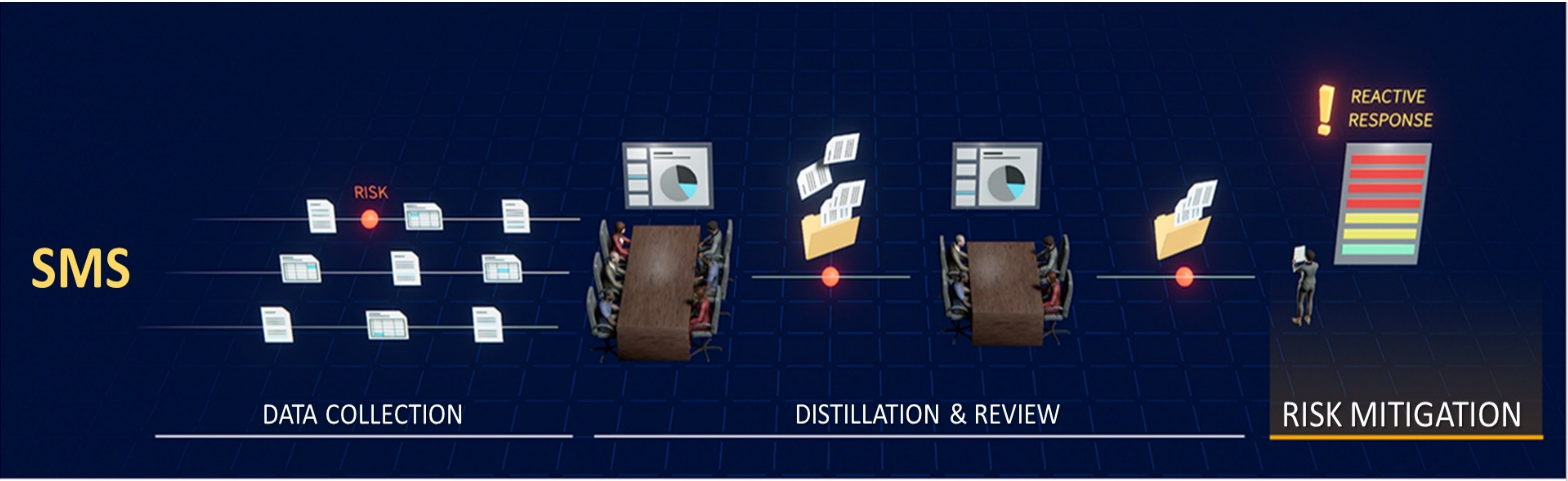
Data-Analysis Groups

Data-Analysis Boards

Company-Wide Boards filter input from Data-Analysis Boards to implement change, develop policies, or create operational standards



Current SMS for Air Carrier Operations



Credit: NASA

Labor intensive
Limited ability to scale
Not fast enough

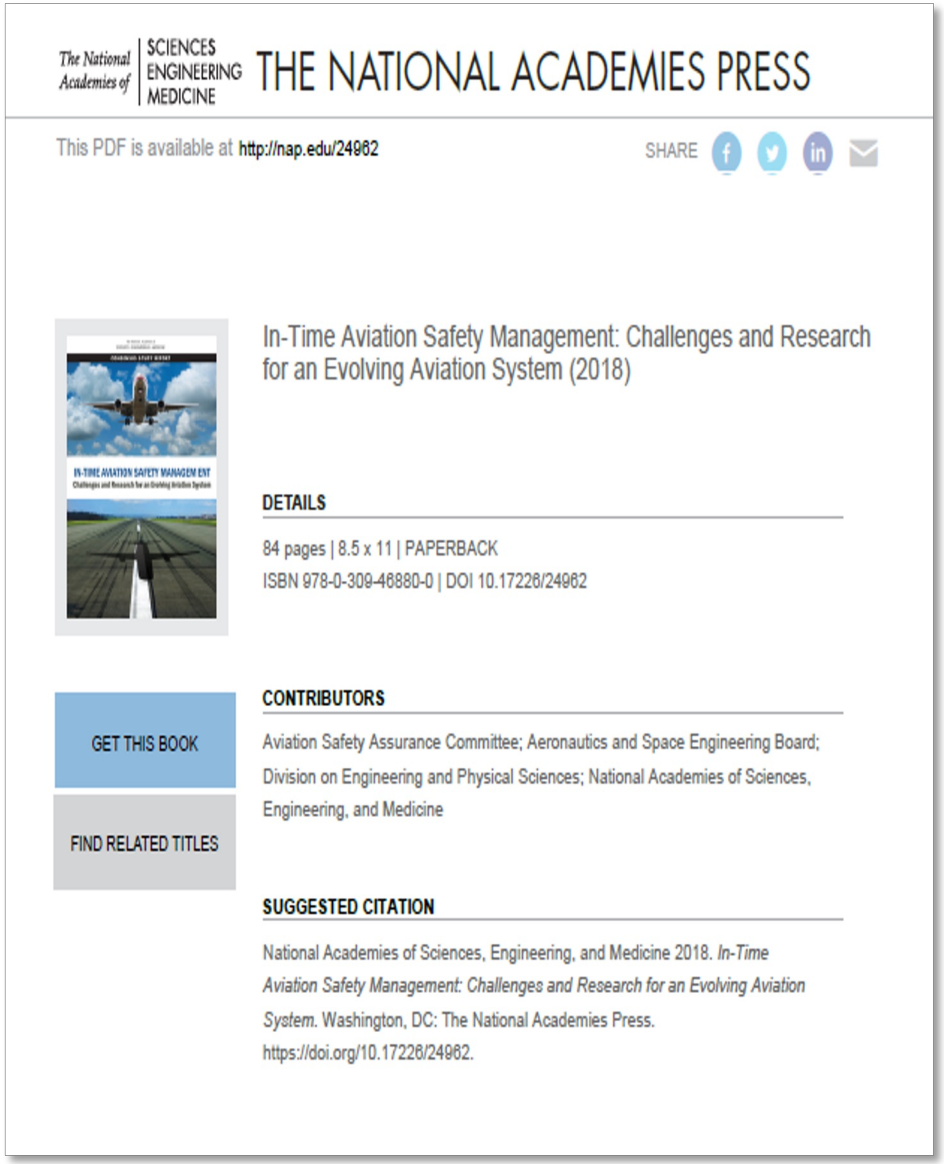
National Academies – IASMS

Outlines need for evolution of the existing Safety Management System

In-Time Aviation Safety Management System (IASMS)

Identifies 4 Fundamental System Element Development Areas:

1. Concept of Operations and Risk Prioritization
2. System Monitoring
3. System Analytics
4. Mitigation and Implementation



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In-Time Aviation Safety Management: Challenges and Research for an Evolving Aviation System (2018)

DETAILS

84 pages | 8.5 x 11 | PAPERBACK
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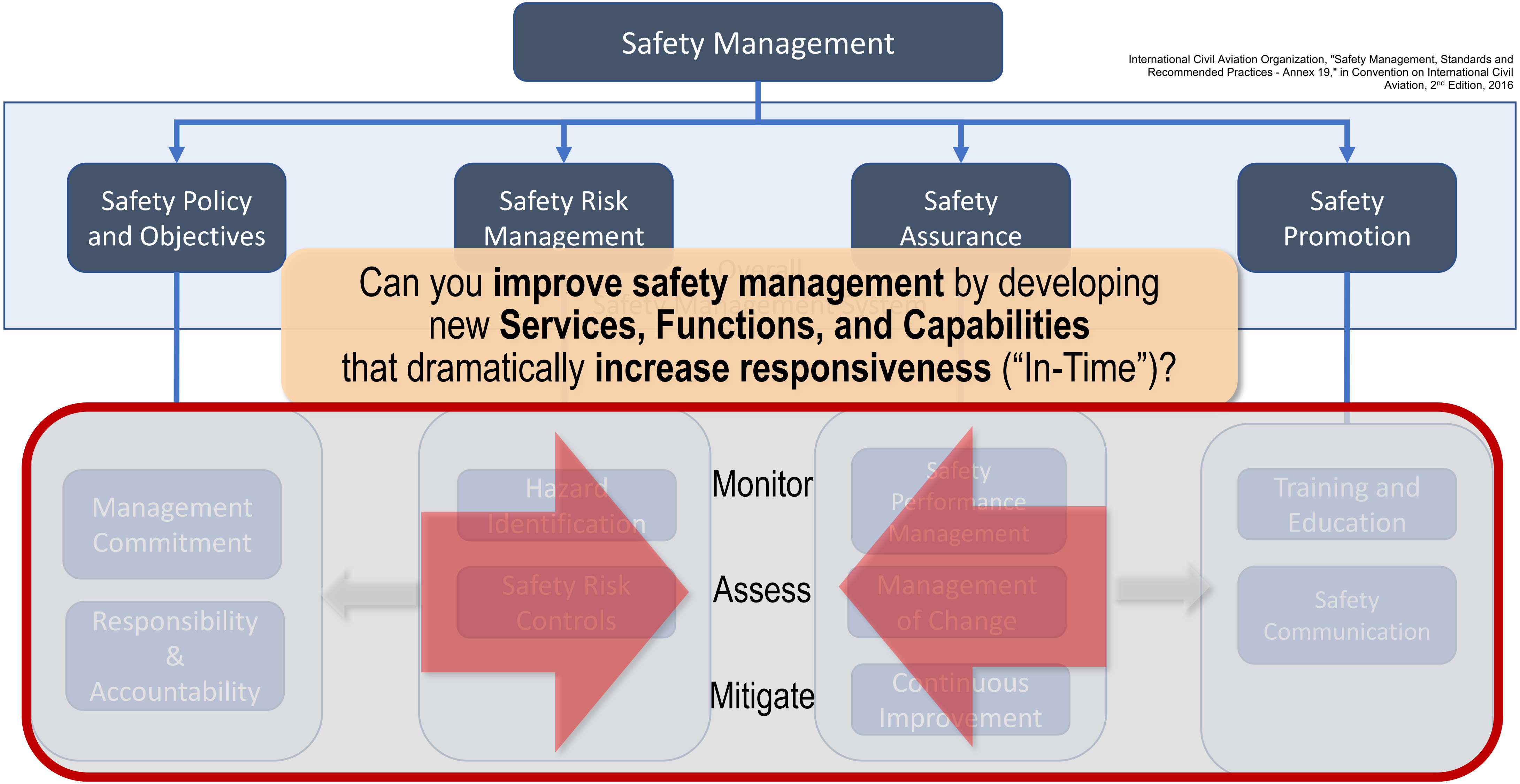
Safety Management System Evolution



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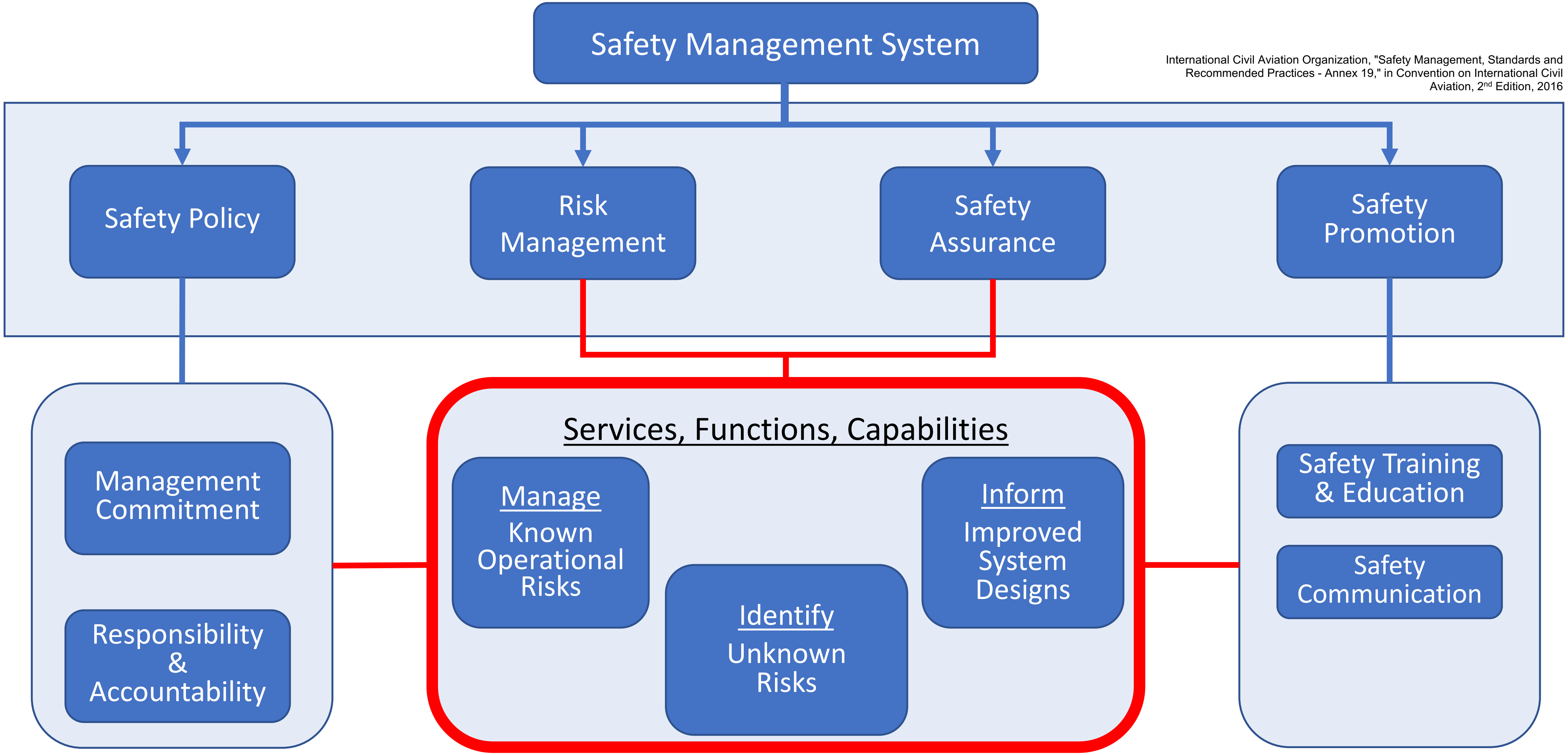


Quickly manage known operational risks at scale

Quickly identify unknown risks

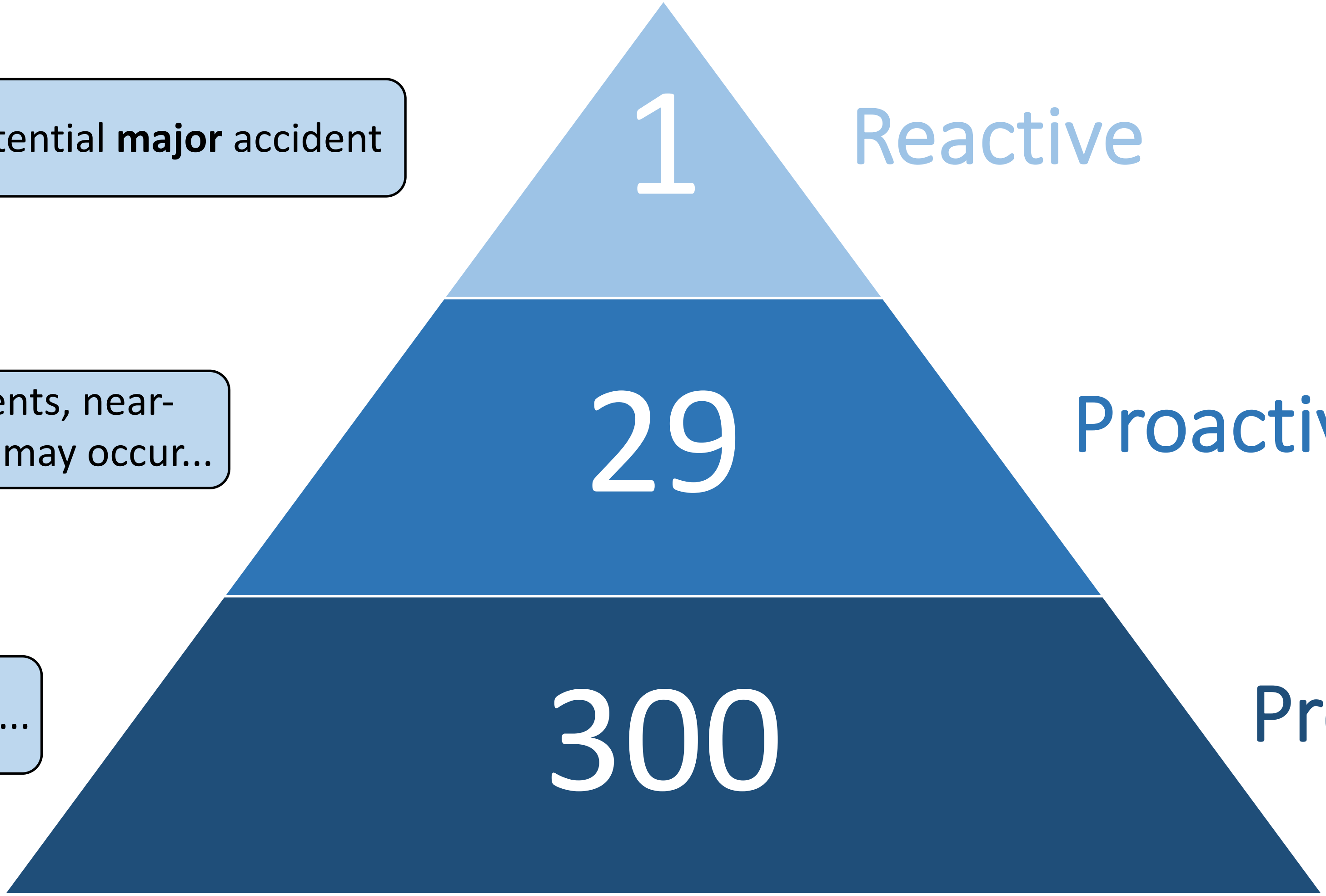
Quickly inform design

Integrated Safety Management

The potential **major** accident

The **minor** incidents, near-misses, etc. that may occur...

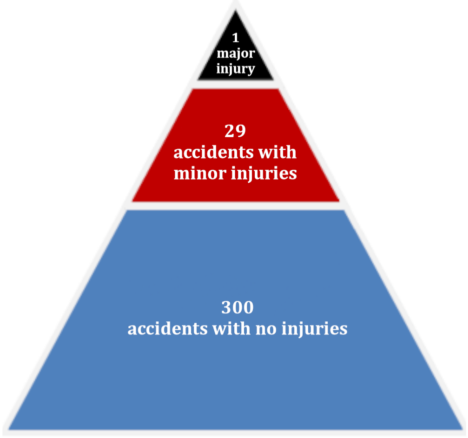
The **conditions** that exist...



Reactive

Proactive

Predictive



Heinrich's Triangle (Original)

https://en.wikipedia.org/wiki/Accident_triangle

Proposed Safety Intelligence Definition

Annex 19 Amendment 2

An outcome of the process of analyzing safety data and safety information to support decision-making

Near-Term Needs and Impact of Safety Intelligence

Need: Wide variation of operator size and complexity of operations necessitates the development of tools and processes to quickly mitigate risks and hazards effectively and economically.

Objective: Improve safety intelligence. Rapidly evaluate existing data patterns and discover new patterns that lead to the next safety event.

Impact: Improved speed and characterization of system-wide risk identification to augment existing SMS processes supporting risk management and safety assurance.

Predictive Safety Management

System-Wide Safety

- Reactive Safety Management

  Do something to address the risks identified in an accident or incident after it has occurred

- Proactive Safety Management

  Do something before an accident happens by utilizing data to identify risks from past accidents or incidents (historical/latent data)

- Predictive Safety Management

  Do something based on potential risk as determined from normal operational data (i.e., not accident data) to reduce the risk of an accident that has not happened (yet); identify safety issues that haven't happened yet, but probably will happen if unaddressed, and act accordingly by updating risk control strategies

System-Wide Safety

Predictive Safety Management

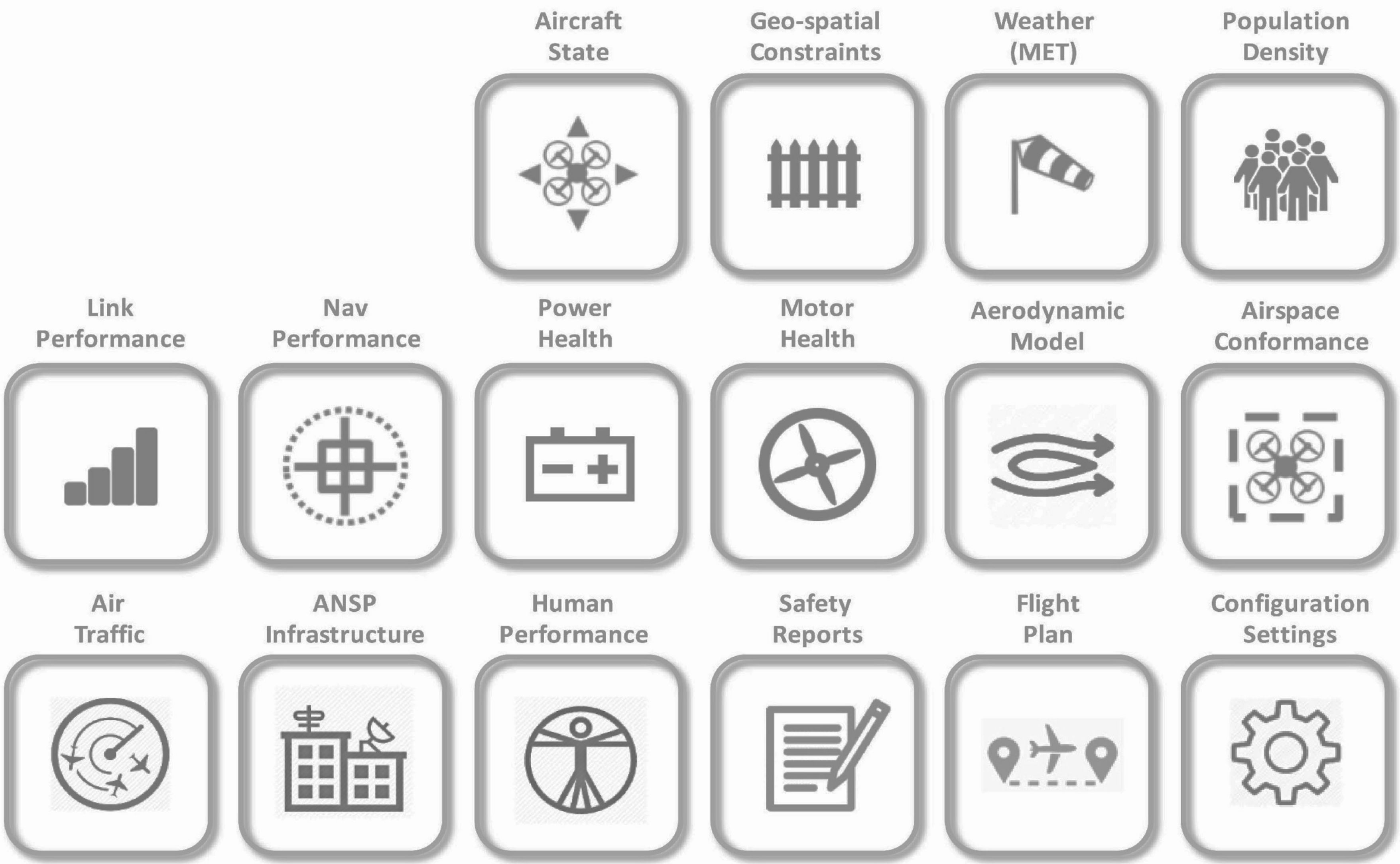
- Reactive Safety Management
  - Mitigating safety events after hazard has occurred;
  - Minimizing damage from critical safety situations;
  - Acting quickly and efficiently in response to undesirable incidents;
  - High quality decision making in reaction to safety data (threats, risk, etc.).
- Proactive Safety Management
  - Identify behaviors that lead to hazard occurrence
  - Stop hazard event before it happens;
  - Identify root causes before they lead to hazard occurrence;
  - Understand safety “inputs”; i.e., underlying causes that lead to safety performance.
- Predictive Safety Management
  - Identify possible risks in a situation based on given circumstances;
  - Identify new threats in hypothetical scenarios; Anticipate needed risk controls.

- ICAO (Annex 19 and Doc 9589) provisions for the use of:
  - Proactive safety activities to collect safety information and safety data;
  - Proactive methods for hazard identification;
  - Predictive safety indicators focused on processes and activities to improve and maintain safety; and,
  - Predictive analysis based upon current operations
- Proactive risk management, which uses aviation leading indicators to directly assess underlying causes and precursors to current performance; and creating expected “ranges” of safety performance, and a framework for future risk exposure
- Predictive risk management makes use of lagging indicators (historical performance) used to predict possible future outcomes
  - Management of change;
  - Risk analysis in hypothetical scenarios; and
  - Forecasting performance data

It Begins with Data…

Information classes useful to enable SMS

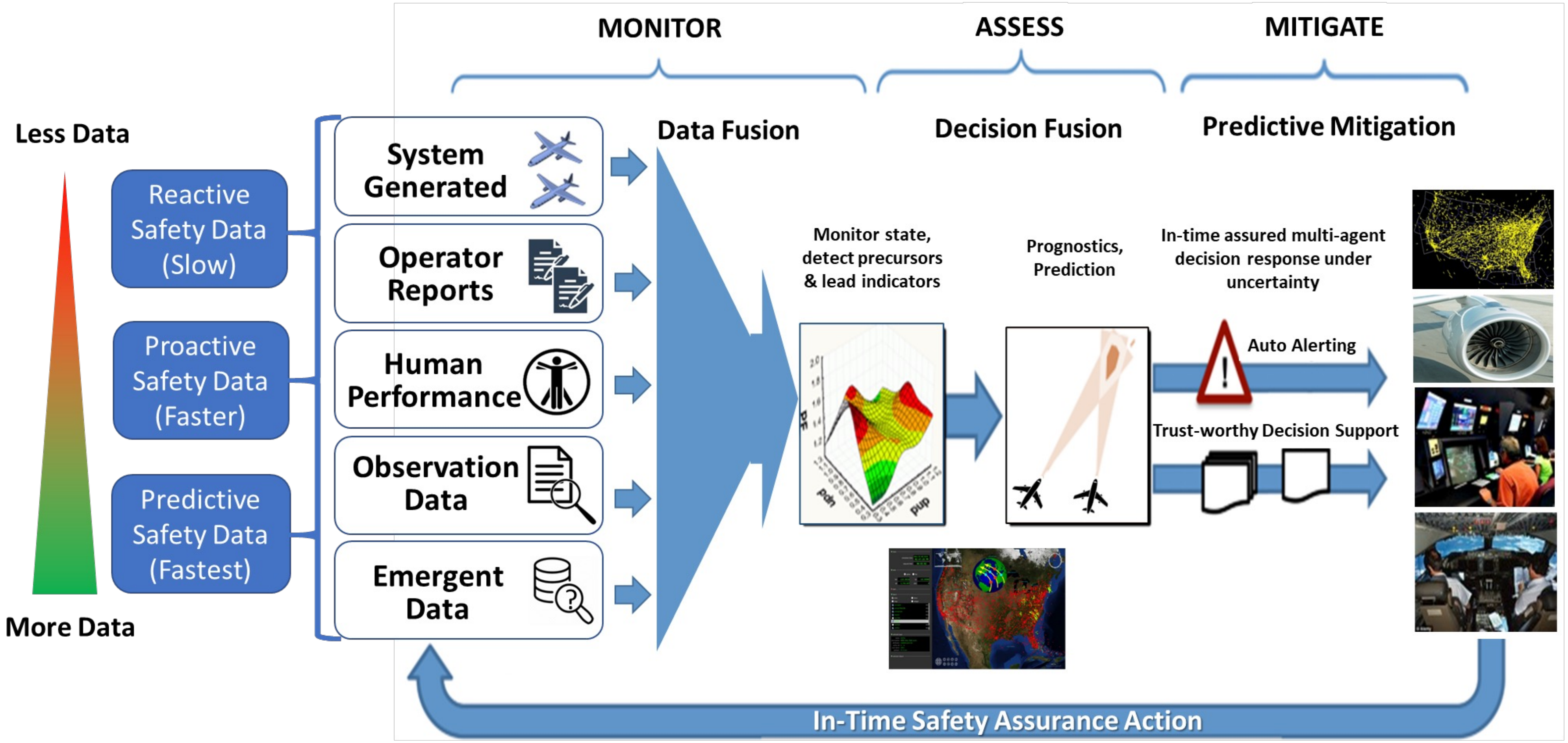
- ➢ Airspace Sourced
- ➢ Vehicle Sourced
- ➢ 3rd Party Data Service Provider
- ➢ System Wide Information Management (SWIM) / Flight Information Management System (FIMS) Sourced
- ➢ Other Sources…



(Young, S., et.al, 2020)

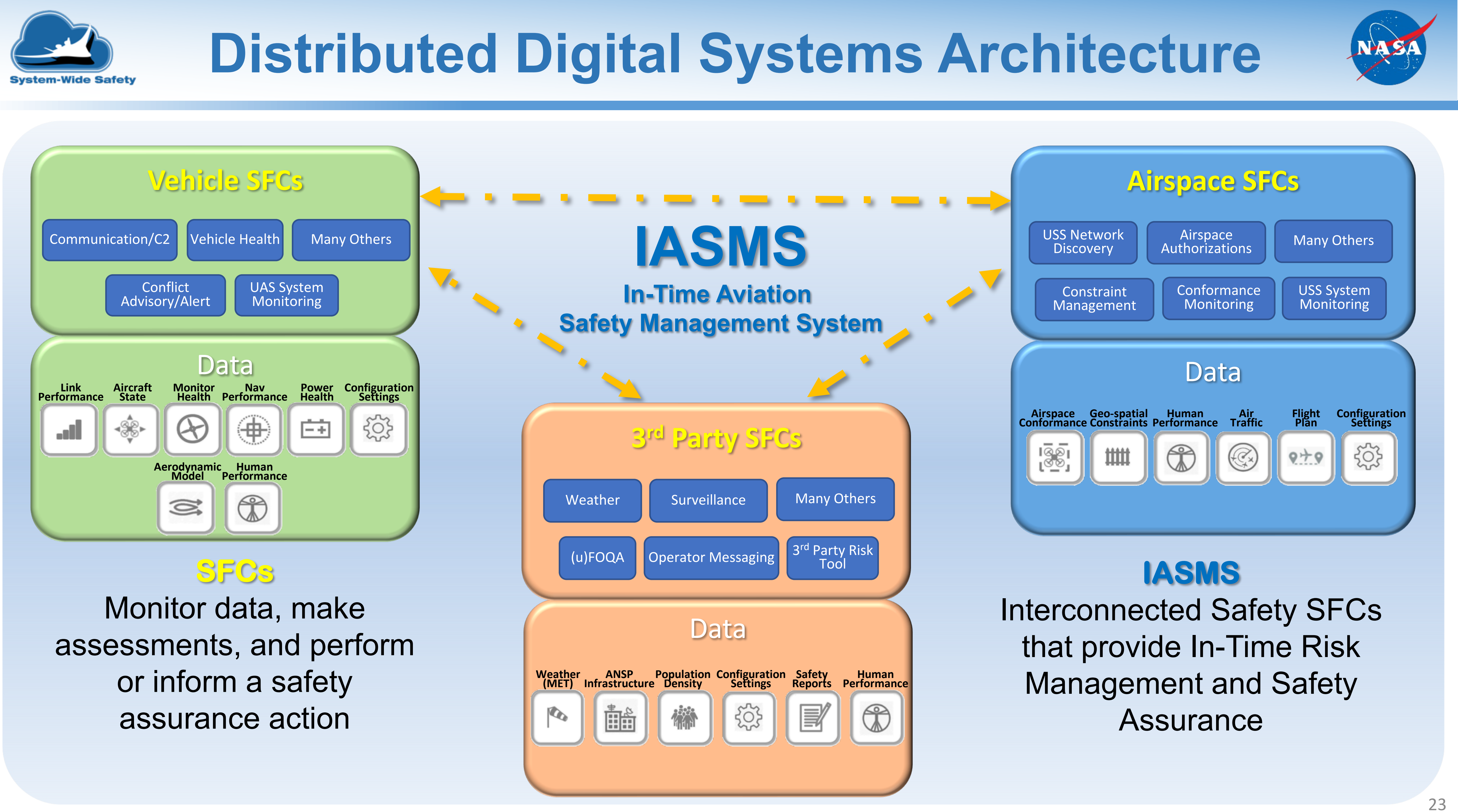
Increasingly In-Time Safety

Operational Needs →	Improve in-time safety	Improve scalability	Improve accessibility	Increase participation
Future Aviation Goals →	In-time Safety Assurance	Tailored Safety	Interoperability	

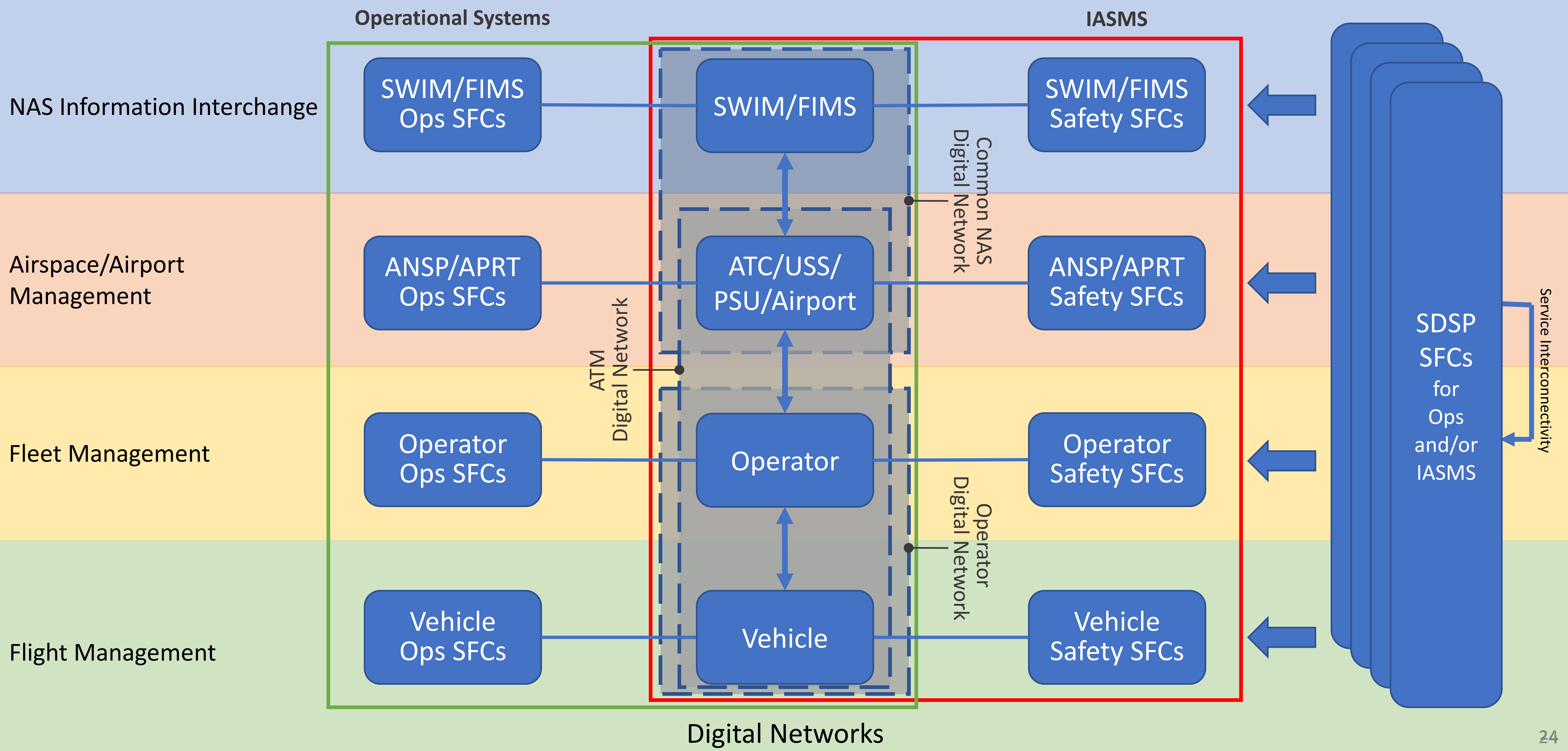


Credit: NASA

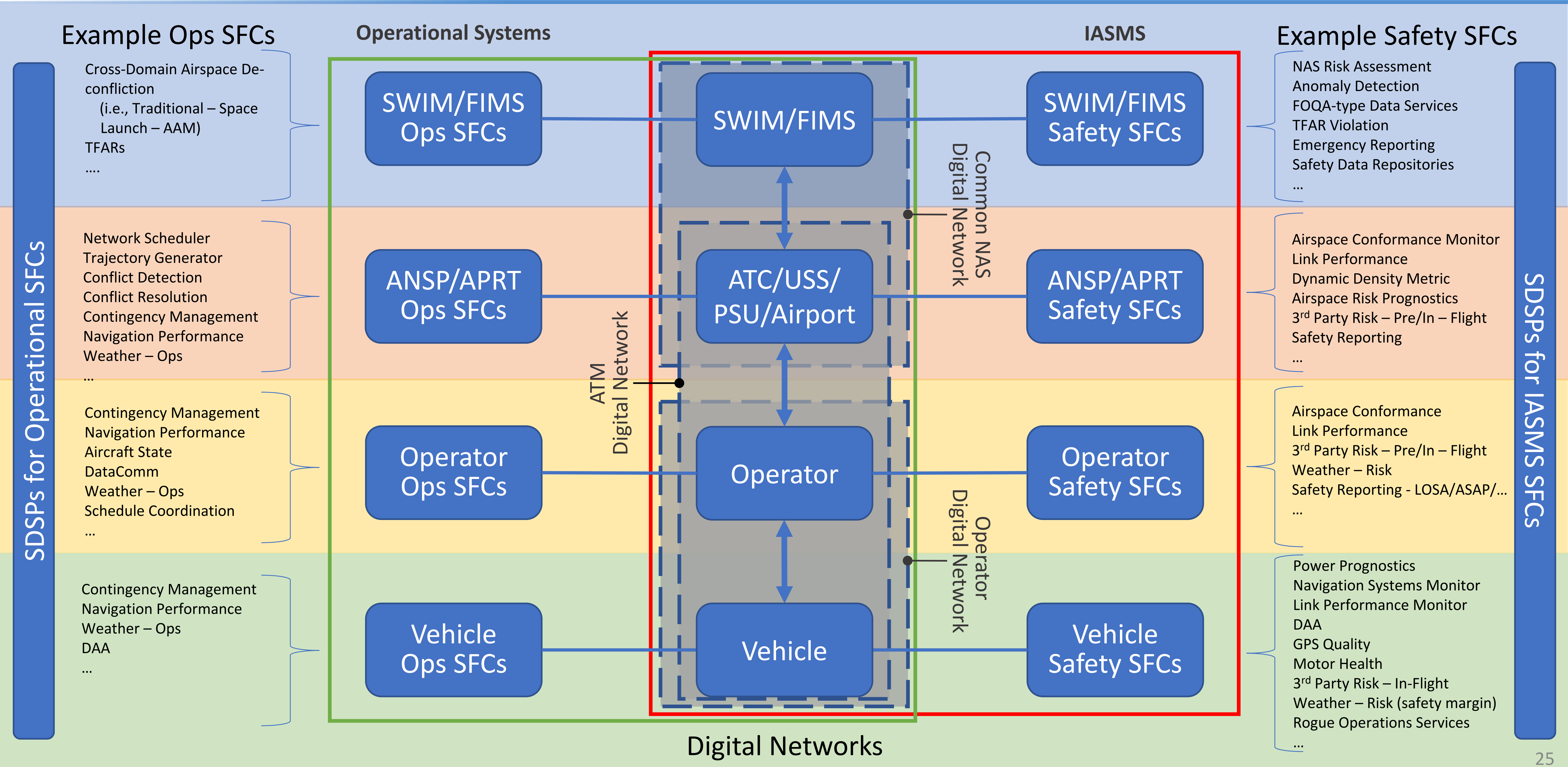
Distributed Digital Systems Architecture



IASMS Integration and Architecture



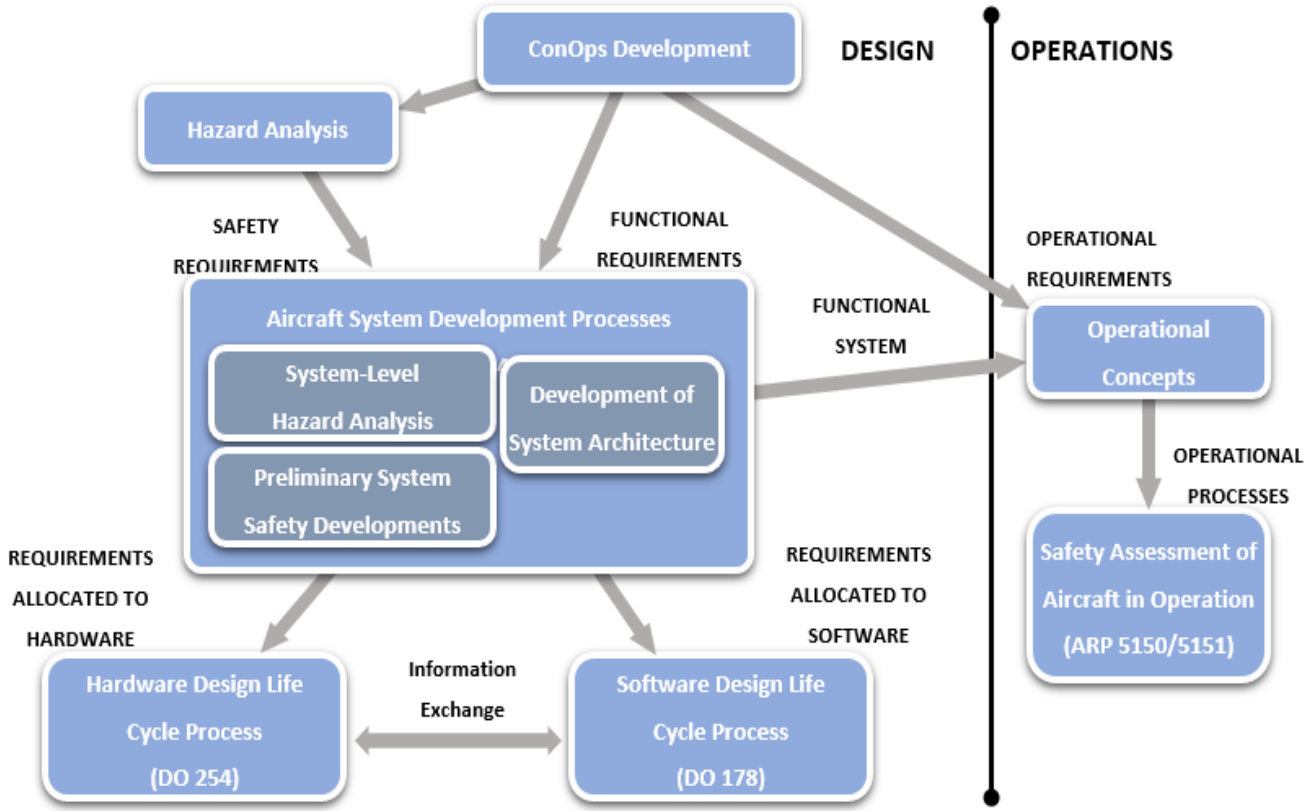
Service-Oriented Architecture



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

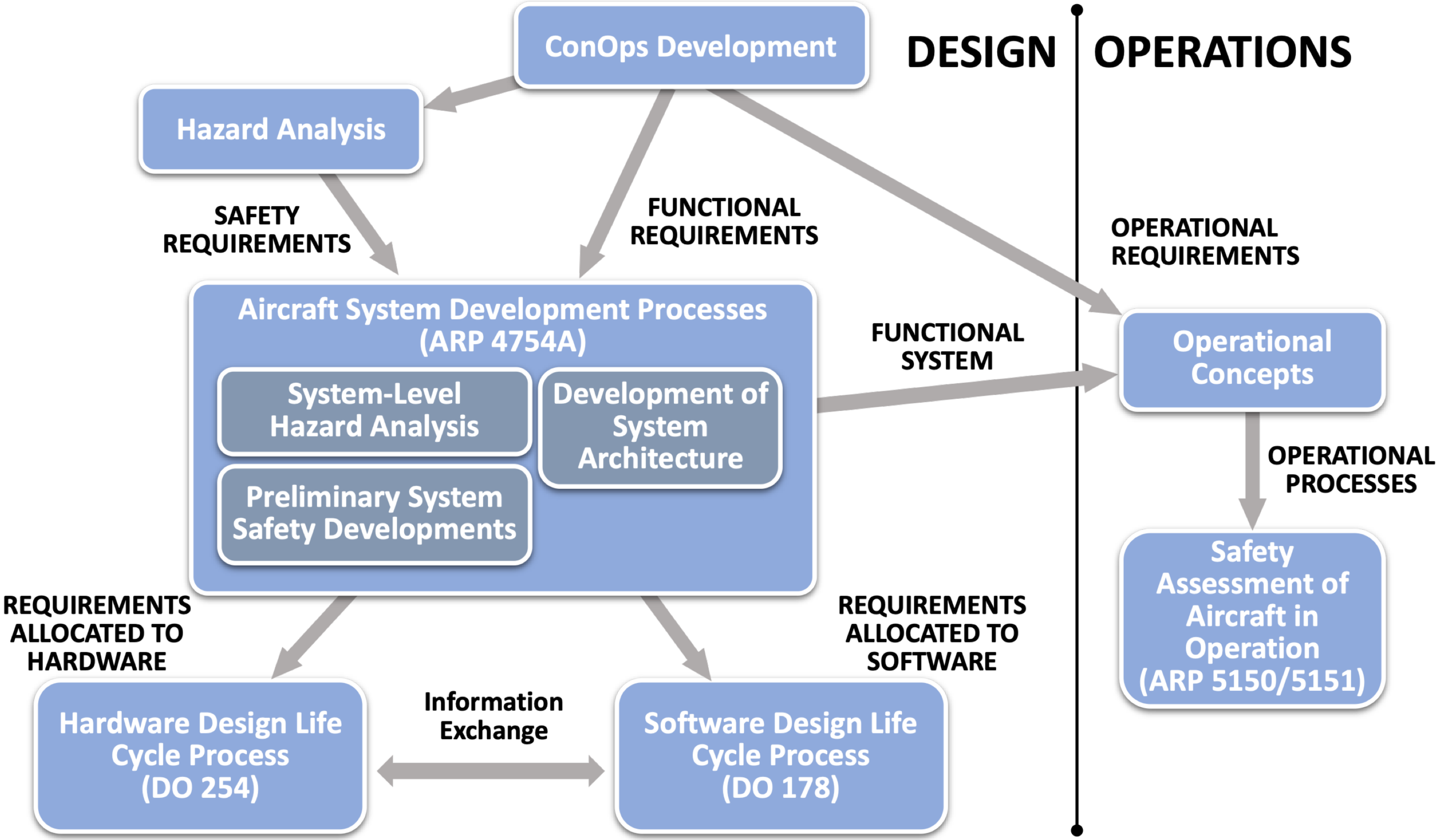
SFCs that

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



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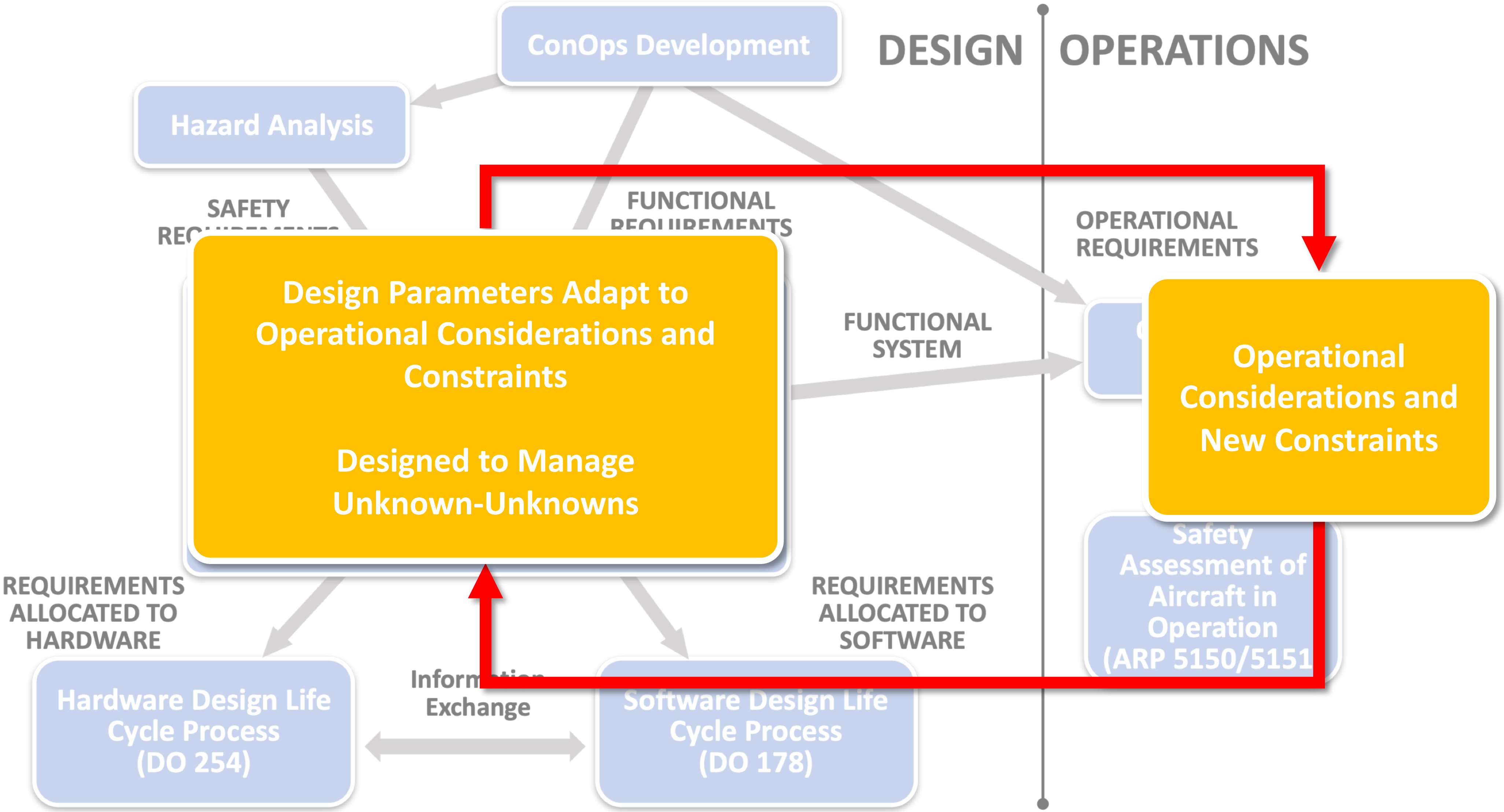
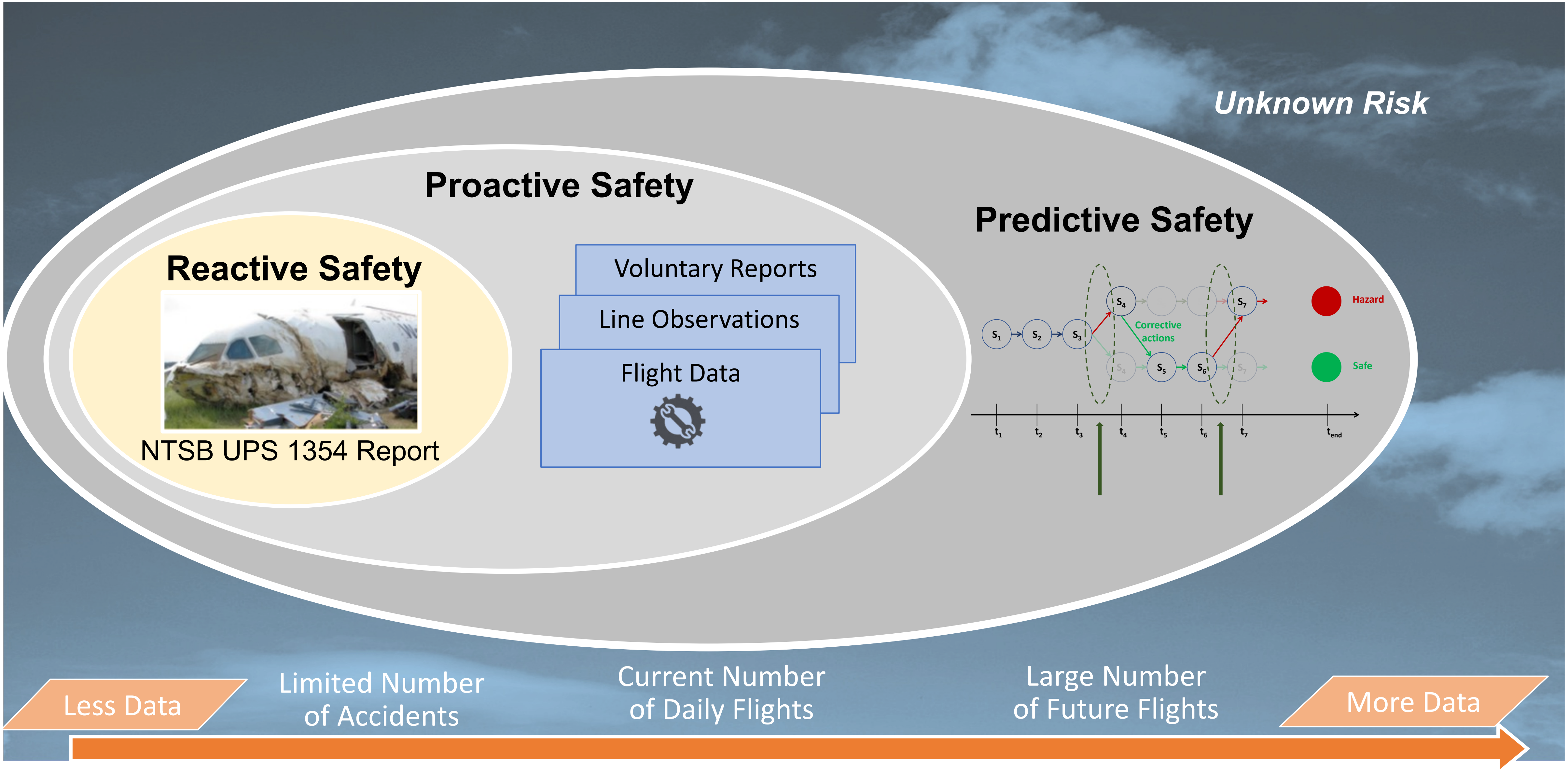


Progression of Safety Intelligence



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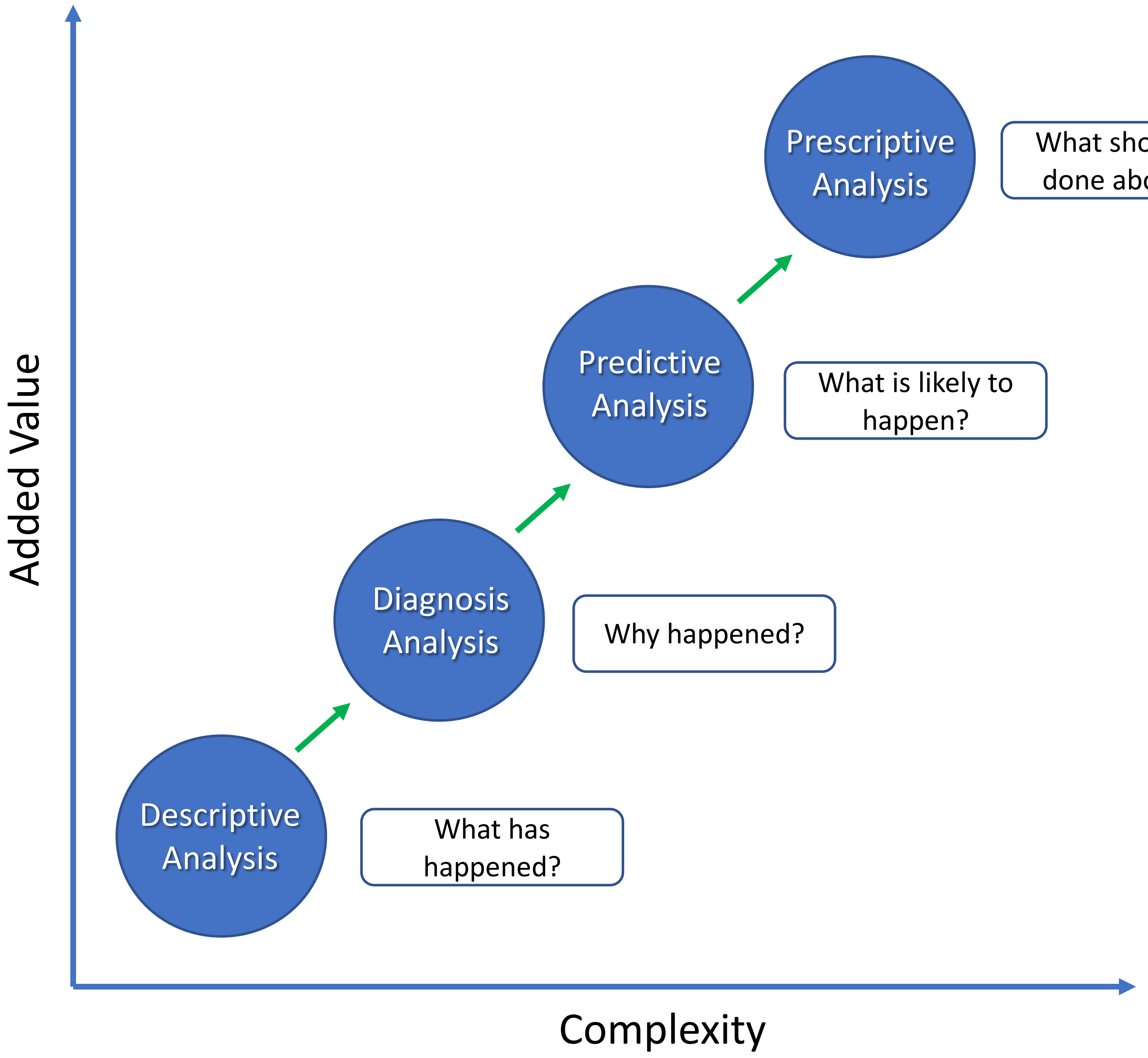
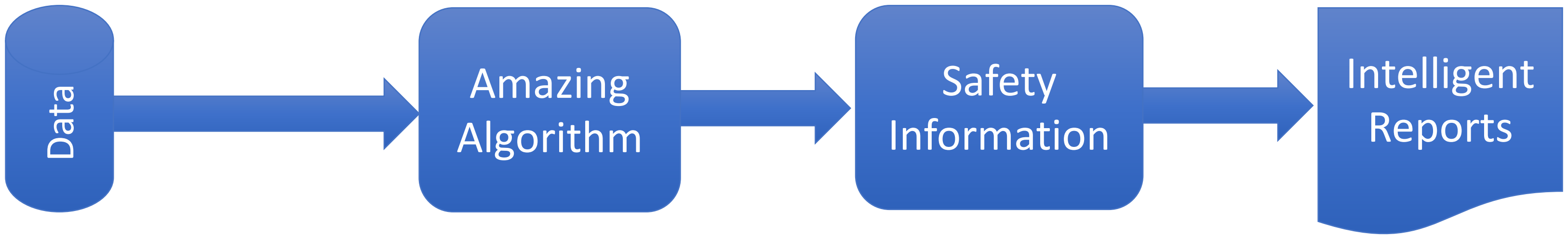
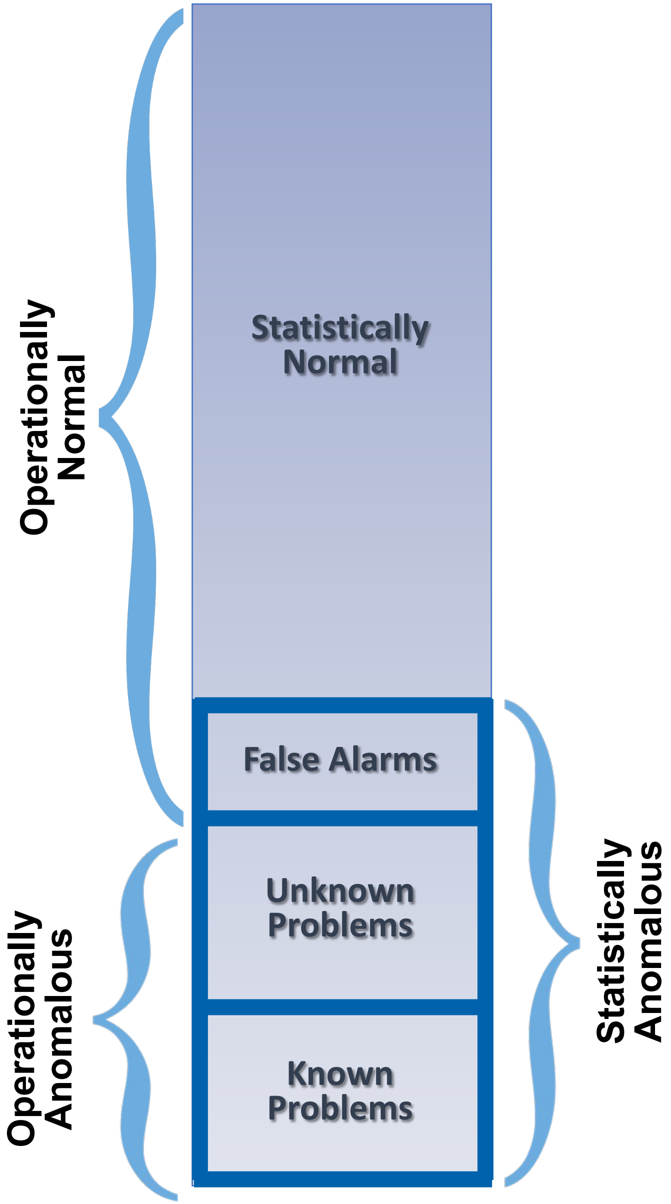


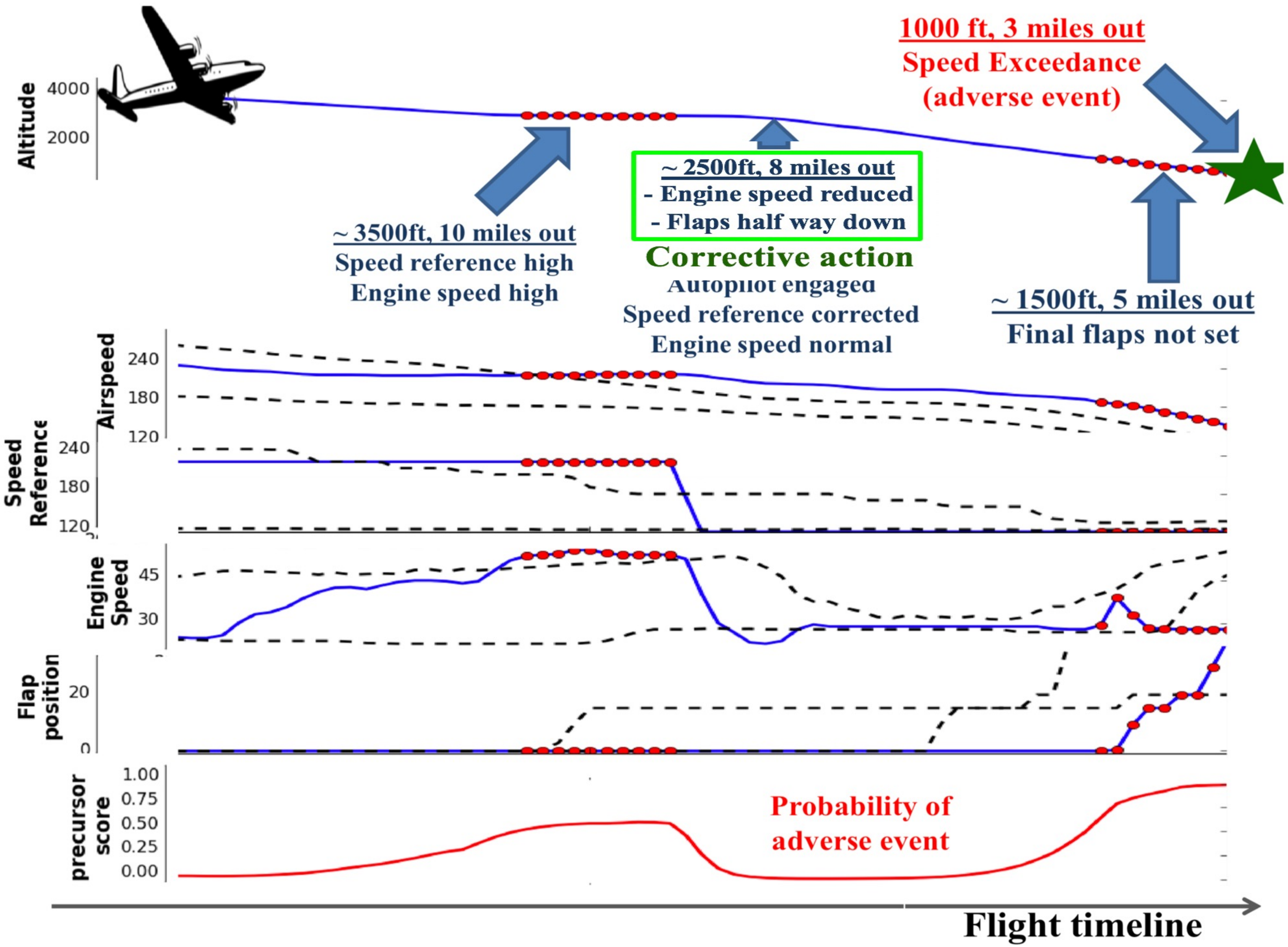
Data Challenges: The Four V's

- Volume:
  - Radar Tracks: 47 facilities (1 year) ~423 GB (Compressed), ~3.2 TB (CSV)
  - Weather and Forecast (Entire NAS): CIWS ~2.8 TB
- Velocity
  - Radar Tracks: 47 Facilities
    - ~35 GB/month (compressed).
    - ~268 GB/month (uncompressed)
  - Weather and Forecast (Entire NAS): CIWS ~233 GB/month
- Veracity
  - Data drop outs
  - Duplicate tracks
  - Track ending in mid air
  - Reused flight identifiers
- Variety
  - Numerical (continuous/binary)
  - Weather (forecast/actual)
  - Radar/Airport meta data
  - ATC Voice
  - ASRS text reports (Pilot/Controller)



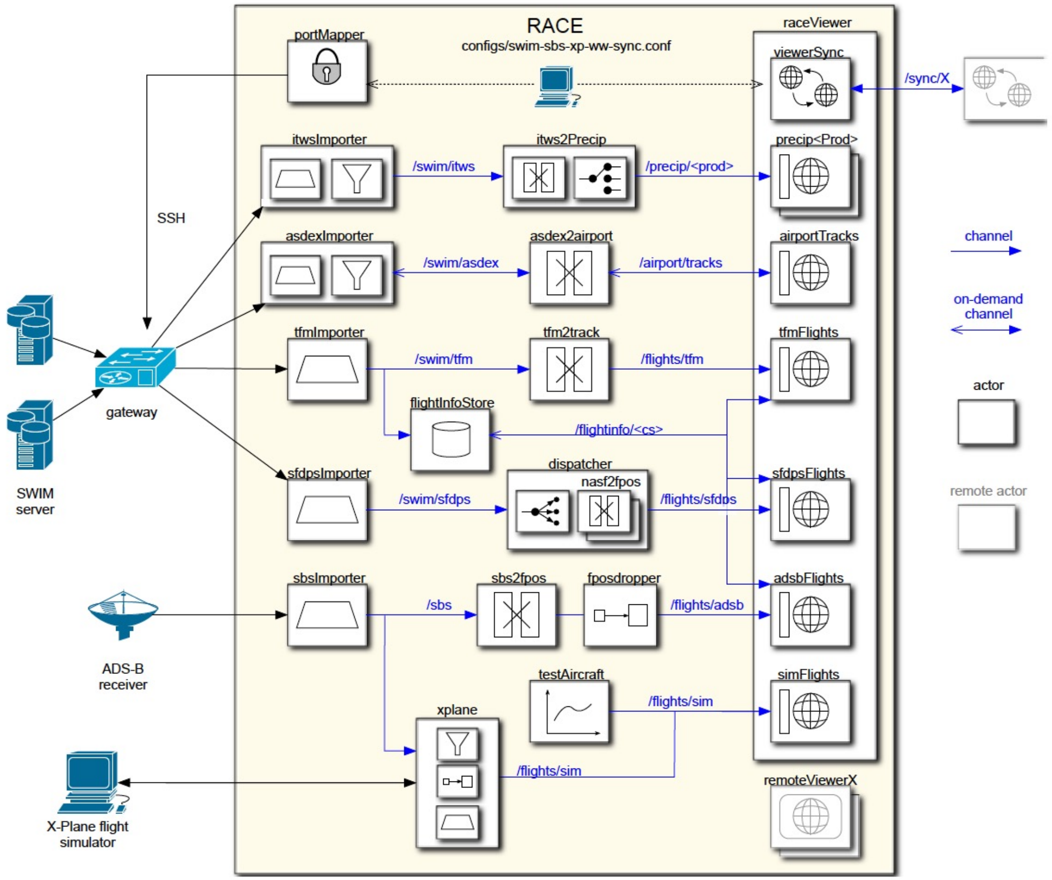
Discovery of Precursors in Time Series Data



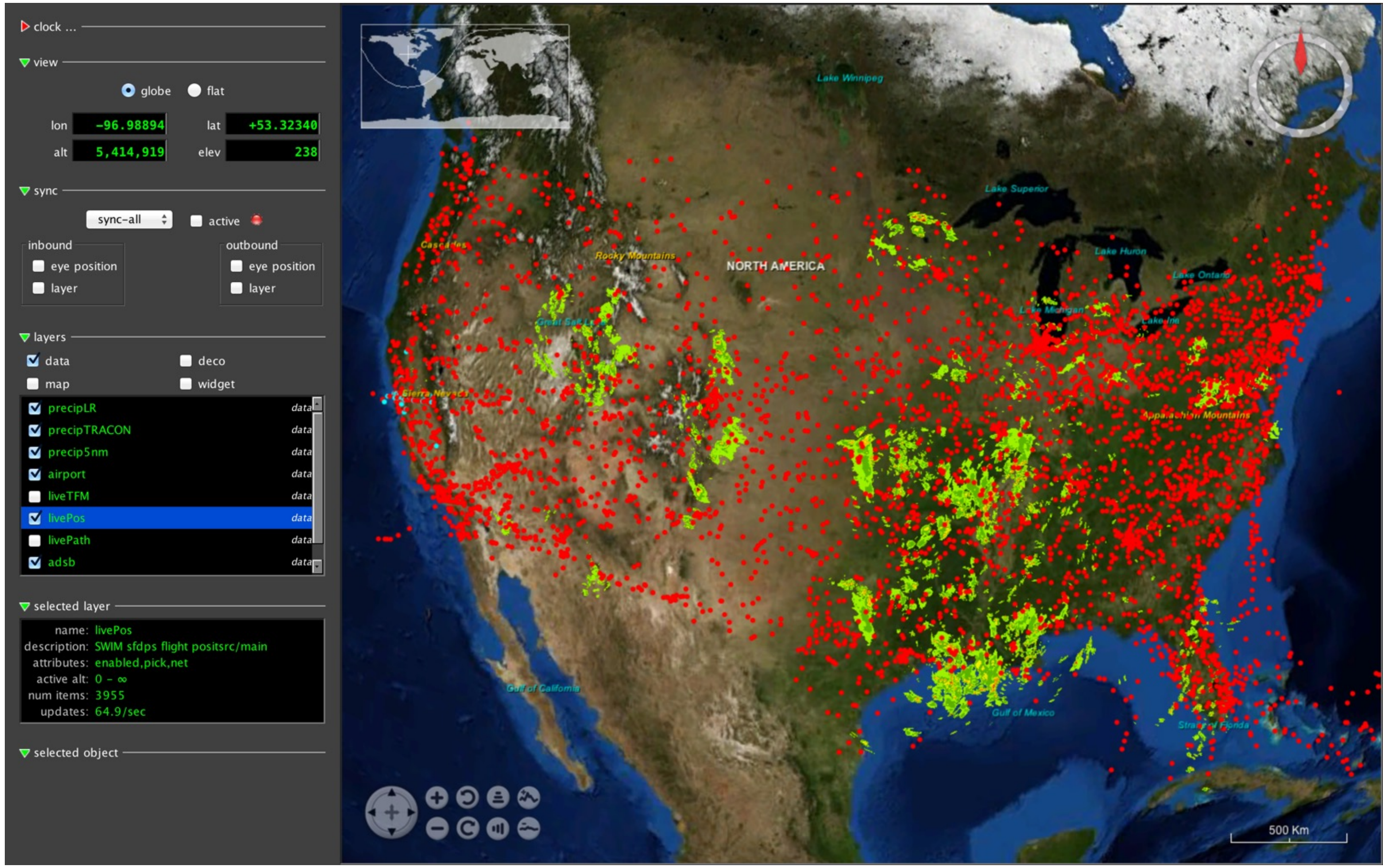


Data Diversity, Volume, and Visualization

Imports Data (1000 msg/sec)



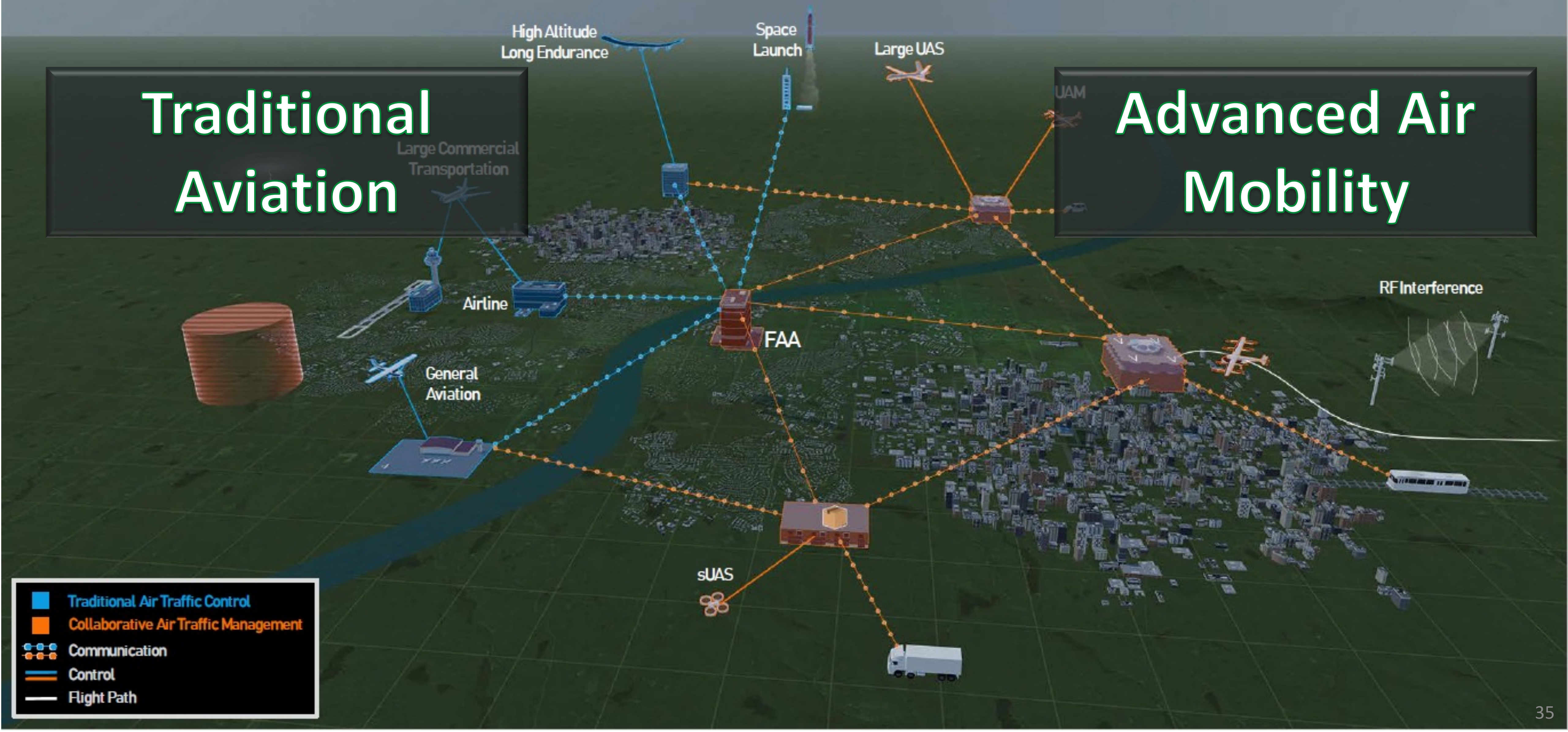
4,500 Simultaneous Flights



Credit: NASA

Transforming Aviation

Transforming Aviation



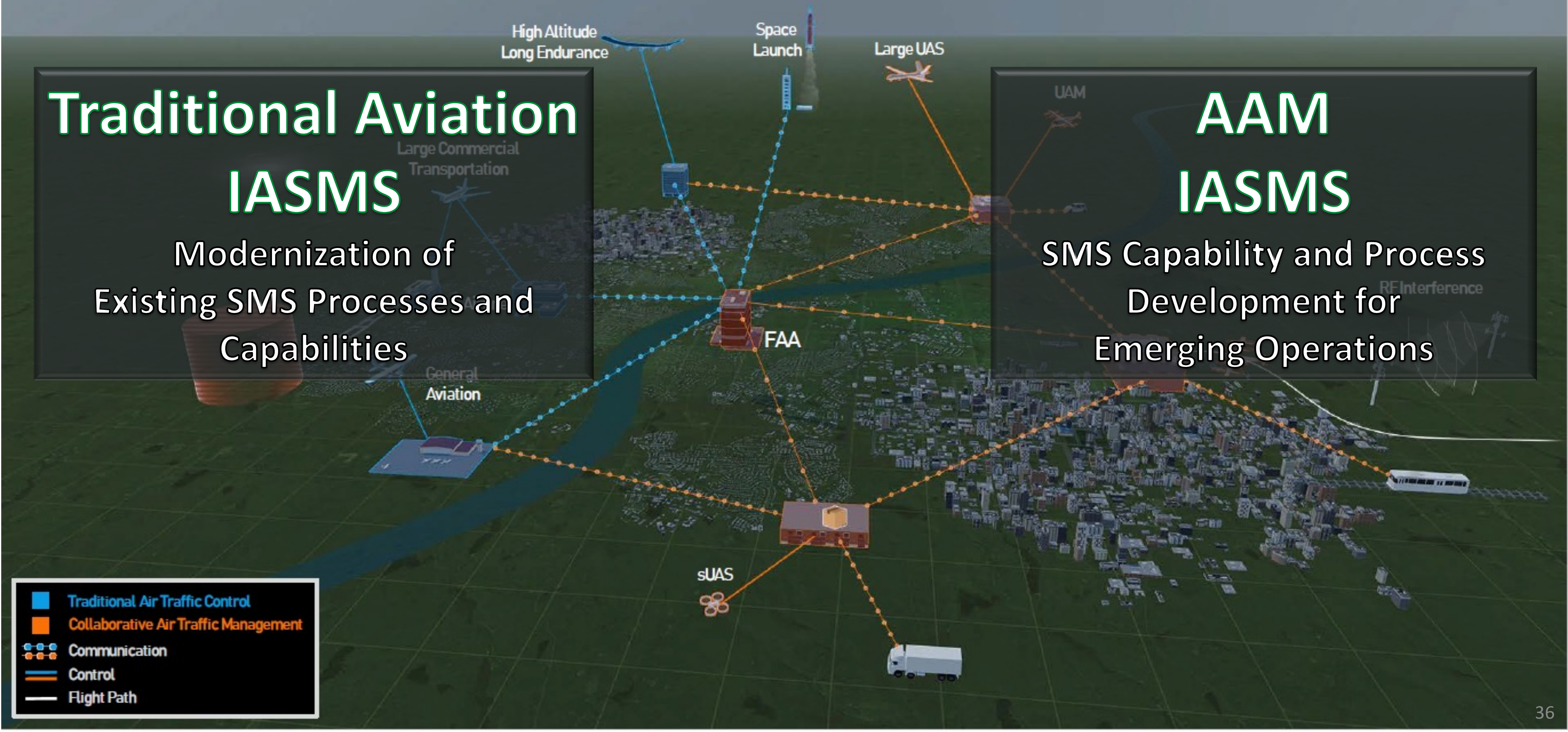
Two Research & Development Threads

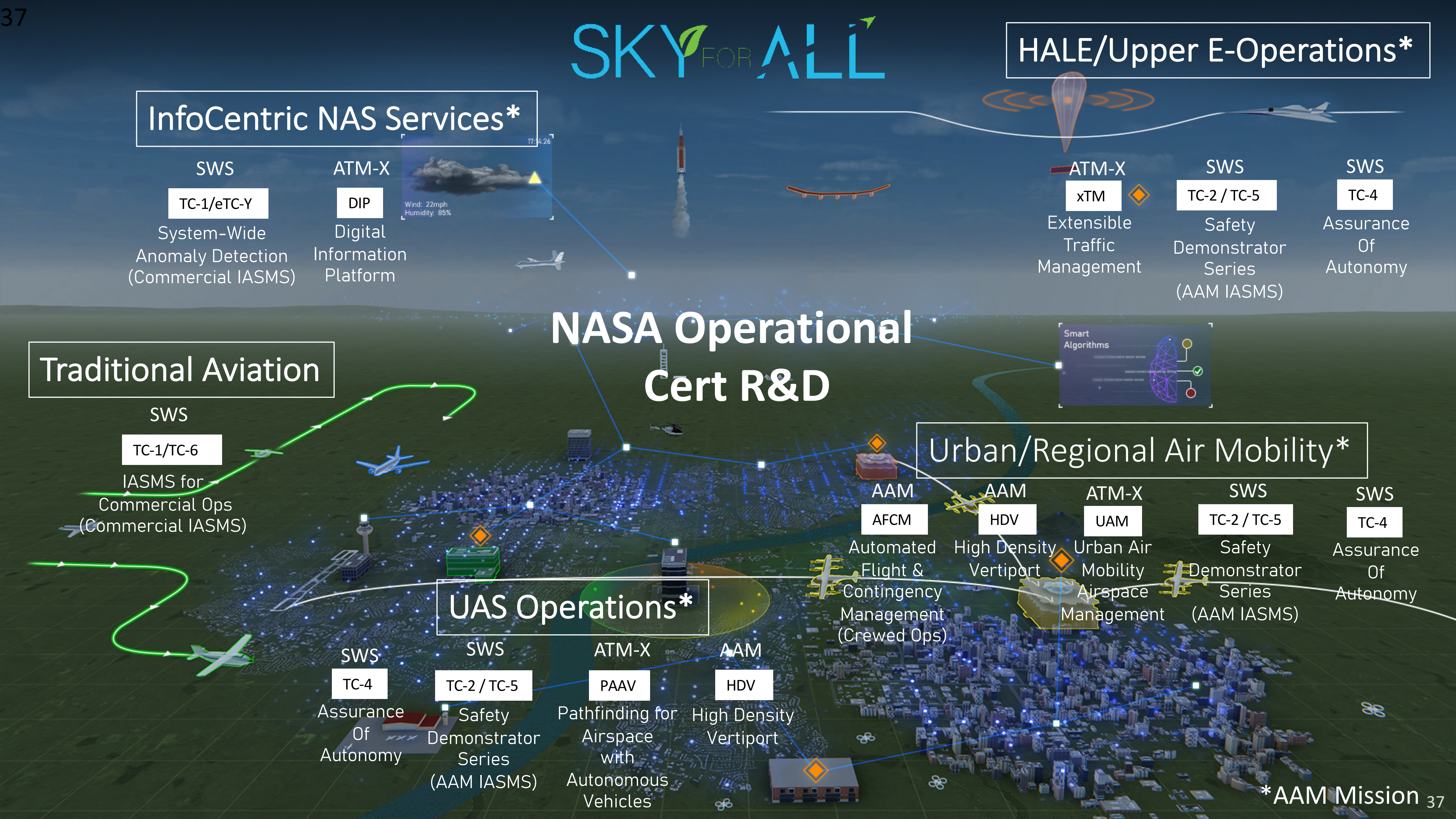
Traditional Aviation IASMS

Modernization of
Existing SMS Processes and
Capabilities

AAM IASMS

SMS Capability and Process
Development for
Emerging Operations




SKY FOR ALL
HALE/Upper E-Operations*
InfoCentric NAS Services*
SWS
TC-1/eTC-Y
System-Wide Anomaly Detection (Commercial IASMS)
ATM-X
DIP
Digital Information Platform
Wind: 22mph
Humidity: 85%
ATM-X
xTM
Extensible Traffic Management
SWS
TC-2 / TC-5
Safety Demonstrator Series (AAM IASMS)
SWS
TC-4
Assurance Of Autonomy
NASA Operational Cert R&D
Smart Algorithms
Traditional Aviation
SWS
TC-1/TC-6
IASMS for Commercial Ops (Commercial IASMS)
Urban/Regional Air Mobility*
AAM
AFCM
Automated Flight & Contingency Management (Crewed Ops)
AAM
HDV
High Density Vertiport
ATM-X
UAM
Urban Air Mobility Airspace Management
SWS
TC-2 / TC-5
Safety Demonstrator Series (AAM IASMS)
SWS
TC-4
Assurance Of Autonomy
UAS Operations*
SWS
TC-4
Assurance Of Autonomy
SWS
TC-2 / TC-5
Safety Demonstrator Series (AAM IASMS)
ATM-X
PAAV
Pathfinding for Airspace with Autonomous Vehicles
AAM
HDV
High Density Vertiport
*AAM Mission


SKY FOR ALL
HALE/Upper E-Operations*
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ATM-X
PAAV
Pathfinding for Airspace with Autonomous Vehicles
AAM
HDV
High Density Vertiport
*AAM Mission

Aviation Safety Information Analysis and Sharing

ASIAS 1.0

Characteristics of the Program:

- Data silos
- Distributed architecture
- Manual data-fusion process
- Sharing of aggregated, de-identified results via web portal
- Baseline governance, roles, and responsibilities
- Commercial and general aviation communities

ASIAS 2.0

Key Changes:

- Integrated production system to support analytic processing requirements
- Higher volumes of data and processing speeds
- Automated capabilities to fuse disparate data sources
- Expanded fusion governance model

ASIAS 3.0

Key Changes:

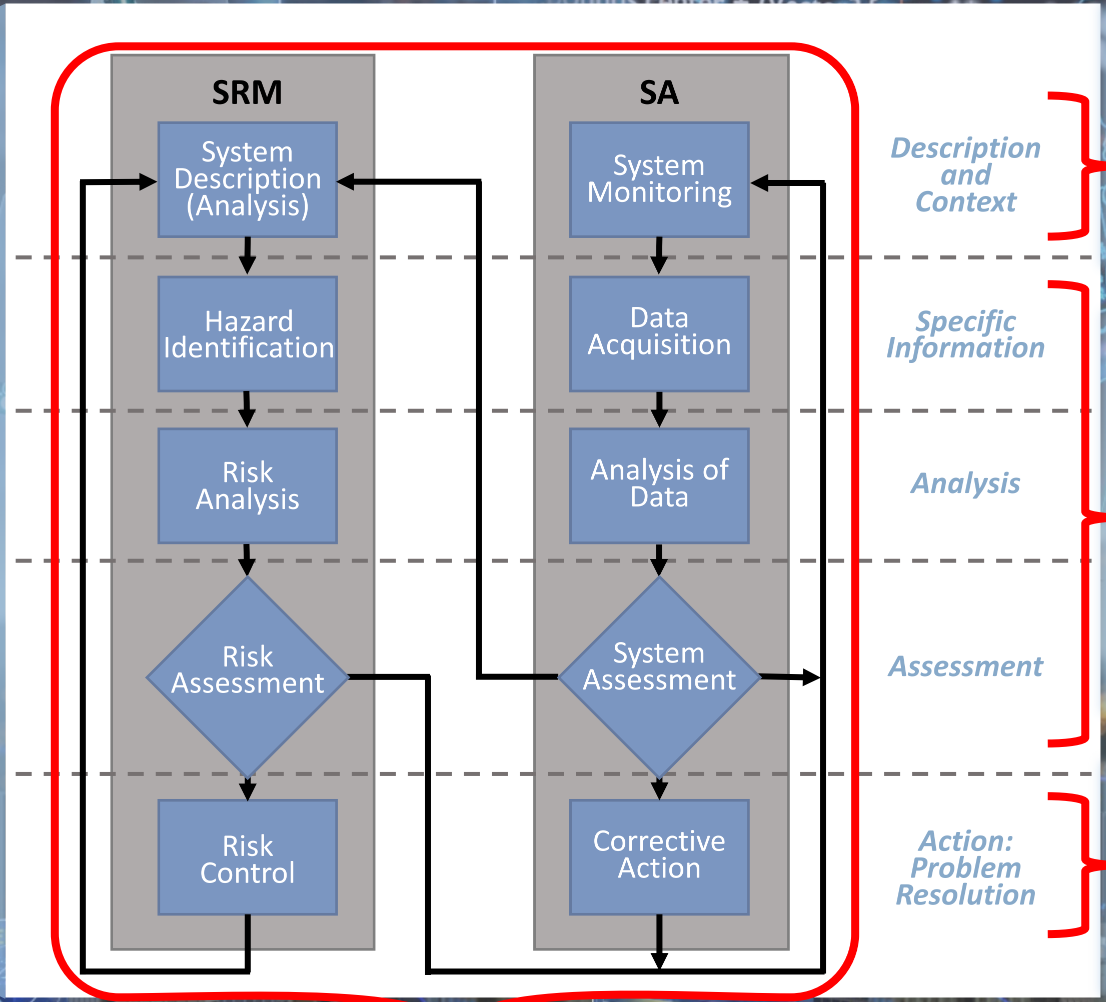
- Predictive analytics and advanced tools to identify emerging risks
- Expansion – new communities, additional data, improved operating processes
- Transformed collaboration – more agile, innovative interactions
- Enhanced access to data by partners, to conduct specific analysis in controlled environments
- Application of fused data to improve quality of analysis

Source: OIG Analysis of the FAA Concept of Operation ASIAS 3.0
DOT Report #AV2021022 (p.15), March 10, 2021

Advanced Safety Management Systems Enabled by Safety Intelligence

Needs

- Timely 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



Monitor

Assess

Mitigate

Assure

- Novel Verification and Validation Methods
- Assurance of Autonomy
- Overarching Properties

R&D Required:

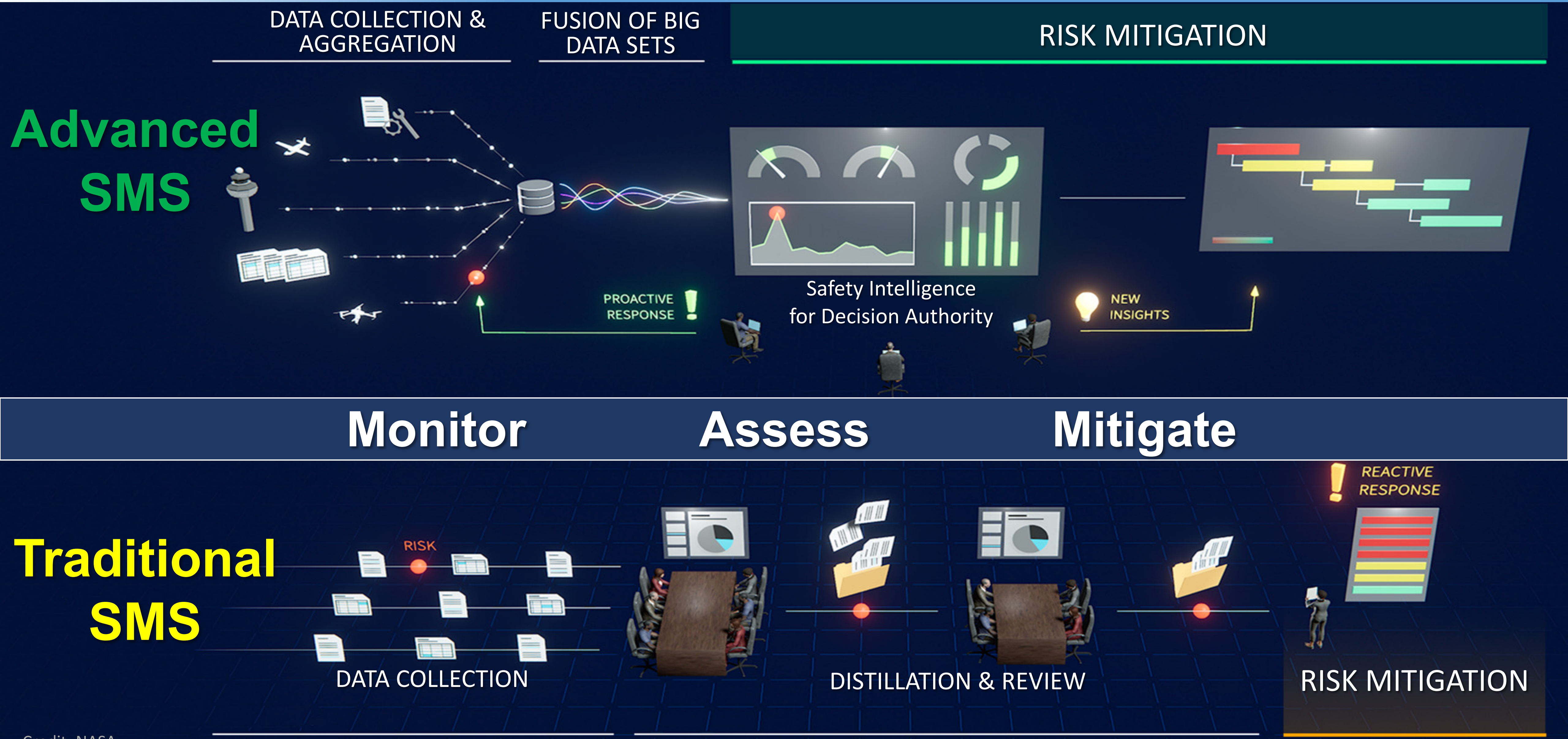
- New Safety Databases
- Non-traditional data
- Data Fusion w/existing services
- Required vs. Voluntary Data
- Synthetic Data Generation

- 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

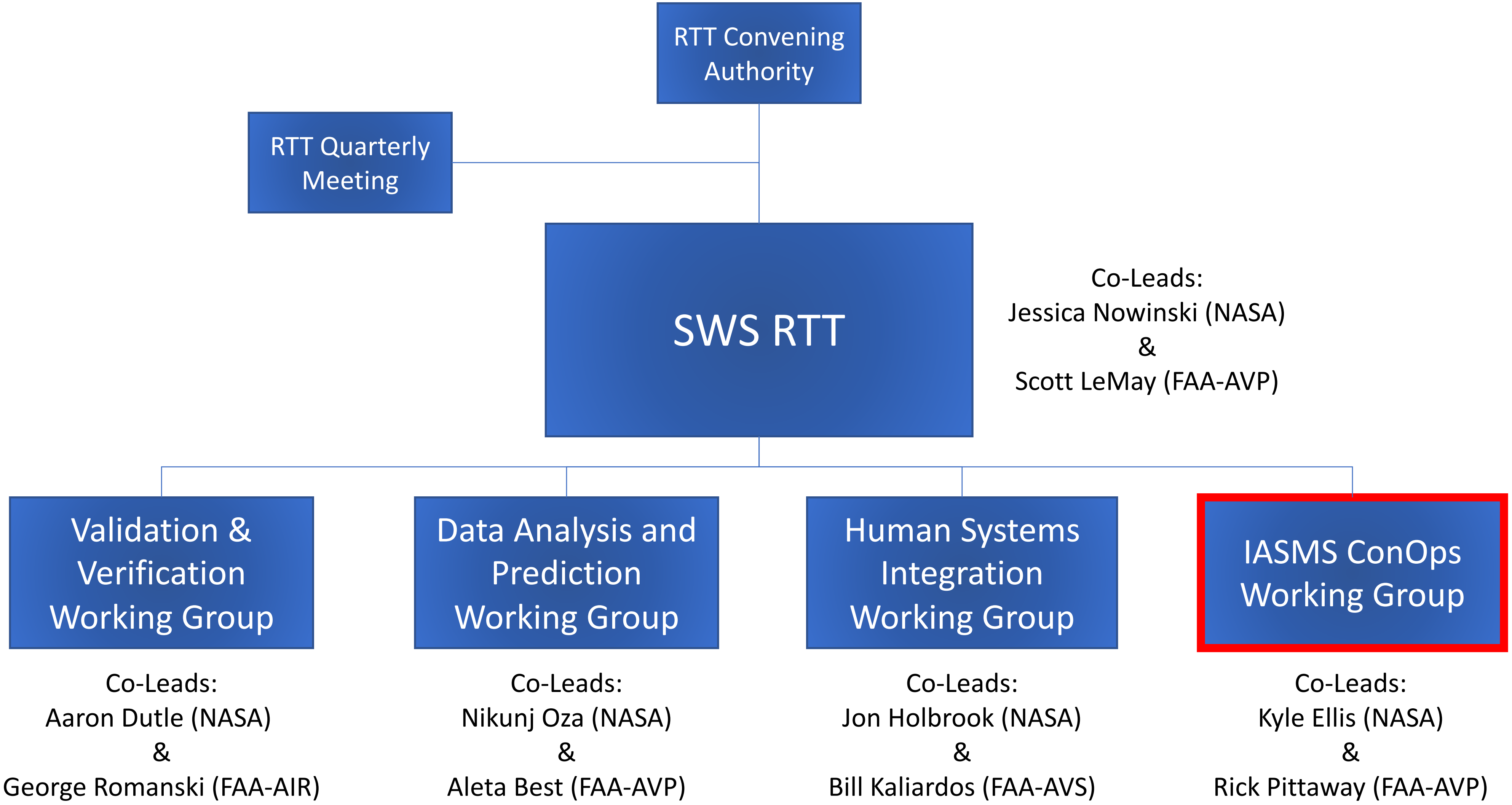
Figure from FAA AC No: 120-92B, Safety Management Systems for Aviation Service Providers

Modernization of SMS

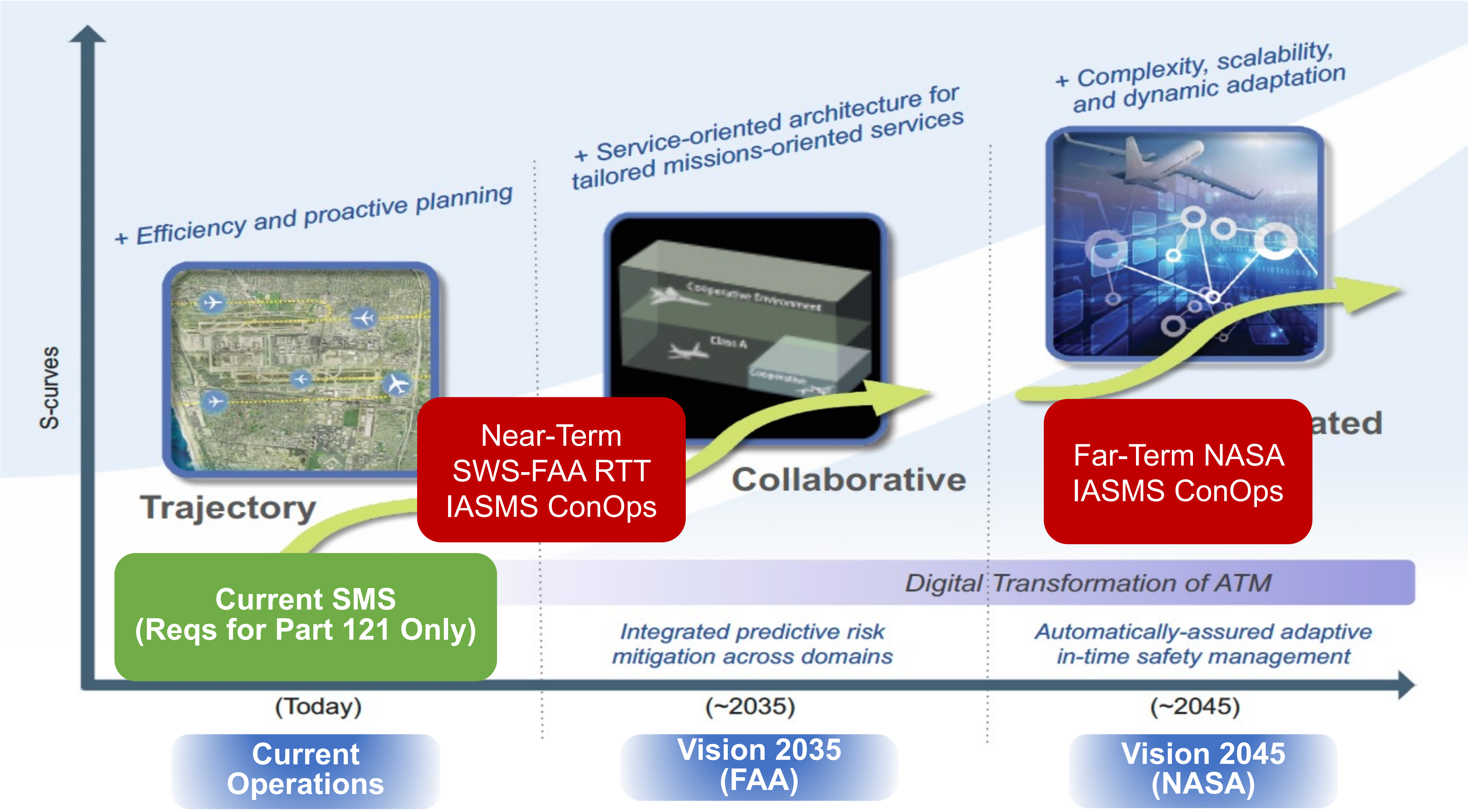


Credit: NASA

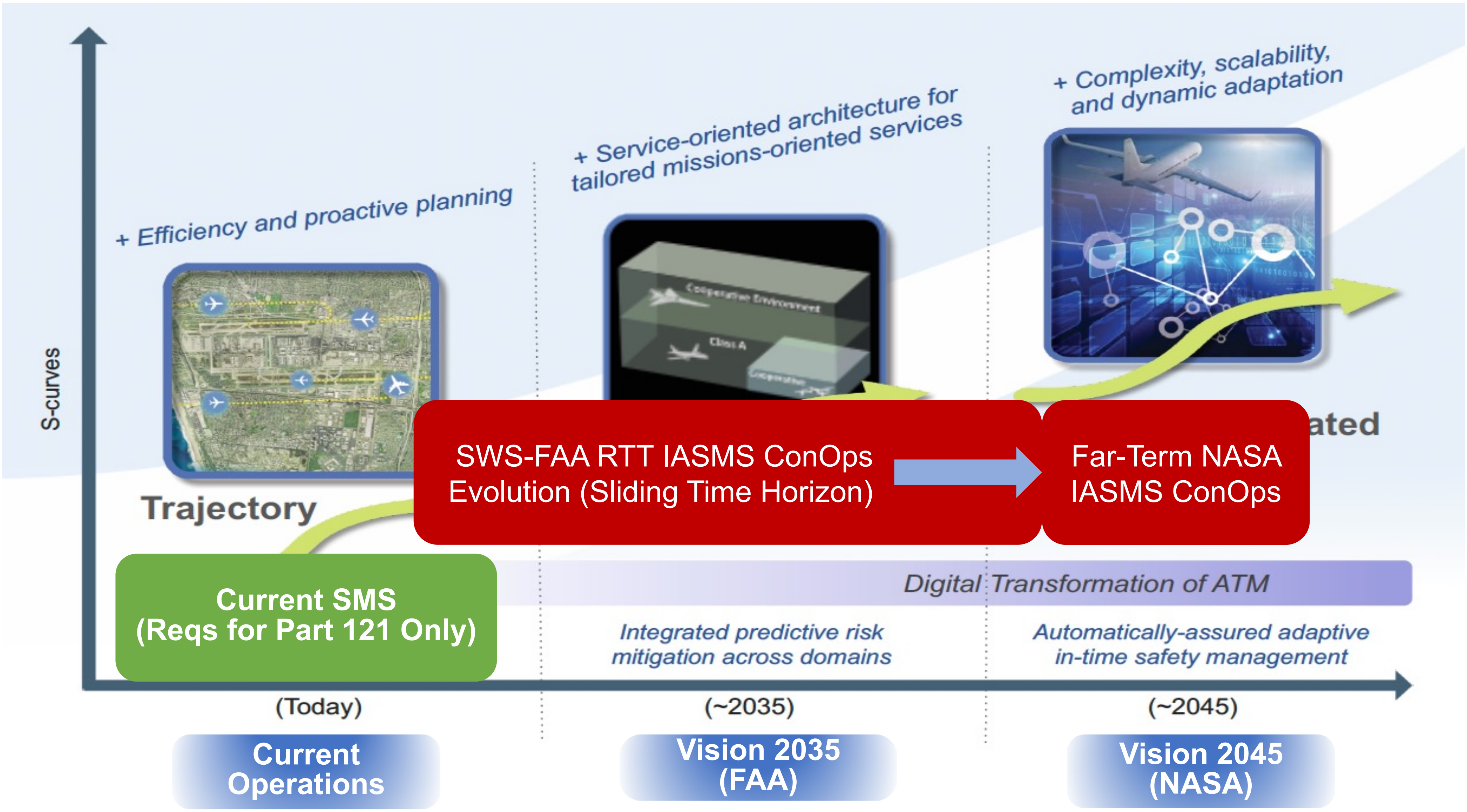
SWS RTT Structure



SWS RTT & IASMS ConOps Development



SWS RTT & IASMS ConOps Development



SMS Path to the Future: IASMS

- Integrates and accelerates the *Reactive*, *Proactive*, and *Predictive* safety processes that are critical to airspace transformation, and intended to help enable and ensure a future interoperable, revolutionary and safe “Sky for All”

- Provides extensible and tailorable risk management and safety assurance approaches that utilize system-wide data to provide in-time alerting and mitigation strategies posited to be more effective and responsive to resolving known and unknown risks

- Key research and technology gaps exist as critical paths for IASMS

Credit: NASA

Safe – Sustainable – Efficient – Scalable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