Evolution of the NAS

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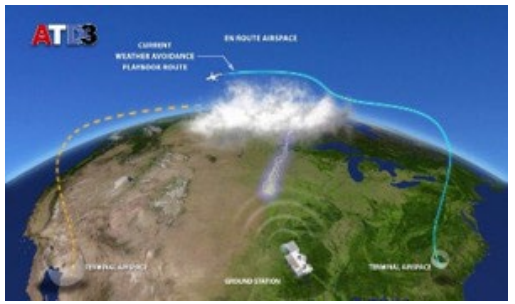
Success Stories: ARMD Research Technology Transfers to FAA

- **Terminal Sequencing and Spacing (TSAS) and Flight Deck Interval Management (FIM) (FY 2011-2017, $102M)**
  - Forecast $500 million national fuel savings
  - FAA national deployment in Time Based Flow Management (TBFM) starting with Denver in 2020
- **Integrated Arrival, Departure, Surface Operations (FY 2015-2021, $128M)**
  - 462,211 gal of fuel saved and 9,552,417 lbs CO_2 emissions reduction, 2,448 hours reduced engine runtime (as of Sept 30, 2019 CLT trials)
  - FAA's Terminal Flight Data Manager (TFDM) Program will deploy IADS capabilities to 27 airports beginning in 2021
- **Efficient Re-routes Around Weather (FY 2015-2019, $57.8M)**
  - Demonstrated re-routes are more direct, fuel-efficient, wind optimal, conflict free, and avoid congested airspace (2018)
  - Multi-flight Common Routes and Dynamic Routing Around Weather informing FAA Traffic Flow Management System (TFMS)

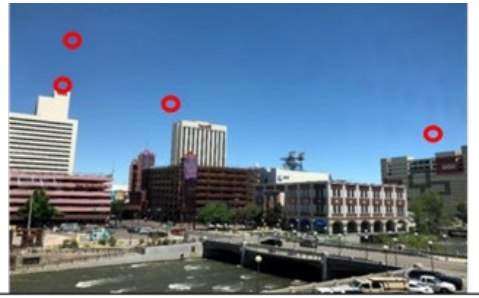
Source: Boeing



Pre-Decisional: For NASA Internal Use Only

Success Stories: ARMD Research Technology Transfers to FAA

- **UAS Traffic Management Low-altitude Small UAS Operations in Dense Urban Environments (FY2015-2021, $107M)**
  - Reno, NV, June 17-28, 2019 and Corpus Christi, TX, August 12-23, 2019
  - Enable FAA's UTM Pilot Program and UAS Integration Pilot Program and Low Altitude Authorization and Notification Capability (LAANC)
- **UAS Integration in the NAS (FY2011-2021, $297M)**
  - Recommendations based on research findings for Detect and Avoid, Command and Control and Human Performance leading to RTCA and FAA Standards (2020)
- **Deliver to Six Commercial Aviation Safety Team (CAST) Safety Enhancements (FY 2015-2019, $ 32M)**
  - Stall prevention and recovery, aircraft state awareness (2019)
  - In response to CAST SE recommendations following accidents
  - Technology transfer algorithms to FAA and airlines to assist in enhanced simulator training for aircraft stall and upset recovery.



Four UAS autonomously flying over Reno managed by UTM

CAST | The Commercial Aviation Safety Team

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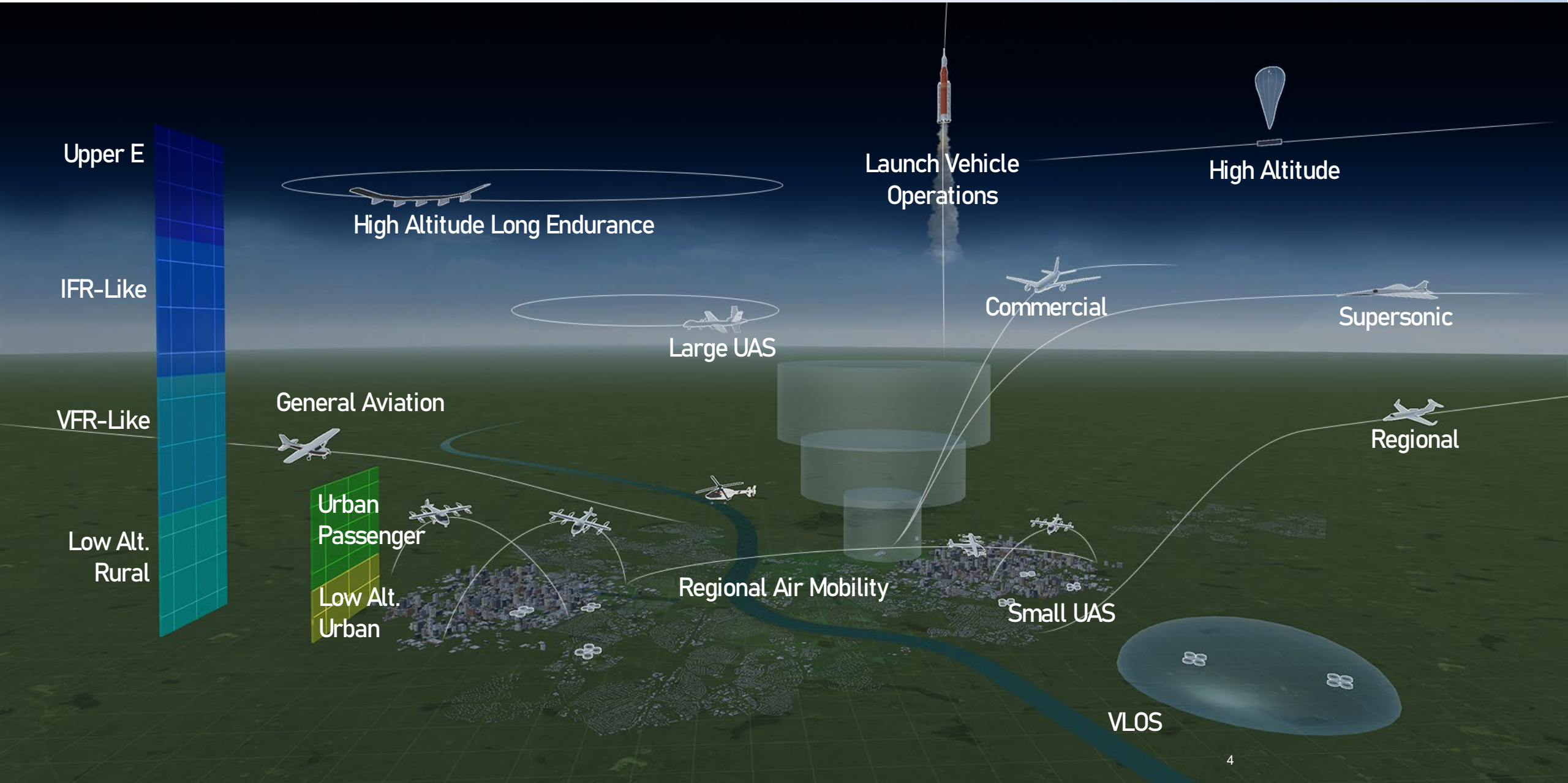
Operational Domains in the Future Airspace

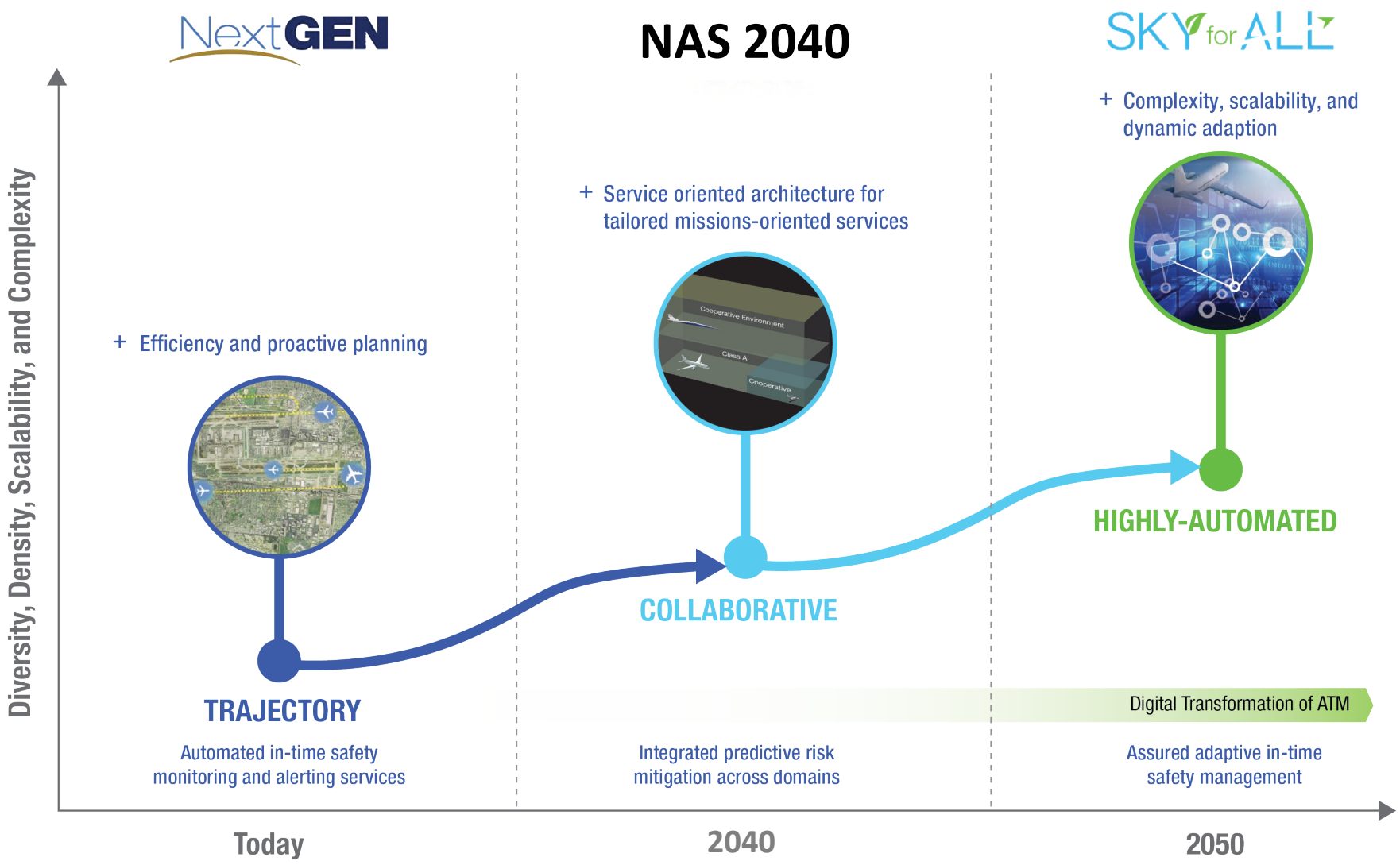


Future Airspace Vision Drivers

- Diversity
  - Vehicles, Performance and Missions
  - Takeoff and landing locations
- Density
  - Operations increase from 10's K to millions
  - Emergent aviation lower altitude operations
- Complexity
  - New operations, airspace
  - Interoperability
- Human-centric approach for provision of airspace and safety services limits scalability

Transformation is Needed to Accommodate Future Operations

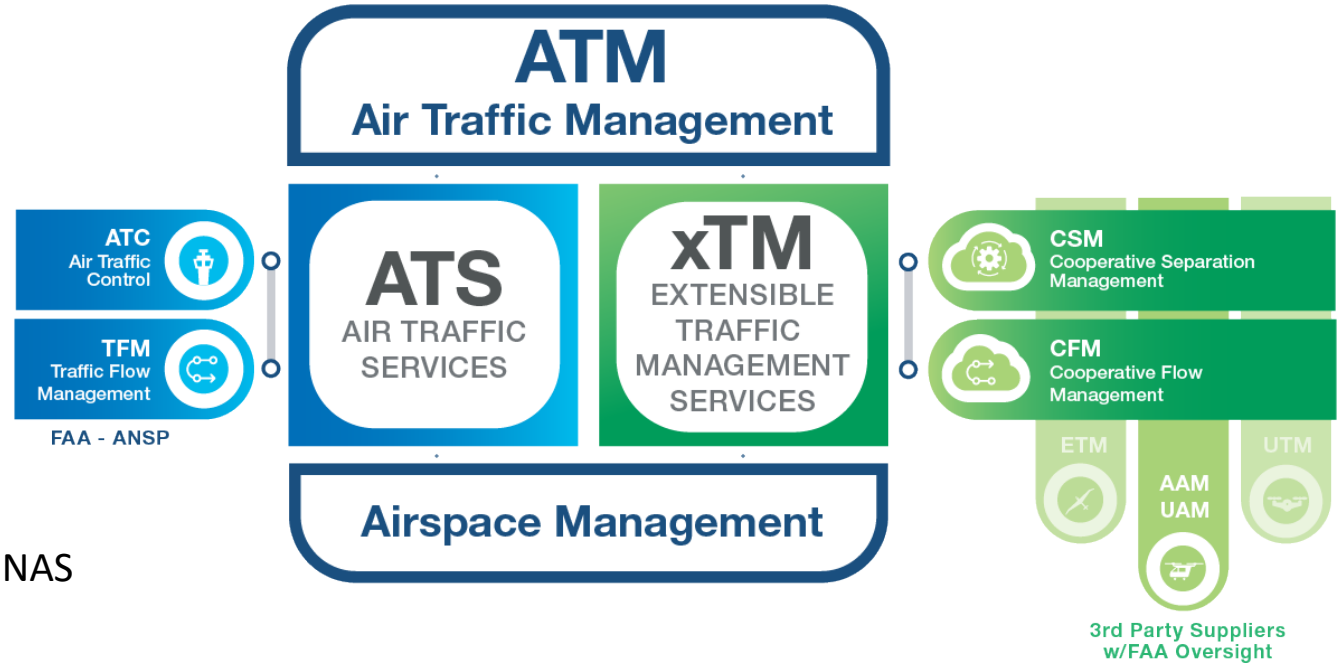
Airspace Vision and Strategy



ICN provides data to power the Sky for All transformation

Airspace Vision and Strategy

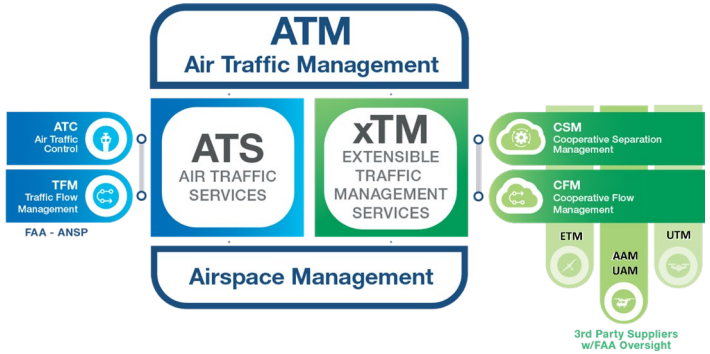
- Seamless Integration of Future Diverse Operations
  - Federated Architecture
  - Mission and Service-Oriented
  - Increasingly Autonomous
  - Prognostic Safety
- Technical Approach
  - Validate xTM Concept
    - Define Architecture and Interoperability
  - Evolution of NAS Operations
    - Data-driven ATM Technology for the Existing NAS
    - Disruptive Capabilities for the Future NAS
  - In-Time Safety Assurance
    - Leverage data analytics toward predictive and prognostic safety services
    - Validate IASMS concept and architecture



Digitized, ML and AI-Enabled, Highly Automated & Increasingly Autonomous

NASA and FAA Jointly Delivering Four NAS 2040 Cornerstones

Extensible Traffic Management (xTM)



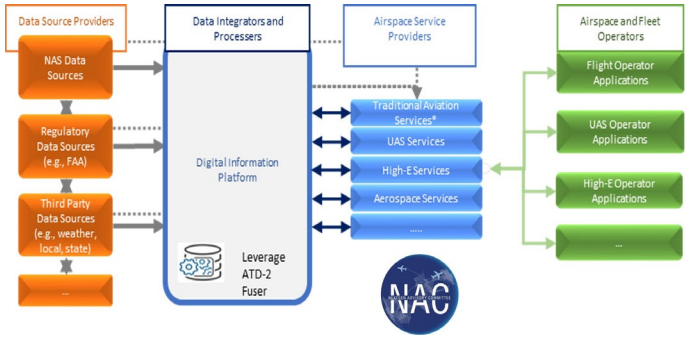
In-Time Aviation Safety Management System (IASMS)

NAS 2040

Integration of Emergent and Autonomous Vehicles

UAS
HALE
AAM-UAM

Digital Services Environment (DIP)



AOSP Contributions Toward Airspace Transformation

Evolve Toward Federated, Service-Oriented NAS

Digital Information Platform – Data fusion, ML/AI, Agile deployment, ATC and airline services, Sustainable ops demos

Pathfinding for Autonomous Airspace and Vehicles – Integration of remotely piloted/supervised ops in the NAS, Infrastructure as a service

In-Time Aviation Safety Management System – In time safety assurance services and SMS

Validate xTM Concept

Upper-E Traffic Management – Cooperative operating practices for diverse ops, Conflict Mgmt

UAS Traffic Management Beyond Visual Line of Sight - Pathfinding for rulemaking Interoperability of services, Validation of services

Air Mobility Pathfinders – Architecture, Cooperative operating practices, Interoperability of services, xTM-ATS Interoperability, Requirements for passenger ops, Vehicle, Safety

In-Time Aviation Safety Management System – In time safety assurance services and architecture

Leveraging NASA/FAA Research Transition Teams

- Advanced Air Mobility RTT
  - Architecture for the xTM Concept
  - Integration of Autonomous Vehicles into the NAS
- Digital Mesh Technology and Applications RTT
  - Digital Information Platform for Commercial Transports Enabling Service-oriented Architecture
  - ML/AI Digital and Intelligent ATM Services
- Upper E Traffic Management
  - xTM Concept and Mission-oriented Architecture
- UAS Traffic Management RTTs
  - BVLOS for UAS
  - Interoperability
- System Wide Safety RTT
  - In-Time Aviation Safety Management
  - Data Analytics
  - V&V of Complex Systems/Assurance of Autonomy
- Wildfire Management RTT
  - Airspace Access
  - Traffic Management

Summary

- Great progress made on alignment and joint evolution of Sky For All
  - FAA, CANSO, SESAR Joint Undertaking, ATCA, NATCA, Flight Safety Foundation
- AOSP portfolio well aligned to deliver key NAS 2040 capabilities
  - xTM, DIP, IASMS
- AAM, ETM, UTM excellent initial pathfinding for NAS 2040 and Sky For All
- Further refinement of Sky For All in FY24-25
  - Initial Concept of Operations, Functional Reference Architecture, R&D Roadmap
- Key Questions/Studies
  - Autonomy Roadmap
  - Future Flight Decks Roadmap
  - CNSS Requirements Roadmap
  - V&V and Assurance of Autonomy