ARMD Strategic Thrust 1: Safe, Efficient Growth in Global Operations

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May 13, 2016

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Thrust 1 Roadmap Briefing Contents

- ARMD Roadmap Elements
- Outcomes, Vision, Benefits, Capabilities
- Strategies and Key Dependencies
- Research Themes
- Roadmap and Roadmap-Required Activities
- NASA and Partner Contributions
- Summary

ARMD Roadmap Elements

ARMD Strategic Implementation Plan

Strategic Thrusts

Outcomes and Vision

Benefits, Capabilities (Expanded Outcomes)

Research Themes

Roadmap and Overarching Technical Challenges

Strategies tie together roadmap elements

Technical Challenges (Determined by programs)

Safe Efficient Growth in Global Operations

Within the United States, NextGen is the focus for a modernized air transportation system that will achieve much greater capacity and operational efficiency while maintaining or improving safety and other performance measures.

- ARMD will contribute specific research and technology to enable the continued development of NextGen and beyond.
- Projected growth in air travel will require a sustained focus on reducing safety risks to maintain acceptable levels of safety.
- ARMD will work with the FAA, the Commercial Aviation Safety Team (CAST), and others to perform research and to contribute technology addressing current and future safety risks.
- Similar ongoing international developments, such as the European Union's (EU's) Single European Sky Air Traffic Management Research (SESAR) effort, are being globally harmonized through the International Civil Aviation Organization (ICAO).

In order to achieve the Strategic Thrust 1 Outcomes, NASA will need to coordinate with it's aviation community partners

- The aviation community, including the FAA and airlines, are the customers for NASA ATM technology. As such it is imperative that we closely coordinate our activities with these partners.
- This coordination, while not explicitly shown, is imbedded in the activities of each Research Theme.

Community Outcomes, Vision & Benefits by Epoch

Community Outcomes, Vision & Benefits by Epoch			
	2015	2025	2035
Outcomes	ATM+1 Improved NextGen Operational Performance in Individual Domains, with Some Integration Between Domains	ATM+2 Full NextGen Integ. Terminal, En Route, Surface, and Arrivals/Departures Operations to Realize TBO	ATM+3 Beyond NextGen Dynamic Autonomous Trajectory Services
Vision	Improve NAS efficiency by implementing ongoing technology development in individual ATM domains and laying the foundation for revolutionary advances for both ATM+2 and ATM+3. It includes: modeling & sim. Tools to test TBO and NextGen concepts, and focus on safety issues such as loss-of-control and hazard awareness and detection	Improve NAS efficiency and predictability by implementing gate-to-gate TBO. Continue progress toward ATM+3 by providing enabling technologies including: new ATM concepts, real-time, predictive modeling & sim tools integrated with safety assurance capabilities and integrated safe autonomous UAS operations	Revolutionary global aviation system with high levels of autonomy and safety prognostics that demonstrate game-changing efficiencies and enable new markets and vehicles
Benefits	Improved domain efficiency at the earliest possible date, supporting cost savings and reduction of environmental impact	System efficiency, predictability, and reliability gains to further improve operations and support traffic growth, including UAS	Dynamic, fully autonomous trajectory services enabling rapid adaption to meet user demand or respond to system perturbations

Community Outcomes, Benefits, and Capabilities

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Capabilities	• Operational domain TBO • Collaborative Decision Making	• Gate to gate TBO and other NextGen capabilities • Implementation of novel ATM capabilities brought on by disruptive technologies	• ATM beyond NextGen • Advanced automation and elements of autonomy integrated into the NAS
	• Initial UAS integration in the NAS	• Integrated autonomous UAS operations & new vehicles types into the NAS	• Safe routine access of all vehicle types & classes in the NAS
	• Improved weather & hazard awareness and Hazard Detection • Weather integrated into core traffic management functionalities	• Safe global operations with all-weather capability & prognostic safety awareness, prediction and alerting • Introduction of cyberphysical systems to enhance safety	• Safe global operations with resilient degradation • Advanced computational methods & platforms, critical data infrastructure / data sharing
	• Modeling & Sim Tools to test new ATM & NextGen Concepts	• Enhanced Modeling & Sim Tools with predictive & alerting capabilities	• Operational modeling to include real-time multi-vehicle near continuous optimization with real-time data
	• Satellite based communications to enable NextGen	• Secure CNSi architecture to support autonomous operations	• Robust CNSi enabling increasing autonomous operations

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Capabilities	• ATD Demos • Domain Metering and domain TBO technologies	• Gate to gate TBO/TFM technologies in conjunction with the FAA • Novel ATM capabilities brought on by disruptive technologies	• Technologies and concepts beyond NextGen • Advanced automation technologies allowing autonomy integrated into the NAS
	• Guidelines & Standards for initial UAS integration in the NAS	• Technologies, Guidelines & Standards for integration of all vehicles types into the NAS	
	• Improved weather & hazard awareness prediction and alerting technologies • Safety analyses for new airspace concepts • Safety technologies for new vehicle concepts	• Technologies for safe global operations with all-weather capability, multi-domain situational awareness and prognostic safety awareness, prediction and alerting	• Technologies for safe global operations with resilient degradation • Adaptation of advanced computational methods & platforms, critical data infrastructure/data sharing
	• SMART-NAS testbed	• Operational SMART-NAS testbed with predictive capabilities	• Modeling to include real-time multi-vehicle near continuous optimization with real-time data
	• Requirements for a secure CNSi system for TBO	• Secure CNSi architecture requirements to support autonomous operations	

Thrust 1 Strategies

- Develop the technologies for NextGen followed by the technologies for revolutionary ATM+3 capabilities in close cooperation with the FAA and other stakeholders (other agencies, airlines, industry and academia), as well as our international partners ensuring global harmonization with international research activities
- Enable full, unimpeded, safe, and secure access to the NAS for all vehicle classes and missions, while minimizing environmental impacts such as noise and emissions
- Develop and support the integration of revolutionary ATM concepts and technologies created by disruptive technologies
- Lead the expansion of ATM capabilities by supporting the implementation of automation/autonomy and prognostic safety technologies as they become available for all parts of the NAS
- Provide a capability to test, validate, and demonstrate complex NAS operational concepts and technologies and mature them to become an active real-time system

Key Dependencies

- Senior level coordination with the FAA continues to be as effective as it is now to support planning, execution and transfer of projects
- RTTs remain in place and function effectively to assist the technology transfer and new activity planning
- Continued support from airlines, airports, industry, academia and international partners to both work with us and support our planning
- Advances in and implementation of automation (robotics, sensor networks, advanced computing capabilities, etc.) and secure communications keep pace with ATM needs

Research Themes

- Advanced Operational Concepts, Technologies, and Automation
  - Research and development of operational efficiency incorporating proactive safety risk management in operational domains
- Safety Management for Emergent Risks
  - Research and development of prognostic safety risk management solutions and concepts for emergent risks
- Integrated Modeling, Simulation, and Testing
  - Development, validation, and application of advanced modeling, simulation, and testing capabilities to assess integrated, end-to-end NextGen trajectory based operations functionality, as well as seamless UAS operations and other future aviation system concepts and architectures
- Airspace Operations Performance Enablers
  - Advanced research to develop performance requirements and guidelines for enablers including operational guidelines and standards for new vehicles, secure CNSi infrastructure requirements, and reliable assurance requirements of safety critical software

Roadmap Chart Format

2015	2025	2035
ATM+1 Improved NextGen Operational Performance in Individual Domains, with Some Integration Between Domains	ATM+2 Full NextGen Integ. Terminal, En Route, Surface, and Arrivals/Departures Operations to Realize TBO	ATM+3 Beyond NextGen Dynamic Autonomous Trajectory Services

Technology Transfer

Advanced Operational Concepts, Technologies, and Automation

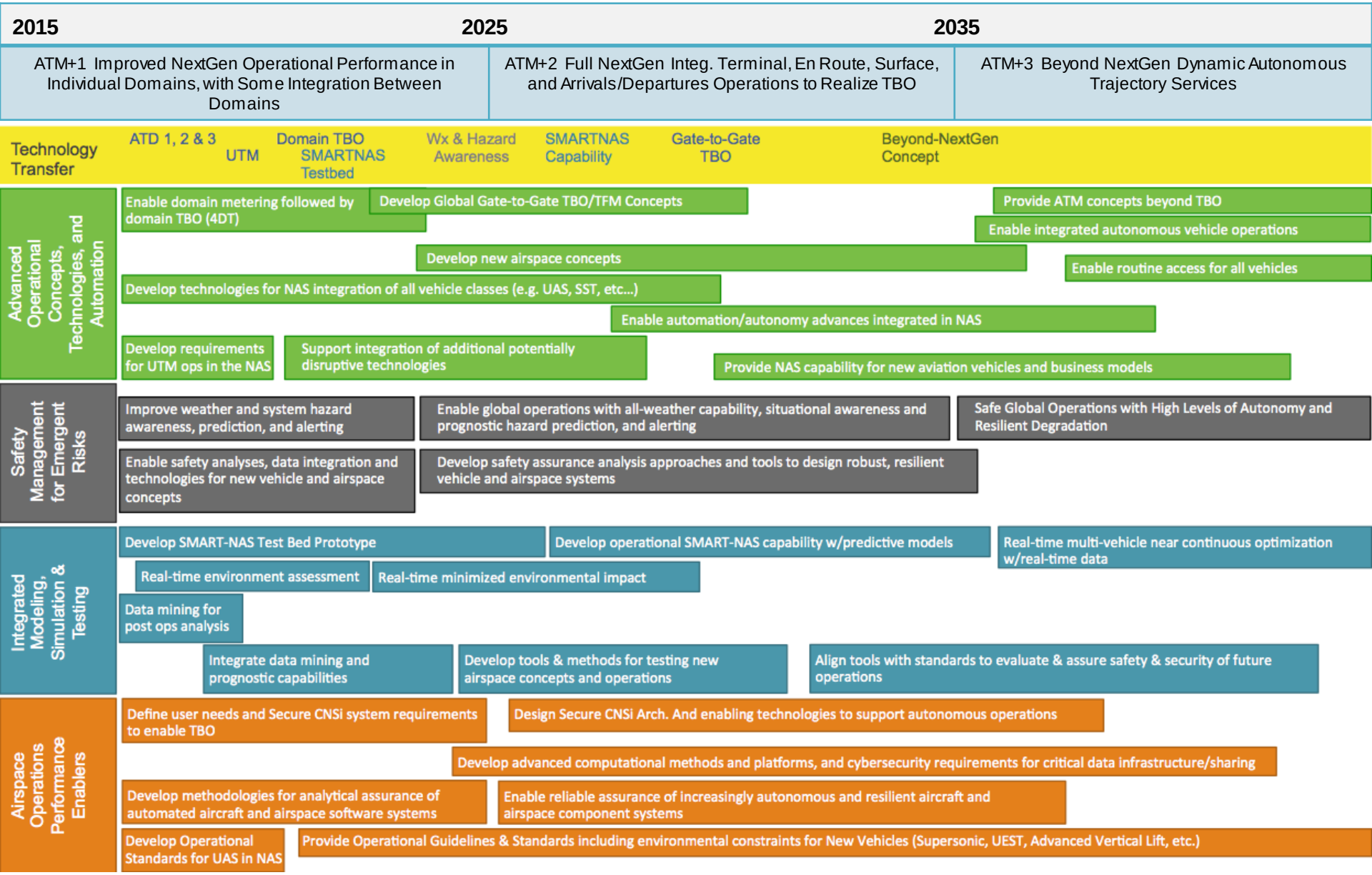
Safety Management for Emergent Risks

Integrated Modeling, Simulation & Testing

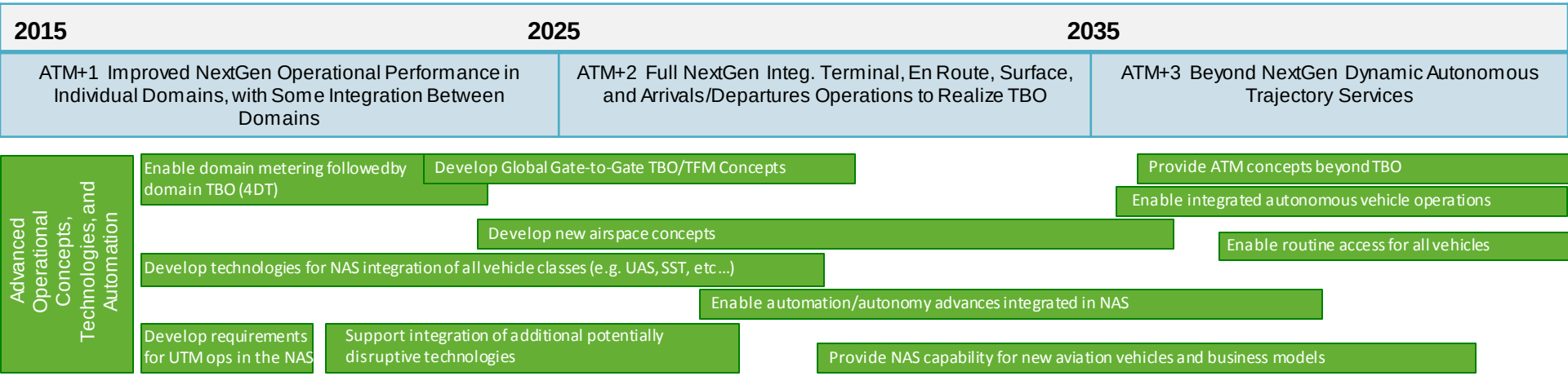
Airspace Operations Performance Enablers

ARMD Roadmap diagram format

Safe, Efficient Growth in Global Operations



Roadmap-Required Activities

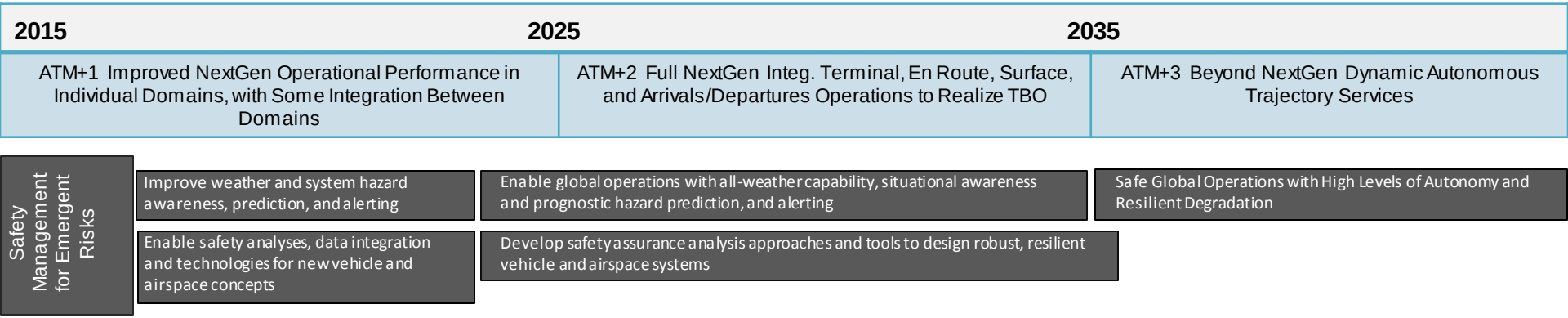


- ATD-1, -2 and -3
- Integrated departure management-trajectory based operations (IDM-TBO)
- ATD-4
- Gate-to-gate TBO architecture & feasibility
- Develop gate-to-gate TBO concepts including integrated user/service provider and datacomm collaborative trajectory services
- Develop requirements for integrating UTM operations in the NAS
- Enable TBO operations in all-weather conditions

- Integrate ATD and gate-to-gate TBO technologies
- Complete high-TRL gate-to-gate TBO Demos
- Define requirements for integrating disruptive technologies in the NAS
- Develop technologies for NAS integration of all vehicle classes (e.g. UAS, SST, etc.)
- Develop concepts for highly automated airspace
- Develop requirements for advanced operational concepts
- Develop technologies for TBO integration in low altitude airspace for high speed vehicles

- Develop requirements for integrating new aviation vehicles and business models in the NAS
- Demonstrate autonomous aircraft operations integrated into ATM system operations
- Integrate operations enabling routine access to all airspace for emerging vehicle classes
- Develop airspace operations concepts for beyond TBO operations

Roadmap-Required Activities

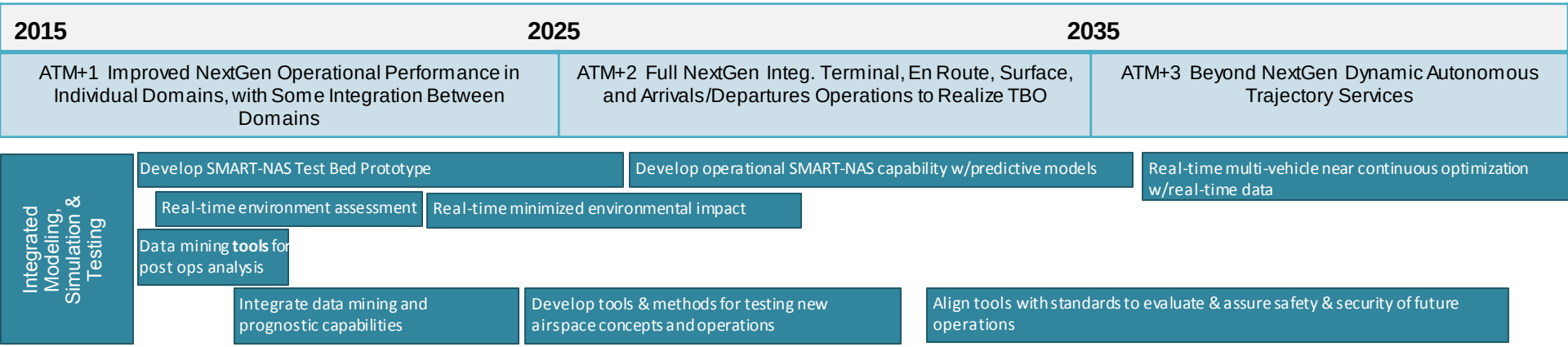


- Enable safe, improved weather prediction and alerting capabilities
- Develop resilient human/system interaction under increasing levels of autonomy
- Develop technologies to enhance airplane state and hazard awareness for resiliency during NAS operations
- Conduct safety analysis for new vehicles and airspace concepts
- Enable data mining techniques to inform and enhance operational system safety and performance

- Enable safe global all-weather operations with prognostic hazard awareness, prediction and alerting
- Develop resilient human/system interaction under high levels of autonomy
- Develop technologies for integrated pilot/vehicle/automation and system state awareness
- Develop safety assurance approaches associated with emerging operational hazards for the design of robust, resilient vehicles and airspace systems

- Develop assured fail safe operations of new vehicles and operational concepts
- Enable assured safe vehicle operations, including vehicle adaption and self-optimization
- Enable safe global operations with high levels of autonomy and resilient degradation
- Design the capability to enable full system situational safety awareness from global environment to a local NAS element

Roadmap-Required Activities

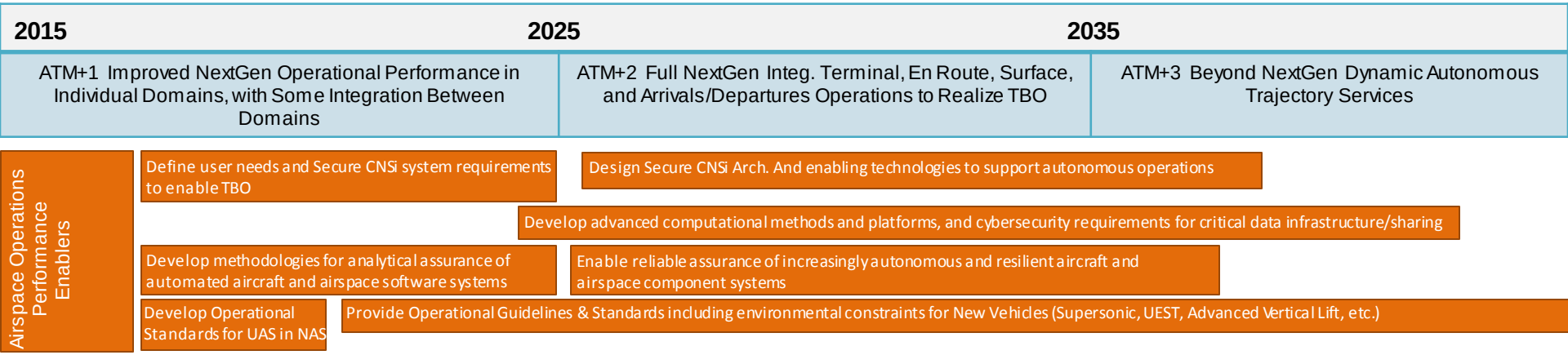


- Define architecture requirements and develop SMARTNAS testbed
- Integrate LVC-DE requirements into SMART-NAS testbed and extend to all airspace & vehicle classes
- Integrate environmental and weather tool-kits for assessment of real-time operations
- Integrate data-mining & safety prognostic tools to conduct post-operations analyses
- Define and develop human performance models
- Define and validate interface and environmental assumptions for newly integrated models, tools and capabilities

- Integrate predictive models for automation and real-time safety assurance into testbed
- Define requirements for new & unconventional vehicle operations
- Develop methods for real-time minimized environmental impact
- Develop tools & methodologies for testing new airspace concepts and operations
- Integrate methodologies to enable in-flight validation tests of advanced operational concepts
- Develop and integrate human performance models for autonomous system interaction

- Integrate human performance models for assessing operators in fully autonomous operations
- Conduct validation of models in airspace simulation toolsets using operational and flight test data
- Integrate models of new vehicle concepts and operations
- Enable real-time optimization of vehicle and system-wide operations using simulated and real-time data
- Align tools with standards to evaluate & assure safety & security of future operations.

Roadmap-Required Activities



- Define secure CNS data & security requirements to enable TBO
- Develop Minimum Operational Performance Standards for UAS Detect & Avoid and Command & Control in Class D/E/G airspace
- Develop methodologies for analytical assurance of aircraft component systems
- Develop techniques and methodologies for future system-wide airspace operations (aircraft and ATM ground systems)
- Define operational requirements for integration of new vehicle concepts in the NAS including environmental constraints

- Develop secure CNS technologies for autonomous operations
- Develop advanced computational methods and platforms, including cybersecurity requirements for systems enabling critical data infrastructure and data sharing
- Develop technologies for reliable assurance of increasingly autonomous and resilient airspace component systems
- Develop operational guidelines and standards for new supersonic and subsonic aircraft, vertical lift and others aimed at increasing mobility and reducing environmental impact

- Implement secure CNS for high levels of autonomy
- Enable optimal decision making for dynamic autonomous trajectory services based on system performance metrics, environmental constraints and safety assurance
- Enable assurance from design to implementation of Large Scale Complex Systems (entire ATM+3)

NASA and Partner Contributions

- Foundational research
- Applied Research
- Conceptual design and trade studies
- Advances in Autonomy
- Computational advances
- Evolving Airframe, Mission & Onboard Capabilities
- Assess business case for evolving and disruptive technologies
- Technical advances in cyber-security
- UAS Mission Requirements
- Development of Guidelines & Standards for Airspace Usage
- Operational Requirements
- Operational Technology Demos
- Risk Mitigation
- Airline industry alignment
- Public policies on evolving and disruptive technologies
- Policies and mechanisms to automatically transfer safety authority between stakeholders
- Automation/ workforce policies
- Deployment
- Operations

NASA	✓	✓	✓	✓		
FAA			✓	✓	✓	✓
Industry	✓	✓	✓	✓		
Academia	✓	✓	✓		✓	
International	✓		✓	✓	✓	✓

Summary

- NASA has developed an initial roadmap for “Safe Efficient Growth in Global Operations” (Strategic Thrust #1)
  - Definition of epochs, outcomes, research themes derived from the ARMD Strategic Implementation Plan
- NASA has developed 5 strategies in definition of Strategic Thrust #1 Roadmap
  - Transitions from current research focused on domain improvements to NextGen vision, and then beyond NextGen to advanced ATM system integrated with highly automated/autonomous operations
  - Operations allow for integration of UAS’ and other types of vehicle operations, while minimizing environmental impacts
  - Addresses the need to support integration of revolutionary ATM concepts & technologies created by “disruptive” technologies
  - Responds to safety needs including short term needs such as loss-of-control, and the long term need to maintain safety of the NAS in the face of increasing number of operations and vehicle types and missions
  - Provide tools to test future NextGen concepts, & advanced concepts looking at highly automated/autonomous operations that also become central to real-time decision-making based on real-time data in the future
- NASA has created a vision for the future that needs to be vetted with our stakeholders, the aviation community and the general public for their feedback and support

Back-Up

Thrust 1 Overarching Strategies

- Develop the technologies for NextGen followed by the technologies for revolutionary ATM+3 capabilities in close cooperation with the FAA and other partners
  - Activities:
    - Successfully complete the ATD-2 2017 and 2020 demos. This will further solidify our FAA relationship.
    - Select and complete comparably important demos for ATD-3 in conjunction with the FAA and appropriate partners.
    - Develop and transfer other enabling TBO technologies.
    - Formalize a partnering arrangement with the FAA for selection of future projects. This should be at the PD level or higher.
    - Continue forming closer ties with the broader aviation community, including international partners.
- Develop revolutionary ATM concepts and technologies to support disruptive technologies
  - Activities
    - Identify new capabilities (e.g., UTM) that will impact the ATM system in a revolutionary way.
    - Enable the development of these concepts by providing ATM related capabilities to support their maturation.
    - Identify and develop new ATM concepts required to enable the integration of these capabilities into the NAS.
    - Include in this strategy disruptive technologies (TBD) as they develop.

Thrust 1 Overarching Strategies II

- Enable full, unimpeded, safe, and secure access to the NAS for all vehicle classes and missions.
  - Activities:
    - Develop technologies enabling integration of all vehicle classes in the NAS (high speed, advanced vertical lift, new subsonic airplane configurations, commercial space operations, and UAS0
    - Develop operational guidelines and standards for new vehicles to operate in the NAS
    - Develop technologies for integrating future autonomous vehicle operations including needs for safe and secure operations.
    - Identify and address UAS-unique ATM needs for safe and secure operations.
    - Form partnerships with stakeholders to leverage technology developments outside of NASA, understand and address emerging demand for nontraditional applications of UAS, and transition NASA-developed technology to implementation.
- Lead the expansion of ATM capabilities by supporting the implementation of automation/autonomy and prognostic safety technologies as they become available
  - Activities:
    - Track the development of automation, autonomy and prognostic safety technologies as related to ATM
    - Provide the enabling technologies for implementation of the appropriate automation and safety capabilities in the NAS.
    - Develop ATM concepts compatible with the new capabilities
    - Provide selected near term safety enhancements
      - Enhance weather and hazard prediction, alerting and automate response utilizing prognostics and incorporating autonomy for resilient degradation
      - Create safety assurance analysis tools for degraded vehicle and airspace systems

Thrust 1 Overarching Strategies III

- Provide a capability to test, validate, and demonstrate complex NAS operational concepts and technologies and mature them to become an active real-time system
  - Activities
    - Provide the research and technology to develop such a system
    - Coordinate activities with the FAA, supplier industries and international partners to ensure the usefulness of the resulting system and to leverage any ongoing external work
    - Enable the development of the desired system:
      - Create a Shadow Mode Assessment Using Realistic Technologies for the National Airspace System (SMART-NAS) testbed
      - Evolve the testbed to a real-time automation capability that becomes central to decision-making and multi-agent optimization based on real-time data