Overview of NASA Aeronautics

Jaiwon Shin
Associate Administrator
Aeronautics Research Mission Directorate
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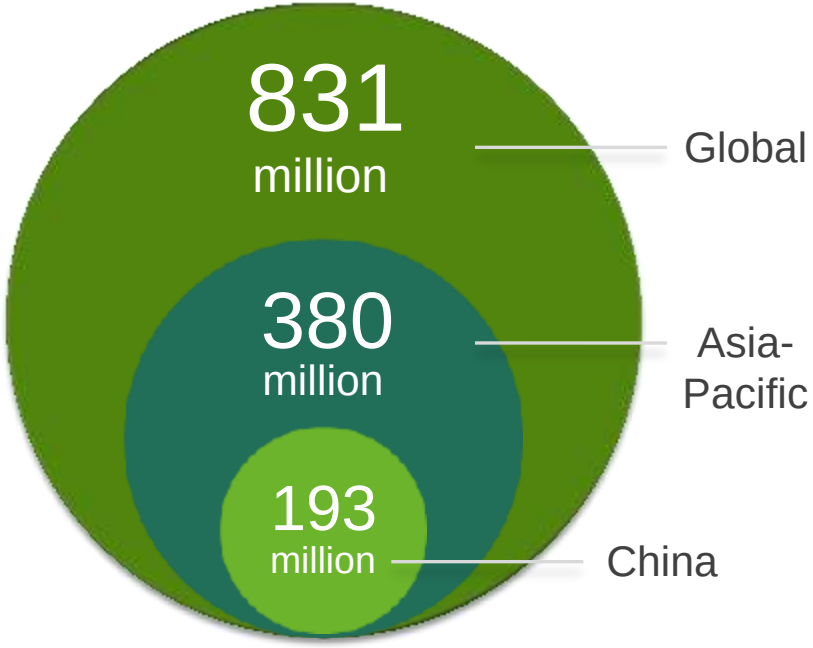
Aviation Market Growing and Moving East

Growth in passengers and traffic dominated by Asia Pacific region and aircraft orders and deliveries reflect this shift



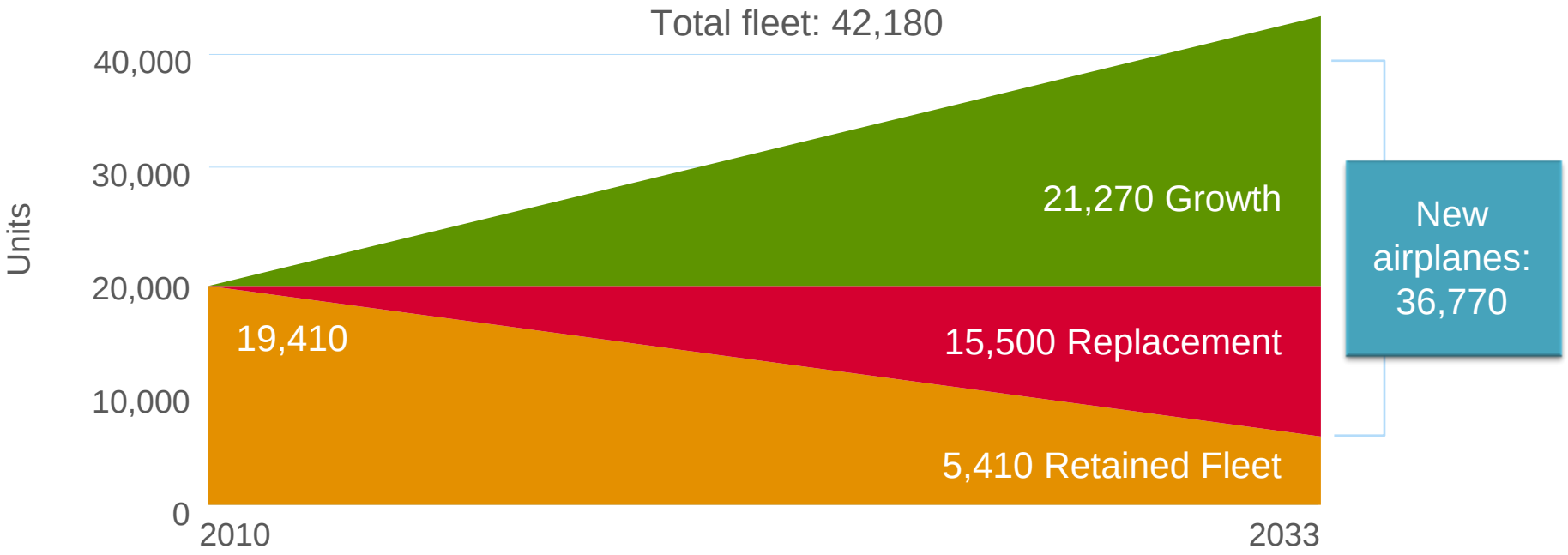
Estimated additional passenger volume in 2016 as compared with 2011

China to add 80 new airports by 2020

India's commercial service airports grow from 80 to 500 by 2021

Asia-Pacific traffic to triple by 2030

Growing Commercial Aircraft Market and Competition



Civil aircraft manufacturers in 2013
Boeing (LCA)
Airbus (LCA)
Embraer (LCA, RJ)
Bombardier (RJ)

Civil aircraft manufacturers in 2033
Boeing (LCA)
Airbus (LCA)
Embraer (LCA, RJ)
Bombardier (LCA, RJ)
Mitsubishi (RJ)
Sukhoi (RJ)
China/COMAC (LCA, RJ)
India (TBD)

Source: Boeing

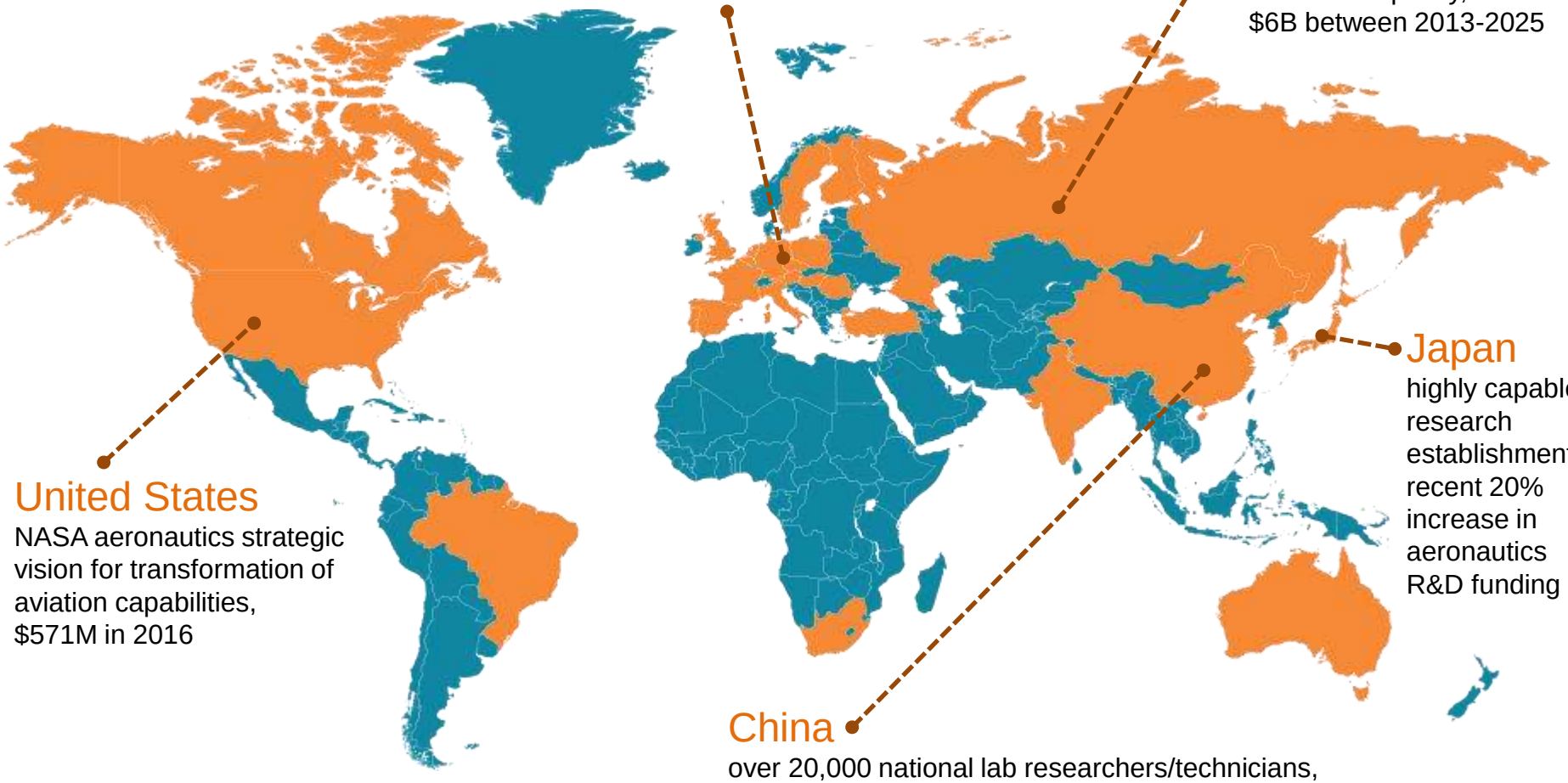
Global Government R&D Investment

Europe

l European countries with leading global aeronautics research establishments and infrastructure, funded through Horizon 2020 and EU member states.

Russia

disciplinary aeronautical research capacity, investing $6B between 2013-2025



United States

NASA aeronautics strategic vision for transformation of aviation capabilities, $571M in 2016

Japan

highly capable research establishment, recent 20% increase in aeronautics R&D funding

China

over 20,000 national lab researchers/technicians, aspires to be a global aeronautics competitor by 2020

Orange indicates membership in International Forum for Aviation Research

NASA Aeronautics Six Strategic Thrusts

3 Mega Drivers

6 Strategic Research and Technology Thrusts

Safe, Efficient Growth in Global Operations

- Enable full NextGen and develop technologies to substantially reduce aircraft safety risks

Innovation in Commercial Supersonic Aircraft

- Achieve a low-boom standard

Ultra-Efficient Commercial Transports

- Pioneer technologies for big leaps in efficiency and environmental performance

Transition to Low-Carbon Propulsion

- Characterize drop-in alternative fuels and pioneer low-carbon propulsion technology

Real-Time System-Wide Safety Assurance

- Develop an integrated prototype of a real-time safety monitoring and assurance system

Assured Autonomy for Aviation Transformation

- Develop high impact aviation autonomy applications

ARMD Programs with Strategic Thrusts

MISSION PROGRAMS

Airspace Operations and Safety Program

- Safe, Efficient Growth in Global Operations
- Real-Time System-Wide Safety Assurance
- Assured Autonomy for Aviation Transformation

Advanced Air Vehicles Program

- Ultra-Efficient Commercial Vehicles
- Innovation in Commercial Supersonic Aircraft
- Transition to Low-Carbon Propulsion
- Assured Autonomy for Aviation Transformation

Integrated Aviation Systems Program

- Flight Research-Oriented Integrated, System-Level R&T support all six thrusts
- X-Planes / Test Environment

SEEDLING PROGRAM

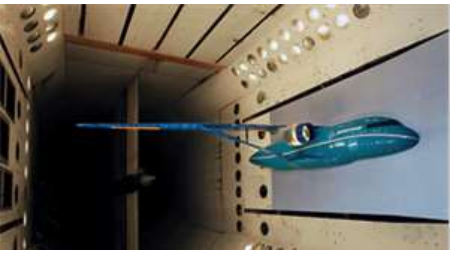
Transformative Aeronautics Concepts Program

- High-risk, leap-frog ideas supporting all six thrusts
- Critical cross-cutting tools and technology development

FY 2016 Budget

Budget Authority	Actual FY 2014	Enacted FY 2015	Request FY 2016	FY 2017	Outyears are Notional FY 2018	FY 2019	FY 2020
Aeronautics	**$566.0**	**$651.0**	**$571.4**	**$580.0**	**$588.7**	**$597.5**	**$606.4**
Airspace Operations Safety		154.0	142.4	153.2	159.6	160.0	163.0
Advanced Air Vehicles		249.6	240.9	243.2	241.2	231.0	232.8
Integrated Aviation Systems		150.0	96.0	85.6	89.0	101.6	104.8
Transformative Aeronautics Concept		97.4	92.1	98.0	98.9	104.9	105.8
Aviation Safety	80.0						
Airspace Systems	91.8						
Fundamental Aeronautics	168.0						
Aeronautics Test	77.0						
Integrated Systems Research	126.5						
Aeronautics Strategy and Management	22.7						

FY 2016 Budget Highlights




World leading UAS integration research:

- Completes a flight test campaign to provide data to the FAA to verify and validate Minimum Operational Performance Standards to enable safe operations of Unmanned Aircraft Systems (UAS) in the National Airspace System.
- Expands upon UAS Traffic Management (UTM) Build 1 capabilities to enable dynamic UAS mission and trajectory adjustments providing increased safety and operational complexity for an expanded range of aircraft and business objectives

Transformative concepts and technologies:

- Develops a detailed conceptual design of a revolutionary hybrid gas-electric propulsion system which has potential benefits of reduced noise, emissions, and energy consumption compared to today's turbine engines

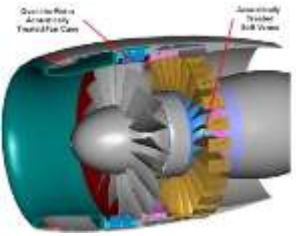
Continued success in transitioning NextGen Air Traffic Management (ATM) technologies to FAA:

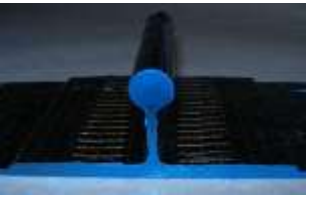
- Completes development of the prototype Flight-Deck Interval Management Avionics for ATM Technology Demonstration-1 and prepares for future flight trial validation

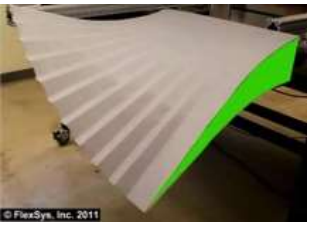
High-Impact collaborations to reduce aircraft environmental impacts:

- Begins a series of flight demonstrations to both mature candidate environmentally friendly technologies and transfer them to US industry
- Begins high-fidelity validation experiments to improve accuracy of computational tools used in advanced aircraft design

Environmentally Responsible Aviation







Mature technologies and study vehicle concepts that together can simultaneously meet the NASA Subsonic Transport System Level Metrics for noise, emissions and fuel burn in the N+2 timeframe.

-75% LTO & -70% Cruise NOx Emissions	42dB below Stage 4 Community Noise	-50% Aircraft Fuel/ Energy Consumption

Technical Focus Areas
Accelerate technology maturation through integrated system research

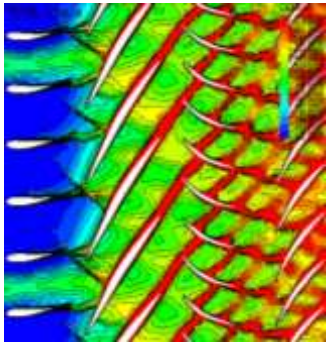
Innovative Flow Control Concepts for Drag Reduction	**Advanced Composites for Weight Reduction**	**Advanced UHB Engines for SFC & Noise Reduction**	**Advanced Combustors for Oxides of Nitrogen reductions**	**Airframe & Engine Integration for Community Noise Reduction**

ERA Cost Sharing Partnerships

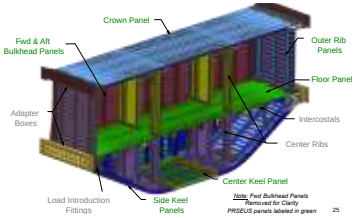
Industry partners provided approximately $78M
of in kind contributions to directly support ERA technology demonstrations

Gulfstream®
A GENERAL DYNAMICS COMPANY

GE Aviation



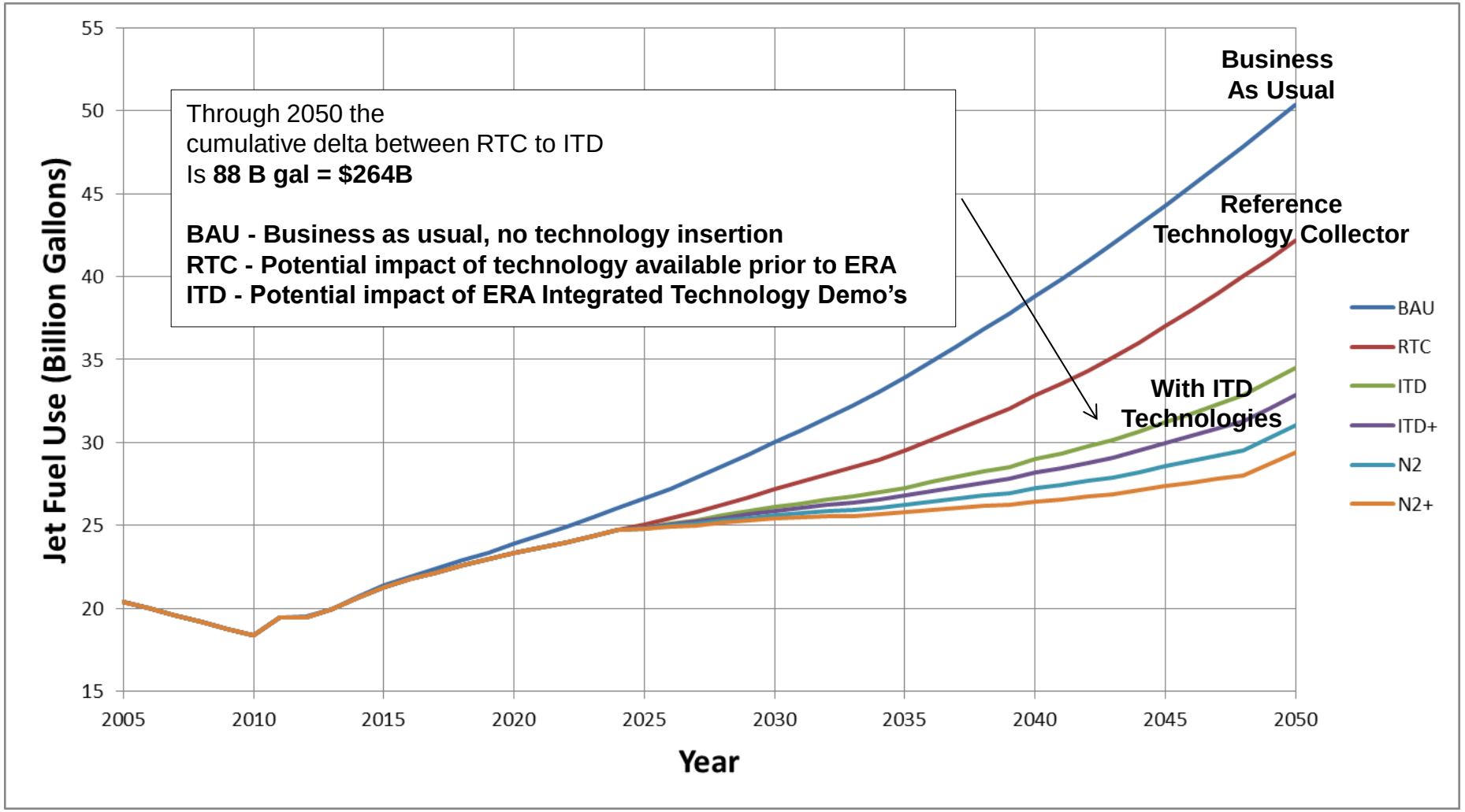
BOEING



Pratt & Whitney
A United Technologies Company

Potential Impact of ERA

Significant POTENTIAL impact on fuel usage by implementing ERA technologies



UAS Integration into NAS

Goal: Provide research findings to reduce technical barriers associated with integrating Unmanned Aircraft Systems into the National Airspace System utilizing integrated system level tests in a relevant environment

Partnership with FAA and RTCA to support development of UAS Performance Standards

TC-ITE: Integrated Test & Evaluation

TC-SAA: Sense and Avoid Performance Standards

TC-HSI: Human Systems Integration

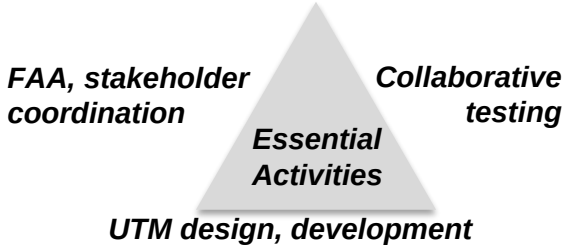
TC-C2: Command & Control Performance Standards

UAS Traffic Management (UTM)

Goal: Safely enable UAS operations at lower altitudes

State-of-the-Art: Commercial low altitude UAS operations are disallowed and demand is likely to grow considerably

Solution: Develop UAS Traffic Management system to support- airspace design, geo-fencing, wind/weather integration, separation management, and contingency operations



Build 1	Build 2	Build 3	Build 4
• Demo: **2015** • Geo-fencing and airspace design • Open/close airspace for wx • Basic procedural separation • Simple scheduling • Initial constraint database	• Demo: **2016** • Dynamic airspace adjustments • Demand/Capacity imbalance • Initial contingency management	• Demo: **2017** • Trajectory conformance monitoring • Web portal for UTM access • Heterogeneous operations	• Demo: **2018** • Large scale contingency management

Partnerships

NASA will be UTM technology developer and conduct collaborative tests

FAA: Research engagement

NOAA: Weather information at low altitudes

Novel partnerships: Vehicle manufacturers, test sites, DOI, insurance companies, academia, communication, surveillance, system integrators, etc.

Google, Amazon, Verizon, 3DRobotics, Airware

Summary

NASA Aeronautics is celebrating 100 years of excellence—from NACA to NASA

NASA Aeronautics is ready to usher in the next 100 years of excellence

- Compelling, community-endorsed vision and strategy
- Demonstrated ability to perform high impact research, complete our commitments, and deliver results
  (Environmentally Responsible Aviation Project, Research Transition Teams)
- Taking on the community's most urgent needs
  (Unmanned Aircraft Systems integration into the National Airspace System)
- Leading the community with transformative concepts and solutions
  (UAS Traffic Management, Future Aircraft Concepts, Computational Fluid Dynamics 2030 Vision)
- Successfully collaborating with universities and industry
  (NASA Research Announcements, cost-sharing cooperative agreements)
- Global thought leaders that are leveraging international capabilities
  (International Forum for Aviation Research)