NASA's Aeronautics Research Strategy: A Reflection of Research Continuity, Strategic Analysis, and Community Dialogue

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Director – Strategy, Architecture & Analysis
NASA Aeronautics Research Mission Directorate

“ARMD provides critical support to our nation’s aeronautics research efforts. They have a strong track record of leading complex, collaborative research with multiple federal agencies, academia, government labs, and industry”

Marion Blakey, Chair – NAC Aeronautics Research Committee

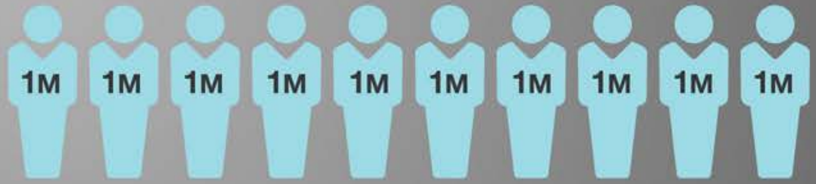
Why is aviation so important?

The air transportation system is critical to U.S. economic vitality.

$1.3 TRILLION
TOTAL U.S. ECONOMIC ACTIVITY
(civil and general aviation, 2009)

$47.1 BILLION
POSITIVE TRADE BALANCE
(civil aviation, 2011)

10.2 MILLION
DIRECT AND INDIRECT JOBS
(civil and general aviation, 2009)



5.2%
OF TOTAL U.S. GROSS DOMESTIC PRODUCT (GDP)
(civil and general aviation, 2009)

Why should I care?

Take the system view. You may not have flown today but something you needed did.

$1.6 TRILLION
VALUE OF FREIGHT TRANSPORTED BY AIR
(exports, domestic, indirect spending, 2008)

$636.1 BILLION
SPENT BY AIR TRAVELERS IN U.S. ECONOMY
(foreign and domestic travelers, 2008)

728 MILLION
PASSENGERS ON U.S. CARRIERS
(domestic and international, 2011)

Aeronautics Research Supports High Quality Manufacturing Jobs

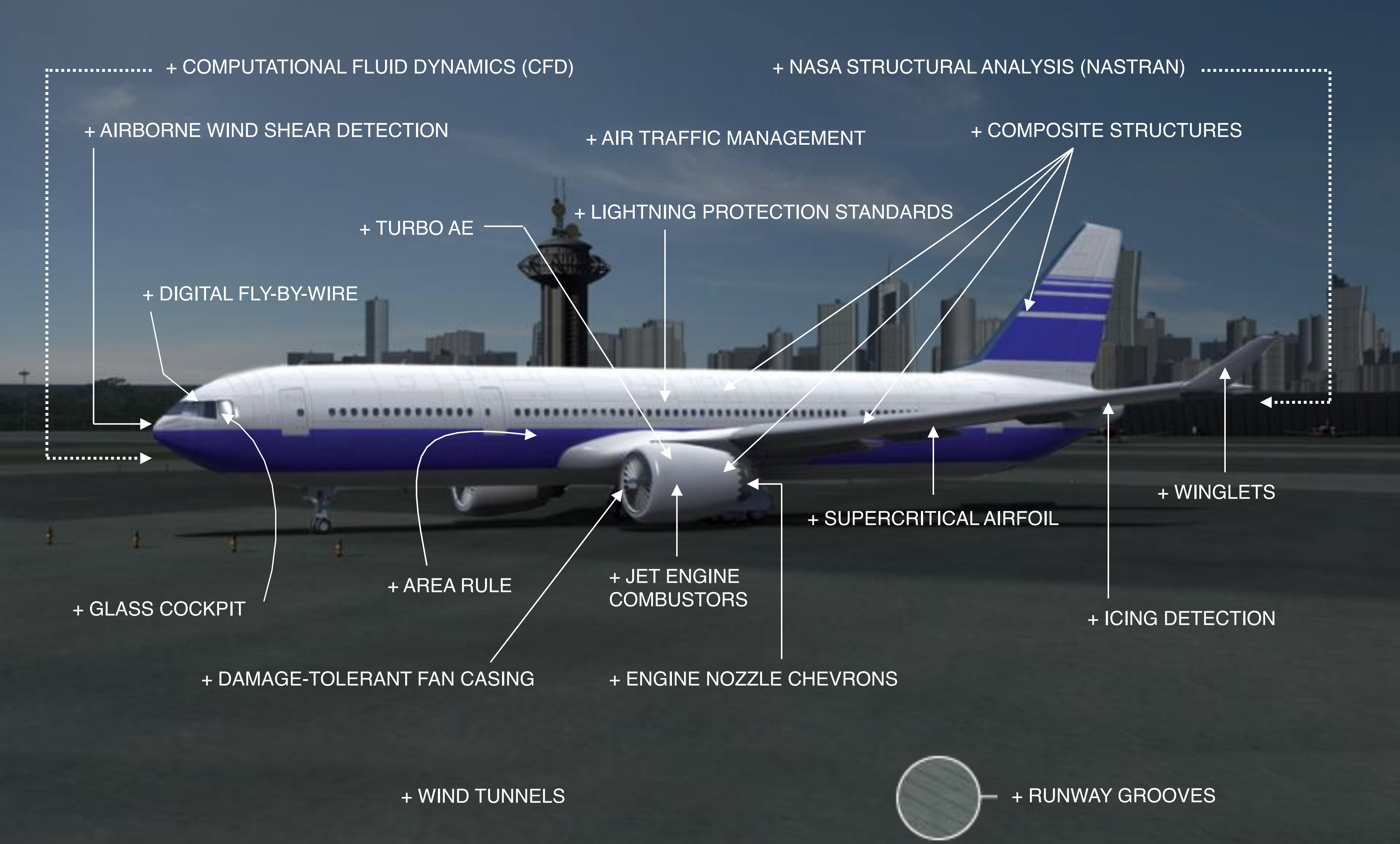
Civil Aeronautics Manufacturing*

2008	1,096,000 jobs
2009	1,112,000 jobs

"Sales orders for all four versions of the GTF engine, which each have an estimated price of $12 million, have prompted Pratt to add nearly 500 engineers at its East Hartford, Conn., headquarters. "We haven't done this in some time," says Sue Gilbert, director of human resources.... Every business in the area, from real estate to dentists to pizzerias, could benefit." – **Time Magazine**

* FAA 2011

NASA Technology Onboard Commercial Fixed-Wing Aircraft



Where do we see NASA's benefits today?

NASA's fundamental research can be traced to ongoing innovation.

Boeing 787

NASA's work on these technologies

- Advanced composite structures
- Chevrons
- Laminar flow aerodynamics
- Advanced CFD and numeric simulation tools
- Advanced ice protection system

Was transferred for use here →

824 confirmed orders through August 2012

Boeing 787

Benefits →

- 20% more fuel efficient/ reduced CO_2 emissions
- 28% lower NO_x emissions
- 60% smaller noise footprint

Source: Boeing

Boeing 747-8

NASA's work on these technologies

- Advanced composite structures
- Chevrons
- Laminar flow aerodynamics
- Advanced CFD and numeric simulation tools

Was transferred for use here →

106 confirmed orders through August 2012

Boeing 747-8

Benefits →

- 16% more fuel efficient/ reduced CO_2 emissions
- 30% lower NO_x emissions
- 30% smaller noise footprint than 747-400

Source: Boeing

P&W PurePower 1000G Geared Turbofan

NASA's work on these technologies

- Low NO_x Talon combustor
- Fan Aerodynamic and Acoustic Measurements
- Low noise, high efficiency fan design
- Ultra High Bypass technology
- Acoustics Modeling and Simulation tools

Was transferred for use here →

Proposed for Airbus A320NEO, Bombardier C-Series, Mitsubishi Regional Jets

P&W PurePower 1000G Geared Turbofan

Benefits →

- 16% reduction in fuel burn/ reduced $C0_2$ emissions
- 50% reduction in No_x
- 20dB noise reduction

Source: Pratt & Whitney

CFM LEAP-1B

NASA's work on these technologies

- Compression system aerodynamic performance advances
- Low NO_x TAPS II combustor
- Low pressure turbine blade materials
- High-pressure turbine shroud material
- Nickel-aluminide bond coat for the high pressure turbine thermal barrier coating

Was transferred for use here →

Proposed for Airbus A320NEO, Boeing 737MAX

CFM LEAP-1B

Benefits →

- 15% reduction in fuel burn/ reduced CO_2 emissions
- 50% less NO_x
- 15dB noise reduction

Source: CFM

Where do we see NASA's benefits today?

NASA's fundamental research can be traced to ongoing innovation.

EDA

NASA's work on these technologies

- Human-in-the-loop simulations
- Joint flight trials with FAA and airlines
- Automated decision support tools
  - Traffic Management Advisor
  - 3-Dimensional Path Arrival Management
- Trajectory and arrival modeling and solutions

Was transferred for use here →

Phased deployment by the FAA of Efficient Descent Advisor starting 2014; full deployment by 2020.

Federal Aviation Administration
Source: FAA

Benefits →

- Fuel-efficient continuous descents
- Potential $300 million jet fuel savings per year (savings vary per spot fuel costs)
- Reduced delays in congested airspace
- Reduced noise and emissions around airports
- Retained safety
- Reduced controller workload through increased automation

Ice Protection

NASA's work on these technologies

- Understanding of icing physics
- Icing test methods and facilities
- Icing computational simulation and certification tools

Was transferred for use here →

Included in manufacture of new models such as Boeing 787

Boeing 787
Source: Boeing

Benefits →

- Reduced cost for aircraft certification
- Reduced time for aircraft certification
- Increased safety

Last updated 10/02/12

Where do we see NASA’s benefits today?

NASA’s fundamental research can be traced to ongoing innovation.

Synthetic and Enhanced Vision Systems

NASA’s work on these technologies

- Sensor-based imaging
- World-wide terrain database
- 3D display avionics
- In-flight data integrity monitoring
- Synthetic Vision
- Gate-to-gate “virtual visual” concepts

Was transferred for use here →

Honeywell, Rockwell-Collins and GE Aviation manufacture synthetic and enhanced vision systems.

Honeywell SVS in G450
Source: Gulfstream

Benefits →

- Improved ability to "see" in poor conditions
- Improved ground hazard avoidance
- Useful for civilian, military and unmanned flight
- Reduced landing ceiling and threshold minimums
- Safe, intuitive training environment for newer pilots

Data Mining

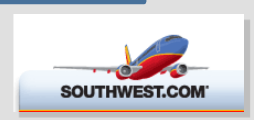
NASA’s work on these technologies

- Massive datasets
- High-end computing
- Data mining algorithms for different data types
- Knowledge discovery of anomalies

Was transferred for use here →

Aviation Safety Information and Analysis Sharing (ASIAS)

FAA’s ASIAS system receives data from entire U.S. civil aviation community. NASA partners with individual airlines.



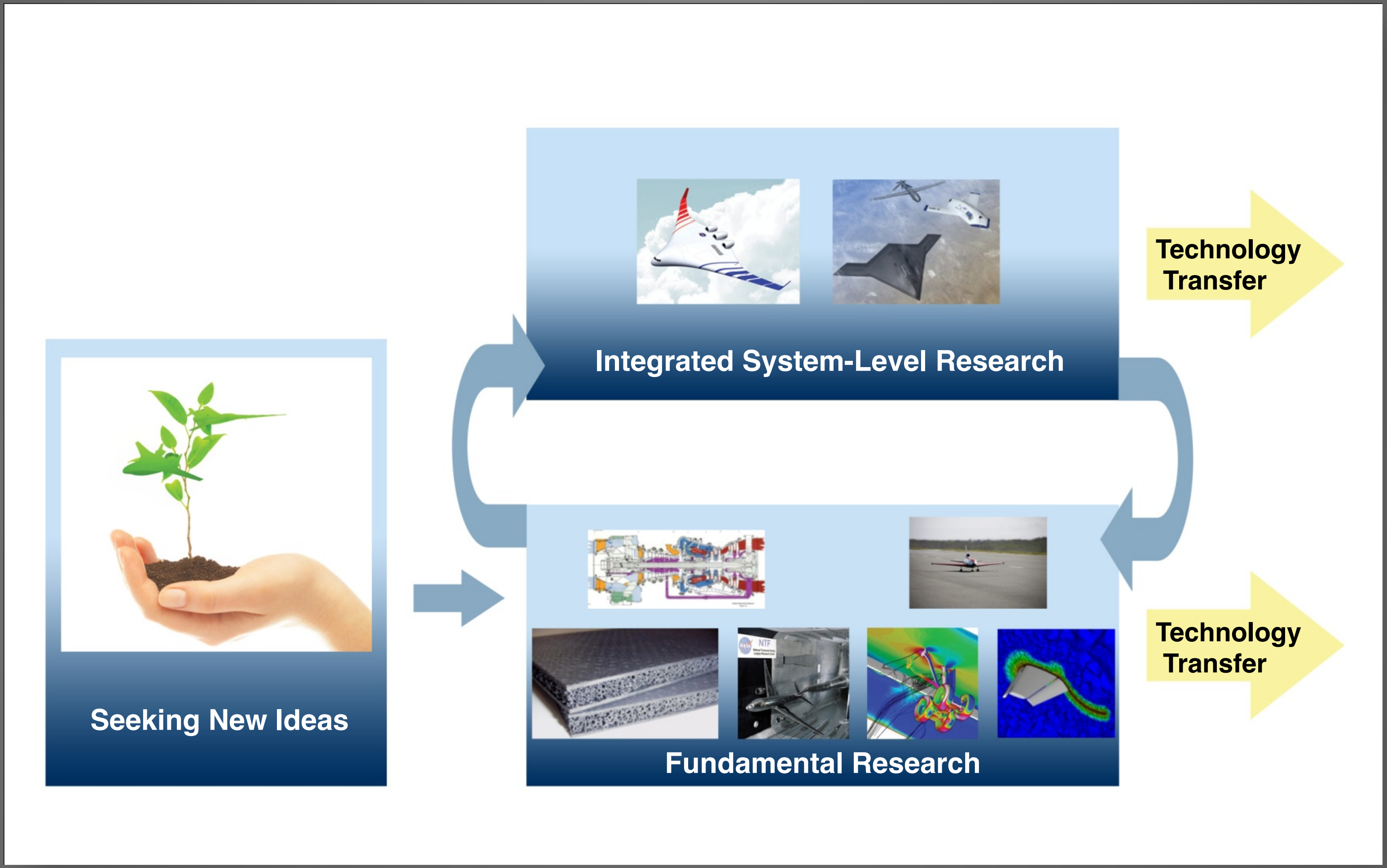
Source: Southwest Airlines

Benefits →

- Improved discovery by individual airlines of relevant operational events
- Increased identification of safety-related incidents
- Increased sharing of safety-related trends across airlines
- Reduced rate of incidents system wide

Last updated 9/18/12

ARMD Investment Strategy



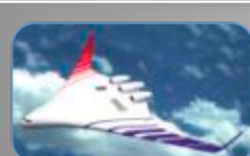
Enabling "Game Changing" concepts and technologies

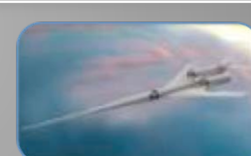
NASA Aeronautics Programs



Integrated Systems Research Program

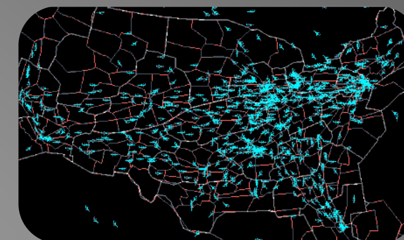
Conducts research at an integrated system-level on promising concepts and technologies and explore, assess and demonstrates the benefits in a relevant environment.





Fundamental Aeronautics Program

Conducts fundamental research to generate innovative concepts, tools, technologies and knowledge to enable revolutionary advances for a wide range of air vehicles.



Airspace Systems Program

Directly addresses the fundamental air traffic management research needs for NextGen by developing revolutionary concepts, capabilities, and technologies that will enable significant increases in the capacity, efficiency and flexibility of the NAS.


Aviation Safety Program

Conducts cutting-edge research to produce innovative concepts, tools, and technologies to improve the intrinsic safety attributes of current and future aircraft and air traffic management systems.




Aeronautics Test Program

Preserves and promotes the testing capabilities of one of the United States' largest, most versatile and comprehensive set of flight and ground-based research facilities.

Collaboration with External Partners

Aeronautics

Other Government Agencies

U.S. Industry

Northrop Grumman
Lockheed Martin
Gulfstream
Raytheon
Boeing
United Technologies Research Center

Academia

International Organizations

JAXA Japan Aerospace Exploration Agency
NRC-CNRC Canada
DLR
NLR
ONERA THE FRENCH AEROSPACE LAB

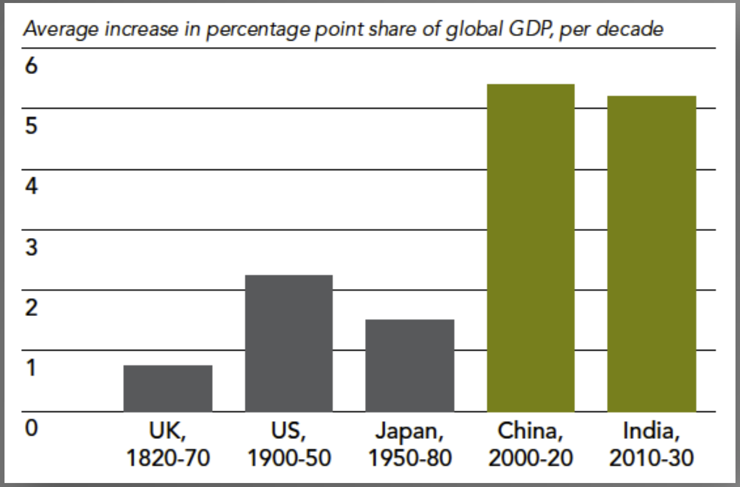
Strategic analysis

Approach to Planning

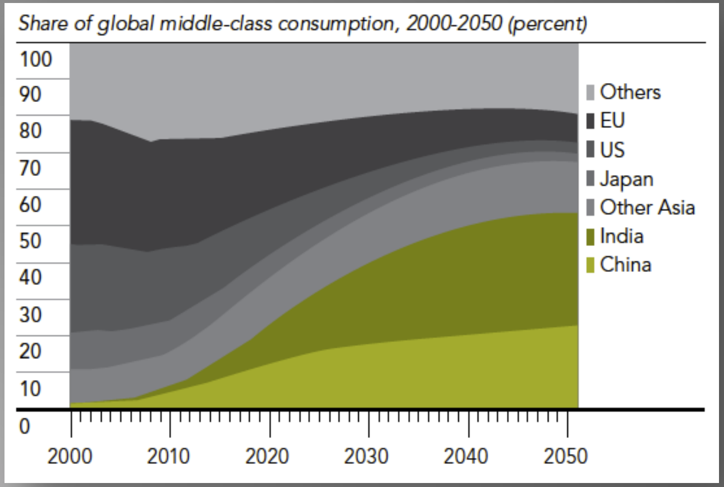
Exploring Strategic Trends

Challenges Traditional Approaches

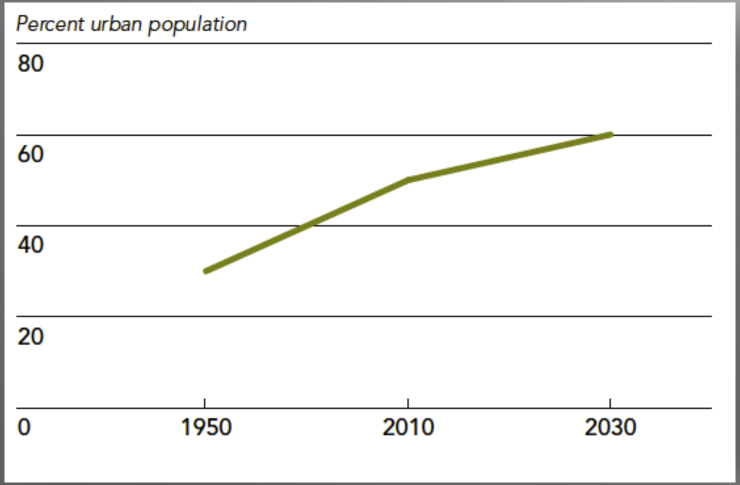
China & India Growing Economically at Historically Unprecedented Rates



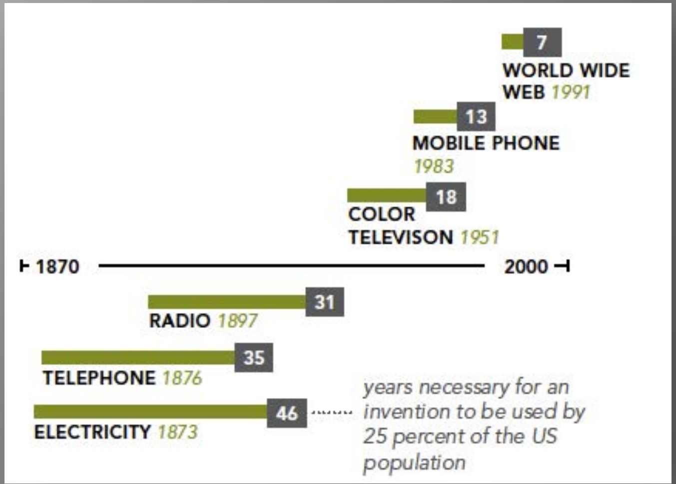
They will have the Largest Middle-Class



The World will be Predominantly Urban



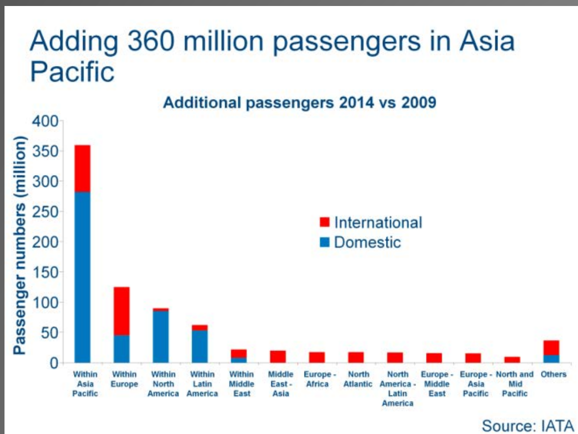
Technology Development & Adoption is Accelerating



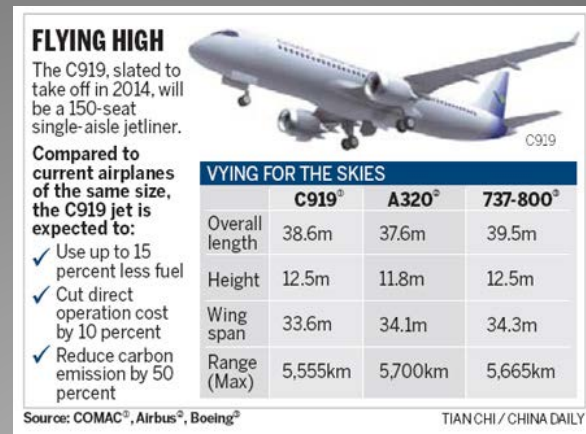
Source: National Intelligence Council

Why are these trends important?

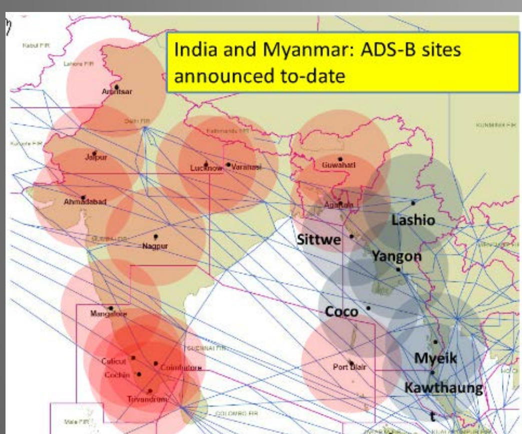
Challenges are multiplying and accelerating – technology is a key lever!



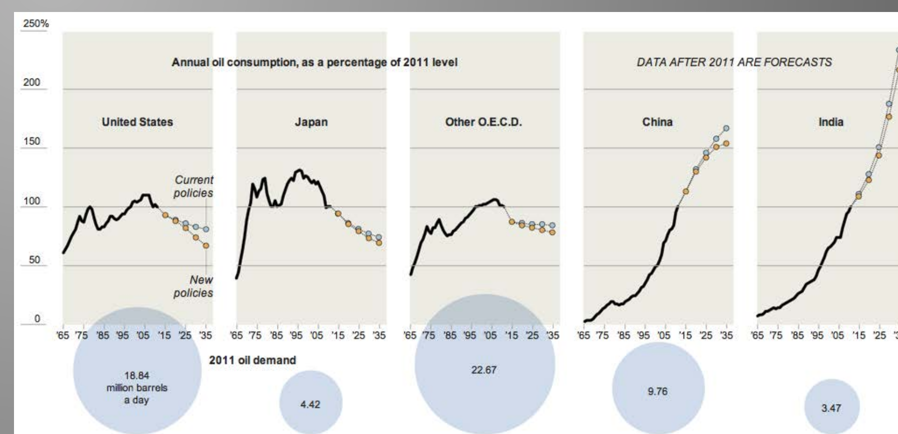
They drive global demand growth for air travel…



They drive expanding competition for high tech manufacturing…



They enable "leapfrog" adoption of new technology/infrastructure…



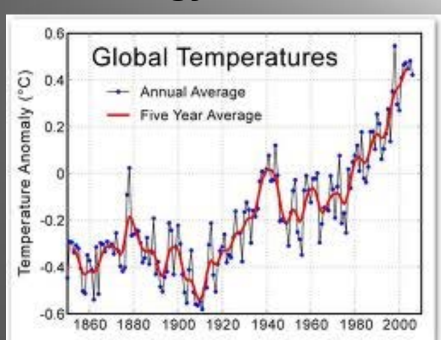
They drive resource use, costs, constraints and impacts…

These Trends Create Aviation Mega-Drivers

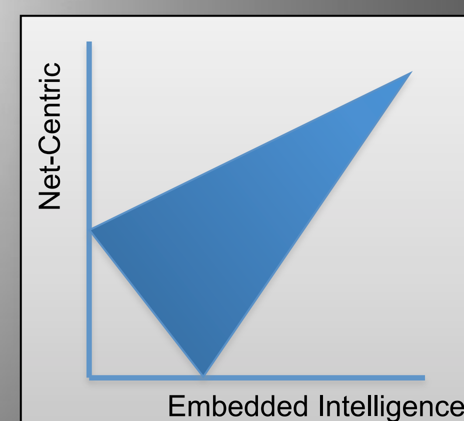
Three critical vectors

Global Growth in Demand for High Speed Mobility

Global Climate Change, Sustainability, & Energy Transition



Technology Convergence

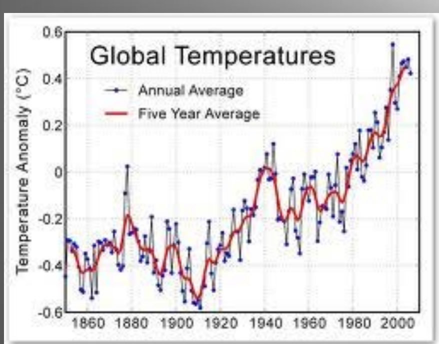


Aviation Mega-Drivers

Three critical vectors

Global Growth in Demand for High Speed Mobility

Global Climate Change, Sustainability, & Energy Transition



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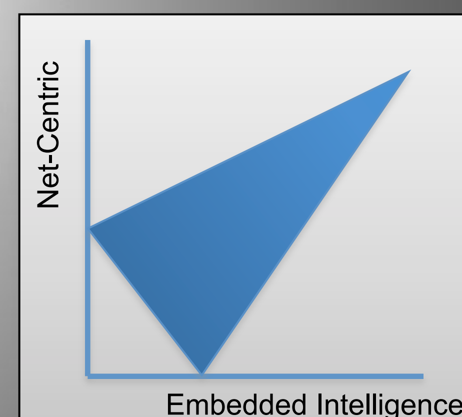
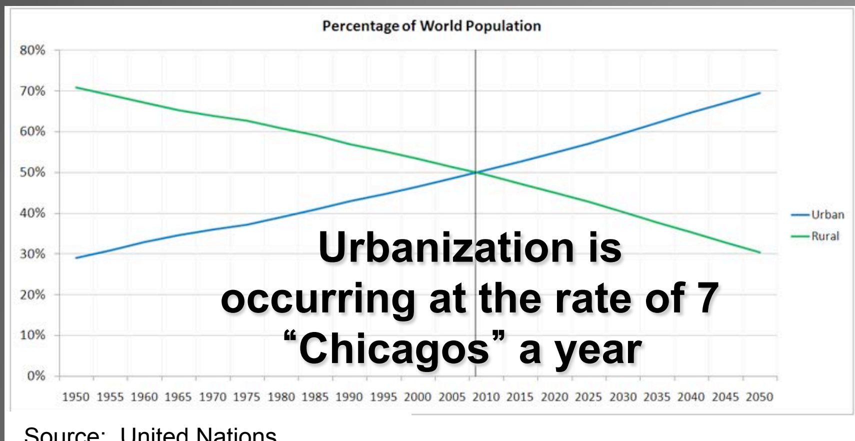
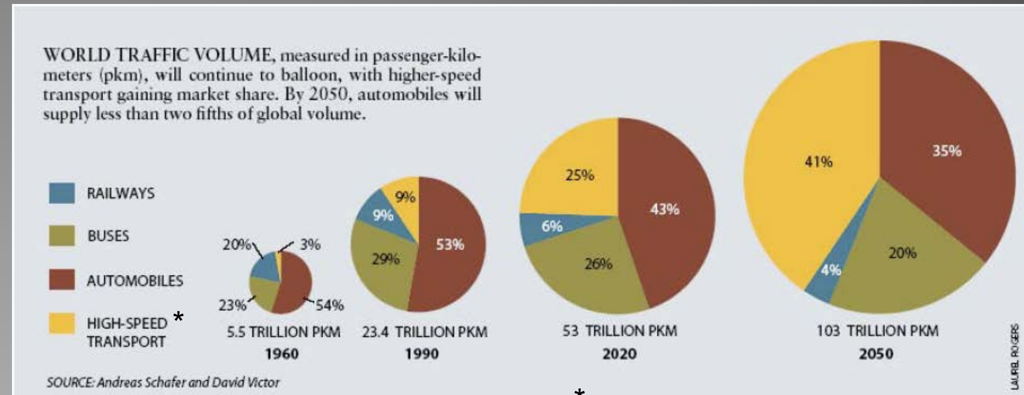


Air Transportation - A Critical Global Capability

Century long trend toward urbanization…



Source: United Nations



* Includes high speed rail and air transportation

Century long trend toward higher speed transport…

International Air Transport Association (IATA) – Vision 2050

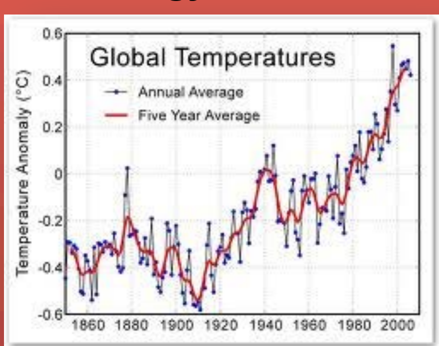
The world in 2050: "Traffic has grown from 2.4 billion to 16 billion passengers in the last 40 years…Technologically advanced aircraft operating on advanced renewable energy sources and capable of carrying anywhere from 2 to 2000 passengers connect intercontinental traffic through a dozen global gateways feeding them to 50-75 regional hubs which redistribute onwards to local airports."

Aviation Mega-Drivers

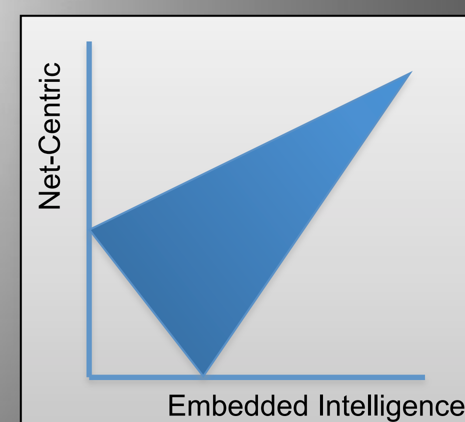
Three critical vectors

Global Growth in Demand for High Speed Mobility

Global Climate Change, Sustainability, & Energy Transition

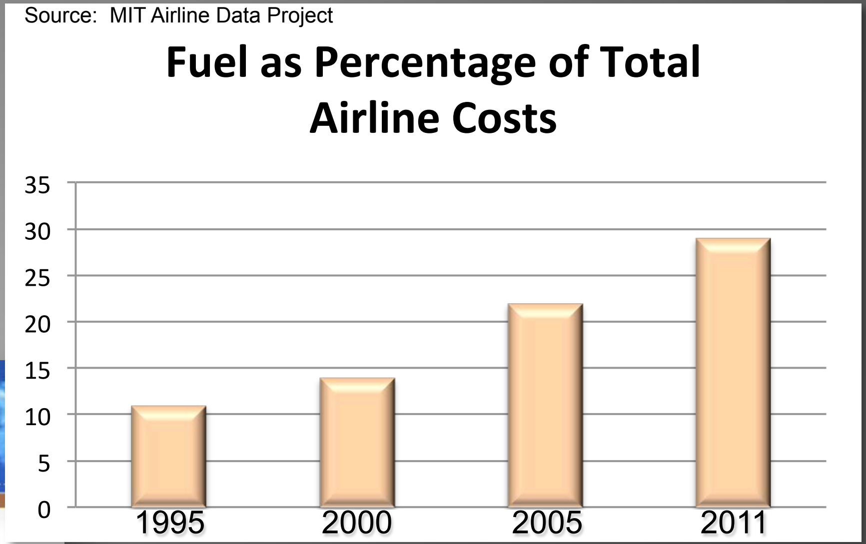


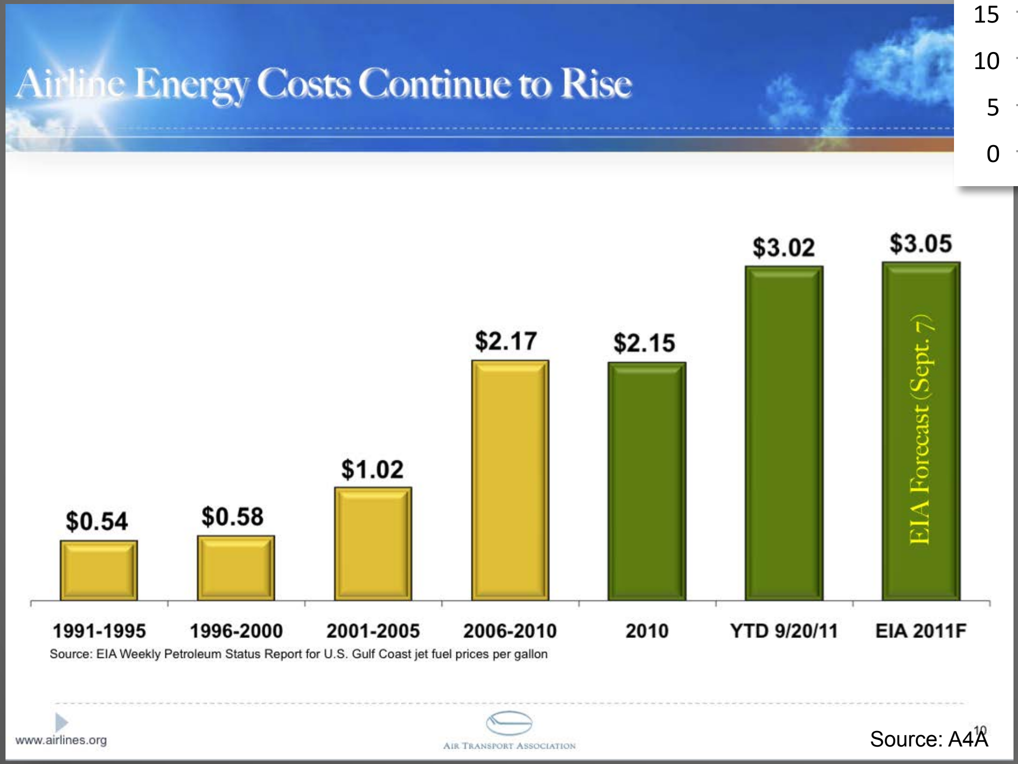
Technology Convergence



Escalating Fuel Prices have a Large Aviation Impact

"Fuel is the only major cost item that has become significantly larger over time"
IATA

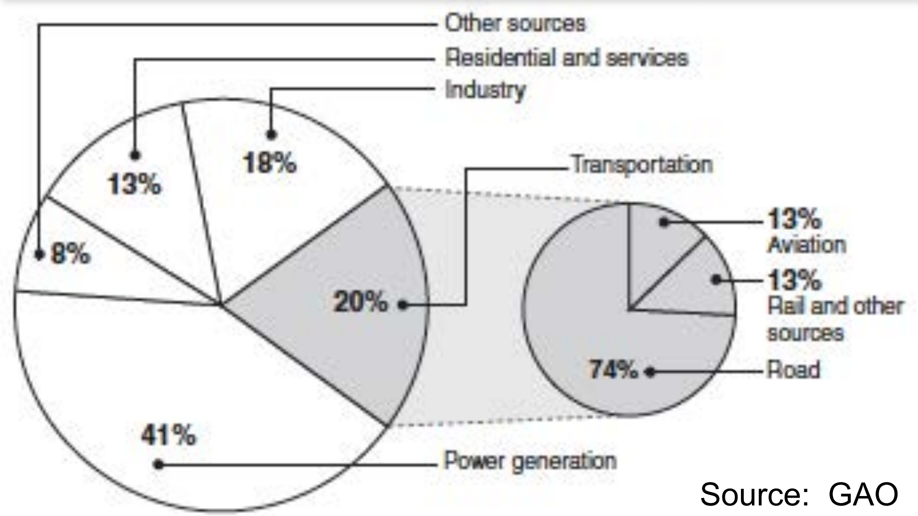




Global Warming Imperative

How do we sustainably satisfy global demand for air transportation?

Global Transportation Contribution to CO_2 Emissions



Source: GAO

"We will respond to the threat of climate change, knowing that the failure to do so would betray our children and future generations."

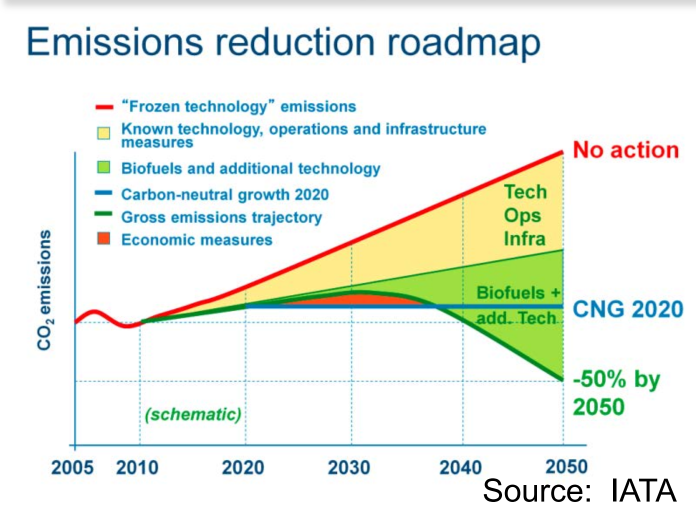
President Barack Obama
Inaugural Address - January 2013

Strategies for Reducing Transportation-Related Greenhouse Gas Emissions

- Reduce the total volume of transportation activity;
- Shift transportation activity to modes that emit fewer GHGs per passenger-mile or ton-mile;
- Reduce the amount of energy required to produce a unit of transport activity (that is, increase the energy efficiency of each mode); or
- Reduce the GHG emissions associated with the use of each unit of energy

Source: NAS

Industry Goals



Source: IATA

Aviation Mega-Drivers

Three critical vectors

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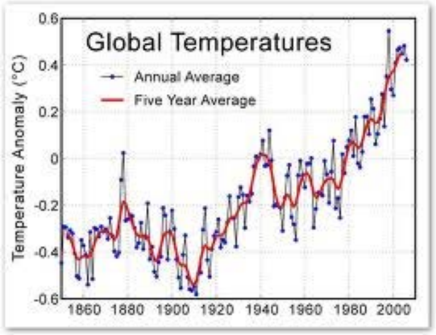
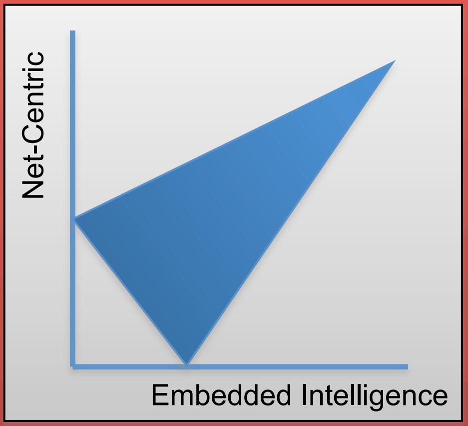


Technology Convergence



Technology Convergence

Enabling Assured Autonomy for Safety Critical Systems

Net-Centric Information – Big Data

Reduce Operations Costs

Improve Performance

Increase Safety

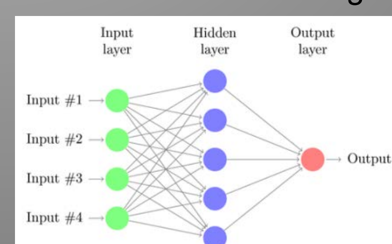
Transform Mobility – On Demand Aviation

Tomorrow

Today

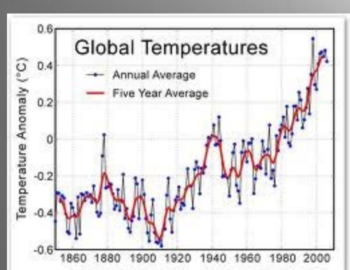
Centralized, Expert Operator

Embedded System Intelligence

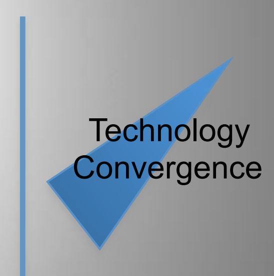


Summary of Strategic Trends

Traditional measures of demand for mobility growing rapidly
- Rapid growth of developing economies
- Global urbanization



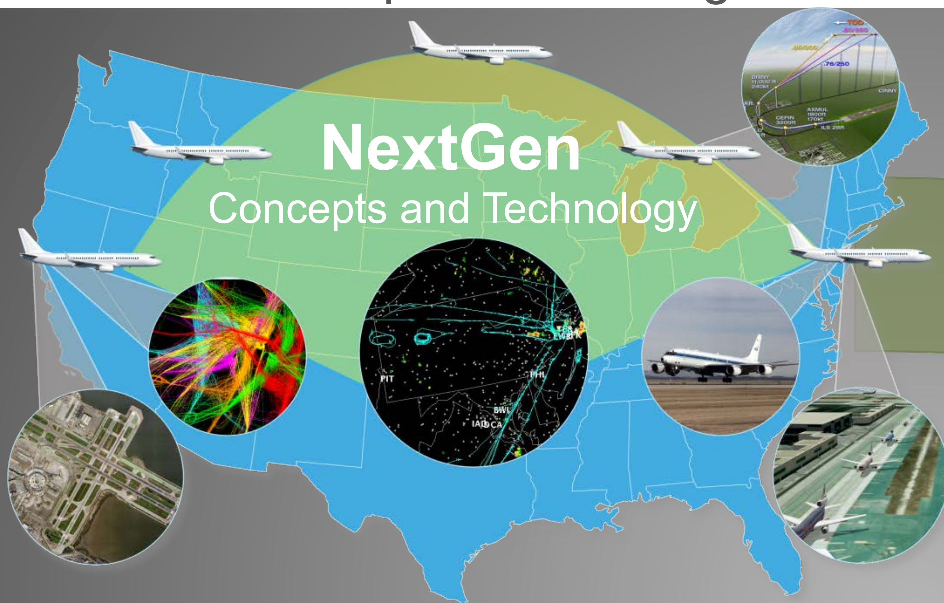
Severe energy and climate issues create enormous affordability and sustainability challenges



Revolution in automation, information and communication technologies enable opportunity for safety critical autonomous systems

Systems & Portfolio Analysis

Example of integrated assessment of core investments in NextGen and N+2 / N+3 Transport Technologies



N+2

Concepts and Technology

N+3

Concepts and Technology

Core Technologies support needed capacity growth and enable simultaneous reduction in energy use, noise and emissions

- Structural, Aerodynamic & Propulsion Component Efficiency
- New Configurations
- Automation for Efficient TBO Operations

However, performance gaps remain to fully account for future challenges in mobility, cost and climate

Low Carbon Fuels and Propulsion closes gaps in carbon emissions

Autonomy closes gaps in cost and enables mobility innovation

Stakeholder Dialogue

Generating Ideas and Insights into Community Priorities

Advance ongoing research in NextGen, Safety, Green Aviation, and UAS Access

Undertake or Expand upon Transformational Enablers
- **Autonomy**
- **Composite Structures**
- **More Electric Aircraft**

Aeronautics R&T Roundtable

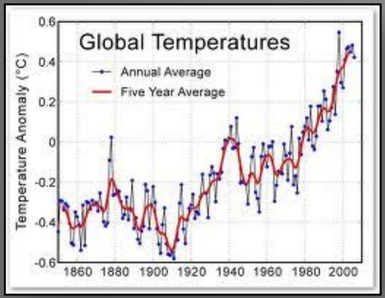
Need Tools for More Rapid Innovation
- **Virtual Testing**
- **V&V of Complex Systems**

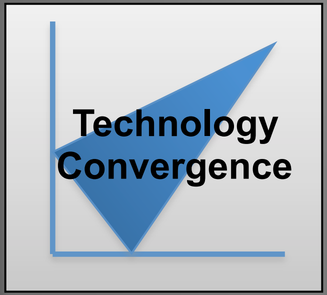
Demonstrate Low-Boom Supersonic Flight

Flight Research is a Critical Element of Technology Maturation and Public-Private Partnership

Strategic Response

3 Mega-Drivers





6 Strategic Research & 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

Vision: A Revolution in Sustainable, High Speed Global Mobility

Continuing to evolve ARMD Programs to respond to new needs and new approaches to innovative research

Doing business differently

Strategic Management Actions Since 2008

Build Upon Strong Fundamental Research and Excellent Technical Progress to Improve Relevance

Reorganized Programs & Strengthened Tech Transfer

Established Top-Down Strategy & Systems Analysis

Aeronautics Research

Relevant
Game Changing

Instituted High TRL Integrated Systems Research and Seedling Fund

Strengthened Interactions and Partnership with the Aviation Community

Next Steps in Strategic Management

Promoting Innovation and Convergent Research

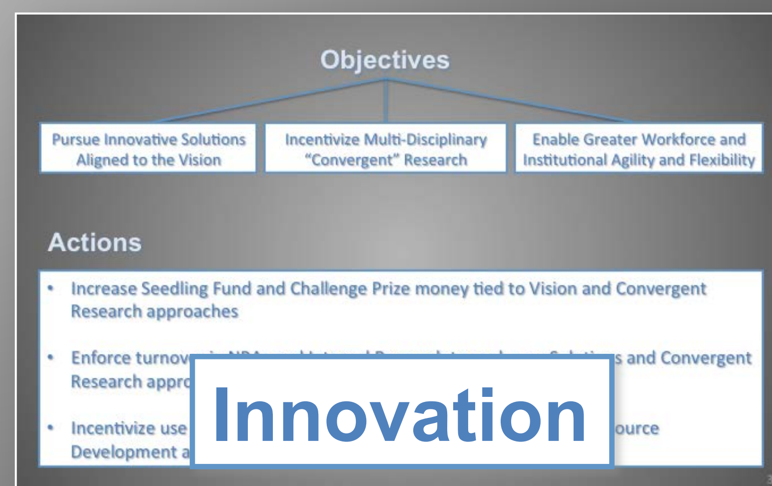
Objectives

- Pursue Innovative Solutions Aligned to the Strategic Thrusts
- Incentivize Multi-Disciplinary "Convergent" Research
- Enable Greater Workforce and Institutional Agility and Flexibility

Actions

- Improve Seedling Fund based on lessons learned and add Challenge Prize to promote focus, excitement and action on innovative solutions to the critical problems aligned with the Strategic Thrusts
- Develop an initiative to organize universities around ground-breaking research directed toward critical problems aligned with the Strategic Thrusts
- Incentivize use of Innovative approaches to Research, such as Open Source Development and more Agile Flight Research
- Expand partnerships beyond traditional aeronautics industry, to capture leverage from energy innovation, autonomy, and other fast developing technologies
- Continue to work with the Agency through the TCAT process to evolve and transform Agency aeronautics capabilities

ARMD Strategic Management Focus



Synergy with STMD

Relationship to the NASA Strategic Space Technology Investment Plan (SSTIP)

Technology Investments	Associated NASA SSTIP Technical Challenge Areas	Associated NRC High Priorities
Launch and In-Space Propulsion	Launch Propulsion Systems; High Power In-Space Propulsion; In-Space Propulsion; Cryogenic Storage and Transfer	Electric Propulsion; (Nuclear) Thermal Propulsion; Turbine Based Combined Cycle (TBCC); Rocket Based Combined Cycle (RBCC); Micro-Propulsion; Propellant Storage and Transfer
Robotics and Autonomous Systems	Autonomous Systems; Robotic Maneuvering, Manipulation, Sensing and Sampling; Autonomous Rendezvous and Docking; Structural Monitoring; Robotic Maneuvering	Extreme Terrain Mobility; GNC (includes Relative Guidance Algorithms, Onboard Autonomous Navigation and Maneuvering); Docking and Capture Mechanisms/Interfaces; Small Body/Microgravity Mobility; Dexterous Manipulation; Robotic Drilling and Sample Processing; Supervisory Control; Vehicle System Management and FDIR
Entry, Descent, and Landing	Advanced Entry, Descent, and Landing; Entry, Descent, and Landing	EDL TPS (includes Rigid TPS, Flexible TPS, and Ascent/Entry TPS); GNC (includes GNC Sensors and Systems [EDL]); EDL Instrumentation and Health Monitoring; EDL Modeling and Simulation; EDL System Integration and Analysis; Atmospheric and Surface Characterization; Deployable Hypersonic Decelerators
Lightweight Space Structures and Materials	Lightweight Space Structures and Materials; Structural Monitoring	Lightweight and Multifunctional Materials and Structures (includes: [Nano] Lightweight Materials and Structures; Structures: Innovative, Multifunctional Concepts; Structures: Lightweight Concepts; Materials: Lightweight Structure; and Structures: Design and Certification Methods)

ARMD Efforts in Hypersonics

With the lack of civil aviation need for hypersonics and the establishment of the space technology program, ARMD is transitioning and reducing investments

Technology Investments	Associated NASA SSTIP Technical Challenge Areas	Associated NRC High Priorities
Launch and In-Space Propulsion	Launch Propulsion Systems; High Power In-Space Propulsion; In-Space Propulsion; Cryogenic Storage and Transfer	Electric Propulsion; (Nuclear) Thermal Propulsion; Turbine Based Combined Cycle (TBCC); Rocket Based Combined Cycle (RBCC); Micro-Propulsion; Propellant Storage and Transfer
ARMD investment in air-breathing hypersonic systems is focused on sustaining core competence and reimbursable activities with DoD to support military requirements		
Entry, Descent, and Landing	Advanced Entry, Descent, and Landing; Entry, Descent, and Landing	EDL TPS (includes Rigid TPS, Flexible TPS, and Ascent/Entry TPS); GNC (includes GNC Sensors and Systems [EDL]); EDL Instrumentation and Health Monitoring; EDL Modeling and Simulation; EDL System Integration and Analysis; Atmospheric and Surface Characterization; Deployable Hypersonic Decelerators
ARMD has transitioned the EDL investment to the Space Technology Program		

Promising Areas of Planned Collaboration Between ARMD and Space Technology

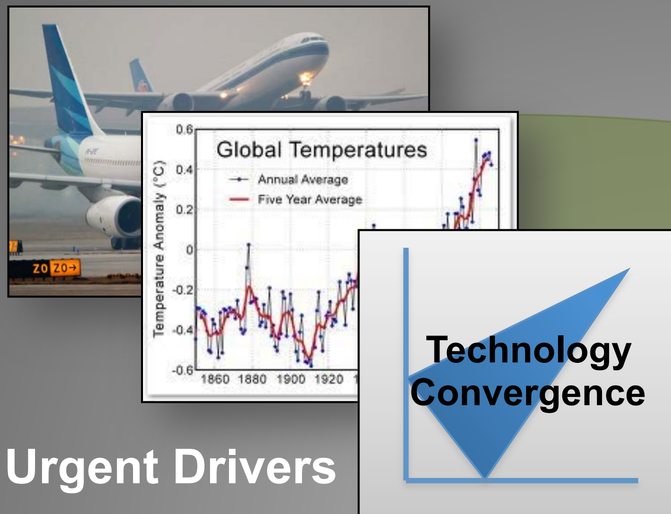
ARMD is planning an expanded investment in composite materials and structures as well as greater focus in autonomous systems

- Opportunity to plan cooperative research activities

Technology Investments	Associated NASA SSTIP Technical Challenge Areas	Associated NRC High Priorities
Robotics and Autonomous Systems	Autonomous Systems; Robotic Maneuvering, Manipulation, Sensing and Sampling; Autonomous Rendezvous and Docking; Structural Monitoring; Robotic Maneuvering	Extreme Terrain Mobility; GNC (includes Relative Guidance Algorithms, Onboard Autonomous Navigation and Maneuvering); Docking and Capture Mechanisms/Interfaces; Small Body/Microgravity Mobility; Dexterous Manipulation; Robotic Drilling and Sample Processing; Supervisory Control; Vehicle System Management and FDIR
Lightweight Space Structures and Materials	Lightweight Space Structures and Materials; Structural Monitoring	Lightweight and Multifunctional Materials and Structures (includes: [Nano] Lightweight Materials and Structures; Structures: Innovative, Multifunctional Concepts; Structures: Lightweight Concepts; Materials: Lightweight Structure; and Structures: Design and Certification Methods)

Summary

Summary



Urgent Drivers

Innovative Solutions & High Payoff Technologies

Economic Growth
High Quality Jobs
Revolutionary Mobility
Long-Term Sustainability