



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

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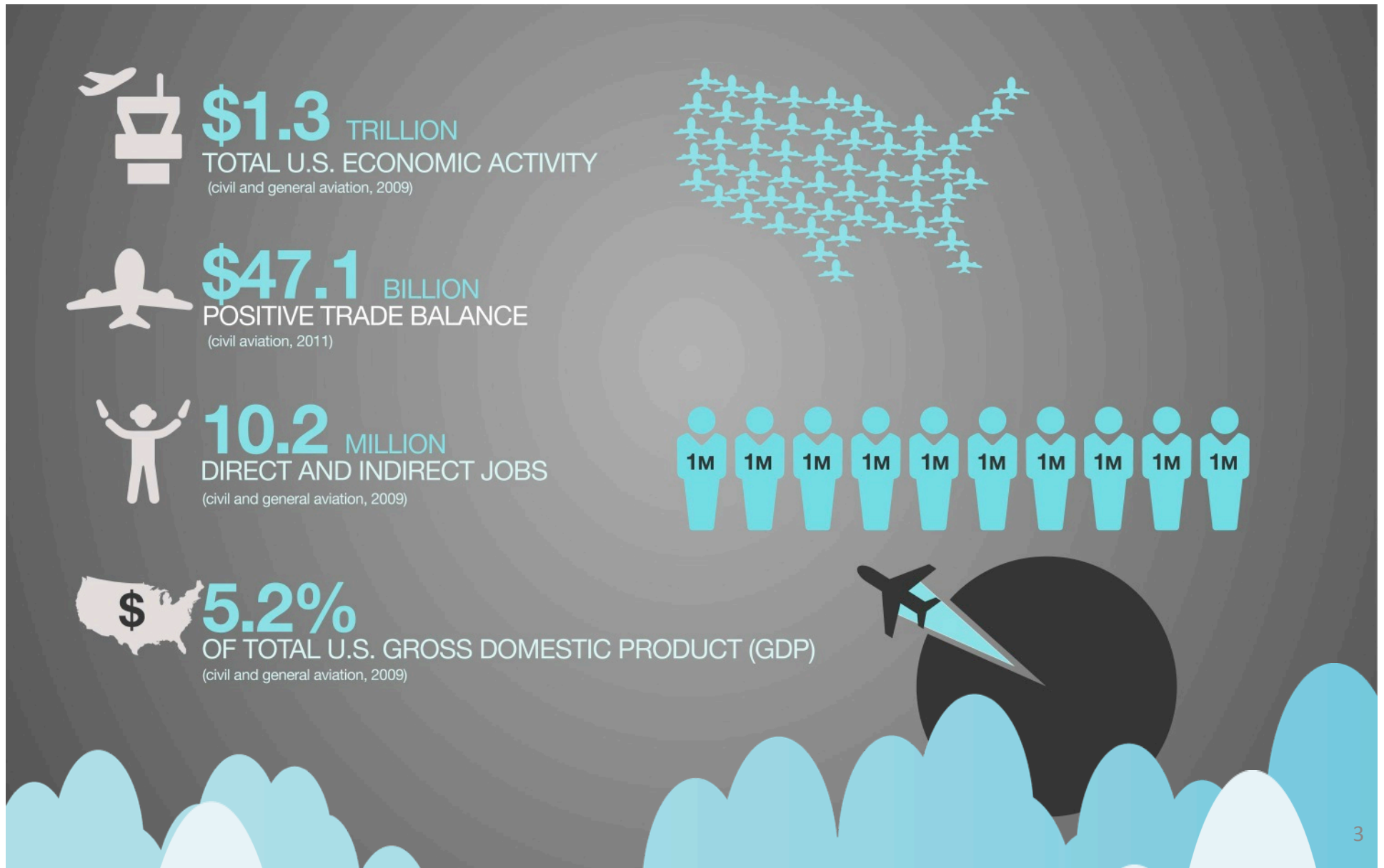
“ARMD provides critical support to our nation’s aeronautics research efforts. They have a strong track record of leading complex, collaborative research with multiple federal agencies, academia, government labs, and industry”

Marion Blakey, Chair – NAC Aeronautics Research Committee

Why is aviation so important?



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



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



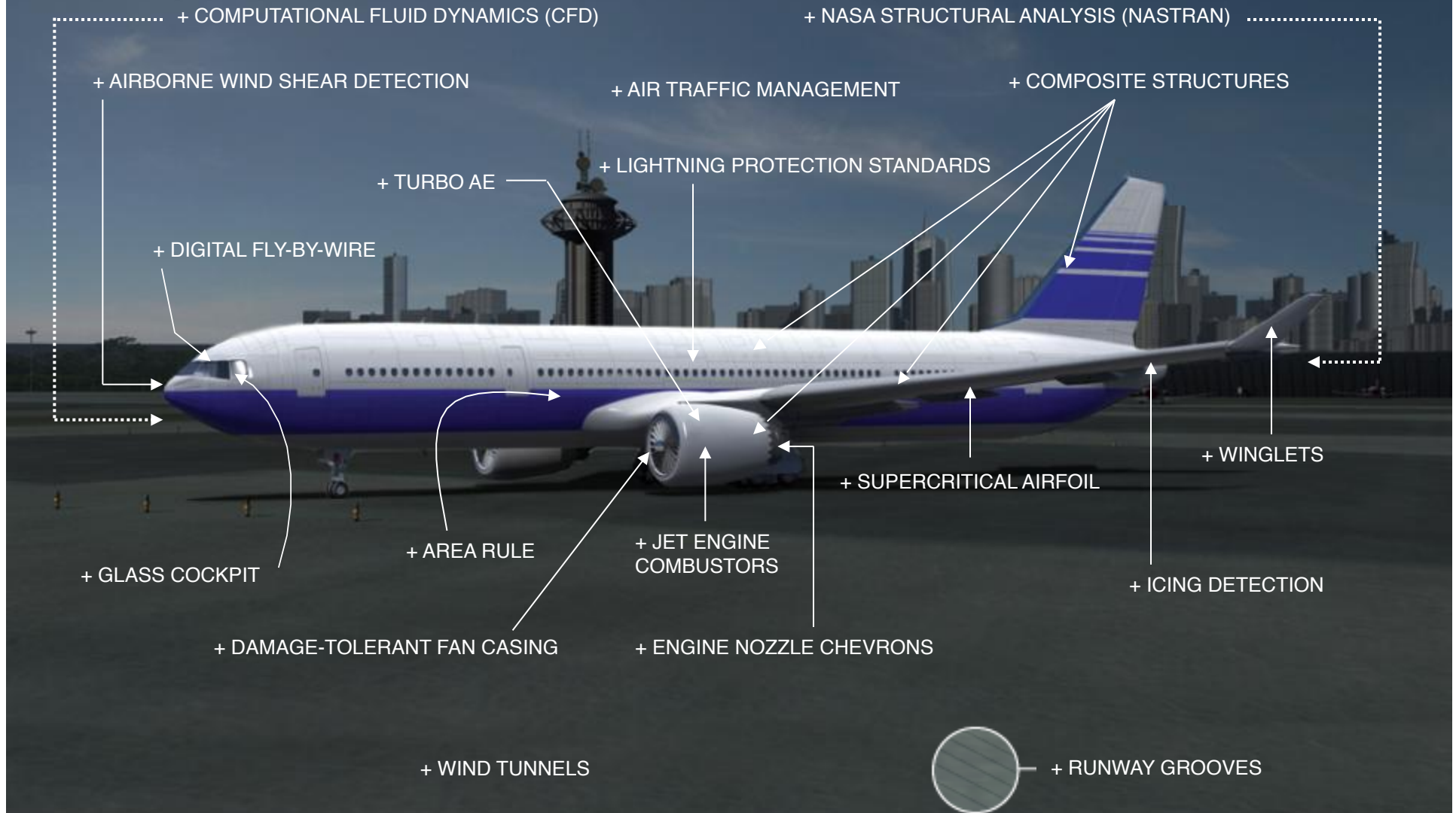
Civil Aeronautics Manufacturing*

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.

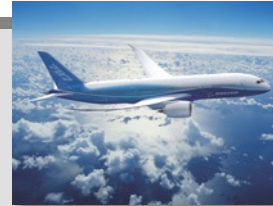
Boeing 787

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 CO₂ 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 CO₂ 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 CO₂
emissions
50% reduction in NO_x
20dB noise reduction

Source: Pratt & Whitney

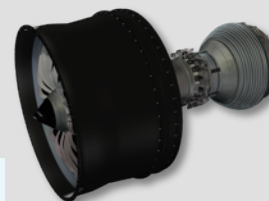
CFM LEAP-1B

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 CO₂ 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

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for use here

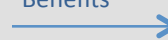


*Phased deployment by the
FAA of Efficient Descent
Advisor starting 2014; full
deployment by 2020.*



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

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for use here

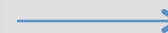


*Included in manufacture
of new models such as
Boeing 787*



Boeing 787
Source: Boeing

Benefits



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

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

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

Aviation Safety
Information and
Analysis Sharing
(ASIAS)



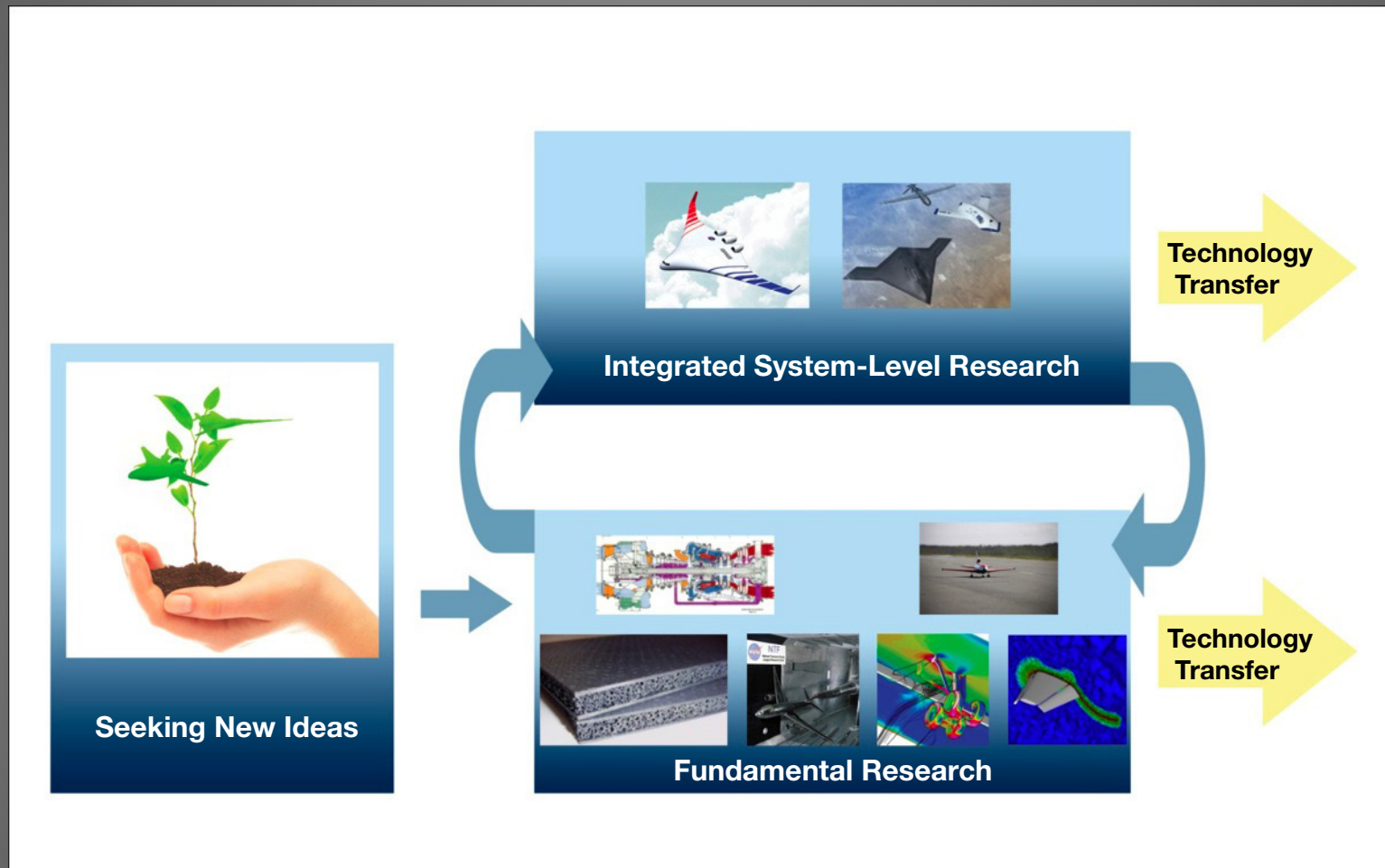
Source: Southwest Airlines

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



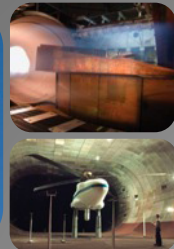
ARMD Investment Strategy



Enabling "Game Changing" concepts and technologies



NASA Aeronautics Programs

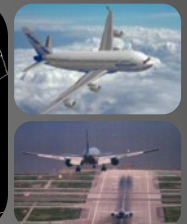
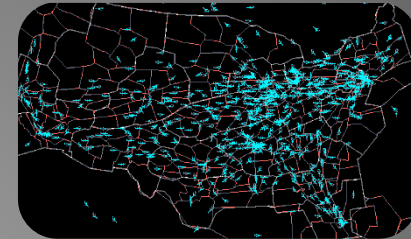


Fundamental Aeronautics Program

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

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.



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.



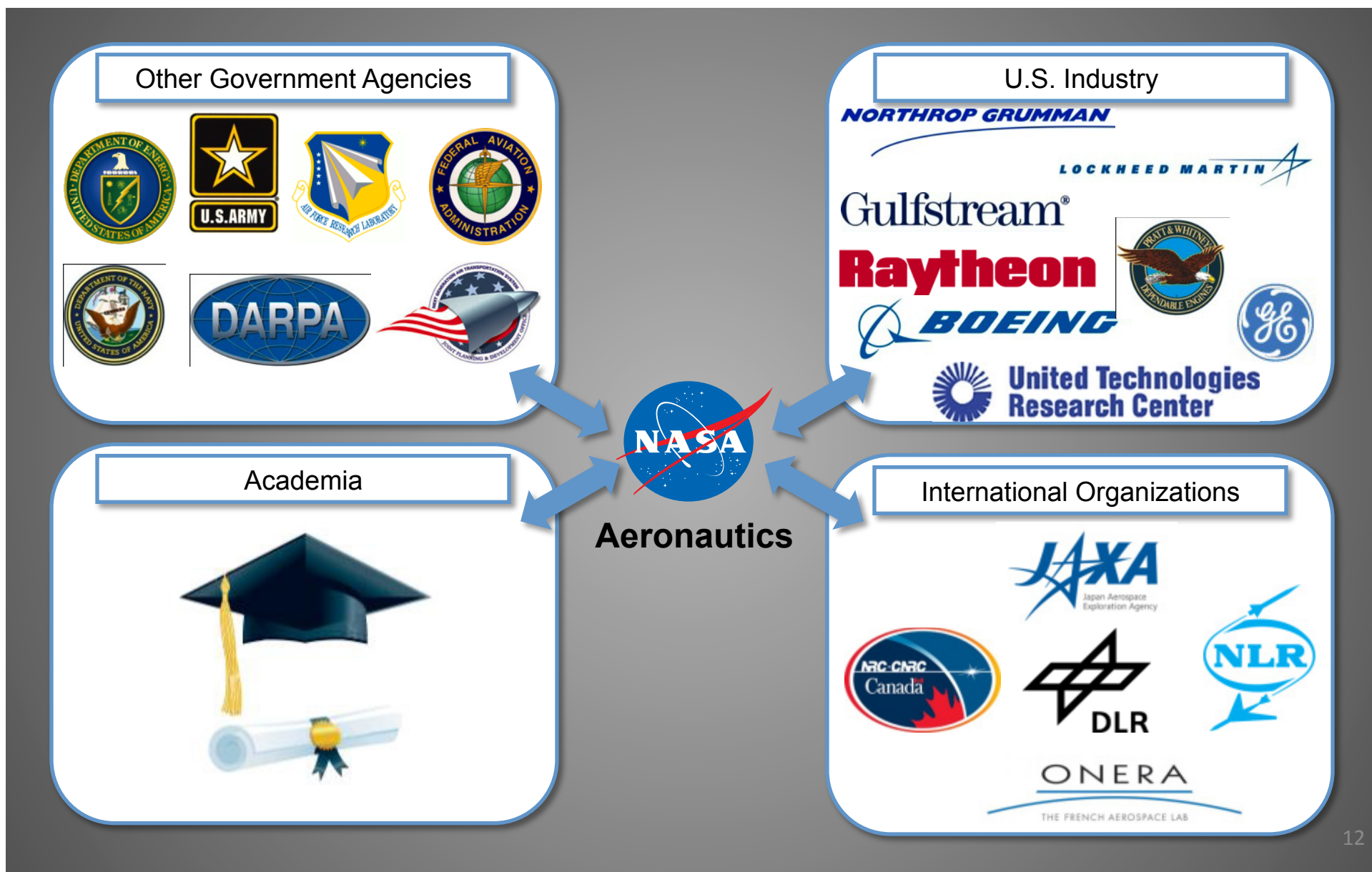
Aeronautics Test Program

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.





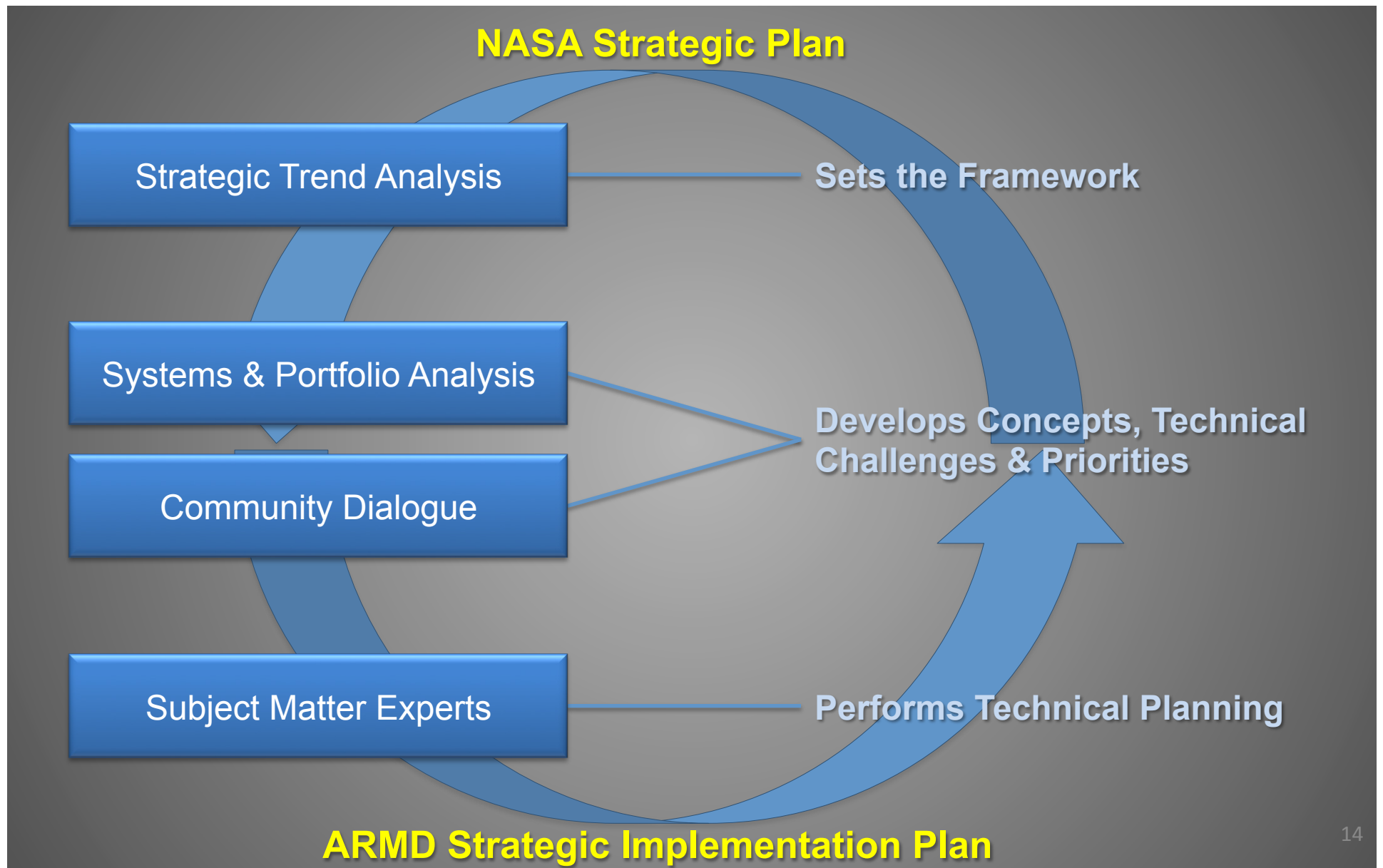
Collaboration with External Partners





STRATEGIC ANALYSIS

Approach to Planning

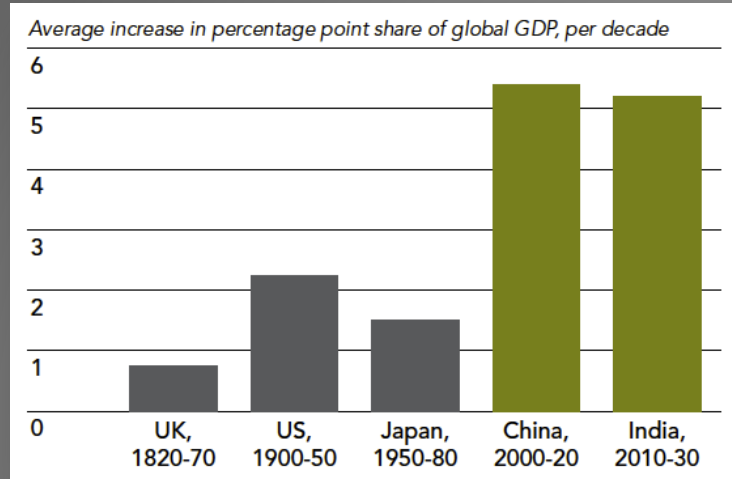


Exploring Strategic Trends

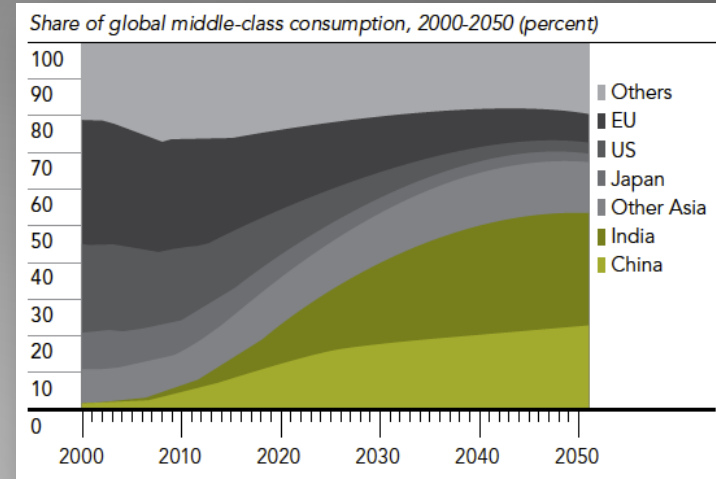
Challenges Traditional Approaches



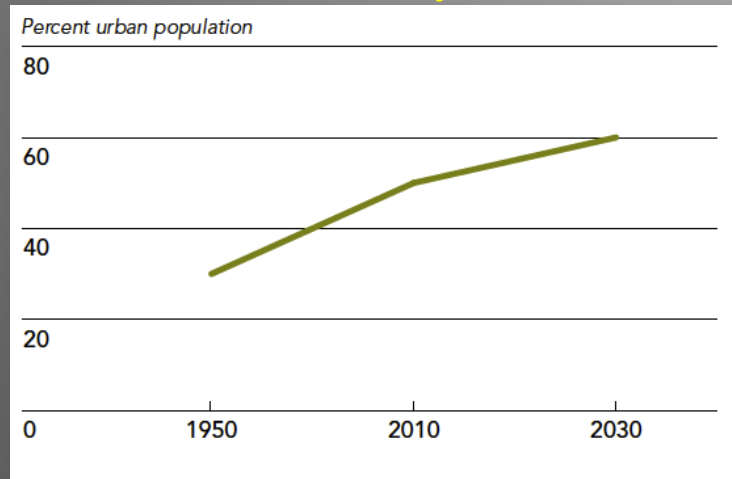
China & India Growing Economically at Historically Unprecedented Rates



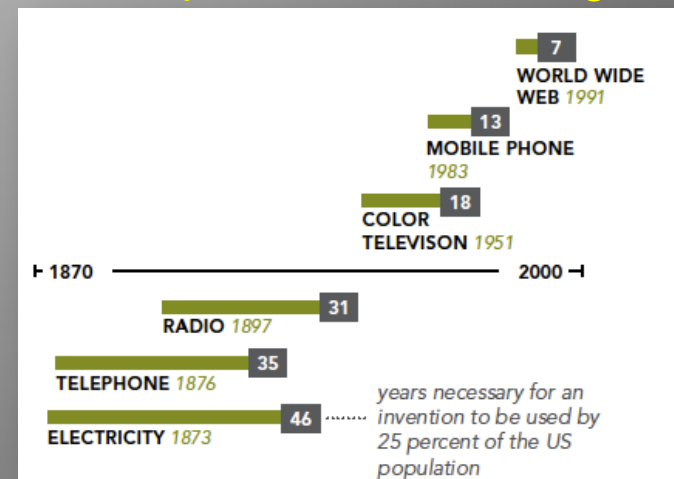
They will have the Largest Middle-Class



The World will be Predominantly Urban



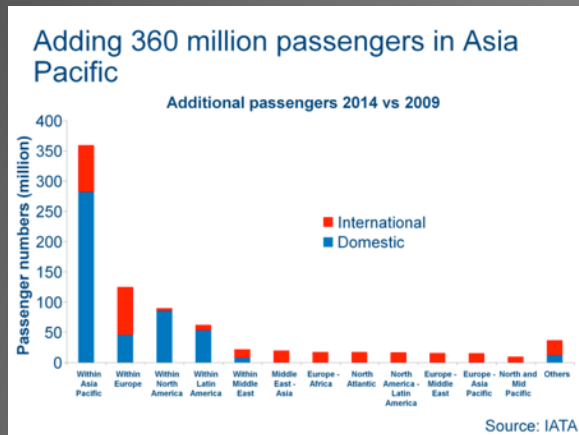
Technology Development & Adoption is Accelerating



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...

FLYING HIGH

The C919, slated to take off in 2014, will be a 150-seat single-aisle jetliner.

Compared to current airplanes of the same size, the C919 jet is expected to:

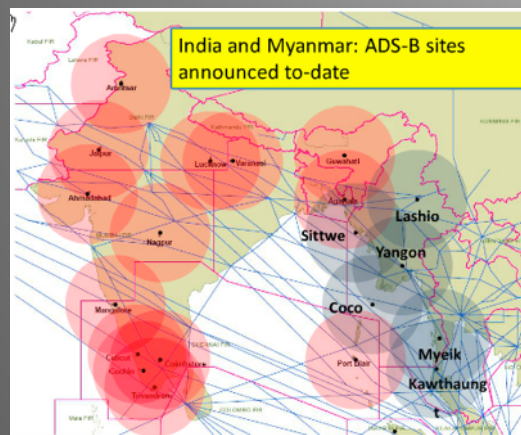
- ✓ Use up to 15 percent less fuel
- ✓ Cut direct operation cost by 10 percent
- ✓ Reduce carbon emission by 50 percent

FLYING FOR THE SKIES

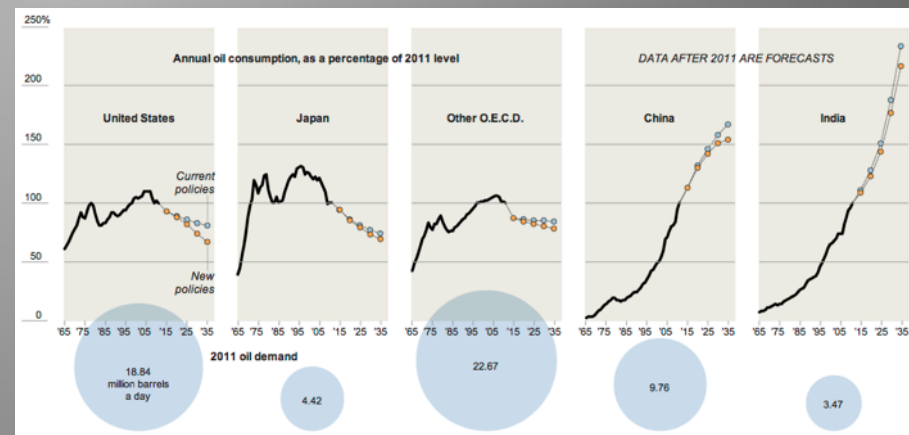
	C919 [®]	A320 [®]	737-800 [®]
Overall length	38.6m	37.6m	39.5m
Height	12.5m	11.8m	12.5m
Wing span	33.6m	34.1m	34.3m
Range (Max)	5,555km	5,700km	5,665km

Source: COMAC[®], Airbus[®], Boeing[®] TIAN CHI / CHINA DAILY

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

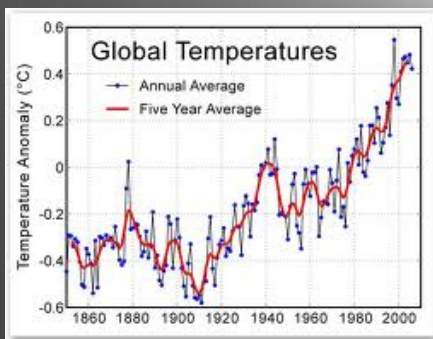
Three critical vectors



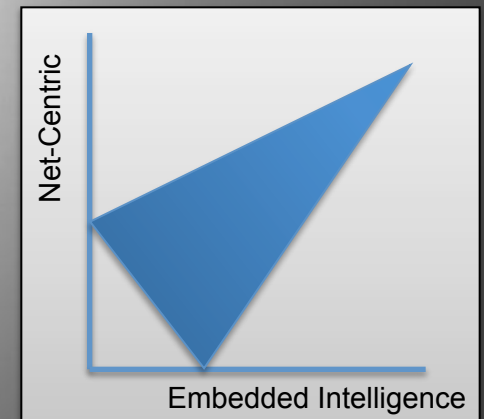
Global Growth in Demand for High Speed Mobility



Global Climate Change, Sustainability, & Energy Transition



Technology Convergence



Aviation Mega-Drivers

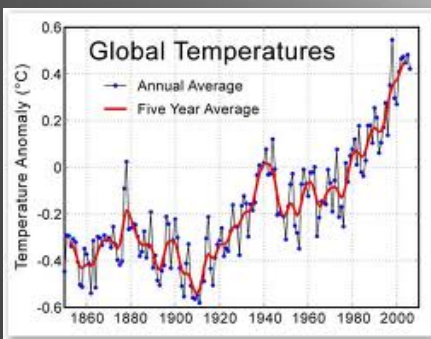
Three critical vectors



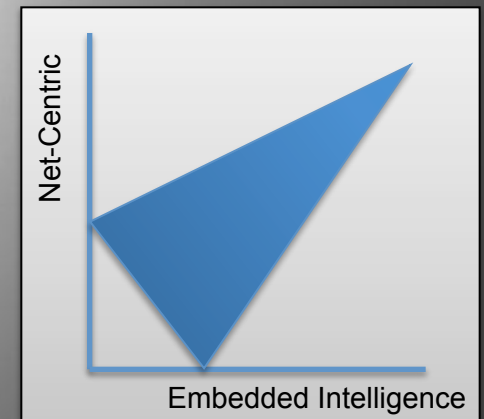
Global Growth in Demand for High Speed Mobility



Global Climate Change, Sustainability, & Energy Transition



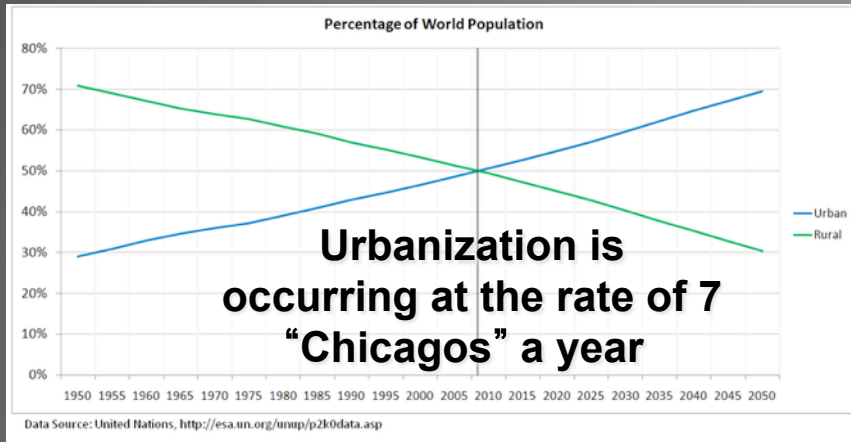
Technology Convergence



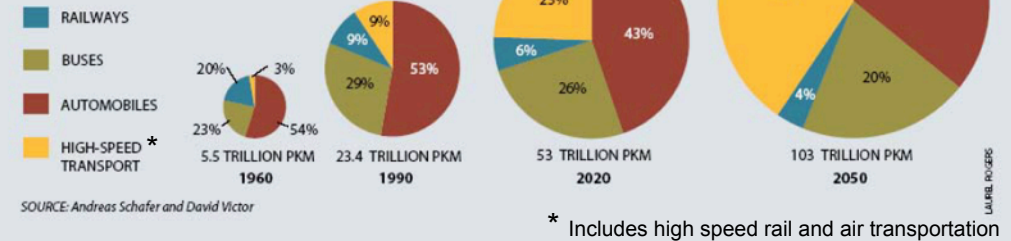
Air Transportation - A Critical Global Capability



Century long trend toward urbanization...



WORLD TRAFFIC VOLUME, measured in passenger-kilometers (pkm), will continue to balloon, with higher-speed transport gaining market share. By 2050, automobiles will supply less than two fifths of global volume.



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

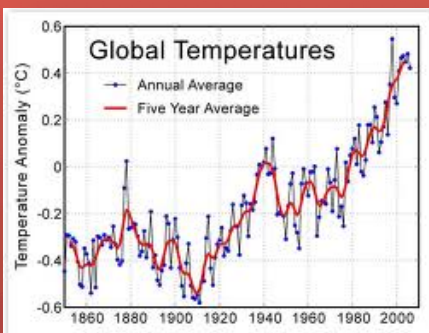
Three critical vectors



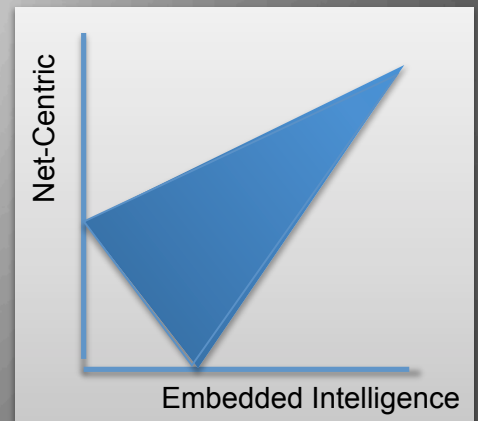
Global Growth in Demand for High Speed Mobility



Global Climate Change, Sustainability, & Energy Transition



Technology Convergence



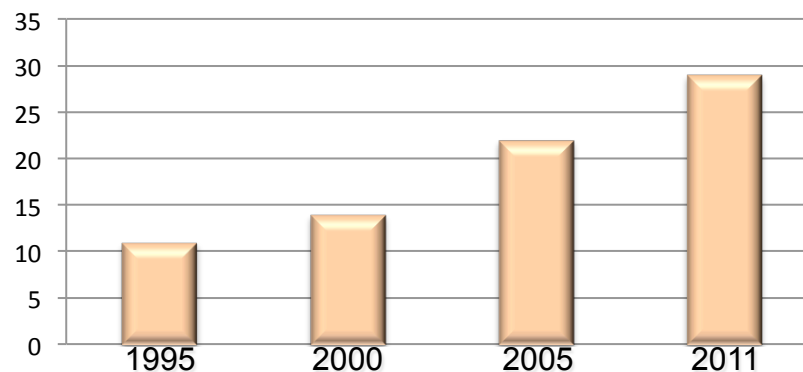
Escalating Fuel Prices have a Large Aviation Impact



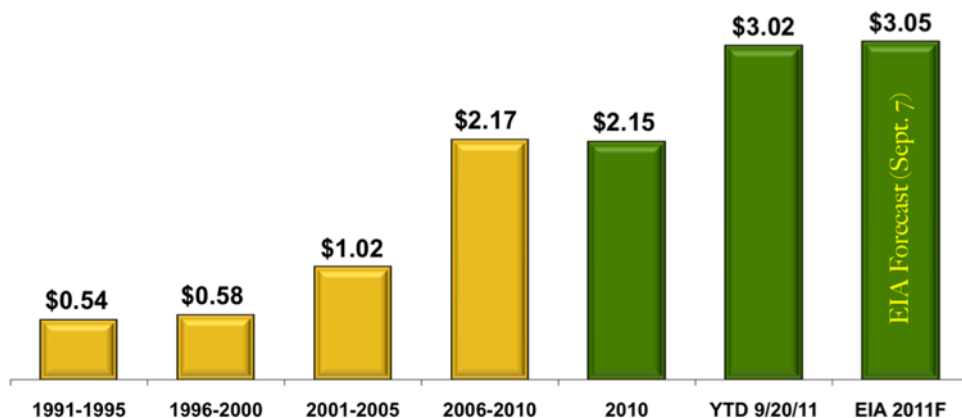
“Fuel is the only major cost item that has become significantly larger over time”
IATA

Source: MIT Airline Data Project

Fuel as Percentage of Total Airline Costs



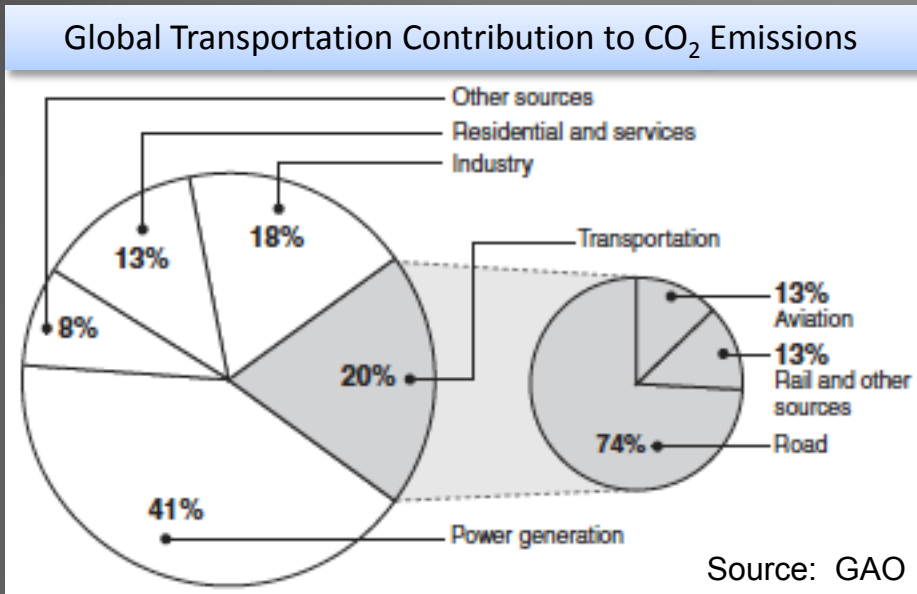
Airline Energy Costs Continue to Rise



Source: EIA Weekly Petroleum Status Report for U.S. Gulf Coast jet fuel prices per gallon

Global Warming Imperative

How do we sustainably satisfy global demand for air transportation?



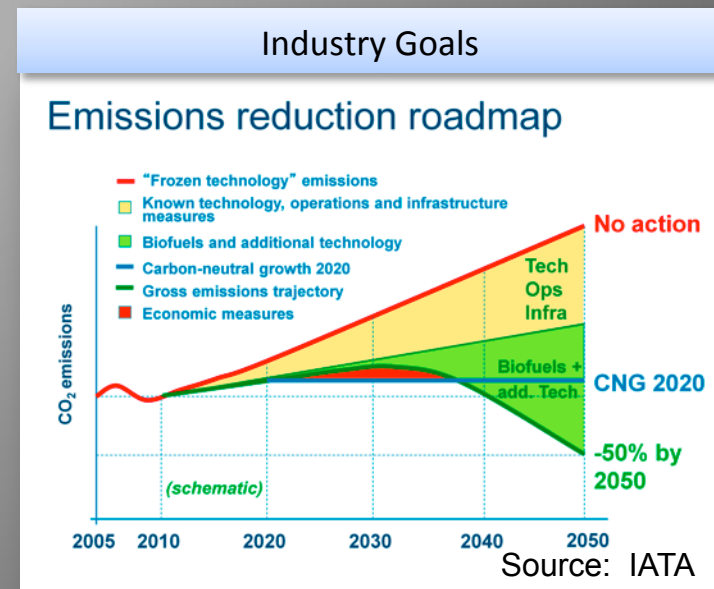
“We will respond to the threat of climate change, knowing that the failure to do so would betray our children and future generations.”

**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



Aviation Mega-Drivers

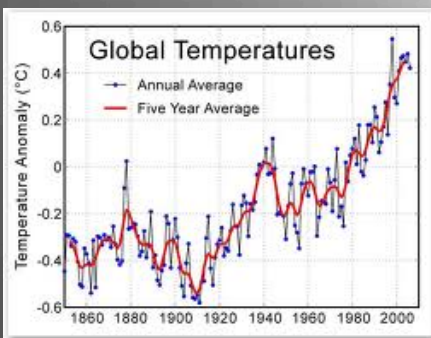
Three critical vectors



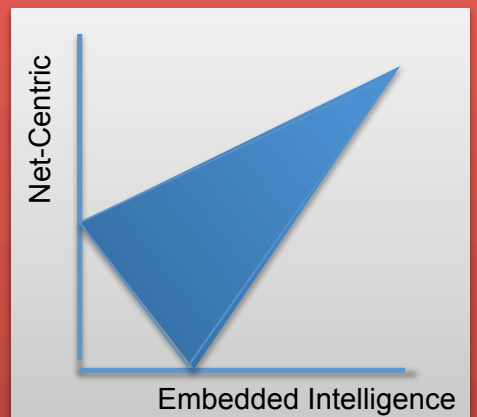
Global Growth in Demand for High Speed Mobility



Global Climate Change, Sustainability, & Energy Transition



Technology Convergence



Technology Convergence

Enabling Assured Autonomy for Safety Critical Systems



Reduce Operations Costs

Improve Performance

Increase Safety

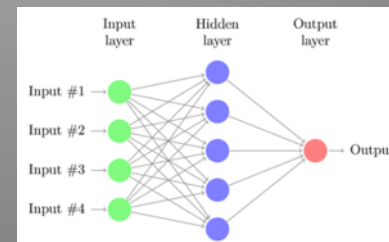
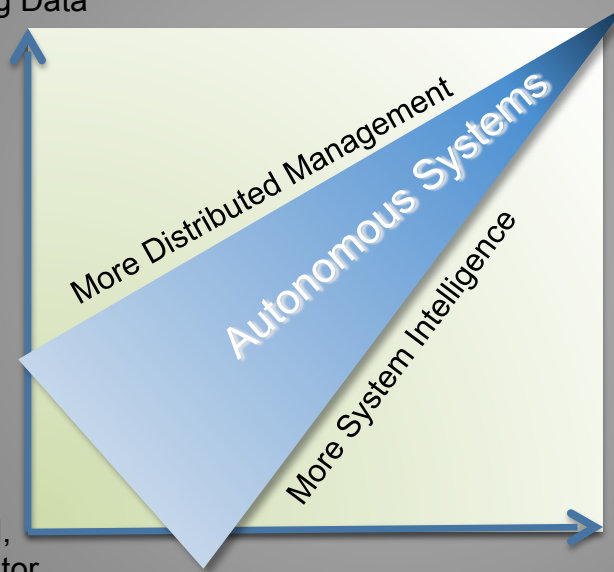
Transform Mobility –
On Demand Aviation

Tomorrow

Net-Centric
Information
– Big Data

Today
Centralized,
Expert Operator

Embedded System
Intelligence

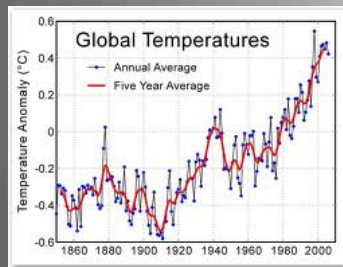


Summary of Strategic Trends



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

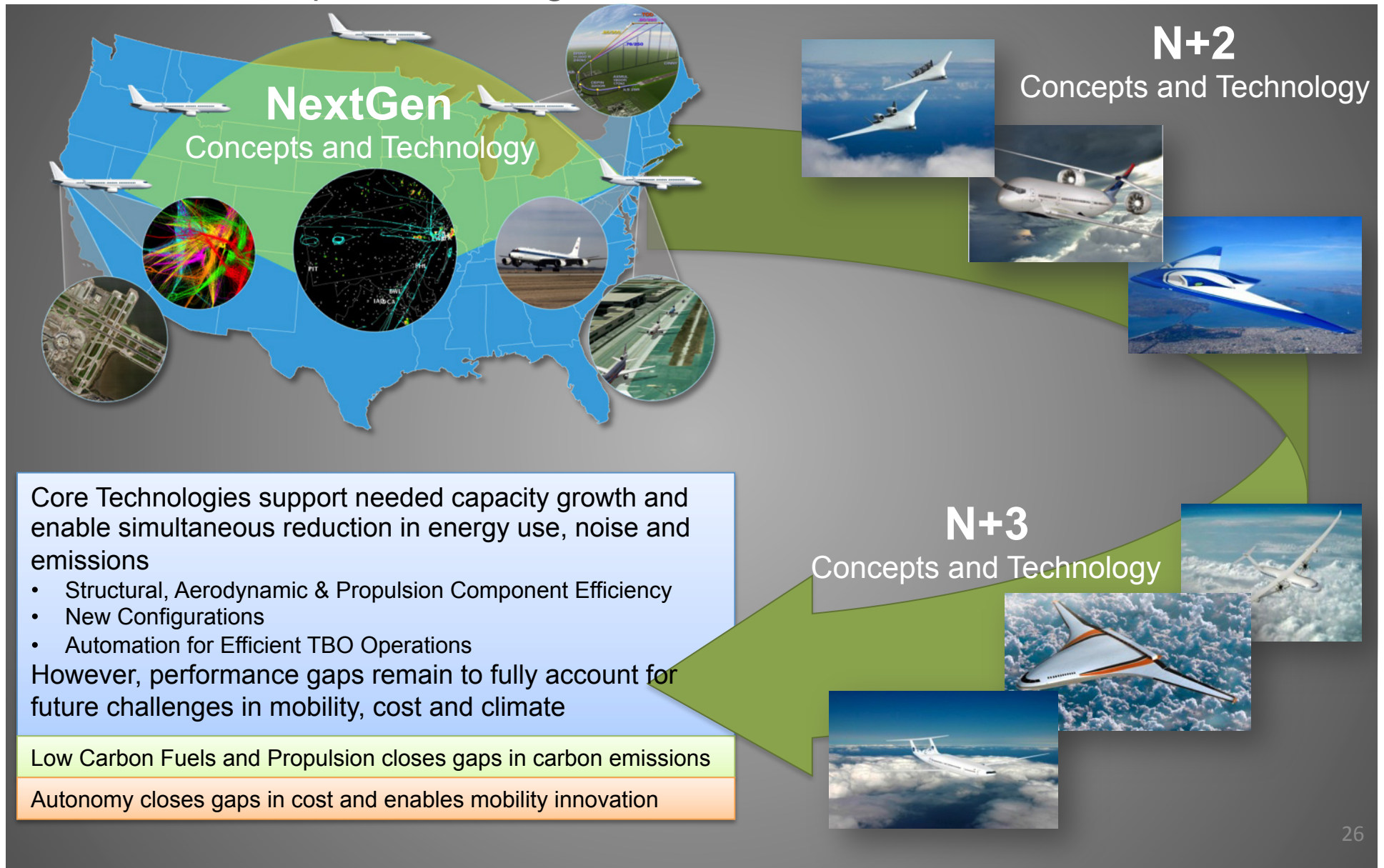


Technology Convergence

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



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

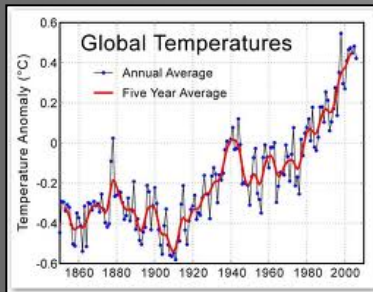
Demonstrate Low-Boom Supersonic Flight

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



Transformative



Sustainable

On-Demand

Fast



Global



**Safety,
NextGen,
Efficiency,
Environment**

Intelligent

Low-Carbon





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**



**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



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
<p>Launch and In-Space Propulsion</p>	<p>Launch Propulsion Systems; High Power In-Space Propulsion; In-Space Propulsion; Cryogenic Storage and Transfer</p>	<p>Electric Propulsion; (Nuclear) Thermal Propulsion; Turbine Based Combined Cycle (TBCC); Rocket Based Combined Cycle (RBCC); Micro-Propulsion; Propellant Storage and Transfer</p>
<p>Robotics and Autonomous Systems</p>	<p>Autonomous Systems; Robotic Maneuvering, Manipulation, Sensing and Sampling; Autonomous Rendezvous and Docking; Structural Monitoring; Robotic Maneuvering</p>	<p>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</p>
<p>Entry, Descent, and Landing</p>	<p>Advanced Entry, Descent, and Landing; Entry, Descent, and Landing</p>	<p>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</p>
<p>Lightweight Space Structures and Materials</p>	<p>Lightweight Space Structures and Materials; Structural Monitoring</p>	<p>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)</p>

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
<p>Launch and In-Space Propulsion</p>	<p>Launch Propulsion Systems; High Power In-Space Propulsion; In-Space Propulsion; Cryogenic Storage and Transfer</p>	<p>Electric Propulsion; (Nuclear) Thermal Propulsion; Turbine Based Combined Cycle (TBCC); Rocket Based Combined Cycle (RBCC); Micro-Propulsion; Propellant Storage and Transfer</p>

ARMD investment in air-breathing hypersonic systems is focused on sustaining core competence and reimbursable activities with DoD to support military requirements

<p>Entry, Descent, and Landing</p>	<p>Advanced Entry, Descent, and Landing; Entry, Descent, and Landing</p>	<p>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</p>
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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

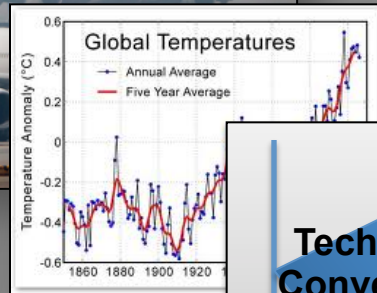
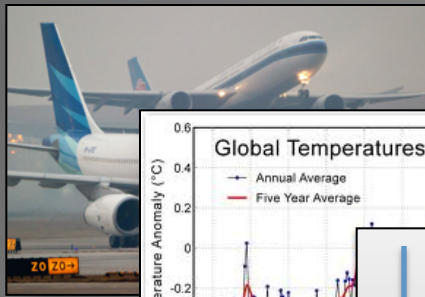
- Opportunity to plan cooperative research activities

Technology Investments	Associated NASA SSTIP Technical Challenge Areas	Associated NRC High Priorities
<p>Robotics and Autonomous Systems</p>	<p>Autonomous Systems; Robotic Maneuvering, Manipulation, Sensing and Sampling; Autonomous Rendezvous and Docking; Structural Monitoring; Robotic Maneuvering</p>	<p>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</p>
<p>Lightweight Space Structures and Materials</p>	<p>Lightweight Space Structures and Materials; Structural Monitoring</p>	<p>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)</p>



Summary

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Urgent Drivers

Economic Growth
High Quality Jobs
Revolutionary Mobility
Long-Term Sustainability



Innovative
Solutions &
High Payoff
Technologies

