National Aeronautics and Space Administration

NASA whitepaper

Aeronautics Research Strategic Vision

A Blueprint for Transforming Global Air Mobility

Aviation touches lives every day. It is about more than being a passenger. While a person may not have flown on a given day, something he or she needed did—a new widescreen LED TV, a smart phone, coffee beans for that daily designer drink, life-saving medicines, or fresh flowers.

The air transportation system has a profound impact on access and economic growth, on technological innovation, on the environment and on the people it serves. Aviation is critical to the global economy and cultural well-being.

NASA's Aeronautics Research Mission Directorate (ARMD) is responsible for developing tools and technologies to improve the efficiency, safety and adaptability of air transportation. ARMD guides its research efforts using a new strategic vision that expands understanding to the world stage and meets the global challenges of the day.

Air Transportation Is Critical to the U.S. Economy

Aviation contributes more than $1.0 trillion annually to the U.S. economy[1] and supports more than 10 million direct and indirect jobs[2], including more than one million high-quality manufacturing jobs. It is one of the few U.S. industries that generates a positive trade balance, which in 2011 was $47.2 billion[3].

Aviation comprises more than five percent of the total U.S. gross domestic product (GDP)[4]. More than $1.5 trillion in freight is transported by air every year[5]. Air travelers alone spend more than $635 billion[6] a year, with more than 734 million domestic and international passengers having been carried on U.S. airlines in 2012.[7] And these numbers are just for the United States with its relatively mature and established system. In much of the rest of the world, the aviation industry is trending toward threefold growth.

[1] $1.3 trillion in total U.S. economic activity from civil and general aviation (2009), "The Economic Impact of Civil Aviation on the U.S. Economy," August 2011, FAA

[2] 10.2 million direct and indirect jobs from civil and general aviation (2011), "The Economic Impact of Civil Aviation on the U.S. Economy" August 2011, FAA

[3] $47.2 billion positive trade balance from civil aviation (2011), International Trade Administration

[4] 5.2% of total U.S. GDP from civil and general aviation (2009), "The Economic Impact of Civil Aviation on the U.S. Economy," August 2011, FAA

[5] $1.6 trillion in domestic freight, exports and indirect spending (2006), "The Economic Impact of Civil Aviation on the U.S. Economy," August 2011, FAA

[6] $636.1 billion spent by foreign and domestic travelers (2011), "The Economic Impact of Civil Aviation on the U.S. Economy," August 2011, FAA

[7] 734 million domestic and international passengers on U.S. carriers (2012), "Passengers: All Carriers, All Airports," Bureau of Transportation Statistics

Global trends drive conditions that influence NASA aeronautics research and development. *Graphic: NASA*

Emerging Global Trends Challenge Traditional Planning
The global nature of aviation requires an understanding of the trends driving demand and shaping the market in which U.S. industry is striving to remain competitive. It is also important to examine trends outside of aviation to understand the factors that will impact and shape future aeronautics research and development.

One such trend is the rapid economic growth that is occurring in Asia. The projected GDP growth rate from now until 2030 for China and India is triple what the United States experienced during its most explosive economic growth period between 1900 and 1950. As a result, they will have the largest middle class in the world. In addition, the world is becoming increasingly urban, with a population equivalent to seven Chicago-sized cities moving to urban centers each year[8]. All of these trends mean that millions more people will desire global mobility and will be better able to afford it. Manufacturers will need to connect them to goods and to other people in each of those urban centers as quickly as possible[9]. These trends point to a shift of exponential growth to Asian markets and growth in trans-Pacific travel, not just trans-Atlantic.

The birth cycle for revolutionary technology is getting shorter, as is the length of time it takes for widespread adoption. It took 46 years starting in the 19th century for 25 percent of the U.S. population to connect to the electrical grid, and only seven years starting in the 20th century for 25 percent to connect to the World Wide Web. As a result of shortening technology birth cycles, evolving Asian markets can "leapfrog" into next generation technologies, leaving behind less-agile markets struggling to adapt legacy systems.

For U.S. aviation companies to more effectively compete and sell, they must look beyond their own shores and focus on nothing less than transforming air transportation – transforming mobility—to be able to at least maintain current levels of business while striving to lead and innovate in meaningful ways.

Trends Create Aviation Mega-Drivers
Understanding these major socio-economic trends is important because they create the major drivers that will change the face of aviation during the next 20-40 years.

Mega-driver 1: Global growth in demand for air mobility
Prompted by Asian market growth and global urbanization, world traffic volume is projected to dramatically expand by 2050, with a greater share going to air travel as compared to ground-based vehicles[10].

Mega-driver 2: Global climate issues, sustainability and energy transition
Climate issues and global growth are challenging global resource sustainability. In addition, energy costs to U.S. airlines nearly tripled between 1995 and 2011, and continue to represent the biggest percentage of operating costs[11]. As a result, aviation must dramatically reduce fuel use and its related emissions.

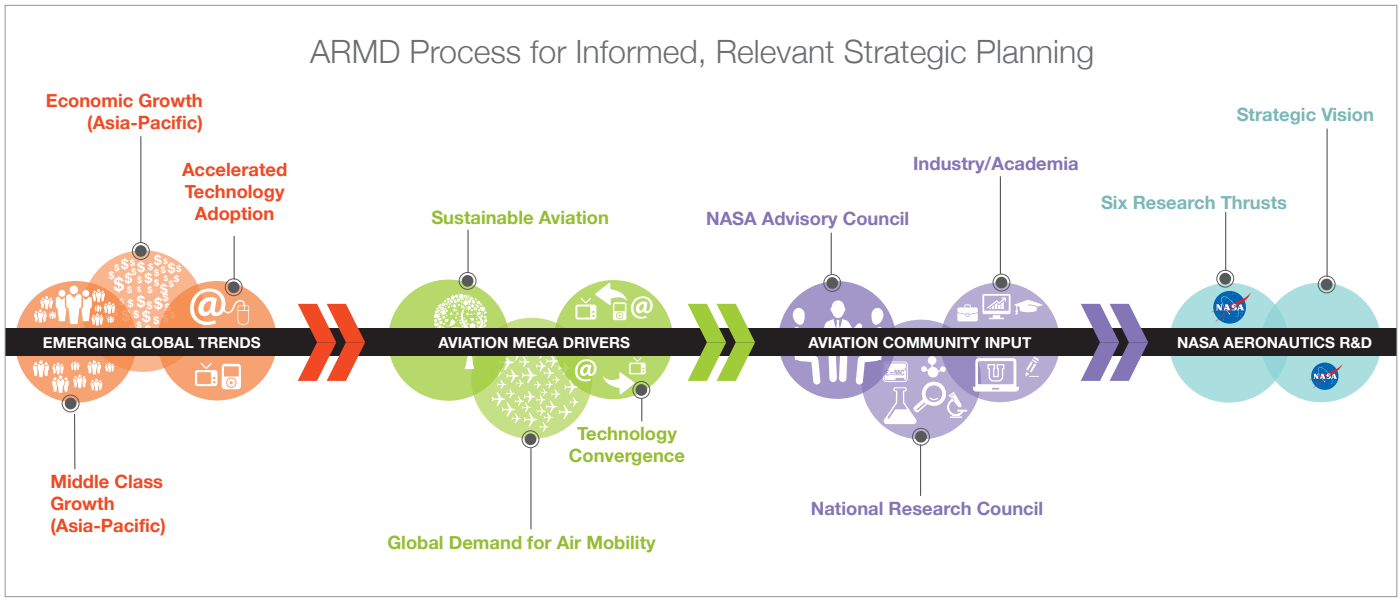
Mega-driver 3: Technology convergence
Aviation will benefit significantly from paying attention to technologies that are revolutionizing other industries—smart materials, additive manufacturing, embedded micro- and nano-sensors. For example, advances in robotics and automation from other sectors are creating a wave of innovation in unmanned aircraft systems.

[8] Global Trends 2030, December 2012, National Intelligence Council

[9] Ibid.

[10] Andreas Shafer and David Victor, 1997 and 2005 studies

[11] MIT Airline Data Project, 2011 data, http://web.mit.edu/airlinedata/www/default.html

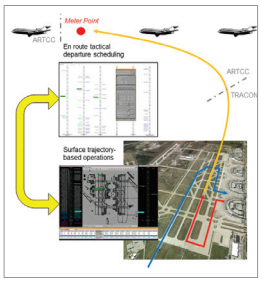


ARMD analyzed global trends, identified the mega-drivers for aviation prompted by those trends, and responded with an updated organizational strategy for its research portfolio and a bold strategic vision. *Graphic: NASA*

Inputs Converge to Define NASA ARMD Research Thrusts

Assessing global trends and identifying mega-drivers are only part of the effort ARMD has undertaken to define its strategy and vision. Ongoing inputs by the aviation community, combined with broadly accepted national aeronautics research goals, have enabled ARMD to strengthen the relevance of its research portfolio.

Safe, efficient growth in global operations



PDRC software will help save flight time and fuel.

- Mega-drivers: Global demand and system growth
- Challenge: Enable the Next Generation Air Transportation System in the United States by 2035 and safely expand capacity of the global airspace system to accommodate growth in air traffic
- Research example: NASA's Precision Departure Release Capability (PDRC) is a software tool that improves the overall efficiency of air traffic management by reducing missed or delayed departures. It allows more aircraft to depart within a given timeframe, saving time and fuel. PDRC was successfully tested in partnership with the FAA, which plans to implement the tool in the future.

Innovation in commercial supersonic aircraft

NASA's supersonic research dissects sonic booms.

- Mega-drivers: Global demand and system growth
- Challenge: Provide data for a low-boom standard that could lead to permission for supersonic flight over land
- Research example: NASA's Waveforms and Sonic Boom Perception and Response research effort used flight tests, sensors and community resident surveys to collect data on the perceptions of sonic booms on the ground. Ongoing research is generating more data that could lead to a change in the ruling prohibiting supersonic flight over land, opening up an entirely new market for high-speed travel.

Ultra-efficient commercial vehicles

Revolutionary technologies will help achieve truly sustainable aviation.

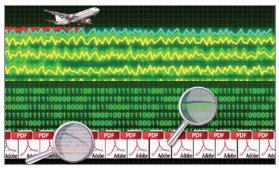
- Mega-drivers: Global demand and system growth, climate change, sustainability, energy costs
- Challenge: Pioneer technologies for future generations of commercial vehicles that simultaneously reduce noise, fuel use and emissions
- Research example: NASA has progressed two designs for aircraft that might enter service in another 15 or 20 years from early concepts to ideas on paper to subscale models and now to wind-tunnel tests. The tests will reveal the designs' ability to dramatically reduce fuel use, noise and emissions.

Transition to low-carbon propulsion

A NASA flight campaign is testing alternative fuel emissions.

- Mega-drivers: Global demand and system growth, climate change, sustainability
- Challenge: Enable transition of industry to low-carbon fuels and alternative propulsion systems
- Research example: NASA's Alternative-Fuel Effects on Contrails and Cruise Emissions flight research effort is investigating whether alternative fuels can reduce aviation's impact on the environment.

Real-time, system-wide safety assurance



NASA's data mining solutions are already helping some airlines improve operations.

- Mega-drivers: Global demand and system growth, technology convergence
- Challenge: Develop tools for use in a prototype of an integrated safety monitoring and assurance system that detects, predicts and prevents safety problems in real time
- Research example: NASA's data mining experts are developing and testing new algorithms—sets of rules that solve problems—to mine terabytes of aircraft data to diagnose and predict problems. Already adopted by airlines and other practitioners in the aviation community, the algorithms improve operations and maintenance.

Assured autonomy for aviation transformation

Using unmanned aerial systems to test advanced communications technologies is part of NASA's work on autonomous flight.

- Mega-drivers: Global demand and system growth, technology convergence
- Challenge: Enable the utilization of higher levels of automation and autonomy across the aviation system
- Research example: NASA flight tested a technology called ADS-B on a NASA unmanned aircraft system (UAS) and confirmed it provided much more detailed position, velocity and altitude information not only to air traffic controllers, but also to airborne pilots of other ADS-B equipped aircraft and to the UAS pilots on the ground.

ARMD Strategic Vision Aims to Transform

NASA's contributions to aviation stretch back nearly a century. Practically every aircraft flying today, and every process in air traffic management, contains a NASA-supported technology.

NASA continues to make great strides in ensuring safety and improving efficiency, with much more to come as the Next Generation Air Transportation System is implemented and aircraft performance is improved.

Yet, given emerging trends, it is no longer enough to focus solely on the challenges that are closest at hand. It is time to acknowledge the global nature of air transportation and anticipate its future.

NASA ARMD through its ongoing research will:

- Continue to work near-term challenges as stepping stones for broader sustainable and transformative aviation;
- Explore the application of more intelligent systems and low-carbon approaches to reducing costs and improving safety to achieve truly sustainable aviation; and
- Develop solutions to make commercial supersonic flight over land possible, and investigate the potential for technology convergence that leads to on-demand, widespread, and fully autonomous flight that transforms aviation and global mobility.

ARMD's strategic vision presents a more challenging direction for the aviation community. *Graphic: NASA*

"We're organizing our research to meet the big global issues facing the world. It's not just about air transportation. It's not just about more efficient air traffic control. It's about how aviation, in partnership with other industries and other organizations in other parts of the economy, meets the global challenges of our day."

- Mr. Robert Pearce, Director of Strategy, Architecture and Analysis, NASA ARMD

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