NASA Aeronautics Research Mission Directorate

May 2018

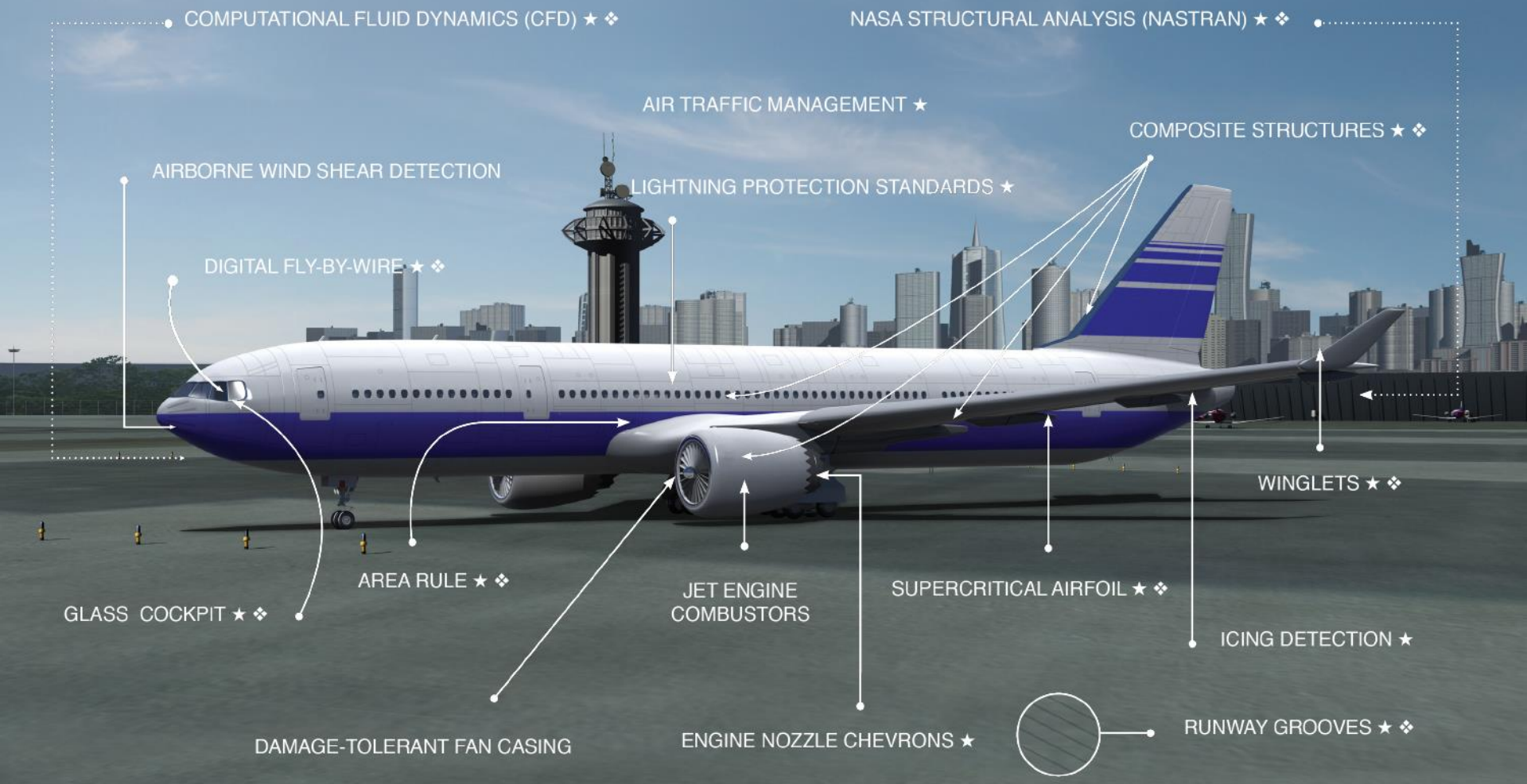
AVIATION IS VITAL TO OUR NATION'S ECONOMY

- $82.5 billion positive trade balance
- $1.6 trillion total U.S. economic activity
- 10.6 million direct/indirect jobs
- $771 billion spent by air travelers in U.S. economy
- 18.1 million tons of freight transported by U.S. airlines

(Sources for statistics listed at https://www.nasa.gov/aero/infographics.html)

NASA HAS MADE DECADES OF CONTRIBUTIONS TO AVIATION

NASA-developed technology is onboard every U.S. commercial aircraft and in every U.S. control tower.



★ Applies also to general aviation aircraft
❖ Applies also to military aircraft

GLOBAL GROWTH IN AVIATION

2016 GLOBAL AVIATION INDUSTRY

3.8 B Passenger Trips

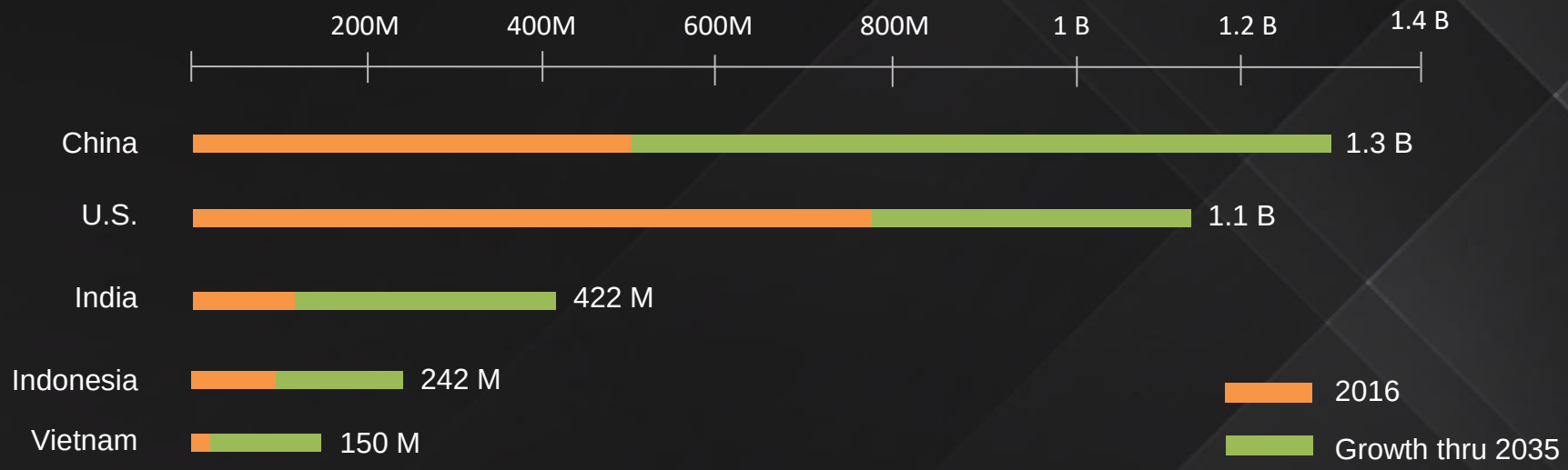
North America & Europe combined is half of all passenger trips

2035 GLOBAL AVIATION INDUSTRY

7.2 B Passenger Trips

Asia-Pacific passenger trips equal to North America & Europe combined

Top Five Fastest-Growing Markets



Over 36,000 new aircraft required
(replacement and growth) over the 20 year period ($4-$5T value)

NASA AERONAUTICS VISION FOR AVIATION IN THE 21ST CENTURY

ARMD continues to evolve and execute the Aeronautics Strategy *https://www.nasa.gov/aeroresearch/strategy*

6 Strategic Thrusts

- Safe, Efficient Growth in Global Operations
- Transition to Alternative Propulsion and Energy
- Innovation in Commercial Supersonic Aircraft
- Real-Time System-Wide Safety Assurance
- Ultra-Efficient Commercial Vehicles
- Assured Autonomy for Aviation Transformation

U.S. leadership for a new era of flight

NASA AERONAUTICS RESEARCH PROGRAMS ALIGN WITH STRATEGIC THRUSTS

MISSION PROGRAMS

Airspace Operations and Safety Program

AOSP

Safe, Efficient Growth in Global Operations

Real-Time System-Wide Safety Assurance

Advanced Air Vehicles Program

AAVP

Ultra-Efficient Commercial Vehicles

Innovation in Commercial Supersonic Aircraft

Transition to Low-Carbon Propulsion

Integrated Aviation Systems Program

IASP

Flight research-oriented, integrated, system-level R&T that supports all six thrusts

X-planes/ test environment

SEEDLING PROGRAM

Transformative Aeronautics Concepts Program

TACP

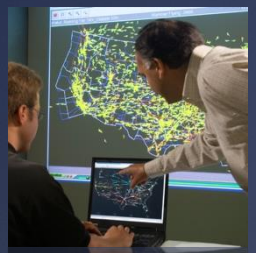
High-risk, leap-frog ideas that support all six thrusts

Critical cross-cutting tool development

Assured autonomy for aviation transformation

STRONG COLLABORATION AMONG NASA RESEARCH CENTERS

ATM Research and Technology & Integration



AMES

Flight Research

ARMSTRONG

Propulsion Research and Technology

GLENN

Vehicle Research and Technology

LANGLEY

Major Areas of Inter-Center Collaboration

Langley/Glenn: Propulsion-Airframe Integration

Ames/Langley: Flight Deck & Ground Based Automation Integration; Flight Mechanics; Aerodynamics

Armstrong/Other Research Centers: Flight Experiment Integration


MARKET: LARGE UAS & HALE
HALE UAS
UPPER E AIRSPACE
NASA
LARGE UAS
SUPERSONIC MANNED AIRCRAFT
SUBSONIC FIXED WING
CLASS A AIRSPACE
LARGE UAS
HELICOPTER
MARKET: THIN / SHORT HAUL
AIRPORT
URBAN VERTIPORT
SMALL AIRPORT
MARKET: URBAN AIR MOBILITY
DRONEPORT
DISTRIBUTION CENTER
MARKET: SMALL / MEDIUM UAS

TECHNOLOGIES TO ENABLE

UAS INTEGRATION INTO NAS

Safe and Efficient Sustained Interoperability of manned and unmanned aircraft within the NAS

"7M SMALL UAS BY 2020 IN THE U.S. . . ."

FAA forecast

UTM

Build an ecosystem with information architecture, data exchange protocols, performance requirements, and establishment of roles and responsibilities of operator and air navigation service provider

UTM / UAM

TRENDS

On-demand

All-electric

Vertical takeoff & landing

Fully autonomous

CHALLENGES

Noise and visual barriers

Cybersecurity

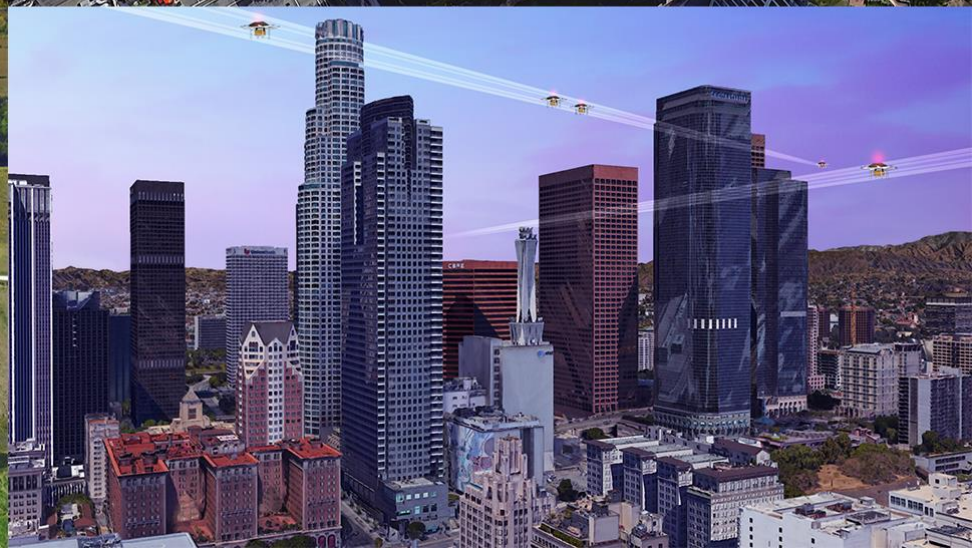
Privacy

Counter drones

Many other non-technical challenges

EMERGING MARKETS - THE CHALLENGE

- Provide users the flexibility to operate when and where required
- Cost effectively accommodate thousands of times the number of vehicles flying today
- Ensure all forms of aviation will be as safe as commercial air transport is today



SAFE USE OF LOW-ALTITUDE DRONES

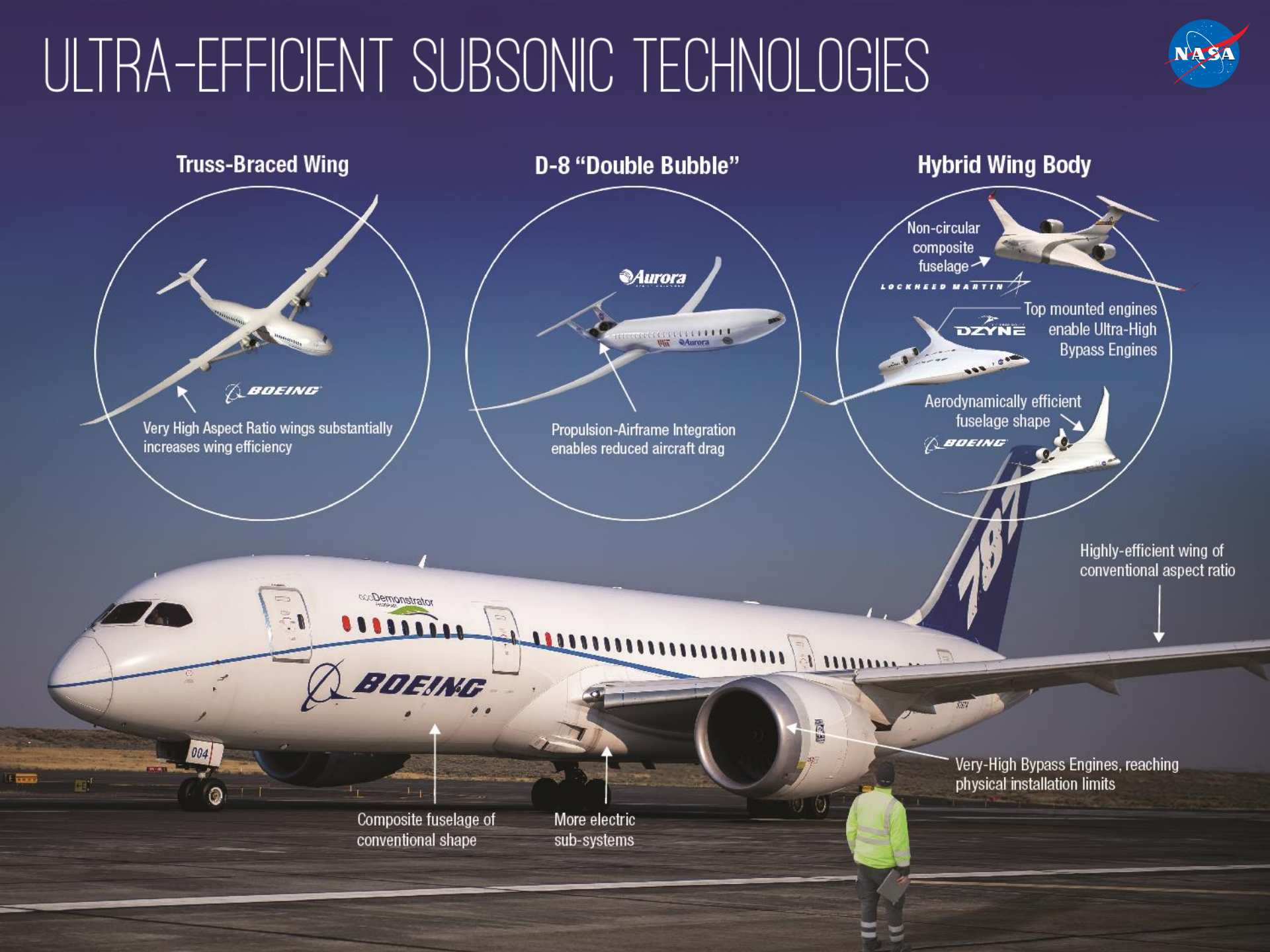
- Developing UAS air traffic management system for low-altitude uncontrolled airspace
- Testing at all 6 FAA test sites with full collaboration with FAA and industry to develop operational standards and building the UAS traffic management eco-system
- Developing and demonstrating increasingly difficult capabilities through phased approach
- Establishing information exchange protocols for coordinated operations

HIGH-PERFORMANCE UAS ROUTINE ACCESS TO NATIONAL AIR SPACE

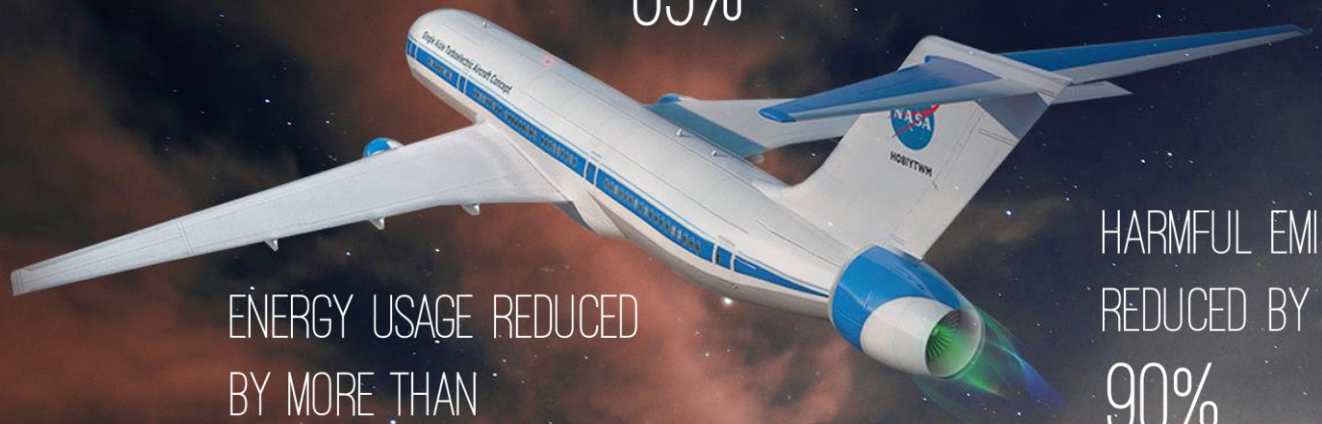
- Series of live, virtual/simulated tests assessed solutions for safely integrating and navigating larger, high performance UAS into high-altitude controlled airspace
- Detect and Avoid: developed algorithms, conducted human-in-the-loop studies to identify best options for alerting ground pilots
- Command and Control: partnered with international community to ensure secure bands and develop security protocols
- Identified minimum operational performance standards for Detect and Avoid, and Command and Control
- Standards submitted to RTCA for review


FROM SONIC BOOM TO
SONIC "THUMP" OVER LAND

ULTRA-EFFICIENT SUBSONIC TECHNOLOGIES



OBJECTIONABLE NOISE
REDUCED BY MORE THAN
65%



HARMFUL EMISSIONS
REDUCED BY MORE THAN
90%

ENERGY USAGE REDUCED
BY MORE THAN
60%

HYBRID ELECTRIC

NEXTGEN ATM: TOOLS FOR MORE EFFICIENT AIR TRAVEL RESULT IN LESS FUEL USE AND FEWER NOISE DELAYS

- NASA/FAA Research Transition Teams make technology transfer fast and efficient
- ATM Technology Demonstrations underway with FAA, airports and airlines to validate major automation advancements
- Five NextGen tools directly transferred to FAA in last five years
- Benefits from use of tools gate-to-gate projected at $200M-$300M annual savings in fuel and similar reduction in carbon emissions

UNIVERSITY LEADERSHIP INITIATIVE (ULI)

New type of interaction between ARMD and university community, where universities take the lead, build their own teams, and set their own research path

- Universities propose innovative ideas to solve complex, multi-disciplinary aeronautics problems
- Teams stay closely connected with stakeholders to promote relevance and technology transition
- Recently completed awards for five university-led teams. Teams are diverse partnerships that include universities, industry, non-profits
- Future solicitations starting in FY2018 – 1-2 awards per year
- Recent recognition from NAC Aero Committee for ULI's ability to promote education of next generation of engineers

UNIVERSITY OF SOUTH CAROLINA

Communication capabilities for improving link/network capacity, reliability, security in support of new ATM applications

Small real-time geometric outer mold line (OML) reconfigurations to minimize boom signatures and drag in response to changing ambient conditions

THE UNIVERSITY OF TENNESSEE KNOXVILLE

Develop slotted, natural laminar flow airfoil to reduce wing profile drag

THE OHIO STATE UNIVERSITY

Advance electric power systems, battery and energy storage, thermal management supporting electric propulsion aircraft

ASU

System-wide, real-time prognostics framework with rigorous V&V for proactive health management of NextGen NAS

INTERNATIONAL COOPERATION

NASA ARMD employs international cooperation in order to meet distinct programmatic needs.

In particular cooperation that:

- Provides access to unique foreign capabilities, resources or data;
- Leverages NASA's investments with those of international partners in like areas of research, either to reduce duplication or obtain synergies from complementary approaches; and/or
- Informs international aviation standards and practices.