NASA Sustainable Flight National Partnership Activities

Aeronautics and Space Engineering Board – The National Academies of Science, Engineering, and Medicine
Irvine, CA

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Outline

- Context
- Sustainable Flight National Partnership (SFNP)
  - Origin
  - Scope
  - Elements and Status
- Beyond the Technical Partnerships
- Concluding Remarks

CONTEXT

Four Transformations for Sustainability, Greater Mobility, and Economic Growth

SFNP Focus
SUBSONIC COMMERCIAL TRANSPORTS

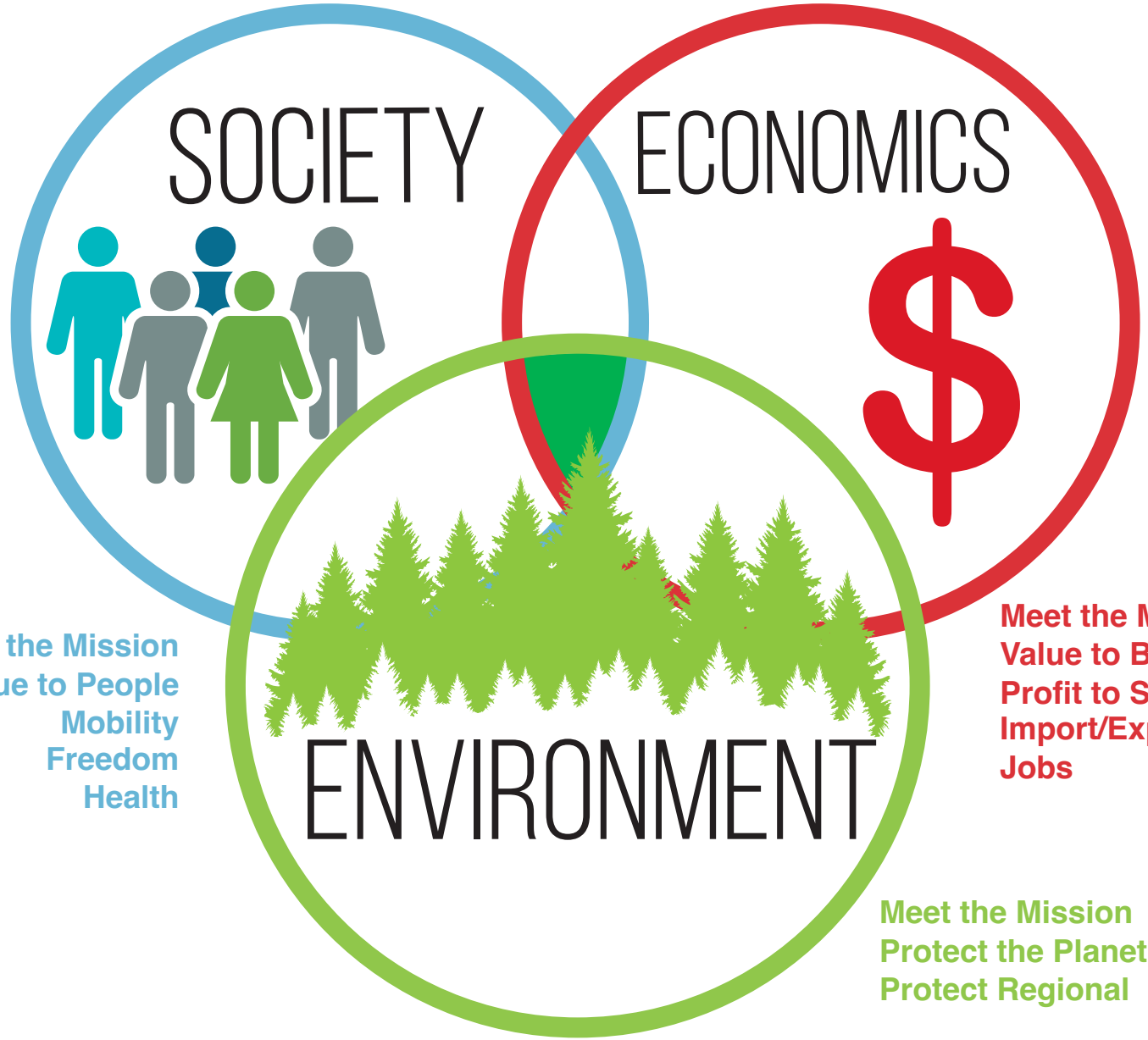
the 24/7 global backbone
of air transportation
now and into the forseeable future

and the key to a sustainable aviation future

Sustainability – a Global View

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

- UN World Commission on Environment and Development

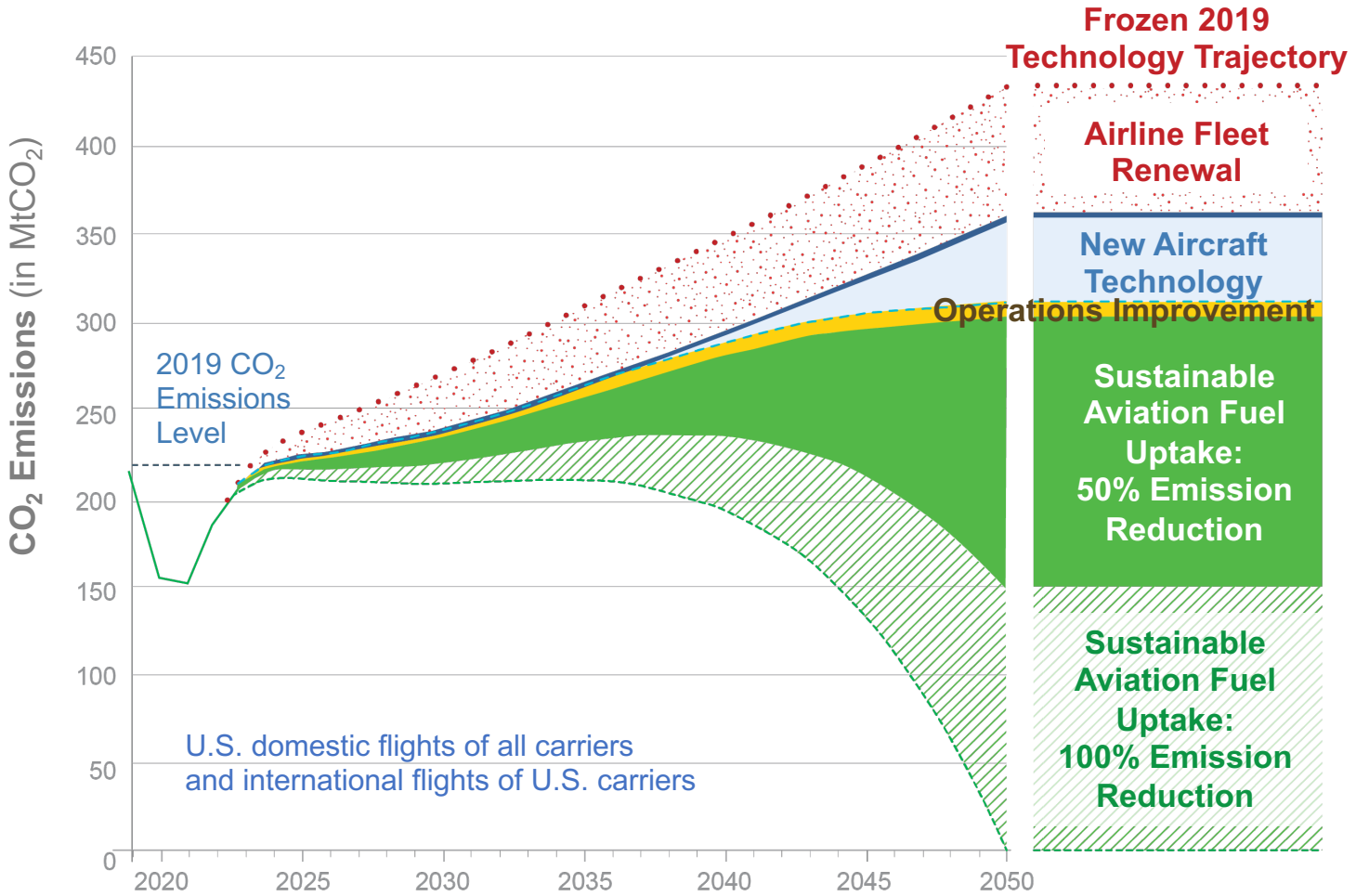


U.S. Aviation Climate Action Plan

Global Context for Sustainable Aviation

U.S. aviation goal is to achieve
net-zero greenhouse gas emissions by 2050.

U.S. Aviation Climate Action Plan is aligned with
- U.S. economy-wide goal
- International Civil Aviation Organization
- Air Transport Action Group



https://www.faa.gov/sites/faa.gov/files/2021-11/Aviation_Climate_Action_Plan.pdf

The U.S. is working with the global community to achieve net-zero greenhouse gas emissions by 2050 using a common basket of measures.

ARMD PROGRAMS

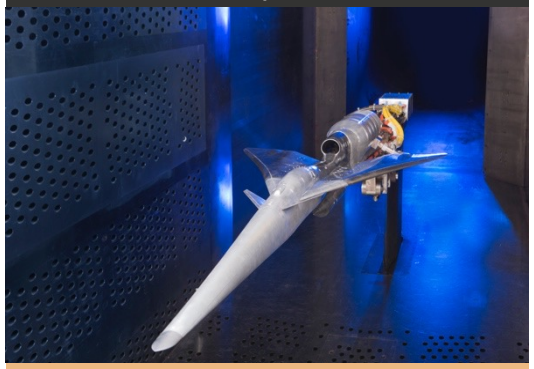
Airspace Operations and Safety Program

Advanced Air Vehicles Program

Integrated Aviation Systems Program

Transformative Aeronautics Concepts Program

Aerosciences Evaluation and Test Capabilities Portfolio



Sustainable Flight National Partnership (SFNP)

NASA Projects

1 Advanced Air Transport Technology (AATT)

2 Hi-rate Composite Aircraft Manufacturing (HiCAM)*

3 Hybrid Thermally Efficient Core (HyTEC)*

4 Electrified Powertrain Flight Demonstrations (EPFD)*

5 Sustainable Flight Demonstrator (SFD)*

6 Air Traffic Management Exploration (ATM-X)

7 Transformational Tools and Technology (TTT)

****focused SFNP***

Sustainable Flight National Partnership (SFNP)

SFNP Scope

in context with broader sustainable aviation portfolio

Sustainable Aviation

with safe, clean, quiet, economical, operable, and marketable products

Sustainable Flight National Partnership (SFNP)
(fully active projects now)

- Accelerating aviation towards net-zero carbon
- Focus on energy efficiency improvements and drop-in Sustainable Aviation Fuels (SAF)
- Demonstrate/transfer promising/likely technology and concepts beyond current next-gen baseline today
- Impact next-generation transport aircraft (2030s) and near-term and future operations (2020s)
- Significant near-term market opportunities

Beyond SFNP
(initial exploratory activity ongoing)

- Powering aviation to net-zero carbon and beyond
- Focus on alternative energy and propulsion architectures and non-CO_2 driven climate impacts
- Explore/early development of technology and concepts for more radical change, demonstrate contrail avoidance for current-gen and beyond aircraft
- Impact beyond next-gen transport aircraft (2040s) and near-term and future aircraft operations (2020s)
- Catalyze and stimulate new energy paradigms

Sustainable Flight National Partnership

Next-Generation Capability on the Path to Net-Zero Greenhouse Gas Emissions by 2050

Advance engine efficiency and emission reduction

Enable integrated trajectory optimization

Advance airframe efficiency and manufacturing rate

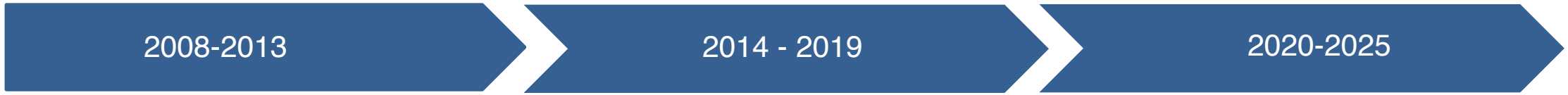
Enable use of 100% sustainable aviation fuels

Achieve net-zero greenhouse emissions by 2050 through 25-30% energy efficiency improvements in next-generation transports, 100% sustainable aviation fuel, and optimal trajectories.

Subsonic Transport Technology

Subsonic Transport Technology Prioritization

NASA Aeronautics Vision and Strategy Established



Subsonic Concept/Technology Studies
Electrified Aircraft Propulsion, Transonic Truss Braced Wing

Environmentally Responsible Aviation (ERA) Project

Flight Demonstrator Studies

Advanced Composites (ACP)

Next Step

Maturation and Integration of Four Key Technologies that will Create a New "S Curve" for Future Subsonic Transports

FAA CLEEN* I

FAA CLEEN* II

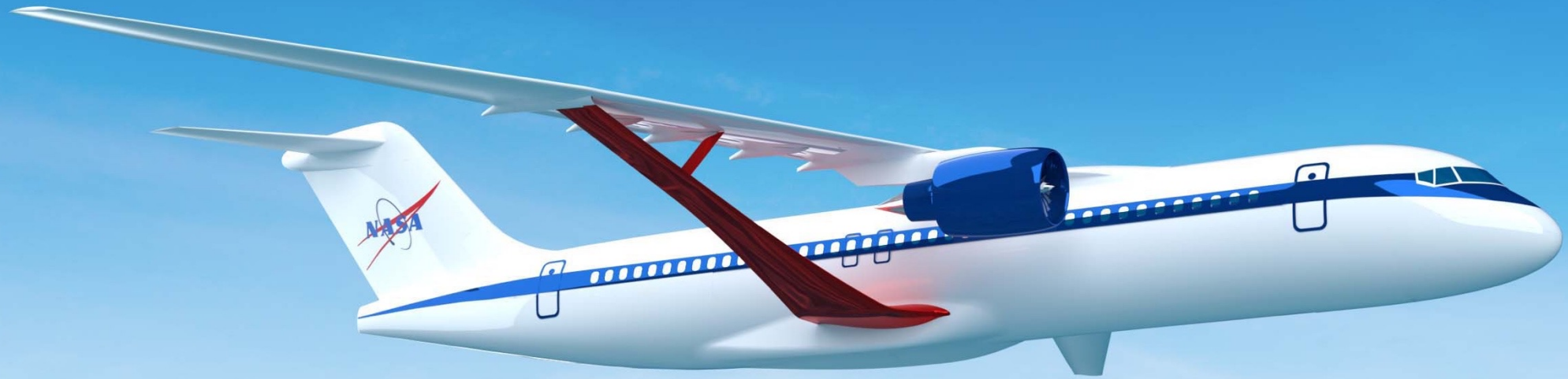
FAA CLEEN* III

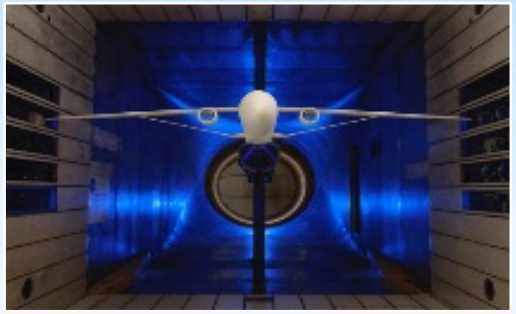
Subsonic Transport Strategy Based on over a Decade of Research, Concept and Technology Development, and NASA-Industry Partnership

* Sponsored by FAA Office of Environment & Energy (AEE)

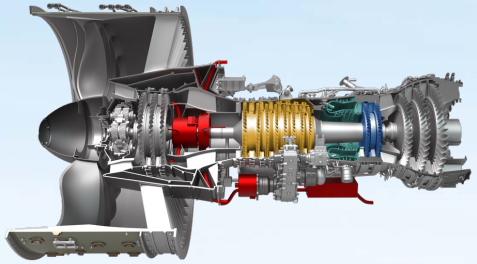
Subsonic Transport Technologies

Ensure U.S. industry is the first to establish the new “S Curve” for the next 50 years of transports

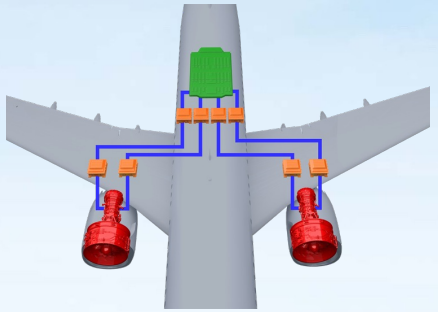




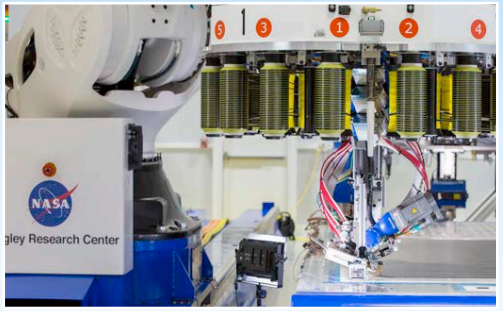
Transonic Truss-Braced Wing
5-10% fuel burn benefit



Small Core Gas Turbine
5-10% fuel burn benefit

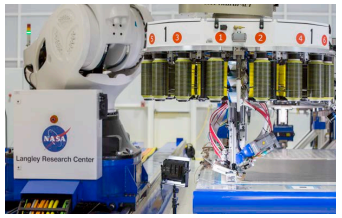


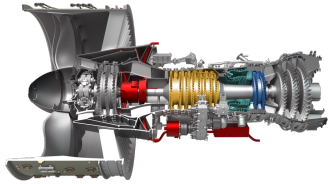
Electrified Aircraft Propulsion
~5% fuel burn and maintenance benefit

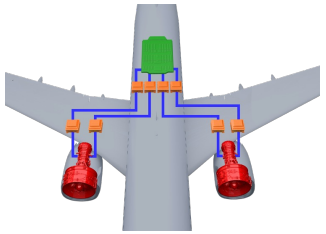


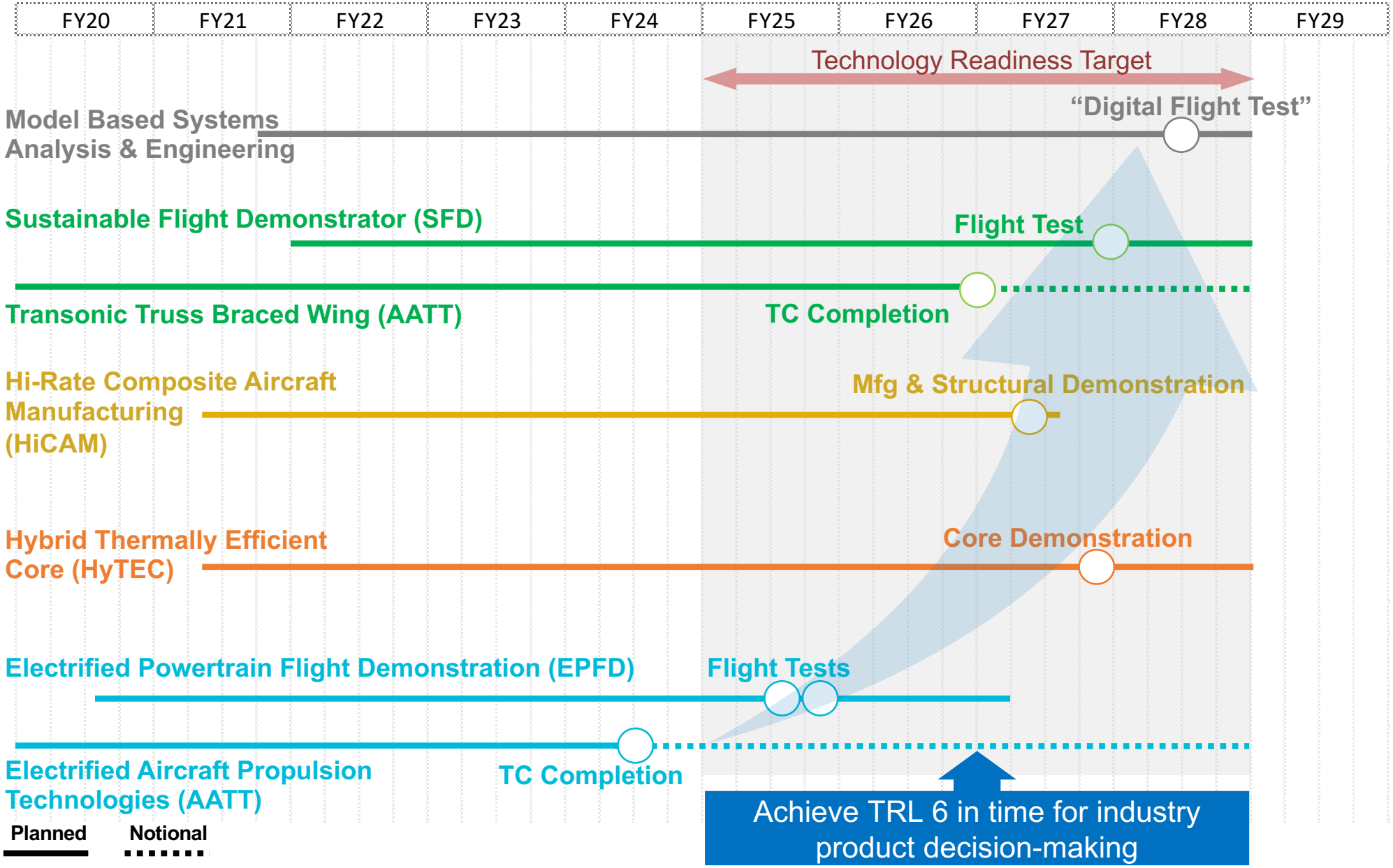
High-Rate Composite Manufacturing
4-6x manufacturing rate increase

Subsonic Transports: Integrated Technology Development

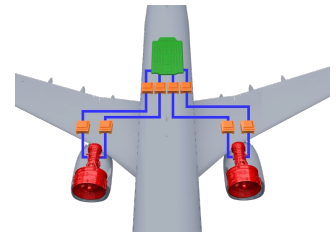


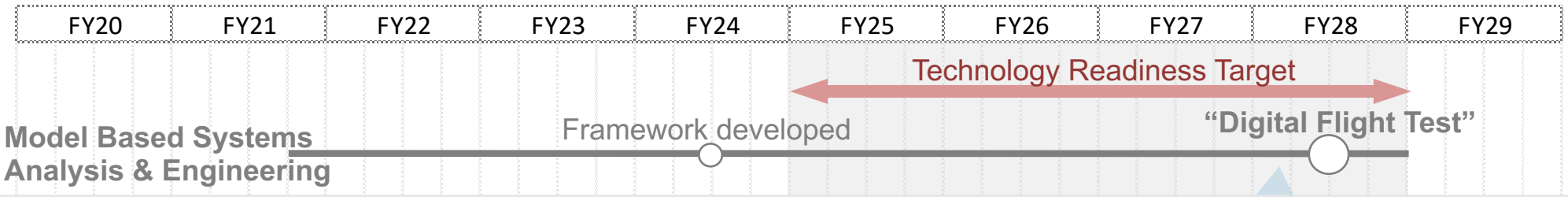






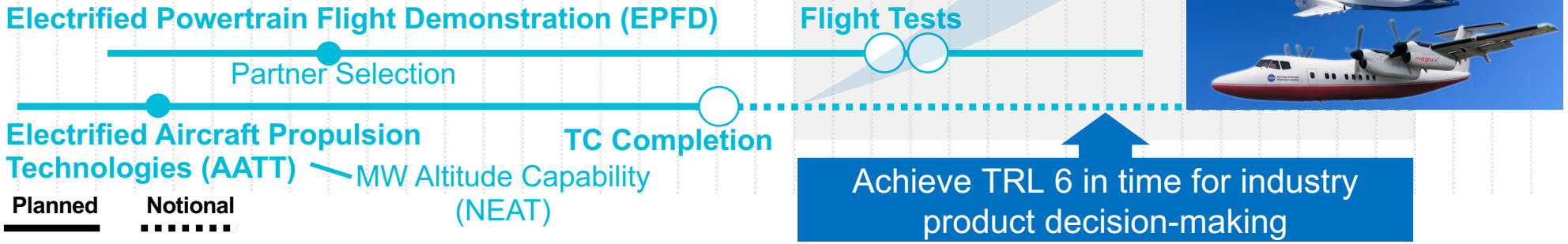
Subsonic Transports: Integrated Technology Development





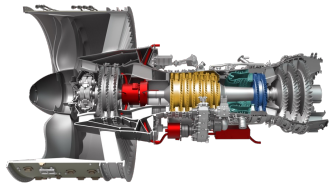
EPFD
- GE Aviation and magniX USA Inc. contracts are in place to mature MW-class hybrid electric propulsion systems & demonstrate flight readiness for single-aisle aircraft.
- GE Preliminary Design Review (PDR) completed in 4QFY22.
- magniX PDR will be in 1QFY24 after completion of configuration trade studies

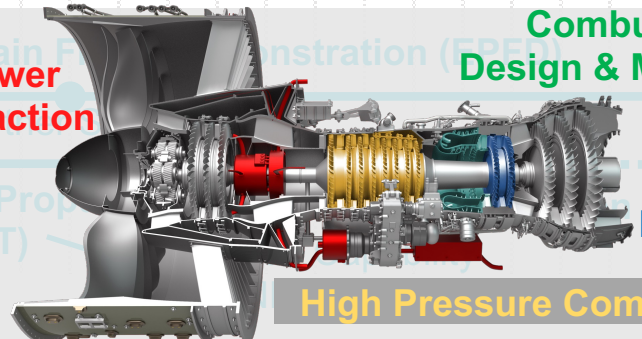
AATT/Electrified Aircraft Propulsion
- Completed Altitude Integrated Test (AIT) with General Electric, demonstrating high-power, high-voltage EAP powertrain at altitude conditions.
- Completed MW-class circuit breaker technology with 3 partners (Navy, GE & Raytheon) as part of EAP Fault Management contracts - one of the key challenges for MW-class EAP powertrains.



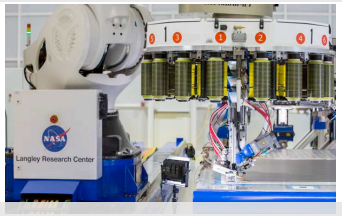
Subsonic Transports: Integrated Technology Development

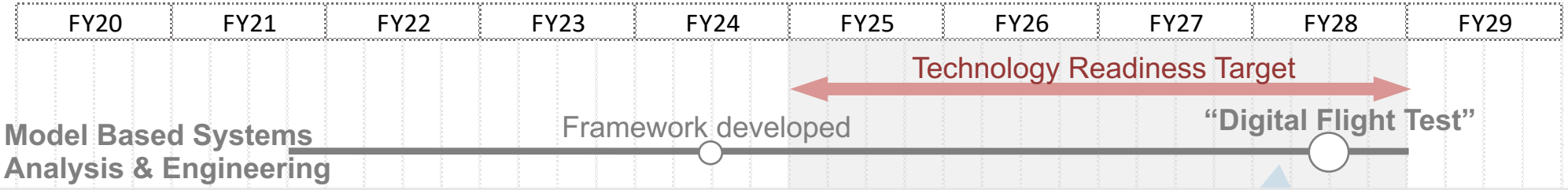
- Small core technologies contracts (9/2021) to GE & P&W targeting TRL 4/5 by 2023. Technology development efforts progressing as planned.
- Additional technology development award (P&W 9/2022) for Small Core Combustor Design with Sustainable Aviation Fuel (SAF) Compatibility.
- Recently completed a Detailed Design Review for TRL 5 dual spool Power Extraction test with GE.





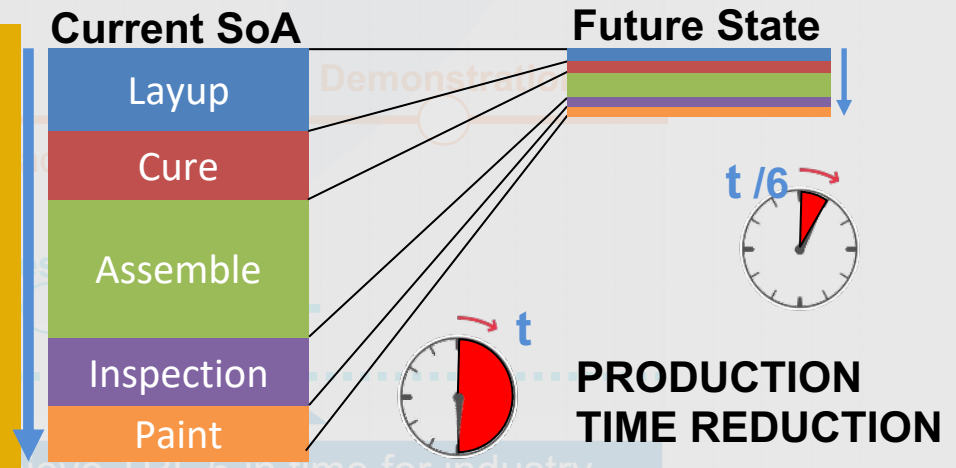
Subsonic Transports: Integrated Technology Development



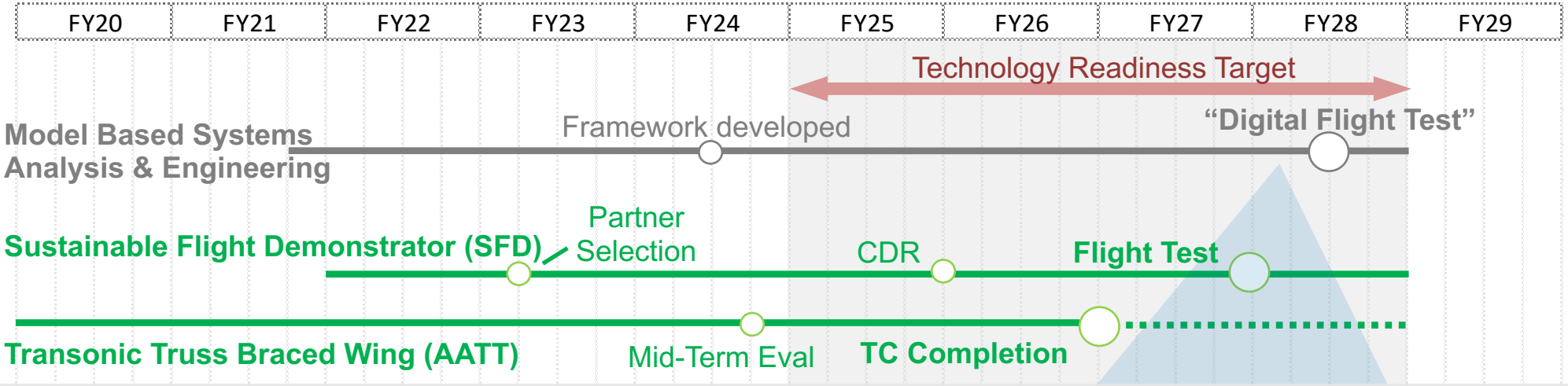


Project implementing Technology Development Phase

- Completed System Requirements, Baseline Definition, Technology Assessments & Development Roadmaps
- Conducted experiments of high-rate materials & manufacturing concepts at coupon/element levels. Data to help estimate potential impact on production rate and to assess material properties & failure mechanisms.
- Multi-party Cooperative Research Teams formed & integrated plans developed. Making awards of Cooperative Agreements for work to be performed July 2022 to June 2024
- Leveraging Advanced Composites Consortium (19 partners)



Subsonic Transports: Integrated Technology Development



Sustainable Flight Demonstrator
- Technical risk reduction contracts completed; final reviews 9/2022.
- Solicitation for demonstrator vehicle closed 9/1/22; partner selection anticipated 1/2023

Ultra Efficient Wing (TTBW)
- High-Speed Buffet Test completed a 4-week investigation in the NASA Ames 11x11 Transonic Wind Tunnel in 2022. Data reduction complete and sufficient buffet margin demonstrated. Final review 9/2022.
- Upcoming aeroelastic wind-tunnel test of a higher aspect ratio wing planned for Feb. and June 2023.

Subsonic Transports: Integrated Technology Development

FY20 | FY21 | FY22 | FY23 | FY24 | FY25 | FY26 | FY27 | FY28 | FY29

Technology Readiness Target

Model Based Systems Analysis & Engineering — Framework developed — **"Digital Flight Test"**

Sustainable Flight Demonstrator (SFD) — Partner Selection — CDR — Flight Test

Transonic Truss Braced Wing (AATT) — Mid-Term Eval — TC Completion

Hi-Rate Composite Aircraft Manufacturing (HiCAM) — Demo(s) Down-select — Mfg & Structural Demonstration

Hybrid Thermally Efficient Core (HyTEC) — Core Award(s) — Power Extraction Test — Core Demonstration

Electrified Powertrain Flight Demonstration (EPFD) — Partner Selection — Flight Tests

Electrified Aircraft Propulsion Technologies (AATT) — MW Altitude Capability (NEAT) — TC Completion

Planned ——— Notional .....

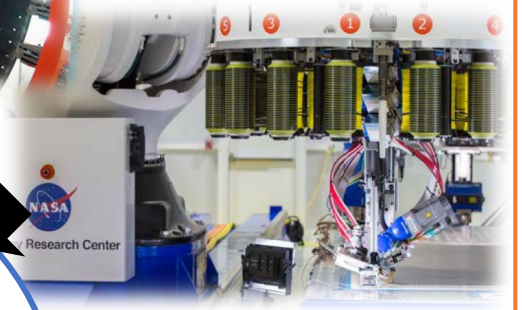
Achieve TRL 6 in time for industry product decision-making

Model-Based Systems Analysis & Engineering

Systems-level Digital Integration across SFNP projects capped by a Digital Flight Test

Advanced Aero-Configuration Ground & Flight Tests (AATT & SFD)

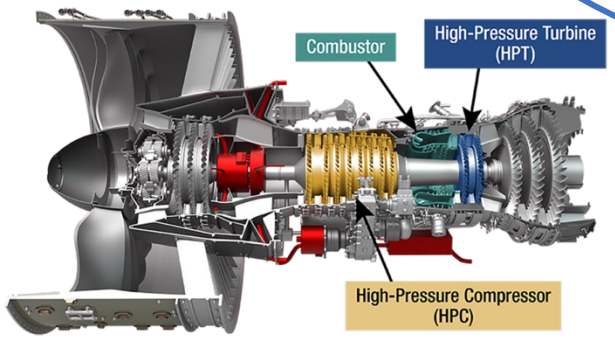
High-Rate Composite Manufacturing Processes (HiCAM)



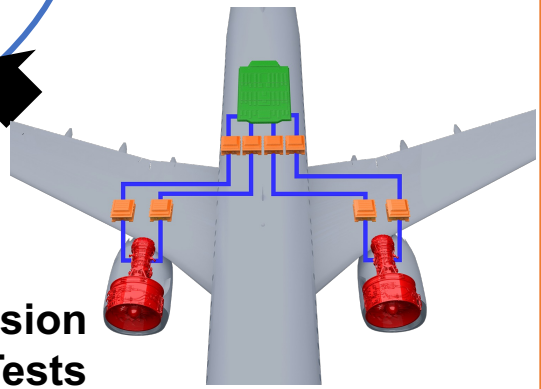
MBSA&E

Digital Integration & Knowledge Capture on Vision Vehicles

Small Core Engine Ground Tests (HyTEC)

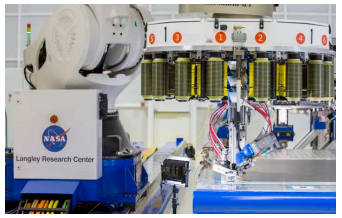


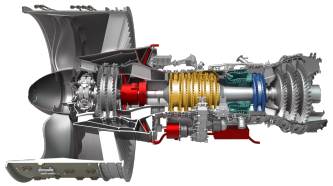
Electrified Propulsion Ground & Flight Tests (AATT & EPFD)

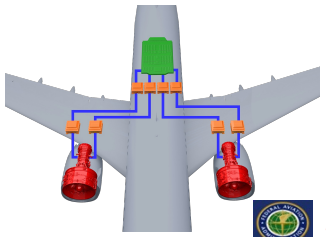


Systems-level, digital integration across SFNP projects capped by a Digital Flight Test

Subsonic Transports: Integrated Technology Development







FY20 | FY21 | FY22 | FY23 | FY24 | FY25 | FY26 | FY27 | FY28 | FY29

Technology Readiness Target

"Digital Flight Test"

Model Based Systems Analysis & Engineering

Sustainable Flight Demonstrator (SFD)

Flight Test

Transonic Truss Braced Wing (AATT)

TC Completion

Hi-Rate Composite Aircraft Manufacturing (HiCAM)

Mfg & Structural Demonstration

Hybrid Thermally Efficient Core (HyTEC)

Core Demonstration

Electrified Powertrain Flight Demonstration (EPFD)

Flight Tests

Electrified Aircraft Propulsion Technologies (AATT)

TC Completion

Technologies being worked concurrently

Sustainable Aviation Fuels, Low Emission Combustion, Engine Propulsors, Operational Concepts and Enabling Aircraft Technologies

Achieve TRL 6 in time for industry product decision-making

Sustainable Aviation Fuel and Non-CO_2 Impacts

Sustainable Aviation Fuels

Enable the use of 100% sustainable aviation fuels (SAF) and reduce climate impact

Scope

- Support adoption of high-blend ratio sustainable aviation jet fuels

Benefits

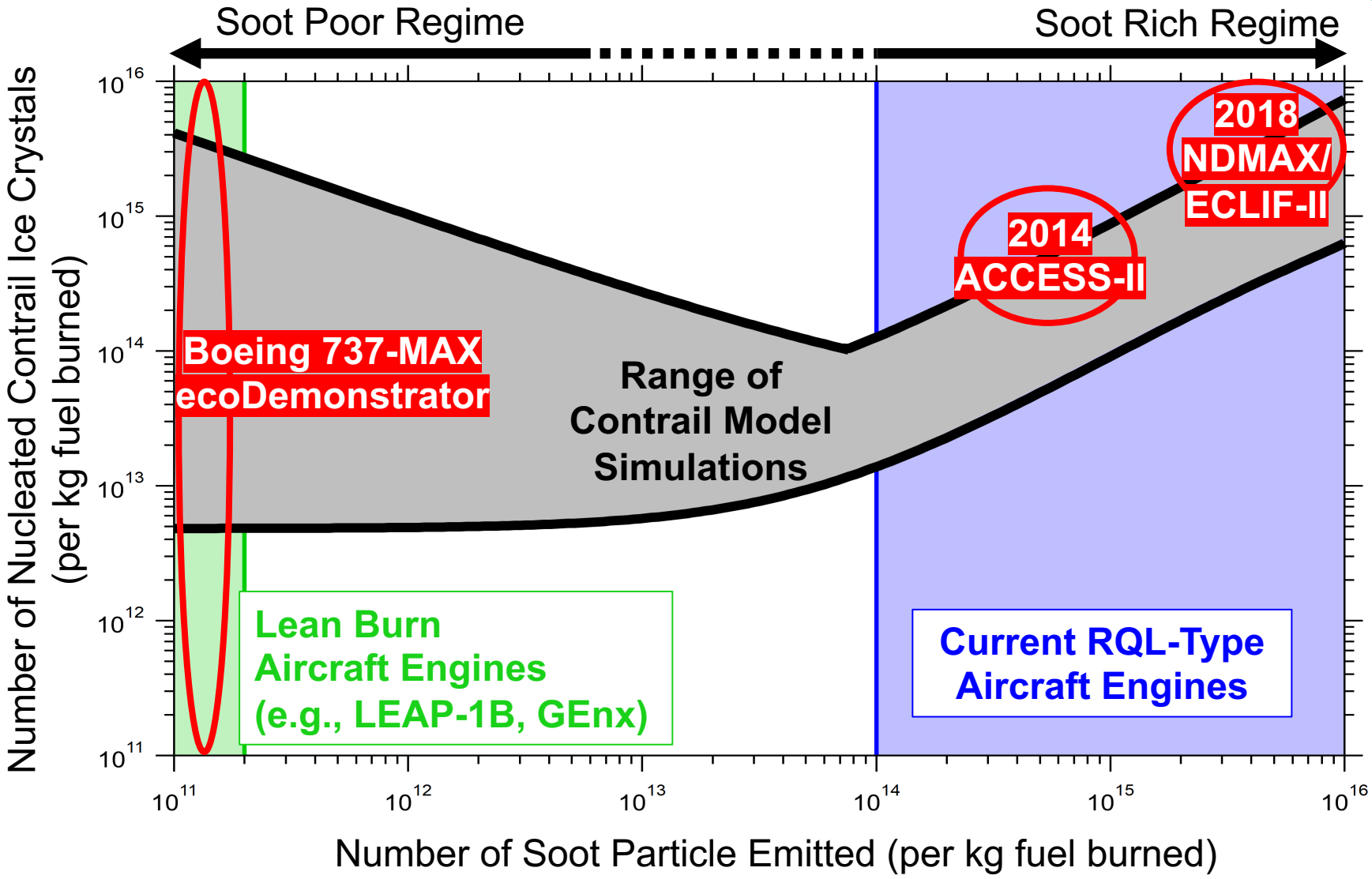
- Reduced aviation environmental impact
- Reduced uncertainty for climate impact of aviation-induced cloudiness
- Improved efficiency/emissions with drop-in synthetic and biofuels

Approach

- Characterize high-blend sustainable aviation jet fuel emissions on ground and in flight

Future SAF Research Plans in Development

Motivation for Flight Campaign - Contrails
Potential of SAF and Advanced Combustor Technology



Need to understand the "soot-poor" regime and do it at flight altitude to understand contrails

Need to fly aircraft with lean burn combustor tech (e.g. 737-MAX) at flight altitude to understand contrails

Figure adapted from Kärcher, *Nature Communications*, 2018.

Red circles show the approximate Number EIs observed during the 2014 ACCESS-II and 2018 ND-MAX/ECLIF-II flight test series.

Moore et al., Nature, 2017; Voigt et al., Nature Comms. Earth & Environ., 2021

Flight Required to Link Emissions to Contrails – Combustor Tech + SAF Important
Future SAF/Emissions Research Plans in Development

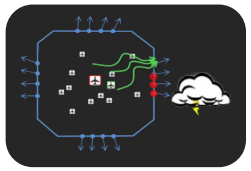
Sustainable Aviation Operations Demonstrations

NASA's Vision for Sustainable Aviation Operations ~2035

- Integrated trajectories optimized for environmental benefit
- Advanced flight deck capabilities to operate on those trajectories
- Tailored services that support safe integration of all diverse operations

Increased operational efficiency reduces fuel burn, carbon emissions, contrail formation, and ozone impact.

Sustainable Aviation Operations Demonstrations



FY20 | FY21 | FY22 | FY23 | FY24 | FY25 | FY26 | FY27 | FY28 | FY29

Digital Information Platform Development

Validate service-oriented architecture and ML services

Validate cloud-based deployment

Transfer to Industry and to FAA through RTP via DMTA RTT

Collaborative Digital Departure Reroute (SA-1a)

Tech Transfer

Complex Airspace (SA-1b)

Tech Transfer

Validate Scalability and New Interfaces

Multi-regional Trajectory Based Operations (SA-2)

Tech Transfer

Validate Scalability and New Interfaces to Flight Deck

Irregular Ops Recovery/Disruption Management (SA-3)

Tech Transfer

4D Trajectory Optimization (SA-4)

Tech Transfer

Planned

Notional

ATM Services

Flight Deck Services

Sustainable Flight
National Partnership

the baseline projects are established and active

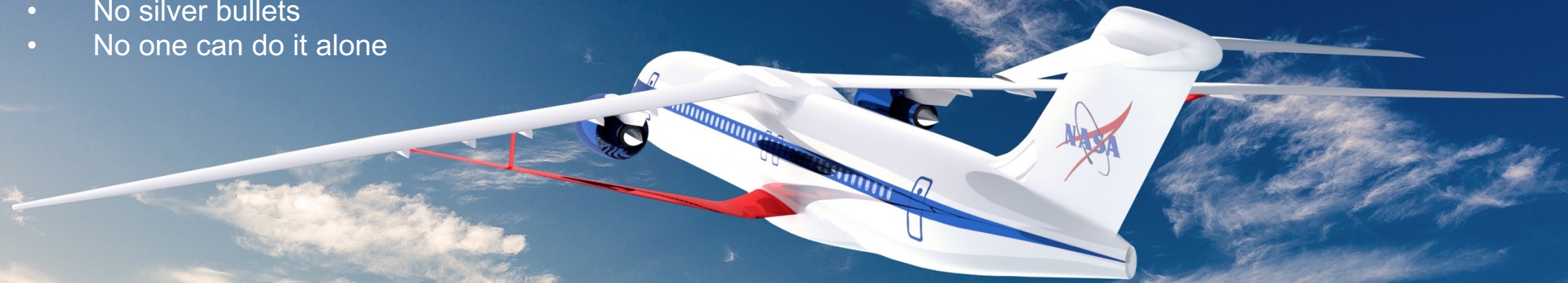
opportunity now to up-level and strengthen the partnership
between the elements and organizations
“TEAM USA”

Exploratory Stage

- **Precompetitive discussion on mutually beneficial topics**
  - **priorities/advocacy for U.S. aviation competitiveness**
  - **inspiring/insuring the next generation aviation workforce**
  - **other**
- **Conceptually no head, but NASA de facto leadership**
  - **NASA + Other Gov’t Agencies**
  - **U.S. aviation community participation based on funded collaborative partnerships**

Concluding Remarks

- Global aviation faces significant challenges to sustainable growth
  - Halt aviation's contribution to global warming without suppressing flight demand and without out-of-sector offsets, while remaining a viable and valued cornerstone of transportation (safe, clean, quiet, efficient, operable, economical, marketable)
  - Challenges require multiple, often interdependent, solutions across technology, operations, and energy domains
  - No silver bullets
  - No one can do it alone



- NASA Aeronautics addressing the challenges of Sustainable Aviation
  - Overall support from key stakeholders continues to be strong
    - ARMD research efforts well synchronized with FAA and are consistent with Administration environmental sustainability priorities.
    - Maturing and demonstrating the most promising solutions for application in the 2030s
    - Exploring innovative solutions for application 2040+

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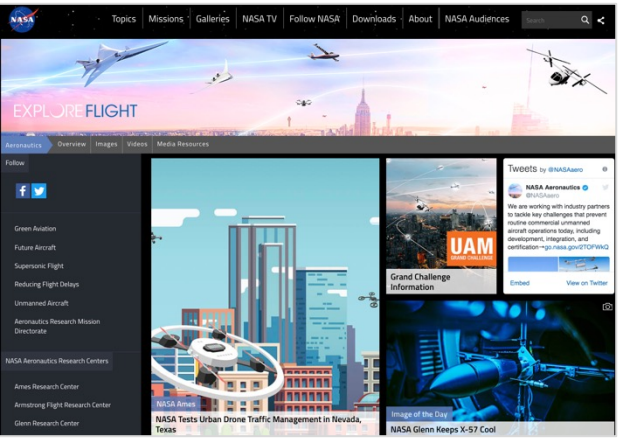

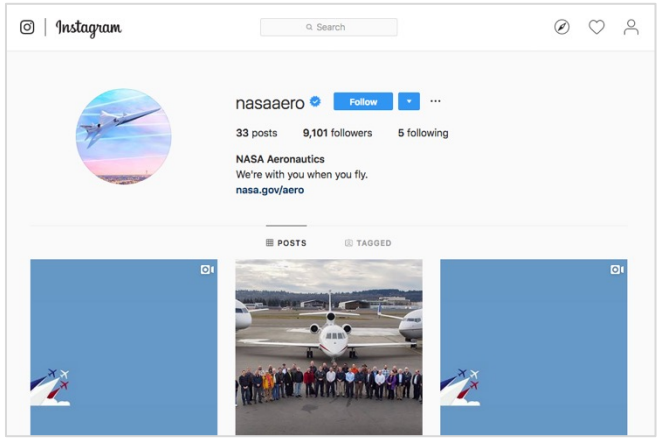

www.nasa.gov/aeroresearch/strategy | www.nasa.gov/aeroresearch/solicitations