NASA Advisory Council Meeting

Aeronautics Committee Report

Mr. John Borghese
Chair

NASA Headquarters | March 28, 2018

Aeronautics Committee Membership

Mr. John Borghese

Chair,
Rockwell Collins

Dr. John Paul Clarke

Georgia Institute
of Technology

Dr. Eric Ducharm

GE Aviation

Dr. Michael Francis

United Technologies

Dr. Greg Hyslop

The Boeing Company

Dr. Karen Thole

Pennsylvania State
University

Areas of Interest Explored at Current Meeting

Topics covered at the Aeronautics Committee Meeting held on March 14, 2018 at NASA Headquarters:

- FY2019 ARMD Budget and Strategy*
- System-Wide Safety Report*
- Advanced Materials and Structures Report*
- Electric Aircraft Technology Development*

* All of the topics have related findings provided by the Aeronautics Committee

A New Era of Flight is Emerging

- NASA Aero's vision and leadership has stimulated national and international aviation and non-aviation communities to pursue a new era of aviation:
  - **Unmanned Aircraft Systems (UAS) Integration into NAS** – Once only relevant to military operations, mid-size to large UAS have developed a range of civil and commercial applications. But data driven standards are needed to make sure they can safety integrate into the National Airspace. NASA has led the nation in performing the flight experiments required to generate standards and validate them to enable safe integration.
  - **UAS Traffic Management (UTM)** – NASA recognized that small UAS operating at low altitude would need an entirely new airspace management construct to enable their operation. NASA developed the UTM idea and developed an expansive National partnership to develop and validate the concept and get it into the hands of FAA and U.S. companies. UTM is now the accepted model all over the world.
  - **Electric Aircraft** – NASA started systems studies and explored this possibility some 20 years ago. Over the past five years, NASA put a strategic focus on the technology and demonstrated the performance required for economic systems was feasible. Now interest from the industry is accelerating and new companies, such as Zunum are actively developing initial commercial products.
  - **System Wide Safety** – NASA has pioneered the concept of in-time system wide safety that is now beginning to take hold in the community. NASA is providing key prognostic algorithms to enable current state-of-the-art analysis capabilities, such as FAA's ASIAS to discover hidden hazards in the aviation system.
  - **Supersonic Aircraft** – For many decades, NASA has advanced the science of supersonic flight. The more recent strategic focus NASA has put on solving one of the most challenging problems – reducing sonic boom noise – has shown the industry and the world that commercial supersonic flight is ready to reemerge. New companies are beginning the development process and ICAO is ready to work on the supersonic flight standards needed to underpin a new era of supersonic transportation.

Aeronautics

($M)	2019	2020	2021	2022	2023
Aeronautics	$634	$609	$609	$609	$609

- Completes a critical design review of the Low Boom Flight Demonstrator X-Plane that will demonstrate quiet overland supersonic flight, which enables a new market for U.S. industry.
- Increases funding for hypersonic fundamental research which will enhance development of tools and methods to more efficiently design future hypersonic vehicles
- Continues to develop and mature key promising subsonic aircraft technologies that dramatically reduce fuel consumption, noise, and emissions.

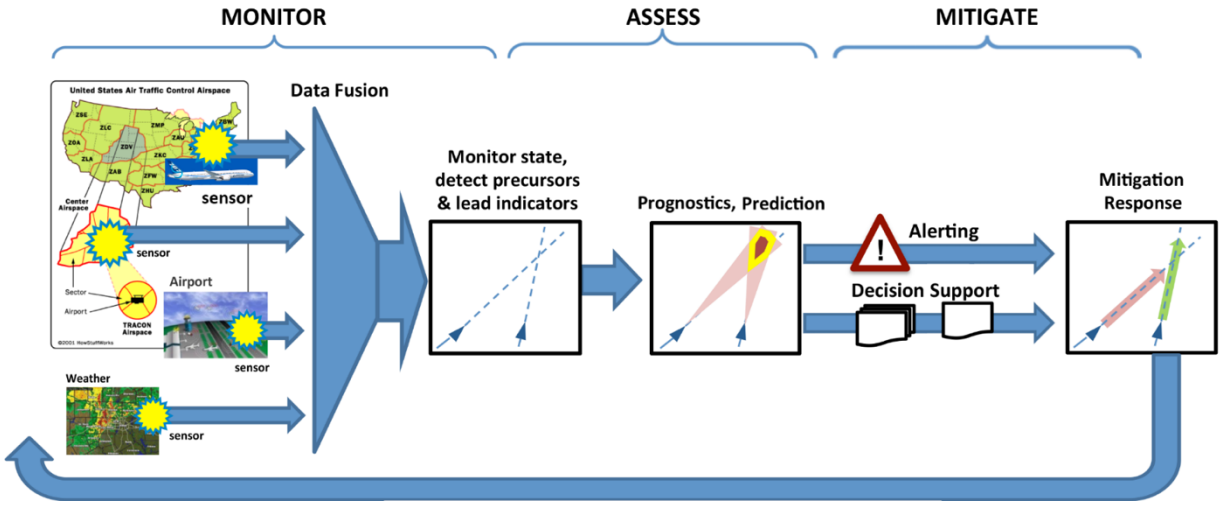
- Advances electric propulsion systems by flight testing an all electric aircraft, the X-57.
- Develops and tests key technologies that will integrate UAS operations in the National Air Space, as well as realize safe, low-altitude operations of small UAS.
- Demonstrates new air traffic management tools that integrate aircraft arrival, departure, and airport surface operations to reduce flight delays and increase air traffic capacity and safety.
- Completes the Advanced Composites project which will deliver a variety of computational tools and guidance that will significantly reduce the time needed to develop and certify new composite structures for aerospace applications.

Committee Finding for ARMD AA – FY19 ARMD Budget and Strategy

The Committee agreed that ARMD's overall portfolio and strategy are aligned to support the future of aviation by being the enabler for new vehicles and airspace. In particular, the committee endorses research in the areas of autonomy and electric vehicles. The Committee also believes that ARMD research should be directed in areas that are not being addressed by commercial industry and other government agencies such as the certification of autonomous systems and the airspace management and other certification methodologies needed for these new classes of vehicles.

Real Time Safety Assurance System (RSSA)
Objective of the Study and Scope

- ARMD requested the National Academies committee develop a research agenda that would (1) identify key challenges to the development of a real-time safety assurance system for the NAS and (2) identify high-priority research projects that would overcome those challenges.



Includes

- Real-time safety assurance is achieved at the system-of-systems level. Cybersecurity unique to the operation of an RSSA

Excludes

- Issues related to design, development, training, or maintenance

Committee Process

- Briefings on safety from important parts of aviation
  - OEMs (Boeing, Airbus, GE, Honeywell)
  - Airlines (Delta, American)
  - Academia (MIT, Ga Tech)
  - Gov't (NASA, FAA)
  - Associations (AOPA, IATA, GAMA)
- Organized in Teams
  - Long-term Future of Air Traffic Management
  - New Entrants and Their Impact Over the Long Term
  - Long-term Issues Associated with Human Operators
  - Long-term Future of Data Analytics

- The committee has developed a research agenda consisting of a set of high-priority research projects organized around four key elements of a real-time aviation safety assurance system: concept of operations and risk prioritization, system monitoring, system analytics, and mitigation and implementation

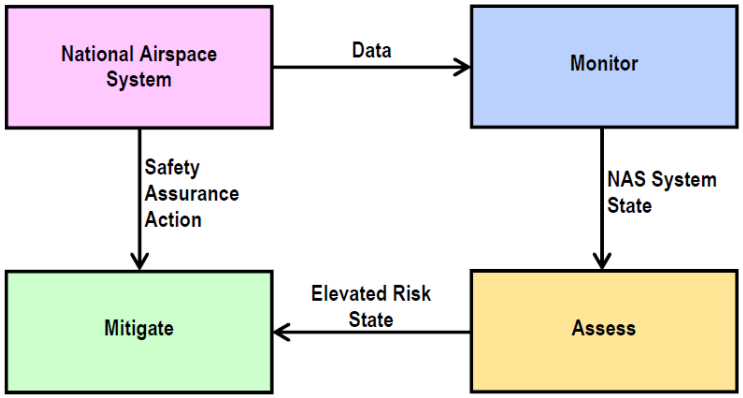
Initial Findings

Replace Real Time with In-Time

RSSA system, however, could operate over a period of minutes, hours, or days on operational trends to identify risks that cannot be identified in real time.

Replace Safety Assurance with Safety Management System

An SMS is more comprehensive than a Safety Assurance System in that it uses "a systematic approach to managing safety including the necessary organization structures, accountabilities and policies and procedures"



Recommendation. ***In-time Aviation Safety Management***

Response to NRC Committee Recommendations

- *Terminology*
  - *Replace Real Time with In-Time*
    - Real-time System-wide Safety Assurance now referred to as In-time System-wide Safety Assurance (ISSA)
  - *Replace Safety Assurance with Safety Management System*
    - Agree on the importance of management in implementation with regard to organization structures, accountabilities and policies and procedures
    - The NASA research agenda is focused on capability development. Implementation by operators will require careful consideration of the above.
- *Top priority: IASMS Concept of Operations and National Airspace System Evolution. Develop a detailed concept of operations for an IASMS using a process that considers multiple possible system architectures, evaluates key trade-offs, and identifies system requirements*
  - New effort developed under System-wide Safety project
    - Multi-center team to develop conops that will better define NASA's vision for:
      - System architectures
      - Roles and responsibilities
      - Phased development
      - Implementation within various domains within the NAS (including UTM, UAM)
      - Develop specific use cases

Committee Finding for ARMD AA – System-Wide Safety (SWS) Report

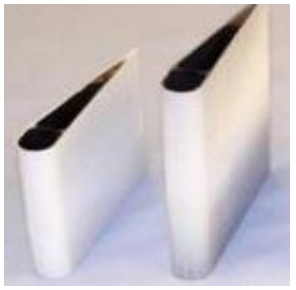
The Committee found that the SWS has many facets and needs to identify which ones provide a real payoff and focus on specific areas. They understand that this project is in formulation and supports ARMD's intent to focus on topics where NASA can provide unique and important contributions to the safety of the NAS as traffic density increases and new entrants enter the airspace. The Committee also believes that SWS should address the cyber security element of NAS management and clearly define yearly objectives.

Advanced Materials and Structures Introduction and Purpose

- Aeronautics Research Mission Directorate (ARMD) chartered a small focus team to envision a future strategy and develop future “investment” alternatives for Materials and Structures (M&S) in the FY2020-2030 timeframe (Dale Hopkins, TACP and Paul Krasa, AAVP)
- Specific guidance
  - Broad, cross-cutting alternatives applicable to aeronautical vehicles of all classes
  - Take a national perspective
  - Select and focus on areas where NASA can best provide impact
  - Be agnostic to Program/Project structure and leverage all Centers’ capabilities
- Today’s briefing provides a glimpse into early thinking; seeking NAC reaction and feedback. Are we on the right track?

Recent Materials and Structures Accomplishments

- Completed development and initial testing of a Ceramic Matrix Composite (CMC) with Environmental Barrier Coating (EBC) Material System that can withstand 2700°F for 1000 hours at 20 ksi in creep and fatigue.
  - Incorporation of 2700°F capable CMCs into turbines as HPT and LPT vanes and blades provides a **net overall reduction of 6.0% in fuel burn and a greater than 33% reduction in NOx emissions** (less cooling air, reduced weight).

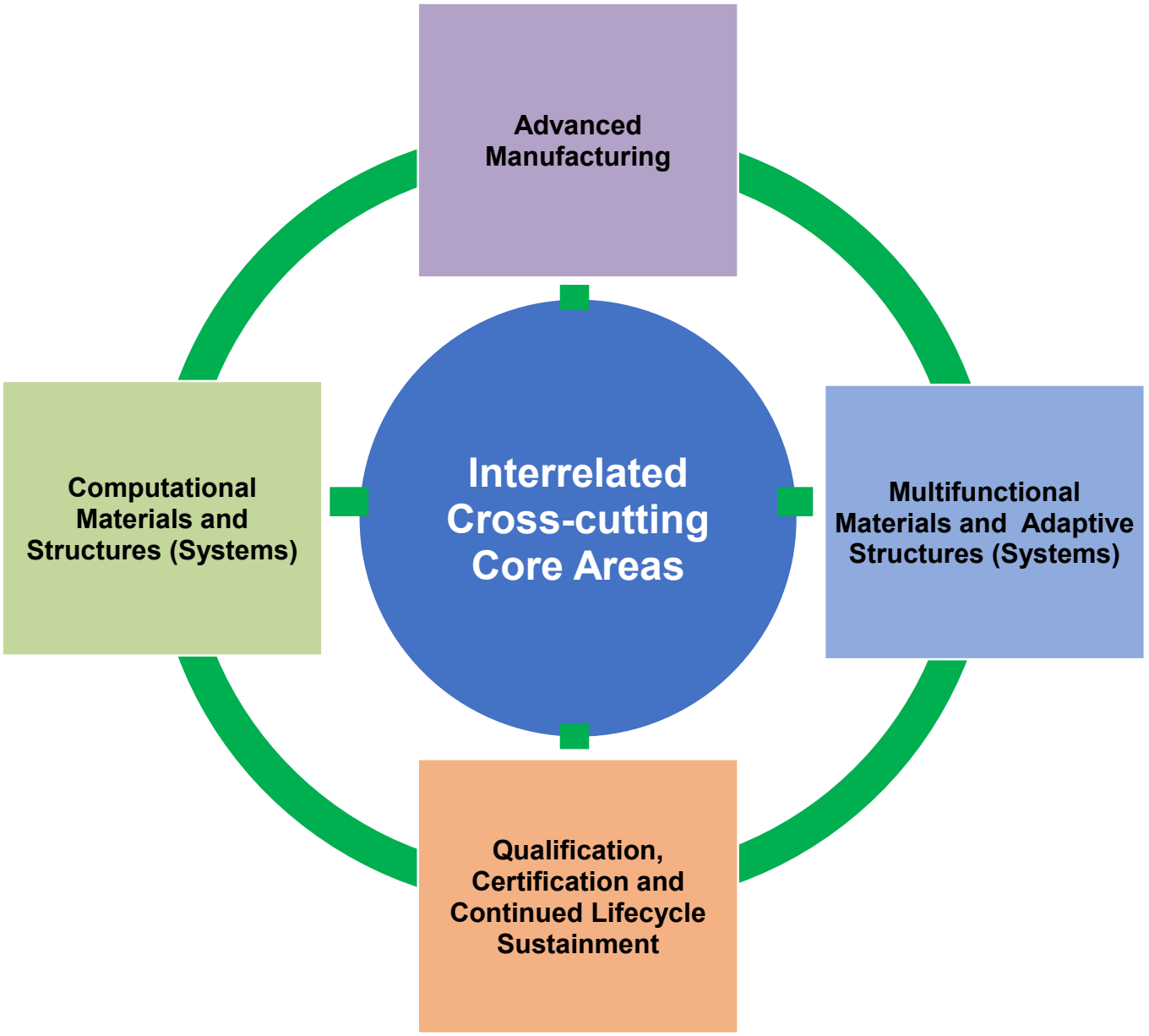


- Developed new Shape Memory Alloy (SMA) materials with transition temperatures, specific work potential, and cyclic stability appropriate for aerospace actuator applications. Demonstrated scale-up to 500-lb. ingot size. Published two approved ASTM standards for SMA materials and actuators qualification testing.
  - Completed successful demonstration of SMA wing-tip actuator in flight.

- Quantified depth of penetration of a spherical projectile on IM7/8552 carbon fiber-epoxy matrix composite panels via impact tests at various velocities to establish calibration parameters for new composite impact modeling/simulation approach.
  - Will enable higher fidelity material models for predicting response of safety-critical composite aircraft/engine structures governed by high energy dynamic impact events.

Post Test Impact Damage

Materials and Structures (M&S) Strategic Core Areas



Summary Comments

- Future M&S work can be most impactful by integrating across strategic core areas: Computational Materials and Systems; Multifunctional Materials and Adaptive Systems; Advanced Manufacturing; Qualification, Certification and Continued Lifecycle Sustainment.
- Future M&S investments may consist of a healthy balance of lower and higher TRL efforts, as well as some efforts that bridge the “mid-TRL gap“.
- A One ARMD approach is vital to success and maximizing value of future M&S investments to sustain continued enhancement of traditional aviation, and, perhaps more importantly, to enable emerging aviation markets (such as Urban Air Mobility).

- Move toward the next step of more detailed planning.

Committee Finding for ARMD AA – Advanced Materials and Structures Strategy

The Committee appreciated being part of the initial planning of this project in order to provide feedback in its infancy. The initial planning has displayed insights into the interrelationship of core areas, including advanced manufacturing, computational materials and structures, multifunctional materials and adaptive structures, and the issues of qualification, certification and lifecycle sustainment. The Committee believes that this research is very important. There is significant multi-agency investment in the government's new manufacturing initiatives that NASA should evaluate, with a focus on ARMD's investments where there are gaps in the research.

Benefits of Electrified Aircraft Propulsion Across Range of Missions

Improvements to highly optimized aircraft like single-aisle transports

- Potential fuel burn reduction estimated using turboelectric distribution to BLI thruster in addition to other benefits from improved engine cores or airframe efficiencies. Later developments could be more advanced electrical distribution and power storage.

Enabling new configurations of VTOL aircraft

- The ability to widely distribute electric motor driven rotors/propulsors operating from one or two battery or turbine power sources, enable new VTOL configurations with potential to transform short and medium distance mobility.

Revitalizing the economic case for small short range aircraft services

- The combination of battery-powered aircraft with higher levels of autonomous operation to reduce pilot requirements could reduce the operating costs of small aircraft operating out of community airports resulting in economically viable regional connectivity with direct, high-speed aircraft services.

Subsonic Transport Technology Strategy

Ensuring U.S. technological leadership

Energy usage reduced by more than **60%**

Harmful emissions reduced by more than **90%**

Objectionable noise reduced by more than **65%**

Prove out transformational propulsion technologies

Prove out transformational airframe technologies

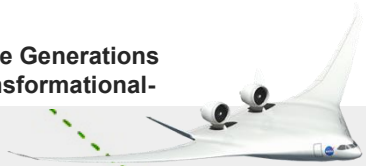
Current Generation

Next Generation -Transitional-

Future Generations -Transformational-

Image Credit: Denis Fedorko

Image Credit: pjs2005 from Hampshire, UK



Create technology pathway for U.S. competitive leadership

2040

2030

2020

Image Credit: Weimeng

Image Credit: Don-vip

Transforming Propulsion – A Breakthrough Opportunity

Turbo-Electric Propulsion Architecture

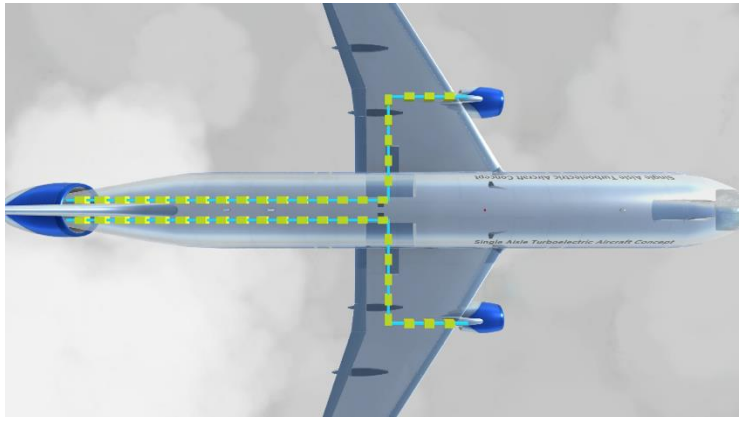
Boundary-Layer Ingesting Propulsor(s)

Ultra-Efficient “Small Core” Turbofan

In whole or in part, transformational propulsion enables the next generation transitional subsonic transport configuration and enables future generation transformational subsonic transports

Concluding Remarks

- Electrified propulsion technology development well underway.
- Specific technologies for development driven by the integrated propulsion systems and the propulsion systems driven by mission requirements
- Continuing to advance technologies and knowledge applicable to variety of missions and systems as well as those critical to enabling the systems



Committee Finding for ARMD AA – Electric Aircraft Technology

The Committee was impressed with the direction that the electric aircraft technology team is headed and how they have used the low carbon study results to guide that direction. The Committee also suggested that NASA's goal be to uncover the regulators primary focus areas, inspiring regulatory solutions while working with industry to address these challenges. The Committee was very impressed with the hybrid electric system research activities and encourages the project to focus on modeling the efficiency of the various configurations.

2018 NAC Aeronautics Committee Draft Work Plan

SPRING (Completed)	SUMMER	FALL
System Wide Safety (SWS) Report (may be moved to a later date)	Urban Air Mobility Strategy	New Aviation Horizons Subsonic Demonstrators
ARMD FY19 Budget & Overview of ARMD Strategy	Challenges & Prizes Strategy	**Vertical Lift Noise**
Electric Aircraft Technology Development	UAS Update	Low Boom Flight Demonstrator (LBFD)
Advanced Materials & Structures Research	ATM-X	**Autonomy Update**

March 14, 2018
NASA Headquarters




BACK-UP

Acronyms

- AAVP – Advanced Air Vehicles Program
- ASTM - American Society for Testing and Materials
- BLI - Boundary-Layer Ingesting
- CMC - Ceramic Matrix Composite
- EBC - Environmental Barrier Coating
- FAA's ASIAS – Federal Aviation Agency's Aviation Safety Information Analysis and Sharing
- ICAO - International Civil Aviation Organization
- ISSA - In-time System-wide Safety Assurance
- IASMS - In-time aviation safety management system
- NAS – National Airspace System
- NRC – National Research Council
- RSSA - Real Time Safety Assurance System
- SMA - Shape Memory Alloy
- SWS – System-Wide Safety
- TACP – Transformative Aeronautics Concepts Program
- T3A ST – Thrust 3A – Subsonic Transport
- T3B VL – Thrust 3B – Vertical Lift
- TRL – Technology readiness level
- UAM – Urban Air Mobility
- UAS - Unmanned Aircraft Systems
- UTM – Unmanned Aircraft Systems (UAS) Traffic Management
- VTOL – Vertical take-off and landing

NASA Aeronautics

NASA Aeronautics Vision for Aviation in the 21st Century

6 Strategic Research and Technology Thrusts

T1 

Safe, Efficient Growth in Global Operations

- Enable full NextGen and develop technologies to substantially
- Reduce aircraft safety risks

T2 

Innovation in Commercial Supersonic Aircraft

- Achieve a low-boom standard

T3A ST
T3B VL 

Ultra-Efficient Commercial Vehicles

- Pioneer technologies for big leaps in efficiency and environmental performance

T4 

Transition to Alternative Propulsion and Energy

- Characterize drop-in alternative fuels and pioneer
- Low-carbon propulsion technology

T5 

Real-Time System-Wide Safety Assurance

- Develop an integrated prototype of a real-time safety monitoring and assurance system

T6 

Assured Autonomy for Aviation Transformation

- Develop high impact aviation autonomy applications