Aeronautical Sciences Project Overview

Acoustics Technical Working Group
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Manager: Jim Heidmann (GRC)
Deputy Manager: Stan Smeltzer (LaRC)
Project Scientist: Mike Rogers (ARC)
Outline

NASA Fundamental Aeronautics Program Structure

Aeronautical Sciences Project Objectives

Aeronautical Sciences Project Team

Technical Disciplines & Key Research Activities

Summary
NASA Aeronautics Programs

**Fundamental Aeronautics Program**
Conduct fundamental research that will produce innovative concepts, tools, and technologies to enable revolutionary changes for vehicles that fly in all speed regimes.

**Aviation Safety Program**
Conduct cutting-edge research that will produce innovative concepts, tools, and technologies to improve the intrinsic safety attributes of current and future aircraft.

**Airspace Systems Program**
Directly address the fundamental ATM 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.

**Integrated Systems Research Program**
Conduct research at an integrated system-level on promising concepts and technologies and explore/assess/demonstrate the benefits in a relevant environment.

**Aeronautics Test Program**
Preserve and promote the testing capabilities of one of the United States’ largest, most versatile and comprehensive set of flight and ground-based research facilities.
Aeronautical Sciences (AS)
Enable fast, efficient design & analysis of advanced aviation systems by developing physics-based tools and methods for cross-cutting technologies.

Fixed Wing (FW)
Explore & develop technologies and concepts for improved energy efficiency & environmental compatibility of fixed wing, subsonic transports

Rotary Wing (RW)
Develop and validate tools, technologies and concepts to overcome key barriers for rotary wing vehicles

High Speed (HS)
Enable tools & technologies and validation capabilities necessary to overcome environmental & performance barriers to practical civil supersonic airliners.
Aeronautical Sciences Connectivities

Fundamental Aeronautics Program

- Rotary Wing Project
- Fixed Wing Project
- High Speed Project

Aeronautical Sciences Project

- Multi-Disciplinary Analysis & Optimization
- Fluids & Combustion
- Structures & Materials
- Instrumentation & Controls

NASA SME Input

External Stakeholders

Aeronautics Seedling Fund
NASA's Aeronautics Research Mission Directorate (ARMD) works to solve the challenges that still exist in our nation's air transportation system: air traffic congestion, safety and environmental impacts.

Solutions to these problems require innovative technical concepts, and dedicated research and development. NASA's ARMD pursues the development of new flight operation concepts, and new tools and technologies that can transition smoothly to industry to become products.
Aeronautical Sciences Project

Why “Aeronautical Sciences”?

NASA Aeronautics requires a home to champion foundational, cross-cutting aeronautics scientific research...

NASA’s Aeronautical Sciences Project
New project as of October 2012
Aeronautical Sciences Project

Enable fast, efficient design & analysis of advanced aviation systems from first principles by developing physics-based tools/methods & cross-cutting technologies, provide new MDAO & systems analysis tools, & support exploratory research with the potential to result in breakthroughs

Vision
- Physics-based predictive methods for improved analysis and design
- Leverage improved understanding and discipline integration toward improved future air vehicles

Scope
- Foundational research and technology for civil air vehicles
- Discipline-based research and system-level integration method development
What Are the Foundational Aeronautics Sciences?

- Aerodynamics
- Fluid Mechanics
- Heat Transfer
- Propulsion
- Aeroacoustics
- Structures
- Material Science
- Aeroelasticity
- Measurement Technologies
- Flight Mechanics
- Combustion
- Systems Analysis
- Controls
- Computational Methods
- MDAO
- Complex Design

notional set of disciplines
Aeronautical Sciences Project Disciplines

**Revolutionary Computational Aerosciences**
- Turbulence Modeling
- Transition Prediction and Modeling
- Numerical Methods
- Geometry/Grid
- Computer Science/Hardware

**Combustion**
- Combustion Physics-Based Modeling
- Combustion Fundamental Experiments
- Active Combustion Control
- Pressure-Gain Combustion

**Structures and Materials**
- Multifunctional Structures & Materials
- Engine Materials Development
- Modeling, Simulation & Validation

**Controls**
- Advanced Flight Controls
- Advanced Propulsion Controls

**Innovative Measurements**
- Advanced Optical Measurements
- Enhanced Sensing
- Improved Data Acquisition

**MDAO & Systems Analysis**
- OpenMDAO
- ANOPP2
- Aeroelasticity
- Complex Design
- Propulsion Airframe Integration
Aeronautical Sciences Project Organization

- Organized by technical disciplines
- Technical leads for disciplines providing overall technical direction and oversight

**Project Manager:** Jim Heidmann (GRC)
**Deputy Project Manager:** Stan Smeltzer (LaRC)
**Project Scientist:** Mike Rogers (ARC)

**Business Integration Manager:** Jacob Jevec (GRC)
**Dryden POC:** Mark Davis (DFRC)
**Scheduler:** Joyce Moran (GRC)

**ARC**
- Program Analyst: Sandra Ramirez

**DFRC**
- Program Analyst: Becky Miani

**GRC**
- Program Analyst: Tom Halstead

**LaRC**
- Program Analyst: Julie Fowler

**TECHNICAL DISCIPLINES**
- Revolutionary Computational Aerosciences: Mujeeb Malik (LaRC)
- Structures and Materials: Dale Hopkins (GRC)
- MDAO & Systems Analysis: Jeff Robinson (LaRC)
- Combustion: Dan Bulzan (GRC)
- Controls: Sanjay Garg (GRC)
- Innovative Measurements: Tom Jones (LaRC)

**PROJECT LEVEL**
- RCA
- SaM
- MDAO
- Measurements
- Controls
- Combustion

**DFRC**
- RCA
- SaM
- MDAO
- Measurements
- Controls
- Combustion

**GRC**
- RCA
- SaM
- MDAO
- Measurements
- Controls
- Combustion

**LaRC**
- RCA
- SaM
- MDAO
- Measurements
- Controls
- Combustion
GOAL:
Identify and down select critical turbulence, transition, and numerical method technologies for improved prediction of turbulent separated flows, evolution of free shear flows and shock-boundary layer interactions on state-of-the-art high performance computing hardware.

APPROACH:
• Turbulence Modeling (and associated validation experiments)
• Transition Prediction and Modeling (and associated validation experiments)
• Numerical Methods
• Validation/Prediction Workshops
• RCA Institute
Technical Challenge: Physics-Based Turbulence Models

Objective
Identify and downselect critical turbulence, transition, and numerical method technologies for improved (by 40%) prediction of turbulent separated flows, evolution of free shear flows and shock-boundary layer interactions on state-of-the-art high performance computing hardware.

Technical Areas and Approaches
• Development of more accurate physics-based methods (e.g. large eddy simulation (LES))
• Validation experiments
• Advanced numerical methods

Benefit/Pay-off
• Capability will be used by the aeronautics community to improve designs and reduce design cycle times
• Facilitates accelerated introduction of advanced air vehicles and propulsion systems into the airspace system.
Structures & Materials

• Demonstrate **multi-functional structures & materials** that reduce weight by simultaneously meeting multiple airframe or engine requirements

• Develop **high temperature engine materials** and associated design tools and life prediction methodology to reduce or eliminate the need for turbine cooling

• Develop a **computational materials design and optimization** capability for airframe & engine materials
Technical Challenge: High Temperature Materials

**Objective**
Develop high-temperature materials for turbine engines that enable a 6% reduction in fuel burn for commercial aircraft, compared to current SOA materials.

**Technical Areas and Approaches**
- Ceramic matrix composite (CMC) materials and the required high-temperature environmental barrier coatings (EBCs) are investigated and developed.
- Modeling and simulation tool development

**Benefit/Pay-off**
- Enables increased engine operating temperature and/or reducing or eliminating the need for engine component cooling
- Improves efficiency and helps reduce emissions
MDAO & Systems Analysis

Goals:
- Develop new methods for multi-disciplinary and multifidelity analysis of unconventional aerospace concepts
- Integration of multidisciplinary analyses with a common geometry model
- Reduce the upfront cost of applying MDAO to aerospace design problems

Approach:
- Tool development at multiple levels of fidelity
- Use of an open source framework as a common engineering platform
- Use of geometry tools that can serve multiple analysis tools and provide analytic derivatives for efficient optimization
- Use of challenge problems to demonstrate capabilities
Next Generation Multi-Fidelity Aircraft Noise Prediction Capability: ANOPP2

PROBLEM
NASA provides the U.S. Government with tools for independent assessment of aircraft system noise and annoyance. NASA Aircraft NOise Prediction Program (ANOPP) started over 30 years ago and is primarily “fixed” fidelity, point source empirical methods, greatly limiting its application to existing and future aircraft designs.

OBJECTIVE
Provide software framework that allows noise prediction for arbitrary aircraft designs (conventional to unconventional), of full-scale and model-scale size by accommodating multi-fidelity analyses from semi-empirical predictions for design to high-fidelity, physics-based predictions to study noise generation, propagation, human annoyance (auralization), and reduction and interface with system level frameworks.

SIGNIFICANCE
ANOPP2 will provide NASA and other government agencies (FAA, DoD, etc) with tools to independently assess aircraft noise and its effects. Potential payoff is significant advantage in the marketplace for the U.S. aircraft industry through production of quieter, more acceptable aircraft while maintaining aerodynamic efficiency.

APPROACH
- Establish a framework where combination of acoustic prediction methods of varied fidelity communicate in a unified system.
- Create a system of Application Programming Interfaces (APIs) enabling building block approach to provide user ‘unlimited’ control of the noise prediction process.
- Suite of APIs provide tools to implement and create predictions modules for ANOPP2.
- Self testing, documenting, and verification enable automated ANOPP2 builds/distribution
- Varied fidelity prediction through use of nested Ffowcs Williams & Hawkings (FW-H) surfaces.
- Data Structures & Command Executive enable nested FW-H approach Fortran 2008 object-oriented programming
- Concurrent aircraft noise assessment of capabilities throughout development, customer as part of development team

PROGRESS TO DATE
- Observer, Propulsion, Flight Path, Atmosphere, Geometry, and Kinematic data structures designed & implemented, testing and documentation underway.
- Observer functionality to accommodate noise suppression enables testing of noise scattering methods. Initial demonstration of prediction-based tools to auralize flyover noise from arbitrary aircraft configurations, flying arbitrary operations, in arbitrary atmospheres.
- ANOPP2 libraries working on Windows, Linux and Mac
- Design of plugin capability for external prediction methods and implementation complete. Testing underway.
- Draft documentation, automated build/verification processes completed and in use

POC: Casey Burley (LaRC), Leonard Lopes (LaRC)
GOAL:
Improve combustion CFD modeling tools and develop new laser diagnostics techniques to improve understanding of combustion processes and concepts that have the potential to meet NASA emissions goals for future aircraft engines.

APPROACH:
- Combustion Physics-Based Modeling
- Combustion Fundamental Experiments
- Active Combustion Control
- Pressure Gain Combustion
• **High Level Objective:** Develop advanced control technologies to enable new capabilities for efficient and autonomous operation of aircraft and propulsion systems

• **Advanced Flight Controls:**
  - Relative Navigation and Sensor Fusion for Formation Flight - DFRC
  - Advanced Control Methods for Autonomy - LaRC
  - Learn to Fly - LaRC

• **Advanced Propulsion Controls (GRC):**
  - Distributed Engine Control
  - Model Based Engine Control
  - Plasma Actuators for Flow Control
Innovative Measurements

PROBLEM
Measurement science technologies have limited fidelity robustness, range of applicability.

OBJECTIVE
Develop and implement advanced capabilities and diagnostic methods to meet measurement challenges not being achieved by techniques currently utilized in NASA ground testing, flight experiments and airframe/engine diagnostics. Developments should be cross-cutting for the vehicle spectrum within FAP.

APPROACH
- Leveraging center expertise from all four research centers to produce integrated instrumentation approaches.
- Emphasize linkages/partnerships with other AS sub-projects and FA projects to fully establish the critical need for this work.
- Partner with ATP to coordinate investments.

SIGNIFICANCE
This will enable new methods for obtaining critical experimental data for validation of computational methods and for diagnostics of airframe and engine components.
MEMS Shear Stress Sensors

PROBLEM
The measurement of shear stress has been the focus of significant effort for many years. Reliable quantitative values, especially two component have been difficult to impossible to obtain except in certain limited situations.

OBJECTIVE
Improved packaging and testing of MEMS two-component direct shear stress sensors to facilitate quantitative shear stress data in ground test facilities and/or flight test vehicles.

SIGNIFICANCE
Direct shear stress measurements are considered one of the key measurements when assessing drag and drag reduction technologies. A new application of significant interest is the measurement of shear stress over acoustic liners in the presence of sound. This never before measured information of drag induced by various liner configurations has become of major interest due to potential for increased noise treatments of aircraft. Relative drag could become a performance criteria in liner design in addition to weight, acoustic performance, and other criteria.

POC: Michael Scott (LaRC)
Simultaneous Flow Field Measurements

PROBLEM
Spectral interference limits the ability to perform simultaneous measurement of several flow field measurements.

OBJECTIVE
Demonstrate simultaneous acquisition of each test technique without instrument cross-talk through spectral separation of light sources and signals.

APPROACH
Demonstrate the technique as part of a US Army sponsored rotor test. The test will utilize existing hardware resources. The test technique will be evaluated for adaptability to any fluid-structure interaction test.

SIGNIFICANCE
The simultaneous data promote better correlation between on-body and off-body phenomena, and greater efficiency in large scale testing. The development will lead to better the methodologies, database management, and data visualization.

POC: J.T. Heineck (ARC), Ed Schairer (ARC)

Mikado RC Helicopter GMBH; Model Edge 813 mm. NACA 0020 with swept and rounded tip.
Enhanced Aeroacoustics Measurements: In-Flow Sensors

PROBLEM
Level-sensing phased microphone arrays need to be adapted to in-flow operation to improve sensor location options for aeroacoustic research while preserving the benefits of improved signal-to-noise ratio and facility noise rejection.

OBJECTIVE
Develop and demonstrate a new-class of in-flow acoustic sensors for measuring acoustic level with significantly reduced background noise based on quiet fairing/strut design and phased-microphone array signal processing methods.

APPROACH
New small microphone array sensors will be designed to be optimized for accurate level sensing in-flow rather than noise source location, reducing size and cost. New sensor fairings will be developed to minimize sensor self-noise and facilitate acoustic field mapping with multiple fixed sensors rather than traversing a single sensor. Prototypes of the new sensor will be demonstrated.

SIGNIFICANCE
The development of quiet in-flow acoustic sensors will provide new flexibility, reduced cost, and improved efficiency in aeroacoustics research studies in acoustically treated or untreated closed and open test section wind tunnels. Test productivity will improve with the use of multiple fixed sensors versus a traversing set-up.

POC: Cliff Horne (ARC)
Advanced Schlieren

PROBLEM
There is a need for non-intrusive field flow measurement tools. Currently, Schlieren is used as a qualitative flow visualization tool, but has high potential to be a quantitative flow field measurement technique.

OBJECTIVE
Advance Schlieren technology from a flow visualization tool to a measurement technique that can be used to make quantitative flow velocity and density measurements.

SIGNIFICANCE
Advancements will enable the visualization of flow characteristics previously not viewable and provide the potential for quantitative velocity measurements. The development of alternate techniques like Background Oriented Schlieren provides a more robust and portable tool that can be used to provide data in non-traditional environments along with quantitative density measurements.

APPROACH
• Evaluate state-of-the-art light source and knife edge (optical phase knife, etc.) improvements to traditional systems to increase sensitivity.
• Develop and demonstrate advanced Schlieren techniques (Background Oriented Schlieren & Focusing Schlieren).
• Develop a capability of acquiring quantitative flow velocity & density measurements using advanced Schlieren techniques

POCs: Michelle Clem / Mark Woike (GRC)

High speed digital images of NASA High Speed Projects / Boeing Sonic Boom Model, Fall 2012 (Right) – Acquired with “Improved” Schlieren system implemented at the 8x6

Background Oriented Schlieren technique undergoing preliminary development / demonstration on nozzle test in CW17 – Fall 2012
Advanced Internal Flow Measurements and Diagnostics

PROBLEM
Internal flowfield measurements have been historically difficult to obtain.

OBJECTIVE
Develop the technology and technique to support optical measurements (strain, skin friction, pressure, temp) in the internal flow path of an inlet or nozzle. In the process of extending this for rotating machinery applications.

SIGNIFICANCE
Previously optical measurements could only be made in areas that were externally viewable. The ability to make global measurements in the internals of a flowpath would represent a major advancement in measurement technology and aeropropulsion system development & testing.

APPROACH
• Leverage off recent efforts and developments in Surface Stress Measurement films, PSP, TSP, etc.
• The emphasis will first be on the development of a miniature camera package that can be used for acquisition
• Future research & development work are for the demonstration of this technique to make internal flowpath measurements

POCs: Mark Woike (GRC)
Advanced Infrared Thermography

PROBLEM
On-board IR thermography has distortion effects and lacks easily obtainable quantified information.

OBJECTIVE
The overall objective is to be able to use infrared thermography more effectively in aerospace testing.

APPROACH
• Develop and exploit existing algorithms for geometric distortion due to camera/optics placement limitations.
• Improved methods for quantitative analysis.
• Improved and develop image processing techniques to enhance visualization of flow phenomena (shock waves, separation bubbles, etc.)
• Research multi-spectral techniques for aerodynamic measurements
• Improved sensor and hardware development

SIGNIFICANCE
Infrared thermography allows the visualization of boundary-layer transition, certain flow phenomena, and surface temperatures. IR thermography is global and non-intrusive.

POC: Dan Banks (DFRC)
Aeronautical Sciences NRAs

24 NRAs in excess of $4M in support of university and industry foundational aeronautics research - highly collaborative with NASA in-house research efforts:

- Revolutionary Computational Aerosciences (14)
- Structures and Materials (2)
- MDAO and Systems Analysis (5)
- Combustion (2)
- Controls (1)

http://nspires.nasaprs.com/external/
Aeronautical Sciences Project Summary

- Improved NASA Aeronautics program/project structure for the advancement of aeronautics research
- Exciting suite of fundamental cross-cutting research
- Aeronautical Sciences Project building toward the future, pursuing multiple collaborative and reimbursable alternatives to augment the portfolio during lean budgetary environment
- Aeronautical Sciences is the steward of NASA aero fundamental research and methods development focused on providing cross-cutting research – the lifeblood of NASA Aeronautics

Opportunities ahead with great technologies on the horizon!

http://www.aeronautics.nasa.gov/fap/aeronautical_sciences.html
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