Fundamental Aeronautics Program ARMD

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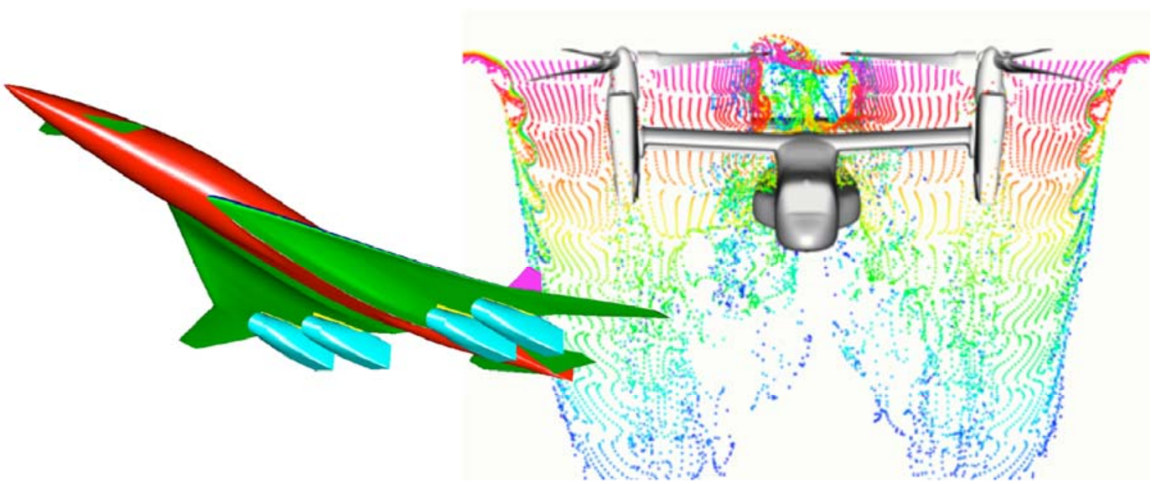


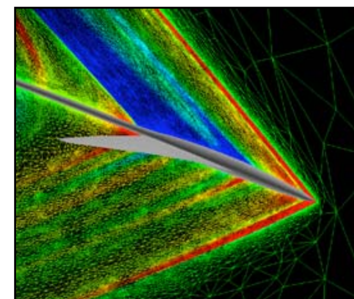
The New Fundamental Aeronautics Program

- Fundamental Aeronautics has transformed from a ***demonstration-based*** program to one focused on ***fundamental technology***
- Emphasis on ***core-capability*** in ***discipline and multidiscipline technology*** critical to sustaining the advancement of aeronautics
- Addressing main concerns of modern air transportation:
  - Public concerns over ***noise and emissions***
  - Increasing costs associated with ***high fuel consumption***
  - Lack of progress towards ***faster means of transportation***
- Aeronautics and space technology are closely related: ***Fundamental Aeronautics contributes to NASA's broader Vision for Space Exploration***
- Emphasis on advanced ***multidisciplinary analysis and design*** capability to
  - Guide our research and technology investments
  - Realize integrated technology advances in future aircraft and spacecraft

Fundamental Aeronautics Program: Mission Statements

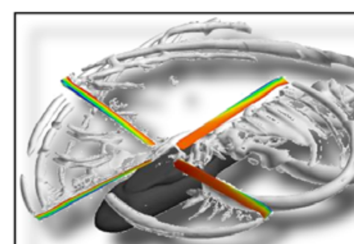
- ***Hypersonics***
  - Fundamental research in all disciplines to **enable very-high speed flight** (for launch vehicles) and **re-entry into planetary atmospheres**
  - High-temperature materials, advanced propulsion, aero thermodynamics, multi-disciplinary analysis and design, GNC, advanced experimental capabilities

- ***Supersonics***
  - **Eliminate environmental and performance barriers** that prevent **practical supersonic vehicles** (cruise efficiency, noise and emissions, vehicle integration and control)
  - Supersonic deceleration technology for **Entry, Descent, and Landing** into Mars



- ***Subsonic Fixed Wing***
  - Develop revolutionary technologies and aircraft concepts with highly **improved performance** while satisfying **strict noise and emission constraints**
  - Focus on **enabling technologies**: acoustics predictions, propulsion / combustion, system integration, high-lift concepts, lightweight and strong materials, GNC

- ***Subsonic Rotary Wing***
  - Improve **competitiveness of rotary wing vehicles** (vs fixed wing) while maintaining their unique benefits
  - Key **advances** in multiple areas through **innovation** in materials, aeromechanics, flow control, propulsion



Hypersonics Project

- Highly Reliable, Reusable Launch System (HRRLS)
  - Absolute speed record set by NASA's X-43 test vehicle: Mach 10 for <10 sec
  - Record for "sustained" hypersonic flight: SR-71 @ Mach 3 for ~2000 miles
  - HRRLS 1st stage for two-stage-to-orbit needs to reach Mach 10-12, and fly back to base
  - Significant challenges in aerothermodynamics, structures and materials, propulsion, GN&C and full vehicle system integration
- Heavy Mass Mars Entry Systems (HMMES)
  - Largest payload to land on Mars ~1 MT (Mars Science Laboratory ~775 kg)
  - Human missions to Mars will need to land 20 to 40 MT
  - Heating rate ~1000 W/cm^2 vs <100 W/cm^2 for MSL
  - Constraints for deceleration from hypersonic atmospheric entry speed and "safe" precision landing cannot be reasonably met with current technology (e.g. without prohibitively expensive propulsive deceleration)

Hypersonic Boundary Layer Transition (HyBoLT) & Sub-Orbital Aerodynamics Re-Entry Experiments (SOAREX)

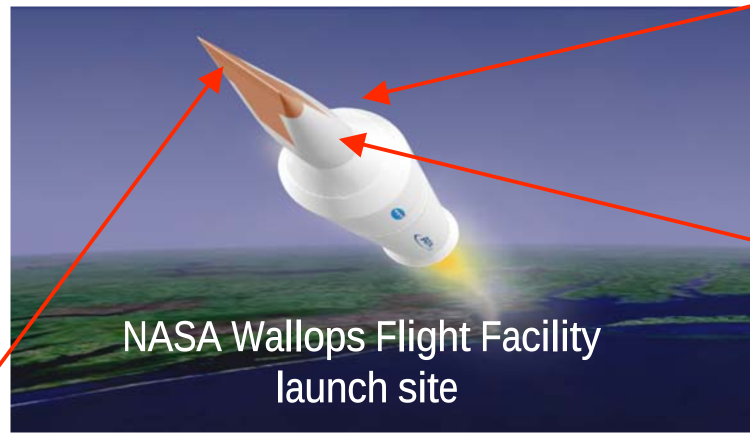
STS-114 gap-filler incident served as a potent reminder of the importance of pursuing mastery of the fundamentals of hypersonic flight.

Mission Objective: Obtain unique flight data for basic flow physics and Mars entry technology

Estimated launch date:
Late 2007

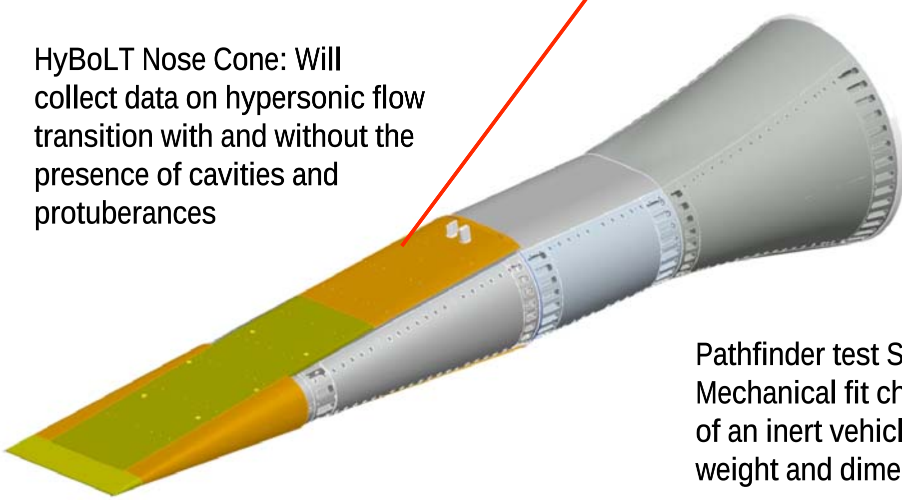
Cost-sharing partners:
NASA
ATK

ATK Launch Vehicle (ALV X-1)



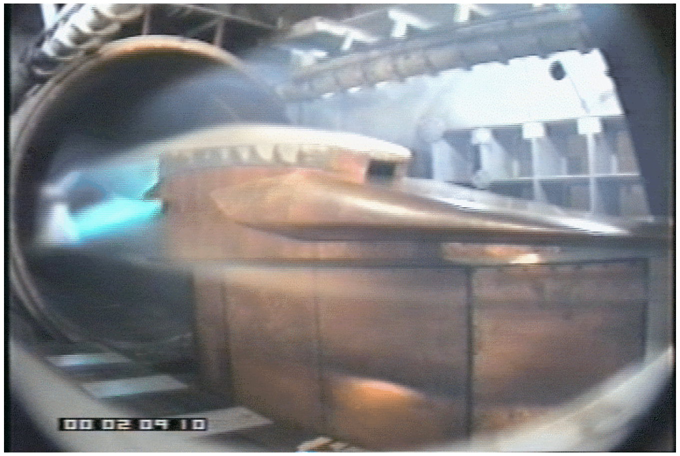
SOAREX will collect aerodynamic data on a re-entry shape during descent. Probe carried internally and ejected at 500 km altitude

HyBoLT Nose Cone: Will collect data on hypersonic flow transition with and without the presence of cavities and protuberances



Pathfinder test Sept 2006:
Mechanical fit check
of an inert vehicle with proper weight and dimensions

Hypersonics: X-51A Scramjet Engine Demonstrator



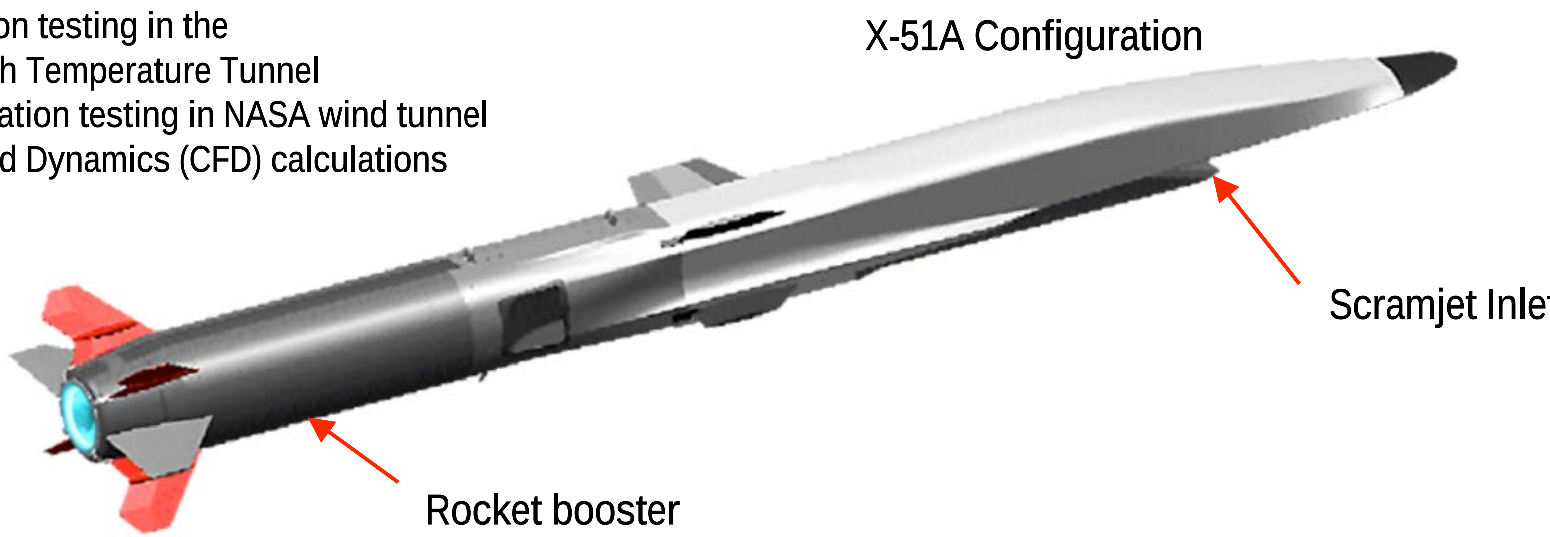
NASA Ground Demonstration Engine 2 Testing

<u>Program Overview</u>

- **Joint AFRL/DARPA/NASA flight demo**
- **Hydrocarbon-fueled and cooled scramjet**
- **Scramjet flight from Mach 4.5 to 6.5**
- **5 minute-plus flight duration**
- **Four to eight flights (FY09 1st flight)**

NASA's Role:

- Full-scale propulsion testing in the NASA 8-Foot High Temperature Tunnel
- Sub-scale configuration testing in NASA wind tunnel
- Computational Fluid Dynamics (CFD) calculations



Supersonics Project

Focus on two vehicle classes:

- **Supersonic Cruise Aircraft**
  - Eliminate the efficiency, environmental and performance barriers to practical supersonic cruise vehicles
- **High Mass Mars Lander**
  - Tools and technologies to address the critical supersonic deceleration phase of future Mars landing

Resolve the following technical challenges:

- **Efficiency Challenges**
  - Supersonic Cruise Efficiency and Light Weight and Durability at High Temperature
- **Environmental Challenges**
  - Airport Noise: Acceptable levels without weight or performance penalty
  - Sonic Boom: Propagation, prediction and design
  - High Altitude Emissions: Emissions impact must be minimized or eliminated
- **Entry Descent and Landing Challenges**
  - Supersonic Entry Deceleration: Develop tools and technologies to support the design and validation of exploration systems capable of landing payloads 100 times larger than current Mars missions
- **Multidisciplinary Design, Analysis and Optimization Challenges**
  - Understanding and exploiting the interactions of all these supersonic technology challenges is the key to the creation of practical designs

Partners include: DARPA, AFRL, JPDO, Gulfstream Aerospace, Lockheed-Martin

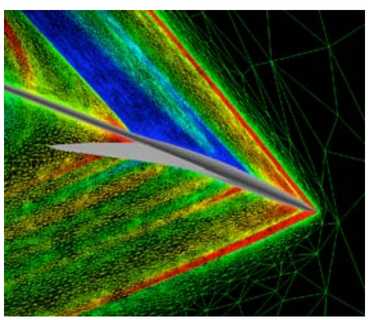
Supersonics: Cruise Efficiency

Problem Statement:

The design of efficient supersonic aircraft that also achieve low levels of sonic boom noise requires that the shape of the vehicle be carefully tailored.

Technical Approach:

- Development of new Computational Fluid Dynamics (CFD) tools
- Development of techniques for mounting wind tunnel models to enable accurate measurements of the flowfield on and around the aft portion of a supersonic aircraft.
- A modified F-15 aircraft will be used to collect in-flight measurements of the effects of the engine exhaust on the shock wave pattern in the near vicinity of the aircraft.



CFD calculation of an off body shock wave solution using an error adapted computational mesh.

Conventional wind tunnel mounting techniques distort the aft end of the model being tested.

NASA's F-15 Research Aircraft can be flown with varying nozzle positions to generate a variety of validation data

Supersonics : Entry, Descent and Landing

Problem Statement:

Supersonic parachute deceleration systems that have been used on recent Mars exploration missions are all based on the 30 year old Viking design. Although these systems have been successful, they are not capable of handling the larger masses required for future unmanned and manned missions to Mars. New concepts for supersonic reentry deceleration need to be explored. These concepts include inflatable aeroshells, inflatable decelerators, propulsive deceleration or improved parachutes.

Technical Approach:

- The Inflatable Reentry Vehicle Experiment (IRVE) will be conducted in F07. This flight experiment will demonstrate aeroshell inflation and survivability. It will also assess the thermal and aerodynamic performance of the inflatable aeroshell concept.
- Improved methods for using high-speed photography and other flow visualization techniques to collect high quality engineering data during inflation and parachute deployment testing will be explored in small scale tests.
- Prediction and validation of of the aerodynamic performance and stability of advanced decelerator concepts will be advanced through computational tool development and ground based experiments.
- For propulsive deceleration, computational and experimental studies will examine the interaction between the external and internal flow during the ignition of a rocket engine at supersonic speeds.



New Concepts for supersonic planetary deceleration are shown at left. New,validated analysis and deign tools are required for the development of these concepts

The IRVE flight test vehicle is shown at left during a ground deployment test

Subsonic Fixed Wing Project

• Air travel expected to increase 2-3 x by 2025

• Current air space reaching capacity, expansion limited by congestion, noise, emissions (JPDO alignment)

- Most travelers (~85%) pass through 64 major hubs

- Over 5000 underutilized airports

• Develop revolutionary new technologies including:

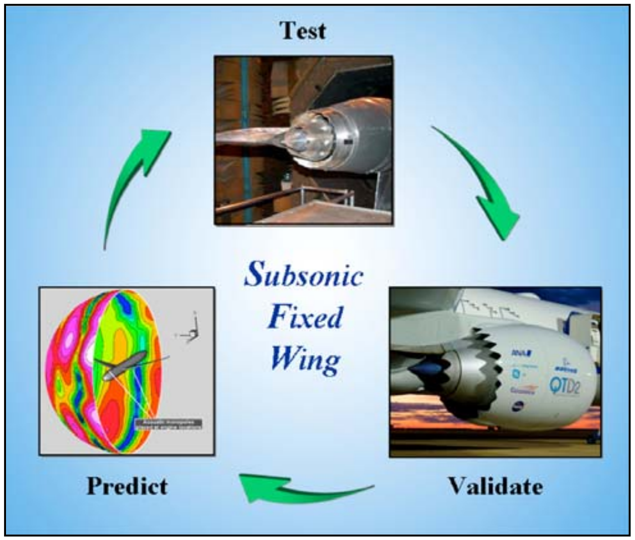
-Lower emissions (e.g. 70-80% NOx reduction)

- Confine landing/takeoff noise foot print to airport boundary

- Increase efficiency (~15-25% less fuel consumption) by advanced lightweight materials, reduced drag

• Increased lift (double lift coefficient to ~6) to open many more airports, rapid climb-out/descent for reduced noise, smaller wing for lower drag

• Partners include: JPDO, Boeing, Northrop-Grumman, Lockheed-Martin, Pratt & Whitney, Air Force / AFRL, among others

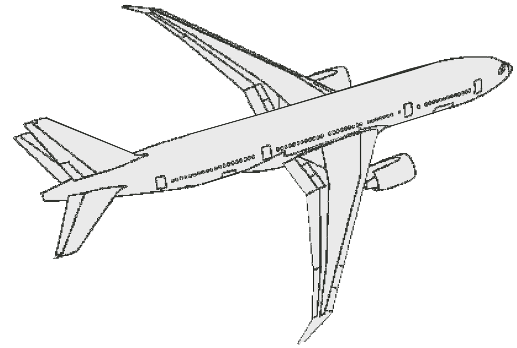


SFW: Noise, Emissions & Performance

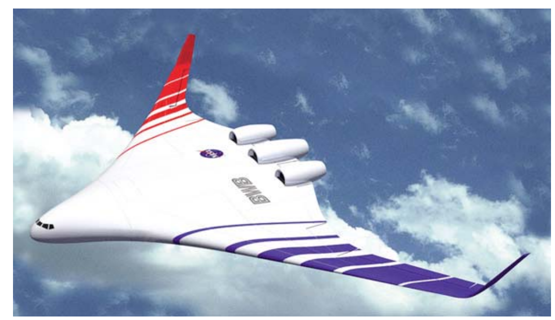
System Level Metrics

	"N+1" Generation Conventional	"N+2" Generation Hybrid Wing
Noise (cum below Stage 3)	- 42 dB	- 52 dB
Emissions (LTO NOx) (below CAEP/2)	- 70%	- 80%
Performance: Aircraft Fuel Burn (relative to 737/CFM56)	- 15%	- 25%

N+1 Conventional



N+2 Unconventional



Approach

- Reduced Uncertainty in Design and Analysis Tools and Processes.
- Major Changes in Engine Cycle/Airframe Configurations.
- Advanced Aerodynamic, Acoustic, Combustion, Aerothermodynamic, and Materials & Structures Based Concepts and Technologies.

Hybrid Wing/Body Research

- **Goal**
  – Collaborate with airframe and engine manufacturers to focus on research opportunities associated with the development of highly integrated transport aircraft with substantial improvements in fuel burn, noise and emissions characteristics.
- **Approach**
  – Focus research efforts on Blended Wing Body and derivatives such as Cambridge/MIT Silent Aircraft Design.
  – Verify new technologies through scale model and full-scale component testing, leading to collaboration on full-scale ground and flight demonstrations.
  – Develop new performance prediction methods that can be validated using experimental data obtained during scale model and full scale testing.

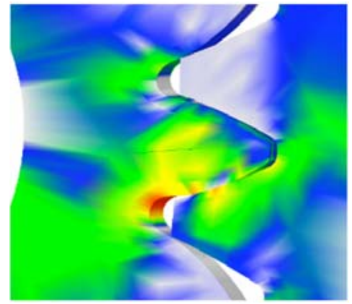
- **Current Opportunities**
  – Boeing Phantom Works and AFRL
    - Develop ground to flight correlations of low speed stability and control data through flight test of the X-48B in early 2007.
    - Validation of CFD-based predictions of wind tunnel and flight data – 2007 and 2008.
    - Conduct high-speed test of the 2-percent model in AEDC 16T in 2008.
  – MIT, Cambridge, Boeing Phantom Works, and Engine Manufacturers
    - Develop research strategies to overcome barriers to realizing “silent” aircraft design attributes- FY2007.
    - Independently verify system attributes of Silent Aircraft design- FY2007.

Subsonic Rotary Wing Project

Strong partnership with the US Army

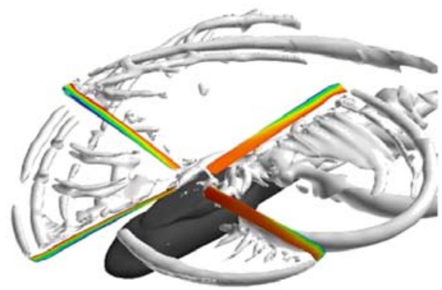
- Solving problems relevant to civil and military applications
- Researchers working side-by-side on fundamental, difficult problems
- Sharing and leveraging experimental and computational expertise

Other partners include: Bell Helicopter, Sikorsky, HeloWerks, AF, DARPA

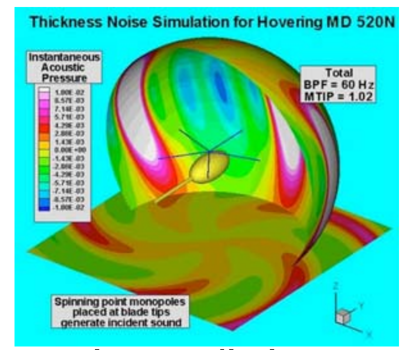


3-D Analysis of Spur / Helical Gears

14- by 22-Foot Subsonic Tunnel



First-Principles Modeling



Noise prediction

Research Areas:

Noise propagation and reduction	➡	Community acceptance
Increase speed and range	➡	Reduce airport congestion
Increase propulsion efficiency	➡	Reduce emissions
Increase payload	➡	Decrease cost, increase utility
Improve control systems	➡	Safe operations for advanced concepts

SRW: Five Technical Integration Challenges

- Integrated Variable Speed Rotorcraft Concept (FY11) *Propulsion / Aeromechanics Integration:* Demonstrate variable-speed rotor concept that reduces rotor tip speed at high speed cruise operating conditions with a variable-speed transmission concept capable of 50% speed reduction from hover to cruise. Enables high-speed advanced rotorcraft concepts and noise reduction concepts.

- Super-Integrated Control Design (FY09) *Flight Controls/Noise/Propulsion/Aeromechanics Integration:* Develop a methodology and a design for an integrated, broadband rotorcraft control system incorporating flight control system, engine control, airframe/drive train/rotor load control, active rotor control of vibration and noise, vehicle heath management, and guidance for low noise operation.

- Advanced Structural and Propulsion Concepts for Interior Noise and Vibration Reduction (FY10) *Structures/Propulsion/Acoustics Integration:* Develop and demonstrate advanced structural concepts for interior noise and vibration reduction using optimized combinations of new material acoustic treatment, reductions in transmission gear vibration, and active noise cancellation.

- Interactional Acoustics Investigation (FY10) *Aeromechanics/Acoustics Integration:* Validate and assess capability to predict rotorcraft behavior, including performance, airloads, flow field, structural loads, and acoustics, by comparing predictions with validation data obtained in advanced wind tunnel experiments.

- Unified Experimental Techniques (FY10) *Integrated Experimental Systems:* Develop and integrate experimental techniques to enable efficient, multi-parameter, simultaneous measurements for characterizing rotorcraft behavior and providing validation data

Fundamental Aeronautics: NRA Status

Project	Number Selected for Negotiation for Award
Fixed Wing	27
Rotary Wing	12
Supersonics	23
Hypersonics	37
Total	99*

* All 99 Awards are expected to be completed by Jan 2007

Next solicitations will be available (estimated dates):

- Hypersonics: mid February
- Supersonics: mid January, a further solicitation available March
- Subsonic Fixed Wing: mid February
- Subsonic Rotary Wing: mid January

Next solicitation awards expected (estimated dates):

- Hypersonics: June/July 2007
- Supersonics: May/June 2007 & July/August 2007
- Subsonic Fixed Wing: June/July 2007
- Subsonic Rotary Wing: May/June 2007

Partnering/Interaction Opportunities

- NRA: universities, industry, research organizations
  - One or two solicitations / year / project (in steady-state)
  - Seeking close interaction with partners (knowledge transfer, visits)
  - NRA as a vehicle can take many forms
  - Filling voids in expertise at NASA and looking for new and innovative ideas
- Space Act Agreements with Industry
  - Actively seeking partnerships that make sense for NASA and industrial partners
  - Focus on pre-competitive research and consortia
  - Look for wide and open dissemination of data
  - Industry days and interaction with projects

For More Information…

http://aeronautics.nasa.gov/programs_fap.htm

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