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# NASA Hypersonic Technology Project - Formulation Overview

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**2016 AFOSR High Speed Aerodynamics Portfolio Review  
and ONR Hypersonics Portfolio Review**

**June/27-30/2016, Arlington, VA.**



# Outline

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- **Background: Hypersonics S&T focus**
- **Hypersonic Technology Project Formulation**
- **HTP Academia Outreach**
- **New Funding Model for NASA's  
Aerosciences Ground Test Facilities**

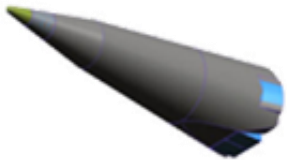


# Hypersonics S&T

## *Technology Application Domains*

*Aircraft and Space Access have Military and Civil Apps*

**Weapons\***  
**Near-Term**



**Aircraft\***  
**Mid- to Far-Term**

**Space Access**  
**Far-Term**



**\* Focus of current investments**



# NASA Hypersonics S&T

## *Two Major Areas of NASA Hypersonic Competencies & Capabilities*



### **Air-breathing: Enabling Potential Future Responsive Space Access**

- On Demand Access To Low Earth Orbit
  - Reusable First Stage
  - Lower Cost To Orbit
- One or Two Stage to orbit

**NASA Aeronautics Focus**



### **Entry, Decent and Landing (EDL): Required for Atmospheric Reentry**

- Reentry of Crew Vehicles to Earth's Atmosphere
- Entry, Descent and Landing on other bodies

**NASA Space Technology Focus**





# USAF Time-Phased Technology Readiness

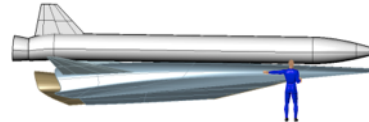
## Reusable Strike/ISR (Runway Takeoff/Landing)



**Tech Ready: 2040**  
*Multi-mission ISR and strike*  
*Aircraft-like operations*

## Limited Reusable Strike/ISR

(e.g., Air Launched)



**Tech Ready: 2030**  
*Tactical strike or ISR of*  
*deep high value targets*

## Expendable Strike



**Tech Ready: 2020**  
*Tactical strike from*  
*standoff*

*Weapons*

Dual-use technologies: Potential civil applications  
(Access to Space & Point to Point Transport)

*Air Platforms*

**Ensure rapid and survivable operations in contested environments**  
**Timeline Resource Based not Technology Availability**



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# **NASA Hypersonic Technologies Project (HTP) Project Formulation**



# Hypersonic Technologies Project



- With the request, NASA will also establish the Hypersonic Technologies Project. NASA will balance investments that support and leverage the work of the Department of Defense (DoD) with investments in fundamental hypersonics research.
- The project objective is to advance and utilize analytical tools, test techniques and capabilities, and critical technologies to ensure U.S. supremacy in hypersonics for future national needs.
- The project will work with the DoD to develop a National Hypersonic Strategy (requested by OMB and OSTP). NASA's investment will be informed by and aligned to the National Strategy.

**President's FY17 Budget Request**



# NASA HTP Project Formulation



## Strategic Thrust

Recapture US Supremacy in hypersonics for future National needs  
NASA going to support AF Roadmaps (leap frog certain technologies)

National Aeronautics Research and Development Plan: In general, the Department of Defense seeks to develop technologies to a level where they can be validated or demonstrated in a relevant environment and ultimately be employed in weapon systems. This validation or demonstration may include flight test, ground test, validated modeling and simulation, and any other means as appropriate to enable the transition of technologies into the development of aviation systems for national security and homeland defense

## Outcomes

Outcomes are derived from and support USAF Hypersonics S&T Roadmaps

Weapon System AOA  
(TRL 6) by 2020

Hypersonic ISR AOA  
(TRL 6) by 2030

Hypersonic Space Access  
AOA (TRL 6) beyond 2030

## Research Themes (RTs): Long term research areas that will enable the outcomes

- System-level design, analysis, validation
- TBCC propulsion technologies
- Reusable vehicle technologies
- High temperature, durable materials

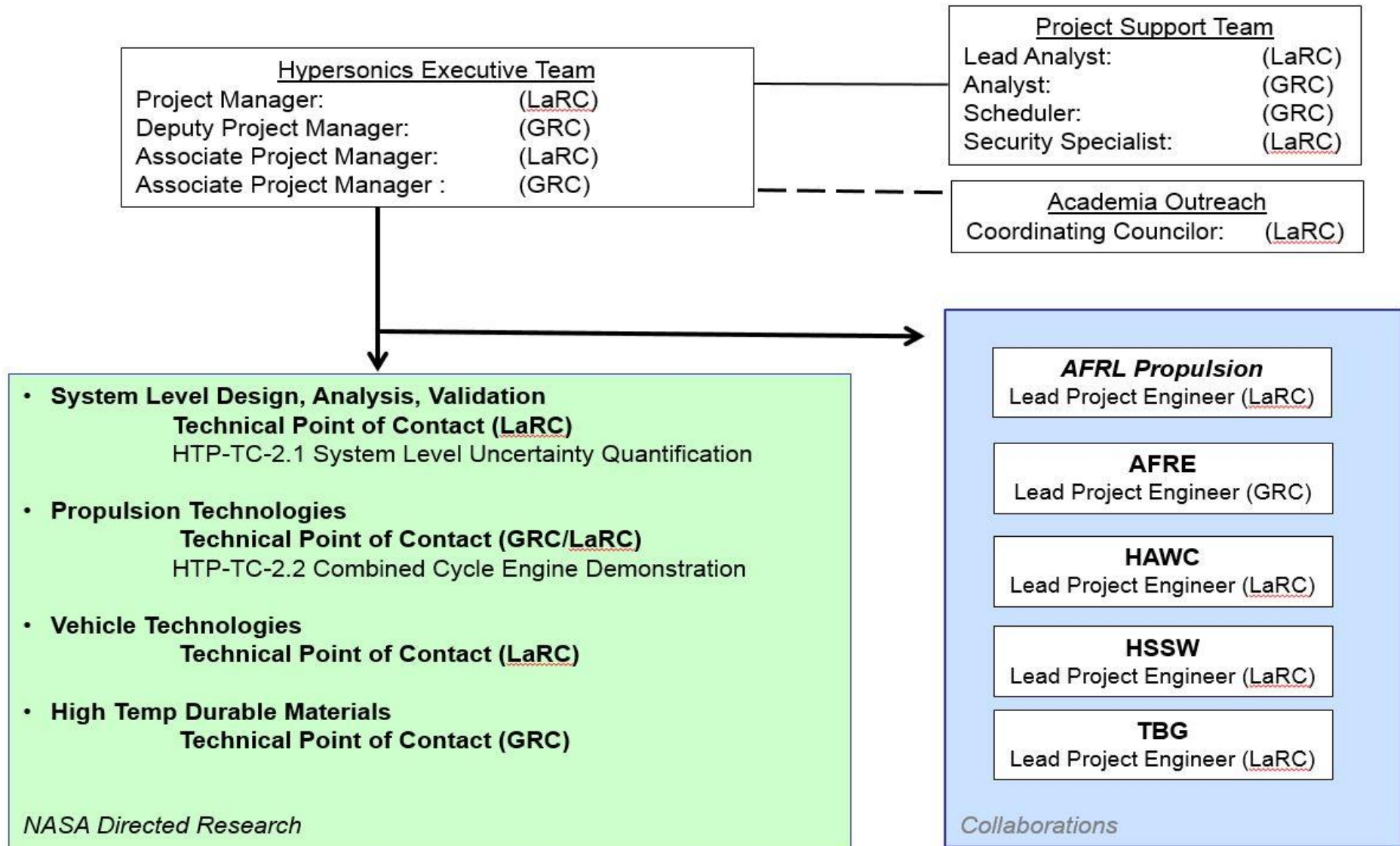
## Technical Challenges (TCs): Specific measurable research commitments w/in the RTs

- HTP-TC-2.1 Uncertainty Quantification and Reduction
- HTP-TC-2.2 Integrated Turbine Based Combined Cycle Propulsion System





# Proposed HTP Structure





# NASA HTP

## Major Emphasis on Reusable Vehicles

### ➤ Mission

- Ensure US supremacy in Hypersonics
- Maintain world class, critical core capabilities
- Conduct fundamental research and advance knowledge base; develop analytical/computational tools; maintain, improve and operate critical experimental facilities, test techniques and diagnostics
- Support national priorities utilizing research, computational tools, experimental capabilities, etc. in support of technology & system development and flight test
- Invigorate US hypersonics workforce

### ➤ Strong partnership between NASA and the Department of Defense

- Systems Analysis & Vehicle Studies (**Uncertainty Methodology Development**)
- Hypersonic Airbreathing Propulsion Technology, Tools, and Techniques
  - **Robust Reusable Scramjet Propulsion**
  - **Turbine Based Combined Cycle Propulsion Systems**
- **High Temperature Structures, Materials, & Seal development** and characterization to increase durability of flight structures, propulsion systems, and control surfaces
- **Aerothermodynamics prediction** capabilities to reduce hypersonic environment uncertainties
- **High Speed Test Measurement Techniques**



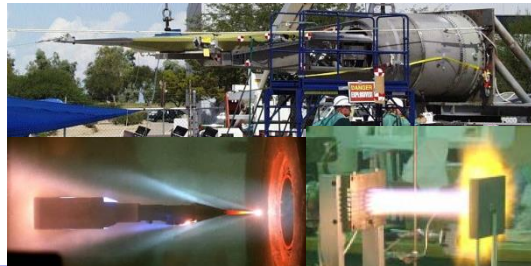
*Combined Cycle Engine Testing*



*Scramjet Testing*



*High Temperature Seals*



*Structures and Materials*



*Hypersonic Vehicles Analysis*



# Langley's New HBLT Team

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- Under the new Hypersonic Technology Project, LaRC is proposing to stand up a high-speed boundary layer transition (HBLT) team that leverages expertise in
  - Laminar-to-turbulent transition physics
  - Hypersonic configuration and propulsion development
  - Computational analyses
  - Quiet tunnel development & operations
  - Advanced instrumentation development
- HBLT team objectives are:
  - Reduction of uncertainty in high-speed boundary-layer transition prediction for relevant geometries in flight by improving and developing experimental, computational, and theoretical tools
  - Maintenance/growth of SMEs, steward knowledge, and foster fundamental research in HBLT to support National needs (establish LaRC team as agency/world leaders in high-speed boundary-layer transition)
  - Enhance interaction with academia to increase the pipeline of students for the next generation of SMEs in hypersonic research



# HBLT Team Activities

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- List of our current capabilities (fundamental research on transition physics and control of transition):

## Computational

Accurate mean-flow computations for high-fidelity transition analysis  
Linear stability & linear/nonlinear PSE for shear flows  
Adjoint versions of LST & PSE for receptivity sensitivity analysis  
Transient growth analysis  
Secondary instability analysis  
DNS/LES

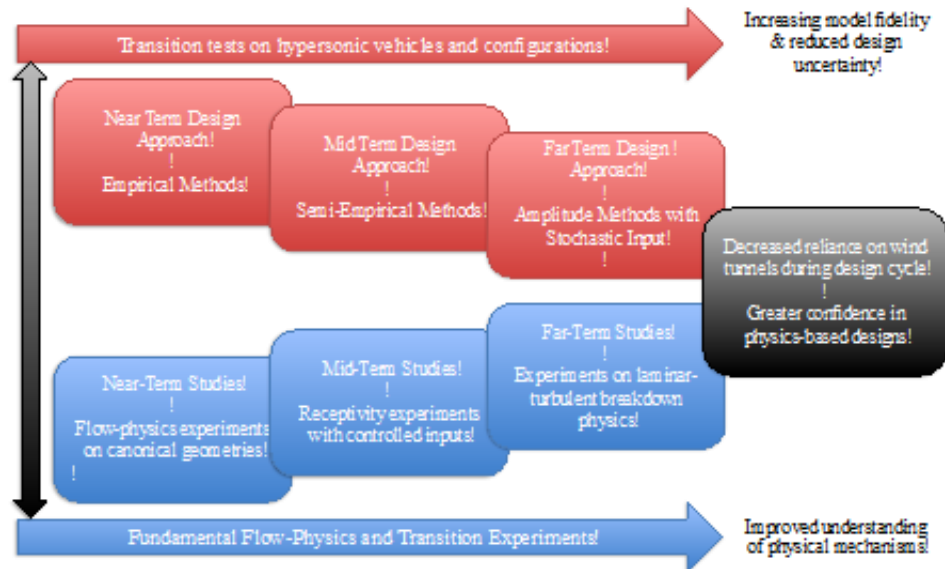
## Experimental

Quiet tunnel research and development  
Surface and off-body unsteady measurements  
Global surface measurements  
Instability & transition measurements  
Discrete roughness correlations  
Unseeded & seeded flow measurement techniques

- Scope of HBLT team research activities to include:
  - Identification of physical mechanisms and interactions that lead to BLT
  - Passive/active tripping for BL control to promote or delay transition
  - Receptivity (conventional & quiet tunnels vs. flight and guidelines for acceptable surface roughness & waviness)
  - Prediction and control of 2<sup>nd</sup>-mode dominated transition
  - Prediction and control of crossflow dominated transition (stationary and/or traveling in flight vs. wind tunnels)
  - Prediction and mitigation of 3D shock/boundary layer interactions (SBLI)



# Notional Roadmap for the Development & Validation of Theoretical Models of Transition\*



\*Implementation of roadmap assumes availability of proposed larger QT

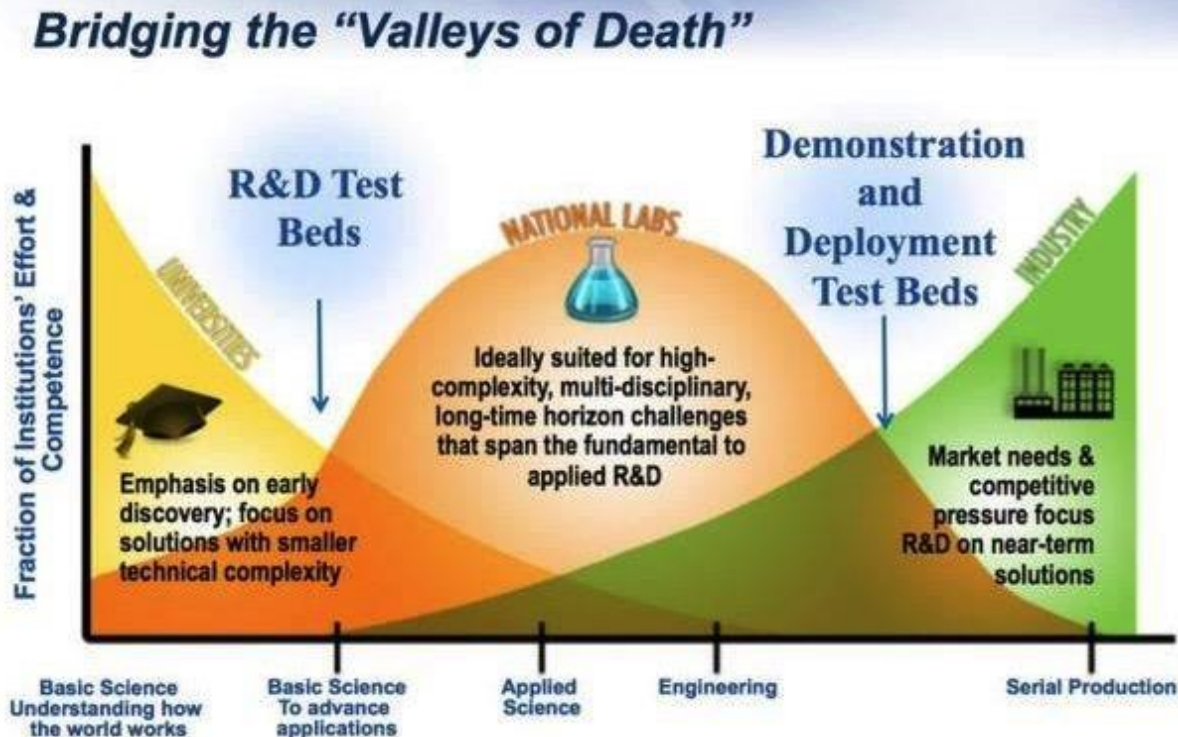
- Top path uses WT transition tests on hypersonic vehicles (an engineering design path) to identify transition issues
  - Near term: empirical correlations are developed through WT testing, confidence gained only after comparisons of WT-to-flight
  - Mid term: adopt semi-empirical methods to account for BL instabilities identified through WT observations
  - Far term: use amplitude methods for BLT based on assumed disturbance inputs, which will only ever be known in some stochastic sense (at this stage, there is much greater reliance on physics-based modeling during design, thus WT would play a less prominent role in the vehicle design cycle)
- Bottom path uses fundamental flow-physics and transition WT experiments to shift focus to developing higher fidelity prediction tools
  - Near term: perform flow-physics experiments on a broad range of canonical geometries (both slender and blunt) that support a range of instability modes (performing detailed off-body measurements of the instabilities and their breakdown to turbulence, which will be used to validate stability calculations and provide the transition data needed to form semi-empirical prediction methods)
  - Mid term: perform studies of boundary-layer receptivity to controlled disturbance inputs
  - Far term: perform studies of the boundary-layer breakdown mechanisms
- Neither path proceeds in isolation, cross-pollination required between paths and computational analysis





# NASA HTP Project Formulation Strategic Assumptions

- Our strength (unique integrated capability: SA-Analytical / Computational, Experimental) is mid-TRL, bridging valley of death
- (mostly) Rely on academia for low-TRL
- Invigorating hypersonic workforce is critical to the Nation
- Systems Analysis technology trades drive priorities
- Expertise to identify emerging technologies that are ready for mid-TRL investment
- Critical to see TRL advancement through to flight-test demo (National Enterprise / partnerships essential)





# HTP Academia Outreach



# Overarching Motivation

Education...a National and Agency priority.

*The nation that  
out-educates us today  
will out-compete us  
tomorrow.*

President Barack Obama  
Speech to the National Academy of Science  
April 27, 2009

*We are committed to inspiring  
the next generation...who will keep America in the forefront of  
technology, innovation and space exploration.*

Charlie Bolden  
White House Science Fair  
May 14, 2011





# Academic Outreach Components

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## ➤ **Mission:**

- Reinvigoration and infusion of the next generation of hypersonic scientists and engineers to enhance the national workforce
- Leverage academia for fundamental research
- Capture of new and exciting ideas

## ➤ **Attributes:**

- High degree of student/NASA researcher interaction
- Significant time spent at a NASA center
- Hands-on experience, including access to NASA facilities and laboratories
- Create student community for enhanced experience
- Integration of student research portfolio (as it makes sense) to maximize interactions

## ➤ **Management Approach:**

- Subproject with allocated resources
- Multiple contracting mechanisms (potentially using: STRF, LaRC & GRC Student Programs, NRA(s), **SAA with universities**)

## ➤ **Areas of focus:**

- Aerodynamics and Aerothermal effects
- High speed propulsion
- High temperature durable materials



# Expectations and Assumptions:

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- Expand upon existing NASA scholarship mechanisms for students (internships, fellowships and scholarships) that are highly motivated to perform research relevant to hypersonic technology maturation.
- Utilize this “pool-of-candidates” to enhance the existing national hypersonic workforce.
- Apply a long-term and sustainable scholastic funding model.
- Develop research topics, of mutual interest, utilizing Space Act Agreements with interested academic institutions, prior to solicitations and awards.



# Expectations and Assumptions:

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- Students will be highly encouraged to reside at both their “home-academic institution” and at least one relevant NASA center while performing the sponsored research effort.
- Applicants will be limited to U.S. citizens.
- Coordination with external NASA partners, such as DOD, AFOSR and AFRL-WPAFB will be encouraged to maximize research relevance to hypersonic applications.
- Suggested improvements to the “framework” are welcomed.
  - POC: Aaron Auslender <aaron.h.auslender@nasa.gov>



<http://afrl.dodlive.mil/2016/06/21/new-exciting-opportunity-to-partner-with-nasa-scientists-and-use-selected-nasas-wind-tunnels-to-carry-out-fundamental-research-in-high-speed-aerothermodynamics/>

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# **NEW EXCITING OPPORTUNITY TO PARTNER WITH NASA SCIENTISTS AND USE SELECTED NASA'S WIND TUNNELS TO CARRY OUT FUNDAMENTAL RESEARCH IN HIGH-SPEED AEROTHERMODYNAMICS**

Posted on [June 21, 2016](#) by [ekrayer](#)

ATTENTION ALL POTENTIAL PRINCIPAL INVESTIGATORS SUBMITTING PROPOSALS FOR FY17

NASA and AFOSR are launching a pilot program whereby grant proposers can partner with one or more NASA researchers and/or propose to use a specific NASA wind tunnel. The use of the wind tunnels would represent minimal extra cost to the proposal as normal test operations will be conducted at no charge. The grant proposers would engage NASA during proposal development to obtain a cost estimate for the test activity envisioned. If awarded, the grant proposer would enter into a Space Act Agreement with NASA as the partnering mechanism. The specific wind tunnels available for this partnership are the Langley Research Center Aerothermodynamics Laboratory. Information on the wind tunnel facilities can be found on the following website: <http://researchdirectoratelarc.nasa.gov/langley-aerothermodynamic-laboratory-la/>

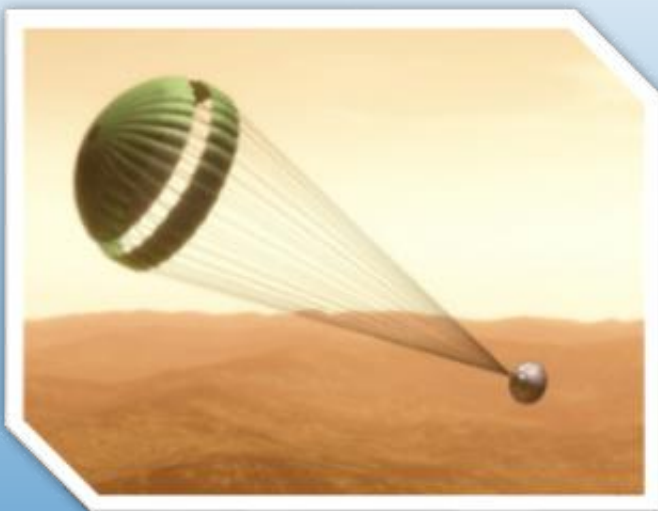
We envision the partnership with NASA researchers to take several forms. For example, a project could have Ph.D. students co-located with NASA researchers during a few months in the term of the grant and have periodic remote mentorship the rest of the time of the grant. Another option is to have NASA researchers to be a part of the Ph.D. defense committee for a student with informal mentorship all throughout the life of the grant. A third option would for NASA researchers to carry out investigations complementary to the grant objectives (computations and/or experiments). Expenses associated with students' travel to NASA facilities need to be included in the grant budget. If a proposed project would like to use one of the above wind tunnels, please include an explanation of how the use of the tunnel would enhance the objectives of the proposal and why such objectives can't be achieved in university facilities. Also, it would preferred that a substantial portion of the overall grant objectives (experimental and computational) are carried out prior to using a NASA facility and the experiments carried out at NASA represent the final validation of the theories or hypothesis developed during the course of the grant.

For this pilot program, the research topics remain the same as stated in the latest BAA for AFOSR on [Grants.gov](#).

For more details email both [ivett.leyva@us.af.mil](mailto:ivett.leyva@us.af.mil) and [kenneth.e.rock@nasa.gov](mailto:kenneth.e.rock@nasa.gov).



## New Funding Model for NASA's Aerosciences Ground Test Facilities





# Vision for the Agency Aeroscience Ground Test Funding Model



- NASA is implementing an Agency Capability Leadership model that maintains critical capabilities to meet current and future mission needs. As part of this new leadership model, the Agency will strategically identify areas where Agency Technical Capability divestments or investments are required to ensure continued success.
- One of the first Agency Capability Leadership area recommendation is a new alternative funding model for **Aerosciences ground test capabilities**.
- **Primary Objective of New Funding Model-** Improve access to our facilities, putting them back in the hands of our researchers and engineers to execute the Agency's missions, programs, and projects.
  - Enable technology innovation and risk reduction by providing easier access to the aerosciences ground test facilities and workforce
  - Make facilities as accessible for small research and engineering projects as they are for large programs
  - Remove cost bias that favors computation over test
  - Reinforce role of facilities as an Agency resource
  - Improve facility utilization
  - Provide a path for facility sustainability
  - Provide an improved measure for facility decisions involving capability partnering, purchase, divestment, and investment.





# Agency Critical Aerosciences Ground Test Facilities



*Agency ground test facilities identified as critical to the NASA Aerosciences Capability*

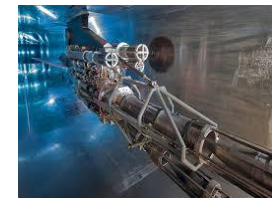
- ARC Unitary Plan Wind Tunnel (11x11' Transonic and 9x7' Supersonic Wind Tunnels)
- GRC 9x15' Low-Speed Wind Tunnel and 8x6' Supersonic Wind Tunnel
- ✓ GRC 10x10' Unitary Plan Wind Tunnel
  - GRC Icing Research Tunnel
- ✓ GRC Propulsion Systems Lab
- ✓ LaRC 8' High Temperature Tunnel
  - LaRC 14x22' Subsonic Wind Tunnel
- ✓ LaRC Aerothermodynamics Lab
  - LaRC National Transonic Facility
  - LaRC Transonic Dynamics Tunnel
- ✓ LaRC Unitary Plan Wind Tunnel\*
  - LaRC 20' Vertical Spin Tunnel\*
- ✓ Potential for Hypersonic Partnerships
- \* New to AETC portfolio in FY17



ARC UPWT



GRC 9x15' Low-Speed Wind Tunnel and 8x6' Supersonic Wind Tunnel



GRC 10x10' UPWT



GRC Icing Research Tunnel



GRC Propulsion Systems Lab



LaRC 8' High Temperature Tunnel



LaRC 14x22' Subsonic Wind Tunnel



LaRC Aerothermodynamics Lab



LaRC UPWT



LaRC 20' Vertical Spin Tunnel



LaRC National Transonic Facility



LaRC Transonic Dynamics Tunnel



# Key Points/Takeaways



Testing Neither **FREE** nor Unlimited

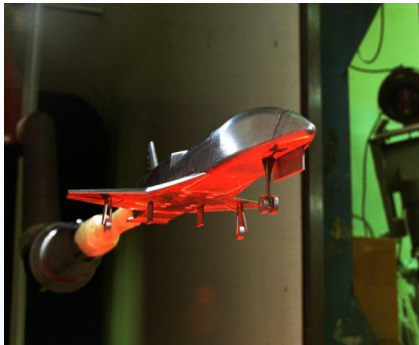
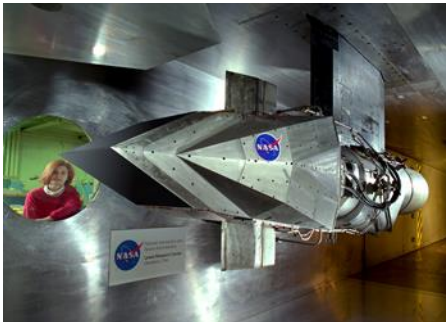
## Starting in FY17

- Test operations labor (civil servant and contactor workforce) for **planned** capacity and select facility-related procurements will be covered by the Agency for *critical aerosciences ground test facilities* for NASA internal customers- see next slides.
  - Funding through a combination of ARMD AETC Project budget plus three Mission Directorate (HEOMD, SMD and STMD) decrements- **NOT JUST ARMD FOCUSED**
  - External customers will continue to pay hourly utilization rates plus consumables
- Test capability consumables (e.g. electricity, LN<sub>2</sub>, R-134a), models consumables, special instrumentation and test techniques, non-facility workforce (e.g. acoustics researchers), and over-capacity hours will be charged to all customers. All customers will also fund model and model-systems development costs.
- **Starting in FY19**, test capability consumables will be covered for internal (NASA and partners) customers.
- Partnerships with external identities can benefit from covered operating costs if data-sharing exists and is benefiting a NASA mission.
- Test utilization allocations have been defined by the Agency for four Mission Directorates (ARMD, HEOMD, SMD, and STMD) and external customers.
- NASA internal customers need to plan now and determine how this new funding model impacts FY17 and beyond testing needs and respond to the AETC Project demand forecast survey in March 2016.





# Partnerships and External Testing



- In partnership with NASA, external partners can qualify for covered operations testing cost in NASA aerospace ground test facilities if the following apply:
  - ✓ Partner testing is sponsored by a NASA project or program and,
  - ✓ Testing is documented with a NASA Space Act or Interagency Agreement and,
  - ✓ In the partnership, one or more of the following apply as it relates to required data sharing:
    - ✓ Enables and/or increases NASA technology readiness
      - Supports Small Business Innovation Research (SBIR) or NASA Research Announcements (NRA)
    - ✓ Lowers NASA research and/or development risks
    - ✓ Accelerates NASA technology transfer
      - Reduces risks of NASA contracted deliverables
      - Enables and/or accelerates delivery of NASA contracted deliverable
- The sponsoring NASA project or program shall be responsible for substantiating covered operations testing costs.
- Issues with regard to supported partnerships will be forwarded to the ATAB for resolution.
- External customers (non-partners) will continue to pay hourly utilization rates plus consumables plus test-specific costs and allow for AETC funds to be used towards additional maintenance, capability advancement, and/or new test technologies.



# Summary

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## ➤ **NASA HTP project formulation FY16**

- NASA will balance investments that support and leverage the work of the Department of Defense (DoD) with investments in fundamental hypersonics research.
- Project emphasis on reusable vehicle technologies for TBCC
- Project will focus on two Technical Challenges
  - System Level Uncertainty Quantification & Reduction methodologies and analysis
  - Integrated Turbine Combined Cycle Propulsion System

## ➤ **Academia Outreach**

- Reinvigorate Nation's hypersonic workforce

## ➤ **New Funding Model for NASA's Aerosciences Ground Test Facilities (FY17)**

- Most of HTP partnerships are covered under this model
  - e.g. NASA/AFOSR Pilot Program