NASA Langley Research Center

Breakthroughs for a New Century:
An Overview of Langley, Hypersonics, and On-orbit Servicing,
Assembly and Manufacturing

Deborah (Debi) Tomek
Deputy Director
Space Technology and Exploration Directorate
LANGLEY HISTORY

Aerospace Innovation Spanning 100+ Years
THE LANGLEY MISSION

AVIATION

EARTH SCIENCE

SPACE EXPLORATION

TRANSFORMATION
AVIATION

Fly Everywhere

**Optimize**  Transform traditional aviation with next-generation improvements to speed, efficiency and safety

**Mobilize**  Make on-demand personal mobility routine, safe and widespread with advanced technologies and testing

**Trailblaze**  Incorporate and fly state-of-the-art innovation to create entirely new aircraft
AVIATION

Innovative Advancements

Ultra-Efficient Aircraft

Aerodynamic Testing

Hypersonics Testing

UAV Research

Advanced Composites

Supersonic Flight
EARTH SCIENCE

Understand Our Home Planet

**Develop**  Create and deploy next-generation sensors on airplanes and spacecraft

**Measure**  Gather continuous regional and global measurements on atmospheric processes

**Understand**  Use the measurements to discern how complex interactions shape planetary weather, air quality and climate
SPACE EXPLORATION

Reach to Deep Space

**Build**  Apply the latest concepts and technologies to autonomous construction of large space structures

**Protect**  Safeguard humans during extended space missions with smart structures and radiation protection

**Arrive**  Safely deliver scientific missions and people to other worlds with planetary entry, descent and landing systems
SPACE EXPLORATION

Deep Space Transportation

- Space Launch System
- MPCV Orion Testing
- Launch Abort System
- System Architectures
- In-Space Assembly
- Deep Space Structures
- Entry, Descent and Landing
- Commercial Crew Testing
Connect  Target groundbreaking ideas, technologies, partnerships and new ways to work

Advance  Cultivate the array of capabilities, skills and solutions needed for NASA missions

Accelerate  Expedite delivery of concepts and technologies for NASA and the nation
Hypersonics is a Broad Mission Area

**Hypersonics**

- **Blunt Body Re-entry**
- **Unpowered Atmospheric Flight**
- **Powered/ Sustained Atmospheric Flight**

Multiple NASA Missions require Mastery of Hypersonic Flight
Hypersonic Technology Project Vision

Enable Routine, Reusable, Airbreathing Hypersonic Flight

Approach
- Conduct fundamental research to enable a broad spectrum of hypersonic systems and missions by advancing the core capabilities and critical technologies underpinning the mastery of hypersonic flight and bringing them to bear on National Programs

Scope
- Fundamental research spanning technology readiness and system complexity levels
- Critical technologies enabling re-usable hypersonic systems
- System-level research, design, analysis, validation
- Engage, invigorate and train the next generation of engineers
HTP Research Topics

RT-1: System Level Design, Analysis, Validation
- Tool Development
- Uncertainty Quantification

RT-2: Propulsion Technologies
- Mode Transition
- Enhanced Mixing and Injection

RT-3: Vehicle Technologies
- Boundary Layer Transition
- Shock-Shock and Shock-Boundary Layer Interactions

RT-4: High Temperature, Durable Materials
- C-C Hot Structures
- Ceramic Matrix Composite Heat Exchanger
NASA/DoD Partnering

**Department of Defense**
- Focus on operational mission (especially in near-term)
- In-house expertise aligned with mission need
- Enhancing test capabilities
- Significant investment (especially in demonstrators)

**NASA**
- Focus on fundamental research (long term emphasis with near term impact)
- Fully utilizes data from demos to advance/validate fundamental capabilities
- Performs independent studies to assess Technology Readiness for advanced civil & military applications
- Maintains unique facilities & skills with unique expertise to benefit broad aerospace community

- **Develop new military capability**
- Developing future workforce
- Fundamental research base for country & future missions

Share valuable data with NASA enables DOD Mission

Provide subject matter experts and key facilities
NASA has the knowledge to develop and apply our world class combination of computational expertise, experimental facilities and flight experience in propulsion, aero thermodynamics, materials, thermal structures, guidance & control and conceptual vehicle design to deliver mission success.
**NASA Hypersonic Propulsion Test Facilities**

- **8-Ft. High Temperature Tunnel (8-Ft. HTT)**
  - Flight Mach Enthalpy: 3-7

- **Propulsion Systems Lab (PSL)**
  - Flight Mach Enthalpy: 4.7-6

- **10x10**
  - Flight Mach: 2.0-3.5

- **Unitary Plan Wind Tunnel (UPWT)**
  - Flight Mach: 1.5-4.6

- **Arc-Heated Scramjet Test Facility (AHSTF)**
  - Flight Mach Enthalpy: 4.7-8

- **Direct-Connect Supersonic Combustion Test Facility (DCSCTF)**
  - Flight Mach Enthalpy: 4.5-7

*Available under the New Funding Model*
Academic Outreach

- Supported 47 student interns in FY17
- Supported over 20 student interns in FY18
- In FY18, granted 4 multi-year scholarships supporting graduate research to be conducted partly in NASA facilities with NASA researchers
  - Additional scholarships to be awarded in FY19
- Partnering with AFOSR, ONR, and universities to bring testing into NASA facilities

(From left to right) Thomas Whalen, Cole Sousa and Dr. Laurence (UMD) at LaRC 20-Inch Mach 6 Tunnel

UTSI professor Dr. Phil Kreth, NASA researcher Dr. Brett Bathel, and graduate student Laura Lash in the LaRC 20-inch M6 Tunnel
Project Organization and Structure

Hypersonic Executive Team:
- Project Manager: Chuck Leonard (LaRC)
- Deputy Project Manager: Steve Sinacore (GRC)
- Associate Project Manager: Open (LaRC)
- Associate Project Manager: Maureen Kudlac (GRC)
- Chief Technologist: Ken Rock (LaRC)

Project Support Team:
- Lead Analyst: Laura Evans (LaRC)
- GRC Analyst: Mark Monaco (GRC)
- Scheduler: Danelle Fogle (GRC)
- Security Specialists: Steve Sanders (LaRC/Lead)
- Alex Oppenheim (GRC)

Academia Outreach:
- Coordinator: Aaron Auslender (LaRC)
- GRC Lead: Laura Evans (GRC)

NASA Directed Research – Research Topics:
- **System Level Design, Analysis, Validation**
  - Technical Point of Contact: Andrea Storch (LaRC)
  - HTP-TC-1: Tom West (LaRC)
- **Propulsion Technologies**
  - Technical Points of Contact & HTP-TC-2: Christine Pastor-Barsi (GRC), David Witte (LaRC)
- **Vehicle Technologies**
  - Technical Point of Contact: Scott Berry (LaRC)
- **High Temperature, Durable Materials**
  - Technical Point of Contact: QuynhGiao Nguyen (GRC)

Collaborations:
- **Advanced Full Range Engine**
  - Lead Project Engineer: Steve Sinacore (GRC)
- **Air Force Research Lab Propulsion**
  - Lead Project Engineer: Rick Gaffney (LaRC)
- **Hypersonic Airbreathing Weapons Concept**
  - Lead Project Engineer: Sal Buccellato (LaRC)
- **Tactical Boost Glide**
  - Lead Project Engineer: Frank Greene (LaRC)
- **Global Hawk Technology Demonstrations**
  - Lead Project Engineer: Melinda Cagle (LaRC)
OSAM
On-Orbit Servicing, Assembly, and Manufacturing

Enabling an Independent, Resilient and Sustainable Presence in Space
OSAM is an emerging set of capabilities that enables servicing, repair, upgrade, modular assembly, and inspection of space assets.

- **Servicing** is the on-orbit alteration of a satellite after its initial launch using another spacecraft.
- **Assembly** involves on-orbit aggregation of components to constitute a spacecraft into a shape or configuration that cannot be achieved with traditional deployment methods and available launch vehicles.
- **Manufacturing** involves on-orbit transformation of raw materials into usable spacecraft components.

**OSAM-enabled technologies and applications**

- **Servicing** includes:
  - Rendezvous and capture
  - GNC and robotics
  - Dextrous robotics
  - Low-latency telerobotics
  - Autonomy

- **Assembly** includes:
  - Mech. interfaces scalable to large structures
  - Standard and commercialized interfaces
  - Multiple-launch supply and rendezvous
  - Resident robotics in application form

- **Manufacturing** includes:
  - Additive manufacturing
  - Advanced materials and processes
  - Inspection and repair
  - Recycling, reuse, and repurpose
  - Construction of infrastructure

**OSAM capabilities combine multiple technologies to enable new missions previously considered impossible.**
The Current Paradigm

Currently, no existing LV to fly an 8 m segmented telescope
- Not even a 4 m monolith
- LVs in the works such as SLS, BFR, New Glenn

- 40 deployable structures
- 178 release mechanisms
Potential Cost and Risk Advantages

1. Potential opportunities for reduced cost
   - No need to design, model, ruggedize, and test complex folding and deployment operations
   - Eliminate mass constraints (which plagued JWST) and associated designs and models for light-weighting
   - Reduce need for ruggedizing the system and its interfaces to survive launch environment
   - Reduce need for new and unique ground test facilities
   - Reduce need for a large standing army during I&T
   - Leverages existing and less-costly medium-lift LVs
   - New instruments can be swapped out over longer periods of time before new additional observatories are needed

2. Potential opportunities for reduced risk
   - Modularize the design enabling repair/replacement of faulty sections
   - Minimize single-point failures
   - OSAM does not require next-generation launch vehicles
   - Launch failure need not be equivalent to mission failure
Why Now?

• Inform emerging missions in Exploration, Science (2020 Decadal Survey) and matters of national security

• Technology development time
  – The process of identifying, developing, and maturing the technologies will take time
  – A technology roadmap and early development efforts are needed, for example using ISS or RESTORE-L as a testbed

• Recent advancements over the last decade
  – Robotics, rendezvous and proximity operations, cheaper and more capable commercial launch systems

• Opportunity to coordinate early
  – Early involvement with industry at GEO and NASA Gateway in cis-lunar offers opportunities to influence studies before designs are “frozen in”
  – Coordination with DoD and OGA’s on cross cutting needs
OSAM Capabilities Enable Bold New Space Missions, Operations, and Infrastructure

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OSAM enables National unprecedented achievements in space
OSAM National Strategic Framework

OBJECTIVES

Facilitate Relationships
Build and maintain relationships with commercial, US Government, and other stakeholders to ensure an informed, integrated approach

Develop and Share Technology
Develop solutions to the most demanding technological challenges and seed the growth of US industry through tech development, sourcing, transfer, and collaboration

Advancing New Concepts and Capabilities
Design and execute innovative mission concepts that enable breakthroughs in human exploration and science and support broader national objectives

Serve as a Knowledge Center
Develop and maintain a repository of data and relationships to ensure broad and consistent awareness of industry and government activity and capabilities

OSAM MISSION

Serve as NASA’s and the nation’s steward for OSAM capability development and mission execution, and as a central hub for engaging the broader OSAM stakeholder community

Coordination leadership and stewardship across government, academia and industry is needed to advance the U.S. space presence and enable bold new missions
Missions Enabled and Strengthened by OSAM

Discoveries and Sustainable Exploration
Telescopes with large diameters must be assembled in space; human exploration of the Moon and Mars requires in-situ infrastructure and maintenance.

Resilient and Reusable Infrastructure
On-orbit refueling stations and maintenance of critical architectures strengthens America’s space presence, especially national security.

Boost US Industry Competitiveness
Commercial industry embracing OSAM capabilities will increase revenues and technology refresh rate and decrease cost and risk.

OSAM capabilities are critical for bold new space missions, operations, and infrastructure.
• NASA is leveraging our heritage to enable an exciting future and a robust, vibrant ecosystem in space, but...

None of this is done alone.

• As government entities we must continue to adapt and transform our traditional way of doing business, and our cultures - to be better partners and seek further collaborations with DoD/OGA’s, academia, and the emerging commercial sector.

• Hypersonics and OSAM are just two examples of where advancing capabilities in the collective is paramount to enabling bold new missions. Let’s do this together.
NASA Langley Research Center
New Funding Model for Aerosciences Ground Test Facilities

“...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...” Aerosciences Capability Leadership Team
Partnership Testing (with NASA) - qualify for covered operations testing if the following apply:

- Mutually beneficial interests only, and
- Sponsored by a NASA project or program, and
- Documented with a NASA Space Act or Interagency Agreement or NASA Research Announcements Cooperative Agreement, and
- One or more of the following apply 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 deliverables
Ground test facilities identified as critical to the NASA Aerosciences Capability and managed by AETC

- **ARC**
  - Unitary Plan Wind Tunnel (11x11’ Transonic and 9x7’ Supersonic Wind Tunnels)

- **GRC**
  - 9x15’ Low-Speed Wind Tunnel and 8x6’ Supersonic Wind Tunnel
  - 10x10’ Supersonic Wind Tunnel
  - Icing Research Tunnel
  - Propulsion Systems Lab

- **LaRC**
  - 14x22’ Subsonic Wind Tunnel
  - National Transonic Facility
  - Transonic Dynamics Tunnel
  - Aerothermodynamics Lab
  - 8’ High Temperature Tunnel
  - 20’ Vertical Spin Tunnel
  - *Unitary Plan Wind Tunnel (new)*

All are available under the New Funding Model.
Customer Testing for FY17-18

**External Testing**

**NASA/Partner Testing**

- Full Cost of Test
  - Fixed Costs
  - Variable Cost (Test Specific)
  - Partner Funds
    - Note: 1 - “Partner Funds” can be NASA Project funds as well as Partner Funds

- NASA Resource Allocation
  - NASA Funds

**Domestic Testing**

- Variable Cost (Test Specific)
  - 50% Fixed Costs
    - Note: 2 - 50% of Fixed Cost paid for by the “Customer Funds” will be shared with the Center generating the revenue for used on aeroscience ground test facilities (in or out of the current AETC Project portfolio).

**International Testing**

- Variable Cost (Test Specific)
  - 100% Fixed Cost

Note:

1 - “Partner Funds” can be NASA Project funds as well as Partner Funds

2 - 50% of Fixed Cost paid for by the “Customer Funds” will be shared with the Center generating the revenue for used on aeroscience ground test facilities (in or out of the current AETC Project portfolio).
**A RICH LEGACY OF OSAM MISSIONS**

**Servicing**
- Solar Max 1984
- HSM1 1993
- HSM2 1997
- HOST 1998
- HSA3A 1999
- HSM3B 2002
- HRSDM 2005
- Orb-Express 2007
- HSM4 2009
- RRM-1,2,3 2011-18
- ROTT 2014
- Raven 2017-19
- Restore-L RLD 2022

**Assembly**
- Apollo CSM-LM 1967-72
- EASE/ACCESS 1985
- ASEM 1992
- International Space Station 1998 – present
- IRMA (Archinaut, Dragonfly, CIRAS) 2015 – present

**Manufacture**
- 3D Printer Micro-G Experiment 1998-2012
- First 3D Printer in Space 2014
- ISS Made in Space Additive Manufacturing Facility 2016
- Refabricator Late 2018
- “FabLab” Facility 2020

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*NASA has a deep heritage in OSAM, both internally and in partnership with OGA’s and the commercial sector*
LaRC Space Technology and Exploration Directorate – Strategic Thrusts

Concepts and Enabling Technologies for...

- **Entry, Descent, and Landing Systems**
  - Technologies for human and robotic exploration (HIAD, SRP, Navigational Doppler LIDAR, Aerosciences, Landing systems)

- **Space Habitation Systems**
  - Includes deep space radiation shielding and mitigation, lightweight structures and materials, and systems analysis

- **Lightweight and Affordable Space Transportation Systems**
  - Includes lightweight structures and materials, advanced manufacturing, aerosciences and environments

- **In Space Assembly, Construction, and Operations**
  - On orbit autonomous assembly and aggregation of large space structures, modular designs, and interfaces

- **Exploration Architectures and Systems Analysis Assessments**
  - Used to develop concepts, guide technology investments, and influence agency solutions
Provides engineering datasets to help investigators truly understand the behavior of vehicles under extreme conditions. Capabilities include the following:

- High-resolution high-speed imaging
- Calibrated thermal imaging
- Hyperspectral imaging
- Ground-based, air-based, and sea-based imaging platforms

A proven track record of delivering flight-truth datasets covering over 25 missions including space shuttle reentry, COTS Demo Flights, CRS missions, SpaceX Drogue Iterative Testing and more.
Entry, Descent and Landing Systems (EDL)

- Addressing the controlled flight of a spacecraft through all appreciable atmospheres

- EDL Systems include entry, descent and safe landing of the spacecraft at its planetary destination, return through Earth’s atmosphere to a safe landing, launch aborts, entry to safe orbital insertion, and descent and landing at bodies without atmospheres.

- Five key areas of focus
  1. Increased Payload of Mass and Delivery Capabilities
  2. Precision Landing
  3. Hazard Detection, Avoidance and Tolerance
  4. Safety and Mission Assurance
  5. Affordability

POC: Jeffrey Herath

Focusing on Exploration of Moon, Mars and Worlds Beyond
Space Habitation Systems and Radiation Protection

• Investigating radiation protection to better understand crew health and safety in space.

• Building prototype designs for habitats and storm shelters for in-space use.

• Langley has expertise in the use of soft goods and inflatables for in-space habitation systems.

• Supports the Advanced Exploration Systems organization at NASA HQ in the requirements, design, testing and development of space habitation architectures.
• Langley’s SACD has over 30 years of systems analysis and architecting experience supporting human and robotic spaceflight programs for STMD, HEOMD, SMD and OCT, as well as projects across NASA centers.

• Enable customers to make better informed decisions by delivering exploration systems analysis products such as
  • mission architectures
  • systems concept designs
  • system and technology trades
  • campaign analyses
  • life-cycle cost and risk analyses
  • the development of tools supporting technical, programmatic, and budgetary analyses