NASA Langley Research Center Space Technology and Exploration Portfolio Overview

Presented to NASA Advisory Council (NAC), Technology, Innovation and Engineering Committee Meeting

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NASA Langley at a Glance 2017

Langley Research Center

Data as of 6/30/17

Langley's Economic Impact (FY 2016)

National economic output of ~$3b and generates over 15,900 high-tech jobs

Virginia economic output of ~$1.2b and generates over 7,300 high-tech jobs

Hampton Roads economic output of ~$1b and generates over 6,500 high-tech jobs

Within Virginia, executed $184m or 57% of obligations to small businesses

FY2017 Budget Estimate……………$922m

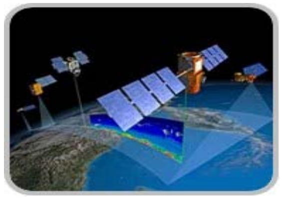
NASA Langley Budget……………$900m
External Business……………$22m

Workforce Estimate……………3,400
Civil Servants……………1,800
Contractors (on/near-site)……………1,600

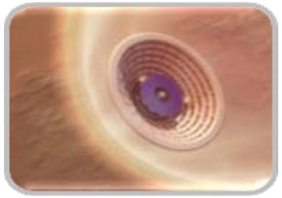
Infrastructure/Facilities
189 Buildings……………764 acres
Replacement Value……………$3.7b

AERONAUTICS
$238m

SCIENCE
$250m



SPACE TECH
$40m



HUMAN EXPLORATION
$54m

EDUCATION
$5m

SAFETY, SECURITY AND MISSION SERVICES

CENTER MANAGEMENT AND OPERATIONS
(Facilities, IT, Engineering, Tech Authority, B&P, IRAD, Safety/Mission Assurance, Legal, Finance, Procurement, Human Resources)

AGENCY MANAGEMENT AND OPERATIONS
(NASA Engineering & Safety Center, Office of the Chief Engineer, Agency IT)

CONSTRUCTION & ENVIRONMENTAL COMPLIANCE AND RESTORATION
(Revitalization Plan)

LaRC Exploration and Space Technology

- The NASA Langley Research Center (LaRC) roots date back to 1917 as the nation's first civilian aeronautics R&D laboratory (under the N.A.C.A., as the Langley Memorial Aeronautical Laboratory)

- We have since served as a critical national R&D center, supporting the NACA (1917-1958) and NASA (1958-present) missions in aeronautics, science and space.

- Our goal is to innovate, develop, and deliver mission enabling space technologies for science and exploration in this century, just as we did for the aviation industry in the last.

- Today, the Space Technology and Exploration Directorate (STED) is the LaRC interface for both the STMD and HEOMD, and for industry, academia and other government agencies with interests in LaRC space technologies, test facilities, and applications.

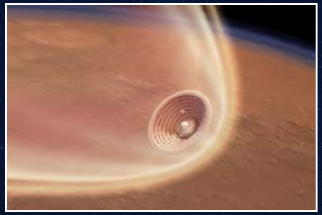
- LaRC Space Technology and Exploration Directorate oversees a LaRC direct budget of approximately **$90M/yr** in direct and reimbursable work for STMD, HEOMD

- LaRC also manages the operations (selection and awards) of approximately **$70M** worth of phase I and II SBIRs for HEOMD and STMD

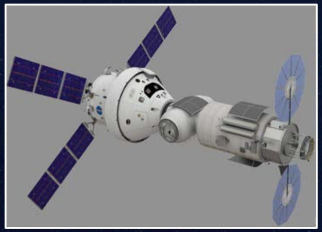
LaRC Space Technology and Exploration Strategic Thrusts

Concepts and Enabling Technologies for...

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



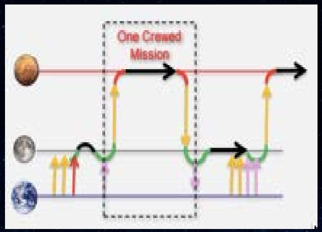
- **Space Habitation Systems**
  - Includes deep space radiation shielding and mitigation, lightweight structures and materials, and systems analysis



- **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



Recent LaRC Successes in Exploration and Space Technology

Space Shuttle Return to Flight

Ares I-X

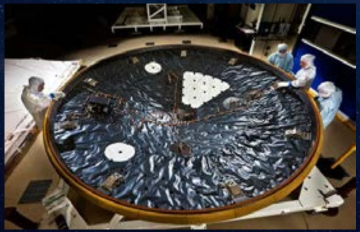
Flight Test Articles

Pad Abort 1

IRVE

Exploration Flight Test #1

Mars Science Laboratory

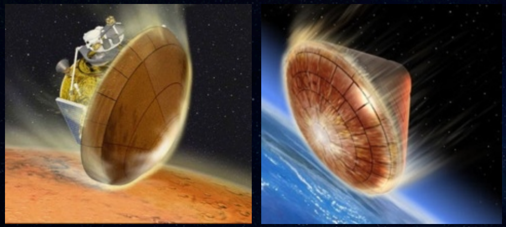


MEDLI/MSL

STORRM LIDAR

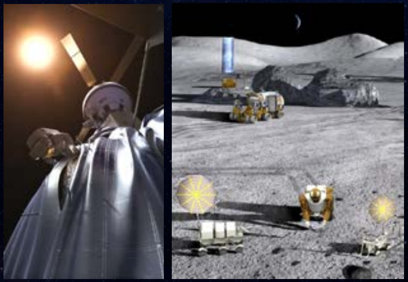
ALHAT/NDL

Composites for Exploration



Aerocapture and MMEEV Technology Development

Launch Abort System Development



Human Architecture Team Leadership

FY17 Space Technology and Exploration Portfolio

Space Technology

EDL Systems
- HIAD2
- Entry Systems Modeling
- PDT SpaceX Red Dragon
- EDL Architecture Study
- COBALT Flight Demo (NDL)
- ADEPT

Radiation Protection and Habitation
- Advanced Radiation Protection

Lightweight Structures and Materials for Space Systems
- GO-1 Composite Tank
- Deployable Composite Booms
- Composites Tech. for Exploration
- Advanced Near Net Shape Tech.
- MISSE-9 Flights
- LCUSP/BMG

In-Space Robotic Manufacturing & Assembly (IRMA)
- CIRAS
- Dragonfly

- Seedling Studies (SLWDT/SAWS/In-Space Assy. Sys. Study)

- STMD/OCT Strategic Analysis

SBIR/STTR/CIF/RED/STRG/Tech. Transfer

Human Exploration and Operations

Systems Analysis (Exploration and Mars Study Teams)

Orion MPCV

SLS

Advanced Exploration Systems
- NextSTEP Habitation
- Radiation Sensors
- Composite Boom RR
- NEA Scout

Human Research Program

Commercial and Reimbursable

Space Act Agreements
- Boeing
- Space-X
- Sierra-Nevada

SCAN/ISS Commercial Crew Support

Flight Projects

- LAS
- MEDLI-2
- ARRM CRS
- AA-2

The LaRC Value Proposition Applied to Space Technology Development

TRL/Technology Life Cycle

Center Partnerships for R&D

Center Partnerships for Missions

Academia/Small Businesses

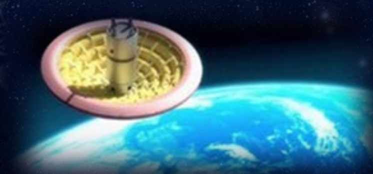
Commercial Partnerships

Concepts and Technologies *Lead*

- Innovative technology solutions and system concepts.
- System-level trade studies to refine the concepts and determine the benefits of technology investments.
- Concept design, analysis, laboratory investigations, ground testing.

Technology Demonstrations *Lead*

- Ground and Flight Demonstrations in Relevant Environments
- Secondary Payloads and Flights of Opportunity



Prototypes/First Copies Risk Reduction *Partner*

- Demonstration Units
- "First Copy" Subsystem Providers
- Pre-CDR Testing and Analysis

Complex System DDT&E Mission Management *Provide*

- Technical Insight/Oversight
- Smart Buyers
- Design, Analysis, Test Support

Human & Robotic Exploration/STED Roadmap

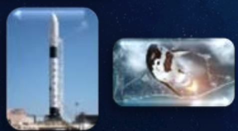
Stakeholder Driven Portfolio

Earth Reliant
Now to 2021

Proving Ground
2020's

Earth Independent
2030's+

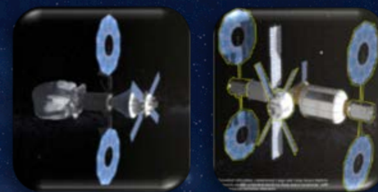
ISS Operation



Commercial Capability Development

SLS and MPCV Block 1

Missions to Earth-Moon Space

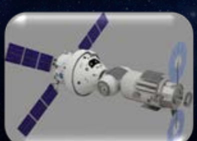


Deep Space Missions

- SLS Block 1B
- Short Duration Hab
- 1-Year Mission
- Multi-Year Mission
- Commercial Crew
- Commercial LEO
- Private-Sector Space Operations
- Mars 2020
- Mars Sample Return
- Mars Robotic Precursor (20+ mton)

Lightweight and Affordable Transportation Systems

Human-Rated Composites
Evolved Heat Shield
Prototype Lander/MAV
Extreme Environment Materials
Advanced Lightweight/High-Strength Materials

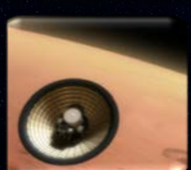


Habitation Systems

Prototype Habitat
Prototype SPE Storm Shelter
GCR Mitigation/Solutions
Surface Habitation
Lightweight Structures
Multi-Functional Materials
Large Solar Array Structures

In-Space Assembly, Construction, and Manufacturing

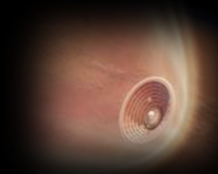
Ground-Based Demo
Flight Demonstration
Autonomous Assembly Capability
ISRU Adv Manufacturing



Human-Scale/Cross-Cutting EDL Systems

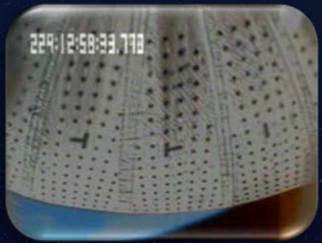
HIAD Tech Development
Flight Demonstrations: HIAD, SRP
Integrated EDL System Demonstrations
MMEEV Development
Planetary Entry Systems

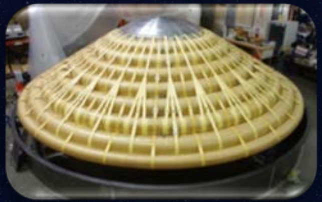
Hypersonic Inflatable Aerodynamic Decelerator Technology Development

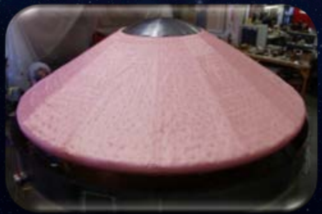


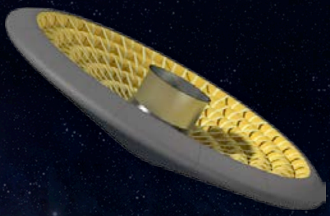
- **Systematic and stepwise technology advancement**
  - ✓ **Ground Test**: Project to Advance Inflatable Decelerators for Atmospheric Entry (PAI-DAE)—Soft goods technology breakthrough
  - ✓ **Flight Test**: Inflatable Reentry Vehicle Experiment (IRVE), 2007: LV anomaly—no experiment
  - ✓ **Flight Test**: IRVE-II, 2009—IRVE “build-to-print” re-flight; first successful HIAD flight
  - ✓ **Ground Test**: HIAD Project improving structural and thermal system performance (Gen-1 & Gen-2)—Extensive work on entire aeroshell assembly
  - ✓ **Flight Test**: IRVE-3, 2012—Improved (Gen-1) 3m IS & F-TPS, higher energy reentry; first controlled lift entry
  - ✓ **Ground Test**: HIAD-2 Project improving on Gen-2 F-TPS, evaluating advanced structures, packing, and manufacturability at scales >10m

- **Next Steps**
  - ⇨ **Ground Effort**: Continue developing *Gen-3 F-TPS, advanced structures, packing, manufacturability at scale >10m, controllability, and demonstrated staging to secondary decelerator.* **Prepares for large-scale flight test and readiness for Mars mission.**
  - ⇨ **Flight Test Possibilities**: *United Launch Alliance (ULA) flight test, and booster recovery at scales and environments relevant to Mars Human EDL precursor (~1/3 scale of human Mars mission)*.





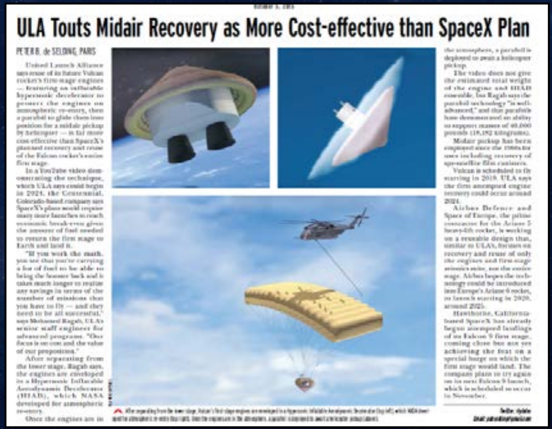




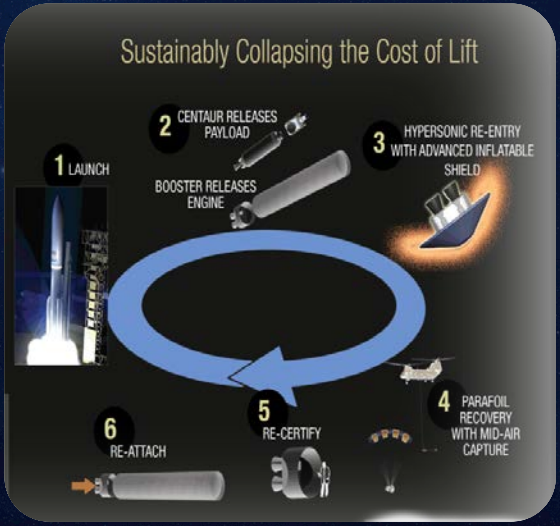
HIAD Engine Recovery Operation Technology Infusion with ULA Vulcan Launch Vehicle

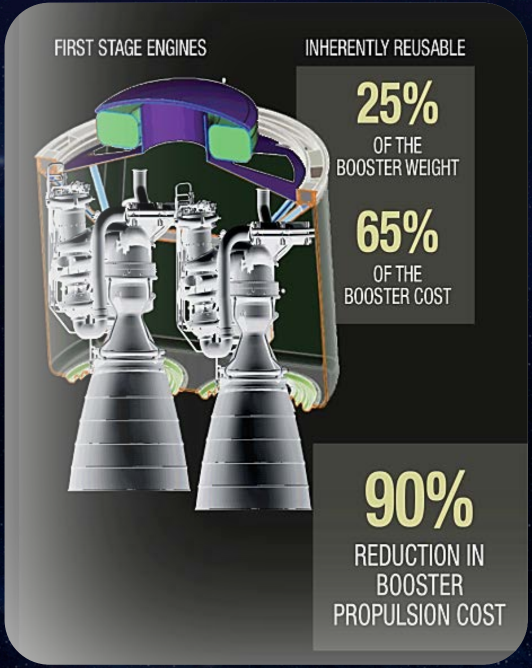
ULA initiated discussions with NASA HIAD team, on a potential flight opportunity and technology infusion path.

- Desire to utilize HIAD technology for SMART Reuse capability; intent to bring back the first stage engines.
- Went public with SMART Reuse option in March 2015, <u>and explicitly identified HIAD as key enabling technology</u>
- First stage engines recovery – would require 10-12m HIAD; next step in development and qualification path to Mars
- Several TIMs with ULA and Orbital-ATK to work HIAD technology commercial applications. Strong public-private partnership opportunities
- NASA intends to collect HIAD performance data from multiple engine recoveries, to improve HIAD design/model correlation


ULA Touts Midair Recovery as More Cost-effective than SpaceX Plan

PETER B. de SELDING, PARIS

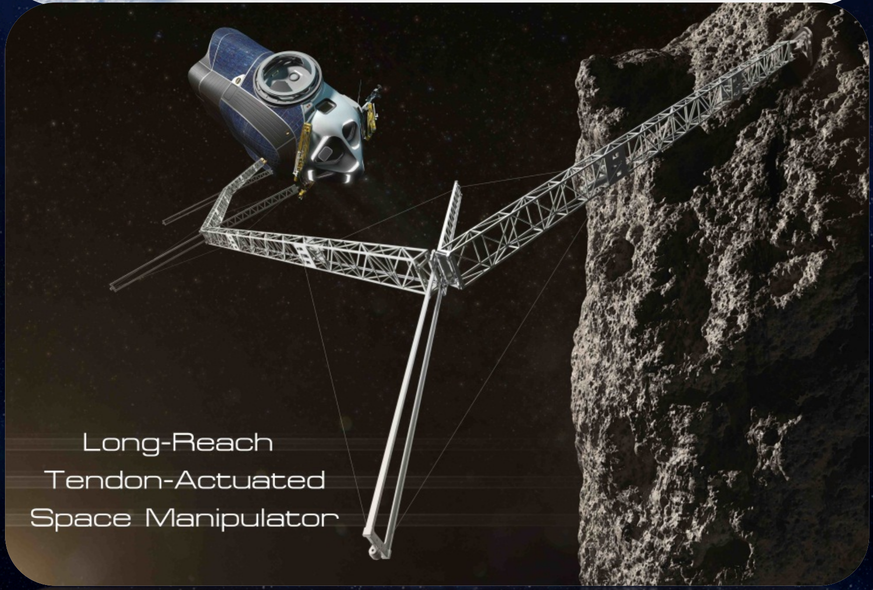




Recent Advances in Long Reach Space Manipulators for Spacecraft & Satellite Servicing

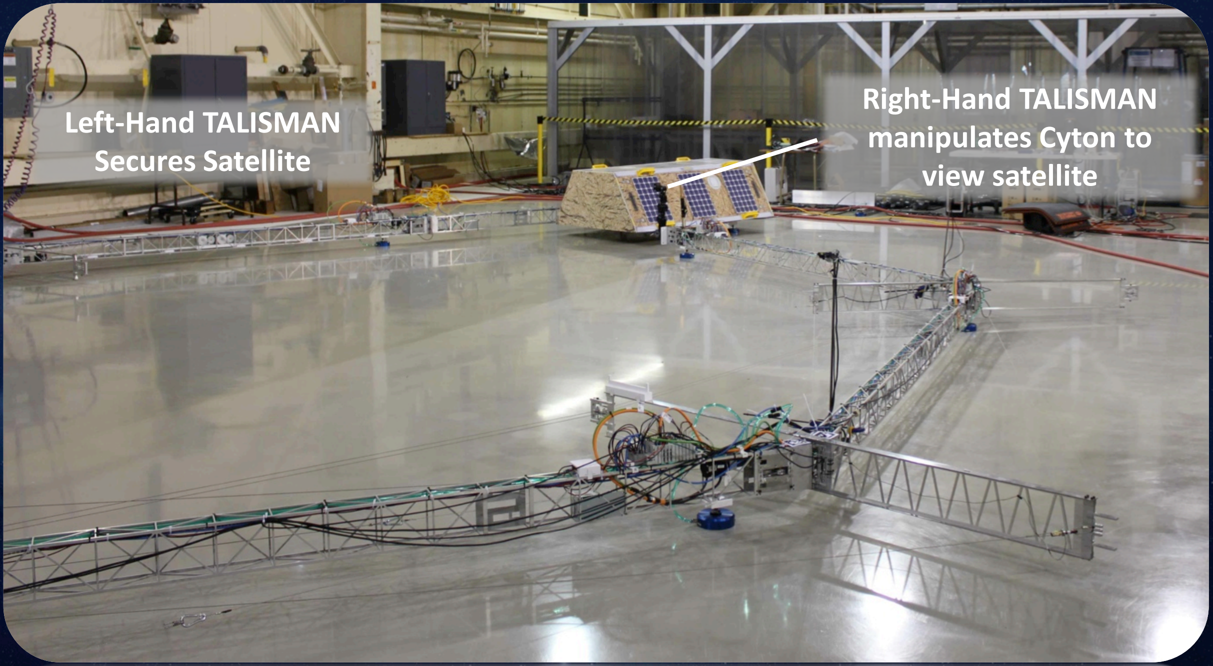
- **State of Art: Shuttle and Space Station Remote Manipulator Systems (SRMS & SSRMS)**
  - **Conventional Robotic Architecture**
  - **Massive joints (co-located joint and motor)**
  - **High compliance**

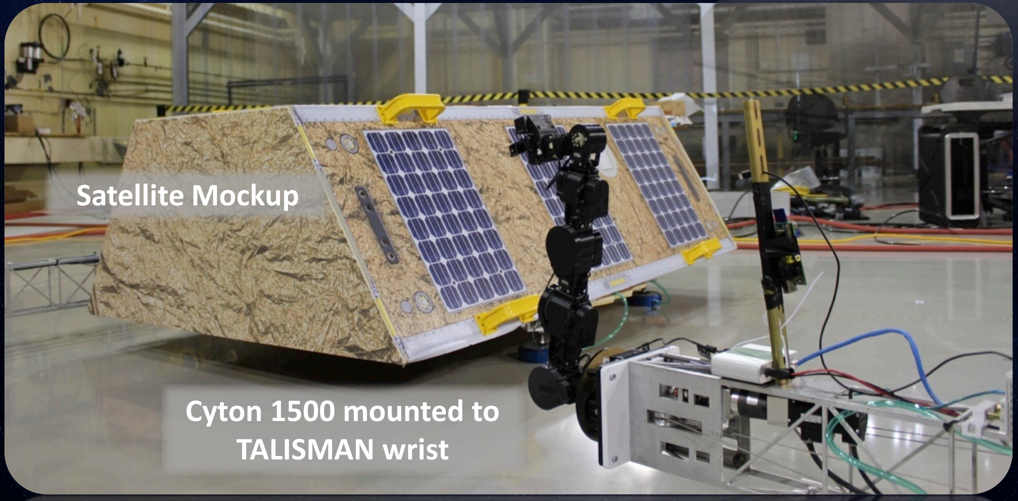
- **Goal - to improve the state-of-the-art (SOA) in space robotic manipulators by increasing:**
  - **Dexterity**
  - **Reach**
  - **Packaging Efficiency**
  - **Structural Efficiency**
  - **Extend to In-Space Assembly**

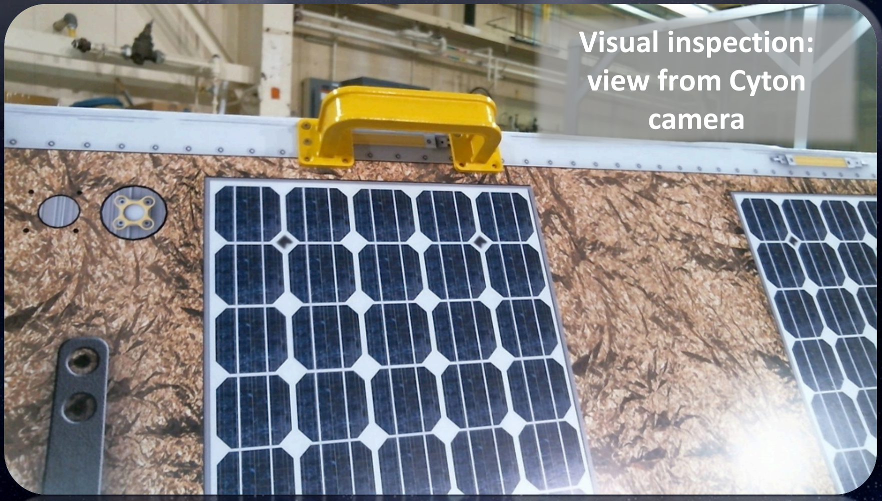


Satellite Servicing Demonstration Using Two Tendon Actuated Lightweight In-Space MANipulators (TALISMANs)

TALISMAN manipulates Cyton 1500 dexterous manipulator and demonstrates satellite inspection capability



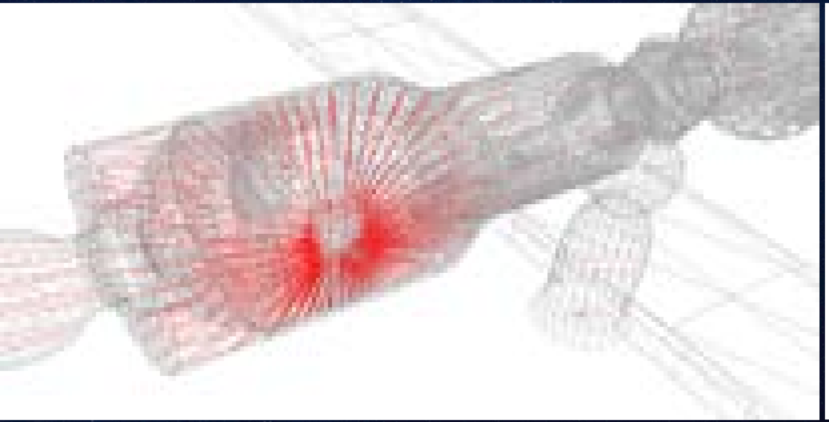


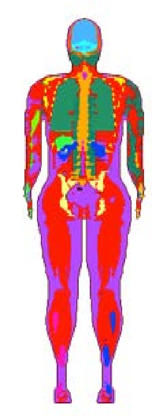


HRP Space Radiation (HEO) + Advanced Radiation Project (STMD)

Technical Accomplishments/Highlights: Physics and Transports

- ✓ April ‘16 Public release of the updated HZETRN code (High charge (Z) and Energy TRaNsport) radiation analysis tool developed to analyze the effects of harmful galactic cosmic rays (GCR) and solar particle events on mission planning and shielding for astronauts and instrumentation. (HEOMD/HRP)





- ✓ Leveraging data and results from the STMD/GCD Thick Shield test at NSRL/BNL (2015-16). HRP is leveraging detector equipment and set-up to fill gaps in light ion double differential cross section measurements data bases (critical to understanding of uncertainties in predicting mixed fields behind shielding in deep space and on the surface of Mars)

NASA Space Radiation Laboratory (NSRL) at Brookhaven National Labs (Long Island, NY)

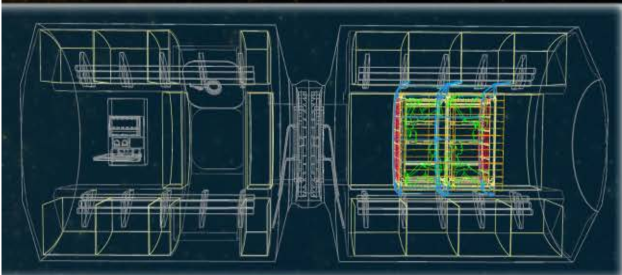
Validated calculations indicating Shield depth minimum will change design paradigm affecting cis-lunar habitats

AES RadWorks Storm Shelter Project

Characterizing Mass Efficient Radiation Protection Systems for Deep Space Exploration

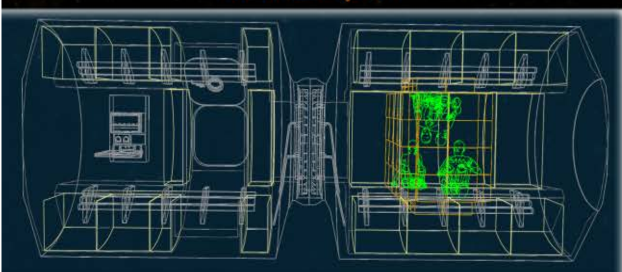
SPE Protection– Developed at LaRC

Crew Quarters-based Shelter Concept



Shielding existing crew quarters regions provides a familiar and comfortable working / resting location

Reconfigurable Logistics Concept

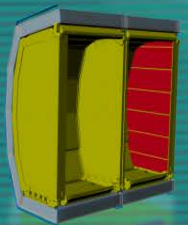


Structural panels may be designed as "Dual Use" components and repositioned to protect additional crewed regions from SPE radiation damage

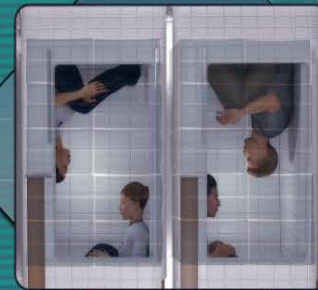
CTB Storage

Move cargo bags from storage to shelter location

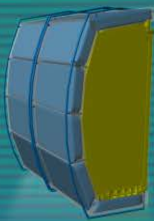
Protective Walls



Top off logistics protecting side walls



Water Wall

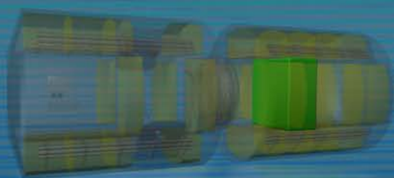


Fill integrated waterwall designed for microgravity

CTB Wall

Maneuver cargo bags to protect front opening

Shelter



Locate shelter in central aisle for group protection

Hang CTB

Hang unfolded cargo bags to serve as frame for attaching logistics

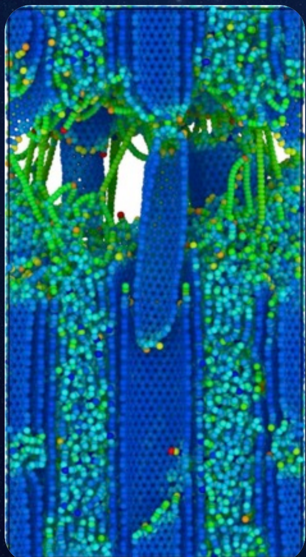
Subsystems

Leverage dense stationary subsystems to reduce parasitic mass

Relocate Logistics

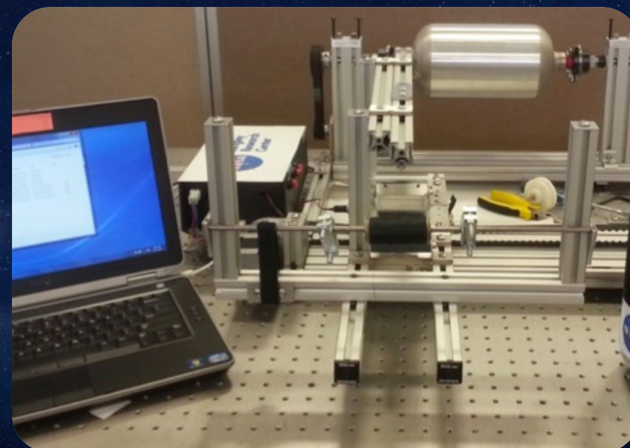
Relocate logistics to increase local protection

Developing Next-Gen Structural Materials



Computational model of CNT composite

CNT composite wound 1.5" ring



In-house developed CNT filament winder

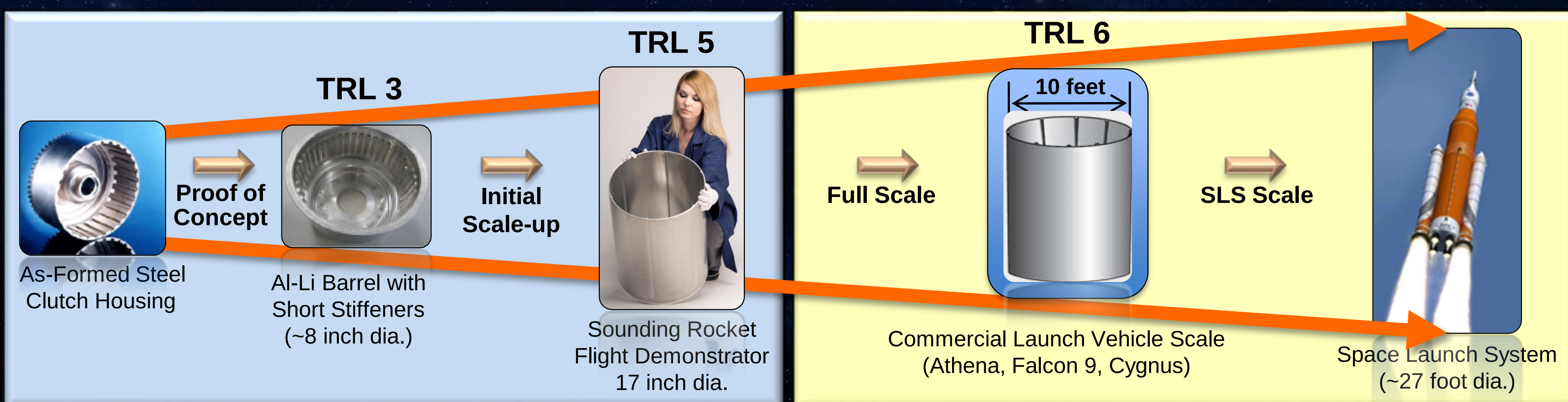
Demonstrate winding a 4" diameter pressure vessel

- Computational modeling of carbon nanotube (CNT) composites to determine axial and transverse tensile properties confirming validity of project goal.
- CNT composite wound ring with tensile properties exceeding equivalent carbon fiber composite wrapped ring.
- Scale-up of CNT filament winder to allow winding of CNT yarn composite around size of pressure vessel to be used in flight test.
- Demonstrate CNT Composite Overwrapped Pressure Vessel performance in ground tests and in sounding rocket flight tests

Metallic Shell Structures — Integrally Stiffened Cylinder (ISC) Process Development

Accomplishments and Technology Firsts:

- **Established the ISC process to successfully form single-piece Al-Li alloy 2195 cylinders with cryogenic tank scale stiffeners (up to 1.0 inch tall).**
- **Cost / benefit analysis shows that using ISC for fabrication of cryogenic tank barrels can reduce manufacturing cost by 50% and mass by ~10%.**
- **Developed strategy for scale-up and technology infusion.**
  - Successful process scale-up, fabrication and flight demonstration of Sounding Rocket primary structure (17 inch diameter).
  - Fabrication of 10 foot diameter ISC (summer 2017).
  - Identified potential vendor to establish ISC capability in the U.S.
  - Partnering with ESA, DLR, MT Aerospace, Leifeld Metal Spinning, Lockheed Martin.



Accomplished to Date　　Future Plans

LaRC Space Technology Summary

NASA LaRC, as one of the government's first R&D Laboratories, remains a vital contributor to the nation's aeronautics and space exploration enterprise.

Our "LaRC Value Proposition" to the Agency and the nation is to innovate, develop, and deliver mission enabling aeronautics and space technologies for science and exploration.

Our goal is to deliver concepts and enable technologies to impact and enable the broadest range of government and commercial space exploration in this century just as we did for the aviation industry in the last.

Langley's contributions to the STMD enterprise, in particular in the low to mid-TRL technology development and demonstration, and the infusion to government and industry missions is an essential part of our strategy and our value to the Agency.

Partnerships with other NASA centers, industry, academia and other Government agencies are critical elements to our current and future success.