National Aeronautics and Space Administration

Preparing NASA for the 21st Century: OCT perspective on EDL

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Office of the Chief Technologist

www.nasa.gov
www.nasa.gov/oct

Advanced Technology at NASA

- NASA pursues **breakthrough technologies** to expand our frontiers in aeronautics and space
- **Advanced technologies are critical** for accomplishing NASA's current missions, and today's **technology investments are required** for the bold missions of NASA's future
- NASA's basic and applied research programs **span all of NASA's mission areas**
- NASA is implementing a portfolio of broadly applicable Space Technology programs to take the **best ideas** of our world's innovators **from concept to flight**

Office Of the Chief Technologist
Roles and Responsibilities

NASA Chief Technologist:

- Serves the Administrator as the principal NASA advisor on matters concerning Agency-wide technology policy and programs.
- Advocates externally for NASA's research and technology programs.

Delegated to NASA Deputy Chief Technologist:

- Integrates, coordinates and tracks the technology investments across the Agency working to infuse technologies into future NASA missions and facilitating Agency technology governance (e.g., risk acceptance, reporting)
- Documents, demonstrates, and communicates the societal impact of NASA technology investments.
- Leads technology transfer and technology commercialization activities across the Agency, facilitating internal creativity and innovation efforts.

Delegated to Space Technology Program Director:

- Directs management and budget authority of the Space Technology Programs.

FY11 Highlights

- Space Technology included in NASA Authorization Act of 2010
- Space Technology approved by Agency PMC for implementation
- NASA has an approved Operating Plan for FY 2011 that funds Space Technology at approximately the authorization level at $350M. Exploration Technology is funded at $185M
- FY 2011 guided technology efforts, some of which were initiated in FY 2010, are proceeding across the NASA Centers
- FY 2011 Space Technology competitive awards announcements made for:
  - Space Technology Research Fellowships (80)
  - Flight Opportunities (Multiple Parabolic, Suborbital)
  - NASA Innovative Advanced Concepts (30 Phase 1)
  - Game Changing Developments (first three in series)
  - Technology Demonstration Missions (three totaling $175M)

- Development of FY 2012 solicitations is underway

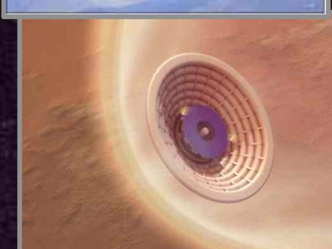
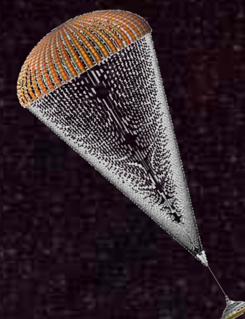
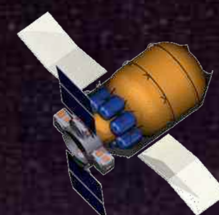
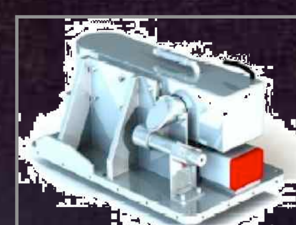
Space Technology Programs Approach

- Strategic Guidance
  - Agency Strategic Plan
  - Grand challenges
  - Technology roadmaps
- Full spectrum of technology programs that provide an infusion path to advance innovative ideas from concept to flight
- Competitive peer-review and selection
  - Competition of ideas building an open community of innovators for the Nation
- Projectized approach to technology development
  - Defined start and end dates
  - Project Managers with full authority and responsibility
  - Project focus in selected set of strategically defined capability areas
- Overarching goal is to re-position NASA on the cutting-edge
  - Technical rigor
  - Pushing the boundaries
  - Take informed risk; when we fail, fail fast and learn in the process
  - Seek disruptive innovation
  - Foster an emerging commercial space industry

The Big Nine

- NASA Space Technology Program consists of hundreds of small projects distributed across the USA
- These projects include the following nine ongoing, high-priority, high-visibility, broadly-applicable activities, each of which has major testing milestones in FY 2012 and FY 2013
- The Big Nine:
    - Laser Communications Relay Demonstration (GSFC)
    - Low Density Supersonic Decelerators (JPL)
    - Cryogenic Propellant Storage and Transfer (GRC)
    - Deep Space Atomic Clock (JPL)
    - Hypersonic Inflatable Aerodynamic Decelerator (LaRC)
    - Composite Cryotanks (MSFC)
    - Robotic Satellite Servicing (GSFC)
    - Solar Sail (L'Garde Inc.)
    - Human-Robotic Systems (JSC)




Exploration-Oriented Project Elements

Game Changing Development Projects

- In-Space Propulsion
- Space Power Generation and Storage
- Nuclear Systems
- Lightweight Materials and Structures
- Composite Cryogenic Propellant Tank
- Human-Robotic Systems
- Next Generation Life Support
- Advanced Radiation Protection
- Autonomous Systems
- Hypersonic Inflatable Aerodynamic Decelerator
- Deployable Aeroshell Concepts and Flexible TPS
- In-Situ Resource Utilization

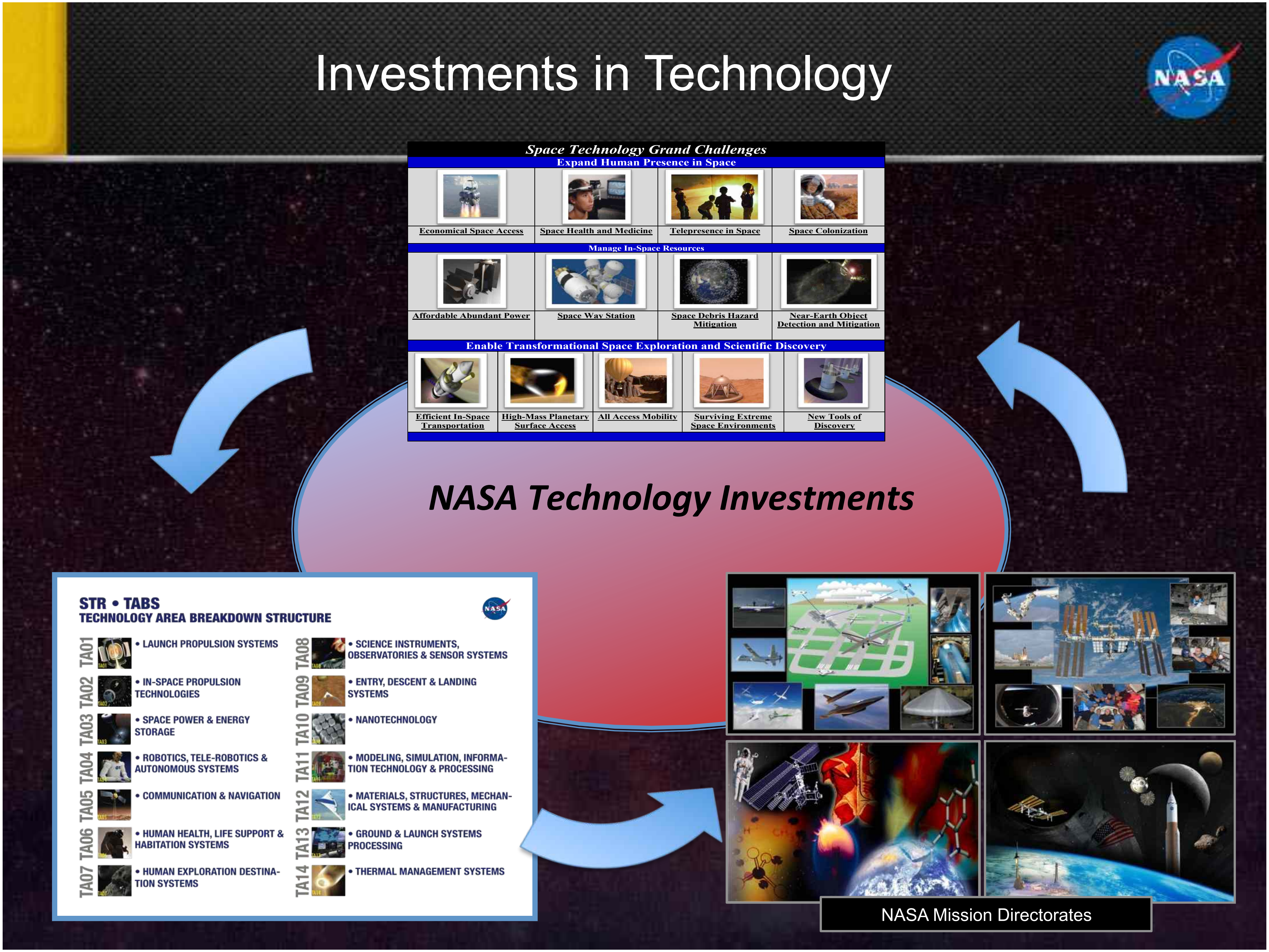
Technology Demonstration Missions

- Cryogenic Propellant Storage & Transfer
- Solar Electric Propulsion
- Human Exploration Tele-robotics
- Autonomous Precision Landing (ALHAT)
- MSL Entry Descent and Landing Instrumentation (MEDLI)

NASA Space Technology Roadmaps

NASA SPACE TECHNOLOGY ROADMAP
TECHNICAL AREA BREAKDOWN STRUCTURE

More information at http://www.nasa.gov/offices/oct/home/roadmaps/index.html


Investments in Technology
Space Technology Grand Challenges
Expand Human Presence in Space
Economical Space Access
Space Health and Medicine
Telepresence in Space
Space Colonization
Manage In-Space Resources
Affordable Abundant Power
Space Way Station
Space Debris Hazard Mitigation
Near-Earth Object Detection and Mitigation
Enable Transformational Space Exploration and Scientific Discovery
Efficient In-Space Transportation
High-Mass Planetary Surface Access
All Access Mobility
Surviving Extreme Space Environments
New Tools of Discovery
NASA Technology Investments
STR • TABS
TECHNOLOGY AREA BREAKDOWN STRUCTURE
TA01 • LAUNCH PROPULSION SYSTEMS
TA02 • IN-SPACE PROPULSION TECHNOLOGIES
TA03 • SPACE POWER & ENERGY STORAGE
TA04 • ROBOTICS, TELE-ROBOTICS & AUTONOMOUS SYSTEMS
TA05 • COMMUNICATION & NAVIGATION
TA06 • HUMAN HEALTH, LIFE SUPPORT & HABITATION SYSTEMS
TA07 • HUMAN EXPLORATION DESTINATION SYSTEMS
TA08 • SCIENCE INSTRUMENTS, OBSERVATORIES & SENSOR SYSTEMS
TA09 • ENTRY, DESCENT & LANDING SYSTEMS
TA10 • NANOTECHNOLOGY
TA11 • MODELING, SIMULATION, INFORMATION TECHNOLOGY & PROCESSING
TA12 • MATERIALS, STRUCTURES, MECHANICAL SYSTEMS & MANUFACTURING
TA13 • GROUND & LAUNCH SYSTEMS PROCESSING
TA14 • THERMAL MANAGEMENT SYSTEMS
NASA Mission Directorates

NRC Report on EDL

		Top Technology Challenges					
Priority	TA 09 Technologies, listed by priority	1. Mass to Surface: Develop the ability to deliver more payload to the destination.	2. Surface Access: Increase the ability to land at a variety of planetary locales and at a variety of times.	3. Precision Landing: Increase the ability to land space vehicles more precisely.	4. Surface Hazard Detection and Avoidance: Increase the robustness of landing systems to surface hazards.	5. Safety and Mission Assurance: Increase the safety, robustness, and reliability of EDL.	6. Affordability: Improve the affordability of EDL systems.
H	9.4.7. GN&C Sensors and Systems (EDL)	○	●	●	●	●	○
H	9.1.1. Rigid Thermal Protection Systems	●	●	○		○	●
H	9.1.2. Flexible Thermal Protection Systems	●	●	○		○	●
H	9.1.4. Deployable Hypersonic Decelerators	●	●	○			○
H	9.4.5. EDL Modeling and Simulation	○	○	●	○	●	●
H	9.4.6. (EDL) Instrumentation and Health Monitoring	○	○	○		●	○
H	9.4.4. Atmosphere and Surface Characterization	○	●	●	●	○	○
H	9.4.3. (EDL) System Integration and Analyses	○	○	○	○	●	●
M	9.2.2. Trailing Deployable Decelerators	●	●	○	○		○
M	9.2.1. Attached Deployable Decelerators	●	●	○			○
M	9.1.3. Rigid Hypersonic Decelerators	○	○	○			○
M	9.3.1. Touchdown Systems	○			○	○	○
M	9.3.5. (EDL) Small Body Systems				○		
M	9.3.3. (EDL) Propulsion Systems				○	○	
L	9.4.2. (EDL) Separation Systems						
L	9.2.3. Supersonic Retropropulsion	○					
L	9.3.2. Egress and Deployment Systems						

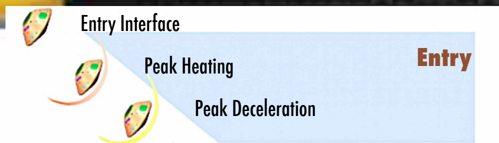
Legend

H	High Priority Technology
M	Medium Priority Technology
L	Low Priority Technology

●	Strong Linkage: Investments by NASA in this technology would likely have a major impact in addressing this challenge.
○	Moderate Linkage: Investments by NASA in this technology would likely have a moderate impact in addressing this challenge.
[blank]	Weak/No Linkage: Investments by NASA in this technology would likely have little or no impact in addressing the challenge.

FIGURE L.3 Level of Support that the Technologies Provide to the Top Technical Challenges for TA09 Entry, Descent, and Landing.

Hypersonic Inflatable Aerodynamic Decelerator (HIAD)

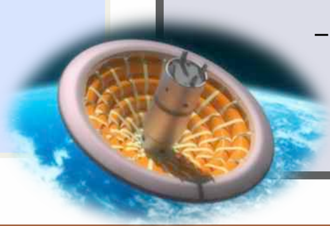


STATUS QUO

- Rigid blunt substructure with TPS overlay; aeroshells that are constrained by the launch vehicle shroud size.
- With the retirement of shuttle there is no demonstrated ISS downmass capability in the US
- Expendable launch vehicles with no assets recovered
- Mars missions limited to ~1000 kg landed payload to landing sites below 0 MOLA

NEW INSIGHTS

- Currently at limit for Mars payload mass capability. Affordable access to space needed.
- Able to exploit materials development over last 40 years.
- The IRVE-II flight demonstrated feasibility of deploying inflatable system.



PROBLEM / NEED BEING ADDRESSED

- A larger aeroshell provides increased delivered payload mass on other planets and enables affordable access to space (TA09). One possible way to achieve this is with a HIAD.

PROGRAM DESCRIPTION:

Develop and qualify materials, control mechanisms, and structural design concepts guided by potential mission architectures. Demonstrate performance through ground-based and flight testing at Earth.

Critical technologies to be matured

- High-temperature flexible TPS materials
- Inflatable structures designed for re-entry loads
- Demonstrate performance of relevant scale HIADs
- System robust to stowing, packing, and deployment
- Investigating benefits and method of controllability

Program approach

- Fabricate relevant-scale hardware
- Aerodynamic and structural testing to anchor design and models
- Develop flexible TPS via coupon tests/feature tests in flight-like environment
- Demonstrate flight performance at subscale in relevant heating environments through sub-orbital test

QUANTITATIVE IMPACT

- HIAD will enable 5X the landed payload mass to current Mars landing sites.
- Will provide the ability to land at higher altitude destinations (Southern Highlands of Mars).
- Provides an alternative to ISS downmass.
- Enables significantly higher payload mass fractions.

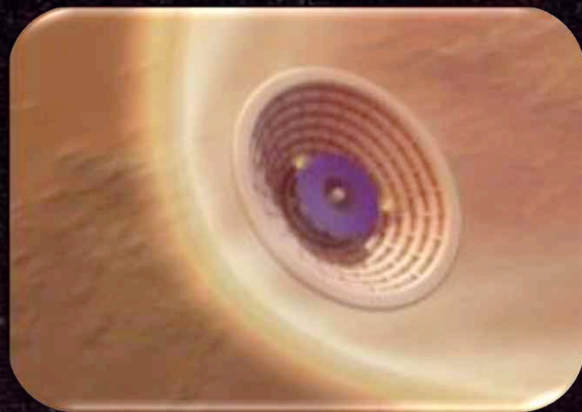
PROGRAM GOAL

- Quantify performance of 1st generation TPS to 30 W/cm^2
- Demonstrate 10-m scale inflatable
- Develop 2nd generation TPS capable of 50 W/cm^2
- Enabler for science missions involving atmospheric entry (Mars, Venus, Titan, Neptune and other gas giants, re-entry from NEO, LEO, etc.)
- Pathfinder for manned missions to Mars

Dramatically increase size of payloads entering planets with atmospheres

GCD: Hypersonic Inflatable Aerodynamic Decelerators (HIAD)

Goals



ADEPT Element

STATUS QUO

Robotic and human missions are limited by decades-old rigid, high ballistic coefficient aeroshells

- Geometry and packaging constraints within launch shroud
- Very high TPS certification and development costs and timeline
- Probe missions to Venus and outer planets experience 100s g's deceleration loads
- Large payload Mars missions require innovative entry system architectures

NEW INSIGHTS

- Low ballistic coefficient aeroshell technology can reduce heat and g-loading during entry
- An innovative, semi-rigid, mechanically deployable system achieves lower areal mass:
  - Alternative approach to inflatable entry systems
  - Advances in 3-D carbon-cloth weaving provides a TPS that doubles as aerosurface
  - Innovative mechanical design and TPS integration

PROBLEM / NEED BEING ADDRESSED

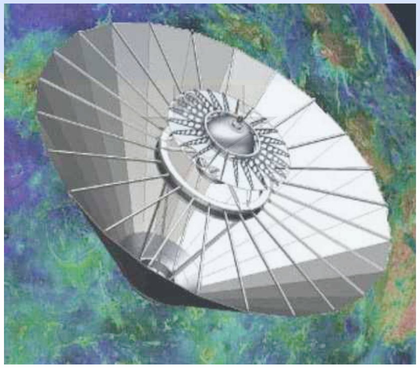
NASA needs to develop mechanically deployable aeroshell entry systems (TA09 Sect 1.1.4) to enable revolutionary capability for Science and Exploration missions beyond Earth

PROGRAM DESCRIPTION:

- ADEPT develops a low ballistic coefficient aeroshell system that consists of a 3-D woven carbon cloth skin stretched over a mechanically deployable ribbed structure (similar to an umbrella)
- Structural analysis to predict loads and that design is predictable via skin/ribs/struts and behaves more like rigid aeroshell system
- ADEPT entry conditions are well within the current arc jet capabilities – testable and certifiable
- Use of carbon cloth permits low ballistic coefficient for various potential mission scenarios
- Characterization of 3D woven carbon fabric for thermal & structural behavior
  - Carbon fabric testing under relevant heating conditions while under sustained bi-directional tension loads
- Development of designs and scaling relationships
- Design, integrate and test a 2m diameter class ground test article with flight-like carbon fabric design and structure attachment
  - Demonstrate carbon cloth manufacturability
  - Demonstrate reliable deployment under load
- 2-year development effort (FY12-13)

QUANTITATIVE IMPACT

- ADEPT enables missions not feasible and can offer a lower risk/cost alternate
  - Enables 10x reduction in peak entry heating and deceleration loads
  - Dramatic 'opening' of missions to Venus, Saturn, Mars. Missions now possible with dramatic science return



PROGRAM GOAL

- Design, test, and demonstrate sub-scale test article to TRL 4/5
- Manufacture of carbon fabric with flight like design features
- Flight test demonstration feasibility

Breakthrough capability to deliver entry system payloads to the most challenging mission destinations

Conformal Ablative *Element*

STATUS QUO

- Limited number of certified TPS
- PICA tile on a rigid heatshields is limited by small size billet manufacturing and low strain-to-failure resulting in high tile count and gaps with filler design
- Honeycombed concepts (AVCOAT) require extensive touch-labor, large curing ovens, and complicated NDE

NEW INSIGHTS

- Impregnate felt-based substrates with various polymers resulting in materials with high strain-to-failure that conform to conventional rigid aeroshells
- Concepts taken to TRL 2-3 under ARMD FAP Hypersonics (FY11) and ESMD EDL TDP showed survivability to stagnation heat fluxes approaching 500 W/cm^2

PROBLEM / NEED BEING ADDRESSED

NASA requires TPS ablator advances (TA14.3.1) to significantly lower the areal mass of TPS concepts, demonstrate extreme environment capability, demonstrate high reliability, demonstrate improved manufacturing consistency and lower cost.

PROGRAM DESCRIPTION:

- TPS Materials Development to TRL 5
  - Leverage NASA Ames TPS expertise, ETDD, and Fundamental Aero- Hypersonics investments
- Perform evaluation of felt substrates, impregnants, material processing and thermal/ablative property optimization
- Small scale tests to show aerothermal survivability at flight-like heat flux, pressure *and* shear including ground test instrumentation
- Measure thermal and structural properties
- Development of mid-fidelity thermal response models for design of mission TPS
- Partner with industry to manufacture materials (both felts and composites) at flight-like scale
- Deliver Conformal 1-m size Manufacturing Demonstration Unit (MDU)
- **2-year development effort (FY12-13)**

QUANTITATIVE IMPACT

- **Low cost, robust TPS solutions for mission applications:**
  - **Mars 2018 class TPS**
  - **COTS (e.g., Dragon)**
  - **ADEPT ViTAL rigid nosetip**

PROGRAM GOAL

Leading conformal candidates

Carbon felt w/ phenolic matrix (PICA Flex)

Other options: Polymer or carbon felts w/ silicone impregnant
Polymer blended felts
Carbon felt w/ phenolic

- **Deliver TRL 5 TPS material solution ready for mission implementation**
  - **Scale up demonstration**
  - **Tech transfer with industry partnership**

Delivery of moderate heat-flux ablative conformal TPS solution to enable innovative concepts for future missions

Woven TPS

STATUS QUO

High entry heating missions (Q > 1500 W/cm^2) including Venus, Outer Planet and NEO return, have only one viable, TPS option: fully dense carbon phenolic (CP)

The CP technology borrowed from the DoD has key challenges:

- No certified carbon fiber exists now
- Chop molded CP (NASA-unique) has not been made for 30 years, requires re-development
- The 2D nature of the tape wrapped CP has critical failure modes (delamination, ply lift) CP is not viable for human missions due to mass

PROBLEM / NEED BEING ADDRESSED

- Current inventory of viable TPS material options limited to only fully dense Carbon Phenolic (CP) for high heat flux (1500 to 10000) W/cm^2 planetary entry and NEO return missions.

QUANTITATIVE IMPACT

- A sustainable approach which relies on US industrial base and utilizes commercial materials and processes
- Fills mid-density TPS gap
- Provides better performing alternative to fully dense Carbon Phenolic (a vanishing capability)

NEW INSIGHTS

- Woven TPS provides a low cost, game-changing approach
- US weaving Industry has focused is stable and has high end products
- We can now tailor a material's properties by the accurate placement of fibers of different composition within the material.
- Woven TPS uses commercially available advanced weaving technology, including equipment, fibers, modeling and design tools to optimize the weave for given missions and predict material properties

PROGRAM DESCRIPTION:

Advance Woven TPS development TRL from 2 to 3.

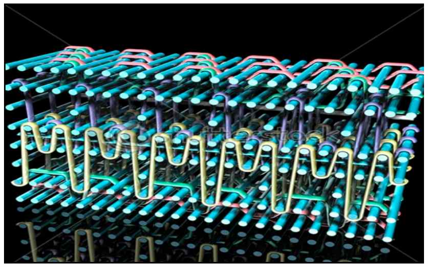
- Manufacture and arc jet test a variety of WTPS materials with different yarn compositions, weave constructions, levels of resin infiltration

Obtain preliminary property database

The anticipated project start date is 1/01/2012 and projected to end on2/28/2013

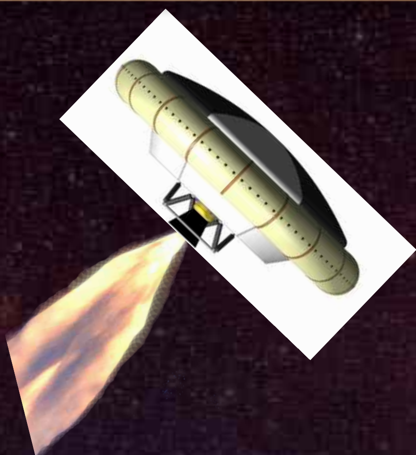
PROGRAM GOAL

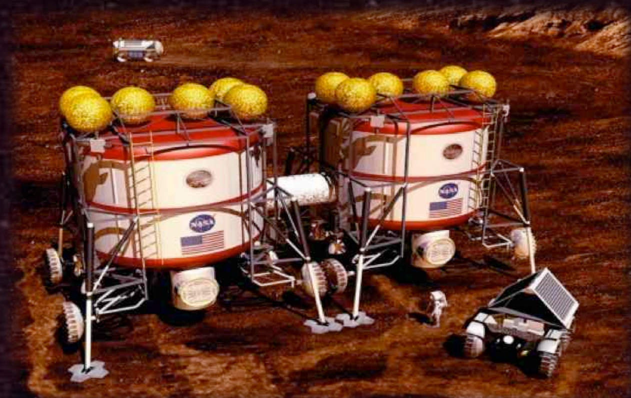
- Advance TRL of woven TPS from 2 to 3
- Compare performance of the high density WTPS with heritage CP

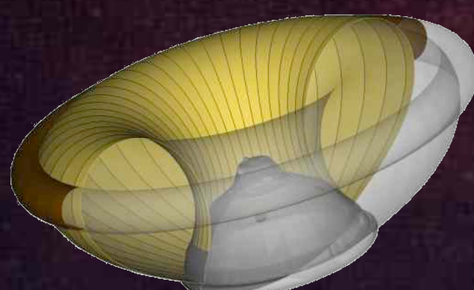


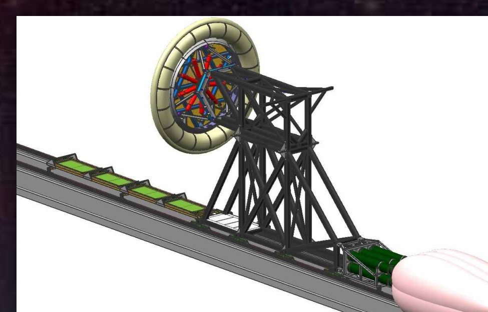
Develop and Prove TPS to fill the mid-density TPS gap and serve as a superior performing replacement to carbon phenolic

TDM: Low Density Supersonic Decelerator (LDSD)









Advanced Technology: Investments in Our Future

- **Enabling Our Future in Space:** By investing in high payoff technology that industry cannot tackle, *Space Technology* matures capabilities for NASA's future missions in science and exploration, while contributing to the needs of government agencies and commercial space activities.
- **Building U.S. Economic Competitiveness:** With a portfolio of innovative, high-risk, high-return research which creates products, services, businesses and jobs, NASA will stimulate the economy and build our Nation's global competitiveness.
- **Technological Leadership is Key to Winning the Future:** *Space Technology* is the central NASA contribution to a revitalized set of federal investments in research, technology and innovation across the Nation.
- **NASA Makes a Difference in Our Lives Everyday:** Past NASA technology investments have changed many aspects of our daily lives. By investing in advanced technology, NASA will continue to make a difference in the world around us.





NASA
Building Blocks