National Aeronautics and Space Administration

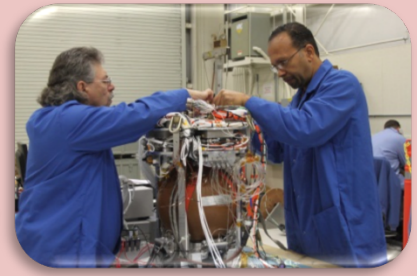
NASA Space Technology Program and Support of EDL Technologies

James Reuther
Space Technology Program
June 18, 2012

Office of the Chief Technologist

Integrates Technology Investment Across the Agency

Serves as Advisor to Administration



Direct Technology Management and Budget Authority for the Space Technology Program

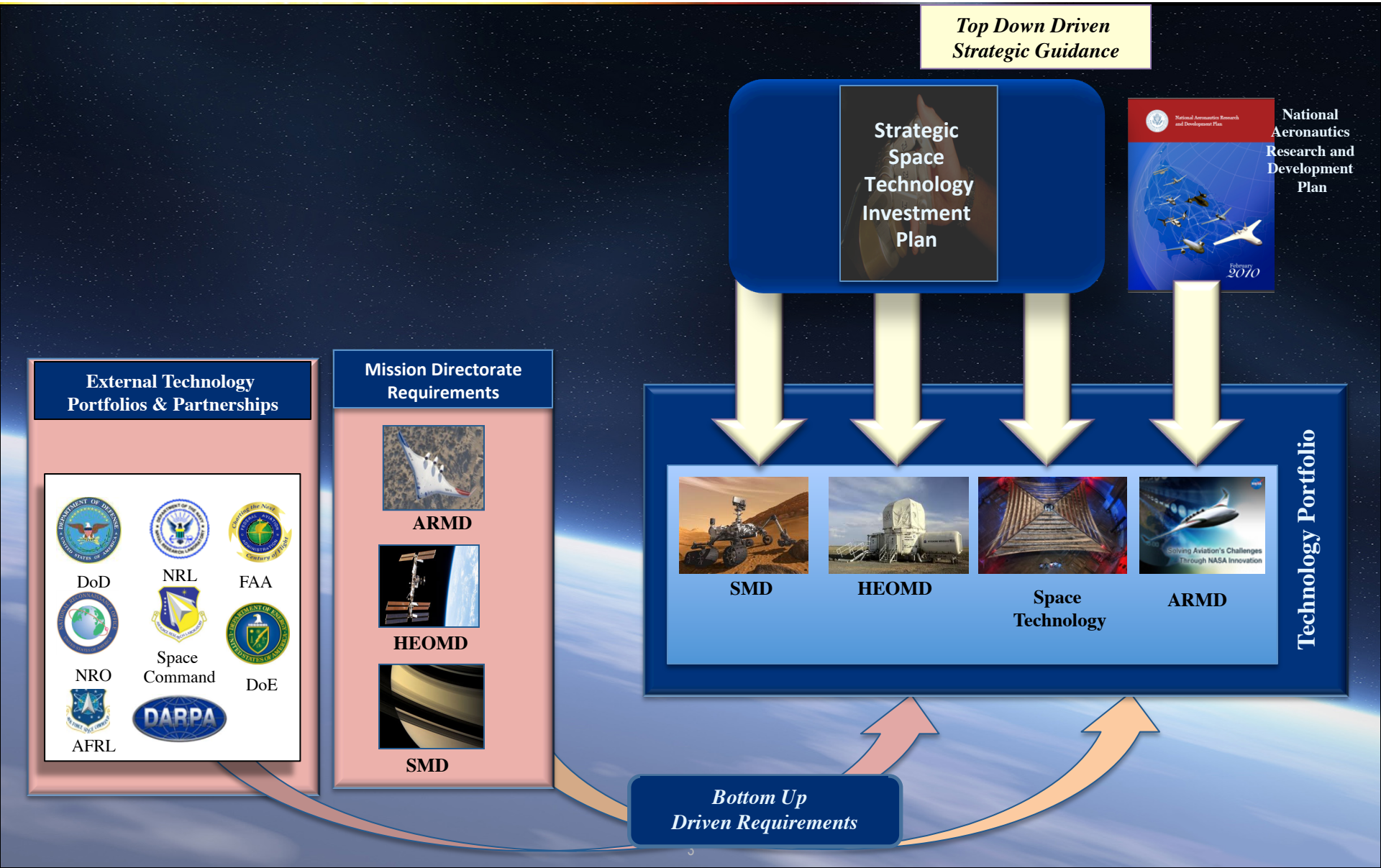
Office of the Chief Technologist

Leads Tech Transfer, Partnerships and Commercialization Activities Across the Agency

Advocates Externally NASA's R&D Programs

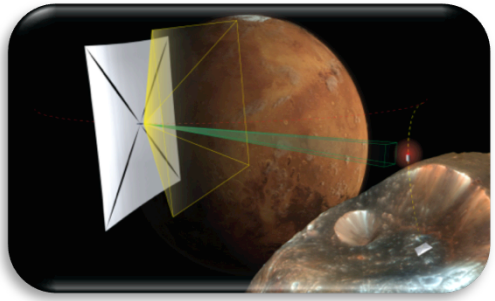
Demonstrates and Communicates Societal Impacts of NASA Technology Investments

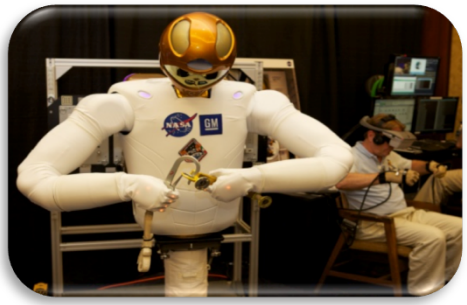
NASA's Space Technology Portfolio



Guiding Principles of the Space Technology Program

- **Adheres to a Stakeholder Based Investment Strategy:** The Strategic Plan, Space Technology Roadmaps / NRC Report and Strategic Space Technology Investment Plan
- **Invests in a Comprehensive Portfolio:** Covers low to high TRL, student fellowships, grants, prize competitions, prototype developments, and technology demonstrations
- **Advances Transformative and Crosscutting Technologies:** Focuses on enabling or broadly applicable technologies with a potential for direct infusion into future missions
- **Selects Using Merit Based Competition:** Research, innovation and technology maturation open to academia, industry, NASA centers and other government agencies
- **Executes with Structured Projects:** Clear start and end dates, defined budgets and schedules, established milestones, and coupled project authority and accountability.
- **Infuses Rapidly or Fails Fast:** Rapid cadence of technology maturation and infusion, informed risk tolerance to either infuse fast or fail fast
- **Positions NASA at the cutting edge of technology:** Results in new inventions, enables new capabilities, promotes new approaches and creates a pipeline of innovators (people) and innovation (ideas) for National needs



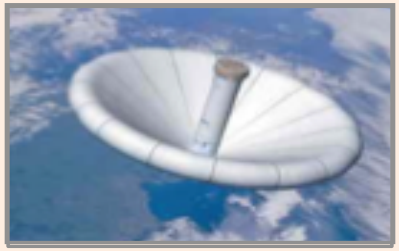


Space Technology Status

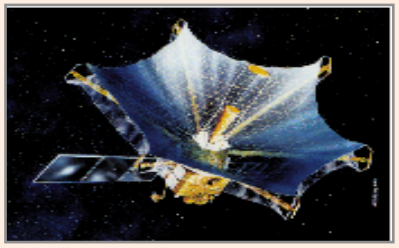
- **Space Technology included in NASA Authorization Act of 2010**
- **FY 2011 Operating Plan funded STP at approximately $350M**
- **FY 2012 Space Technology Program funded at $575M**
- **The Space Technology Program formulated a "Portfolio" with 10 programs:**
  - Combination of new programs and existing programs
  - Combination of directed and new, competitively selected content
  - 400 NASA employees in FY 2011; 900 NASA employees in FY 2012
- **Portfolio Commitment Agreement signed August 2011**
- **Released 9 Space Technology Solicitations from Dec 2011- May 2012 including:**
  - **Space Technology Research Grants:** Fellowships, Early Career Faculty and Early Stage Innovation
  - **Game Changing Technology:** Suborbital Payloads and Solar Array Systems
  - **Technology Demonstration Missions:** Green Propellants
  - **Edison Small Satellites:** Phase I and Phase II
  - **NASA Innovative Advanced Concepts**
- **Executing over 1000 projects**

Space Technology Programs

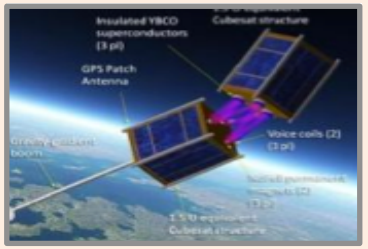
Transformative & Crosscutting Technology Breakthroughs



Game Changing Development Program



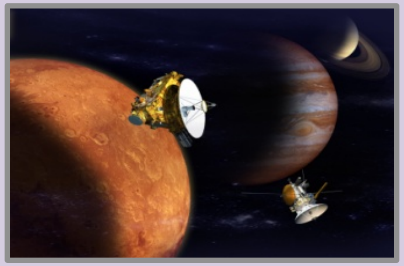
Technology Demonstration Missions Program



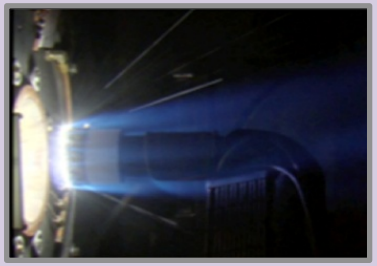
Small Spacecraft Technologies Program

Revolutionary Concepts/ Developing Workforce

Space Technology Research Grant Program



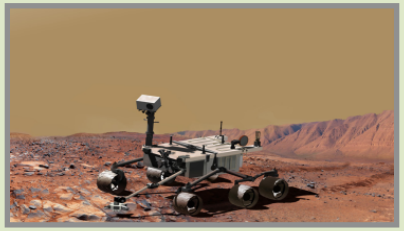
NASA Innovative Advanced Concepts (NIAC) Program



Center Innovation Fund Program

Creating Markets & Employing Alternate Approaches

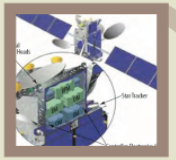
Centennial Challenges Prize Program



Small Business Innovation Research & Small Business Technology Transfer (SBIR/STTR) Program

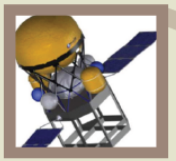
Flight Opportunities Program

Big Nine Projects



CSTD-TDM
Laser Communications

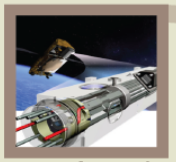
Increases space-based broadband, delivering data rates 10-to-100 times faster than today's systems, addressing the demands of future missions.



ETD-TDM
Cryogenic Propellant Storage & Transfer

Better fuel handling technology will improve spacecraft fuel economy. Required for Cryogenic Propulsion Stage (Space Launch System - SLS - upper-stage).

This tiny atomic clock is 10-times more accurate than today's ground-based navigation systems, enabling precise, in-space navigation.



CSTD-TDM
Deep Space Atomic Clock

This solar sail has an area 7 times larger than ever flown in space, enabling propellant free propulsion and next generation space weather systems.

CSTD-TDM
Large-Scale Solar Sail

Demonstrates new parachutes and inflatable braking systems at supersonic velocities enabling precise landing of large payloads on planetary surfaces.

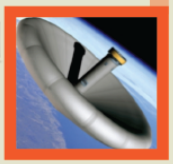
CSTD-TDM
Low Density Supersonic Decelerators

ETD-TDM
& ETD-GCD
Human Exploration Telerobotics & Human-Robotic Systems

Developing advanced systems capable of remotely operating robots to assist in future exploration; maturing new robots capable of assisting humans in routine and tedious work.

ETD-GCD
CCTD

Demonstrating large composite, light weight fuel tanks that can reduce the mass and cost of the next generation SLS.



ETD-GCD
HIAD

Demonstrates new inflatable braking systems for use at hypersonic velocities enabling precise landing of large payloads on planetary surfaces, and returning payloads from the ISS to Earth.

Develops and improves technology to enable service, repair, refueling and relocating satellites through the use of robotics.

CSTD-GCD
Robotic Satellite Servicing

Human Missions

Science Missions

NASA Space Technology
big9 projects

Notable Space Technology EDL Investments

- Space Technology Research Fellowships
- Low Density Supersonic Decelerators – LDSD (TDM)
- Hypersonic Inflatable Aerodynamic Decelerators – HIAD (GCD)
- Deployable aeroshell concepts – ADEPT (GCD)
- Conformal / flexible ablative TPS (GCD)
- Woven TPS (CIF, GCD)
- ALHAT (TDM)
- MEDLI (TDM)
- Regolith Derived Heat Shield (NIAC)

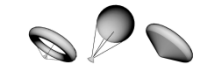
Space Technology Research Grants Program Overview

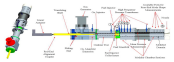
PROGRAM: To accelerate the development of push technologies through innovative efforts with high risk/high payoff and develop the next generation of innovators through:

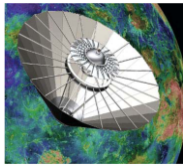
- **Space Technology Research Fellowships:** Competitive selection of U.S. Citizen / permanent resident graduate students developing promising technologies in support of future NASA missions and strategic goals
- **Space Technology Research Opportunities:**
  - Early Career Faculty (STRO-ECF): Promotes early career faculty development at U.S. universities focused on high priority space technologies
  - Early Stage Innovation (STRO-ESI): University focused technology development of groundbreaking research in advanced space technology

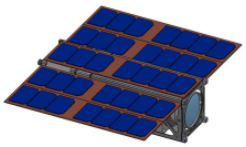
ACCOMPLISHMENTS/MILESTONES (FY 2012/2013):

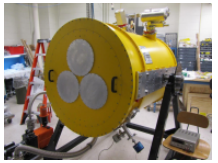
- 80 Fellows in inaugural FY 2011 fellowships class
- 48 Fellows in 2nd year FY 2012 fellowships class
- 2 new solicitations for research opportunities

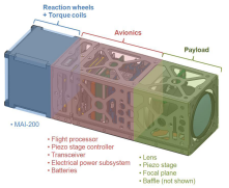




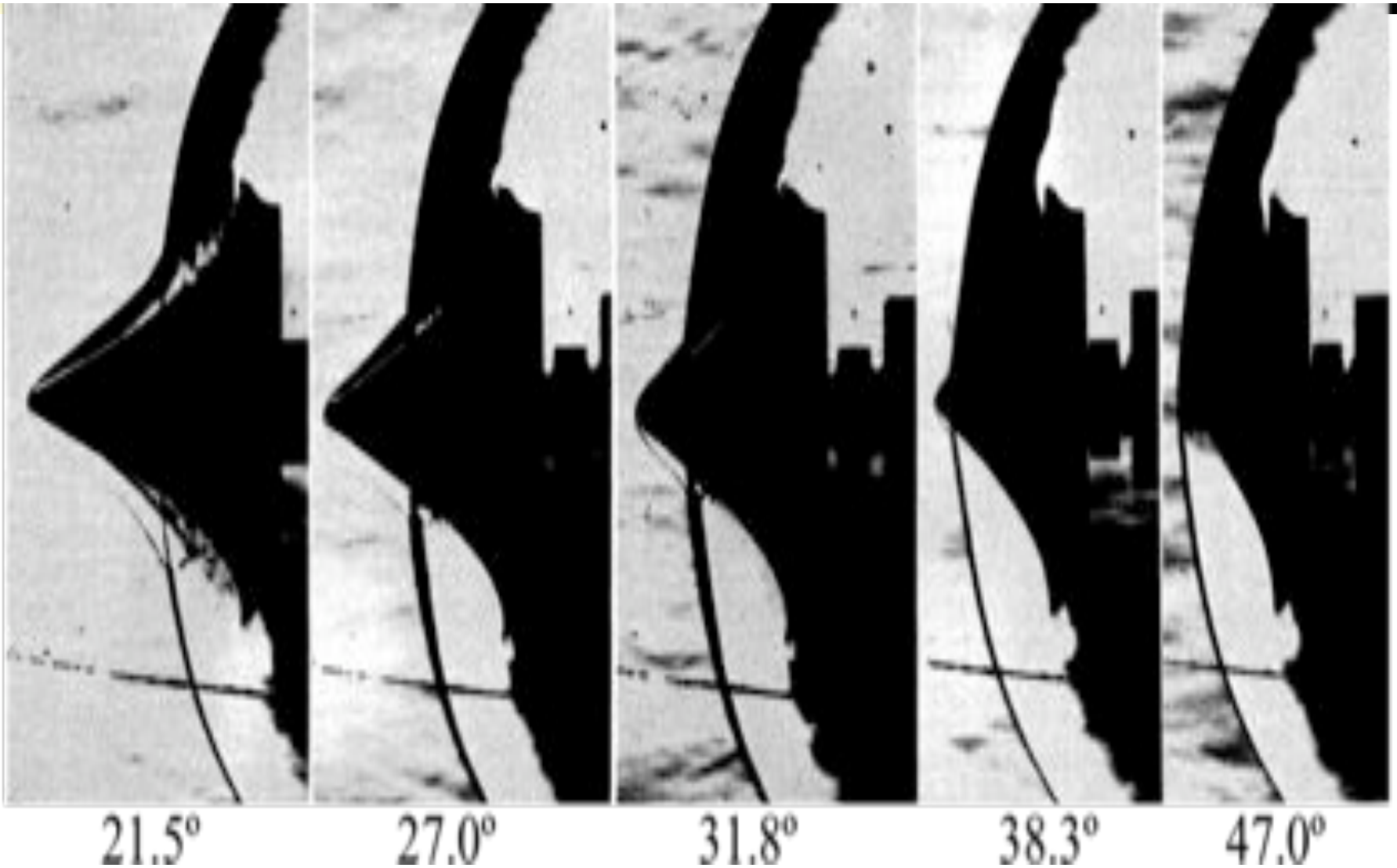




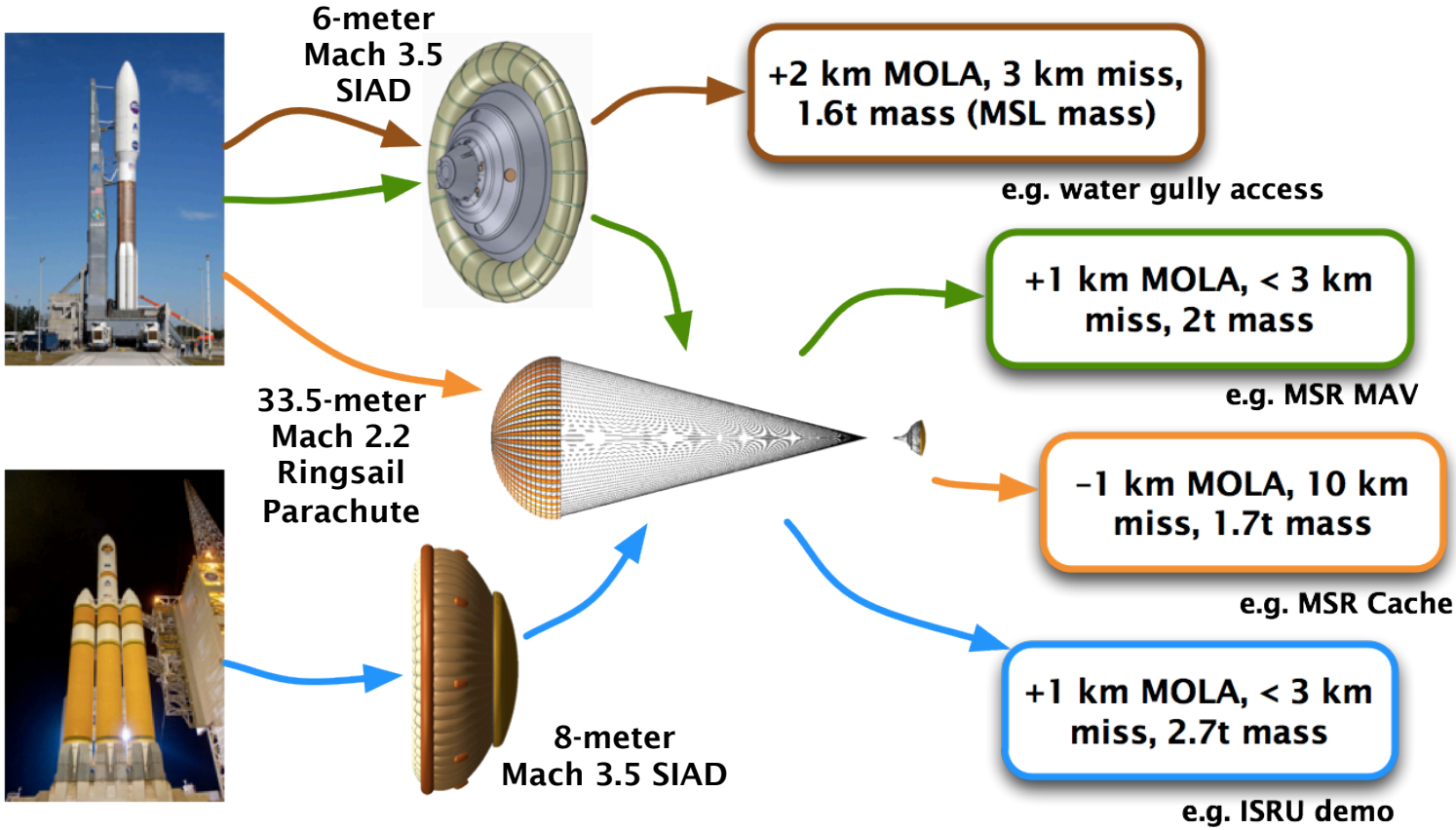




Supersonic Decelerator Development History



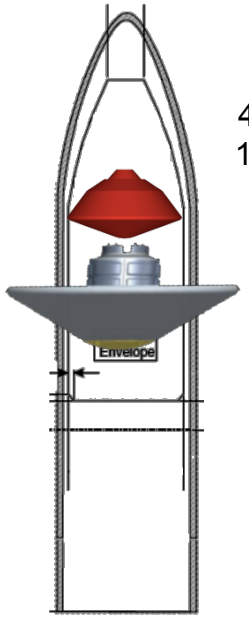
LDSD Technologies and Benefits



- Example trades between altitude and mass shown — others possible
- Mass can be used for propellant to reduce 3 km miss distance even further
  - Inertial to 2 km miss distance, terrain-relative navigation to < 1 km miss distance
- –1 km MOLA covers 48% of Mars, +1 km MOLA covers 72%

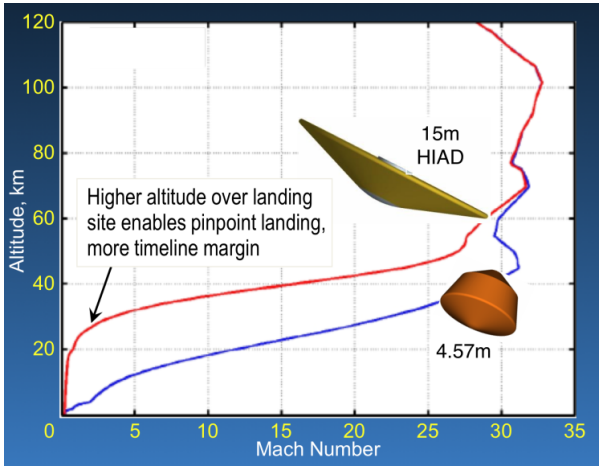
Motivation for HIAD

- **Current science payload size and altitudes limited by Viking EDL architecture**
- **Aeroshell size limited by Launch Vehicle fairing**
- **Thin Mars atmosphere makes deceleration of large masses and altitude access challenging**
- **After inflation, HIADs behave like a rigid device**
  - Aerodynamics are scalable
  - Aerocapture or direct entry
  - Reduced heat rates
  - HIADs are lighter for equivalent diameters
- **Lower ballistic coefficient from increased drag area allows higher altitude deceleration**
  - Higher surface elevations
  - Increase in landed mass
  - Improved precision landing



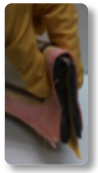
MSL	HEART
3300 kg	3500 kg
4.5 m Dia	8.5 m Dia
125 kg/m^2	40 kg/m^2

Comparable Entry Masses

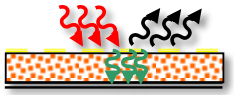


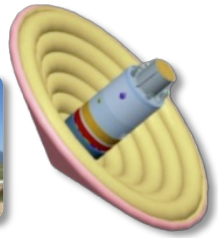
Vision for HIAD Mission Infusion

System Development and Qualification



TPS

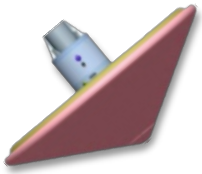




Inflatable Structures

Development and ground testing of HIAD components.

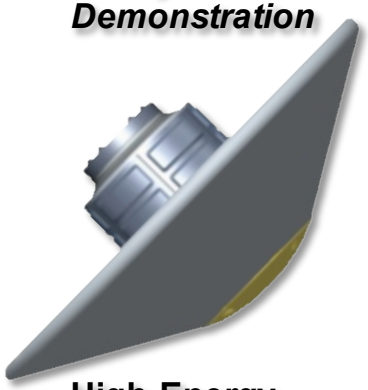
Sub-Orbital Flight Testing



IRVE-3 & 4

Sub-orbital flight tests on a cost-effective test platform (heating, lift, maneuverability).

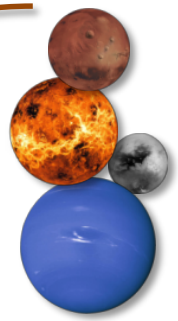
System Demonstration



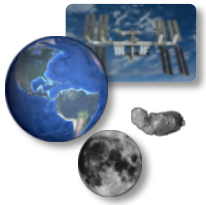
High-Energy Atmospheric Reentry Test

Flight test to demonstrate system performance at relevant scales and environments.

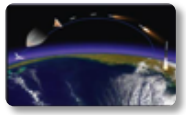
6–25 meter HIAD Class



Robotic Missions
(entry or aerocapture):
– *Mars*
– *Venus*
– *Titan*
– *Neptune (and other gas giants)*



Robotic or Crewed Earth Return
(entry or aerocapture):
– *LEO (including ISS)*
– *GEO, NEO, Lunar*



DoD Applications

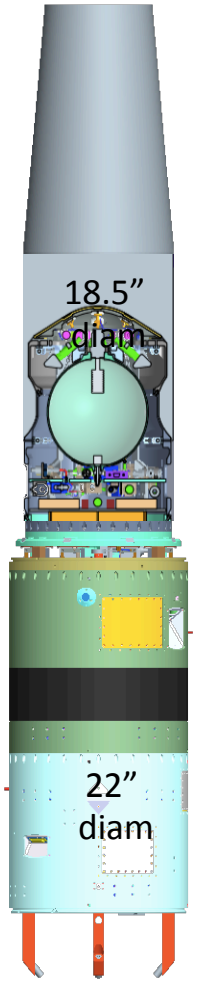
Technology Development & Risk Reduction for Human Mars Missions

Proposed initial GCT investment spans these elements

Potential on-ramps for future investments.

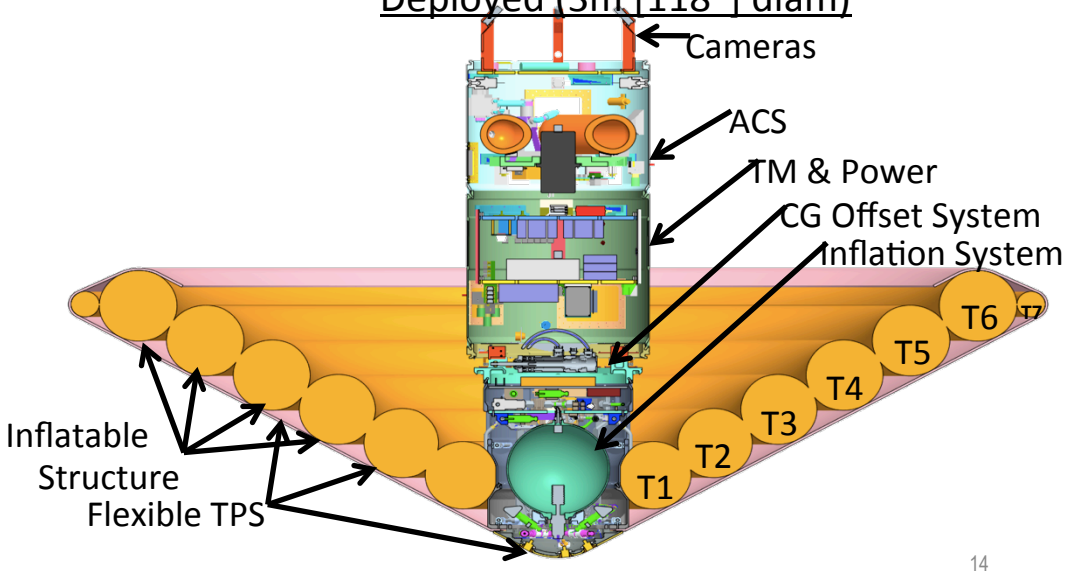
IRVE-3 Design Overview

Stowed (18.5”)

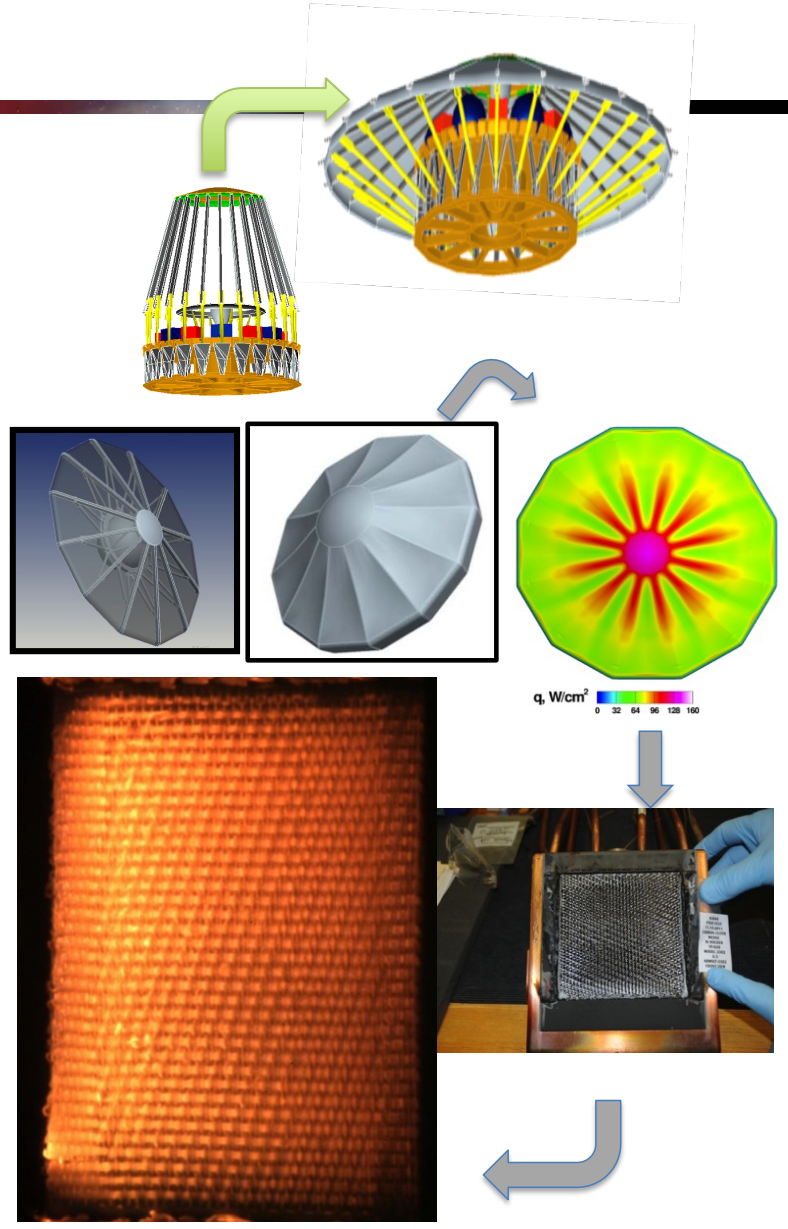


- 3m [118”] diam inflatable aeroshell with flexible TPS on forward surface
- Centerbody houses inflation system, CG offset mechanism, telemetry module, power system (batteries), ACS, cameras
- Inflatable aeroshell packs to 18.5” diam inside nose cone for launch
- Restraint cover holds aeroshell packed for launch; pyrotechnic release
- Inflation system fills aeroshell from 3000psi Nitrogen tank
- Attitude control system uses cold Argon thrusters to reorient for entry
- CG Offset mechanism allows evaluation of inflatable aeroshell L/D

Deployed (3m [118”] diam)



ADEPT – Adaptive Deployable Entry and Placement Technology



ADEPT is an STP GCD Project started in FY12

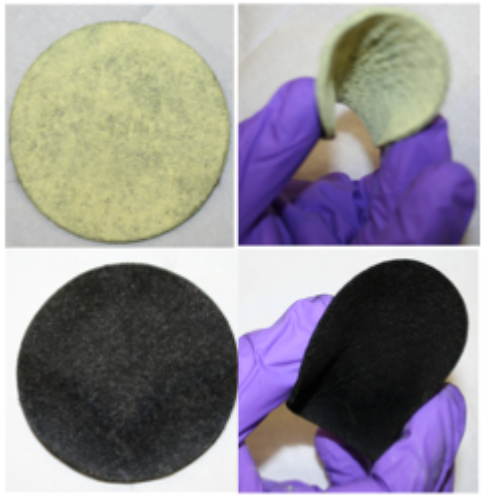
Project Deliverables

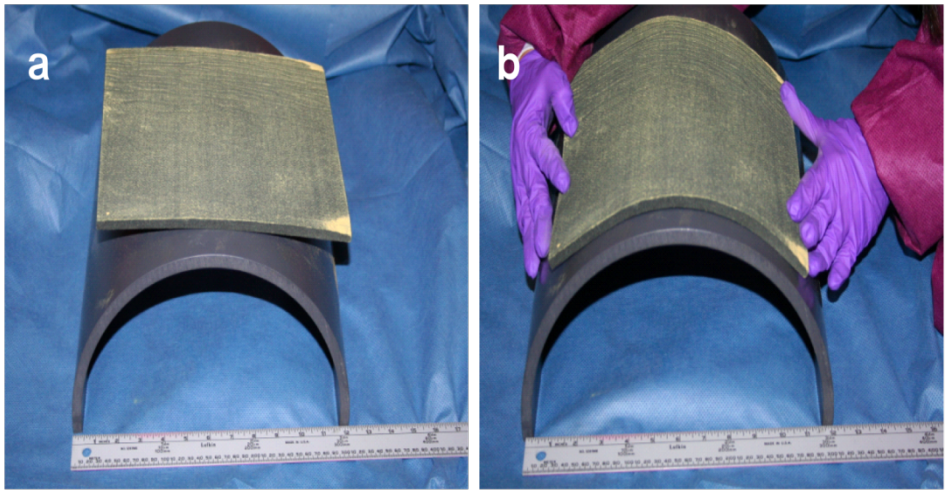
- **Characterize thermal and mechanical performance of 3D woven carbon fabric**
  - Produce flight like woven fabric skin for ground test article and integrate with breadboard structural/mechanical system
  - *Capable to 250W/cm²*
- **Perform mission feasibility study to understand requirements and scaling**
- **Design, fabricate and test sub-scale ground article (~2m diameter)**
  - Fabricate rib/strut/ring/nose structures using COTS type extruded shapes for breadboard structural support system
  - Design and procure COTS hinge/joint/deployment mechanisms to simulate behavior of ADEPT for ground testing
- **Conduct Mission Concept Assessment for a flight demonstration**

Flexible / Conformal Ablative Materials for High Heat Flux Environments Overview

Virgin Flexible Ablator

Charred Flexible Ablator





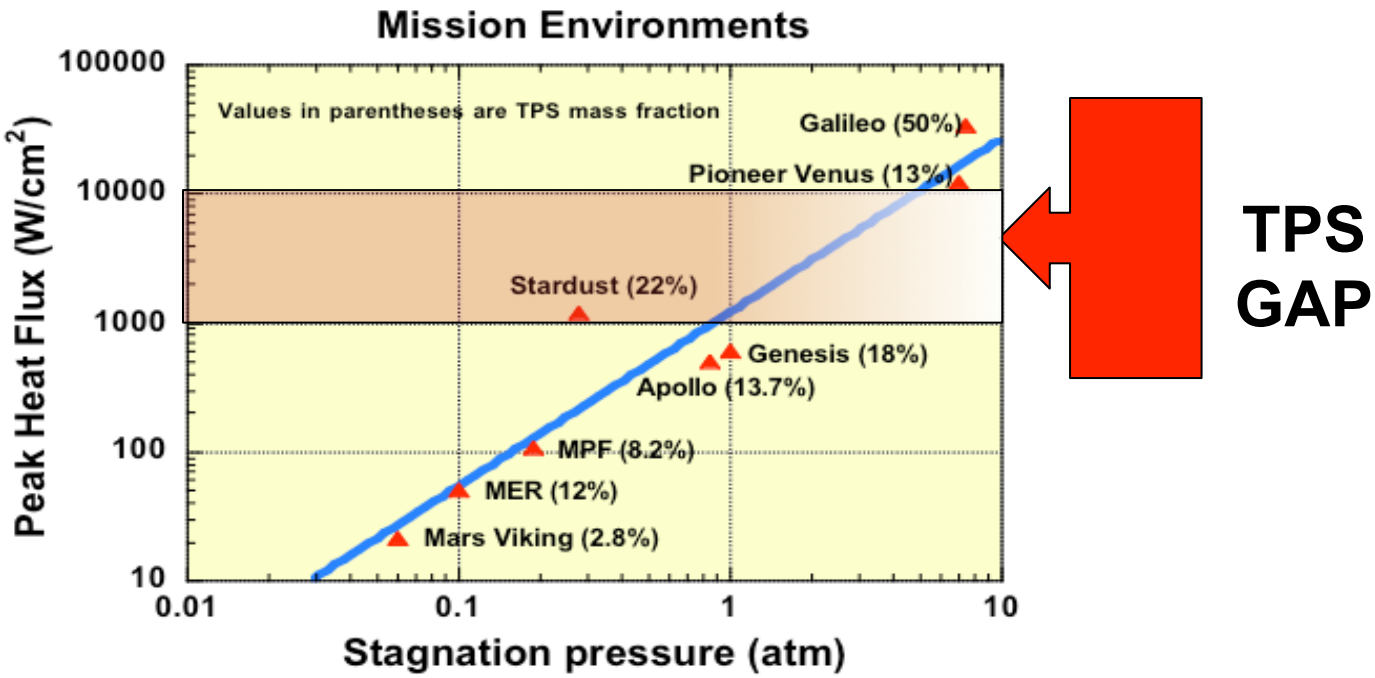
Flexible / conformable ablative materials enables:

- Design of smaller stowable or deployable aeroshells for high heat flux entries
- Integration of large rigid aeroshells without problems associated with conventional rigid TPS and failure due to strain

Goals:

- Bring flexible / conformable ablative material to TRL 5 and build a ~1-m diameter rigid aeroshell manufacturing demonstration unit

Challenges with TPS Status Quo



No viable TPS option, due to vanishing Carbon Phenolic, for

- Human Missions beyond Lunar Return Speeds (NEA and Human Mars)
- High Speed Sample Return (majority of asteriods/comets sample return)
- Venus/Saturn/Uranus/Neptune in-situ missions

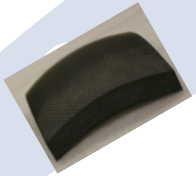
Solution: Develop and Insert Woven TPS into these Opportunities

Woven TPS: An Enabling Technology Rapid Development and Mission Insertion

April, 2011

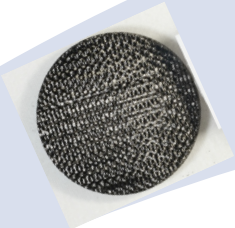
ARC CIF Selection

September, 2011



Game Changing BAA Proposal

January, 2012



Woven TPS Project :

Demonstrate Weaving TPS using Advanced Textile Manufacturing

June, 2012

3-D MAT joint SPT and MPCV Funded Project:

Multifunctional Material Solution to enable Lunar capability of Orion

FY'13

Heatshield for Extreme Entry Environment Technology (HEEET):

Enabling In-Situ Venus, Saturn and Outer Planet and Sample Return Science Missions

Conclusions

- Space Technology brings a focused project oriented investment strategy to EDL technologies
- New concepts and new people within EDL are presently, and will continue, to enjoy robust support through Space Technology:
  - Center Innovation Fund (CIF) – Woven TPS
  - NASA Innovative Advanced Concepts (NIAC) – Regolith derived TPS
  - Space Technology Research Grants (STRG) – Multiple student fellowships
  - SBIR / STTR
  - Centennial Challenges – vertical take-off and landing
- The Space Technology Program is supporting technology development and hardware testing of EDL systems and TPS materials:
  - Game Changing Development – Flexible / Conformal / Woven TPS, HIAD, ADEPT
  - Flight Opportunities – suborbital vehicle development
- Relevant Environment Demonstrations continue to occur:
  - Technology Demonstration Missions – MEDLI, ALHAT, LDSD
- Bottom line is that the NASA Space Technology Program provides robust EDL investments across a full pipeline of TRLs