Exploration Technology Development Project Summary

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NASA Advisory Council
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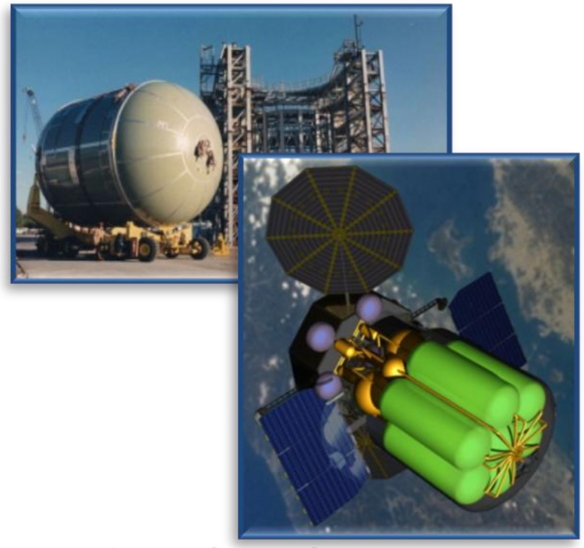
Advanced Technology at NASA



- 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
- These same investments **benefit the United States economy** through creation of new industries, products, services, scientific discoveries, and societal benefits
- 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 nation's innovators **from concept to flight**

Exploration Technology Development Portfolio

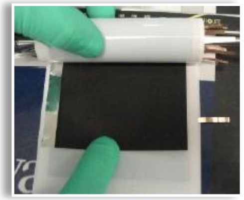
Game-Changing Development Program

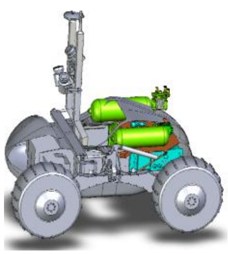
Space Power Generation and Storage Systems
- *Lightweight Materials and Structures*
- *Human-Robotic Systems*
- *Next Generation Life Support*
- *Autonomous Systems*
- *In-Situ Resource Utilization*
- Advanced Radiation Analysis Tools
- In-Space Propulsion
- Solar Electric Propulsion
- Nuclear Systems
- Composite Cryogenic Propellant Tank
- Hypersonic Inflatable Aerodynamic Decelerator (HIAD)
- Deployable Aeroshell Concepts & Conformal Ablative TPS

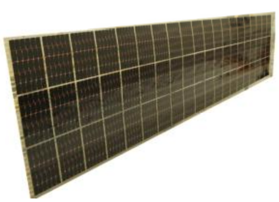
Red text = project synergy with AES

Technology Demonstration Missions Program
- *Autonomous Landing and Hazard Avoidance Technology (ALHAT)*
- Cryogenic Propellant Storage and Transfer
- Human Exploration Telerobotics
- Mars Entry, Descent, and Landing Instrumentation (MEDLI)
- Materials International Space Station Experiment (MISSE-X)

Space Power Generation and Storage







Goals:

- Develop reliable and abundant power sources for space exploration

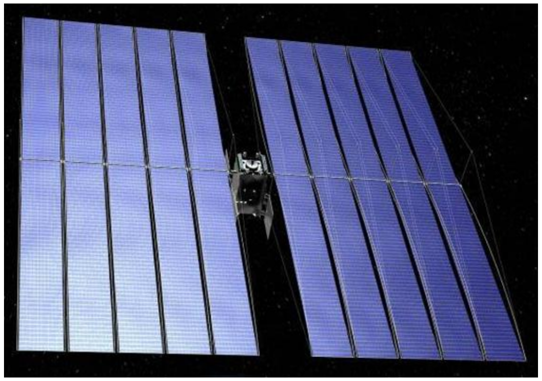
Objectives:

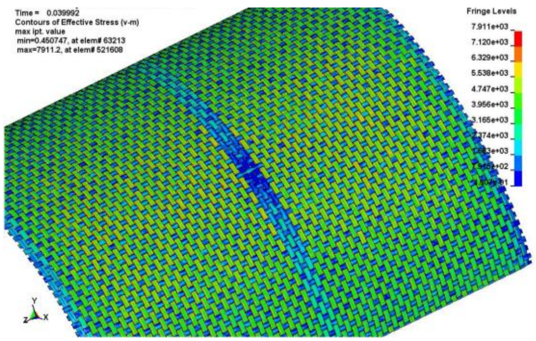
- Mature technologies for
  - Advanced lithium ion batteries
  - Regenerative fuel cells
  - Photovoltaic arrays

Outcomes:

- Increased battery life to extend EVA missions
- High reliability regenerative fuel cells for mobility, planetary surface operations
- Significant cost reduction in photovoltaic array components

Lightweight Materials and Structures (LMS)





Goals:

- Mature large flexible substrate solar array structures to TRL 5 to support crewed NEO class missions with solar electric propulsion
- Demonstrate long term durability of inflatable structures for 10-20 year mission life

Objectives:

- Mature 2 or more robust solar array designs for high-power SEP tugs to TRL 5
- Quantify and establish creep and damage behavior of inflatable structures
  - Creep characterization of restraint layer webbing
  - Perform Damage Tolerance experiments to evaluate uncertainties in damage behavior.

Outcomes:

- Increase deployable solar array surface area capability from 150 m^2 to 1500 m^2 at TRL 5
- Correlate accelerated creep test data with real-time data within 10% of predictive analysis
- Demonstrate damage-tolerant experimental data within 10% of predictive analysis.

Human-Robotic Systems

Purpose/Goals:

- Invent, design and build robot components and prototype systems for exploration
- Apply and test new components and techniques
- Integrate and prototype systems for evaluation

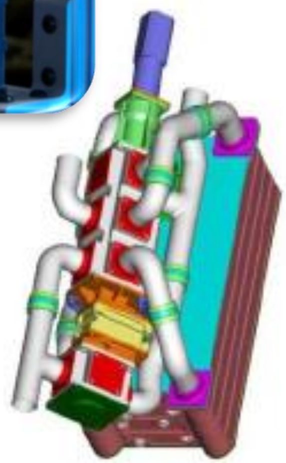
Objectives:

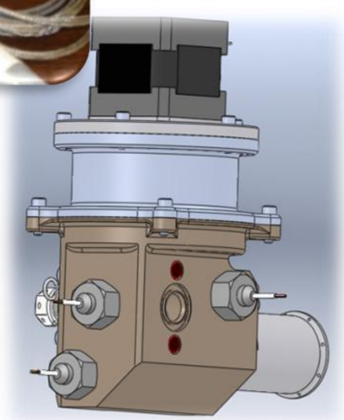
- Position human-robotics technology for candidate missions
    - Bound candidate missions with OCT Roadmaps
    - Pursue “tech push” opportunities
- Test components for application in system prototypes
- Test prototype systems as integrated solutions
- Mature HRS components and integrated systems to SRL 6

Outcomes:

- Quickly implement/prototype ideas identified by NASA architecture teams and evaluate merit, before making key mission decisions

Next Generation Life Support (NGLS)





Goals:

- Develop key technologies to enable required capabilities in EVA portable life support systems (PLSS) and in water recovery to extend human presence beyond low earth orbit

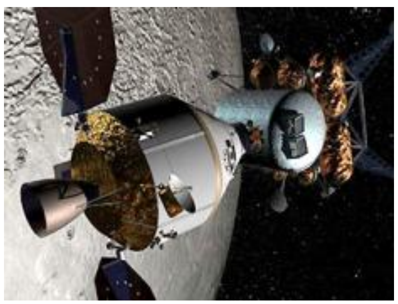
Objectives:

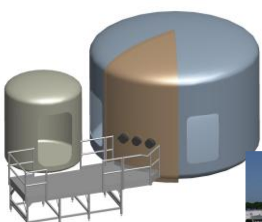
- Develop and demonstrate Rapid Cycle Amine swingbed prototype for CO_2 removal
- Demonstrate variable oxygen regulator prototype for greater control of oxygen pressure
- Demonstrate alternative water processsor prototypes

Outcomes:

- Reduce hardware mass by factor of three & eliminate EVA duration limits for EVA CO_2 removal hardware
- Increase number of EVA pressure settings to enable operational flexibility and suit-port operations
- Recover all exploration waste water at >95% recovery rate

Autonomous Systems





Goals:

- Develop and demonstrate software technology to automate operation of habitats and of cryogenic loading, including Systems Health Management.

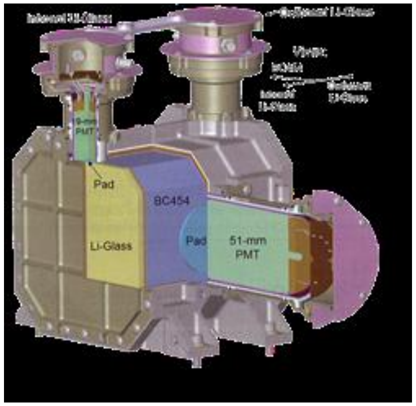
Objectives:

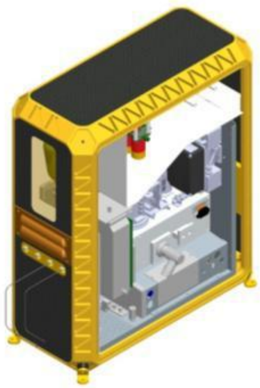
- Develop and integrate software tools to demonstrate procedure and command generation, anomaly detection, fault detection, and diagnostics.
- Demonstrate and test the software using two major testbeds
    - Deep Space Hab at JSC
    - Autonomous Cryogenic Loading Operations testbed at KSC

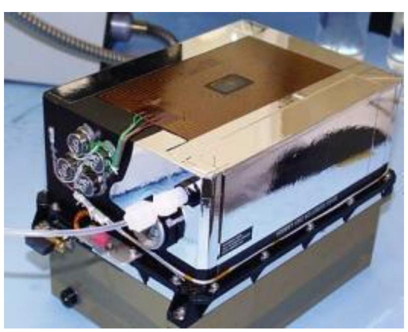
Outcomes:

- Demonstration of on-board fault management capability working with goal-directed autonomy
- Capability to reduce ground operations costs through automation of monitoring and control functions

In-Situ Resource Utilization (ISRU)







Goals:

- Develop sensing instruments that can detect ice, volatile elements on planetary surfaces
  - Once detected, resources can be extracted and processed into propellants and consumables for use at the site

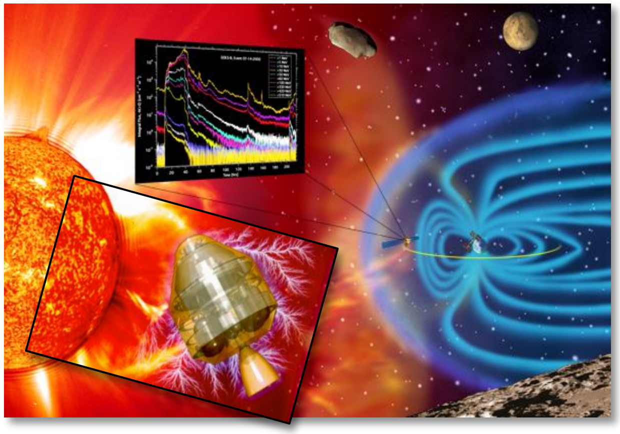
Objectives:

- Design and develop neutron spectrometer for sensing of water ice
- Design and develop gas chromatograph/mass spectrum analyzer for volatile prospecting
- Design near infrared spectrometer for volatile prospecting
  - Fabrication will be completed by AES project

Outcomes:

- Instrument design complete end of FY12
- Fabrication and bench testing complete end of FY13

Advanced Radiation Analysis Tools



Goals:

- Develop capability to forecast solar radiation events
- Develop analytical methods to assess radiation effects on space structures

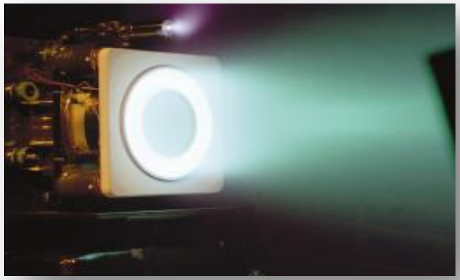
Objectives:

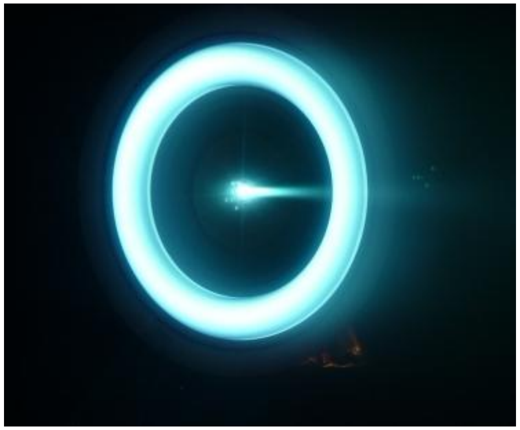
- Develop Integrated Solar Energetic Proton (SEP) Event Alert Warning System to mitigate operational effects of SEP events
- Develop Monte Carlo Radiation Analysis of CAD Models toolset to analyze candidate radiation shielding designs

Outcomes:

- Improved SEP warning system informs risk mitigation steps for mission operations, crew protection
- High fidelity radiation analysis of shielding reduces high mass requirements of conservative designs

In-Space Propulsion





Goals:

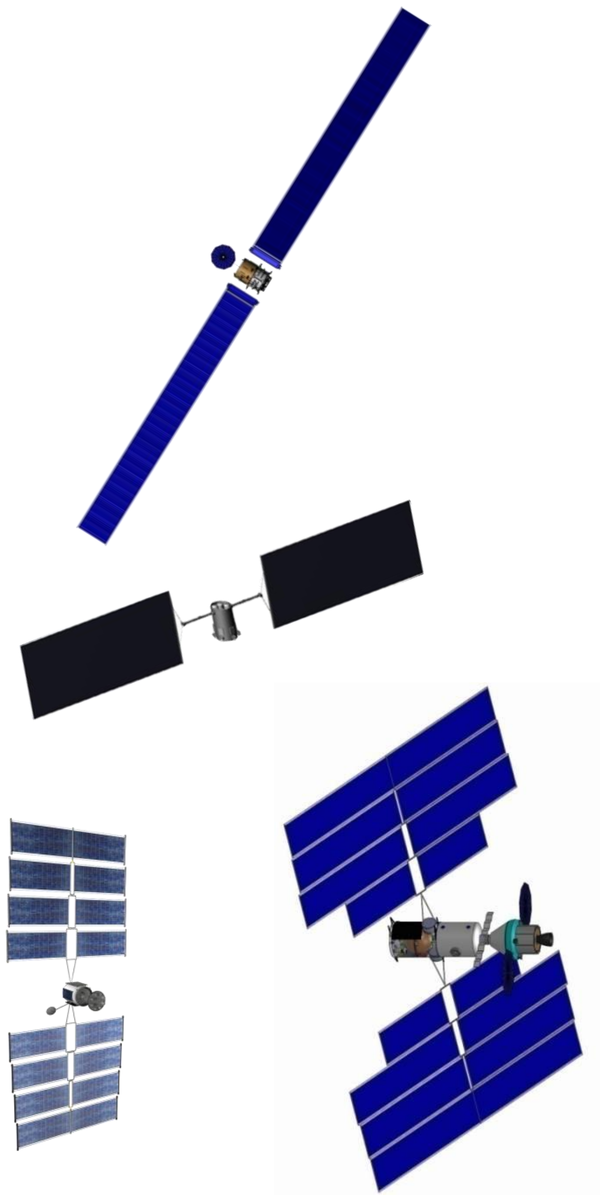
- Mature high power electric propulsion thrusters, power processing units for application to SEP demonstrations

Objectives:

- Leverage hardware investments by AFRL in two areas
  - 13 kW Hall thruster from AFRL Transformational Satellite project (TSAT)
  - 160V – 200V Power Processing Unit from AFRL High Power Propulsion System assets
- Design and develop proto-flight versions of these hardware elements, conduct integrated testing of these systems to reach TRL 6

Outcomes:

- TRL 6 Hall thruster and power processing unit ready to support SEP TDM demo

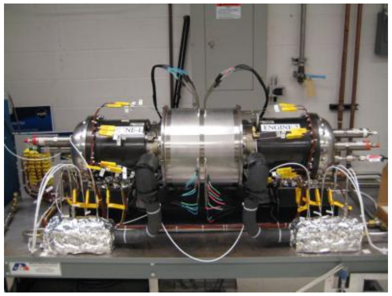


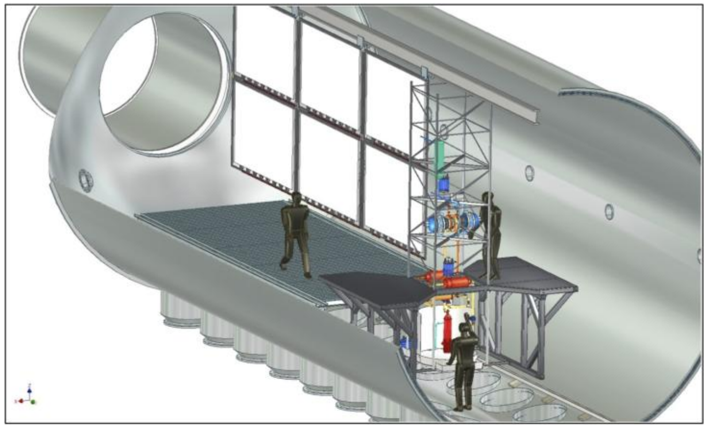
Solar Electric Propulsion

Goals:
- Develop solar electric propulsion (SEP) free flyer demonstration to prove out critical technologies

Objectives:
- Develop point of departure concepts
  - 5 studies in FY12 for mission concepts and operations will inform concept development
- Develop approaches for leveraging other ETD investments in Lightweight Materials and Structures, Space Power Generation and Storage to support SEP
- Transition SEP project from Game Changing to TDM in FY15, target a launch in FY18

Outcomes:
- On-orbit verification of integrated SEP solar array, power conversion and propulsion element
- Technology will support future exploration to L2, NEA/NEO and beyond





Goals:

- Provide abundant low cost, reliable electric power for long duration missions to challenging environments
- Non-nuclear demonstration of fission power subsystem-level readiness in a relevant environment

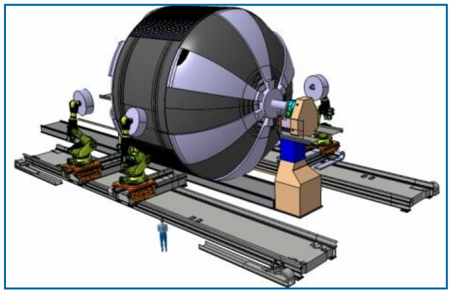
Objectives:

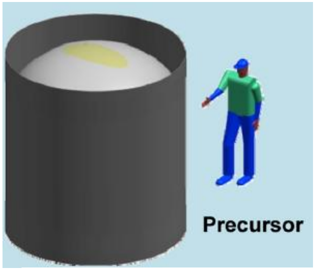
- Component maturation
  - Stirling engine for power conversion
  - Reactor core element simulator
  - Na-K pump
- Technology Development Unit
  - Integrates component technolgies for end to end subsystem evaluations

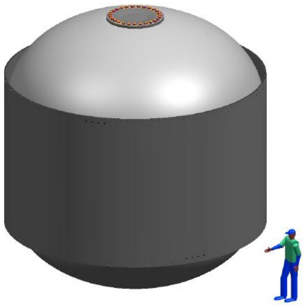
Outcomes:

- Integrated verification of TRL of non-nuclear subsystem elements
- Provides starting point for introduction of nuclear system elements

Composite Cryogenic Technologies and Demonstration (CCTD)







Goals:

- Advance the technologies for composite cryogenic propellant tanks at diameters suitable for future heavy lift vehicles and other in-space applications with a goal of reducing weight and cost.
- Identify spin-off capabilities for NASA, DOD and industry

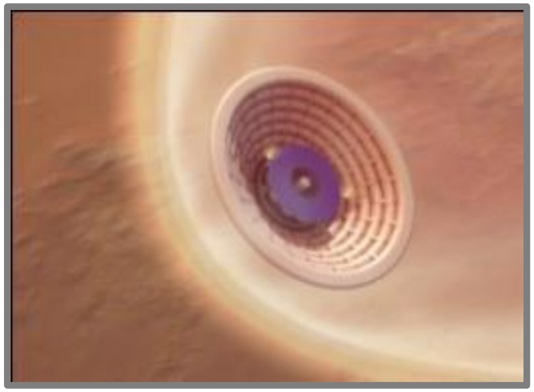
Objectives:

- Develop and demonstrate composite tank critical technologies – Materials, Structures, and Out-of-Autoclave Manufacturing
- Focus on achieving affordability, technical performance, verified through agreement between experimental results and analysis predictions
- Design, Build, and Test, 2.4-meter and 5-meter diameter out-of-autoclave composite cryotanks

Outcomes:

- Produce a major advancement in technology readiness
- Successfully test 5-meter diameter composite hydrogen fuel tank
- Achieve 30% weight savings and 25% cost savings compared to state of the art metallic tanks(Al-Li)

Hypersonic Inflatable Aerodynamic Decelerators (HIAD)



Goals:

- Develop and qualify thermal protection and inflatable structures systems for hypersonic deceleration
- Demonstrate system performance at relevant scales

Objectives:

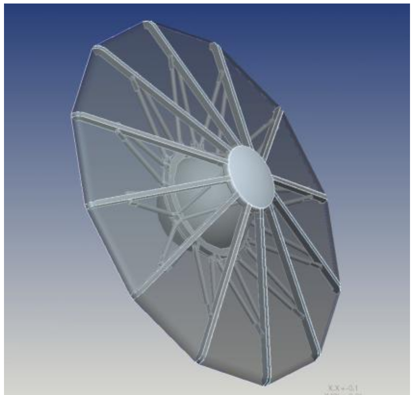
- Demonstrate performance of TPS and aeroshell structures in relevant heating environment (17-18 W/cm^2)
- Demonstrate relevant-scale (8.5-meter) structural concept
  - *Aerodynamic load testing*
  - *Manufacturing demonstration*
- Develop approach for 10-15-meter HIADs

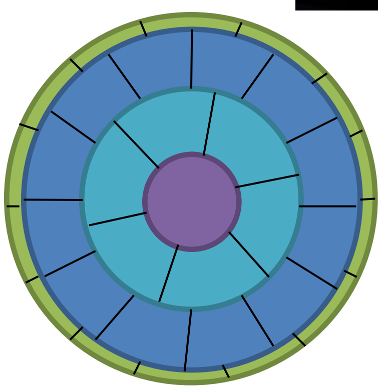
Outcomes:

- *Development and Qualification of Thermal Protection System*
- *Development and Qualification of Inflatable Structure*
- *IRVE-3 Demonstration in relevant heating environment*
- *Develop Future Flight Concepts*

- **HIAD concept ready for orbital flight demonstration**

Deployable Aeroshell Concepts and Conformal TPS





Goals:

- Develop Adaptive Deployable Entry aeroshell concepts to provide low mass alternatives to rigid aeroshells for planetary entry
- Demonstrate conformal ablative TPS concepts to reduce assembly and integration costs, improve structural design options for rigid aeroshells

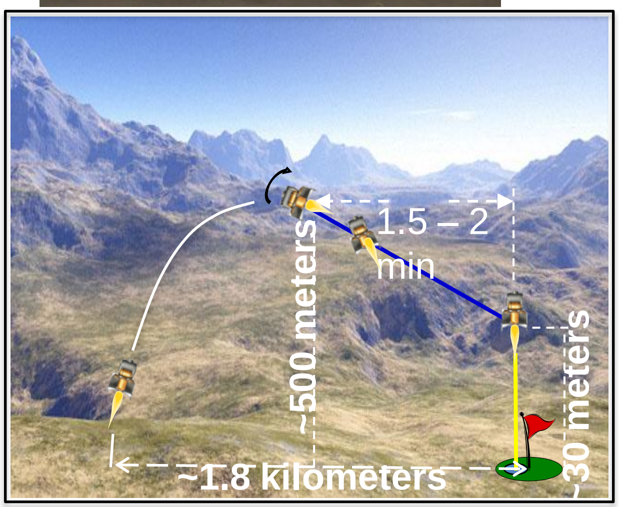
Objectives:

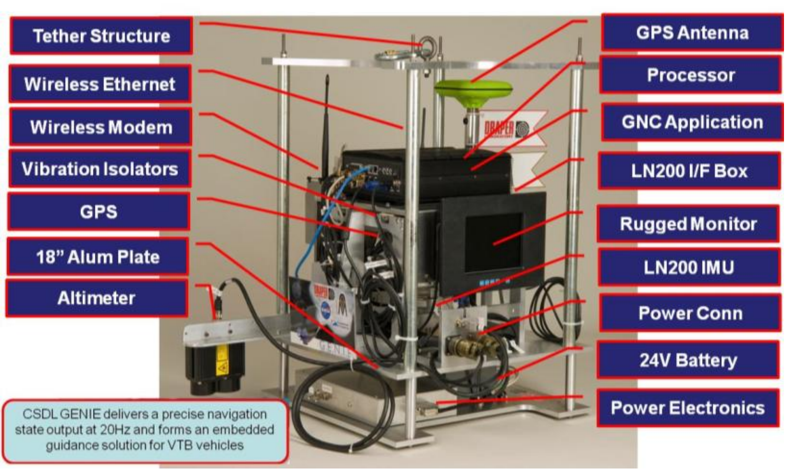
- Deployable aeroshells
  - Characterize thermal and mechanical performance of 3D woven carbon fiber fabric
  - Develop deployable aeroshell requirements, develop and test subscale ground test article
- Conformal TPS
  - Develop and produce baseline material concepts
  - Conduct material testing, arcjet testing

Outcomes:

- Deployable aeroshell technology that can reduce g-loads and peak heating for entry by a factor of 10
- Mature Conformal TPS to readiness level of TRL 5

Autonomous Landing & Hazard Avoidance Technology (ALHAT)





Goals:

- Development of precision landing and hazard avoidance landing system technologies for human planetary missions including crew and cargo and systems
- Support precision navigation relative to hazards

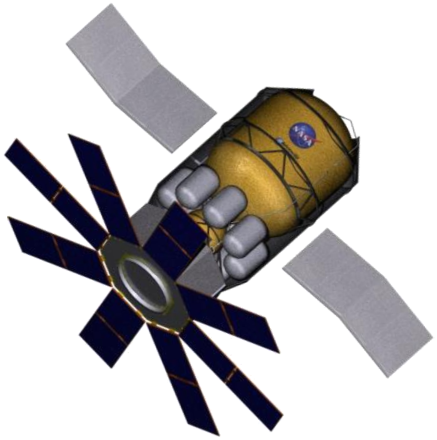
Objectives:

- Demonstrate a closed loop hazard detection and avoidance phase of the ALHAT Autonomous GNC hardware and software system on a terrestrial Vertical TestBed (VTB)

Outcomes:

- Demonstration of autonomous precision landing of a spacecraft
- Demonstration of real-time Identification & avoidance of surface hazards
- Demonstration of landing to within tens of meters of designated landing sites anywhere on a planetary surface under any lighting conditions

Cryogenic Propellant Storage and Transfer



Goals:

- Develop Space flight mission to demonstrate a single fluid (LH2), passive/active cryogenic propellant storage, transfer, and gauging systems for infusion into future extended in-space missions.

Objectives in FY12:

- Tech Maturation
  - Ground tests to reduce hydrogen boil off, liquid acquisition device and line chilldown, thermal insulation for support structure
- Completion of system engineering studies to flesh out mission concepts
- MCR 4/12, SRR 9/12
  - Firm up mission approach, requirements
  - Develop scope appropriate to available budget

Outcomes:

Support exploration beyond LEO

- Demo long duration in-space storage of cryogenic propellants.
- Demo in-space transfer of cryogenic propellants.

Human Exploration Telerobotics

Goals:

- ISS demos to assess how advanced, remotely operated robots can improve human exploration.
- Ground demos for addressing planetary surface ops

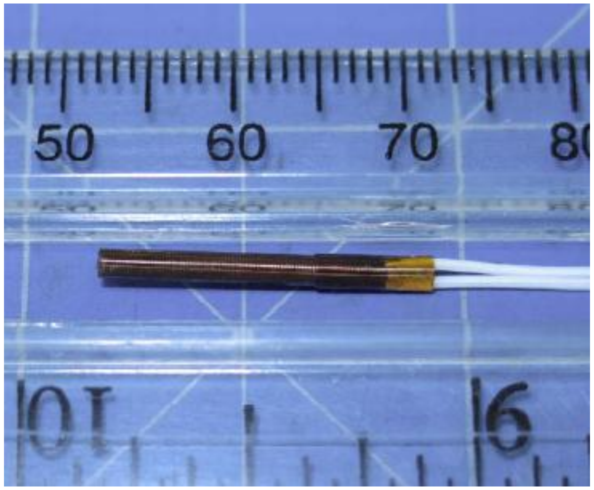
Objectives:

- ISS demos using
  - Robonaut 2
  - SPHERES IVA free flyer
  - Android Smartphone
- Ground Evaluations using
  - ATHLETE
  - K10

Outcomes:

- Improve the efficiency and productivity of human explorers
- Increase the mission return (science, engineering, etc.)
- Off-load routine, repetitive tasks to robots & ground control

Mars Science Lab EDL Instrumentation (MEDLI)



Goals:

- Use instrumentation suite installed in the heatshield of the Mars Science Laboratory's (MSL) Entry Vehicle that will gather data on the atmosphere and on aerothermal, Thermal Protection System and aerodynamic characteristics of the Entry Vehicle during entry and descent providing engineering data for future Mars missions

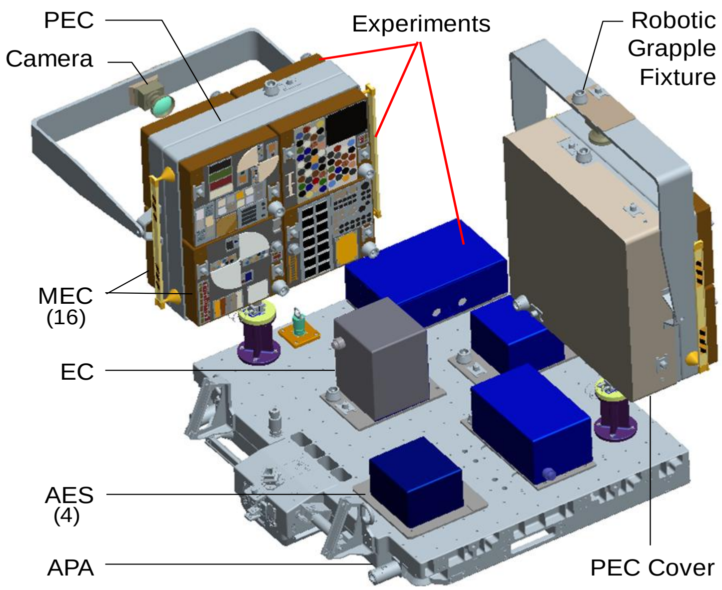
Objectives:

- Use sensors to gather environment data
- Thermocouple/recession sensor data to define aeroheating uncertainties and determine performance limits of heritage materials
- Pressure data for accurate trajectory reconstruction, separation of aerodynamic/atmospheric uncertainties in the hypersonic and supersonic regimes

Outcomes:

- Data set that will revolutionize our understanding of Mars entry vehicle performance, and should set a standard of instrumentation for ALL entry vehicles.
- Lessons learned being applied to EFT-1, HIAD, SIAD

Materials International Space Station Experiment (MISSE-X)



Goals:

- To test the stability and durability of materials and devices in the space environment

Objectives:

- Measure experiment exposure to the following space environments
  - Atomic Oxygen Fluence
  - Radiation Dose
  - Radiation SEUs
  - Thermal Environment
  - Surface and IESD Charging
  - Plasma Environment
  - Contamination Environment

Outcomes:

- Environment data can be combined with updated space environment models to improve design criteria for future missions

Space Technology: Investments in Our Future

- **Through NASA, America Continues to Dream Big**
  - NASA's future aeronautics, science and exploration missions are grand in scope and bold in stature
- **Enabling Our Future in Space**
  - Investing in high payoff, disruptive technology that industry cannot tackle today, *Space Technology* matures the technology required for NASA's future missions in science and exploration while proving the capabilities and lowering the cost of other government agencies and commercial space activities.
- **NASA at the Cutting Edge**
  - Pushing the boundaries of aeroscience and taking informed-risk, *Space Technology* allows NASA and our Nation to remain at the cutting-edge.
- **Technological leadership is the "Space Race" of the 21st Century**
- **NASA makes a difference in our lives everyday**
  - Knowledge provided by weather and navigational spacecraft
  - Efficiency improvements in both ground and air transportation
  - Solar- and wind-generated energy
  - Cameras found in many of today's cell phones
  - Improved biomedical applications including advanced medical imaging
  - More nutritious infant formula
  - Protective gear that keeps our military, firefighters and police safe

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