NASA In-Space Propulsion Technologies and Their Infusion Potential

The In-Space Propulsion Technology (ISPT) program has been developing in-space propulsion technologies that will enable or enhance NASA robotic science missions. The ISPT program is currently developing technology in four areas that include Propulsion System Technologies (Electric and Chemical), Entry Vehicle Technologies (Aerocapture and Earth entry vehicles), Spacecraft Bus and Sample Return Propulsion Technologies (components and ascent vehicles), and Systems/Mission Analysis. Three technologies are ready for flight infusion: 1) the high-temperature Advanced Material Bipropellant Rocket (AMBR) engine providing higher performance; 2) NASA's Evolutionary Xenon Thruster (NEXT) ion propulsion system, a 0.6-7 kW throttle-able gridded ion system; and 3) Aerocapture technology development with investments in a family of thermal protection system (TPS) materials and structures; guidance, navigation, and control (GN&C) models of blunt-body rigid aeroshells; and aerothermal effect models. Two component technologies that will be ready for flight infusion in the near future will be Advanced Xenon Flow Control System, and ultra-lightweight propellant tank technologies. Future focuses for ISPT are sample return missions and other spacecraft bus technologies like: 1) Mars Ascent Vehicles (MAV); 2) multi-mission technologies for Earth Entry Vehicles (MMEEV) for sample return missions; and 3) electric propulsion for sample return and low cost missions. These technologies are more vehicle-focused, and present a different set of technology infusion challenges. While the Systems/Mission Analysis area is focused on developing tools and assessing the application of propulsion technologies to a wide variety of mission concepts. These in-space propulsion technologies are applicable, and potentially enabling for future NASA Discovery, New Frontiers, and sample return missions currently under consideration, as well as having broad applicability to potential Flagship missions. This paper provides a brief overview of the ISPT program, describing the development status and technology infusion readiness of in-space propulsion technologies in the areas of electric propulsion, aerocapture, Earth entry vehicles, propulsion components, Mars ascent vehicle, and mission/systems analysis.

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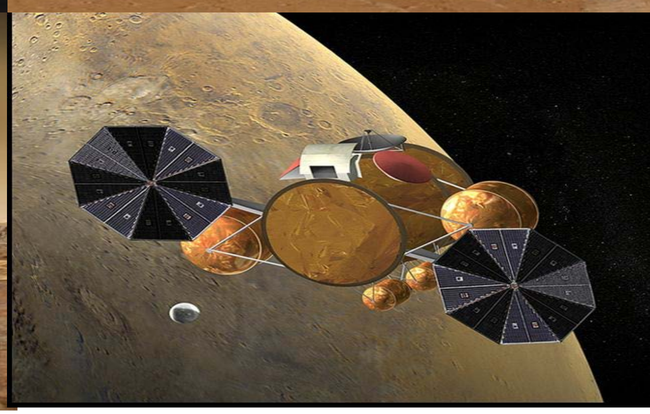
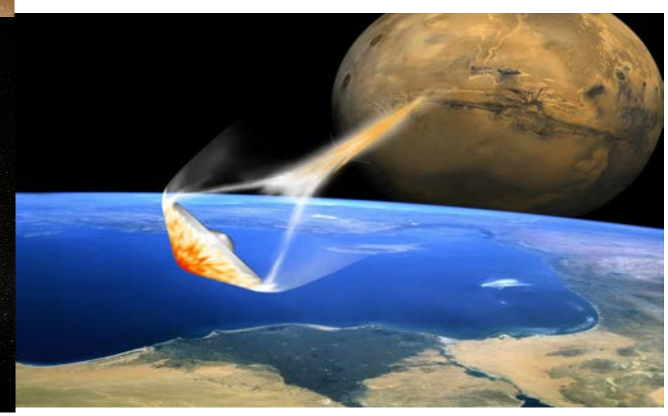




David Anderson, Michelle Munk, Eric Pencil, John Dankanich, Lou Glaab, Todd Peterson, and Dan Vento

2012 Joint Propulsion Conference, July 30- August 1, 2012

NASA's In-Space Propulsion Technology (ISPT) Program

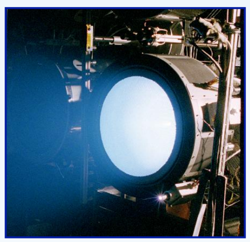
NASA's ISPT Program develops critical propulsion, entry vehicle, and other spacecraft and platform subsystem technologies to enable or significantly enhance future planetary science missions. The current ISPT focus is TRL 3-6+ product development.

- *Develop technologies that enable access to more challenging and interesting science destinations or benefit the agency's future robotic science missions by significantly reducing travel times to distant bodies, increasing scientific payload capability, or reducing mission cost and risk.*

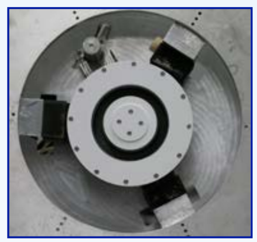
Propulsion System Technologies

AMBR High-Temp Rocket Engine

7 kW NEXT Ion Propulsion System

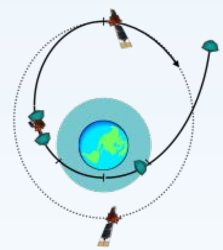


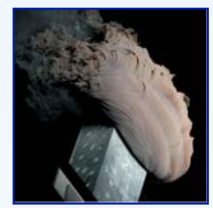
4 kW HIVHAC Thruster & Hall Propulsion System



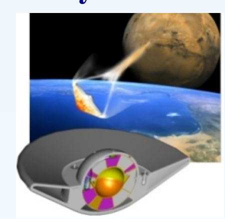
Entry Vehicle Technologies

Aerocapture





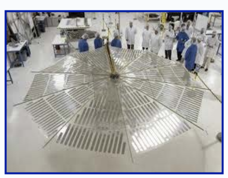
Multi-Mission Earth Entry Vehicle



Spacecraft Bus & Sample Return Technologies

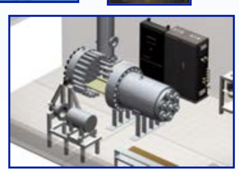
Mars Ascent Vehicle

PV Array Systems for planetary missions



Spacecraft Bus Components

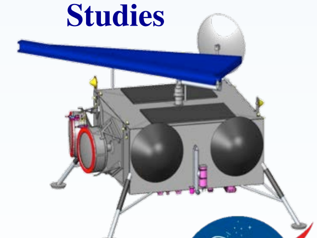
Extreme Environments



Systems & Mission Studies

Mission Analysis Tools

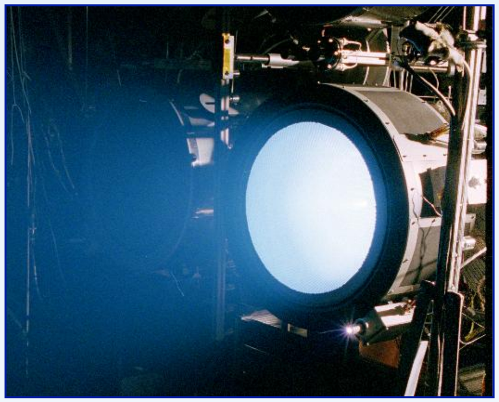
Mission and System Studies



NASA's Evolutionary Xenon Thruster (NEXT)
Expanding SEP Applications For Science Missions

Objective: Improve the performance and life of gridded ion engines to reduce user costs and enhance/enable a broad range of NASA SMD missions

NEXT gridded ion thruster



NEXT PM ion thruster operation at NASA GRC

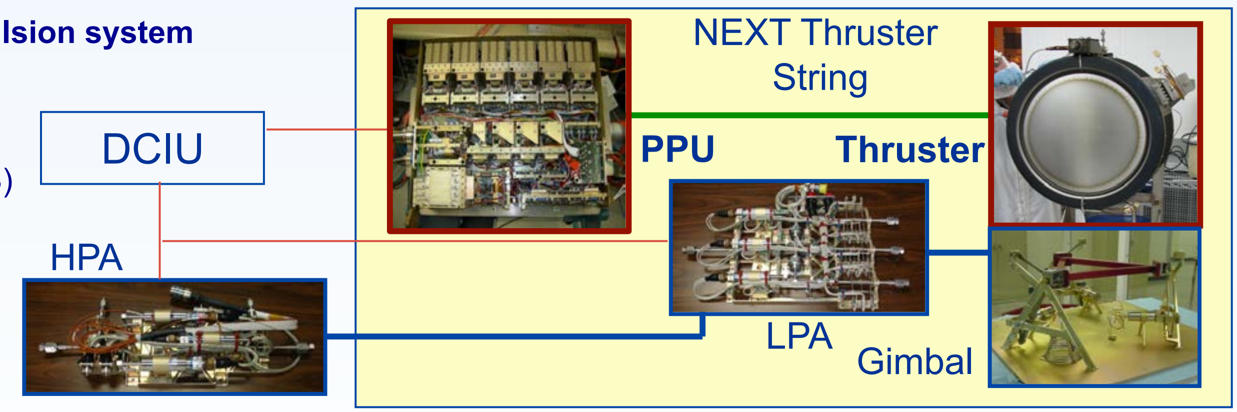
Thruster Attribute	
Thruster power range, kW	**0.5 - 6.9**
Max. Specific Impulse, s	**4,190**
Thrust range, mN	**26 - 236**
Propellant Throughput, kg	**450***
Mass (with harness), kg	**13.5**
Envelope dimensions, cm	**43.5 x 58.0**
Power Processing Unit Attribute	
Power Processing Unit mass, kg	**33.9**
Envelope dimensions, cm	**42 x 53 x 14**
Input voltage range, V	**80 - 160**
Feed System Attribute	
High Pressure Assembly mass, kg	**1.9**
Low Pressure Assembly mass, kg	**3.1**

NEXT addresses the entire ion propulsion system

- Gridded ion thruster
- Power processing unit (PPU)
- Propellant management system (PMS)
- System integration (including gimbal and control functions)

Primary Partners

- NASA Glenn Research Center: Lead
- JPL, Aerojet Corp., L3 Comm.

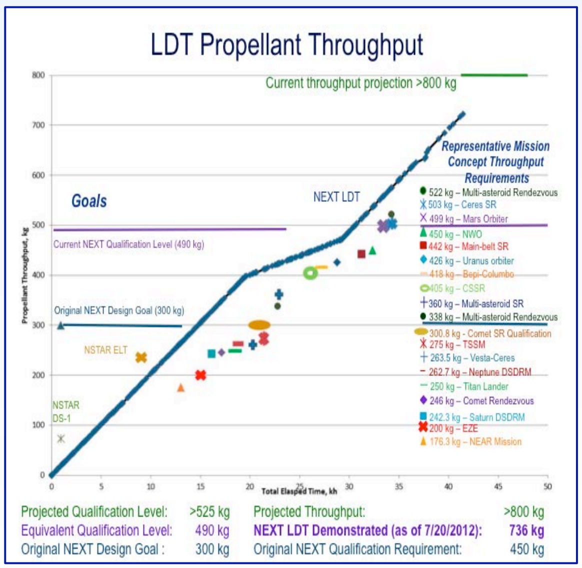


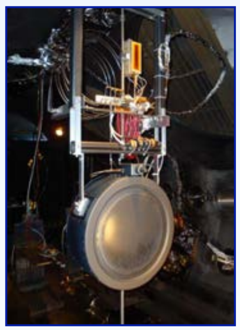
* Rated Capability Goal 300Kg → Design/Qualification Goal (1.5x Rated) 450Kg
Projected Life Limit >800Kg → Potential Rated Capability >530Kg

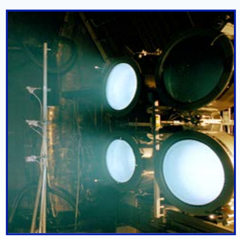
NEXT TRL6 Status and Mission Benefits

NEXT is Ready for Infusion

- Single-String System Integration Test: **Complete**
- Multi-String System Integration Test: **Complete**
- Thruster Life Test: 450Kg throughput goal **Completed**
  - **As of July 20, 2012, the LDT has achieved >736kg xenon throughput, >42,087 hours of operation and >28.1 MN-sec of total impulse**
  - Life Test will continue through FY14 or demonstrate thruster life limit
- Unprecedented diagnostics used for NEXT thruster performance characterization and spacecraft interaction effects testing on-going at TAC

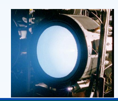
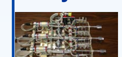






NEXT Mission Benefits & Applicability

CHARACTERISTIC	NSTAR (SOA)	NEXT	Improve-ment	NEXT BENEFIT
Max. Thruster Power (kW)	2.3	6.9	3x	Enables high power missions with fewer thruster strings
Max. Thrust (mN)	91	236	2.6x	
Throttling Range (Max./Min. Thrust)	4.9	13.8	3x	Allows use over broader range of distances from Sun
Max. Specific Impulse (sec)	3120	4190	32%	Reduces propellant mass, enabling more payload and/or lighter spacecraft
Total Impulse (10^6 N-sec)	4.6	>18	>3.9x	Enables low power, high ΔV Discovery-class missions with a single thruster
Propellant Throughput (kg)	150	450	3x	

Critical tests have been completed, or are imminent, on high fidelity hardware	PM1 	PM1R 	PPU 	Feed System 	Gimbal 
Functional & Performance Testing	Complete	Complete	Complete	Complete	Complete
Qual-Level Vibe Test & Analysis	Complete	Complete	Not planned	Complete	Complete
Qual-Level Thermal / Vacuum Test & Analysis	Complete	Complete	Not planned	Complete	Not planned

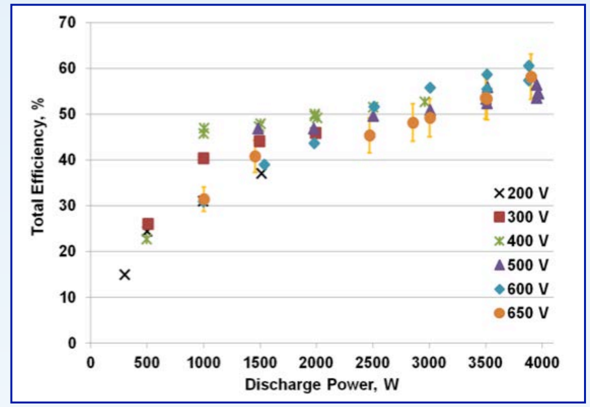
High Voltage Hall Accelerator (HIVHAC)
for low cost Discovery-class and Sample Return Missions

Objective

Develop low power, long-life Hall thrusters to reduce the cost of Discovery-class missions compared to SOA ion and hall thrusters

Input Power	**0.3 – 3.9 kW**
Specific Impulse	**860 - 2700 s**
Max Efficiency	**62%**
Thrust	**20 – 207 mN**
Propellant Throughput	**> 300 kg**
Specific Mass	**2.4 kg/kW**
Operational Life	**> 10,000 hrs**

HIVHAC EDU



Approach

Hall thruster numerical erosion models

- Implement advanced numerical simulations of Hall thruster channel erosion, and evaluate against experimental data

Thruster fabrication and extended life test

- NASA-103M (ASOA) Hall thruster with in-situ replacement of channel ceramic walls to improve Xenon throughput to 300-kg
- Incorporate lessons-learned from NASA-103M.XL wear test into the design of an **Engineering Development Unit (EDU)** 3.5 kW HIVHAC thruster

Primary Partners

- NASA Glenn Research Center: Lead
- Aerojet Corp.

Key Milestones/Accomplishments

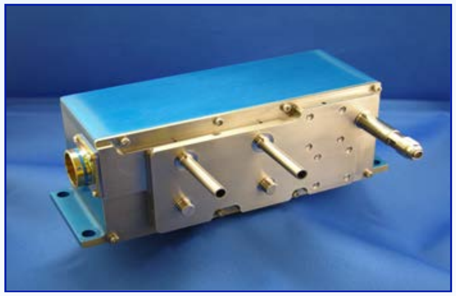
- **Preliminary Design Review** of **Engineering Development Unit (EDU-1)** thruster completed August 2008.
- **Testing of EDU-1 Thruster revealed design challenges** related to high voltage isolation, thermal designs, mechanism actuation, and magnetic fields.
- **EDU-2 thruster design and fabrication** completed November 2011.
- **Performance Acceptance Test** completed December 2011. Thruster design met performance goals.
- **Environmental vibration testing** completed in March 2012.
- **Hot-fire mechanism actuation test** completed in April 2012.
- Environmental thermal vacuum testing is scheduled Nov 2012.
- Long Duration Test initiation is anticipated Dec/Jan 2013.

Advanced Xenon Feed System (AXFS)

OBJECTIVE

- ISPT award a contract with VACCO industries to develop a modular Advanced Xenon Flow System (AXFS) with significant reductions in mass, cost, and volume over SOA while increasing system reliability.
  - Flow control accuracy error < 3% EOL
  - System designed to operate NEXT
  - Complete feed system and controller
  - TRL 6 testing
  - Award for two FCMs, 1 PCM, 1 controller with LabVIEW software

Dawn Feed System



VACCO XFSM

STATUS

- The ISPT project has invested in an AXFS, developed by VACCO Industries:
- Completed limited qualification level environmental testing
  - Demonstrated hot-fire operation
  - Pressure control
  - Current control
- Demonstrated 70% reduction in Mass,
- 50% reduction in footprint, and
- Expected 50% cost reduction over NEXT SOA PMS.

- **The VACCO AXFS is ready for technology infusion.**

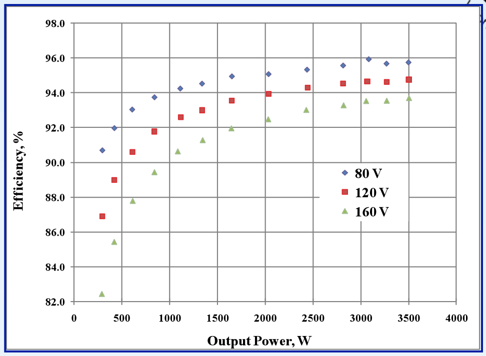
	NSTAR	NEXT	AXFS	XFCM
Mass, kg	11.4	5.0	1.5	1.25
Estimate Footprint, cm^2	1,900*	1,654	800	115
# Channels Controlled	2	3	3	2
Duration to Throttle, min	45	<1	<1	<1
Average Power (Max), W		7.9(81)	<0.01	<0.01

* Does not include plenum tanks

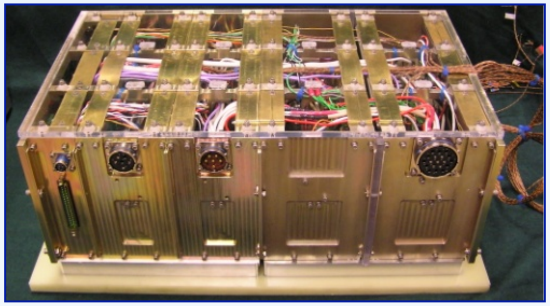
The AXFS was a small investment on feed system technology independent of NEXT to leverage commercial investments and push the limits of technology without adding risk to the NEXT project.

Power Processing Unit (PPU) Options for HIVHAC

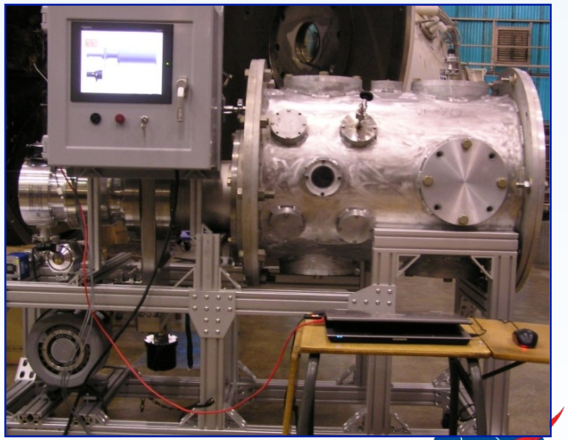
- The functional power requirements of a HIVHAC PPU are that it operates:
  - Power range 0.3 to 3.9 kW
  - Input voltage range 80 to 160 V
  - Output Voltage range 200 to 700 Vdc
  - Output current range 1.4 to 5 A



- NASA is looking at various options to perform some critical design and testing of PPU converter topologies dependent on funding availability.
  - The near term plan is to leverage converter/PPU development by other projects where possible and applicable



- One option for developing a HIVHAC PPU is modifying the design of the BPT-4000 PPU



- Another option is to develop a HIVHAC PPU that is a new custom design

- Within NASA's small business innovative research (SBIR) program, there are three projects that are developing wide range discharge modules for integration with Hall thrusters

Ultra Lightweight Tank Technology (ULTT)
for future planetary missions

Description

- This effort aims to develop the Composite Overwrapped Pressure Vessel (COPV) tanks for propellants and pressurants for Mars Sample Return (MSR) mission
- Tanks are most often the heaviest component on a spacecraft
- Currently component technologies are maturing and ready to be "harvested"

Objective

- To design ultra-lightweight propellant and pressurant tanks sized for MSL/MSR Skycrane with an option to manufacture and qualify.
- Goal: Achieve highest mass saving with reliability

Benefits

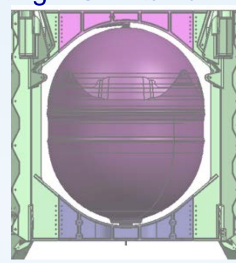
- **23** kg mass savings are achievable for 3 tanks sized for the Skycrane **(48% mass reduction)**
  - Mass savings can be passed on to the scientific payload or increase mass margin
- Broad impact to virtually ALL space missions as most use liquid propellants or pressurant
  - Europa Explorer tank mass can be reduced by 60 kg

Baseline Approach

- To complete CDR design package (August 2012)
- Option: To build and test three (3) Skycrane size tanks
- Option: To ready the tanks for flight demonstration in 2018 or beyond

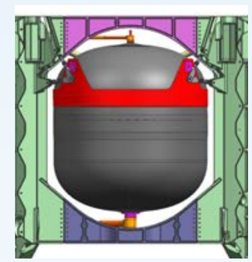
Descent Stage Propellant Tanks

Existing MSL Titanium Tank

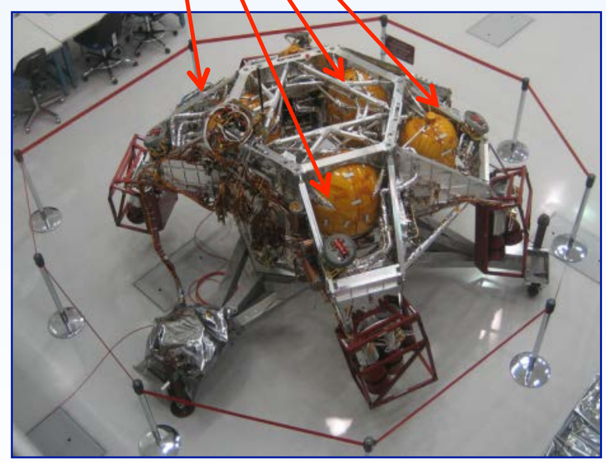


594mm Diameter, ~720mm Tall

Drop in replacement ultralight tank



594mm Diameter, 684mm Tall



NDI for Ultra-lightweight Tank Development

Critical Non-Destructive Inspection (NDI) effort: to establish what crack size can be detected consistently (probability of detection demonstration) using new methods

- JPL and LaRC in-house activity
- NDI results feed into ultra-lightweight tank design and development tasks
  - Detection limit ultimately will set wall thickness of metal liner.
- An automated eddy current inspection technique has been developed and tested for the detection of small fatigue cracks in thin titanium panels.
- The improved detection capability promises to find 0.003 inch cracks reliably, which represents a 2x improvement over state-of-art (SOA) detection techniques.

Indication of .006” deep crack

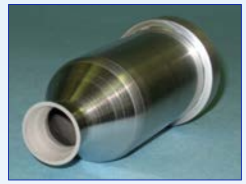
Eddy current NDI technique

Surface wave ultrasonic NDI technique

Advanced Materials Bipropellant Rocket (AMBR)

Objective

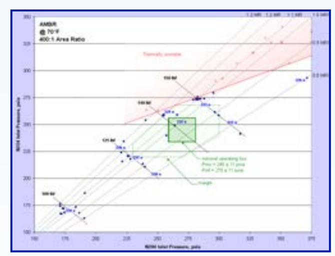
- Improve the HiPAT bipropellant engine Isp performance by fully exploiting the benefits of advanced thrust chamber materials
- Performance
  - * 333 seconds Isp with NTO/N2H4
  - * Over 1 hour operating (firing) time
  - * 140 lbf thrust
  - * 3-10 years mission life (goal)
  - * Lower cost (up to 30% savings on the chamber)



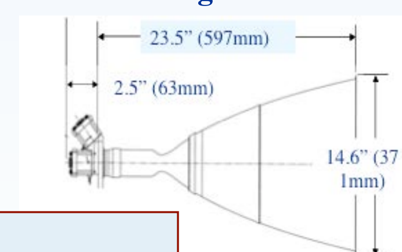
Completed EL-Form Ir/Re Chamber

Total Propulsion System Mass Reduction (Kg)					
Isp (sec)	320	325	330	**332.5**	335
GTO to GEO	0	16	30	**37**	45
Europa Orbiter	NA	0	12	**16**	24
Mars Orbiter	N/A	0	14	**22**	29
T-E Orbiter	N/A	0	29	**45**	60

- **Performance Tests**
  - – Completed 89 engine starts
  - – 9,138s of total firing time (152.3 minutes)
    - ▪ 2,700s (45 minutes) longest single burn duration
  - – 3,935°F (2,160°C) steady state chamber temperature
  - – 99 – 289 psia operating chamber pressure
  - – 333.5 seconds maximum specific impulse
  - – Defined complete operational range
- **Environmental Tests**
  - – Passed qualification level vibration test
  - – Passed shock test
- **Future Use**
  - – Commercial interest, DoD interest, constellation interest, and decadal studies



AMBR Engine Dimensions



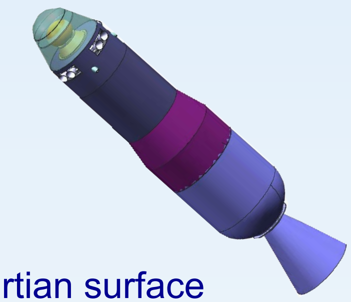
The AMBR technology is an improvement upon the existing HiPAT™ engine

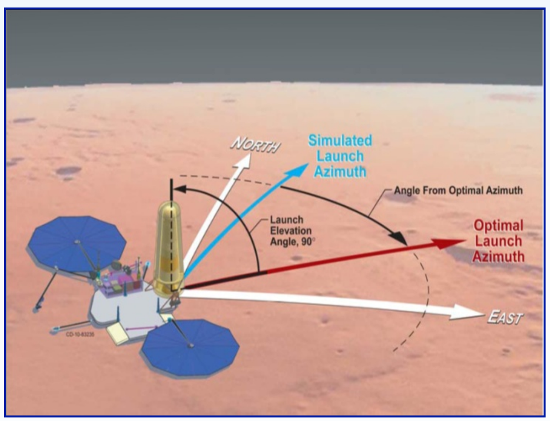
- The HiPAT™ engine is one of the Aerojet Corporation’s R-4D Family of thrusters
- The R-4D family of thrusters carries the heritage: >1000 engines delivered, >650 flown, 100% success

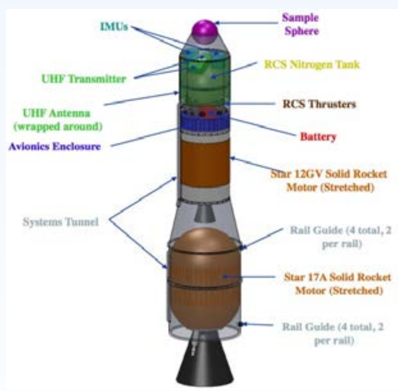
Mars Ascent Vehicle (MAV)

Top Level Requirements

- Launch to Mars orbit
  - 500 km ±100 km
  - 45^o latitude
  - Delta V > 3.3 km/s
- MAV spends 90 + sols on Martian surface
- 5 kg Orbiting Sample (OS), with 0.5-1.0 kg of samples
- Single-fault tolerant avionics & thermal control
- Desire to meet interface requirements of MSL EDL. EDL produces ≥ 20 g's







MAV Notional Development Plan

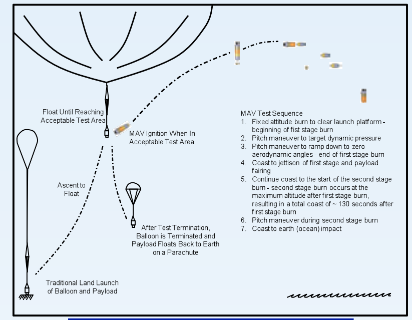
- **Phase 1: Early investment**
  - System definition and development studies (~6 months)
  - Propulsion subsystem development and tests for select MAV concepts (~3 years)
- **Phase 2: Component technology development to TRL 6 and system architecture selections (~3-year, ~$40M)**
  - Develop component technologies to reach TRL6. Test components' performance in realistic temperatures, storage, EDL g-loads as appropriate.
  - Culminates in the final downselect to a single concept, whose high-risk components have known performance and survivability characteristics

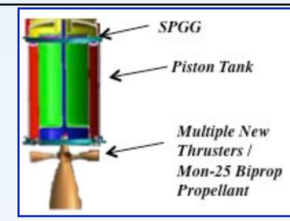
Phase 3: Integrate and develop a MAV. Perform integrated testing and qualification. (~5 years, ~$210M, includes Phase 3 options)

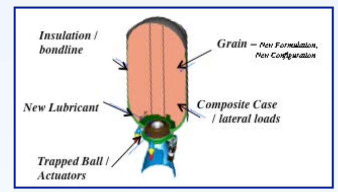
- Perform three high-altitude flight tests to assure at least two successful tests and measure performance prior to MSR lander PDR.
- At least one flight test must be performed on unit that has successfully completed environmental qualification/life testing

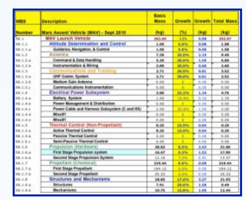
MAV Component Technology Development

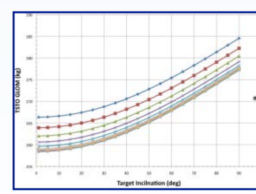
- FY11/FY12 Accomplishments:
  - Awarded three contracts to Lockheed Martin, ATK, and Northrop Grumman
  - MAV: Published MAV study guidelines
  - MAV: Completed Multiple Team-X and COMPASS studies
  - MAV: Completed High Altitude Balloon Test Study
  - MAV: NRA Phase 2 Awards due by end of FY 11 – Not implemented
- Key Issues for FY 12
  - Hold until joint Mars Program Planning Group (MPPG) architecture clarifies options?
  - Initiating certain long-lead tasks (e.g., propellant aging)
  - Possible go-forward options
    - Complete current MAV development to establish technology baseline?
    - Re-compete for alternate architectures (e.g., mobile vs fixed launch) and/or longer-term/higher payoff technologies?
    - Re-vector MAV funds to other propulsion and/or spacecraft bus technology priorities?

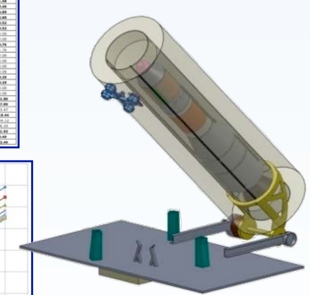








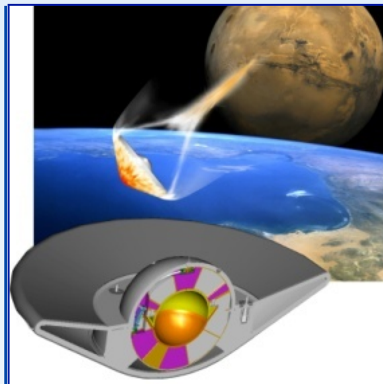


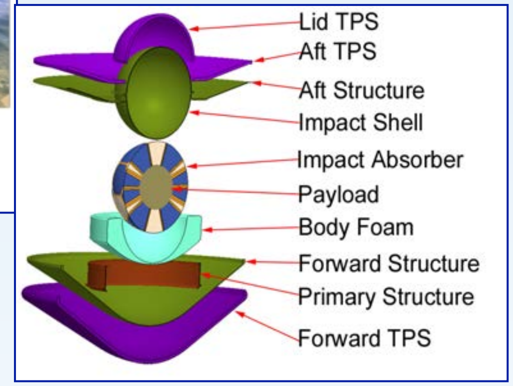


Multi-Mission Earth Entry Vehicle (MMEEV) Technology

Description

- Earth Entry Vehicles (EEVs) are necessary for bringing samples of material from our Solar System safely back to Earth's surface.
- The Multi-Mission EEV approach seeks to develop and implement common design principles on multiple missions such as New Frontiers, Discovery, and eventual planetary sample returns.





Objective

- To develop technologies that enable future sample return missions
- To apply common design features to multiple flights, to improve reliability to the 10^{-6} level

Benefits

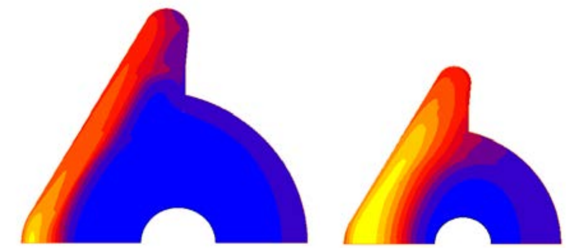
- Maximize efficient use of technology investments, saving Agency costs over the long term
- Establish validation data for risk reduction on future missions that require extremely high probabilities of success.

Discipline Areas

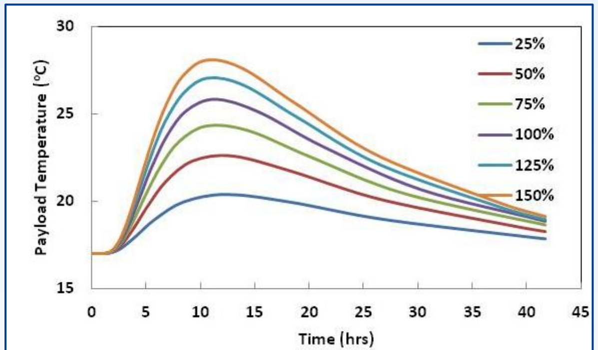
- Materials development
- Aerodynamics
- Aerothermodynamic modeling
- Systems engineering and integration
- Advanced materials for TPS, structures, and impact protection
- Thermal control
- Mechanical Design/Packaging
- Systems Engineering

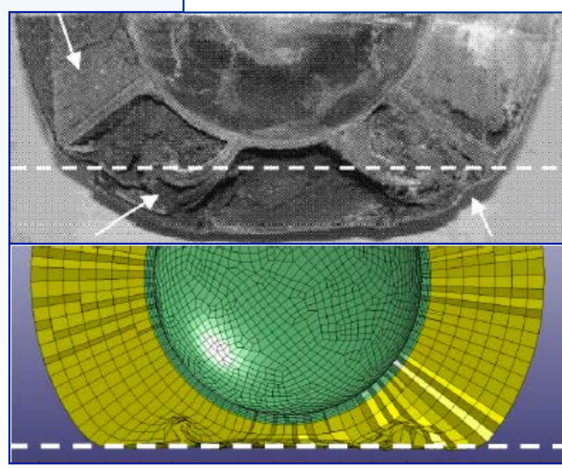
MMEEV Annual Highlights

- Continued development and validation of Multi-mission System Analysis for Planetary Entry (M-SAPE) tool
  - Multi-disciplinary optimization
  - Varying levels of fidelity for design support
- Developed a NASTRAN finite element model for vehicle impact and compared results to previous drop tests
- Developed a parametric Thermal Soak model for MMEEVs; published results
- Completed foam impact testing; thermal properties testing underway



1.6 m diameter   0.9 m diameter





MMEEV Annual Highlights

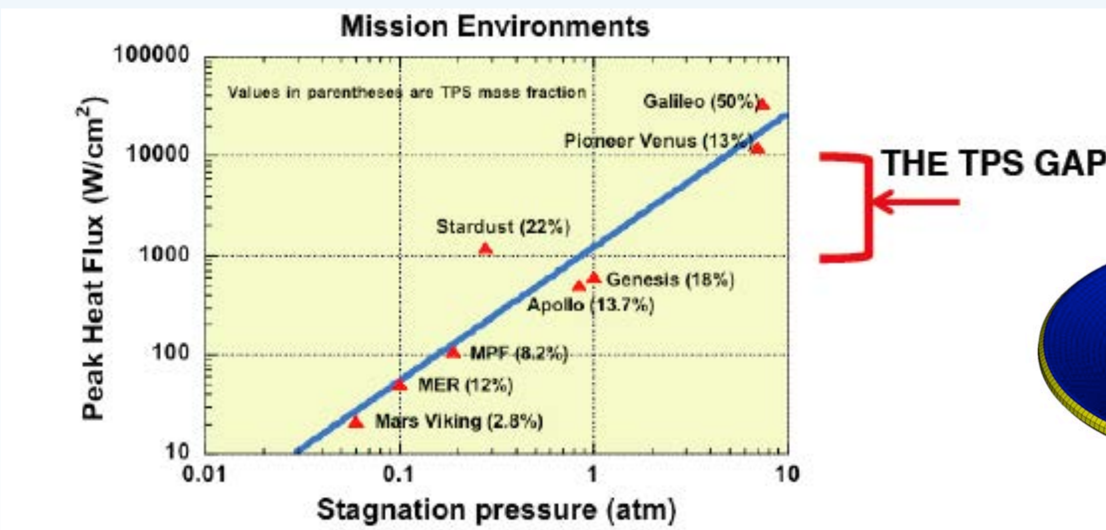
– Completed carbonization of heritage Avtex rayon stock, plus alternate rayons: NARC, LYOCELL, ENKA, and C2B. In storage at ARC.

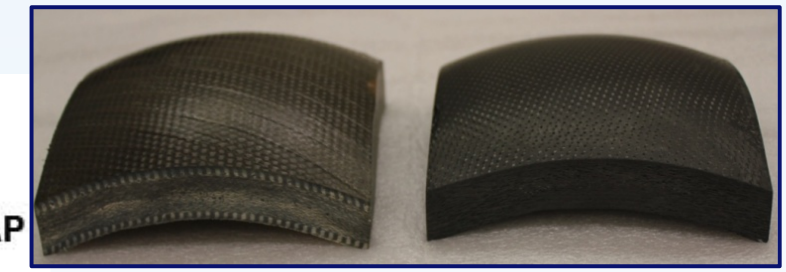
– Received chopped molded carbon phenolic billet from ATK; will be machined this summer for comparison testing in FY13

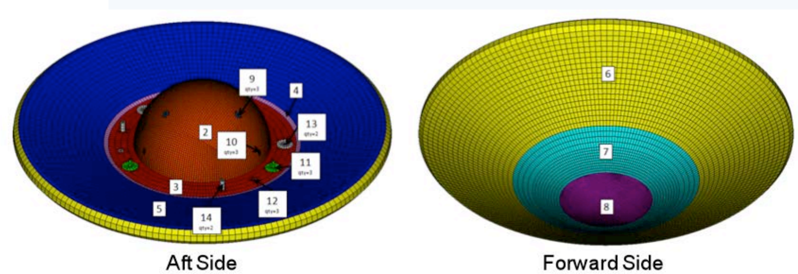
– Conducted 2nd Carbon Phenolic and Beyond Workshop—April, 2012

  • Coordinating TPS investments with NASA's Offices of the Chief Technologist (OCT) and Chief Engineer (OCE)

  • Roadmapping Effort underway to define path to TPS readiness for next SMD mission solicitations



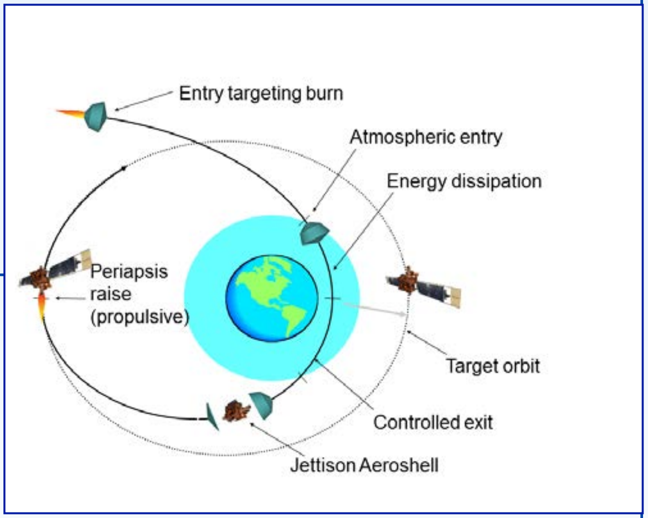




Aerocapture Overview and Benefits

Description

- Aerocapture is a spaceflight maneuver executed upon arrival at a body in which atmospheric drag, instead of propulsive fuel, is used to decelerate the spacecraft into a specific orbit.
- Aerocapture is a natural extension of other commonly-used flight maneuvers using atmospheres: aeroentry and aerobraking.

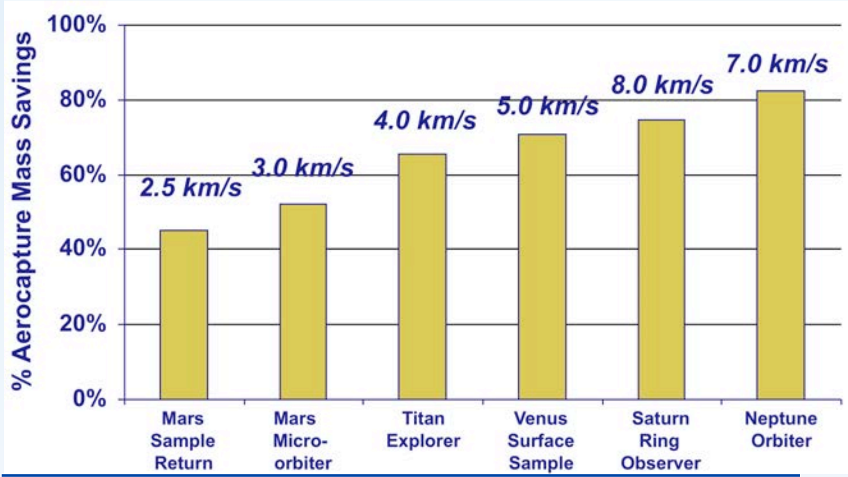


Objective

- To develop Aerocapture systems for exploration of the Solar System and to validate those systems in their relevant environments
- Raise Aerocapture propulsion to TRL 6+ through the development of subsystems, operations tools, and system level validation and verification

Benefits

- All values are compared to the mass of an all-propulsive capture
- Equivalent ΔV from Aerocapture noted above each column



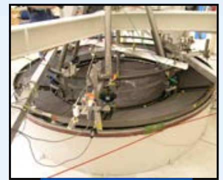
Discipline Areas

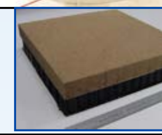
- Aerocapture builds upon well established entry system design processes and tools:
  - Atmospheric modeling
  - GN&C algorithm advancement
  - Materials development
  - Aerodynamics
  - Aerothermodynamic modeling
  - Systems engineering and integration
  - Rigid aeroshell technology including: TPS, structures, adhesives and sensors
  - Inflatable deceleration system concepts

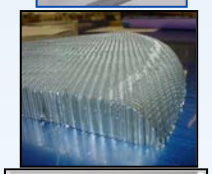
Aerocapture Technology Development Products

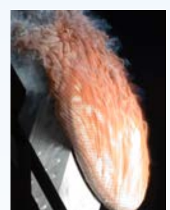
Elements at TRL6 and Ready to Infuse

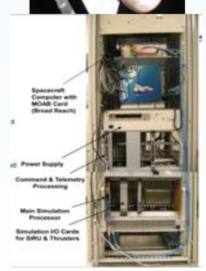
- **Rigid aeroshell and TPS products**
  - **Carbon-Carbon hot structure**
    - 2-meter rib-stiffened 70-deg aeroshell tested and finite element model validated, capable up to 700 W/cm^2, 30% lighter than Genesis capsule equivalent
  - **High-temperature aeroshell structures** (composite and honeycomb sandwich):
    - Composite honeycomb and modified adhesives raise TPS bondline by 65˚C, system stagnation tested to over 300 W/cm^2, 15% lighter than MER
    - Titanium honeycomb and modified facesheet resins and fibers, coupon tested and manufactured at 2.65-meter scale, raises bondline by 150˚C, reducing system mass up to 30% over traditional
  - **Ablative Thermal Protection System Materials**
    - "Family system" approach provides range of densities and robustness levels for wide range of applications: 50 to 1,100 W/cm^2
    - Extensive arcjet testing, application at flat-panel, 1-meter, and 2.65-meter (pending) scales







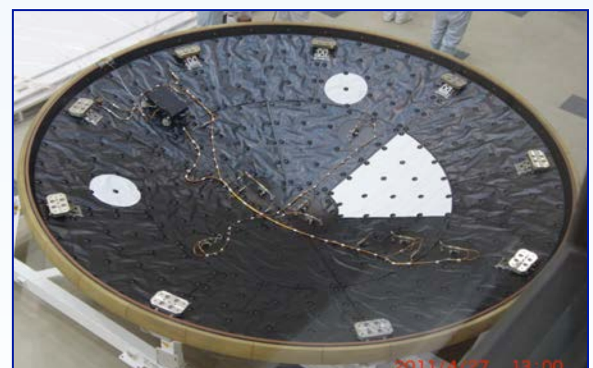




- **Aerocapture Guidance and Control Hardware-in-the-Loop Testbed**:
  - Real-Time simulation testbench written in flight software code, hosted on flight space computer with flight or flight-like interfaces
  - Demonstrates execution within flight-like avionics system, verifies communication paths and the absence of timing issues
  - Brings Analytic Predictor-Corrector Algorithm to TRL6
- **Aerothermal and atmospheric codes**
  - Improved aerothermal prediction capabilities, particularly by validating codes through ground test of fundamental physics
  - Engineering-level atmospheric models developed and improved for nearly every destination in the Solar System; incorporated directly into high-fidelity flight dynamics simulations
- **Aerocapture Quick-Look Tool**
  - End-to-end engineering-level conceptual design and trade tool for assessing aerocapture concepts
  - Available through LaRC software request process

Aerocapture Annual Highlights

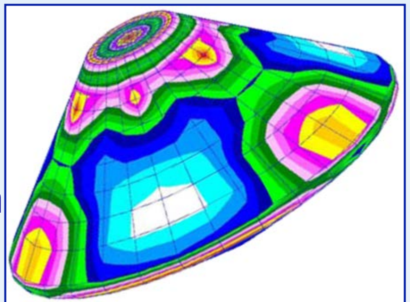
- 2.65-m aeroshell manufacturing demonstration unit complete June, 2012; CT scan by end of CY
- CT scan of Sandia Solar Tower tested advanced 1-m aeroshell
- Space Environmental Effects arcjet testing underway, to be completed August, 2012
- Aerocapture flight test formulation continued, to identify opportunities to advance to TRL7
- MEDLI entering Mars atmosphere on August 6, 2012 - *ISPT hardware infusion*

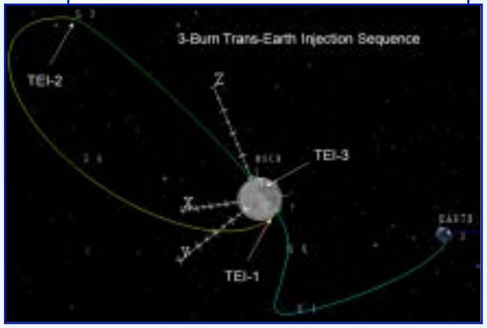


ISPT - Systems Analysis

Objectives:

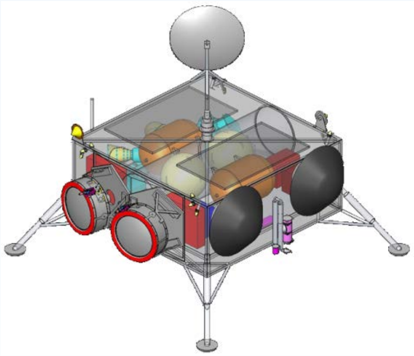
1) Conduct systems and mission studies to prioritize and guide investments and quantify mission benefit of ISPT products.
    - NEXT throttle table, HIVHAC power and life requirements, etc.
2) Develop tools for the user community to assist in ISPT product infusion
    - Low Thrust Trajectory Tool (LTTT) suite
    - Aerocapture Quicklook Tool (a.k.a. SAPE)
    - Advanced Chemical Propulsion System (ACPS) tool





Recent Studies:

1) Barbara SR, Ceres SR, Mars Moons' SR, NEARER, Discovery Cost Viability, etc.
2) Supported ½ of all decadal studies: Uranus, Neptune, Chiron, Trojans, Vesta and Hebe, and Mercury
    - While performing the mission design, infused ISPT products as baseline for every mission!



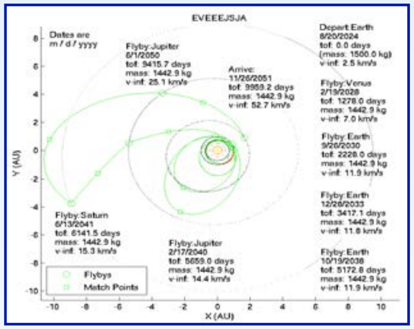
Tool Success:

1) Agency point-of-contact for trajectory analyses (e.g. HILTOP Validation)
2) Provided tool training for MALTO, OTIS, and Copernicus
    - 100s from all NASA centers, academia and industry
    - Copernicus baseline tool for exploration (Constellation)
    - OTIS (GRC Led) NASA Software of the year
3) Mystic used for Dawn mission operations, and tools used in Discovery proposals

Mission Design Tools / Systems Analysis

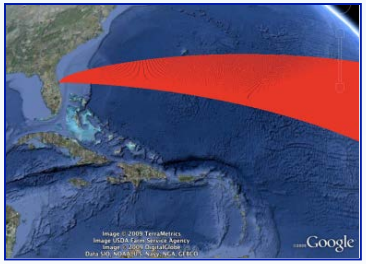
In order to infuse new technologies, users must be able to assess the payoff.

- Sponsored development of Mystic, MALTO, Copernicus, and OTIS
  - Initiated because results could not be independently validated
- Held MALTO training course in 2008
- Held Copernicus training course in 2009
- OTIS training as needed (most recent 2011)
- Aerocapture Quicklook Tool Released in 2010



Mission / system design studies define technology requirements

- Critical to quantify mission benefits before hardware investment
- Mission design for NEXT requirements
- Refocus Study led to NEXT throttle table extension
- Refocus Study led to HIVHAC power range, life requirement
- Decadal study support quantified science benefit for SEP, REP, and AMBR engine technology



"If we want people to buy cars, they need to learn to drive." - Oleson

In-Space Propulsion Technology Summary
Infusion Ready Products

- The In-Space Propulsion Technology (ISPT) portfolio continues to invest in high-priority technologies identified in the 2011 Planetary Decadal Survey
- The ISP Project is completing development of several propulsion technologies in support of future Flagship, Discovery, and New Frontiers missions.
  - **NASA's Evolutionary Xenon Thruster (NEXT)** system development nearing completion
    - Achieved >715Kg Xe throughput. Completing PPU refurbishment and will resume performance and environmental testing.
  - The **AMBR high-temperature chemical thruster** development completed 2009
  - High-priority **aerocapture ground-development** activities are nearing completion
  - Low-cost Hall systems for Discovery-class missions and Earth Return Vehicles (ERV)
    - Completing **High Voltage Hall Accelerator (HiVHAC)** thruster EM Thruster development, and initiating other subsystem technology developments
  - HIVHAC applicable to ERV, transfer stages, and Discovery-class missions.
  - Other recent products include an Advanced Xenon Flow Control System (AXFS), Mixture Ratio Control Balanced Flow Meter (BFM), and the MEDLI sensor which will be used on MSL entry at Mars

ISPT Technology Infusion

- ISPT is pursuing opportunities to take technologies beyond TRL6
  - Technology infusion incentives were offered under the recent Discovery and New Frontiers AO’s for NEXT, AMBR, and Aerocapture
  - Mars Science Laboratory (MSL) using ISPT developed HEAT sensors as part of the MSL Entry, Descent, and Landing Instrumentation (MEDLI) package
  - Working to develop and fabricate 2 flight qualified AXFS. Interest has increased due to pursuing the flight qualification step!
  - Developing ultra-light weight propellant tank design as a drop-in replacement for Skycrane on a future Mars mission.
    - Mission pull/applicability important to get the technology qualified. Goal would be to build and flight-qualify if funding can be arranged.
    - Once this tank design has been qualified, the “validated” technology will be broadly applicable to most spacecraft. Assessing other mission opportunities.
  - Supporting use of ISPT developed technologies on proposals to OCT BAA’s (AMBR, Solar Sails, Balance Flow Meter, and ultra-light weight propellant tank)

- ISPT has several technologies which are ready for infusion
- ISPT has several more technologies which will be ready tech infusion in the next several years
- ISPT is assessing the next set of technologies to enable future planetary science missions

Questions?

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