Planetary Science Division

Planetary Exploration Science Technology Office (PESTO)

Carolyn Mercer
Manager, PESTO
NASA Glenn Research Center

Briefing to the Mars Exploration Program Analysis Group (MEPAG)
April 4, 2018
Crystal City, VA

Planetary Exploration Science Technology Office
(PESTO)

New HQ office managed at GRC to:

Recommend technology investment strategy for future planetary science missions

- Instruments
- Spacecraft Technology
- Mission Support Technology

Manage PSD technology development (non-mission specific, non-nuclear)

- PICASSO, MatISSE, HOTTech, COLDTech, DALI, …

Coordinate planetary science-relevant technologies

- Within the Planetary Science Division, Science Mission Directorate, and Space Technology Mission Directorate, …

Promote technology infusion

- Infusion starts before solicitations are written, ends with mission adoption

Technology Investment Goal: Per the Decadal, 6-8% of Planetary Science Division budget
$110-150M per year for technology, excluding infrastructure investments or sustainment

Jim Green
PSD Division Chief

David Schurr
PSD Deputy Division Chief

Tibor Kremic
GRC Science Office Chief

Len Dudzinski
PSD Chief Technologist

Jonathan Rall
PSD R&A Director

Planetary Exploration Science Technology Office
Headquarters Office, Managed at Glenn

New office – these roles may change!

Carolyn Mercer – Propulsion, Autonomy
Jim Gaier – Instruments
Ryan Stephan – Heat Shields, COLDTech, Lunar
Viet Nguyen – HOTTech, Precision Landing
Pat Beauchamp – Mars, Assessment Reports
Dave Anderson – Structures/Materials, Financial
Rainee Simons – Instruments, Communications

Ad Hoc members for Strategy
Florence Tan
Stephanie Getty

PICASSO
Jim Gaier

MatISSE
Rainee Simons

HOTTech
Viet Nguyen

COLDTech
Ryan Stephan

DALI
Jim Gaier

Existing program managers remain managing the existing programs

Planetary Exploration Science Technology Office

PESTO

Investment Strategy

- Identified high priority technologies
- Quantifying Technology Goals, State-of-the-Art, and Science Case for each high priority tech
- Writing Investment Strategies for each
- Conducting Technology Reviews
- Assessing Technology Development Costs

Coordination

- Earth Science, Heliophysics, Astrophysics
- Space Technology Mission Directorate
  - SBIR/STTR
  - Early Stage Innovation
  - Space Technology Research Institute
  - Small Spacecraft Program
  - Game Changing Development Program
- Human Exploration and Operations Mission Directorate

Management

- **PICASSO** – low-TRL Instruments
- **MatISSE** – mid-TRL Instruments
- **DALI** – Lunar Instruments
- **COLDTech** & **Icy Satellites** – Instruments and Spacecraft Technology for Ocean Worlds
- **HOTTech** – spacecraft technology for Venus

Infusion

- Focus Solicitations
  - Infusion begins before the solicitation is written
- Infusion Mentors
  - Bring flight perspective early on
- Workshops
- TRL Assessment / Advancement
- Communication

How to determine “the most important technology items”?

- Planetary Technology Working Group Members surveyed the VEXAG, OPAG, SBAG, Mars Program, and the Decadal Survey

- Then assessed each technology identified by the AGs using the following Figures of Merit:
  - Critical Technology for Future Mission(s) of Interest
  - Degree of Applicability across PSD Missions/needs
  - Work Required to Complete
  - Opportunity for Cost Sharing
  - Likelihood of Successful Development and Infusion
  - Commercial Sustainability

- Corporate knowledge includes previous studies, e.g.:
  - *“NASA Planetary Science Division Technology Plan,” P. Beauchamp et. al, 12/20/2015*
  - *“Planetary Science Technology Review Panel,” T. Kremic et. al, 7/29/2011*
  - *“PSD Relevant Technologies,” G. Johnston 1/7/2011*
  - https://solarsystem.nasa.gov/missions/techreports

	TRL 6 and above
	High TRL - limited development and testing needed
	Moderate TRL - major R&D needed
	Low TRL - notable technical challenges

Outer Planets input based on the OPAG white paper "Outer Planet "Roadmap of 2009

Community Technology Inputs

(VEXAG, OPAG, SBAG, Mars Program, Decadal, Surveys)
from: Planetary Science Technology Plan, April 9, 2015

		This decadal					Next decadal					After that				
		NEAR TERM MISSIONS					MID TERM MISSIONS					FAR TERM MISSIONS				
	Applicable Technology	Small Bodies	Outer Planets	Venus	Mars	Moon	Small Bodies	Outer Planets	Venus	Mars	Moon	Small Bodies	Outer Planets	Venus	Mars	Moon
SYSTEM TECHNOLOGIES	In Space Propulsion															
	Aerocapture/Aeroassist															
	Entry (including at Earth)															
	Descent and Deployment															
	Landing at target object															
	Aerial Platforms															
	Landers - Short Duration															
	Landers - Long Duration															
	Mobile platform - surface, near surface															
	Ascent Vehicle															
	Sample Return															
	Planetary Protection															
SUBSYSTEM TECHNOLOGIES	Energy Storage - Batteries															
	Power Generation - Solar															
	Power Generation - RPS										?					
	Thermal Control - Passive															
	Thermal Control - Active															
	Rad Hard Electronics															
	Extreme Temp Mechanisms															
	Extreme Temp Electronics															
	Communications															
	Autonomous Operations															
	GN&C															
INSTRUMENT	Remote Sensing - Active															
	Remote Sensing - Passive															
	Probe - Aerial Platform															
	In Situ - Space Physics															
	In Situ Surface - Geophysical															
	Sampling															
	In Situ Surface - Long Duration - Mobile															

Planetary Science Division High Priority Technologies

April 2016

PLANETARY TECHNOLOGIES

- Electronics (high temperature)
- Communications (high bandwidth, high datarate)
- Solar Power (low intensity, low temp)
- Power Systems (high temperature)
- RPS surface power
- RPS orbital power
- System autonomy (GNC, Prox Ops, C&DH, sampling ops, FDIR)
- Small Spacecraft Power, GNC, Propulsion, Comm
- Planetary Ascent Vehicle for Sample Return
- Heat Shield technologies for planetary entry and sample return
- Computing and FPGAs (high performance/low power/rad hard)

INSTRUMENTS

- Life Detection for Ocean Worlds
- Low mass, low power instruments for cold, high rad ocean world environments
- Low mass, low power instruments for small spacecraft

OCEAN WORLDS

- Electronics (low temp, low power, rad-hard)
- Actuators/mechanisms (low temp)
- Planetary Protection Techniques/component and material compatibility
- Ice Acquisition and Handling (>0.2 m depth)
- Ice Sample Return
- Pinpoint Landing on Titan

EUROPA

- Ice Acquisition and Handling (surface, cryo)
- Batteries (low temp)
- Pinpoint Landing on Europa
- Landing Hazard Avoidance

Planetary Technologies

- **High-Temperature Compatible Electronics**
- **High Bandwidth, High Data Rate Communications**
  - Large Deployable Reflectors and High Power TWTs
- **Low Intensity/Low Temperature Solar Power**
- **High-Temperature Compatible Power Systems**
  - Batteries
  - Power Generation
  - Low-Intensity High-Temperature Solar Cells
- **RPS Power**
  - Orbital and Surface: Radioisotope Thermoelectric Generator – eMMRTG
  - Orbital: Radioisotope Thermoelectric Generator - Next Gen RTG
  - Orbital and Surface: Dynamic RPS
- **System Autonomy**
  - Autonomous Navigation for EDL
  - Reactive Science Autonomy
  - Efficient Planetary Surface Science Ops
- **Small Spacecraft**
  - Propulsion – Electric & Non-Toxic Chem
  - Power, GNC,& Communications
- **Planetary Ascent Vehicle for Sample Return - Mars Ascent Vehicle**
- **Heat Shield Technologies for Planetary Entry and Sample Return**
  - Thermal Protection Systems
  - Aerocapture
- **High performance/low power/rad hard computing and FPGAs**
  - Chiplet Augmentation, Advanced Space Memory, Co-Processors/Accelerators, System Software, Development Environment, Power, Computer

Prioritized Technologies: Mars

Funded by Mars Program

- **Planetary Ascent Vehicle for Sample Return - Mars Ascent Vehicle**
- **System Autonomy**
  - Efficient Planetary Surface Science Ops (Roving autonomy – site selection)
  - Autonomous Navigation for EDL Terrain Relative Navigation
  - ~~Reactive Science Autonomy~~
- **Heat Shield Technologies for Planetary Entry and Sample Return**
  High reliability entry systems

Existing RPS program

- **RPS Power**
  - Orbital and Surface: Radioisotope Thermoelectric Generator – eMMRTG
  - Orbital: Radioisotope Thermoelectric Generator - Next Gen RTG
  - Orbital and Surface: Dynamic RPS

- **Small Spacecraft** DRAFT TIER 1 (propulsion)
  - Propulsion – Electric & Chemical
  - Power, GNC,& Communications

- **High Bandwidth, High Data Rate Communications** DRAFT TIER 2
  - Large Deployable Reflectors and High Power TWTs

- **High performance/low power/rad hard computing and FPGAs** DRAFT TIER 3
  - Chiplet Augmentation, Advanced Space Memory, Co-Processors/Accelerators, System Software, Development Environment, Power, Computer

- **High-Temperature Compatible Electronics and Batteries**
  - **As needed for planetary protection**

- **NEW Micro-landers on Mars**
- **NEW Aerial mobility on Mars**

Prioritized Technology: Small Satellites – Electric Propulsion

Technical Goal

(1) Long-duration thruster firings are required to generate high delta-V, therefore high Isp is needed to reduce the propellant mass and volume to fit within a SmallSat. Rad-tolerant to survive long-duration flight in deep space. Requires high power solar arrays.

a. Packages to 3U-4U. 150-300 W (I_2 or Xe) (1300 – 1500 sec, 2,000 to 10,000 hours).

b. ESPA-class. 300-600 W (Xe or I_2) (1300 – 1500 sec, 6,000 to 10,000 hours(.

(2) System packages to <1U. Rad-tolerant to survive long-duration flight in deep space. <100 W, 0.1 to 1.2 mN, 2000-5000 sec Isp, 5,000 to 15,000 hours. Typically BIT (Xe or I_2), or electrospray (ionic liquids).

Mission Applications

(1) Direct transportation to the moon, Mars, Venus, and main asteroid belt from GTO; higher power missions e.g. to Europa.

a. CubeSat missions

b. ESPA-class missions, enables larger science payload.

(2) Enables low power, rideshare missions <12U. Missions like LunaH-Map, Lunar IceCube, and DAVID. No new power system requirements.

Technical Status

The gap is lifetime.

1) 100 to 600 W electric thrusters performance has been demonstrated with the required Isp and thrust. Flight-like power processing units have not been developed (compact, high power density, rad hard). Iodine cathodes have not yet been developed.

a. 200 W Xe thrusters have demonstrated 1800 hours of operation (then soft failure), and 80 hours using iodine propellant (test ended before failure). 200 W, 30 krad iSat flight PPU being built.

b. 600 W I_2 thrusters have demonstrated 80 hours of operation (test ended before failure). 600 W brassboard PPU being built

(2) 100 microNewton thruster performance demonstrated to 200 hours until failure (MIT). In-space demo with limited operability (MIT 2015 and 2016, Busek 2018). BIT thruster 500 hour life test. MicroNewton thrusters flew on LISA Pathfinder.