Advanced Propulsion Technologies
October 29, 2014
### In-Space Propulsion

R&D investments in key areas enable evolved capability and offer modest gains in capability – progress is predictable.

**TODAY**
- ARM Mission
- AES / NCPS
- E-Cryo Lander

**CREW FLY-BY**
- Electric / Plasma Propulsion
- Nuclear Thermal Propulsion

**CREW STAY**
- Chemical Propulsion

**BASES & SETTLEMENTS**

### Advanced Propulsion

Sustained fundamental research enables possibility for new, revolutionary technologies - progress cannot be predicted.

**Antimatter**

**Pulsed Fission/Fusion**

**Gas Core NTR**

**Advanced Energy Physics**

**Pulsed Fusion**

**Pulsed Fission**

Emerging High-Capability Propulsion Concepts

Sustained, Low-Level Funding

Research in Advanced Energetic Processes and Concepts
A Prototype Engine for Additive Manufacturing
TRL Advancement

Injector Water Flow Testing
Injector Body with Lox Dome
Lox Pump Components
AM Turbine Bowl, with Bypass and Turbine Exhaust Nozzle
Development for nozzle and MCC liners
Fuel Pump Components
Assembled Valve and Actuator
Main Chamber Liner
Main Chamber Manufacturing
Iodine Satellite (iSAT) Project

iSAT is the maturation of iodine Hall technology to enable high ΔV primary propulsion for small satellites culminating in a technology flight demonstration targeted for 2017.
Marshall is developing the solar sail propulsion system for NEA Scout and Lunar Flashlight, drawing from our extensive history in solar sail technology development.

Solar sails derive thrust by reflecting sunlight and therefore never run out of fuel, enabling many heretofore impossible robotic missions.

20-m ground demos (MSFC Program Management 2005)

~9-m NEA Scout (MSFC / JPL 2017)

~9-m Lunar Flashlight (JPL / MSFC 2017)

3.5-m NanoSail-D (MSFC 2010)
Nuclear thermal propulsion (NTP) is a fundamentally new capability enhancing mission opportunities to Mars and beyond

- Energy from fission, not chemical reactions—virtually unlimited energy density

**Enables shortest trip times with less launches**

- Exposes astronauts to less galactic cosmic radiation and zero-g time

**Higher Technology Readiness Level (TRL)**

- Current TRL 4 for fuel and TRL 5-6 for non-nuclear “rocket” engine components (due to materials/environment)
- Flight demo mission in 2020s and human mission to Mars by 2030s

**Affordable Development Strategy**

- Currently working fuel element development at Oak Ridge National Laboratory and Marshall Space Flight Center
- Affordable non-nuclear testing to help resolve significant issues (including fuel endurance at temperature) using Marshall Nuclear Thermal Rocket Element Environmental Simulator (NTREES), Compact Fuel Element Environmental Test (CFEET) System, and other capabilities
- Possible use of low enriched uranium to reduce cost and schedule and increase programmatic flexibility
Fusion Propulsion Research

Round trip to Mars in 7 months (20 year development time)

Experimental and Theoretical Fusion

Z-Pinch

Lithium Deuteride Plasma Column

Developing Thermonuclear Propulsion

D^6 Li Nozzle

D^4 Li fuel

Thrust