In-Space Propulsion

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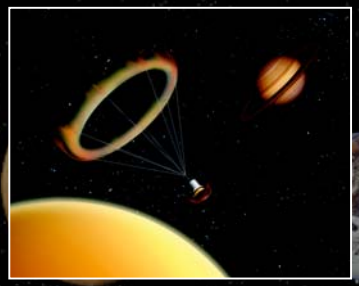
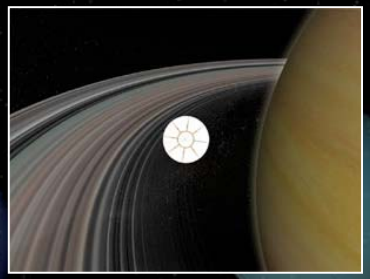
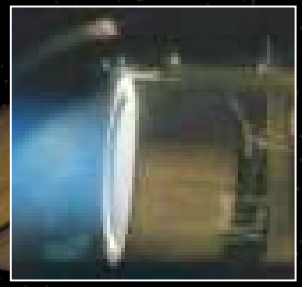


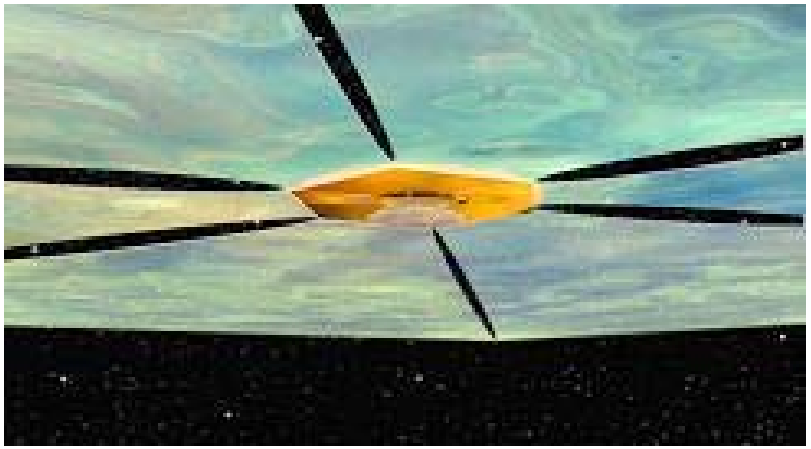
In-Space Propulsion Project (ISP) Objective:

To develop in-space propulsion technologies that can enable and/or benefit near and mid-term NASA science missions by significantly reducing cost, mass, and/or travel times.



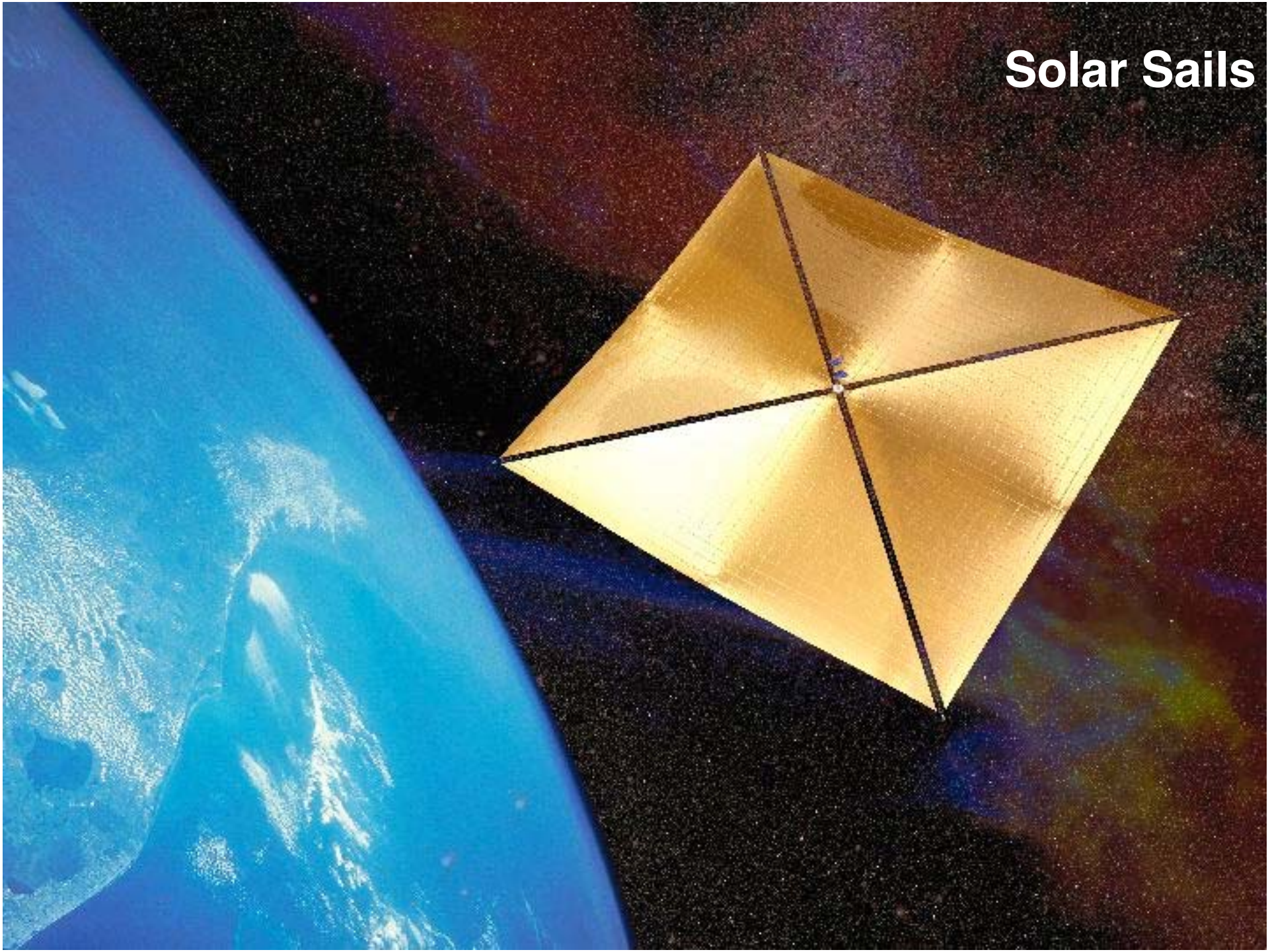


In-Space Propulsion Program Overview

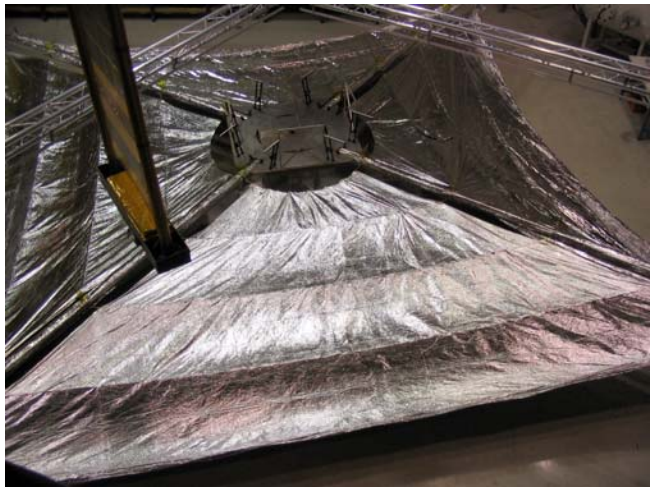


- In-Space Propulsion is managed by the NASA Science Mission Directorate
- ISP competes the majority of its technical work via the NRA process
  - ROSS
- Directed efforts
  - To fill "gaps" in competed technology program

- **High Priority Technologies:**
  - Solar Sail Propulsion
  - Aerocapture Technologies
  - Next Generation Electric Propulsion (solar electric)
- **Other Technologies**
  - Chemical & Thermal Propulsion
  - Emerging Propulsion Technologies


Solar Sails

Solar Sails Ground Technology Efforts



General Description:

Propellantless propulsion utilizes solar photon pressure (<9 Newtons/km^2) to obtain thrust. Sail film is compactly stowed for launch and deployed / supported by ultra-light weight trusses.

Technology Benefits:

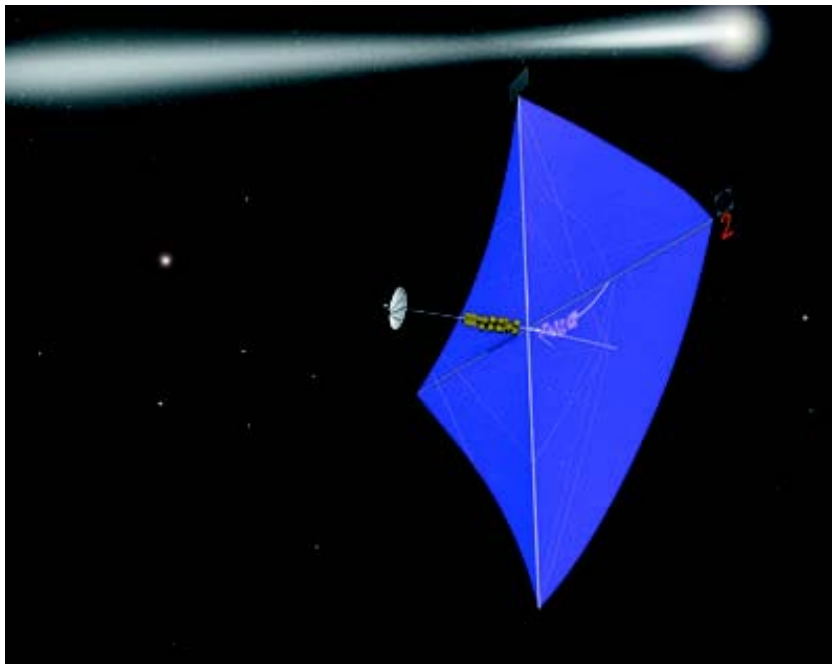
- No propellants required
- Low system complexity (challenge is scaling to large area with ultra-low density)
- Low environmental impact on payload
- Enables access to previously inaccessible orbits (e. g., non-Keplerian, fixed reference, and high solar latitudes, etc.)

Technology Area Status:

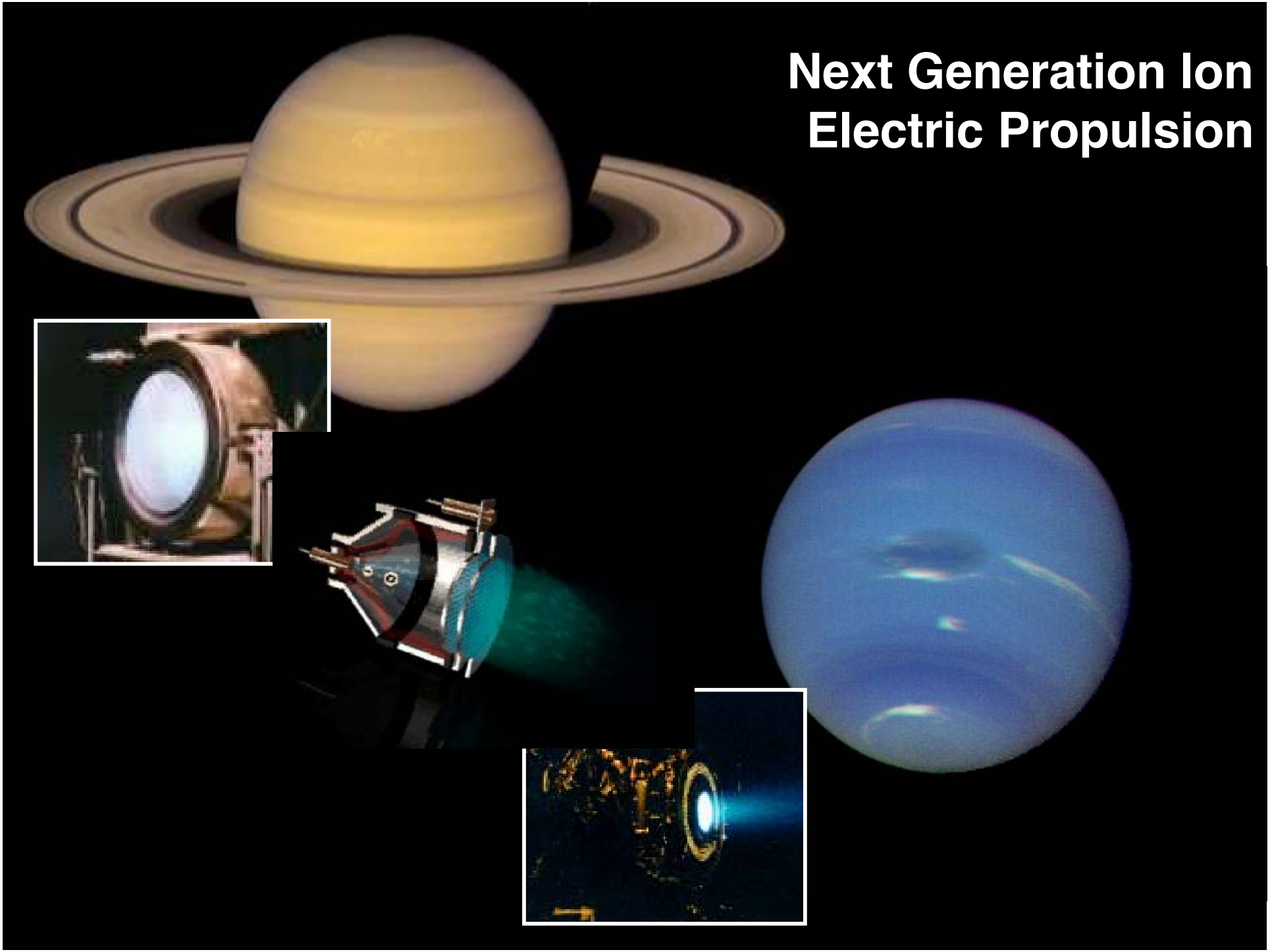
- Two awards to design, fabricate and test competing Sail concepts for system level ground demonstration
  - 10 m Ground demonstrations completed
  - 20 m Ground demonstration planned for mid FY05
- Multiple awards to develop and test high-fidelity computational models, tools, and diagnostics.
- Long term environmental evaluation of ultra-thin sail material

Solar Sail Propulsion Flight Validation

- **The In-Space Propulsion Technology Program is negotiating a partnership with the New Millennium Program for co-funding a potential flight validation demonstration on ST-9.**
  - One of two possible ISP/NMP partnerships (the other being aerocapture)
  - Provides continuity of technology advancement from ground to flight

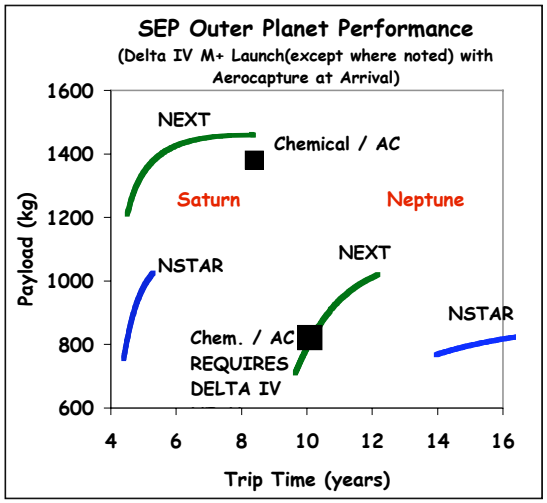


Next Generation Ion Electric Propulsion



Next Generation Electric Propulsion

GRC's NEXT Thruster



Technology Description

Electric propulsion is most broadly defined as the acceleration of propellants by electrical heating, electric body forces, and/or magnetic body forces. Electric propulsion devices are capable of generating low thrust for long periods of time. The final velocities for many destinations are at least the same or higher than that achieved with chemical propulsion, because electric rockets accelerate much longer.

General Benefits:

- Low propellant consumption (_V. High performance)
- Reduced insertion mass, lower launch costs
- Reduced planetary trip times
- Reduced propulsion /payload mass fractions over SOA chemical

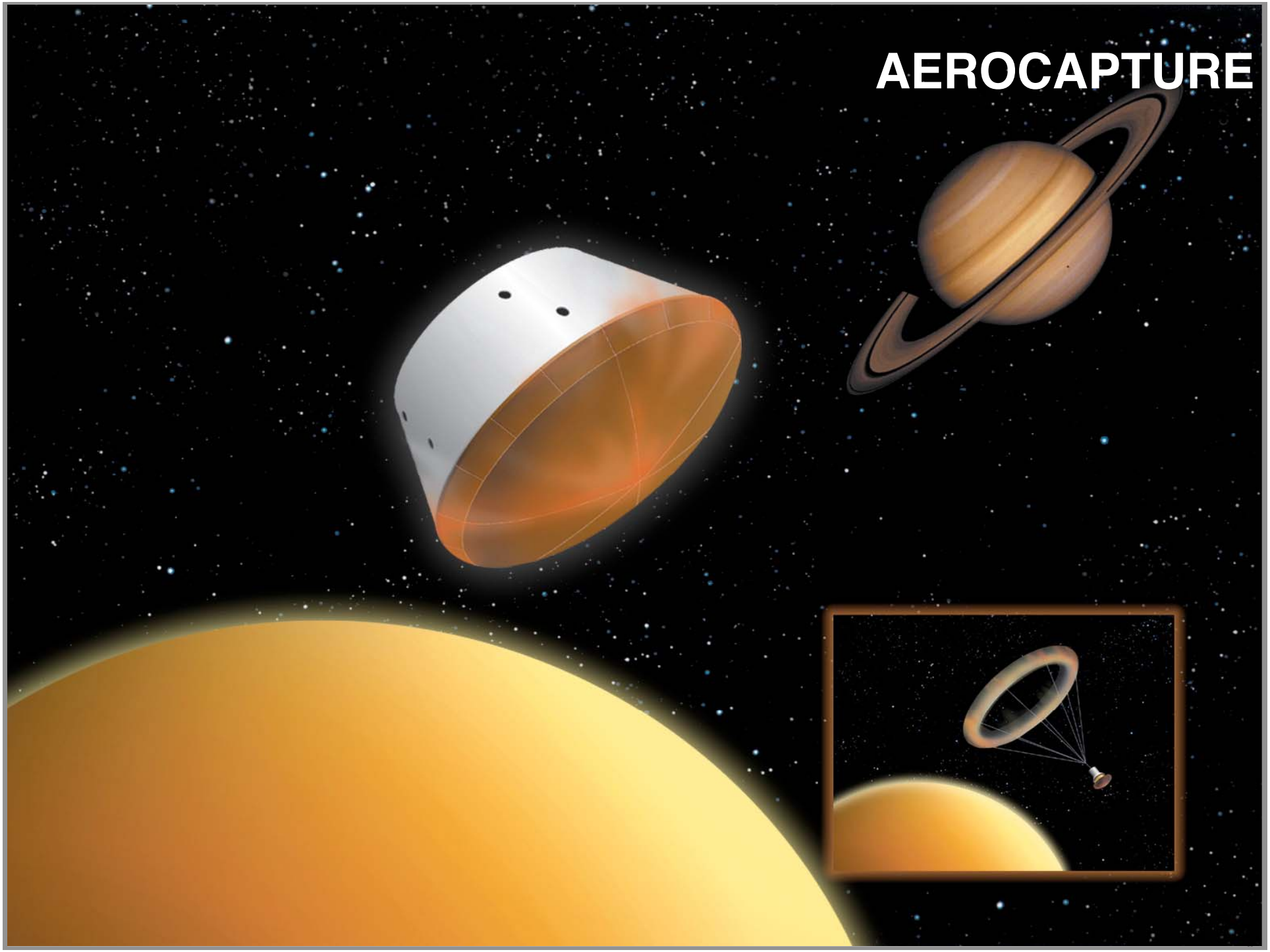
Ion Propulsion Technology Status:

- The ground test of the NSTAR Ion engine completed over 30,000 hours of thruster operation, demonstrating >225 kg of propellant throughput – hardware is currently being analyzed to provide thruster "wear" data to ongoing thruster development efforts.
- Development of NASA's advanced Ion Propulsion system (NASA's Evolutionary Xenon Thruster - NEXT) at GRC has already produced a EM 40-cm thruster, a breadboard PPU, and a breadboard PMS. These subsystem components have been successfully integrated and tested in a single string system test. On-going efforts will develop flight-prototype and engineering model units for long duration life and multi-thruster system testing. NEXT is expected to reach TRL 6 in CY2006, except for full life testing. Advancements over state of the art (NSTAR) are provided below.

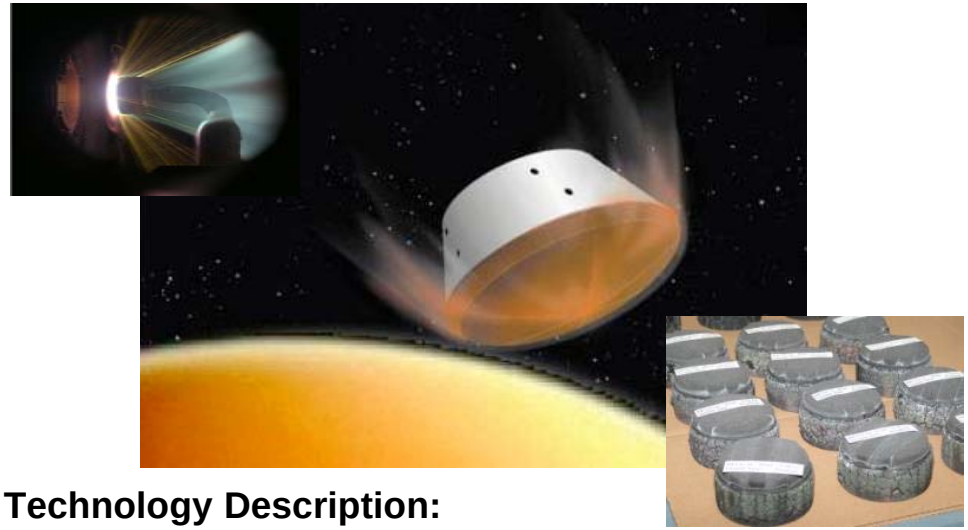
Thruster Attribute	*NSTAR*	*NEXT*
Max. Input Power, kW	2.3	Up to 7
Throttle Range	4:1	Up to 7:1
Max. Specific Impulse, S	3,170	4,050
Efficiency @ Full Power	62%	68%
Propellant Throughput, kg	83 design	>270
Specific Mass, kg/kW	3.6	~2.5

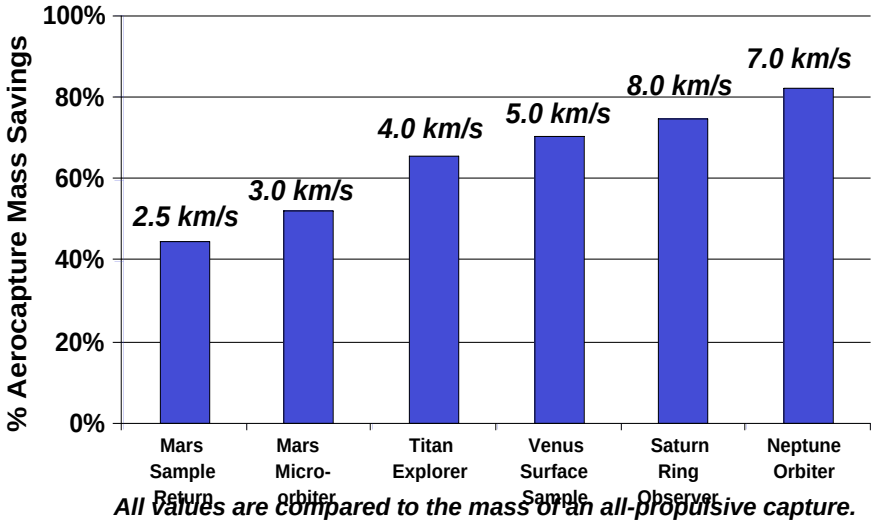
- Other technology activities include development of Carbon-based Ion Optics for 40-cm Ion thrusters (Pyrolytic-Graphite & Carbon-Carbon grids)

AEROCAPTURE



Aerocapture





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

Technology Description:

Aerocapture technology uses the atmospheres of bodies to reduce the speed of a vehicle allowing for quick, near-propellantless orbit capture. The atmosphere is used as a brake, transferring the energy associated with the vehicle's high speed into thermal energy.

Benefits:

- Capable of high delta V at target arrival (multi-g deceleration).
- Significant reduction in trip times to outer planets (by allowing higher Earth departure or encounter energies).
- No or very little propellant required for orbit insertion/entry; saves mass which can save cost or enable greater scientific return.
- Autonomous aerodynamic control technology also enables precision landing.

Technology Area Status

- Four awards developing advanced TPS concepts, structures and adhesives to enable a low-mass aeroshell with integrated TPS – hardware development and tests are underway
- Trade Studies, conceptual design, and hardware development and testing in the areas of advanced aerodynamic decelerators (trailing ballutes, attached ballutes and inflatable aeroshells)
- Heat flux and recession sensors in development for rigid aeroshells. Preliminary sensor design complete, fabrication underway.
- In-depth systems definition studies of aerocapture at Titan and Neptune complete. Systems definition study of aerocapture at Mars and Venus to begin in FY05.

Summary

- **Solar Sail Propulsion is one of three high priority technologies within the In-Space Propulsion Technology Program's portfolio**
- **An ISP goal is to mature the technology to the point that a flight program can successfully implement solar sail propulsion on a science mission**
- **Flight validation of solar sail propulsion is an essential step toward mission implementation**
  - ST-9 is the near-term flight validation opportunity