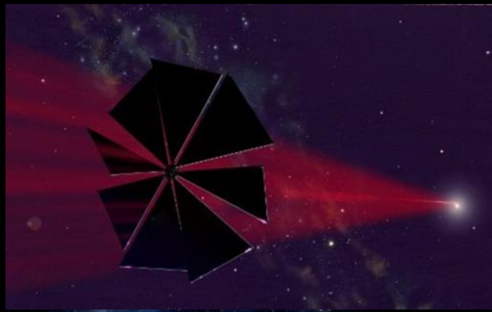
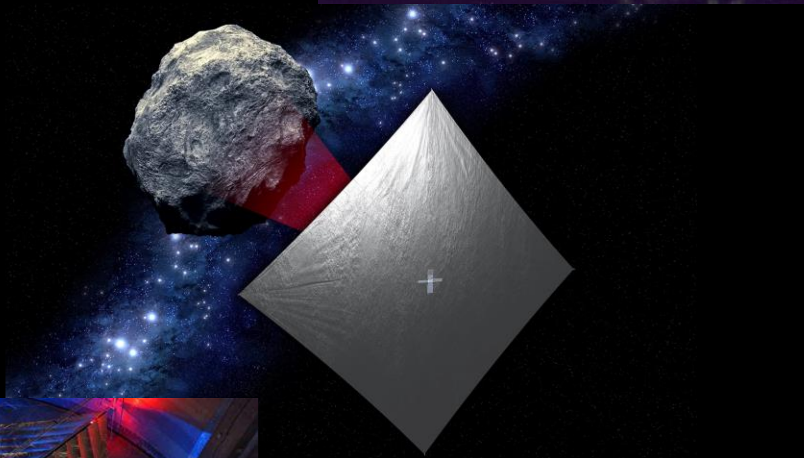
The Long Slog toward Technology Flight Demonstration

One PI’s Journey and Lessons Learned

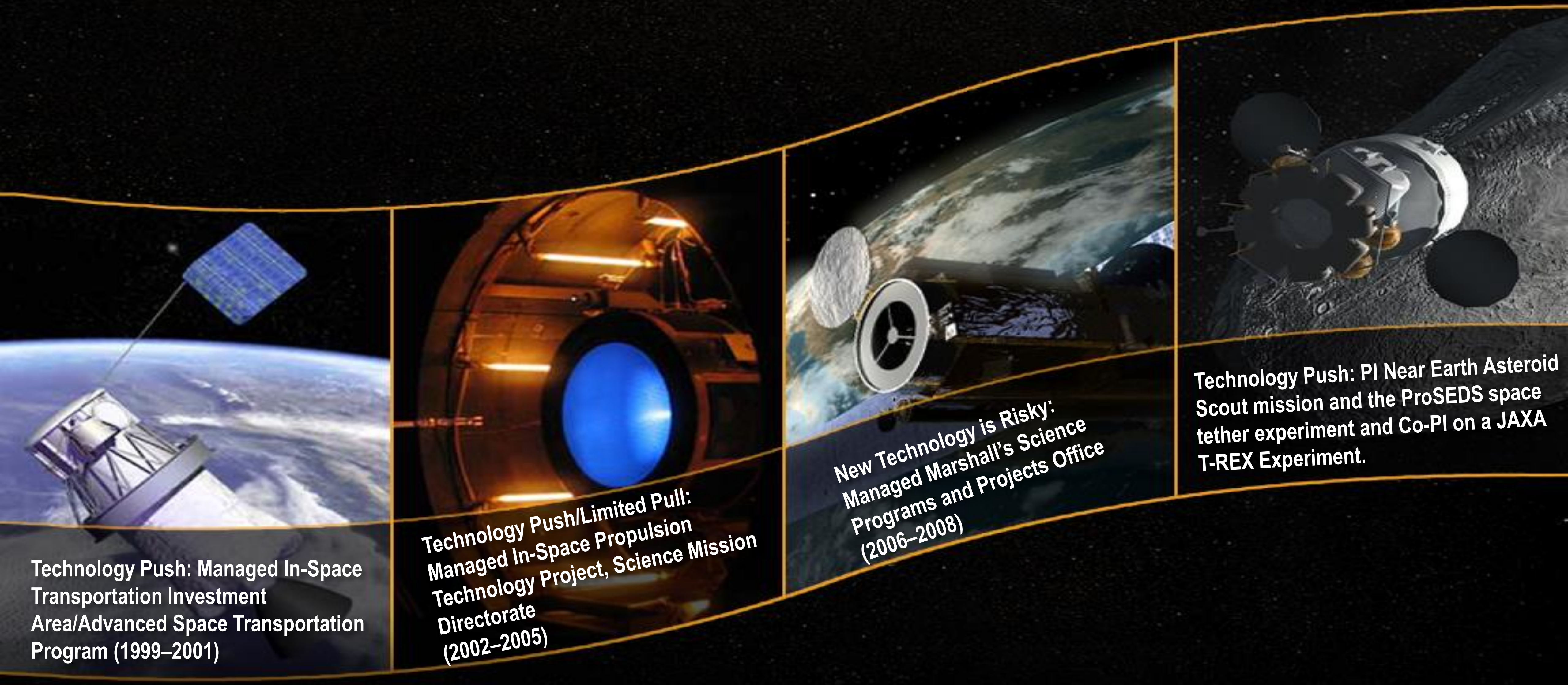




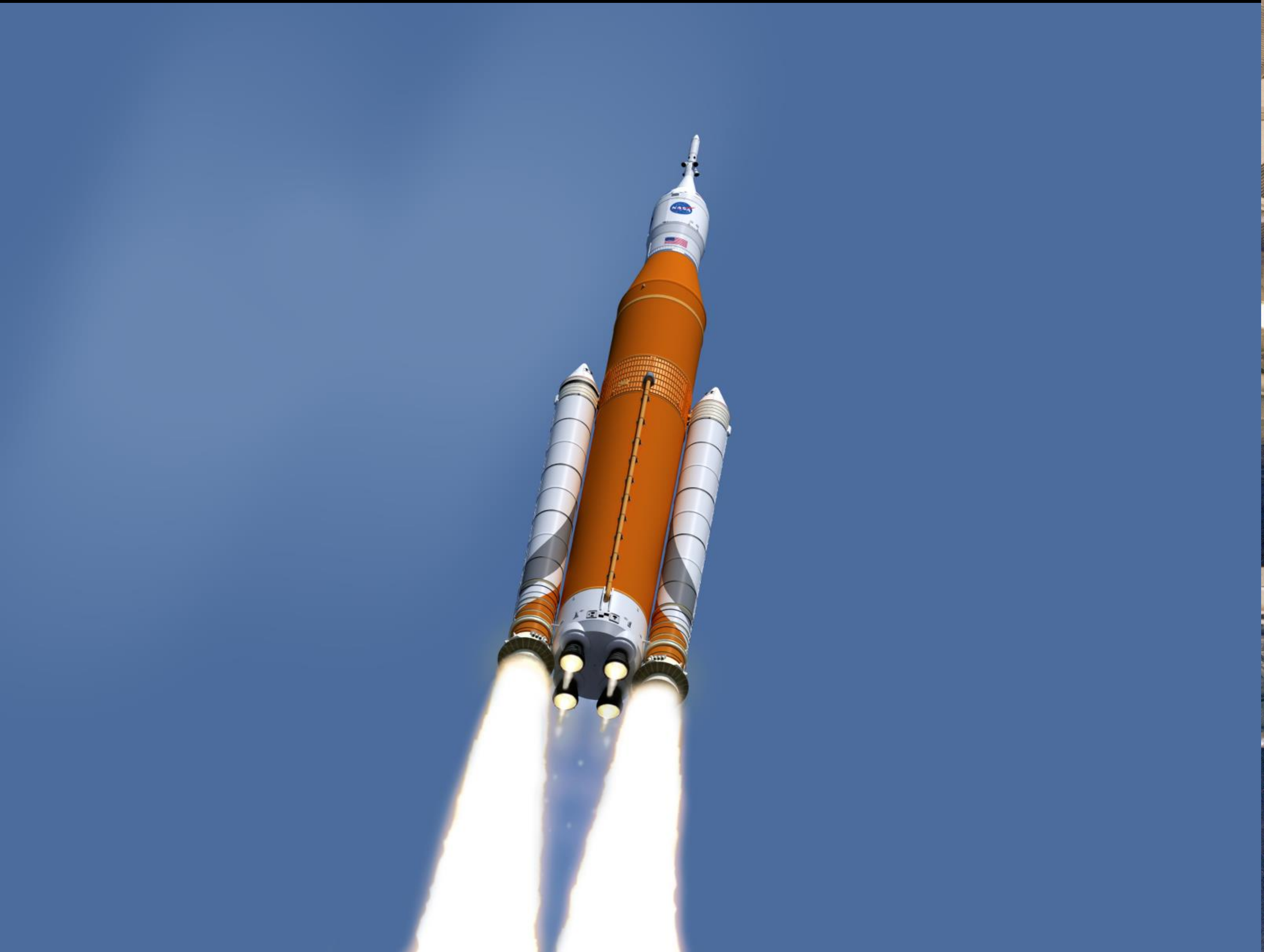
Les Johnson

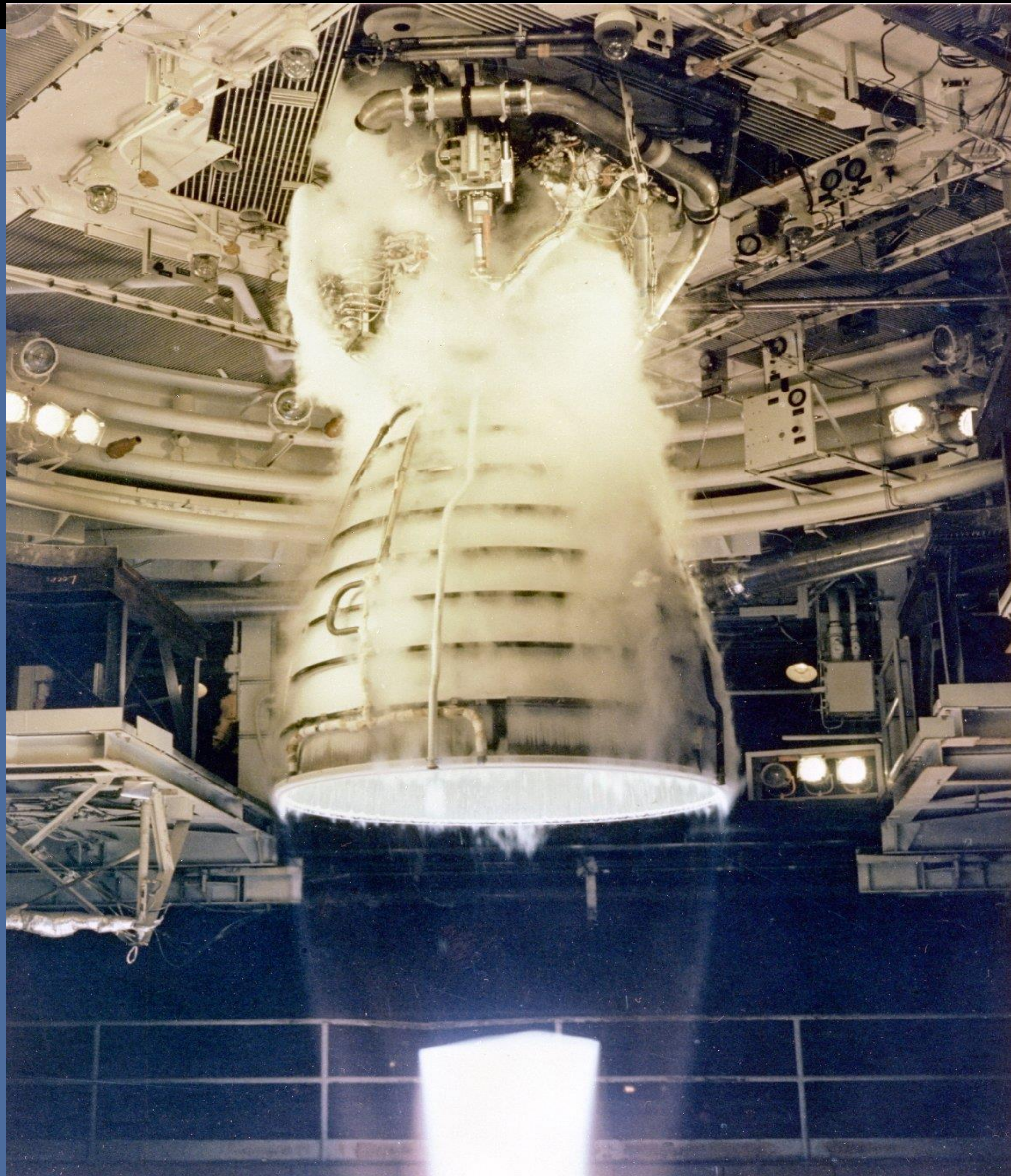
NASA George C. Marshall Space Flight Center

The Long and Winding Road



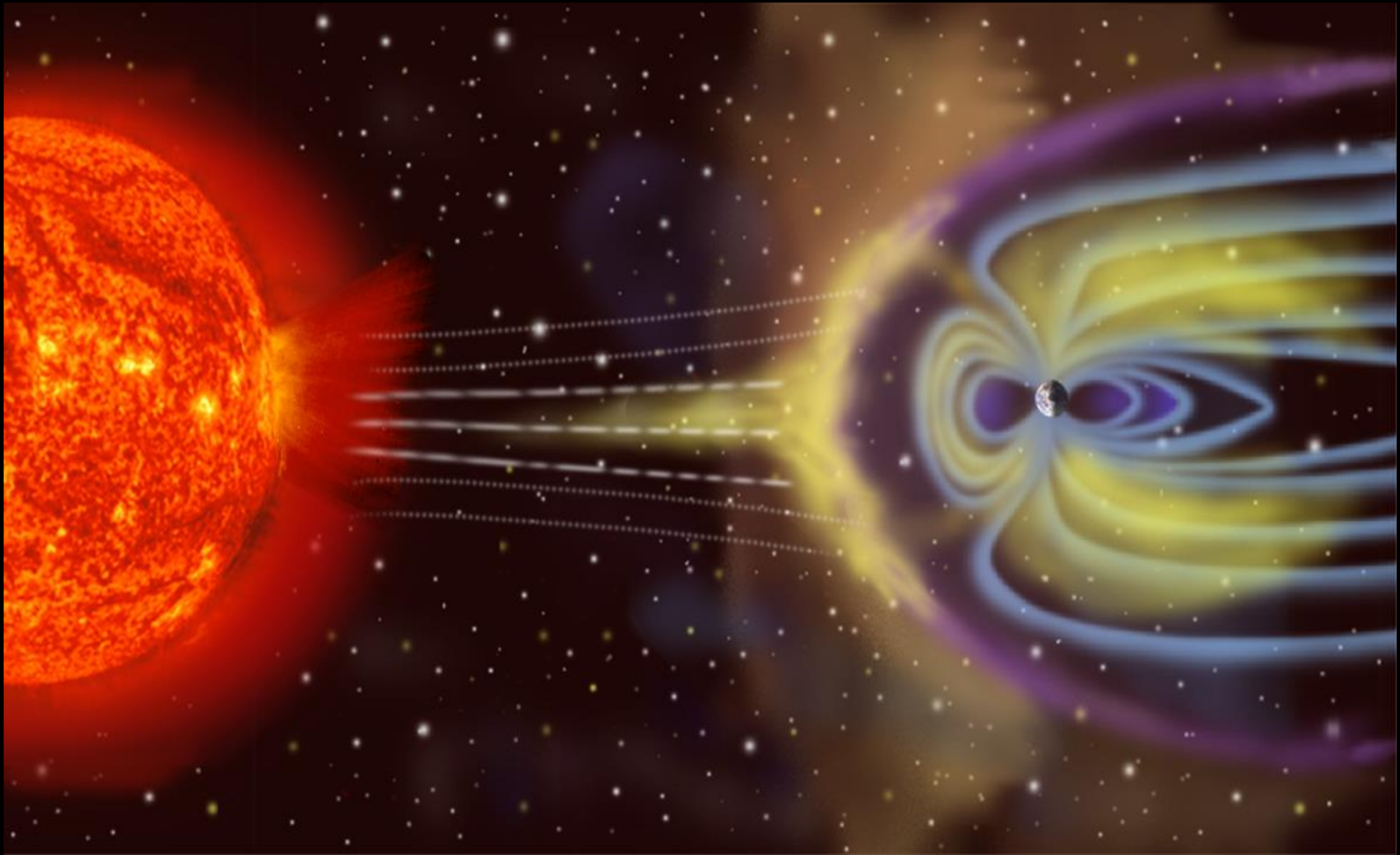
Working at NASA's "Rocket Center" and the Challenge of Thinking Differently





My MSFC Colleagues See …

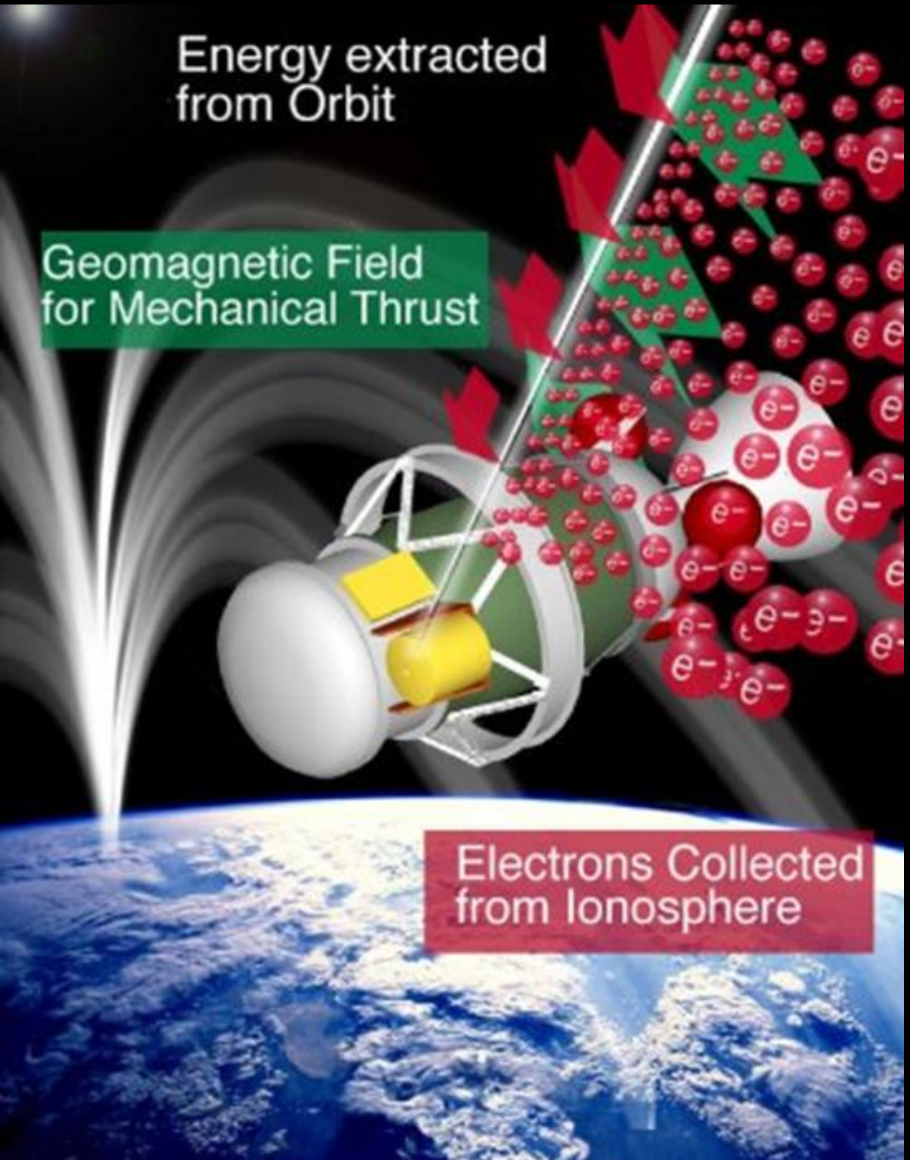
While I see…



Reboost of the ISS – the ‘Killer App” for ED Tethers

- Propellantless reboost in case of emergency (such as stand-down of ability to resupply, etc.)

Propulsive Small Expendable Deployer System (ProSEDS)



- ProSEDS was to demonstrate ED tether propulsion in LEO
- Letter of endorsement from the Space Station Chief Engineer was vital to the experiment being funded

ProSEDS Tether Is Really Several Tethers

National Aeronautics and Space Administration
George C. Marshall Space Flight Center

Exploring the Future

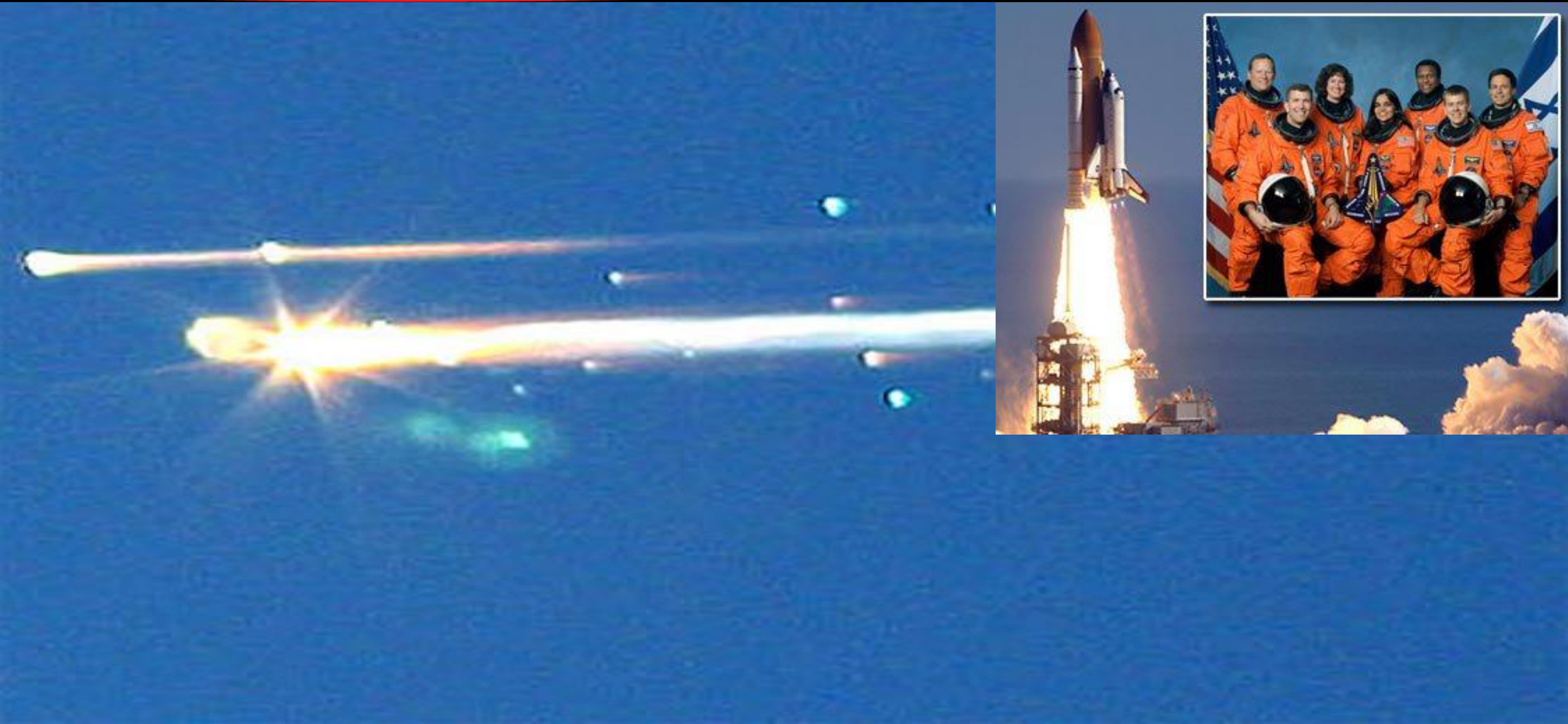
- Tether Section a - b
  - 20-meter Kevlar-coated Spectra
- Tether Section b-c
  - 10-kilometer Spectra
- Tether Section c-d
  - 5-kilometer coated aluminum wire (Kevlar core)

ProSEDS Deployer on the Delta II (during fit check)

- ProSEDS will use the flight-proven SEDS
  - Flown successfully four times
  - Developed by Tether Applications
- Deployment initiated by spring ejection
- Dimensions: ~2' x 2'

ProSEDS Deployer model on Delta stage

One month before ProSEDS launch, Tragedy Happened…



ProSEDS Was Canceled

ProSEDS Canceled Due to Perceived Risk To ISS

ProSEDS Canceled Due to Perceived Risk To ISS

And sustaining ISS in just such an emergency was exactly why we were funded in the first place!

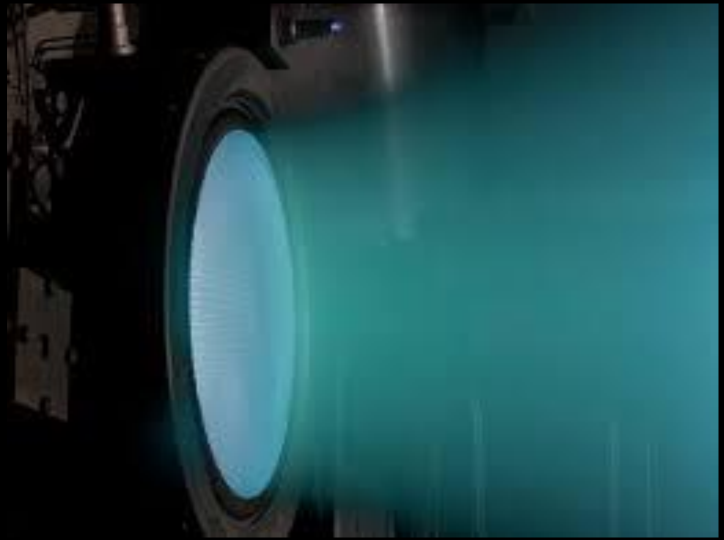
Lessons Learned

Technology “push” is difficult (paying customer is needed)

Better to have technology “pull”

A project isn’t ‘sold’ until it has flown and all data analysis is complete

In Space Propulsion Technology Project



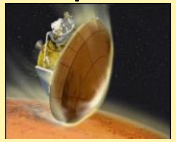
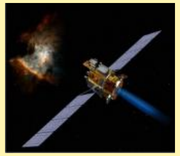
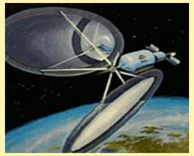
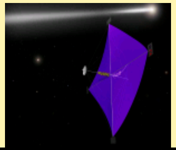
- Managed the In Space Propulsion Technology Project from 2002 through 2007 for the Science Mission Directorate

- Project Goal: 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.

- Total funding : $200M (total; over 5 years)

- Project Philosophy
  - Develop mid-TRL technologies to the point of flight validation
  - Manage technology development with mission infusion as the goal

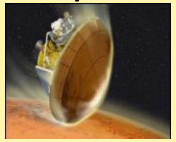
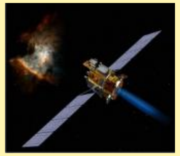
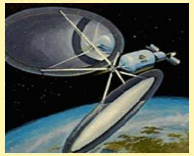
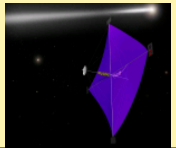
In-Space Propulsion Technology Investment Priorities Evolved

High Priority	Medium Priority	Low Priority	High Payoff High Risk
Aerocapture 	Adv. Chem. 		1 g/m2 S. Sails 
Next Gen. Ion 	SEP <50 kW 	Solar Thermal 	MXER Tethers 
Solar Sails 	SEP Hall 100kW 		Plasma Sails 

ISPT Priorities 2002

- Addressed propulsion needs for all of NASA (exploration and science)
- Low level technology push included

In-Space Propulsion Technology Investment Priorities Evolved

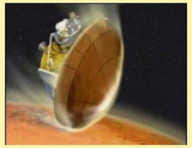
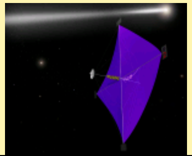
High Priority	Medium Priority	Low Priority	High Payoff High Risk
Aerocapture 	Adv. Chem. 		1 g/m2 S. Sails 
Next Gen. Ion 	SEP <50 kW 	Solar Thermal 	MXER Tethers 
Solar Sails 	SEP Hall 100kW 		Plasma Sails 

ISPT Priorities as of 2007

- Focus changed to support near term deliverables for science only (exploration-specific technologies were eliminated)
- Technology push eliminated

ISPT Priorities 2002

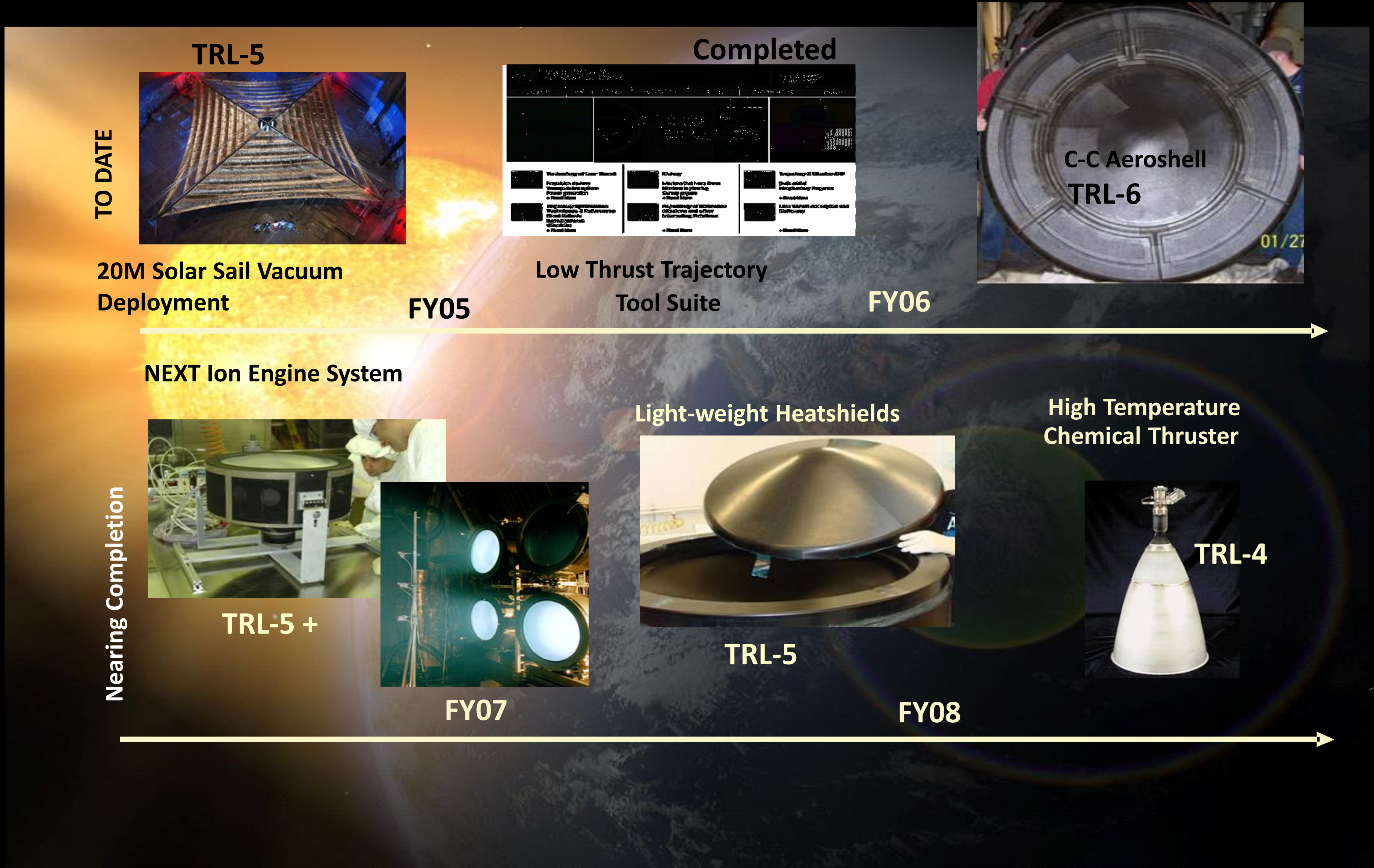
- Addressed propulsion needs for all of NASA (exploration and science)
- Low level technology push included

High Prio	Medium Priority	Low Priority	High Payoff High Risk
Aerocapture 	Adv. Chem 		
Solar Electric 			
Solar Sails 			

Nuclear Systems Initiative (evolved to become JIMO)

- Nuclear propulsion was originally part of the In-Space Propulsion Technology Project but was spun-off as a separate project in 2003
  - Fission power and power conversion
  - High power electric propulsion (not nuclear thermal propulsion)
- As originally envisioned, the Nuclear Systems Initiative (NSI) would develop technology for 5 years before a flight demo decision due to the technology's immaturity for near-term implementation
- NASA leadership in 2003/2004 decided that NSI was unsustainable as a technology project and transitioned it into the Jupiter Icy Moons Orbiter (JIMO) flight project
- When the cost of JIMO dramatically increase, due in large part to the immaturity of the technology, it was canceled (2005)

What Happened to the ISPT Project?



<u>After being 100% successful</u>, funding for ISPT and NASA Technologies in general disappeared to support Project Constellation – which was subsequently canceled...

Lessons Learned

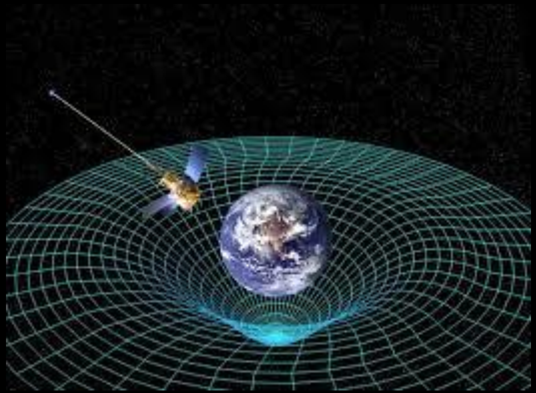
Develop technology using a systems approach with an eye toward eventual flight

Deliver incremental products in a timely fashion (no more than 3 years)

Discourage premature move from technology development to flight (JIMO!)

Managed MSFC's Science Programs and Projects Office

- From managing a NASA-level program to managing an MSFC-level *implementing* programs and projects office



Lesson Learned

Professional

Programs are inherently risk averse and view any new technology as a technical, cost and schedule risk

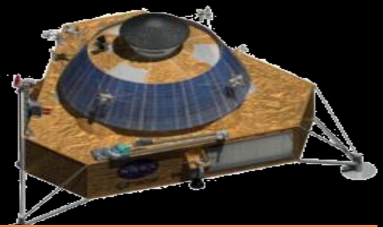
Personal

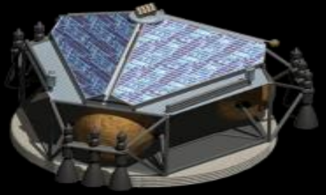
If you enjoy making things happen in project implementation, don’t accept promotions that take you from being a ‘project manager’ to an ‘office manager’

NASA MSFC Advanced Concepts Office Technical Assistant

We answer the questions:
Will it work?
What will it look like?
What is the preliminary design?

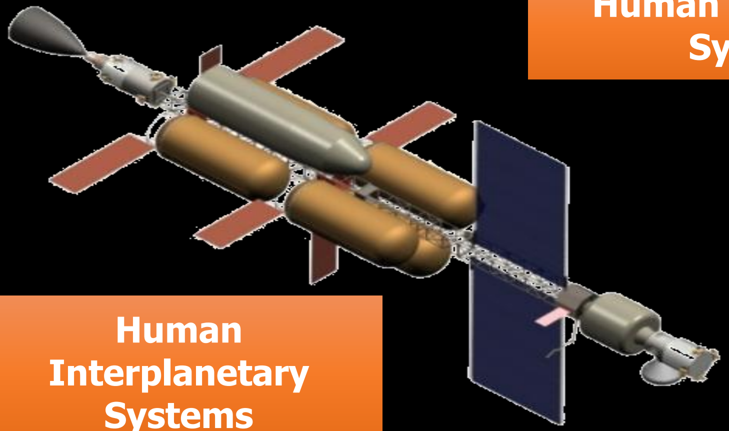
Launch Vehicle Systems





Robotic & Science Systems

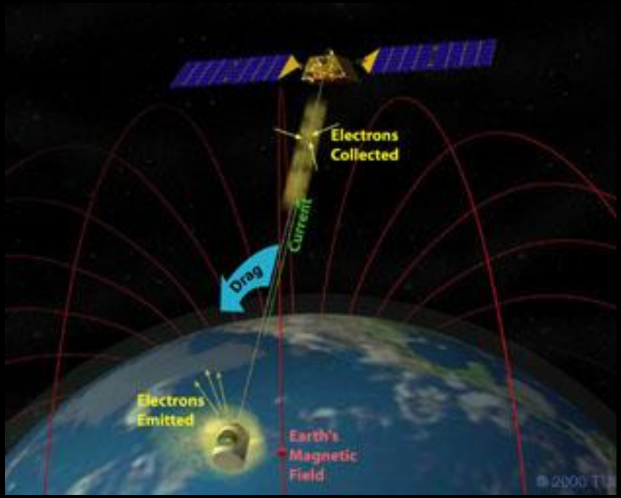
Human Exploration Systems

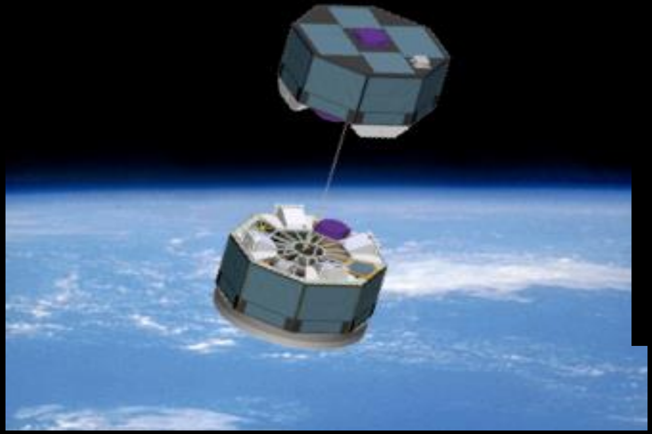


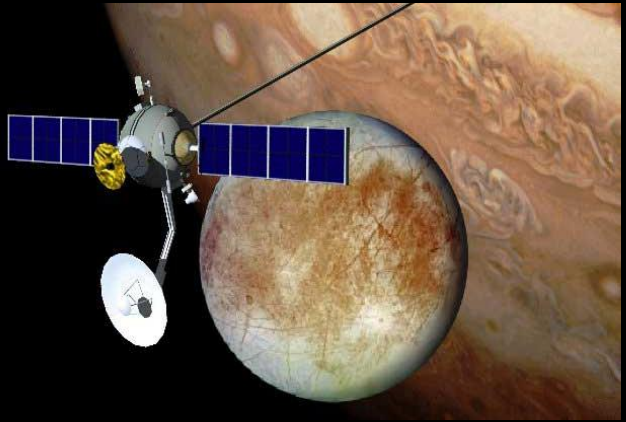
Human Interplanetary Systems

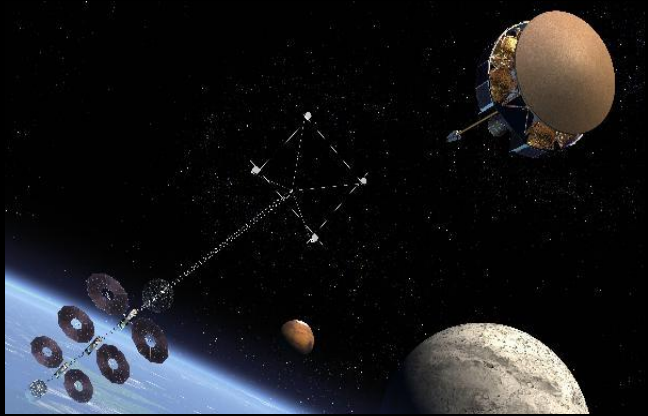
Co-Investigator of the JAXA T-Rex Tether Experiment

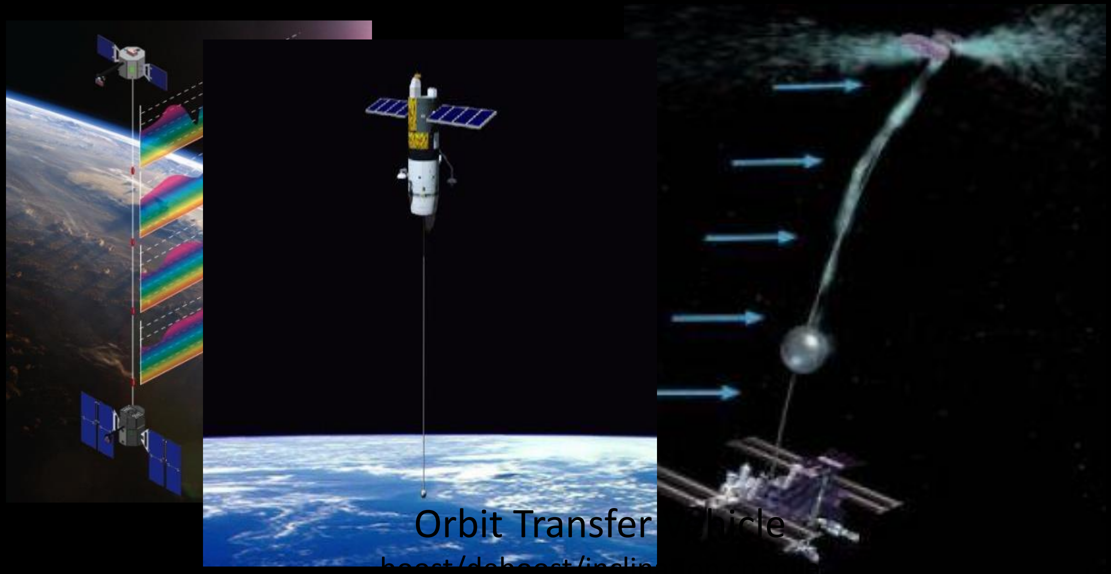
Tethers Still A Priority



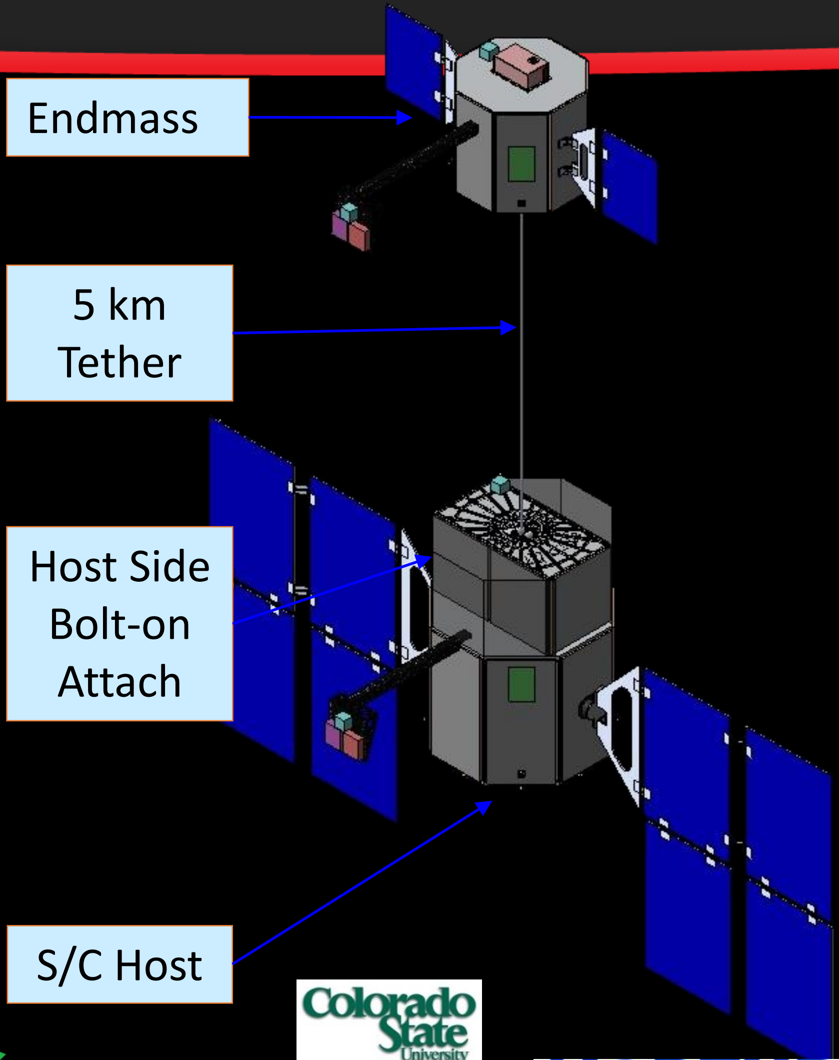








Propulsion using Electrodynamics (Propel)



Propel: robust and safe electrodynamic tether propulsion in Low Earth Orbit to enable multiple Space Science, Exploration and Space Utilization Missions for a variety of users

- Proposed to NASA in the first Technology Demonstration Mission (TDM) solicitation
- Significant DoD co-sponsorship

PropEl: a Space Flight Demonstration of Electrodynamic Tether Propulsion for Rapid Infusion into NASA Missions

TDM’s Choice

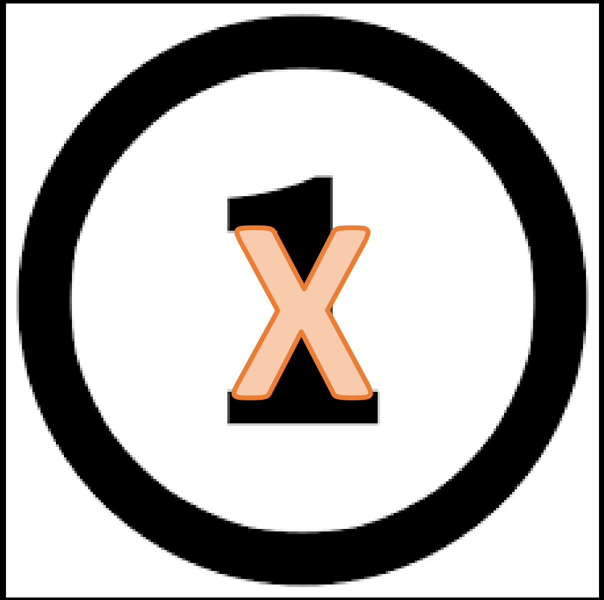
Other Missions

OR

Propel

Propel not selected by TDM

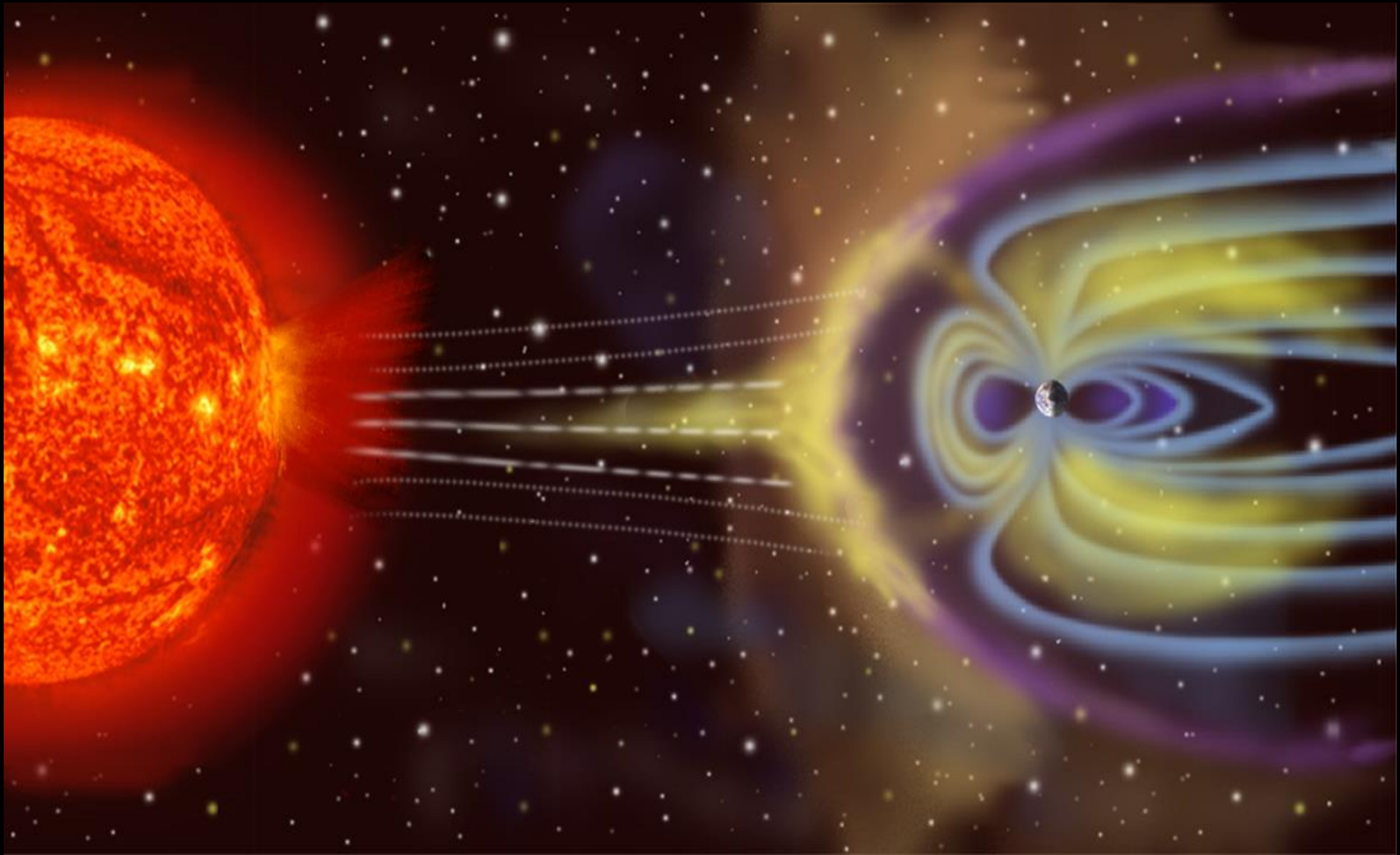
OR



Other Missions

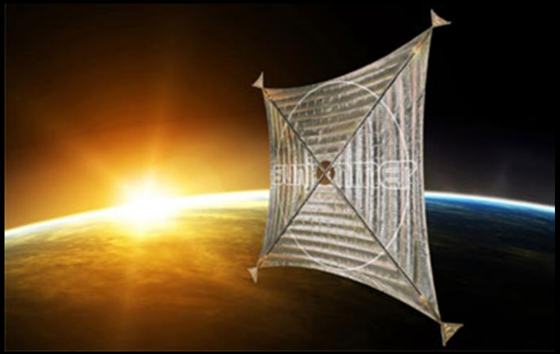
Propel

What else do you see?

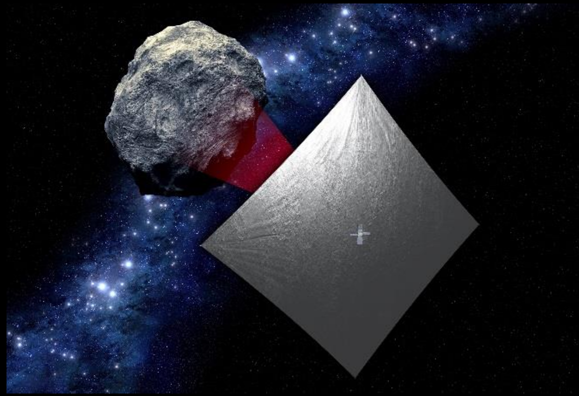


Solar Sails Parallel ED Tethers

NASA ST-7 & ST-9 Space Demos

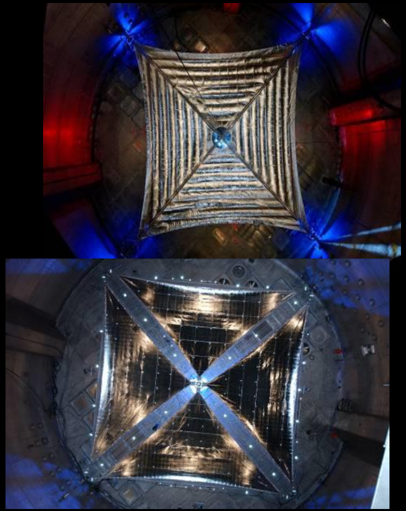


NASA Sunjammer

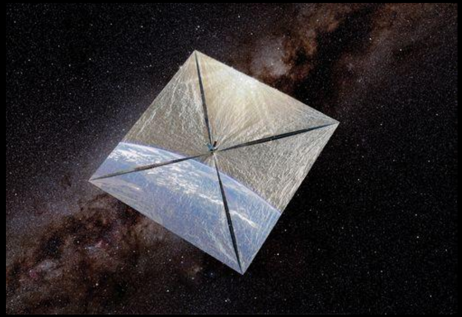


NASA Near Earth Asteroid Scout

NASA Ground Demos



NASA NanoSail-D2

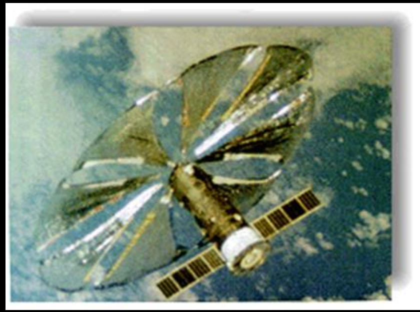


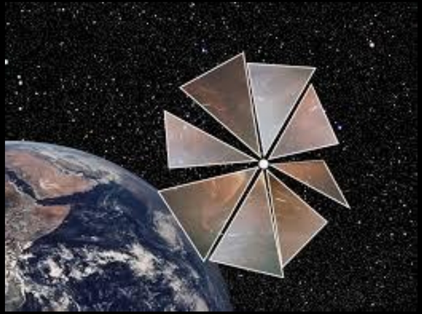
JAXA IKAROS

Planetary Society LightSail-A

Planetary Society LightSail-2

USSR Znamya



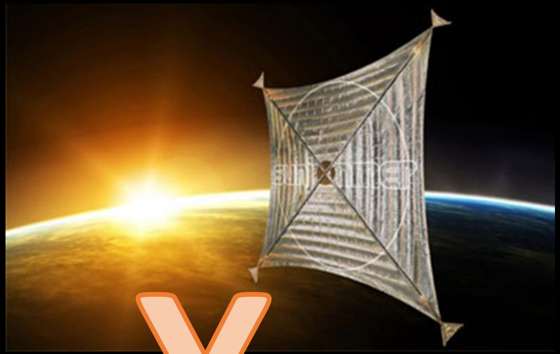


Planetary Society Cosmos-1

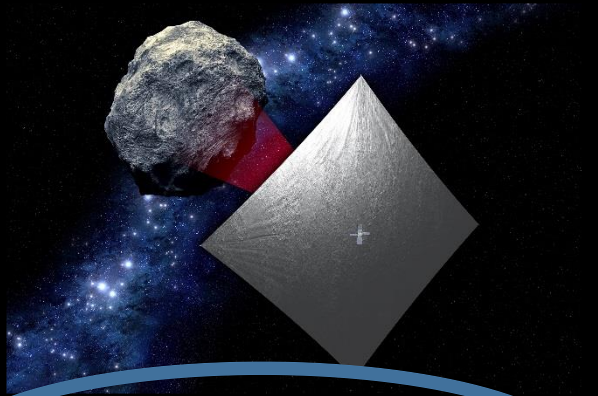
Solar Sails Parallel ED Tethers

NASA T & ST-9
Space mos

NASA NanoSail-D2



NASA jammer



NASA Near Earth Asteroid Scout

USSR Znamya

Plan y Society
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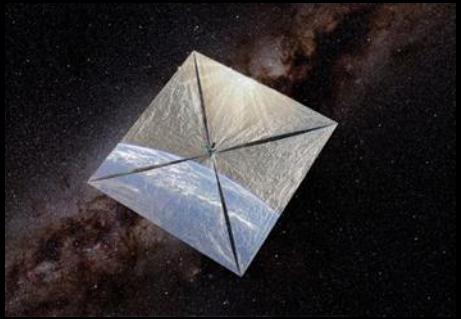


JAXA IKAROS

Planetary Society LightSail-A

Planetary Society LightSail-2

Near Earth Asteroid Scout

The Near Earth Asteroid Scout Will

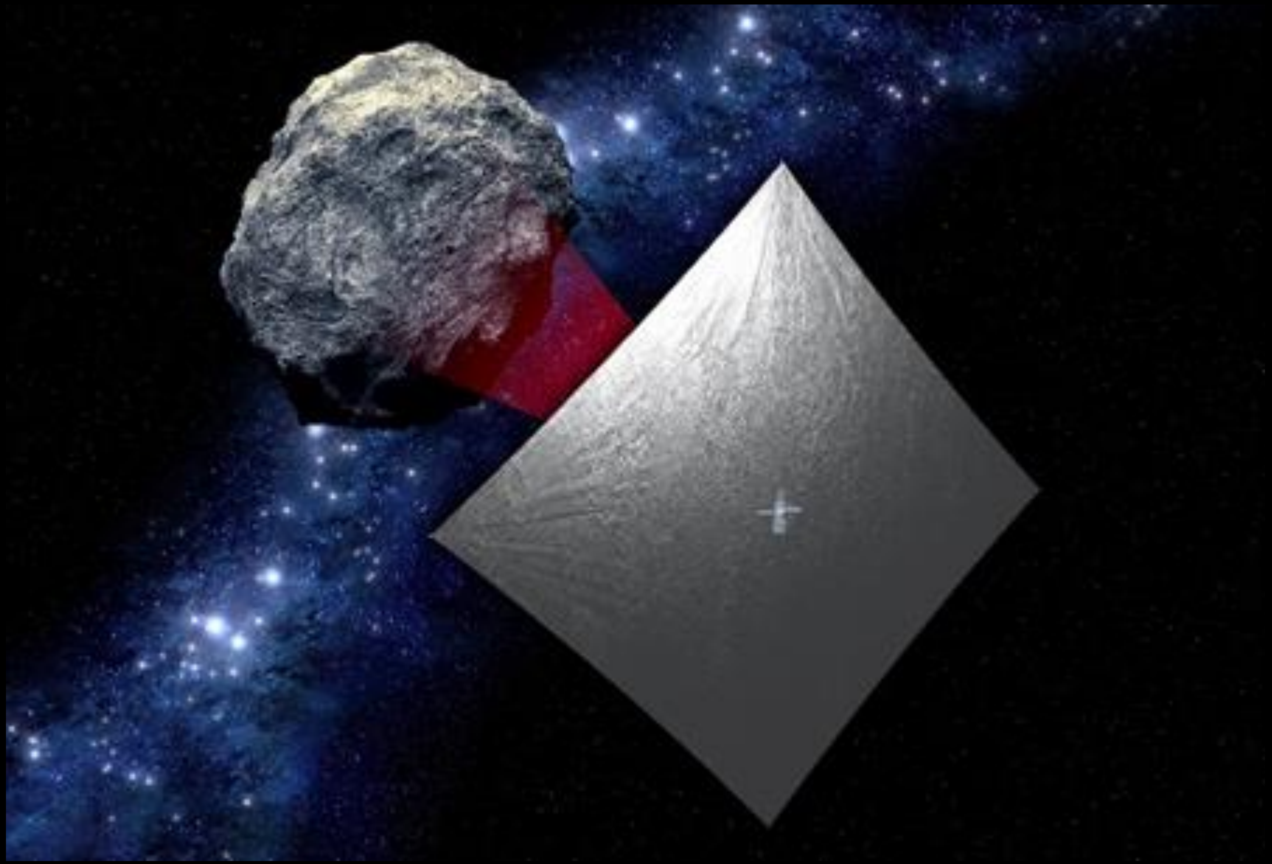
- Image/characterize a NEA during a slow flyby
- Demonstrate a low cost asteroid reconnaissance capability

Key Spacecraft & Mission Parameters

- 6U cubesat (20 cm X 10 cm X 30 cm)
- ~86 m^2 solar sail propulsion system
- Manifested for launch on the Space Launch System (EM-1/2018)
- Up to 2.5 year mission duration
- 1 AU maximum distance from Earth

Solar Sail Propulsion System Characteristics

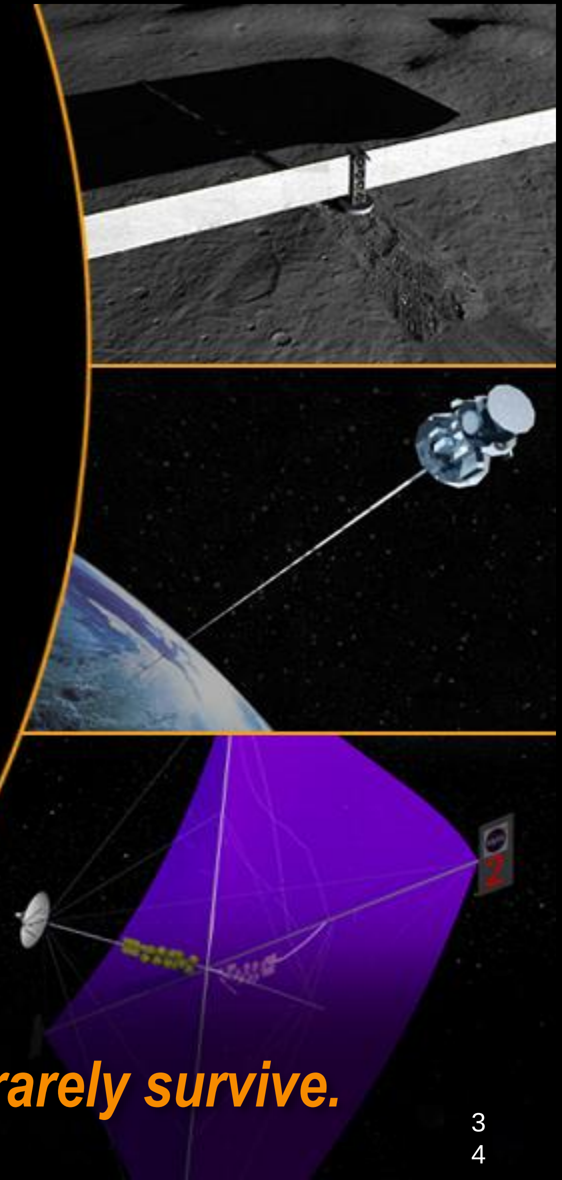
- ~ 7.3 m Trac booms
- 2.5μ aluminized CP-1 substrate
- > 90% reflectivity



NEA Scout Approximate Scale

Technology "Push" Versus "Pull"

- NASA funds an abundance of research and development
- Technologies with strong mission pull are most likely to successfully transition from research to flight
- Fundamental research is mostly push, not pull
- Most technologies are not developed with a "take it to flight" mentality
- Current technology programs are based on mission pull
- Flight projects and selection processes are highly risk averse
- PIs rarely propose a mission that requires new technology because it will reduce the likelihood of being selected; there is little mission pull



Technologies that enter the "Valley of Death" rarely survive.

Welcome to the Dreaded Technology Readiness Level (TRL) "Valley of Death"

- Exploration through the ages has been enabled by advanced technologies

- New technologies are key to going farther, faster, and reaping the ultimate rewards of R&D investments

- Many potentially useful, enabling, or revolutionary technologies don't survive the journey from ground development to mission implementation

Exploration beyond Earth orbit opens limitless possibilities.

Why are New Technologies so Difficult to Field?

- Technologists are NOT Flight Hardware Engineers
  - Little thought is given to how a bench-top demo might actually become flight hardware (materials selection, power requirements, required operating conditions, etc.)
- Technology Managers are NOT Flight Project Managers
  - Limited understanding of the system-level impact of actually infusing the technology into a flight system
  - Focus is on the research (NASA Research Announcements (NRAs), grants, etc.) with little appreciation of how to get flight projects to adopt the technology
  - Reluctance to fund ongoing systems studies to guide future investments — "studies aren't technologies!"
- Cost and risk models for flight systems consider new technologies to be expensive and risky
  - Budgets are limited and risks are not easily tolerated by "the system"

Flight system models consider new technologies to be too costly and risky.

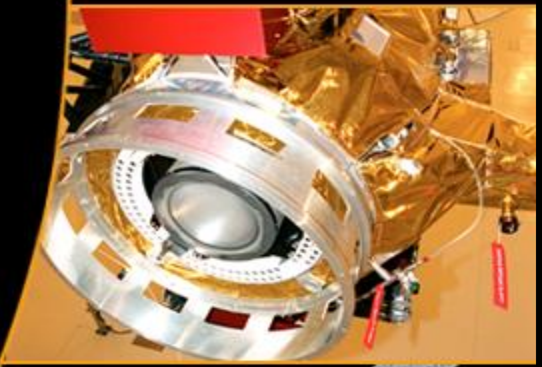
Why Are New Technologies So Difficult to Field?

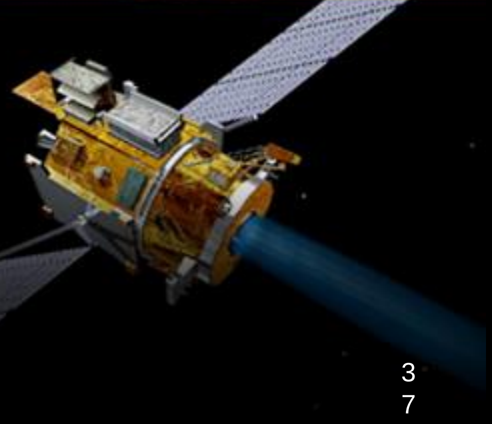
(Continued)

- Rigorous mission selection process favors science with low risk and potential cost growth over innovative and revolutionary science enabled with new technology, which has high risk and probability of cost growth

- Example Result: Solar Electric Propulsion
  - The Deep Space 1 mission in 1998 demonstrated this technology
  - NASA has selected only one additional Solar Electric Propulsion flight mission, Dawn, which launched in 2007

NASA needs an integrated approach to validating new technologies in space to retire the risk.





Gedankenexperiment

Scenario

- You are a Principal Investigator
- You may have two flight missions in your career
- You want to do great science

Criteria

- Highly competitive proposal process
- Ground rules include low risk and low cost
- New technology is considered high risk

The Challenge

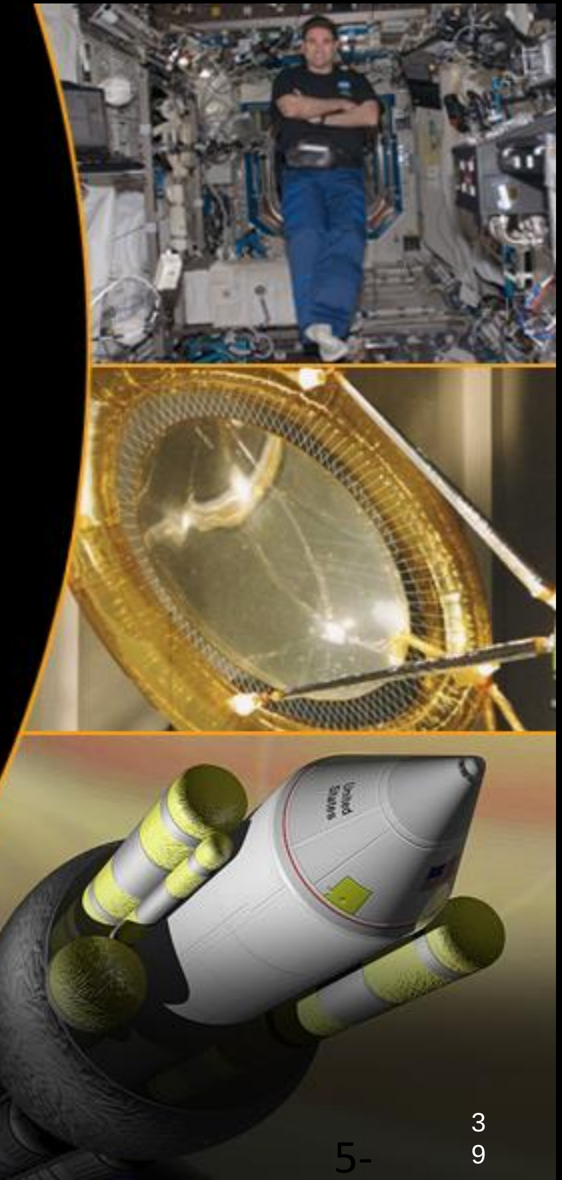
- How would you advocate for a flight experiment that requires advancing new technologies to obtain GREAT science?

Advocacy can make the impossible possible.

Conclusion and Recommendations

- Fundamental research is critical to taking the next giant leap in the scientific exploration of space
  - NASA should be pushing the envelope and asking "what if?"
- Technology push enables new capabilities
  - When NASA began, everything was enabling
- Technology pull is often required to meet current mission requirements
- Technology management requires more than issuing NRAs and overseeing contracts
  - Continuous assessment, peer review, and system systems studies are vital to credible TRL advancement

A strategy for taking technology R&D to new heights will lead to discoveries at far-reaching destinations.



Conclusion and Recommendations *(Continued)*

- There must be a plan or opportunities for flight validation
  - To reduce the bottleneck of new technologies at the TRL Valley of Death
  - To allow frequent infusion of new technologies into flight missions
- Risk must be tolerated for new technology flight experiments
  - They are experiments, not missions!
- Risk must also be accepted on early-adopting missions
  - Enabling new capabilities is often worth the extra risk
- Still an increased risk and cost to the Mission

Traversing the TRL Valley of Death will propel the next giant leap in space exploration.

One PI's Dream