National Aeronautics and Space Administration

A New Space Enterprise

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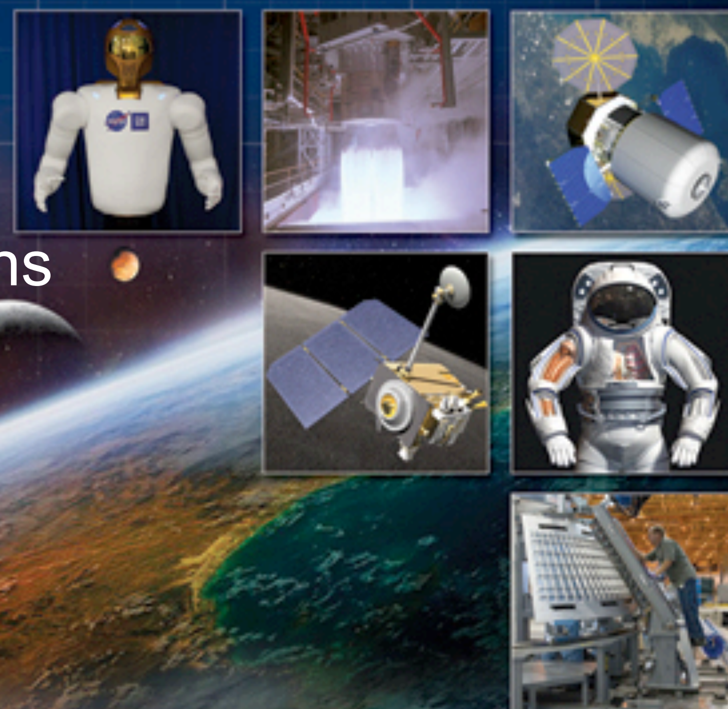
Flagship Technology Demonstrations

Point of Departure (POD) Plans

May 25, 2010



Disclaimer

This chart set was presented by the Flagship Technology Demonstration (FTD) study team on May 25, 2010 at the NASA Exploration Enterprise Workshop held in Galveston, TX. The purpose of this workshop was to present NASA's initial plans for the potential programs announced in the FY2011 Budget Request to industry, academia, and other NASA colleagues. Engaging outside organizations allows NASA to make informed decisions as program objectives and expectations are established.

The FTD presentation begins with an explanation of what is meant by flagship technology demonstrations, why they are needed, and how the proposed program will interface and collaborate with other partners (both internal to NASA and external). The presentation goes into some detail about the four technology demonstrations that would be initiated in FY2011, pending Congressional approval. The presentation concludes with a schedule of the next steps that the team will take over the summer and a notional acquisition strategy.

DISCLAIMER: The following charts represent at "point of departure" which will continue to be refined throughout the summer and the coming years. They capture the results of planning activities as of the May 25, 2010 date, but are in no way meant to represent final plans. In fact, not all proposed missions and investments fit in the budget at this time. They provide a starting point for engagement with outside organizations (international, industry, academia, and other Government Agencies). Any specific launch dates and missions are likely to change to reflect the addition of Orion Emergency Rescue Vehicle, updated priorities, and new information from NASA's space partners.

FTD Outline

- Overview
- Interfaces
- Point of Departure Missions
- Next Steps
- Summary

FTD Overview

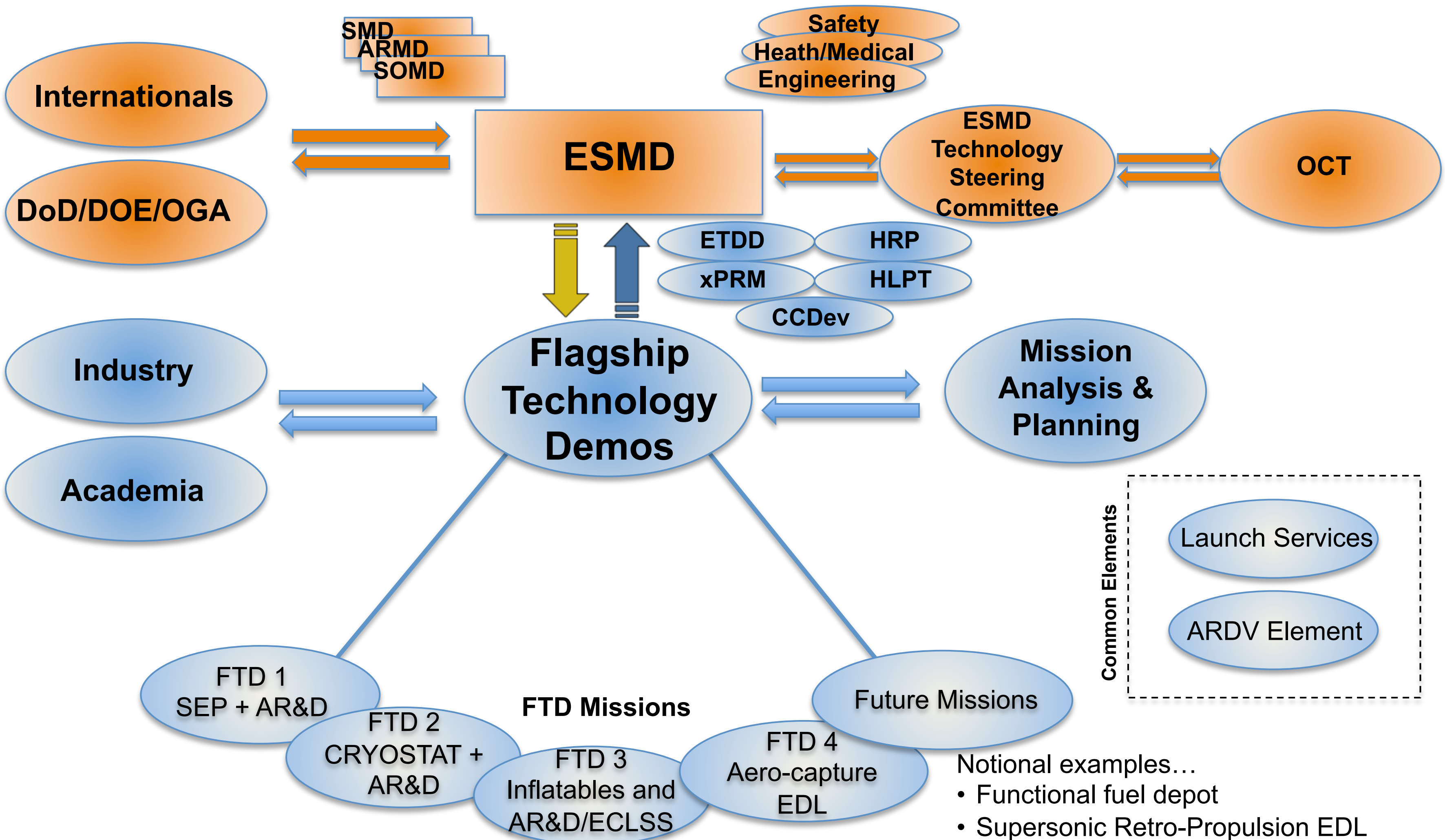
What are Flagship Technology Demonstrations (part of the Exploration and Demonstration Programs)?

- Demonstrates the technologies needed to reduce the cost and expand the capability of future space exploration activities
  - They are large scale demonstrations in space of technologies that could be transformational
  - Improves the capability and reduce the cost of future exploration missions
- General Principles guiding the preliminary selection and implementation of the projects:
  - Costs, from initiation to launch, should range from $400M to $1B each, including launch vehicle
    - Project lifetime no longer than five years (initiation to launch)
    - First in-space demo should be targeted for no later than 2014
    - International, commercial and other government agency partners should be actively pursued as integrated team members where appropriate
    - No single NASA Center should have responsibility for all demos

FTD Overview (Cont'd)

- In FY 2010, develop long-term roadmap and approach for proposed near-term missions
- Evaluation underway of highest leverage demonstrations; Mars destination is a driving case for high leverage demonstration and technology
- The following technologies would be integrated and tested through four Flagship class missions:
    - In-orbit propellant transfer and storage
    - Lightweight/inflatable modules
    - Automated/autonomous rendezvous and docking
    - Aero-assist/entry, descent and landing
    - Closed loop life support
    - Advanced in-space propulsion (ion/plasma, etc)
- Identify potential partnerships with industry, other agencies, and international partners and leverage ISS for technology demonstrations, as appropriate
- Plan to initiate four technology demonstrations in FY 2011
    - Solar Electric Propulsion/AR&D
    - Propellant Storage and Transfer Demonstration
    - Inflatable Module to ISS/Advanced Life Support
    - Aero-assist/ Entry Decent and Landing

FTD Keystone Interfaces/Collaborations



Notional examples…

- Functional fuel depot
- Supersonic Retro-Propulsion EDL
- Higher power advanced propulsion
- Self healing structures
- Human/robotic interface

Advanced In-Space Propulsion Demonstration
Solar Electric Propulsion (SEP) Stage

Goals and Objectives:
Deliver revolutionary benefits by combining advanced space propulsion with efficient, lightweight, array technology, and demonstrate AR&D capability

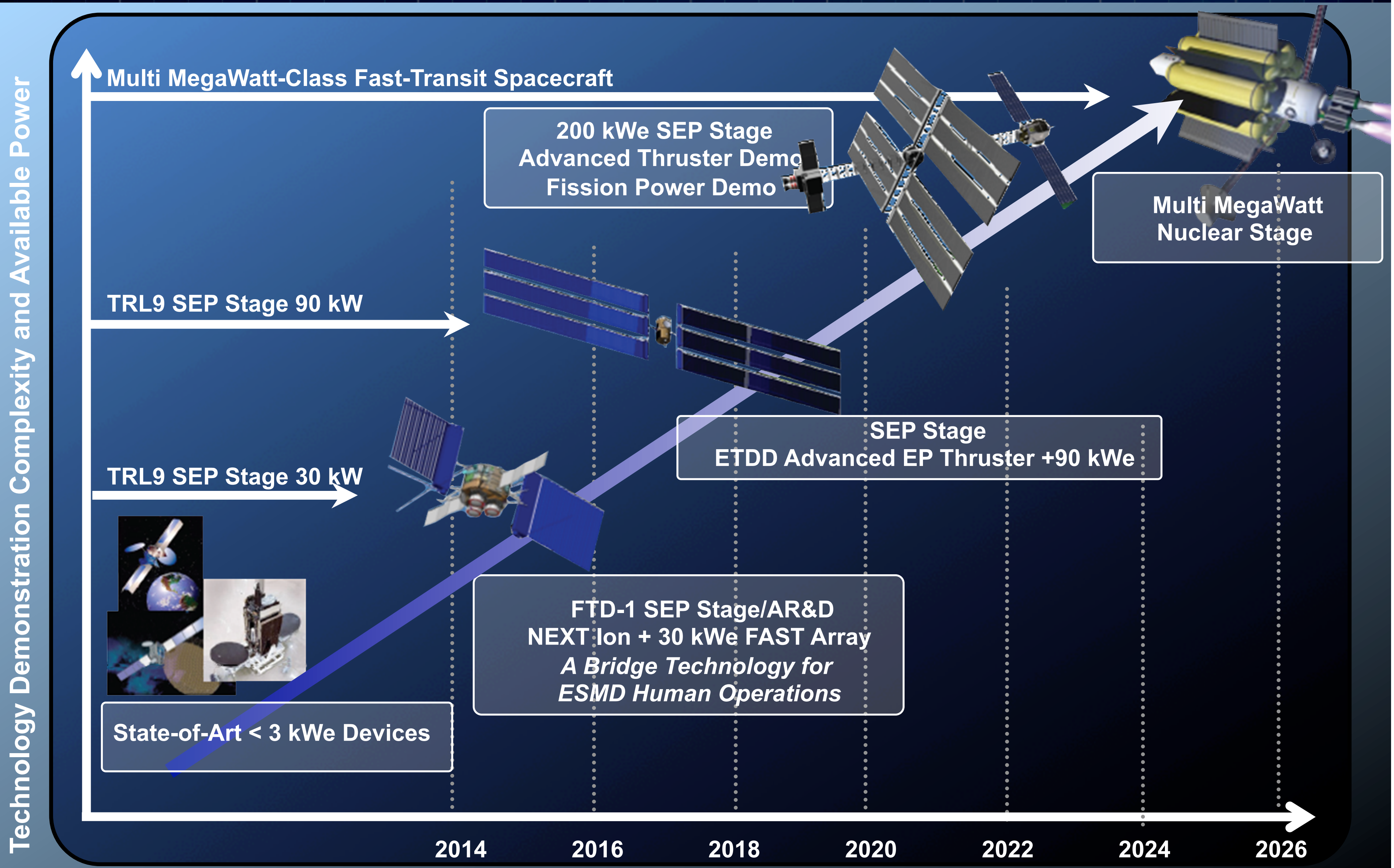
Flagship Would:
- Enable Pathway for Development of Advanced Propulsion in support of Human Operations (30 kW → MW {VASIMR, etc.})
- Build a new capability to enable exploration
- Dramatically enhance the competitiveness of existing U.S. launchers by reducing cost & minimizing the requirement for on-orbit propellant

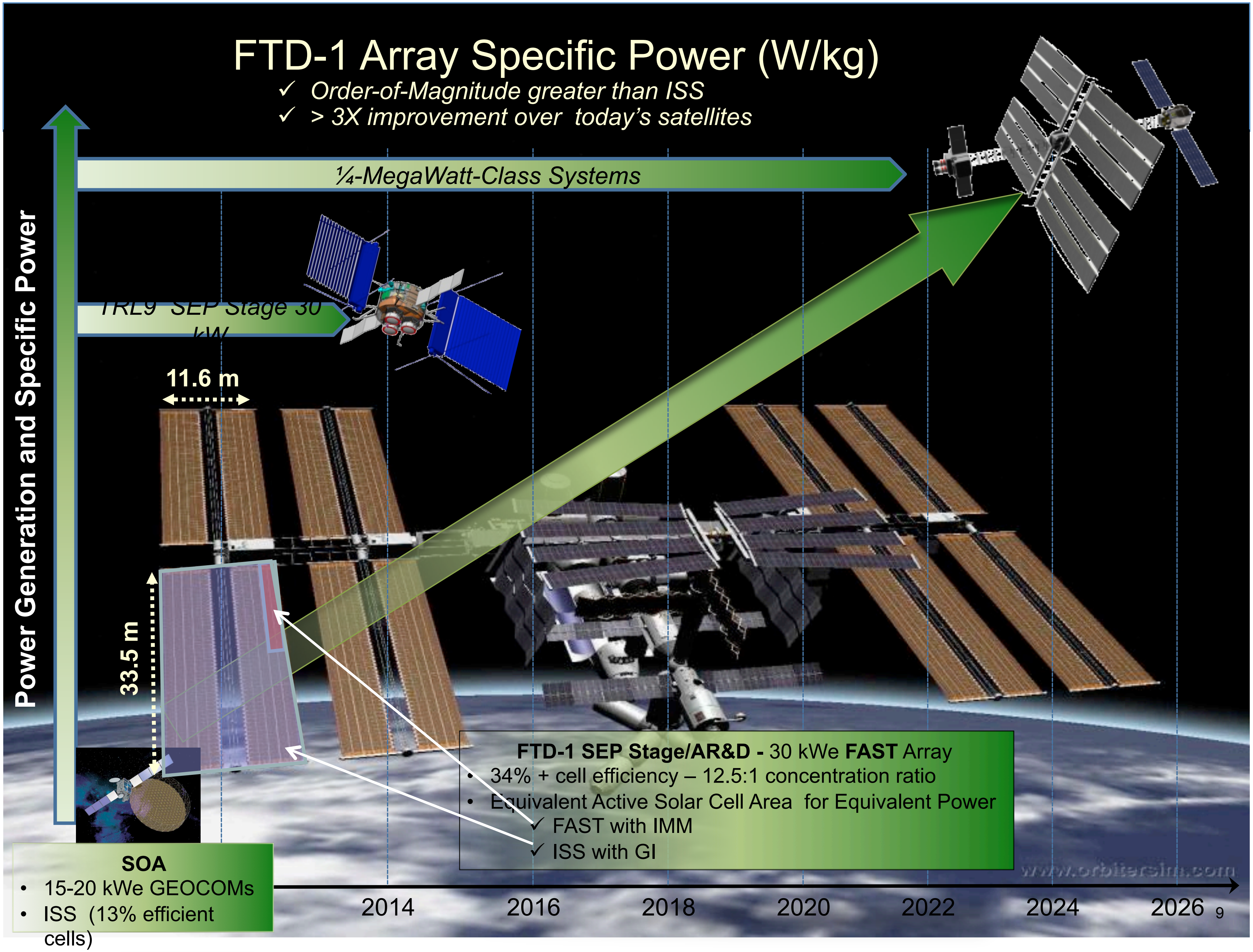
Applications:
- NASA: Step toward direct ESMD Human and Robotic Operations; Science Mission Applications
- DoD: Earth-Space Operational missions
- Commercial: OTV, OS, Orbital Debris Removal, GEO

Potential Partnerships: DoD and Commercial

Other Aspects:
- POD Mission: Launch 2014, with a 2 year mission duration
- Secondary Payload Opportunities

FTD-1 Roadmap for Advanced



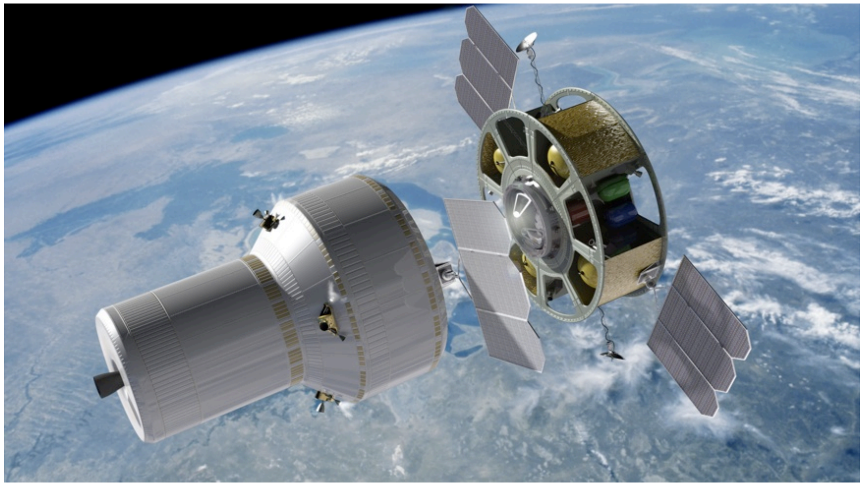

FTD-1 Array Specific Power (W/kg)
✓ Order-of-Magnitude greater than ISS
✓ > 3X improvement over today's satellites
¼-MegaWatt-Class Systems
TRL9 SEP Stage 30 kW
Power Generation and Specific Power
11.6 m
33.5 m
FTD-1 SEP Stage/AR&D - 30 kWe FAST Array
• 34% + cell efficiency – 12.5:1 concentration ratio
• Equivalent Active Solar Cell Area for Equivalent Power
✓ FAST with IMM
✓ ISS with GI
SOA
• 15-20 kWe GEOCOMs
• ISS (13% efficient cells)
2014
2016
2018
2020
2022
2024
2026
www.orbitersim.com

Cryogenic Propellant Storage and Transfer Mission: *CRYOSTAT Overview*

Goals and Objectives:

- Mission would demonstrate key technologies required for the development of cryogenetic propellant storage and transfer, and AR&D… thus supporting exploration beyond Low Earth Orbit.

- Specifically, the mission would:
  1. Demonstrate in-space cryogenic fluid management systems
  2. Demonstrate in-space propellant transfer
  3. Demonstrate LOX/Methane engine in-space thrust-on-need.
  4. Demonstrate in-space quick disconnects
  5. Demonstrate Automated/Autonomous Rendezvous and Docking



Applications:

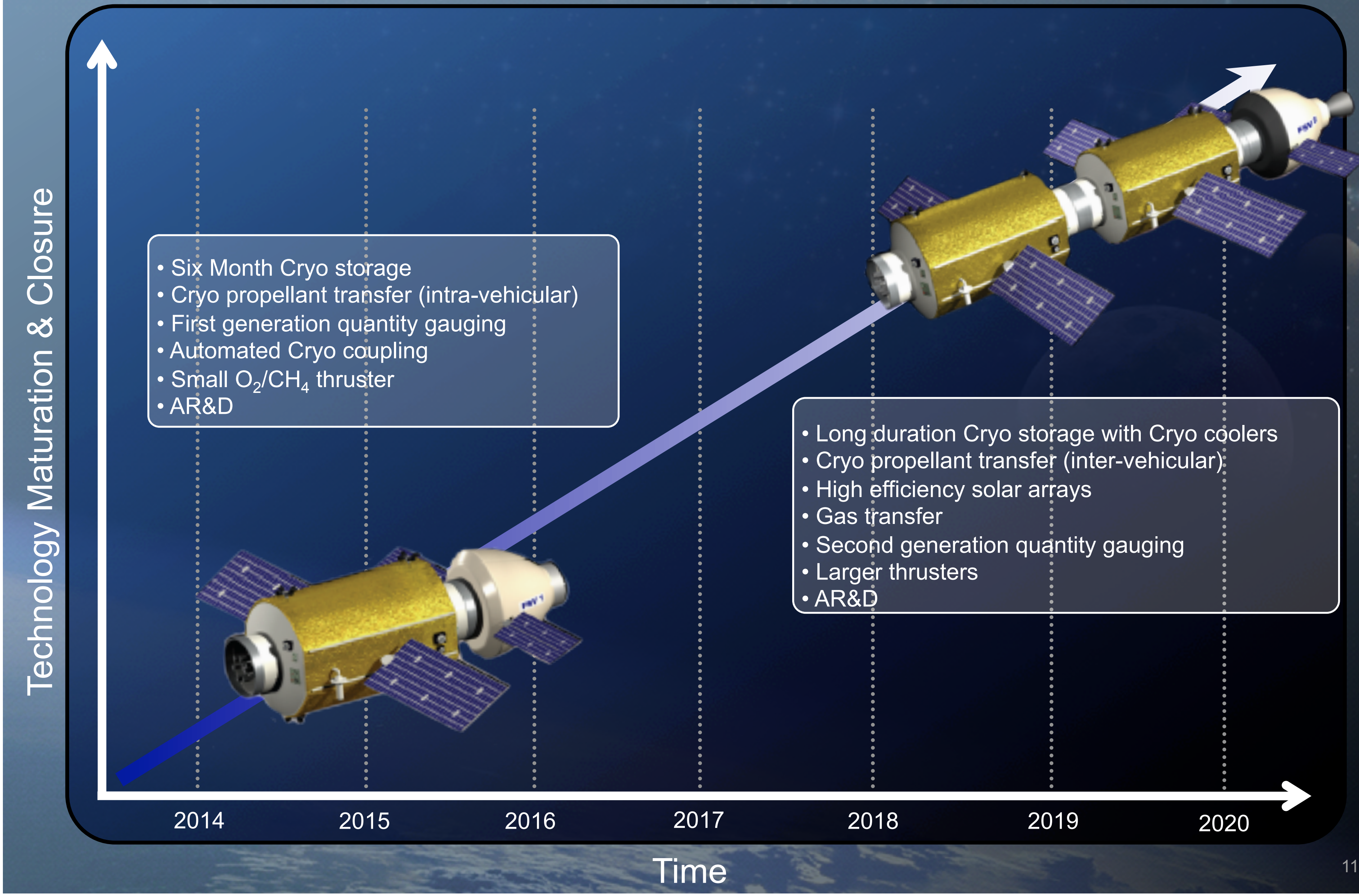
- Long duration storage of cryogenic propellants for future exploration missions
- Replenishment/transfer of propellants in-space for NASA, commercial, international, DoD assets

Potential Partnerships: Commercial, International, DoD, Academic

Other Aspects:

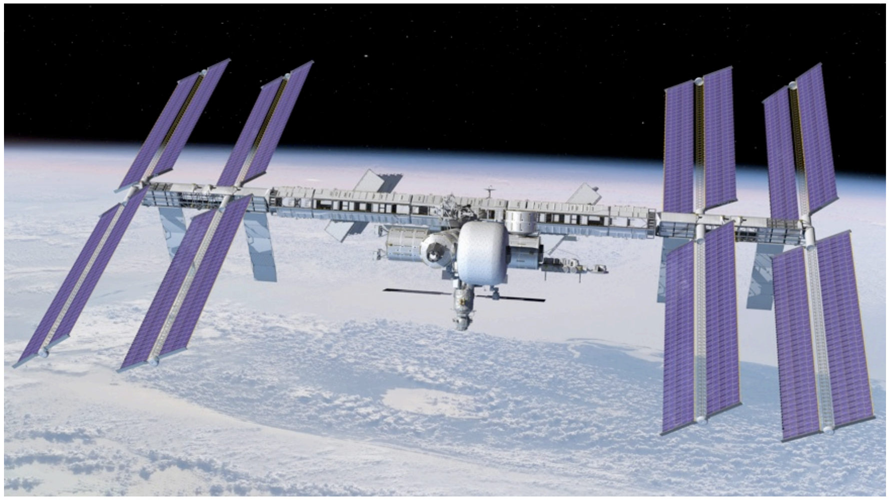
- POD Mission: Launch 2015, with a mission duration of no less than 200 days
- Secondary Payload Opportunities

In-Space Propellant Transfer & Storage Mission Roadmap



Inflatable ISS Mission Module

Goals and Objectives: Advance, demonstrate and integrate technologies needed for lightweight/ inflatable modules, and AR&D delivery capabilities



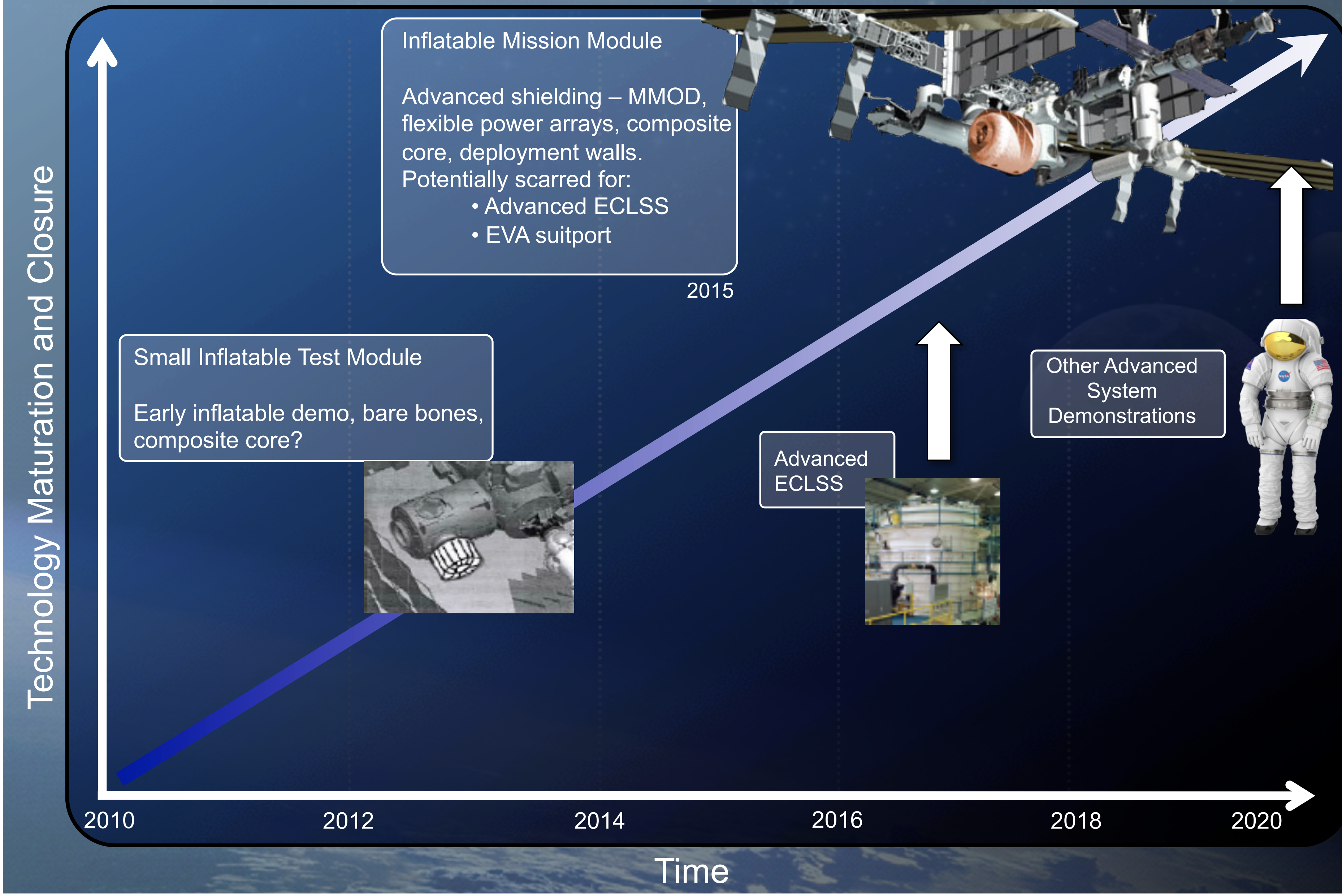
Flagship would:
- Demonstrate ability to deploy a human scale inflatable structure in space
- Demonstrate long duration of an inflatable habitat in space environment (MMOD, thermal) while being occupied daily by humans
- Demonstrate integration of advanced technology systems for environmental control and life support (ECLS), waste management and reduced logistics with an inflatable structure… advanced lightweight materials
- Demonstrated total AR&D capabilities

Applications:
- Orbital science and/or industrial modules as part future space stations
- Inflatable spacecraft for habitation during long duration transit for exploration missions
- Surface habitats during off-world planetary exploration
- Improved and efficient, Earth-based, recycling systems based on closed-loop ECLS technologies

Potential Partnerships: Commercial, internationals, and academia

Other Aspects:
- POD Mission: Launch 2015, with a mission duration 36-48months (possibly to end of ISS life)
  Closed-Loop ECLS system delivered post 2015
- Secondary Payload Opportunities

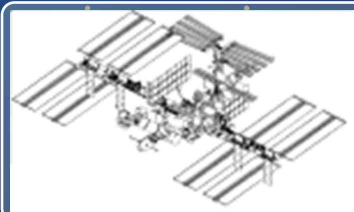
Inflatable Mission Module Capability Roadmap



Closed Loop Life Support is an Enabling Capability for Long Duration Human missions Beyond Low Earth Orbit

Flagship Flight Demonstration

- Flight validation of closed loop life support and associated technologies including monitoring, thermal control & habitation



ISS Utilization

- Gather lessons learned from operational systems on ISS

Ground Based Integrated Testing & Demonstration

- Advance TRL Maturity of subsystems and systems to TRL 5 & 6 in preparation for Flagship Demo

Technology Development and Maturation

- Advance TRL Maturity of subsystems and process technologies to TRL 4 & 5

Technology Maturation and Closure

2010 | 2012 | 2014 | 2016 | 2018 | 2020

Time

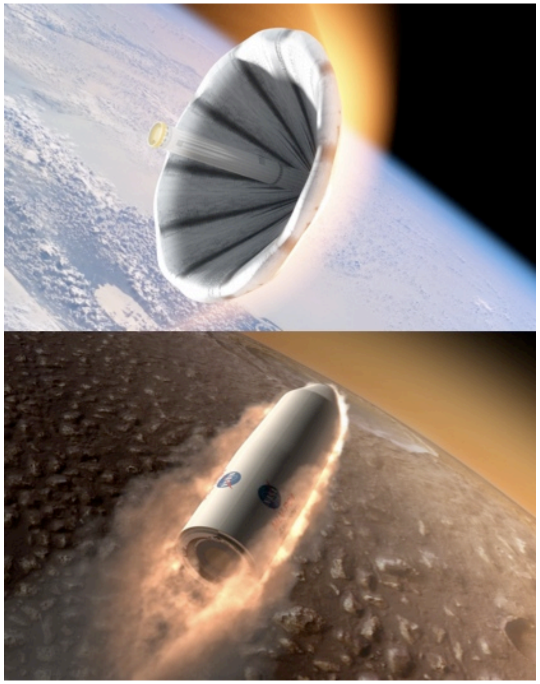
Earth- or Mars-Based Aero-assist Demonstration

Goals and Objectives: Enable higher mass missions and higher altitude landing sites on Mars and other destinations with atmosphere and enhance the Earth-EDL stage of round-trip missions to the moon and elsewhere.

	SOA	Post-Flagship
Mars Surface Payload	1 mT	10 mT
Landing Accuracy	10 km	1 km
Mars Destination Altitude	0 km	+1 km

Earth Based Mission would demonstrate:

- Advanced aero-capture and large mass delivery EDL technologies using instrumented Earth based flight technology demonstration system
- Includes a separate Inflatable entry vehicle to demonstrate environmental survivability and control of a Hypersonic Inflatable Aero Decelerators (HIAD)



Notional Mars-Based Mission would demonstrate:

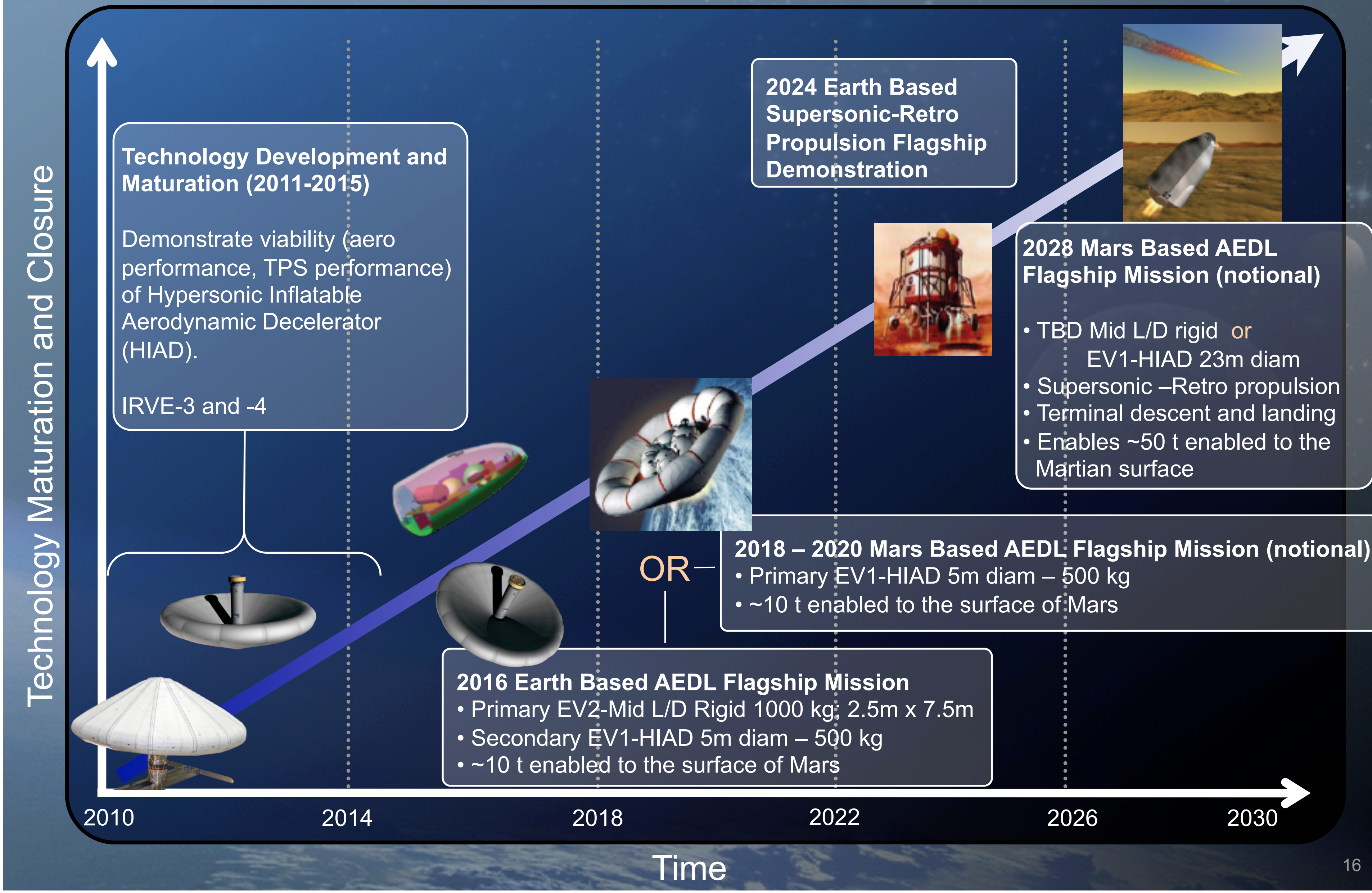
- AEDL technologies in an integrated trajectory from hyperbolic approach to the surface
- Advanced aero-capture and large mass delivery EDL technologies using instrumented in-situ Mars based flight technology demonstration system
- Either or a combination of rigid or flexible vehicles for hypersonic and supersonic entry

Potential Partnerships: International, industry, and commercial launch providers

Other Aspects:

- POD Mission: Launch in either 2016 or 2018, with a mission duration 1 month (Earth Based) or 13 months (Mars-based)

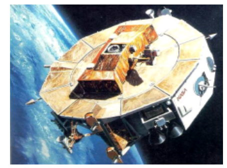
Aero-EDL Capability Development in Support of Flagship Demonstrations



AR&D Vehicle (ARDV)

Goals and Objectives:

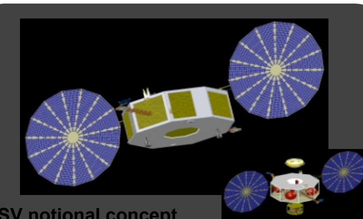
- Evolutionary flight testing of integrated AR&D systems.
  - Sensor suites
  - Mission Manager System
  - Two-way communication including ranging
- Provide in-orbit transportation and delivery to FTD missions.
- Provide robust ISS rated spacecraft system elements for later FTD missions.
- Build upon past experience and lessons learned in AR&D

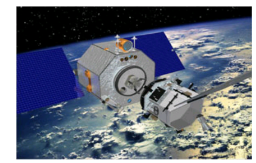

OMV circa 1986


ATV

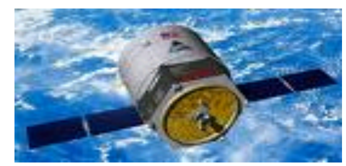

HTV


HRSDM


FSV notional concept


Orbital Express


DragonLab


Cygnus

Applications:

- Automated rendezvous, proximity operations, and docking of multiple spaced-based assets supporting human exploration of the solar system
- Robotic cargo delivery systems
- Robotic clean-up/de-orbiting/safe-orbiting of unpowered satellites and orbital debris
- Improved efficiency and safety of Earth-based transportation systems (aviation, shipping, rail, trucking)

Potential Partnerships: Commercial, DoD, Internationals

Flagship Technology Demonstration AR&D Evolution

AR&D System Elements	
Mission Manager (Overall Vehicle Flight Management System)	Evolutionary build through all flights.
Sensors	Maturation through FTD 1, 2, and 3
GN&C	Maturation through all flights and ground.
Docking Mechanism	Ground DDT&E, first , then flight tests. Converge to IDS

Increasing Capability & Fault Tolerant Autonomy

AR&D Capability Anywhere in the Solar System

FTD-3

FTD-2

FTD-1

6DOF HWIL testing begins in 2011 and continues throughout as part of flight V&V.

FY2011-2013	FY2014	FY2015	FY2016	→ FY2026

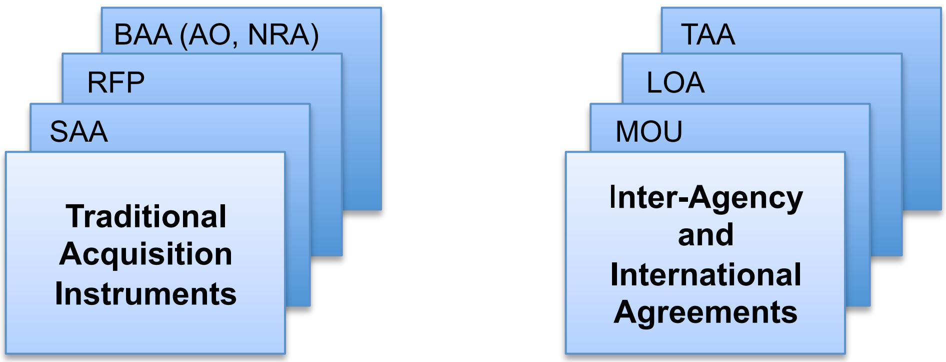
AR&D Goals during FTD Missions 1, 2, and 3

Mission Description	FTD-1: Solar Electric Propulsion Multiple nominal sorties to the deployed target	FTD-2 : Cryogenic Propellant Storage and Transfer Mission Multiple sorties to include inserted faults/ contingencies to deployed target(s)	FTD-3: Inflatable ISS Mission Module Multiple sorties to ISS
Sensors	Fly full sensor suite plus test units	Narrow sensor choice to minimum required suite	Include redundancies required for visiting vehicles
Mission Manager	Simple functionality performing nominal mission and selected portions of AR&D	Added functionality to react to contingency situations	Include advanced FDIR and replanning. Human rated for ISS.
GN&C	Algorithms to support nominal scenarios	Algorithms supporting nominal and contingency scenarios	Full suite of core algorithms in matured stated
Docking Mech.	No docking system, simulated docking sorties	iLIDS flight unit	iLIDS use to dock with ISS

Next Steps

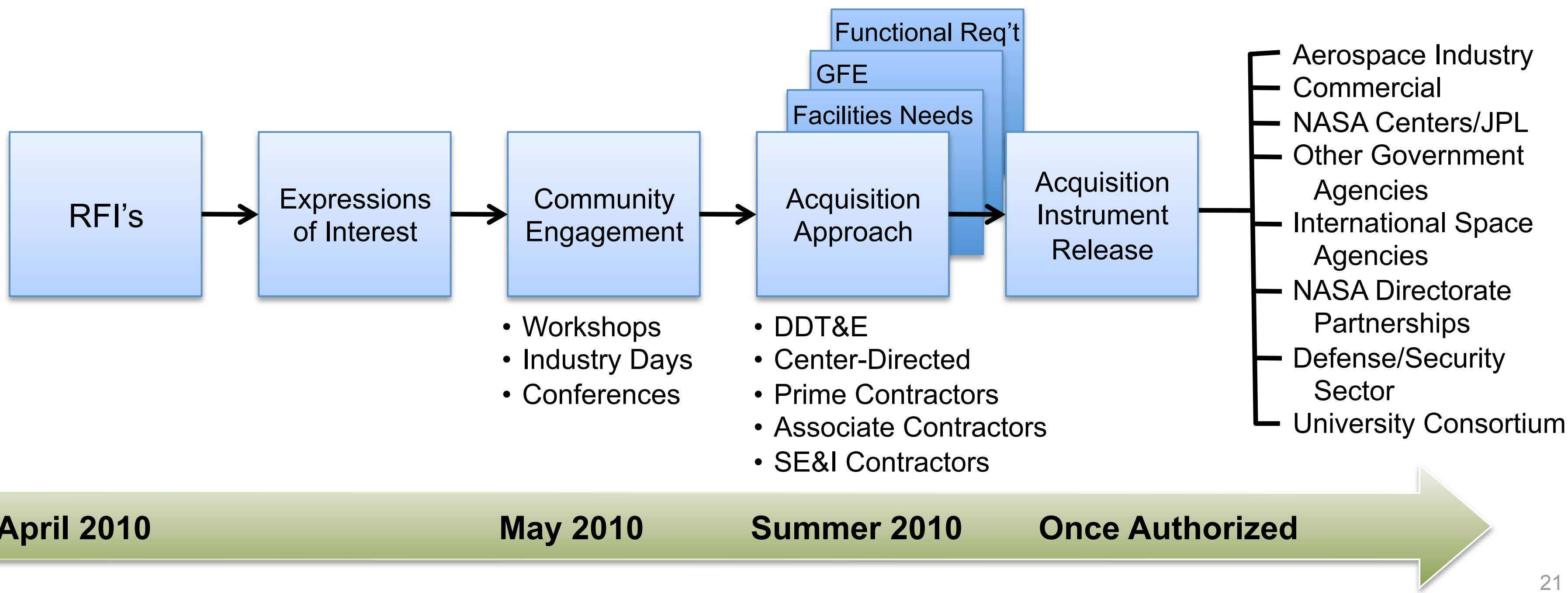
June 10	RFI responses due
June – July	Synthesis of RFI inputs and finalize missions set
June – July	Update budget and workforce estimates based on feedback from NASA Centers
July – August	Establish functional requirements for each mission set based on mission analysis and planning, and RFI synthesis
August-September	Define procurement strategy and ready procurement documents

FTD Notional Acquisition Strategy



Flagship Missions

- Significant in scope
- Potential for high downstream cost savings
- Demonstrates new exploration capabilities



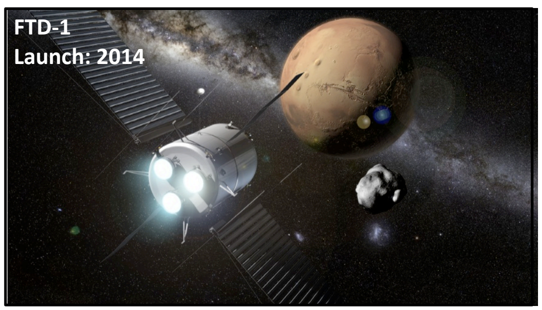
FTD Summary and Conclusions

- **Four Reference Flagship Technology Demonstrations (FTD) missions serve as a point of departure**
  - RFI inputs will be used to refine the missions
- **The following technologies will be integrated and tested through four Flagship class missions.**
  - Advanced in-space propulsion (ion/plasma, etc)
  - In-orbit propellant transfer and storage
  - Lightweight/inflatable modules
  - Aero-capture/entry, descent and landing
  - Advanced life support
  - Automated/autonomous rendezvous and docking(AR&D)
- **The four POD missions under consideration in the order of potential launch dates are**
  - Advanced in-space propulsion/AR&D ; Launch - 2014
  - In-orbit propellant transfer and storage/AR&D; Launch -2015
  - Lightweight/inflatable modules to ISS with Advanced Life Support capability; Launch – 2015
  - Aero-capture/entry, descent and landing (option for either an Earth-based or Mars-based mission); Launch – 2016 or 2018
- **More details will be provided in tomorrow's session**

Flagship Technology Demonstrations (FTD)

NASA's Flagship Technology Demonstrations (FTD) would capitalize on the technology maturation and ground test bed activities from both within and external to NASA. FTD demonstrates "transformational capabilities" at the proper scale and performance regime necessary to affordably conduct future human exploration missions to select destinations in the inner solar system.

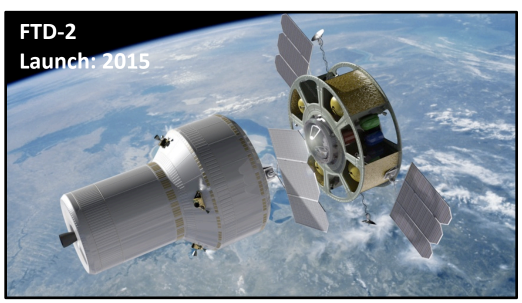
Beginning in 2014, the first set of FTD missions would focus on:



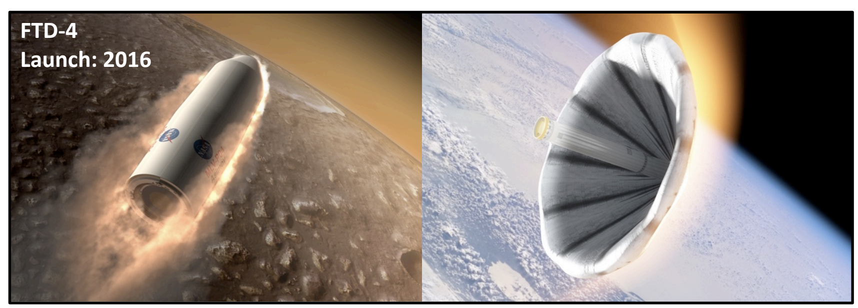
Advanced in-space propulsion

Automated Rendezvous & Docking AR&D

Inflatable ISS mission module, with Closed-loop Environmental Control and Life Support (ECLS)



In-Space propellant transfer and storage



Aero-Assist Entry-Descent-Landing (AEDL)