National Aeronautics and Space Administration

Space Technology Mission Directorate

NAC T&I Committee

Presented by:
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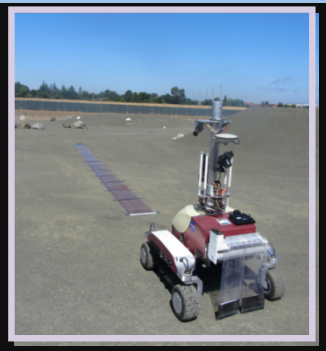
Associate Administrator

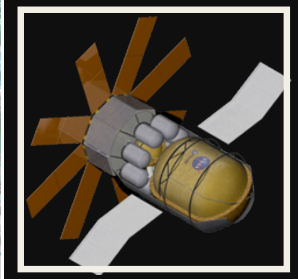
December 2013

FY 2013 Major Highlights

Sunjammer Solar Sail is entering final design and fabrication stage, progressing toward system integration and flight readiness review; launch in late CY 2014.



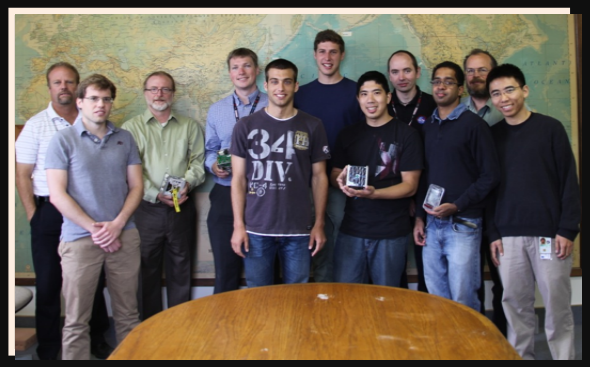
Green Propellant Infusion Mission- Aerojet Rocketdyne Technician prepares for the successful 22N thruster test.

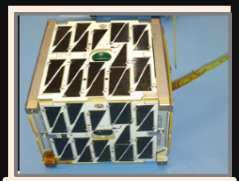


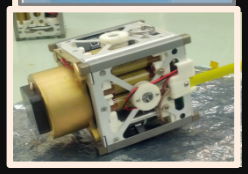
Cryogenic Propellant Storage and Transfer Project has completed a substantial technology maturation effort to prepare them for flight demonstration and NASA hosted a series of technology maturation workshops.

K10 Rover successfully operated by astronauts aboard ISS demonstrating human and robotic partnership for future planetary exploration.

FY 2013 Major Highlights

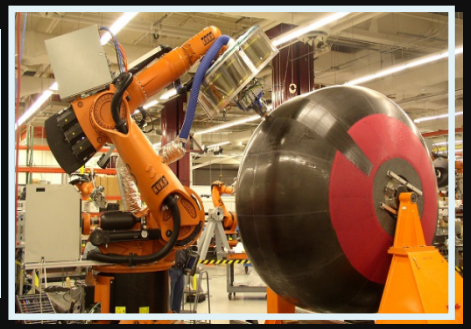


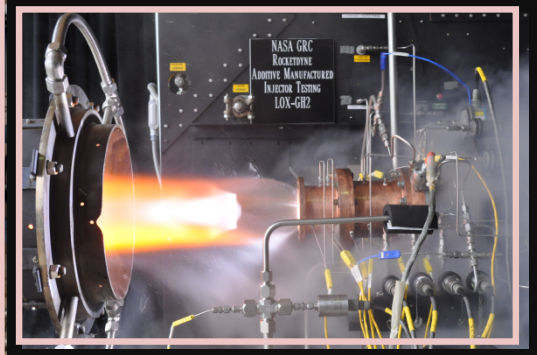




The PhoneSat mission launched as a rideshare on the inaugural flight of the Orbital Sciences Corporation's Antares vehicle, to demonstrate command and control capability of operational satellites.

Successfully fabricated a 2.4-meter composite cryogenic propellant tank in FY 2012, and completed testing in FY 2013 (summer). Follow on fabrication and testing a 5.5-meter diameter full scale tank in FY 2014.





Manufacturing Initiative -Liquid oxygen/gaseous hydrogen rocket injector assembly built using additive manufacturing technology is hot-fire tested at NASA Glenn Research Center's Rocket Combustion Laboratory in Cleveland.

Flight Opportunities has flown 28 technologies so far in FY 2013 on four different commercial platforms, with an additional 13 payload flights in the pipeline to be flown on seven flights.

"Big 9" FY 2013 Milestones

Key: KDP, Launch, Testing, Development, Review, Critical Event

FY 2013

Projects	Oct-12	Nov-12	Dec-12	Jan-13	Feb-13	Mar-13	Apr-13	May-13	Jun-13	Jul-13	Aug-13	Sept-13
Composite Cryogenic Propellant Tank		5.5m Preliminary Test Plan & Fixture Review		Tooling Design Review; CDR; MRR	5.5 m Janicki Fab. Complete			Delta CDR	2.4m Pressure Test Complete			
Hypersonic Inflatable Aerodynamic Decelerators	HIAD Annual Review						2nd Generation TPS Fabrication Complete	HIAD Mid-Year Review		IRVE-4 LaRC Systems Functional Checkout	Structural Model V1.0 Release	6m Inflatable Structure Fabrication
Human Exploration Telerobotics & Human Robotic Systems	Ground conducts ISS survey	Crew conducts simulated EVA repairs with teleop gear							Demonstrate New XGDS	Gnd controls mobile camera	Complete Testing Prototypes Jetpack; Spring Tires, Arm for Delivery	
Low Density Supersonic Decelerators	PDV CDR	Sled Test 1 & 2	KDP-C				SFDT CDR	Parachute Test		Parachute Test	Parachute Test	
Deep Space Atomic Clock							PDR					
Sunjammer Solar Sail		MSFC EMC; KDP-C	Range Safety TIM	'89 Boom Test 1, 2, 3; Satellite Tool Kit TIM		Fluidics, Mech. & Structure SS Peer Review		Sail SS Peer Review		Sail Deploy Test	ETU/Beam Deploy & Quadrant Test	H/W I&T Peer Review
Cryogenic Propellant Storage and Transfer								STMD PMC; 1st & 2nd Technology Maturation W/S			3rd & 4th Technology Maturation W/S	MSN-P/L SRR/MDR
Laser Comm. Relay Demo.			KDP-A			SRR		KDP-B				
Robotic Satellite Servicing		RRM-Phase 2 CDR				Servicing Payload SRR		RRM-On Orbit Operations	RRM-Phase 2a HW Delivery		RRM-Phase 2a Launch	

"Big 9" FY 2014 Upcoming Milestones

Key: KDP, Launch, Testing, Development, Review, Critical Event

FY 2014

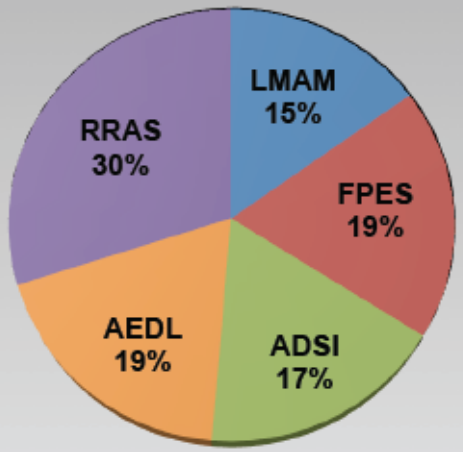
Projects	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sept-14
Composite Cryotank Tech and Demo	5.5 Fabrication		5.5 Delivery			5.5 Integrated TRR						
Solar Electric Propulsion		ATK TRR; DSS TRR	Complete FDR of 15kW Class Hall Thruster	ATK: Thermal Vacuum Tests for Solar Arrays		DSS: Thermal Vacuum Tests for Solar Arrays	ATK P1 Final Review; Complete Performance Testing of 15kW Class Hall Thruster	DSS P1 Final Review		Complete Diagnostic Testing with 15kW Class Hall Thruster	SEP MCR	Comp. testing of Brassboard DDU & PPU with 15kW Class Hall Thruster
Human Exploration Telerobotics & Human Robotic Systems	R2 Climbing Legs on-dock			Launch Climbing Legs	Delivery Robonaut 2 Fleet Leader Battery				R2 Crew Control Stowage IFC	SS Ground Control Telepresence	R2 Ground Control IVA Mobility	EOM; Dem. Realistic Physic w/ Asteroid Capture Test bed
Low Density Supersonic Decelerators	Annual Review; Sys. Integ. Rev		Parachute Test			Sled Test			Flight Demo			
Deep Space Atomic Clock		KDP-C	CDR			Payload Testing						KDP-D
Sunjammer Solar Sail	S/W I&T Peer Review	CDR		KDP-D				Acceptance Test				FRR
Cryogenic Propellant Storage and Transfer		KDP-B	Payload SRR							PDR	KDP-C	
Laser Comm. Relay Demo.	PDR		KDP-C									
Green Propellant Infusion Mission		Thruster Gnd Sys Test	CDR		KDP-D					Payload Testing		

FY13/FY14 GCD: Firsts!

Lightweight Materials and Advance Manufacturing

- **CCTD:** First and largest composite cryotank in the world to be fabricated out-of-autoclave
- **Nanotechnology:** 20% weight reduction in payload faring beyond advanced composite materials used today
- **Adv. Man.** processes to create on-demand spacecraft parts, reducing waste by 80% and manufacturing time from months to weeks; 3D Printer to ISS for first on orbit demonstration

Distribution for FY13/FY14



Future Propulsion and Energy Systems

- Advanced **batteries** with double the life expectancy, and more than double the energy capacity of state of the art.
- A **regenerative fuel cell** that produces abundant and efficient power from hydrogen and oxygen; will operate up to 10,000 hours maintenance free.
- Inductive pulsed plasma **thruster** operated at a repetition rate at an input power above 1kW
- Developed 10kWe non-nuclear tech demo unit for fission power reactor to test heat-to-power conversion.

Affordable Destination Systems and Instruments

- **Water Processor** that recovers and reuses 85% more wastewater, and reduces water processor resupply requirements by 20%; needed to maintain the life support for astronauts.
- **Deep Space Optical Comm:** Developed new photon counting detector technology with highest efficiency and potential for >7 year lifetime in space.

Advanced Entry, Descent and Landing

- Novel materials for thermal protection of spacecraft that dramatically simplify manufacturing process; adaptable to variety of spacecraft demands.
- Demonstrated variability of woven TPS, provides new options to enhance performance and reduce mass of TPS.
- Developed first 4” thick conformal rayon felt for use on deployable aeroshell concepts.

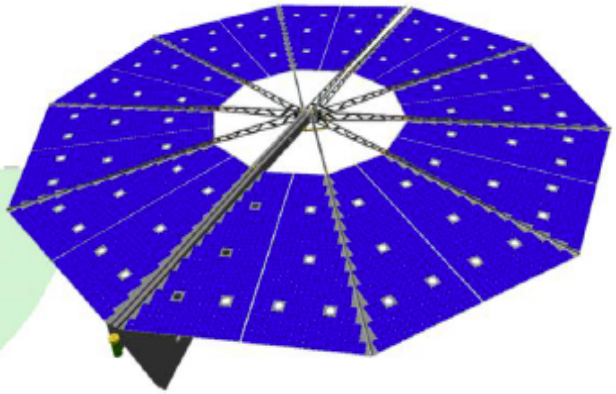
Revolutionary Robotics and Autonomous Systems

- First successful test of a **hands free jet pack**
- Fully **automated loading** of cryogenic propellant; developed algorithms for simulating chill down and two phase flow loading.
- Developed a valve health monitoring system with embedded algorithms in the solenoid valves to monitor status, degradation and failures.

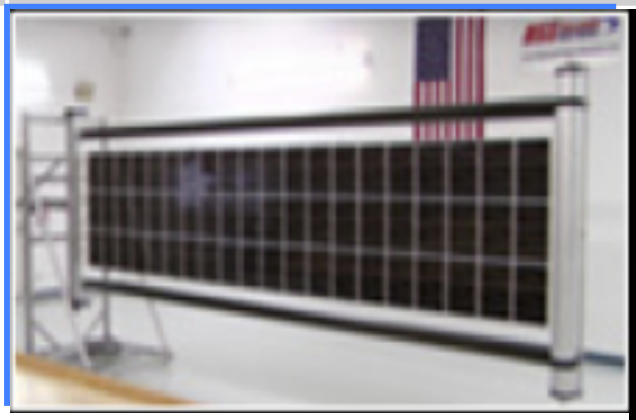
SEP Technology Investment

- Current focused NASA STMD investments on advanced next-gen solar arrays and higher power electric propulsion technologies to enable 30kW-class SEP
- Two providers selected through competitive NRA for development of solar array systems (SAS): Alliant Techsystems Inc. (ATK) & Deployable Space Systems (DSS)
- NASA in-house EP development of 15kW class HET system using either direct-drive and/or high voltage power processing unit
- Additional investments in PV cells and HV, rad-hard electronic parts

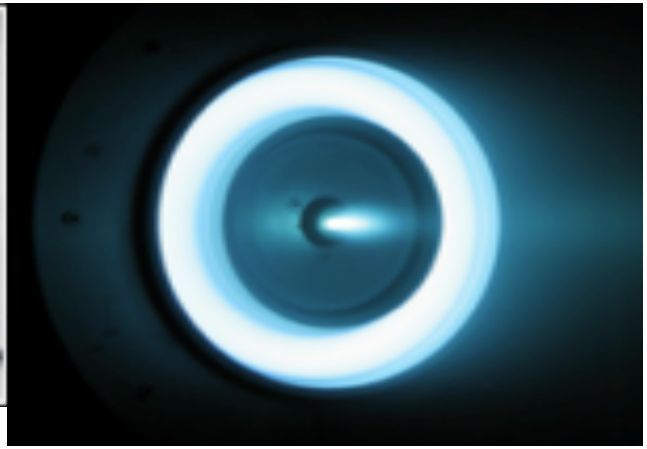
ATK MegaFlex:
Partners – AMA, Ball, Emcore, JPL, SpectroLab
Start Date: October 2012
Anticipated Duration: 18 months



DSS Roll Out Solar Array (ROSA):
Partners - Emcore and JPL
Start Date: October 2012
Anticipated Duration: 18 months



In-house EP System Development:
Partners - GRC and JPL
Start Date: January 2012
Anticipated Duration: 36 months



STMD's SEP Demo Mission Objectives

Technology

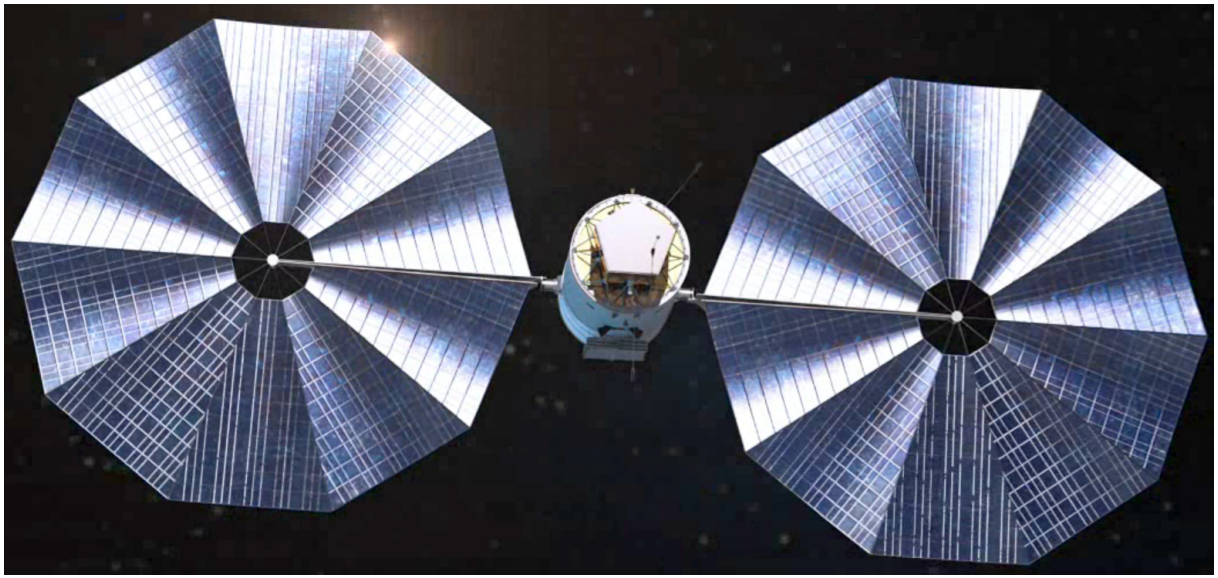
Demonstrate enabling SEP technologies in all relevant space environments (from LEO to beyond GEO)

- Next gen electric propulsion
- Solar arrays
- High voltage
- Tech infusion

Integrated System

Solve the system technology and operational issues related to implementation of a high performance SEP vehicle

- Power system dynamic behavior
- Thermal control
- Attitude control



Extensibility

Provide an evolutionary step to the high power SEP systems needed for future human exploration

- Prove low thrust systems can deliver heavy payloads
- Build upon the recent success of AEHF
- Inform future exploration architecture studies
- Retire risks associated with Van Allen radiation belts

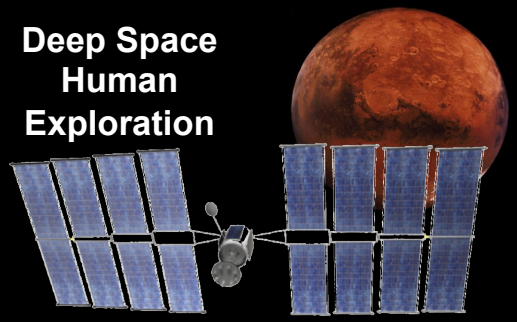
Capability

Provide a valuable beyond-LEO payload delivery capability

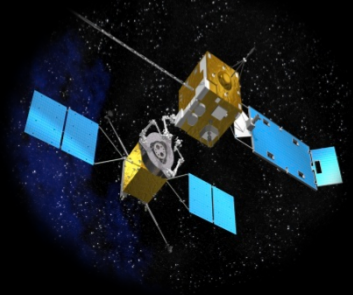
- Wide range of potential missions (HEOMD, SMD, DoD, Commercial Space)
- Enables cost savings via launch vehicle step down
- Operational capability enables partnership opportunities

High-powered SEP Enables Multiple Applications

Deep Space Human Exploration

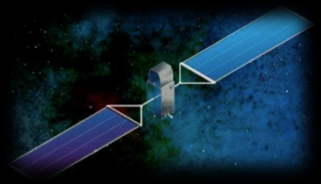


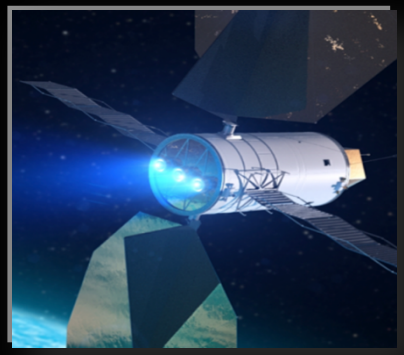
Satellite Servicing



Payload Delivery

Commercial Space Applications





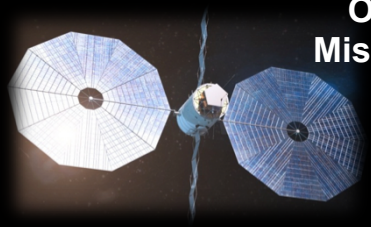
ISS Utilization

Solar Electric Propulsion

Orbital Debris Removal

Space Scien Mission

OGA Missions

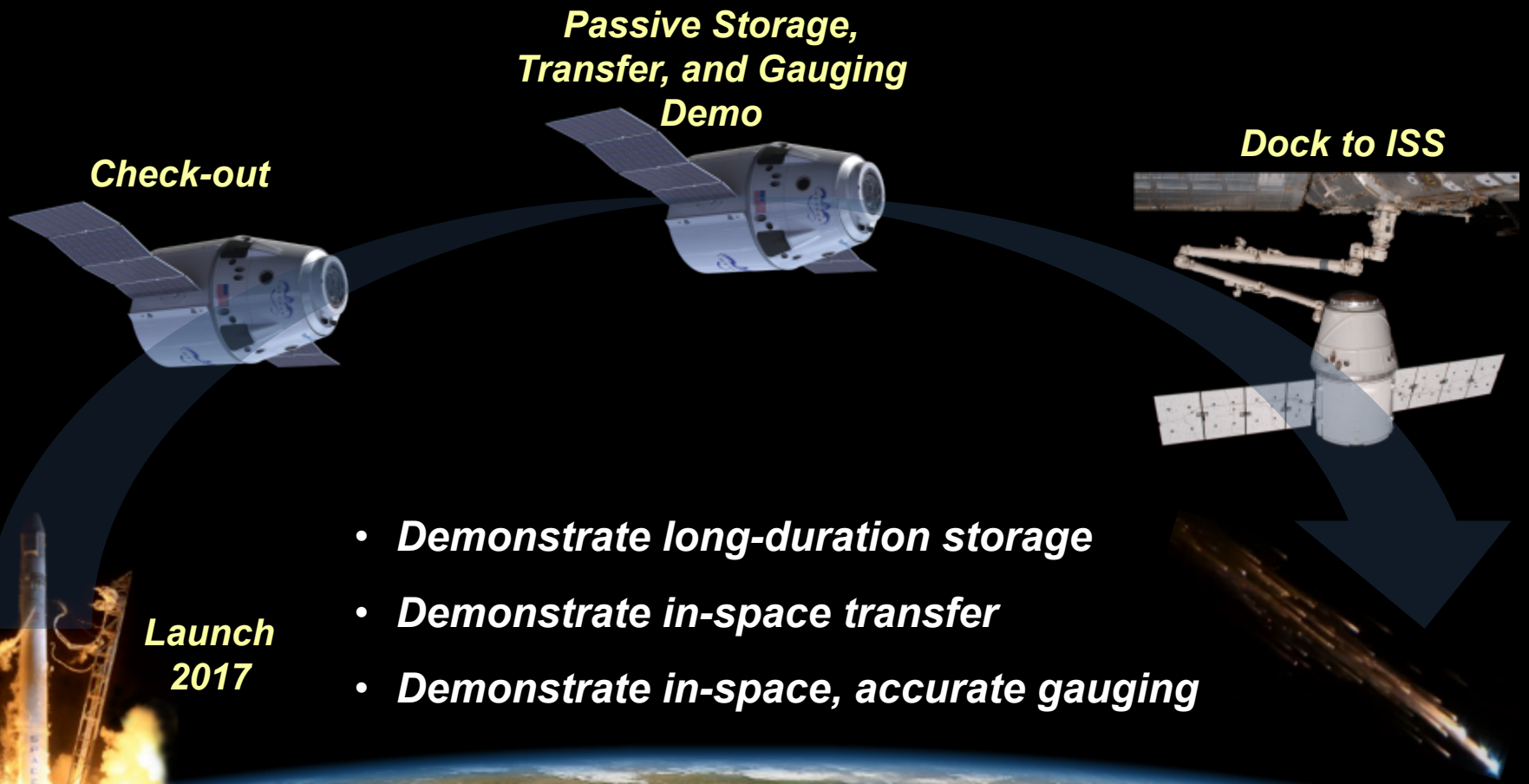


The First Steps Upwards to Mars……

Sequence \ Mission	Current ISS Mission	Asteroid Redirect Mission	Long Stay In Deep Space	Humans to Mars Orbit	Humans to Surface, Short Stay	Humans to Surface, Long Stay
In Situ Resource Utilization & Surface Power						X
Surface Habitat						X
Entry Descent Landing, Human Lander					X	X
Aero-capture				X	X	X
Advanced Cryogenic Upper Stage				X	X	X
Deep Space Habitat	*	→	X	X	X	X
High Reliability Life Support	*	→	X	X	X	X
Autonomous Assembly	*	→	X	X	X	X
Solar Electric Propulsion for Cargo		X	X	X	X	X
Deep Space Guidance Navigation and Control		X	X	X	X	X
Crew Operations beyond LEO (Orion)		X	X	X	X	X
Crew Return from Beyond LEO – High Speed Entry (Orion)		X	X	X	X	X
Heavy Lift Beyond LEO (SLS)		X	X	X	X	X

Cryogenic Propellant Storage and Transfer Technology Demonstration Concept Vision

Extending human reach into deep space by advancing cryogenic propellant storage and transfer technologies to meet the needs of both NASA exploration systems and commercial launch providers



- *Demonstrate long-duration storage*
- *Demonstrate in-space transfer*
- *Demonstrate in-space, accurate gauging*

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