National Aeronautics and
Space Administration

Technology Demonstration Missions Program

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Program Executive
Space Technology Mission Directorate

July 30, 2013

www.nasa.gov/spacetech

STMD Programs

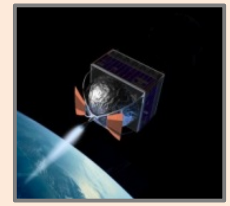
Transformative & Crosscutting Technology Breakthroughs

Pioneering Concepts/ Developing Innovation Community

Creating Markets & Growing Innovation Economy

Game Changing Development Program

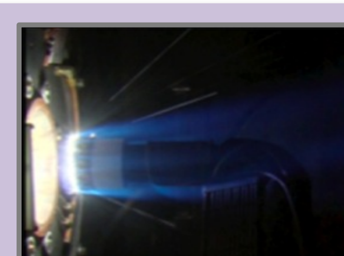
Technology Demonstration Missions Program



Small Spacecraft Technologies Program

Space Technology Research Grant Program

NASA Innovative Advanced Concepts (NIAC) Program



Center Innovation Fund Program

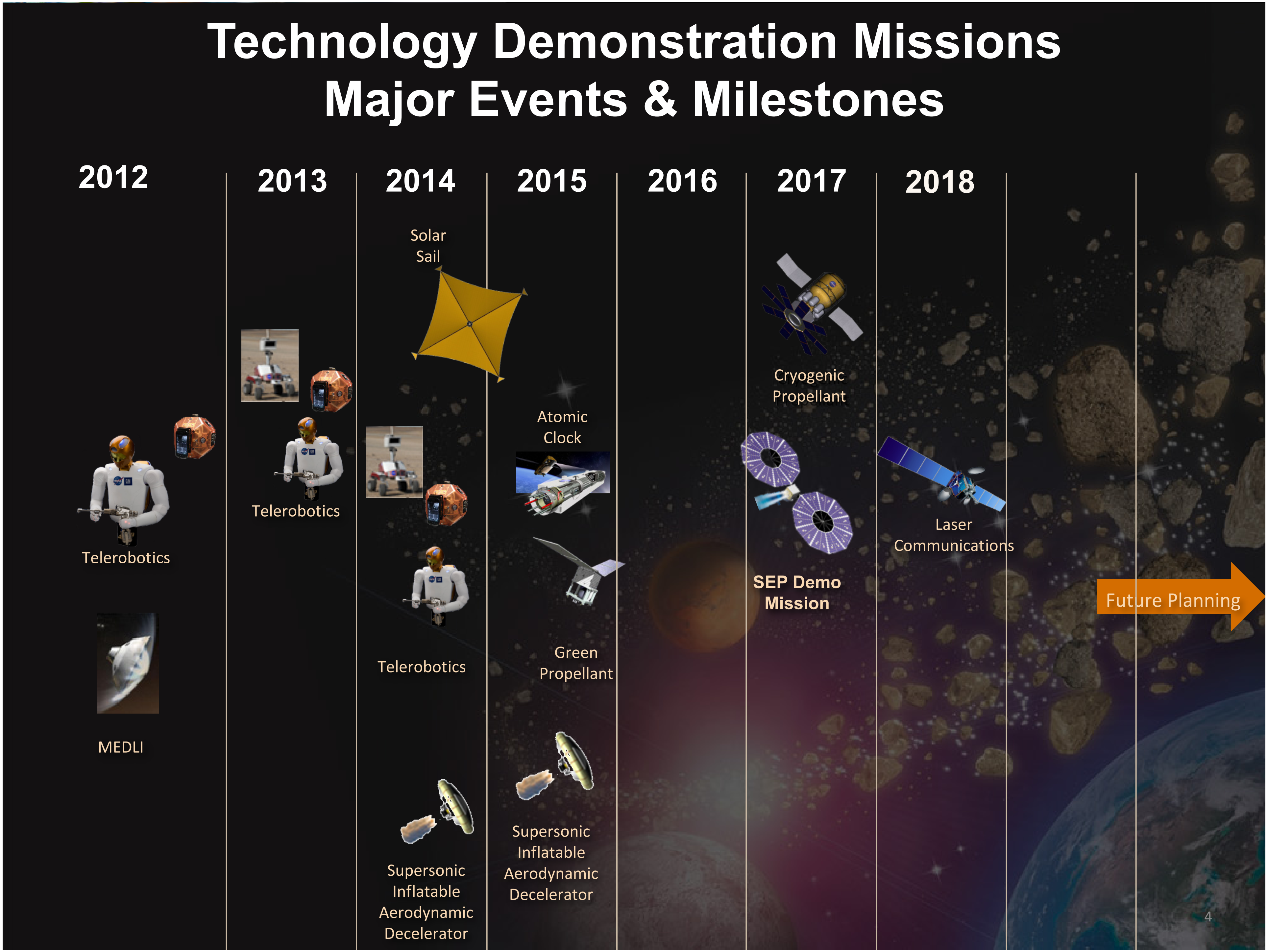
Centennial Challenges Prize Program

Small Business Innovation Research & Small Business Technology Transfer (SBIR/STTR) Program

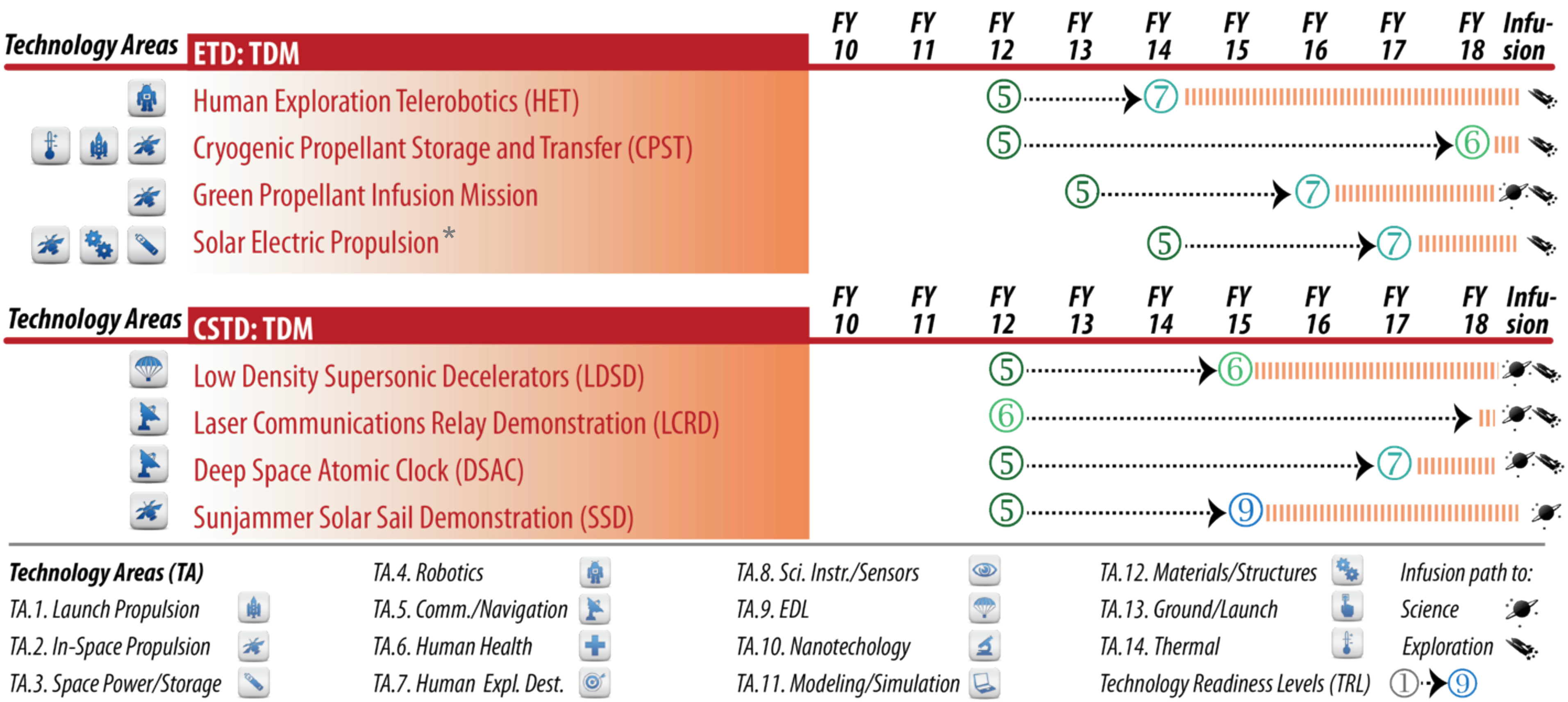
Flight Opportunities Program

Why TDM

Infusing Revolutionary, Crosscutting Technologies to Benefit NASA and the Nation

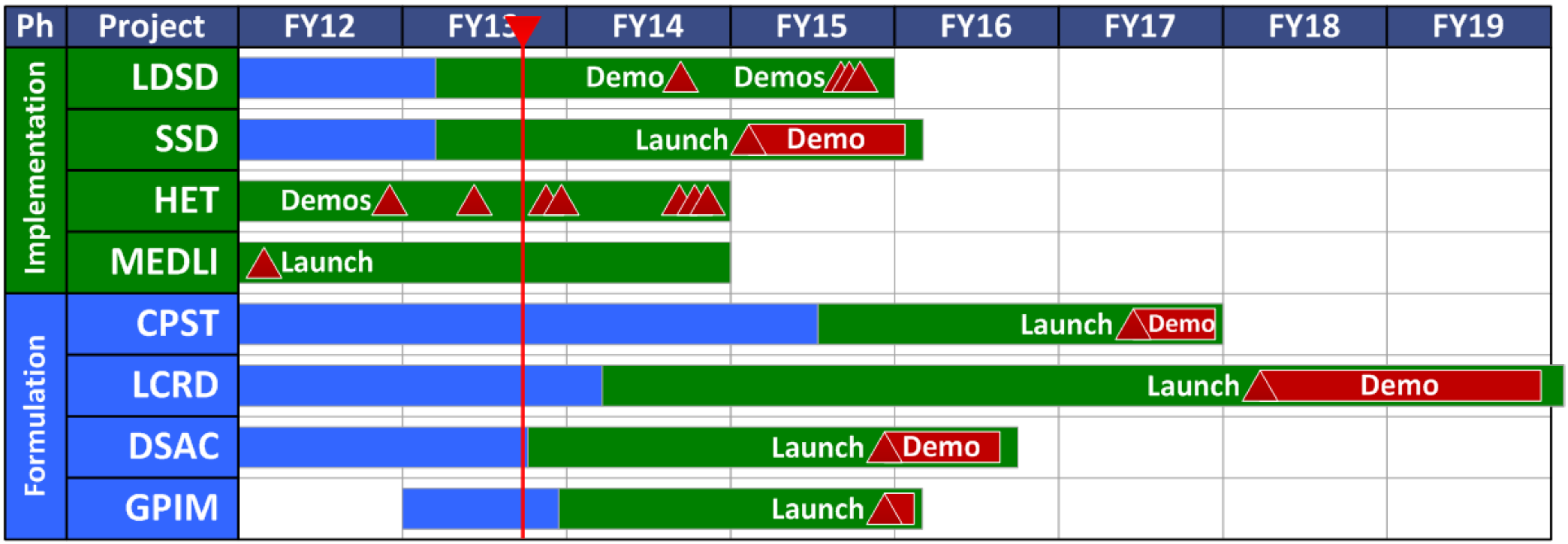

Technology Demonstration Missions
Major Events & Milestones
2012
2013
2014
2015
2016
2017
2018
Telerobotics
MEDLI
Telerobotics
Solar Sail
Telerobotics
Supersonic Inflatable Aerodynamic Decelerator
Atomic Clock
Green Propellant
Supersonic Inflatable Aerodynamic Decelerator
Cryogenic Propellant
SEP Demo Mission
Laser Communications
Future Planning
4

TDM Portfolio



*SEP does not become a TDM until FY2014

TDM Portfolio



Green Propellant Infusion Mission (GPIM) Overview

Overview: GPIM is a spaceflight demonstration of a complete propulsion system for spacecraft attitude control and primary propulsion using the "Green Propellant" AF-M315E developed by AFRL as a substitute to Hydrazine

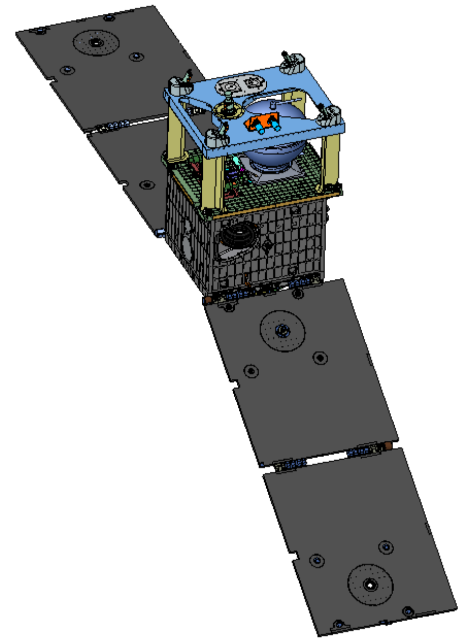
Benefits: Utilizing AFM-315E will significantly reduce the safety restrictions and complexities placed on hydrazine ground operations while substantially increasing performance (50% improvement over hydrazine)

Thrusters: One 22 N and four 1 N thrusters with new high-temperature catalyst technology designed, developed, and tested by Aerojet. Cost comparable to hydrazine thrusters.

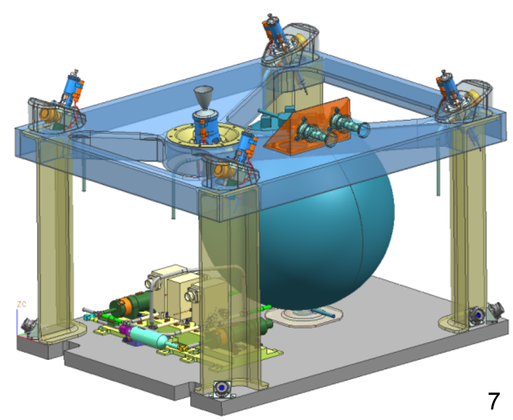
Spacecraft bus: Flight-proven Ball Configurable Platform (BCP) 100 bus

Access to space: Secondary payload (ESPA compatible) on DOD Space Test Program launch STP-2 (Falcon Heavy) in Fall 2015

Team members: Ball Aerospace (lead), Aerojet, Air Force Research Laboratory, Space & Missile Systems Center, NASA Glenn Research Center, NASA Kennedy Space Center



GPIM spacecraft

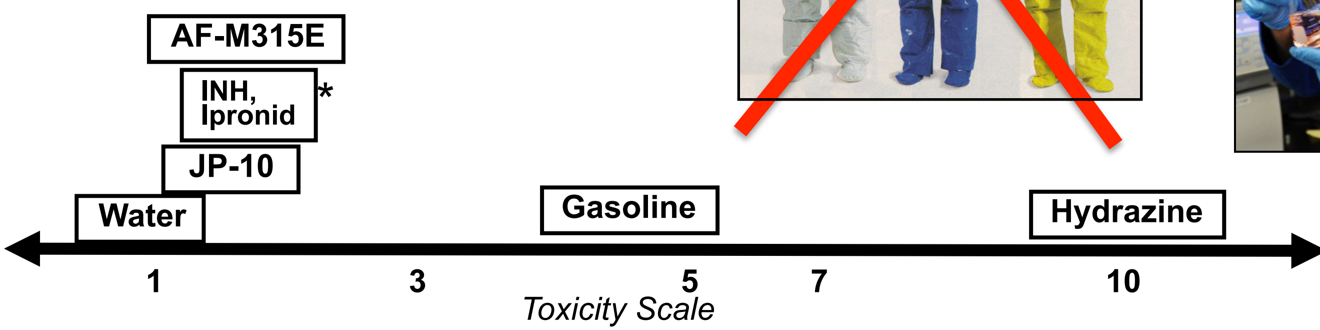


GPIM propulsion system

Propellant Characteristics

- AMF-315E was developed by AFRL in 1998 as an alternative to Hydrazine
  - Focus on reducing toxicity and increasing performance
- Propellant is an ionic salt blend of HAN (Hydroxylammonium Nitrate) solid oxidizer with water and a compatible fuel
- >50% improvement in volumetric performance versus hydrazine

• Less toxic (LD50) than caffeine
• Negligible vapor toxicity allows propellant loading with typical PPE (no SCAPE or monitoring requirement)



***, INH used in treating tuberculosis; Ipronid is an antidepressant drug**

Project Team

Ball Aerospace
- Program Lead – PM & PI
- Project System Engineering
- Mission requirements
- Flight thruster performance verification
- Ground and flight data review
- BCP-100
- AI&T
- Launch and Flight Support

Aerojet Redmond Operations – Co-I
- Green propulsion payload
- 1N and 22N thruster development
- Payload integration
- Ground and flight data review

Air Force SMC
- Mission Operations
- Ground Segment Support
- STPSat GSE

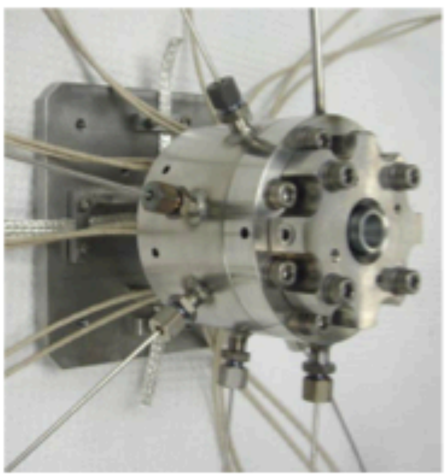
NASA GRC – Co-I
- Plume modeling
- Thruster independent testing
- Experimental plume diagnostics
- Ground and flight data review

Kennedy Space Center – Co-I
- IMLI for flight experiment
- Green propellant handling, loading processes
- Propellant assay analysis
- Ground and flight data review

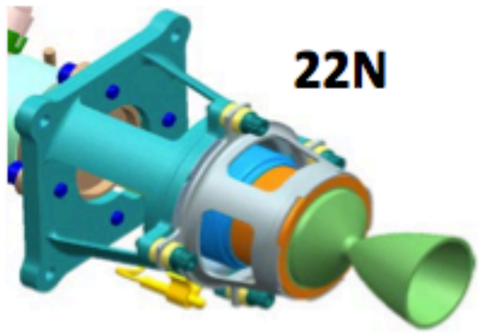
AFRL Edwards – Co-I
- Propellant (contribution)
- Propellant loading cart (contribution)
- Propellant loading
- Ground and flight data review

Thruster Development

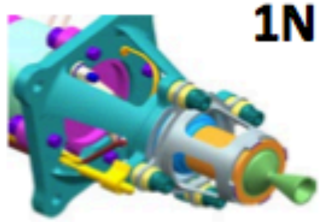
Lab Model (LM) Thruster → Engineering Model (EM) Thrusters → Flight Model (FM) Thrusters



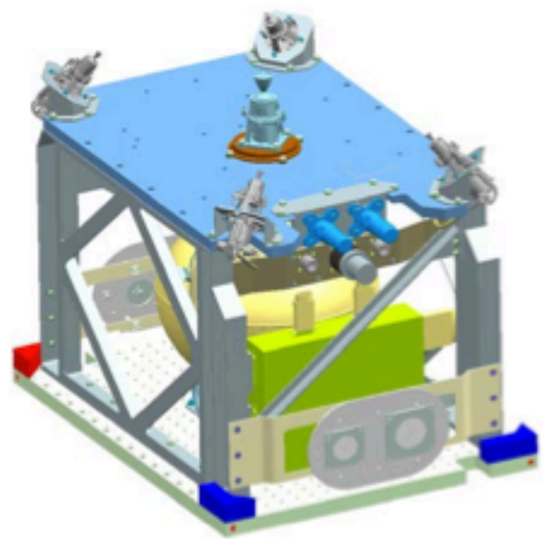
22N



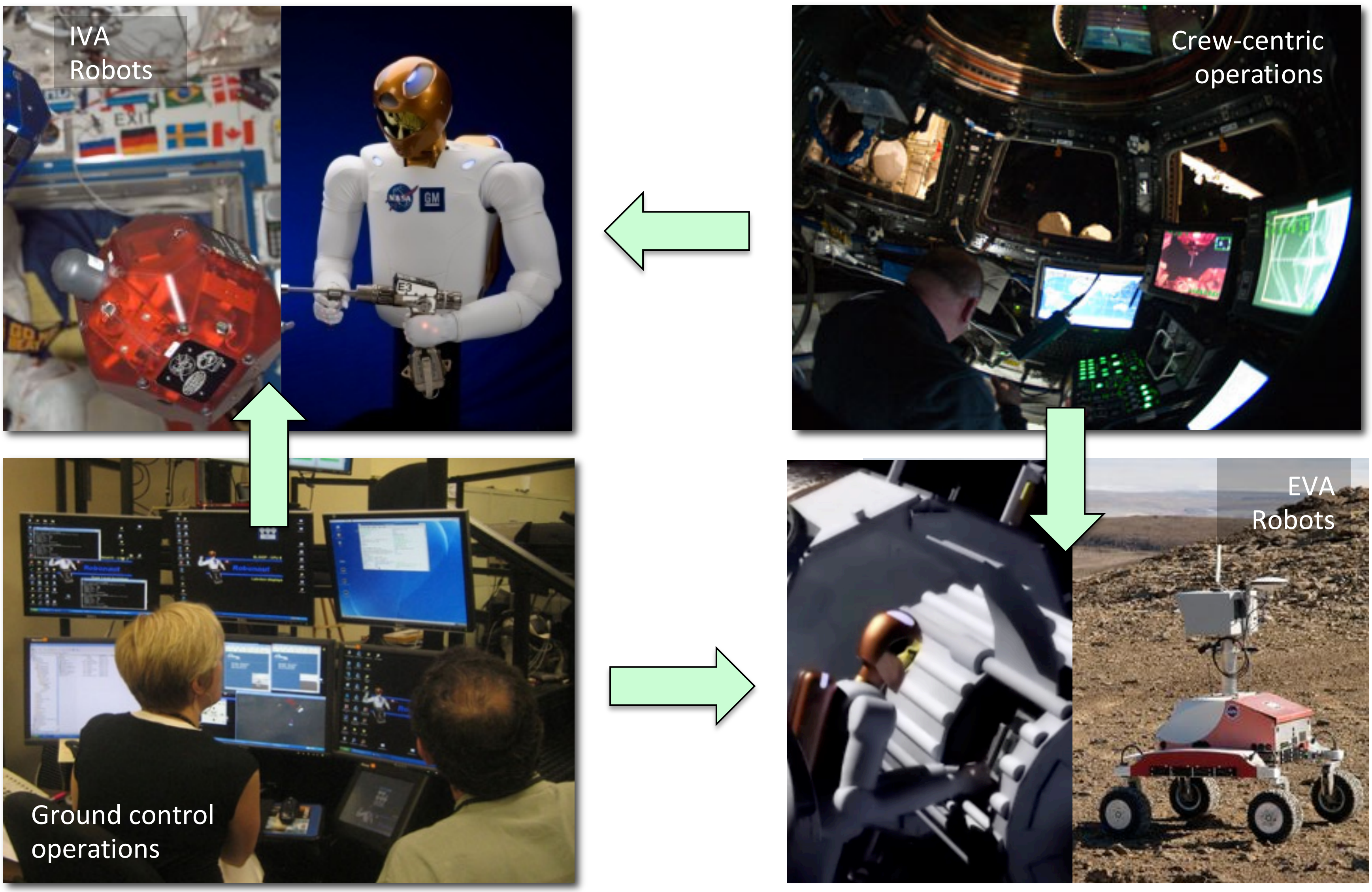
22N



1N



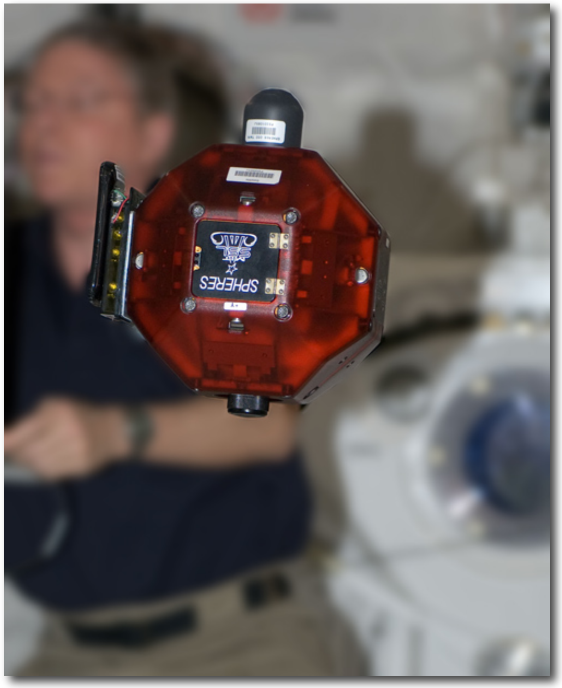
Human Exploration Telerobotics



Telerobotics Systems

Robonaut 2 (R2)

- Humanoid robot (42 DOF, human-scale/ safe)
- Ground control and crew centric operations
- Perform dexterous manipulation tasks



Smart SPHERES

- Free-flying robot (6 axis, cold-gas propulsion)
- Ground control and crew centric operations
- Perform remotely operated mobile sensor tasks

Surface Telerobotics

- Mobile robot on surface (Moon, asteroid, Mars)
- Crew centric operations from inside flight vehicle
- Perform surface activities before/support/after crew

Surface Telerobotics Roadmap

Ground Analogs

Develop systems for crew teleoperation of surface robots

Implement and test multiple conops

Simulate future human mission concepts

ISS Laboratory

Obtain baseline system engineering data

Validate & correlate prior ground simulations via high-fidelity ops sims

Reduce risk (exploration architectures based on inaccurate assumptions)

Beyond LEO

Enable crew to operate telerobots when site, dynamics and distance preclude ground control

Enable crew to operate surface robot from orbit when circumstances preclude ground control

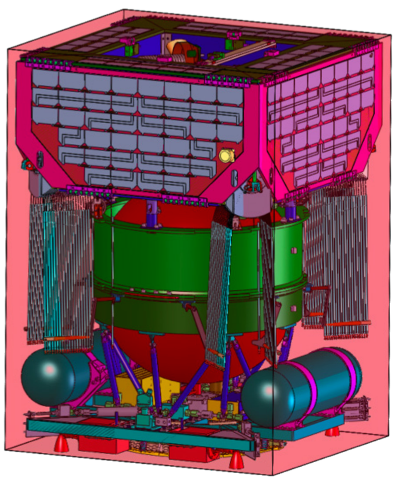
HRS, AES — **HET** — *HEOMD missions*

Surface Telerobotics

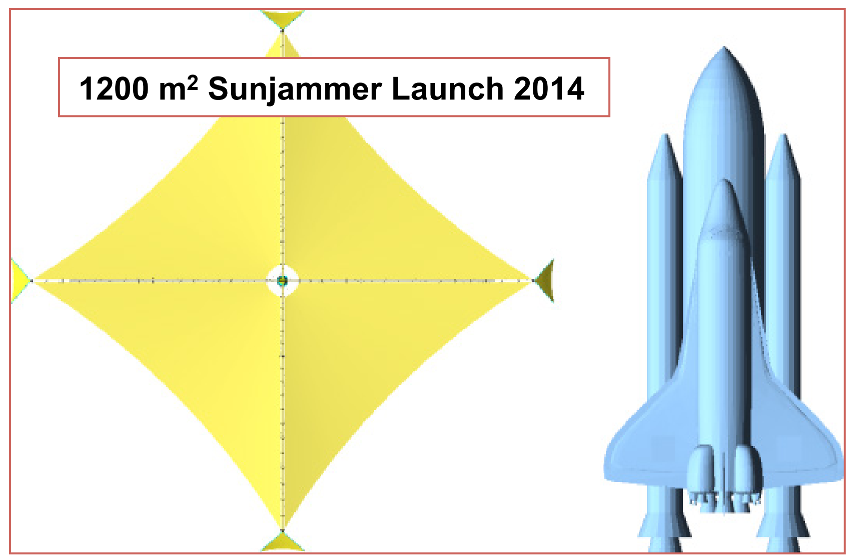
Surface Telerobotics

Sunjammer

- Demonstration of a mission infusable solar sail co-manifestested with DSCOVR
- Sunjammer mission objectives
  - Deployment
  - Attitude Control
  - Navigation

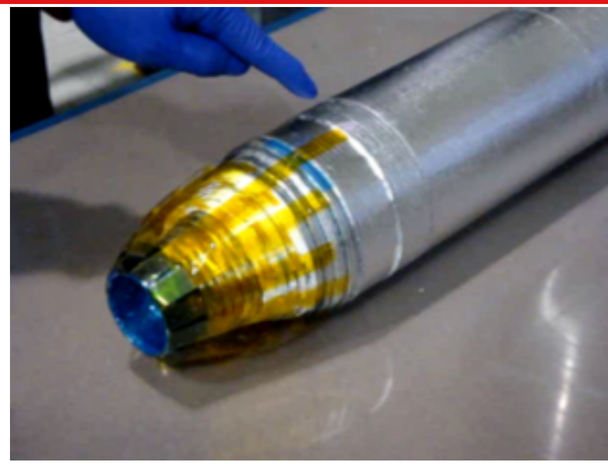


Dim.: 28in x <u>28in</u> x 38in
Mass: 153kg (wet)



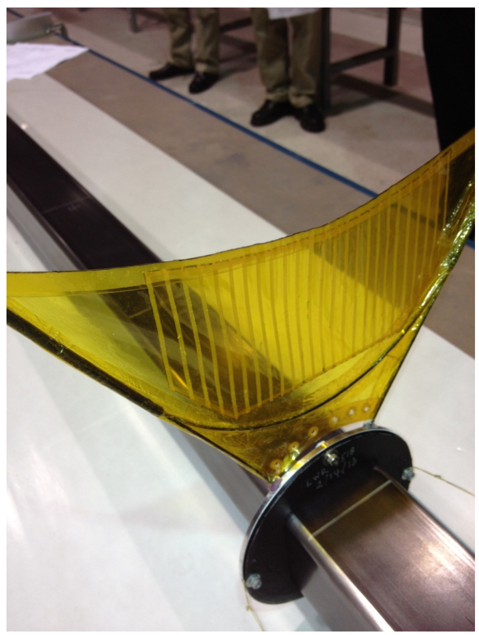
Sunjammer

Boom Stowed



Full Length Boom Deployed

Spreader Web with
Spreader Lines Stowed

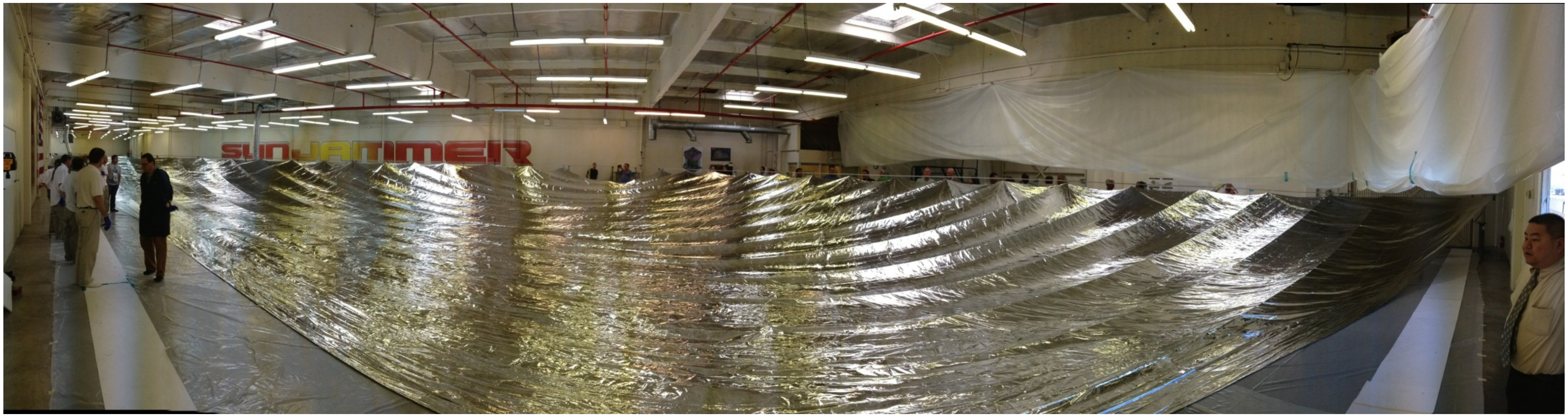


Spreader Web with
Spreader Lines Deployed

Sunjammer

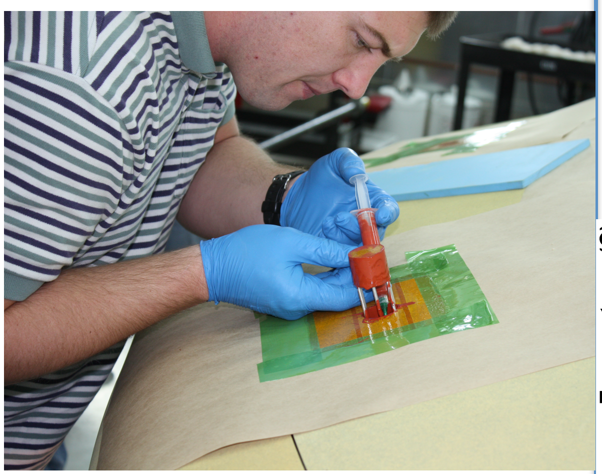
ETU Sail Deployment Development June 2013

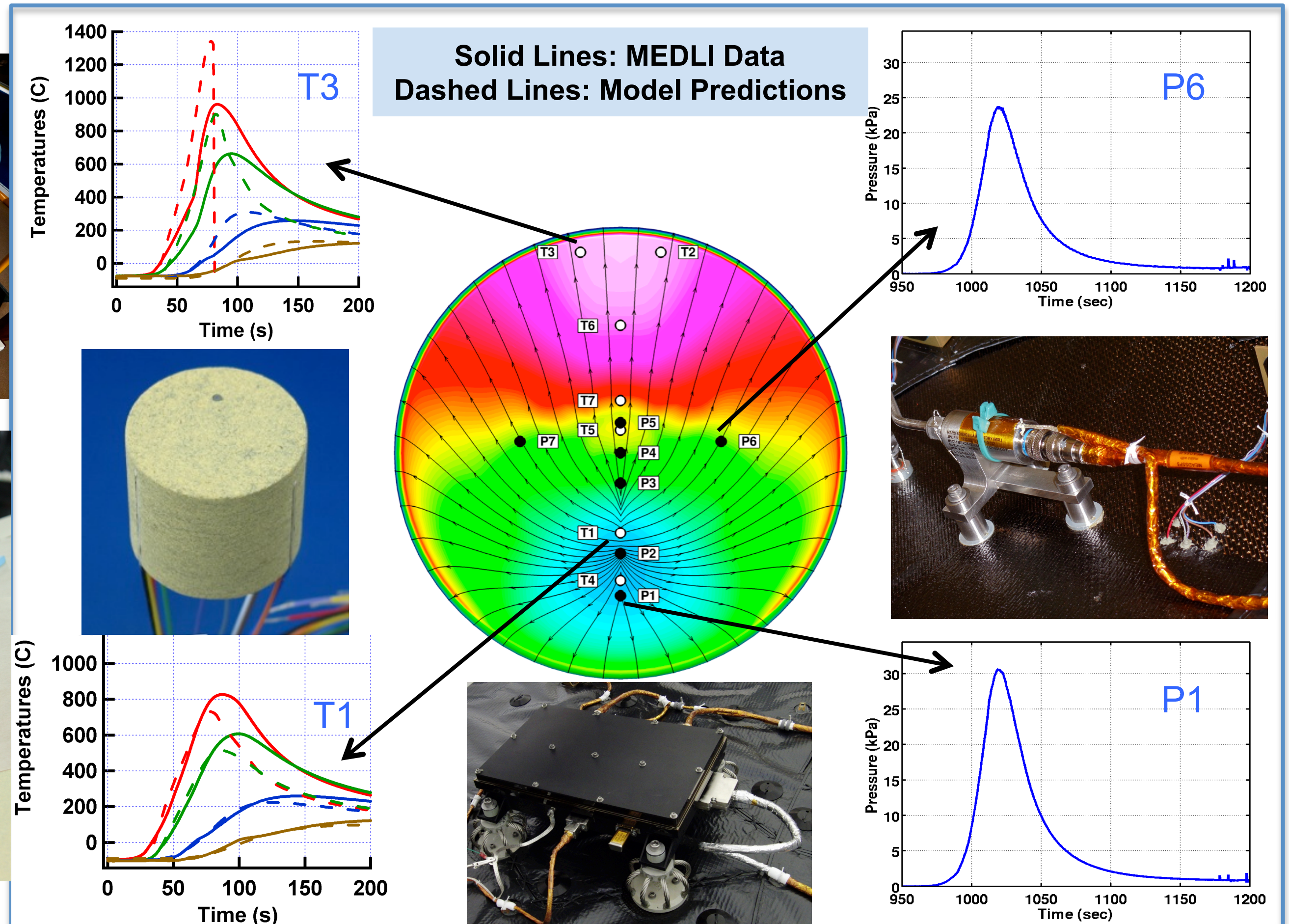
Video - Typical Sail Folding Technique (ISP Sail)



Full Scale ETU Sail Suspended from Manual Deployment Fixture

MSL Entry, Descent and Landing Instrument Flight Data

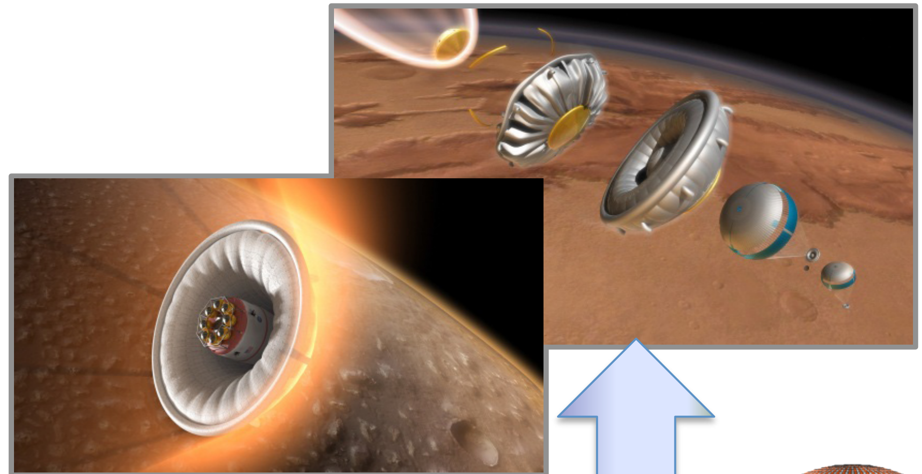


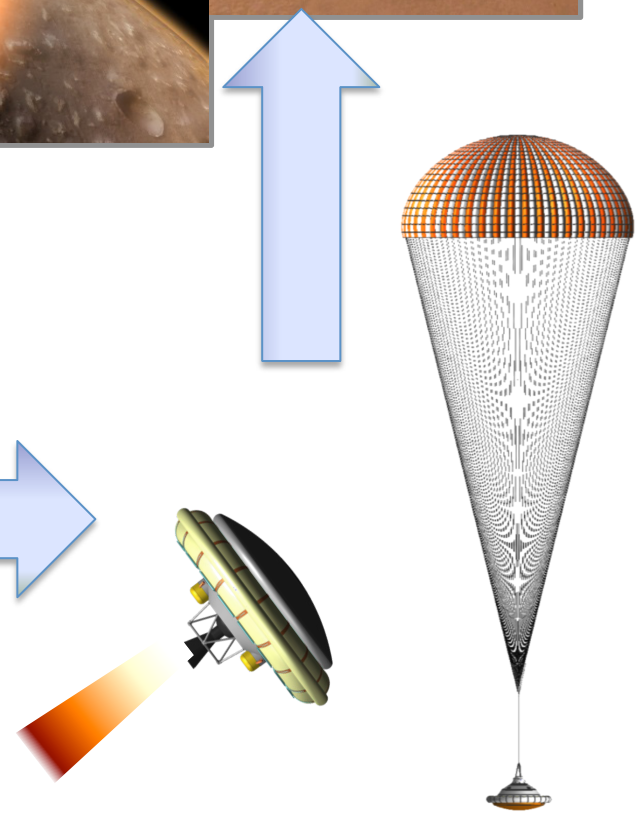


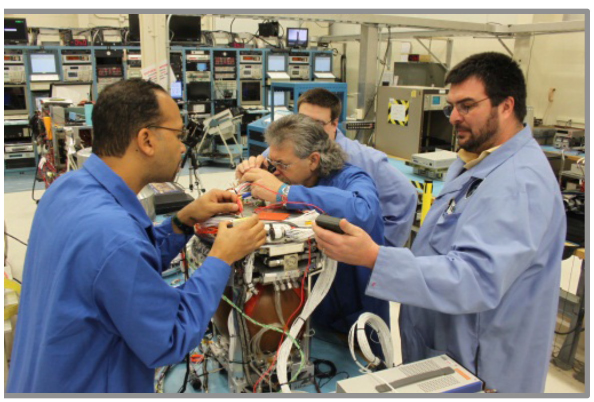
- **MEDLI** (Mars Science Laboratory (MSL) Entry, Descent and Landing Instrumentation) successfully measured temperature and pressure on MSL's heatshield during Mars entry on August 6, 2012.
- **MEDLI Thermal data** shows heating predictions were high in some places and low in others; recession less than 0.1"
- **MEDLI Pressure data** shows the spacecraft flew as expected, and encountered some winds below 15 km

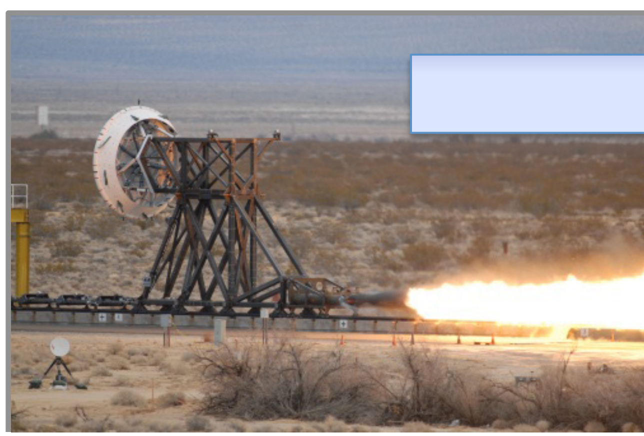
Low Density Supersonic Decelerator

- LDSD is designing and testing EDL systems to enable a new class of planetary entry vehicles
- Improvement over MSL
  - Up to 1mt increase in landed mass
  - 25% increase in elevation
  - 3x reduction in landing ellipse









LDSD Components

SIAD-R (6m) Decelerator

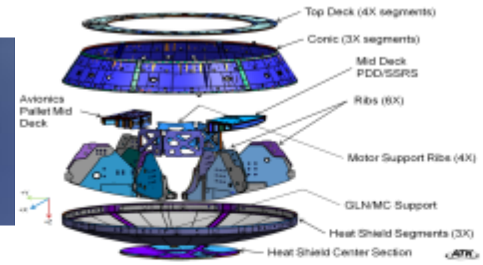
or

SIAD-E (8m) Decelerator

Ballute (4.4m) (Chute Deployment Device)

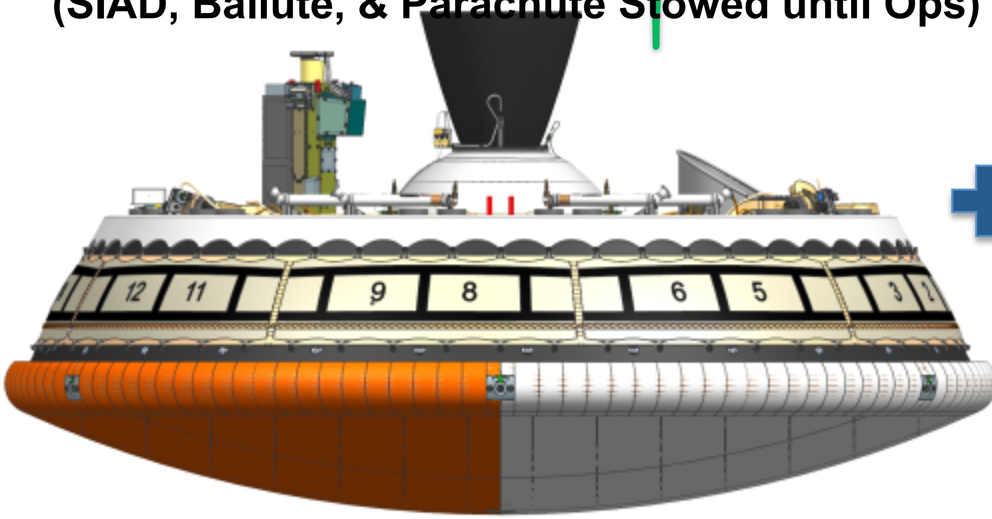
Supersonic Parachute (30.5m)

Core Structure (Including Heatshield)



The components <u>above</u> along with the Avionics Pallet, Star 48-Motor, Spin Motors, GLN-MAC (IMU), cameras, etc. comprise the Test Vehicle shown below

Test Vehicle (TV) (SIAD, Ballute, & Parachute Stowed until Ops)

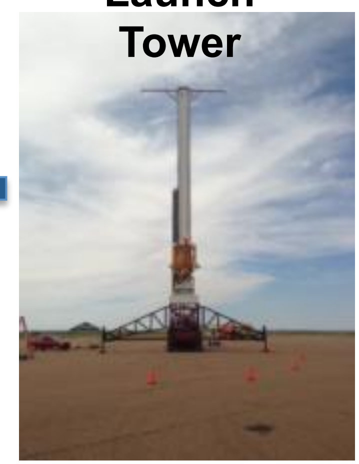


+

Balloon

+

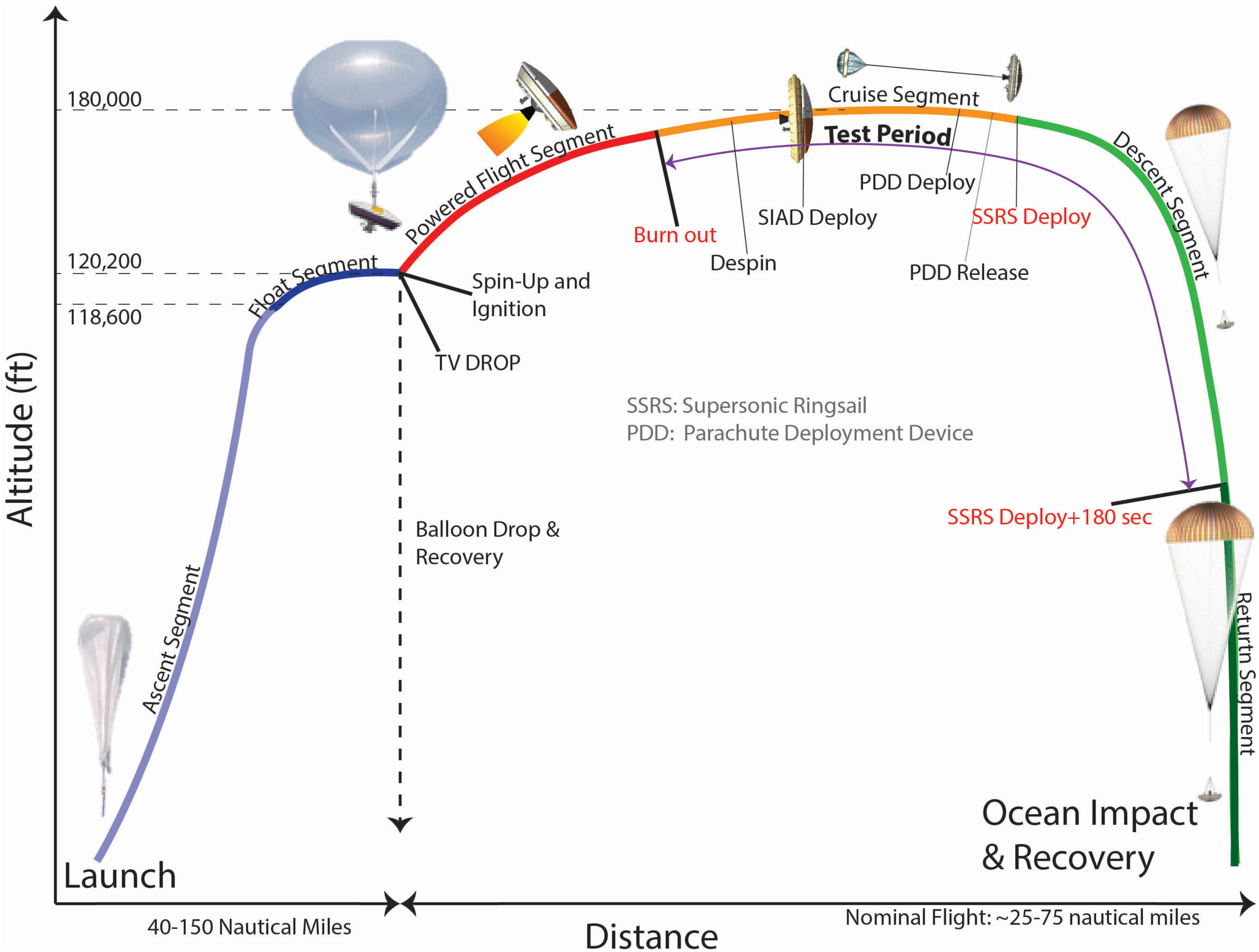
Launch Tower



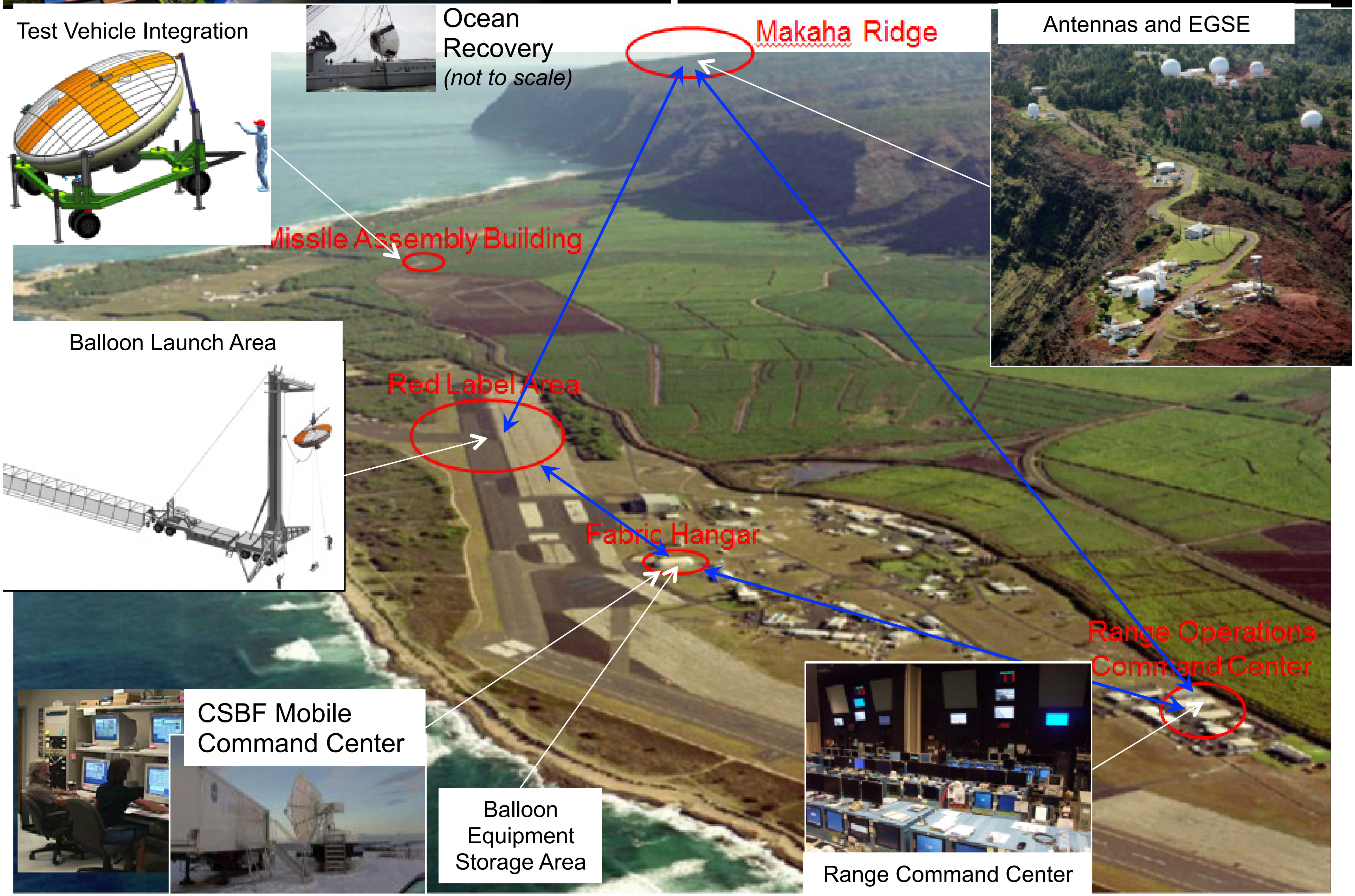
= **SFDT Launch**

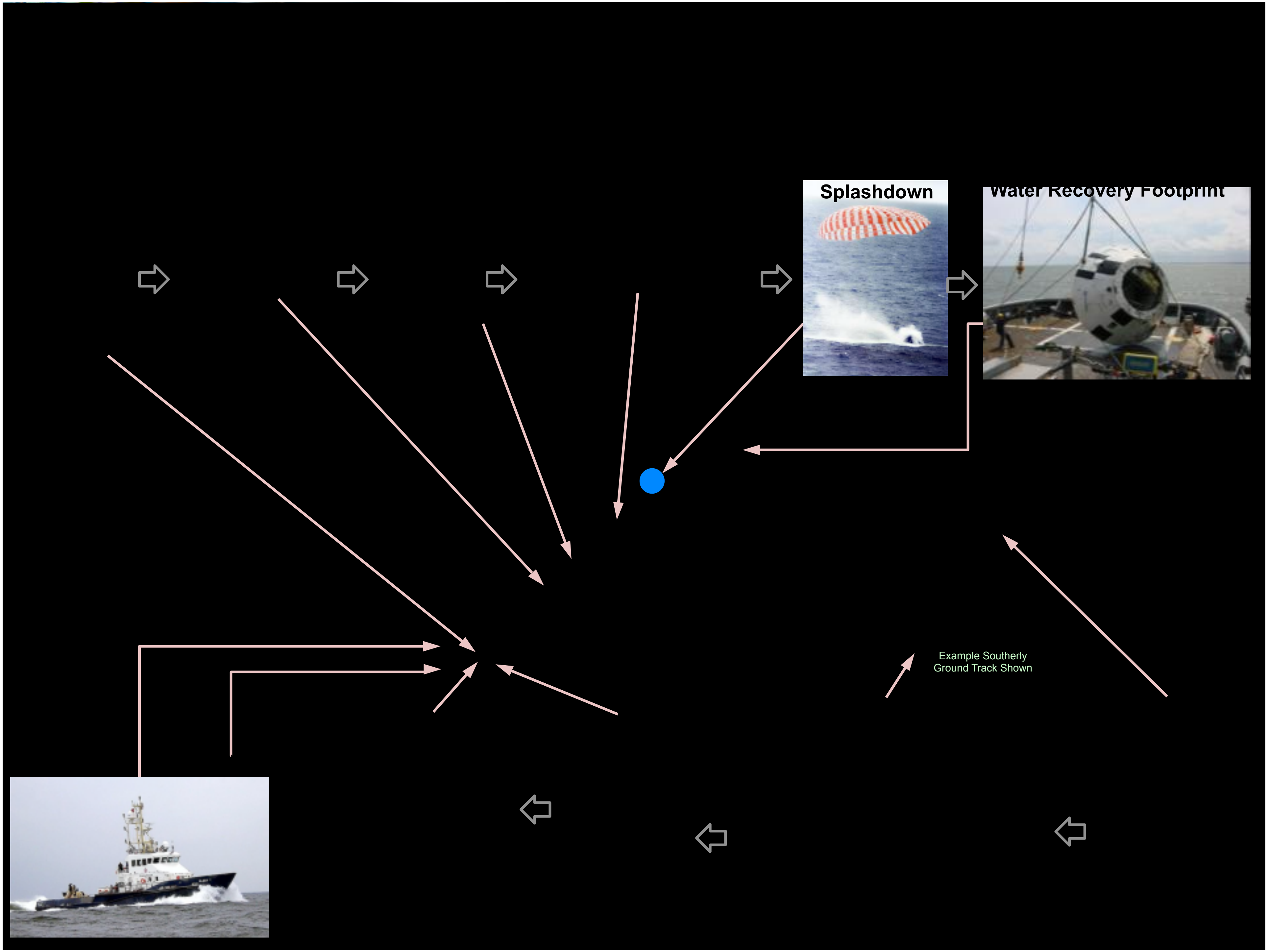
(Not to Scale)

Launch & Trajectory Overview



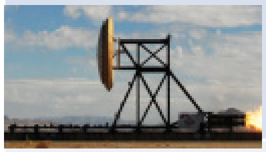
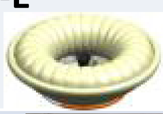
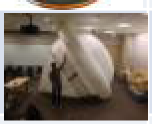
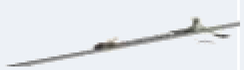
PMRF Operations





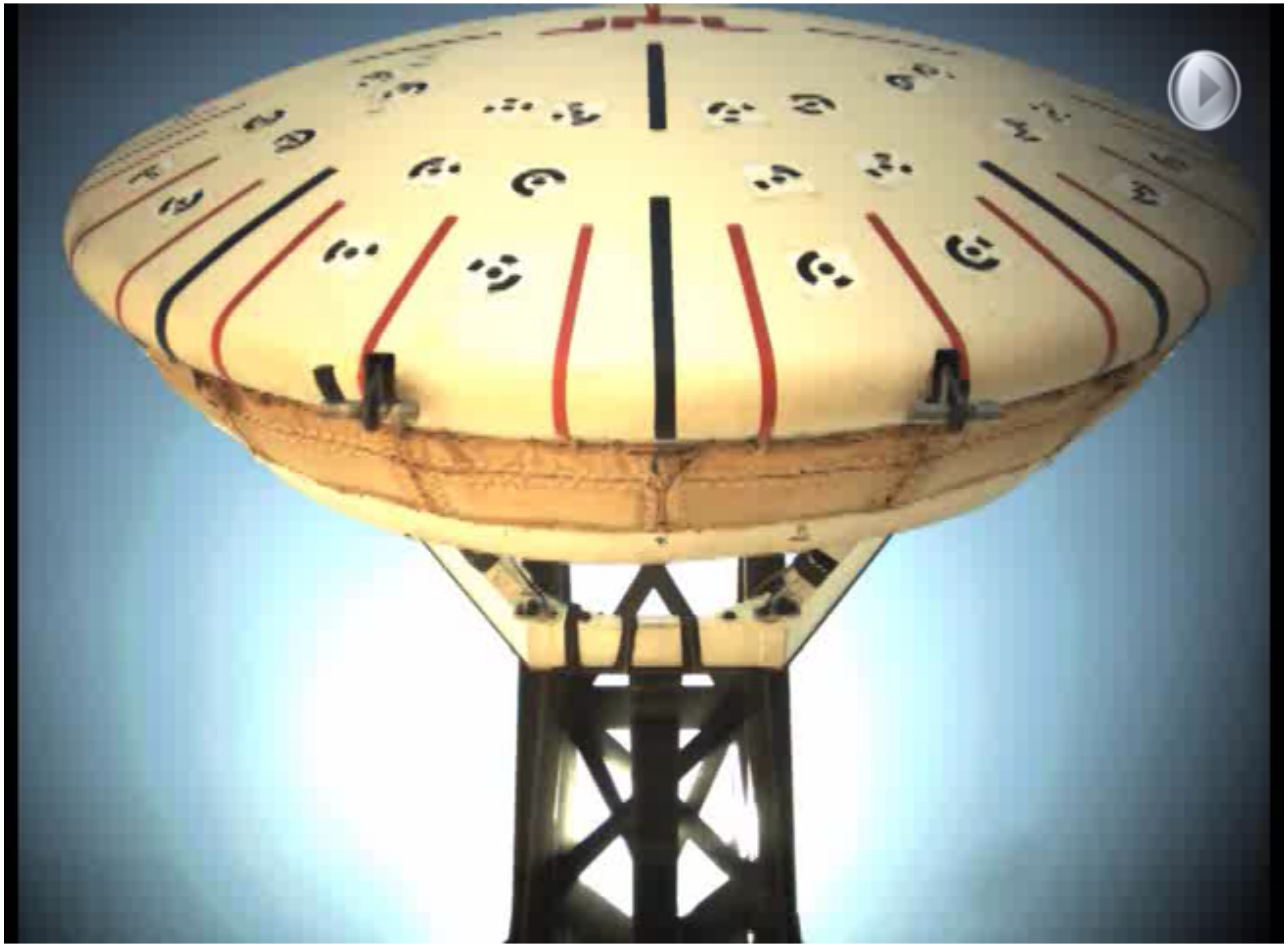
Splashdown
Water Recovery Footprint
Example Southerly
Ground Track Shown

Component Milestones

LDSD Component	Status	Next Milestone Event or Phase	SFDT #s* 1 - Jun 2014 (-R) 2 - Jun 2015 (-R) 3 - Jul 2015 (-R) 4 - Aug 2015 (-E)
SIAD-R 	Completed all Fab and Proof tests Development including Rocket Sled tests at China Lake, and Rapid Inflation Tests; Flight Units in Fab	Flight SIAD-R will be integrated to test Vehicle during I&T at JPL Jan - Mar 2014	1 - 3
SIAD-E 	Final stages of Designing and beginning Fab	SIAD Development Verification Tests using Rocket Sled at China Lake Jan - Mar 2014	4 (fly on last Balloon flight)
Ballute 	Design completed; Fab of the first test ballute has started.	Structural & Inflation Sept - Oct 2013	1 - 4
Parachute  	Final stages of Design and Development Testing; Fab of first two test parachutes (Disk Sail and Ring Sail) has started and one if nearing completion.	Conduct next round of Parachute Verification Tests at China Lake Sept - Dec 2013	1 - 4
Core Structure 	In Fabrication	Complete fab and Testing NLT Dec 2013 for I&T at JPL Jan - Mar 2014	1 - 4
Launch Tower 	Fabrication and Check-Out Completed; Shipped to Ft. Summer	Integrated with Small Balloon and TV Simulator and tested at Ft. Summer, NM in Aug 2013	1 - 4

Rocket Sled Test at China Lake (Nov 2012)

Rocket Sled Test at China Lake (Nov 2012)

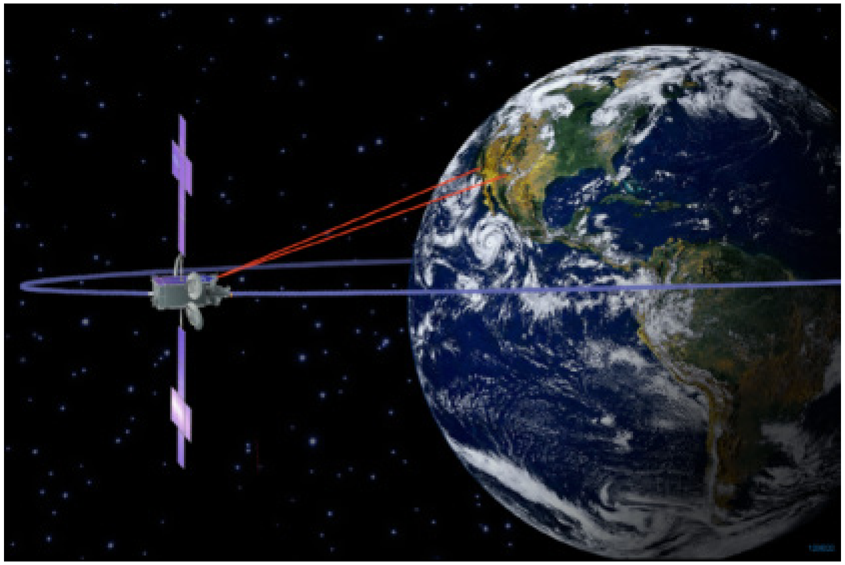



National Aeronautics and
Space Administration
www.nasa.gov/spacetech

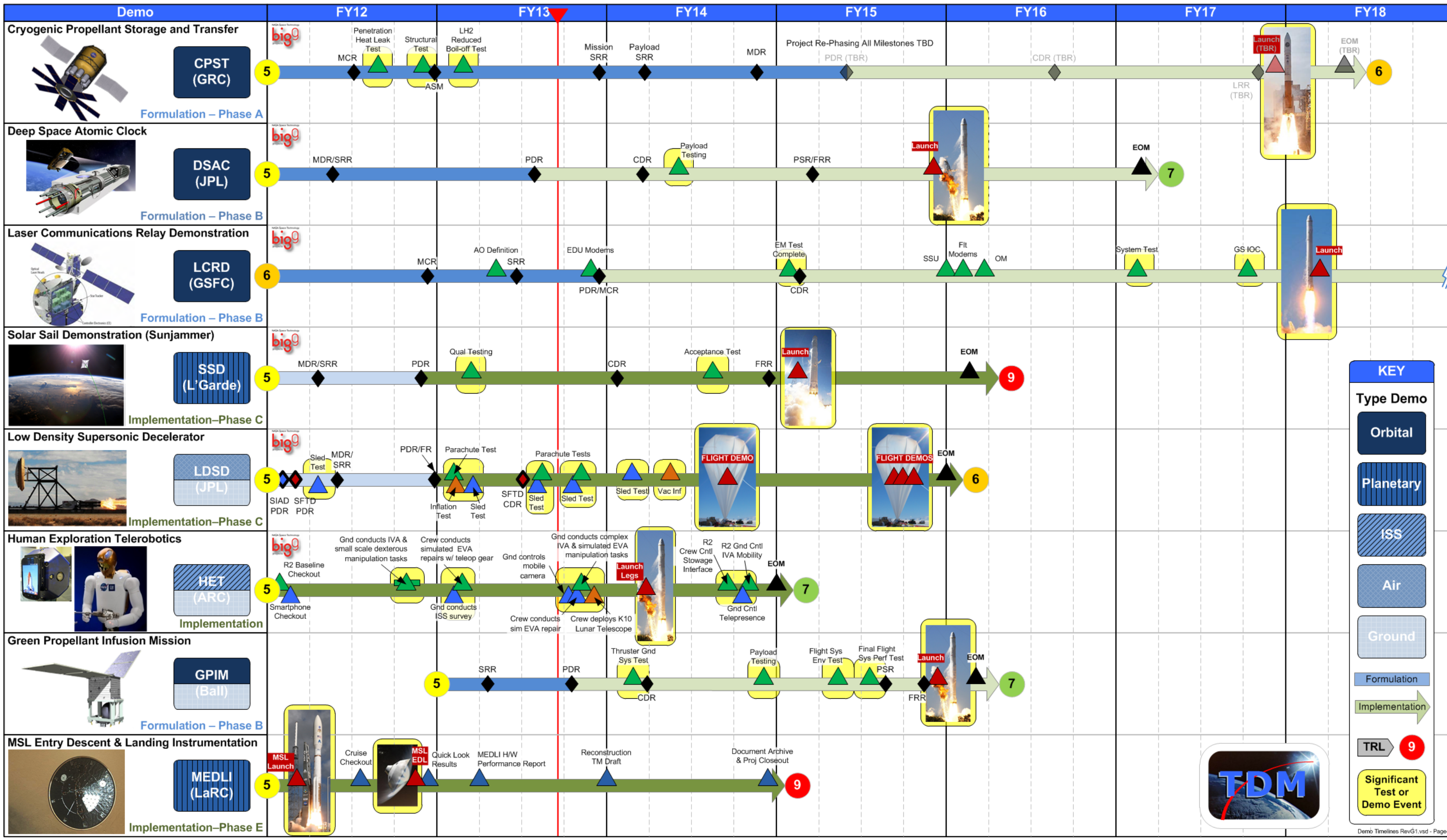
Build Charts

Laser Communications Relay Demonstration

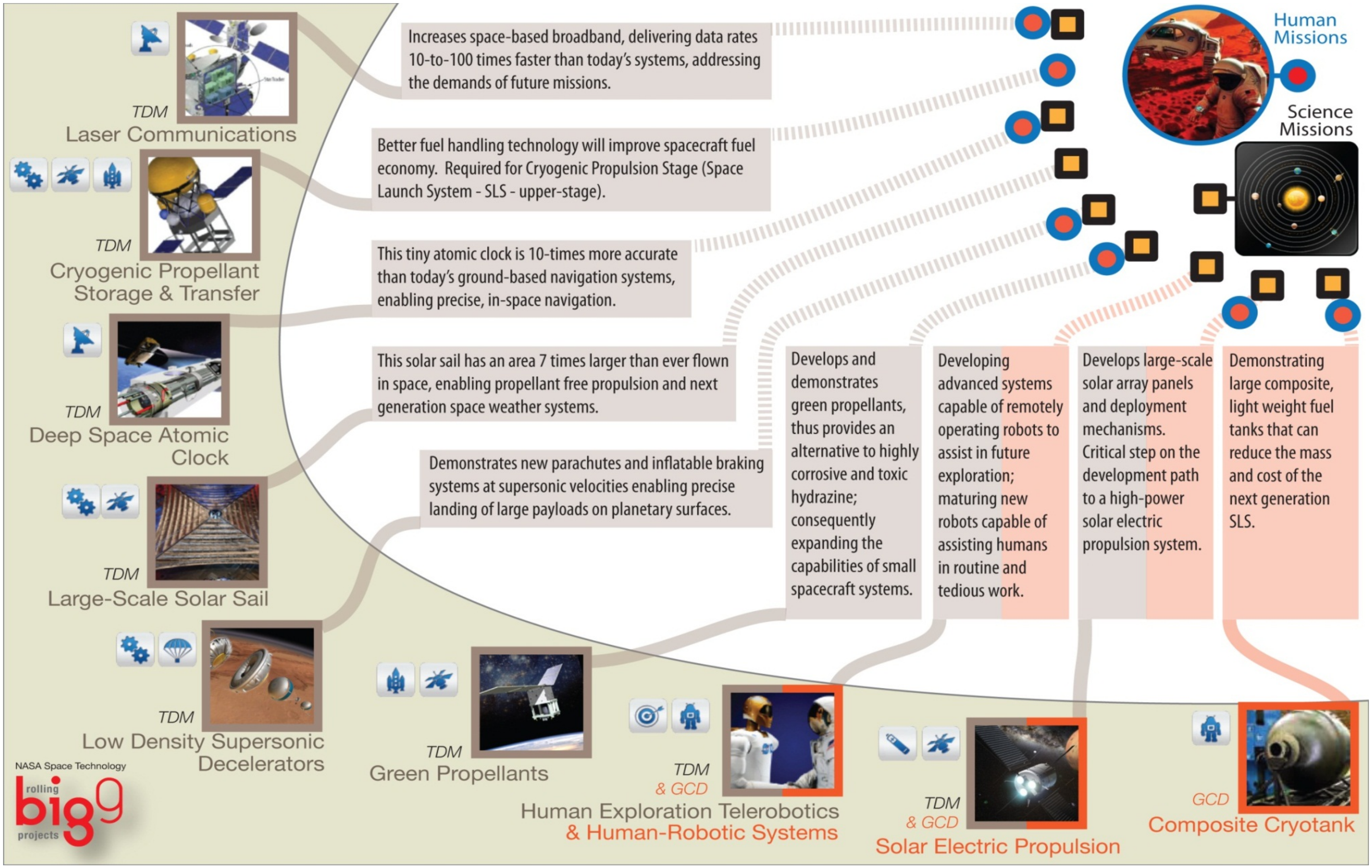
Project Summary: NASA's first, long-duration optical communications mission. The project will help mature concepts and deliver technologies applicable to both near-Earth and deep-space communication network missions.



Major Milestones



FY2014 Big Nine



Robonaut Roadmap

JSC Laboratory

Develop dexterous robot suitable for human tasks

Explicitly human safe motions

Fixed base and mobile robot prototypes

HRS, RSAA

ISS Laboratory

Verify 0g operations

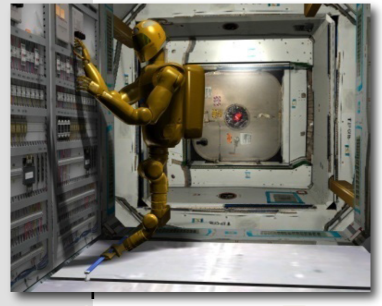
Characterize robot performance parameters in LEO

Develop capabilities to perform useful IVA work

Fixed base robot

HET

ISS IVA



Assist IVA crew

Routine maintenance

Interior cleaning

Equipment calibration

Remote science

Mobile robot

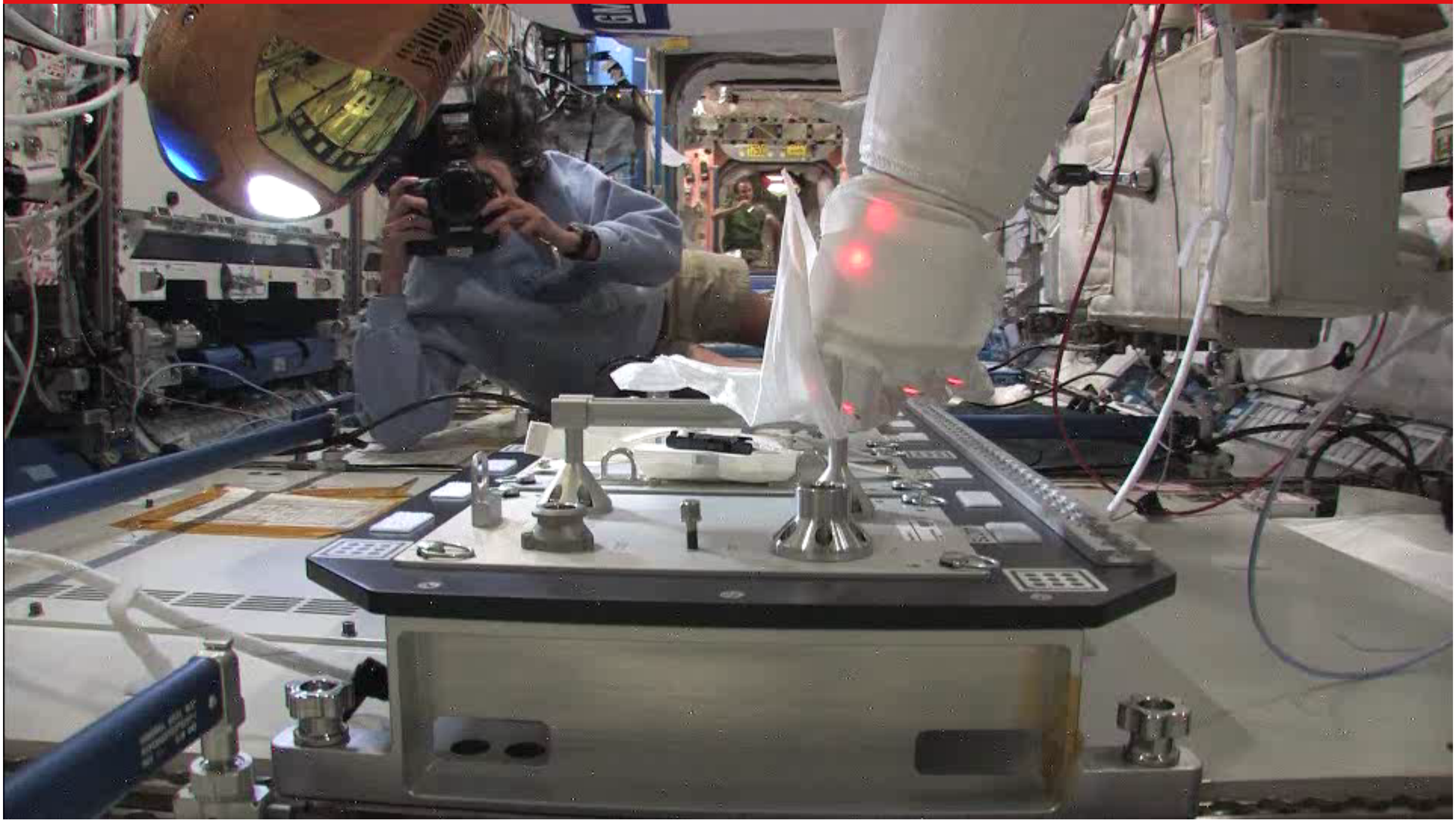
ISS EVA

Improve EVA efficiency through worksite prep & tear-down / stow

Expand EVA capabilities while reducing risks to the crew

ISS Program

Robonaut 2



Smart SPHERES Roadmap

ARC Laboratory

Enable SPHERES to be used as a teleoperated robot

Upgrade existing SPHERES platform

Telerobotic free-flyer prototypes

ISS Laboratory

Demonstrate IVA & EVA tasks using “Smart SPHERES”

Demonstrate ground and crew control with “Smart SPHERES”

ISS IVA

Video surveys

RFID inventory

Dosimetry readings

Mobile ground support (camera, procedure prompt, etc.) for crew

ISS EVA

Routine inspections

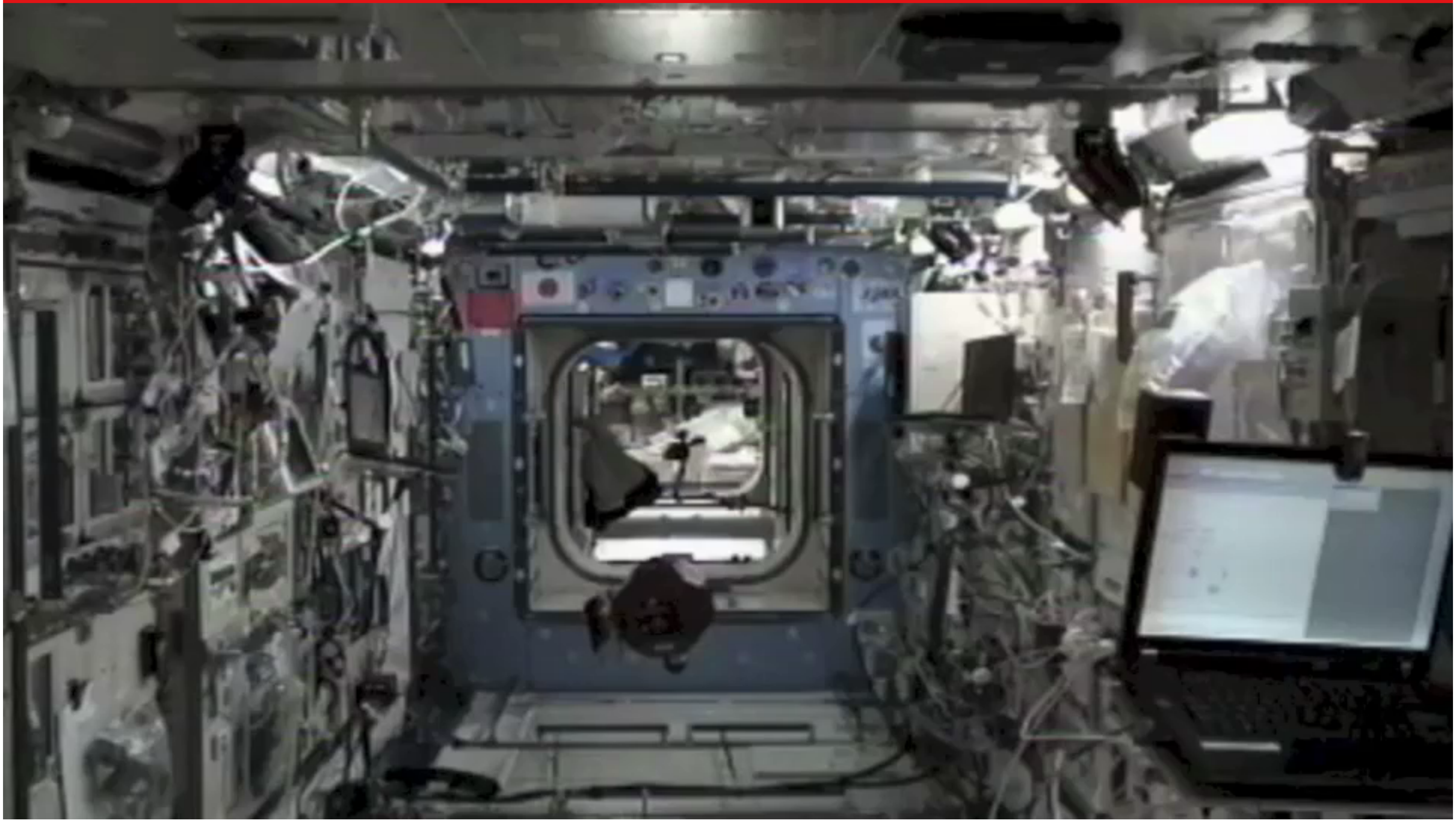
Emergency inspections

HRS, DARPA

HET

ISS Program

Smart SPHERES



Surface Telerobotics