



NASA'S JOURNEY TO

MARS

HEOMD Update to the NAC HEO Committee

Greg Williams

HEOMD Deputy AA for Policy & Plans

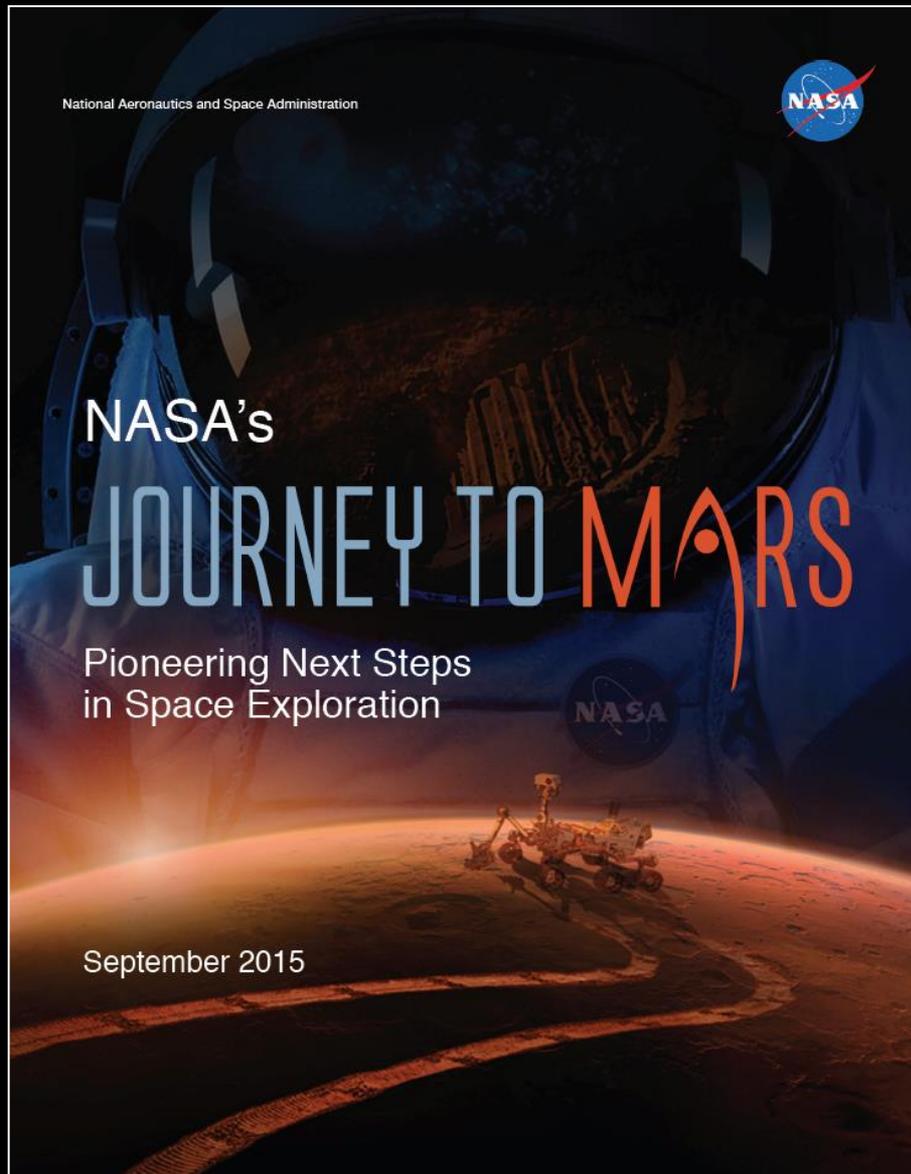
November 4, 2015

Key Events Since Last NAC HEO Meeting



- **ISS: One-year crew mission reaches halfway point; 15 years of continuous ISS crewed operations**
- **CCP:**
 - ❖ Boeing CDR held; SpaceX CDR underway
 - ❖ EKDP-I review held
- **ESD:**
 - ❖ SLS CDR
 - ❖ Orion PDR completion & CDR kickoff
 - ❖ GSDO CDR kickoff
 - ❖ Vertical Assembly Center handover and demonstration welds
 - ❖ Completion of RS-25 test firing series
- **SCaN**
 - ❖ TDRS-M development completed; launch services contract awarded for Atlas V 401 for October 2017
 - ❖ World Radio Conference underway in Geneva
- **LSP**
 - ❖ Awarded 3 new small launch vehicle contracts
- **SLPSRA**
 - ❖ Released first MaterialsLab NRA

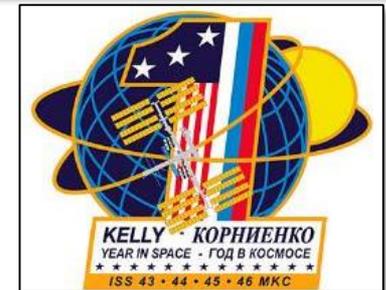
Now Available At a Website Near You...



ISS One-Year Mission



- **Completed First 6-months of One-year Mission**
 - ❖ Mission Progressing Well and Benefits of Collaborative Work Using Joint Capabilities and Resources are Being Realized
 - ❖ Astronaut Scott Kelly set the record for the longest duration American space mission on day 215
- **All Studies in the US-Russian Joint Research Plan have Been Implemented**
 - ❖ Physical and Functional Performance Assessments
 - ❖ Behavioral Health Studies
 - ❖ Ocular Health Monitoring and Changes
 - ❖ Metabolic and Immune System Studies
 - ❖ Microbial Population Changes
 - ❖ Long-Duration Mission Human Factors Studies
- **US/Russian Fluids Shift Experiment**
 - ❖ Most complex biomedical experiment implemented on ISS
 - ❖ Experiment could only be undertaken using both US and Russian hardware, subjects, and crew time
 - ❖ Studies body fluids redistribution during long-duration missions that may cause the visual and intracranial pressure changes that occur in crewmembers



Twins Study



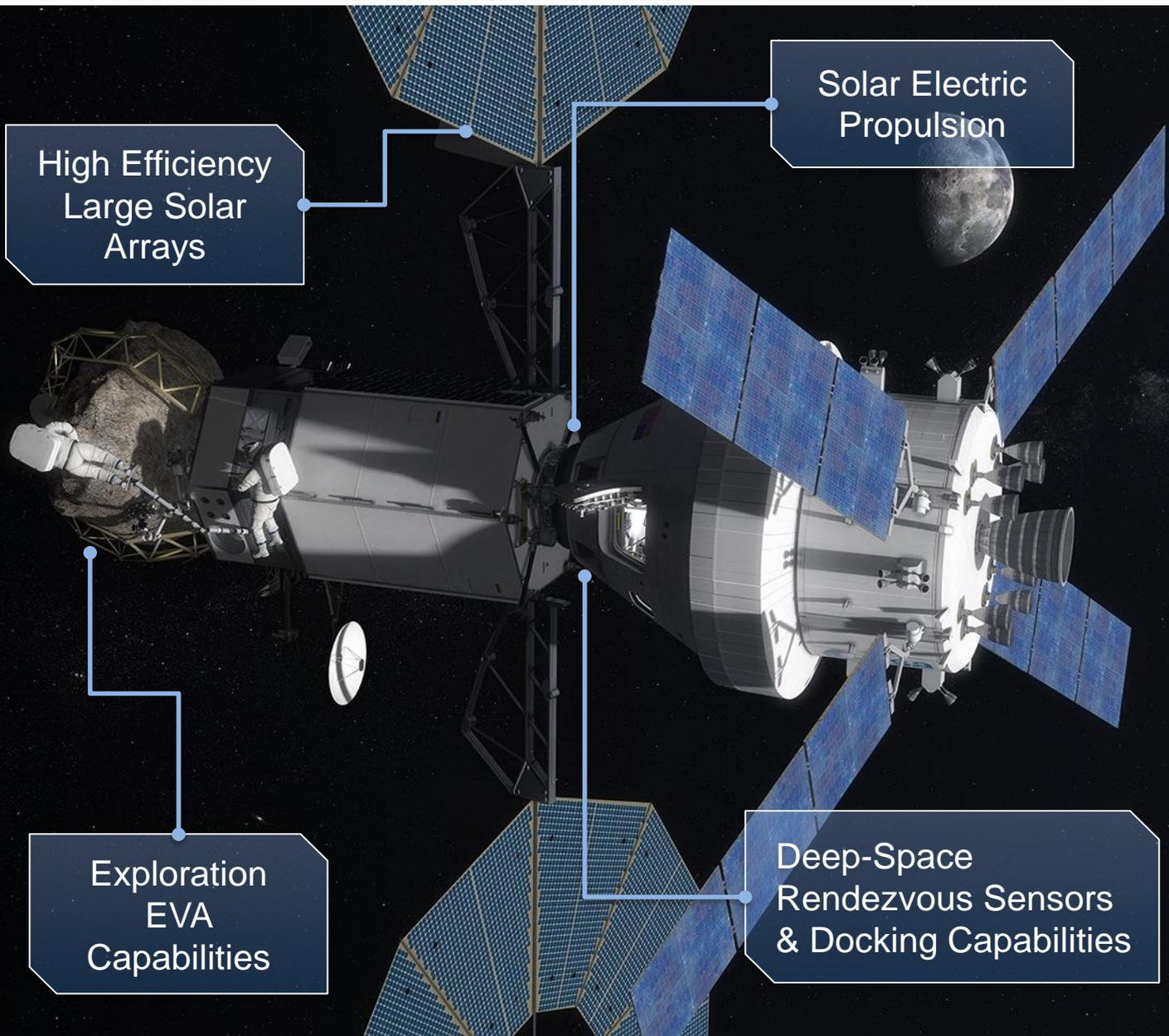
- **Twins Study (Scott and Mark Kelly)**
 - ❖ Sample collection is preceding well
 - ❖ Scott and Mark received influenza vaccination to test differential immune system response
- **Objective is to Begin Examining Next Generation Genomics Solutions to Mitigating Crew Health and Performance Risks**
 - ❖ Personalized countermeasures approaches
- **Twins Study National Research Team will Examine**
 - ❖ Genome, telomeres, epigenome
 - ❖ Transcriptome and epitranscriptome
 - ❖ Proteome, Metabolome, Microbiome
 - ❖ Physiology and Cognition
- **Significant Privacy and Ethics Issues**
 - ❖ NASA is developing new genomics policy (modeled after NIH policy) that addresses informed consent, data privacy approaches, and genetic counseling on consequences of discovery (individual, family)





- **Acquisition Strategy for the Asteroid Redirect Robotic Mission (ARRM) completed in August**
 - NASA will significantly leverage commercially available spacecraft bus capabilities in an acquisition of a ~5t propellant capacity vehicle
 - More synergy in future commercial industrial base and other potential near term applications with this vehicle class.
 - Leveraging current commercially available spacecraft bus capabilities and future plans can decrease cost risk for NASA's Asteroid Redirect Mission
- **NASA chartered the ARM Formulation Assessment and Support Team to provide timely inputs for mission requirements formulation in support of the ARRM Requirements Closure Technical Interchange Meeting (TIM) planned for December 15-16, 2015**
 - Assist in mission requirements development
 - Develop an initial list of potential mission investigations,
 - Provide input on potential hosted payloads and partnerships.
 - 8 members, largely comprising universities and research institute/laboratories
- **2008EV5 is still the reference target asteroid.**

ARM: An Early Mission in the Proving Ground of Cis-Lunar Space



IN-SPACE POWER & PROPULSION:

- High efficiency 40kW SEP extensible to Mars cargo missions
- Power enhancements feed forward to deep space habitats and transit vehicles

EXTRAVEHICULAR ACTIVITIES:

- Two in space EVAs of four hours each
- Primary Life Support System design accommodates Mars
- Sample selection, collection, containment, and return

TRANSPORTATION & OPERATIONS:

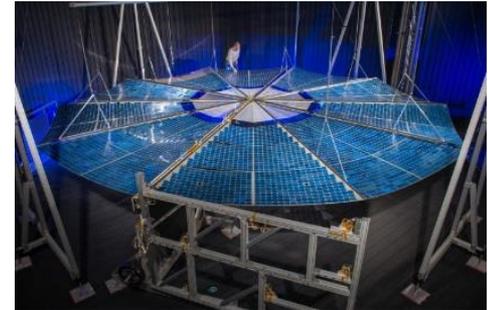
- Capture and control of non cooperative objects
- Common rendezvous sensors and docking systems for deep space
- Cis lunar operations are proving ground for deep space operations, trajectory, and navigation

Major SEP Risk Reduction Activities Completed by Glenn Research Center



Solar Array Development Contracts Fully Successful

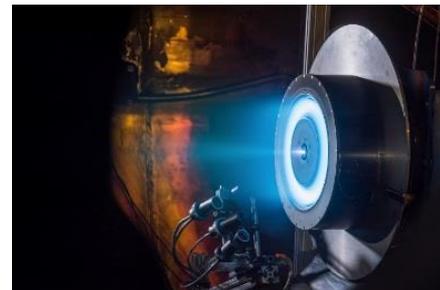
- MegaFlex Engineering Development Unit (ATK)
- ROSA Engineering Development Unit (DSS)
- Both arrays achieved all SOA-related goals including:
 - 4x rad tolerance
 - 1.7x power/mass (kW/kg)
 - 4x stowed volume efficiency
 - 20x deployed strength
- SSL and DSS partnered on commercial ROSA (12.5 kW)



Technology Development Thruster and Power Processing Unit Tests at GRC

- Confirmed thruster magnetic shielding (enables long-life operation)
- Power Processing Unit vacuum tests successfully completed
- Conducted 12.5 kW thruster integrated tests with 300-V and 120-V PPUUs
- *Development procurement proposals in review*

Demonstrated full performance compatibility between thruster and PPUUs

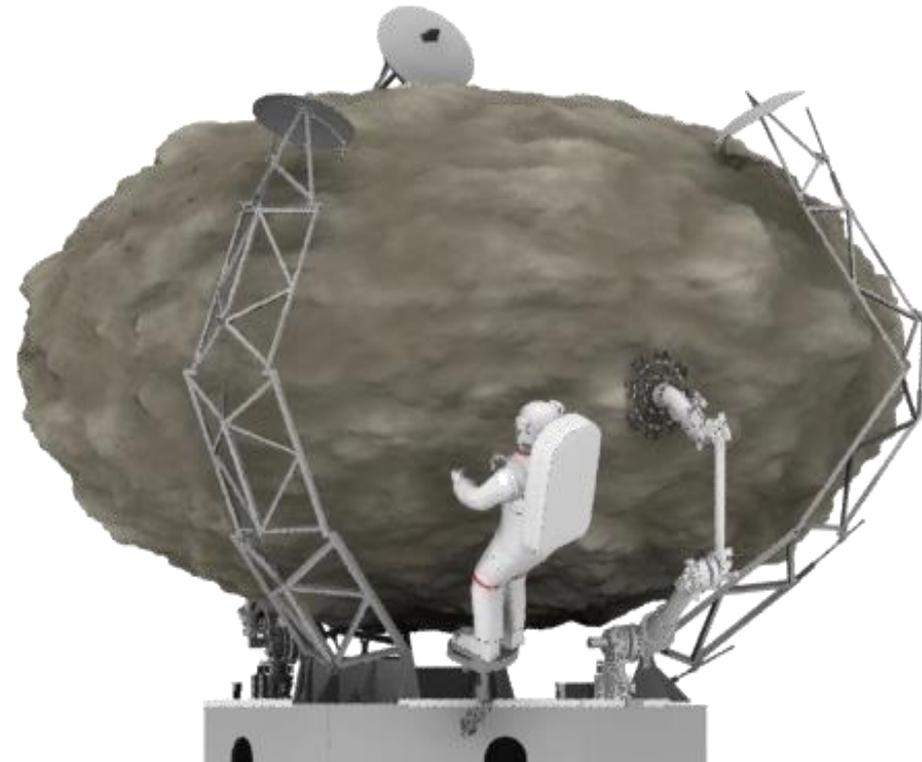


Capture System Prototyping and Testing at Langley Research Center and Goddard Space Flight Center

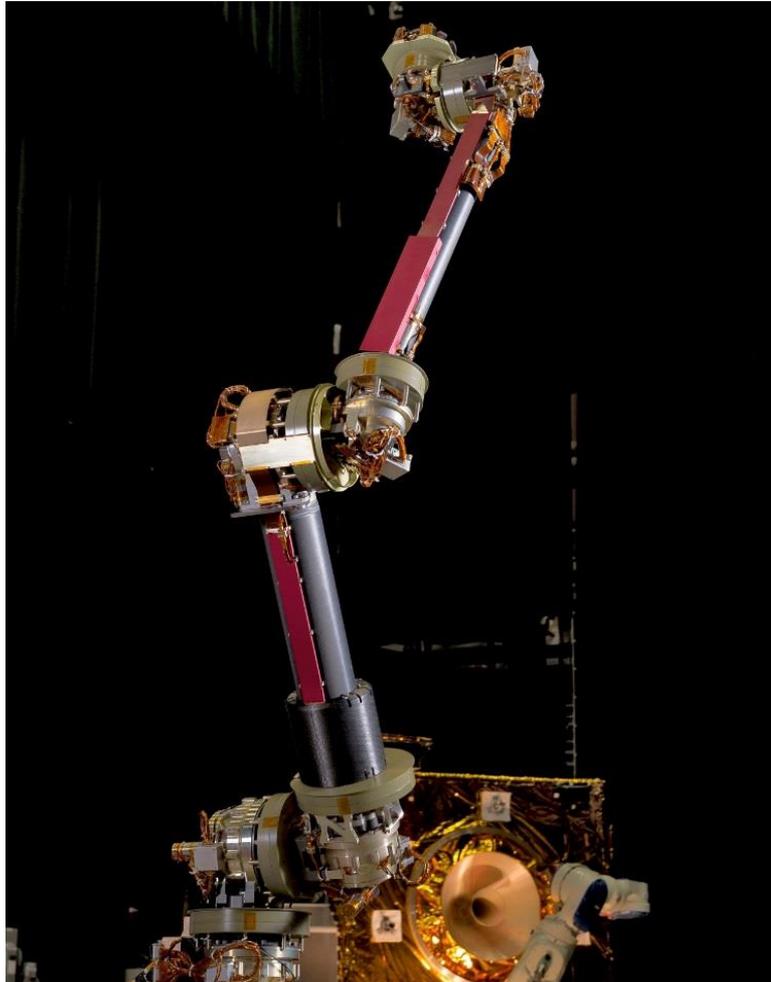


- Full scale welded metal prototype delivered
- Flat-floor testing of landing, extraction, and ascent underway

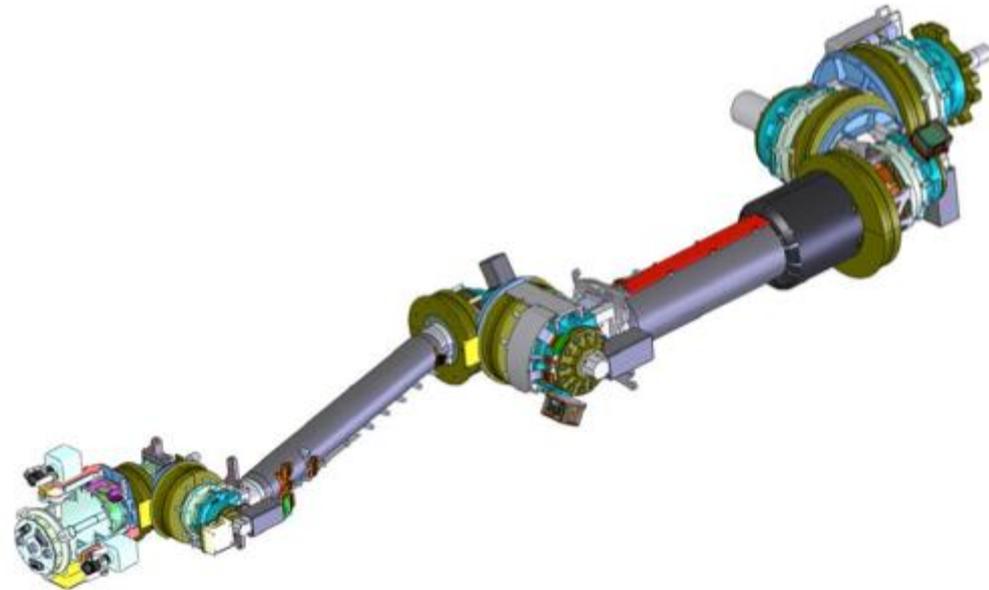
Prototype full-scale flat floor Contact and Restraint System development at Langley Research Center



Leveraging In-Space Robotic Servicing Robot Subsystem



7-DOF Robot "Capture" Arm
Restore common development robot arm
with Robot Electronics Unit controller.



Capture arm EDU – direct heritage from
FREND, synergy with Restore-L

Robot Subsystem - Microspine Gripper Jet Propulsion Laboratory



- Uses ~2000 independent hooks to opportunistically grip the surface
- Fast release capability
- Integrated rotary-percussive anchoring drill augments Microspine grip capability
- Design update from risk reduction

Technology Update

- Updated design of gripper, drill, drivetrain, and anchor
- Prototypes completed and tested with surrogate asteroid material

Mars Human Landing Site Study Overview

Goals of this Study:

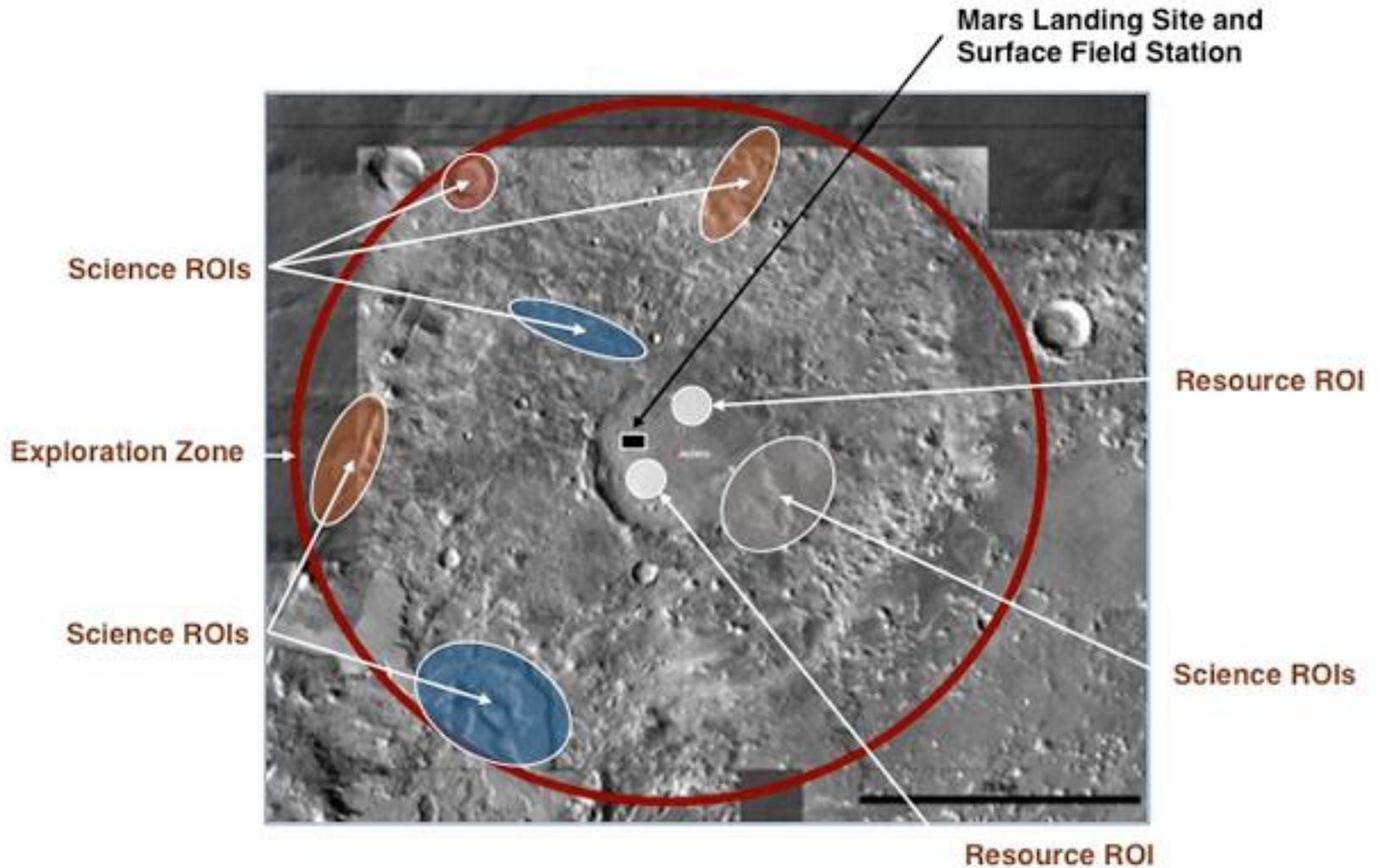
- Identify landing sites for human surface exploration of Mars.
 - These landing sites provide access to Exploration Zones which are regions on Mars that contain multiple sites of scientific interest as well as satisfying engineering and human constraints for human exploration
 - Leverage Mars Reconnaissance Orbiter (MRO) data collection capabilities to acquire data of potential human Mars landing sites within the exploration zones.
 - Exploration Zones will be chosen to maximize science return as well as support human operations.
 - This work will result in a database of high science interest sites, which can easily be updated as we learn more about Mars and what is needed to support humans on the planet.

This effort will be a joint HEOMD/SMD study.

The involvement of organizations such as MEPAG and the Human Spaceflight Architecture Team (HAT) is critical to ensure robust and enabling results.

- We need your ideas and creativity!

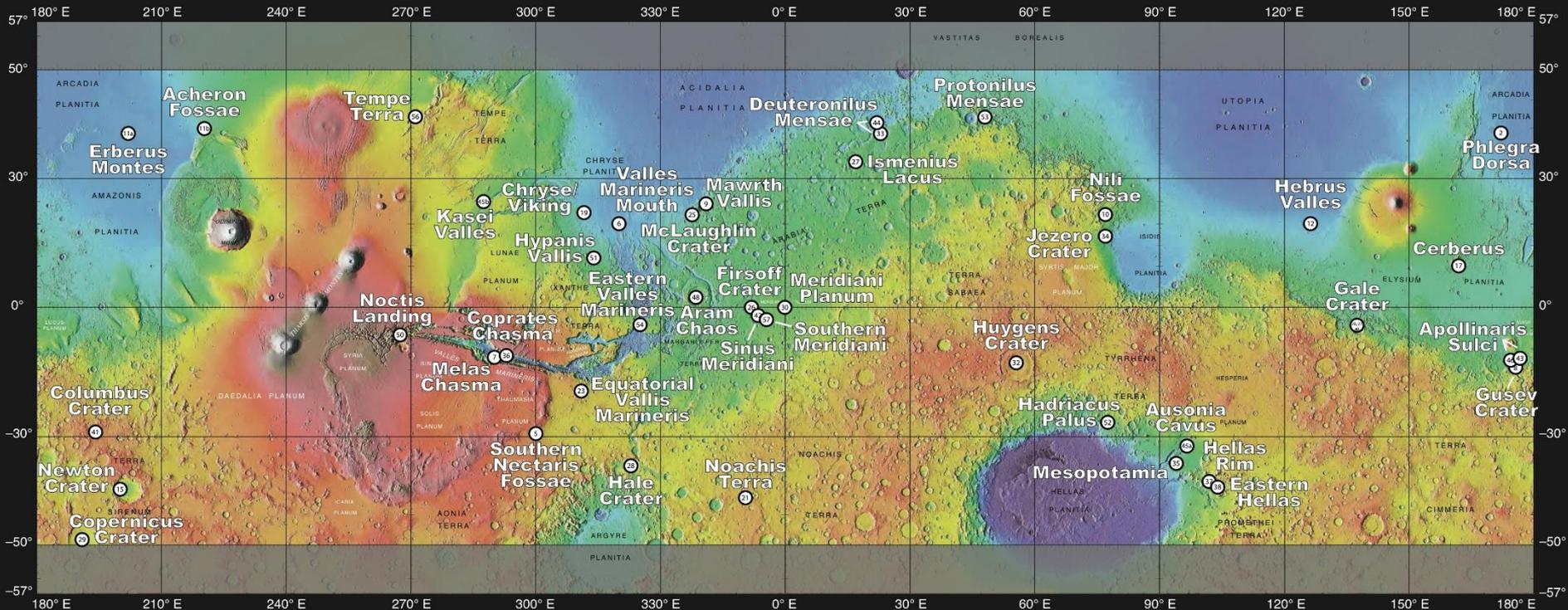
Exploration Zone Layout Considerations



Workshop Overview

- Held at the LPI in Houston, Oct 27-30th
- Over 120 attendees
 - Science/ISRU/engineering/mining communities represented
- 45 Exploration Zones presented

Potential Exploration Zones for Human Missions to the Surface of Mars



Exploration Zones proposed for humans to Mars.
Numbers correspond to the abstract submission #
At the equator, circles are ~100km radius

Workshop Takeaways

- There are multiple locations on Mars where EMC-like surface operations would enable excellent science to be conducted.
 - These are located at a wide range of latitudes and elevations.
- Largest unknown is how to utilize the different sources of water for ISRU.
 - Buried ice, hydrated minerals, hydrated dunes, RSLs
- High priority is to better understand the potential of these difference sources
- Discussion of holding small focused resource workshops
 - Would consider ease of extraction (power, slopes, engineering, chemistry)

SCaN Accomplishments



- Maintained network proficiencies continue above required 95%:
 - AUGUST 2015: DSN @ 99.0% NEN @ 99.86% SN @ 99.96%
- Successfully completed the Blossom Point Relay Station ORR on time and within budget, transitioning the first Single Access service on TDRS-9 into operations.
- Resolved Federal Aviation Administration (FAA) concerns regarding potential spectrum interference and testing of SOYUZ Very High Frequency-2 (VHF-2) emergency transmissions required to ensure NASA crew safety.
- NEN/USN relocated Poker Flat antennas (7.3m and 11m) to North Pole facility and are now undergoing certification testing. USN has consolidated their Alaska location to one site to increase reliability and efficiency.
- SN performed security testing in conjunction with the NASA CIO and the recent GAO Engagement for High Impact Systems.
- TDRS-M is now scheduled for launch in Oct 2017.

DSS-36 was slightly tipped over for the first time on September 20th to test the counterweight.



Missions Expected/Supported by SCan in FY 2016



ROBOTIC

Jason 3 (12/15)
Balloons GRIPS & STO 2
(12/15)
TES 6 (2016)
CPOD (06/16)
Asteria (08/16)

ISS RESUPPLY

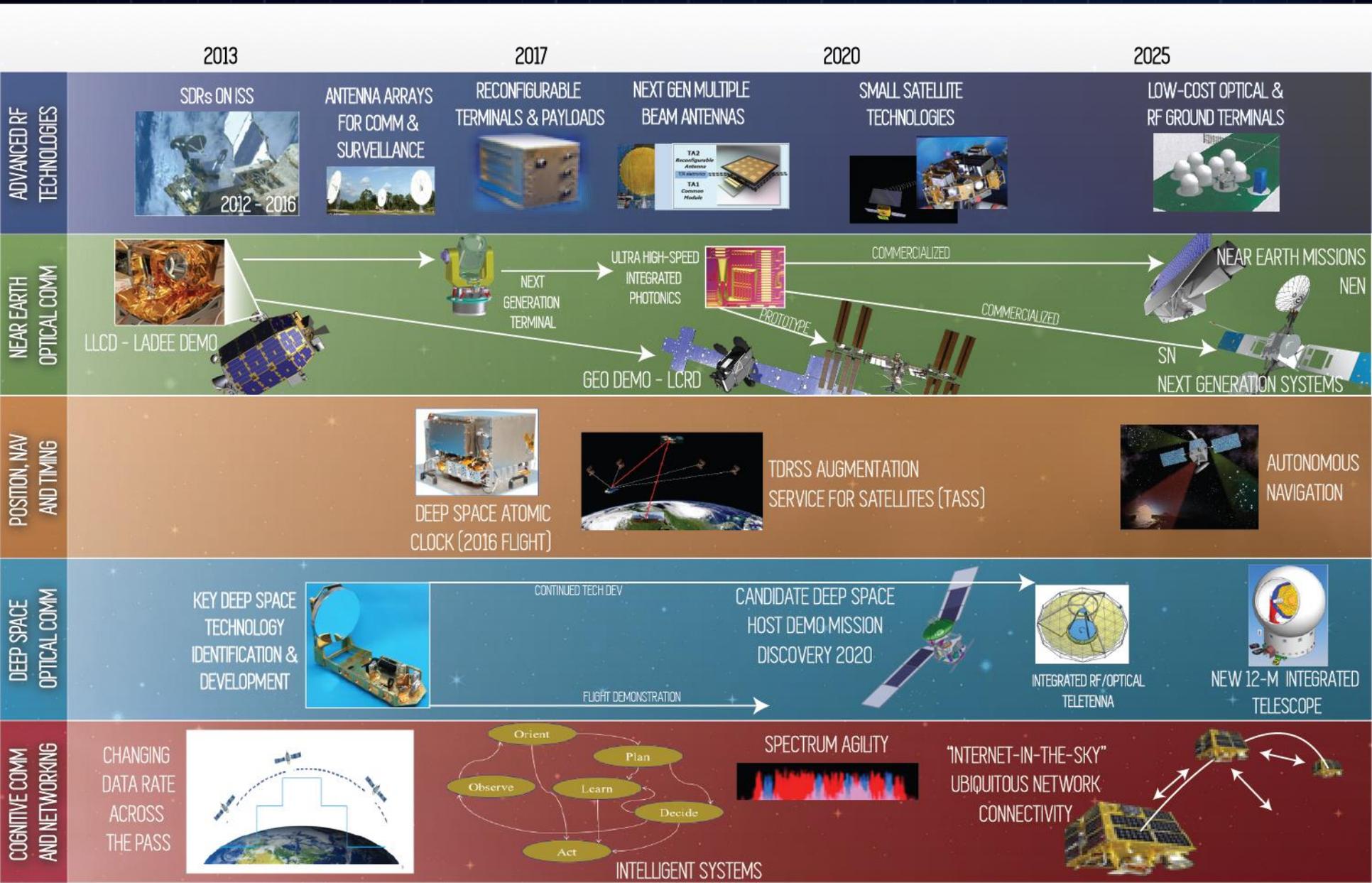
CRS/OA 4 (12/15)
Soyuz 45S (12/15)
CRS/SpaceX 08 (01/16)
Soyuz 46S (03/16)
CRS/SpaceX 09 (03/16)
CRS/OA 6 (03/16)
Soyuz 47S (05/16)
CRS/SpaceX 10 (06/16)
CRS/OA 5 (2016)
CRS/SpaceX 11 (2016)
Soyuz 48S (09/16)

ELVs

*Atlas V/MexSat 2 (10/15)
*Atlas V/NROL 55 (10/15)
Atlas V/GPS IIF 11 (10/15)
Atlas V/OA 4 (12/15)
Atlas V/ GPS IIF 12 (02/16)
Atlas V/InSight and MarCO
(03/16)
Atlas V/OA 6 (03/16)
Atlas V/MUOS 5 (05/16)
Delta IV/NROI 37 (05/16)
ALASA CC Tests 1 7 (2016)
Atlas V/NROL 61 (06/16)
Delta IV/AFSPC 6 (07/16)
Atlas V/SBIRS GEO 4 (07/16)
Atlas V/OSIRIS Rex (09/16)
ALASA Demo 1 (09/16)
Atlas V/Worldview 4 (09/16)
Delta IV/WGS 8 (09/16)

**Supported*

ScaN Technology Development Roadmap





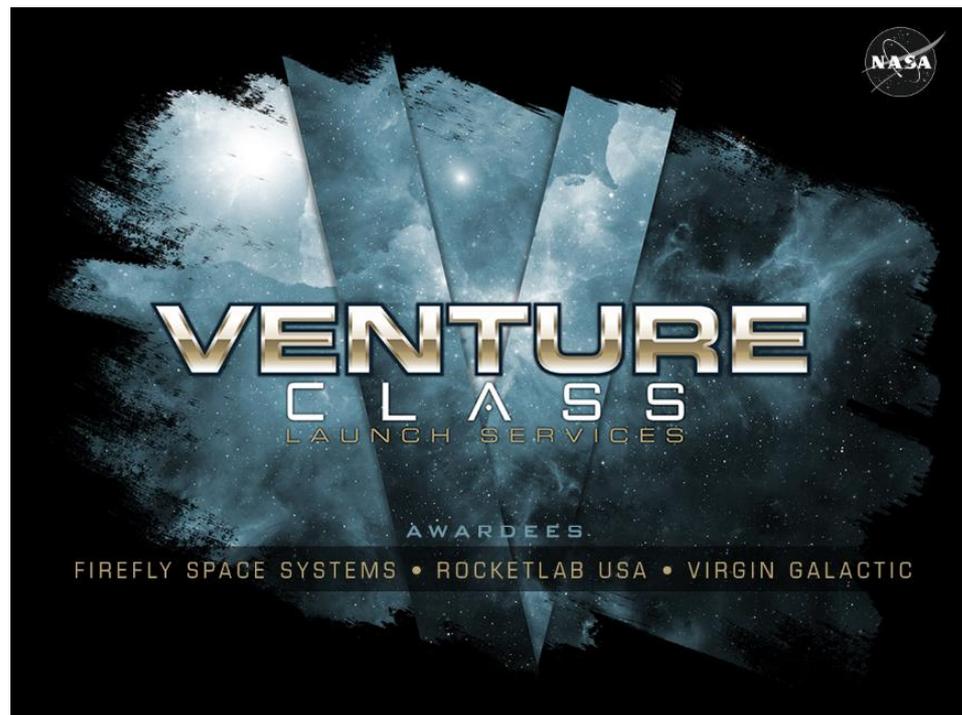
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Venture Class Launch Services (VCLS)



- Joint HEO/SMD investment to enable emerging commercial SmallSat launch market
- Awarded dedicated demonstration launches of CubeSats, to three separate providers
- Providers responsible for non-reoccurring development costs

- 425km orbit at provider selected inclination between 33° – 98°
- Launch no later than April 15, 2018
- Milestones-based payment structure, w/LSP insight to launch vehicle design reviews
- Success of Awardees enables new low cost launch options for Science (~1/10th price of current lowest cost dedicated launch option)





VCLS Awardees

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**Firefly
Alpha 1.0** \$5.5M

- ~75 feet tall
- ~1 meter fairing
- 2 Stage liquid propulsion
- Composite Structure
- ~150 – 400kg to LEO
- Actively seeking additional investment funding

**VCLS Launch targeting
March 2018**



**Rocket Lab
Electron** \$6.9M

- ~60 feet tall
- ~1 meter fairing
- 2 Stage liquid propulsion
- Composite Structure
- ~100 – 250kg to LEO
- Development is fully funded

**VCLS Launch targeting
April 2017**



**Virgin
LauncherOne** \$4.7M

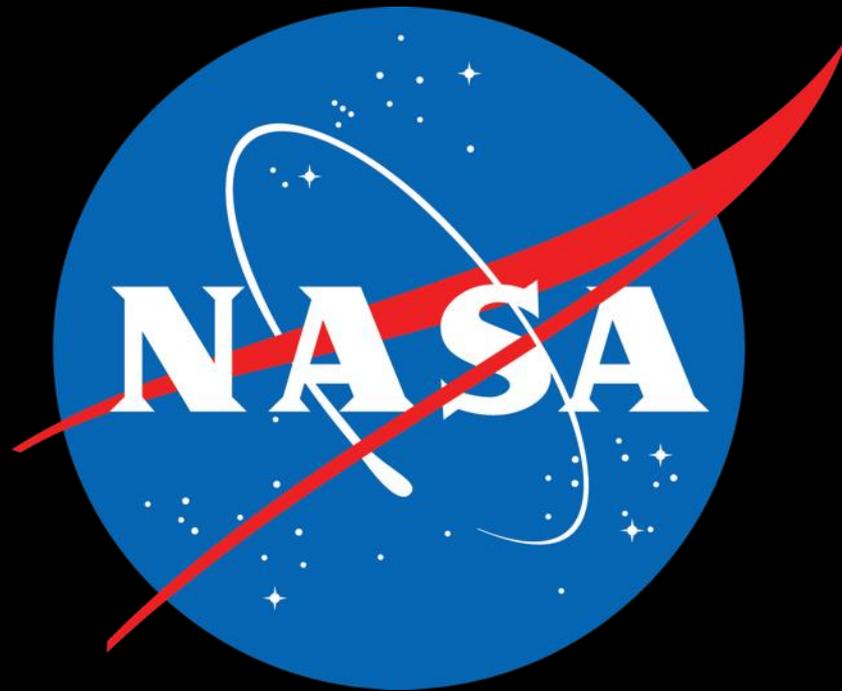
- ~65 feet long
- ~1 meter fairing
- 2 Stage liquid propulsion
- Carrier aircraft launched
- Composite Structure
- ~150 – 350kg to LEO
- Development is fully funded

**VCLS Launch targeting
late 2017**



- **FY16 final Appropriations / FY17 President's Budget Request**
- **Resumption of CRS flights**
- **Orion CDR / ESA SM CDR**
- **GSDO CDR completion**
- **ESD Build-to-Sync**
- **One-year crew mission completion in March**
- **Continued architecture studies in FY16**

Questions?





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Backup



VENTURE
CLASSES

Spectrum Management Upcoming Events



World Radiocommunication Conference (WRC-15) – November 2-27

- Treaty Negotiation(s)
- Finalizing preparations
- Approved US Proposals/Inter American Proposals on almost all US/NASA Agenda Items. Inter American Proposal on NASA Agenda Items:
 - Earth Exploration (X-Band Uplink)
 - Proximity Operations for ISS
- Most Future Agenda Items approved
- US interests – Spectrum for commercial broadband
 - International Mobile Telecommunications IMT/Mobile Broadband – WRC -15 Agenda Item and future WRCs.



SCaN Accomplishments (Continued)



DSN Aperture Enhancement Project (DAEP)

- DSS-36
 - Reflector lift completed ahead of schedule
 - Working to hold October 2016 delivery, with inclusion of S-Band
- MDSCC DSS-56/53
 - Design work continues for excavation and blasting plan
 - Initiating new plan to issue excavation, antenna, pedestal, and construction contracts from Spain

TDRS Replenishment

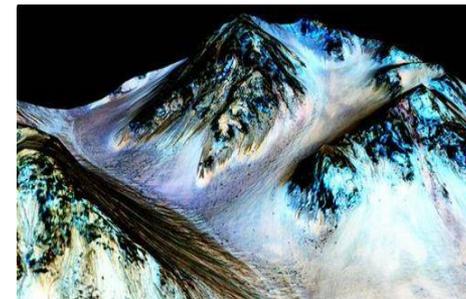
- TDRS-M Final Integrated Systems Test (FIST) completed and spacecraft moved into storage tent with a nitrogen purge.
- TDRS M Post Storage: Proposal received from Boeing. Currently in review and evaluation.
- TDRS-M Pre-Storage Review 14/15 Oct

Space Network Ground Segment Sustainment (SGSS)

- Completed Wide Band Modem Factory Acceptance Test (FAT). The FAT was partially successful with a packet timestamp issue preventing full acceptance. The issue has since been resolved and a delta FAT was successfully completed in September.
- Completed successful network analyzer testing of the redesigned radial combiner (qualification unit) on 8/28 at Ciao. The qualification unit was shipped to Harris and successfully underwent low power testing and high power “burn-in” testing at 1000 Watts for 168 hours, completed.
- A4 software and command completed on 9/4.



DSS-36 was slightly tipped over for the first time on September 20th to test the counterweight.



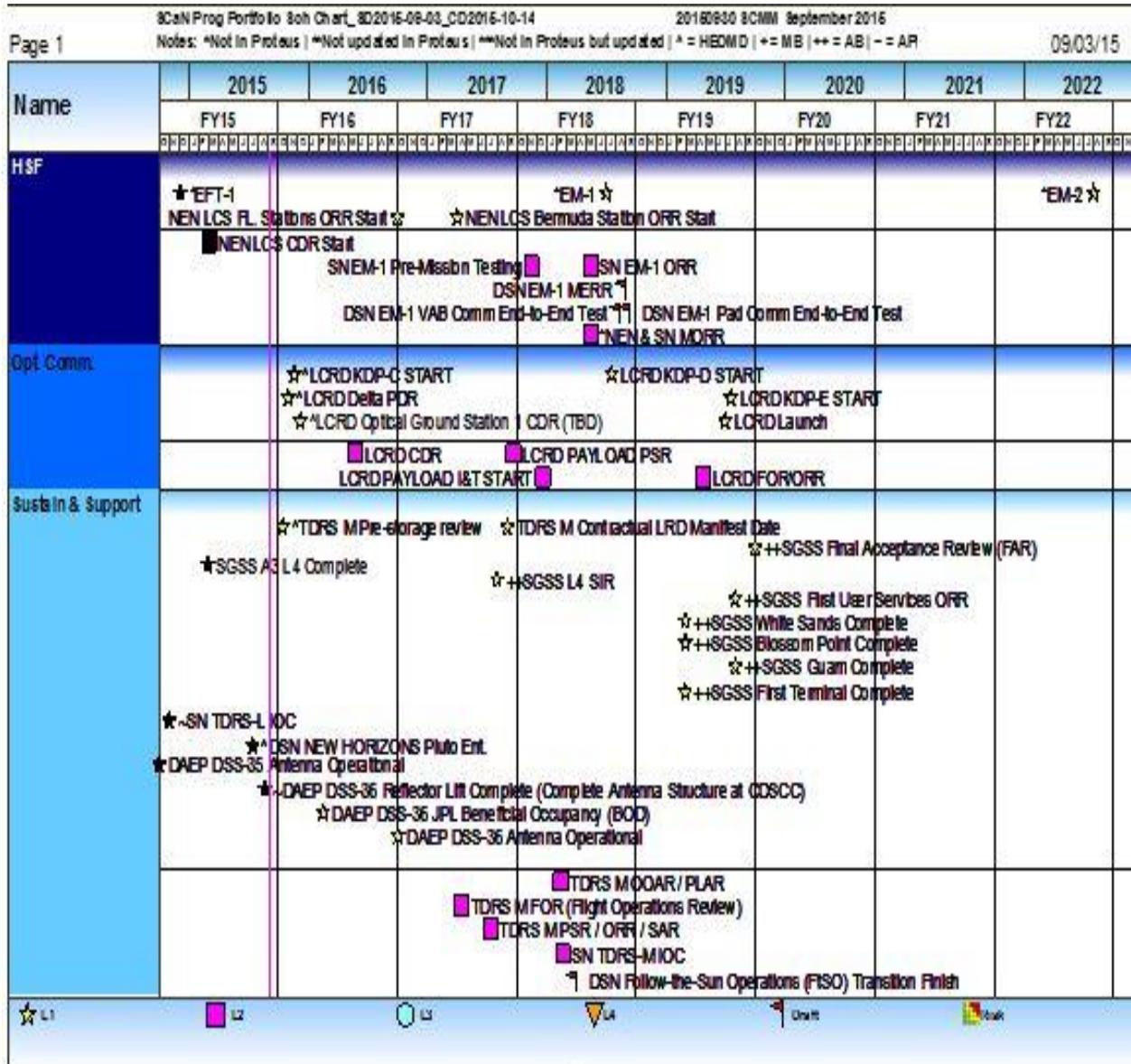
NASA confirms evidence, liquid water flows on Mars. [#DSN](#) provides communication tracking.

Launch Forecast



10/30/15	ATLAS V /GPS-2F11
11/16/15	SPACEX/Dragon CRS-8
12/03/15	ATLAS V/ORB-4 (Return to Flight)
12/15/15	Soyuz 45S
12/XX/15	SPACEX/Falcon-9/JASON-3
01/03/16	<u>SpaceX</u> CRS-9
02/03/16	ATLAS V/GPS-2F-12
02/10/15	Delta IV/NROL-45

SCaN Program Portfolio Schedule Chart (L1 & L2)



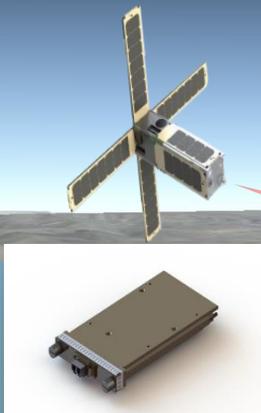
LCRD and LEO DTE– Status Update



- ✓ **LCRD Ground Modem successfully demonstrated full interoperability with the MIT Lincoln Laboratory Optical Terminal Verification Testbed (OTVT) Modem at MIT Lincoln Laboratory! TECH TRANSFER SUCCESS!**



LCRD GM#1 in the MIT LL OTVT Facility



- ✓ **NOW TRL 6: 100 Gbps COTS Integrated Modem for LEO DTE Modem passed NASA “GEVS” vibration, shock, and 3 weeks of TVAC testing with no performance degradation**
- **Radiation testing now being planned for GEO levels**