Small Spacecraft Lunar Communications and Navigation Workshop

June 11

Ames research Center

Interplanetary Network Directorate (IND) Standard Support Service Packages for Smallsat Missions from MarCO to EM-1 and Beyond

Glen Elliott

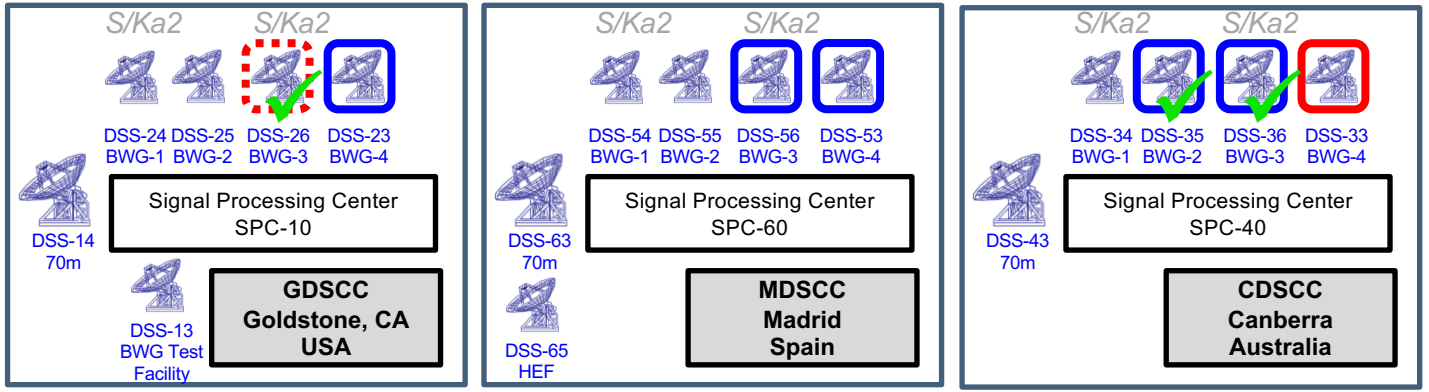
Manager Office 912 Mission Support Definition and Commitments Office

Jet Propulsion Laboratory
California Institute of Technology

Outline

- From first to future – smallsats supported by DSN
  - MarCO
  - SpaceIL
  - Future - EM-1
  - Standard Support Packages
  - New Initiatives
  - Next…

Baseline DAEP Rollout Roadmap



DAEP Developments

80-kW *TX Only*

80-kW BWG

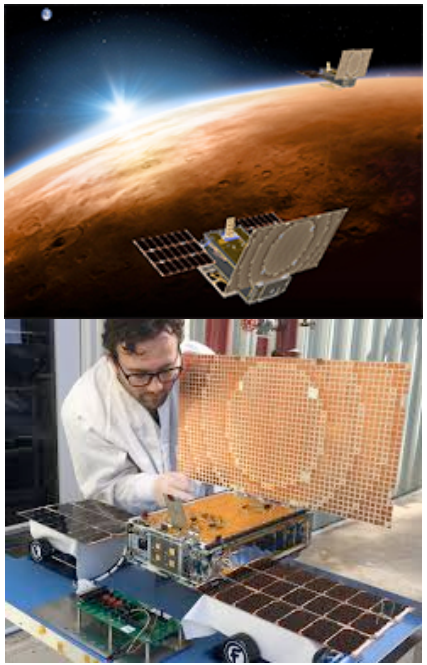
20-kW BWG

Ka2 ✓

26-GHz Dn Complete

Station	XX/Ka	S	Ka2
DSS-26		10/2017	(TBD)
DSS-35	10/2014	-	-
DSS-36	10/2016	10/2016	(TBD)
DSS-56	09/2020	03/2020	03/2020
DSS-53	01/2021	-	-
DSS-23	10/2024	-	-
DSS-33	10/2026	-	-

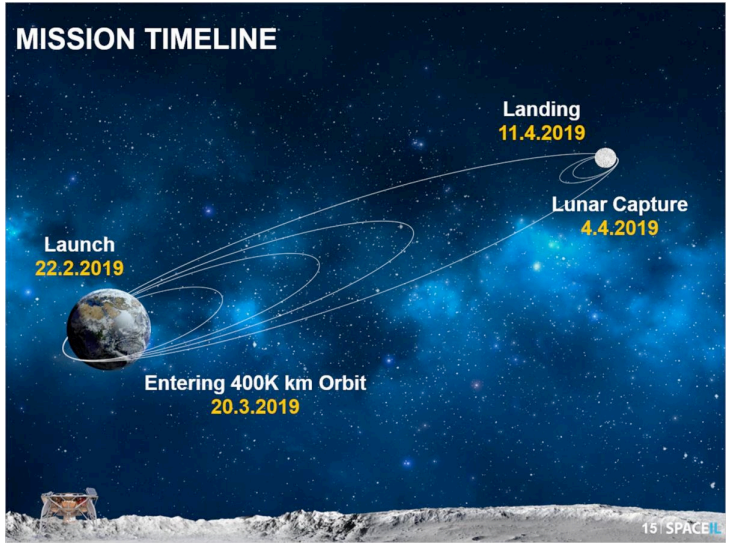
MarCO

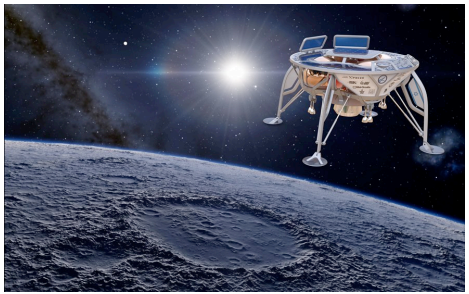


https://mars.nasa.gov/internal_resources/344/

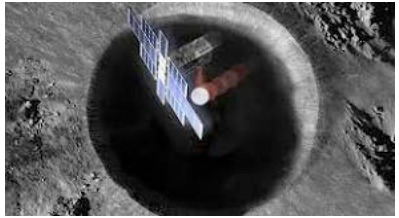
- The MarCOs were the first smallsats, cubesats, supported by the DSN. This occurred in 2018.
  - The primary mission objective of MarCO mission was to provide INSIGHT's Entry Descent and Landing (EDL) relay data in real time.
  - The second objective of MarCO is to provide a technical demonstration for future cubesat relay support.
  - Both MarCO-A and MarCO-B utilized the Iris radio at deep space X-band frequencies to successfully accomplish their mission objectives
  - Both MarCOs utilized the DSN 34m BWG and 70M subnets successfully
  - To the DSN the MarCO were much like any non-smallsat mission. The standard support package provided to the MarCO's consisted of:
    - Telemetry, Tracking, and Command, support interface for SPK and scheduling
  - The DSN support for MarCO was a first for cubesats but looked much the same as any previous mission to operations due to the extensive of DSN legacy standards
  - From a communication perspective all aspects of MarCO were that expected for a deep space mission utilizing X-band communication
  - From a NAV perspective standard services were provided, JPL NAV is the authority for any navigation work for MarCO, as they followed the trajectory of INSIGHT to Mars as they were secondary payloads on the INSIGHT launch vehicle

SpaceIL

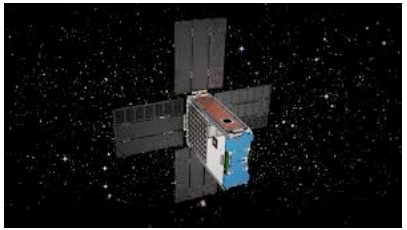




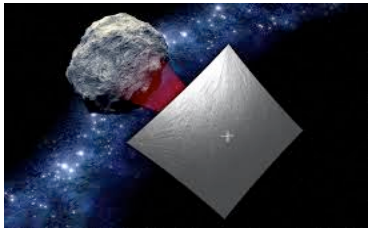
- SpaceIL, or Beresheet “Genesis,” mission was the second smallsat supported by the DSN from February to April 2019.
  - Originally a Google Lunar X Prize participant with objectives to: 1) perform a soft landing of an unmanned spacecraft on the surface of the Moon and 2) transmit to Earth high definition images and video
- Beresheet was a S-band mission
- All control, NAV, and comm services were carried out by the Isreali Aerospace Industries and SpaceIL team
- The DSN 34m BWG subnet provided support for Beresheet until EOM in April 2019
- Again, to the DSN, SpaceIL was much like any non-smallsat mission. The standard support package provided to the MarCO’s consisted of:
  - Telemetry and Command
    - Web-based interface
  - Standard interface for SPK file delivery etc.



Lunar Flashlight

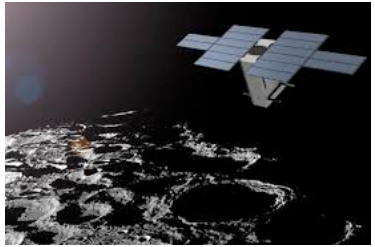


BioSentinel

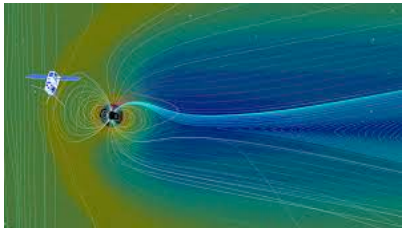


Near Earth Asteroid Scout

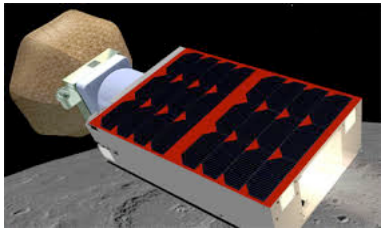
Lunar Ice Cube



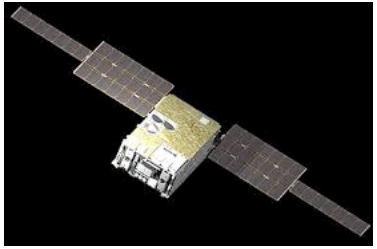
LunaH-map



CuSP

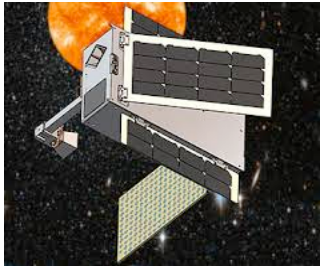


OMOTENASHI

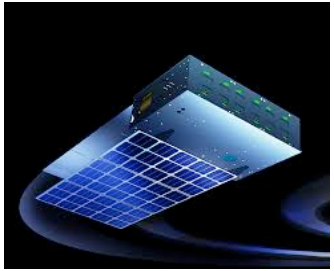


EQUULEUS

Argomoon



CU-E3



Team Miles

Next Chapter in IND smallsat support…

Future – Exploration Mission 1 (EM-1)

- The DSN will provide tracking support for up to eleven (11) of the secondary smallsat payloads flying on EM-1 when it launches in late 2020
- Seven (7) of those smallsats, cubesats, will utilize the Iris radio for an X/X configuration. Six are NASA and one is Italian, ASI (Agenzia Spaziale Italiana) as sponsor.
  - Five (5) will utilize near Earth X-band frequencies
  - Two (2) will utilize deep space X-band frequencies
  - One will demonstrate DTN capability from the spacecraft
- Two (2) cubesats are from JAXA
  - OMOTENASHI and EQUULEUS
  - They each use a radio designed by JAXA and Tokyo University
  - Each uses an X/X configuration
  - Trajectory: after separation from ICPS is TBD
- Two (2) are shadow track only for the CubeQuest Challenge Coordinator at ARC
  - Team Miles
  - Colorado University (Boulder) Earth Escape Explorer (CU-E3)
- Navigation providers span the gamut: JPL, FDF, Kinetx, the mission
- Communications for all will be tested and validated during RF Compatibility tests at DTF-21 in Monrovia by Peraton, the DSN O&M contractor from February to July 2019
  - Seven (7) spacecraft have been successfully tested and validated for end-to-end dataflow as of May 31, 2019

Future – EM-1 Standard DSN Support Package

- DSN Services from the DSN Service Catalog located at: https://deepspace.jpl.nasa.gov/about/commitments-office/mission-documents/
  - Telemetry service: (**CCSDS**)
    - SLE Return Link Service Interface
      - Recommend Return All Frame (RAF); Bluebook 911.1-B-4, and 2
  - Command Service: (**CCSDS**)
    - SLE Forward Link Service Interface; Bluebook 912.3-B-4, and 2
  - Track Service: (**CCSDS**)
    - CCSDS Tracking Data Message (TDM); Bluebook 503.0-B-1
    - Delta-DOR
      - Bluebook 506-B-1
      - Magenta Books 506.0-M-2, 506.3-M-1
  - Track Service:(non-CCSDS)
    - TRK-2-34 Realtime and Postpass files
  - Service Management: (non-CCSDS)
    - MON-0158 (possible)
    - SPS Scheduling interface
  - Test Support
    - DSN Testing
      - RF Compatibility at DTF21
      - End-to-end Data flow testing in flight ops like environment (with DTF21)

New Initiatives

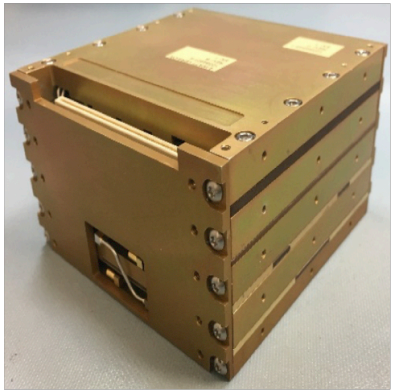
- Commercial Lunar Payload Services (CLPS)
  - Three chosen for flight in May 2019
    - Two have chosen to utilize the DSN for a portion of flight
      - All are using X-band frequency and standard encoding techniques
      - No new communication technology or frequency
- Powered Propulsion Element
  - New and just starting work with Maxar Inc. to solidify network requirements
  - Per BAA requirements
    - New uplink at Ka-band anticipated
    - Higher downlink rates at both X and Ka-band
    - Wide usage of all LDPC encoding types
- Formation Flying
  - Low Earth orbit initially but proposed for lunar in the proposal world
- DTN
  - DSN implementation coming by early 2021
- Lunar Relay
  - Collaboration in work through IND

Next…

- Between June 2018 and May 2019 IND has been contacted by over 30 missions in some form of proposal
  - Over half of the total are cubesat or smallsat in size ranging from 6U to 24U in size
  - All of the cubesats/smallsats are destined for lunar proximity
  - Over half have explored the usage of the Iris radio for X/X communication
  - All have explored X/X or X/X with Ka for downlink only
  - The movement to commercial space capabilities and NASA's encouragement have contributed to a surge in requests for support by IND of both network (DSN) and ground data systems (GDS) services and capabilities
  - Last, secondary ride alongs are becoming common as MarCO pioneered for INSIGHT
- The future will be busy for providers of all aspects of space services especially commercial providers

Backup

Iris Radio – courtesy of Kris Angkasa



Iris V2.1 Transponder stack

Specification	Units	
Downlink frequencies	MHz	8400-8600
Uplnk frequencies	MHz	7146-7235
Turn-around ratio		880/749
Downlink symbol rates	sps	62.5-6.25 M
Uplink data rates	bps	62.5-8000
Modulation waveforms		PCM/PSK/PM w/subcarrier
		PCM/PM w/biphase-L, BPSK
Telemetry encoding		Turbo (1/2, 1/3, 1/6)
Receiver noise figure (NF)	dB	3.5
Carrier tracking threshold	dBm	-151 @ 20-Hz LBW
RF output power	Watts	> 3.8
Navigation		Nonregenerative ranging
		Delta-DOR, Doppler
Transmit phase noise		
(one-way noncoherent)	dBc/Hz	≤ -20 @ 1-100 Hz
		≤ -60 @ 100-100,000 Hz
Oscillator stability	ppm	0.001 @ Δt = 1 sec
Mass	k	≤ 1.0
Volume	U	0.56 (excl. SSPA/LNA)
Power consumption	Watts	12.0 Rx-only
		33.7 Full Tx/Rx
Sapcecraft bus interace		1-MHz SPI
Bus voltage range	V	9-28
Allowable flight temperatures	degC	-20 to +50
Dynamics		14.1 grms random vibe
Radiation tolarenace (total ionizing doze)		> 23.0 krad
Radiation tolerance (single event latch-up)		> 37 MeV-cm2/mg

Iris V2.1 Key Specifications

- The Iris radio, manufactured by Space Dynamics Laboratory, Logan UT., is the radio of choice of smallsats supported to date by the DSN, SpaceIL excepted
- It is a X/X transponder capable of usage within both the near Earth and deep space x-band frequency bands
  - Use by MarCO was in deep space
  - Exploration Mission 1 (EM-1) secondary payloads will use both bands
- The current stack and specification sheet is shown to the left

EM-1 Secondaries Specifics – IRIS radio users

- The missions, and limited specifics for each, are noted below:
  - Lunar Hydrogen Mapper
    - SMD is sponsor, ROSES winner
    - ASU Tempe will build and operate
    - Target destination is lunar proximity
    - Trajectory: after separation from ICPS is TBD
  - Lunar Ice Cube
    - STMD is sponsor
    - Morehead State University will build and operate
    - Target destination is lunar proximity
    - Trajectory after separation from ICPS is TBD
  - Lunar Fashlight
    - AES is sponsor
    - JPL will build and operate
    - Target destination is lunar orbit
    - Trajectory after separation from ICPS is TBD
  - Cubesat for study of Solar Particles (CuSP)
    - SMD is sponsor
    - SwRI will build and GSFC will operate
    - Target destination is heliocentric
    - Trajectory after separation from ICPS is TBD
- BioSentinel
  - AES is sponsor
  - ARC will build and operate
  - Target destination is heliocentric
  - Trajectory: after separation from ICPS is TBD
- Near Earth Asteroid Scout
  - AES is sponsor
  - MSFC will build and operate
  - Target destination is an asteroid
  - Trajectory after separation from ICPS is TBD
- Argomoon
  - ASI is sponsor
  - Astrotech will build and operate in Torino, Italy
  - Target destination is lunar proximity
  - Trajectory after separation from ICPS is TBD

Future – EM-1 AMMOS Services

- In addition to all EM-1 secondaries adhering to a standard set of CCSDS compliant services from the DSN all of the missions are utilizing a set of standard services from MGSS (Multimission Ground System and Services) AMMOS (Advanced MultiMission Operating System):
  - All cubesats are utilizing Multimission Resource Scheduling Service (MRSS) to schedule DSN assets
  - Several of the cubesats are utilizing JPL NAV for navigation services (MONTE only as a service through MGSS)
  - Two (2) of the missions are utilizing the AMMOS Instrument Toolkit (AIT) for flight operations
  - Two (2) of the missions ate utilizing AMMOS Mission Data Processing and Control System (AMPCS) for flight operations

Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov