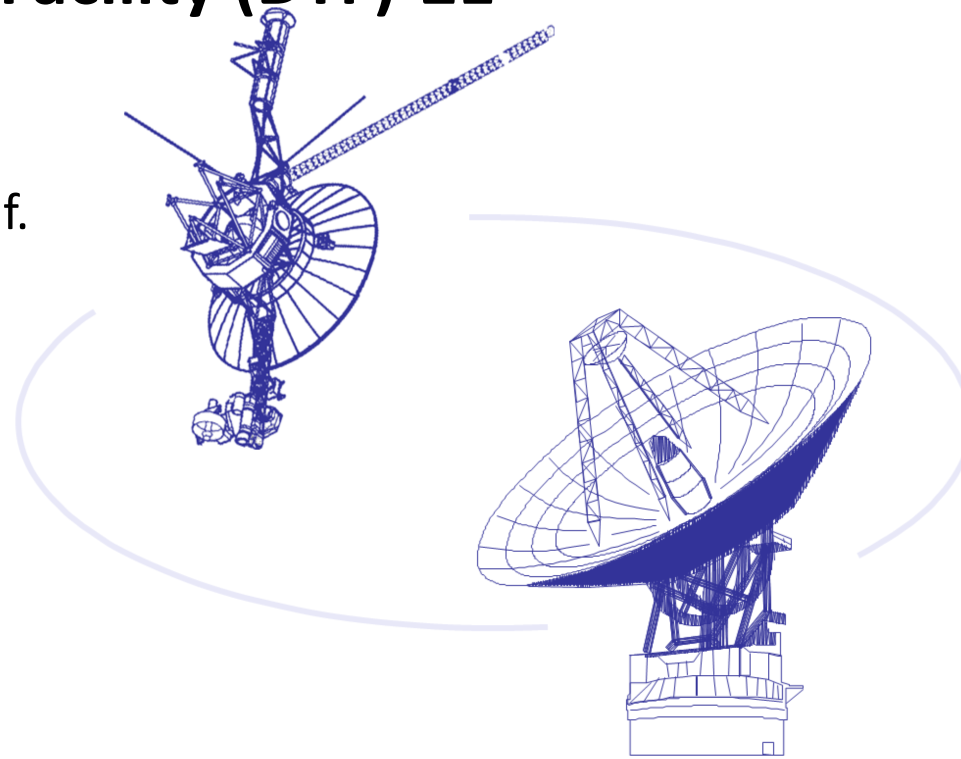
Iris Deep Space Transponder Testing at Space Dynamics Lab (SDL), Jet Propulsion Lab (JPL), and DSN Test Facility (DTF)-21

2019 Interplanetary Small Satellite Conf.
San Luis Obispo, California, USA
29-30 April 2019



K. Angkasa, A. Babuscia, L. McNally, B. Burgett, J. Lux
Jet Propulsion Laboratory at the California Institute of Technology

CL#17-1879

Outline

- History of Iris Deep Space Transponder
- 6 EM-1 CubeSats Using Iris
  - Lunar Polar Hydrogen Mapper (LunaH-Map)
  - Lunar IceCube
  - Lunar Flashlight
  - CubeSat for Solar Particles (CuSP)
  - BioSentinel
  - Near-Earth Asteroid Scout (NEA Scout)
- Iris vendor testing at Space Dynamics Lab (SDL)
- Iris mission-specific testing at Jet Propulsion Lab (JPL)
- Iris DSN RF Compatibility at DSN Test Facility (DTF)-21

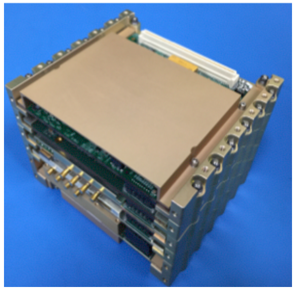
Iris History

- **<u>Iris V1.0</u>**: To extend CubeSat/SmallSat deep space capability, JPL introduced the Interplanetary NanoSpacecraft Pathfinder In Relevant Environment (INSPIRE) mission[1], coupled with the first-generation of Iris deep-space transponder[2].

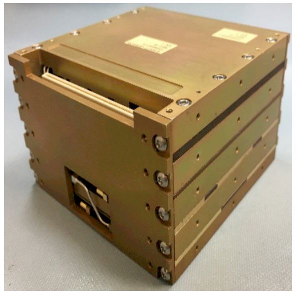
- **<u>Iris V2.0</u>**: The radio was further developed, matured, and in 2018 successfully flown onboard Mars Cube One (MarCO), to support InSight's Mars Entry, Descent, and Landing (EDL)[3].

- **<u>Iris V2.1</u>**: The latest version of Iris includes design updates that support EM-1 CubeSats missions[4].

Iris V1.0 Transponder Stack



Iris V2.0 Transponder Stack



Iris V2.1 Transponder Stack

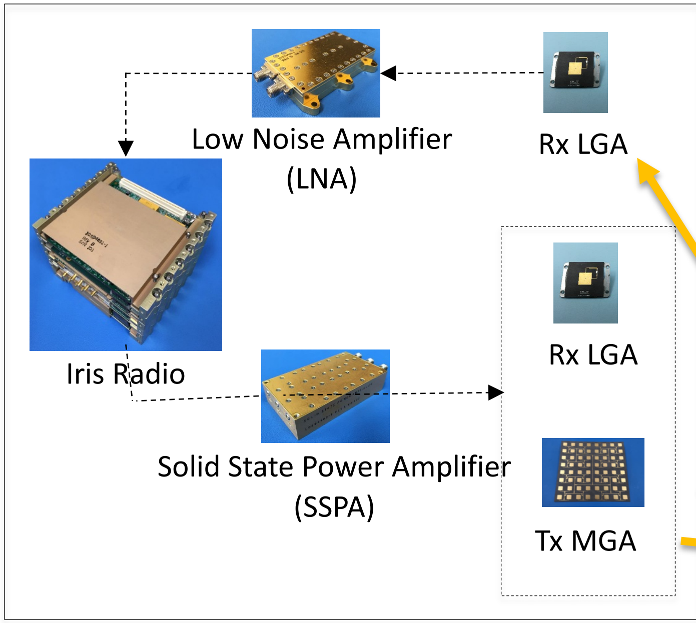
Specification	Units	
Downlink frequencies	MHz	8400-8600
Uplnk frequencies	MHz	7146-7235
Turn-around ratio		880/749
Downlink symbol rates	sps	62.5-6.25 M
Uplink data rates	bps	62.5-8000
Modulation waveforms		PCM/PSK/PM w/subcarrier
		PCM/PM w/biphase-L, BPSK
Telemetry encoding		Turbo (1/2, 1/3, 1/6)
Receiver noise figure (NF)	dB	3.5
Carrier tracking threshold	dBm	-151 @ 20-Hz LBW
RF output power	Watts	> 3.8
Navigation		Nonregenerative ranging
		Dela-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	28-Sep
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)		> 23.0 MeV-c2/mg

Iris V2.1 Key Specifications

[1] A. Klesh et al., "INSPIRE: Interplanetary NanoSpacecraft Pathfinder In Relevant Environment," in *AIAA SPACE Conf. and Expo.*, San Diego, CA, 2013.
[2] C. B. Duncan et al., "Iris Transponder – Communications and Navigation for Deep Space", in *Small Satellite Conf.*, Logan, UT, 2014.
[3] A. Klesh et al., "MarCO: Early Operations of the First CubeSats to Mars," in *Small Satellite Conf.*, Logan, UT, 2018.
[4] M. M. Kobayashi, "Iris Deep-Space Transponder for SLS EM-1 CubeSat Missions," in *Small Satellite Conf.*, Logan, UT, 2017.

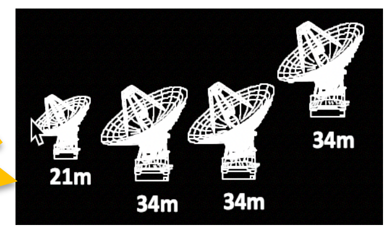
6 EM-1 CubeSats Using Iris

- 6 EM-1 CubeSats have baselined to use Iris for basic telecom & navigations.
- They share common Telecom Hardware (Iris Radio, LNA/SSPA, Rx/Tx antennas) with different science goals & target destinations.



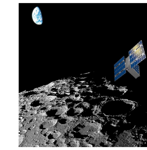
EM-1 CubeSat Telecom Hardware Using Iris

Mission Name	Target Destination	Max Range
LunaH-Map	Lunar	~ 1 Mkm
Lunar IceCube	Lunar	~ 1 Mkm
Lunar Flashlight	Lunar	~ 1 Mkm
CubeSat for Solar Particles	Heliocentric	~ 15 Mkm
BioSentinel	Heliocentric	~ 84 Mkm
Near Earth Asteroid Scout	Asteroid	~180 Mkm

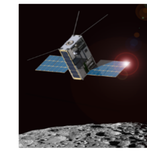


Deep Space Network (DSN)

- As such, the next few slides show the different test approaches taken at various test facilities (SDL, JPL, DTF-21) based on the commonality of Telecom Hardware and/or mission-specific requirements combined such as,
  - Higher data rates for lunar missions vs. heliocentric missions
  - Use of turn-around ranging, as opposed to Delta-DOR

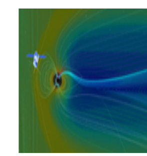


LunaH-Map

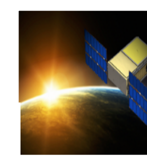


Lunar IceCube

Lunar Flashlight



CuSP



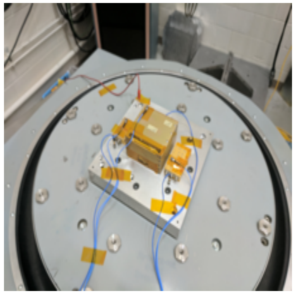
BioSentinel

NEA Scout

Iris Vendor Testing at SDL

- Making the most of the commonality of the EM-1 CubeSat Telecom Hardware, testing at the Iris vendor (SDL) takes on the following approach:
  - Environmental Testing using the Engineering Unit (EDU)
    - TVAC Test at Qual. Temp. (-55C,+25C,+70C)
    - Vibration Testing
    - EMC Testing[1]
  - And performed on each Flight Unit (FM)
    - Thermal Test at AFT (-20C,+25C,+50C)

TVAC Test with EDU

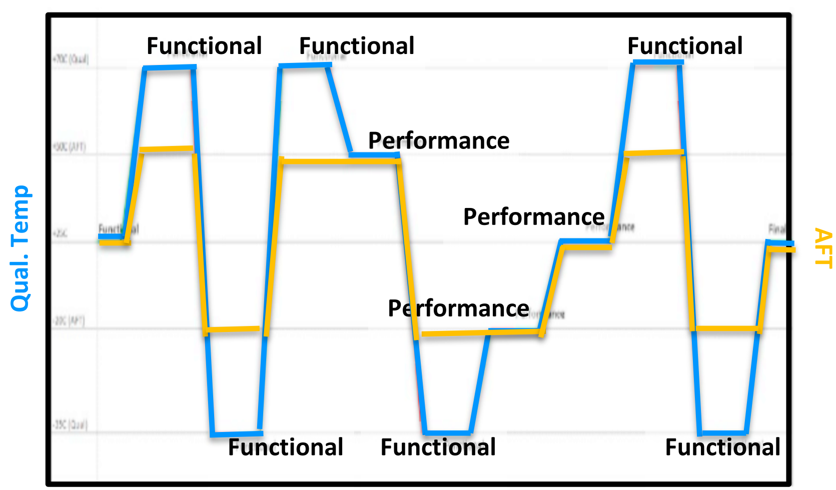


Vibration Test with EDU

EMC Test with EDU

Sample of Performance Tests
- Boot
- In-Rush & Pwr. Consumption 9V, 12V, 18V, 24V
- Firecode
- Coherency
- Transmit Spectrum
- Downlink Data Test
- BER

Sample of Functional Tests
- Boot
- In-Rush & Pwr. Consumption 12V
- Firecode
- Coherency
- Transmit Spectrum
- Downlink Data Test

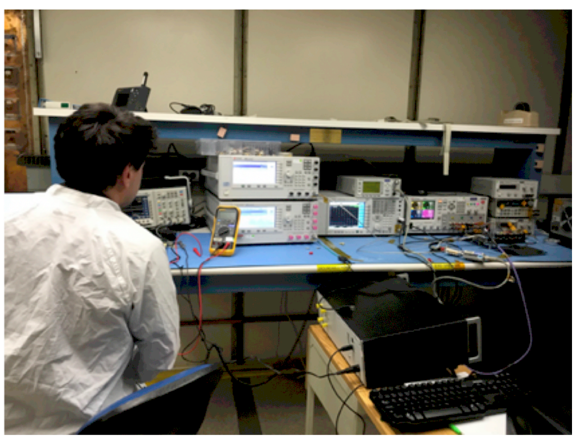


Temperature Profile

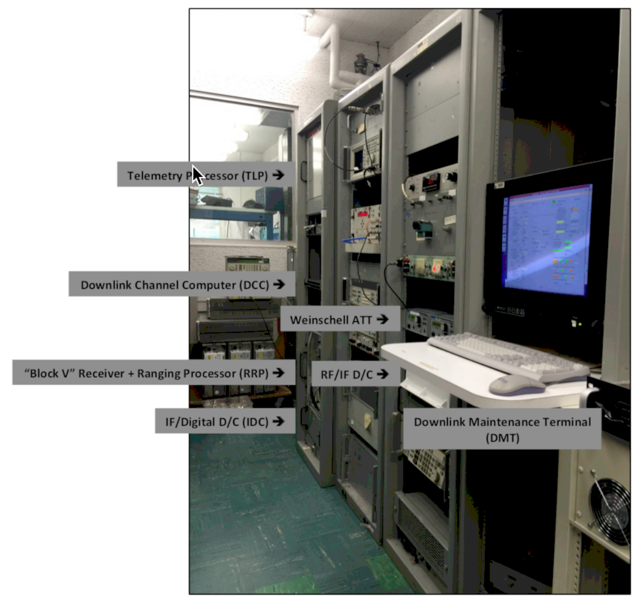
[1] performed at JPL including, bonding, grounding & isolation, RE, CE, for information only.

Iris Mission-Specific Testing at JPL

- After delivery from SDL, mission-specific tests can be performed at JPL such as,
  - Higher data rate tests for the lunar missions e.g. downlink 256kbps Turbo codes test using the JPL-lab equipped DSN Block V Receiver.
  - This is a useful "precursor" to the DSN RF Compatibility Test at DTF-21, which will include, not only the downlink/telemetry test (using the DSN Block V Receiver), but also the uplink/commanding & ranging tests using the DSN Uplink and Ranging Assemblies.



Iris Hardware Inside the Screen Room (adjacent to DSN Block V Receiver)



JPL-lab Equipped - DSN Block V Receiver

Iris RF Compatibility Testing at DTF-21

- The RF Compatibility Test is performed to verify compatibility with the Deep Space Network, which takes place at the DSN Test Facility (DTF)-21 in Monrovia, CA.
- This is a spacecraft level test.

Test Number	Test Name
RF0	RF Link Calibration
RF1	Uplink Receiver Threshold and AGC Calibration
RF2	Uplink Receiver Acquisition and Tracking Range
RF3	Uplink Receiver Tracking Range
RF4	Downlink Transmitter RF Power Output
RF5	Downlink RF Spectrum Analysis
RF6	Downlink Receiver Threshold
CMD1	Command Performance
TLM2	Telemetry Performance
RNG1	Spacecraft Range Delay Measurements
RNG2	Range Delay Measurement and Polarity Check

Sample of RF Compatibility Test List

- At the time of this writing, thirty percent of the 6 EM-1 CubeSats using the Iris Deep Space Transponder, have gone through the DSN RF Compatibility Testing.
- Test Reports are available through the respective DSN Mission Interface Manager (MIM) at JPL.

Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov