Iris Deep Space CubeSat Transponder

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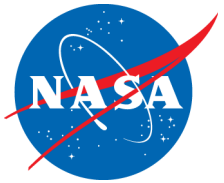
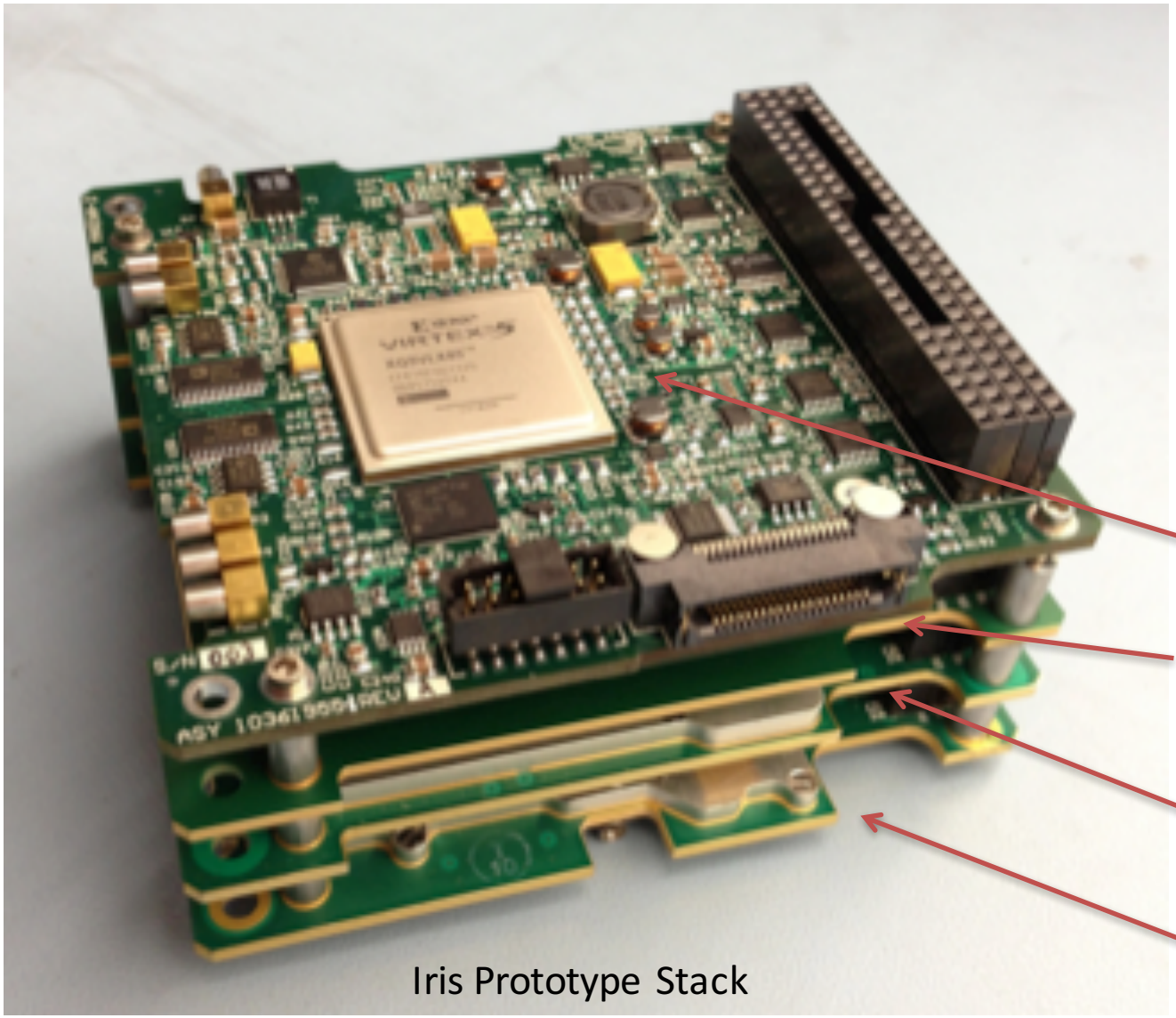


Iris Overview
Deep Space Transponder

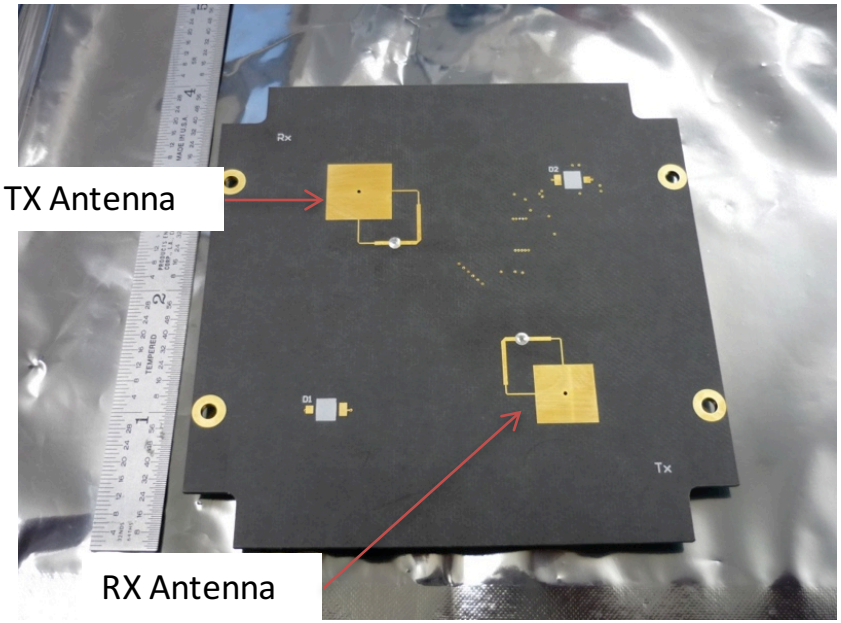
- CubeSat Compatible – DSN Compatible
- Architecture supports
  - micro- and nano-spacecraft deep space missions
  - Direct To Earth (DTE) and Proximity Operations
- Communications and Navigation
  - Uplink and Downlink – various rates – CCSDS
    - Wide range of data rates needed for wide range of distances
  - Doppler, Ranging and Delta-DOR
    - No GPS in deep space – even at the moon

Iris V1



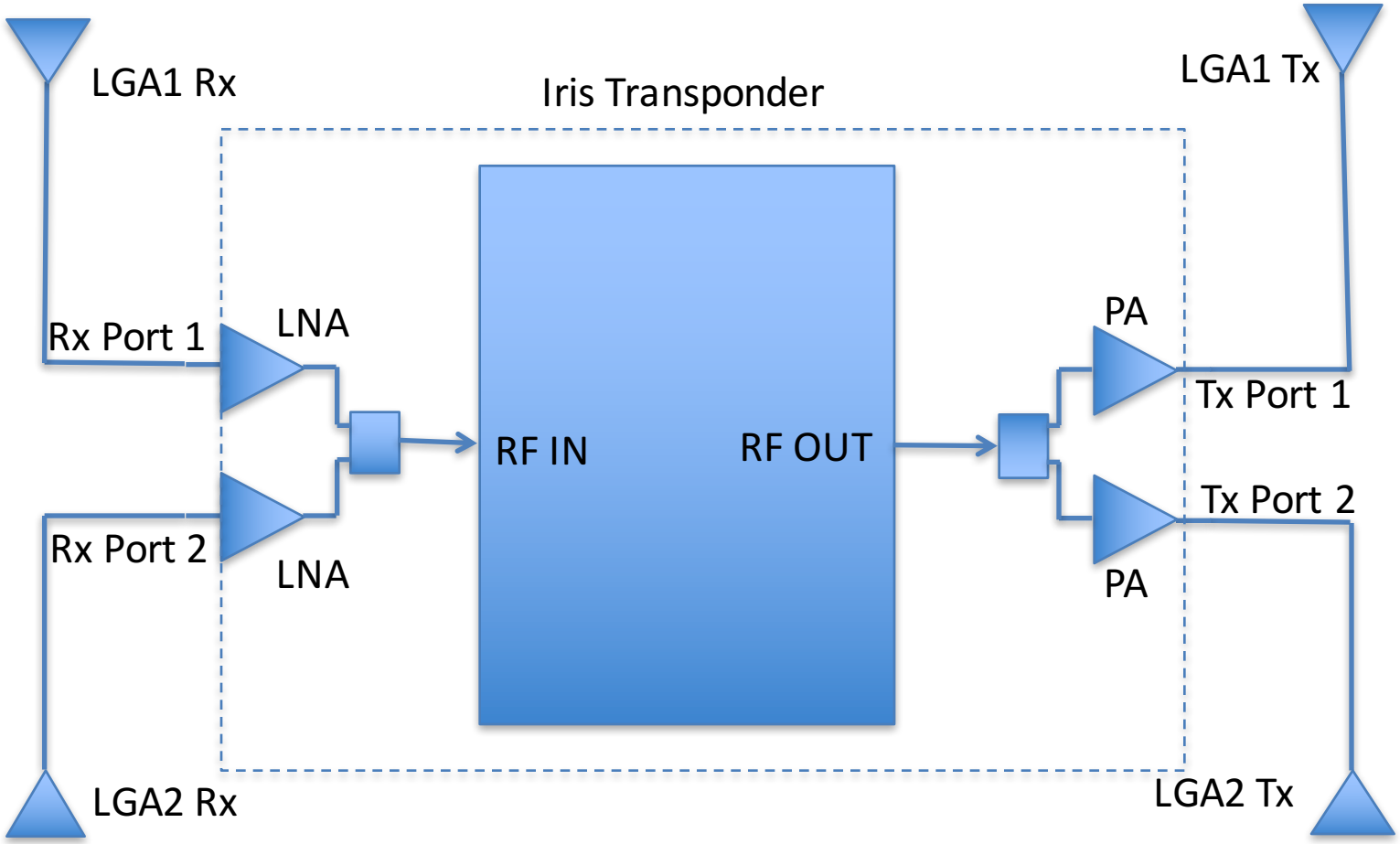
Iris Prototype Stack

Iris V1 Antenna Board



- TX/RX Antennas
  - (also hosts spacecraft sun sensor)
- 1 on each end of S/C
  - 4 patches total
  - Independently selectable
- X-Band Frequencies
  - Receive: 7.145-7.235GHz
  - Transmit: 8.400-8.500 GHz
  - Deep Space and Near Earth
    - All channels supported
- Prototype Test Results:
  - Return Loss > 18dB
  - TX/RX Isolation > 35dB
- Prototype Mass = 40g (each)

Iris / Patch Antennas Configuration



Iris Specs

- CubeSat Compatible
  - < 0.5 U + antennas
  - < 500 g
  - 12.8 W DC in for full transpond, 6.4 W receive only
- DSN Compatible
  - Navigation
    - Full duplex Doppler, Ranging
    - V2 to support Delta-DOR
  - Telecomm performance
    - 62.5 – 256k bps telemetry, subcarrier, low rate tones to 8 Mbps available
    - 1000 bps command, other rates available when needed
    - 25 dBm transmit, higher power available for more DC input
    - -130 dBm receive sensitivity
- Software Defined Radio
  - Future versions to be reconfigurable in flight
  - SPI interface to C&DH
    - C&DH thread performs framing and protocol
  - Multimission Telecommunications Interface (MTIF) FPGA code
    - Handles standard coding
- COTS parts with “path to flight”
- Developed January ‘13 – March ’14, first mission: INSPIRE

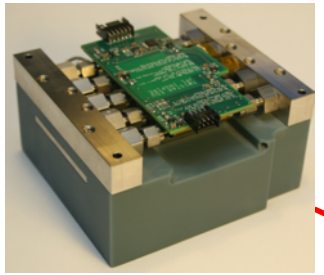
INSPIRE CubeSat

Overview:
Volume: 3U (10x10x30cm)
Mass: 4.4 kg
Power Generation:
3 Axis Stabilized: 20 W
Tumbling: 13 W
Data Rate: 62-256000 bps

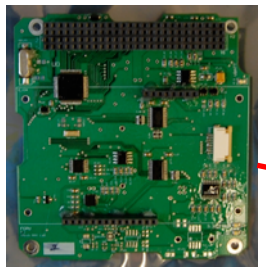
Operations:
Primary: DSN
Secondary (Receive only): DSS-13 (JPL), & Peach Mountain (U. Michigan)

X-Band Patch Antennas (JPL) [two sets]

UHF Antenna

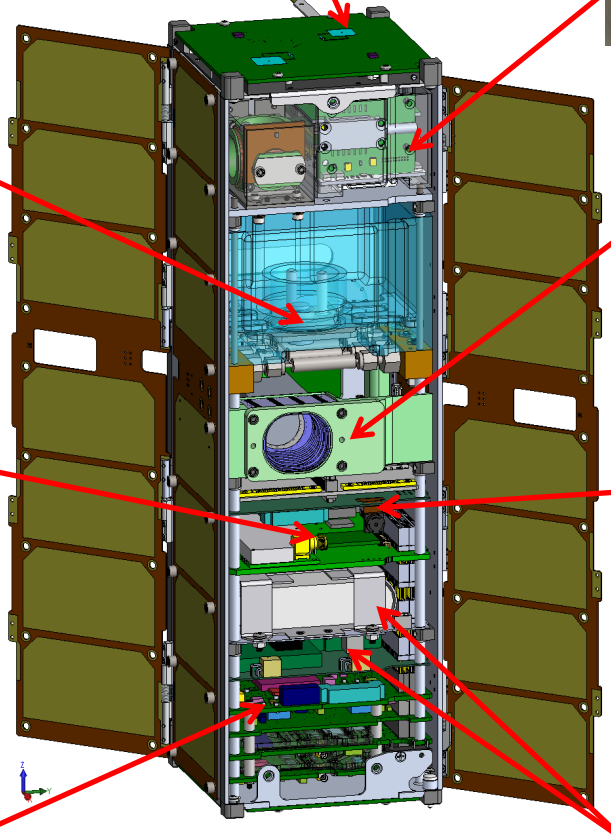


Cold-Gas ACS



C&DH + Watchdog Board + Lithium UHF

Nav/Comm X-Band Radio (JPL)

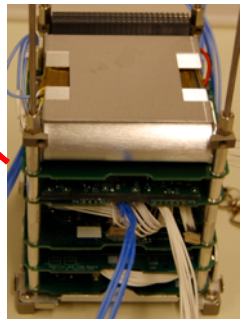


Deployable Solar Panels + Structure

Magnetometer

Star Tracker

Processing Board



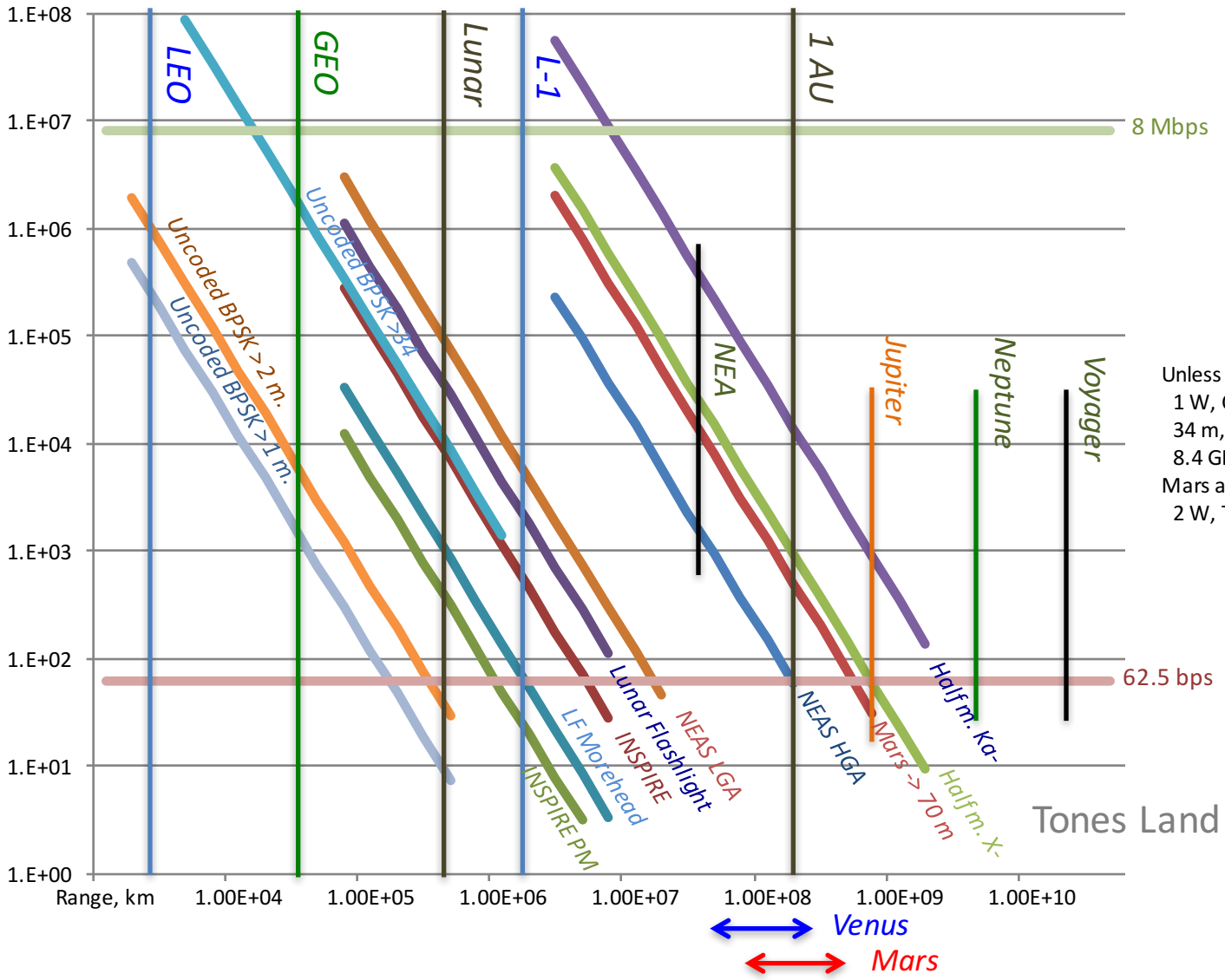
Electrical Power System + Battery Board

Potential Future Missions – Iris V2

(none yet approved)

- Lunar Flashlight 6U – south pole of the moon
  - Iris V1, 1W to same patch antennas
- NEA Scout 6U – to an asteroid ~ 0.3 AU
  - Iris @ 2W out and patch array gain antenna for downlink (~20 W DC in)
- Lunar Impactor 3U (UCSC)
  - Iris V1 with live streaming data feature
- Others in proposal or inquiry stage

Iris Downlink Rates



Unless otherwise noted:
1 W, Conv. K=7, r=1/2
34 m, 45K
8.4 GHz
Mars and beyond:
2 W, Turbo 1/6 1728

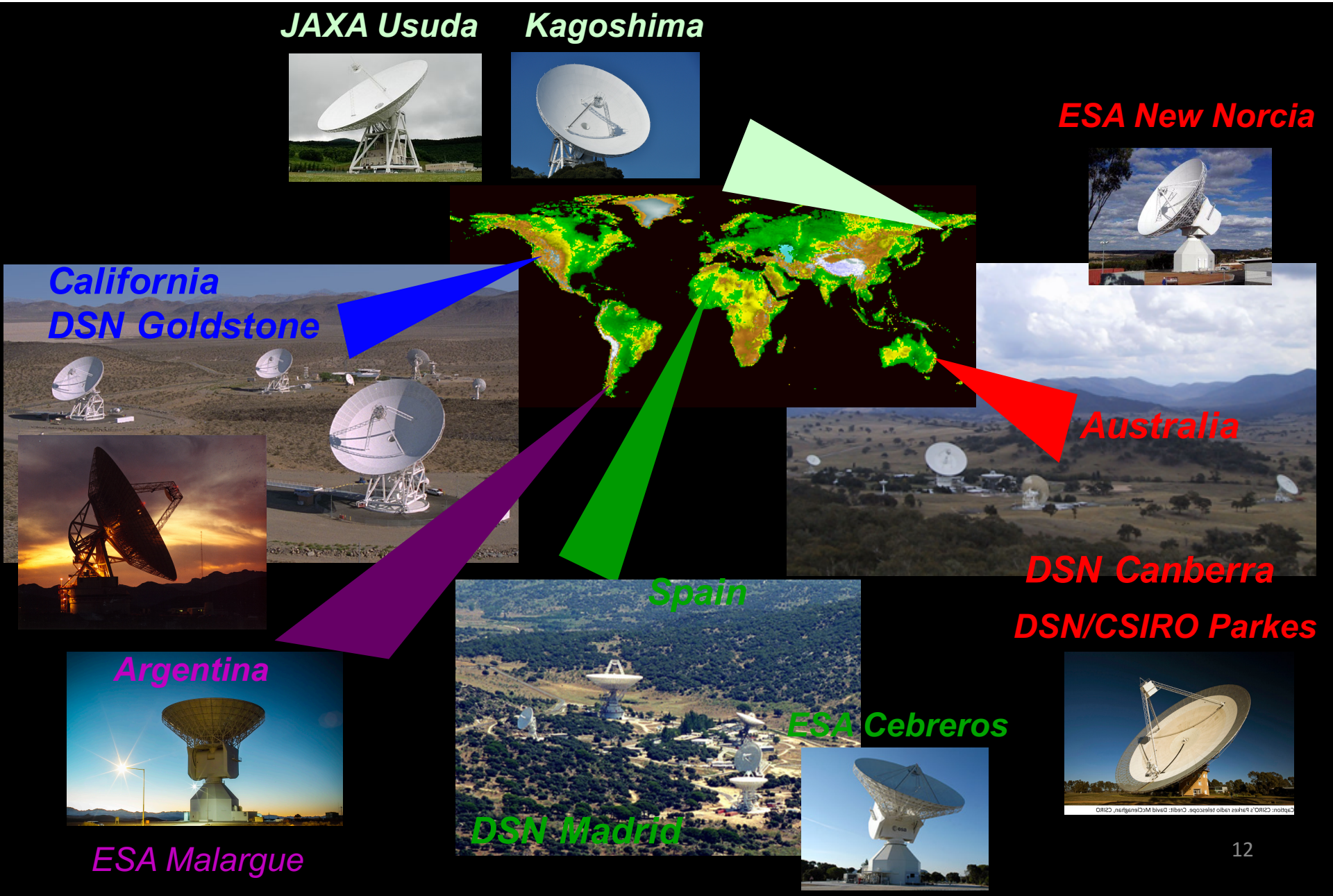
Iris Transponder vs. LEO Transceivers

- Why does Iris use so much power?
- LEO CubeSats
  - Half duplex transceivers and GPS
  - Limited duty cycle – very low power “monitor” mode (like cellphone)
- Deep Space
  - Slant range is orders of magnitude greater
  - Higher power and highly directional gain antennas needed
  - Long, equilibrium transpond sessions for weak signals
    - Low rate data
    - Nav arcs
  - Many missions leave transmitter on throughout
- Bottom line
  - Much higher average power than CubeSat radios
  - And much higher nominal heat dissipation – must equilibrate
  - Tougher environments: radiation, temperatures, longevity

DSN

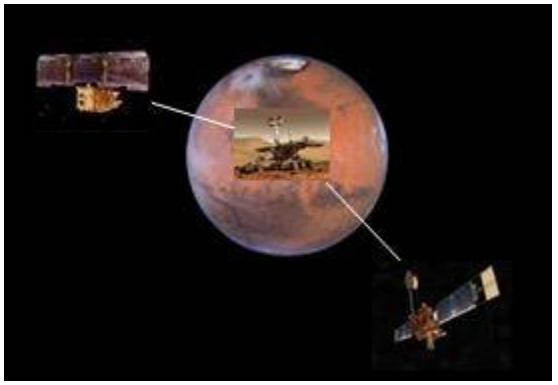
- The earth station partner that makes deep space operations possible
- 34 and 70 m apertures – high gains
  - Precision pointing
- Quiet front ends – 45K *system* noise temperature
- High uplink power – 20 KW
- High performance coding and other modulation schemes, > 10 dB of further improvements

Deep Space Network (DSN): Comprises DSN and Partner 34-70m tracking sites around the globe to provide continuous communication and navigation support



The Big Picture

DSN Antenna

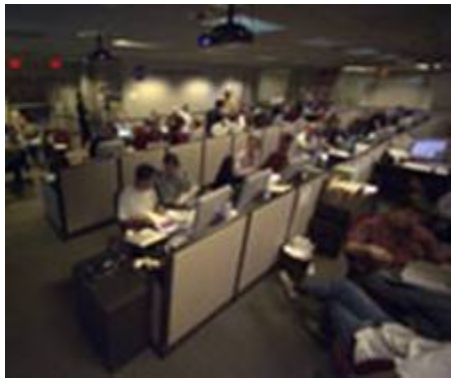


Spacecraft Operations

DSCC Signal Processing Center (SPC)

WAN

JPL Deep Space Operations Center (DSOC)



Mission Support Area (MSA)

DSN ConOps

- Sequence
  - *No "real time" handshake possible in "deep" space due to light time distances*
  - S/C transmits – DSS slews to find S/C on plane of sky
  - DSS locks on downlink at BLF uncoherent
  - DSS starts uplink – sweeps through uplink range
    - S/C locks on uplink – follows coherently, downlink re-locks carrier
    - Uplink sweeps to operating frequency
  - DSS downlink process
    - Locks on subcarrier
    - Demodulates symbols
    - Decodes into bits
  - S/C uplink process similar
  - DSS processes uplink commands and downlink data
  - DSS collects Doppler data
  - Ranging (tones or PN) or DOR tones optional

- Not your LEO CubeSat Beacon, Ping and Query process!
  - Or receive-only GPS

DSN

- World Class Facility
  - Decades of research and development to address “enormous distance” and quality of service issues
  - Backends for data, command, and navigation
  - Expertise at JPL for these plus mission design
- Your “DSN” should work like this
  - For interoperability
  - Cooperation and assistance in deep space

Iris Architecture: Not Just X-Band DTE

- RF boards for
  - Ka-Band – high bandwidth and gain for future missions
  - UHF & S-Band – proximity ops at planets, in formations
  - "Exciter only" version can drive TWTs
- Protocol (firmware / software) for
  - Prox Ops – partners with other Iris, Electra, or UST
  - DTE
  - Earth Orbit high rate
- Various antenna options
- Reduced DC input power baseband in development
  - PS, PA, CPU
  - 15 W system goal
- JPL Heritage and Relatives
  - UST, Electra MTIF, COVE, LMRST-Sat

Iris (Ιρις) – (not an acronym)

The goddess Iris is associated with:

communication, messages,

the rainbow,

new endeavors