Iris DSN Compatible Small Satellite Navigation and Communications Transponder

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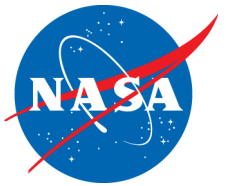
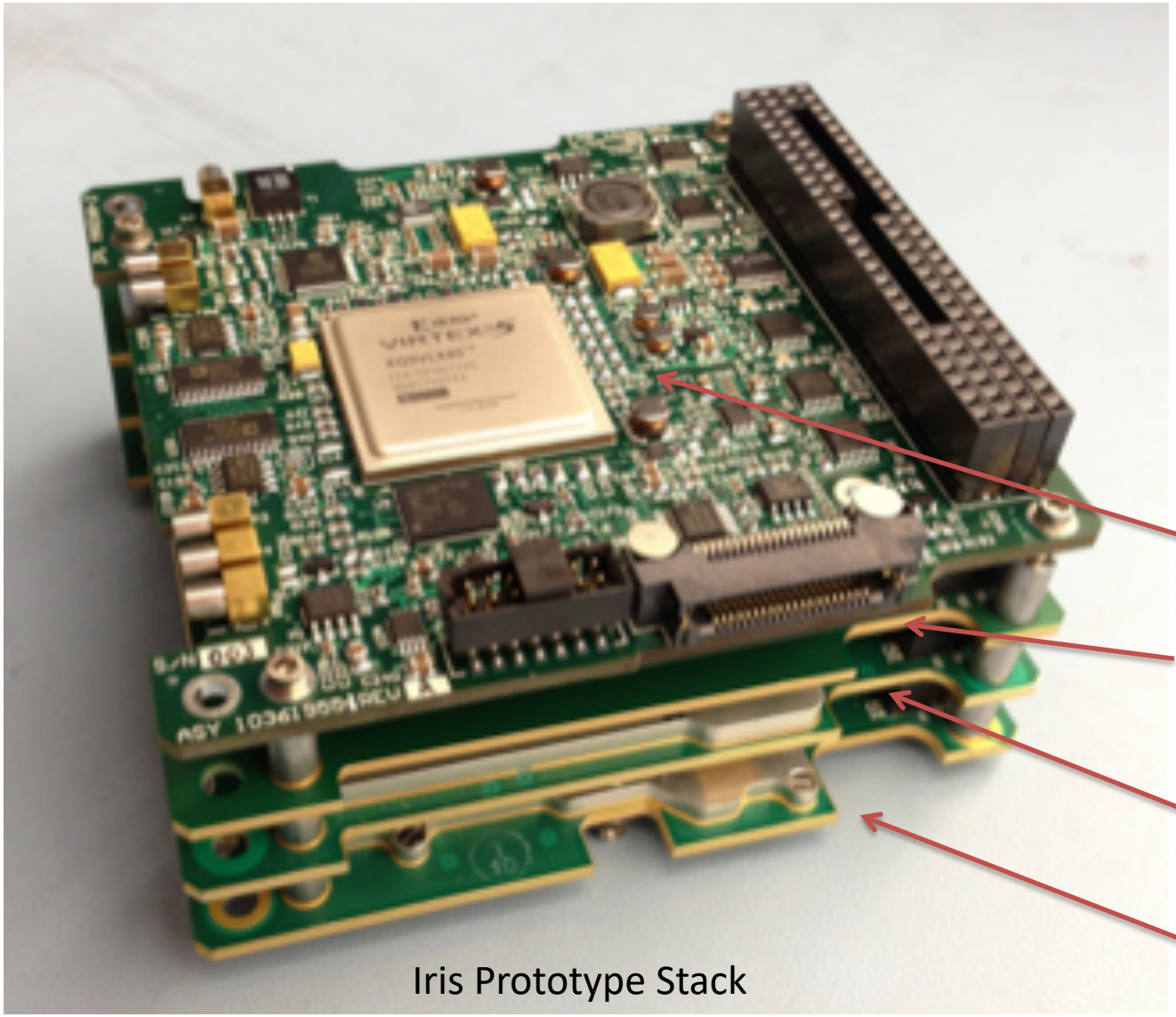


Transponders vs. Transceivers

- LEO CubeSats use half or full duplex transceivers
  - Commands and data only
  - Limited duty cycle – very low power “monitor” mode (like cellphone)
  - GPS for navigation
- Deep Space
  - Slant range is orders of magnitude greater
  - Higher power and highly directional gain antennas needed
  - Long, equilibrium 100% duty cycle transponder sessions for weak signals
    - Low rate commands and data supported, (more Eb)
    - Navigation arcs
  - Many spacecraft transmit continuously throughout their missions
- Bottom line
  - Much higher average power than CubeSat transceivers
  - And much higher nominal heat dissipation – must equilibrate
  - Tougher environments: radiation, temperatures, longevity

Iris Transponder

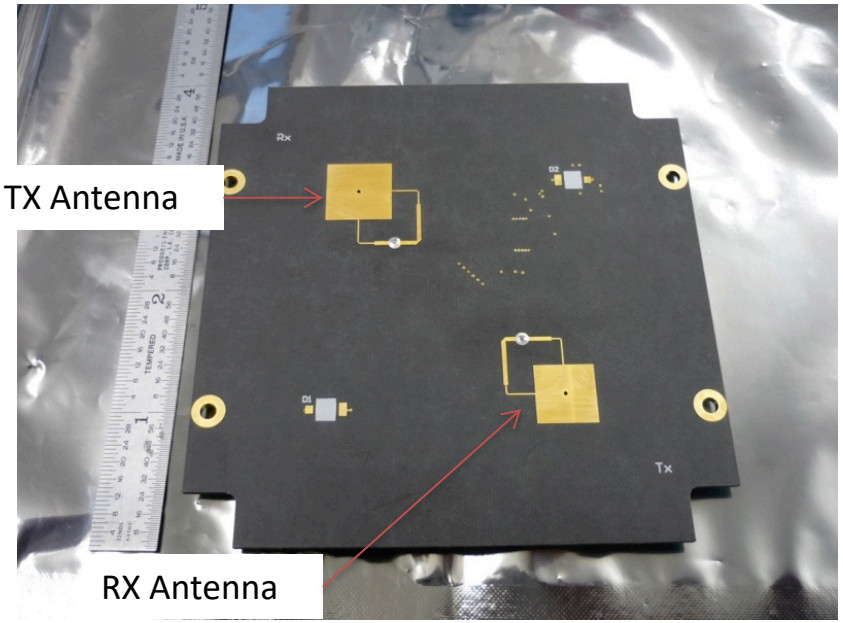


Iris Prototype Stack

Iris Transponder Overview

- 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 Patch Antennas



- 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 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

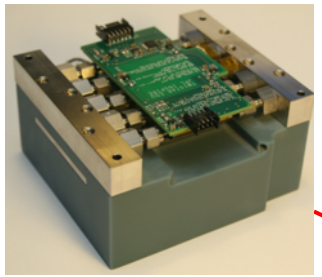
Operations:

Primary: DSN

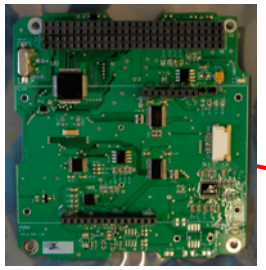
Secondary (Receive only): DSS-13 (JPL), & Peach Mountain (U. Michigan)

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

UHF Antenna

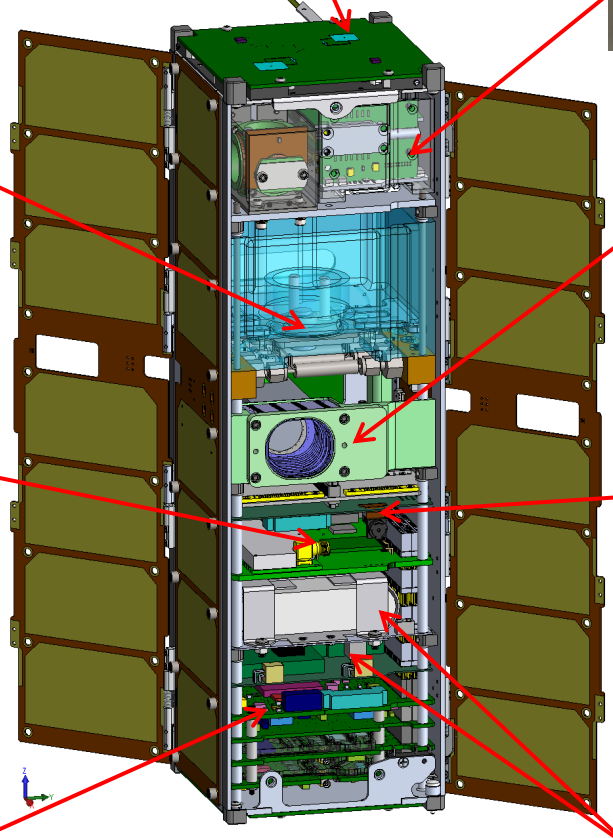


Cold-Gas ACS



C&DH + Watchdog Board + Lithium UHF

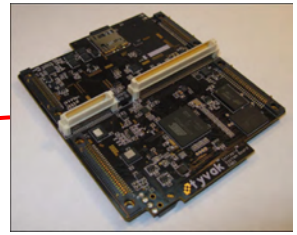
Iris Nav/Comm X-Band Radio (JPL)



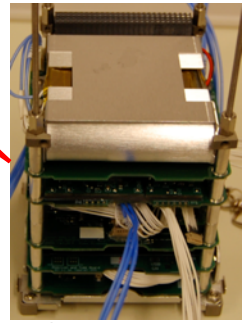
Deployable Solar Panels + Structure

Magnetometer

Star Tracker



Processing Board



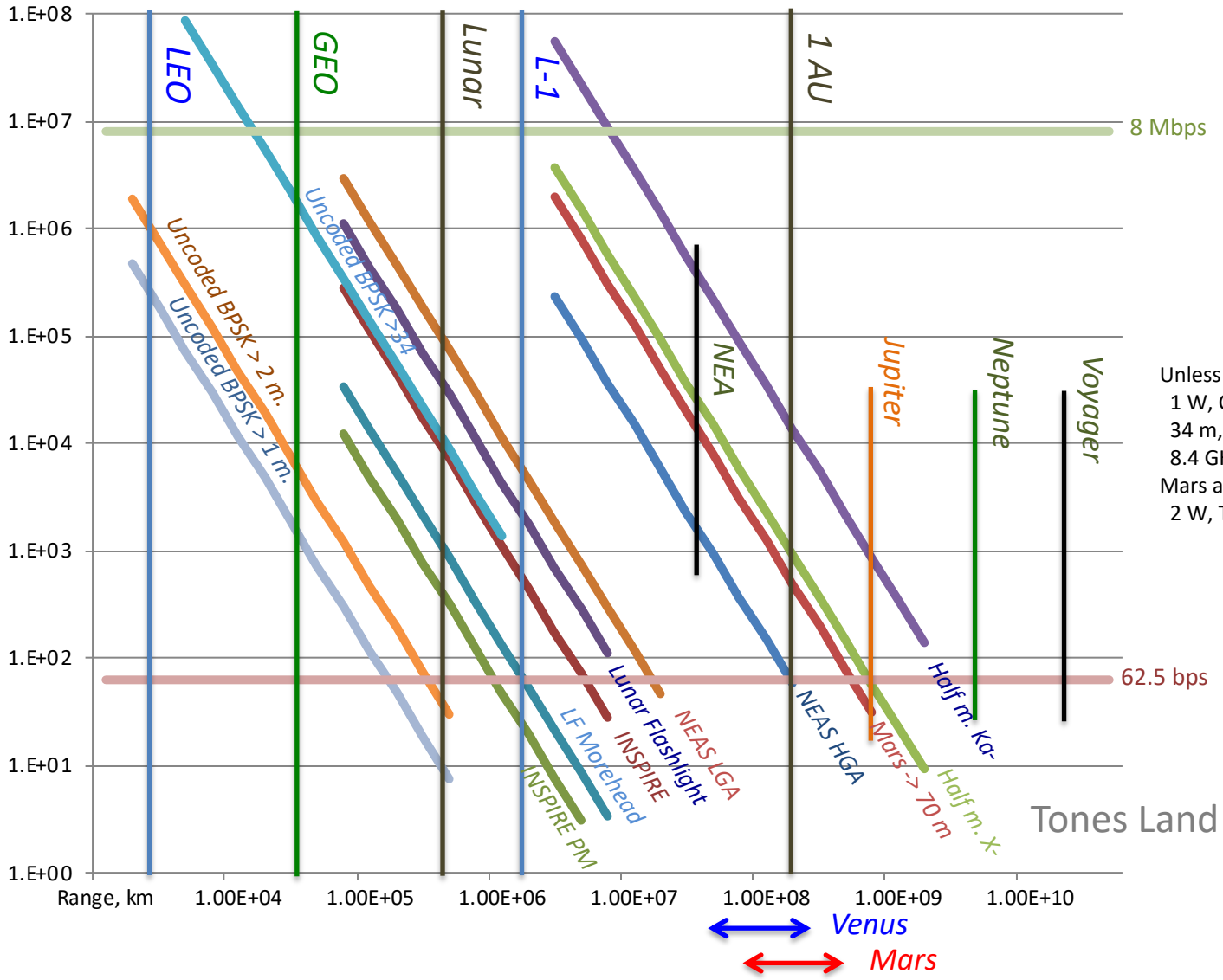
Electrical Power System + Battery Board

Future Missions in Study – Iris

(none yet approved)

- Lunar Flashlight 6U – south pole of the moon
  - Iris @ 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 @ 1W 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

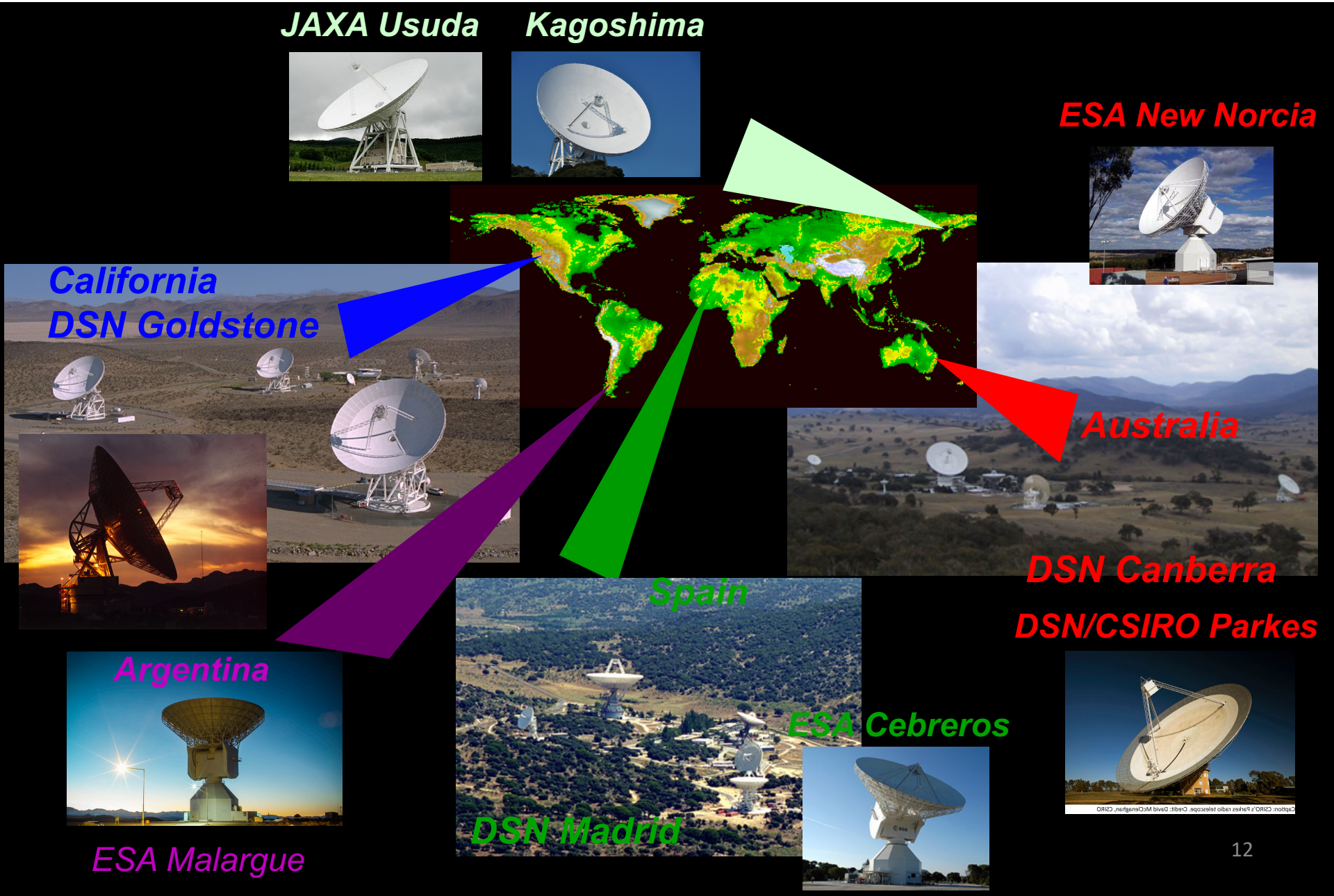
SmallSats in Deep Space

- Current Iris design – power levels – patches <-> DSN
  - lunar or L1 appears to be the “sweet spot”
- Similar to proximity operations at planetary systems like Saturn or Jupiter
  - UHF and S-Band variants are planned
- DTE to DSN ~1 AU (Venus, Mars, NEAs)
  - Enabled by higher gain antennas
    - and consequent pointing requirements, *driven by transponder, not necessarily the science*
    - Such antennas are in development at JPL
  - Few hundred bps data rates and navigation
  - Further out at higher frequency (2x distance at Ka-Band) and better codes
- Smaller commercial / university apertures also possible
  - Lower data rates than DSN
  - “Transceiver mindset” – more ground equipment needed for navigation
- JPL can help with
  - DSN coordination
  - Mission design, analysis, navigation, and science tools
  - Iris

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
- Worldwide, coordinated

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



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, >= 30 dB
- 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