IRIS VERSION 2 DEEP SPACE COMMUNICATIONS, NAVIGATION, AND RADIO SCIENCE FOR SMALL SPACE CRAFT

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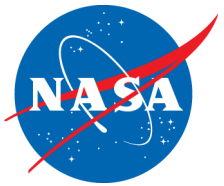
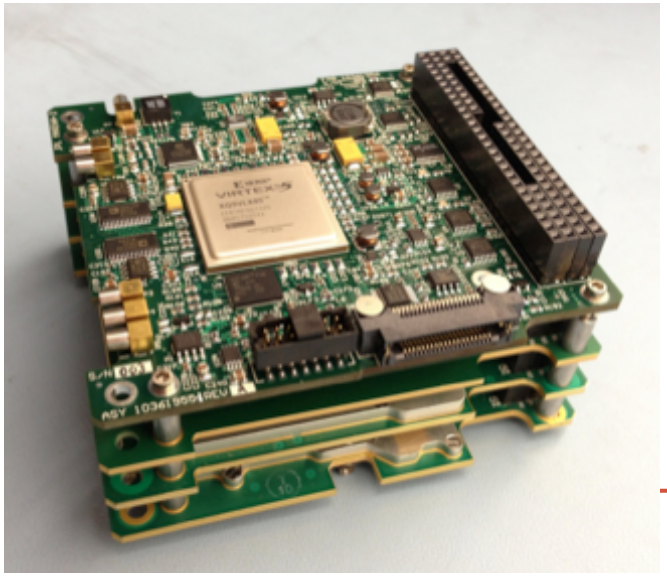


Iris Version 1 Transponder, 2014

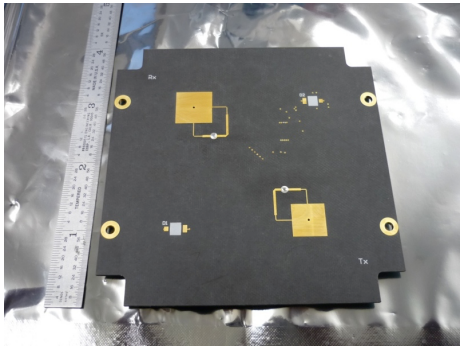


Iris V1 Prototype Stack

Marina-2 Virtex 5 Modem Processor
Power Supply Board, 13 W @ 7.5 VDC
X-Band Receiver 7.2 GHz
X-Band Exciter 8.4 GHz
    0.25 W RF output
Independent, selectable antennas
    (Amp power switching, not RF switching)
    2 transmit, 2 receive

- JPL's INSPIRE Mission
  - Two 3U CubeSats
  - 10 M km deep space
  - 90 day max, COTS parts
- In Hibernation June 2014
  - Waiting launch opportunity

- Firmware Modems – CCSDS
  - DSN compatibility certified
  - Reed-Solomon and Convolutional Codes
- SPI spacecraft interface
- Full Duplex
  - Coherent Doppler
  - Range
  - Command
  - Telemetry
- FireCode



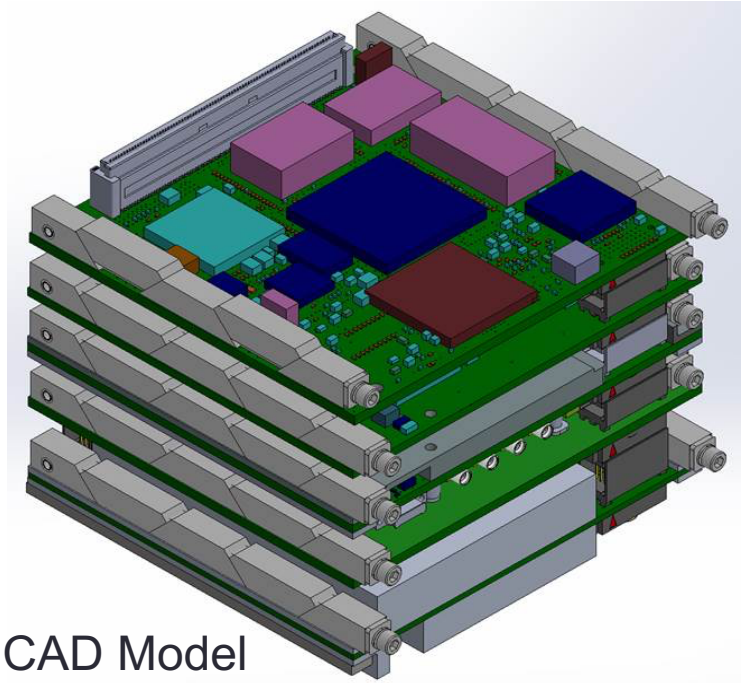
TX / RX LGA

Iris V2 from V1 Lessons Learned

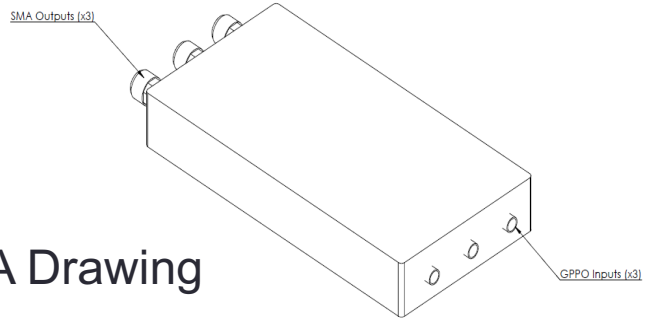
- Higher power output needed for truly deep space
  - *Hundreds* of millions of km
  - A few Astronomical Units
  - More distant is likely better served by a larger mission using Universal Space Transponder (UST) and/or proximity operations
- Missions of years rather than months, just to get there
  - As much hardening as is ‘affordable’
- C&DH interface
  - Commands versus ‘peeks and pokes’
- CubeSats are small for 10s of W of heat dissipation, requires intentional design
  - Wedgelocks
  - SSPAs on radiators – semi-custom spacecraft design

Iris V2 Description, 2015

- Four Board Stack plus external SSPAs
  - X-Band Exciter
    - SSPA 4 W RF out
  - X-Band Receiver
  - UHF Receiver (slice architecture)
  - RadiX Virtex-6 board
  - Power Supply Board
    - 27 W input CBE @ 12 VDC
    - RX-only, Digital-only lower powers
- 500 g, 0.5 U
  - 6U Spacecraft compatible
- 2-3 year design life



Iris V2 CAD Model



SSPA Drawing

Iris V2 Features

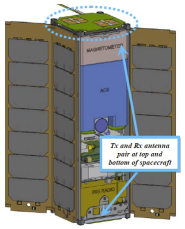
- All Iris V1 Features, plus:
- Delta DOR navigation support
  - Plane of sky technique in cooperation with DSN
- Direct carrier modulation with residual carrier
- Turbo Codes, Manchester, and scrambling
- Command and Telemetry Dictionary
- Independent, selectable antennas
  - Power switching to amplifiers, not radio frequency switching
  - 3 transmit
  - 3 receive

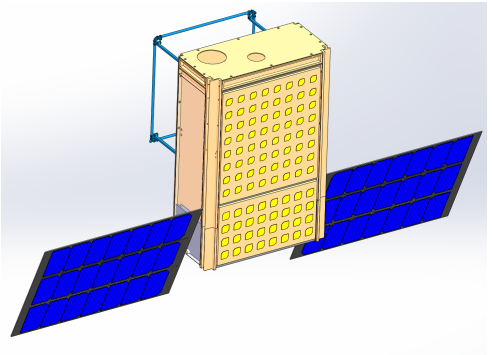
Iris V2 Features

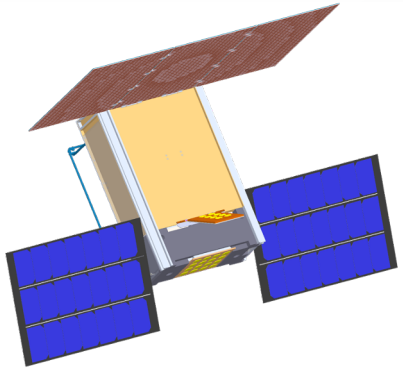
- CPU
  - Gaissler LEON3-FT softcore on Virtex 6
- Memory
  - 32 Mbit non-volatile NOR-Flash (radiation tolerant)
    - Multiple FPGA bitfiles (8.8 Mbit each)
      - Backup copies and future reprogramability
    - Vector tables for TurboCoding, (2 Mb)
    - Boot PROM and software image storage (for LEON)
    - Boot PROM copies application to SRAM for execution
  - 20 Mbyte of volatile SRAM (radiation tolerant)
    - One 16 Mbyte part / One 4 Mbyte part for EDAC
    - LEON program execution, stack, and storage
    - Data storage

CubeSat X-Band Antennas

- Estimates to DSN 34 m.
  - For 20 m., 100 Kelvin, divide by 10
  - For 70 m., multiply by 4
- LGA, included with Iris
  - 10s of bps (semaphores) from Mars
    - (at arrival ~1 AU)
- MGA – side of a CubeSat
  - Needs pointing
  - Hundreds of bps from Mars
- HGA – Deployable (MarCO)
  - Needs good pointing
  - 2000 bps from Mars
    - (at arrival ~1 AU)
  - Ka-Band 3U Turkey Tail version also in development





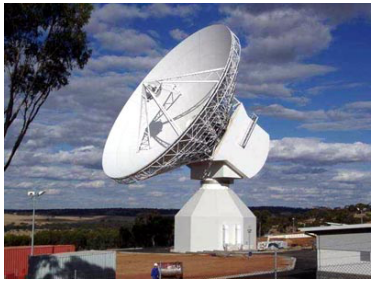


Iris V2 Status and Availability

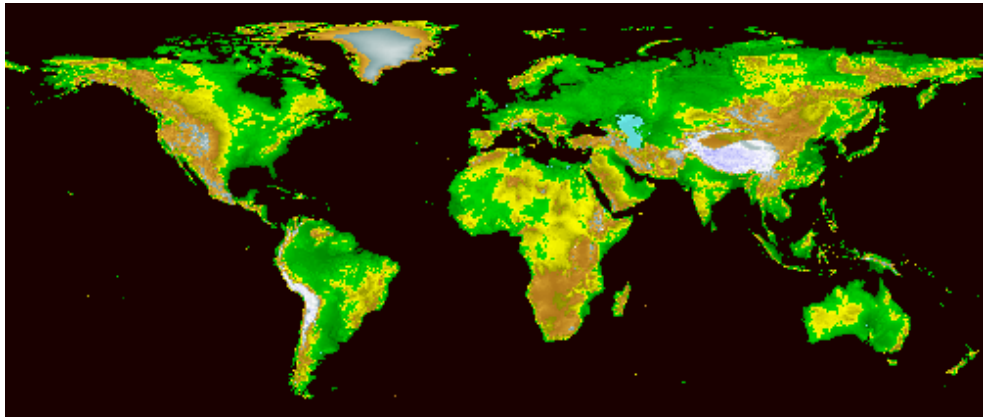
- Missions
  - MarCO flying prototypes, delivery August 2015 launch March 2016
  - EM-1 secondaries, various, launch 2018
- MarCo flight boards in work now
  - Boards built and in test
  - Firmware and software being written
  - Delivery to MarCO and DSN compatibility August 2015
- Ground Support Equipment (GSE) in progress
- Production copies to be produced
  - By a to-be-named partner company
- Orders / Contracts expected third quarter 2015
  - EM-1 and later missions
- Early deliveries first quarter 2016
- Cost is dependent on mission difficulty and market volume
  - JPL is happy to help assess the cost

Summary

- JPL and Deep Space Network (DSN) are committed to supporting deep space SmallSats and CubeSats
- Initial Iris V2 testing for MarCO project has been successful
- JPL working towards a commercial implementation
  - Success depends on the market



Caption: CSIRO's Parkes radio telescope. Credit: David McClenaghan, CSIRO

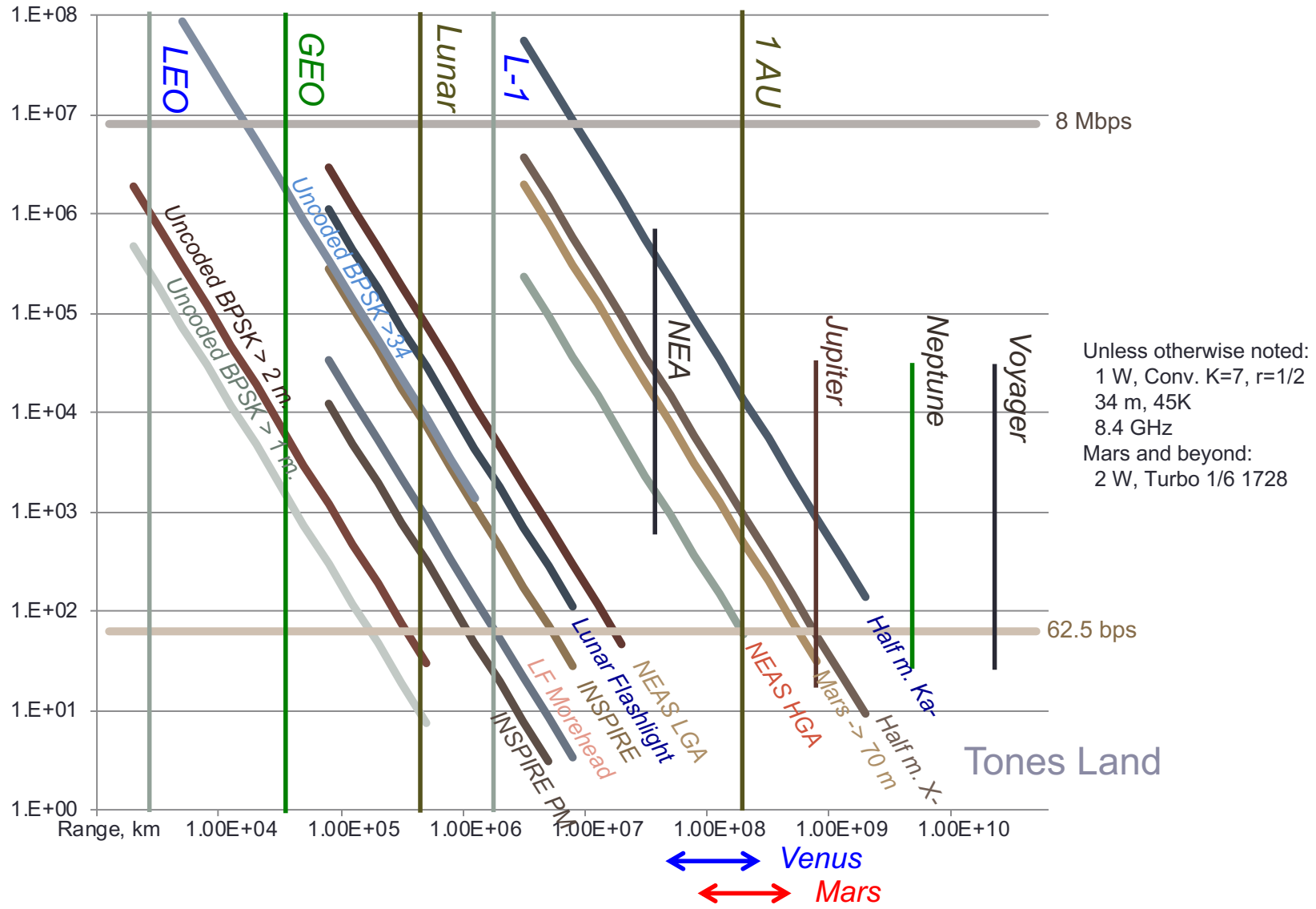


BACKUP

Abstract

- The Iris CubeSat Compatible, deep space transponder is now in Version 2 development for several planned deep space CubeSat missions. Iris V2 features X-Band power output of four watts, designed flight longevity of 2-3 years in deep space, and proper thermal management within a SmallSat context. These and other improved Iris features enable telecommand, telemetry, and radio science from destinations up to a few Astronomical Units from Earth.

Iris Downlink Rates



Iris (Ιρις) – (not an acronym)

The goddess Iris is associated with:

communication, messages,

the rainbow,

new endeavors