Enhancements and Redesign of the Iris Radio

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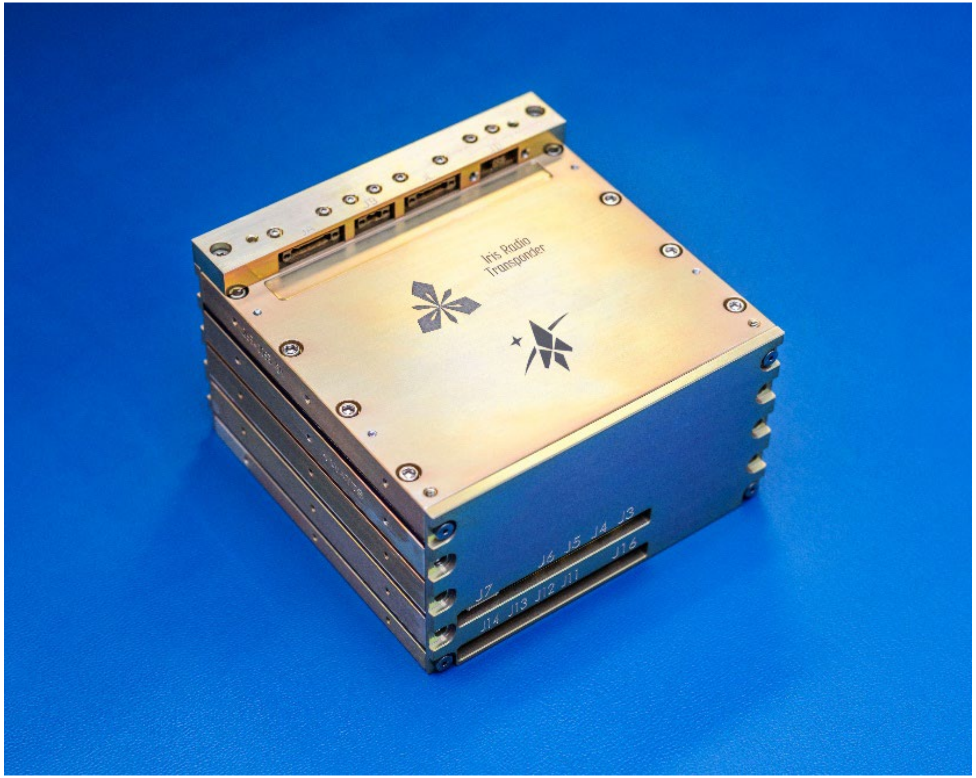
Traditional Comms Requirement for Deep Space SmallSat Missions

- Primarily communicate with the DSN
  - S-Band, X-Band and Ka Band
  - Full duplex coherent operation
  - Moderate bit rates 10 bps – 10 Mbps
  - Radiometric ranging
- Small hardware package
  - Typically 1U or less
  - Weight ~500-1,000 grams
- Radiation Tolerance
  - Class C or D requirements
  - > 25 krad minimum with > 100 krad desired
- Low cost without losing too many features

Iris Radio Meets Traditional Requirements

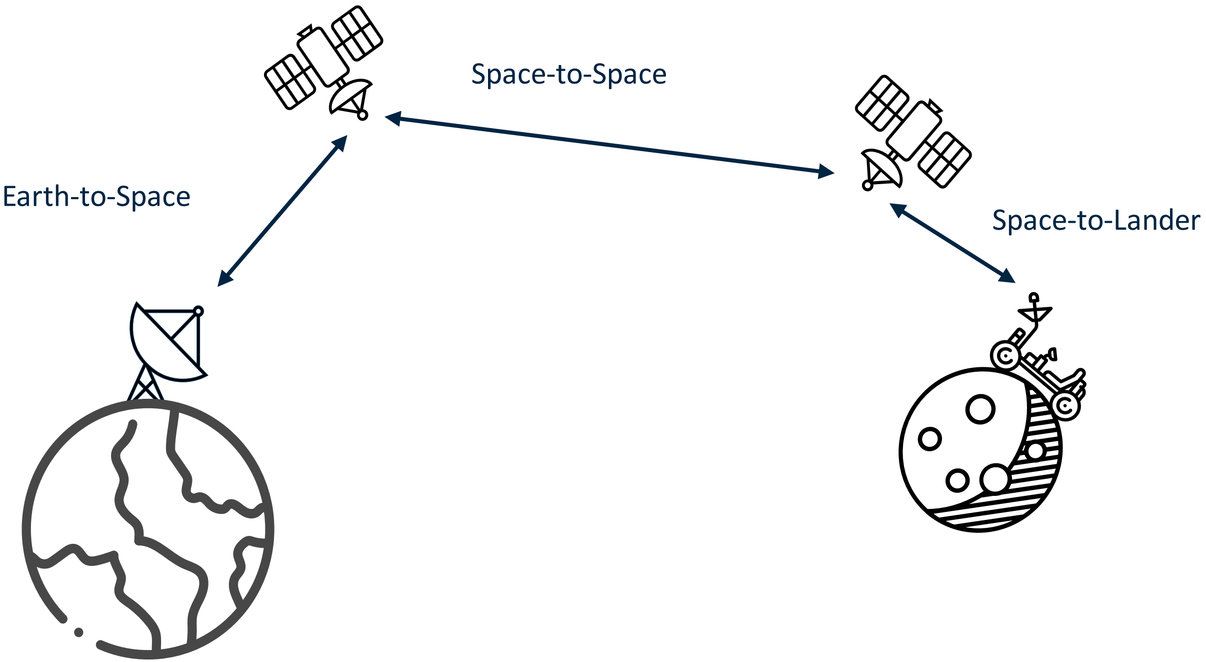
- Communication with the Deep Space Network
  - All modes and features are tested for compliance at DTF-21
- Size 1U x 1U x 56mm, ~1 kg
- Radiation tolerant to ~37 krad
- Full-duplex X-band direct-to-earth only
- Value
  - Reliable
    - No mission using Iris radio has failed due to comms failure
  - Quality maintained by 99+% inhouse design and build
  - Cost is competitive within DSN communication market



More Demanding Comms Requirements Expected

- Previously only concerned about direct-to-earth requirements
- Now we need to consider:
  - Satellite to Satellite
  - Satellite to Lunar or Planetary Surface
  - Constellation Flying
  - Higher Data Rates
  - More Accurate Ranging
  - Precision Timing
  - Deeper Space Missions
  - Longer Missions
  - More Severe Environments
  - Store and Forward
  - Delay-Tolerant Networking
  - Shorter Program Timelines
  - Smaller Budgets

- Did we miss any?

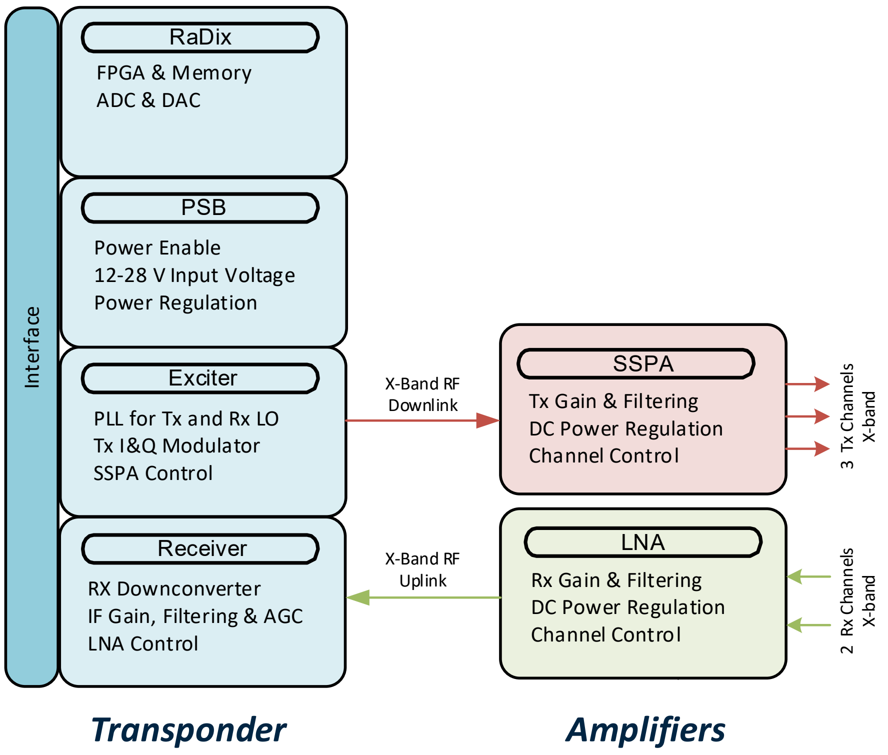


Tailoring Iris to Meet New Mission Requirements

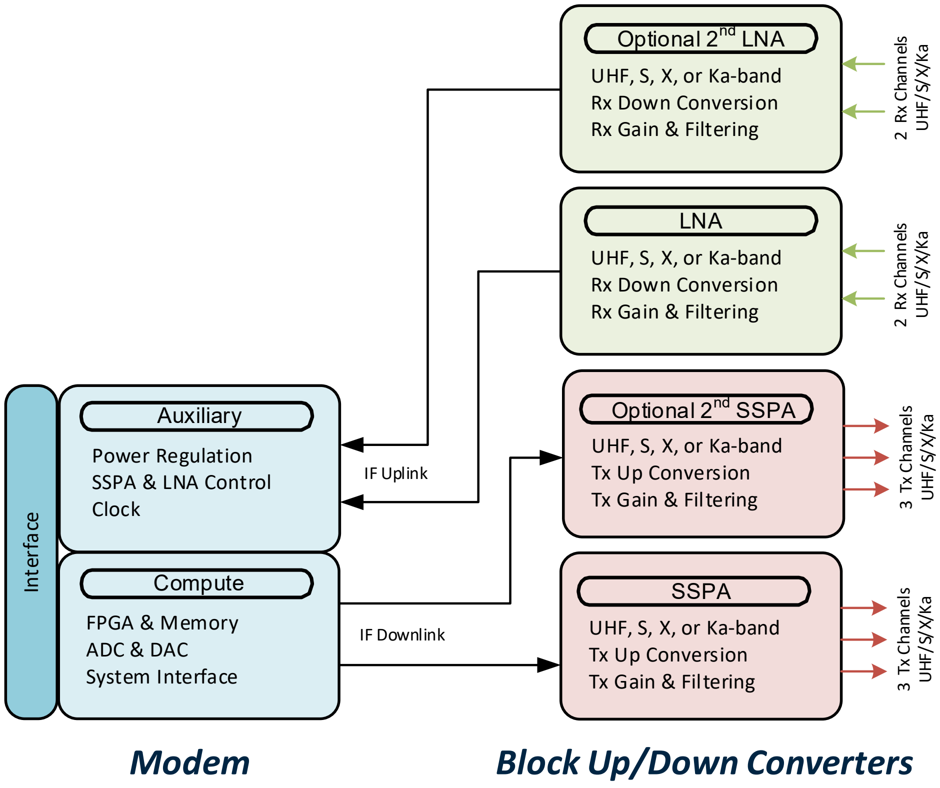
- Custom configurations and features to meet mission needs
  - Features added by one mission are available for other missions
- Past examples of mission-driven customizations:
  - CSAC one-way ranging
  - Regenerative two-way ranging
  - Time transfer
  - Specialized waveforms
  - Encryption (NASA-STD-1006)
  - Reversed-band operation
  - Amplifier power adjustments
  - Many others
- However, future improvements are limited by present hardware capabilities
  - FPGA, memory, and other hardware limitations
  - Adding frequency bands requires significant transponder redesign

Revised Iris Radio Hardware

Present Architecture

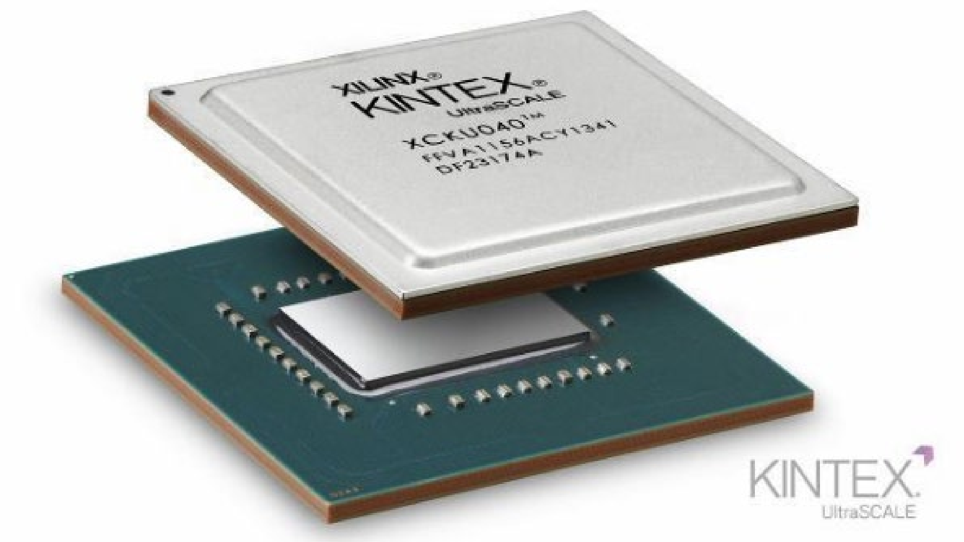


Revised Architecture



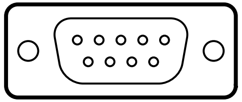
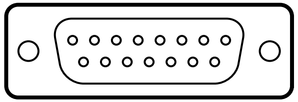
Updated Modem Details

- Reduced from four to two layers (~40% size reduction)
- New FPGA
  - Reduced power consumption
  - Approximately 4x fabric
    - Supports multi-channel modem
- New Memory
  - Increased from 32 Mb to up to 8 Gb
    - MRAM-based, non-volatile
    - Inherently immune to radiation
- New Transmit Architecture
  - Use one DAC per Tx channel instead of three DACs
  - Reduced power consumption, cost
  - Higher bandwidth
- New Clock
  - Higher stability
  - Tunable



Spacecraft Hardware Interface Improvements

- Current Iris only supports SpaceWire or SPI
- New interface has dedicated LVDS (SpaceWire) port and optional flexible second port
- Flexible command/data interfacing, for example:
  - Separate configuration and data interfaces
  - Two independent data interfaces (useful with dual-channel operation)
- Increased bus voltage range: 12 – 38 V
- Better connectors
  - SMPM-T
  - Nano-D

Port 1  Nano-D	LVDS (SpaceWire)
Port 2 (optional)  Nano-D	Configurable • LVDS • RS-422 • Ethernet • SpaceWire • SPI • Ad-hoc protocols, e.g. for bulk encryptors

SSPA Standardization: Two Board Assembly

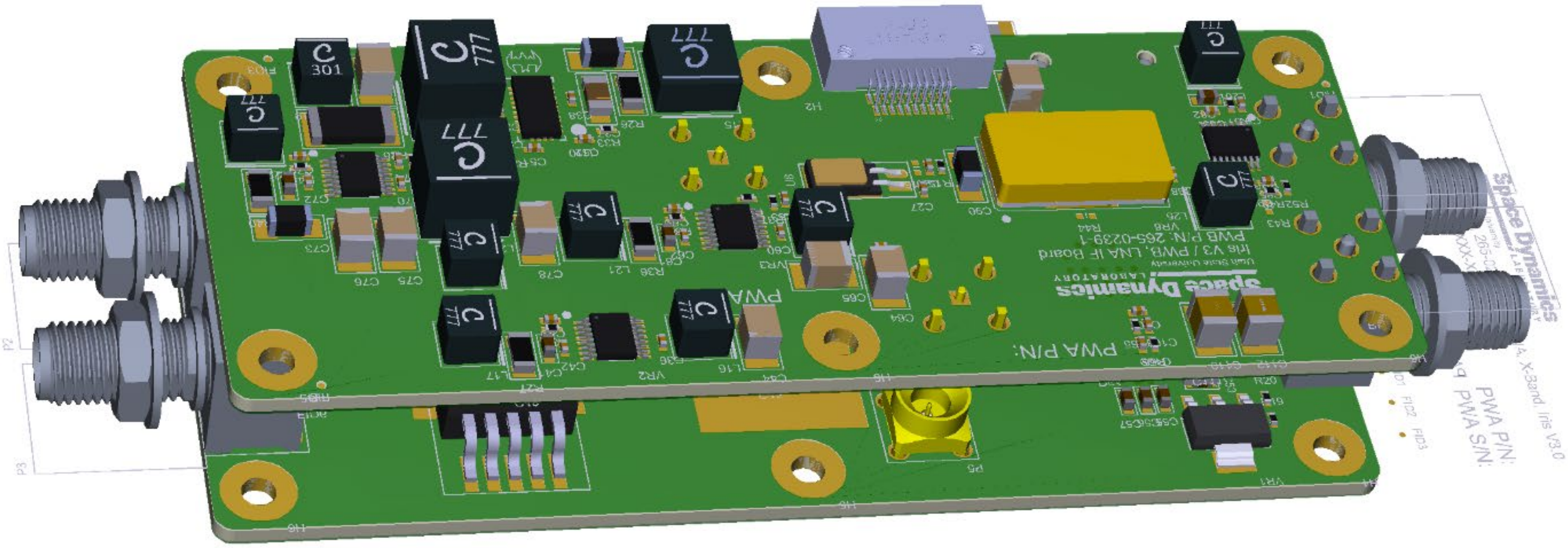
- Auxiliary Board—Common Functions
  - Modem Interface
  - Power Supplies
  - IF Conditioning
- RF Board—Frequency Specific Functions
  - Upconversion to desired band
  - RF Amplification
  - Spectral Filters
  - Isolators

Updated SSPA Details

- DC power supplied directly from the spacecraft bus supply
  - Higher efficiency—less converter loss
  - Use of GaN possible—higher output power available
  - Less heat in the transponder
  - Greater flexibility in the design process
- Two or three output channels—only one active
- SSPA power out as required for the mission
  - Standard power levels being considered:
    - UHF +40 dBm | S-Band +37 dBm | X-Band +36 dBm | Ka-Band +33 dBm
  - Other bands and power levels possible including non DSN Channels
- Isolator/Circulator prevents most integration mishaps
- Common IF & LO configurations
- Adjustable output power
- Operation from -25 C to +60 C

LNA Standardization: Two Board Assembly

- Auxiliary Board—Common Functions
  - Modem Interface
  - Power Supplies
  - IF Conditioning
- RF Board—Frequency Specific Functions
  - Noise Match
  - RF Gain
  - RF Filtering
  - Downconversion to IF



Updated LNA Details

- DC power supplied directly from the spacecraft bus supply
  – Greater flexibility in the design process
- Two Channels—Only one active
- Other bands and power levels possible including non DSN channels
- Common IF & LO configurations
- Noise Figure 2 dB Maximum / <1 dB typical
- SAW Filtering 14 MHz receive bandwidth
- Input Tolerance
  – 0d Bm without damage
  – -60 dBm operational
- Operational Temperature -30 C to +60 C

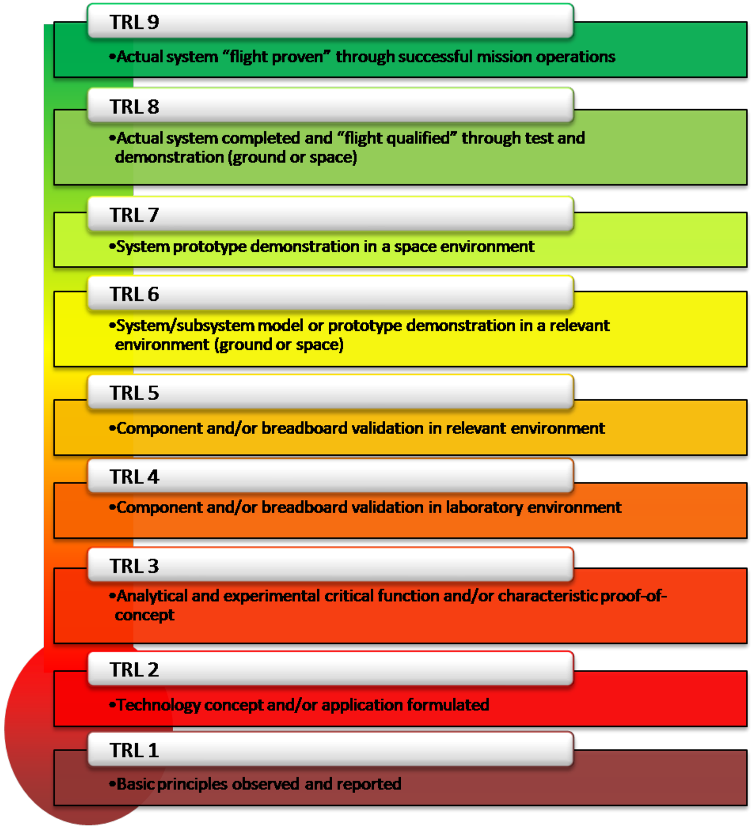
Spacecraft Software Interface Improvements

- Uses standard CCSDS Space Packets
- Loosely based on SCPI protocol
  - "RX:CMD:SYM_RATE 2e3"
- All parameters/telemetry use engineering units
  - dB, °C, Hz, degrees, etc.
- Clear interactions between parameters
- Extensive verification of each parameter and mode
  - Human-readable error messages
- Easy to add new configuration modes/parameters/commands/telemetry
- Easy to test!

Header	Data
RX:CMD	1
RX:CMD:PCM/PSK/PM	1
RX:CMD:PCM/PM	0
RX:CMD:BPSK	0
RX:CMD:SYM_RATE	1999.997
RX:CMD:CODING	BCH-SEC
RX:CMD:FRAME_TYPE	TC
RX:CMD:LOOP_BW	16.5
RX:CMD:LOCKED	1
RX:CMD:LOCK_THRESH	0.08
RX:CMD:LOCK_VALUE	0.49
RX:CMD:EBN0	8.72
RX:CMD:BUF_SIZE	253
RX:CMD:BUF_COUNT	4
RX:CMD:DROP_COUNT	0
RX:CMD:OVERFLOW_COUNT	0
RX:CMD:CODEBLOCK_COUNT	987

Tech Readiness Level

- Updates currently internally funded
- Expect TRL 4 by Summer 2024
- Expect TRL 6 by Summer 2025
- Schedule dependent on mission needs



New Mission Opportunities

- Updates enable new mission architectures
  - Ranging in S band with simultaneous comms in X/Ka band
  - Spacecraft-to-spacecraft ranging
  - Enhanced one-way ranging
  - Reversed frequency channel for satellite crosslinks, with regular channel for DTE
  - Relay orbiter with UHF (Prox-1) to lander and X/Ka DTE
  - Bent pipe relay operation
  - Delay-tolerant relay network
  - Architectures requiring precision timing and time transfer

- Did we miss any?