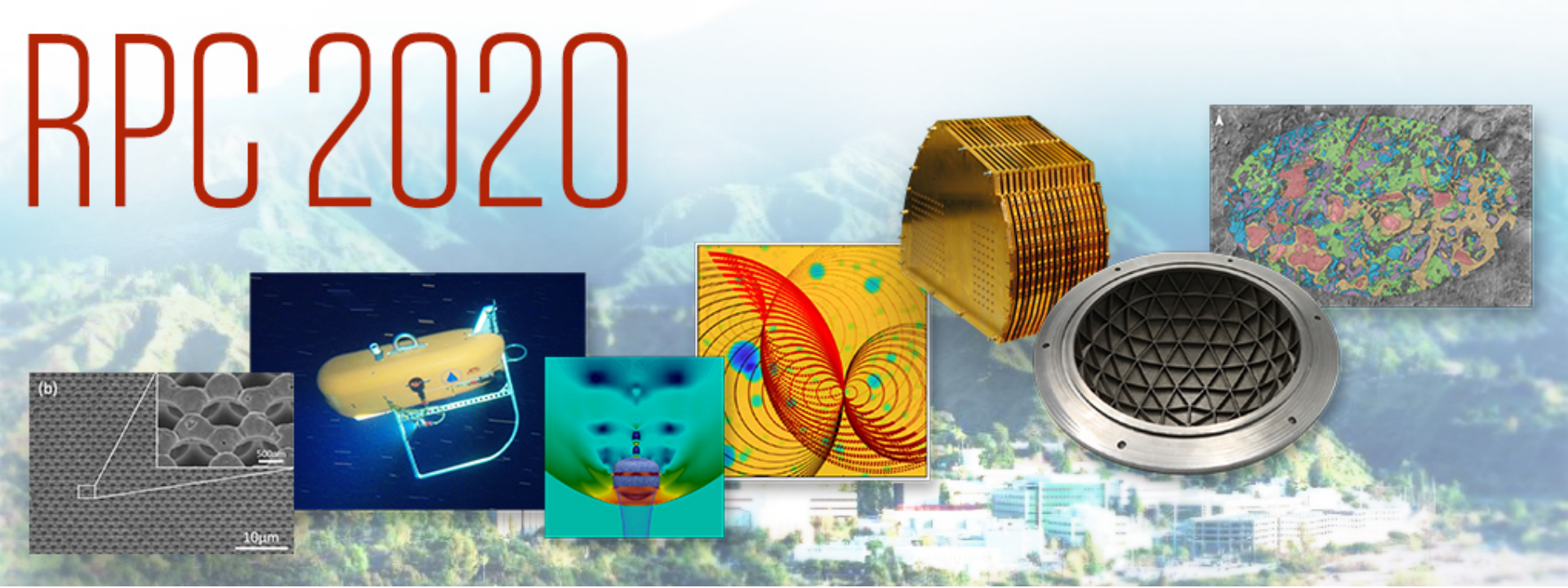
RPC 2020



Virtual Research Presentation Conference

Iris Transponder for Radio Science

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Program: Strategic Initiative

Assigned Presentation # RPC-285

Jet Propulsion Laboratory
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Introduction

Abstract

For over five decades, radio science techniques linking spacecraft and Deep Space Network antennas have provided unique information about solar system bodies, the solar wind, and fundamental physics. With continued development of smallsat radio technologies, small spacecraft for which radio science is the only instrument are now feasible, allowing investigations with significantly increased spatial and temporal coverage of atmospheres, gravity fields, surfaces, interiors, and other phenomena.

The goal of the Iris Transponder for Radio Science R&TD Task is to develop a smallsat radio with cutting-edge radiometric capabilities including dual band (UHF, S-, X-, and/or K-bands) and dual one-way single-band within smallsat size, weight, and power (SWaP) constraints.

The Iris Transponder for Radio Science R&TD advances JPL smallsat radio science and telecommunication technologies, providing enhanced radio science capabilities for future deep space smallsat missions and solidifying JPL's leadership position in this field.

Problem Description - Context

The high interest in and subsequent current move towards more frequent missions to Venus, Mars, and the outer planets motivates the development of advanced small spacecraft radio science capabilities.

The smallsat transponder developed under this task enables small spacecraft missions with spatial and temporal radio science coverage not possible with current flight mission technologies, resulting in break-through solar system science.

Problem Description - Current state-of-the-art

The JPL Iris Software Defined Radio (TRL-9) is designed to enable both direct-to-earth and relay telecomm and represents the current SOA for cubesat form factor spacecraft.

Although the Universal Space Transponder (TRL-6) supports dual-band operation, but is not suitable for most smallsat missions due to SWaP constraints.

Other spacegrade transponders likewise do not satisfy SWaP constraints imposed by smallsat requirements, and are also limited in radio science capability.

Radio	Mass	Power	Capabilities
UST-Lite	~1 kg	~15 W	Dual-band Transponding Cross-link phase/amplitude capture Open-loop sampling capture
Universal Space Transponder / UST (JPL)	7 kg	60 W	Dual-band Transponding Cross-link phase/amplitude capture Open-loop sampling capture
Small Deep Space Transponder / SDST (General Dynamics)	3.2 kg	20 W	Single-band Uplink, dual downlink No cross-link support No open-loop sampling
Frontier Radio (APL)	2.3 kg	14 W	Single-band Uplink, dual downlink No cross-link support Limited open-loop sampling
Integrated Deep Space Transponder / IDST Prototype Only (Italian Space Agency)	4 kg	22 W	Dual-band Transponding No cross-link support No open-loop sampling

Comparison of UST-Lite with space-grade transponder competitors. Key specs/capabilties are compared against SmallSat radio science needs (green = sufficient, yellow = borderline, red = insufficient).

Problem Description – Relevance to NASA and JPL

Radio science-enabled smallsats create opportunities for future small spacecraft missions capable of high spatial and temporal resolution measurements not currently feasible:

- Smallsat constellations for global radio occultation measurements,
- Venus, Mars, and Titan in situ measurements of atmospheric dynamics and atmospheric properties using balloons, small probes and dropsondes, and other aerobots,
- Multiple smallsat in situ missions for improved spatial coverage at Venus and giant planets,
- Small spacecraft for global time-variable gravity science.

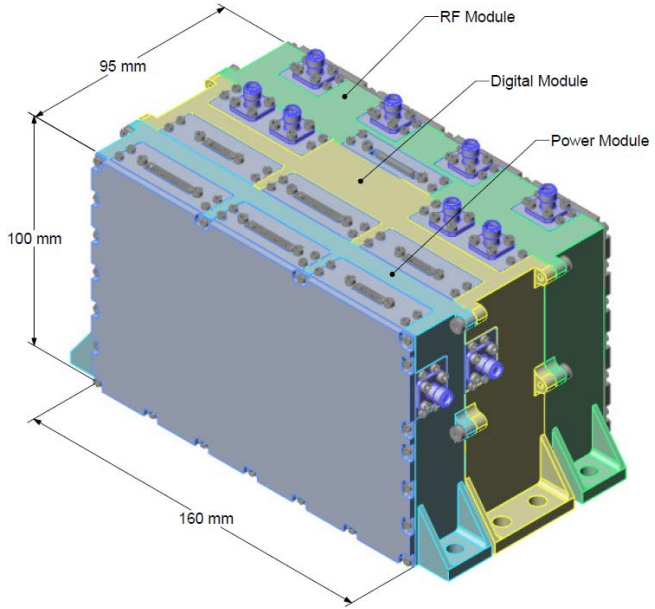
Future flight opportunities with potential for major radio science contributions from spacecraft include

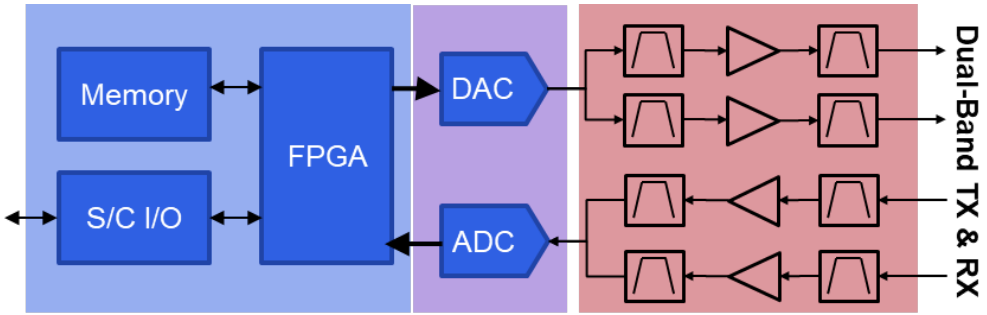
- NASA Discovery 2020, NF-5, and possible future flagship missions to Venus and ice giants,
- Current and future ESA L-, M-, and possibly F-class opportunities,
- Missions from other national space agencies.

In particular, Venus, Saturn, and the ice giants are current targets of extremely high interest.

Methodology

- The UST-Lite transponder is designed for the combination of low SWaP and advance radio-science capabilities to enable flag-ship quality radio science in a SmallSat
- Incorporates miniaturization techniques from the Iris CubeSat radio but with the space-grade parts and packaging needed to support higher class missions (Iris is limited to Class-D)
- Leverages the latest space-grade digital components with direct conversion between digital and multiple RF bands to miniaturize the software defined radio

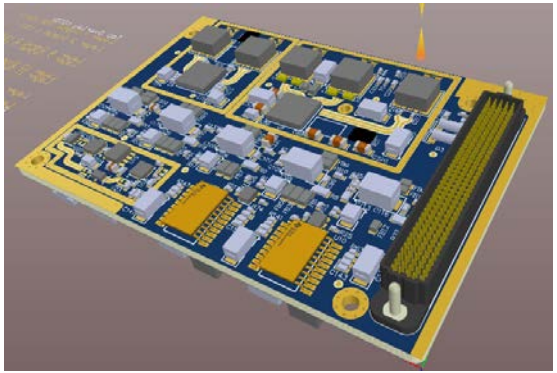




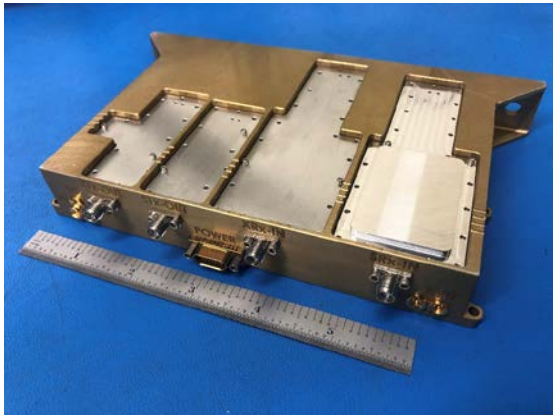
- Supports JPL SDR SW/FW library with wide-range of telecom and radiometric functions, ensuring that a single UST-Lite can cover all the radio needs for any spacecraft

Results

- UST-Lite design makes use of the 3x developed Common Instrument Electronics (CIE), which provides a digital board with standardized digital interfaces and powerful processing capabilities.
- To integrate with the CIE, the team developed a radio application mezzanine card capable of direct sampling receive signal as high as X-band (8 GHz) and generating transmit signals as high as S-band (2 GHz).
- An RF module was designed to support both S- and X-band transmit and receive filtering and amplification, with only X-band transmit requiring upconversion.
- Firmware was developed for the Kintex FPGA on the CIE board to support the radio science SDR applications, as many radio functions, including data rates from 10 bps to >100 Mbps.
- With the design complete and prototype mostly assembled, the UST-Lite is ready for ambient and environmental testing to bring it to TRL-5.



Radio Application Card



X- and S-band RF Module

Publications and References

Asmar, S.W., et al. “Solar System Interiors, Atmospheres, and Surfaces Investigations via Radio Links: goals for the Next Decade,” *Planetary Science and Astrobiology Decadal Survey 2023-2032*.

Asmar, S.W., et al., “Planetary atmospheres, Interiors, and Surfaces Investigations Via Communication Links – Goals for the Next Decade,” *43rd COSPAR Scientific Assembly 2020 Space Studies of the Earth-Moon System, Planets, and Small Bodies of the Solar System (B), Planetary Instruments (B0.6).* (Meeting postponed to 28 January - 4 February, 2021)

Asmar, S.W., et al. “Venus Atmospheric Dynamics Investigated via Ballutes Radio Links,” *17th International Planetary Probe Workshop* (Meeting cancelled due to Coronavirus)

Asmar, S.W., et al., “Enhanced Planetary Science with the Iris Radio for Smallsat Radio Science,” *American Geophysical Union Annual Conference*, San Francisco, 9-13 Dec. 2019

Atkinson, D.H. and S.W. Asmar “Ice Giant Atmospheric Dynamics and Composition from Radiometric Tracking of an Ice Giant Entry Probe,” *URSI GASS 2020, Rome, Italy, 29 August - 5 September 2020 (Conference Postponed).*

Atkinson, D.H., et al., “A Radio Science Instrument Enabling Multiple Small Spacecraft Missions,” *43rd COSPAR Scientific Assembly 2020 Space Studies of the Earth-Moon System, Planets, and Small Bodies of the Solar System (B), Planetary Instruments (B0.6).* (Meeting postponed to 28 January - 4 February, 2021)

Vergados et al. “Investigating the Venusian surface-atmosphere dynamic coupling,” *American Geophysical Union Annual Conference*, San Francisco, 9-13 Dec. 2019.

Vergados, P., “Request for Community Comments on VEXAG’s Venus Exploration Documents: Part II,” *VEXAG GOI 2019*.

Thank you!

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