

1994 – 2024: Celebrating 30 Years of GNSS Radio Occultation Innovation at JPL

Garth Franklin, Chi Ao, Yoaz Bar-Sever, Angie Dorsey, Chad Galley, George Hajj, Byron Iijima, Kameron Larsen, Anthony Mannucci, Thomas Meehan, Surya Ravikumar, Jeffrey Tien, Panagiotis Vergados, Olga Verkhoglyadova, Kuo-Nung Wang



IROWG-10 2024 Boulder, CO
September 12-18, 2024
URS27187_CLA24-4089

Jet Propulsion Laboratory (JPL), California Institute of Technology, Pasadena CA

Poster No. 11

Summary and Innovations

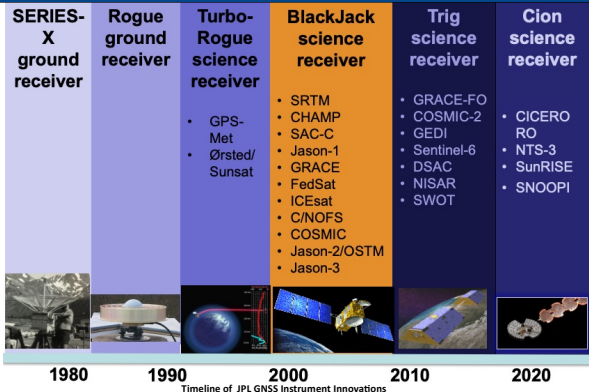
Over the past 30 years, NASA's Jet Propulsion Laboratory (JPL) has been at the forefront of developing and advancing Radio Occultation (RO) technology for space-based atmospheric and ionospheric measurements.

Since the first JPL-developed radio occultation receiver flew on the GPS/MET mission, JPL has continually improved its instrumentation and processing techniques with the goal of returning the highest-quality atmospheric observations. JPL is ready to support and innovate with the next generation of GNSS RO Instruments for the next 30 years!

KEY JPL GNSS INNOVATIONS:

- Wrote the book on GPS Earth Radio Occultations: Melbourne et al.,
- Autonomous scheduling and tracking of dual frequency GPS occultations
- First GPS dual frequency phase-based radio occultation from space
- Reprogrammable Digital Processing – Providing SW and FW on orbit updates
- Multi-antenna dual frequency processing, 16 sats, ~10 Watts
- Integrated microwave crosslinks with GPS POD timing and position for gravity
- Open-loop model for lower altitudes. Demonstration of first rising RO obs
- Digital beamforming for highest RO SNR with operational NWP processing
- PAZ mission launched with Polarimetric RO (PRO) on a TrIG receiver and validated with help from JPL
- Licensed TrIG technology to GeoOptics and co developed a low SWaP Cion for RO on CICERO
- First known GLONASS RO observations from space
- Top to bottom open-loop processing of radio occultations

Instrument Generations and Missions

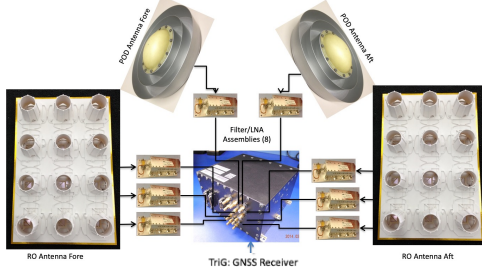


TrIG SCIENCE RECEIVER CAPABILITIES

The JPL TrIG GNSS Science Receiver was developed in collaboration with Moog BroadReach in 2005. It was designed with a flexible architecture with the POD processor card (Nav CPU) based on the legacy BlackJack design and a new Linux based Science processor (RO DSP) for Radio Occultations and Surface Reflections. Each RF card has 4 RF inputs with four downconverters each providing the ability to track GPS, GLONASS and Galileo. Up to four cards could be used in this design for a total of 16 antenna inputs.

COSMIC-2 Implementation of the TrIG:

- JPL designed a highly efficient RO antenna with three arrays of four elements that are RF phased to focus on Earth's limb and digitally beam steered for azimuthal combining of arrays increasing the SNR's to over 3000 V/V.
- The canted choke-ring antennas are optimized for space weather ionospheric observations and combined for the POD (precise orbit determination) solution.
- Filters specifically designed to filter out in band transmitters.



One of six COSMIC-2 RO systems delivered to NSPO and funded by NOAA and USAF SMC

REFERENCES

- Radio Occultations Using Earth Satellites: A Wave Theory Treatment**
William G. Melbourne et al., ISBN: 978-0-471-71222-0, November 2004
- Wickert et al., (2006) GPS BASED ATMOSPHERIC SOUNDING WITH CHAMP: RESULTS ACHIEVED AFTER FOUR YRS**
J. Wickert (1), G. Beyerte (1), T. Schmidt (1), S. B. Healy (2), S. Heise (1), R. König(1), G. Michalak(1), M. Rothacher (1)
(1) Geo-ForschungsZentrum (GFZ) Potsdam, Germany
(2) European Centre for Medium-Range Weather Forecasts (ECMWF)

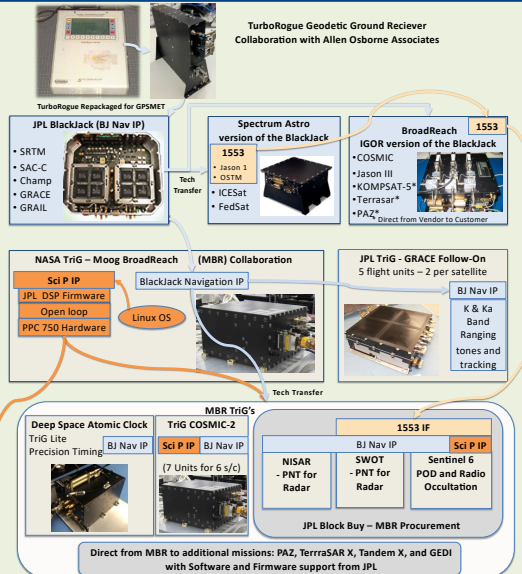
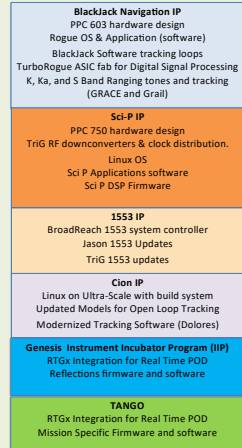
ACKNOWLEDGMENTS

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. Additional supporters include NOAA, USAF, UCAR, NSF and AFRL.

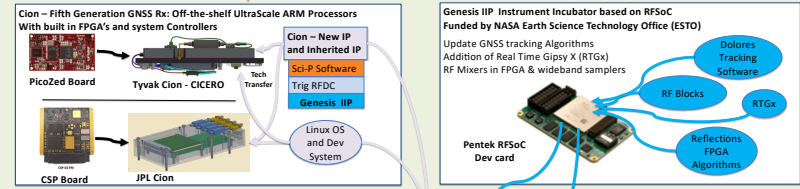
Copyright 2024. All rights reserved. Government sponsorship acknowledged.

BlackJack, TrIG, Cion and the Future – Intellectual Property (IP) and hardware flow over time

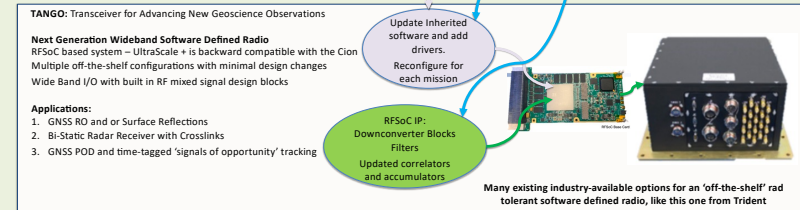
JPL IP Evolution Mapped to Hardware Platforms and missions



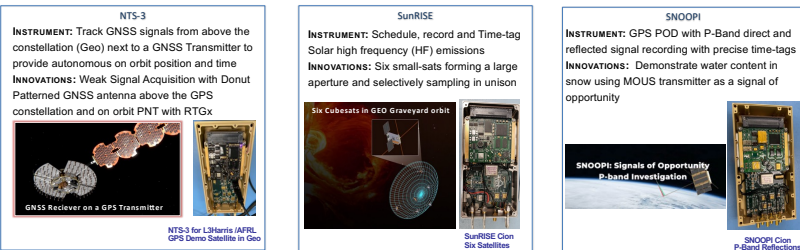
Current Instrument Developments



Planned Instrument Developments



CION – RECENT MISSIONS – BEYOND POD AND RO



CONCLUSIONS

JPL has been producing and delivering high quality GNSS flight receivers, often with an industrial partner, for over 30 years with continuous innovations in on orbit updatable software and firmware for RO instruments that demonstrate new and innovative observations with publicly available algorithms. The advent of software defined radios and System on a Chip technology, like the RFSoc, will enable a new class of GNSS receivers that can receive and transmit a variety of frequencies and modulation schemes with precision time tagging to enable a new class of mission enabling space flight instruments.

CONTACTS

Garth Franklin: garth.franklin@jpl.nasa.gov