National Aeronautics and Space Administration

Cubesat Bistatic Radar for Small Body Tomography

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Program: FY22 R&TD Strategic Initiative

Strategic Focus Area: Radar Advances to Accelerate Earth and Planetary Missions - Strategic Initiative Leader: Darmindra D Arumugam

Objectives:

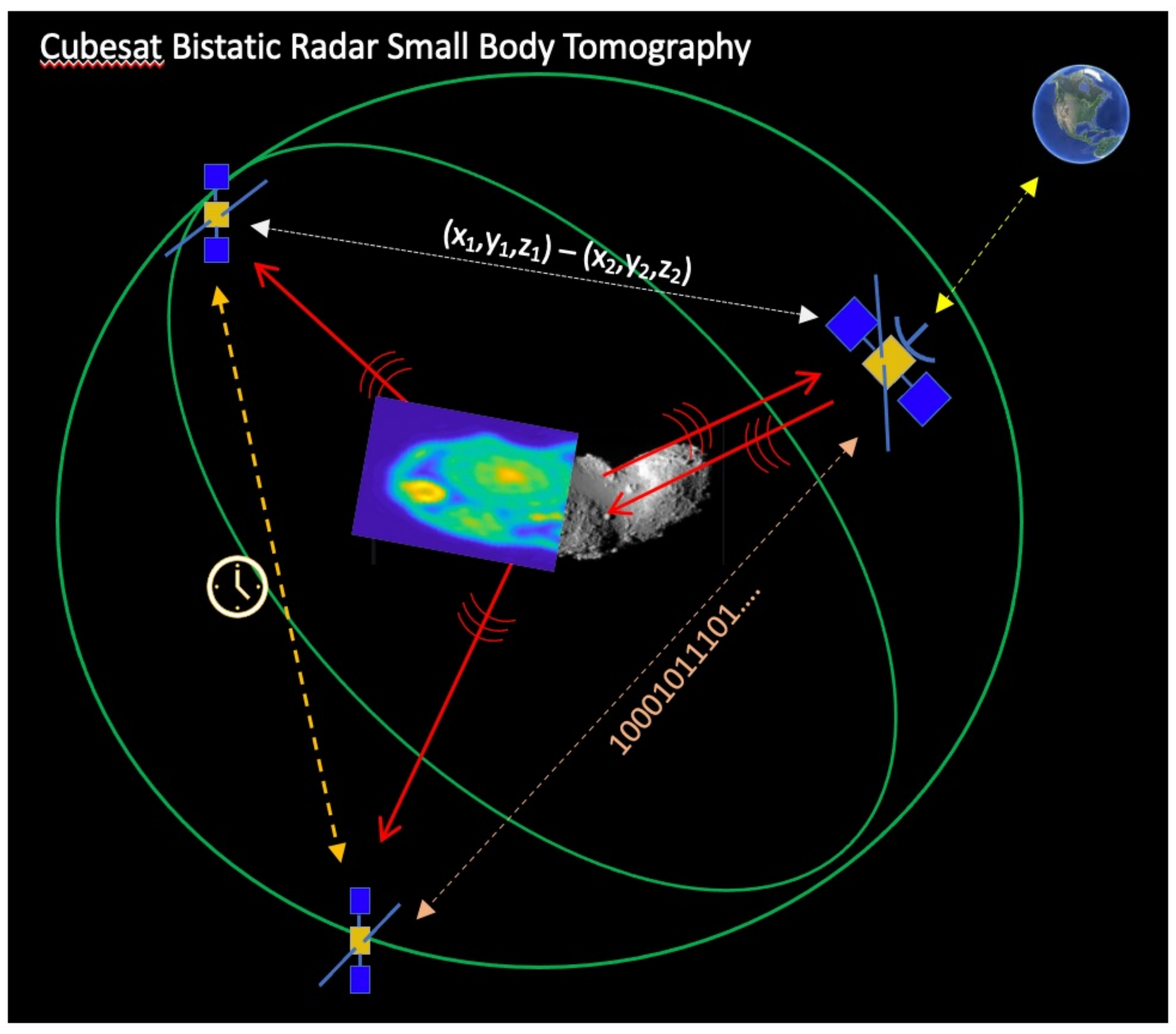
The objective of this 3-year effort is to advance to TRL 5 key subsystems of cubesat low-frequency (VHF) bistatic radar sounders built to map the dielectric interiors of solar system small bodies using advanced radar tomography.

Approach:

Hardware design and testing is driven by answering:

- What part of the distributed radar system requires knowledge vs control in real-time vs post?
- What part of the distributed radar system must be managed by the instrument vs the flight system?

To accelerate the path to flight, the Section 337 Universal Space Transponder-lite (UST-lite) will be used to implement the bistatic radar.



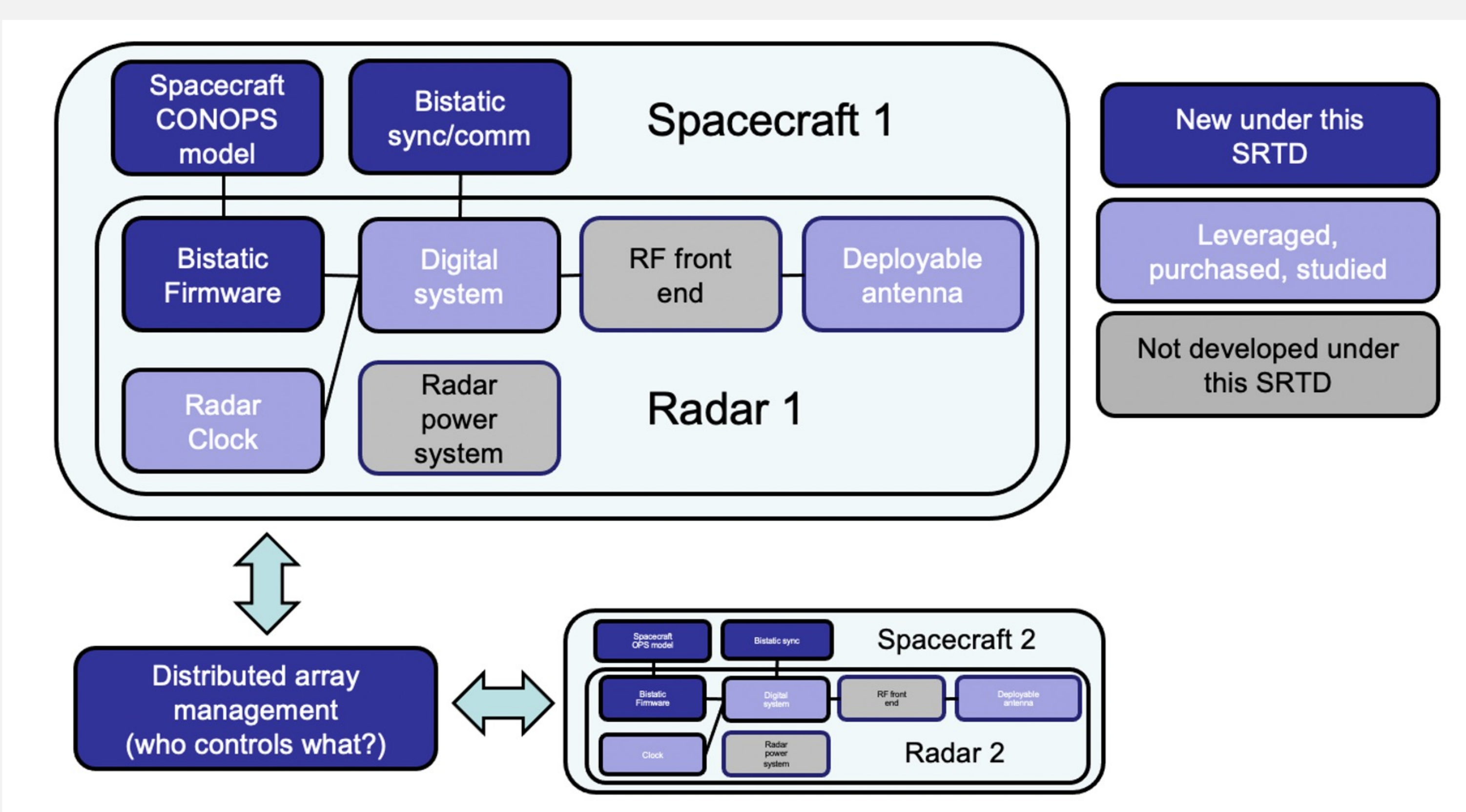
Background:

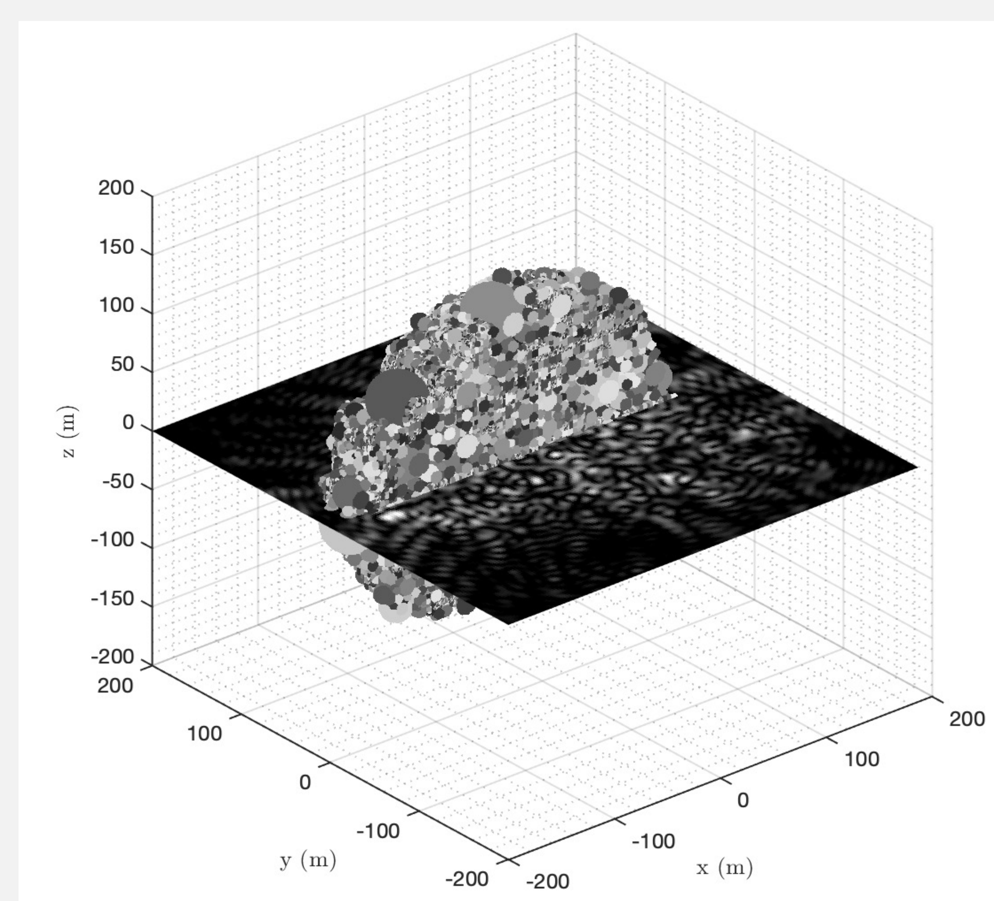
A low-frequency bistatic radar instrument will enable future planetary missions that are capable of multi-spacecraft proximity imaging of small body dielectric interiors using advanced tomography techniques. These techniques create images of volumetric backscatter and 3D dielectric via model-based inversion that reveal both structure and dielectric distribution of the interior. This information is required in order to resolve outstanding hypothesis about small body interior structure, which provides constraints on their formation and the origin of planets. Interior structure is also of vital importance for developing mitigation strategies for potentially-hazardous near-Earth asteroids (NEAs).

Technical challenges:

Three technical challenges specific to small body bistatic radar:

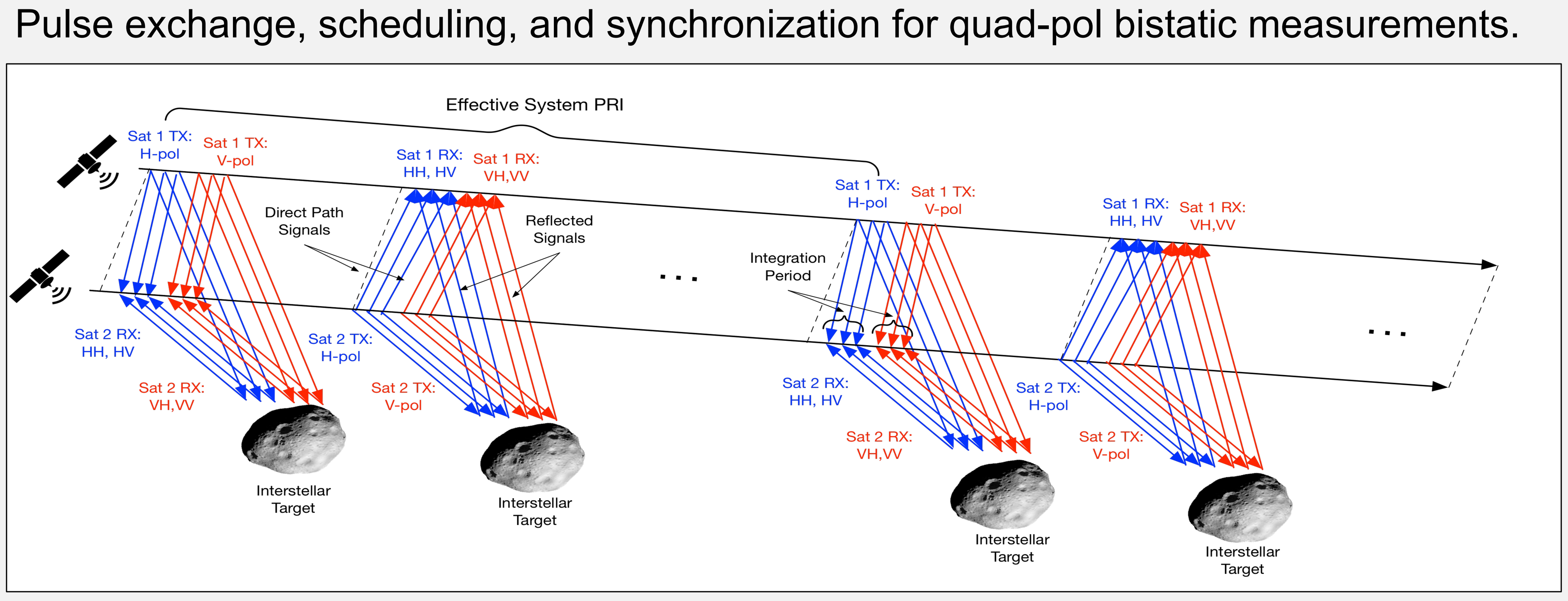
1) Bistatic scheduler to command and control two distributed radars
2) GPS-denied radar synchronization better than 1/20th wavelength (<25 cm at 60 MHz)
3) Dynamic range to capture line-of-sight signal and scattered signal from the object.



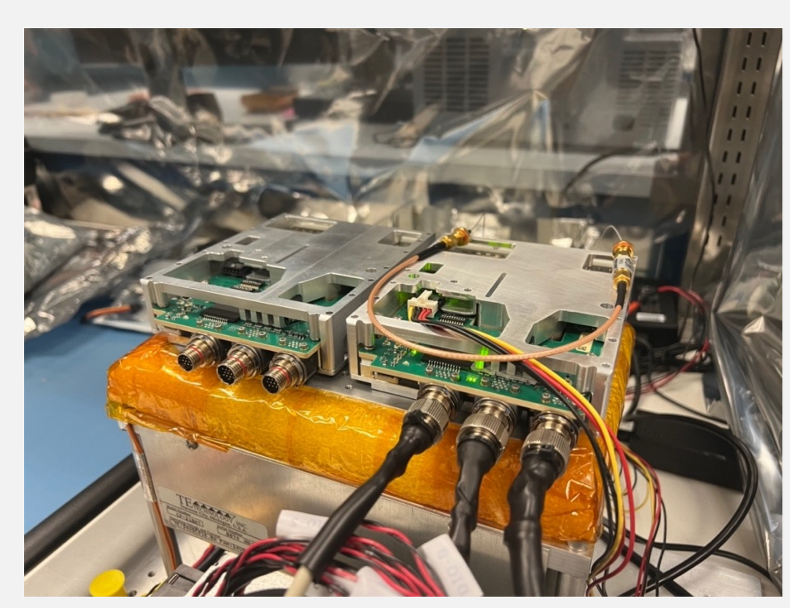


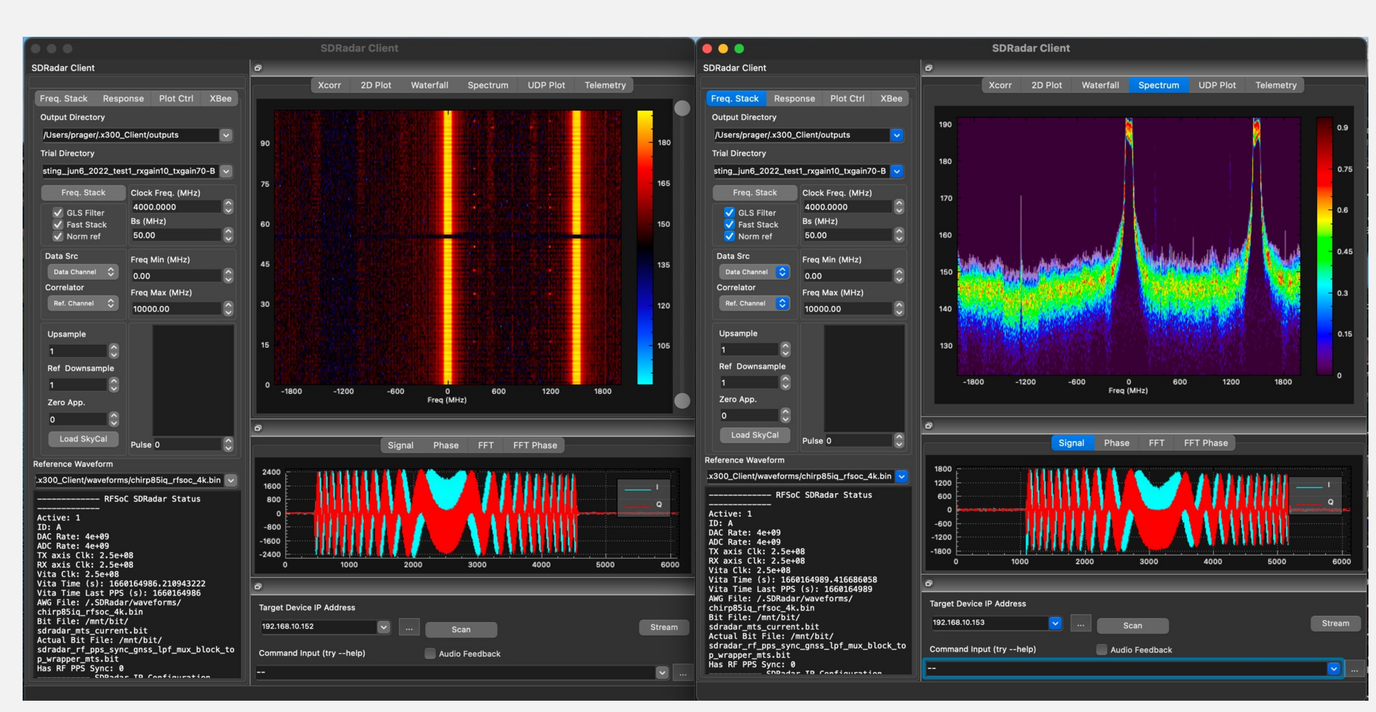
Simulated radar tomography of the interior of the 300-meter rubble-pile asteroid at 9.5 MHz. Forward model predictions generated from MoM-CBFM on JPL HPC.

Pulse exchange, scheduling, and synchronization for quad-pol bistatic measurements.



(Right) Digital test bed (COTS RF System on a Chip) for developing bistatic timing synchronization firmware. (Bottom) GUI control and display of real-time bistatic synchronization.





Significance/Benefits to JPL and NASA:

This effort is advancing critical subsystems of a bistatic tomography radar for a future SIMPLEx, Discovery, or rapid-response planetary defense mission. The instrument serves future distributed radar sounder systems, e.g., for Earth ice sheet sounding and any future low-frequency radar for the Moon, Mars and icy worlds.

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Publications:

M. S. Haynes, A. Herique, I. Fenni, B. Davidsson, C. Raymond, P. Michel, "Study of Bistatic Radar Transmission Geometries for Characterizing Asteroid Interiors," 53rd Lunar and Planetary Society Conference, 2022.

M. S. Haynes, I. Fenni, "T-matrix Backprojection Tomography for Scalar and Electromagnetic Waves," IEEE Transactions on Antennas and Propagation, *in review*.

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