National Aeronautics and Space Administration

FY23 Strategic Initiatives Research and Technology Development (SRTD)

STV Multi-frequency Implementation using Quantum Rydberg POLinSAR

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Strategic Focus Area: Next Earth Science Decadal Survey: Technology & Architecture for Planetary Boundary Layer (PBL)/ Surface Topography & Vegetation | **Strategic Initiative Leader:** Rashmi Shah

Study Motivation

Key technology gaps in state-of-art radar remote sensing for earth science applications include 1) optimal frequency or multi-frequency technologies for observing various earth science variables (vegetation, snow, terrain, etc.), 2) miniaturized radar antennas and electronics needed at various bands, and 3) development of low-cost systems for access to various bands for different applications. Addressing these through a disruptive quantum sensing technology is the focus of this study.

Objective

To study and advance our understanding of a disruptive quantum Rydberg architecture enabling high sensitivity, dynamic and rapidly tunable radar remote sensing throughout the entire radio window with no traditional RF front end electronics. In addition, to develop a concept for Surface, Topography, and Vegetation (STV) mission in the 2030's using the Rydberg architecture.

Findings

Using signals of opportunity between I-K bands (0.1-20 GHz) measurement of key Earth Science variables spanning numerous science applications can be enabled in a (1) post-launch dynamic/rapid on-the-fly tunable, (2) very low power, (3) small-sat instrument, (4) no science antennas required. The Rydberg radar concept can address most radar applications (e.g.: SAR, inSAR, POLinSAR, Vertical Profiling, Tomography).

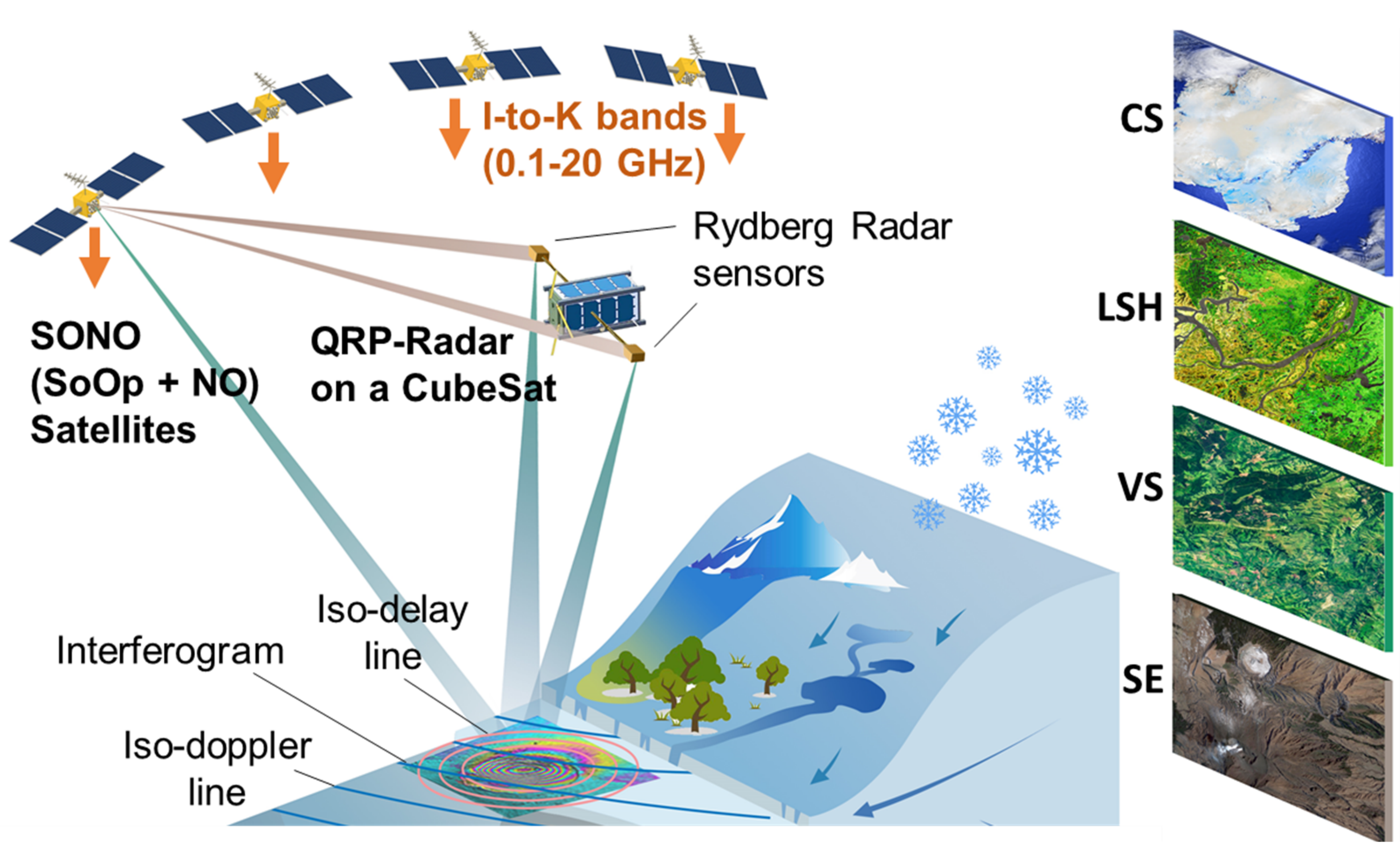

Figure 1. Mission concept for STV (Surface, Topography, and Vegetation) using Rydberg Radar sensors.

Study Recommendations

- Quantum Rydberg Radars (QRR) enables dynamic remote sensing capabilities covering multiple Earth Science applications. A key initial focus is application to the STV (Surface, Topography, and Vegetation) future mission. A key tech demo is ongoing to validate QRR sensitivity to remote sensing with SoOp signals for STV. QRR additionally requires a polarization sensitive architecture that requires validation via a technology demonstration. Tech demo support for this is critically needed to support an InVest proposal 2025/27.
- An airborne validation is critically needed to support a future InVest 2025/27 proposal. The validation itself can be supported by a future IIP, however study funds are needed to conduct trade-studies to select between ballooning and aircraft-based validation.
- Radar remote sensing (SAR, inSAR) performance modeling and algorithm efforts for STV is highly specific and focused, and require investments through an internal research funding. This is crucial for STV to select QRR, and needed within the next year (FY23).
- Overall, QRR needs a ISC and SRTD/AC support in FY23 and FY24

Study Follow-on

Several external proposals were successful to include:

- NASA IIP-ICD (Instrument Incubator Program)
- NASA NIAC Phase 1 (NASA Innovative Advanced Concepts)
- NASA NIAC Phase 2
- JPL Spontaneous Concept (ISC)
- JPL SRTD (8x Strategi)

2023 Updates and Implications. Vision for JPL

The technology is viewed as a highly promising area of R&D. Multiple active projects are advancing the TRL towards an airborne tech demo.

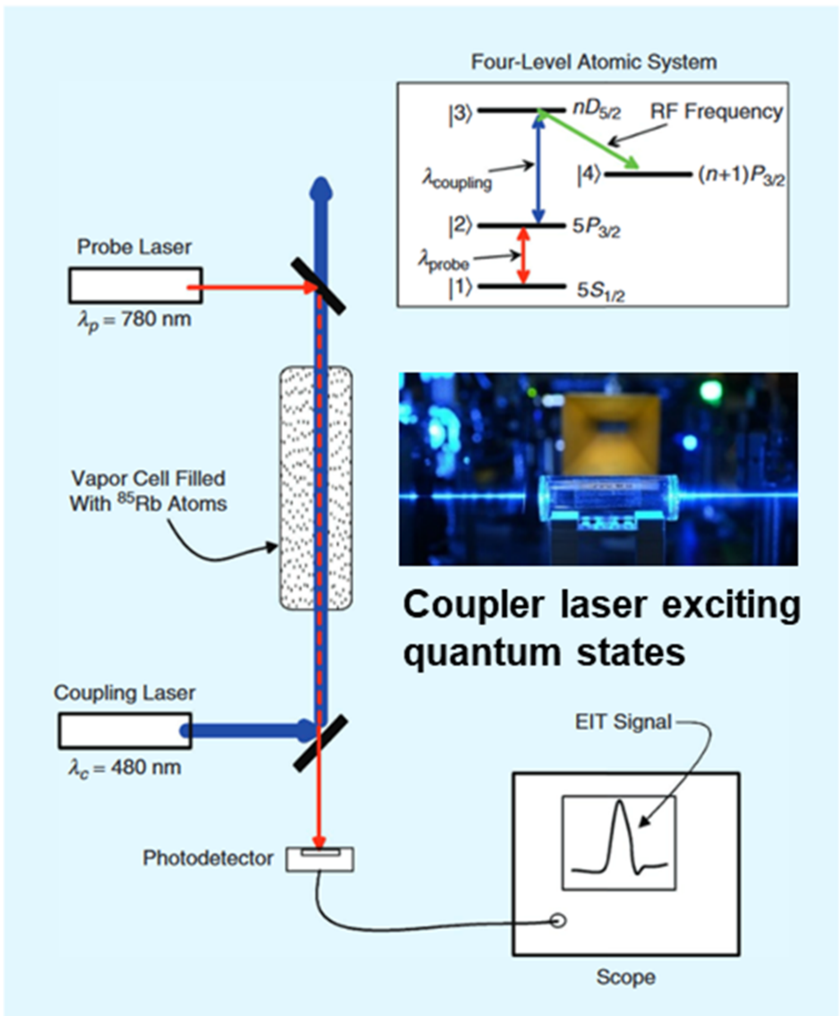

Figure 2. A four-level system and the vapor cell setup for measuring EIT, with a counterpropagating probe and coupling beams.

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