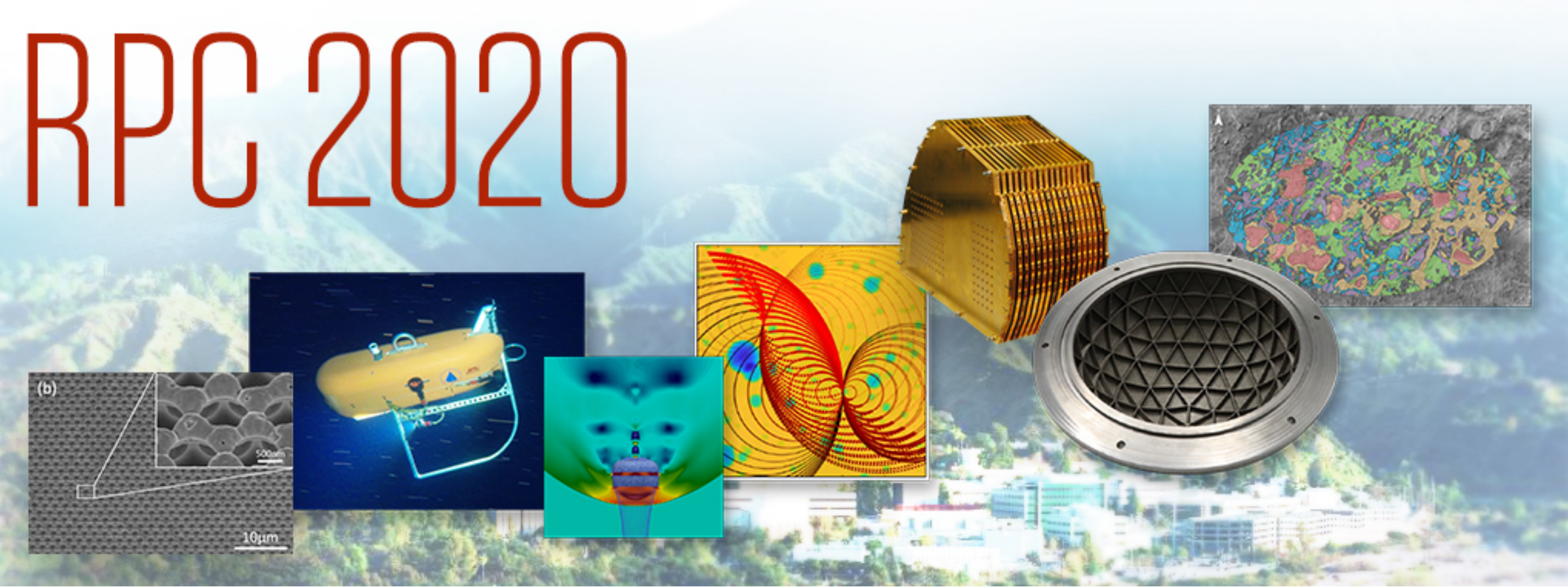

Virtual Research Presentation Conference

Distributed Aperture Radar Tomographic Sensors (DARTS): Trade Study and Technology Demonstration

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Program: Strategic Initiative

Assigned Presentation RPC-293

Jet Propulsion Laboratory
California Institute of Technology

Tutorial Introduction

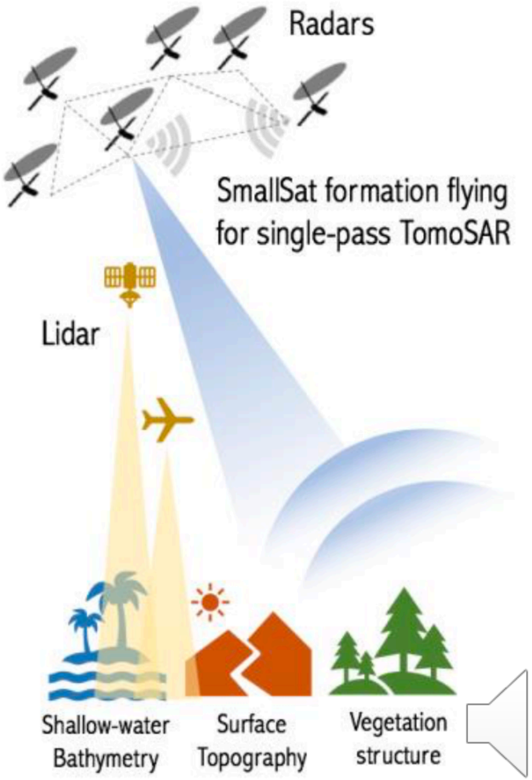
Abstract

DARTS (Distributed Aperture Radar Tomographic Sensor) is an observing technology leveraging SmallSat SAR formations to enable simultaneous SAR tomography from space.

In DARTS:

- One or more satellite(s) transmit a radar signal and multiple spacecrafts in close formation receive the scattered echoes
- Transmitted and received signals are locked to the same phase and timing reference
- Platforms position is known accurately either real-time or in post-processing
- Received signals are coherently processed to generate tomograms (conceptually similar to lidar waveforms)

DARTS enables mapping of vertical structure via tomograms from which a variety of products such as bare-Earth topography, biomass or tree height can be extracted.

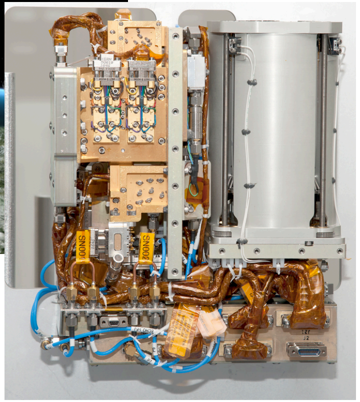


Problem Description

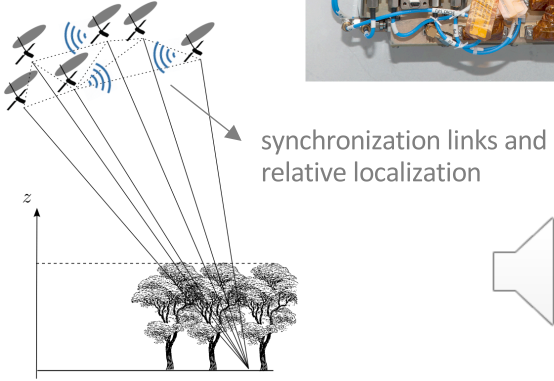
- Context
  1. Decadal Survey 2017 recommended 3D Vegetation Structure and Dynamics as an incubation observable (e.g., 3-5m vert., 50m horiz., global, 5+ years)
  2. Small-sats enable constellations, new measurements and advanced corrections for 3D Vegetation mapping
  3. Radar/antenna technology became compact and digital
- Challenges
  1. Mutual signal phase referencing (synchronization) is required between DARTS members (< 1-2deg)
  2. Accurate distributed localization (< 1cm orbit knowledge, ~1arcsec relative position determination)
  3. Integrated system performance with compact radar architectures (MIMOSAR never demonstrated so far)
  4. Level of system intelligence (N_{Tx} N_{Rx} phase centers)
  5. Scale demonstration from e.g. drones to space
- Problems being solved in this task
  1. Can we demonstrate compact and efficient radar signal synchronization and localization for TomoSAR using drones?
  2. What are the optimal orbital and hardware configurations that enables TomoSAR given Decadal Survey's goals?

JPL-led Decadal Survey RFI#2

RainCube compact radar

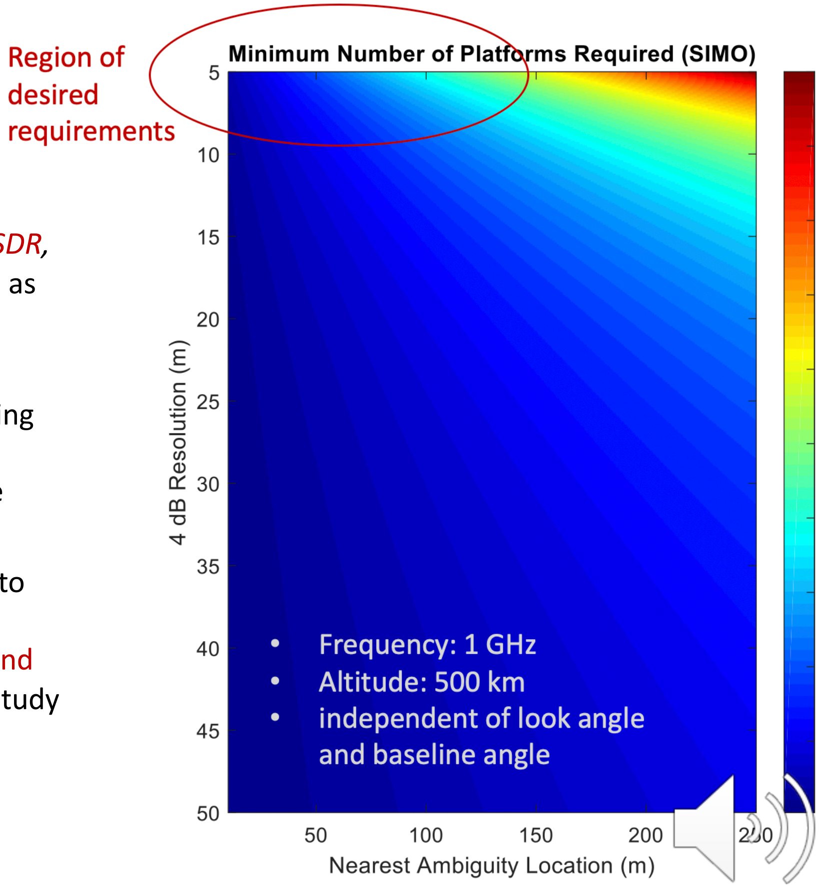


Distributed formation of small-sat SARs



Methodology

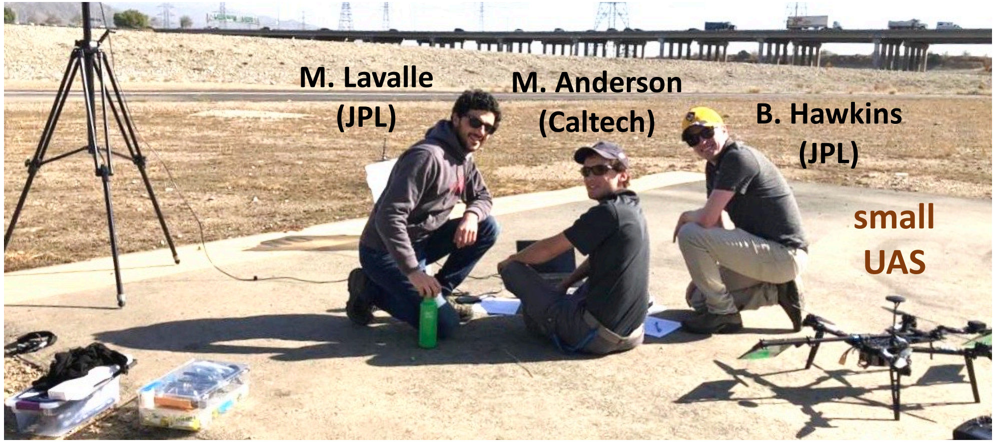
1. Build, test and deploy on Caltech *drones* state-of-the-art technologies (*SDR, atomic clocks, RFSoC*) that allow efficient radar signal processing as well as precise localization and synchronization of Tx/Rx radar signals between multiple radar platforms.
2. Conduct a rigorous mission trade study that accounts for platform viewing geometries, intersatellite communication, radar parameters, orbital trajectories, common error sources and signal sensitivity using available small-sat bus options and intersat communication technologies.
3. Characterize the multi-static SAR signal properties, including sensitivity to varying system parameters, measurement techniques and scene characteristics by examining the tomographic data acquired by tower- and drone-based synchronized radars to validate the outcome of the trade study and advance its modeling approach.

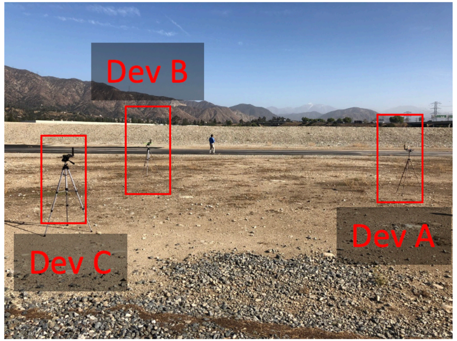


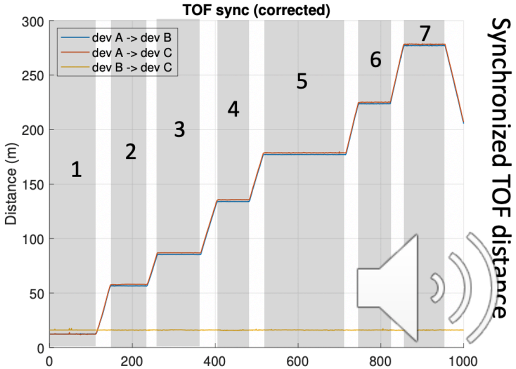
Results

- Conducted experiment with Ettus 321 SDR at 2.4 GHz near Santa Fe Dam RC Airfield. Device A moved away from fixed device B, C sensors in 7 50m steps to test the synchronization algorithm performance
- Time of flight (TOF) was recorded as expected, although high levels of 2.4 GHz interference due to multiple high power model RC airplane transmitters operating in close vicinity degraded results
- Implemented basic TomoSAR simulator and studied the number of platforms required to reach a given resolution and level of ambiguity (previous slide)

This S-RTD task ended 6 months after KO because the DARTS team won a NASA IIP







Publications and References

- One journal publication on signal synchronization from our team member S. Prager submitted and accepted in IEEE Transactions on Antennas and Propagation
- References:

1. Prager, S., T. Thrivikraman, M. Haynes, J. Stang, D. Hawkins and M. Moghaddam, "Ultra-wideband synthesis for high-range resolution software defined radar," 2018 IEEE Radar Conference (RadarConf18), Oklahoma City, OK, 2018, pp. 1089-1094
2. Lavalle, M., B. Hawkins, and S. Hensley, “Tomographic Imaging with UAVSAR: Current status and new results from the 2016 AfriSAR campaign,” in 2017 IEEE Intern. Geosc. and Rem. Sens. Sympos. (IGARSS), July 2017.

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Wireless Sub-Nanosecond RF Synchronization for Ultra-Wideband Coherent MIMO Software Defined Radar

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Key figure in the manuscript describing the signal synchronization algorithm: