

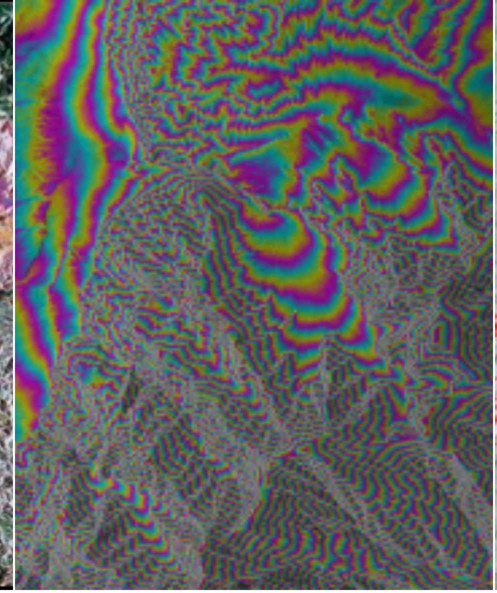


Future SAR Imaging System: Goals, Plans, Challenges, and Opportunities

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Background – 2018 SAR Workshop

Future SAR Imaging Systems Working Group Recommendation: A Goal of Coordination

- Agencies adopt an optimized systems approach to the overall constellation of planned and proposed missions.
  - Better filling of gaps and higher repeat coverage by slight adjustment of orbit, node crossings or local crossing time.
  - Quick response for time critical applications.
  - Better continuity of observations over a long period of time (multi decadal).
  - Enable new multiple system capabilities such as bistatic observations and multi-interferometric observations.
  - Left/right imaging coordination to overcome shadowing
- Examples:
  - NISAR Left-looking + Sentinel-1 Right-Looking
  - ROSE-L + Tandem-L + SDC

Plans
Civil Systems

- Upcoming SAR launches:
  - ALOS-4, NISAR, BIOMASS, Sentinel-1C/D, COSMO-Skymed NG.
  - Mostly planned without coordination
  - Even with these mature developments, there are opportunities to coordinate observation plans for these systems
    - Prioritizing quad-pol global measurements for ALOS-4, since NISAR is delivering comprehensive dual-pol global coverage also at L-band
    - Further coordination of vector measurements for Sentinel-1 and NISAR, by augmenting ascending+descending in dedicated campaigns outside of Europe
  - Science campaigns that use the fast-repeat and fine resolution capabilities of COSMO-Skymed for fast motion and disasters

Plans
Civil Systems

- Missions in Study or Formulation
  - ESA/EU ROSE-L operational extension of Copernicus
  - DLR Tandem-L mission for geo, cryo, hydro, ecospheres
  - DLR HRWS/MirrorSAR for next generation multi-static observations
  - NASA Surface Deformation and Change (SDC)
    - Provide continuity with NISAR, and in some cases with finer temporal sampling or finer resolution
    - NASA is presently engaged in a study to define its next-generation architecture to achieve these capabilities affordably, and is encouraging the exploration of commercial capabilities, innovative distributed architectures, as well as international partnerships or leveraging opportunities

Plans
Commercial Systems

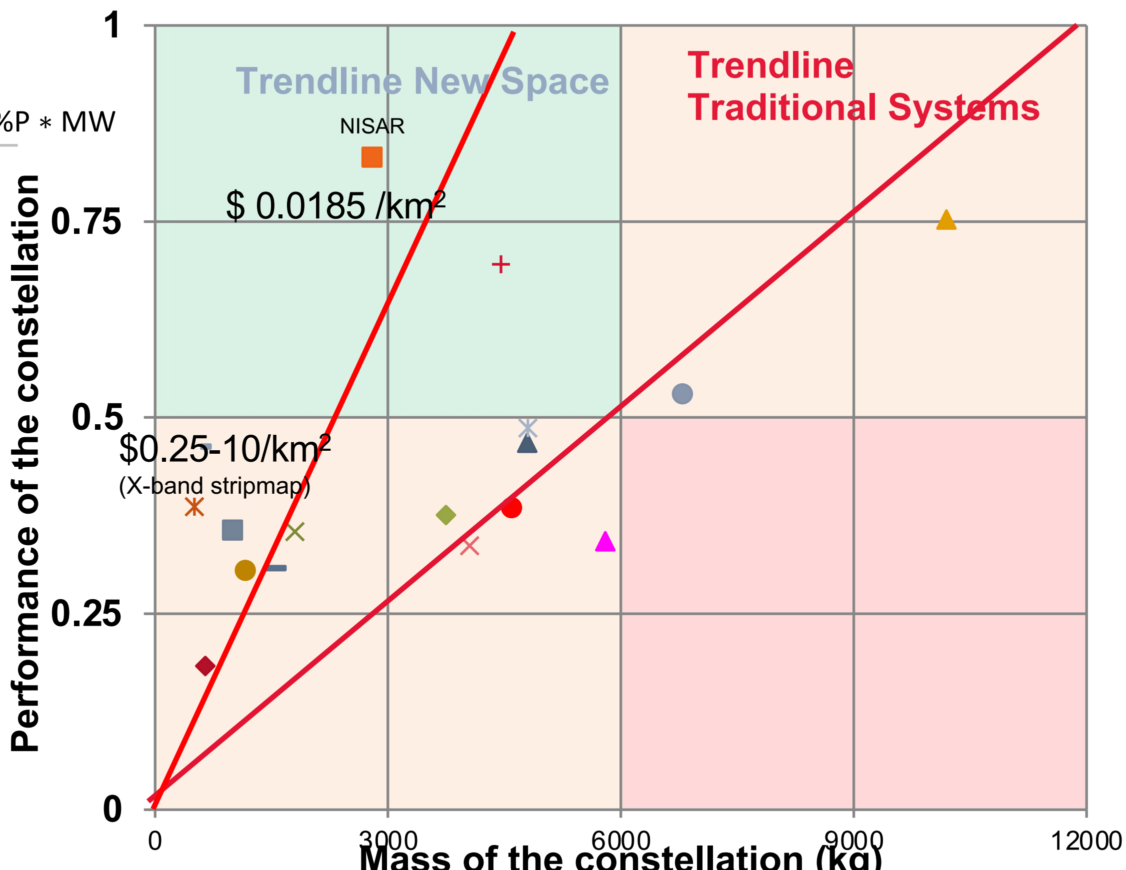
- Legacy Commercial Systems:
  - Radarsat-2, ALOS-2, COSMO-Skymed and TerraSAR-X
- Newer Commercial Systems:
  - Denali, Iceye, NovaSAR, Asnaro-2 and iQPS
- Influential on civil SAR systems in several ways:
  - Commercial SAR systems will offer data that can supplement scientific data from civil systems.
    - Reduces burden on civil systems to cover the totality of needs from complete global coverage at modest resolution to targeted observations at fine resolution and fast temporal sampling.
  - Commercial SAR developments may influence the directions space agencies take in technology and flight system development.

The New Space Environment for SAR

Constellation Performance = $\frac{\%RR\ \ \%SW\ \%AT\ \ \%PP\ \ \%P * MW}{5}$

RR: Range resolution
SW: Swath width
AT: Acquisition time per orbit
PP: Peak power
P: Polarimetry
MW: Maturity Weight (0.7 – 1) somewhat ad hoc

- NISAR already lies on New Space Performance versus Mass curve
- Resolution factors heavily in performance
- Equivalent area coverage rate to NISAR requires many small satellites (10-100 depending on the small satellite)



Commercial Systems are likely part of the solution, but not the complete solution for science and applications

Plans
Commercial Systems

- Example: constellation of 50 commercial X-band SAR systems
  - Each satellite with a limited capability but collectively able to cover the fast-moving portions of major ice streams and glaciers around the world
  - By covering these targets with fast sampling, it relaxes the need for civil systems to deliver these fast revisit data for science
  - This has major implications for the attributes of the civil constellation, including spectrum, coverage requirements, number of satellites, and vector diversity

Challenges

- Agencies respond to the needs of their stakeholders – funders, elected officials and other ministers, scientists – and each agency has a unique set of priorities.
- Funding cycles are typically incommensurate and funding priorities can change with election cycles and economic conditions.
- Technological and industrial competition, as well as export control restriction, can introduce programmatic as well as technical challenges to partnerships.
- Long term agreements about data exchange on equal basis and common data acquisition planning.
  - Openness of data from missions can be an obstacle for partnership, particularly when the policies differ among partners.
- Commercial systems are market driven, which can be difficult to control for scientific purposes.

Opportunities

- Bilateral collaborations:
  - E.g. Augmentation of the Sentinel-1 C-band or ROSE-L L-band constellation with a co-flyer designed to measure vector displacement or topography.
- Loose collaboration:
  - E.g. Augmentation of ROSE-L with SDC satellites in the same orbit but phased to improve revisit for science targets where short revisit is needed, or for disaster monitoring
- International constellation design:
  - Development of a common multi-band SAR platform specification
  - Designed to achieve observational continuity for an agreed-upon set of multi-decade scientific and operational requirements.
  - Designing a confederation around this common goal, even if difficult to realize in practice, could help crystallize the distinction between common and agency unique priorities.

Summary

- With over twenty SAR satellites in orbit, and even greater numbers being built or planned, there are tremendous opportunities to cooperate and coordinate among space agencies.
- Creating an optimized systems approach to design and development of international SAR missions would have great potential impact.
- The May 2018 SAR Coordination Workshop began the dialogue. The October 2021 Workshop will develop a set of follow-on recommendations to engage proponents of SAR worldwide in this endeavor.