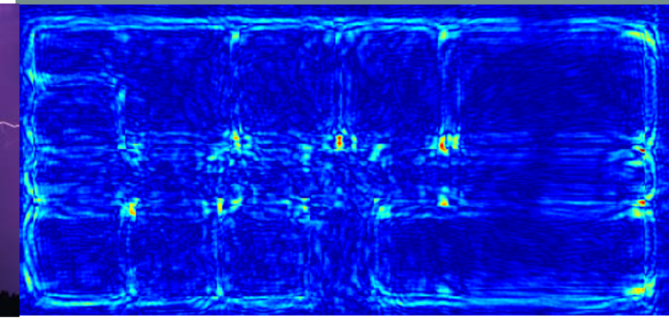
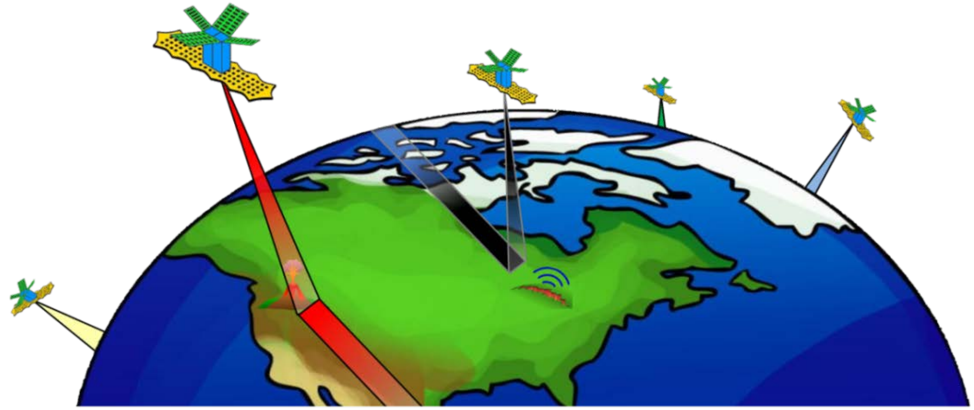


SRI CubeSat Imaging Radar for Earth Science (SRI-CIRES)

Earth Science Technology Forum 2015



Lauren Wye
SRI International
24 June 2015

Collaborators: Simon Lee, John Buonocore, Troy Stevens, Roman Novosolev, David Watt, Steven Chen, Joe Wilhelm, Patrick Rennich, Prof. Howard Zebker

NASA

ESTO
Earth Science Technology Office

Synthetic Aperture Radar (SAR)

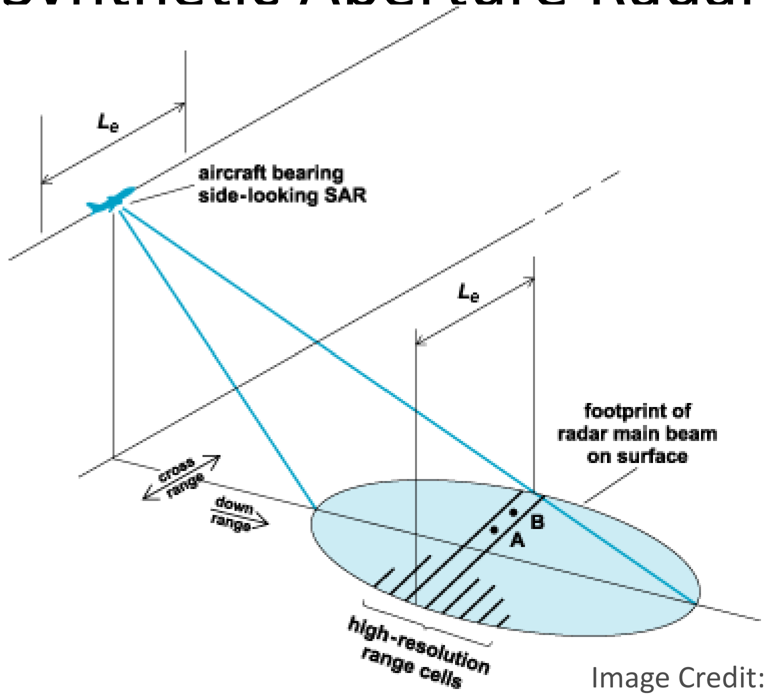


Image Credit: McGraw-Hill

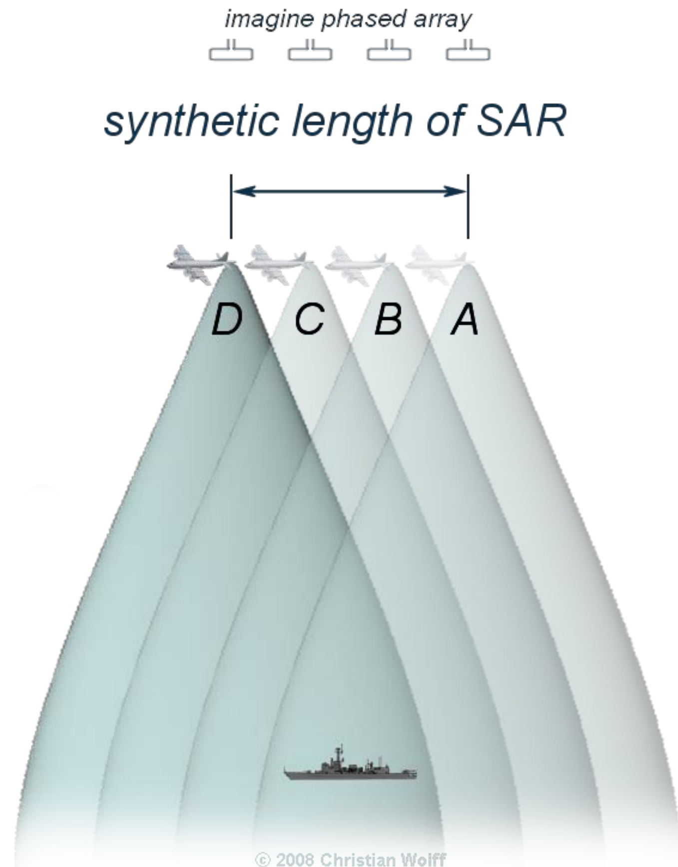


Image Credit: Christian Wolff

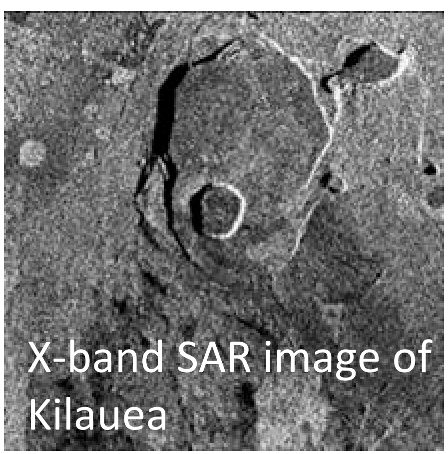


Image credits: NASA/JPL-Caltech

- Range resolution achieved through pulse compression of broad-bandwidth pulse
- Cross-range resolution achieved with Doppler processing

Interferometric Synthetic Aperture Radar (InSAR)

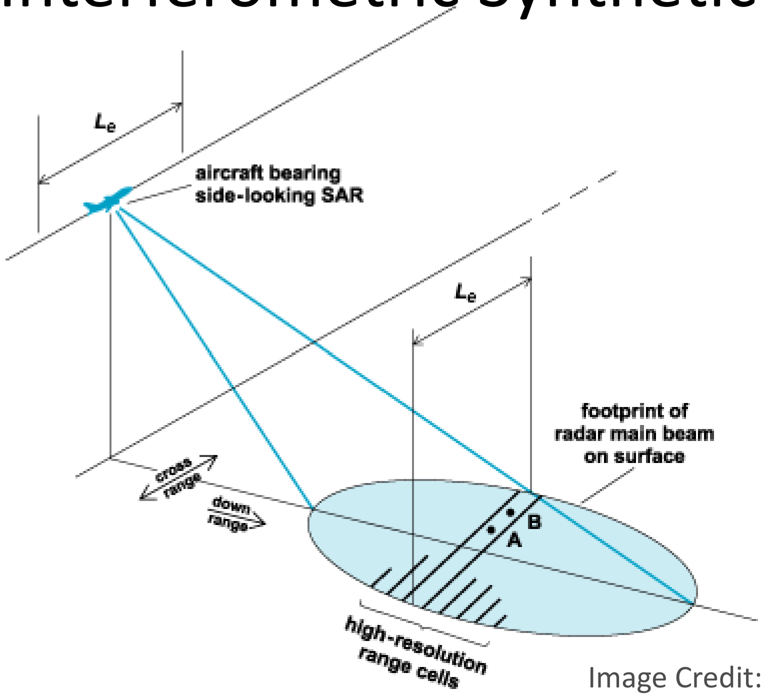


Image Credit: McGraw-Hill

Repeat-pass InSAR enables spatially-dense, precise ground-deformation measurements over large areas.

Applications to Earth Science:

- Natural hazard prediction (volcanoes, earthquakes, landslides, subsidence and structural integrity)
- Natural resource monitoring (aquifer, fracking, vegetation)
- Disaster relief

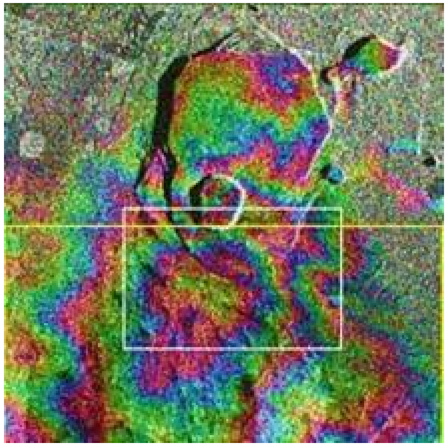


Image credits: NASA/JPL-Caltech

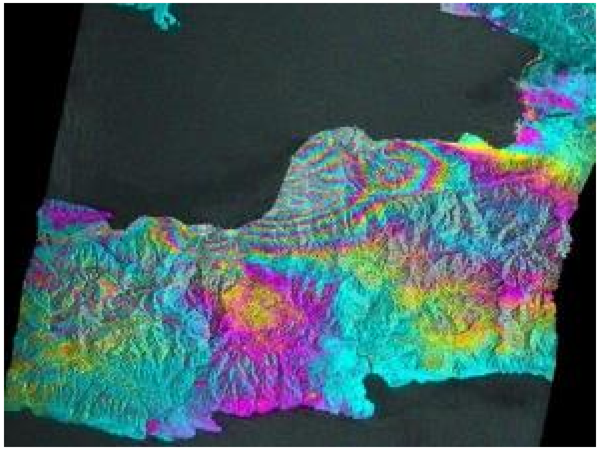


Image credits: NASA/JPL/JAXA/METI

Need for a constellation of InSAR Sensors

- Time-variable geophysical processes require more frequent monitoring than a single InSAR sensor can provide
  - The revisit time of a single platform is restricted by orbital mechanics and spatial coverage requirements (e.g. every 16 days while achieving global coverage)
- Many science applications require sub-cm level deformation measurements, but each individual SAR measurement is corrupted by up to several cm of atmospheric noise.
  - Multiple acquisitions need to be averaged together to reduce atmospheric artifacts

InSAR Constellation Advances Solid-Earth Science by Understanding Geophysical Hazards

CIRES Address NASA Science Goal: Understanding Extreme Events including Earthquakes and Volcanic Eruptions

Sub-centimeter surface deformation measurements with high temporal resolution will advance our knowledge of critical Earth science questions related to natural hazards and resource mining activities.

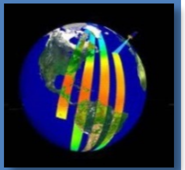
The Need for a Low-Cost Constellation of InSAR Satellites

Interferometric synthetic aperture radar (InSAR) is the only tool for measuring spatially dense deformation on a global scale.

Global spatial coverage is needed to capture the infrequent occurrence of natural and human-induced hazards.

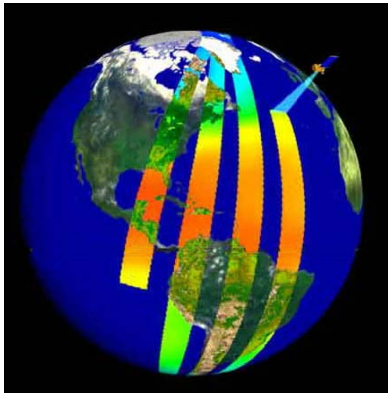
Individual SAR satellites cannot provide the rapid revisit times required to characterize geophysical events.

On-orbit Demonstration Enables New Science Missions

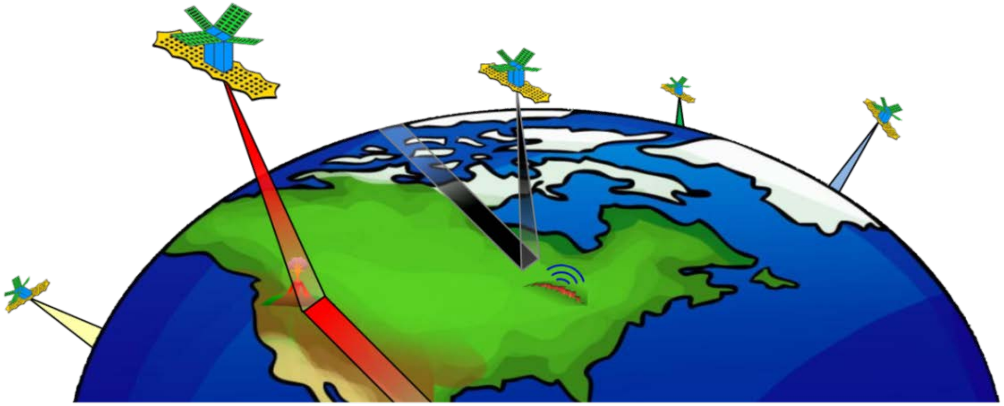


A large constellation of InSAR CubeSats with spatial-temporal flexibility is needed to properly characterize time-variable processes and improve predictive geophysical models.

CubeSat Technology enables a constellation of InSAR Sensors



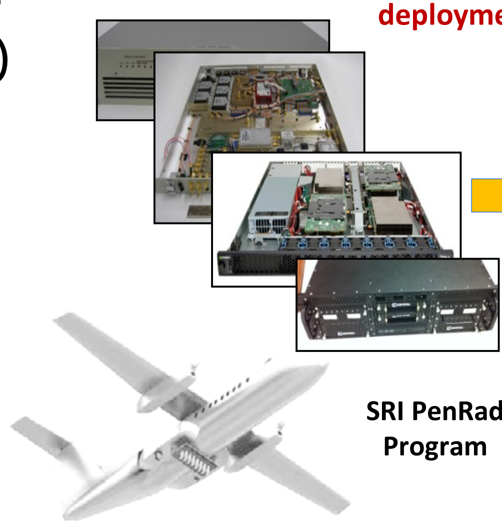
- Low-cost alternative to traditional sensors
  - Existing InSAR technology is large (>1000kg) and expensive (>$300M)
  - COTS components, cheaper launch opportunities
- Rapid-Development (1-2 yr vs. 4-10 yr)
  - COTS components, simplified launch integration
- Replenishable: constellation has indefinite life-time
  - Existing single-platform SAR sensors have a 3-10 year lifetime and are more susceptible to single point failures; some time-variable processes evolve on decadal timescales and thus benefit from long observation campaigns
  - Test bed for innovative radar technology and processing algorithms
- Operational flexibility
  - Formation flying to achieve different baseline configurations



SRI CubeSat Imaging Radar for Earth Science (SRI-CIRES)

- Miniaturized SAR for CubeSats
  - ACT 2014 award (Jan 2015 start)
  - S-band (2.9 GHz)
  - Designed for 500 km altitude
  - 25 meter spatial resolution
  - 3.2 m x 1.6 m supporting antenna
  - Sub-centimeter level accuracy

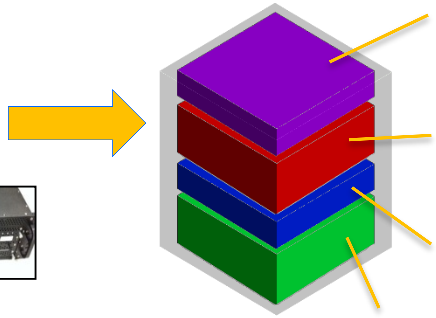
SRI Airborne UHF SAR Heritage
Over 20 years of DT&E and Operational deployments

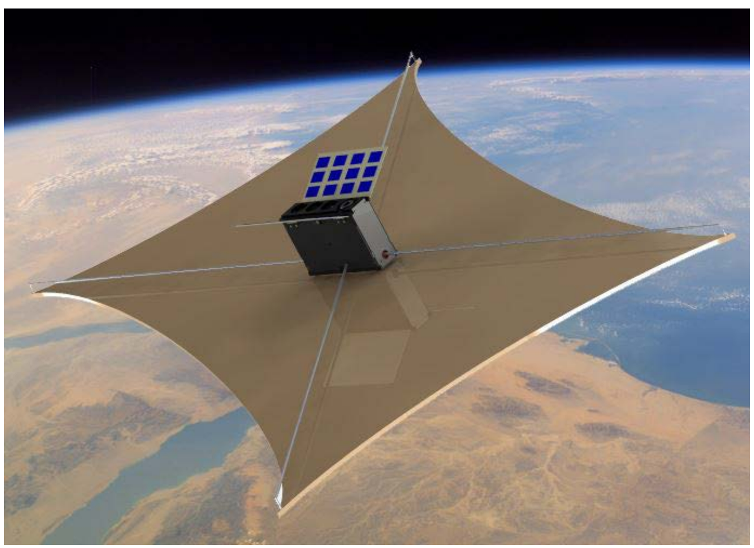


SRI PenRad Program

S-Band SAR Subsystem

SRI-CIRES
(<1U CubeSat Volume)

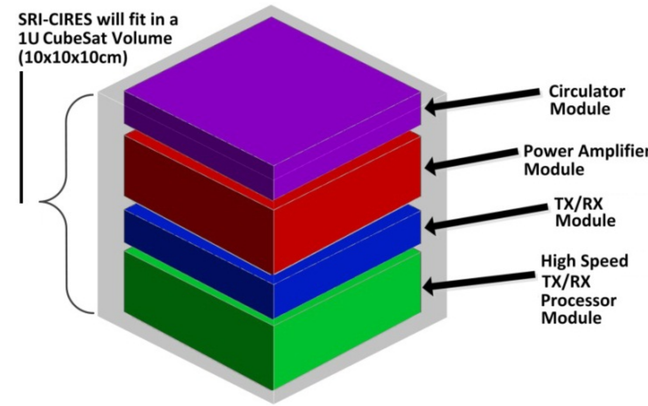


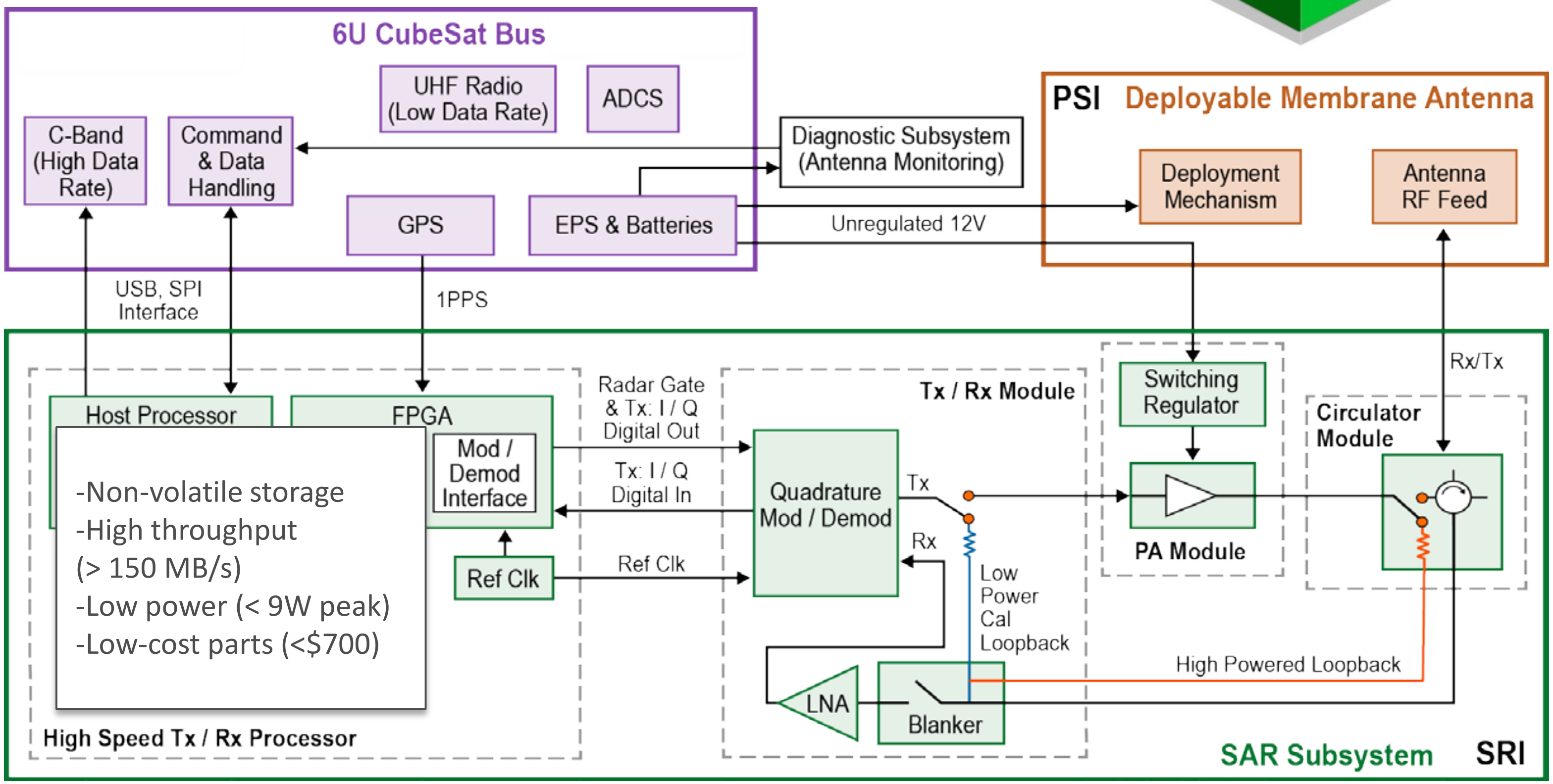


SRI-CIRES Overview

Four modules/subassemblies:

- Circulator
- Power Amplifier (PA)
- Transmit/ Receive (TX/RX)
- High Speed TX/RX Processor





The SRI-CIRES radar subsystem will fit in a 6U bus

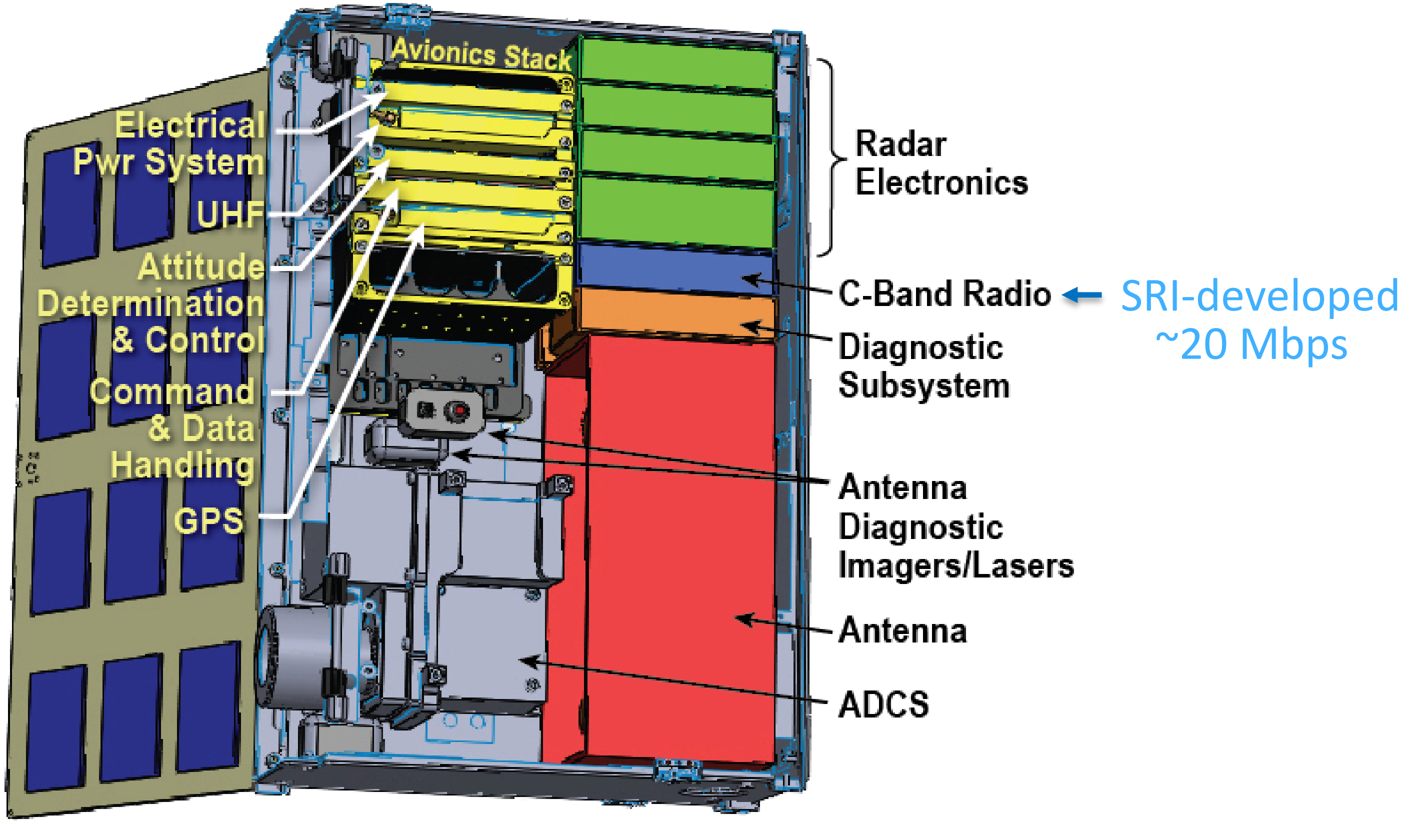


Table 2: CIRES-A Satellite Mass

CIRES-A Subsystems	TRL	Mass (kg)	Margin (%)	Mass + Margin
SAR electronics (includes cables)	5	1.8	25%	2.3
Deployable antenna (includes cables)	5	2.3	25%	2.9
6U Bus (C&DH, EPS, batteries, reaction wheels, structure, UHF radio, cables, C-band radio at TRL-5)	9	7.3	5%	7.7
			Total Mass + Margin	**12.9**

Table 3: CIRES-A Daily Downlink Capacity

Parameter/Quality	Value
Ground station contact time (JES, ATA, and Arecibo)	33 mins per day
C-band radio data transmission rate	20 to 40 Mbps
SAR imaging data rate	98 Mbps
SAR imaging time per day	**7 to 13 minutes**
SAR electronics – solid state drive data storage capacity	600 GB (13.9 hrs of SAR imaging)

SRI-CubeSat Imaging Radar for Earth Science (SRI-CIRES)

PI: Lauren Wye, SRI International

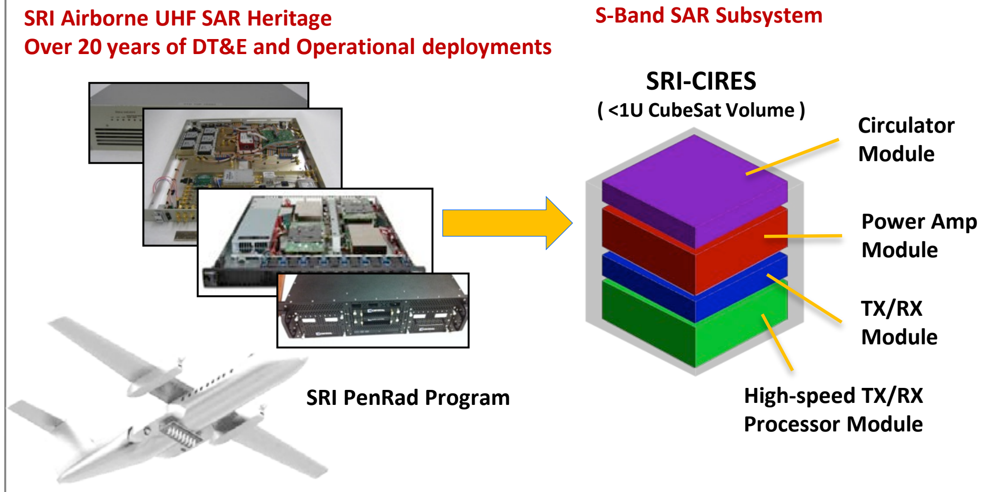
Objective

For the **CubeSat** platform, develop an **S-Band** radar subsystem capable of interferometric synthetic aperture radar (InSAR) operations

- Volume less than 1 U (10x10x10 cm) and <750g
- Low phase noise (e.g., accurate, stable reference clock)

Satisfy the performance requirements of Earth Science applications that most benefit from **rapid-repeat InSAR**, e.g. natural hazard and resource monitoring

- High-quality imaging (SNR>13dB)
- Sub-cm level InSAR accuracy
- Spatial resolution better than 30 m



Approach:

SAR Radar Development

- Leverage SRI expertise in UHF SAR and InSAR development (e.g. TRL-9 deployed coherent change detection airborne system) & miniaturizing payloads for the CubeSat platform (e.g. RAX & CTIP)
- Leverage SRI internal R&D on a CubeSat high-speed I/Q data processor and storage (120 MBps)

CubeSat SAR End-to-End Testing

- Validate prototype SAR subsystem performance in the lab & relevant environments (e.g. vibe, thermal, & vacuum)

Science PI: Prof. Howard Zebker (Stanford University)

Key Milestones

• Performance Reqs, Design, Analysis (TRL-3)	06/2015
• Breadboard Demonstration (TRL-4)	11/2015
• Prototype Manufacture, Assembly & Test	06/2016
• Prototype Relevant Environments (TRL-5)	11/2016

TRL_{in} = 2

Earth Science Technology Office

Thank you!