SRI CubeSat Imaging Radar for Earth Science (SRI-CIRES): Initial Flight Demonstrations

Earth Science Technology Forum

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SRI International

Earth Science Technology Office

Earth Science 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.

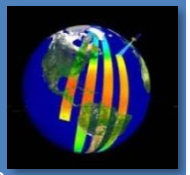
The Need for a Low-Cost Constellation of InSAR Satellites

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.

CIRES: CubeSat Imaging Radar for Earth Science

Miniaturized Synthetic Aperture Radar (SAR) payload for resource-constrained platforms
Designed to support interferometric (InSAR) operation from 500 km altitudes

CIRES S-band Radar Payload (17 m range res now, 5 m res in mid-2018)

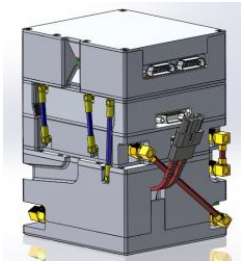
Tx/Rx Module: Transmit and Receive RF analog chains, calibration loopback circuits, integrated ADC and DAC capability.

High Speed Processor Module: Power Regulation, FPGA, Data Storage, Multi-core Processor

PA Module: Includes internal power regulation, power driver stages and RF power amplification. (2.9-3.1 GHz)

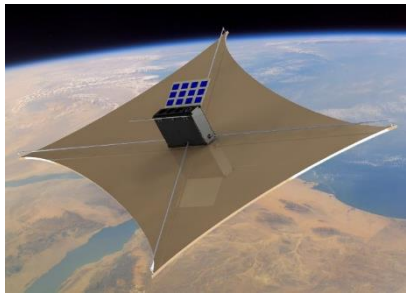
Custom Phased Array Radar Antenna: High-power waveguide distribution, printed microstrip membrane emitter elements, 20+ dB gain (UAV version), tapered design for low sidelobes, high fractional BW
(built by Physical Sciences Inc.)

Designed to rapidly integrate with 16U bus and deployable antenna



SRI SAR Electronics
(1.25U form factor)

+



~6.5 m^2 Deployable
Membrane Antenna

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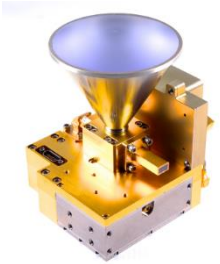

Ka-band downlink (320+ Mbps)

+

Long 16U bus

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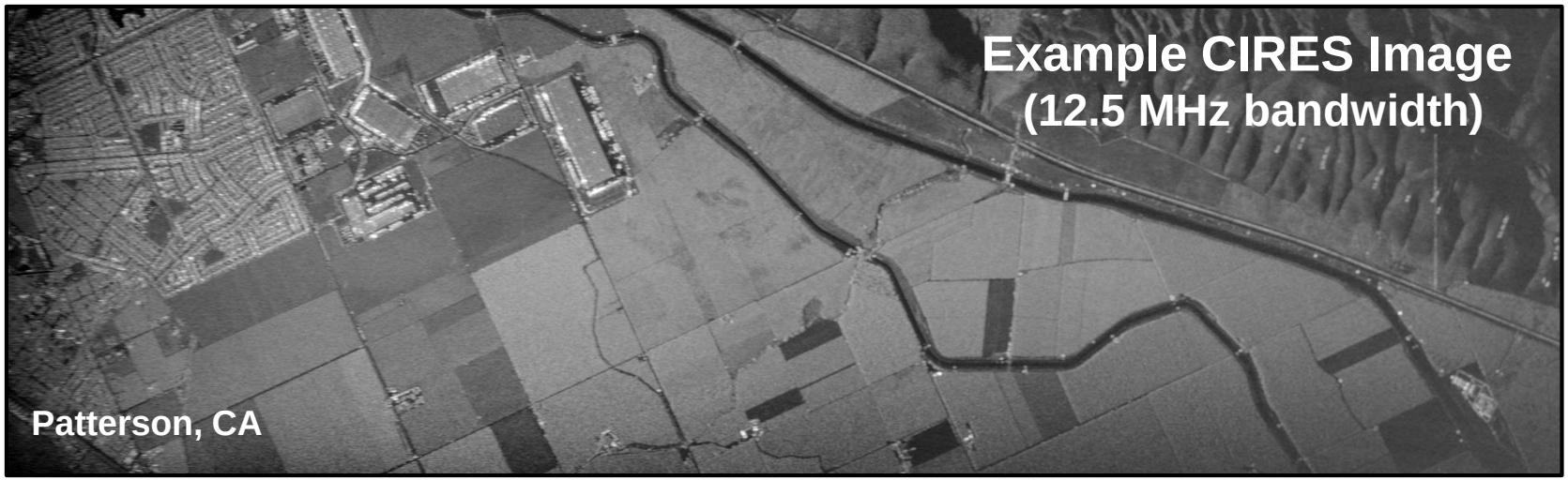
CIRES Key Technologies and Demonstrations

- Key Technologies
  - Compact S-band SAR instrument
  - On-Orbit Deployable Antenna (~6.5 m^2, Gain: >36 dB including losses)
- Instrument Demonstrations
  - CIRES CarSAR – SAR from a ground vehicle platform*
  - CIRES SkySAR – SAR from a commercial aircraft platform**



10x30 km image, 9000 ft altitude, 20 m resolution, multiple looks, non-coherently averaged

* CarSAR test platform developed on NASA ESTO IIP funds

** Aircraft collections funded by SRI International

CIRES Technology Progression

ESTO Advanced Component Technology (ACT) Funds

Radar Hardware Subsystem
TRL-2 → TRL-5

ESTO In-Space Validation of Earth Science Technologies (InVEST) Funds (Proposed)

On-Orbit Instrument Validation

SMD Earth System Science Pathfinder (ESSP) Earth Venture Suborbital (EVS) Funds (Proposed)

Operational Airborne Science Mission

2015 2016 2017 2018 2019 2020

ESTO Instrument Incubator Program (IIP) Funds*

- Deployable Membrane Antenna (TRL-4 → TRL-6)
- Radar Hardware + Software Integrated Instrument (TRL-4 → TRL-6)
- UAV Instrument Development and Science Demo

* ESTO PM Parminder Ghuman

CIRES SAR Electronics Subsystem (TRL-5)

ESTO ACT-funded

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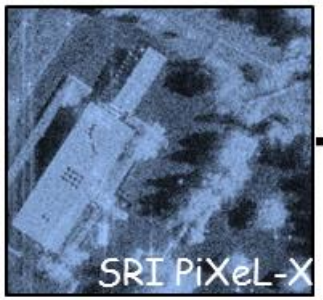
CIRES SAR Imaging Software (TRL-4)



SRI-funded

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High-Gain Deployable Membrane Antenna Subsystem (TRL-4)

SBIR-funded; to be revised, developed, and tested

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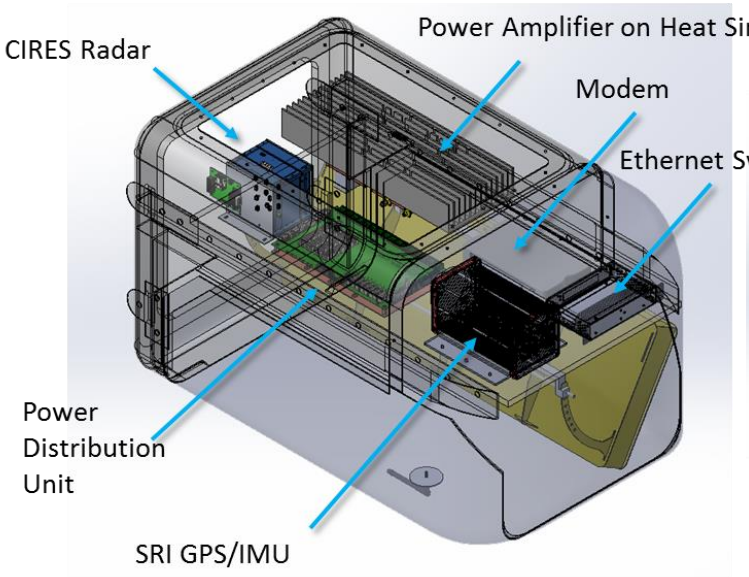
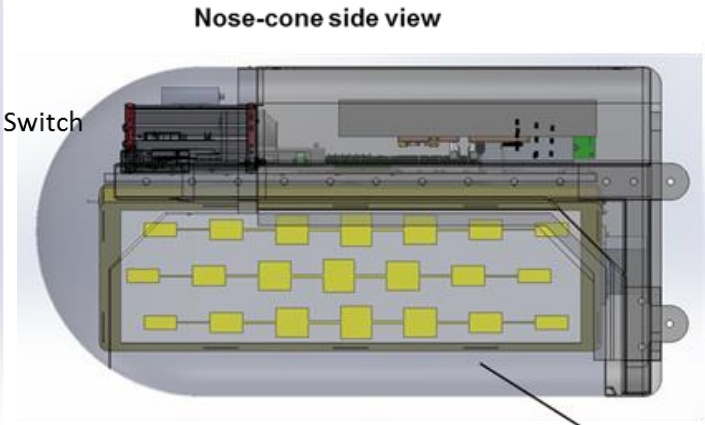
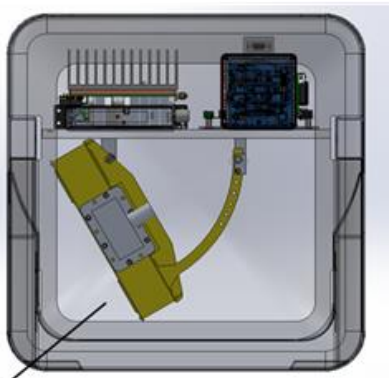
CIRES to be tested on a UAV platform with ESTO IIP funds

SIERRA-B UAV platform provided by NASA Airborne Sciences Program







PSI UAV Antenna mounted inside UAV nose-cone

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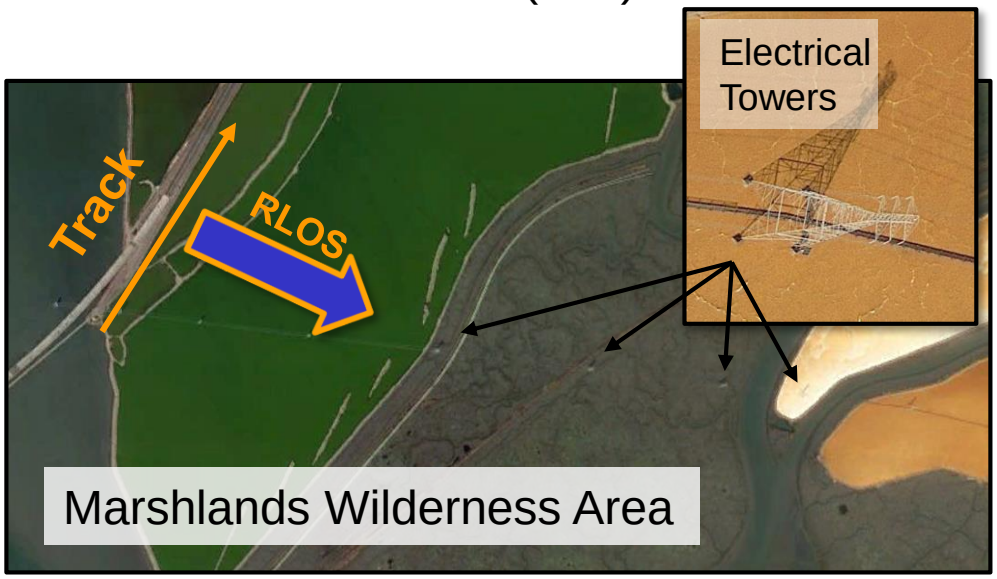
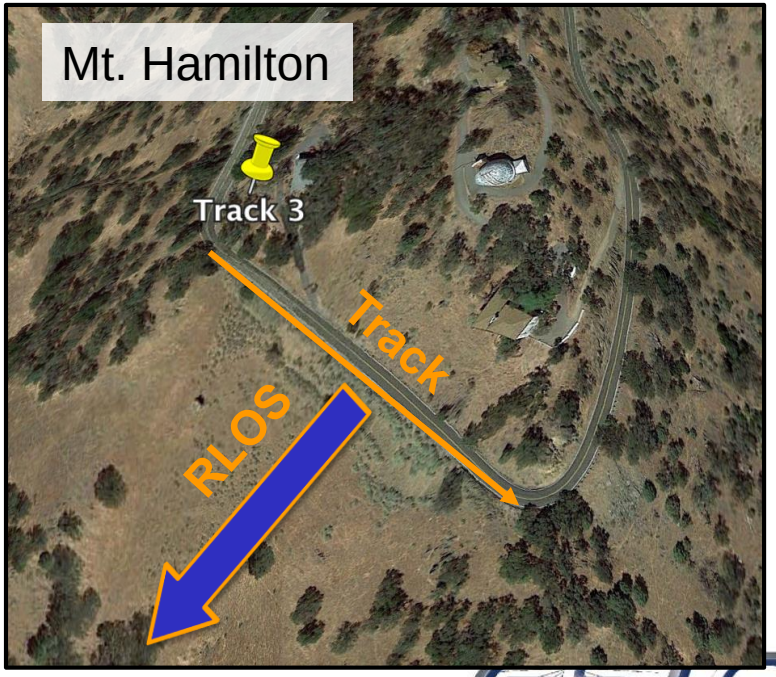
CIRES CarSAR Demonstration Overview

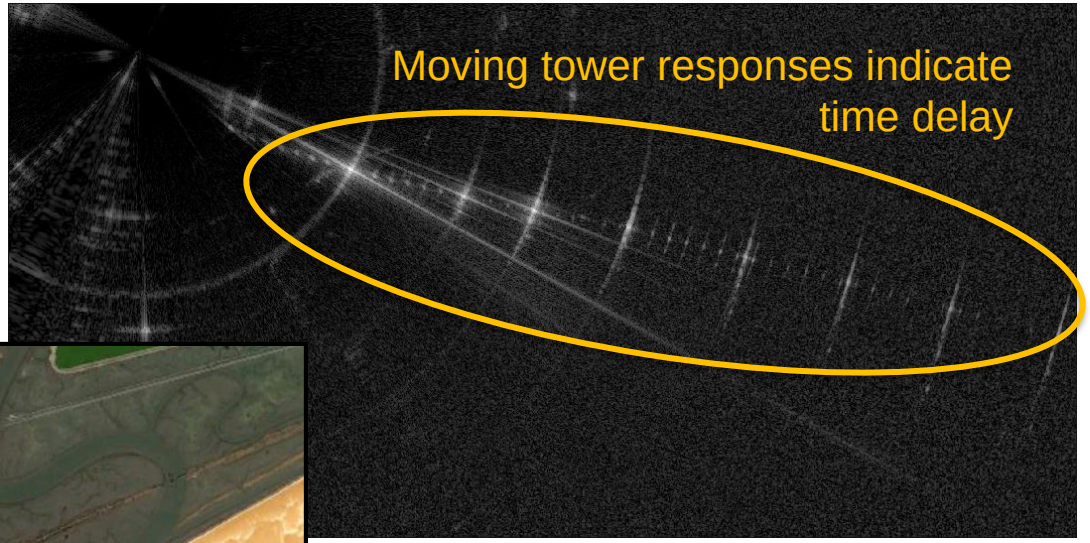
- Allows for flight configuration to be tested on ground
- Easily deployed to locations local to SRI in Menlo Park, CA
- Locations:
  - Marshlands Road (20 min.)
  - Mt. Hamilton (1 hr)
  - Anderson Reservoir (1 hr)

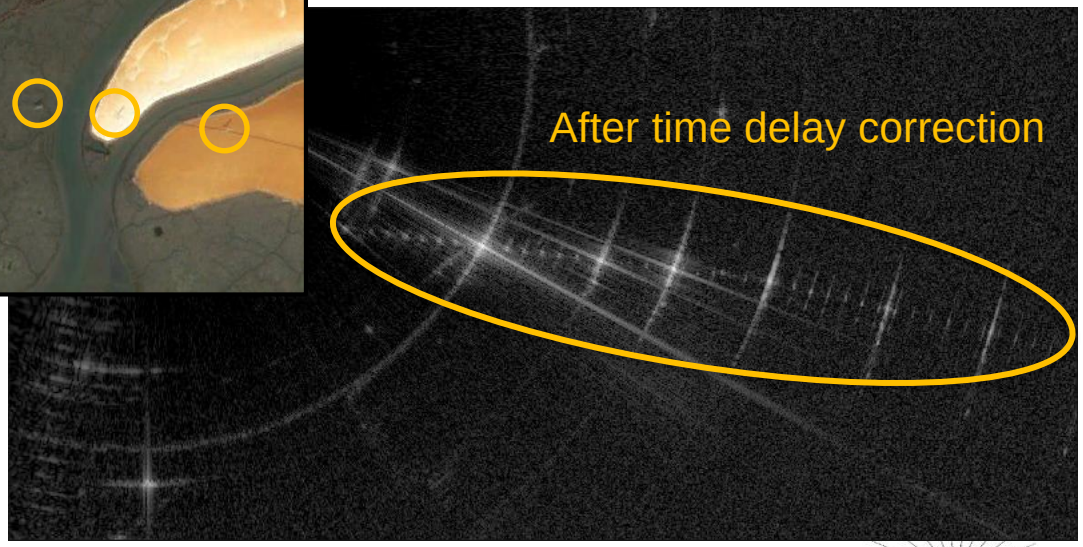




CIRES CarSAR Reveals Instrument Time Delays

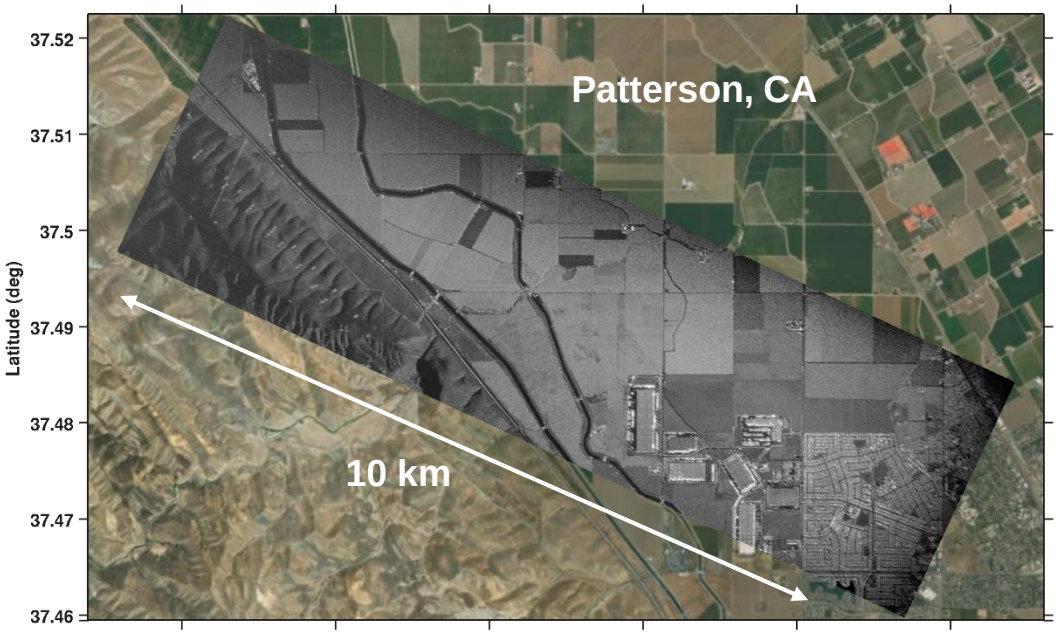
- Scene
  - Fremont, CA Marshlands
  - Convenient location to SRI
  - Enables quick assessment of sensor calibration

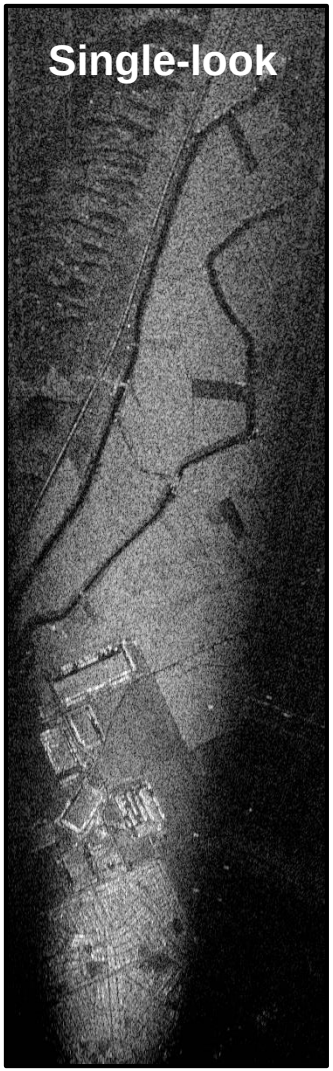




View in presentation mode for animation

CIRES SkySAR Airborne Demonstration*

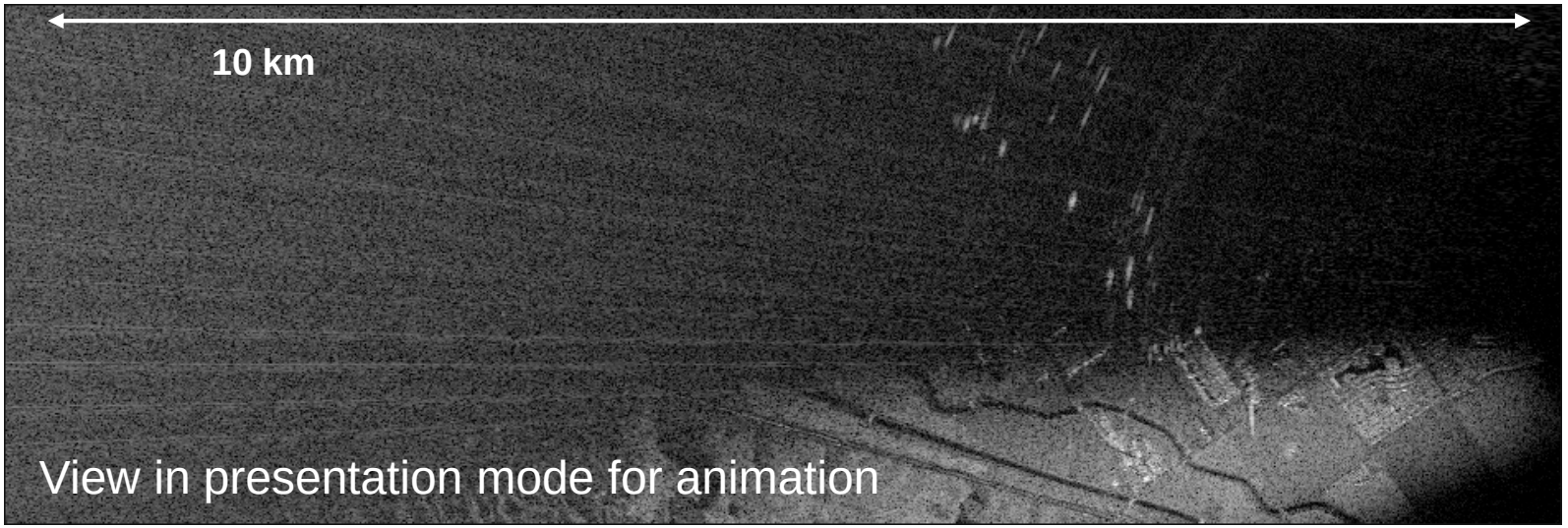




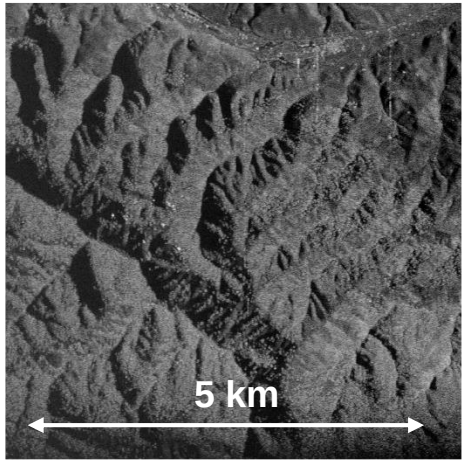
- 10x30 km image, 9000 ft altitude, 20 m resolution

* Aircraft collections funded by SRI International

Additional CIRES Airborne Imagery*

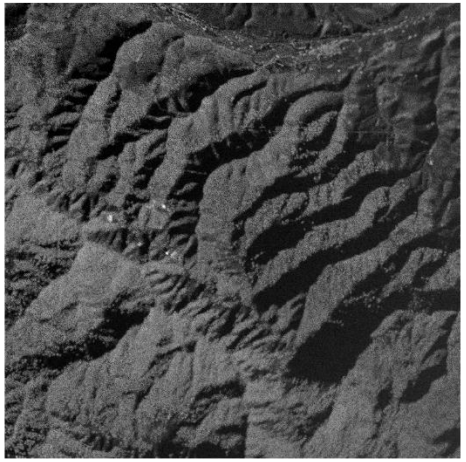


Look 1, 270°



Look 2, 330°

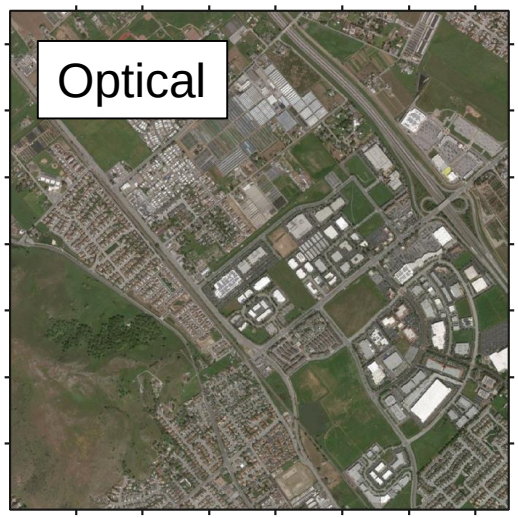
Look 3, 125°

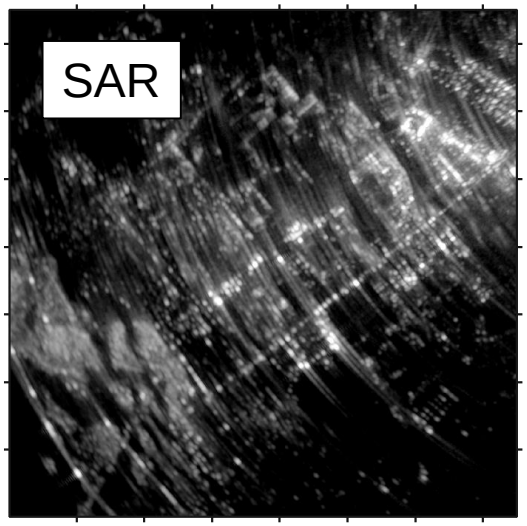


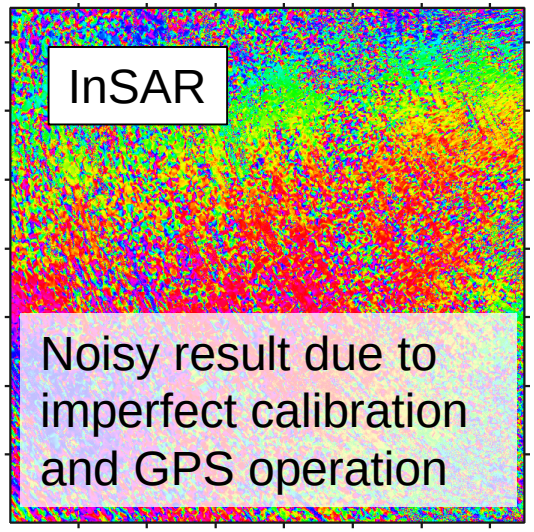
Composite

* Aircraft collections funded by SRI International

Very First SRI-CIRES Interferogram (CarSAR)







- Two passes with CarSAR
- Site: Anderson Reservoir overlooking Morgan Hill valley (CA)
- Date: 1 June 2018, 12:36 pm

- CarSAR testing enables early diagnosis of interferometric instrument calibration and subsystem operation
  - Time-delay calibration improvements in progress
  - GPS sub-system refinements for InSAR operation in progress

Summary

- SRI-CIRES designed and developed for limited-resource environments (e.g., CubeSats, UAVs)
- CIRES instrument tested and verified on moving ground vehicle and airborne platforms in early 2018; interferometric calibration in progress.
- CIRES instrument to be integrated with SIERRA-B UAV late-2018
- UAV-based science relevancy demonstrations to be conducted in 2019 on NASA ESTO IIP funds
- CIRES on-orbit antenna in development; sub-scale version ready for 2019 on-orbit testing and demonstrations

QUESTIONS?