

# High Altitude, Long Endurance (HALE) InSAR for Continual and Precise Measurement of Earth's Changing Surface

A NASA ESTO Instrument Incubator Program (IIP) 2022-2025 Project

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# Aloft Sensing, Inc. Introduction and Mission

Formed in early-2020, Aloft applies innovative algorithmic solutions to state-of-the-art hardware to create compact advanced radar systems for autonomous platforms.





## Leadership Team Three Seasoned Radar Experts

## Lauren Wye

CEO

#### Ph.D. EE – Stanford Univ.

Former Associate Director at SRI International. 15+ years experience leading innovative radar R&D development, including PI / PM for compact space and stratospheric programs.



## CTO Patrick Rennich

#### M.S. EE – Northeastern Univ.

Former Project Manager and Principal Engineer at SRI International. 25+ years experience in radar algorithms and processing. Algorithm lead for in-theater TRL-9 airborne radar.



## Chief Engineer Brian Pollard

#### Ph.D. EE – Univ. of Massachusetts

Former Principal Systems Engineer and Instrument Manager at JPL and Remote Sensing Solutions.
30+ years experience in designing, developing, and testing advanced radar and sonar systems. Aloft's mission is to enable high-performance **radar sensing** and **precision navigation** across <u>all domains</u>.







Specialized radar experience, plus key industry partnerships, provide a solid foundation for sensing & navigation development and production.





## Primary Advantages

- Persistent, rapid revisit (hours)
- Long endurance (months)
- Large swath
- Secondary Advantages
  - Loiter over disaster-area/science-target
  - Multiple viewing angles
    - 3-D deformation
  - Reconfigurable formations
  - No ionospheric distortion
  - Renewable payload

## • Challenges & Solutions

- 1. Low Velocity of HALE Platforms
  - ✓ Aloft's precise navigation updates maintain coherence over long integration times
- 2. Pass Repeatability (Coarse Trajectory Control)
  - ✓ Large fractional bandwidth and precision DEM relaxes trajectory constraints
- 3. Low-SWaP Payload Capacity
  - ✓ Advances in RFIC and SoC technology + AloftPNT enable low-SWaP







500 km

# IIP Objective: Realize the benefits of HALE Platforms



Small Sat Constellation > 100 Small Sats for Hourly Revisit



Earth Science Technology Office

Aloft's payload provides 15-30 cm imaging resolution, mm-level

change, cm-level topography independently of the specific platform.



# Aloft's IIP HALE-InSAR Project



Innovative Algorithms combined with State-of-the-Art Hardware Enable NISAR High-Performance InSAR Capability on Low-SWaP HALE Platforms NASA and ISRO Millimetric Change LiDAR-quality Topography 2.5 cm Atmos 0.5 cm Kea Aerospace 2 cm Airship 3 cm SULF Sceve Swift Engineering 1-σ = 20 cm  $1 - \sigma = 1.5 \, \text{mm}$ UAVSAR NASA Imagery (meter) AloftPNT Aloft Sensing, Inc. positioning and timing Change (millimeter) Topography (centimeter) techniques ("AloftPNT") enable aperture reconstruction over long and complex stratospheric vehicle trajectories, enabling Aloft Sensing's HALE-InSAR Payload high quality, stratospheric InSAR products. X-band (9.6 GHz) Aloft's HALE InSAR payload is compatible with some SWaP: <7kg, <250W, 25cm x 25 cm x 15 cm of the tightest SWaP constraints. IMU **Pulse Processing** SAR Imagery: 0.3m resolution Navigation Ground deformation & change: mm-level Topographic maps: cm-level (LiDAR quality) Kalman **Backprojection Imagery** Multi-Phase Center AESA Blending Altitudes of operation: up to 30km  $\downarrow \downarrow \downarrow \downarrow$ ••• Swath: 5-60km BLUE **Coherent Processing** Fully steerable in azimuth & elevation: +45° Estimator



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<sup>+</sup> AloftPNT is a computational radar-based technique that provides micron-level positioning, milli-degree orientation, and picosecond timing; Patent-pending.



# Aloft X-band SAR Roadmap

2015-2019: SAR/InSAR from compact radars developed for Space, UAS, and Stratosphere\* \*conducted at SRI International



performance imaging from

2019-2020: Precision InSAR from Mid-Altitude Aircraft\*\* \*collected at SRI International, processed at Aloft Sensing



Unique autofocus technique + Multi-baseline registration compact hardware achieve hightechniques increase measurement precision. resource-constrained platforms.



Aloft Team purpose-built antenna hardware + COTs SDRr demonstrate AloftPNT, imaging, and MTI from drone.



full-AESA software-defined SAR; demonstration of AloftPNT, high quality imagery, and advanced products from the stratosphere.

2024-: Modular X-band SARs across domains







**High-Altitude** 



High quality near real-time imaging, ultra-high precision navigation, multi-statics, advanced interferometric products.





# Year 1 IIP Developments Status

## **HALE InSAR Hardware Maturation**

Transitioning to full steerability, 1:1 AESA: end-to-end tile (1/16<sup>th</sup> array) 2D steering tests recently successfully completed.





Transitioning from commercial Software Defined Radar (SDRr) to custom stratospheric-ready SDRr with AloftPNT onboard (leverages Aloft's complimentary DSI project).

25cm

Transitioning from a commercial tacticalgrade GNSS/IMU receiver to a built-in MEMS IMU paired with AloftPNT; reduces SWaP while providing the ultra-high accuracy trajectory reconstruction required to generate advanced InSAR products.







development and verification.

Aloft's 1<sup>st</sup> Gen X-band SAR & 1<sup>st</sup> Gen W-band

prototype serve as testbeds for algorithm



Test data is processed both offline (for InSAR & PNT verification) and in real-time for embedded algorithm development.



3cm x 3cm resolution processed from 76GHz radar



**ALOFT SENSING** 

PNT validation with real data provides sub-100 µm position accuracy over several seconds



Airborne flight demonstration planned for late CY2023. First stratospheric flight demonstration planned for mid CY2024.





# **IIP Project Summary**

- Solar-powered HALE aircraft and airships offer affordable persistent regional access.
  - Potential to capture the high-frequency dynamics of critical geophysical processes
- Aloft is applying novel algorithms & state-of-the-art electronics to **reduce the SWaP of InSAR** instrumentation and enable integration onto the smaller and more affordable HALE platforms.

**ALOFT SENSING** 

- Aloft is refining these algorithms to **overcome the challenges** associated with HALE operations: relatively slow velocities, often irregular trajectories, and coarse navigation control.
  - AloftPNT maintains the sensor coherence over longer collection times and across wider spatial baselines
- Aloft's HALE InSAR has the potential to **improve revisit times** from weekly to sub-hourly (a 100x benefit), while also providing **ultra-precise sensitivity over broad-areas**, for a new level of regional presence and data accessibility.

