National Aeronautics and
Space Administration

EXPLORE EARTH

NASA use of HAPS for Earth Observations

Matt Fladeland - NASA Ames Research Center
Susan Schoenung – Bay Area Environmental Research Institute

Prepared with inputs from numerous colleagues from NASA HQ, centers, and research community

2nd SOARS Meeting – Grand Forks, ND – March 13, 2024

Matthew Fladeland

- **Airborne Science Manager** at NASA Ames Research Center
  - Managing Agency-wide engineering support to science and aircraft teams
  - Advanced Planning, Analysis and Reporting
  - New Technology Portfolio

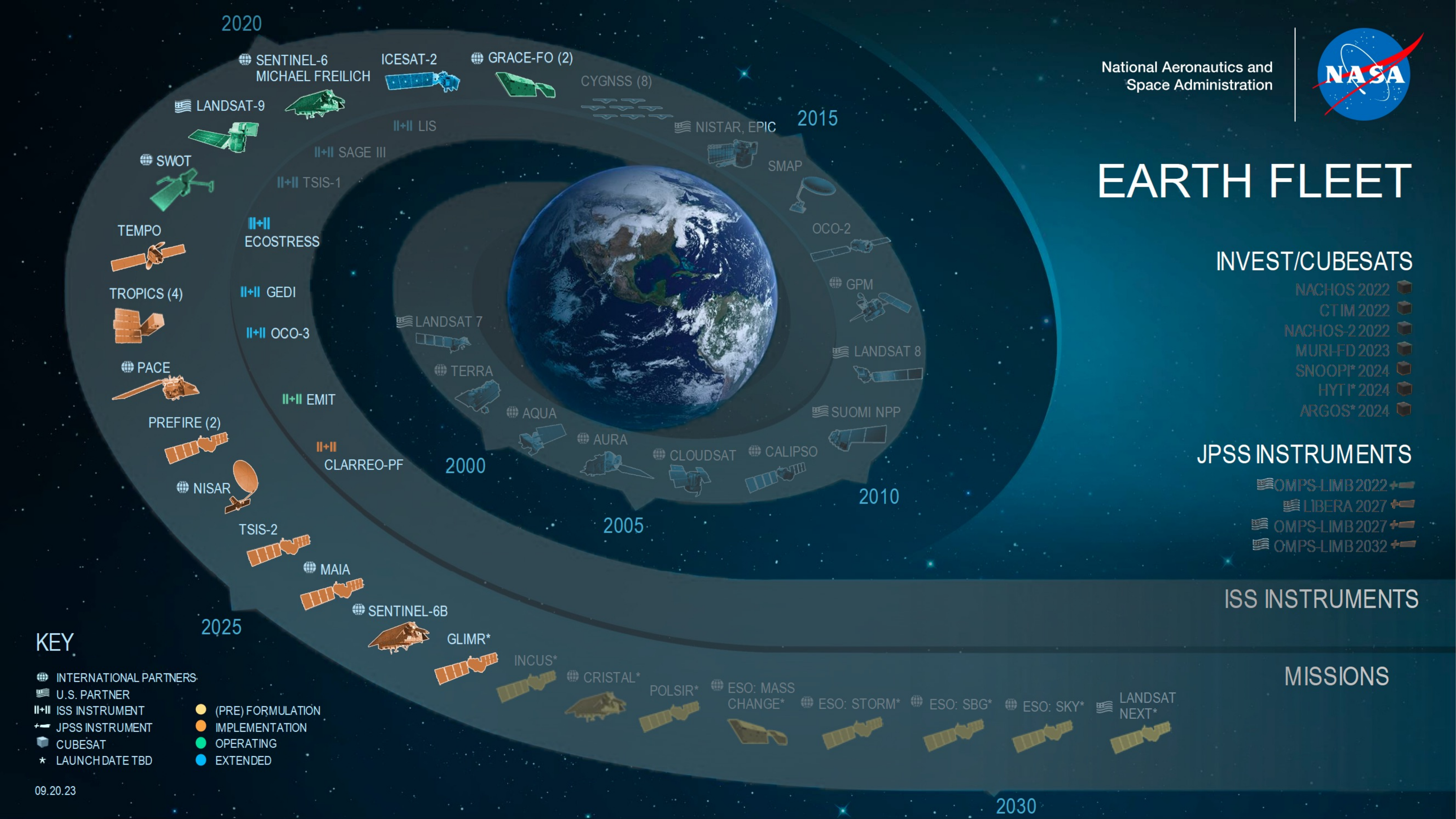
- **Subtopic Manager and COR** for NASA SBIR projects including Xiomas, BlackSwift S2, Swift HAPS, and Electra HAPS

Past projects:

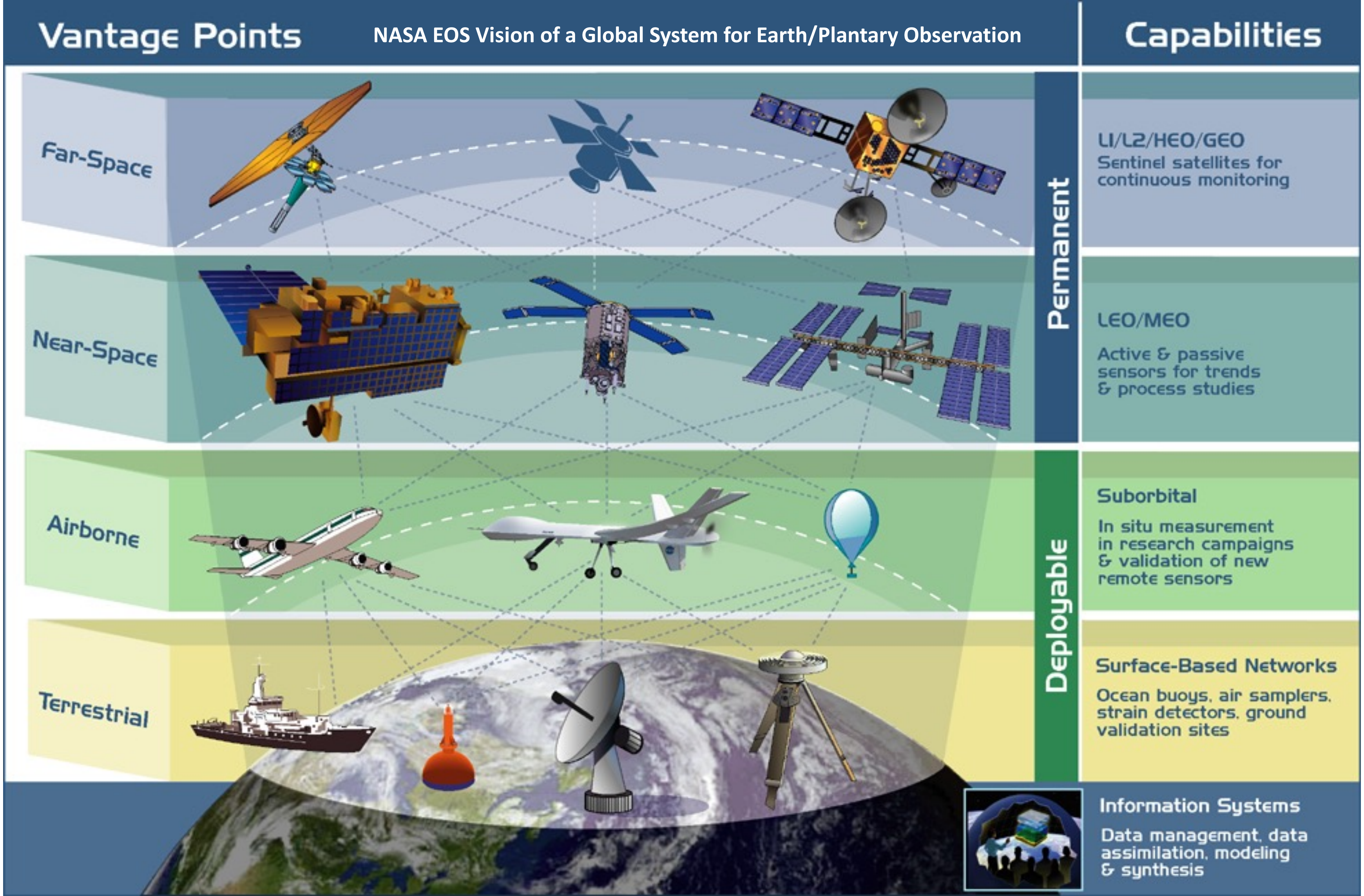
- **Principle Investigator** for NASA SIERRA-A UAS
- **Co-Principle Investigator** for NASA Dragon Eye
- **COR** for Vanilla SBIR

Outline

- The NASA Earth System Observatory
- Science requirements for HAPS
- Platforms capabilities
- Demonstration projects
- Technology development
- Challenges
- Conclusions



National Aeronautics and Space Administration
NASA
EARTH FLEET
2020
2015
2010
2005
2000
2025
2030
SENTINEL-6 MICHAEL FREILICH
ICESAT-2
GRACE-FO (2)
CYGNSS (8)
NISTAR, EPIC
SMAP
OCO-2
GPM
LANDSAT 8
SUOMI NPP
CALIPSO
CLOUDSAT
AURA
AQUA
TERRA
LANDSAT 7
LANDSAT-9
SWOT
TEMPO
TROPICS (4)
PACE
PREFIRE (2)
NISAR
TSIS-2
MAIA
SENTINEL-6B
GLIMR*
INCUS*
CRISTAL*
POLSIR*
ESO: MASS CHANGE*
ESO: STORM*
ESO: SBG*
ESO: SKY*
LANDSAT NEXT*
LIS
SAGE III
TSIS-1
ECOSTRESS
GEDI
OCO-3
EMIT
CLARREO-PF
INVEST/CUBESATS
NACHOS 2022
CTIM 2022
NACHOS-2 2022
MURI-FD 2023
SNOOPI* 2024
HYTI* 2024
ARGOS* 2024
JPSS INSTRUMENTS
OMPS-LIMB 2022
LIBERA 2027
OMPS-LIMB 2027
OMPS-LIMB 2032
ISS INSTRUMENTS
MISSIONS
KEY
INTERNATIONAL PARTNERS
U.S. PARTNER
ISS INSTRUMENT
JPSS INSTRUMENT
CUBESAT
LAUNCH DATE TBD
(PRE) FORMULATION
IMPLEMENTATION
OPERATING
EXTENDED
09.20.23


Vantage Points
NASA EOS Vision of a Global System for Earth/Plantary Observation
Capabilities
Far-Space
Near-Space
Airborne
Terrestrial
Permanent
Deployable
L1/L2/HEO/GEO
Sentinel satellites for continuous monitoring
LEO/MEO
Active & passive sensors for trends & process studies
Suborbital
In situ measurement in research campaigns & validation of new remote sensors
Surface-Based Networks
Ocean buoys, air samplers, strain detectors, ground validation sites
Information Systems
Data management, data assimilation, modeling & synthesis

NASA Earth Science to Action (ES2A)

NASA SMD's 10-year Earth Science Strategic Plan.

A new mission, vision, and goals.

Roll-out in March 2024 (Mar 13th at Ames)

NASA Directorates and Programs aligned w/ HAPS

- NASA Science Mission Directorate (SMD)
  - Earth Science Technology Office
- NASA Aeronautics Research Mission Directorate (ARMD)
  - Upper E Traffic Management
- NASA Space Technology Mission Directorate (STMD)
  - Flight Opportunities Program
- NASA Small Business Innovative Research (SBIR) Program
  - Phase I, II, -IIE, Climate Sequentials


NASA
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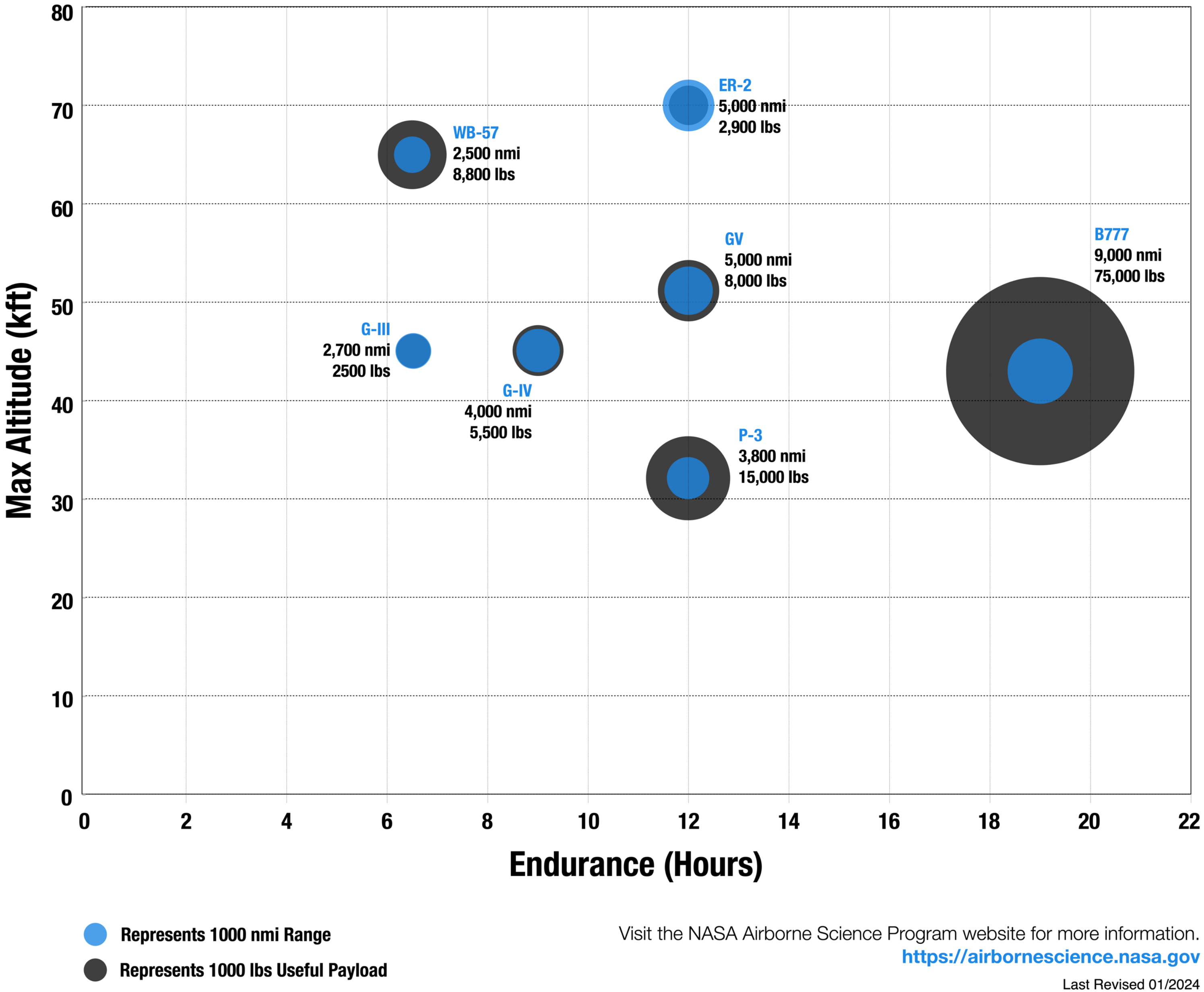
UNITED STATES OF AMERICA
ARMSTRONG FLIGHT RESEARCH CENTER
EARTH SCIENCE
Airborne Science Program
National Aeronautics and Space Administration
AIRBORNE SCIENCE PROGRAM
NASA

AIRBORNE SCIENCE PROGRAM AIRCRAFT PERFORMANCE

National Aeronautics and Space Administration



Visit the NASA Airborne Science Program website for more information.
https://airbornescience.nasa.gov

Last Revised 01/2024

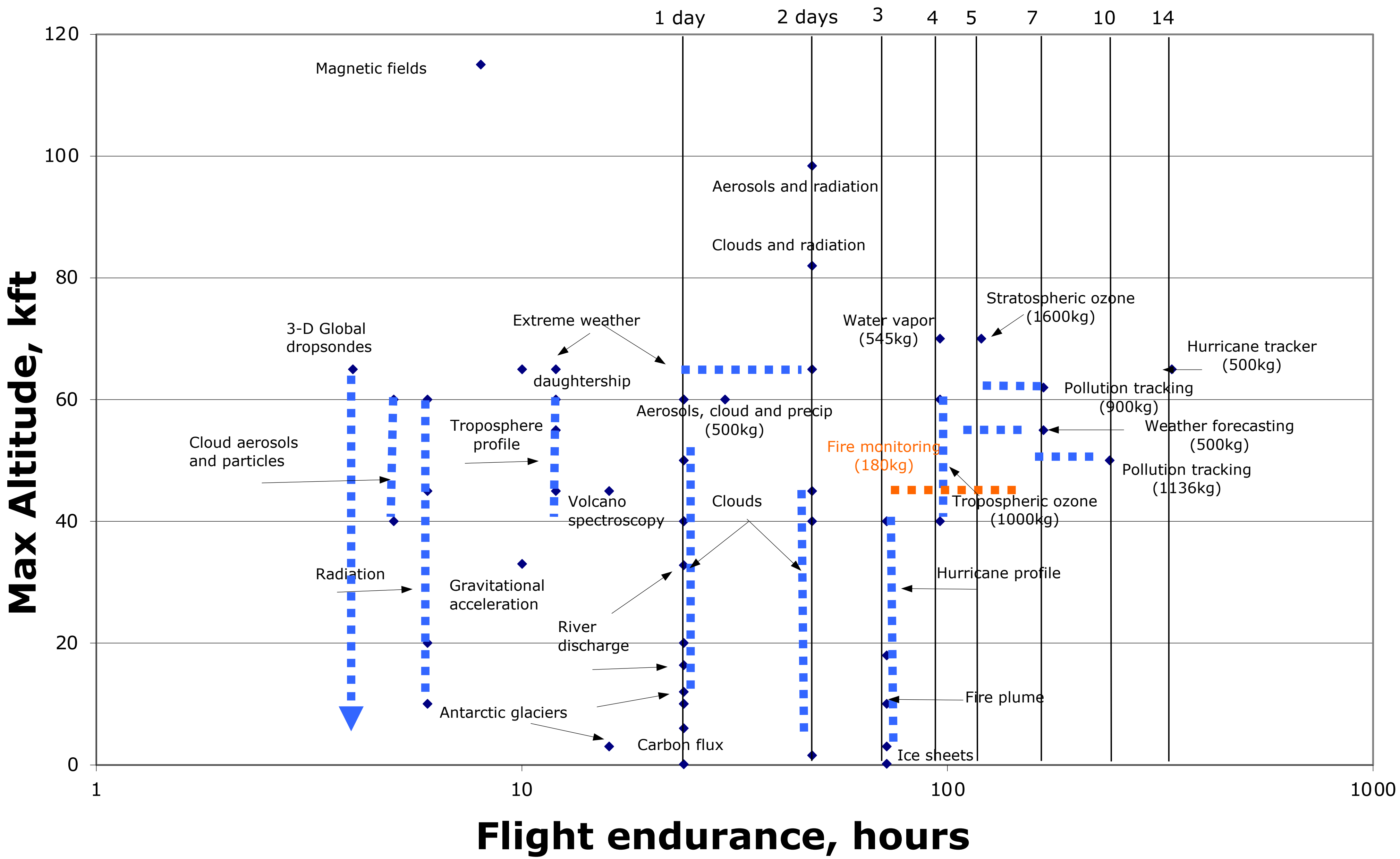
National Academies of Sciences, Engineering, and Medicine. 2021. Airborne Platforms to Advance NASA Earth System Science Priorities: Assessing the Future Need for a Large Aircraft. Washington, DC: The National Academies Press. https://doi.org/10.17226/26079.

"Measurements from long-duration UAS or stratospheric balloons could now have the capability of tracking the evolution of weather phenomena that have long lifetimes, such as the evolution of tropical cyclones, where it is important to observe the process of rapid intensification; the complete life cycle of cyclones as they traverse the United States; and collection of routine statistics on various meteorological phenomena." Pg. 75

"Finally, because rapid deployment and high temporal sampling are key requirements for disaster response, UAS measurements can be essential for capturing transient processes associated with geological disasters on timescales of hours and days, filling the data gap left by satellite observations." Pp. 115

However, while there are some promising developments in high-altitude, long-duration UAS and in steerable balloons, these technologies may not advance quickly enough to contribute significantly to Earth system science research within the next decade. PP 142 [emphasis added]

NASA Suborbital Science Missions of the Future (2004) : Science needs for HAPS



Science Needs – Surface Topography & Vegetation

Landslides generate significant time-varying topography. Given sufficiently fine spatial resolution, topography time-series are used to measure surface motion and detect changes from nearby background rates.

Following catastrophic landslides, differential topography can be used to infer large-scale displacements and landslide volumes, which can then be used to constrain physical models.

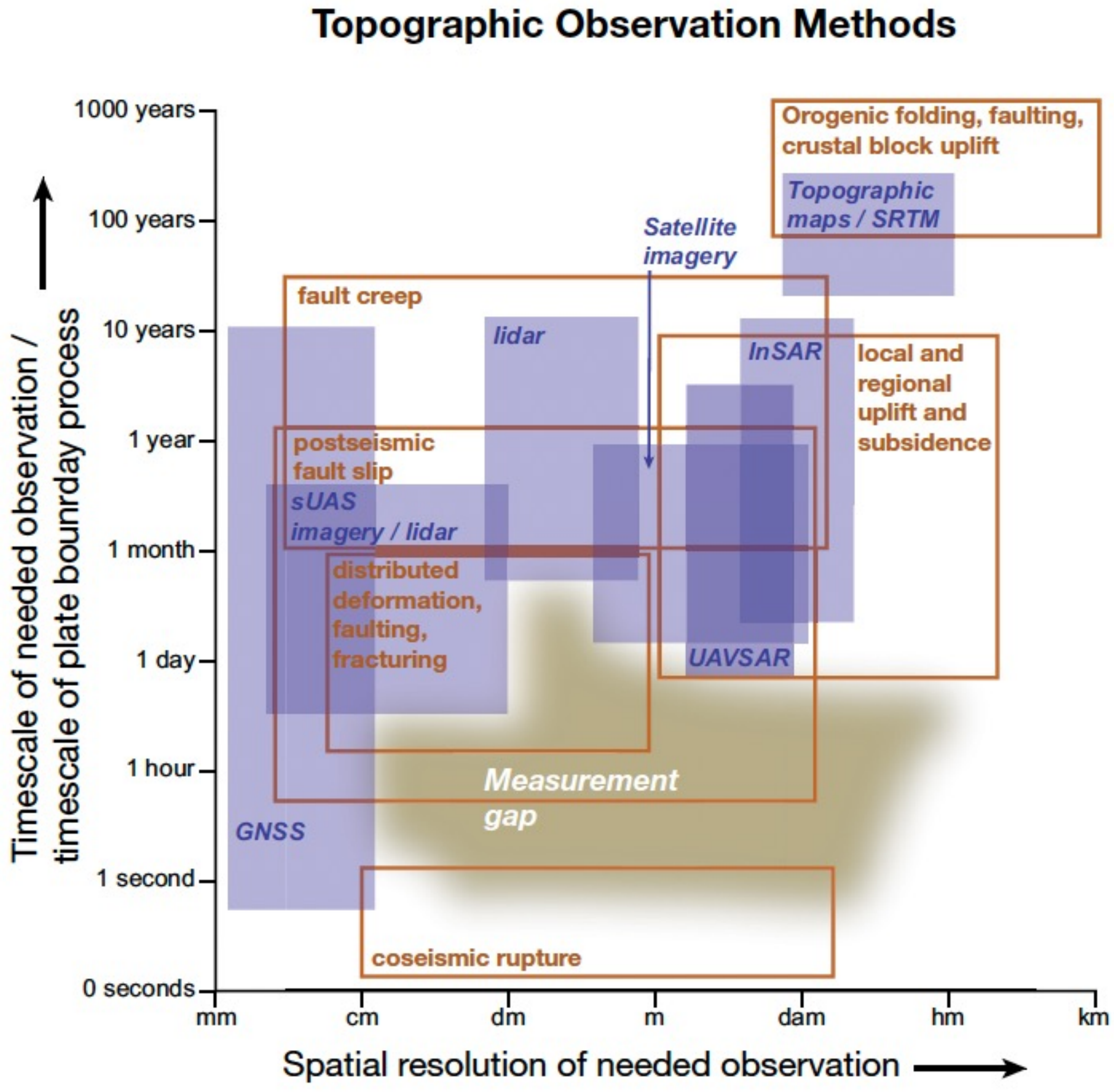
Rapidly capture the transient processes following disasters for improved predictive modeling, as well as response and mitigation through optimal re-tasking and analysis of space data. (DS: S-2a).

"High-resolution topography enables quantified assessments of landscape change due to erosion, deposition, and vegetation disturbance. An important objective for all of these data is the rapid dissemination of higher-level products to local emergency responders and the global scientific community."

Assess surface deformation, extent of surface change…of volcanic products following a volcanic eruption (hourly to daily temporal sampling). (DS: S-2b)

This focuses on volcano disaster response and builds on S-2a. Relevant topography data would include short repeat interval topography at low latency to measure loss and depositional changes to the landscape that would affect

FIGURE 3-3. Summary of current estimates of the spatial resolution and the timescale of needed observations. Relevant timescale of the solid earth process of interest. Measurement gap emphasizes need for high-frequency observations over a range of spatial scales and resolutions.



Medium Altitude Long Endurance (MALE) UAS for polar studies

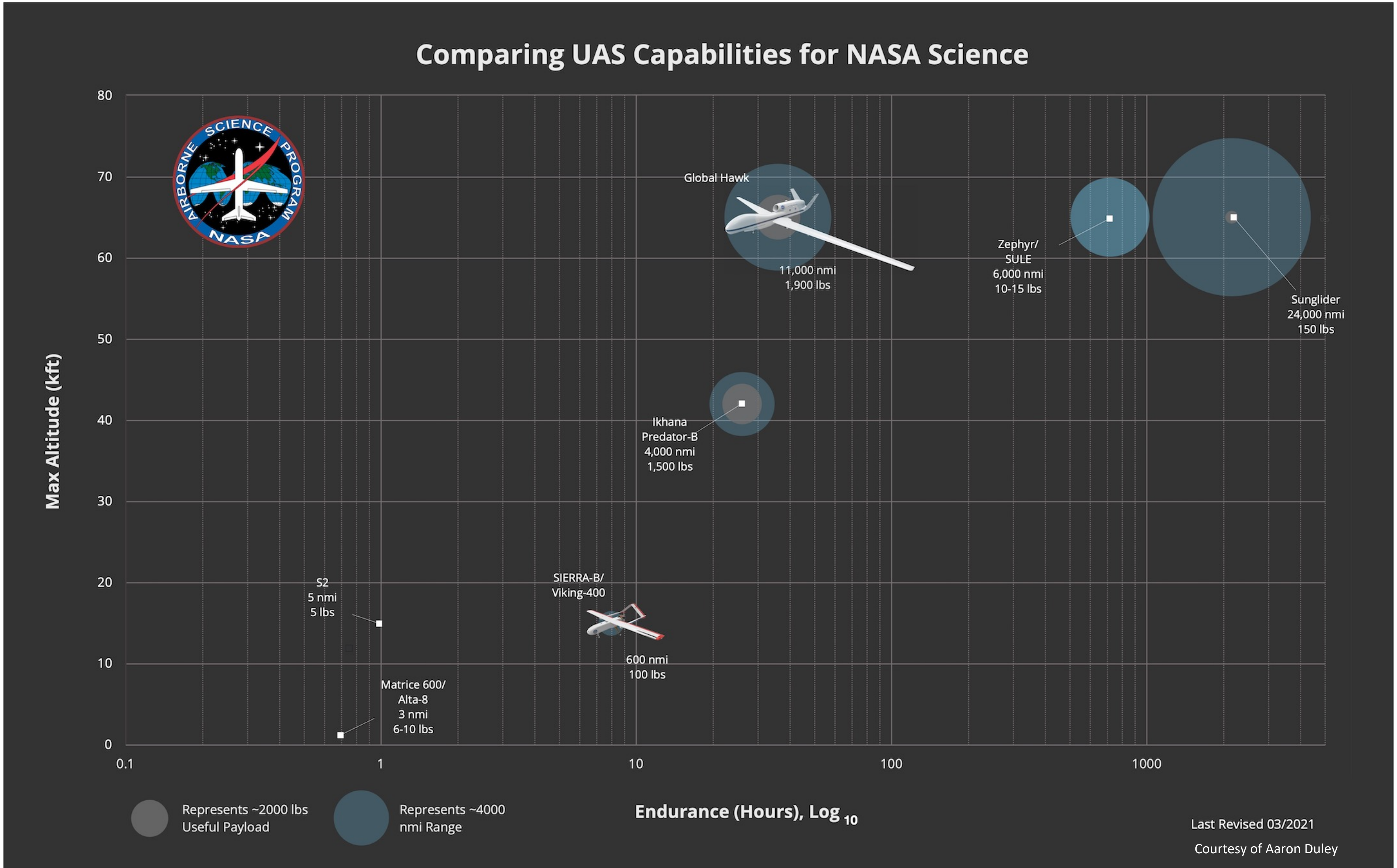
View of the Chamberlin Glacier from the tail camera of the Vanilla aircraft.
Photo credit: Platform Aerospace

- NASA Earth Science Cryospheric Science Program funded flights of the Vanilla MALE UAS (Platform Aerospace LLC)-carrying a snow radar as a pathfinder flight demonstration in 2021 over sea ice out of Alaska and in 2023 over the Greenland ice sheet

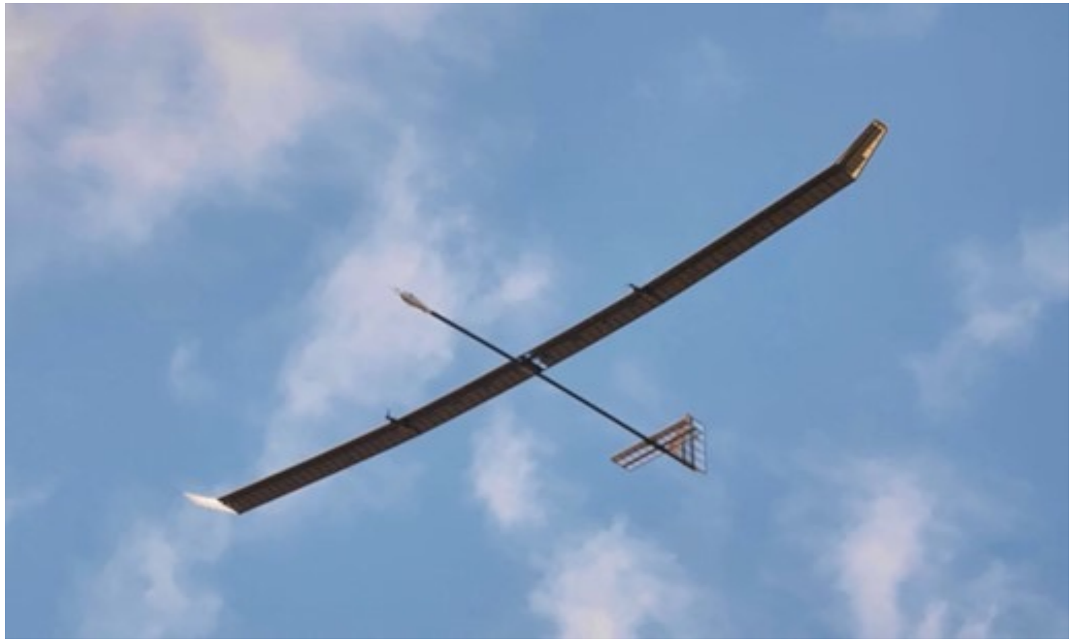
- University of Kansas (KU) Center for Remote Sensing of Ice Sheets (CReSIS) Snow Radar measures the snow thickness over sea ice and snow accumulation layers over glaciers and ice sheets.

- Snow depth on sea ice and snow accumulation are some of the most critically needed polar observations that cannot be taken from space.

PI: Dr. Brooke Medley, NASA GSFC


Comparing UAS Capabilities for NASA Science
Max Altitude (kft)
80
70
60
50
40
30
20
10
0
0.1
1
10
100
1000
Endurance (Hours), Log 10
AIRBORNE SCIENCE PROGRAM
NASA
Global Hawk
11,000 nmi
1,900 lbs
Zephyr/
SULE
6,000 nmi
10-15 lbs
Sunglider
24,000 nmi
150 lbs
Ikhana
Predator-B
4,000 nmi
1,500 lbs
S2
5 nmi
5 lbs
SIERRA-B/
Viking-400
600 nmi
100 lbs
Matrice 600/
Alta-8
3 nmi
6-10 lbs
Represents ~2000 lbs
Useful Payload
Represents ~4000
nmi Range
Last Revised 03/2021
Courtesy of Aaron Duley

Swift Engineering Ultra Long Endurance (SULE) aircraft
San Clemente, California, USA



Weight: 175 lbs
Altitude: 50-65k ft
Endurance: 100+ days
Payload capacity: Up to 15 lbs

- SBIR Phase II-Extended
- Primary payload in the nose compartment
- Currently operating from SpacePort

High-Altitude Long-Endurance Experiment (HALE-X)

Persistent IR imaging of wildfires

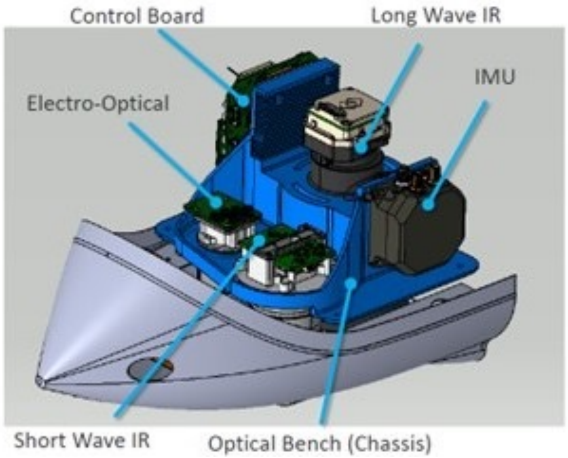
Sean Triplett (USFS), Matt Fladeland (NASA), Erik Rodin (USFS), Chris Bolz (USFS), Sam Markson (USFS)

A USFS-NASA partnership to demonstrate infrared observations for weeks to months using next generation solar-electric UAS

Goals:

- Provide **continuous realtime L2 data products on fire location and perimeter** for wildfire science and management.
- Demonstrate technical and procedural feasibility of airspace integration, logistics, and cost of operations for fixed-wing HALE UAS.
- Identify barriers to introducing this capability across the Nation for disaster response.

Swift Ultra Long Endurance UAS releasing from launch vehicle during first flight in July 2020 in New Mexico The vehicle was designed to stay aloft for 30 days at 20km with a 5kg payload.



HALE-X payload built by Swift with Sensor Labs and Lucent

NASA SBIR funded platform; NASA Ames is supporting Airworthiness/Safety and Airspace Integration with NASA ASP Project management

USDA/USFS/NIFC funded the payload development, integration and flight demonstration from New Mexico SpacePort

Next milestones:

- **Stratospheric tests in March 2024**
- **Flight demonstration in Summer 2024**

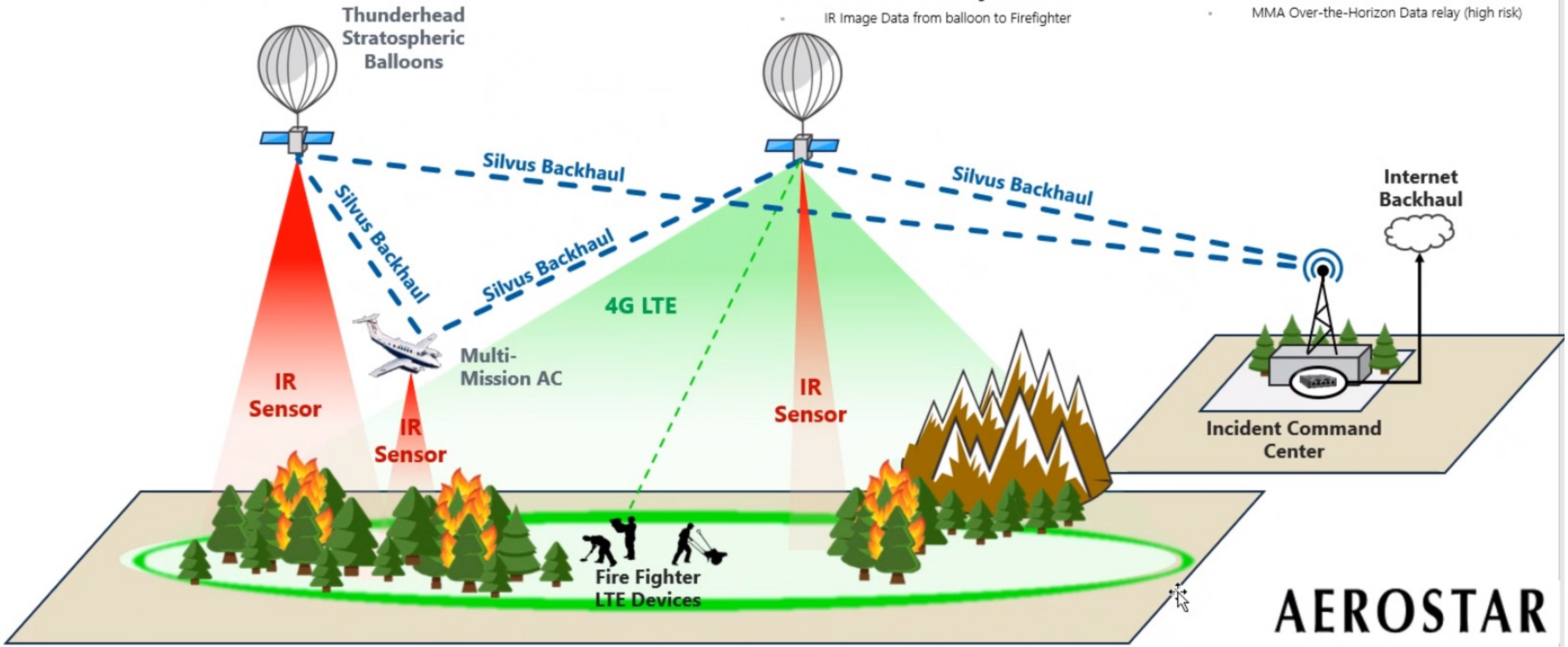
STRATO Background

- The USFS requires solutions for last mile connectivity to push data to the incident command center and staff on the fire-line
  - Improve incident response through low latency situational awareness
  - Adapt to quickly changing fires to save life and property
  - FirstNet tethered balloons provide limited coverage, are difficult to deploy and move
- NASA ARMD and SMD are formulating multi-year Programs to use NASA tools and technology for improving observations, models, and response to wildfires.
  - Improved models and observations rely on last mile connectivity to have an impact on management
  - One way to improve fire progression and emission models is to initialize models with data near-real time data from the incident
- This joint effort is intended to baseline the best available technology for providing persistent communications and observations to remote fire management teams
  - Enable NIFC/USDA/USFS to understand the cost and complexity of contracting for this service
  - Identify opportunities to improve the capability for NASA Science and Applications

NIFC FIRE COMMS CONOPS

Qty 2 Thunderhead Stratospheric Flights Proposed

- 4G LTE + Silvus + StratoCam
  - All previously flown payloads
  - Potential Demonstration Value
    - Voice, Text, and Data from IC to Firefighters
    - Voice and Text from Firefighters to IC
    - IR Image Data from balloon to Firefighter
- GFE Camera + Silvus
  - New camera integration
  - Potential Demonstration Value
    - Multispectral imagery taken from Stratosphere
    - Imagery backhaul to IC
    - MMA Over-the-Horizon Data relay (high risk)



AEROSTAR

High Altitude Long Endurance Platforms
NASA 2022 SBIR Phase 1 selections

<u>Guiding development of next generation platforms for science</u>

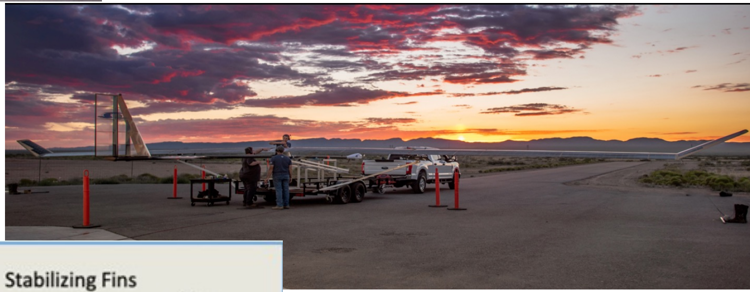
The NASA SBIR Program recently selected 5 new aircraft for Phase 1 funding. We are working across NASA Centers to support these teams during concept development and

<u>Goals:</u> Enable persistence over a science target with a 10kg payload for 30+ days and

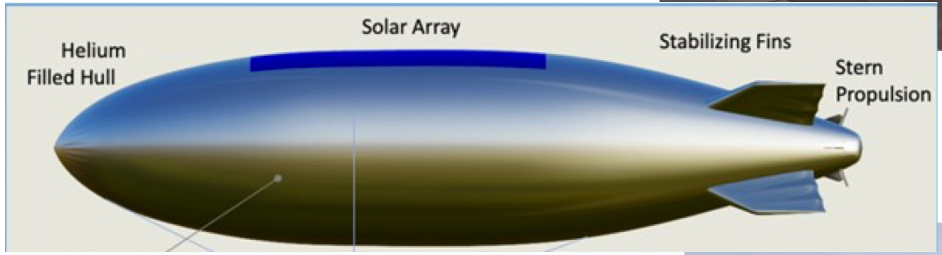
<u>Science interests</u>; Wildfire, hurricane formation and intensification, upper atmospheric chemistry, volcanic processes

SACOS (Electra)

Skydweller



SULE II (Swift)



S-HALE (Moonprint)

S2-VTOL (BlackSwift)

S16.04-1968 - Integrated Flight Validation of HALE UAP Avionics & Propulsion Systems for Science Missions

SBIR · STTR America's Seed Fund™ POWERED BY NASA

PI: James Stewart , Electra Aero Inc - Falls Church, VA

NON-PROPRIETARY DATA

IDENTIFICATION AND SIGNIFICANCE OF INNOVATION

The Stratospheric Airborne Climate Observing System (SACOS) is a solar powered, high altitude, long endurance (HALE) UAS that will be capable of remaining aloft up to a year at altitudes up to 85,000 feet to host active and passive payloads for climate science. The goal of the vehicle is to be a platform for instruments that have been under development at Harvard University for decades to collect in-situ and remotely sensed data that is crucial to strengthen the critical links between theory and global climate models. These small scale, yet highly sensitive instruments will help further our understanding of the physics that is so critical to ultimately developing science-based national and international economic policies to combat global climate change and address risks.

TECHNICAL OBJECTIVES AND PROPOSED DELIVERABLES

Objective 1 – Objective Aircraft Development. Complete the evaluation of the science sensor payloads and define the mechanical, electrical, and software interface into the SACOS concept to minimize weight (similar to the modular experiment interface panel). Refine the Objective Aircraft sizing point and complete the conceptual design (airframe, avionics, propulsion, etc.) for that vehicle. Present a Concept Design Review (CoDR) on the results.

Objective 2 – Propulsion and Avionics Development.
Procure and ground test an integrated battery pack (4 modules) including Avionics-BMS systems and interface to allow for integrated testing on the Dawn One demonstrator aircraft. Test charge/discharge/SOC management across packs in charge/discharge representing diurnal cycles. Procure and test the avionics architecture and integrate onto the copper bird for testing. Build and test objective aircraft HILSIM (including vehicle model) and test interface with copper bird.

Objective 3 – System Integration and Flight Testing.
Integrate avionics package into subscale surrogate aircraft to test "up and away" avionics package and reduce test risk on the objective aircraft. Integrate new avionics package and propulsion into Dawn One aircraft and complete ground test. Conduct low-altitude flight test of the new technologies on the aircraft. Document lessons and findings during testing.

TRL

Estimated

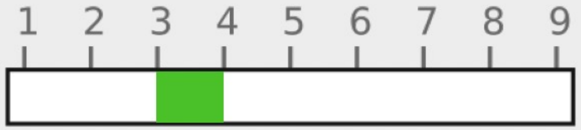


IMAGE TITLE: Electra "SACOS" HALE UAS

NASA APPLICATIONS

Numerous climate science related missions identified by stakeholder engagements with the NASA Airborne Science Program (Matt Fladeland), Cryospheric Science Program (Thorsten Markus), and NASA Goddard (Dave Harding).

NON-NASA APPLICATIONS

Science Missions: High Latitude Ice Observations (Antarctic Ice Shelf Collapse Forecasting, Greenland Glacier Flow Prediction), Direct Stratospheric Sampling (Sampling of Stratospheric Aerosols, In-situ Measurement of Storm Driven Stratospheric Chemistry), Drought, Wildfire, and Flood Monitoring (Coastal Flood Monitoring, Drought and Wildfire Prediction), Oceanic Surface and Cyclone Monitoring.

FIRM CONTACTS

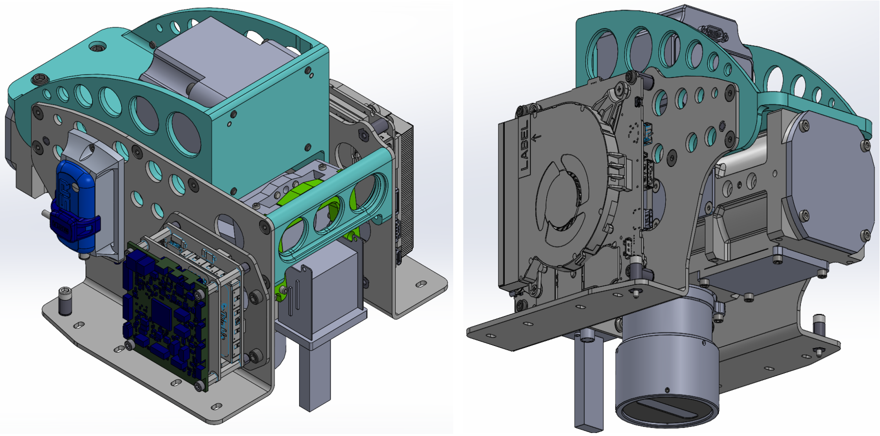
Ben Marchionna
Electra Aero Inc
EMAIL: marchionna.ben@electra.aero
PHONE: (248) 860-5606


Wingspan = 35m
Endurance = 30+ days
GTOW = 91 kg
Payload = 10 kg
Cruise Speed = 15 KEAS
Cruise Altitude = 20 km MSL
Max Climb Speed = 1 m/s
ELECTRA.AERO
SACOS – Dawn One
First Flight

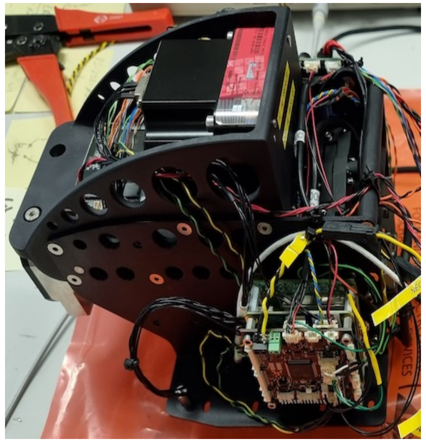
USGS/ARC Mjolnir V-1240 Hyperspectral Instrument

Project

- USGS National Land Imaging Program has interests related to Sustainable Land Imaging Program and mineral mapping while NASA is developing the Surface Biology and Geology Mission.
- This interagency partnership is intended to calibrate and fly the Hyspex Mjolnir as an example of science quality COT instruments for HAPS



CAD Model of the Mjolnir V-1240 Hyperspectral Instrument



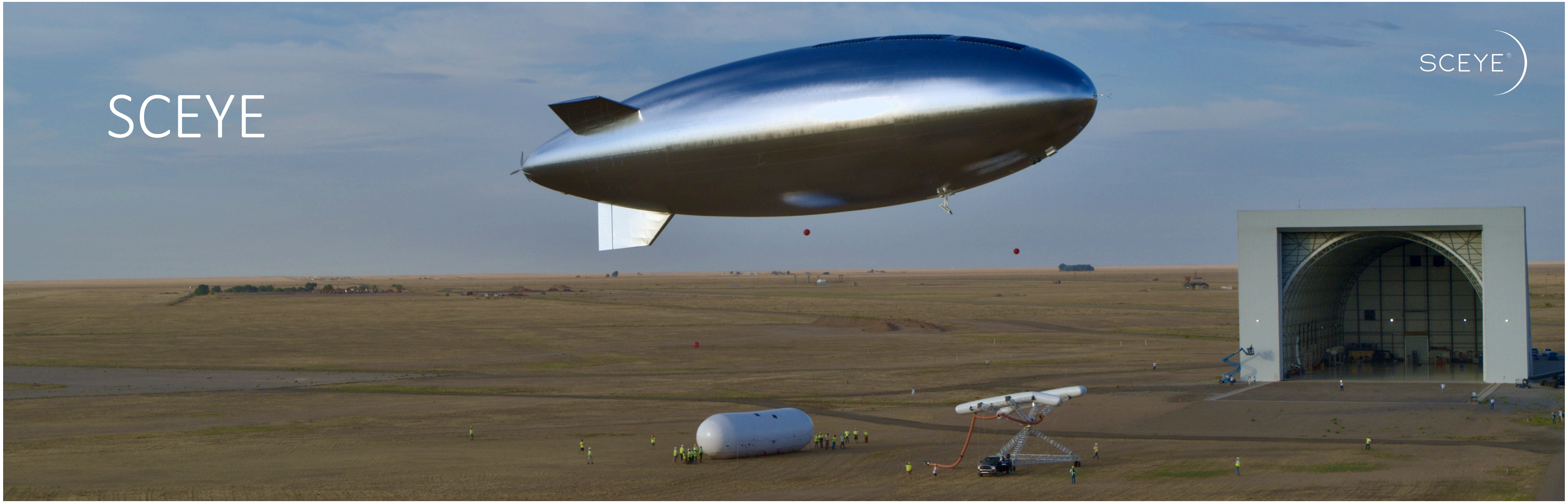
Mjolnir V-1240

Milestones

- Fly USGS Mjolnir V-1240 hyperspectral instrument on ER-2 on a non-interference basis during WDTS flight campaign – Fall 2022
- Collect in-flight data to characterize and evaluate the instrument performance including assessing data quality
- Evaluate instrument performance at the NASA Ames Airborne Sensor Facility (ASF) – 2023

Next Steps

- Secondary payload on SCEYE HAPS airship
- Flight on Swift Engineering HAPS for SBIR Phase IIE science demonstration
- Comparative analysis against PICARD and AVIRIS-C/-NG from WDTS flights



Platform

- The lighter-than-air platform is designed for month-long operations in ±40th latitude
- Combines station-keeping with significant payload capacity

Payload

- Existing payload includes wide-area LTE, high-resolution and hyperspectral cameras and IoT
- Platform is designed to be capable of lifting 100s of kg

Current Status

- Sceye completed 4-flight ascent dynamics program in 2023
- Flights in 2024 are focussed on finalizing testing, especially with regards to control dynamics

S1.08-7453 - Three Band Thermal Infrared Detector for CubeSats and UAS

PI: John Green , Xiomas Technologies, LLC - Ann Arbor, MI

SBIR · STTR America's Seed Fund™ POWERED BY NASA

NON-PROPRIETARY DATA

IDENTIFICATION AND SIGNIFICANCE OF INNOVATION

The overall objective of the SBIR is to develop a high performance, inexpensive, three-band thermal infrared camera system, suitable for deployment in Unmanned Airborne Systems and CubeSats. This imaging system will be capable of mapping thermal features on the surface of the earth with a high revisit rate and high spatial resolution. Xiomas believes the Three Band Infrared Detector (TBIRD) System will see significant demand as a small multiband thermal sensor onboard small to medium sized unmanned airborne vehicles (UAV) and space-based cubesat applications, in both the commercial and military markets.

TECHNICAL OBJECTIVES AND WORK PLAN

The overall objective of the SBIR is to develop a high performance, inexpensive, three-band thermal infrared camera system, suitable for deployment in small manned or Unmanned Airborne Systems (UAS) and CubeSats. This imaging system will be capable of mapping thermal features on the surface of the earth with a wide field of view, a high revisit rate, and high spatial resolution. Xiomas believes the Three Band Infrared Detector (TBIRD) System will see significant demand as a small multiband thermal sensor onboard small manned aircraft, small to medium sized unmanned airborne systems (UAS), and space-based cubesat, in both the civilian and military markets. The system will be useful for a wide variety of environmental research, disaster response, wildfire science, wildfire detection and mapping, oil spill mapping and detection, and thermal anomaly mapping in general.

During Phase II a TRL 7 flight ready prototype will be built, characterized, and flight-tested. During Phase II we propose to fly 2 flight tests in manned aircraft or small UAVs.

TRL

Estimated

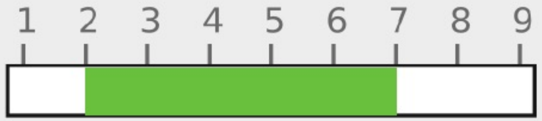
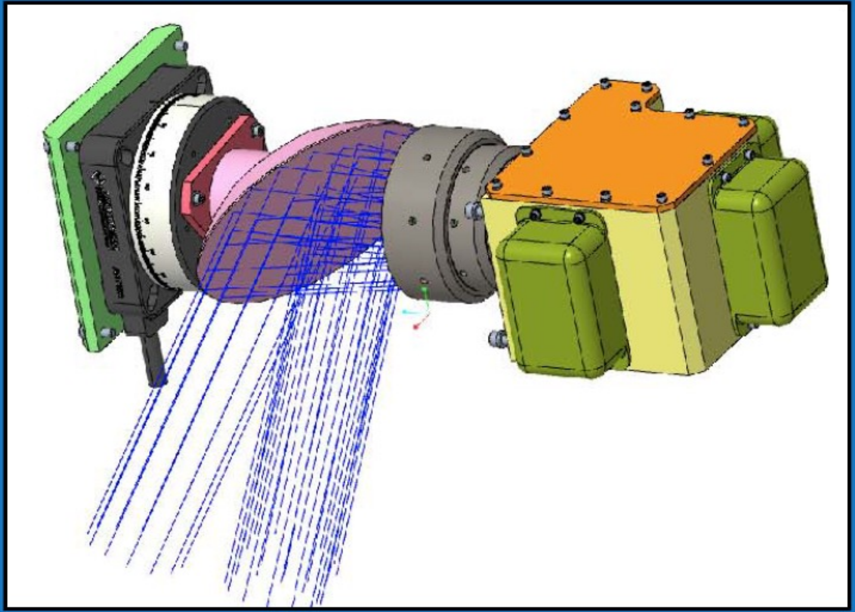


IMAGE TITLE: TBIRD



NASA APPLICATIONS

The system will be useful for a wide variety of environmental research, disaster response, wildfire science, wildfire detection and mapping, oil spill mapping and detection, and thermal anomaly mapping in general.

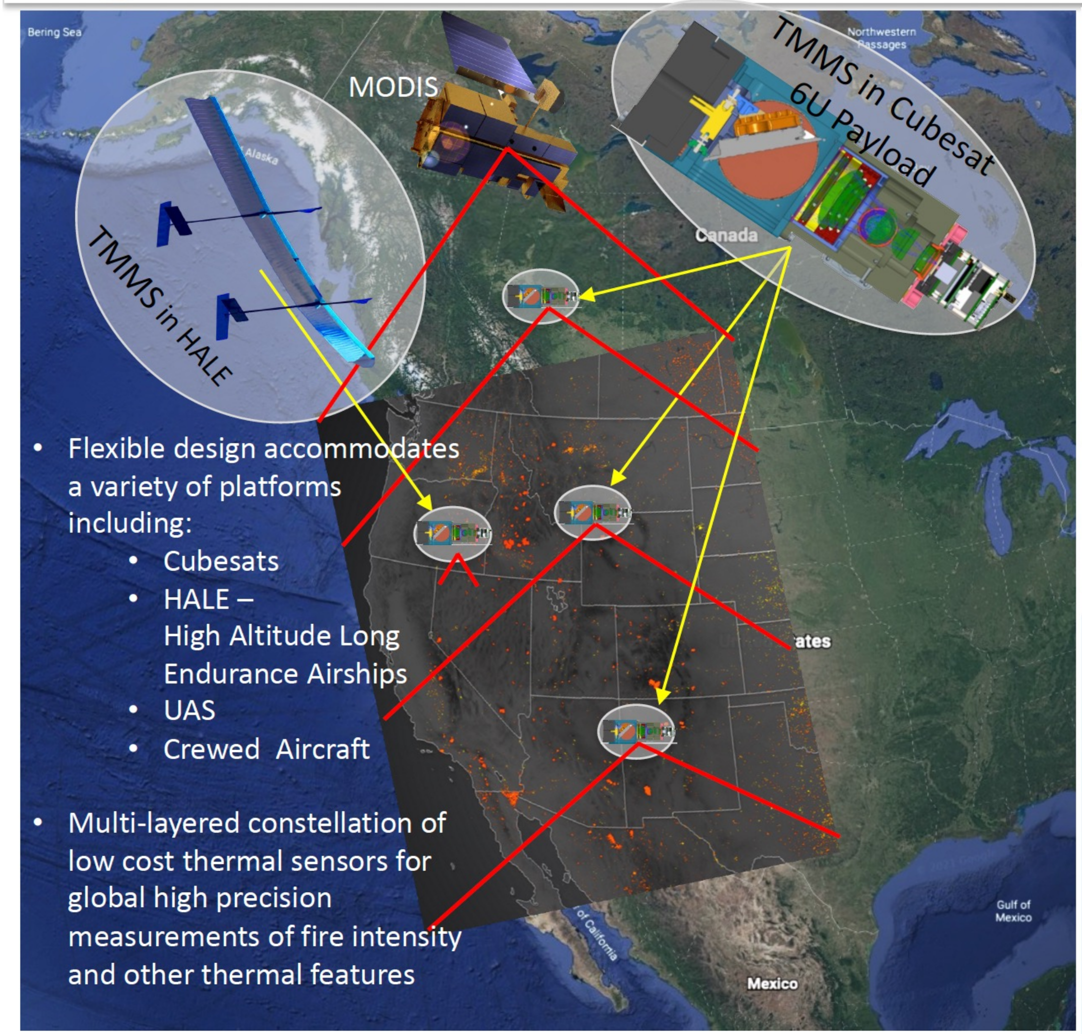
NON-NASA APPLICATIONS

Wildfire mapping, ground water mapping, heat loss studies
Military and Intelligence applications

FIRM CONTACTS

John Green
Xiomas Technologies, LLC
EMAIL: johngreen@xiomas.com
PHONE: (734) 646-6535

TMAS Sequential SBIR – NASA Contract 80NSSC23CA038
Thermal Mapping and Measurement System (TMMS)



- Flexible design accommodates a variety of platforms including:
  - Cubesats
  - HALE – High Altitude Long Endurance Airships
  - UAS
  - Crewed Aircraft
- Multi-layered constellation of low cost thermal sensors for global high precision measurements of fire intensity and other thermal features

	MODIS (LWIR)	24 TMMS in LEO	TMMS in HALE
Orbit	Polar 705 km AGL	Polar 705 km AGL	20 km AGL
Resolution	1,000 m	106 m	3 m
Swath	2300 km	2300 km	57 km diameter
Revisit	1 to 2 days	1 to 2 hours	Persistent 5 to 10 mins.

Flexible design allows any 3 bands between 3 and 12 um

- TMMS Propose Bands:
  - 3.96 um (60nm)
  - 9.05 um (300 nm)
  - 10.6 um (500 nm)

Flexible Design allows multi-layered constellation
  - Polar LEO
  - Elliptical LEO
  - HALE Stratospheric Platforms
  - Low Altitude Crewed Acft. and UAS

XIOMAS

Xiomas Technologies, L.L.C. https://xiomas.com johngreen@xiomas.com 734-646-6535

Compact Midwave Imaging System (CMIS)

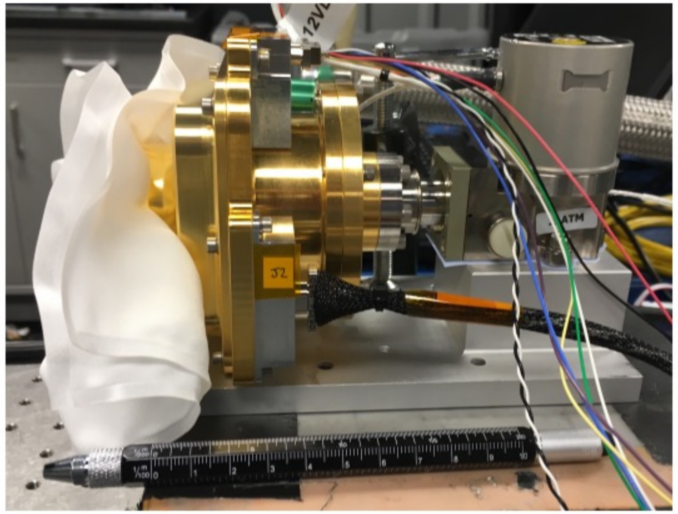
PI: Michael Kelly, Johns Hopkins University/Applied Physics Laboratory

Objective

Develop a midwave imager to provide key observations to meet objectives for the Planetary Boundary Layer (PBL) in the 2017 Earth Science Decadal Survey. The imager must:

- Achieve low weight, low volume and low power to enable accommodation on CubeSats
- Obtain radiometrically calibrated multi-spectral, multi-angular (nadir, fore, aft) imagery for accurate measurements of cloud heights and atmospheric motion vectors (AMVs)
- Provide wide field of view (53º) imagery to enable broad area coverage to complement lidar measurements
- Achieve high sensitivity across large dynamic range to support PBL studies in warm and cold regions (e.g. Arctic/Antarctic)

Conduct airborne flights on the LaRC Gulfstream-III to demonstrate CMIS capabilities that meet science measurement requirements.



CMIS Imager in the laboratory during integration and test phase

Approach

- Design and build imager with small size (< 2500 cm^3), low weight (3 kg), and low power (< 7 W)
- Perform laboratory and airborne geometric and radiometric calibration demonstrating NEdT <1 K at 233 K
- Develop and test data processing software, and generate higher level science products (e.g. cloud heights and AMVs)
- Conduct airborne test flights for scientifically relevant scenes to acquire planetary boundary layer (PBL) observations at three spectral bands (2.25, 3.75, 4.05 μm)

Co-Is/ Partners: Dong L Wu, GSFC; Sam Yee, JHU/APL; Andrew Heidinger, NOAA/NESDIS; Carole Anne Clayson, Woods Hole

Key Milestones

• Board functional tests complete	04/19
• Camera structure complete	05/19
• Focal plane module characterized	05/19
• CMIS electronics module integration	06/19
• CMIS Integration and Flight Campaign I	07/20
• Imagery correction in software	08/20
• Update laboratory calibration	10/20
• Flight Campaign II (2 science flights)	01/21
• Final report	03/21
• Publish final Results	03/21

TRL_{In} = 4 $TRL_{Current}$ = 5

A miniaturized payload for stratospheric aerosol composition and radiative properties from HALE aircraft

PI: Frank Keutsch/Harvard University

Target: Evaluate impact of non-sulfate component of stratospheric aerosol on satellite retrievals and atmospheric correction.

Science:

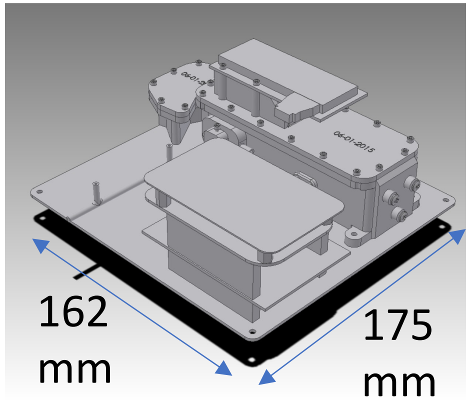
Utilize unique capability of HALE platform to provide critical mechanistic insights into stratospheric aerosol:

- How are the optical properties of stratospheric aerosols transformed over time, due to aging and mixing?
- How do aerosol composition, microphysics, and radiative properties vary for volcanic and wildfire sources?
- What are the sources of organic content in stratospheric aerosol?

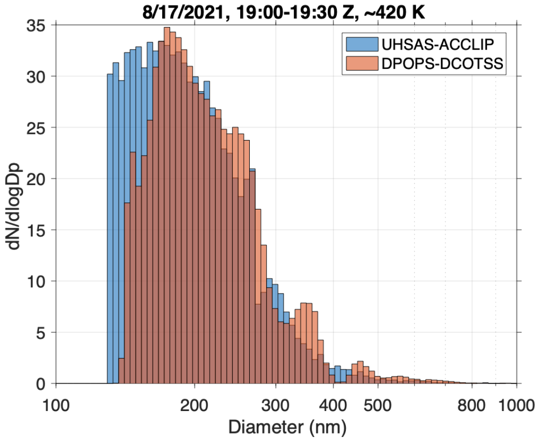
Objectives:

- Integrate customized off-the-shelf POPS (Portable Optical Particle Counter) optical particle counter (OPC) with SULE for a 30-day stratospheric deployment
- Support target selection and flight planning
- Perform scientific analysis of unique Lagrangian observations
- Provide mechanistic insights into spatial distribution and temporal variability of non-sulfate aerosol and their implications for satellite observations

CoIs: John Dykema/Harvard University



POPS OPC



Validated high-resolution size distribution measurements

Key Milestones:

- (M1) Analyze mechanical, thermal, and air sampling interfaces for HALE integration
- (M3) Fabricate mechanical fixture and sampling inlet and plumbing
- (M4) Assemble system and perform environmental test, calibrate
- (M5) Perform science calibration on laboratory bench
- (M6) Integrate with aircraft and functional test
- (M7) Conduct flight operations
- (M8) Recover instrument, return to laboratory
- (M9) Complete post-flight calibration and produce preliminary data product
- (M10) Science analysis and data finalization
- (M11) Conduct review with aircraft team
- (M12) Submit publication to atmospheric technology journal

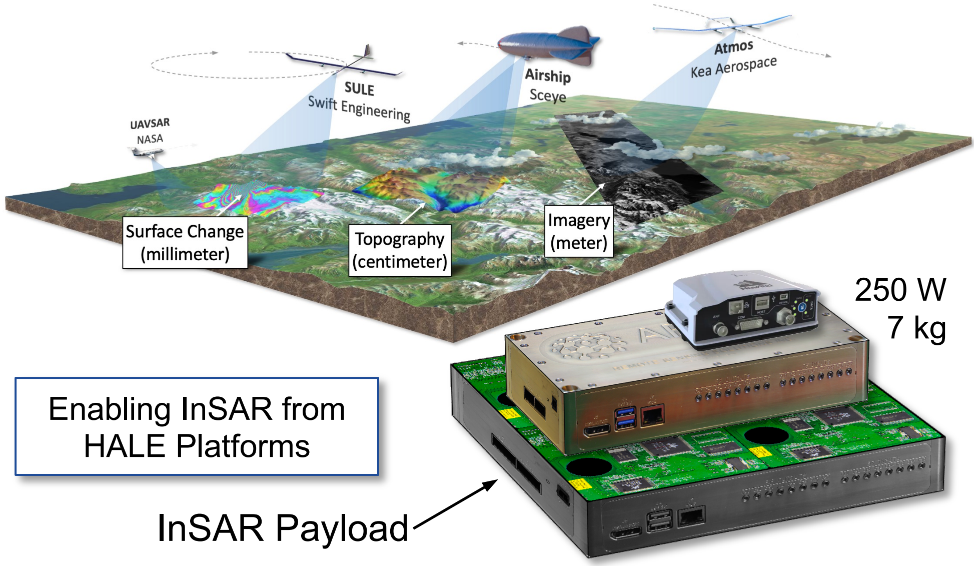
TRL 5 to 6

HALE InSAR: Continual and Precise Measurement of Earth's Changing Surface

PI: Lauren C. Wye, Aloft Sensing, Inc.

Objective

- Develop and demonstrate a compact (<7 kg, <250 W) X-band InSAR payload for stratospheric High Altitude Long Endurance (HALE) platforms to capture the high-frequency dynamics of critical geophysical processes in support of Solid Earth science
- HALE-proven low-SWaP InSAR payload will provide mm-level deformation and cm-level topographic measurements
  - Solar-powered HALE aircraft and airships offer affordable persistent regional access
  - Together, HALE-based InSAR enables continual and precise observation of science targets, currently unattainable with existing methods
- Develop and validate algorithms that overcome the challenges of HALE operations, such as low platform velocities and coarse trajectory control



Approach

- Prototype algorithms and verify operation with simulations
- Modify firmware and interfaces on software defined radar (SDRr)
- Design, build, and test active electronically steered array (AESA)
- Redesign Swift Ultra Long Endurance (SULE) nosecone to accommodate HALE-InSAR payload
- Integrate payload and complete first stratospheric flight
- Conduct long duration stratospheric flight
- Assess performance against models

Co-Is/Partners: P. Rennich, B. Pollard, Aloft; K. Sabet, EMAG; J. Carswell, RSS; H. Khalkhali, Swift; M. Fladeland, NASA ARC; . J. Stock, USGS

Key Milestones

• AESA Tile verified	11/22
• HALE algorithm prototypes verified	12/22
• AESA panel verified	06/23
• AESA system verified	08/23
• InSAR payload prototype complete	09/23
• Stratospheric first flight	01/24
• Long duration Stratospheric flight	07/24
• Embedded algorithm prototypes	10/24

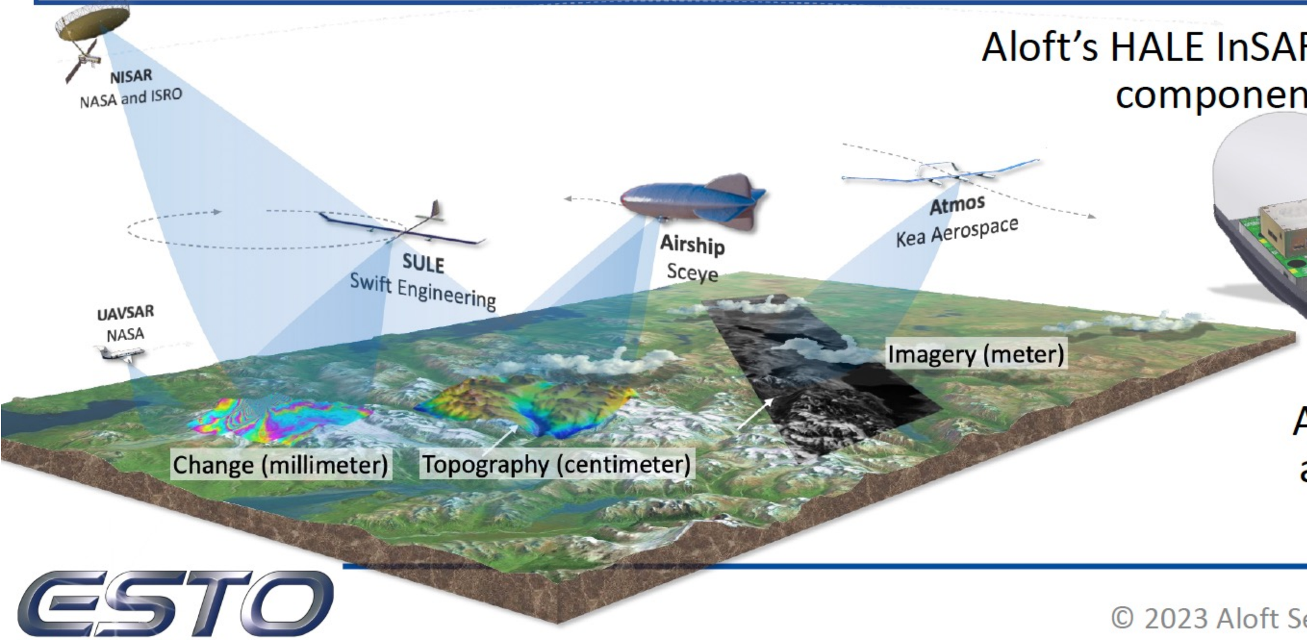
TRL_{in} = 2 **$TRL_{current}$ = 2**

Aloft IIP Project Summary

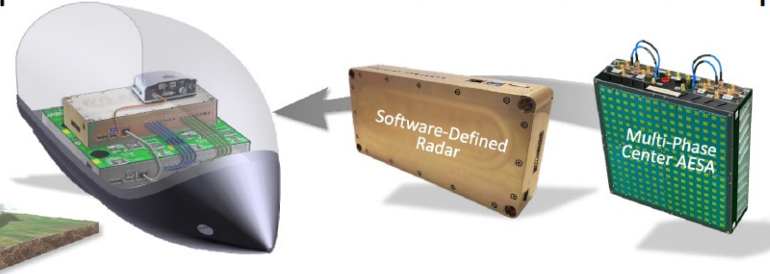
ALOFT SENSING

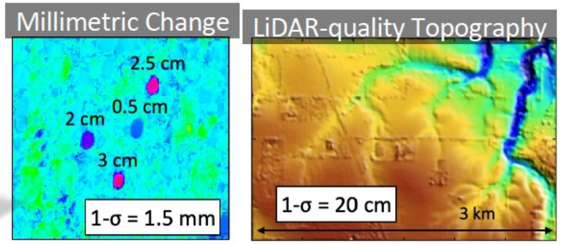
High Altitude, Long Endurance (HALE) InSAR for Continual and Precise Measurement of Earth's Changing Surface

- 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 smaller and more affordable HALE platforms.
- Aloft is refining these algorithms to **overcome the challenges** associated with HALE operations: relatively slow velocities, often irregular trajectories, and coarse navigation control.
  - Aloft positioning and timing techniques ("AloftPNT") maintain sensor coherence over long collection times and wide 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.



Aloft's HALE InSAR system is currently in development, with key technology components on schedule for a CY2024 stratospheric demonstration.





Aloft stratospheric demonstrations will show **mm-level deformation** and **cm-level topographic maps** at a **high repeat rate**, achieving the requirements of many key SDC and STV science objectives.

ESTO
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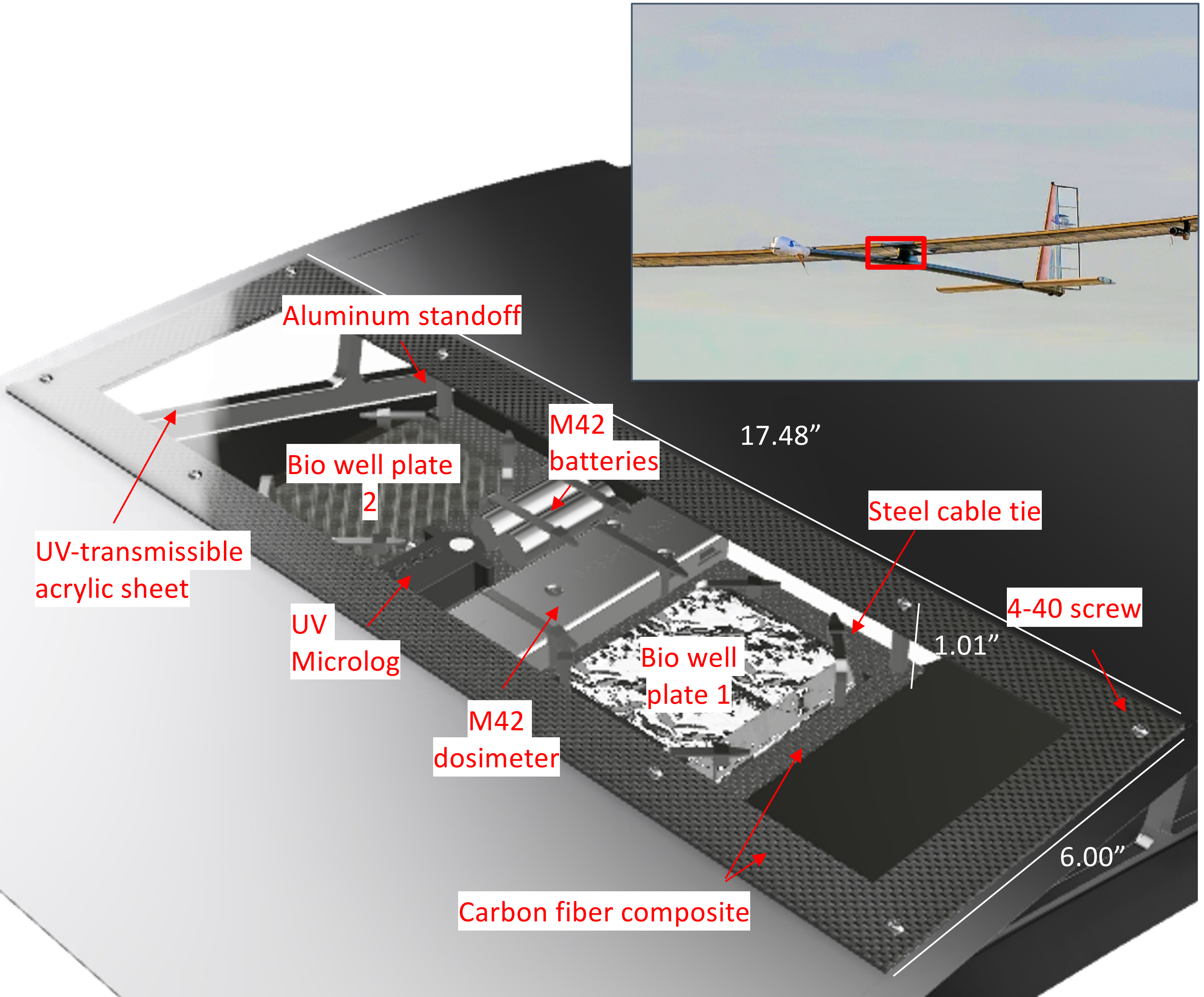
Contact: info@aloftsensing.com

RadBREAD secondary payload overview



- **Biological experiment:**
  - Study survival and gene expression of yeast (*S. cerevisiae*) exposed to stratosphere
- **Science objectives:**
  - Explore Swift HALE as a potential Mars analog research platform
  - Investigate countermeasures in extreme environments for future spaceflight missions
- **Collaborations:**
  - ***German Aerospace Center (DLR):*** M42 dosimeter
  - ***NASA ARC GeneLab:*** post-flight biological transcriptomic analysis

PI: Sigrid Reinsch, NASA Ames

Intelligent Long Endurance Observing System

PI: M. Chandarana (NASA Ames Research Center)

Objective

Intelligent Long Endurance Observing System (ILEOS):

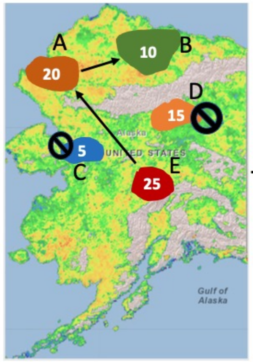
A *Science activity planning* system to enable NOS consisting of satellites and *HALE UAS-mounted instruments.*

Optimize *fine-grained spatio-temporal resolution data collection of GHG-relevant gases* using HALE UAS.

Incorporates *coarse-grained satellite GHG-data* and near real-time environmental (wind, weather, airspace constraints) data to generate high-value fine-grained resolution data collection plans.

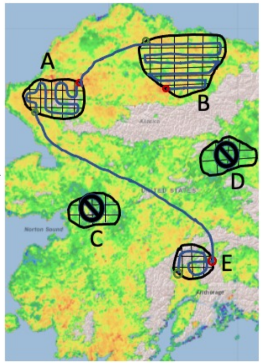
Designed for human operators; *plan explanation and data provenance features* will ensure science mission planners understand all key choices made while generating targets and plans.

IMPACT: Reduced cost for GHG observations in environments ranging from arctic to urban to offshore (some previously inaccessible), continuous observations not possible for current field/in-situ campaigns, improved science and health outcomes



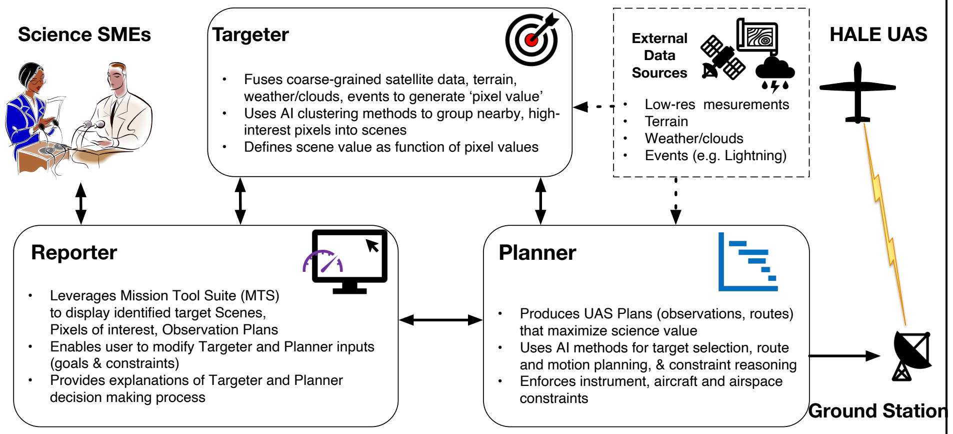
Scene Sequencing:
E ➡A ➡B

Route + Motion Planning Output (UAS plan)		
Plan Step	**Start time**	**Duration**
Travel from Start Location to **D** entry point	1	30 mins
Scan **D**: Lawnmower pattern	2	2 hours
Travel from **D** exit point to **A** entry point ETM: Avoid trajectory <x,y,z,t>	4	1 hour
Scan **A**: Spiral pattern	5	1 hour
Travel from **A** exit pt. to **B** entry pt.	6	30 mins
Scan **B**: Loiter over a single position	7	1 hour



Generated Flight Path

Approach



Co-Is/Partners: NASA GSFC, USGS, JHU

Key Milestones

- Complete ILEOS requirements / design — Q4/22
- Prototype ILEOS for NO2 science use case — Q4/23
- Prototype ILEOS for CH4 science use case — Q1/24
- 3d year proposal to AIST program — Q4/23
- User testing and evaluation of ILEOS — Q2/24
- Airborne Science Program integration reqts/design — Q3/24
- Infusion into Airborne Sciences Program — Q2/25
- Final Report / Project Closeout — Q2/25

$TRL_{in} = 3$
$TRL_{out} = 5$

ESTO
Earth Science Technology Office

Challenges

- Airspace management
  - Need to expand UTM-like tools for all altitudes for scheduling, tracking and deconfliction
  - Need ADS-B and BVLOS related technologies for improved knowledge of airspace users
  - International cooperation is needed to enable flights between flight regions
  - More flexibility in launch and recovery locations as well as glide and descent trajectories that enable ”fair weather following”

- Payload and subsystem mass reduction
  - SUAS and Cubesat engineering are a forcing function towards science-quality HAPS payloads
  - Lower SWAP SATCOM for smaller vehicles to enable BVLOS and spectrum deconfliction
  - Lighter and more power dense batteries

- Environmental considerations
  - Icing detection and mitigation
  - Higher wind tolerance

- Spectrum deconfliction
  - Need for dedicated aviation frequencies at all altitudes for this class of vehicle for radio line-of-site

Conclusions

- HAPS will play an important role in the NASA Earth System Observatory by complementing satellite measurements with higher spatial and temporal resolution
- The HALE-X and STRATO projects will fly in 2024
- NASA/SMD ESTO is investing in low SWAP payloads and planning/scheduling tools
- NASA/ARMD is furthering the development upper E traffic management systems

Thank you for attending SOARS!

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