



NASA Flight Opportunities

Fly, Fix, Fly: Using High-Altitude Balloons to Advance Technologies with Earth and Space Applications

Sean Bryan, Associate Research Professor, School of Earth and Space Exploration, Arizona State University

Community of Practice Webinar Series – December 7, 2022

Session will start at 10 a.m. PT – Please mute your microphone and turn off your camera

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1

NASA FLIGHT OPPORTUNITIES

NASA

Welcome to the Community of Practice Webinar Series!

First, a bit of housekeeping...

- Please mute your microphone and turn off your camera
- Today's session will be recorded
- Recordings for this and all future session will be posted on the Flight Opportunities website
- Please engage!
 - Use the chat throughout the session to ask questions

2

NASA FLIGHT OPPORTUNITIES

National Aeronautics and Space Administration

Flight Opportunities Mission

The Flight Opportunities program facilitates **rapid demonstration** of promising technologies for space exploration, discovery, and the expansion of space commerce through **suborbital testing with industry flight providers**.



3

3

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Join us for future Community of Practice webinars!

Watch our website and newsletter for next month's topic

nasa.gov/directorates/spacotech/flightopportunities/newsletter

Future webinars


- Webinars are held 1st Wednesday of each month at 10 a.m. PT
- Topics will be announced in the Flight Opportunities newsletter and website
- Session recordings will be posted on the Flight Opportunities website
- Let us know session topics you would like to see covered

4


4

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National Aeronautics and Space Administration



Today's Speaker

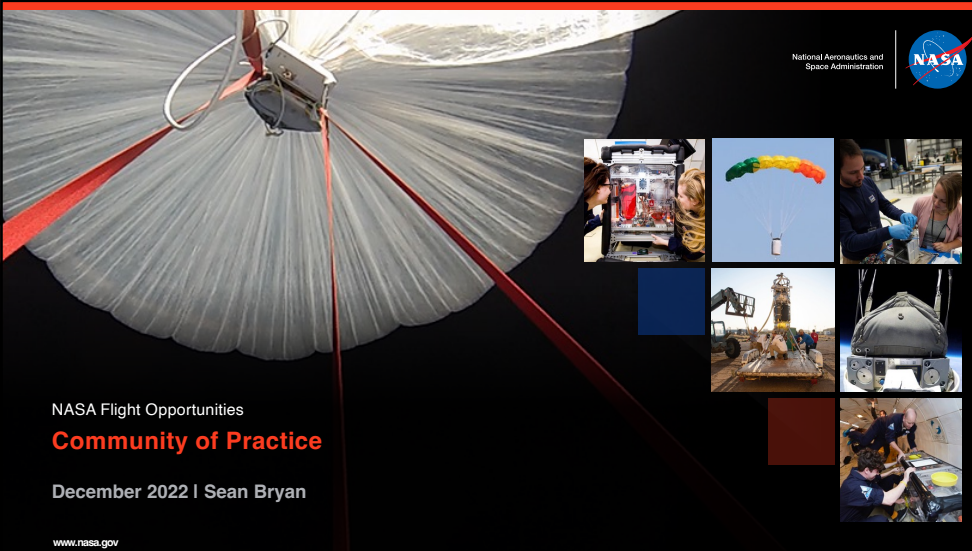



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Associate Research Professor
School of Earth and Space Exploration
Arizona State University

5

5

National Aeronautics and Space Administration



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December 2022 | Sean Bryan

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6



7

Atmospheric Temperature vs Altitude
 (Humidity Signal at 180 GHz)

1km | 3km | 5km | 7km | 9km | 11km | 13km | 15km

CubeSounder Technology Maturation

- **Deliver 3D weather data with microwave sounding**
 - Current leading driver of weather forecast accuracy
 - CubeSounder brings this capability to low-SWaP-C platforms for the first time
- **Mature ASU-developed technology to TRL6 with high-altitude balloon flights with World View**

mm-wave LNA

mm-wave Filter Bank

Diode Power Detectors

52 GHz (3 km temp.) 57 GHz (13 km temp.)

ASU School of Earth and Space Exploration
 Arizona State University
 Bryan, CubeSounder-3

8

CubeSounder Team

- **SESE:** PI Sean Bryan, Delondrae Carter, Walter Goodwin, Co-I Christopher Groppi, Jonathan Greenfield, Jae Joiner, Kyle Massingill, Co-I Philip Mauskopf, Bianca Pina, Philip Rybak, Joseph Tinlin, Peter Wullen



- **WISCA/ECEE:** Co-I Daniel Bliss, Michael Baricuatro, Roshni Suresh



- **NewSpace/SESE:** Scott Smas



9

THE IMPORTANCE OF EARTH INFORMATION

Earth-observing satellites provide critical information about our planet. This information supports a broad range of societal needs and enables the scientific discovery required to meet those needs, making us all healthier, safer, and more efficient.

HELPING PLAN OUR DAY

300 billion weather forecasts used by Americans every year

100+ million American adults use internet-based mapping services

Americans rely on sophisticated Earth information throughout their everyday lives, from weather forecasts to navigation applications in their cars. Satellites are the original sources of much of the data.

PROTECTING OUR HEALTH

6.5 million premature deaths from air pollution around the world every year

Earth-observing satellites track the concentration of harmful pollutants across the country, providing air quality data for rural areas without ground-based monitoring systems and measuring the effects of air quality regulations.

50% of the world's population is at risk from malaria.

Satellite observations of temperature, vegetation, and rainfall help predict the spread of mosquito-borne illnesses like malaria, Zika, and West Nile Virus.

KEEPING US SECURE

The estimated value of NASA and NOAA information services to the U.S. Navy's operational effectiveness is **\$2 billion** per year.

The U.S. Navy and other U.S. defense agencies partner with NASA and NOAA to use satellite data, to access operational services, and to leverage their scientific progress.

MITIGATING NATURAL DISASTERS

Extreme weather and fires have cost the federal government more than **\$350 billion** over the past decade.

Satellite measurements play a critical role in tracking the paths of hurricanes and wildfires so that we can warn populations at risk, assess the damages, and avoid future costs.

ENSURING RESOURCE AVAILABILITY

Advanced technology, including many types of Earth information will unlock up to **\$1.6 trillion** in economic savings for energy generation and use by 2025.

Satellite observations can also help ensure water availability, which is particularly important to the 20% of the world now living in areas of water scarcity.

Slide: NAS/NASA Decadal Survey

10

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Weather

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Weather for Military Operations

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MITIGATING NATURAL DISASTERS

Extreme weather and fires have cost the federal government **\$350 billion** over the past decade.

Hurricanes, Disasters, Storms

Real-time satellite data is tracking the path of hurricanes and other storms as they develop.

ENSURING RESOURCE AVAILABILITY

Advanced technology, including many types of Earth information, will unlock up to **\$1.6 trillion** in economic potential for energy generation and use by 2025.

Water, Studying the Desert

Satellite observations can help us to monitor water availability, which is increasingly important to the well-being of the world's growing population.

Slide: NAS/NASA Decadal Survey

11

CubeSounder Nominal Design: Comparison with State of the Art


- Bring state-of-the-art **3D weather sensing capability to low-SWaP-C platforms for the first time**
- Enable wider deployment with **~10x improved SWaP-C for better coverage to improve forecast accuracy and lead time**

	SOA (ATMS)	Advancement
SWaP	70x60x40 cm 185 lbs 130 Watts	<32x22x22cm <11 lbs <20 Watts
Frequency Coverage	22 channels 24-190 GHz	18 channels 50-183 GHz
Sensitivity	NE(Δ)T: 36-266 mK√s ±1-2% rel. humidity ±0.25-0.4 K temperature in 2 km vertical bins per s	30-41 mK√s ±1-3% ±0.3-0.8 K in 2 km bins per s
Stability	LO Frequency Instability	Inherently Stable

12

World View Capabilities

- Fly commercial high-altitude balloons with earth-observing and communications payload modules
- Provide continuous coverage of the Continental US and other regions with station-keeping capability

WORLD VIEW

Based in Tucson, AZ

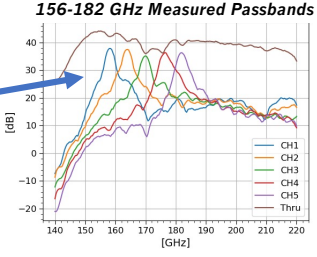
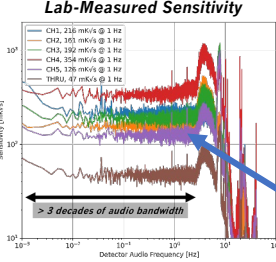
Persistent Coverage

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13

Sensitivity and Passband Performance

- **Measure channel passbands and sensitivity**
 - Passbands with mm-wave VNA
 - Liquid nitrogen source as sensitivity reference
- **Deliver further sensitivity improvement by selecting higher-performance COTS detectors in future mission**
- **Integrate 60 GHz system working on bench into flight test payload**

156-182 GHz Measured Passbands

Well-controlled sensor passbands

Lab-Measured Sensitivity

Near-SoA lab-measured sensor sensitivity and stability across broad audio bandwidth (i.e. 10s to 1000+ km spatial scales)

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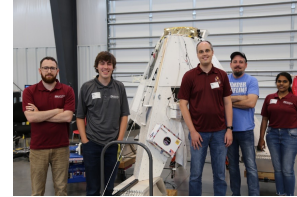
14

Payload/Vehicle Integration Team for Flight Test

- Mature sensor technology to **TRL6** after successful balloon flight of prototype payload **April 9-13th 2022**

- 100 hours of flight data
- 60,000 - 75,000 ft altitudes

October 2021 Vehicle Integration Team

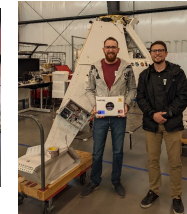


- Upgrade electronics, replace 183 GHz LNAs, and add 60 GHz band for next balloon flight

April 2022 Launch



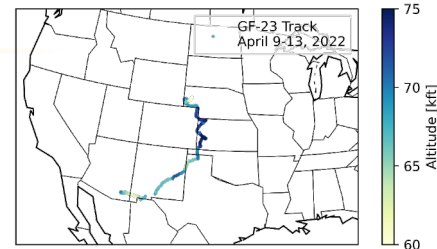
April 2022 Vehicle Integration Team



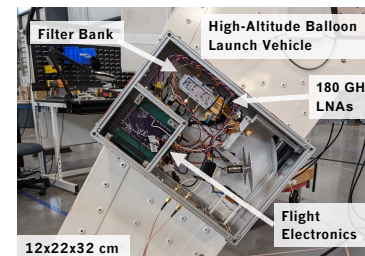
Flight Test

- Mature sensor technology to **TRL6** after successful balloon flight of prototype payload **April 9-13th 2022**

- 100 hours of flight data
- 60,000 - 75,000 ft altitudes
- Provided through ongoing CubeSounder NASA Flight Opportunities program



- Upgrade electronics, replace 183 GHz LNAs, and add 60 GHz band for next balloon flight



Conclusions

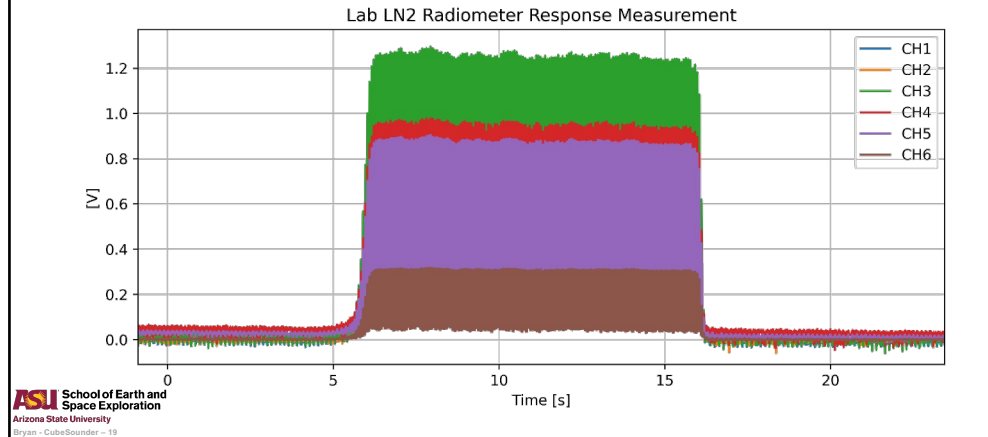
- **Mature ASU-developed weather sensing technology to TRL6 with high-altitude balloon flights with World View**
- **Learn from results of the successful April 2022 flight**
- **Integrate upgraded hardware already working on the bench into payload for upcoming flight**

Additional Material: 180 GHz Sensor Calibration Details

- **Characterize sensor noise level and stability in the lab**

Evaluating the Balloon Prototype Payload: Lab

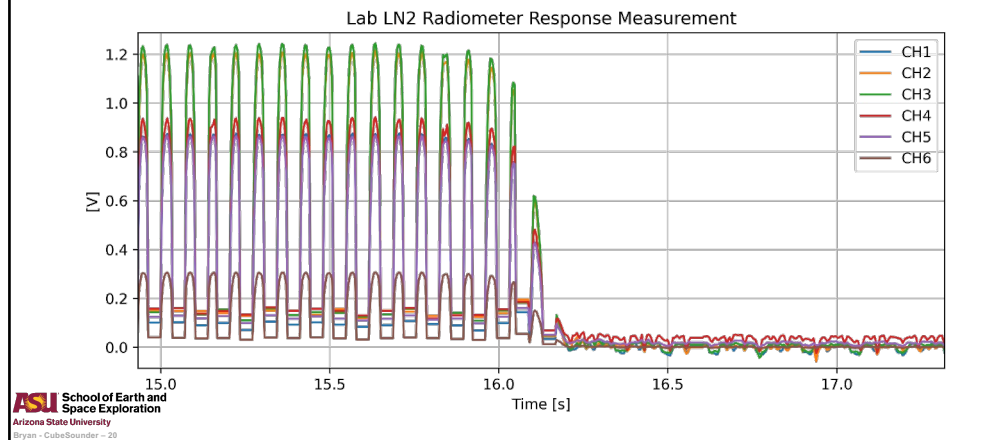
- Calibrate with liquid nitrogen load



19

Evaluating the Balloon Prototype Payload: Lab

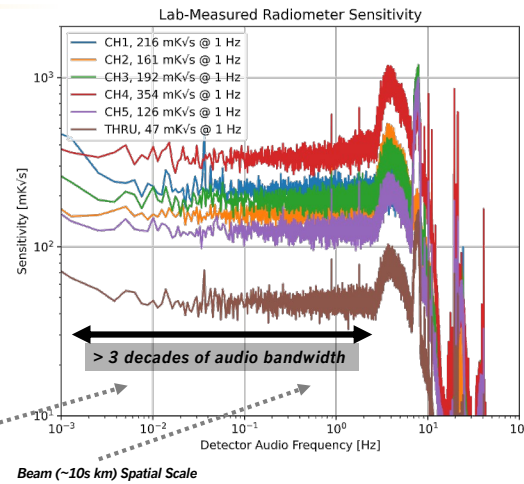
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20

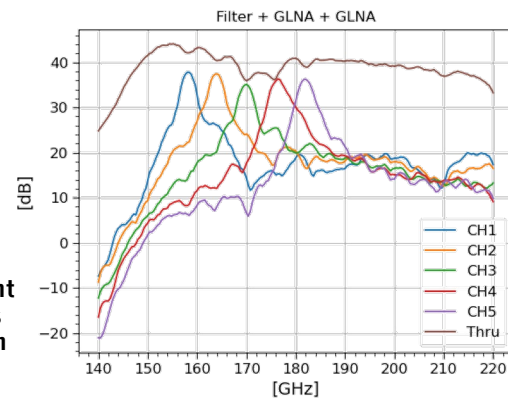
Evaluating the Balloon Prototype Payload: Lab

- **Measure noise stability with flight readout electronics**
 - Improved white noise level due to upgraded LNA and ADCs
 - Stability over >1000 s timescales to 3 Hz, >three decades of audio BW
- **Compare with 36-226 mKrts sensitivity in SoA 150-180 GHz ATMS sensor**
 - ~10x SWaP-C improvement
- **Scale system towards theoretical limit of 30-40 mKrts**



Measured Sensor Passbands

- **Use vector network analyzer (VNA) to measure passbands of filter bank and gain profile of each LNA**
- **Combine measurements to yield end-to-end passbands of each radiometer channel**
- **Demonstrate excellent agreement between as-build measurements and filter bank theoretical design**




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Thank you!

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<http://nasa.gov/flightopportunities>

Contact us:
NASA-FlightOpportunities@mail.nasa.gov



23 www.nasa.gov