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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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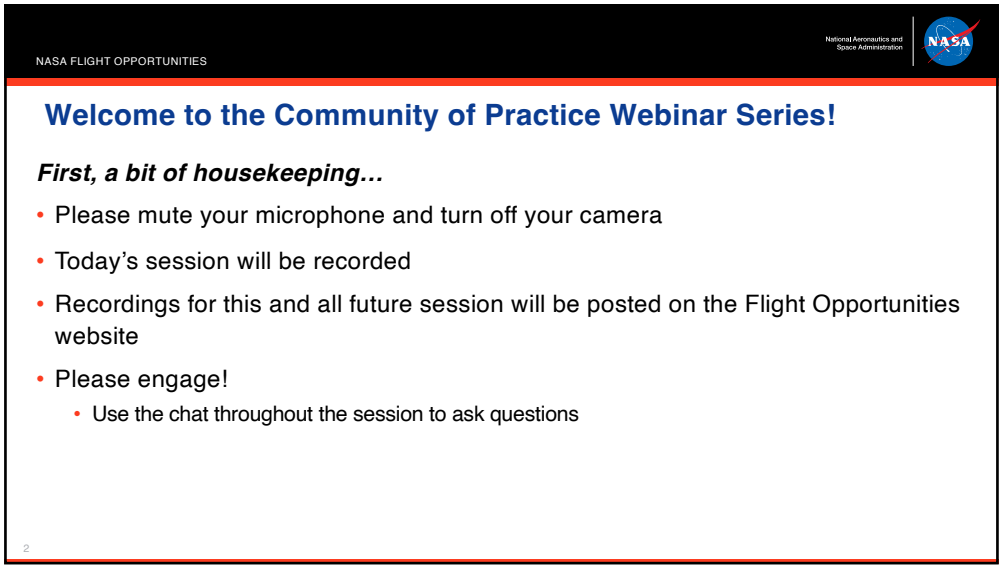
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Welcome to the Community of Practice Webinar Series!
First, a bit of housekeeping…
Please mute your microphone and turn off your camera
Today's session will be recorded
Recordings for this and all future session will be posted on the Flight Opportunities website
Please engage!
Use the chat throughout the session to ask questions
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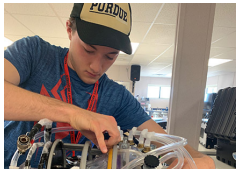
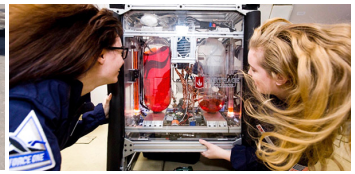
National Aeronautics and Space Administration

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**.





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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/spacetech/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

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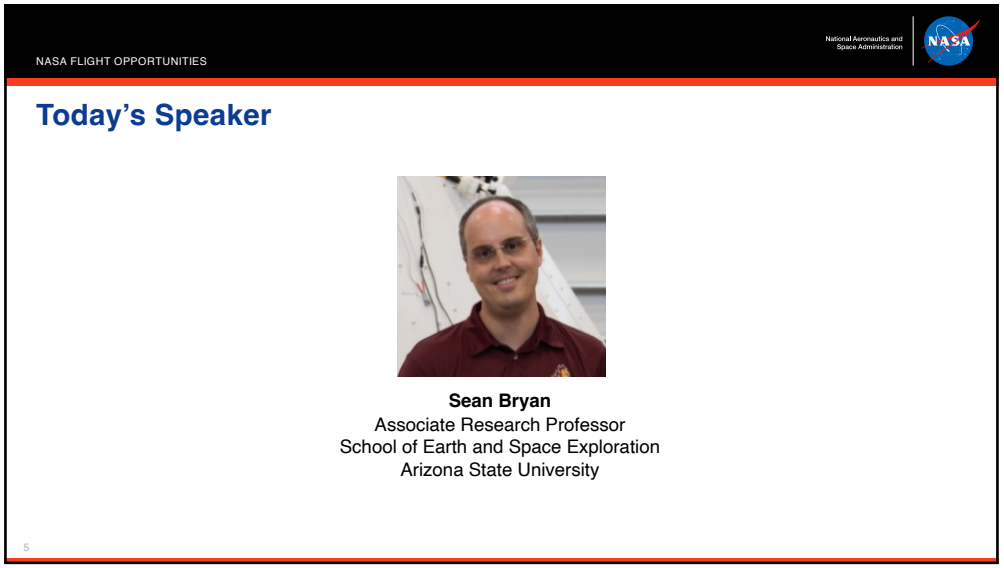
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Today's Speaker
Sean Bryan
Associate Research Professor
School of Earth and Space Exploration
Arizona State University
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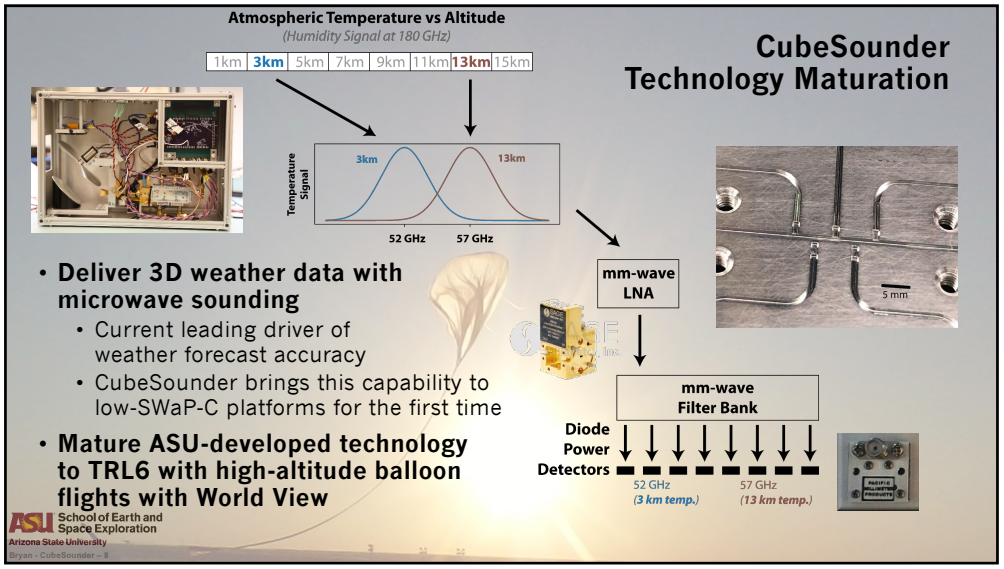
Atmospheric Temperature vs Altitude
(Humidity Signal at 180 GHz)
1km 3km 5km 7km 9km 11km 13km 15km
Temperature Signal
3km
13km
52 GHz
57 GHz
CubeSounder Technology Maturation
mm-wave LNA
mm-wave Filter Bank
Diode Power Detectors
52 GHz (3 km temp.)
57 GHz (13 km temp.)
5 mm
• Deliver 3D weather data 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
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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

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WISCA
Center for Wireless Information Systems and Computational Architectures

ASU NewSpace
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WORLD VIEW

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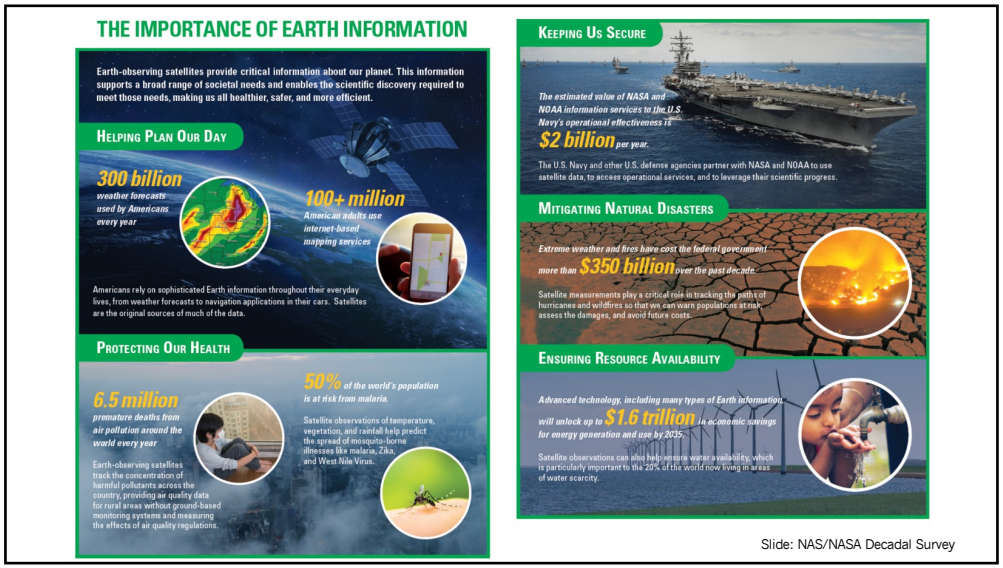

Slide: NAS/NASA Decadal Survey

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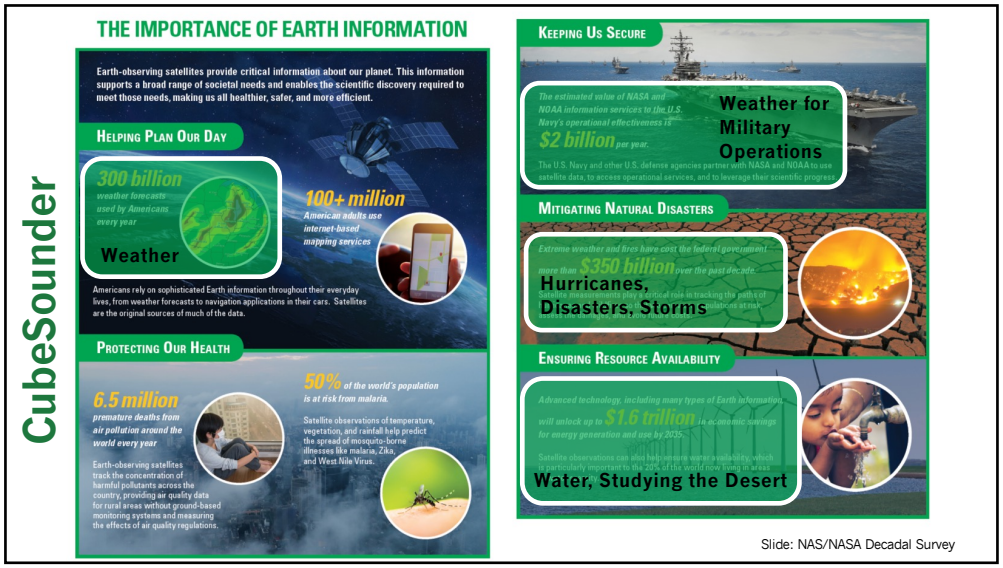

Slide: NAS/NASA Decadal Survey

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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**

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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

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WORLD VIEW

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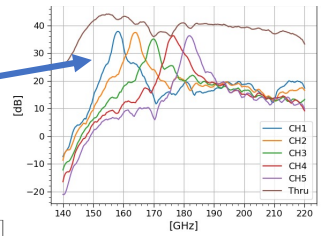
Sensitivity and Passband Performance

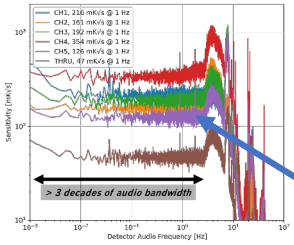
- **Measure channel passbands and sensitivity**
  - Passbands with mm-wave VNA
  - Liquid nitrogen source as sensitivity reference
- **Deliver further sensitivity improvement by selecting higher-performance COTS detectors in future mission**
- **Integrate 60 GHz system working on bench into flight test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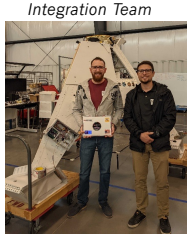
Payload/Vehicle Integration Team for Flight Test

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

October 2021 Vehicle Integration Team

April 2022 Vehicle Integration Team



April 2022 Launch

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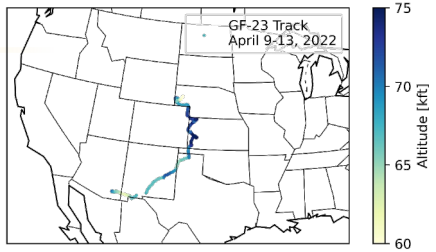
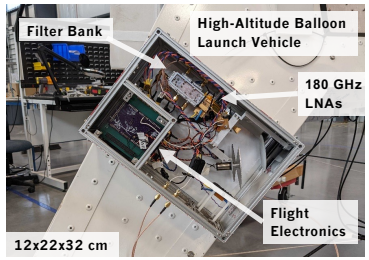
Flight Test

- **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**





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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

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Additional Material: 180 GHz Sensor Calibration Details

- Characterize sensor noise level and stability in the lab

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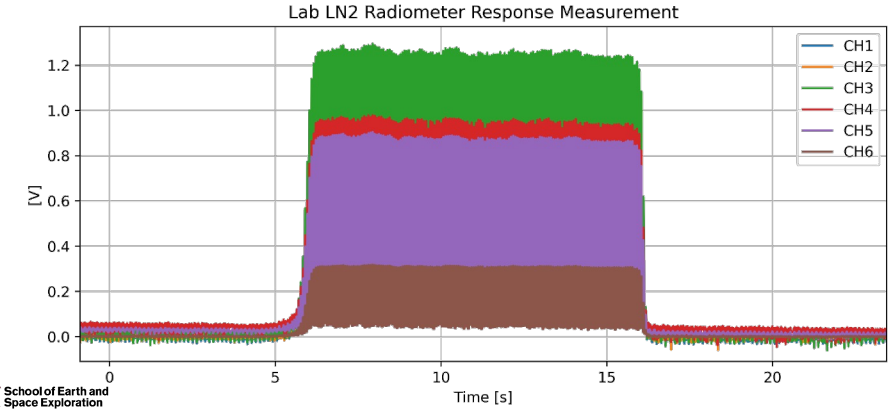
Evaluating the Balloon Prototype Payload: Lab

- **Calibrate with liquid nitrogen load**



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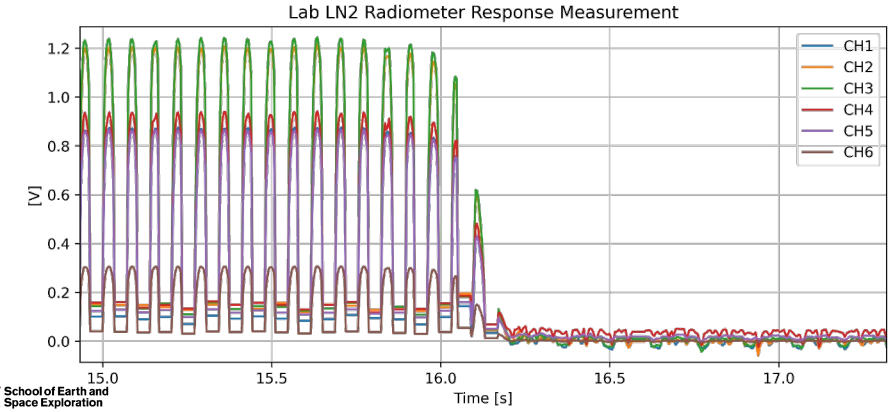
Evaluating the Balloon Prototype Payload: Lab

- **Calibrate with liquid nitrogen load**



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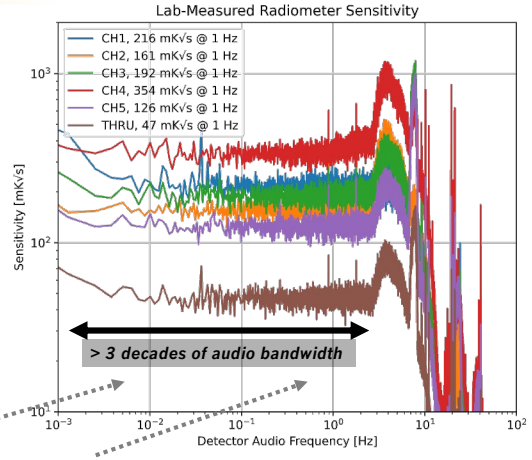
Evaluating the Balloon Prototype Payload: Lab

- **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**



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Continent (~1000s km) Spatial Scale

Beam (~10s km) Spatial Scale

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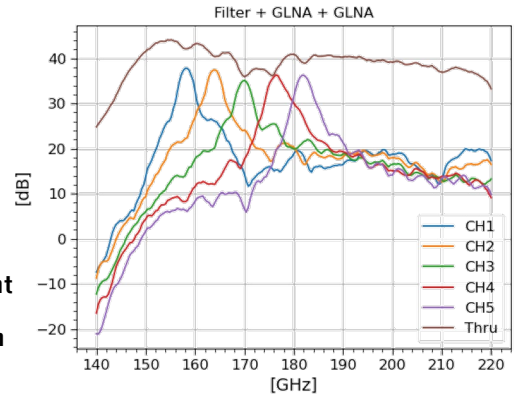
Measured Sensor Passbands

- **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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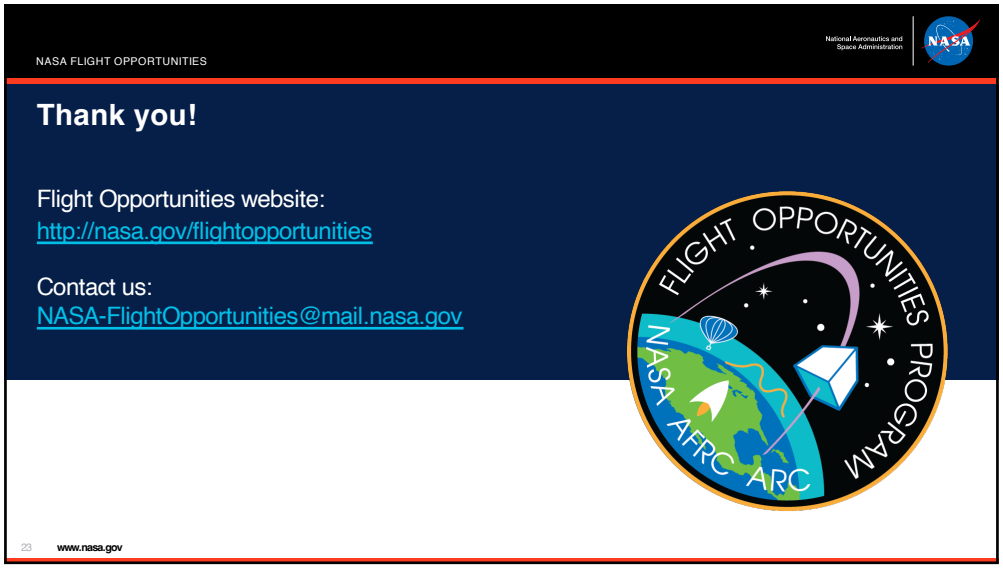
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