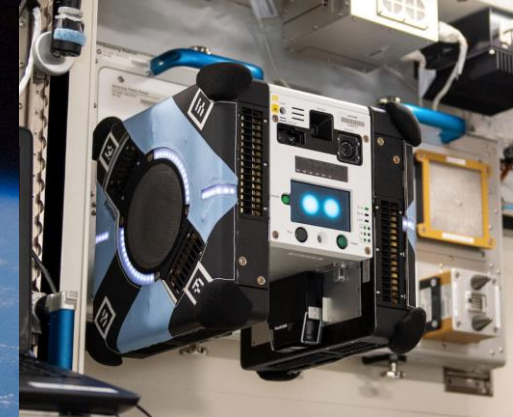
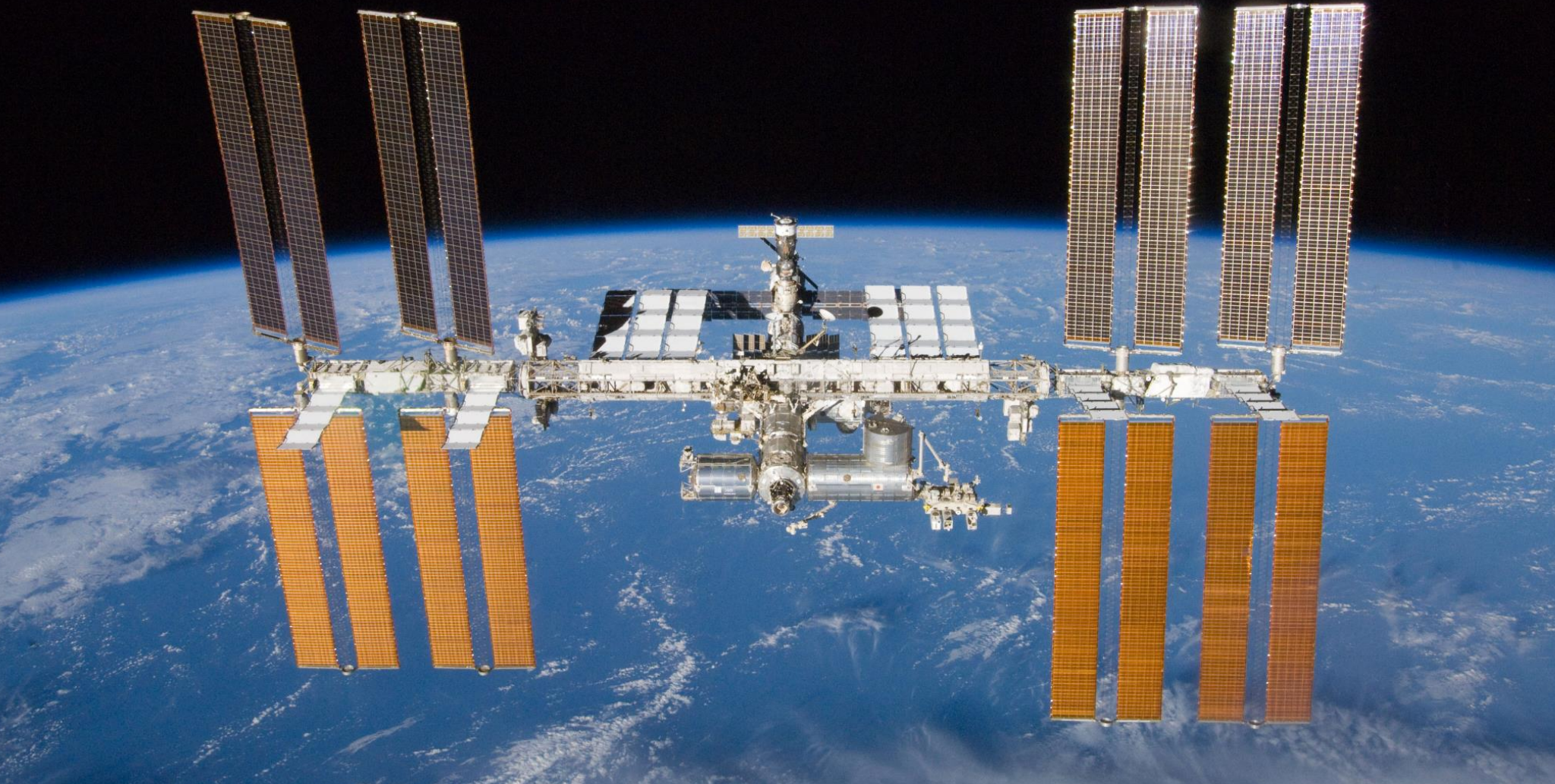


# SoundSee Mission – Acoustic Monitoring of the International Space Station



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# Bosch SoundSee and NASA's Astrobee



SoundSee



Astrobee

SoundSee is a guest-science payload  
on the Astrobee



The Astrobee robot has been developed by NASA Ames Research Center

# SoundSee's Primary Mission Objectives



Acoustic mapping

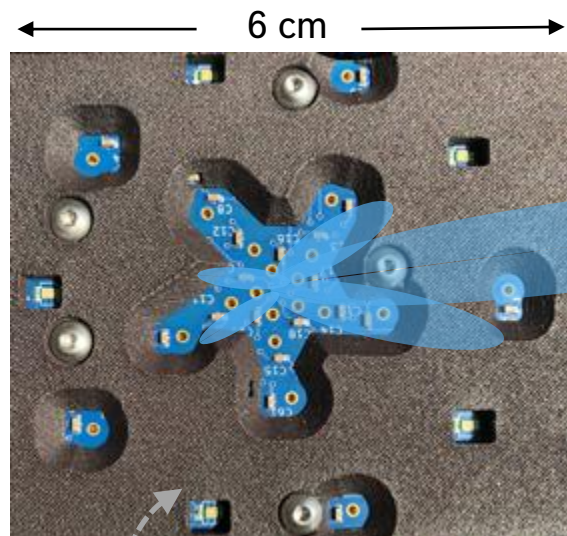


Audio AI for machine health monitoring

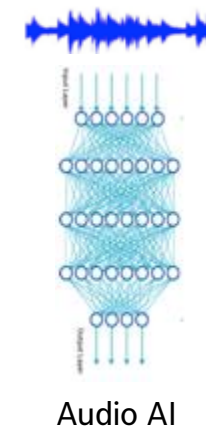
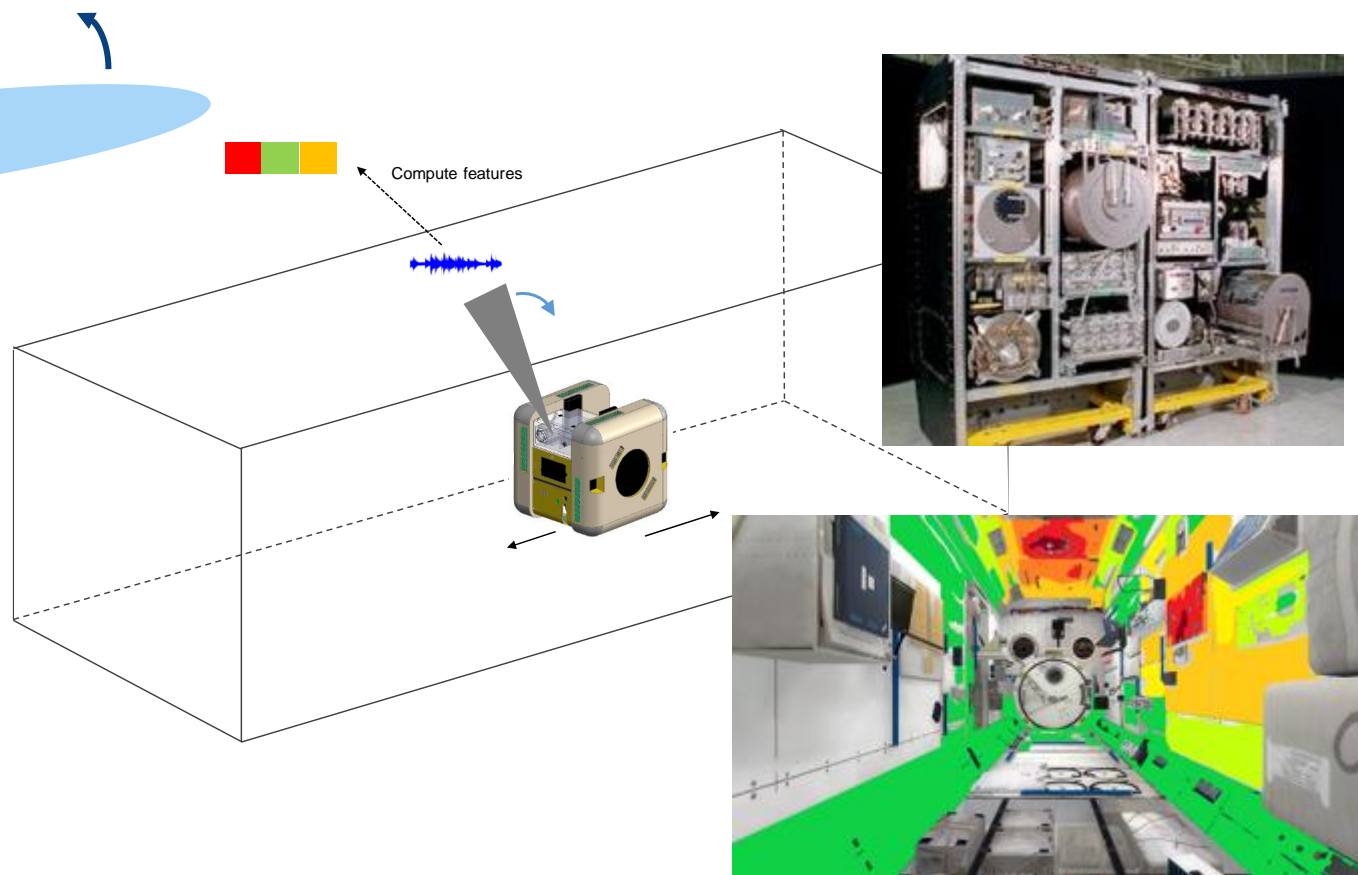


# SoundSee Sensor Capabilities

## Basic mapping mechanisms and frequency range



100 Hz – 80kHz [ innermost ring for ultrasonic ]



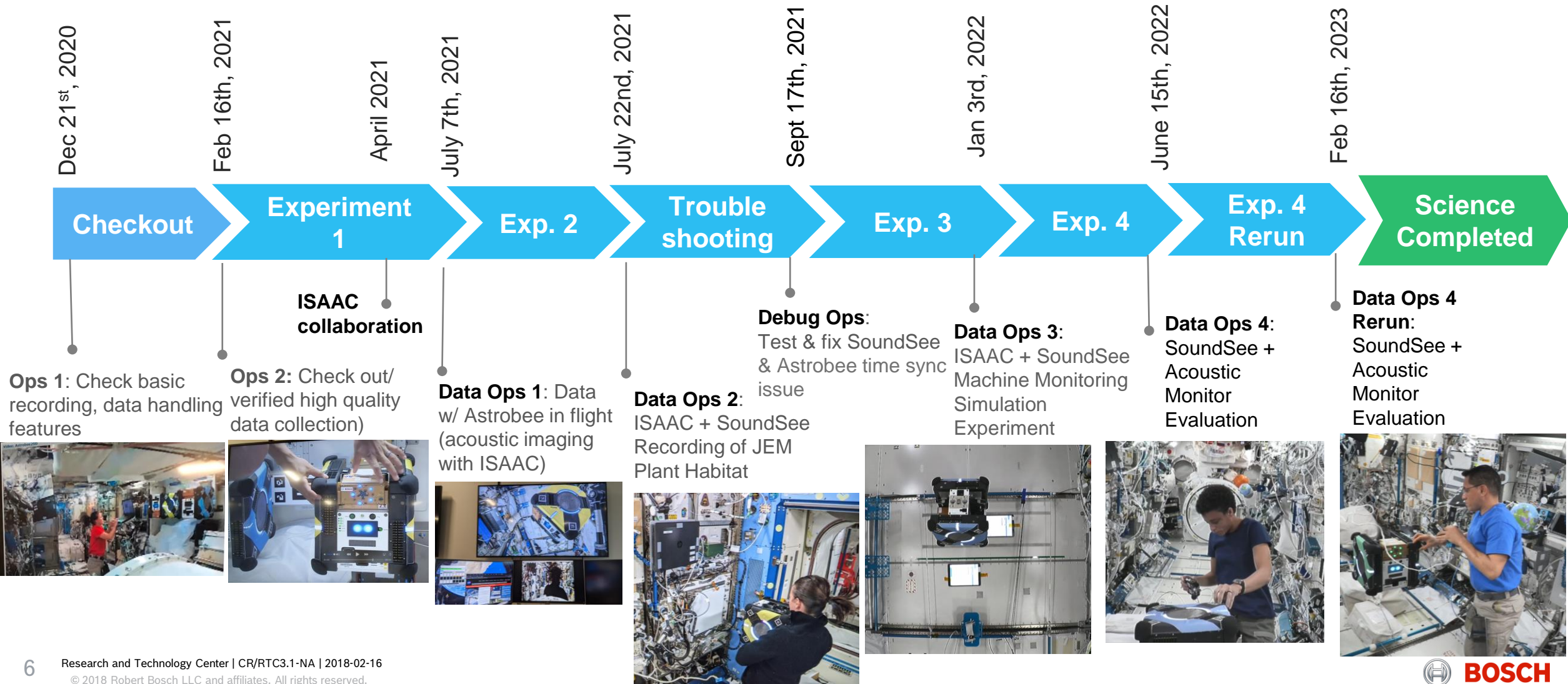
**20 MEMS microphones** (spiral array, 4 rings)

# Current Status and On-orbit Ops Timeline

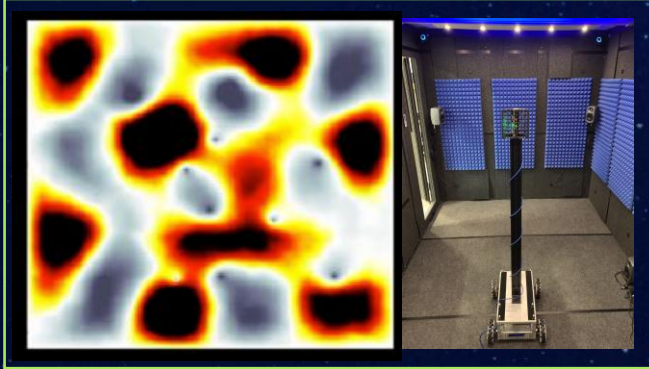
First experimental data collected on-orbit (07/07/2021)



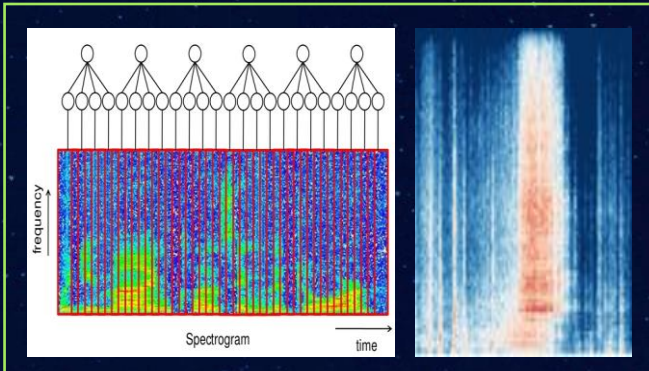
Crewtime sponsored



# Current Status and Ongoing Work



Acoustic imaging experiments



Deep audio analytics research



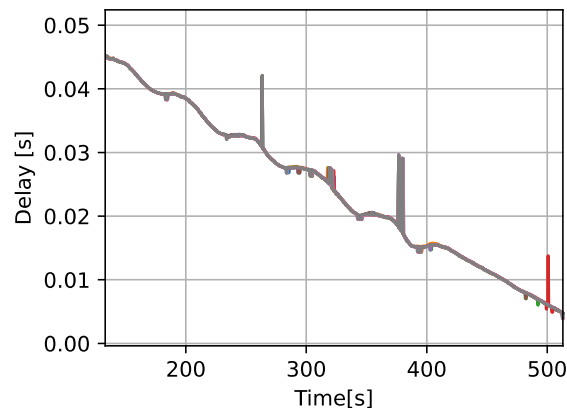
# SoundSee Data Ops + Ground Experiments + Simulation

## Challenges of sound experiments in space

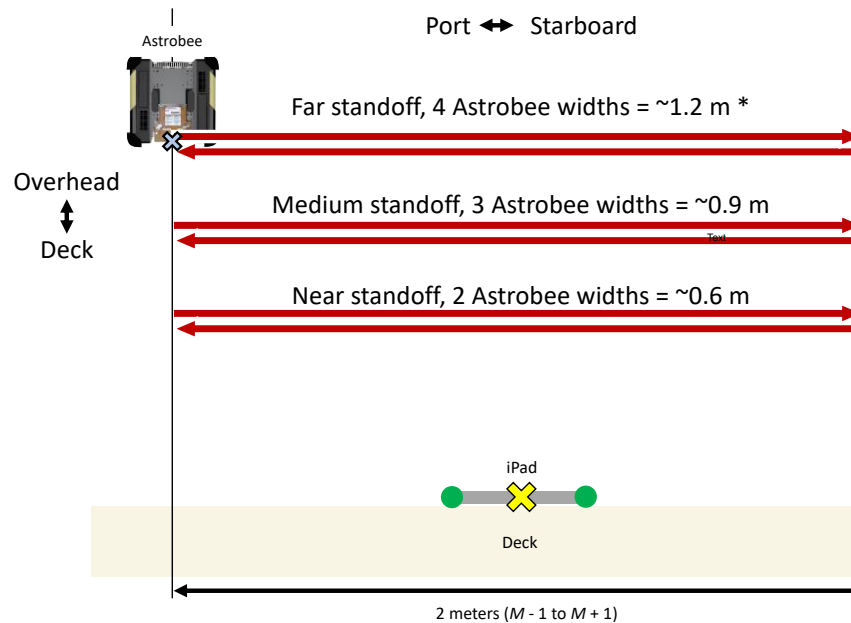
### ► Asynchronous systems

- video-cameras
- robot telemetry
- SoundSee recordings
- sound sources

### ► Synchronization is vital for acoustic imaging



### ► First attempt to match simulation, lab measurements, ISS acquisitions



### ► Joint paper with NASA submitted to ICASSP 2022

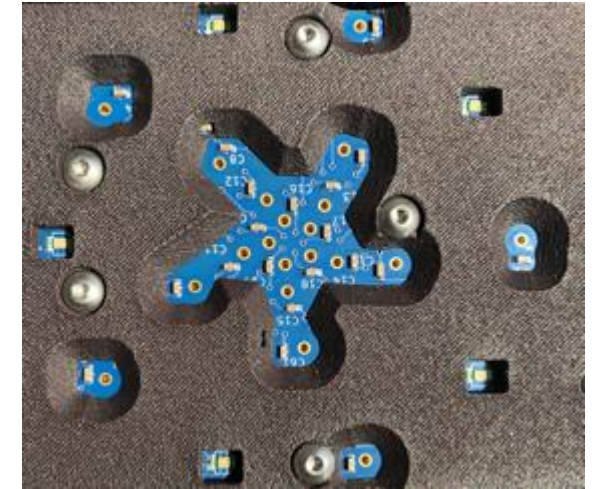


# SoundSee Data Ops 4

## SoundSee High Frequency Audio & Acoustic Monitor Comparison

### ► Two Objectives for Data Ops 4

- Validate capability of SoundSee high frequency (96 kHz & 192 kHz) microphone arrays
  - 8 out of 10 microphones functional for 44 kHz array
  - **8 out of 10 microphones functional for 96 kHz array**
  - **3 out of 5 microphones functional for 192 kHz array**
- Compare audio data captured with ISS acoustic monitor to audio data captured with SoundSee
  - **Acoustic monitor data lost due to operator error not caught during experiment**
  - **Experiment was rerun in Feb 2023 and all data was captured**

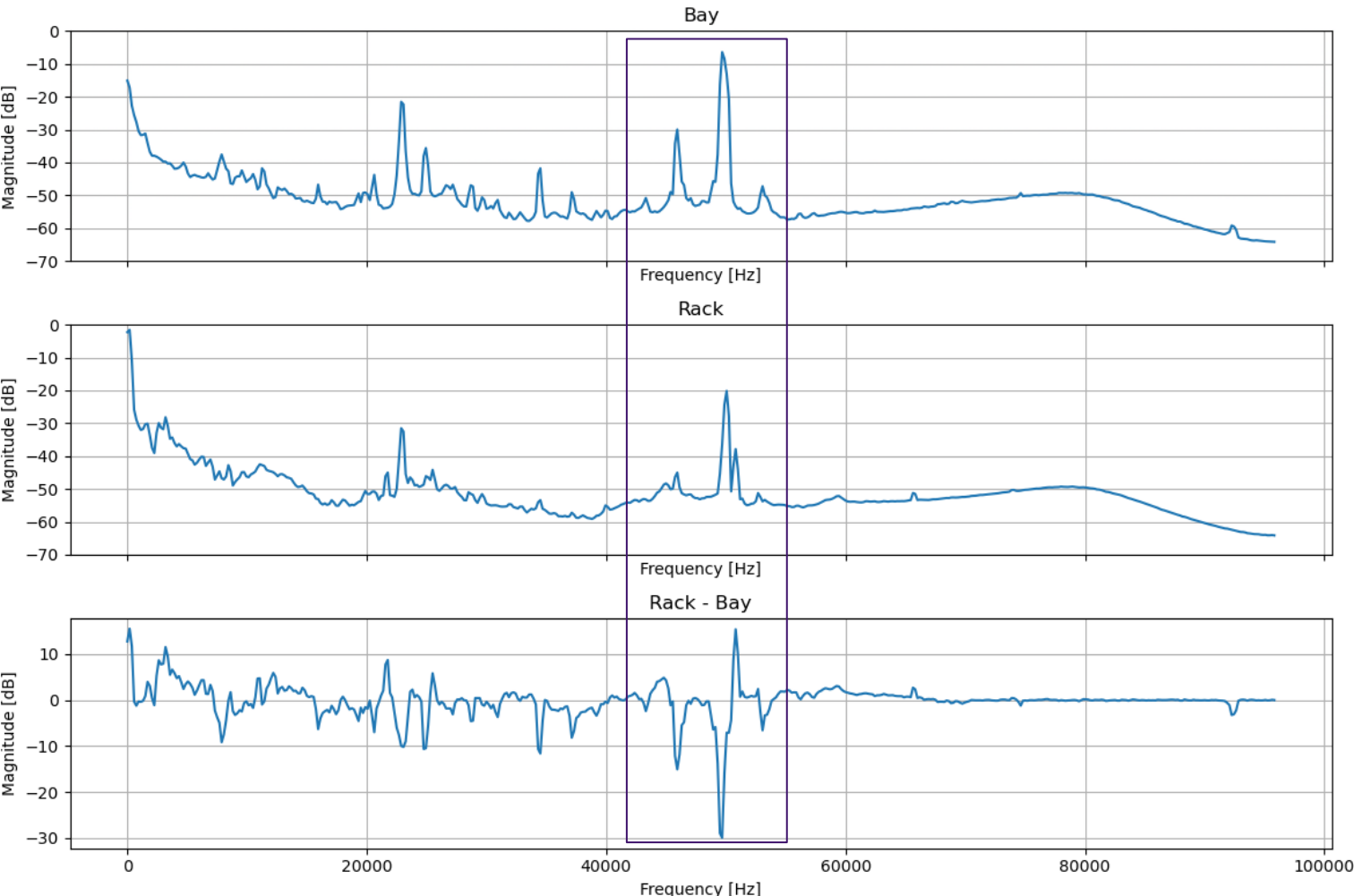


VS



# SoundSee Data Ops 4 (Part 1 – June 2022)

## Differences in Audio Signature Captured at High Frequencies



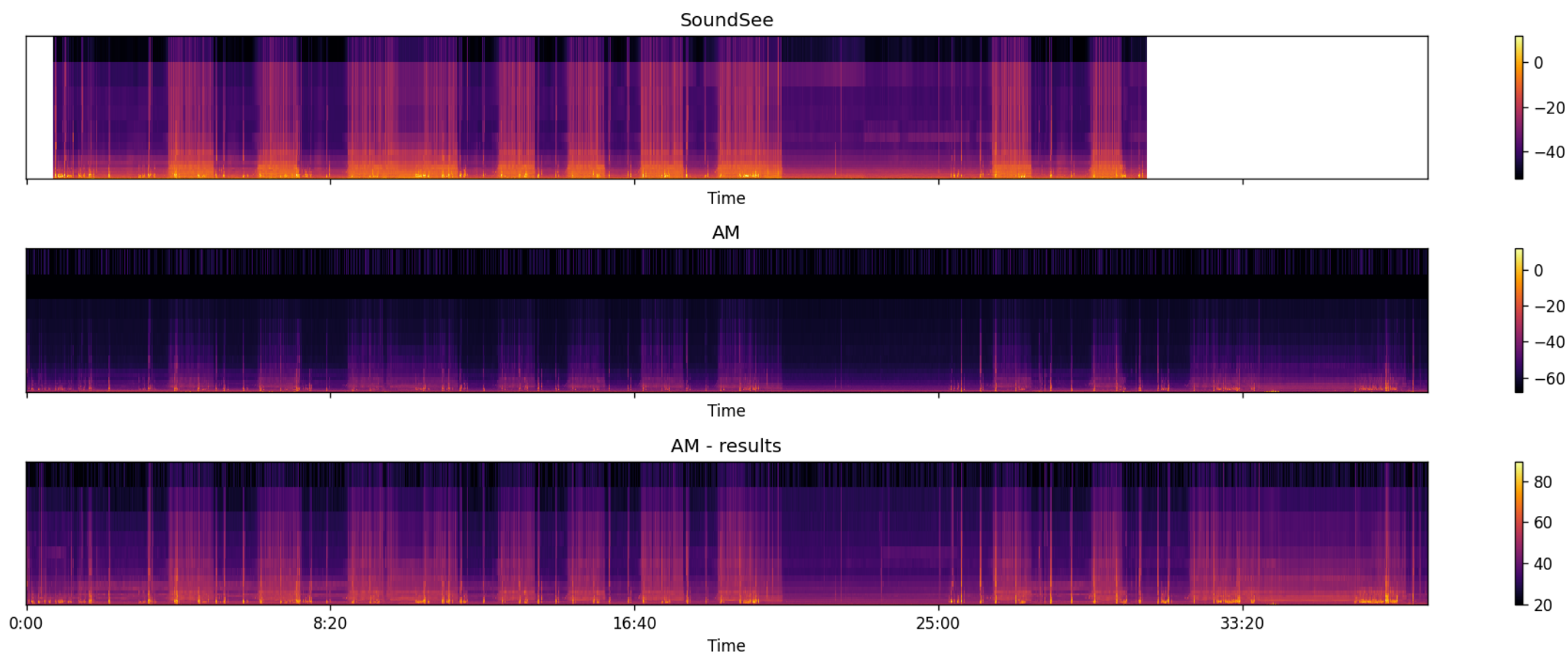
**PSD of 1 minute recording,  
in front of Bay**  
**AstroBee fan not active**

**PSD of 1 minute recording,  
in front of Rack**  
**AstroBee fan not active**

**Band of highest differences between bay  
and rack within 40k and 60k**

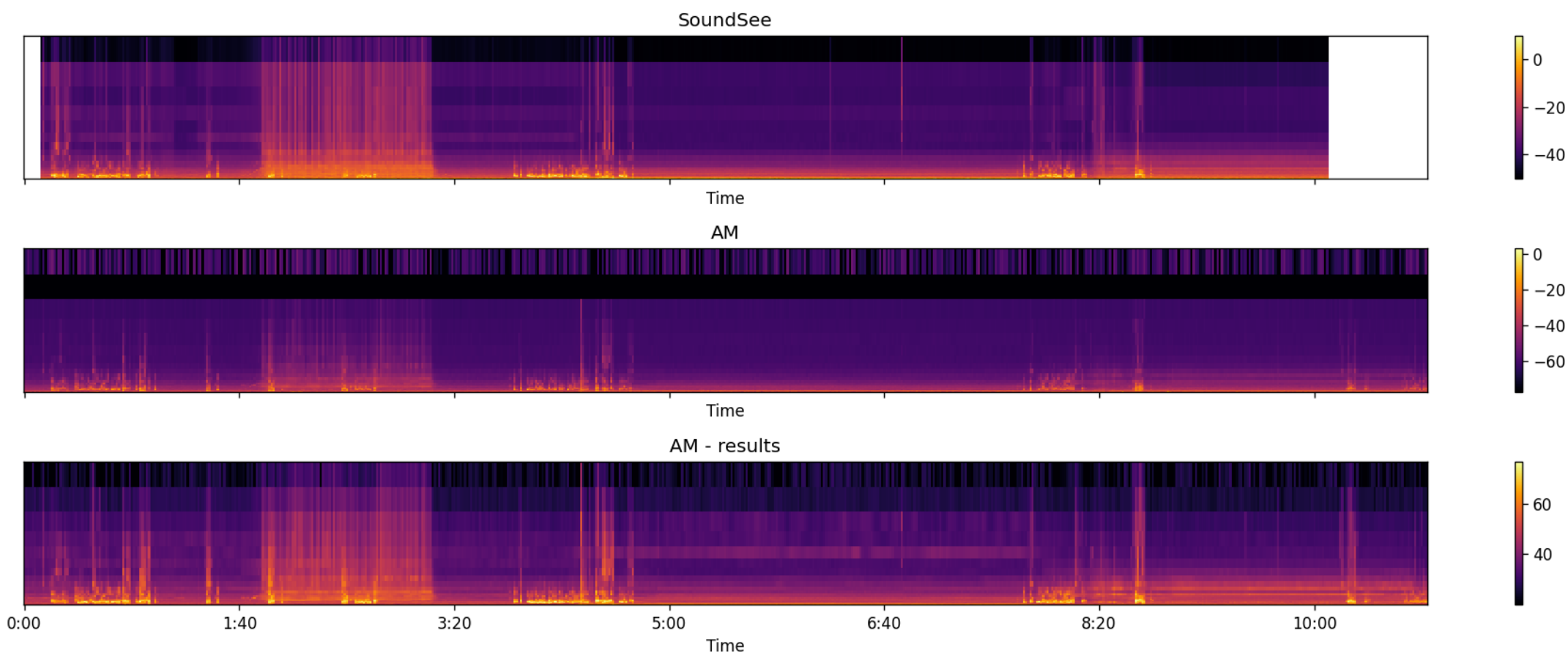
# SoundSee Data Ops 4 (Part 2 – February 2023)

## 30 Minute Audio Recording – Positions 1-9



# SoundSee Data Ops 4 (Part 2 – February 2023)

## 10 Minute Audio Recording – Position 10



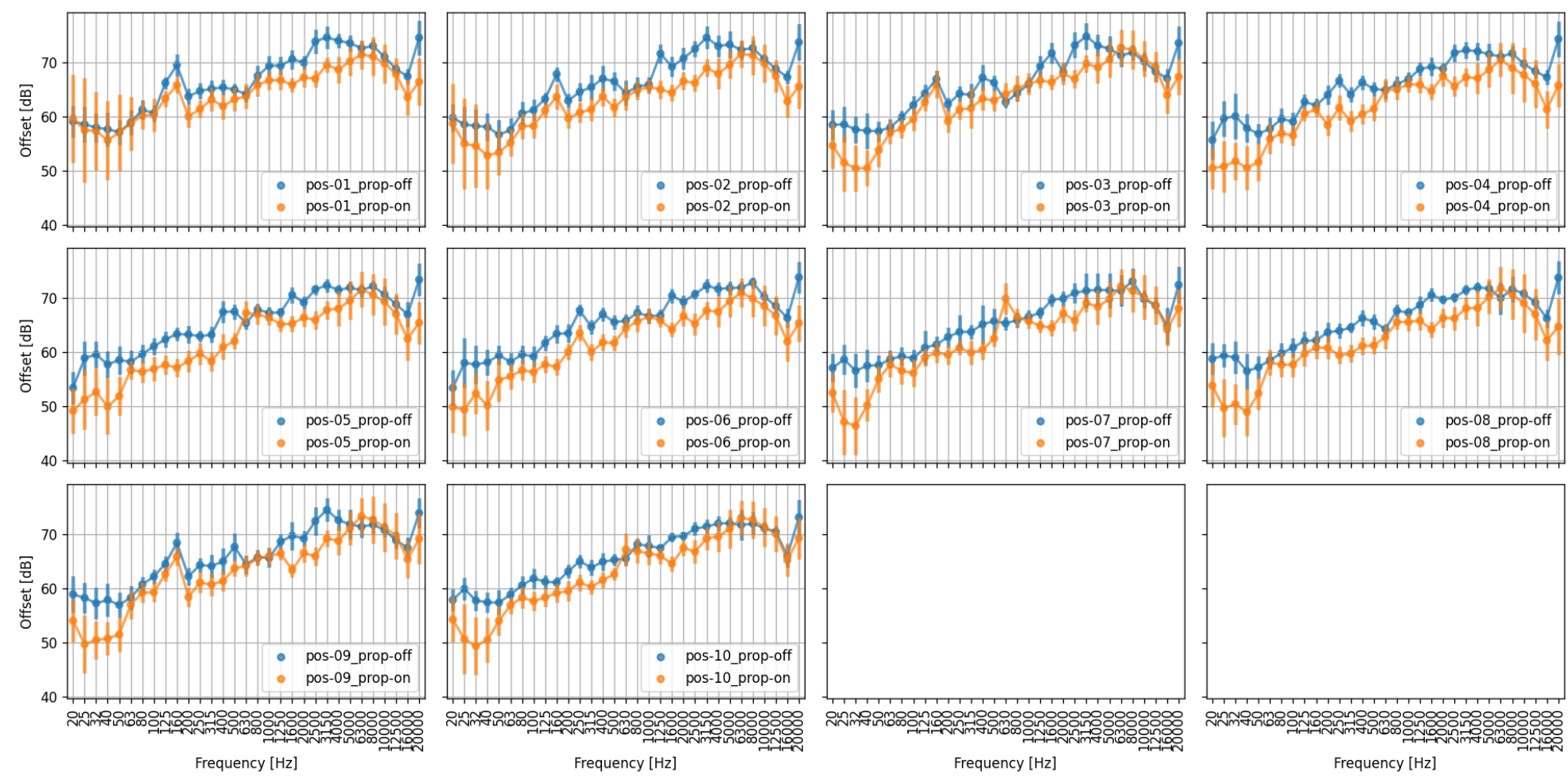
# SoundSee Data Ops 4 (Part 2 – February 2023)

## Audio Data Analysis – SoundSee vs Acoustic Monitor

- ▶ Computed third-octave spectrogram from SoundSee recordings
  - ▶ Magnitude spectrogram from all channels is averaged
- ▶ Aligned SoundSee and AM spectrograms
- ▶ Computed offset between spectrograms frame by frame
- ▶ Plotted the average offset with standard deviation error bars for different sections of the recordings
  - ▶ Positions 1-10 – Ten recording positions
  - ▶ Prop on, off: Astrobee propulsion state

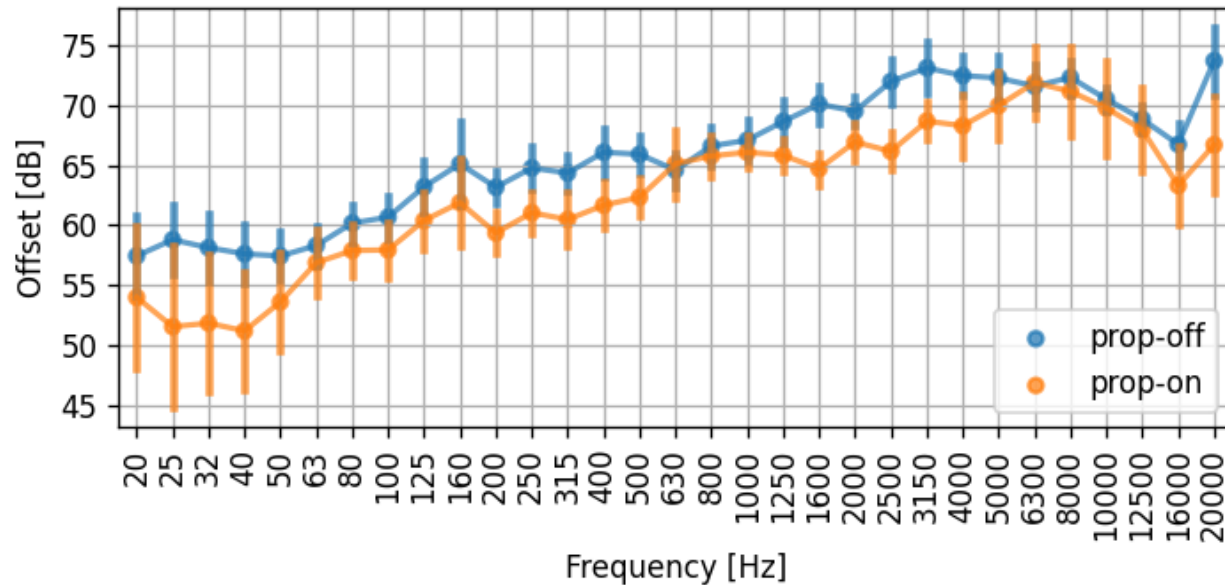
# SoundSee Data Ops 4 (Part 2 – February 2023)

## Offset Per Test Position Recorded



# SoundSee Data Ops 4 (Part 2 – February 2023)

## Initial Comparison Results



### Preliminary Analysis

- Consistent trend across positions
- Significant variability below 100Hz
  - Expected as the MEMS capsules have cutoff at 100Hz
  - In A-weighted SPL measurements this will not affect significantly
- Significant variability above 5000Hz
  - Directionality is significant at those frequencies, as well as masking from AstroBee
- Variability is reduced when propulsion is off
- SoundSee w/Astrobee may be used for automated SPL monitoring
- Further evaluation in controlled environment may be needed to validate results

Finally, many thanks to the Astrobeer/NASA team!