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# AtmoSOFAR

## Verifying the Presence of an Acoustic Duct with Balloon-borne Infrasound

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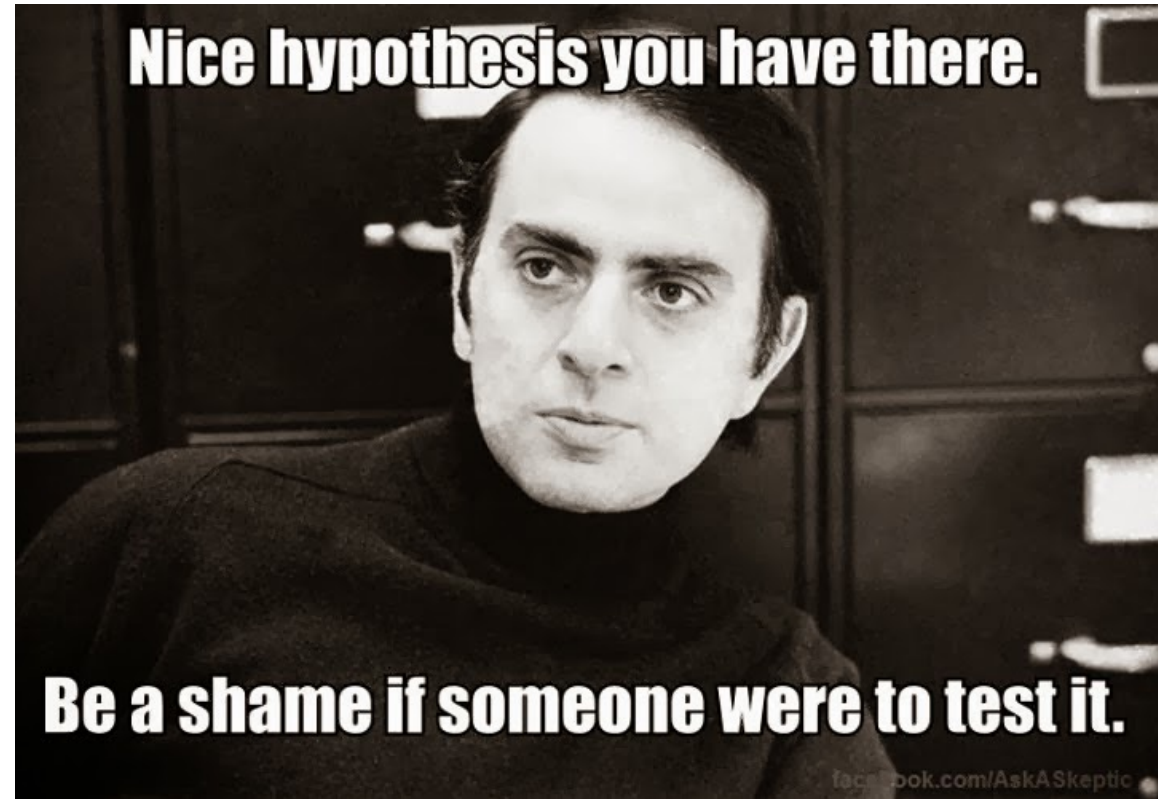
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## Reality Check and Impact

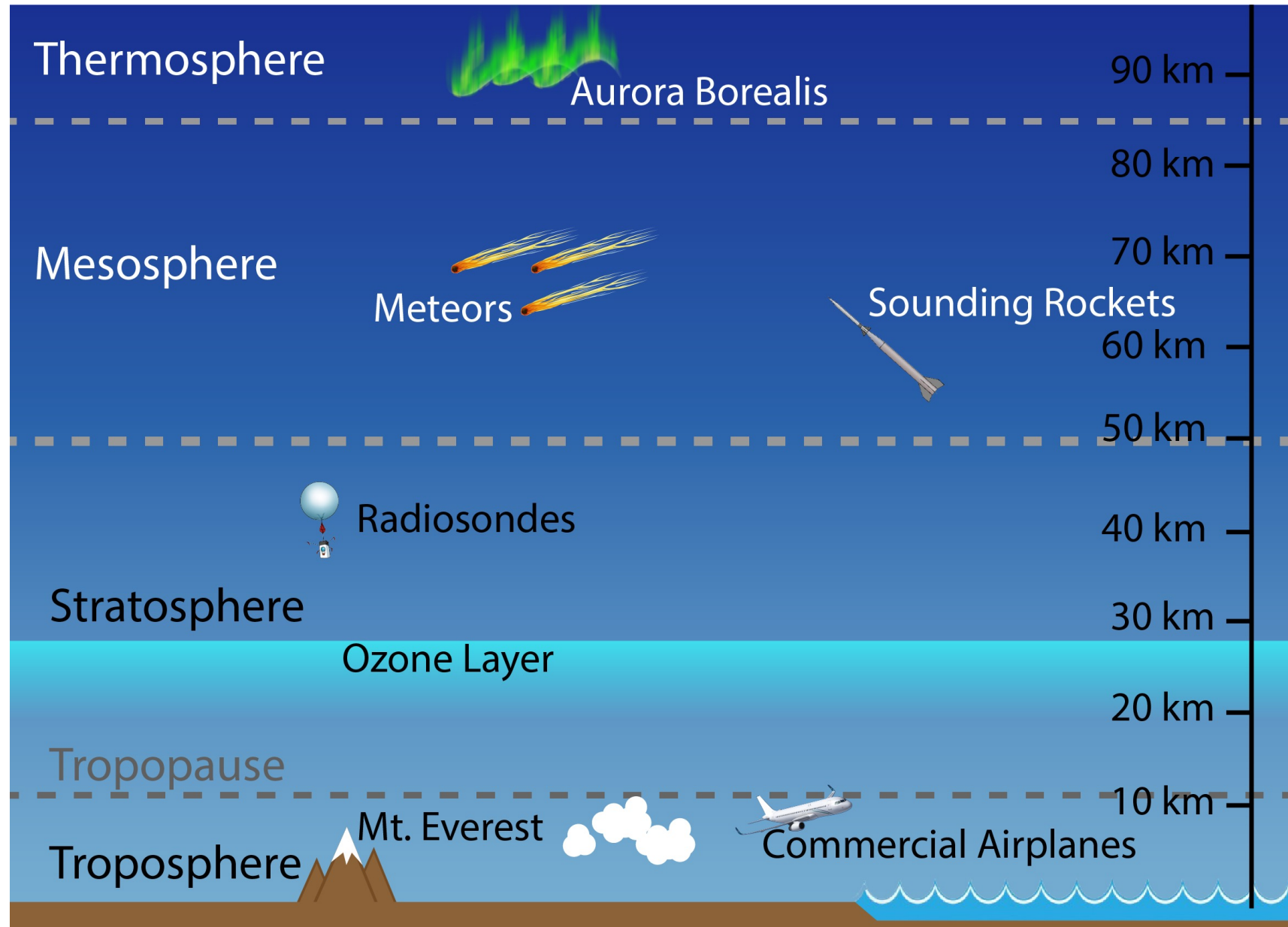
Us to the customer: "Within minutes of recovering the data we'll be able to tell you if the rocket was detected."



This work proves the ability to **detect events of interest in the AtmoSOFAR channel** and highlights a **surprisingly complex acoustic background** structure at altitude.



# Layers of the Atmosphere





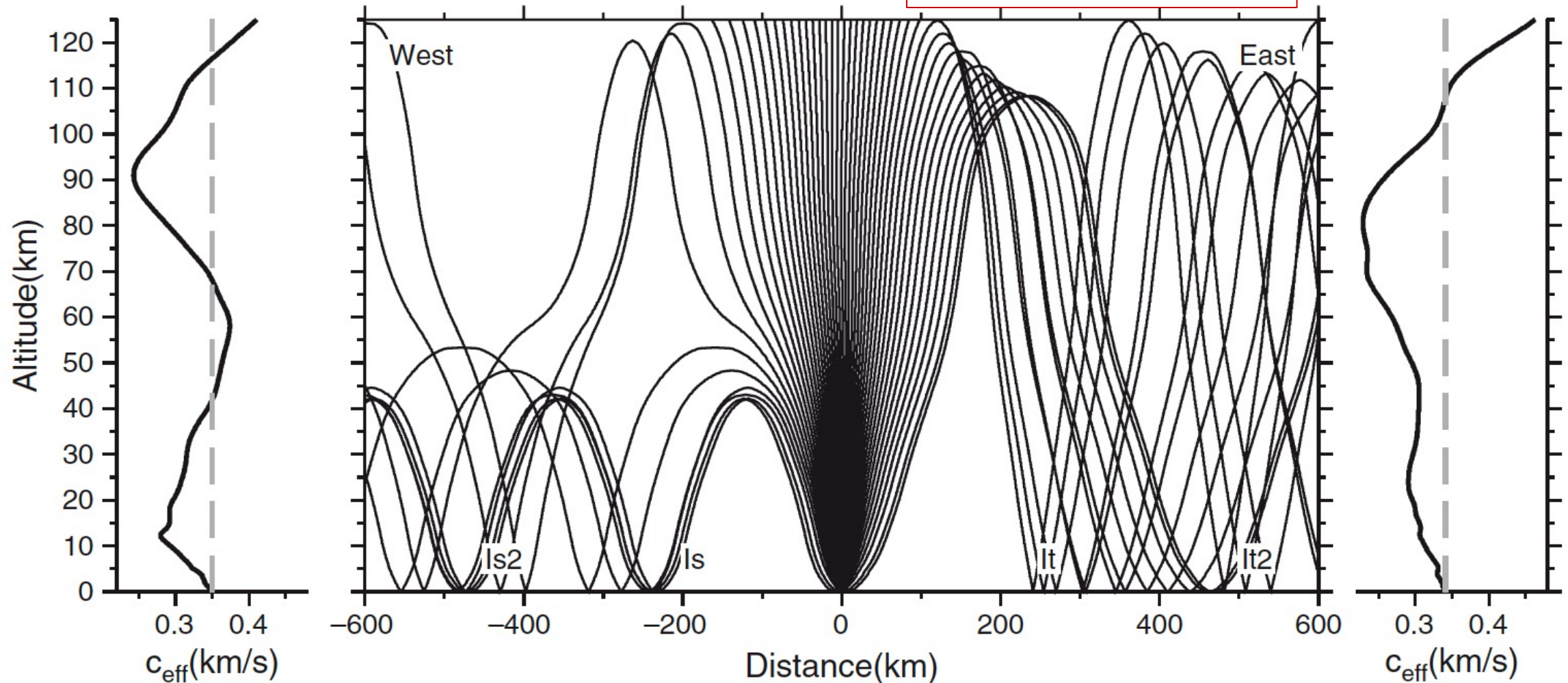
# Infrasound Propagation

Wave “turning height” depends on effective sound speed

$$c_{eff} \approx 20.04\sqrt{T} + \vec{n} \cdot \vec{w}$$

wind component

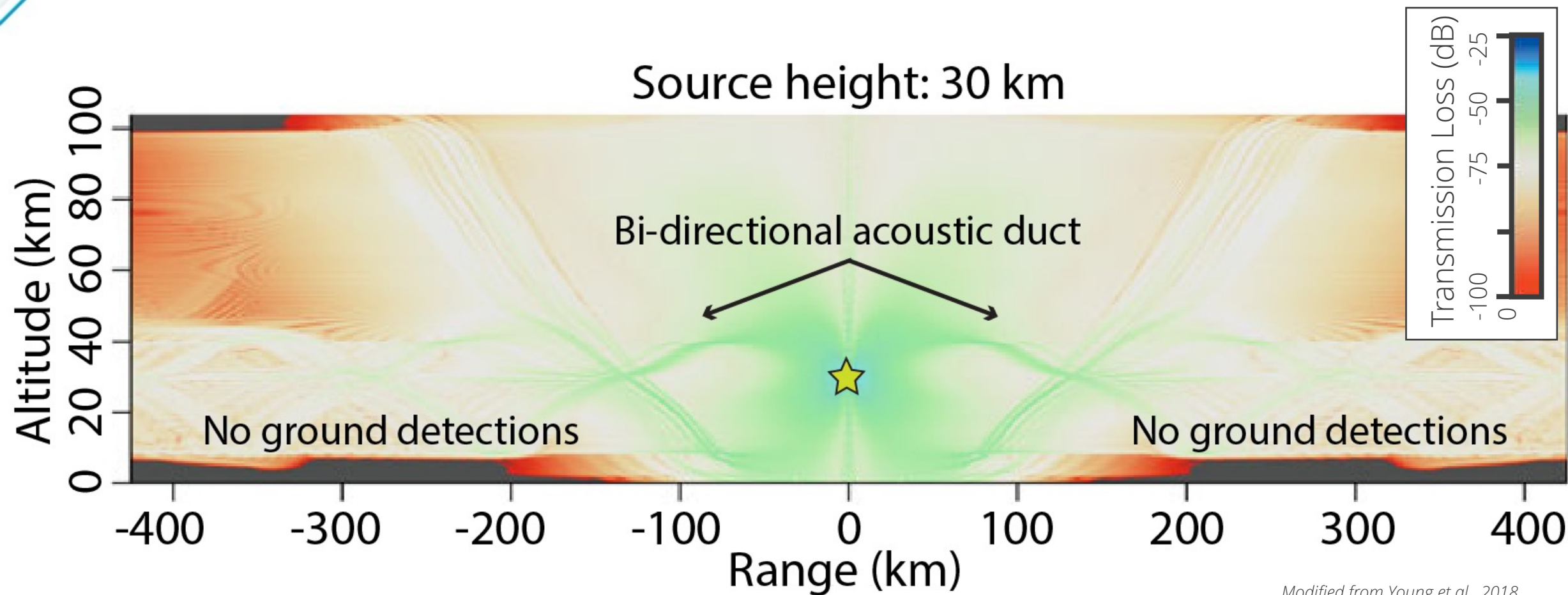
temperature component







## Atmospheric SOFAR (AtmoSOFAR) Channel



*Modified from Young et al., 2018*



## Solar Balloon Design



*Bowman et. al, 2020*

### 6 m Heliotrope Solar Balloon

- Lightweight, plastic, balloon – darkened with charcoal powder
- Infrasonic sensor/digitizer, GPS tracking, temperature sensor
- High-resolution GEM infrasonic logger, when possible
- Two flight campaigns

The logo features a central dark blue diamond containing the text "Blue Origin" and "NS-15" in white. This diamond is surrounded by a white border and is flanked by two diagonal lines that form a larger diamond shape. These lines are composed of segments in various colors: cyan, light blue, purple, red, orange, green, and dark blue. The background is white with faint, stylized rocket trails in the corners.

# Blue Origin NS-15

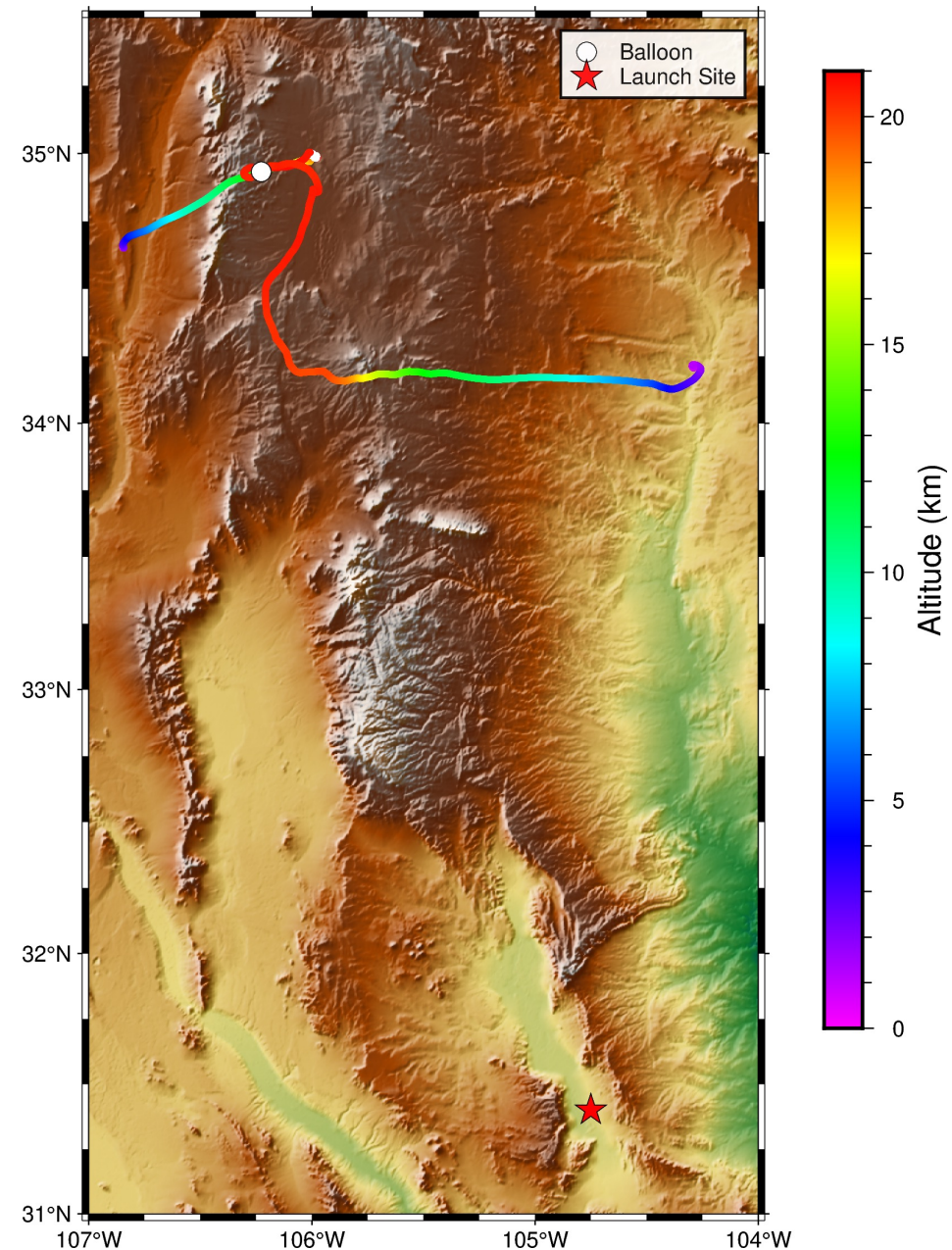
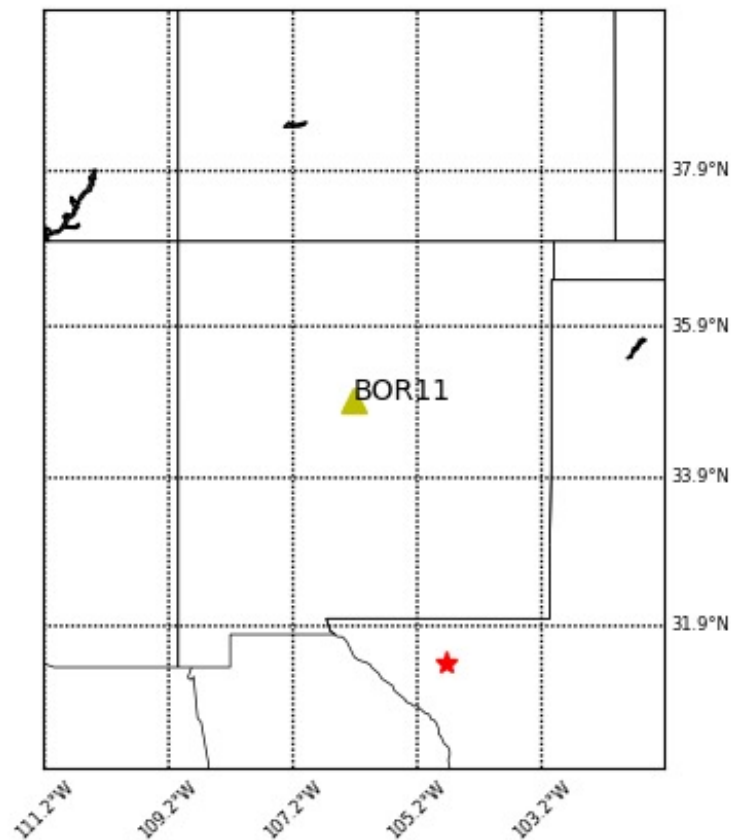




# Launch Information

## Blue Origin NS-15

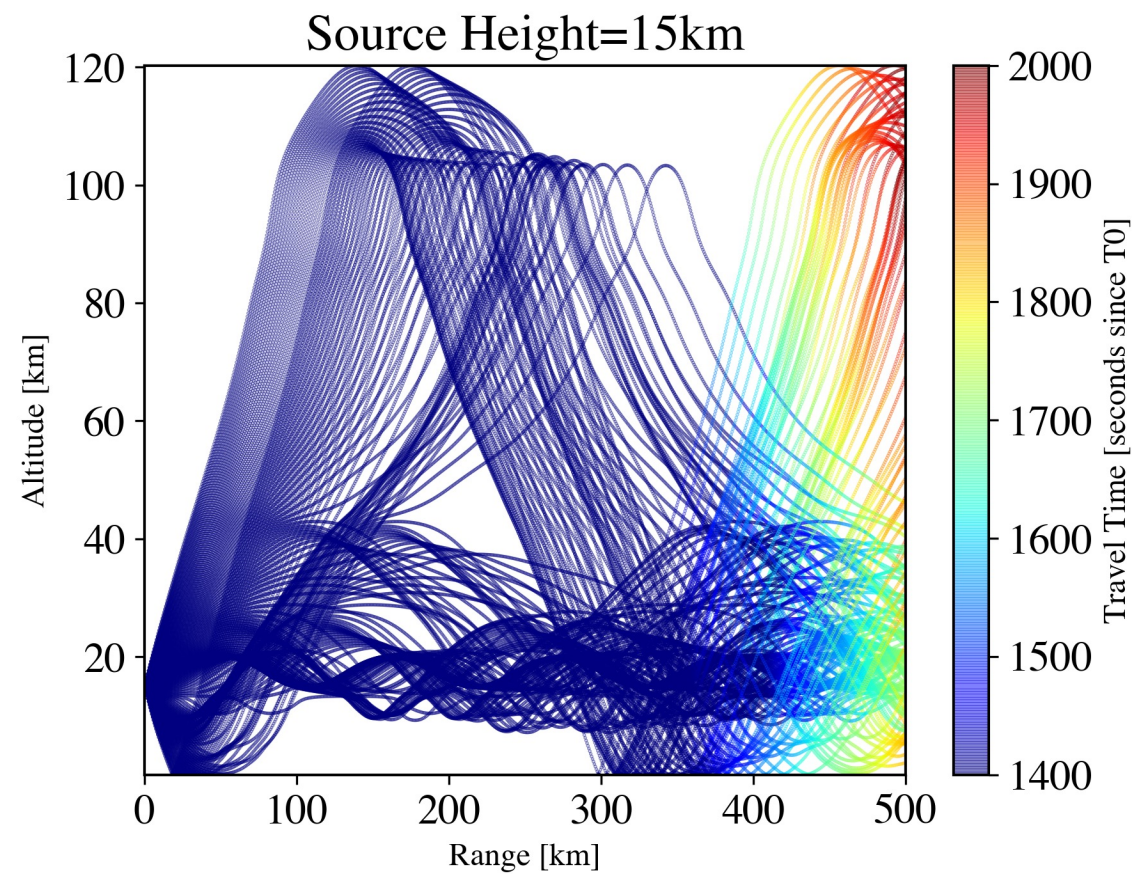
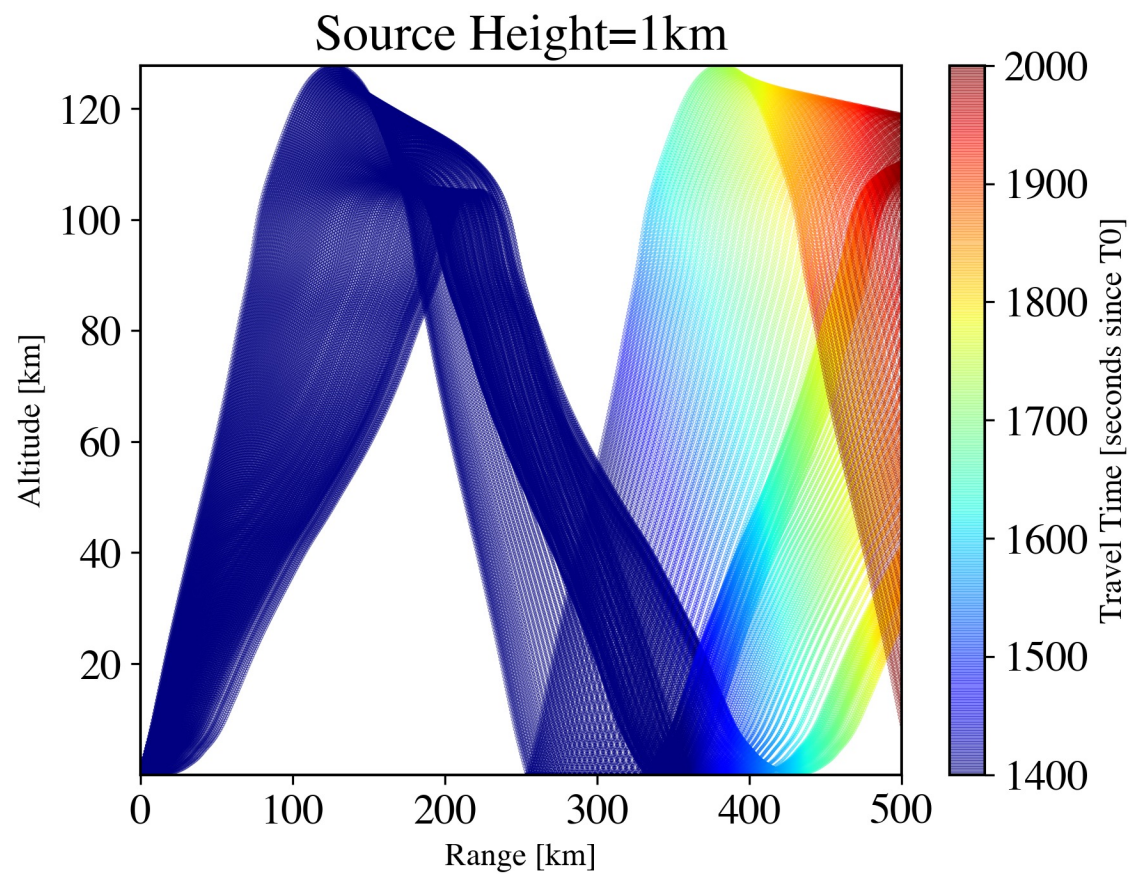
- April 14, 2021
- Uncrewed test flight
- 1 balloon
- ~415 km range







# Propagation Modeling

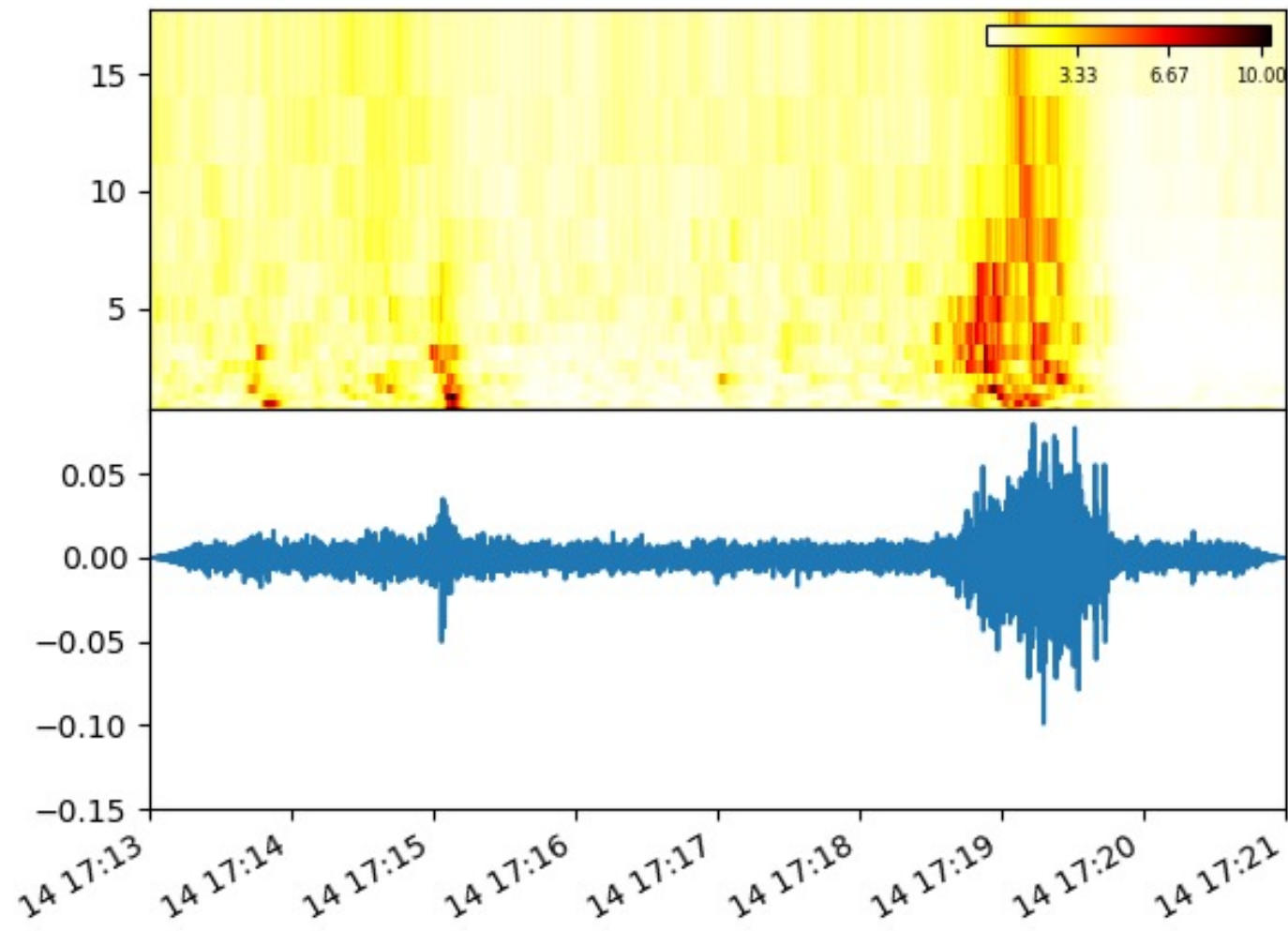


Blue Origin NS-15

ULA Landsat 9



# Time Series Analysis

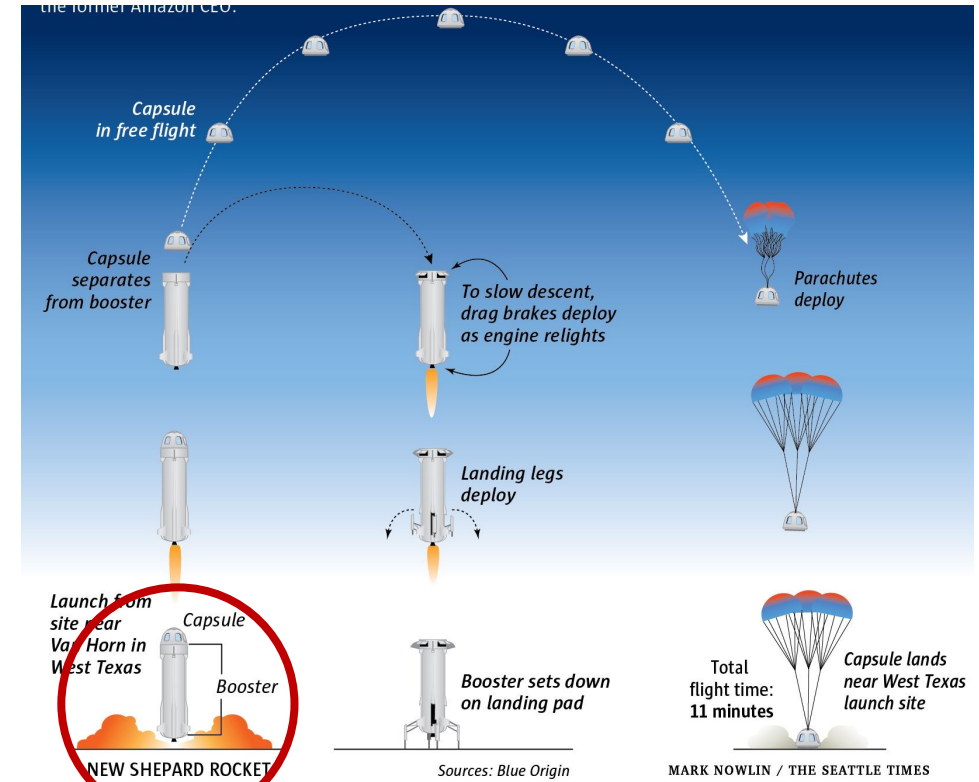
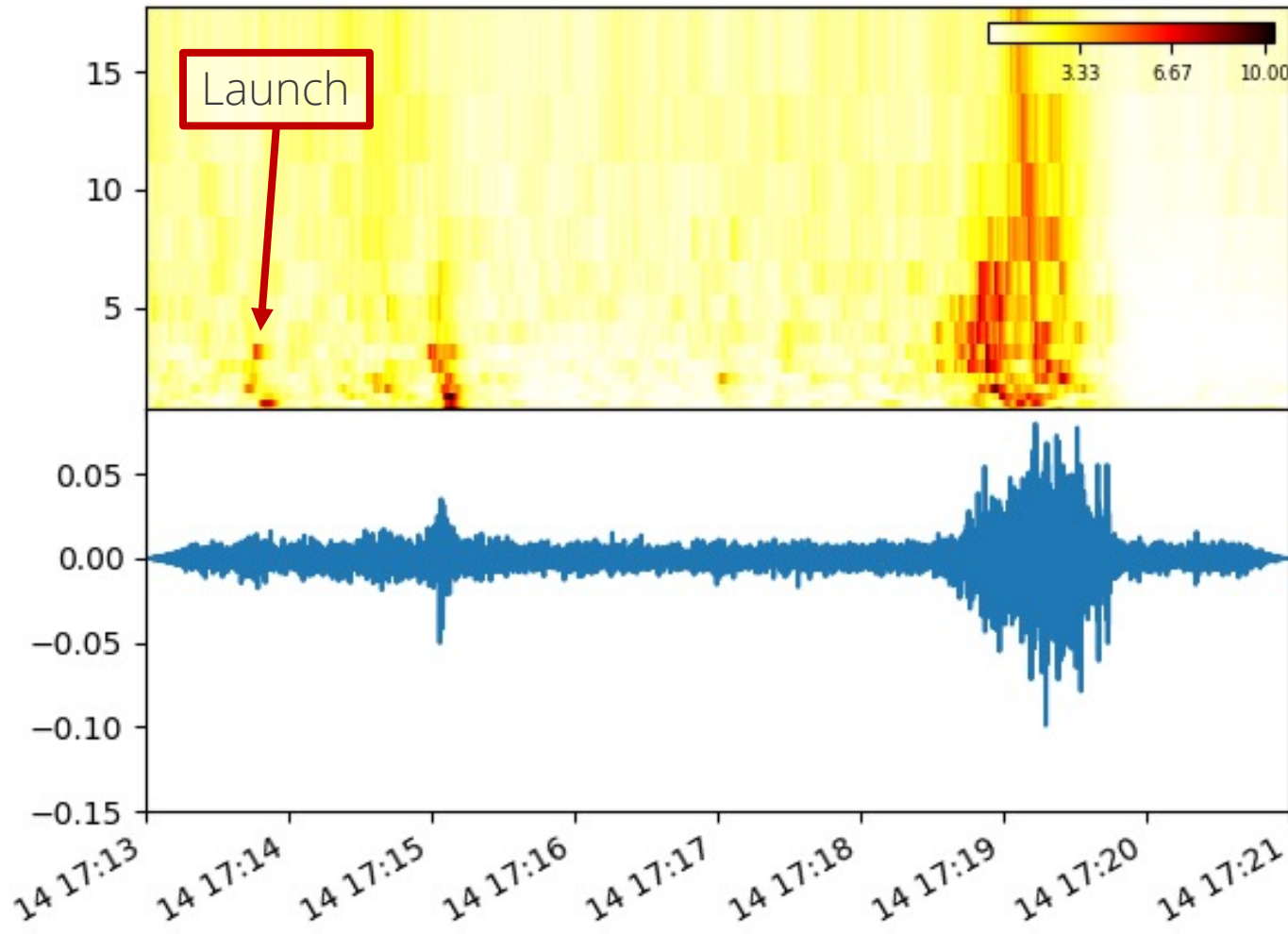


Blue Origin NS-15

ULA Landsat 9



# Time Series Analysis



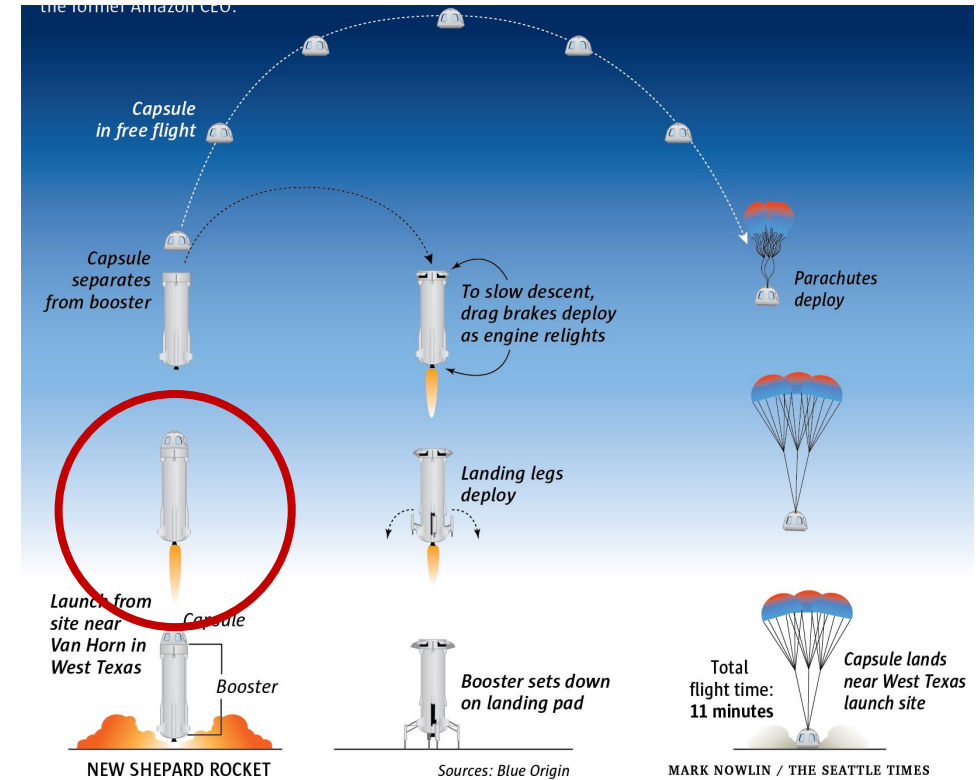
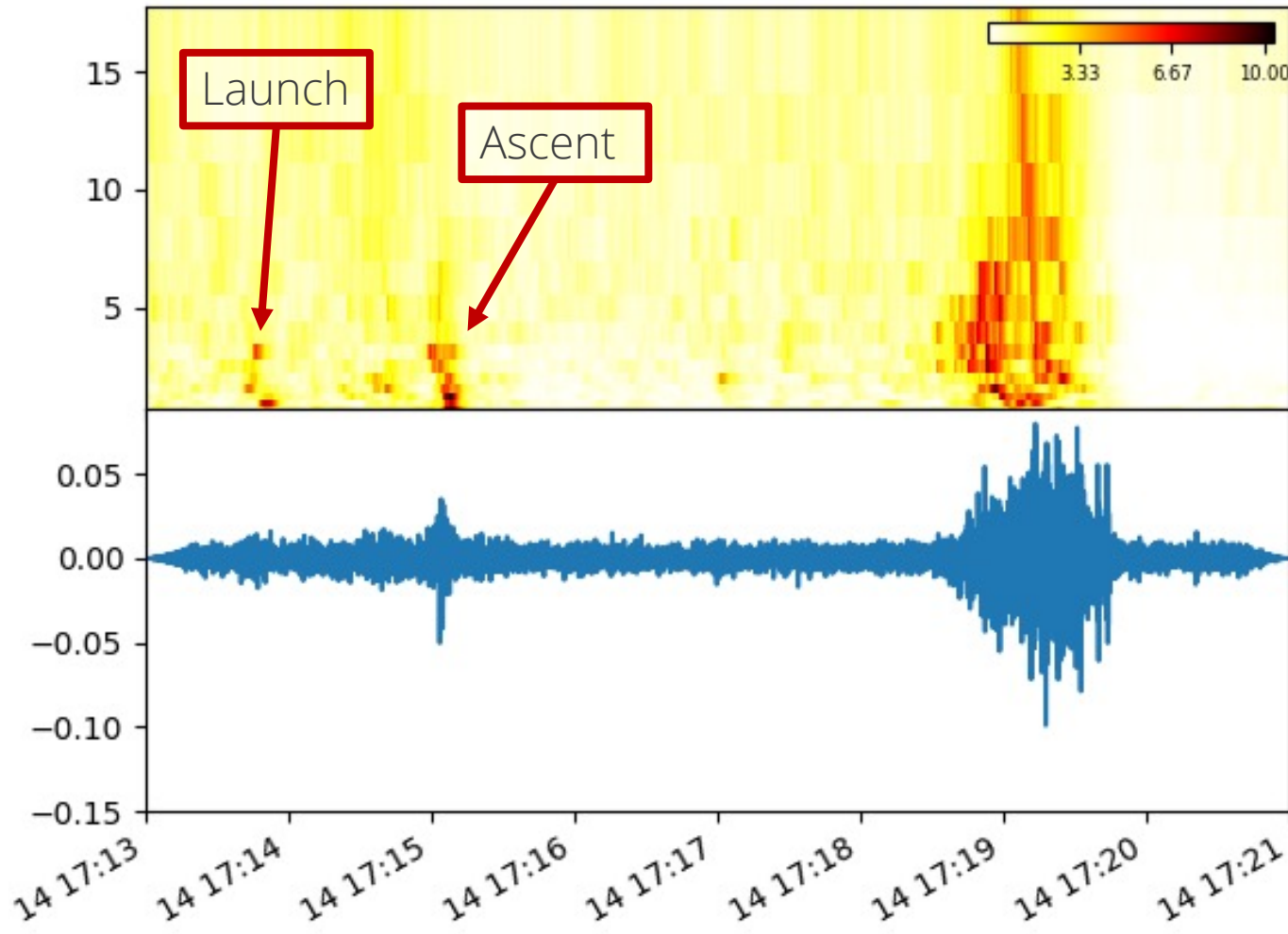
Blue Origin NS-15

ULA Landsat 9





# Time Series Analysis



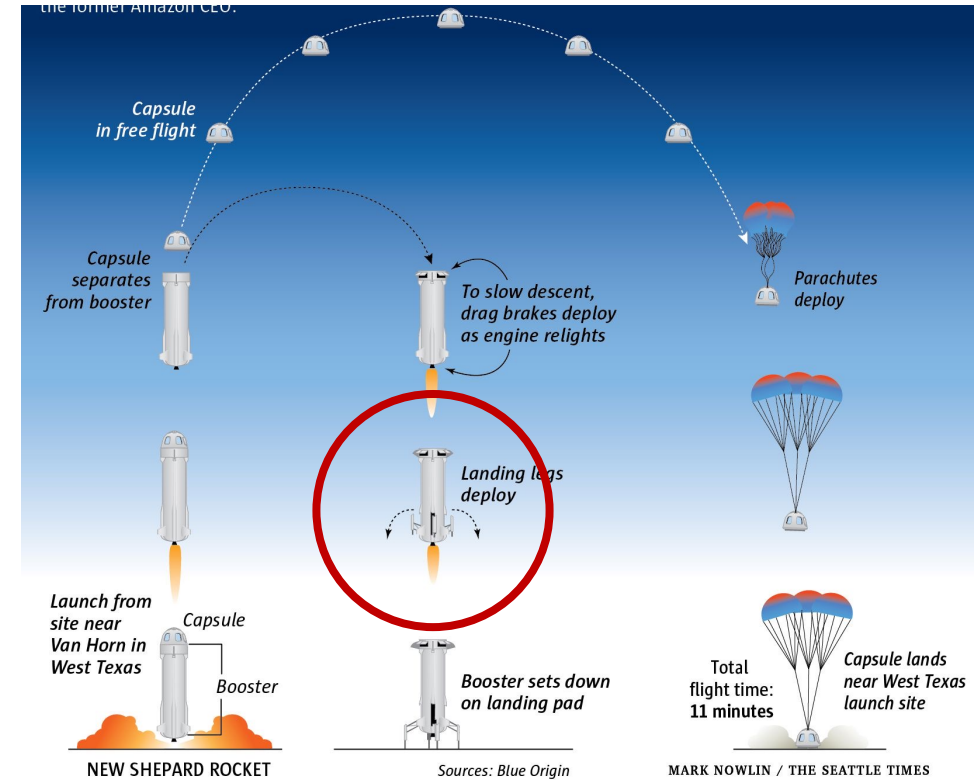
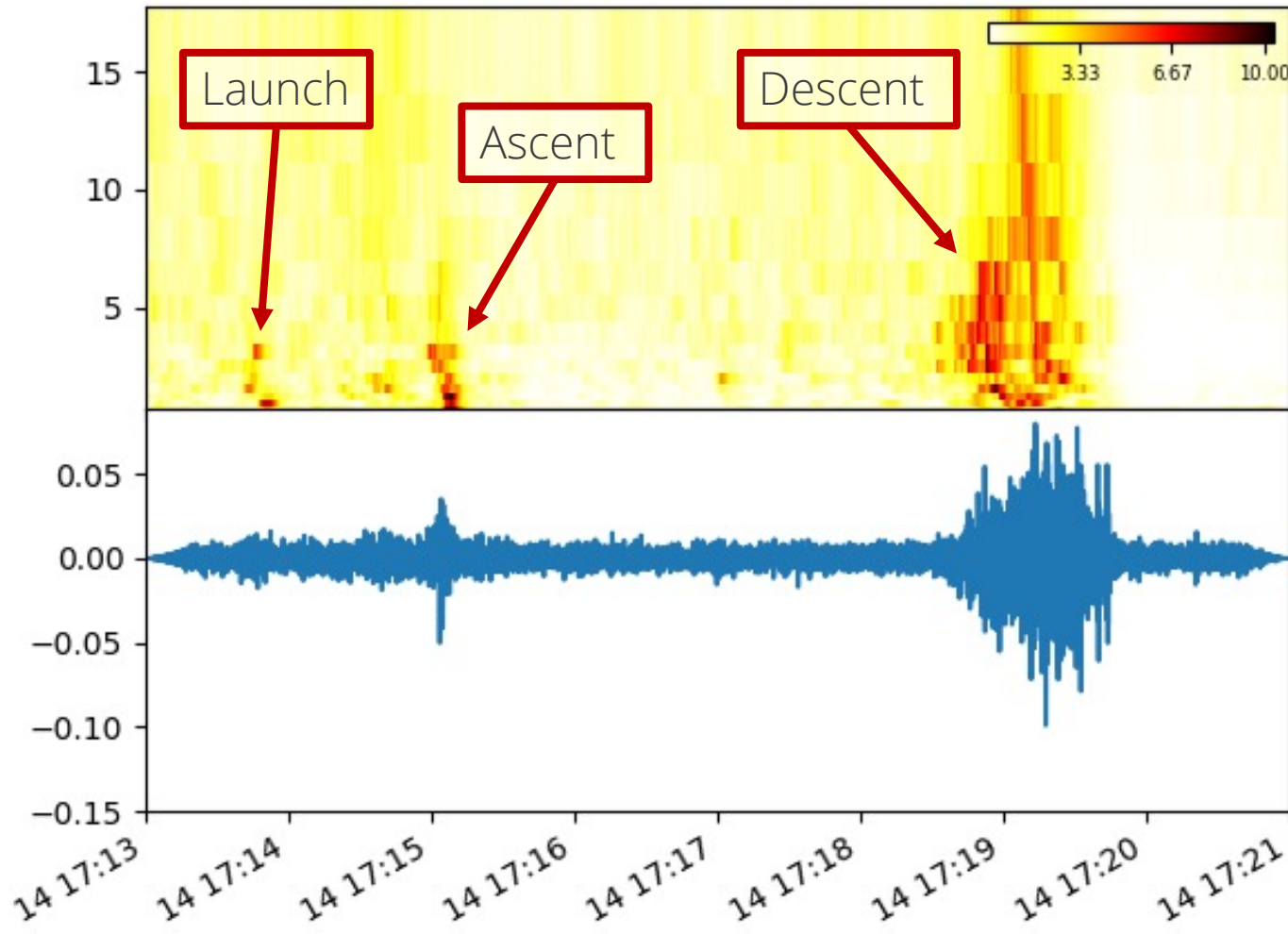
Blue Origin NS-15

ULA Landsat 9





# Time Series Analysis

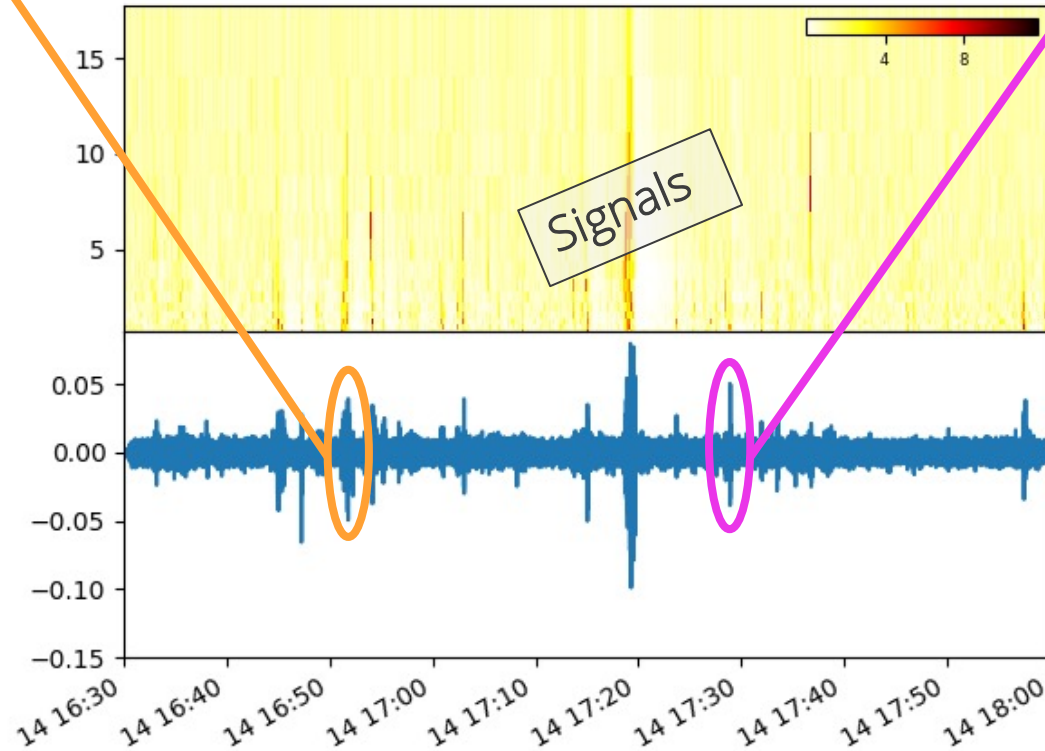
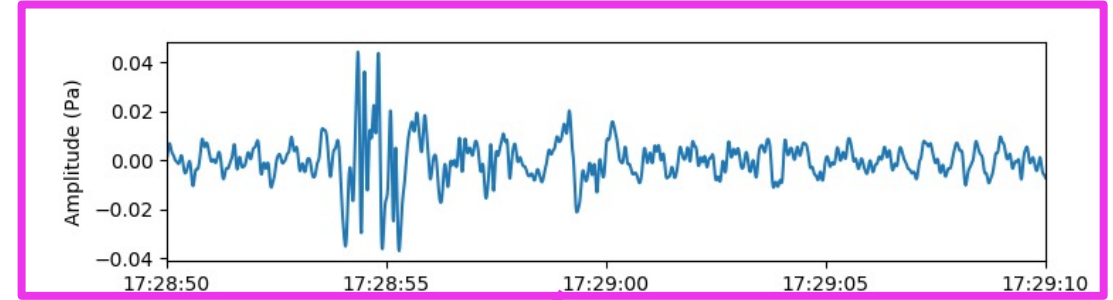
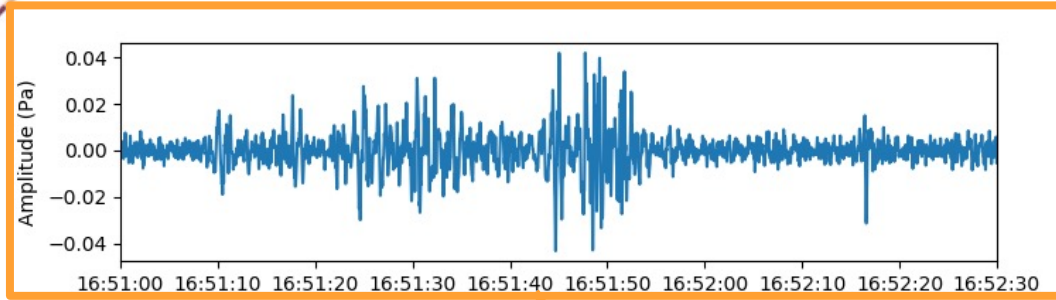


Blue Origin NS-15

ULA Landsat 9



# Background Noise



Blue Origin NS-15

ULA Landsat 9

The image features a central dark blue diamond shape with a white border. Inside the diamond, the text "ULA Landsat 9" is written in white. Two diagonal lines, composed of small colored segments (cyan, orange, green, red, purple), cross the diamond from the corners. The background is white with faint, light blue satellite imagery visible in the upper right corner.

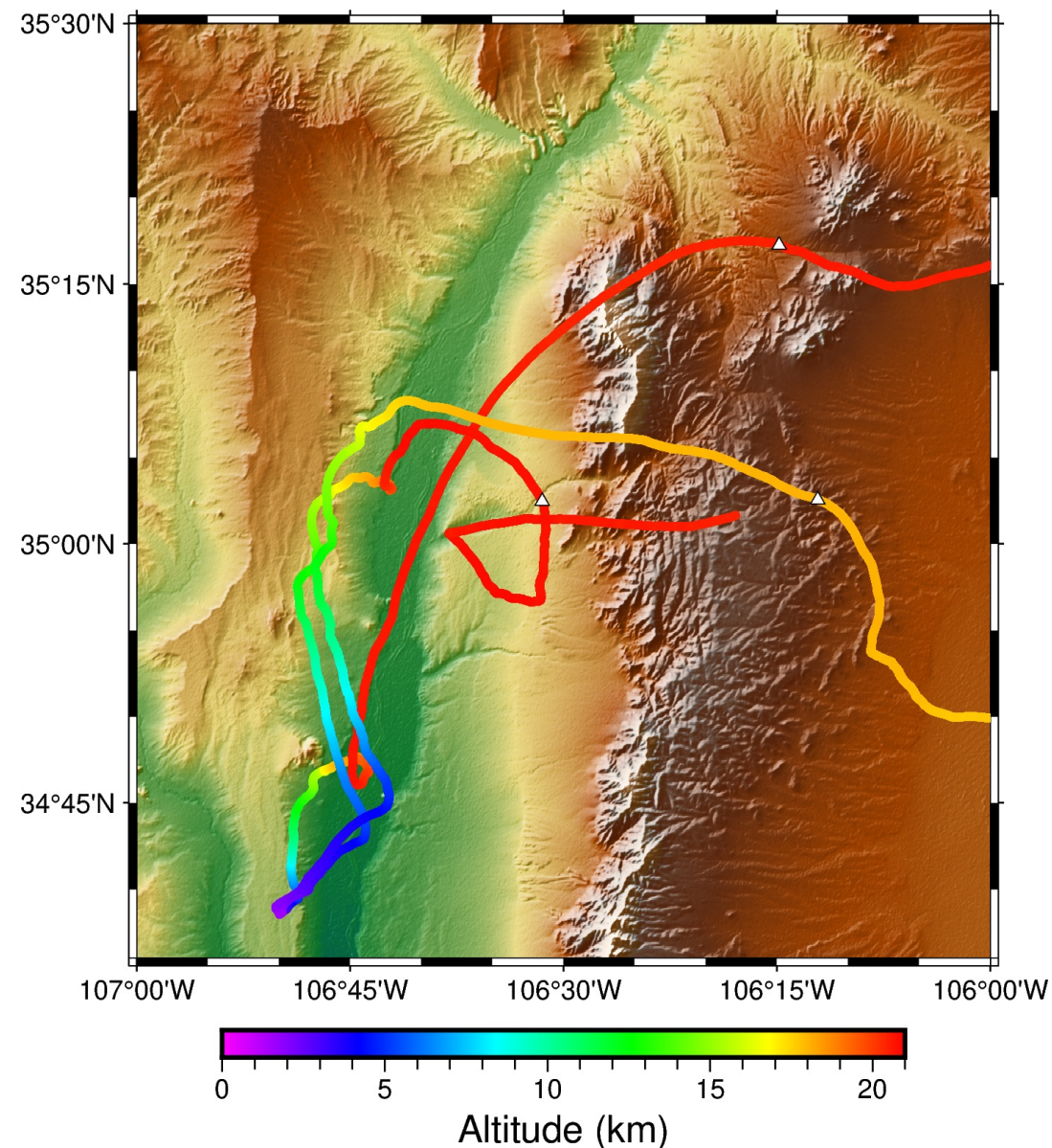
# ULA Landsat 9



# Launch Information

## ULA Landsat 9

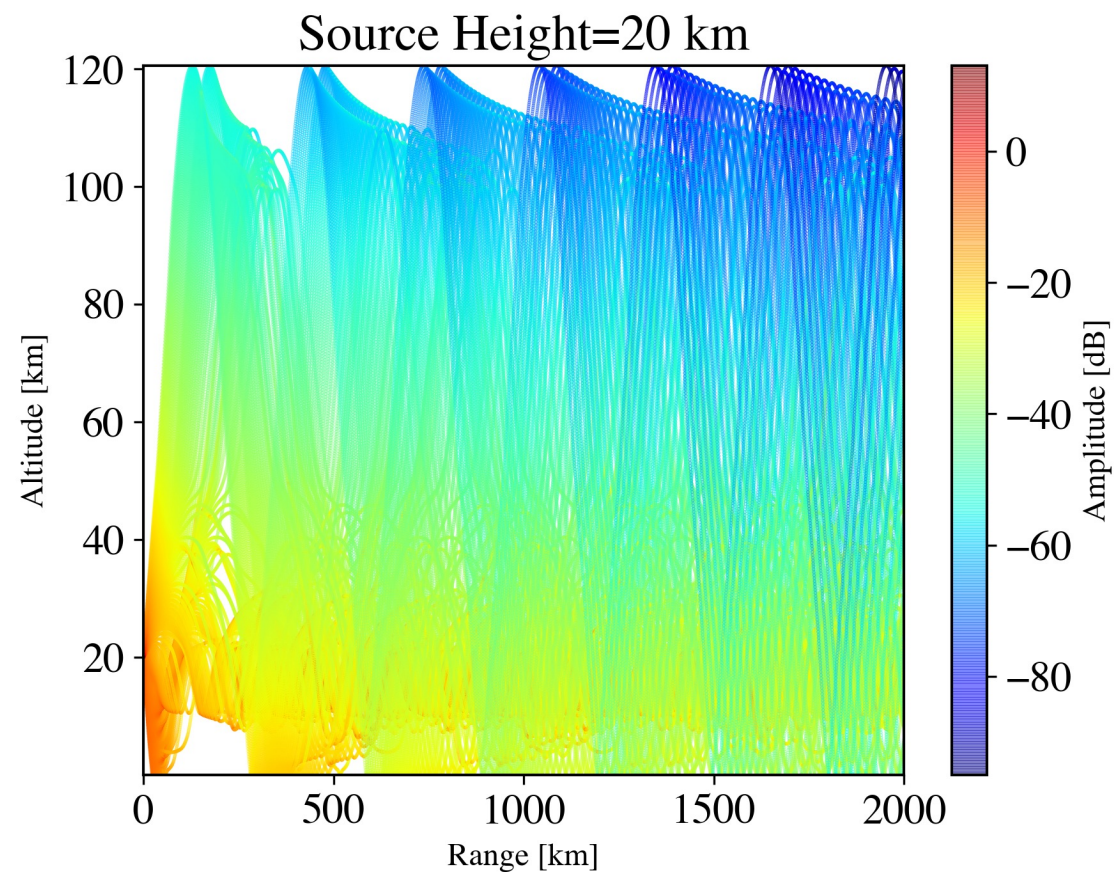
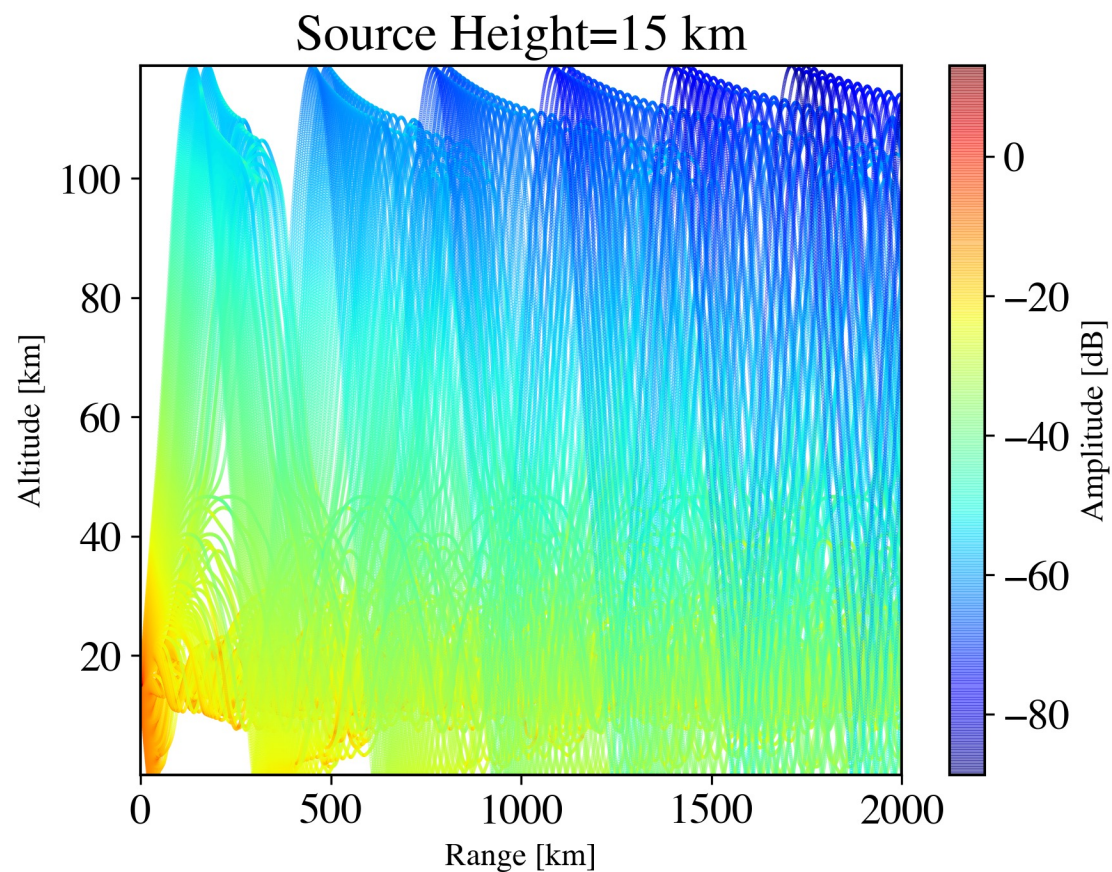
- September 27, 2021
- Science payload
- Atlas V rocket
- 4 balloons:
  - Balloon 1: GEM infrasound sensor
  - Balloon 2: GEM infrasound sensor
  - Balloon 3: iPhone with Redvox - not yet analyzed
  - Balloon 4: Datacube infrasound logger
- ~1300 km range







# Propagation Modeling

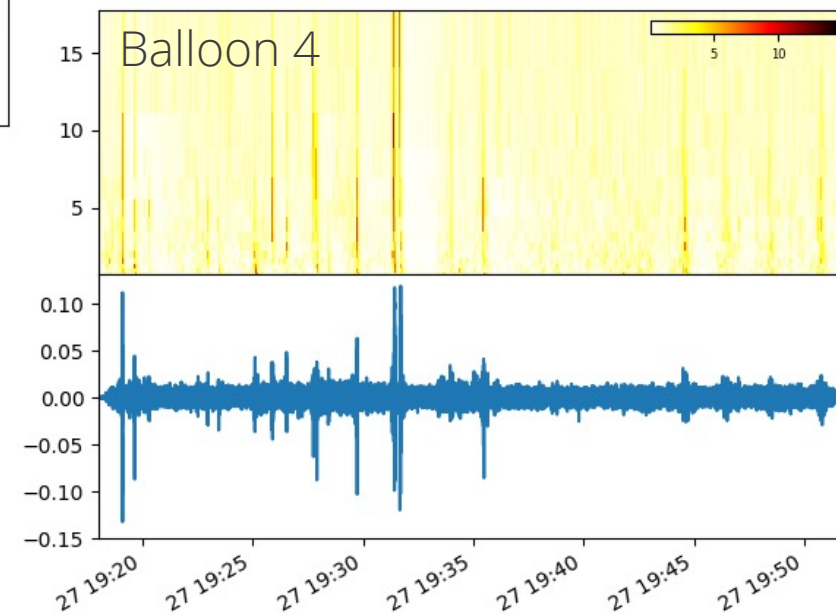
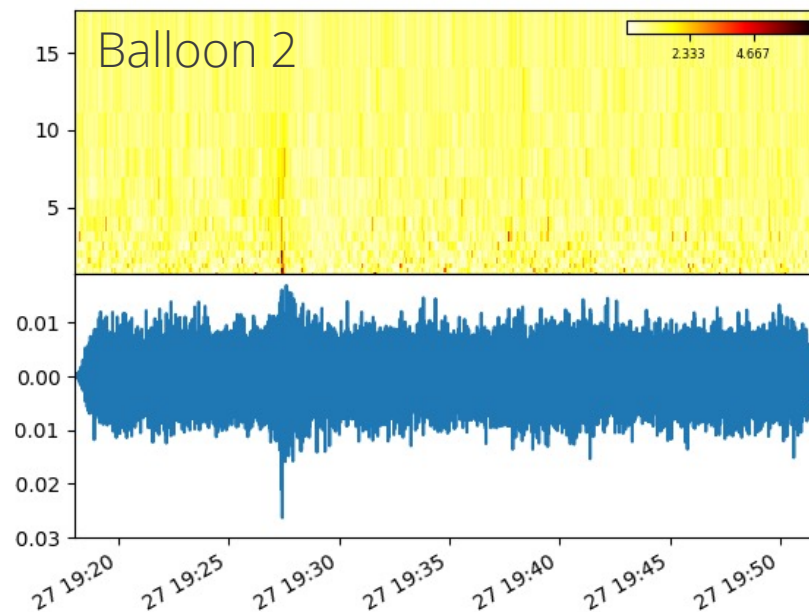
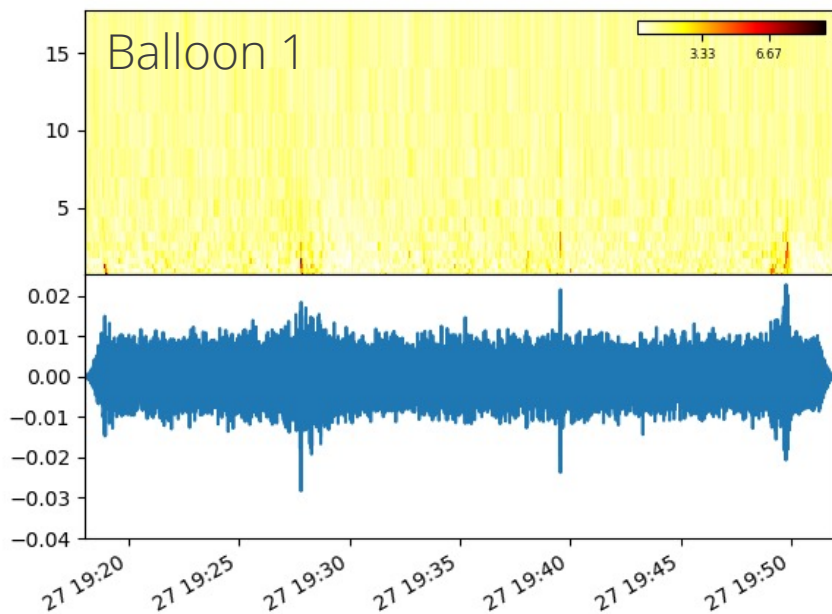


Blue Origin NS-15

ULA Landsat 9



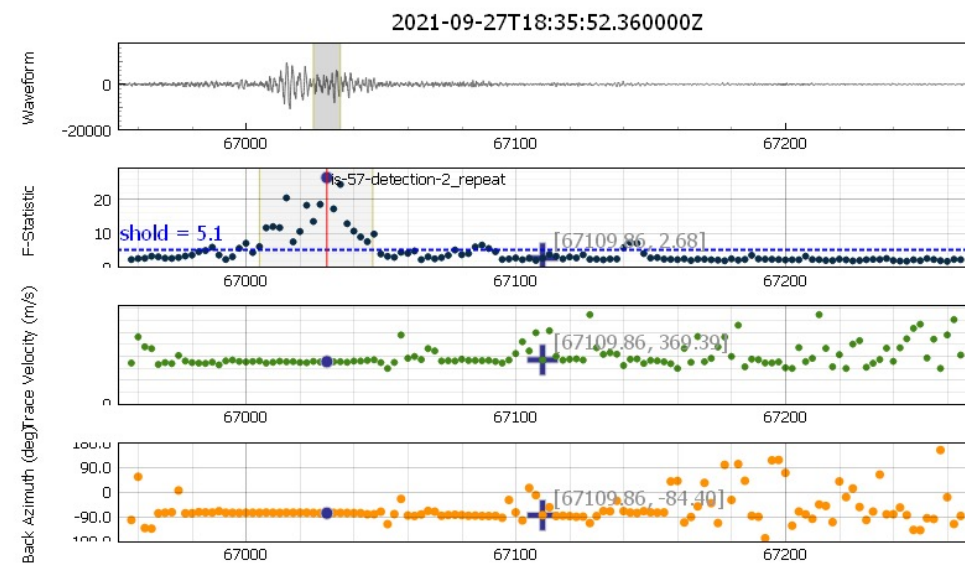
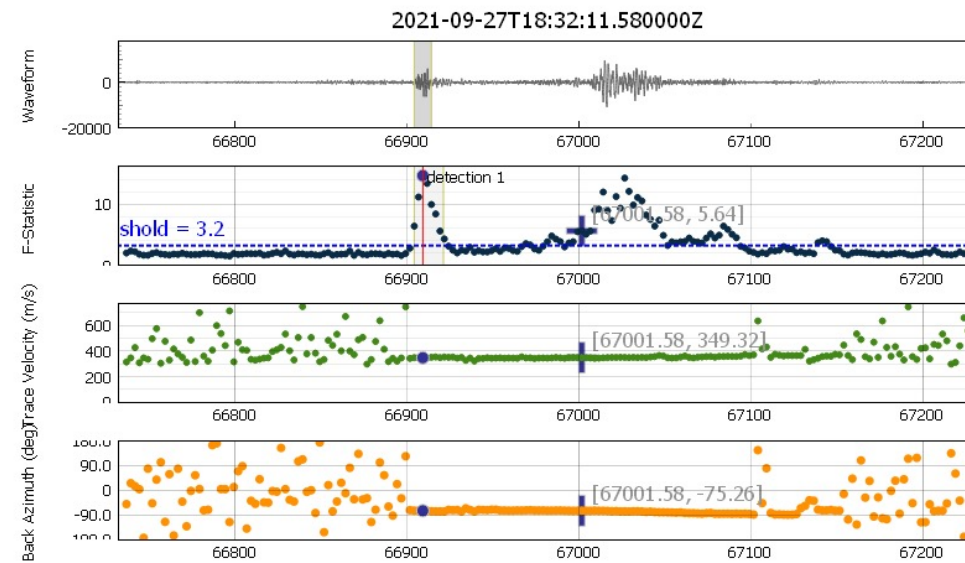
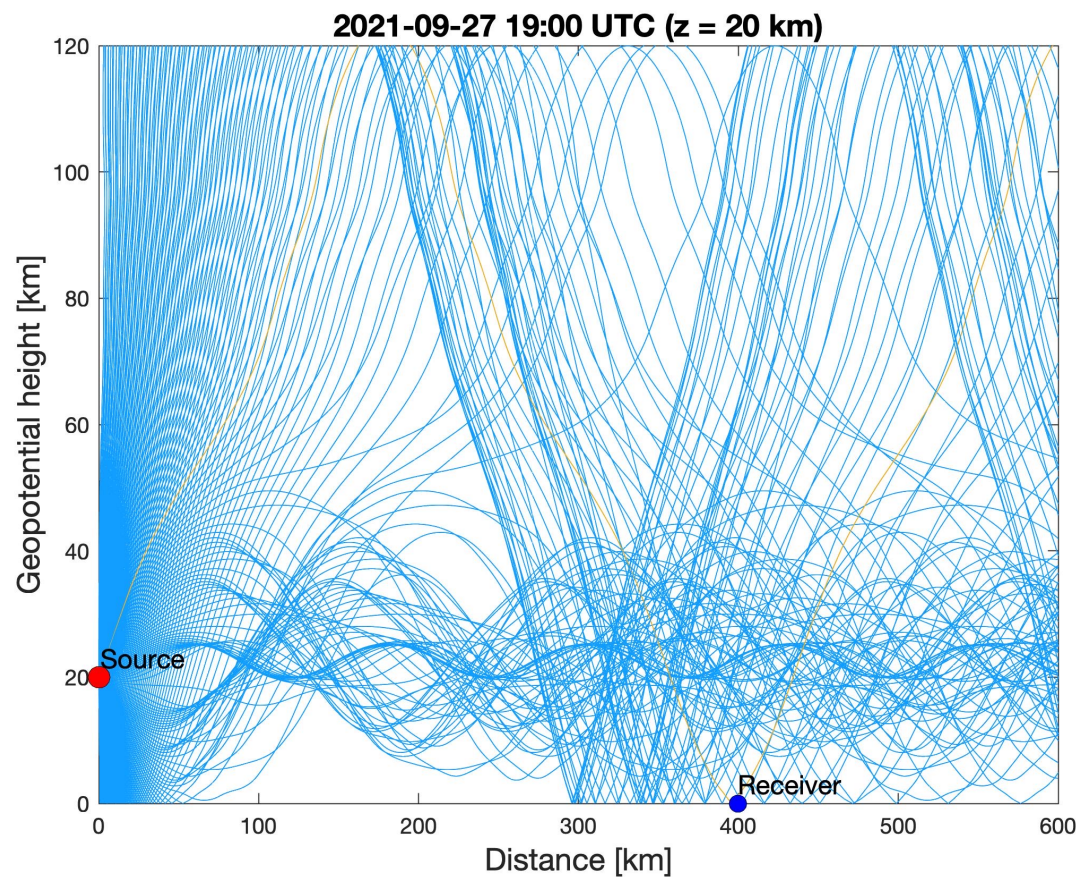
# Time Series Analysis





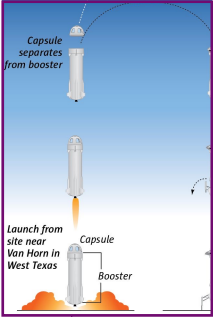


# IMS Network Detections

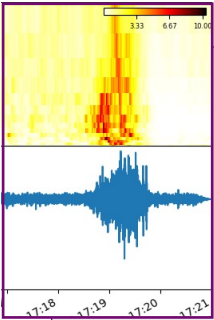




## Conclusions



Able to detect events in the AtmoSOFAR channel under certain conditions

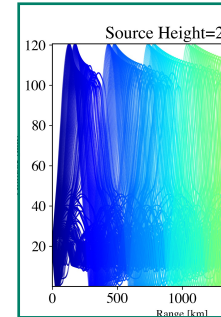


Rocket re-entry signal seems to be stronger



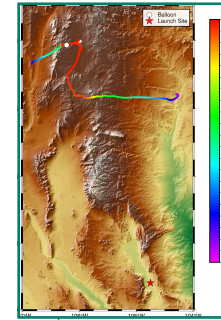
Acoustic background is much more complex than previously thought

## Future Work

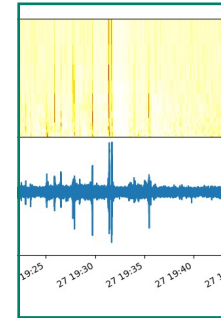


Target two more launches

- At least one Blue Origin



Determine detection range



Investigate acoustic background noise