

Low Altitude Aerial Infrasond Measurements

Mike Pauken, Attila Komjathy, Jim Cutts, Siddharth Krishnamoorthy

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Outline

- ▶ System Design Description
- ▶ Readiness
- ▶ Risk
- ▶ Operations
- ▶ Post-Shot Deliverables
- ▶ Lessons Learned
- ▶ Next Steps

Infrasound Measurement System Design

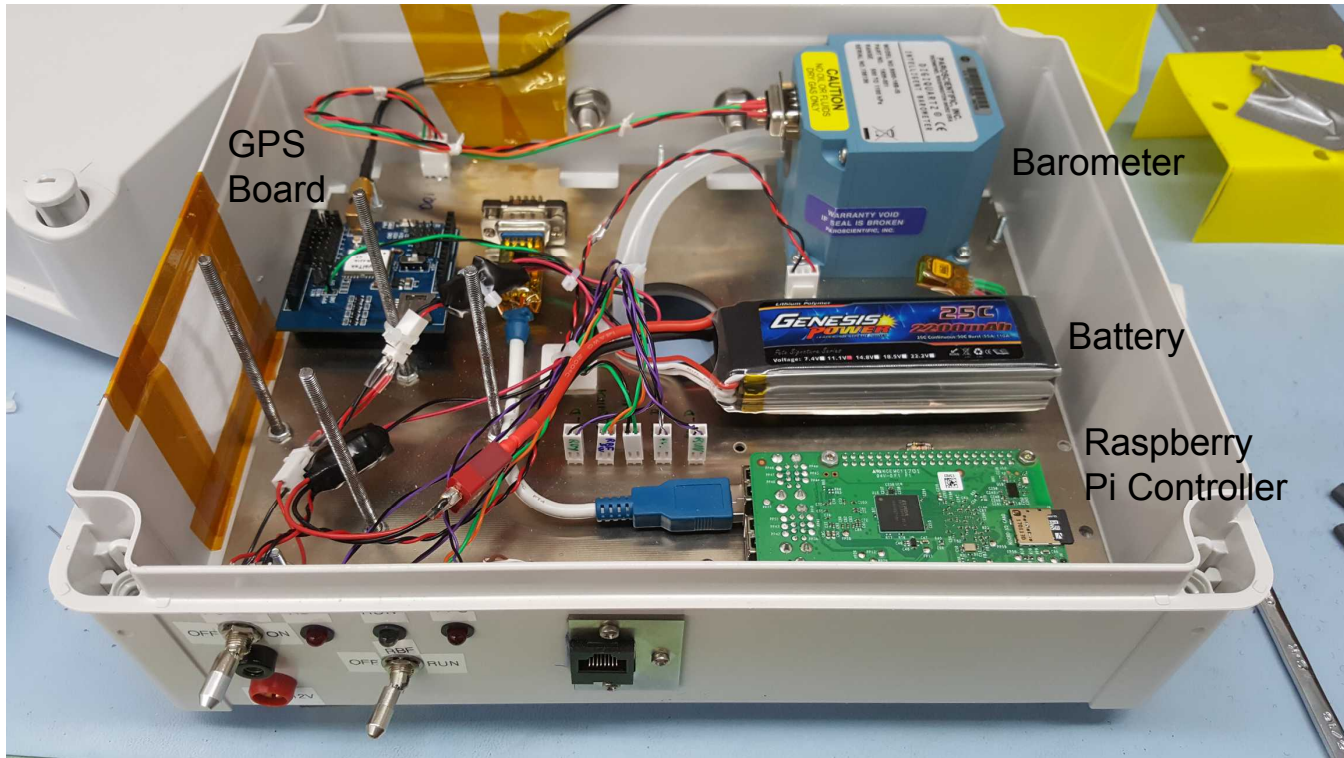
- ▶ Science objective: Develop a correlation coupling ground motion generated by the DAG experiment and the infrasound energy waves detected in the atmosphere. This enables us to develop tools for detecting naturally occurring infrasound waves on Venus and decipher their sources to identify potential seismic, volcanic or storm related activity.
- ▶ Summary of Sensors & Systems
- ▶ The instruments for measuring infrasound are Paroscientific Model 6000-16B-IS microbarometers.
- ▶ GPS units for location, position and orientation data and time stamping data.
- ▶ Inertial Measurement Units provide localized motion data.
- ▶ Raspberry PI controllers operate the instrument and collect data.
- ▶ No live telemetry uplink/downlink is included in instrument package.

Infrasound Measurement Experiment Design

- ▶ Infrasound Measurement Experiment consists of 2 aerial assets:
- ▶ 1. A tethered helium aerostat, SkyDoc Model #18, 1000 cu ft with 48 lb lift capacity.
- ▶ 2. A free flying low altitude (1000 to 2000 ft AGL) helium aerostat. This is a tethered helium balloon that is released from the tether a few minutes prior to the DAG explosion. It is set to neutral buoyancy. After the explosion, the balloon is ruptured with a radio command device and the instrument is returned via parachute for recovery.
- ▶ Each aerostat carries 2 instrument packages suspended on a bridle under the balloon.

Diagnostics System Design

► Infrasound Instrument, Internal Components



Diagnostics System Design

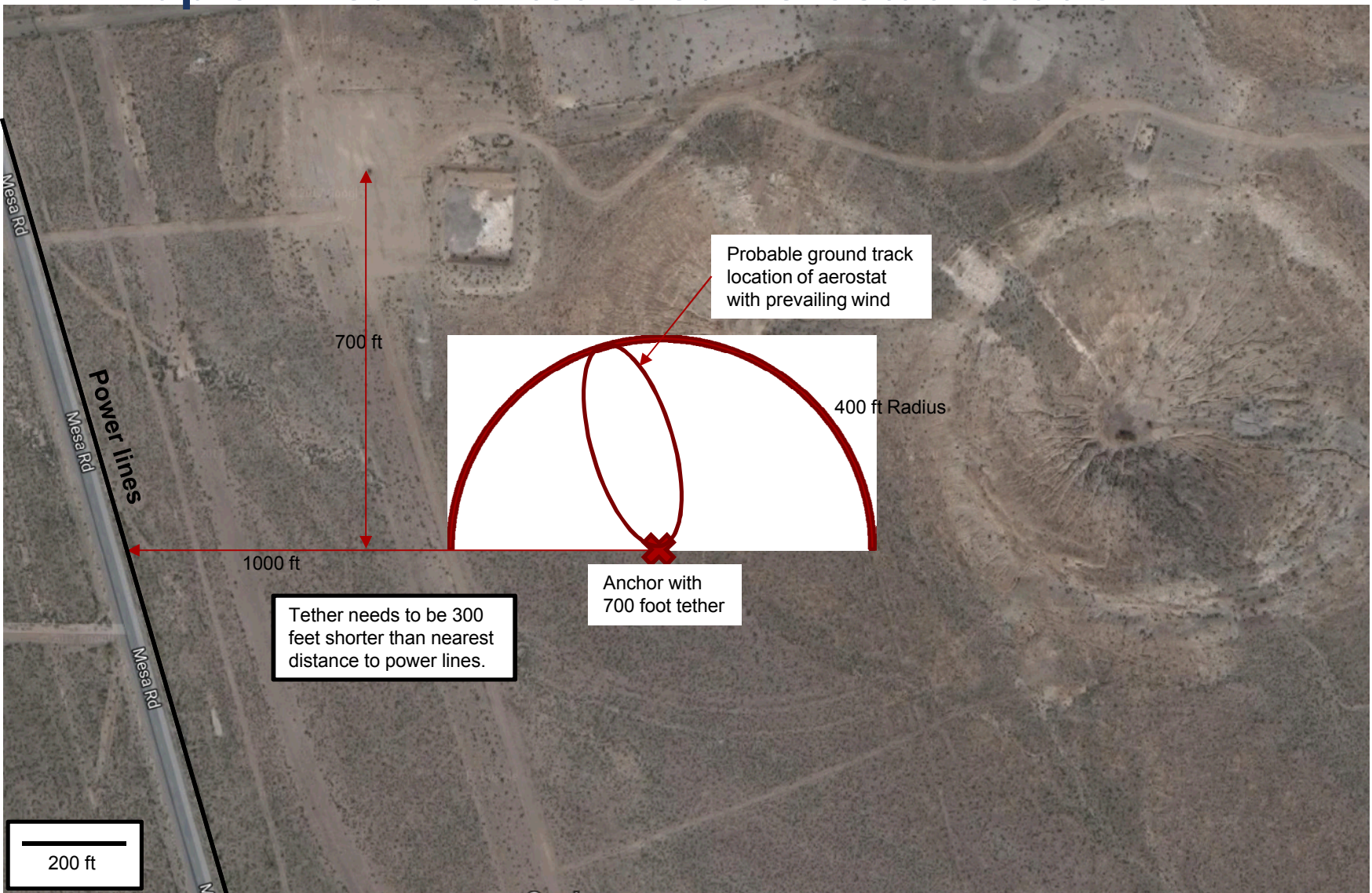
► Infrasound Instrument, Package Configuration



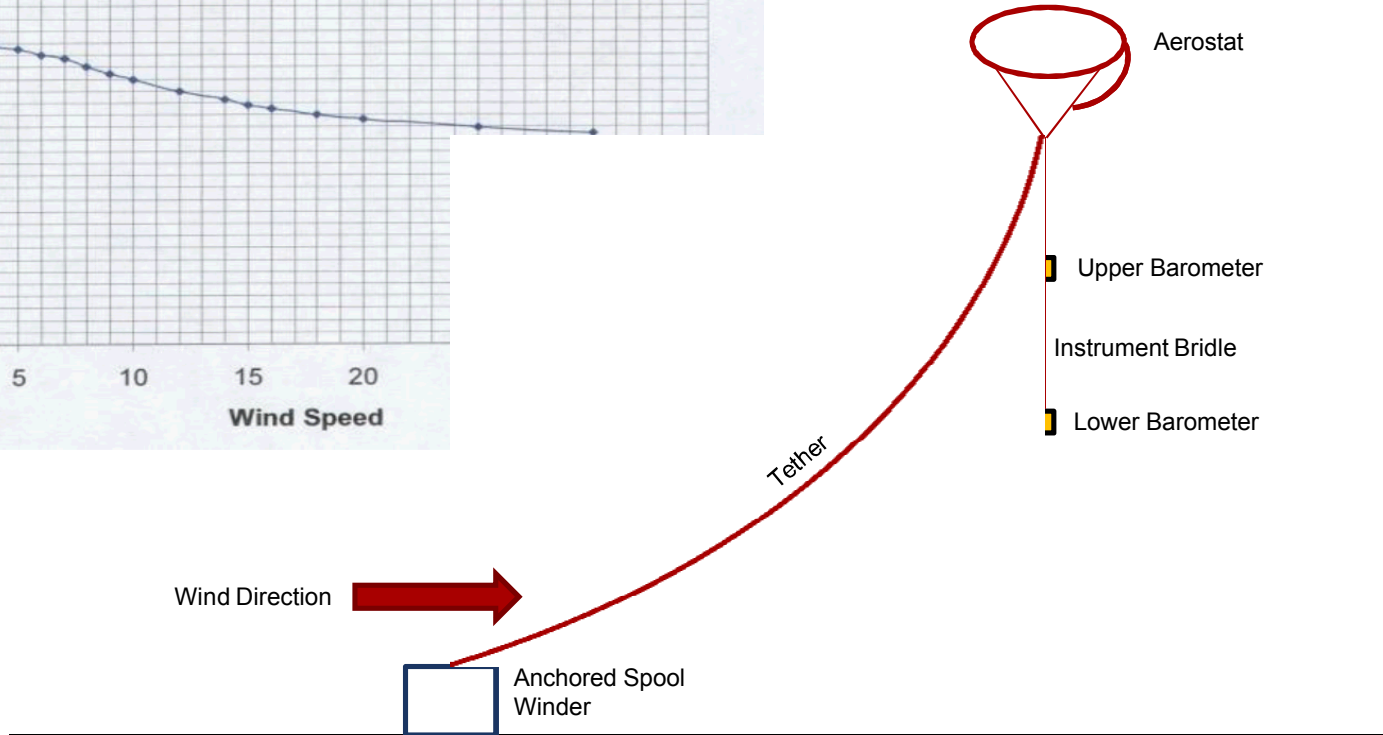
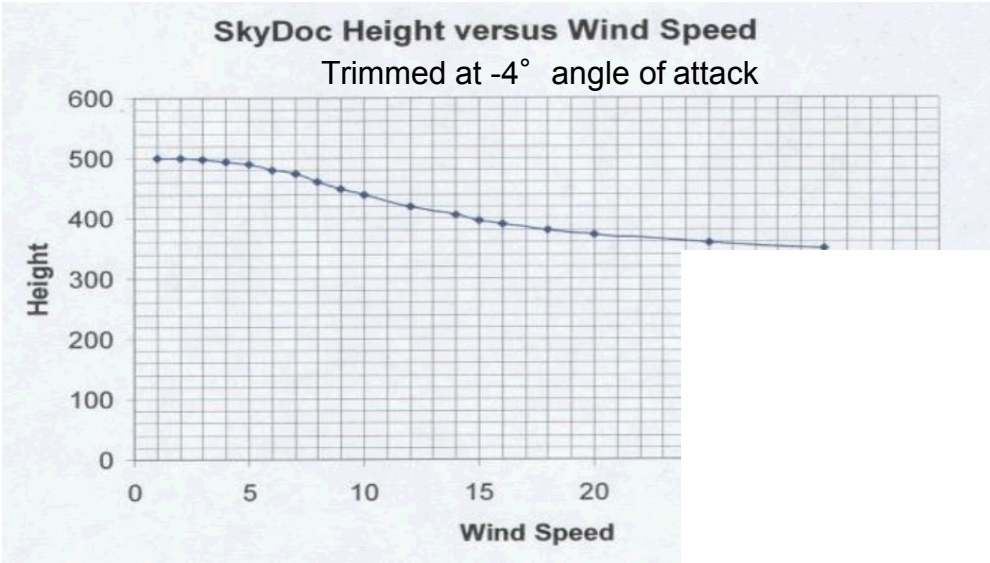
Instrument Package

Noise Filter Inlet Port

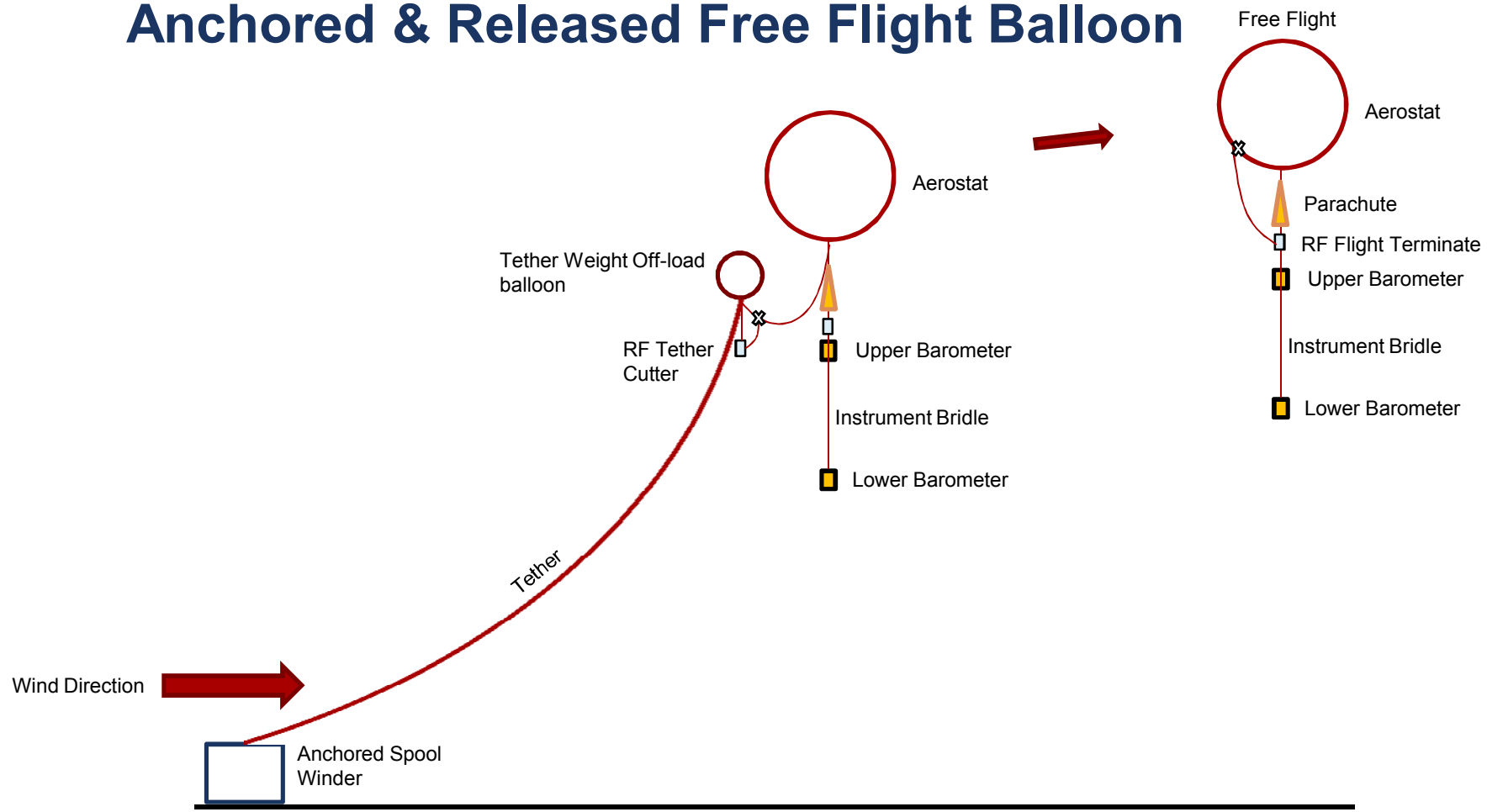
Map of Area with tethered Aerostat location



Tethered Aerostat Flight Geometry (not to scale)



Anchored & Released Free Flight Balloon



FAR 101 Exemption

- ▶ [for an] unmanned free balloon that—
- ▶ (i) Carries a payload package that weighs less than four pounds and has a weight/size ratio of less than three ounces per square inch on any surface of the package, determined by dividing the total weight in ounces of the payload package by the area in square inches of its smallest surface;
- ▶ (ii) Carries a payload package that weighs less than six pounds;
- ▶ (iii) Carries a payload, of two or more packages, that weighs less than 12 pounds; and
- ▶ (iv) Uses a rope or other device for suspension of the payload that requires an impact force of less than 50 pounds to separate the suspended payload from the balloon.

Examples: Weather balloons, small scientific balloons

Electronic Code of Federal Regulations: <https://www.ecfr.gov/cgi-bin/ECFR?page=browse>

Readiness

► Technical

■ Design

- Tethered balloon: COTS SkyDoc Model #18.
- Free flying balloon: COTS latex weather balloon, inflated/ballast to neutral buoyancy between 1000 and 2000 ft AGL. RF command flight terminate box and GPS flight terminate box (back up). Latex balloon and RF line cutter for tether weight off-load.
- Existing instrument payloads used in prior testing at Pahrump NV. Adding new GPS/IMU units to the instrument.
- Custom spool winders for tethered balloon and anchor for free flying balloon.

■ Hardware/Assembly

- Assembly of hardware performed at JPL, minimal configuration changes required on sight.

■ Qualification/Demonstration

- Tethered balloon tested in June 2017 at Pahrump NV Seismic Hammer test.
- Free flying balloon set up and test to be performed by JPL prior to the NNSS test.

Readiness

- ▶ Procedures/Checklists
 - Daily trajectory predictions leading up to shot day
 - Launch operations contingent on ground conditions, flight path, and predicted landing zone
 - Assume no launch unless told otherwise
- ▶ Authorizations
 - Balloon work is included in NSTEC REOP
 - Work Packages based on JPL test plan/procedure documentation
- ▶ Installation Needs from the NNSS
 - Helium, compressed gas, approximately 2000 cu ft. 6-pack cylinders preferred. JPL will bring regulators.
- ▶ Training
 - Pressure Operator Training, if participating in helium balloon inflation

Risk

▶ Sensor/System Risks

- Payload lands in inaccessible/denied area
- Shot occurs after free flying balloon flight termination due to delays
- Free Flying Balloon drifts out of range of infrasound signal

▶ Weather Risks

- Poor ground conditions
 - Winds above 5 m/s during launch operations

Risk (Continued)

► Risks to participation

- Personal injury
 - 50 ft. radius exclusion zone during inflation operations
- Impact to power lines or buildings
 - Limit tether length to keep aerial assets at least 100 m from structures or power lines
- Interference with other airborne diagnostics
 - Release free flying balloon from anchor 10 minutes prior to shot time
- Flight anomaly results in free flying balloon landing on ground assets
 - Mitigate by launching balloon on eastern end of Thor line

Operations

- ▶ Access needed before shots: T-6 to T-1 hours
- ▶ Location of personnel during shots: BEEF
- ▶ Timeline of Fielding Activities
 - T-24 hours: Evaluate trajectories, decide to proceed or cancel
 - Shot day, dawn: Evaluate trajectories and ground conditions, decide to proceed or cancel
 - T-6 hours: Set up tethered aerostat and anchor for free flying balloon
 - T-10 minutes: Release free flying helium balloon from anchor
- ▶ Fielding Team: Mike Pauken, Attila Komjathy, Jim Cutts, Gerry Walsh plus 2 more TBD team members for support.
- ▶ Resources needed from Execution Team
 - Helium, compressed gas, 2000 cu ft in 6-pack cylinders.
 - Power, desk space

Operations

- ▶ Frequencies provided to NNSS
 - RF to flight terminate boxes
- ▶ Dry Run and Shot Expectations
 - Dry run: Simulate launch sequence
 - Shot: Proceed if weather, trajectory, and operational conditions allow
- ▶ ES&H Concerns
 - Only personnel with pressure systems training shall be within 50 feet of helium inflation of balloon systems.
- ▶ Go/No Go Criteria
 - Ground conditions amenable for launch operations
 - Acceptable trajectory
 - Clearance from OCC
 - Clearance from NNSS airspace coordinators
 - Clearance from all other diagnostics

Post Shot Data Deliverable

- ▶ Required deliverable: seismic data from NNSS, infrasound data to Sandia.
- ▶ Timeline for delivery: 4-8 weeks after test
- ▶ Quality analysis: Evaluate signal to noise ratio from test data
- ▶ Written documentation: Report on infrasound detection, and waveform characteristics

Lesson Learned from Past Experiments

- ▶ Lessons learned from Seismic Hammer Test in Pahrump NV
 - Need to have 2 independent teams to cover the tethered aerostat and the free flying balloons. Single point of contact for coordinating both teams.
 - All personnel should be cross-trained to perform any job function in the set up and execution of the test.
 - The location of the tethered balloon should be portable to adjust anchor location in the event of shifting winds. Having the anchor in the bed of a pickup truck can accomplish this.
 - Aerostat should be larger and have more lift capability than the SkyDoc model #15. This is addressed by using a model #18 in this test, it has 48 lbs of lift compared to 28 lbs for model #15.

Next Steps

- ▶ Describe next steps
 - Determine range of measureable infrasound signals from DAG shots (JPL will work with ISAE to predict amplitudes in the test area).
 - Write detailed plan of operations for dissemination to NSTEC, NNSS air traffic control, NNSS weather, and other parties
 - Execute test flights of proposed free flying balloon systems.