SAND2017-9640PE

Secondary: High Altitude Infrasound

Danny Bowman

9-13-17

Outline

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

Diagnostics System Design

- Science objective of document: Capture infrasound from the DAG shots in the upper troposphere/lower stratosphere
- Secondary Diagnostic
- Target DAG – 2 through DAG – 4
- Builds on 2017 LDRD express project (photo below)

Diagnostics System Design

- Summary of Sensors & Systems
  - Flight System
    - Mylar helium balloon (weather balloon)
    - Heliotrope (solar hot air balloon)
  - Decelerator
    - Two redundant parachutes (weather balloon)
    - Parachute and balloon envelope (solar hot air balloon)
  - Tracking
    - Ping 200Si transponder
    - SPOT Trace asset tracker
    - Onboard GPS Logger (Adafruit Ultimate GPS Shield/Omnirecs Datacube)
  - Scientific Payload
    - Gem Infrasound Sensor/Digitizer
    - Raspberry Pi based Sensor/Digitizer
    - Chaparral 60 / InfrasBSU microphones with Omnirecs Datacube

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

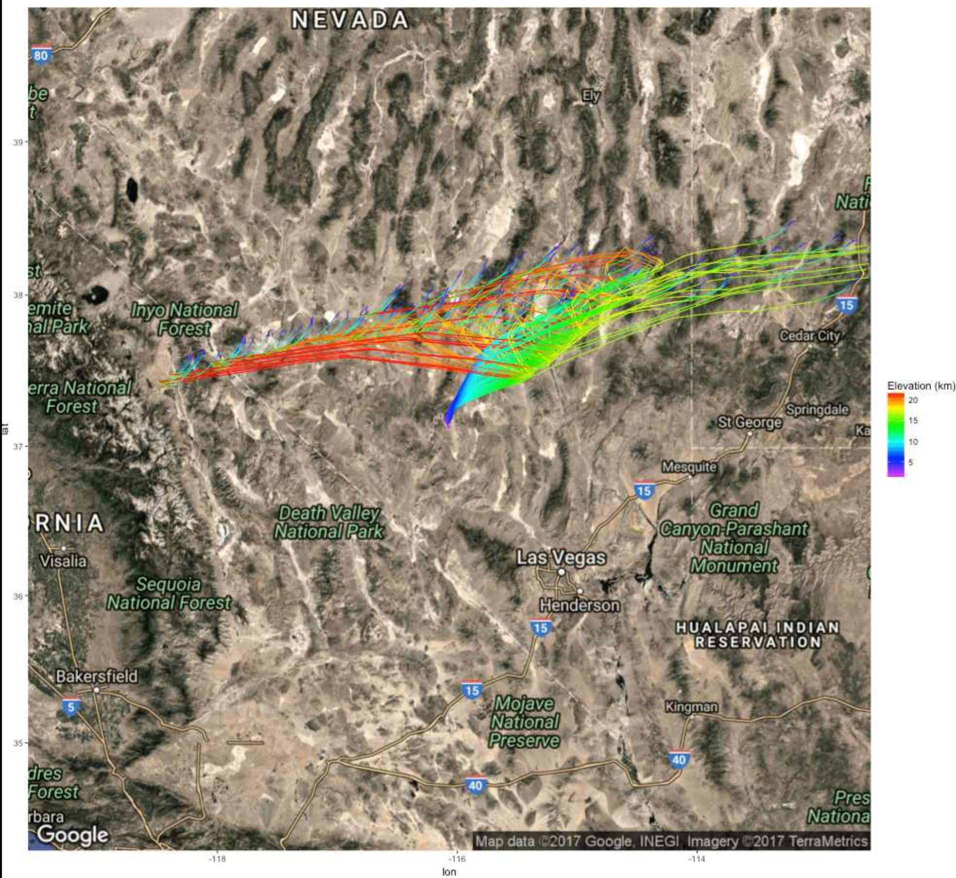
Electronic Code of Federal Regulations: https://www.ecfr.gov/cgi-bin/ECFR?page=browse

Flight Systems

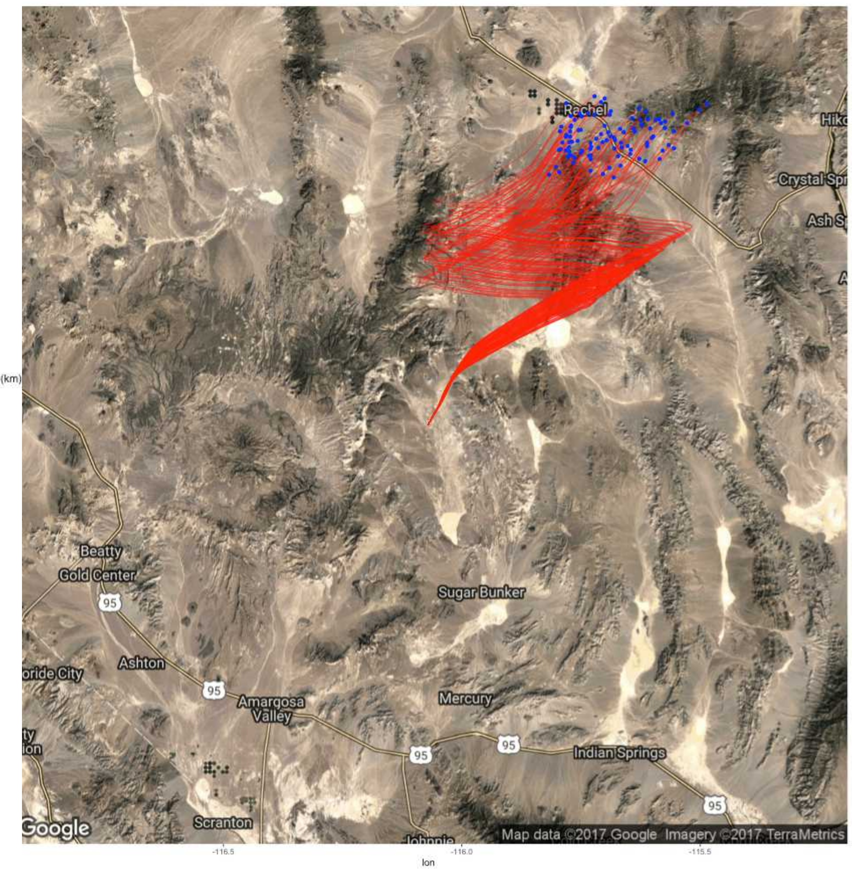
Payload and Parachute(s)

Trajectory Modeling

Solar Balloon: Flight Lasts 10+ hours
Validated: Heliotrope Mission



Helium Balloon: Flight Lasts ~3 hours
Validated: Eclipse Flight



Recovery

Readiness

- Technical
  - Design
    - 20-40 ft. diameter solar balloon or 1-3 kg Mylar balloon
    - Infrasound payloads, tracker, decelerators,and GPS module validated on previous flights
    - Transponder adds weight and complexity; consider removing
  - Hardware/Assembly
    - Some infrasound equipment needs to be purchased
    - Flight systems and payload to be assembled at Sandia
  - Qualification/Demonstration
    - Test flights in Socorro, NM, planned for this fall
    - Goals: measure background noise levels and validate flight systems
    - Any flight configuration attempted at NNSS must be validated in Socorro first

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 Sandia's Heliotrope documentation
- Training
  - Pressure Operator Training, if participating in helium balloon inflation

Risk

- Sensor/System Risks
  - Payload lands in inaccessible/denied area
  - Shot occurs after helium balloon flight termination due to delays
  - Balloon drifts out of range of infrasound signal
- Weather Risks
  - Poor ground conditions
    - Winds above 5 m/s during launch operations
    - Cloud cover likely 0-2 hours after launch (solar hot air balloons only)
  - Unacceptable trajectory, defined as
    - Landing site likely to be in urban area, or
    - Landing site likely to be in sensitive area, or
    - Landing site appears extremely rugged and/or remote, or
    - Neutral buoyancy level below 50,000 ft.

Risk (Continued)

- Risks to participation
  - Personal injury
    - 100 ft. radius exclusion zone during launch operations
    - Any person inside exclusion zone must either wear a hard hat or take shelter in a car
  - Impact to power lines or buildings
    - Launch at least 100 m from structures or power lines
  - Interference with other airborne diagnostics
    - Launches will occur at least one hour prior to shot time
  - Flight anomaly results in balloon landing on ground assets
    - Mitigate by launching balloon on eastern end of Thor line

Operations

- Access needed before shots: east end of Thor line, 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
  - Dawn + 45 minutes to T-3 hours: Launch solar hot air balloon
  - T-2 to T-1 hours: Launch helium balloon
- Fielding Team: Danny Bowman and Sarah Albert (Heliotrope launch team) and Walt Schalk
- Resources needed from Execution Team
  - Power
  - COM
  - Triggers
  - Interface to other diagnostics

Operations (Continued)

- Resources needed from Execution Team
  - Power, internet, and desk space
  - COM
- Frequencies provided to NNSS: SPOT Trace transmit frequency, transponder frequency
- Dry Run and Shot Expectations
  - Dry run: Simulate launch sequence
  - Shot: Proceed if weather, trajectory, and operational conditions allow
- ES&H Concerns
  - Personnel within 100 ft. of launch operations must either wear a hard hat or remain in a vehicle

Operations (Continued)

- 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: Infrasound and trajectory data
- Timeline for delivery: 4 weeks after balloon recovery
- Quality analysis: Evaluate signal to noise ratio during flight
- Written documentation: Report on flight operations, trajectory, infrasound detection, and waveform characteristics

Lesson Learned from Past Experiments

- Lessons from 2015 UNC weather balloon / 2017 eclipse flight
  - Sometimes helium balloons burst late (and go higher than expected)
  - Wind noise drops dramatically about 20 km altitude
  - During the summer, higher altitudes move the landing point westward
- Lessons from the Heliotrope experiment (Summer 2017):
  - Assume the actual flight can follow any of the predicted paths
  - Cold temperatures can be an issue on solar hot air balloon flights
  - Small changes in payload mass have a dramatic effect on solar hot air balloon maximum altitude
  - Near-dawn flights are underpowered
  - Moderate wind and cirrus clouds do not preclude launching

Next Steps

- Determine if infrasound signals from DAG shots are recoverable at altitude (work with Keehoon and Kale to predict amplitudes in the upper troposphere/lower stratosphere)
- Simulate balloon trajectories in past years to determine typical flight paths in the summer
- Write detailed plan of operations for dissemination to NSTec, NNSS air traffic control, NNSS weather, and other parties
- Execute test flights of proposed balloon-borne systems out of Socorro, New Mexico