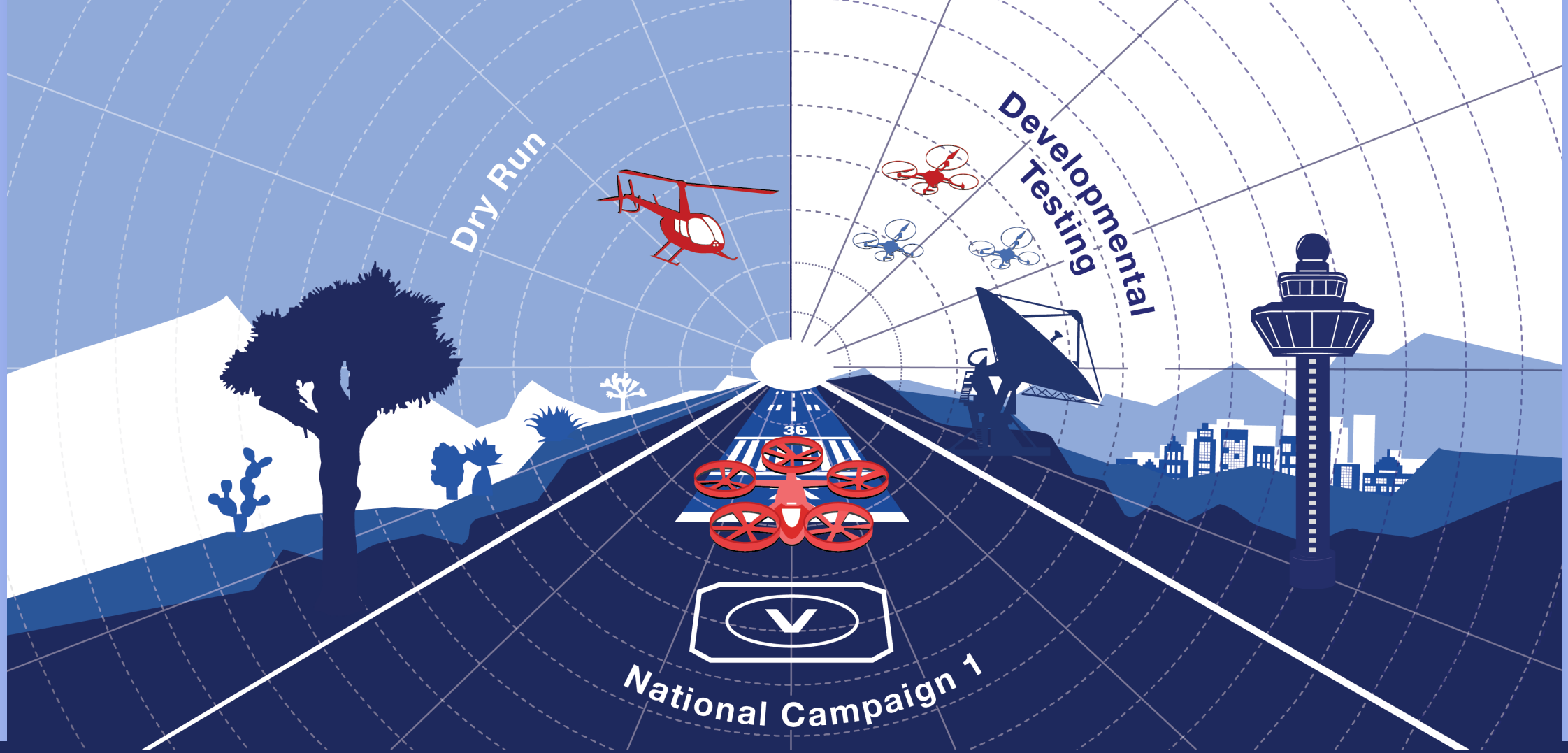

The Advanced Air Mobility National Campaign:
An Overview and Plans for Acoustic Testing

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AAM National Campaign Lead

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AAM National Campaign Acoustics Lead

2020 Fall Acoustics Technical Working Group
November 4, 2020

Acoustics Testing – NC Scenario 4

From the National Campaign standpoint,

- Goals for NC-Developmental Test (DT), and NC-1:
  - **Identify Community Integration Needs**: Conduct initial characterization of the community noise of AAM vehicles through measurements of vehicle ground noise
    - NC-DT partnering with Joby Aviation
    - Develop and tailor the noise data collection scenario based on vehicle partner(s) and external range(s) locations/geography

- NC-2 and greater:
  - Underdefined, but hope to
    - Coordinate with industry, external ranges, and local governments to characterize community considerations through community outreach activities.

From a research standpoint, with permission by the vehicle partners,

Collect data to

- Validate prediction and modeling tools/toolchains
  - CAMRAD II, PAS
  - AARON, ANOPP2-ABEAT, ASNIFM, etc.

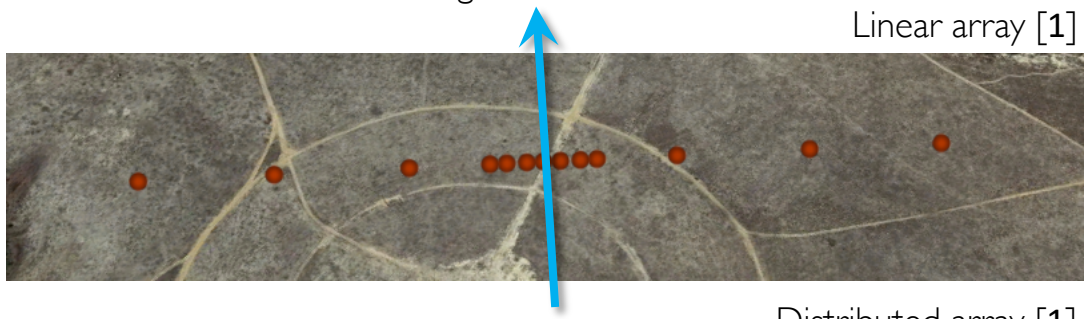
- Devise appropriate metrics
- Enable psychoacoustic testing

Acoustics Testing Methodology

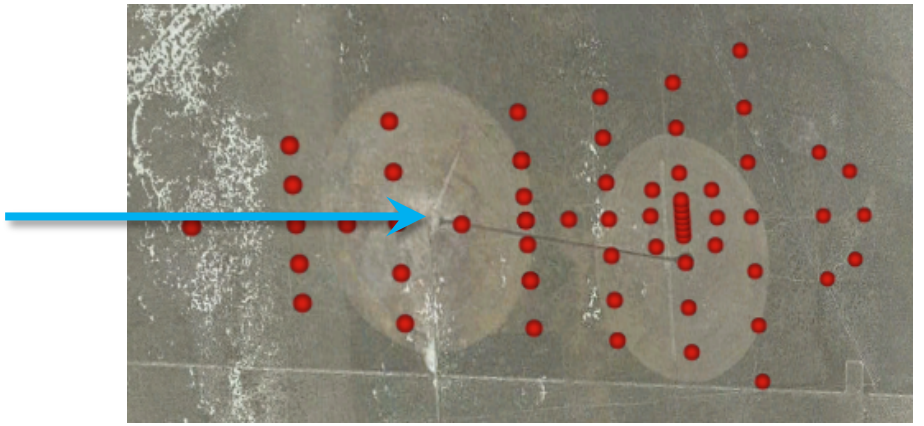
- What type of acoustic measurements will best characterize AAM vehicles?
  - **Linear arrays** - source noise representations
  - **Distributed (2D) arrays** – ground noise contours for full effect of unsteady flight procedures
  - **Phased arrays** - could increase SNR, perhaps useful for broadband noise, but rotating partially coherent sources may introduce uncertainty
- How to build/prioritize test matrix?
  - Configuration/operational mode dependent
  - Estimated impact of each phase of flight
  - Insight into dominant noise sources
- NC requires deployability – testing at external ranges

Flight direction

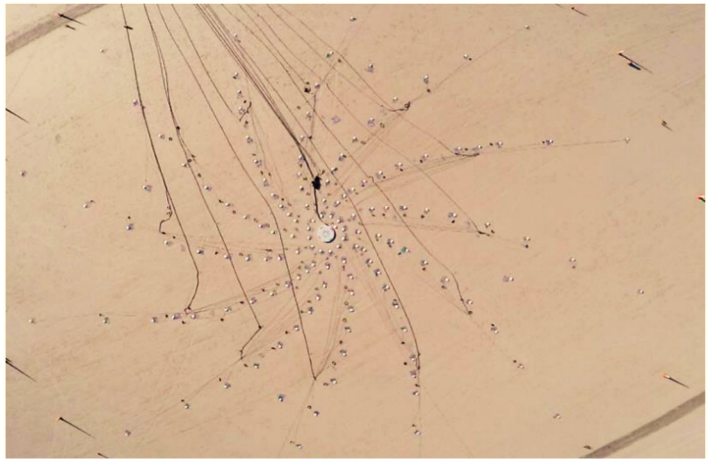
Linear array [1]



Distributed array [1]



Phased array [2]



[1]Watts et al., NASA TM 2019-220264, 2019.
[2]Khorrami et al., AIAA 2016-2972, 2016.

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Vectored thrust

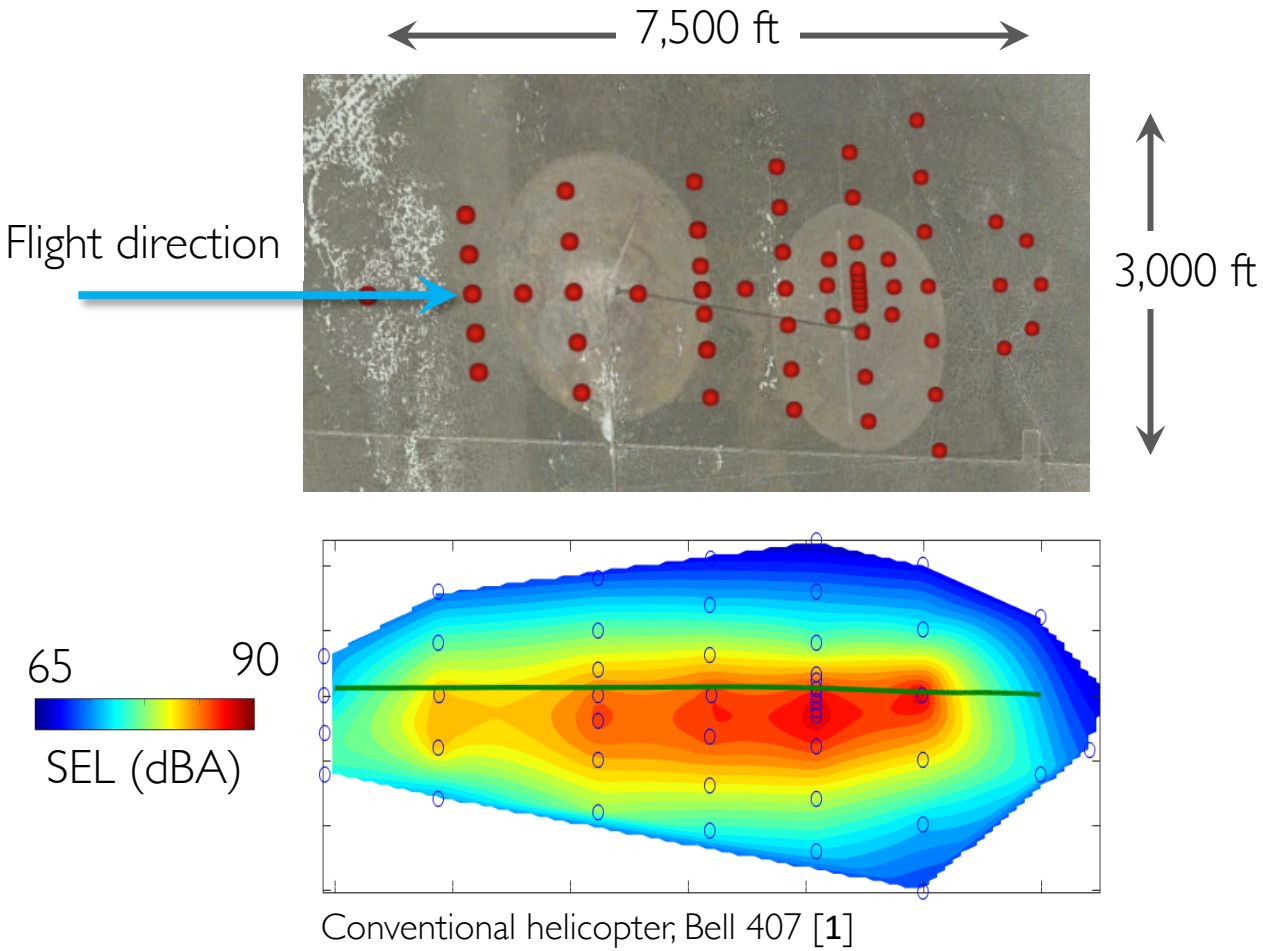
Wingless (multicopter)

Lift + Cruise

Electric or Hybrid Rotorcraft

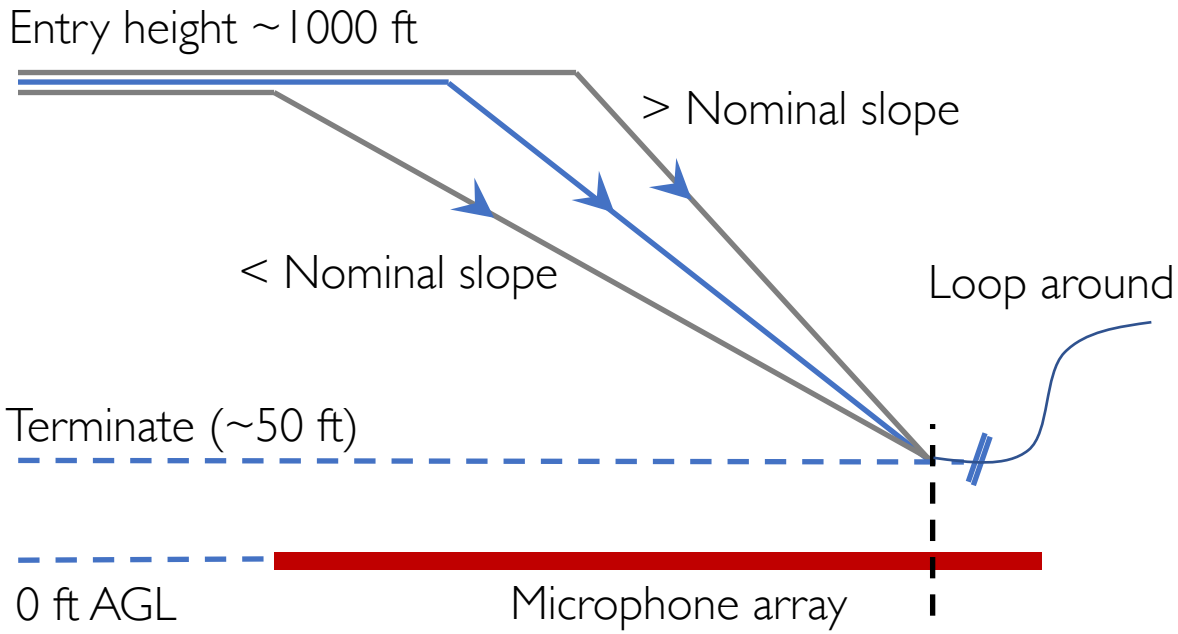
Array sizing and layout

- To characterize **unsteady** flight conditions
  - Approaches, takeoff, maneuvers



Conventional helicopter, Bell 407 [1]

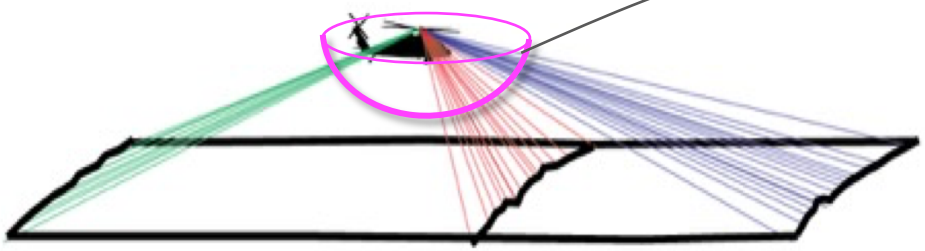
- Length dependent on nominal procedures
- Width dependent on lower noise bound of interest
  65 dB contours popular consideration

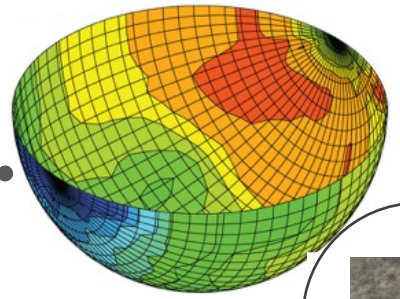


[1]Watts et al., "Noise Abatement Flight Test Data Report," NASA TM 2019-220264, 2019.

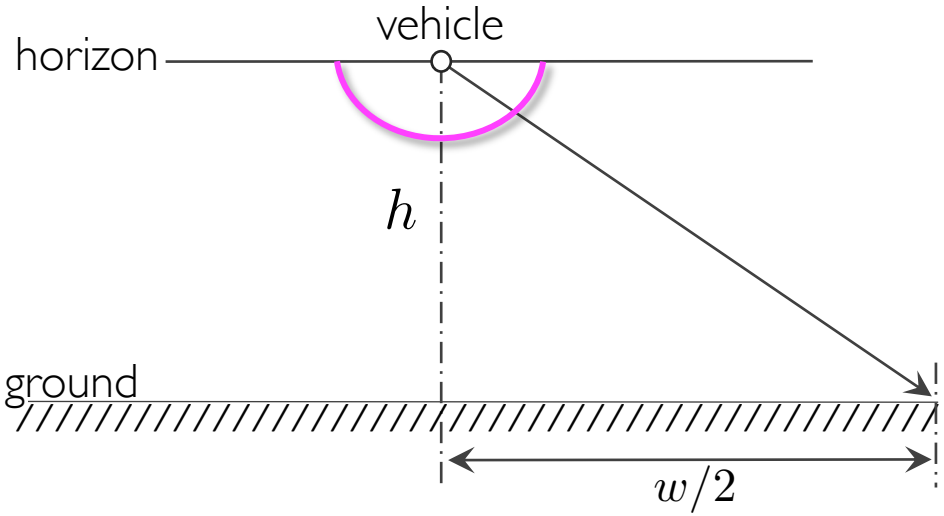
Source noise representation

To characterize **steady** flight conditions



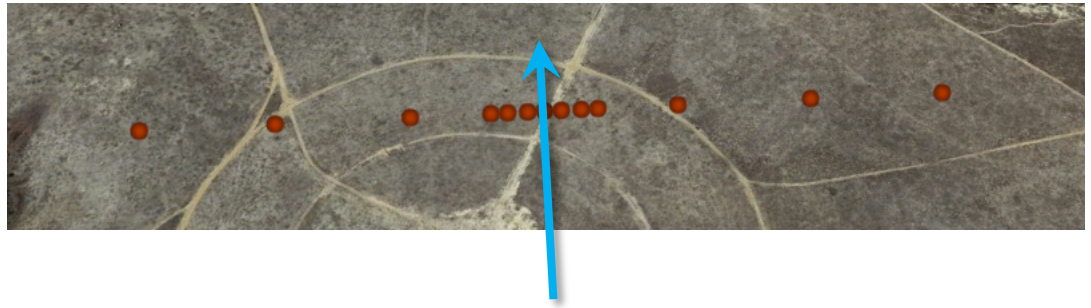


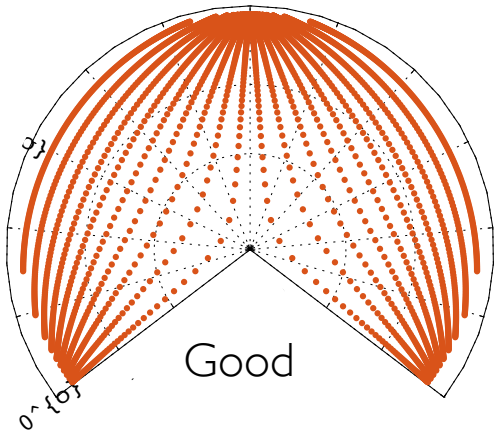
$$L = f(\phi, \theta, f)$$



View: aircraft flying into page

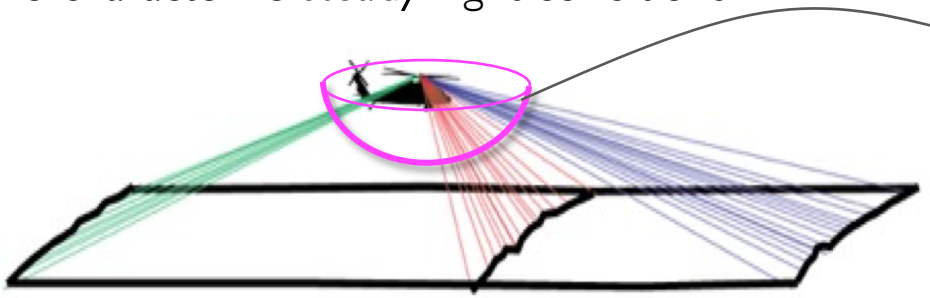
Directivity resolution depends on vehicle altitude, speed

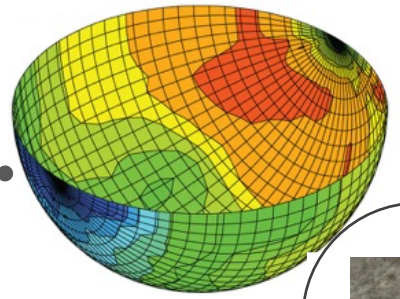




Source noise representation

To characterize **steady** flight conditions





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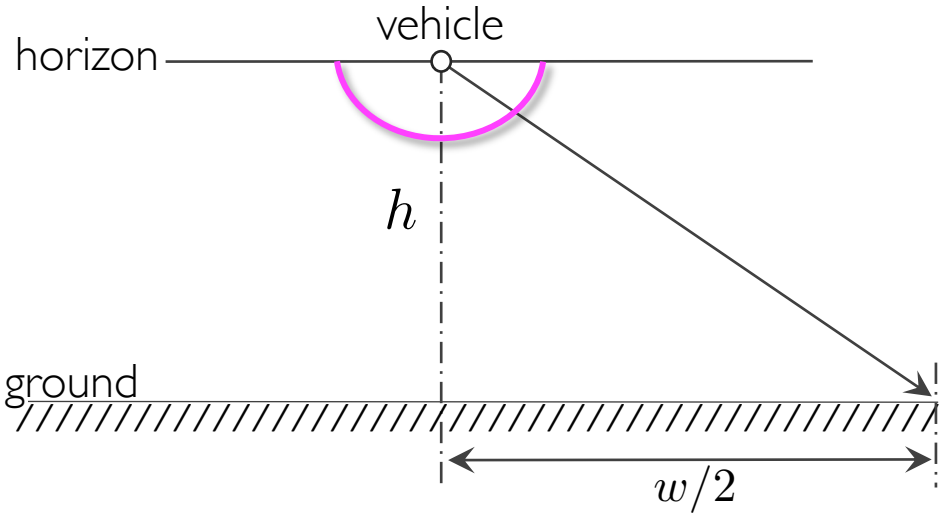

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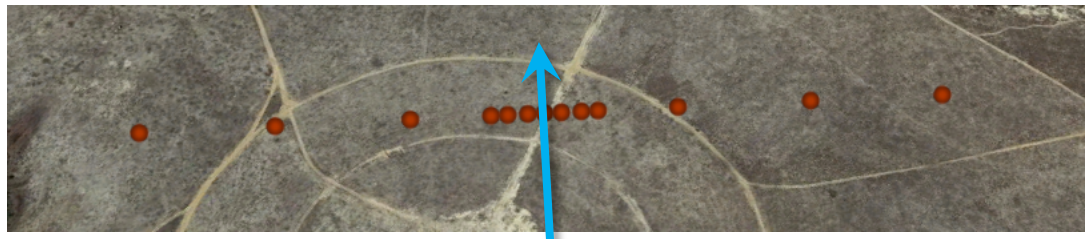
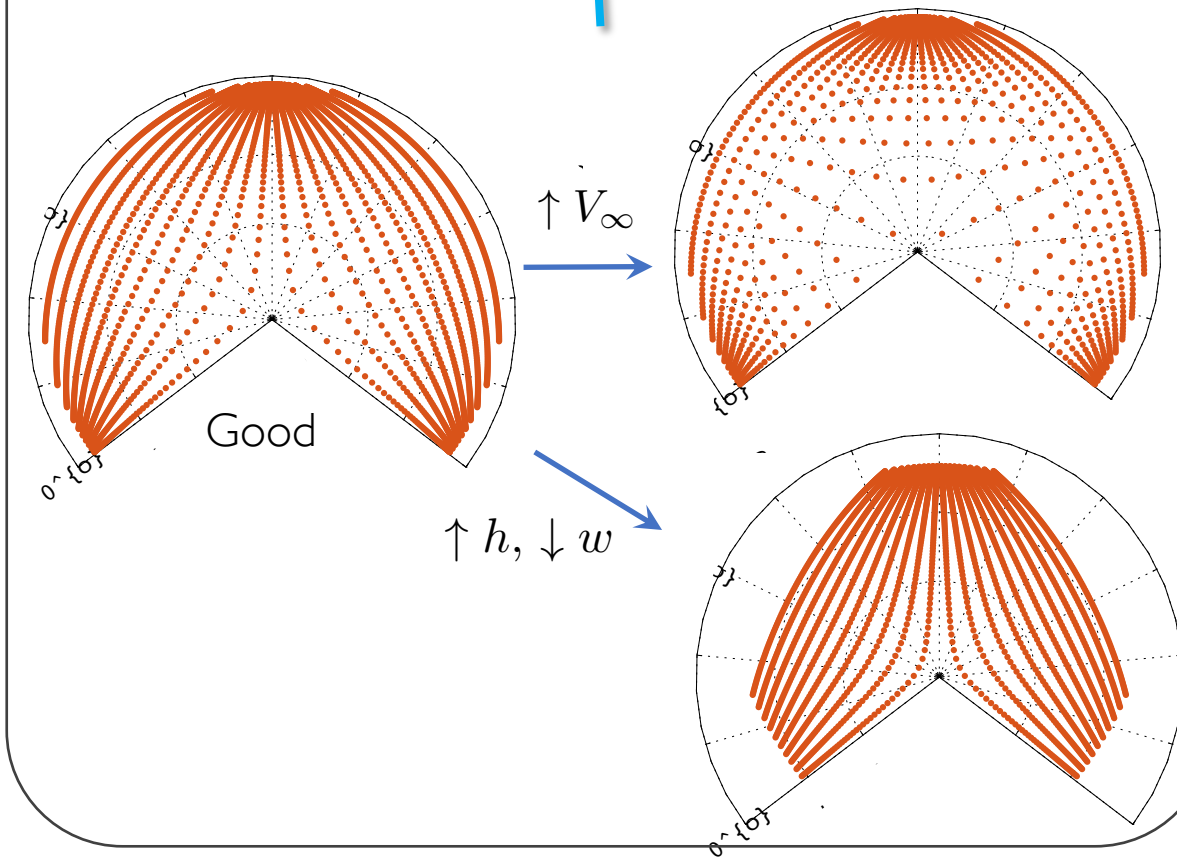
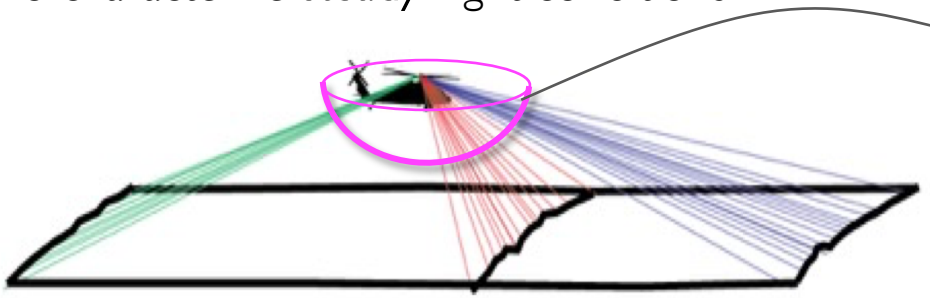
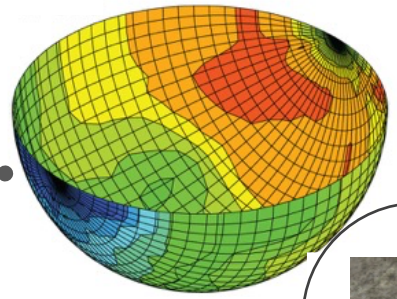




Source noise representation

To characterize **steady** flight conditions





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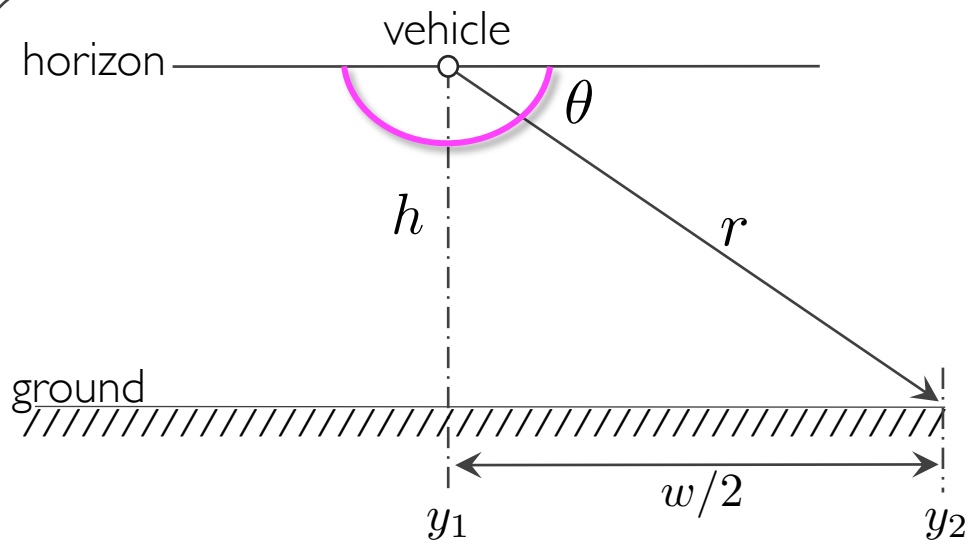
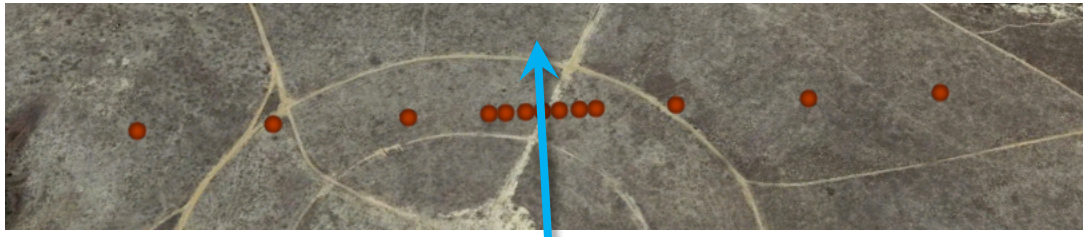
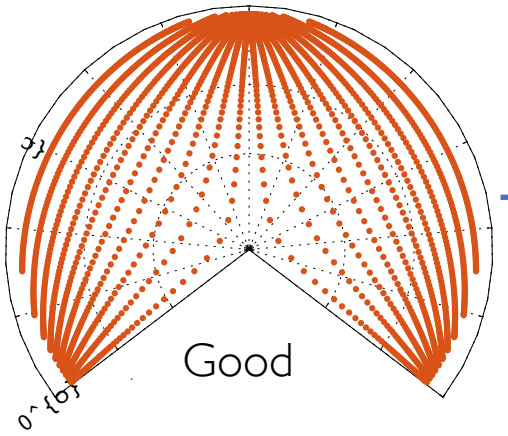


$$SNR = 20\log_{10}\left(\frac{p_{rms}}{n_{rms}}\right) \qquad \Delta SNR_{y_1,y_2} = 20\log 10(\sin\theta)$$

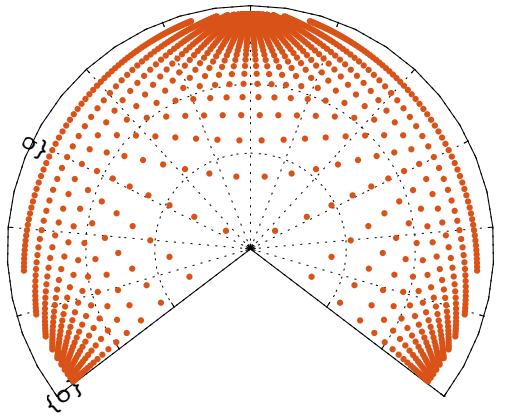
e.g., $\theta = 10° \rightarrow \Delta SNR_{y_1,y_2} = 15$ dB

Directivity resolution depends on vehicle altitude, speed

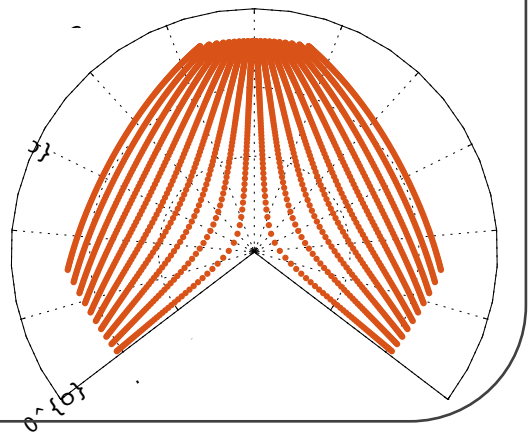




$\uparrow V_\infty$

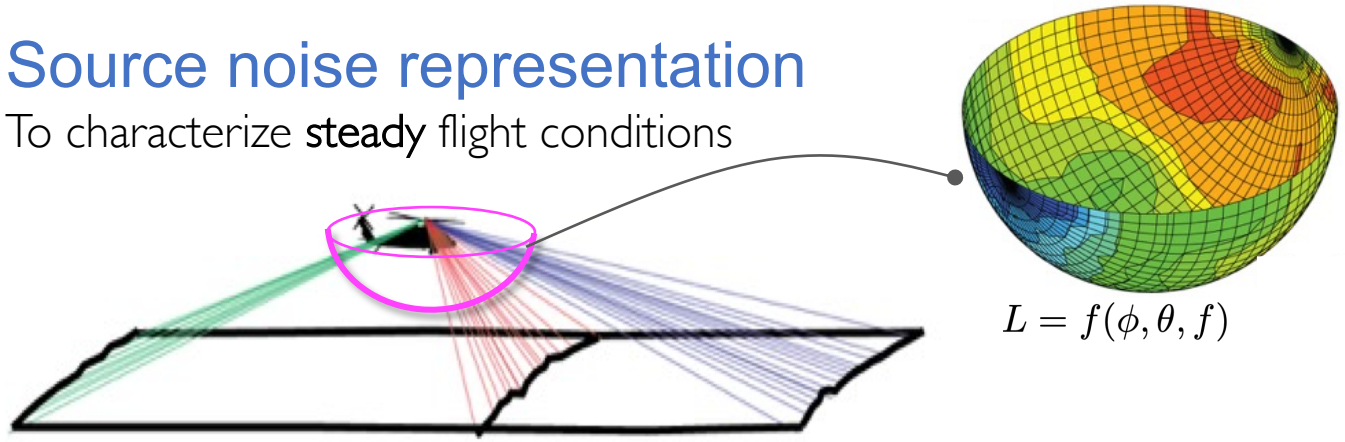


$\uparrow h, \downarrow w$



Source noise representation

To characterize **steady** flight conditions



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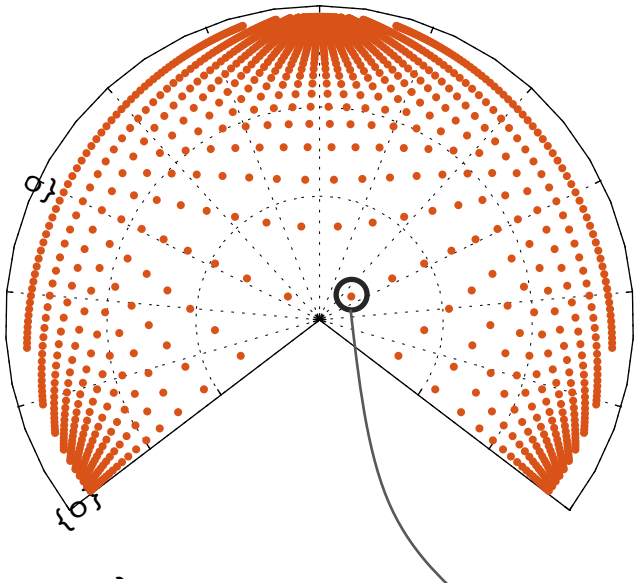


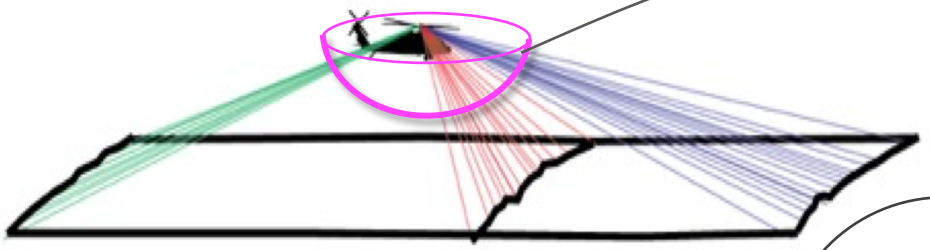
0.5 s independent data segments

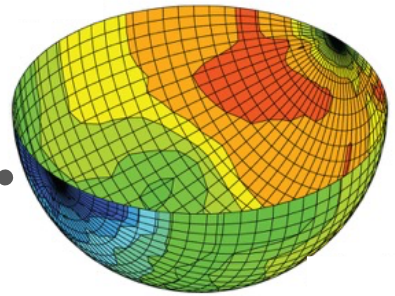
Signal processing considerations

- Directivity resolution by segmenting time series
  - Uniform segmenting, or is there something better?
- Spectral uncertainty
  - Deterministic (periodic)
  - Nondeterministic (aperiodic random)
    - Example:
      - Sample at 25 kHz, segment into 0.5 s, process with 10 Hz resolution → 33% (2 dB) uncertainty in random component of autospectra
- Can choose processing parameters post-flight test

Source noise representation

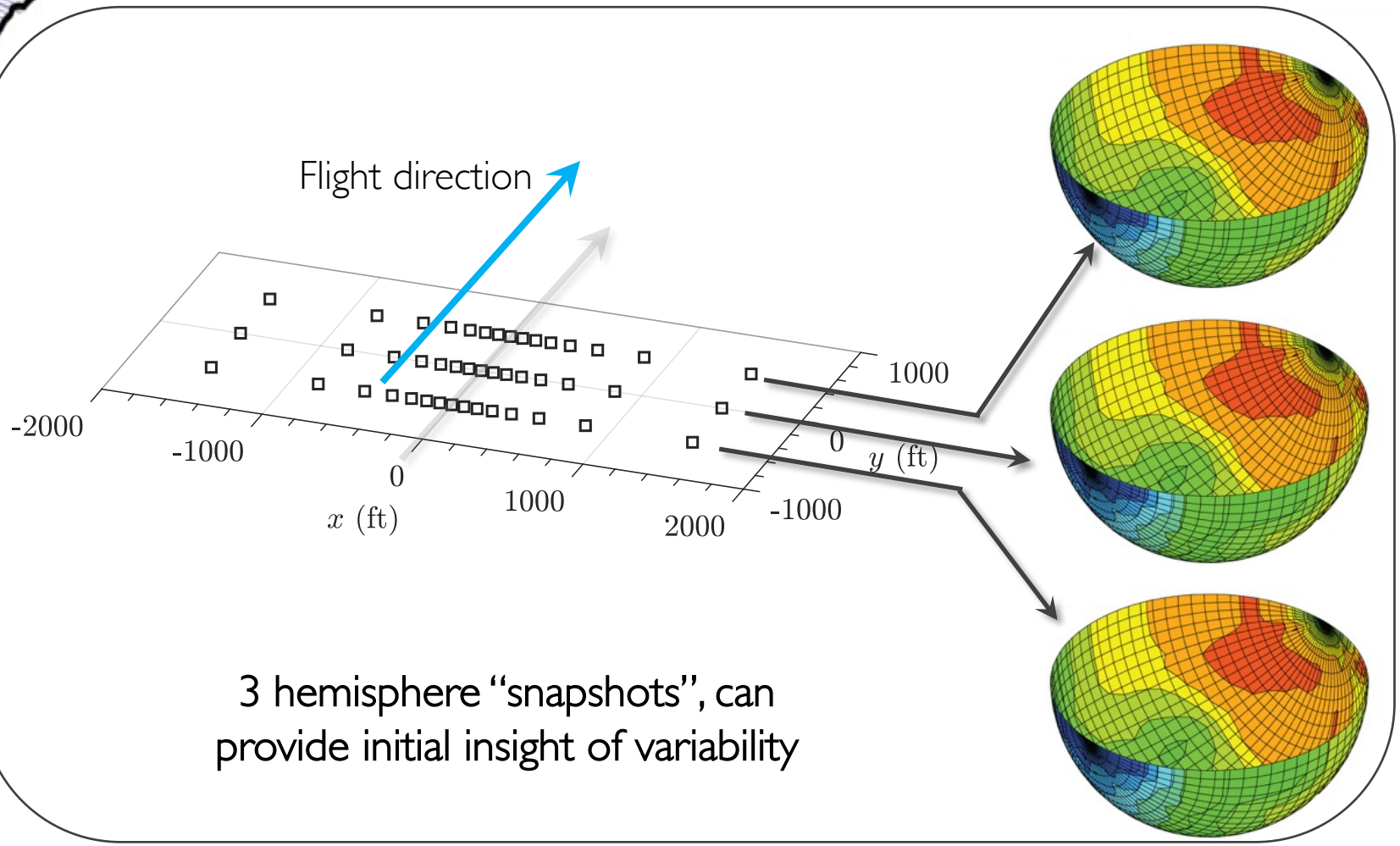
To characterize **steady** flight conditions





$$L = f(\phi, \theta, f)$$

- Previous slides all assumed source stationarity
- What about source variability?
  - Constantly varying rotor rotation rates
  - Wind gusts – may be more important for lighter vehicles



3 hemisphere "snapshots", can provide initial insight of variability

Acoustics Equipment

1/2" GRAS 67 AX

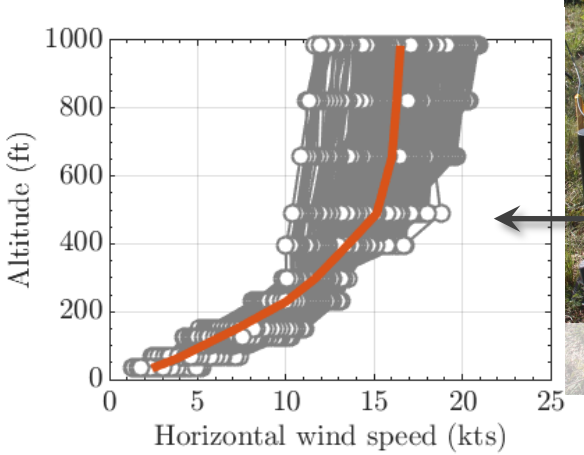
- Not shown
  - PAPI system
  - Aircraft tracking
  - (3) UTVs
  - Ground and air communication

Weather

*Additional support from NC team

Ground weather stations

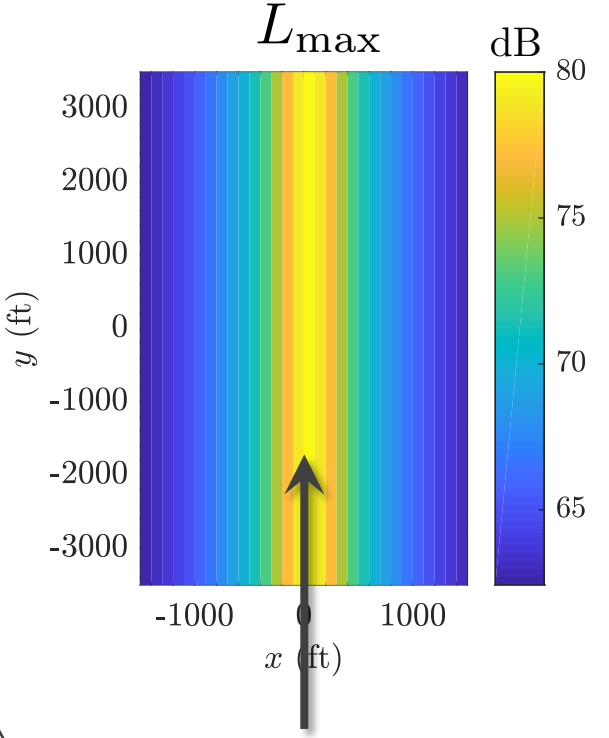
Tethered balloon

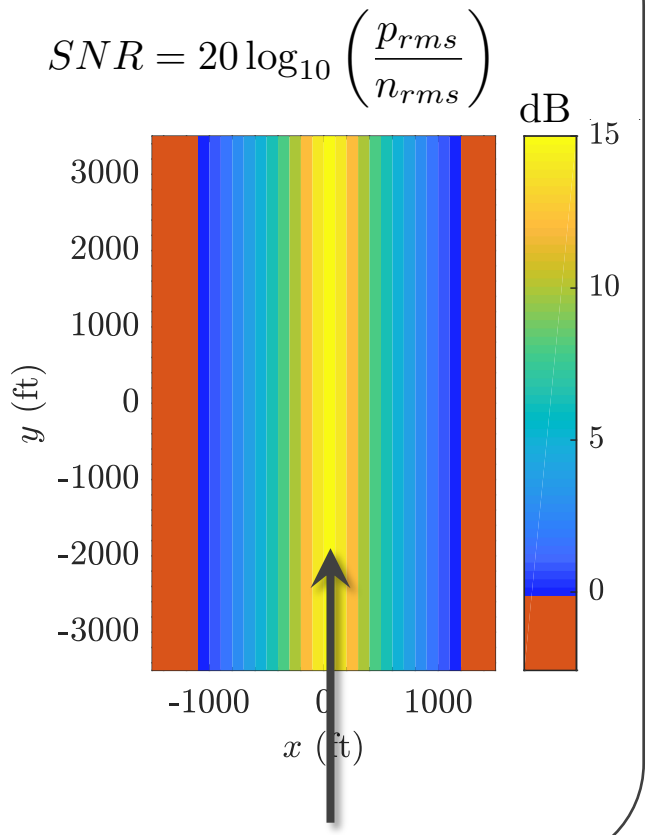


LIDAR

Upgrades to MAF

Notional example of near-real time information, view of ground plane



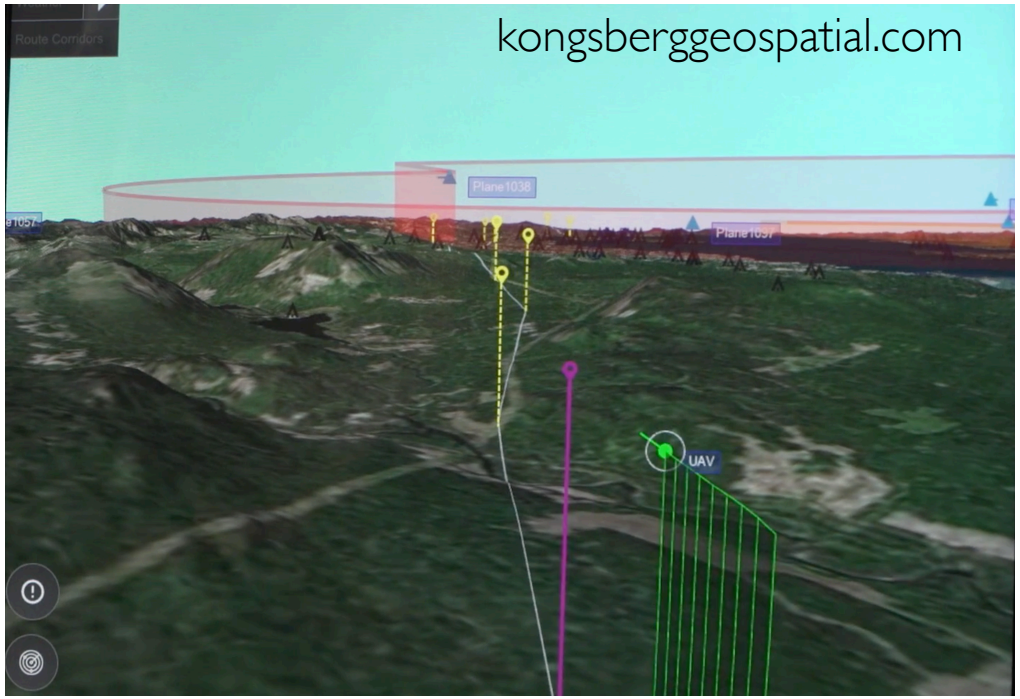


Moving monopole source used

Real-time vehicle tracking

pingStation
uavionix.com

- 2D or 3D map and terrain data
- Real-time data from ADS-B equipped aircraft
- Will enable trajectory feedback



Concluding remarks

- A lot to consider!
  - Combined array layouts (multiple linear + distributed) for source noise and unsteady flight may prove useful
  - Signal processing parameters should be assessed
    - Balance between spectral uncertainty/directivity/SNR
  - Each flight test will need to be tailored to vehicle operational modes/capabilities
    - After AAM acoustics is better understood, perhaps generalizations can be made per vehicle category
  - Need high degree of deployability → MAF is perfect for this, upgrades tailored to NC needs

www.nasa.gov/aamnationalcampaign