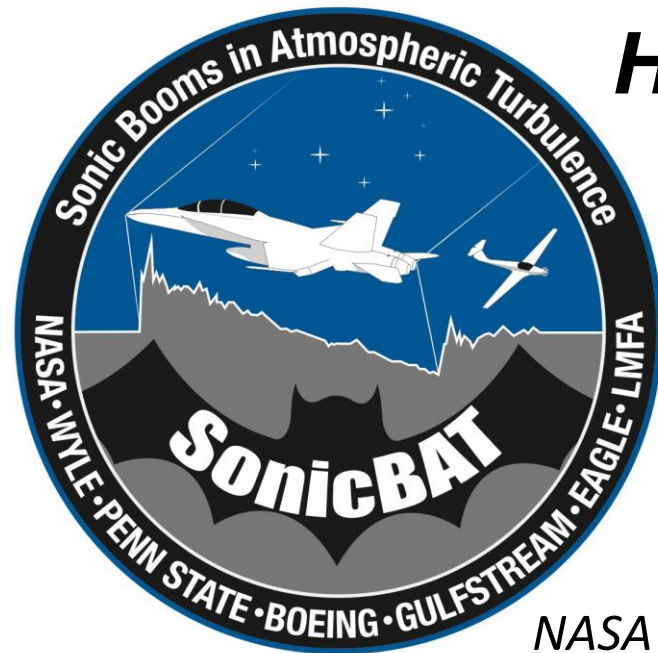




**3PNSB1**

**SONIC BOOMS IN ATMOSPHERIC TURBULENCE  
(SONICBAT):  
GROUND MEASUREMENTS IN A  
HOT DESERT CLIMATE**



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NASA Armstrong Flight Research Center*

*Acoustics 2017 Boston  
27 June 2017*

The Sonic Booms in Atmospheric Turbulence (SonicBAT) Project flew a series of 20 F-18 flights with 69 supersonic passes at Edwards Air Force Base in July 2016 to quantify the effect of atmospheric turbulence on sonic booms. Most of the passes were at a pressure altitude of 32,000 ft and a Mach number of 1.4, yielding a nominal sonic boom overpressure of 1.6 pounds per square foot.

Atmospheric sensors such as GPSsonde balloons, Sonic Detection and Ranging (SODAR) acoustic sounders, and ultrasonic anemometers were used to characterize the turbulence state of the atmosphere for each flight. Spiked signatures in excess of 7 pounds per square foot were measured at some locations, as well as rounded sonic-boom signatures with levels much lower than the nominal. This presentation will quantify the range of overpressure and Perceived Level of the sonic boom as a function of turbulence parameters, and also present the spatial variation of these quantities over the array. Comparison with historical data will also be shown.

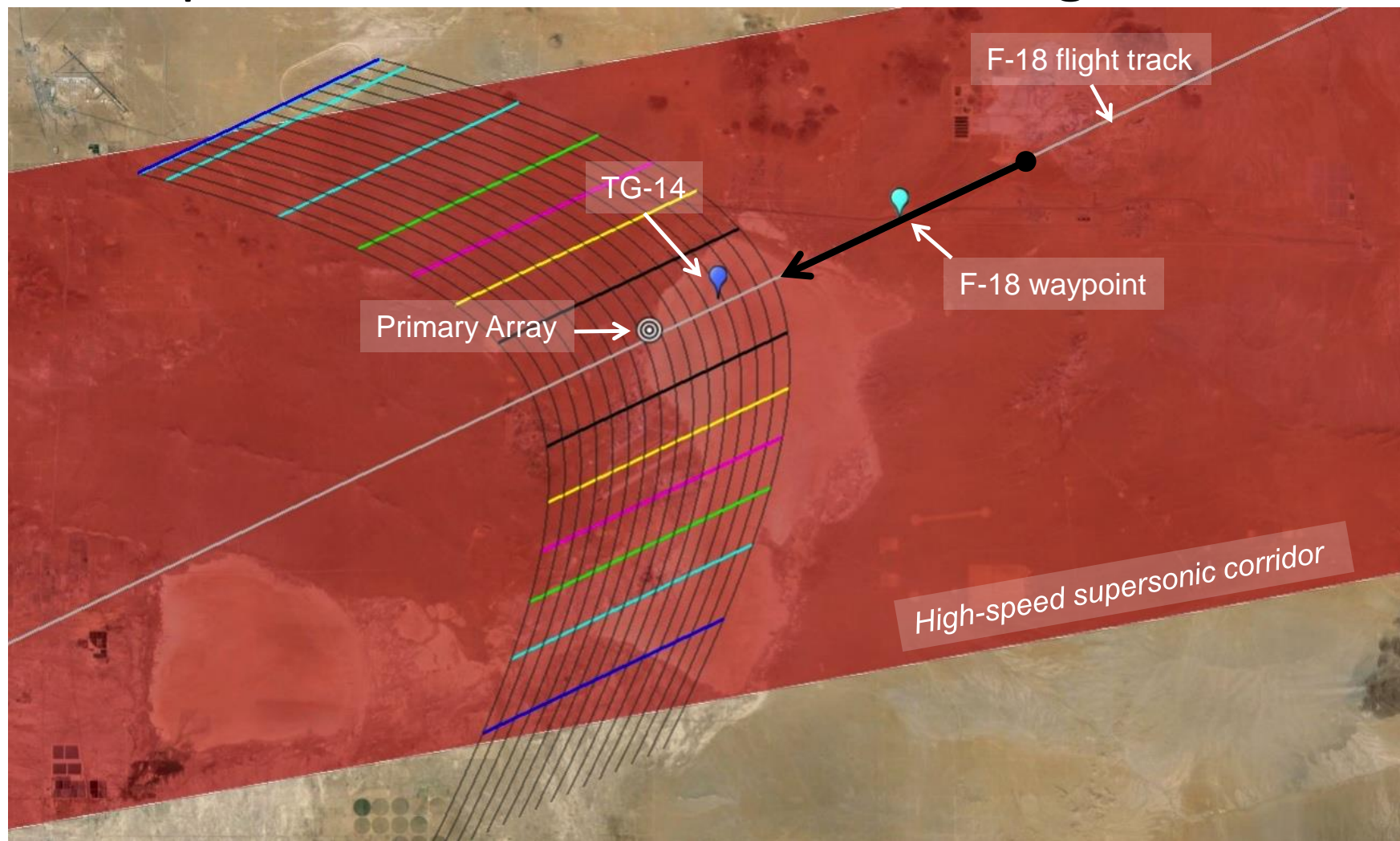
The NASA Armstrong Research Center's team is made up of KBR Wyle, Gulfstream, Boeing, Pennsylvania State University, Lockheed Martin, Eagle Aeronautics and Laboratoire de Mécanique des Fluides et d'Acoustique (LMFA in France).



# RESEARCH FLIGHT PROFILE/PLAN

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- Primary test point: F-18 On-track, Hp=32,000 ft, Mach 1.40, 245-deg true

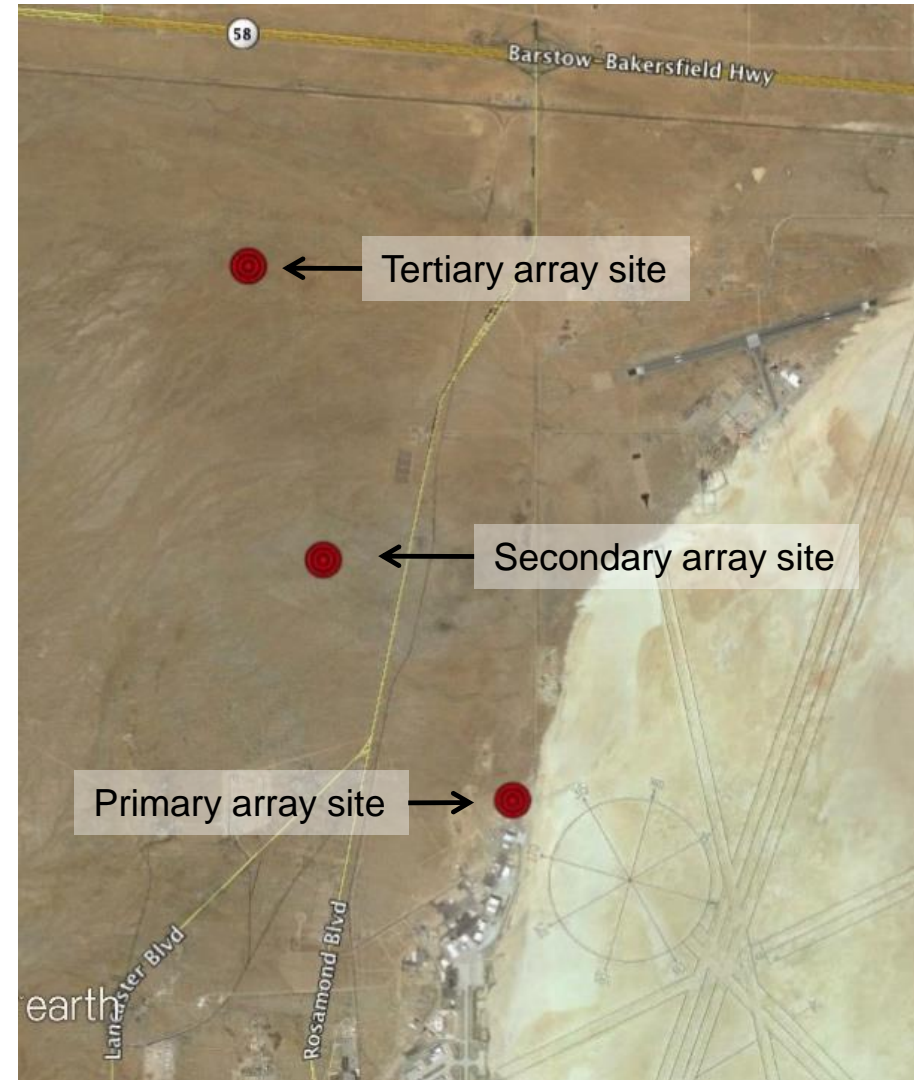




# GROUND INSTRUMENTATION ARRAYS

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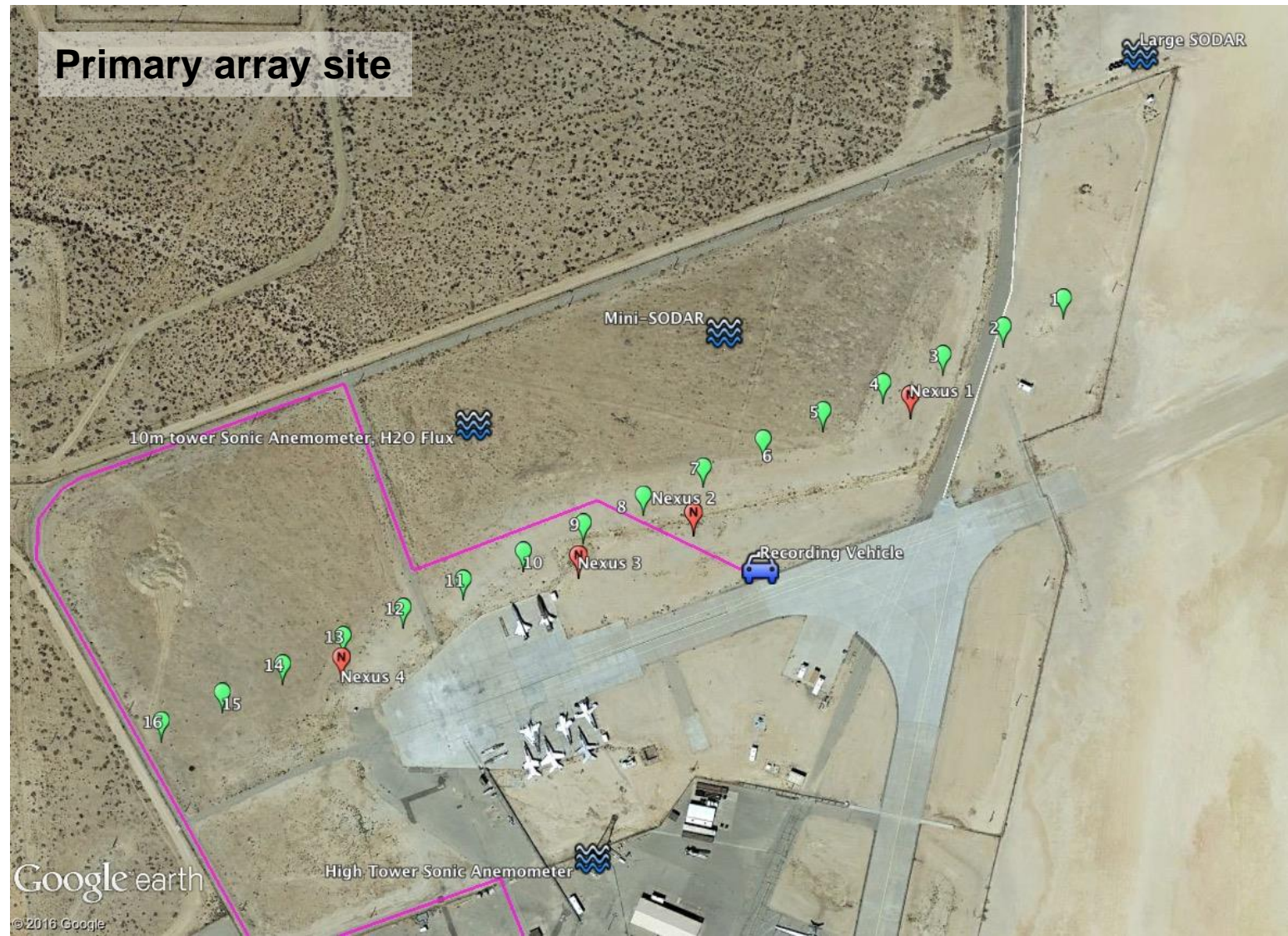
- Primary array configuration:
  - 1,500 ft. linear array of 16 microphones
    - 100 feet apart
    - 245-degree true heading
- Secondary array configuration:
  - 1.42 miles offset north
  - Two (2) 300 ft. linear sub-arrays of 4 microphones each (8 total)
    - 100 feet apart
    - cruciform
- Tertiary array configuration:
  - 2.78 miles offset north
  - Two (2) 300 ft. linear sub-arrays of 4 microphones each (8 total)
    - 100 feet apart
    - cruciform





# GROUND INSTRUMENTATION, PRIMARY ARRAY

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# ATMOSPHERIC INSTRUMENTATION

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- Sonic Anemometer
  - 10m (32.8 ft) tower
  - 44m (144 ft) tower
  - Amb. temperature, 30 sample/s
  - 3 component winds, 30 sample/s
  - $Ct^2$  and  $Cv^2$
- SODAR
  - Model 4000 Mini-SODAR (250m=820 ft)
  - Model 2000 Large SODAR (700m=2296 ft)
  - 3 component winds
  - $Ct^2$  and  $Cv^2$
- GPSsonde
  - One for each takeoff time to 12km (40K ft)
  - EAFB or local launch
- 3m (10 ft) weather tower
  - Temp., Press., Humidity, Wind Speed & Dir
  - One at each array

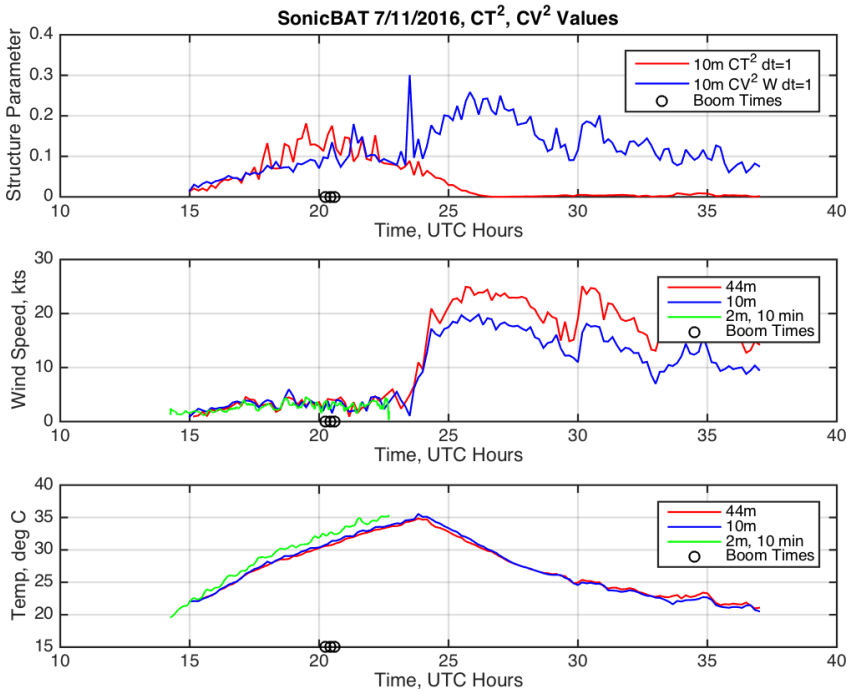
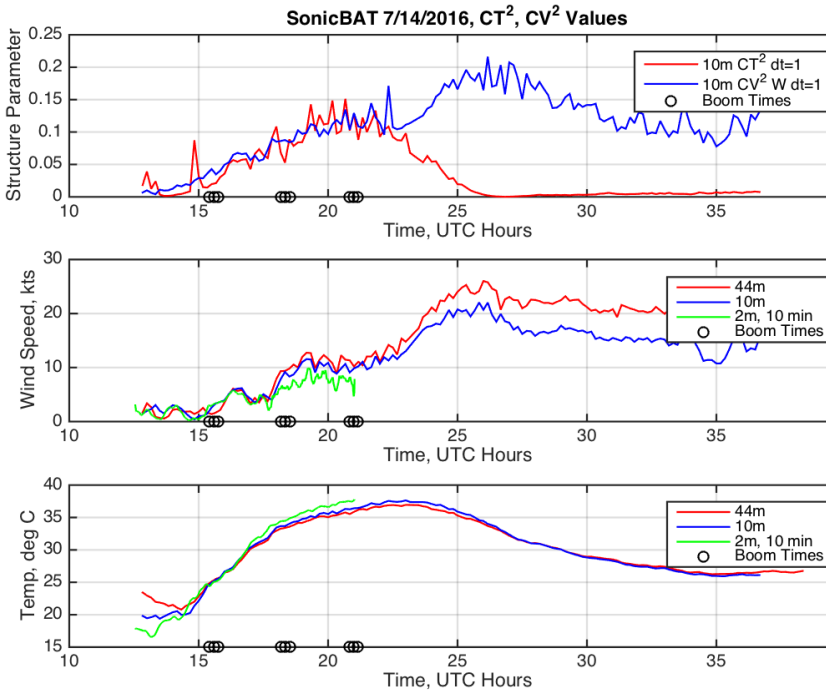




# TURBULENCE MODEL INPUTS

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- $CT^2$ : solar heating, e.g. 0.02, 0.10, 0.13
- $CV^2$ : winds, e.g. 0.04, 0.10, 0.13
- Boundary layer height: 2,000 – 13,000 ft range

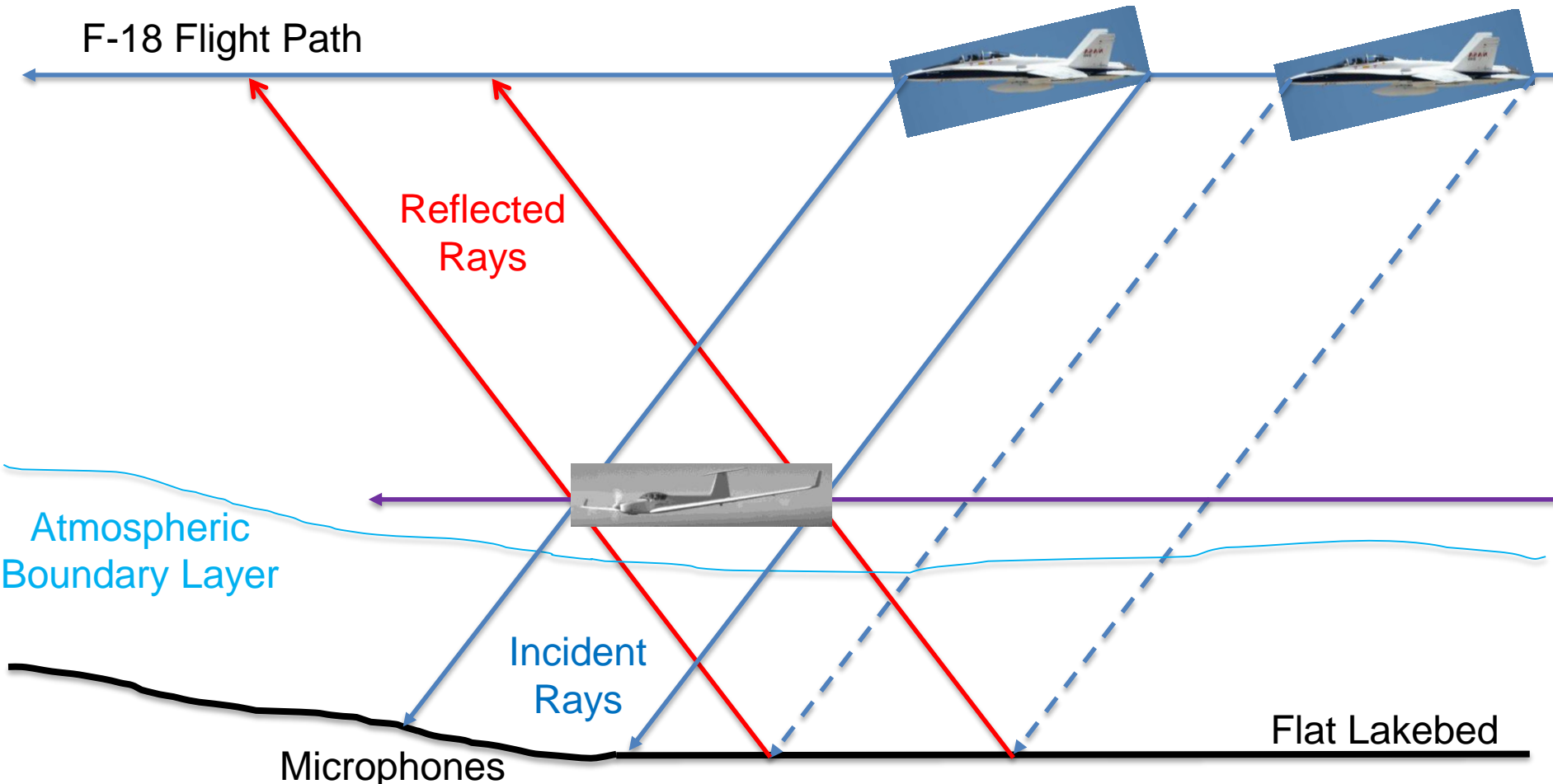




# INCIDENT AND REFLECTED RAYPATHS ON TG-14

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- Clean incident signature recorded first
- Reflected signatures go through turbulence twice



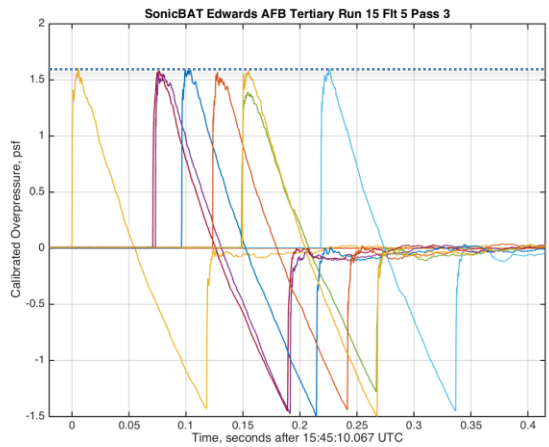
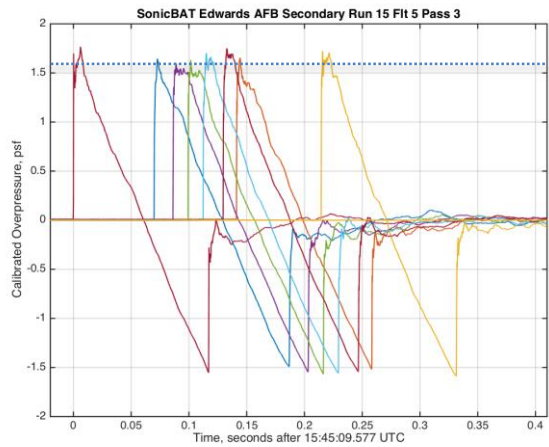
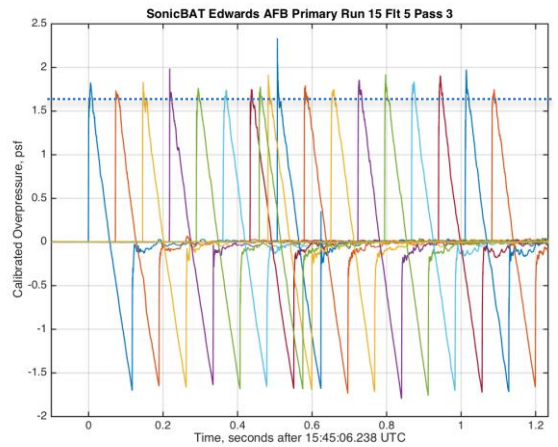
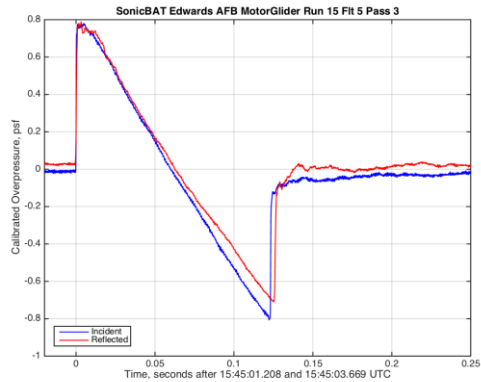




# LOW TURBULENCE, $CT^2=0.02$ , $CV^2=0.04$

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- TG-14 incident and reflected booms similar
- All ground booms nearly the same
- Minimal spiking, rounding

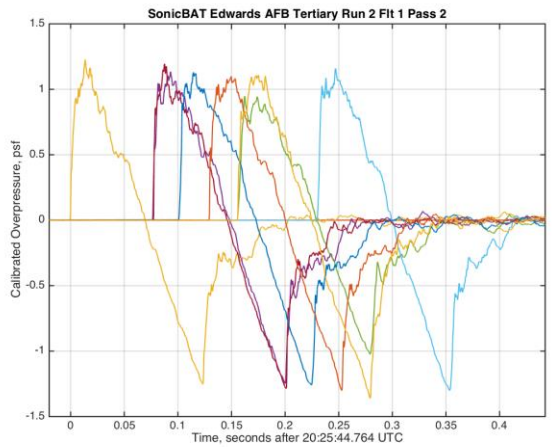
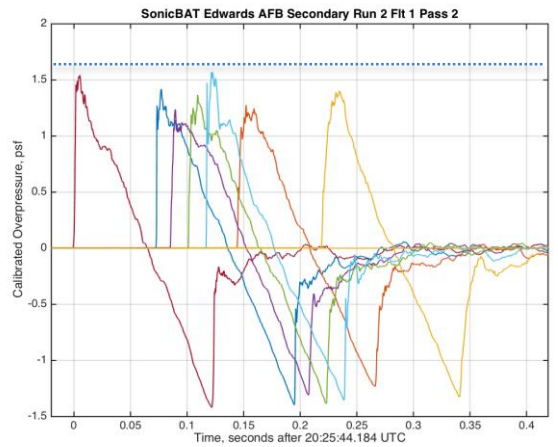
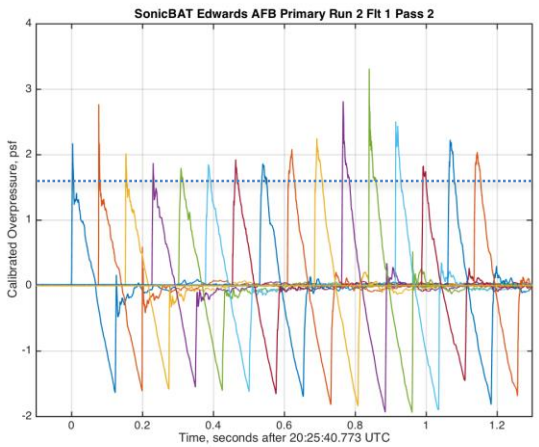
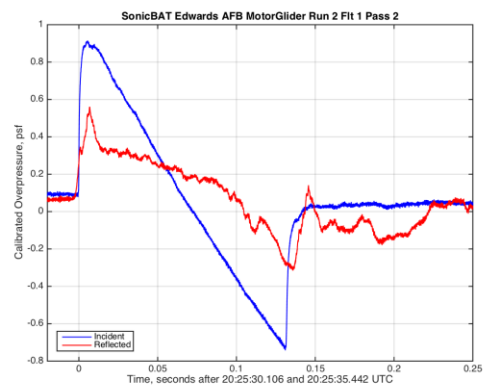




# MEDIUM TURBULENCE , $CT^2=0.10$ , $CV^2=0.10$

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- TG-14 reflected boom distorted
- Some spiking to double nominal
- Rounded signatures over larger portion of array



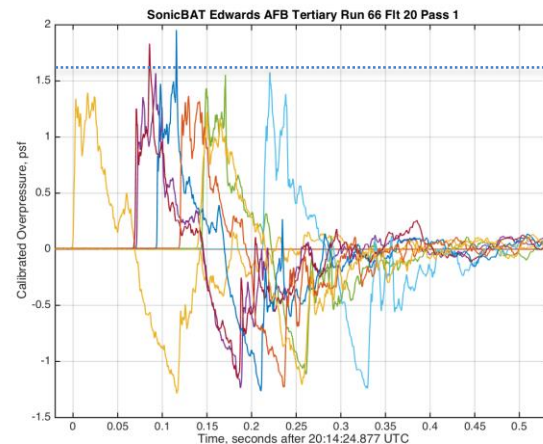
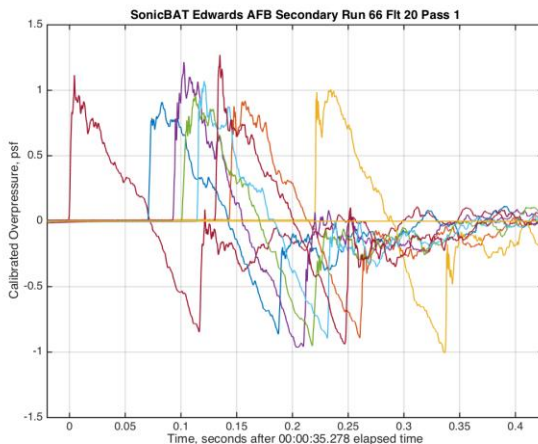
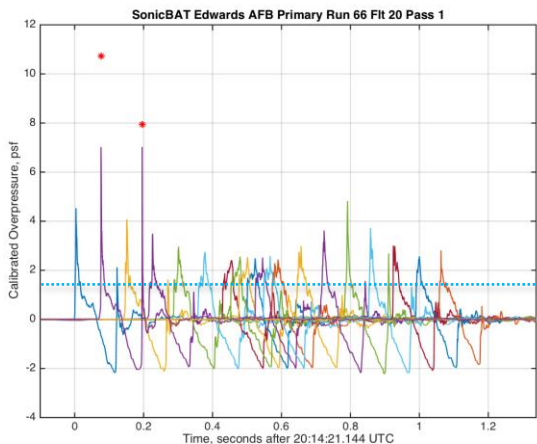


# HIGH TURBULENCE , $CT^2=0.13$ , $CV^2=0.13$

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- Too windy for TG-14 flight
- Spiking exceeded 7 psf, possibly 11 psf
- Rounded signatures over larger portion of array

\*Maximum estimated above clipped data, true data probably lower



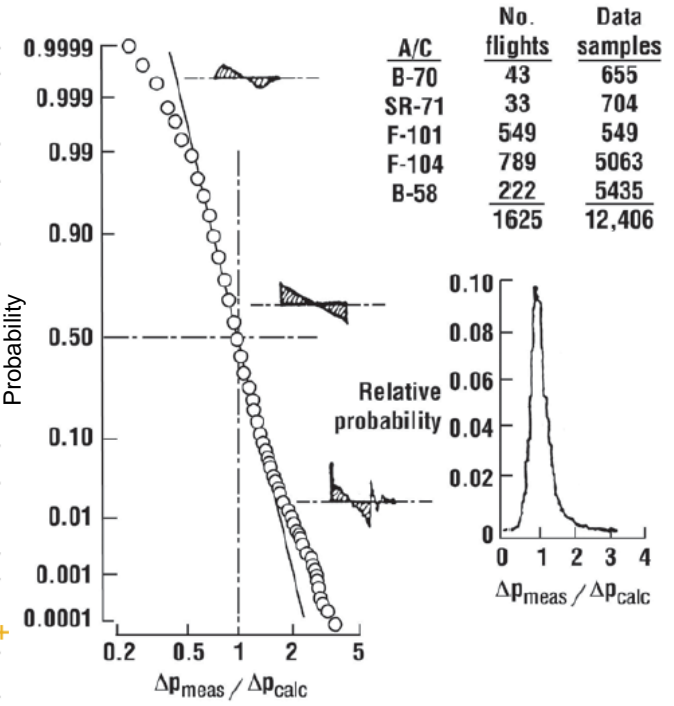
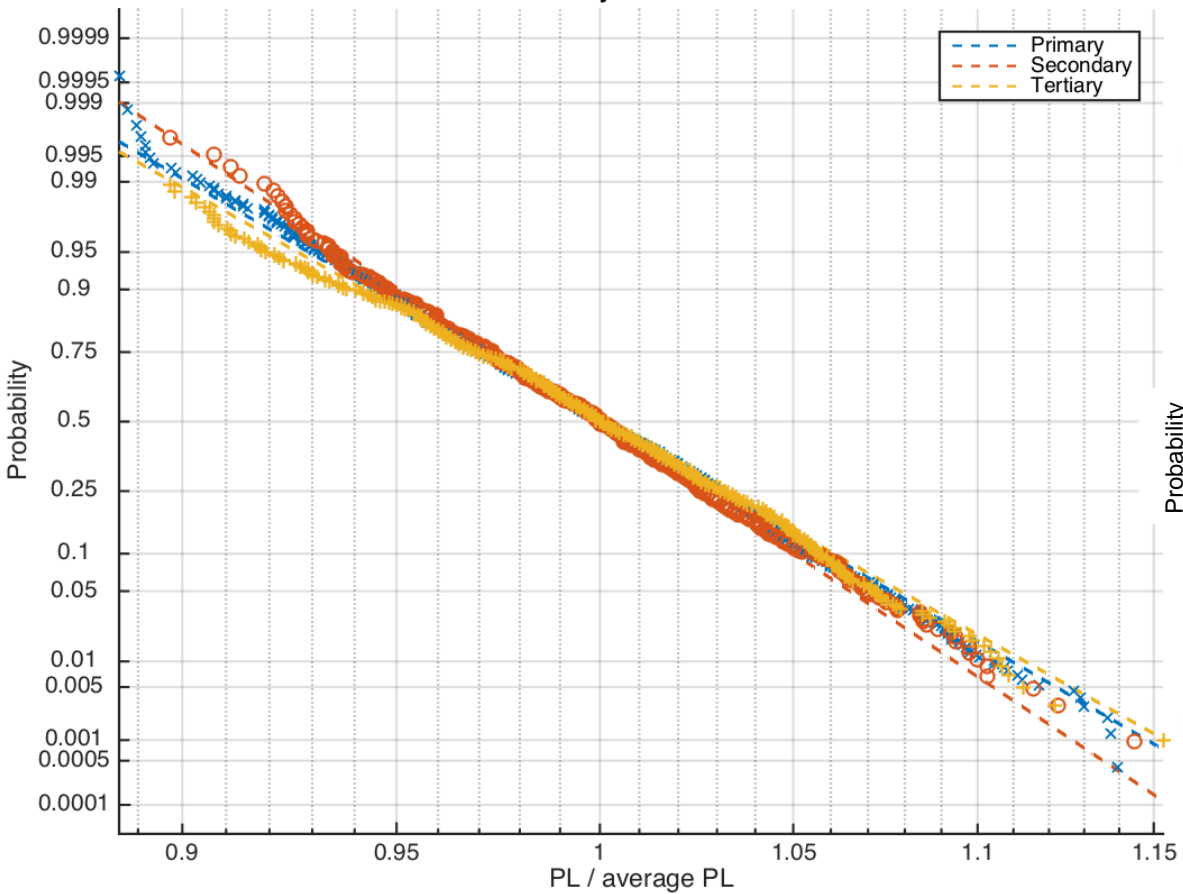


# PLDB PROBABILITY, F-18 FOR SONICBAT AT EAFB

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- All three arrays show similar trends

SonicBAT July 2016 Edwards AFB





# CONCLUDING REMARKS

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- Only tested F-18, conventional loud booms
- Anticipate low booms to be less affected by turbulence
- Larger portion of array has rounding, lower PLdB
- Smaller portion of array has spiking, higher PLdB
- Large arrays, many passes needed to measure spiking
- High humidity test planned for August, 2017 in Florida
  - Expect increasing PLdB due to higher humidity
  - First flight day during solar eclipse, minimal  $CT^2$
- Large high-quality dataset to validate sonic boom turbulence models





# MORE ON SONICBAT

*Armstrong Flight Research Center*

- Stay tuned: Same SonicBAT Session,  
Same SonicBAT Channel
  - 3pNSb2. Statistics of supersonic signatures propagated through simulated atmospheric turbulence T.A. Stout; V. Sparrow
- Earlier Paper:
  - 2pNSb9. A study of reflected sonic booms using airborne measurements S.R. Kantor; L.J. Cliatt



# BACKUP SLIDES

*Armstrong Flight Research Center*