QSF18 Community Response Testing:

Flight Test Planning, Field Operations and Test Execution

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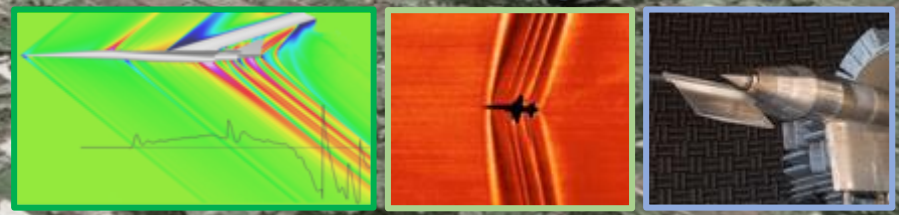
Commercial Supersonic Technology Project



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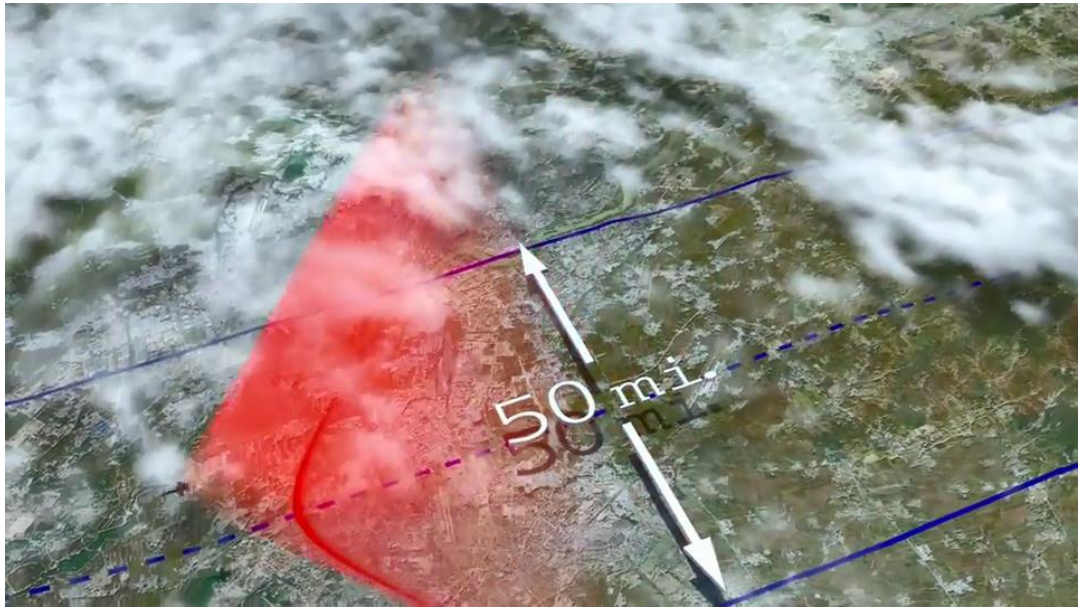
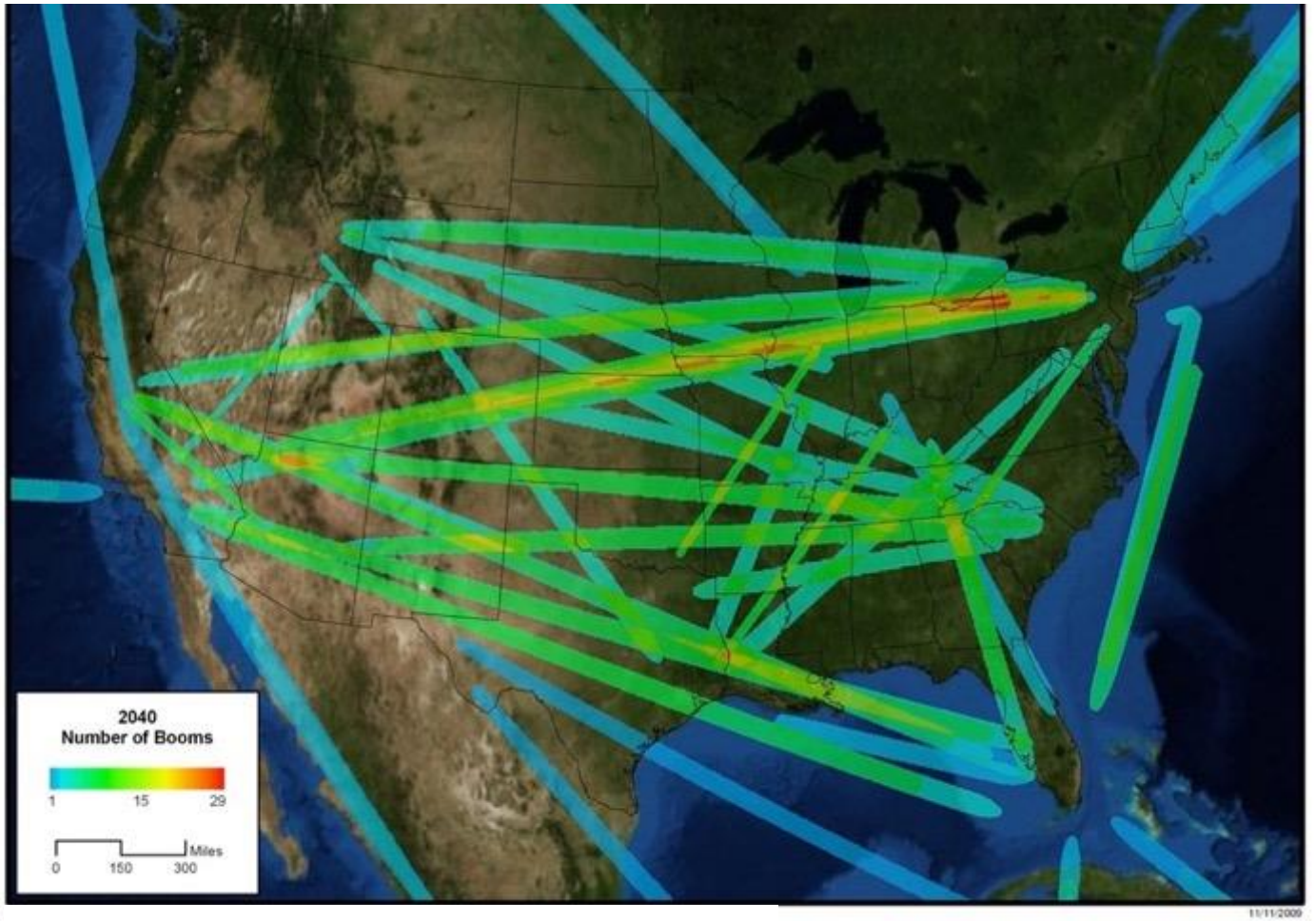
Topics of Discussion – Quiet Supersonic Flights 2018

- Motivation
- Deployment
- Airspace Approval & Flight Planning
- Instrumentation Site Selection
- Field Instrumentation & Operations
- Test Execution & Community Interaction
- Sonic Thump Results

Goal: Acceptable Supersonic Flight Overland





Source: J. Rachami and J. Page. AIAA 2010-1385.

Objective: identify and minimize risks for community testing with X-59 QueSST aircraft

Community Engagement

- Communications tailored to following audiences:
- Elected officials
- Residents exposed to sonic thumps
- Mariners exposed to sonic booms
- Survey participants
- Local science students

Remote Basing and Operations

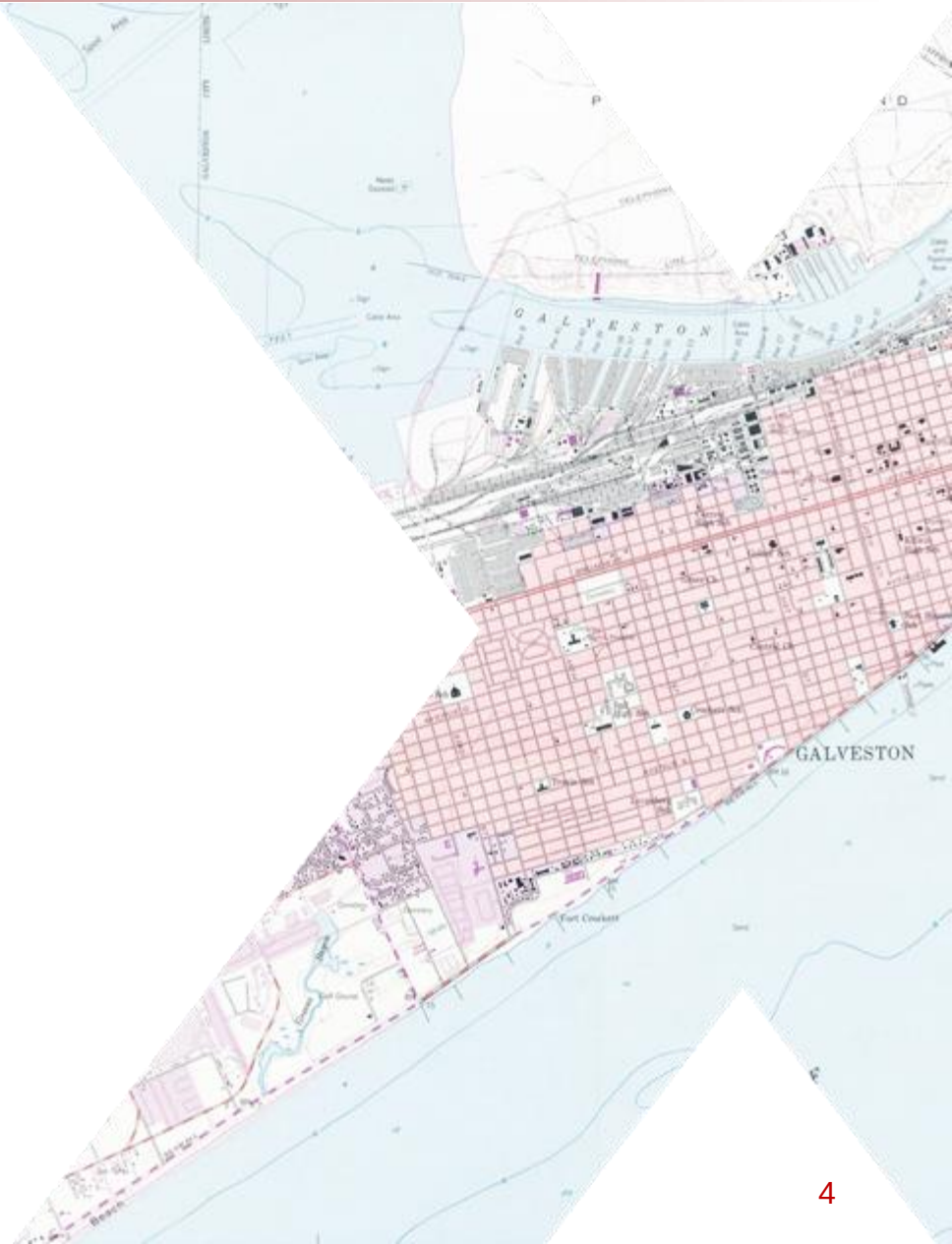
- F-18 aircraft based at Ellington Field in Houston
- ATC “Assigned Airspace”
- FAA Southwest Regional Office briefing
- NEPA approval expected in Oct

Sonic Boom Measurements

- 21 noise monitors across 60 sq. mile survey area linked via cellular network to host station
- Field crew to deploy, calibrate, and retrieve monitors daily

Social Survey

- Web-based survey
- OMB approval granted
- IRB ethical review complete
- Participant enrollment via postal mail in Sep—Oct
- Incremental increase in sound levels

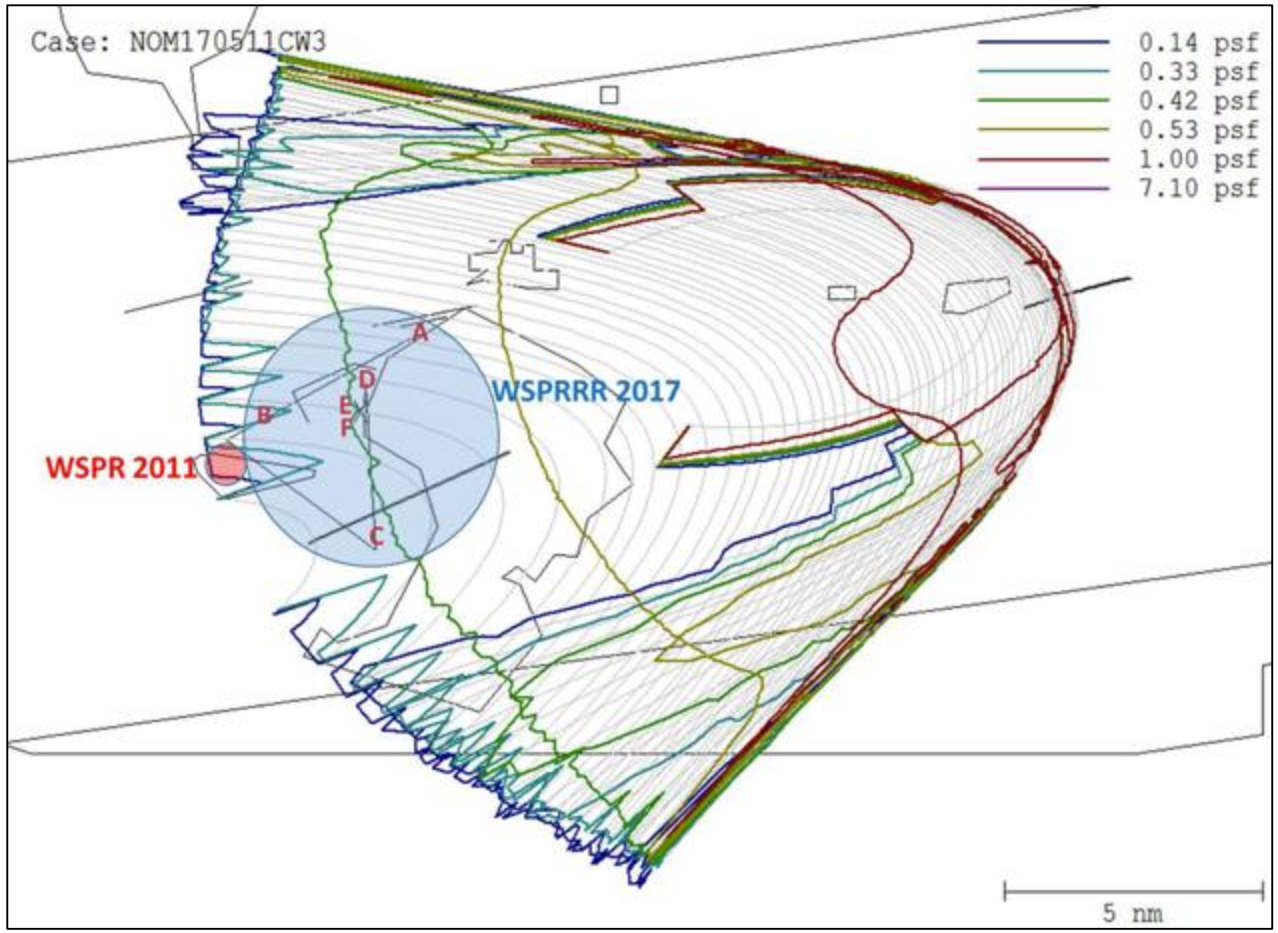


QSF18 builds on previous successes

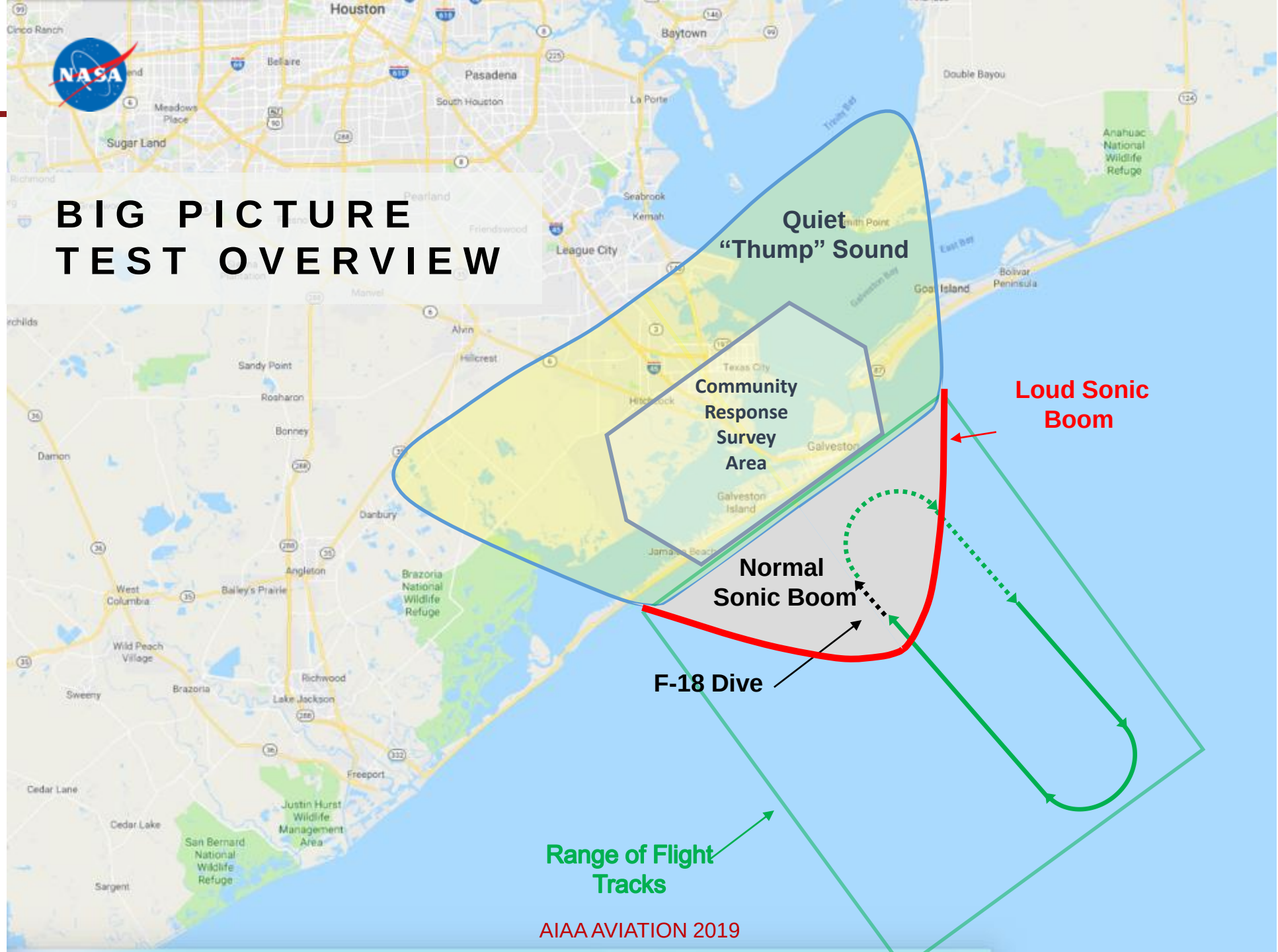
	WSPR 2011	WSPRRR 2017	QSF18 2018	QueSST Early 2020s
Aircraft	F-18	F-18	F-18	X-59 QueSST
On/Off Base	On base	On base	Off base	Off base (multiple)
Noise Monitor Coverage Area [sq mi.]	1	12	60	~2000
Number of survey participants	100	61	500	TBD
Number of flight days	10	3	8	TBD
Research Goal	Risk Reduction	Risk Reduction	Risk Reduction	Data for Regulators

WSPRRR 2017

- 21 low-boom dives (across 9 flights)
- 5 Gulfstream SBUDAS (first use of cellular capabilities) and 4 NASA SPIKEs
- Eliminating suspect data (large calibration difference, etc.) results in 171 measured metric values for comparison



BIG PICTURE TEST OVERVIEW



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Deployment

Flight Planning

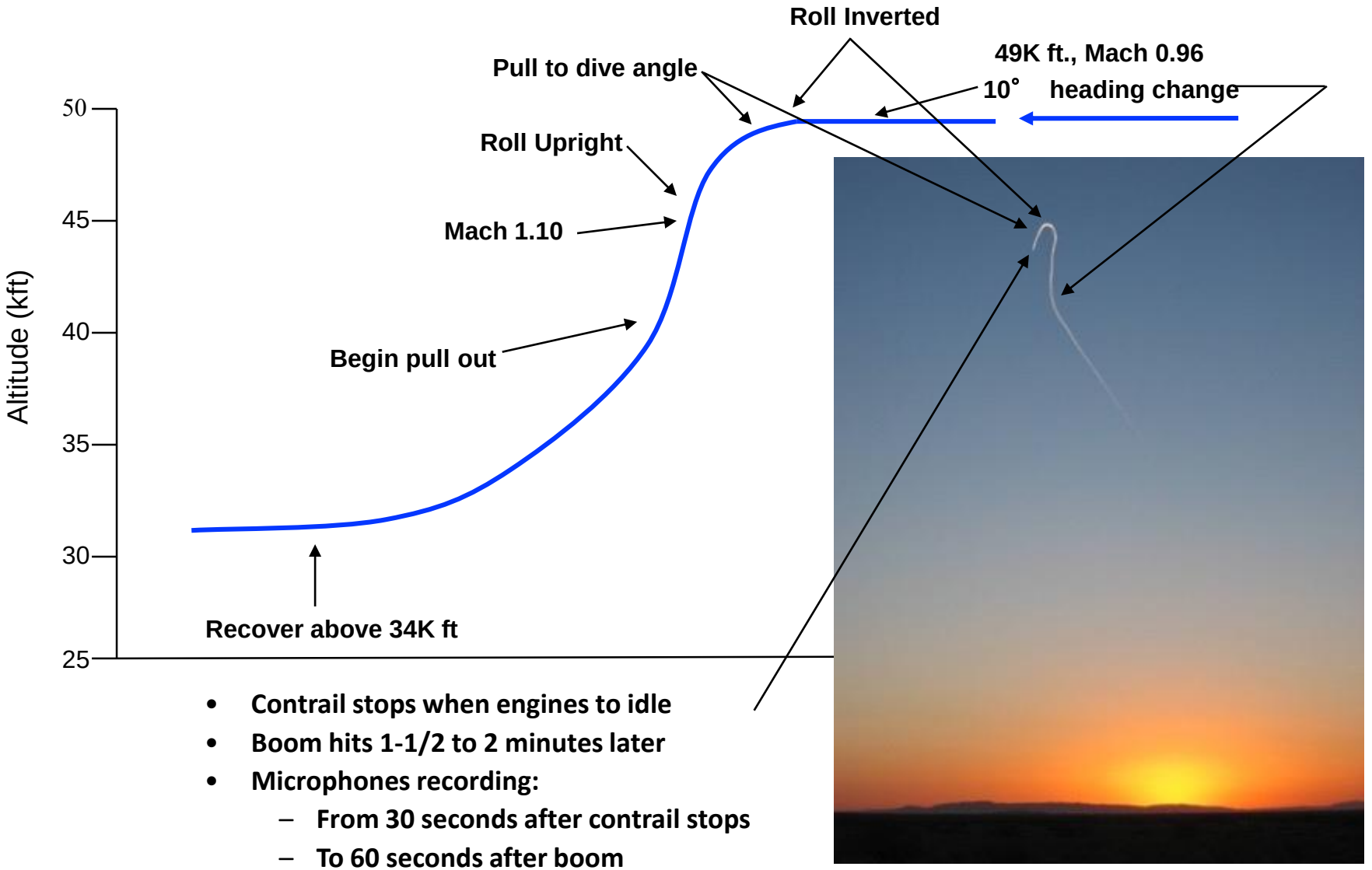
- Months before deployment
  - Measured F-18 low boom dive trajectory from Edwards AFB
  - Removed Edwards AFB winds
  - Galveston climate data: monthly temp/wind profiles Oct/Nov
    - Combinations of +/- 3 sigma winds
  - Ran through PCBoom software (KBRwyle), determine lateral shifts in carpet
  - Applied lateral shifts to trajectories
  - Added buffer laterally, added more buffer longitudinally for varying dB on subjects
  - Worked with FAA/DoD for airspace designation
- Hours before flight
  - Used model weather profile data for flight time in PCBoom
  - Footprint generated
  - Sometimes had to shift aircraft course to get desired exposure
  - Determine several dive points for different exposure
- During flights
  - Feedback from field sensors / observers after each pass to adjust which dive point to use for next pass

Specialized airspace codename: “Whisper”

Altitudes between 30 – 50 kft. Higher than civil/commercial airplanes

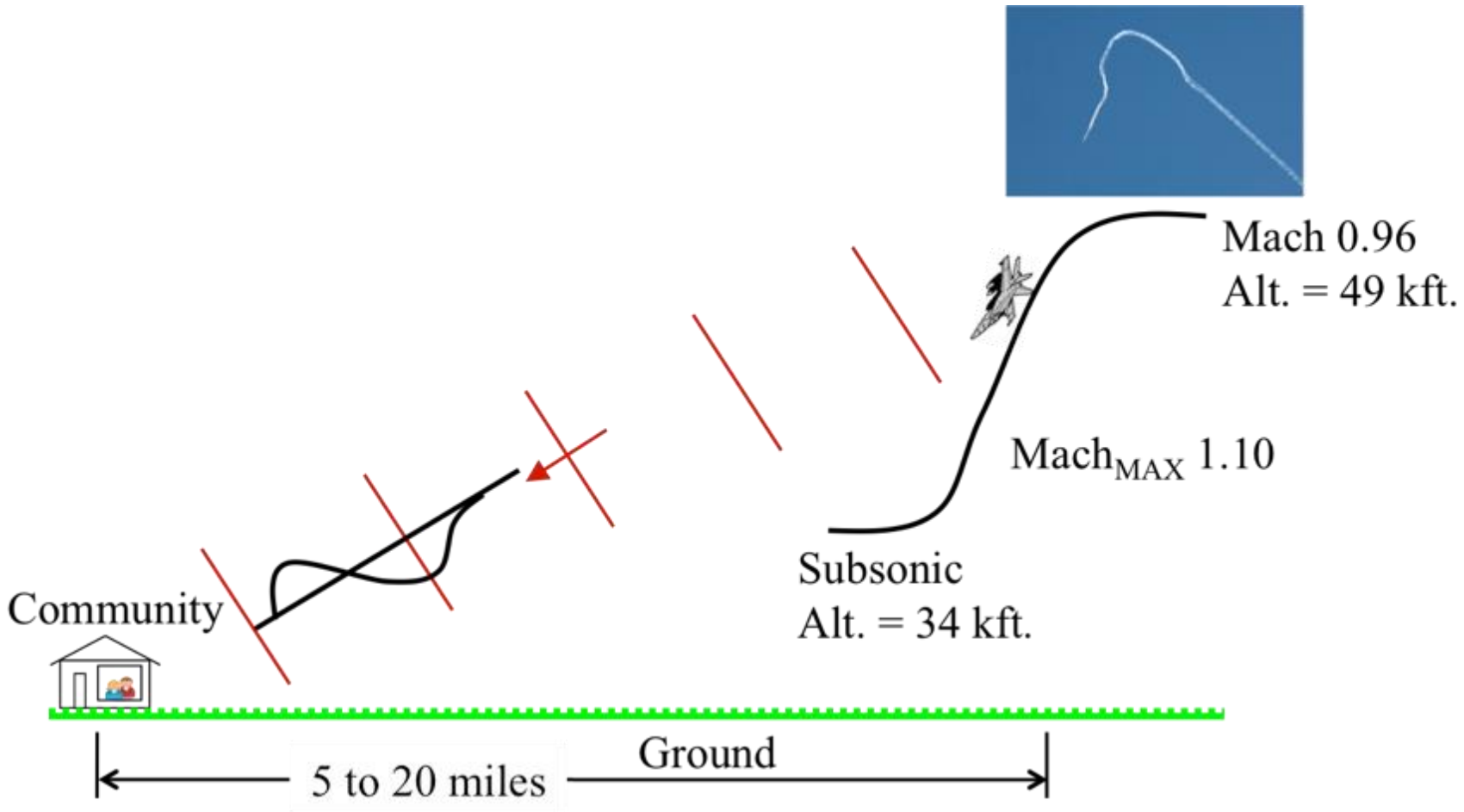
FAA-coordinated Air Traffic Control Assigned Airspace (ATCAA).

Low Boom Dive Maneuver



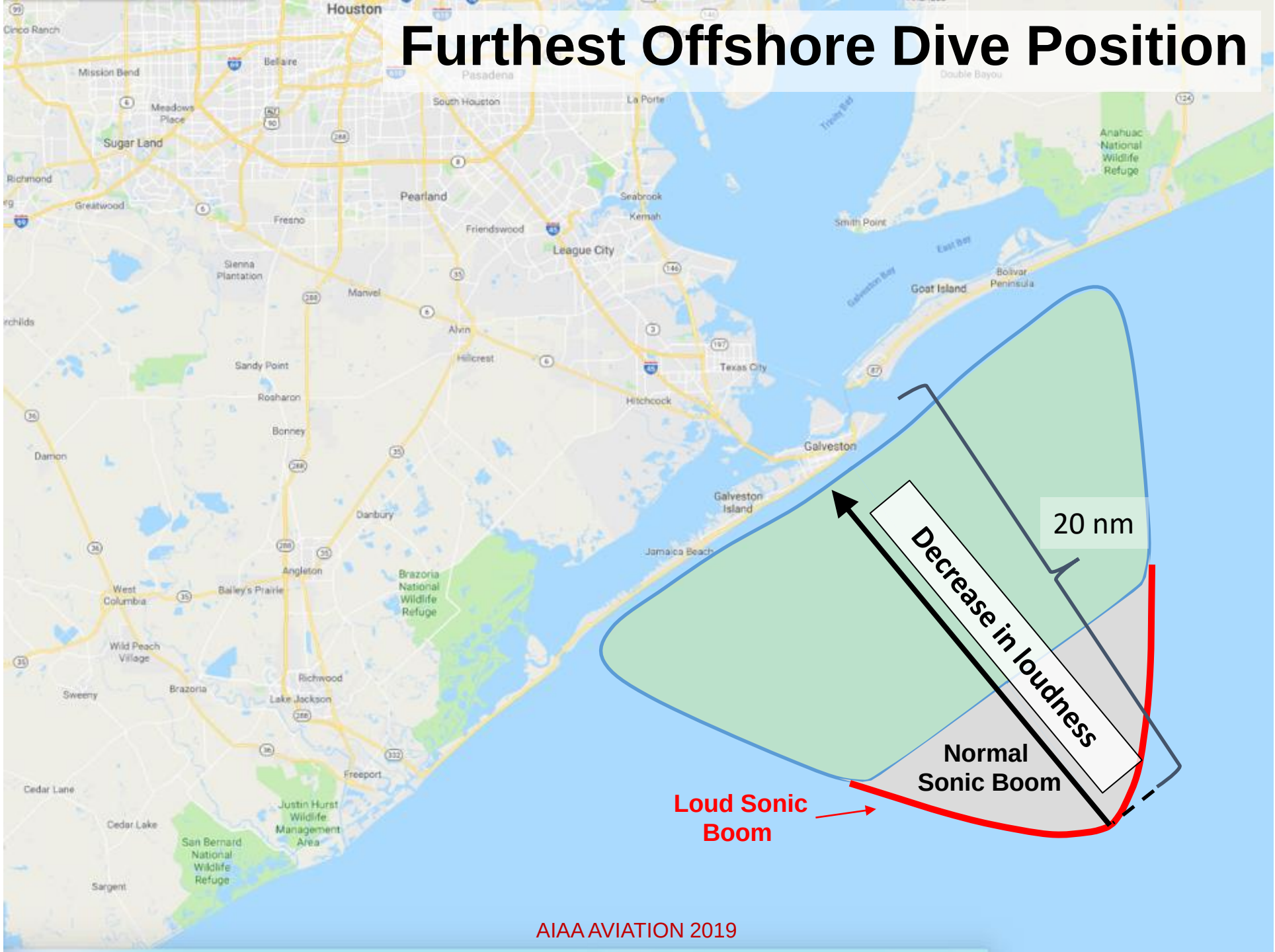
- Contrail stops when engines to idle
- Boom hits 1-1/2 to 2 minutes later
- Microphones recording:
  - From 30 seconds after contrail stops
  - To 60 seconds after boom
- Recordings used for boom simulators

Low Boom Dive Maneuver – Propagation Distance

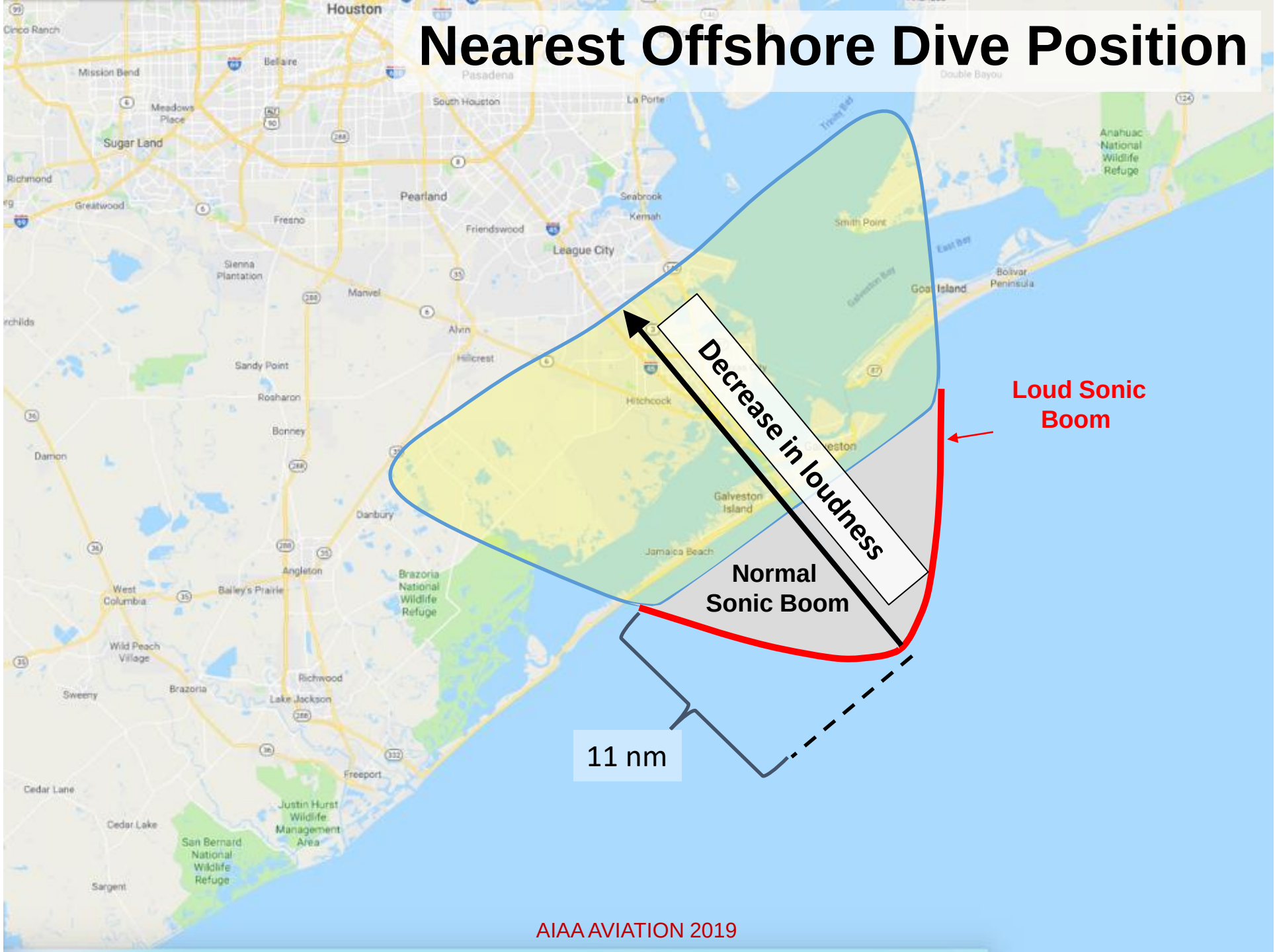


F-18 low boom dive maneuver

Furthest Offshore Dive Position

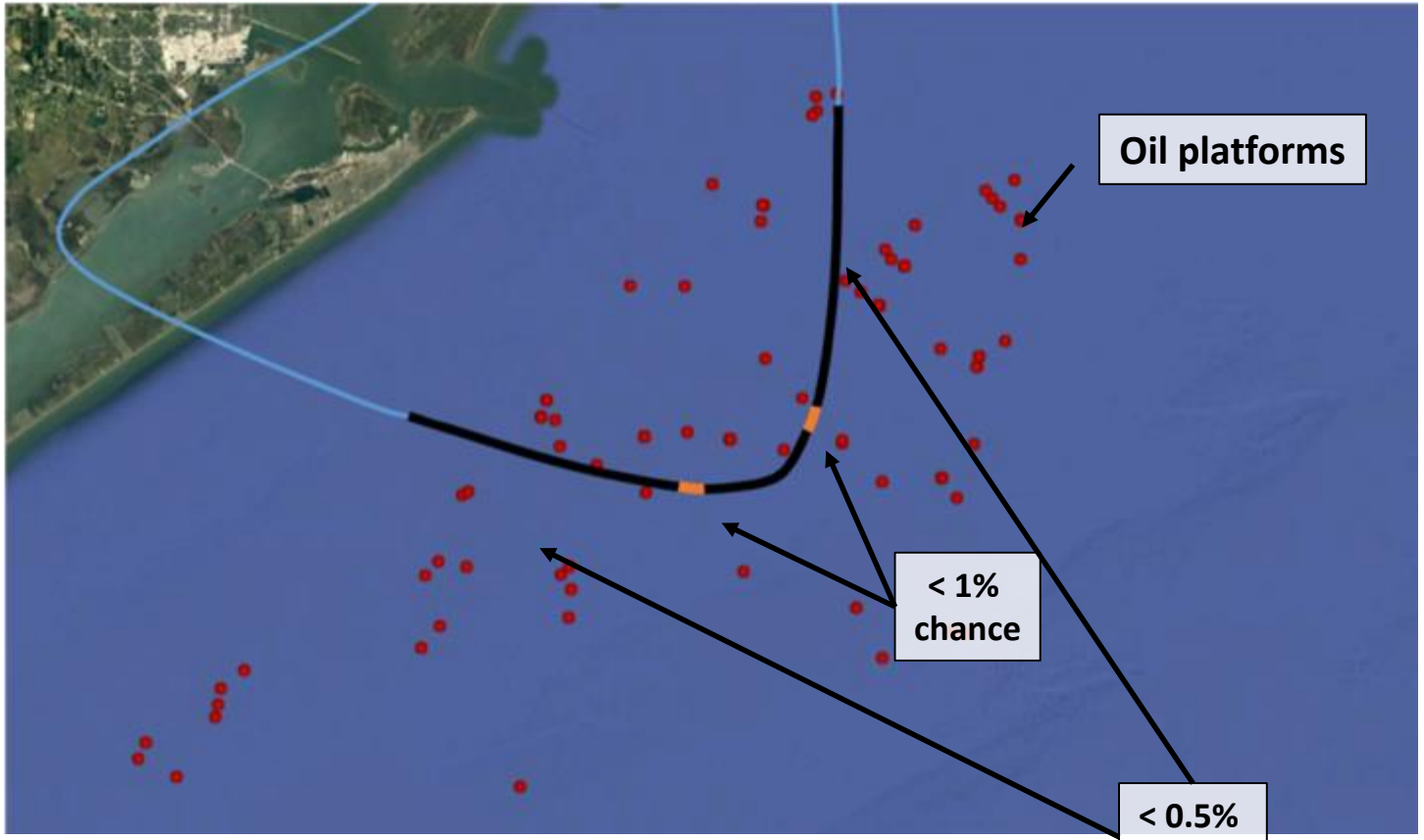


Nearest Offshore Dive Position



Offshore Noise Levels

- Dive maneuver will create louder noise levels offshore
- Loudest noise exposure area is small with respect to maritime community area
- USCG Command Duty Officer will brief maritime community before each sonic thump via mandatory Channel 16
- Noise will not be at levels known to cause damage to hearing or equipment



Probability of sonic booms breaking glass.

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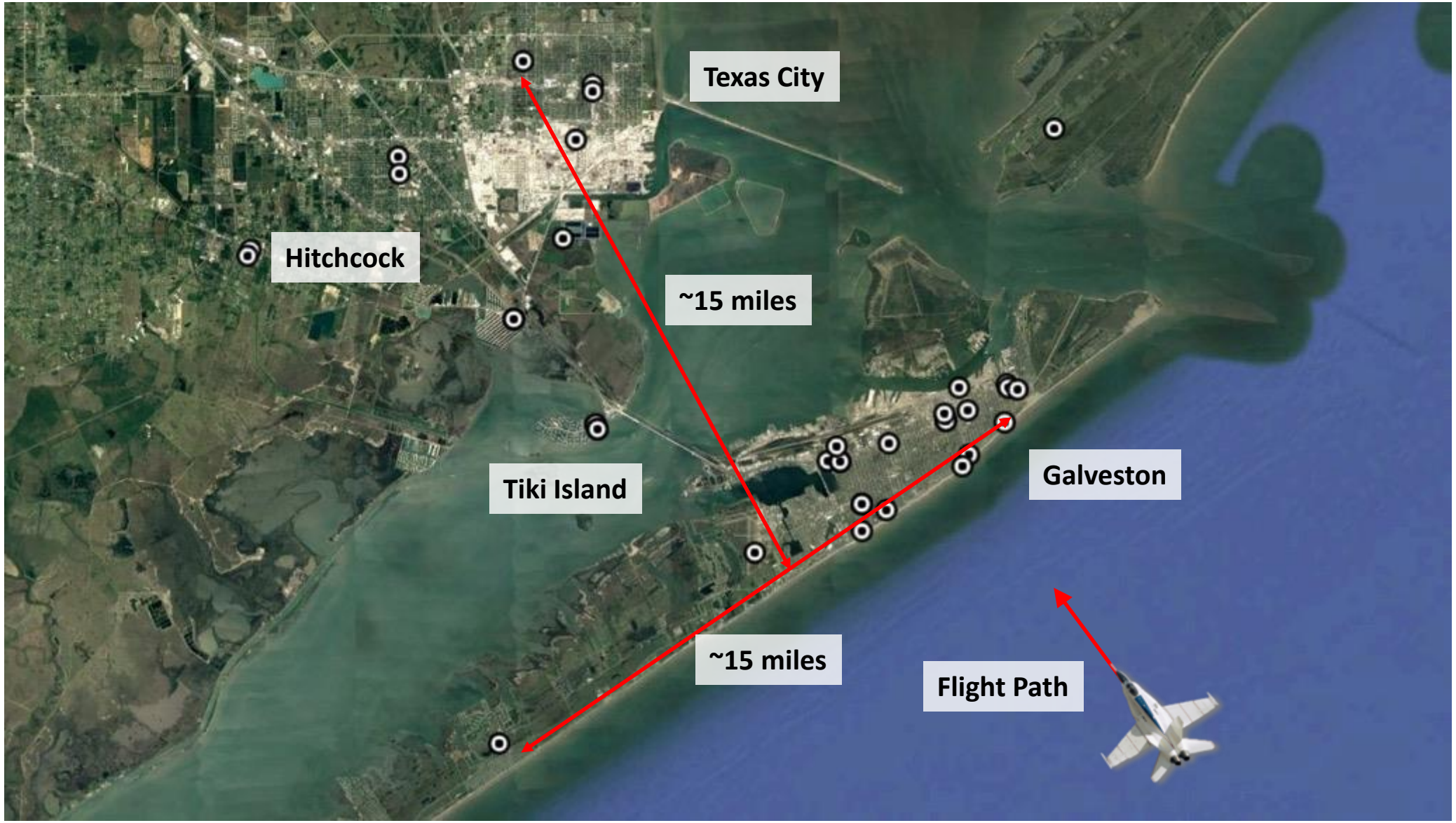
Field Instrumentation Locations, Initial Locations



Field Instrumentation Locations, Selection Criteria

- **Zoning and Topography of Area**
  - Note if the area residential, commercial, industrial, mixed use, parks, protected natural area.
  - Are there notable changes in topography?
  - Do we need to avoid protected wildlife areas?
  - Consider ideal locations for equipment as well as perceived higher risk areas to avoid.
- **Environmental Noise**
  - Note the noise environment to minimize external noise sources as possible. Identify if site is in close proximity to other noise sources such as traffic, airports, railways or wind turbine installations.
- **Coastal Area Hazards**
  - Wind speed
  - Flood plain
- **Building Construction Variables**
  - Residential: Is it single family home, multi-family home, duplex, row house, manufactured/pre-fab, modular or mobile home, tiny house, house boat/floating home, McMansion.
  - Workplace: Are there box stores (Walmart, etc), warehouses, 2 story office buildings, high rise or skyscraper?

Field Instrumentation Locations, Final Locations

Field Instrumentation

- Acoustic Recording Instrumentation – some combination of microphone with windscreen, attached to a signal conditioning unit and data storage device with triggering mechanism
  - 12 - SBUDAS (Sonic Boom Unattended Data Acquisition System), provided by Gulfstream
    - Host Station for remote triggering
  - 4 - COUGAR (Compact Outdoor Unit for Ground-based Acoustical Recordings), provided by BYU
  - 5 - SPIKE (Sonic Pressure Integrated Kit Electronics), provided by NASA

Field Instrumentation

- Atmospheric Instrumentation
  - 2 - Weather Towers
    - Anemometers, hygrometers, wind vanes, thermometers, and a barometer
    - Systems are solar-powered and operate autonomously for long-term data logging
    - Approximately 10-feet tall
  - 1 - Weather Balloon launched within 1 hour of takeoff
    - Wind Speed & Direction
    - Altitude
    - Pressure
    - Temperature
    - Relative Humidity

Weather Balloon


Weather Tower

Field Instrument – Community Presence

- Varying levels of positive to negative reactions with individuals who were deploying instrumentation.
  - Deployment to a location where information had not flowed down to some personnel. They were not aware and did not allow us to deploy that day. After discussions between QSF18 and the site, we were allowed back on.
  - Mowing crews were polite to mow around our instrumentation or try and mow before we arrive.
  - People in businesses around instrumentation sometimes asked QSF18 personnel to come inside for AC and coffee instead of sitting outside all day.

Field Operations

Photo by Carla Thomas

Field Operations

Planned Deployment Schedule
November

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
28	29	30 Research Team Travel	31 Maintenance Travels Noise Monitor setup/checkout	01 F/18's fly out Noise monitor setup/checkout	02 Motorcycle Rally Practice Flight	03 Motorcycle Rally Backup Practice Flight
04 Motorcycle Rally Down Day (Daylight Savings Ends)	05 Fly	06 Fly	07 Fly	08 Down Day	09 Fly	10 Fly
11 **Veteran's Day** Fly	12 **Veteran's Day Observed** Fly	13 Fly	14 Down Day	15 Backup Flight/equipment teardown	16 Backup Flight/equipment teardown	17 Backup Flight/equipment teardown
18 Equipment teardown	19 Travel	20	21	22 **THANKSGIVING**	23	24

Field Operations

Actual Deployment Schedule
November

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
28	29	30 Research Team Travel	31 Maintenance Travels Noise Monitor setup/checkout	01 F/18's fly out Noise monitor setup/checkout	02 Motorcycle Rally Practice Flight	03 Motorcycle Rally Down Day
04 Motorcycle Rally Down Day (Daylight Savings Ends)	05 Fly	06 Fly	07 Fly	08 Fly	09 Down Day	10 Fly
11 **Veteran's Day** Fly	12 **Veteran's Day Observed** Down Day	13 Fly	14 Fly	15 Fly	16 Travel	17
18	19	20	21	22 **THANKSGIVING**	23	24

Flight and Field Operations

- Day in the life
  - 0700: Crew arrives on site
    - Field crew sets up sensors, performs pre-flight calibrations
    - Aircrew Briefing starts
    - Maintenance begins preflight
  - 0730: Waypoint file emailed to aircrew, aircrew loads file onto two Garmin 496s
  - 0830: Go/No Go check
  - 0900: F-18 Takeoff
    - GPSSonde Weather Balloon launch
  - 1000: End of flight (approximate)
  - 1130: Waypoint files emailed to aircrew, aircrew loads file onto two Garmin 496s
  - 1230: Go/No Go check
  - 1300: F-18 Takeoff
    - GPSSonde Weather Balloon launch
  - 1400: End of flight (approximate)
  - 1430: Go/No Go check
  - 1500: F-18 Takeoff
    - GPSSonde Weather Balloon launch
  - 1600: End of flight (approximate)
    - Field crew performs post-flight calibrations and stows sensors
  - 1730: Aircrew Debrief
    - Field Crew Debrief & Data Review
  - 1800: All Crew Leaves

Flight #1

Flight #2

Flight #3

Field Operations – Takeaways

- Clear communication across the whole team is vital. Pre and Post day briefings to help coordinate and organize large teams helped. LMR (Land Mobile Radio) network facilitated real time communication.
- Clear description, delineation, and training of duties is imperative.
- Clear communication with sites where instrumentation will deploy is vital.
- Having individuals at actual locations to better describe what they were hearing and match that up with data in real time to direct waypoint planning and troubleshoot odd signals was helpful
- Having all personnel stay at the same hotel for long deployments was helpful for scheduling and rapport.
- In Urban settings, parking can/will be an issue for deploying sensors.
- The real world is noisy. Planes, Trains, and Automobiles, children's birthday parties in the park, school activities, bugs, birds, etc.

- **For X-59, there will be logistical challenges to scale up from 21 sensors spread across 60 square miles to ~150 sensors spread across 2500 square miles.**

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Test Execution

- 22 mission flights completed in 9 flight days (Nov. 5 – 15, 2019)
- 52 “thumps” ranging in loudness from 60 – 90 PLdB (full success)
- Detailed acoustic data recorded for approximately 600 sonic boom waveforms including realistic community background noise
- Substantial survey participation: ~15,500 surveys collected from ~500 survey participants (after each sonic boom and end of each day)
- Other feedback from the community (social media, calls to local emergency response organizations, QSF18 community information line) trended up and down with sound levels.


Photo by Carla Thomas


Photo by Carla Thomas

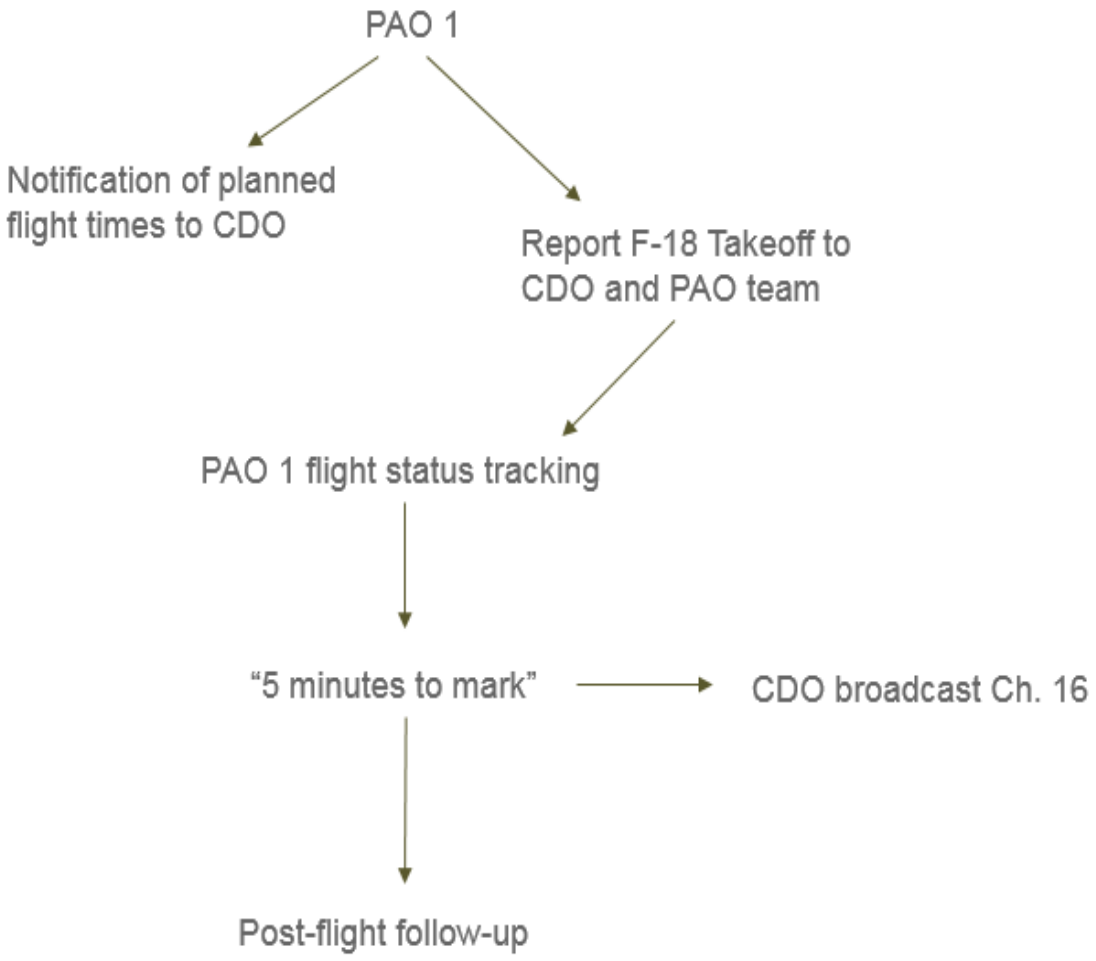
Real-time Communications with Communities

- On-Land Responders Communication
  - Galveston Police, Fire, 911, were informed of planned flight times following morning briefing
  - Services were provided talking points for callers
  - PAO team reached out to Police, Fire, 911 after each flight to gather feedback and caller data
  - Galveston City Hall was contacted after each end-of-day flight for feedback and caller data

- Continued Callers and Data Mapping
  - Police, fire, 911 inquired about reason for call
    - Callers reporting the noise as “loud” or suggesting “nuisance” were requested to provide general location and time of noise
    - Mapping of critical calls for debrief
    - Continued Callers had two options:
      - Provide a number for a PAO to call them back and discuss
      - Reach out directly to PAO via hotline
      - Both routes resulted in a conversation about the individual’s thoughts or concerns

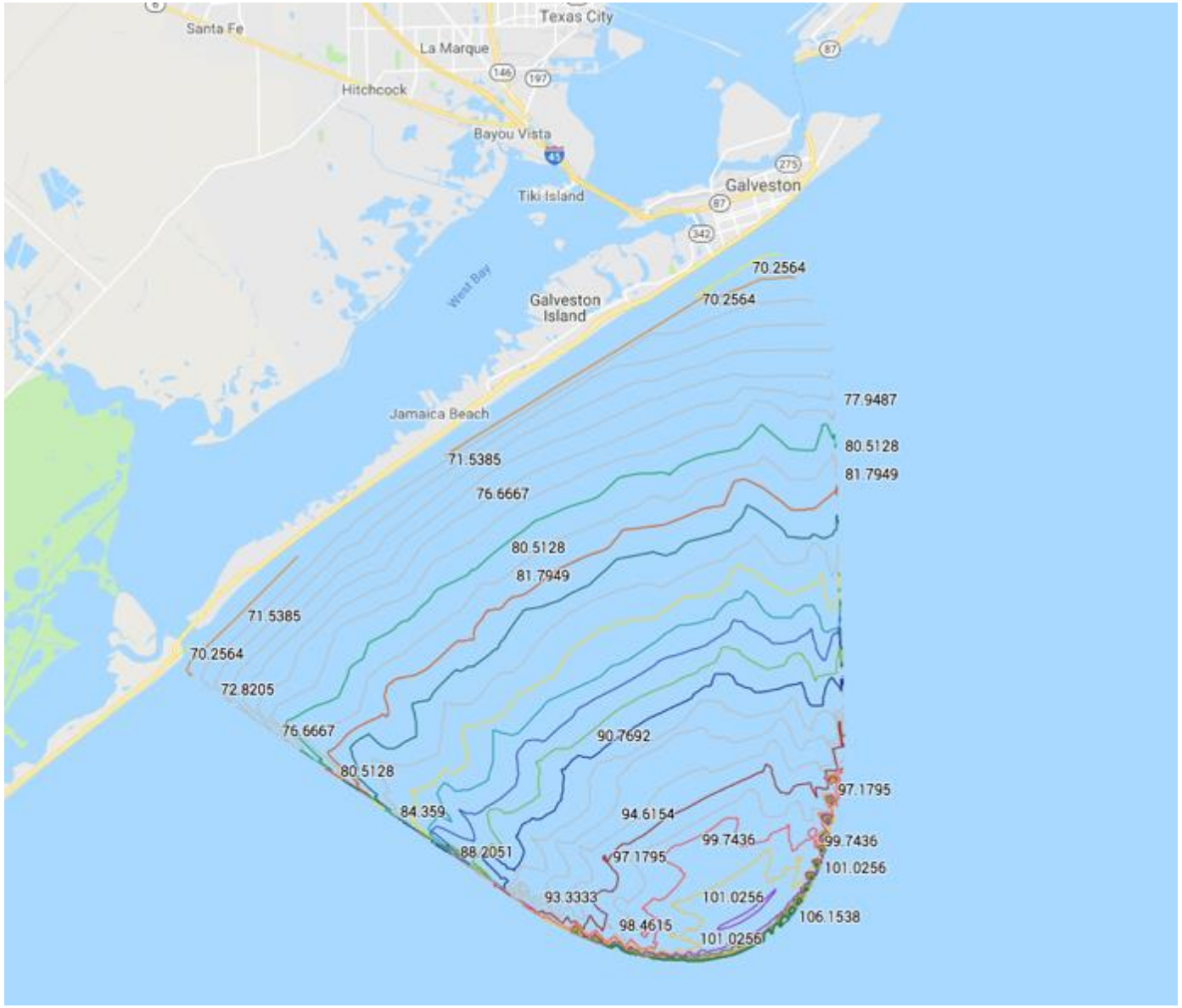
Maritime Communications

- NASA/USCG news release to platforms, oil refineries (Gulf to Texas City)
- USCG CDO began looping broadcasts to vessels on 11/5, via required emergency Channel 16
- PAO 1 at Ellington Field
- Notification of planned flight times to USCG CDO Backups
- F-18 takeoff
- Flight tracking via communications
- Approximate 5-minute to mark update
- USCG Public Affairs talking points and caller data collection



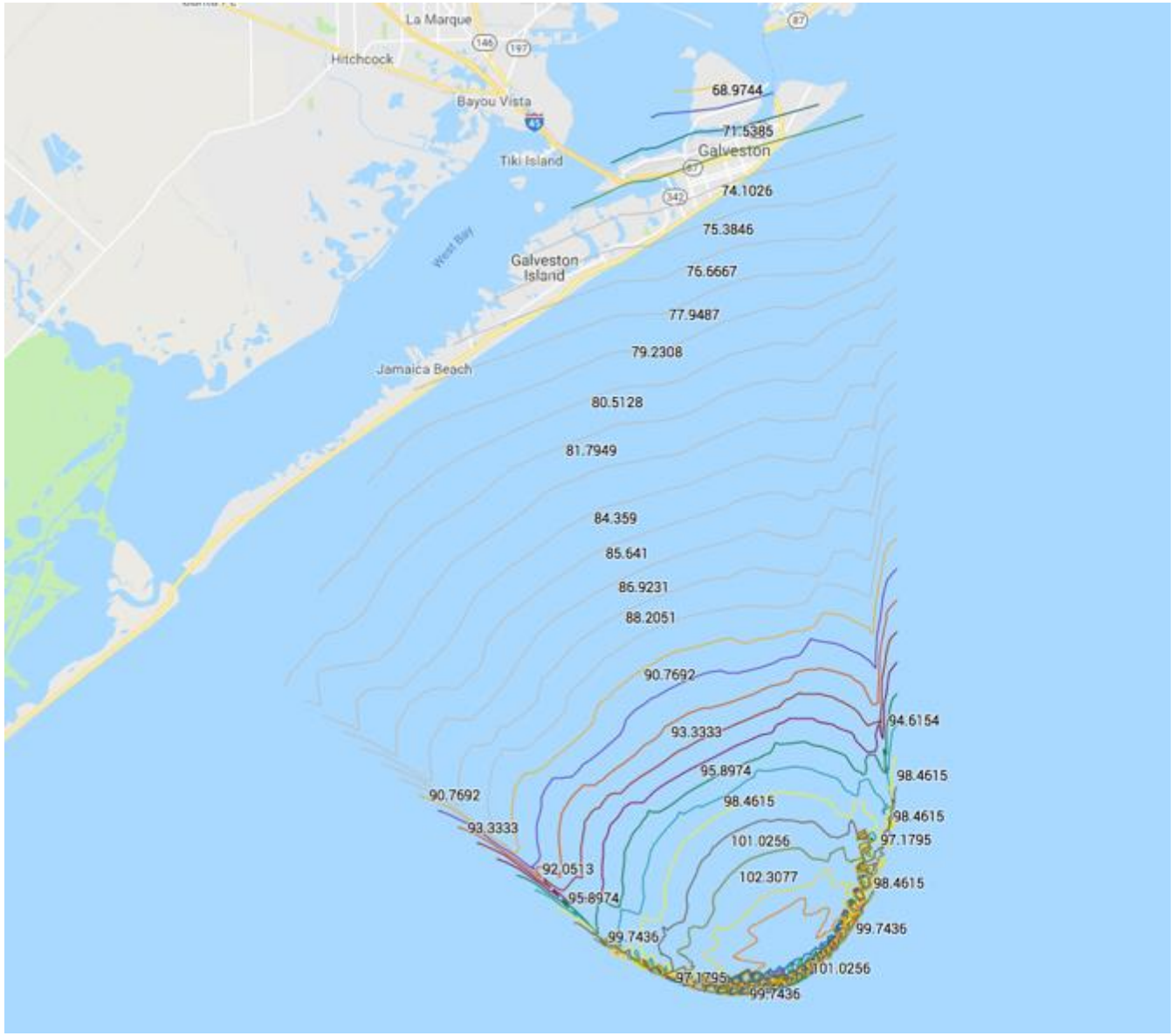
QSF18 Sonic Boom Results

- Flight 2, pass 1
- Post-flight analysis
  - sBoom software (NASA)
- Well-behaved sonic boom carpet



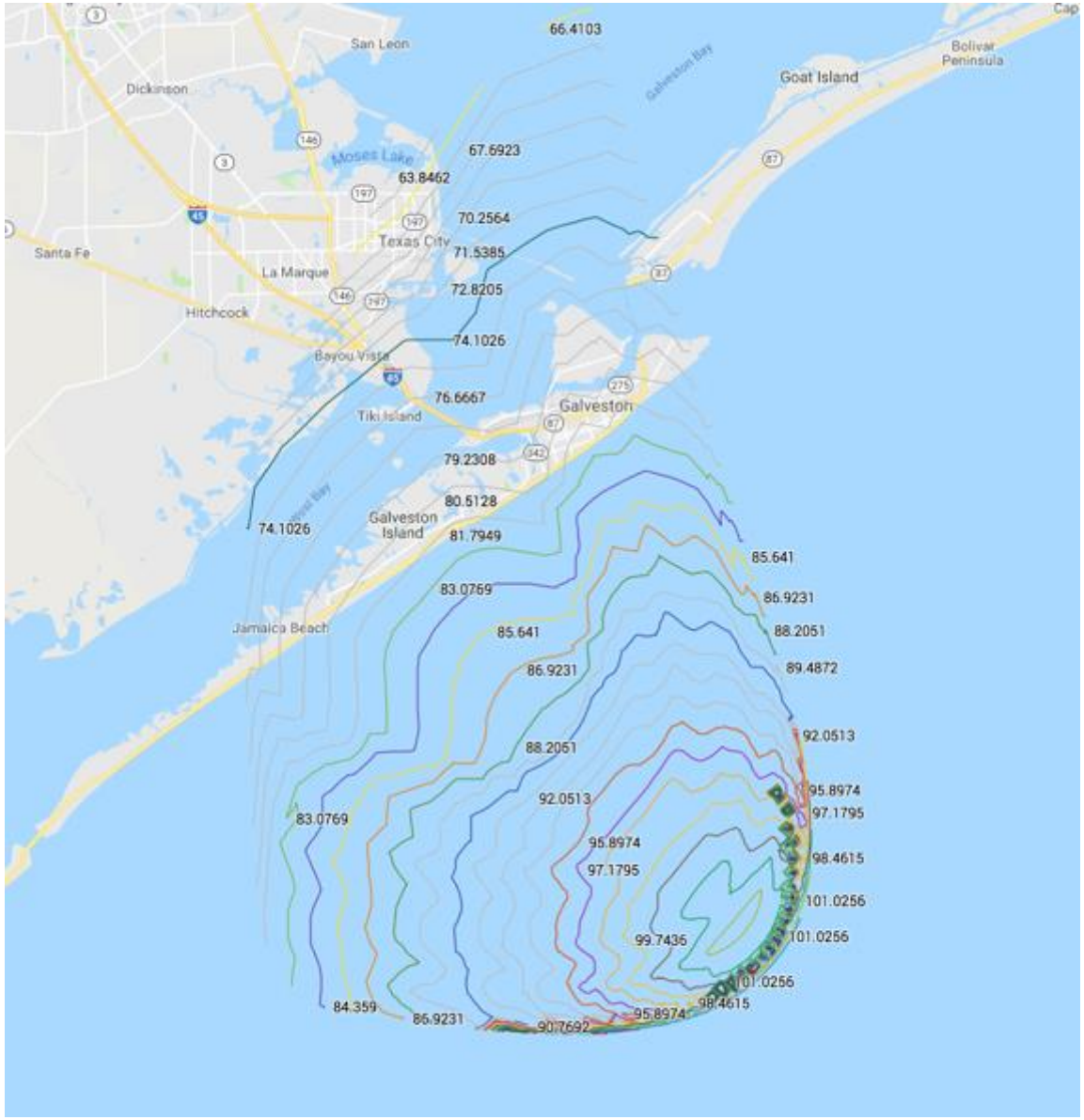
QSF18 Sonic Boom Results

- Flight 4, pass 1
- Post-flight analysis
  - sBoom software (NASA)
- Mild cross winds



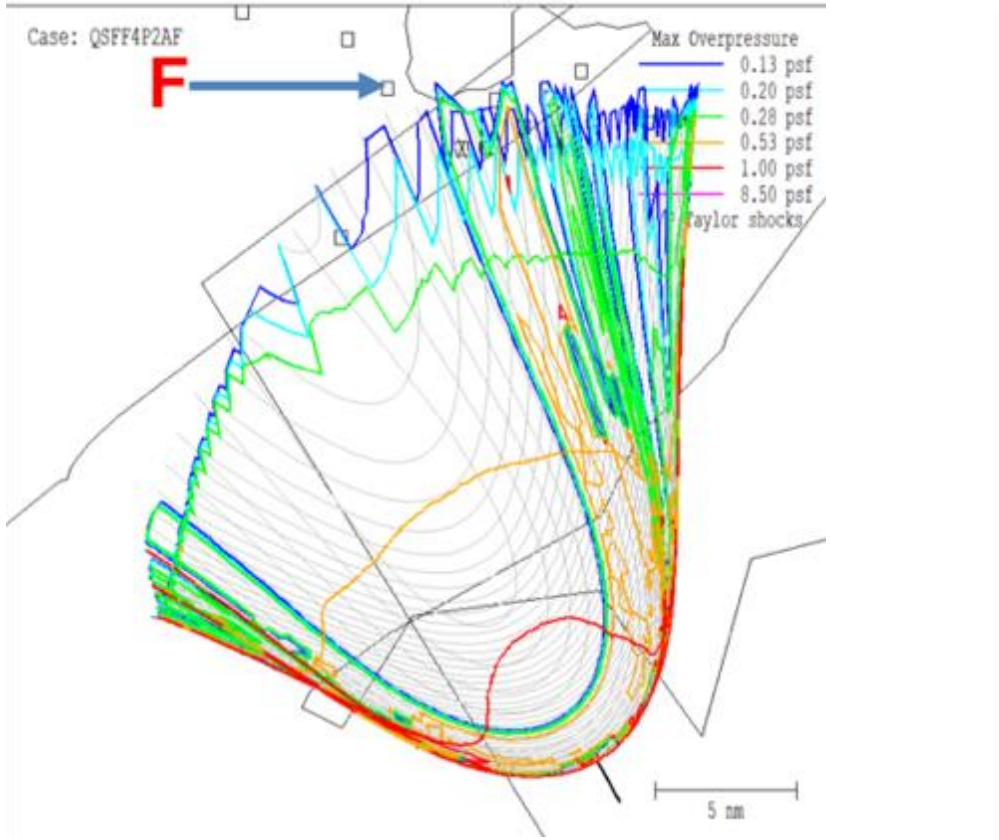
QSF18 Sonic Boom Results

- Flight 9, pass 1
- Post-flight analysis
  - sBoom
- Strong crosswinds

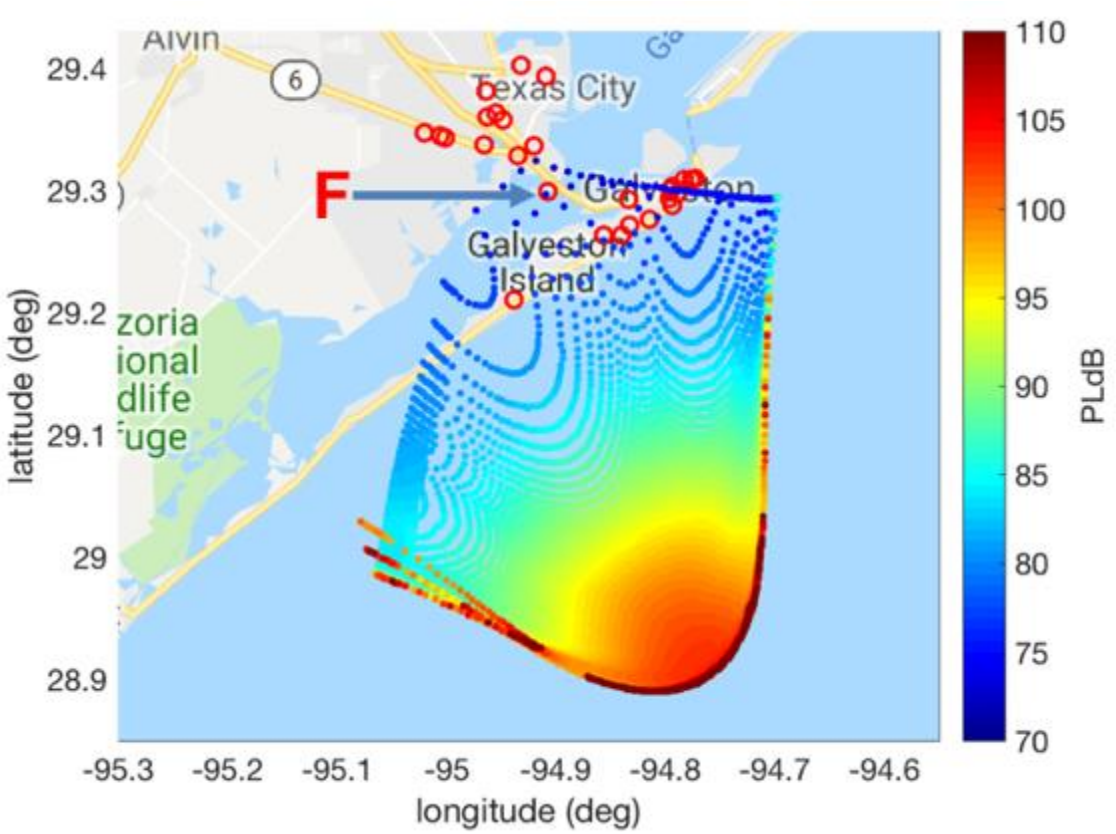


Sonic Boom Analysis – Ray Tracing Effects

- Flight 4, pass 2
- Schulten Flat predicted that Foxtrot is within the carpet.
- Legacy predicted that Foxtrot is outside the carpet.
- Measurement showed that it picked up the signal.



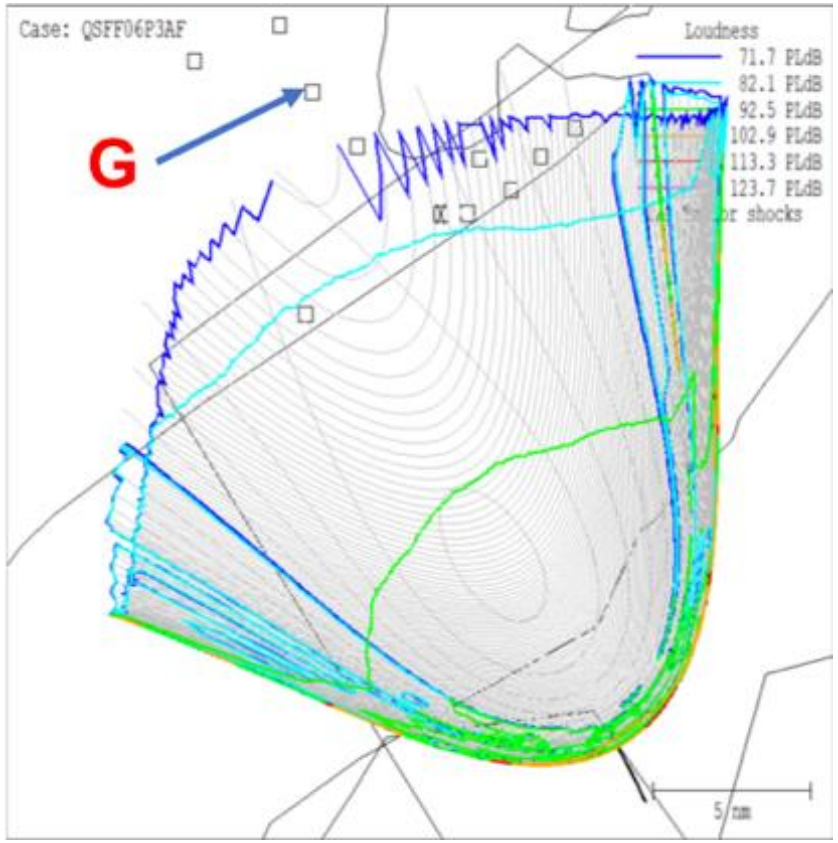
Legacy Flat Earth(Thomas 2D)



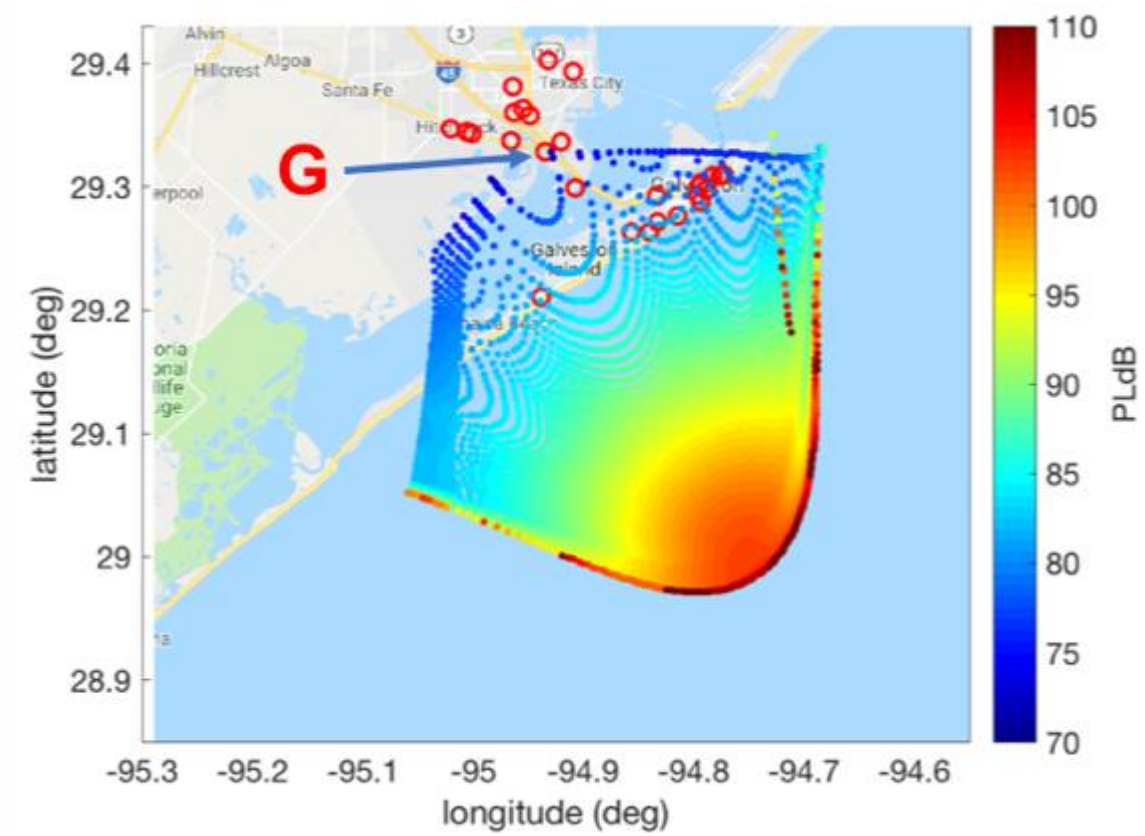
Schulten Flat Earth (3D)

Sonic Boom Analysis – Ray Tracing Effects

- Flight 6, pass 3
- Schulten Flat predicted that Golf is at the edge of carpet.
- Legacy predicted that Golf is well outside the carpet
- Measurement showed that it picked up the signal.



Legacy (Thomas 2D) Flat Earth



Schulten (3D) Flat Earth

Acknowledgements

- Matt Kamlet, NASA Armstrong Flight Research Center
  - Public Affairs Office
- Sriram Rallabhandi, NASA Langley Research Center
  - Sonic boom analysis
- Joel Lonzaga, NASA Langley Research Center
  - Sonic boom analysis
- Partners
  - Applied Physical Sciences
  - Volpe
  - Penn State
  - Gulfstream
  - KBRwyle
  - Eagle Aeronautics
  - Gaugler Associates

Questions

Environmental Concerns

National Aeronautics and Space Administration (NASA) Armstrong Flight Research Center (AFRC) began the preliminary environmental analysis in accordance with the National Environmental Policy Act (NEPA) for the Quiet Supersonic Flights 2018 (QSF18) project in April 2018. The analysis determined that QSF18 would have no significant adverse environmental impact. A Categorical Exclusion (CATEX) was signed on October 23, 2018. A copy of the CATEX can be made available upon request.

NASA AFRC consulted with the following agencies regarding the QFS18 project:

- **Federal**
  - NOAA Nation Marine Fisheries Services (NMFS)
    - Reason for consultation: QSF18 is a federally funded project. The project area contains endangered and threatened species, and critical habitat. According to Section 7 of the Endangered Species Act (ESA), Federal agencies are to insure that their actions are not likely to jeopardize the continued existence of endangered or threatened species or adversely modify or destroy their designated critical habitat.
    - NOTE: NOAA NMFS has jurisdiction over marine species and marine habitat (i.e. five species of sea turtles, West Indian Manatee)
    - NASA AFRC determination: In accordance with Section 7 of the Endangered Species Act of 1973, NASA AFRC determined that QSF18 "may affect, not likely to adversely affect" federally listed species and critical habitat.
    - NOAA NMFS concurrence: On October 11, 2018, NASA AFRC received a letter of concurrence from NOAA NMFS stating, "Because all potential project effects to listed species were found to be discountable or insignificant, we conclude that the proposed action is not likely to adversely affect listed species under NMFS's purview."
  -
  - United States Fish and Wildlife Service (USFWS)
    - Reason for consultation: QSF18 is a federally funded project. The project area contains endangered and threatened species, and critical habitat. According to Section 7 of the Endangered Species Act (ESA), Federal agencies are to insure that their actions are not likely to jeopardize the continued existence of endangered or threatened species or adversely modify or destroy their designated critical habitat.
    - NOTE: For QSF18, USFWS has jurisdiction over land species and land habitat (i.e. Attwater's greater Prairie-chicken, Piping Plover, Red Knot)
    - NASA AFRC determination: In accordance with Section 7 of the Endangered Species Act of 1973, NASA AFRC determined that QSF18 will have "no effect" federally listed species and critical habitat.
    - USFWS concurrence: On October 23, 2018, NASA AFRC received an e-mail stating concurrence from USFWS stating, "Based on additional information provided in an e-mail dated October 16, 2018, the U.S. Fish and Wildlife agrees with the NASA determination of no effect stated in your letter dated September 4, 2018 regarding NASA's two week project Quiet Supersonic Flights 2018 (QSF18)."
- **State**
  - Texas Historical Commission (THC)
    - Reason for consultation: NASA AFRC submitted a project review under Section 106 Consultation of the National Historic Preservation Act for QSF18 because the project involved the use and placement of sensors throughout the Galveston area. Section 106 of the National Historic Preservation Act requires Federal agencies to consider the effects of federally funded projects on historic properties to afford the Advisory Council on Historic Preservation (ACHP) an opportunity to comment on such projects prior to the expenditure of any Federal funds.
    - THC Response:
      - Above-Ground Resources
        - "Property/properties are eligible for listing or already listed in the National Register of Historic Places"
        - "No adverse effects on historic properties"
      - Archeology Comments
        - "No historic properties present or affected. However, if buried cultural material are encountered during construction or disturbance activities, work should cease in the immediate area; work can continue where no cultural materials are present. Please contact the THC's Archeology Division at 512-463-6096 to consult on further actions that may be necessary to protect the cultural remains."

Citizen Scientist Activity

- Available to the general public via web page at nasa.gov
- Provided way for non-official respondents in the entire QSF affected area to comment
- Promoted via social media (Aero centers, JSC, Galveston City)
- Data was exported to researchers at end of flight campaign