An Overview of Lessons Learned from Sonic-boom Flight Research Projects Conducted by NASA Armstrong Flight Research Center

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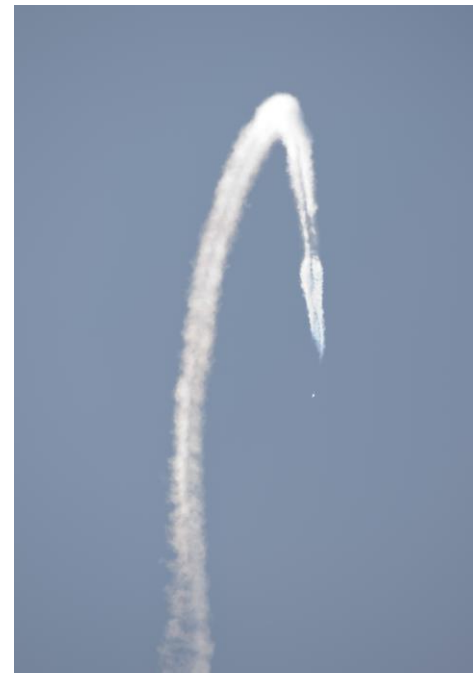

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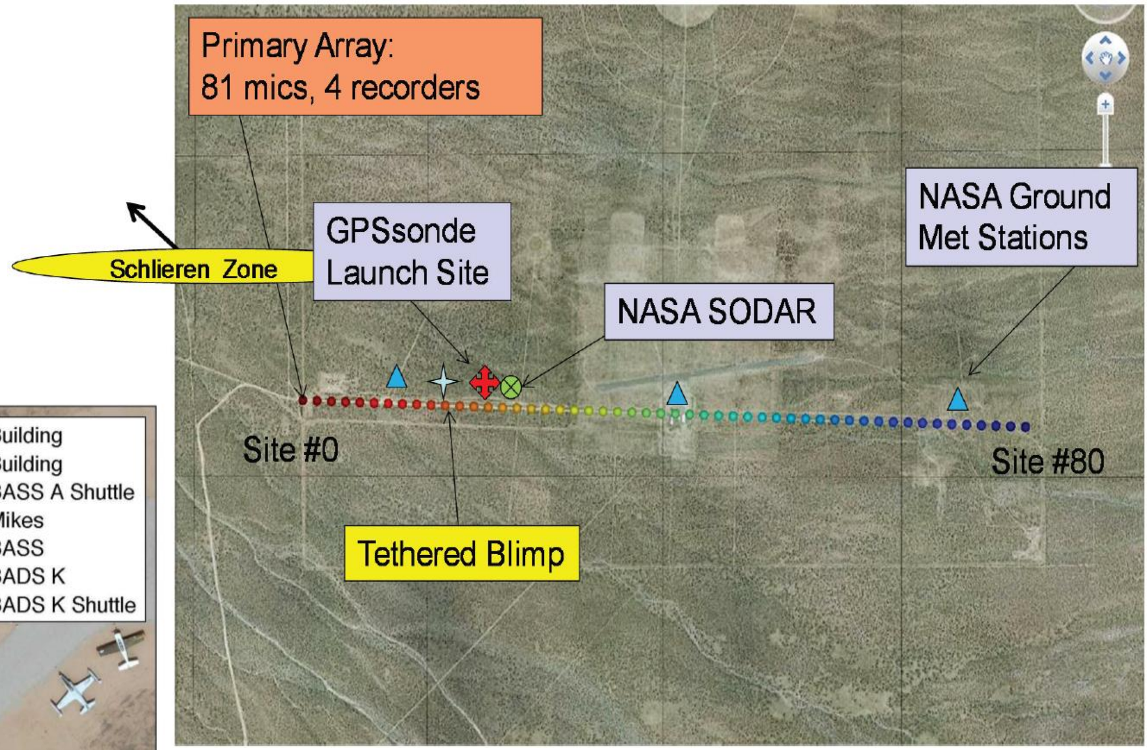
Background

- Definition: "Tests conducted for the purpose of researching sonic-boom signatures on a ground and building level"
- Four Projects in Four Years
  - All Funded by Commercial Supersonic Technology (CST) project within the NASA Aeronautics Research Mission Directorate (ARMD)
  - Increasing in scale in terms of size and number of partners involved
  - For more information about the projects discussed, there are multiple papers on each
- Sonic Booms on Big Structures (SonicBOBS)
  - 3 buildings on Edwards AFB instrumented; 5 partner organizations
- Superboom Caustic Analysis and Measurement Project (SCAMP)
  - 81 mics over 10,000 feet at Cuddeback Lake, CA; 13 partner organizations
- Waveforms and Sonic boom Perception and Response (WSPR)
  - Instrumented residential section of Edwards AFB; 6 partner organizations and volunteer respondents
- Farfield Investigation of No-boom Thresholds (FaINT)
  - 122 mics on lakebed at Edwards AFB; 8 partner organizations

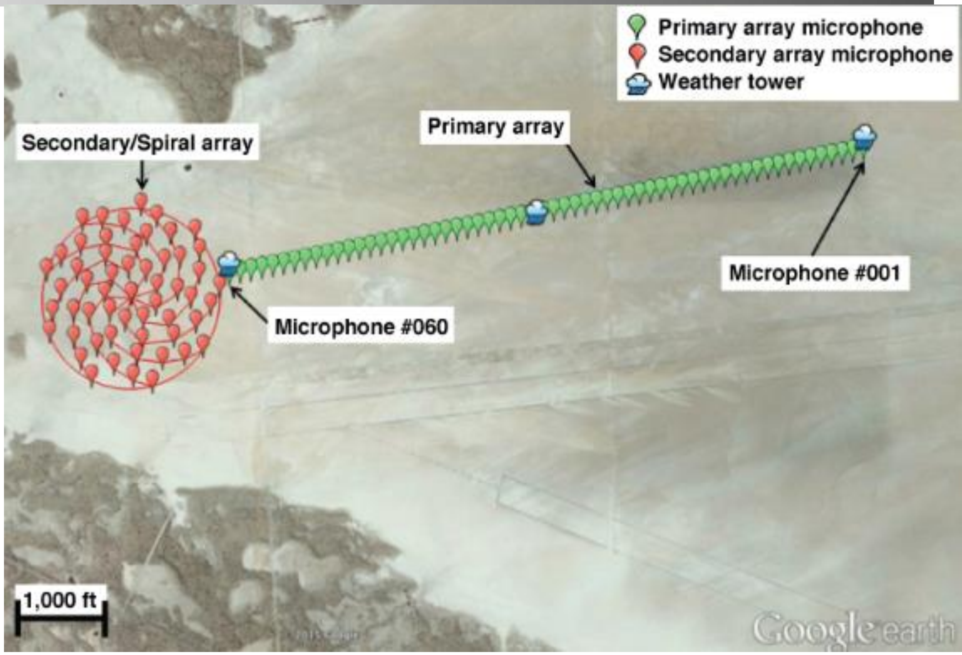
Background

SonicBOBS



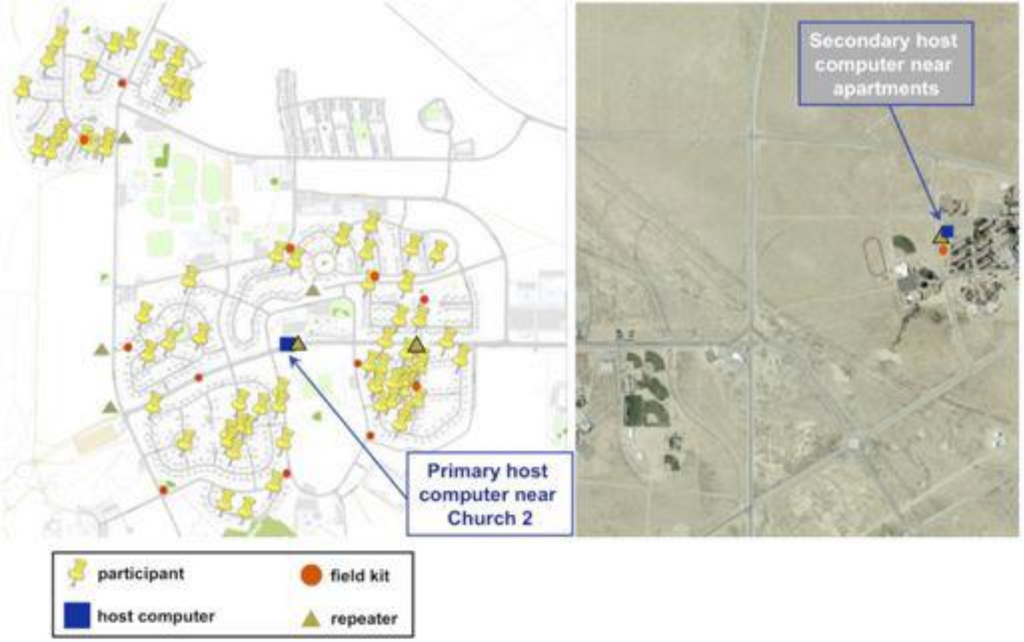
SCAMP

Background



WSPR

FaINT



Summary

1. Schedule: Everything will take longer than you initially estimate
   a) Rule of Thumb: 6 months to a year required for coordination and planning prior to flight test phase, depending on location and relationships
2. Planning: The biggest driver of success is thorough, detailed planning
   a) Make time to look at the project step-by-step from an operational and logistical standpoint
3. Communication: Early communication with all stakeholders is the essential
   a) Set/manage and document all expectations in the planning phase
4. Field Crew: To successfully execute this type or scale of test, a large field crew is required
   a) Crew rest is crucial

Pre-flight Phase

- Formulation Phase
  - Identify and develop project concepts and technologies
  - Establish the project's structure & scope, and lay the groundwork for coordination
  - Set requirements
  - Complete preliminary design
- Includes:
  - Project Planning
  - Test Deployment Planning
  - Project Coordination
  - Logistics and Test Scheduling

Pre-flight Phase: Project Planning

- Definition of Test Objectives and Requirements
  - Parse out “highly desired” objectives or capabilities from required objectives or capabilities
  - Set what must be accomplished to be “fully successful” and “stretch objectives”
  - Establish requirements and objectives early, and do not allow scope creep
  - Requirement: Set the test dates as early as possible in the planning phase to allow planning with partner organizations and coordination of assets
- Selection of the Test Site
  - Consider: Quiet, ease of access, airspace restrictions, required test assets
  - Multiple site visits are crucial to project success
    - Look for unexpected noise sources & other impedances and ways to mitigate both
    - Look at sites through the lens of logistics
- Collaborating with Partners
  - Allow time for agreements
  - Early on, set hard deadlines for participation & definition of assets
  - Fully understand and document stakeholder expectations
  - Volunteer recruitment & continued participation requires time, effort, & incentive

Pre-flight: Test Deployment Planning

- Local vs Remote
  - Local: On Edwards, but not near NASA AFRC campus
  - Remote: Off of Edwards
- Reasons for Test Deployment
  - Fully understand why the project must deploy
    - May drive site selection
    - Will likely need to justify increase in project complexity
- Cost Impact and Added Project Complexity
  - Deployments are expensive!
    - The added planning and logistics required also impact the schedule substantially
  - Equipment and personnel transport; equipment security; shelter, water, and facilities for crew; battery charging; power; first aid; emergency response (first aid, spill kits, who to call/how to tell responders where you are, etc); and crew rest are all impacted

Pre-flight: Project Coordination

- Coordinating with Government Entities
  - It is critical that the project team work out a plan of action for each part of the test – from the receipt and set-up of test equipment to teardown and equipment return shipping
    - Minimizes confusion and chance that any given task will be overlooked & allows team to identify what additional personnel or assets are required
  - Only one POC as seen by each outside organization
  - More coordination and detail in the pre-flight phase can lessen oversight during the flight phase
  - Coordination starts now, but continues through post-flight
  - In general, the following 5 groups need be involved in the coordination and execution of most tests that involve government assets

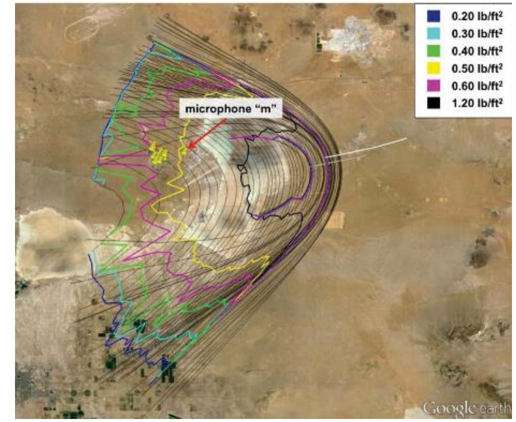
Pre-flight: Project Coordination

1. Airfield Management
   - Critical to establish contact as early as possible!
     - Controls airfield schedule, can inform the about any possible weather restrictions, and may place restrictions that impact layout, set-up, teardown, or storage plans
2. Environmental
   - Contact simultaneous to Airfield Management
   - Usually, an environmental survey is required; the results of the survey can impact what equipment and activities are allowed at the test site
3. Air Traffic Control
   - Develop SOP for airfield access, entry and exit, EPs, communication protocols, and the use of unusual equipment
   - Consider acoustic spacing & artificial instrumentation effects in airspace discussions
4. Frequency Management
   - Need approval to use equipment with transmit and/or receive functions
   - Government-led tests or tests on government sites cannot use "camping radios"
     - VHF, UHF, or LMR can be used with a frequency request
5. Access to Military Bases/Government Facilities
   - Determine the process and appoint a non-field crew POC

Pre-flight: Project Coordination

- Facilities Use
  - Make requests of building residents as early as possible – people often want to help
  - Consider how equipment may be impacted by being in an occupied building or high-traffic area
  - Give as much detail as possible concerning number of sensors, size of instrumentation, how the data will be recorded, what will be recorded, and how equipment will be placed/mounted as soon as possible
- Coordination of Land and Airspace
  - Determining who is the authority over a test site can be difficult
  - The authority over the test site may have other processes that must be complete prior to testing
- Coordinating with Partners
  - Determine how many people will travel for the test, when they will arrive, how partner equipment will be shipped and handled, and what everyone's role is during the flight phase
  - Set expectations with a document and a signature page and ensure that every team member understands where they fit into the bigger picture and schedule

Pre-flight: Project Coordination



- Navigating Potential Roadblocks
- Sonic-boom-related Stigmas
  - Many people have never experienced a sonic-boom; opinions based on news articles, movies, and second-hand accounts
  - Must educate stakeholders – including public – prior to testing
    - Low booms, sonic-boom carpets, and sonic-boom carpet placement
  - All booms during a flight test window will be attributed to the publicized project
  - Projects must be sensitive to community events
- Use of Land and Facilities for Instrumentation
  - Some people don't mind being near a test, but do not want the test to have any impact on their day (adverse to delaying equipment use, or using a different door, for example)
  - Privacy concerns related to recording acoustic data, especially in residential areas
    - Auto-trigger only during prescribe flight times or manual trigger only
- Equipment Integrity and Security
  - Cabling typically left in place; other hardware is stored near the recording site
  - Protect against Weather and Wildlife: Rodent chew-through of cable is a common issue; need durable water-tight, heavy cases for overnight equipment storage

Pre-flight: Logistics & Test Scheduling

- Setting the Research Flight Phase Schedule
  - There is always pressure to condense flight test window (deployments are expensive)
  - Make time in the schedule to review data between flights
  - <u>Be realistic</u>: allow for troubleshooting during initial set-up, budget time daily for set-up and pick-up, plan for time to remove the equipment from the test site at completion
  - Make the schedule with one eye on crew rest!
- Planning the Daily Test Schedule
  - Must balance conflicting interests: Desired weather, the need for multiple flights in a day, VFR restrictions, and tower/airfield operating hours
- Radio Frequency Scheduling
  - Minor delays add up: Schedule for the entire day, if possible to avoid further delays or possibly cancelling due to coordinating to extend or get new frequencies
- Daily Meetings
  - Mandatory morning field meetings provide a forum to address schedule changes or operational changes

Pre-flight: Logistics & Test Scheduling

- Crew Rest
  - Aggressive flight days mean long days for the field crew – again, be realistic!
  - Set partner expectations and stakeholder expectations well in advance of the flight test phase

Table 1. Planned daily schedule for the Superboom Caustic Analysis and Measurement Project (SCAMP)

• Setup and calibration of ground instrumentation		(0400)
• Airplane instrumentation checks		(0600)
– Pre-flight at beginning of flight week		
– Day of flight each flight day		
• Compute waypoints and deliver to pilots		(0615)
• 1st research flight takeoff		(0700)
– Flight	(1 hr)	
– Field crew break	(1 hr)	
– F-18 turn-around	(2 hr)	
– TG-14 turn-around	(2 hr)	
• 2nd research flight takeoff		(1000)
– Flight	(1 hr)	
– Field crew break	(1 hr)	
– F-18 turn-around	(2.5 hr)	
– TG-14 turn-around	(2 hr)	
• 3rd research flight takeoff		(1330)
– Flight	(1 hr)	
• Airplane shutdown and GPS downloads		(1430)
• Crew de-brief		(1530)
• Crew brief for next day		(1600)
• End of duty day		(1730)

Pre-flight: Logistics & Test Scheduling

- Test Site Checkout and Receiving Equipment
  - As a minimum, the local field crew must visit the test site prior to equipment setup
    - Ideally, the whole team would complete several site visits to become familiar
    - Check/learn the possible routes to the test site, determine if anything about the test site has changed, radio/hot spot/cell phone reception checks
    - Mark all routes to the test site and generate maps – reflectors may be necessary
  - One large equipment storage and staging area is required
    - Set a firm delivery deadline, with time allowed for shipping complications (customs, damaged equipment, etc) to ensure there is time to perform a full systems check before deployment
- Personnel Training
  - Location specific training (wildlife, undetonated munitions, heat-stress, etc)
    - If possible, combine with Day One Brief, or complete via videoconference/teleconference to make tracking easier
  - Day One Briefing
    - Review training and ROE
    - Review daily & overall test schedule; show personnel where they are in the big picture
    - Review expected sonic-boom sounds and when to be quiet
    - Hands-on communications training
    - Training sessions for human-response volunteers should be condensed for uniformity

- Operator Error
  - Schedule time for new (and rusty) operators to set-up and use the equipment prior to the flight phase
  - Create a detailed user manual, a list of commonly encountered issues and their fixes, and a check list including last minute “final checks”
  - If a mistake was made once, it will likely be made again unless addressed
- Environmental Considerations
  - Wildlife
    - No cable damage when 500 feet from lakebed “shore”; commercial sprays are ineffective
  - Weather
    - Wind can cause overpressure triggers to falsely record
    - Direct sun or heat can cause equipment to shutdown
    - Large temperature swings can cause significant calibrations shifts in all equipment
    - Sunshields, pre- and post-calibration, understanding how weather impacts instrumentation
- Hardware Considerations
  - Minimize extraneous software on all PCs used to record data
  - Trust but verify all new equipment; have at least one backup for each component
  - Design a minimum-success array as a backup
  - Label each unit prior to deployment with location

- TG-14 Motorized Glider
  - Captures the sonic-boom between origination and ground; must be at a specific altitude and airspeed with the motor off at a pre-determined time after the boom is created
  - Determine if or to what extent the sonic-boom producing aircraft will wait on the TG-14 to get back into place
  - Set test points from high to low and allow the TG-14 to takeoff at least 15 minutes early
  - FTEs familiar with the equipment from extensive use on the ground yield are best
  - Perform extensive ground tests to determine if EMI will impact any instrumentation

- Tethered Blimp
  - Used to loft microphones and recorders
  - Higher density altitudes meant that only 2 (instead of 3) recorders could be lofted
  - Test on-site prior to first flight & design conservatively

Flight Phase

- Test Equipment Deployment, Operations, and Retrieval
- Flight and Field Crew Responsibilities
- Research Team Communications
- Documentation

Flight Phase: Test Equipment Deployment, Operations, and Retrieval

- Surveying and Marking
  - Understand where each microphone is located and ensure that the survey is complete prior to removing markers or equipment
- Equipment Calibration
  - Consider any tests that your team may perform in the next year and calibrate the equipment accordingly (i.e. install or remove a low frequency adaptor)
- Equipment Deployment
  - The amount of physical effort needed to set-up an array is very large (FaINT: 30 People)
  - Label all equipment, stack on pallets, diagrams/checklists indicating where each piece of equipment goes
  - Schedule a deployment walk-through: check the contents of each pallet or container, what piece of equipment goes where, who is responsible for it, and in what order the equipment should be deployed
- Equipment Pickup
  - Include scheduled days after the completion of the flight phase to remove equipment from the test site and communicate the intent well prior to the flight test phase

Flight Phase

- Flight and Field Crew Responsibilities
  - Do not overtask any one person or group
    - Especially the PI who does the pre-flight planning and may need time to troubleshoot
  - All team members must know their daily duties & how those duties fit into the big picture
  - Pre-flight planning
    - Maintain a backup copy of the planning code; if booms of varying levels are required, maintain separate code for louder/quieter booms as well
- Research Team Communications
  - Land Mobile Radios (LMRs) are best
  - Brief, implement, and enforce a well thought out communications plan
  - Communicate expected propagation times to field crew
  - At least one field crew member to attend pre- and post flight briefs; daily field crew briefing in the field prior to start of each day
- Documentation
  - Use photography to document the array layout as a back-up to GPS data
  - Field note templates help capture all of the desired information, but make sure the notes will make sense several weeks after the test is complete

Post-flight Phase

- Logistics
  - Return of equipment is best facilitated by the equipment owner
  - Time-syncing all of the data takes time: set a realistic timeline and communicate said timeline to stakeholders in the planning phase
- Recording Project Details
  - Organize and “decode” all field notes immediately
  - Ground reports document anything that happened in the field during a flight
  - Document lessons learned immediately after the flight phase!
- Post-flight Data Processing
  - Start as soon as practical
  - Document common issues and the fix (i.e. early weather balloon termination fixed by creating a standard process for piecing together other balloon data)
- Communicating Appreciation
  - Formal event can be used to simultaneously collect survey tools & distribute incentives
  - Thank the organizations that the project coordinated with, share what the project accomplished, and how the organization specifically impacted project success
  - Informal gathering for team solidifies bonds for future projects

Conclusion

- SonicBOBS, SCAMP, WSPR, and FaINT were all successful
- Project teams can learn a great deal from successful projects
- Tribal knowledge must be documented to prevent loss
- Start planning and coordination very early, be meticulous in planning, communicate prolifically, and plan to use a very large field crew