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

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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

Museum Sensor Layout, 9/12/09

Primary Array:
81 mics, 4 recorders

Schlieren Zone

GPSsonde Launch Site

NASA Ground Met Stations

NASA SODAR

Site #0

Site #80

Tethered Blimp

SCAMP
Background

WSPR

FalNT
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
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 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
• 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
  – **Be realistic:** 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
• 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)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setup and calibration of ground instrumentation</td>
<td>(0400)</td>
</tr>
<tr>
<td>Airplane instrumentation checks</td>
<td>(0600)</td>
</tr>
<tr>
<td>Pre-flight at beginning of flight week</td>
<td>(0615)</td>
</tr>
<tr>
<td>Day of flight each flight day</td>
<td>(0700)</td>
</tr>
<tr>
<td>Compute waypoints and deliver to pilots</td>
<td>(0715)</td>
</tr>
<tr>
<td>1st research flight takeoff</td>
<td>(1000)</td>
</tr>
<tr>
<td>– Flight</td>
<td>(1 hr)</td>
</tr>
<tr>
<td>– Field crew break</td>
<td>(1 hr)</td>
</tr>
<tr>
<td>– F-18 turn-around</td>
<td>(2 hr)</td>
</tr>
<tr>
<td>– TG-14 turn-around</td>
<td>(2 hr)</td>
</tr>
<tr>
<td>2nd research flight takeoff</td>
<td></td>
</tr>
<tr>
<td>– Flight</td>
<td>(1 hr)</td>
</tr>
<tr>
<td>– Field crew break</td>
<td>(1 hr)</td>
</tr>
<tr>
<td>– F-18 turn-around</td>
<td>(2.5 hr)</td>
</tr>
<tr>
<td>– TG-14 turn-around</td>
<td>(2 hr)</td>
</tr>
<tr>
<td>3rd research flight takeoff</td>
<td></td>
</tr>
<tr>
<td>– Flight</td>
<td>(1 hr)</td>
</tr>
<tr>
<td>Airplane shutdown and GPS downloads</td>
<td>(1430)</td>
</tr>
<tr>
<td>Crew de-brief</td>
<td>(1530)</td>
</tr>
<tr>
<td>Crew brief for next day</td>
<td>(1600)</td>
</tr>
<tr>
<td>End of duty day</td>
<td>(1730)</td>
</tr>
</tbody>
</table>
• 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
Methods of Data Collection: Ground Instrumentation

• 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
Methods of Data Collection: Airborne Instrumentation

• 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