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Development of a Sonic Boom Measurement System at JAXA

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Agenda

- Background
- Requirements for Measurement System
- Development of Measurement System
- Flight Test
- Summary







Supersonic Transport Research at JAXA



Technologies for Economically Viable and Environmentally Friendly



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D-SEND Program

- Drop test for Simplified Evaluation of Non-symmetrically Distributed sonic boom
- Objective
 - To validate JAXA's aircraft design concepts for sonic boom mitigation.
- Test Procedure
 - Drop test models with and without "low-boom" design
 - Measure sonic booms on and above the ground



D-SEND #1 (Spring, 2011)



D-SEND #2 Test Model

- W = 1000 kg
- L x Dia. x Span = 7.7 m x 0.48 m x 3.5 m
- Span = 3.5 m
- CL = 0.12 (M = 1.4, H = 8 km)
- Swing = 4.92 m²
- EGI (INS+GPS)

D-SEND #2 (Summer, 2013)

Measuring Sonic Booms

- Accurate measurement of sonic boom
 - Key technology for D-SEND Program
- Special requirements for measurement system
 - Unique acoustic characteristics of sonic booms

What is a Sonic Boom?

- Shock wave created from aircraft flying at a supersonic speed
- Impulsive, loud noise similar to explosion
- Supersonic flights over land currently banned due to sonic booms
- Reduction of sonic booms be necessary for next-gen. SST

Acoustic Properties of Sonic Boom

- Wide Frequency Range
 - Overall infrasonic components < 1 Hz
 - Rapid pressure rises > 10 kHz
- Wide Dynamic Range
 - Large pressure > 200 Pa (140 dB SPL)
 - Small pressure fluctuation in "postboom noise" < 0.1 Pa (74 dB SPL)
- Transient Noise
 - Short duration < 0.3 sec

Requirements for Sonic-Boom Measurement System

- Accuracy
- Flexibility
- Reliability
- Convenience

Requirement: Accuracy

- Need to capture sonic-boom pressure time histories in detail
 - Wide range of frequency
 - 0.5 10,000 Hz
 - Wide dynamic range
 - 0.1 200 Pa

Requirement: Flexibility

- Need to use various types of transducers
 - Microphones and accelerometers
 - Different set-ups for different channels
 - AC- and DC-couplings
 - With and without IEPE excitation
 - Ability to increase the number of channels

Requirement: Reliability

- Need to record sonic booms without fail
 - Flight test be costly
 - Long continuous recording
 - Up to 1 hr
 - Multiple channels with simultaneous sampling
 - 16 ch, 48-kHz sampling rate
 - Real-time monitoring
 - Quick review of recorded data

Requirement: Convenience

- Need to use/analyze recorded data afterward
 - Post-recording data extraction and analysis
 - Only a portion of recorded data is useful
 - Time stamping
 - Time alignment with data obtained with different systems set at different locations, e.g. aircraft position data.

Solution: Hardware

- NI PXI System
 - Wide variety of modules to meet requirements

- NI 8353
- NI PXI-1044
- NI PXI-8360
- NI PXI-6652
- NI PXI-6682
- NI PXI-4472B

Hardware Solution: Input Module

- NI PXI-4472B
 - High resolution: 24-bit ADCs
 - Wide dynamic range: 110 dB
 - Low cut-off frequency: 0.5 Hz for AC coupling
 - Software-configurable AC/DC coupling and IEPE conditioning

Hardware Solution: Timing Modules

- NI PXI-6652 & NI PXI-6682
 - Synchronize PXI systems using GPS antenna

Hardware Solution: Controller & Interface

- NI 8353
 - High-speed data streaming: RAID 0 configuration
 - Large-capacity storage: 4 x 250 GB HDD
- NI PXI-PCIe8362
 - MXI 4 High-throughput: Up to 160 MB/s

Software Solution: LabVIEW

- Set-up
 - Detailed set-up for each channel
 - Transducer information
- Control Measurement
 - Effective binary format of TDMS suitable for multi-channel, long recording
- Real-time monitoring

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Software Solution: LabVIEW

- Quick review of recorded data
 - Can check recorded data right after each flight.
 - Can modify flight/measurement conditions for the next trial.
- Post-recording data analysis
 - Variety of analysis functions of Sound and Vibration add-on.

Preliminary Flight Test

- Overview
 - Measured sonic booms of actual supersonic aircraft (i.e. not research aircraft/model)
 - September, 2009 in Sweden.
- Objectives
 - To verify preliminary sonic-boom measurement system
 - To identify appropriate transducers and set-ups
- Flights
 - 5 flyovers
 - 3 flight conditions

Flight Test: Measurement Scheme

- On the ground, measured:
 - Sonic booms outdoors
 - Sonic booms indoors
 - Vibration of windows and walls of building
- Above the ground, measured:
 - Sonic booms at altitude of 3,300 ft

Flight Test: Instruments Set-Up

Flight Test: Measured Data

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Summary

- Sonic boom measurement system has been developed at JAXA.
- The system is based on NI PXI system and LabVIEW.
- Preliminary measurement system has been validated in flight test.

Summary

- NI PXI system and LabVIEW chosen because of their:
 - Accuracy
 - Flexibility
 - Reliability
 - Convenience
 - Cost effectiveness
- System developed with close relationship with NI staff
 - Consulting by specialist in sound and vibration applications
 - Knowledge and know-how from world-wide network
 - On-site technical support in software development

Future Test Schedule

• 2nd preliminary flight test (September 2010)

• D-SEND #1 (Spring 2011)

• D-SEND #2 (Summer 2013)

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Expansion Plan

- Apply NI products to aerial measurement
 - New input module in development
 - Suitable for sonic boom measurement
 - 0.12 Hz cut-off for AC-coupling
 - 24-bit resolution
 - Suitable for aerial measurement
 - Compact and light-weight
 - No external power supply needed. (USB bus-powered)
 - Low Frequency Microphone: GRAS 40 AZ-S1
 - 0.09 Hz cut-off
 - IEPE-type microphone

Tentative Expansion Plan

- Compact, stand-alone systems distributed.
- Executable LabVIEW program in each PC.
- Controlled via wireless LAN.

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