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Development of a Sonic Boom Measurement System at JAXA

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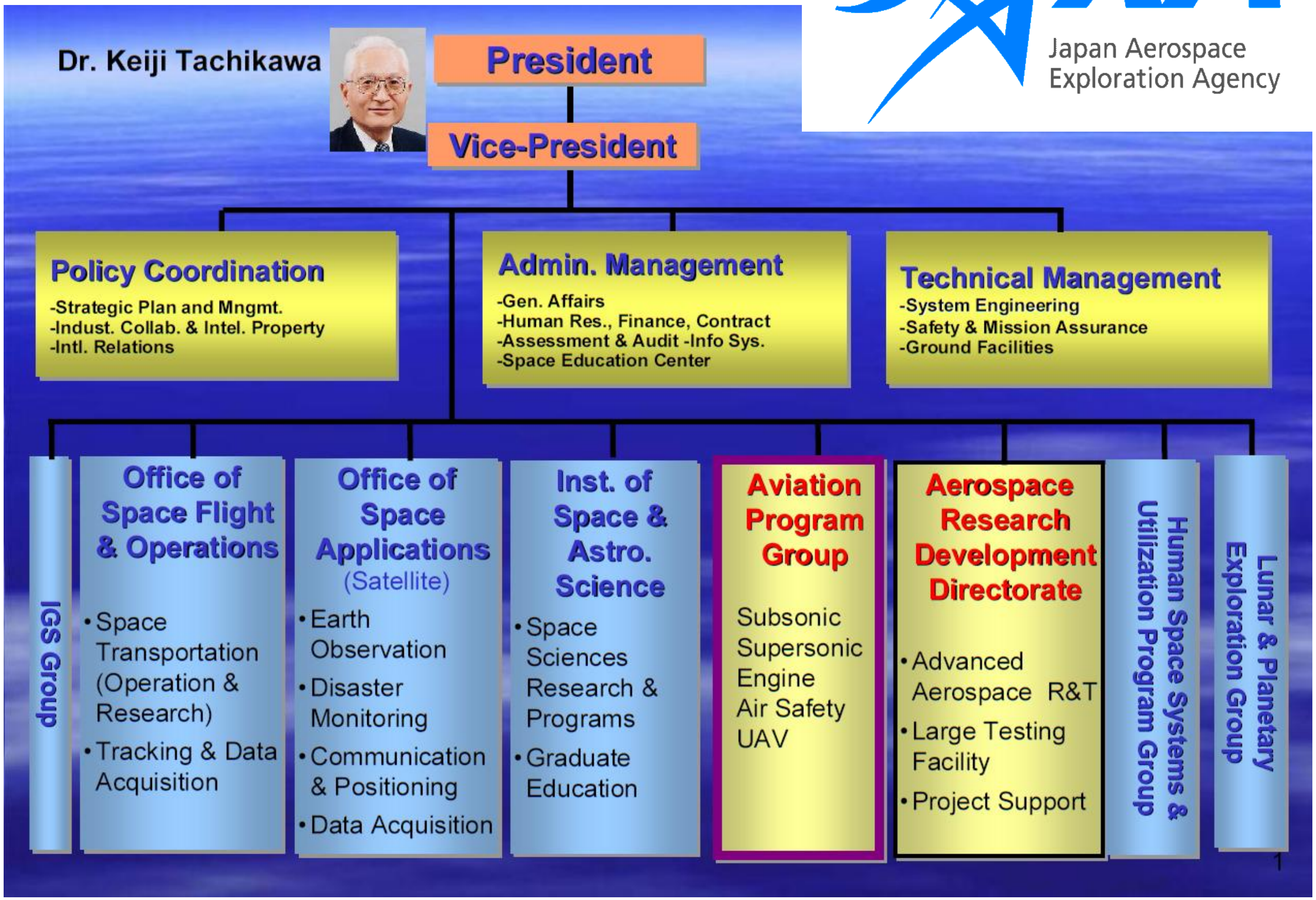
Agenda

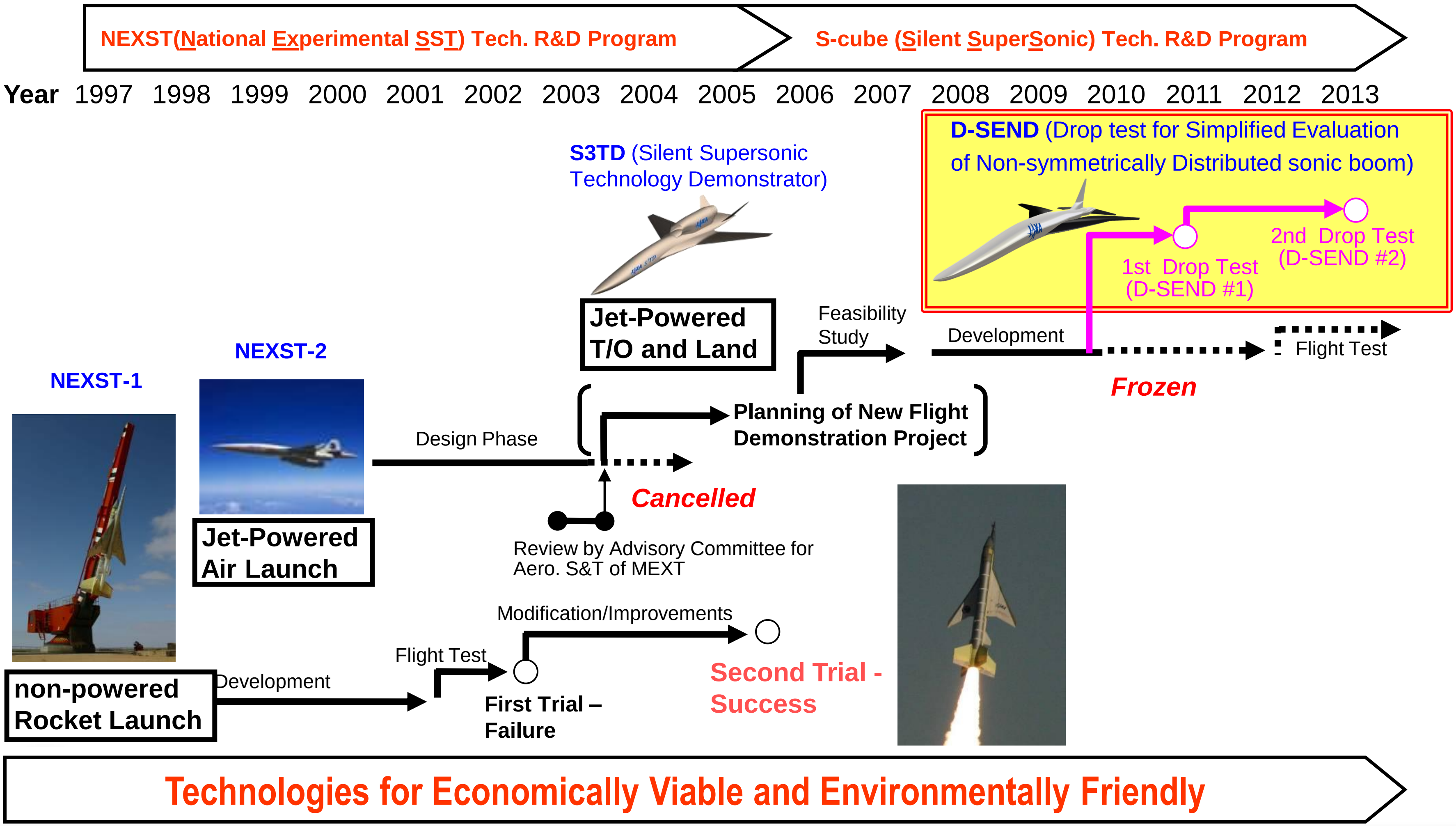
- Background
- Requirements for Measurement System
- Development of Measurement System
- Flight Test
- Summary

About JAXA

Japan Aerospace Exploration Agency



Supersonic Transport Research at JAXA



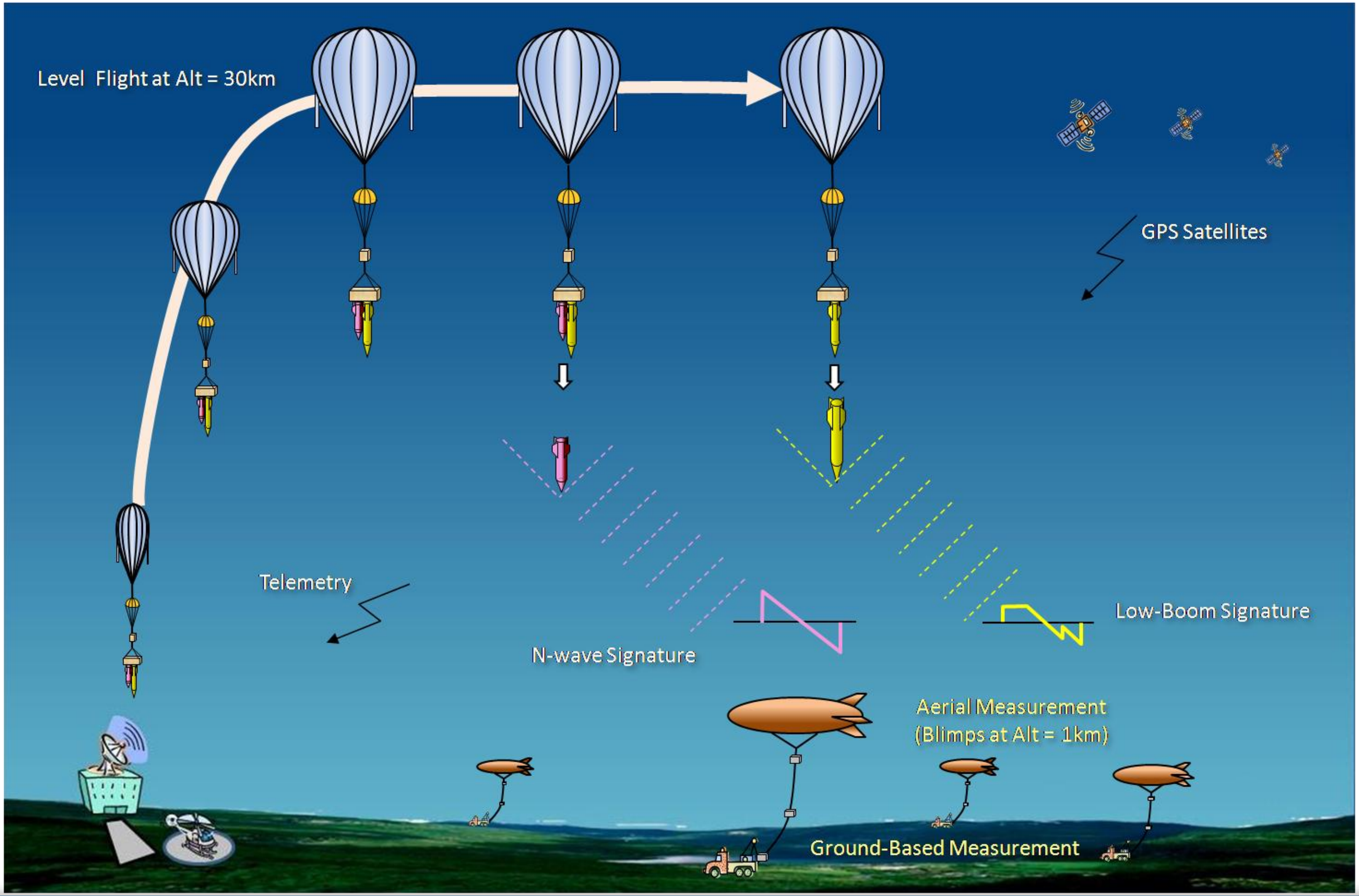
D-SEND Program

- **D**rop test for **S**implified **E**valuation of **N**on-symmetrically **D**istributed sonic boom

- Objective
  - To validate JAXA's aircraft design concepts for sonic boom mitigation.

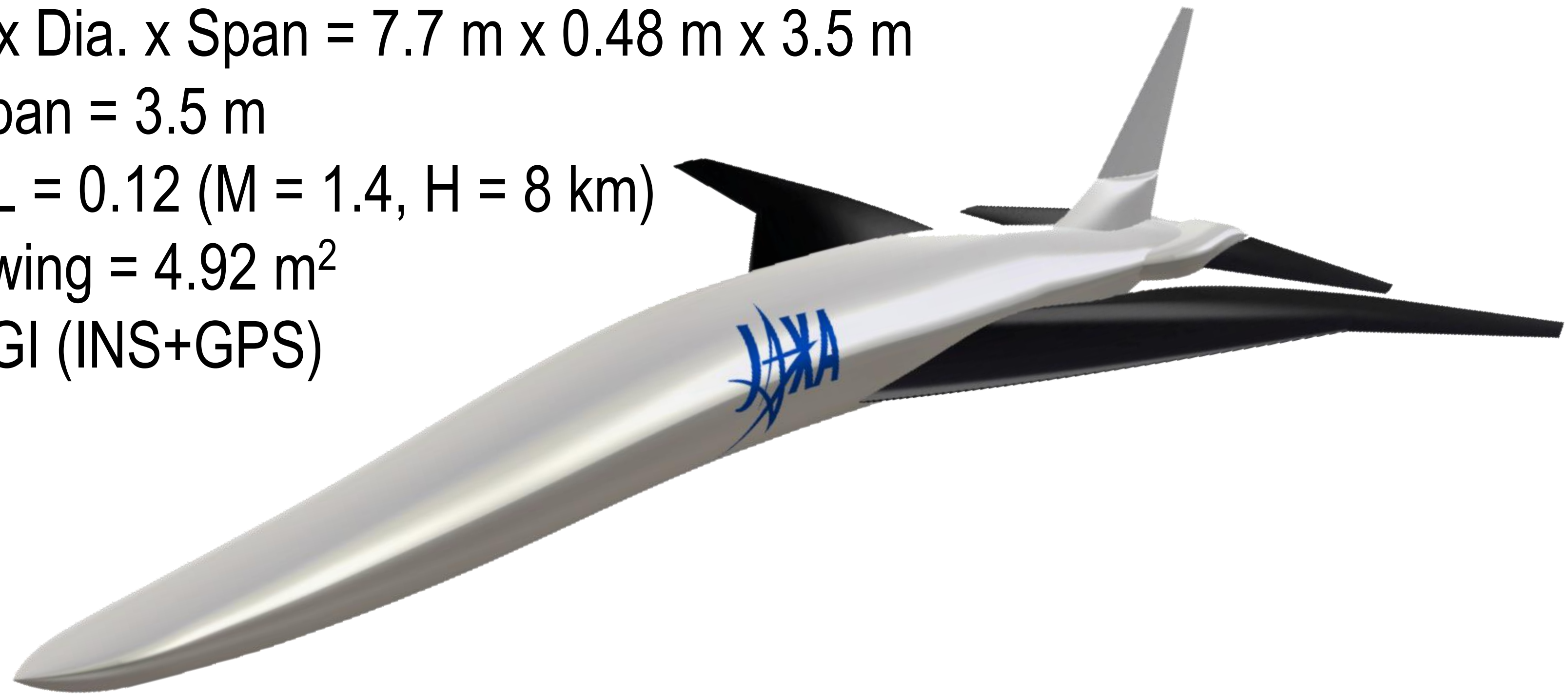
- Test Procedure
  - Drop test models with and without "low-boom" design
  - Measure sonic booms on and above the ground

D-SEND #1 (Spring, 2011)

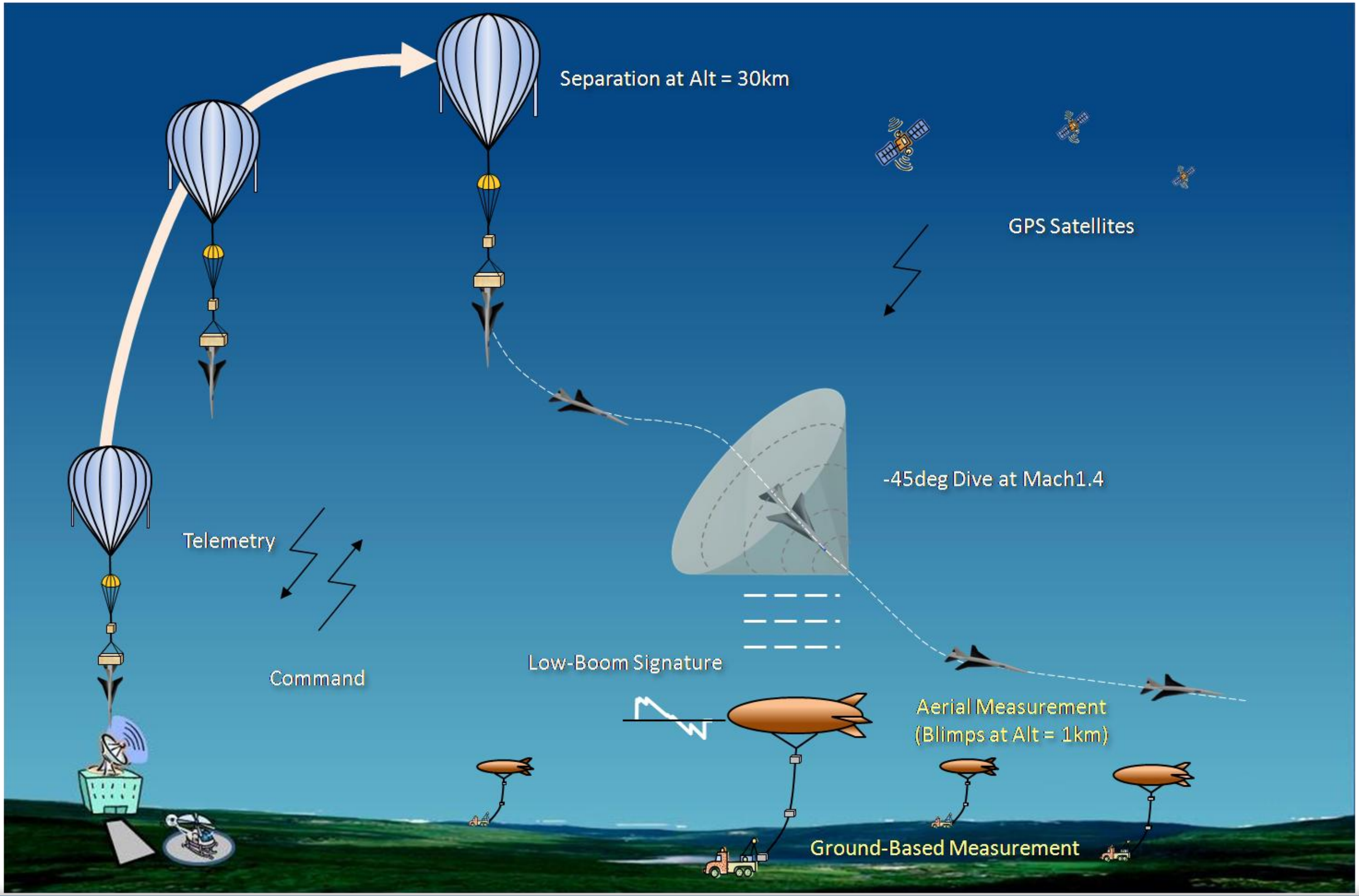


D-SEND #2 Test Model

- 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 m^2
- EGI (INS+GPS)



D-SEND #2 (Summer, 2013)

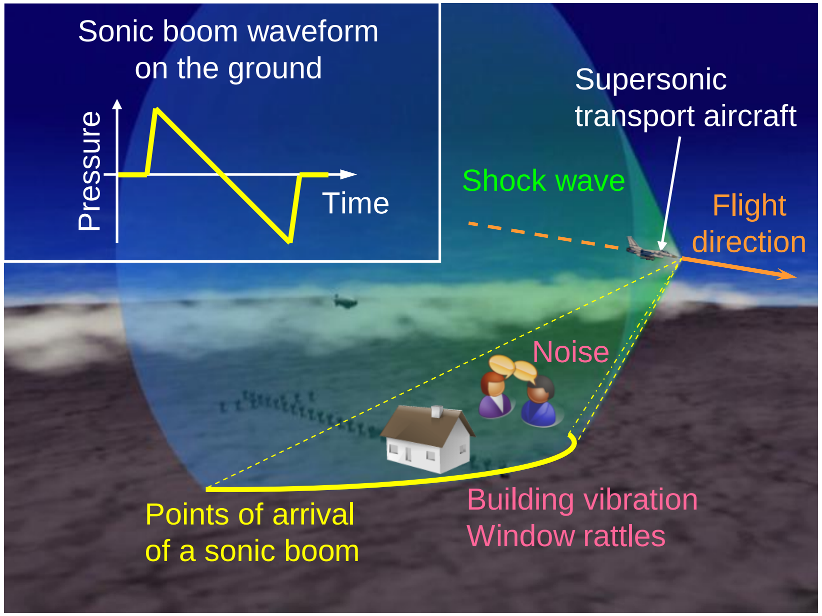


Measuring Sonic Booms

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

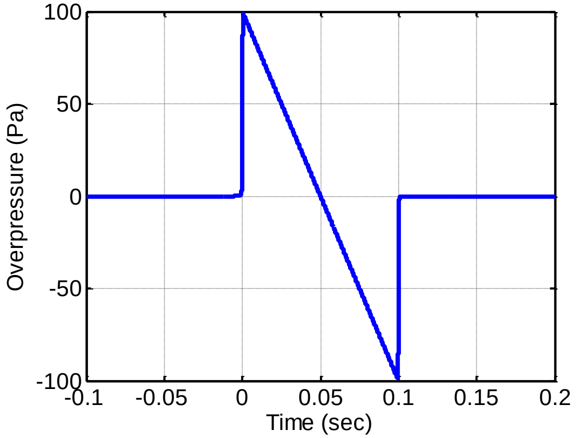
What is a Sonic Boom?

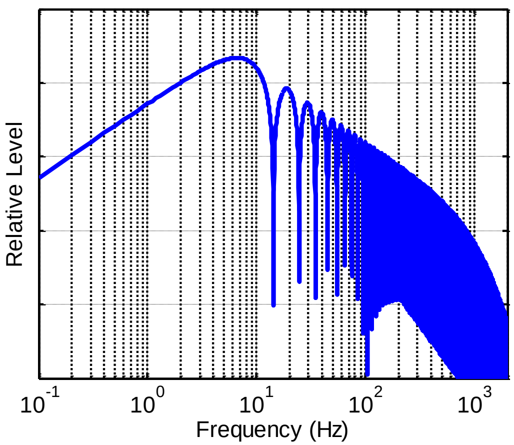
- Shock wave created from aircraft flying at a supersonic speed
- Impulsive, loud noise similar to explosion
- Supersonic flights over land currently banned due to sonic booms
- Reduction of sonic booms be necessary for next-gen. SST



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 "post-boom 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

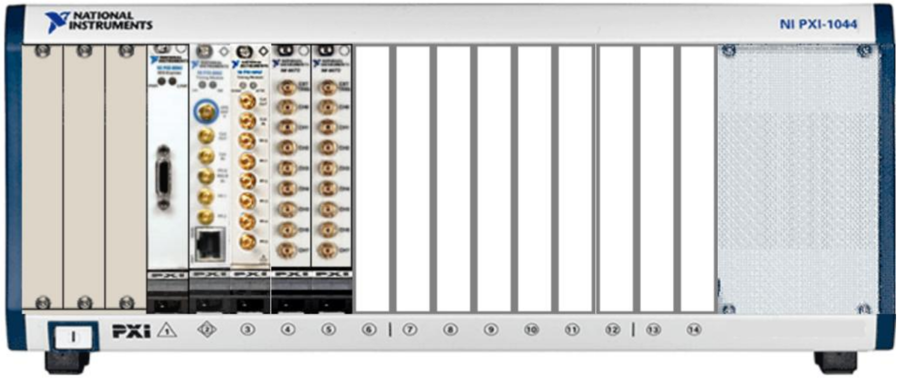
Requirement: Convenience

- 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

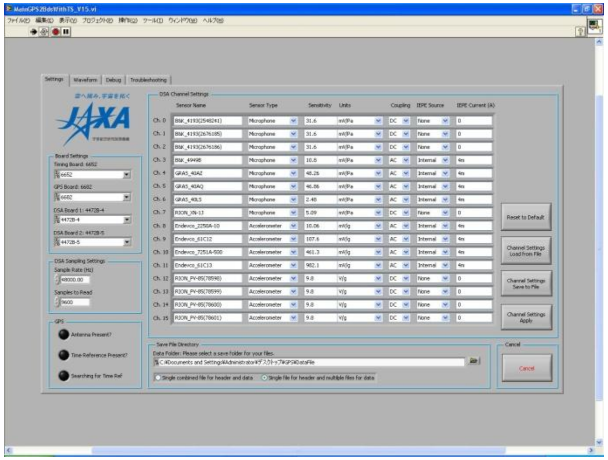
Hardware Solution: Controller & Interface

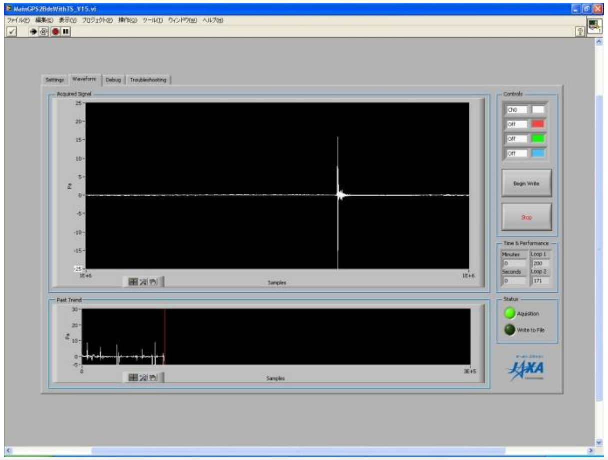
- NI 8353
  - High-speed data streaming: RAID 0 configuration
  - Large-capacity storage: 4 x 250 GB HDD

- NI PXI-PCIe8362
  - MXI 4 High-throughput: Up to 160 MB/s

Software Solution: LabVIEW

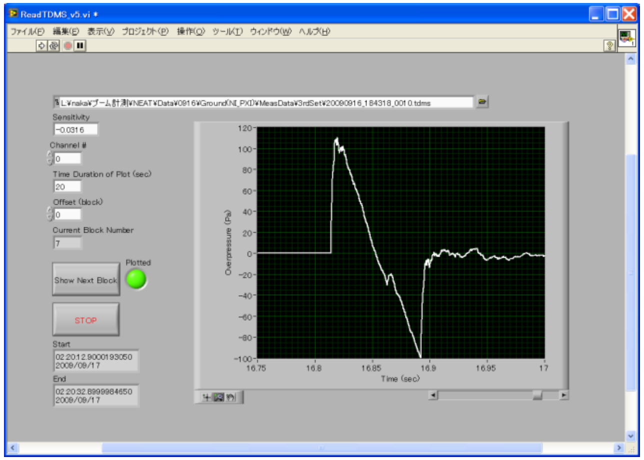
- Set-up
  - Detailed set-up for each channel
  - Transducer information
- Control Measurement
  - Effective binary format of TDMS suitable for multi-channel, long recording
- Real-time monitoring





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.

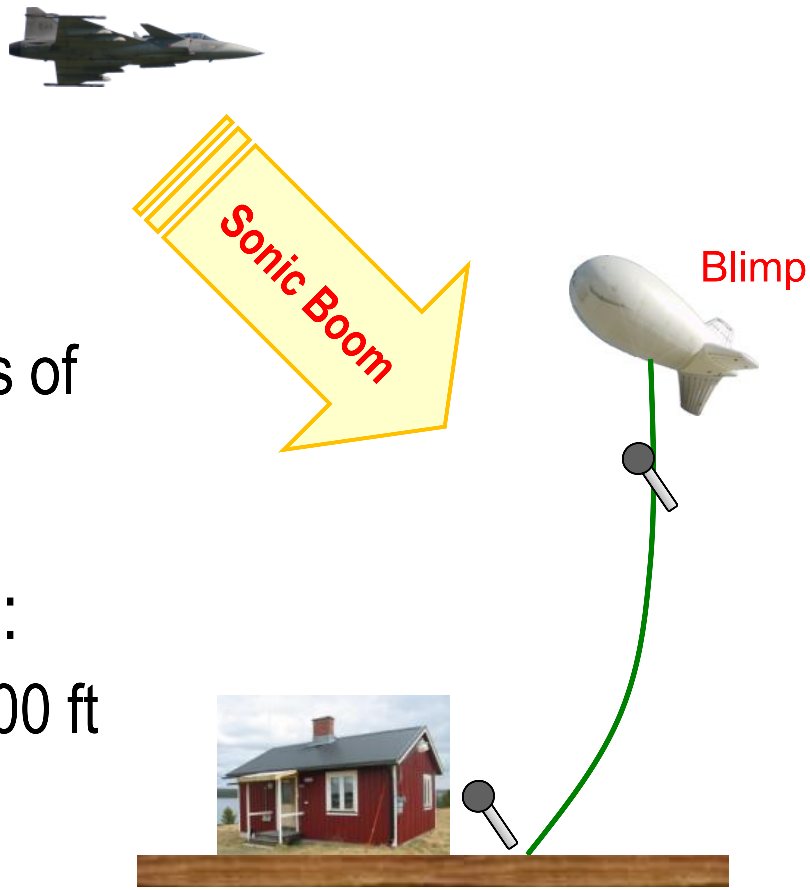


Preliminary Flight Test

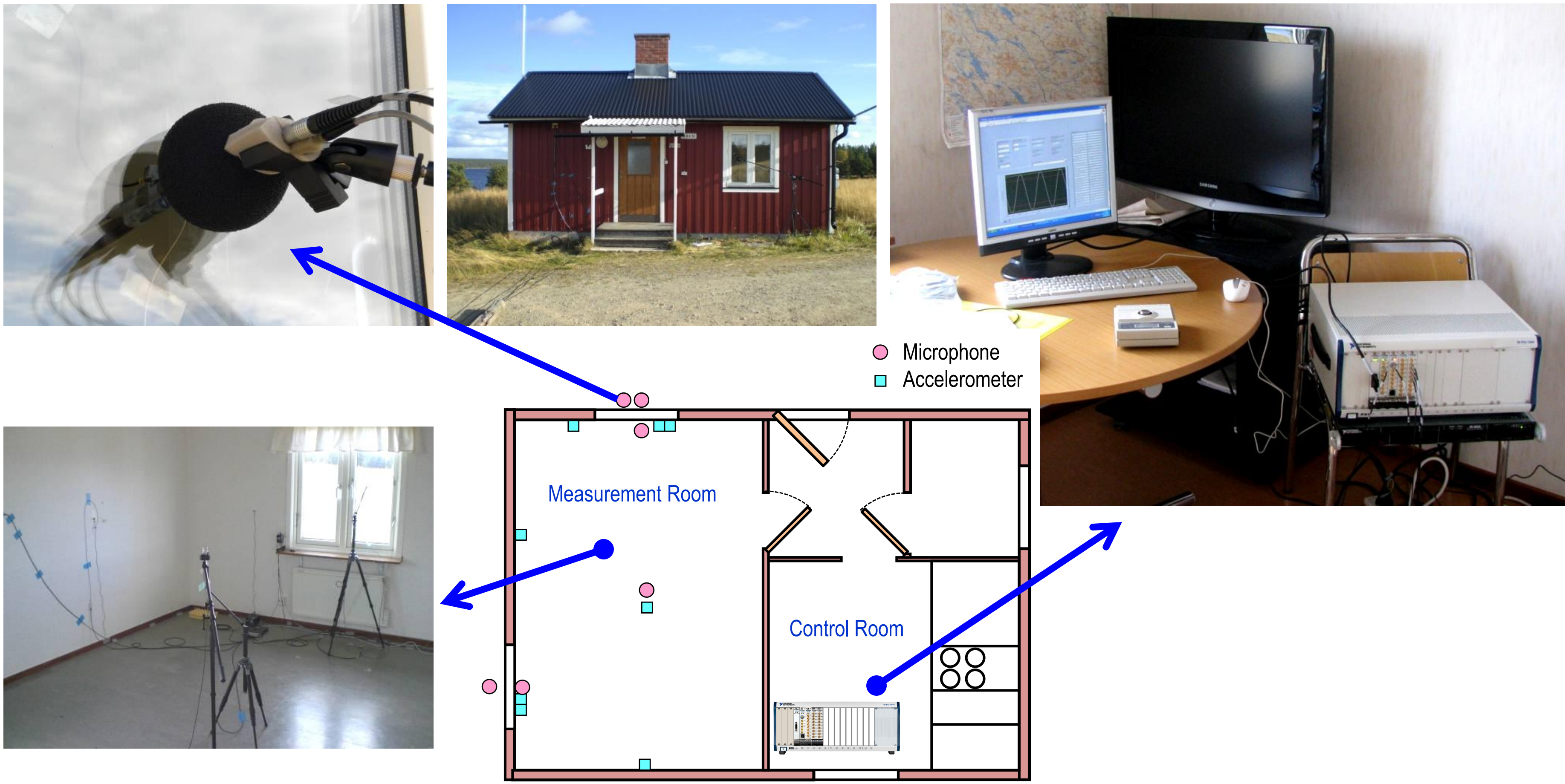
- Overview
  - Measured sonic booms of actual supersonic aircraft (i.e. not research aircraft/model)
  - September, 2009 in Sweden.
- Objectives
  - To verify preliminary sonic-boom measurement system
  - To identify appropriate transducers and set-ups
- Flights
  - 5 flyovers
  - 3 flight conditions

Flight Test: Measurement Scheme

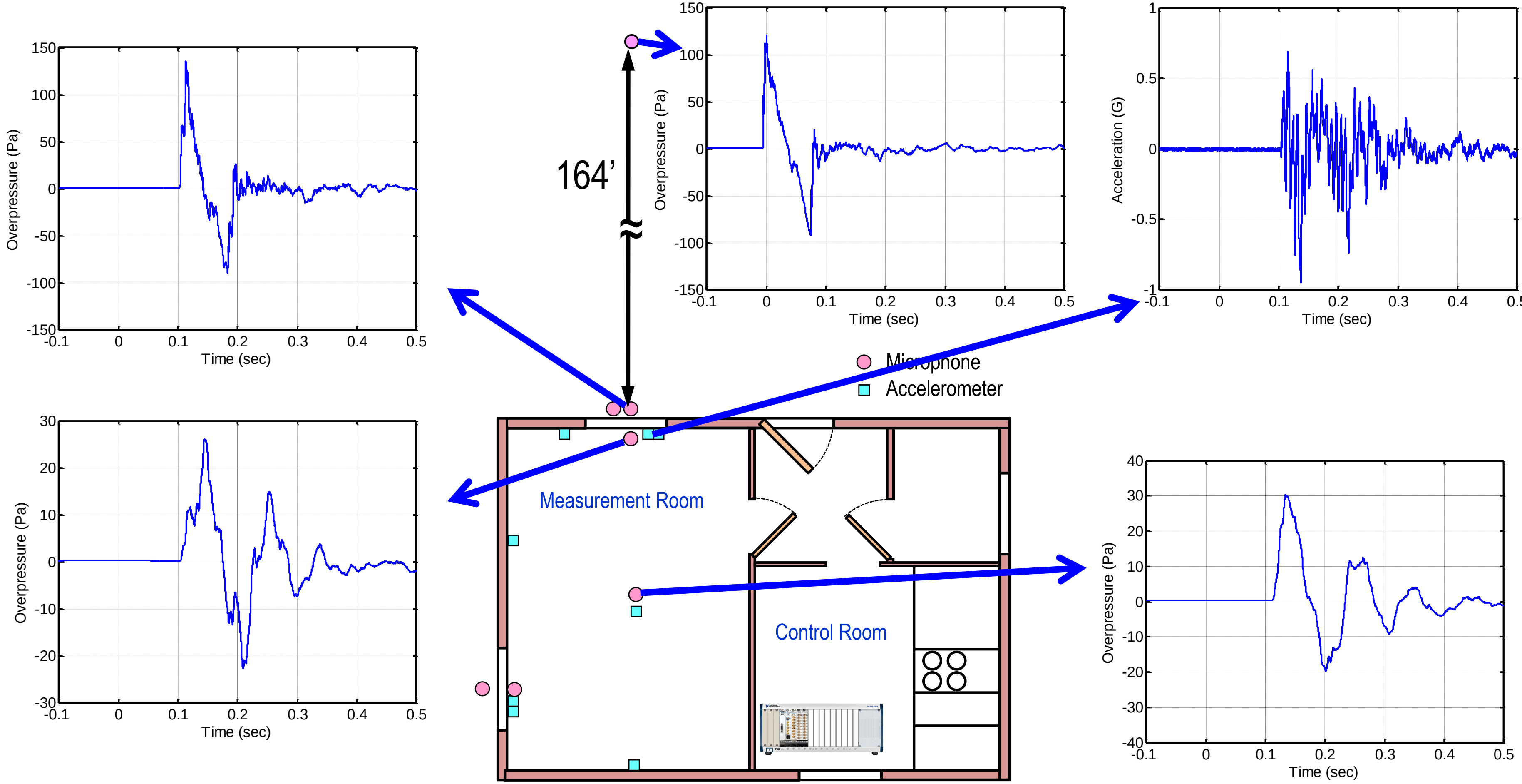
- On the ground, measured:
  - Sonic booms outdoors
  - Sonic booms indoors
  - Vibration of windows and walls of building
- Above the ground, measured:
  - Sonic booms at altitude of 3,300 ft



Flight Test: Instruments Set-Up



Flight Test: Measured Data



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

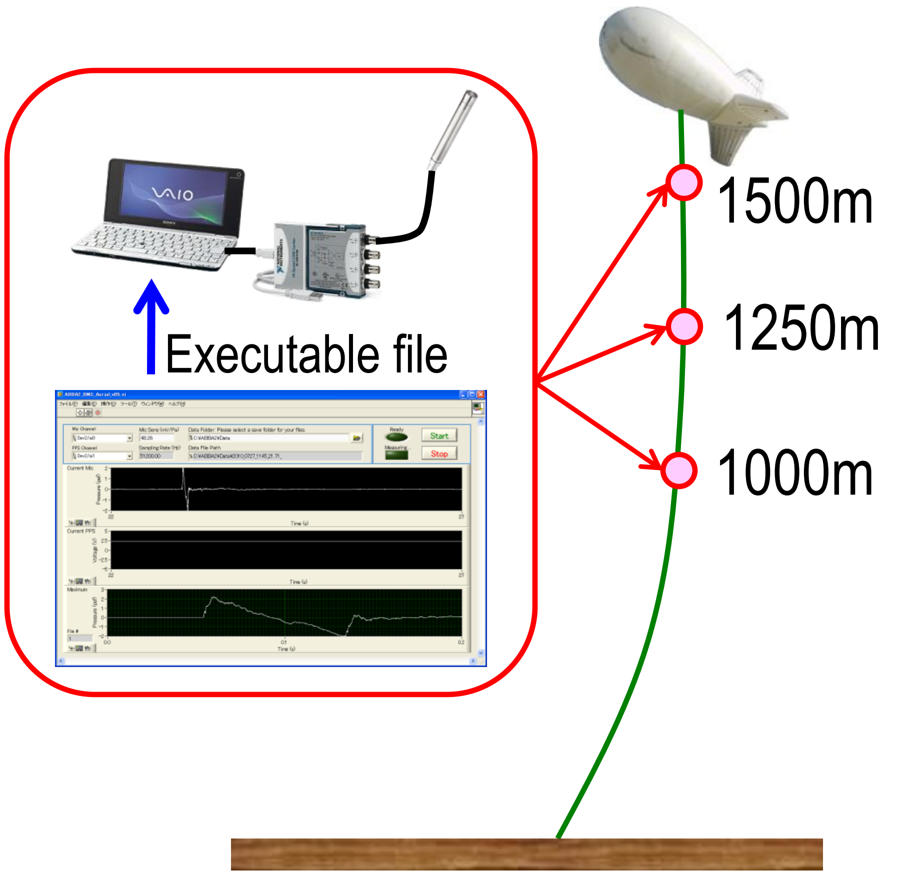
- 2nd preliminary flight test (September 2010)
- D-SEND #1 (Spring 2011)
- D-SEND #2 (Summer 2013)

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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