Acoustics Splinter

POIWG
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Christopher S. Allen, JSC Acoustics Office Manager, ISS Acoustics System Manager, Chair ISS AWG
christopher.s.allen@nasa.gov

Holly Smith-Dalenberg, ISS Acoustics System Manager Deputy, ISS Payload Acoustics Lead
holly.a.smith@nasa.gov

Outline

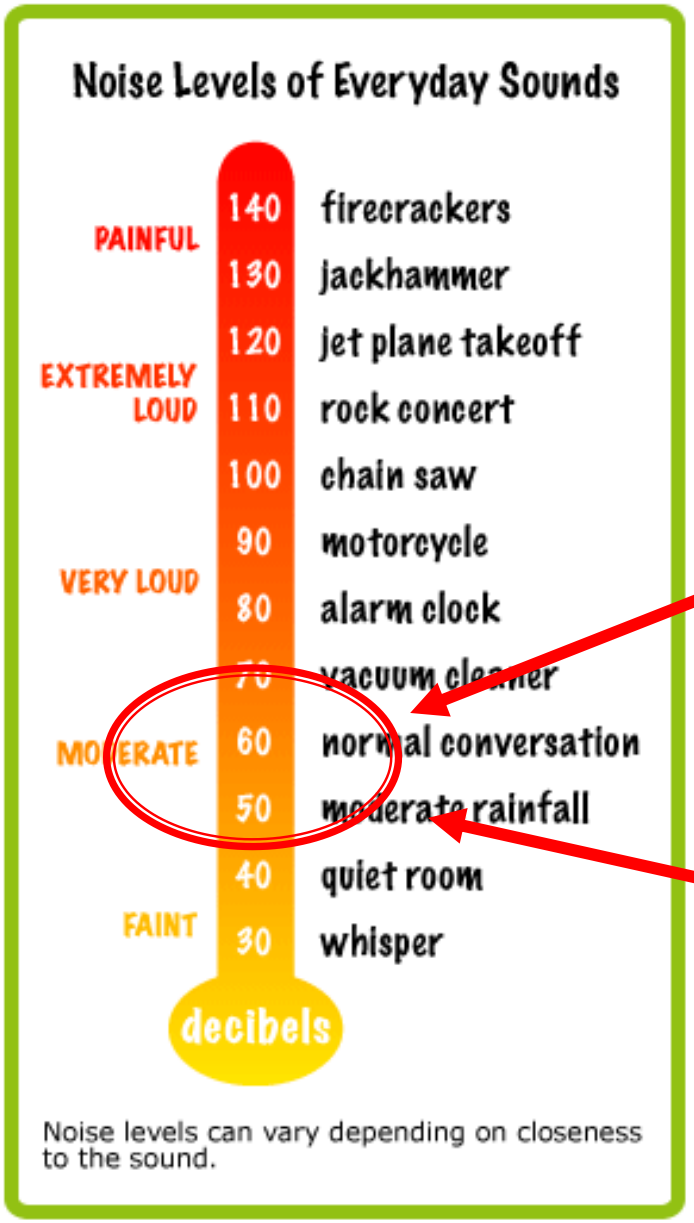
- Background
- Offices / Groups / Teams
- Payload Acoustic Data Flow
- Payload Noise Control
- JSC Acoustics and Noise Control Lab (ANCL) Services
- ISS On-orbit Acoustic Monitoring

Goals of Acoustics Team

Control NOISE impacts on Crew Health and Mission Safety

Consider effects of spaceflight sound levels on:	
*Risks for developing hearing loss *(permanent, temporary)*	*dBA, Leq_{24}*
*Interference with speech intelligibility and communications due to noise	*NC curves SIL(4) in dB*
*Possible reduction in Alarm Audibility due to noise	*SNR*
*Possible disruptions of crew sleep due to noise	*Intermittent Impulse*
*Possible interference with crew task performance due to noise	*NC curves Tonal*

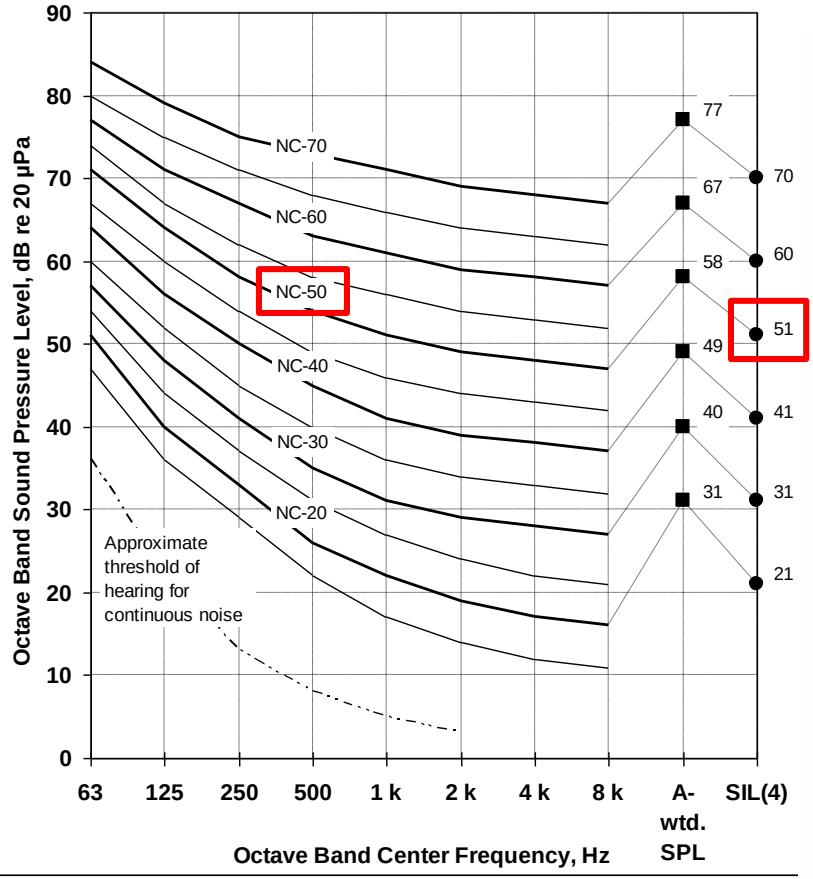
Noise Thermometer : A-weighted Sound Levels



Typical ISS Environment In dBA

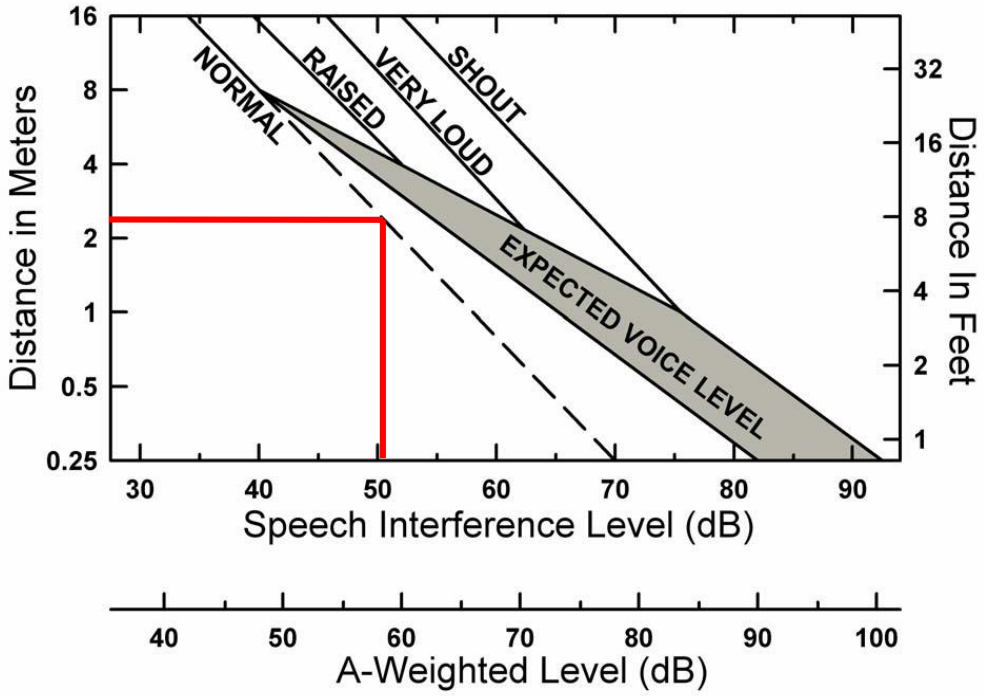
Relationship Between Metrics

Habitability (NC Curves) and Communication (SIL)



Distance for Just-reliable Communications

SIL= Ave. of
500Hz + 1 KHz+ 2 KHz + 4 KHz dB readings



Acoustics Office

- The Acoustics Office is responsible for maintaining safe, healthy and habitable vehicle acoustic environments, in which astronaut crews can live, communicate, and work.

- The Acoustic Office manages the Acoustics and Noise Control Laboratory (ANCL), which is used to:
  - Perform hardware acoustic verification testing (also use other facilities)
  - Develop noise controls
  - Develop flight-certified acoustic materials
  - Acoustic demonstrations
  - Validate acoustic modeling techniques

- Acoustic Office personnel support all Programs
  - Noise control engineers (4)
  - Acoustic modeling specialists (2)
  - Technician/Lab Manager

Acoustics Working Group (AWG)

- The AWG is a JSC advisory group, chaired by the Acoustics Office Lead, and supported by the following organizations
  - Acoustics Office
  - Audiology and Hearing Conservation
  - Boeing Environments
  - Boeing SE&I
  - Astronaut Office
  - Safety
  - ISS Program (OM)
  - Ad-hoc members as-needed
- The AWG reviews significant acoustic issues, waivers, exceptions, Safety Non-Compliance Reports (NCRs).
- The AWG builds consensus in the acoustics community and advises the ISS Program

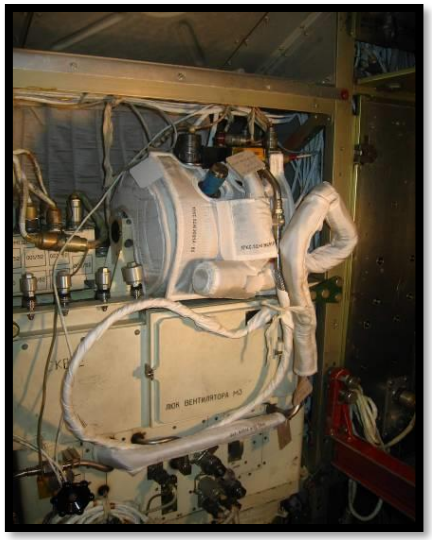
MMOP Acoustics Sub-working Group

- The Multilateral Medical Operations Panel (MMOP) Acoustics Sub-working Group coordinates input from the international partners regarding acoustics issues for the maintenance of astronaut's health and optimal performance

- Provides guidance regarding acoustics and hearing issues
  - Includes both engineering and medical disciplines
  - Provides updates on ISS acoustic environments and risks
  - Clarifies ISS acoustics priorities
  - Discusses issues, shares plans (e.g. acoustical monitoring)
  - Revises Requirements (e.g. MORD) and Acoustic Flight Rules
  - Develops organization of subgroup, as well as processes for decision-making and problem resolution

Types of Noise and their Primary Sources

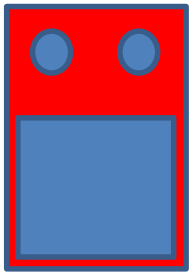
- **Continuous noise**, caused by ventilation and thermal control systems
  - Primarily fans and pumps, e.g. ECLSS, Cold Storage, many Payloads
  - Reverberation environment important
- **Intermittent noise**, caused by intermittently operating or variable setting equipment
  - e.g. CDRA, Vacuum Cleaner, WHC, T2, MPEV, many Payloads
- **Impulse noise**, not many significant sources



Sub-Rack Payload Verification Test

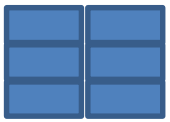
Vehicle plus Payload Noise Predictions for SORR/CoFR

Module Verification Test Data



Stand-alone Rack Verification Test Data

Non-Rack Verification Test Data



Sub-rack Verification Test Data

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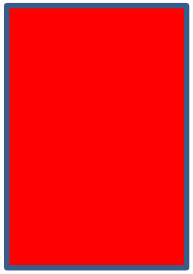

Rack facility Verification Test Data

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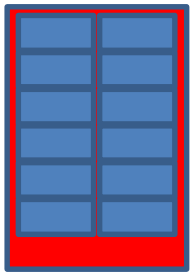
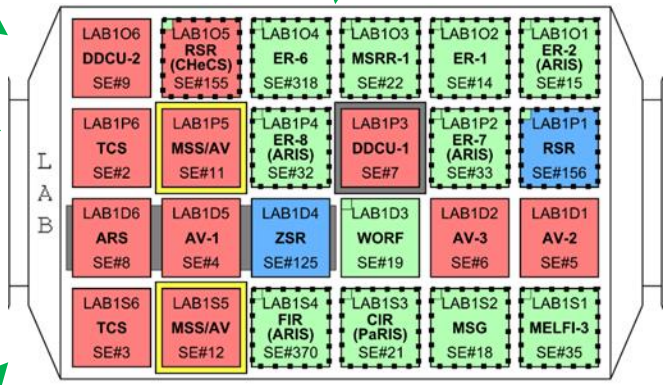
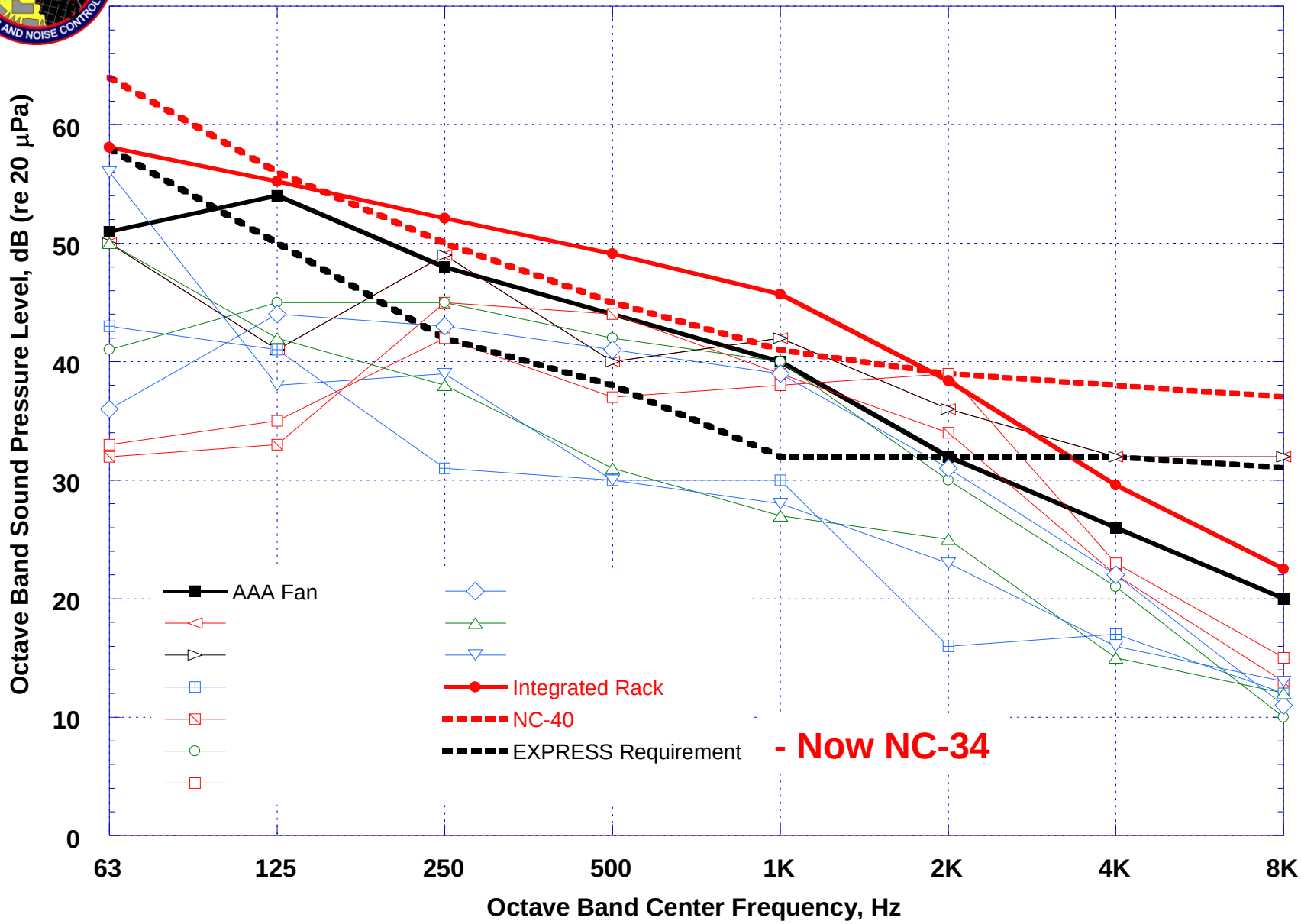


Integrated Rack Predicted Data



Acoustic model used to predict integrated noise environment and compare with requirement

Rack Verification from Model



System-level (Vehicle + Payload) Analysis

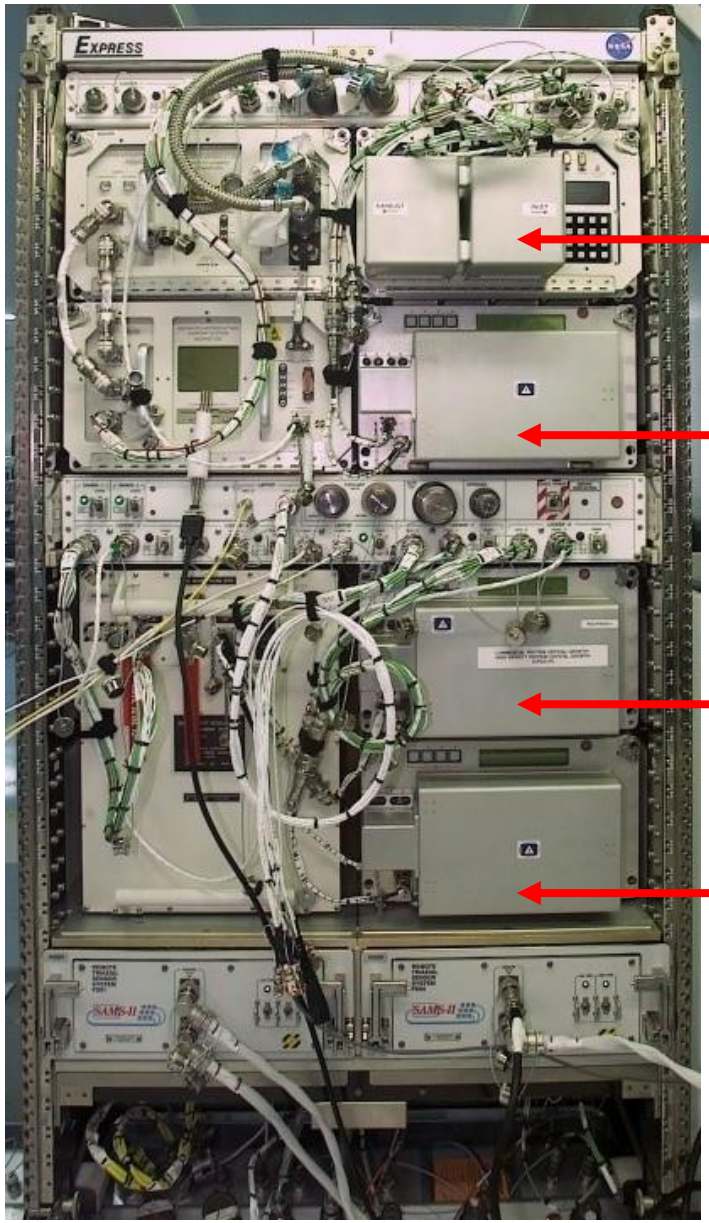
TABLE 2.1.2-1 INTEGRATED REQUIREMENT COMPARISON

		63	125	250	500	1000	2000	4000	8000
Increment 55 [SpX-14 Docked]	Aft, Cent, Fwd Average	62.1	62.8	59.1	55.9	52.8	51.6	48.0	41.5
Increment 55 [Through Increment]	Aft, Cent, Fwd Average	59.2	62.9	59.1	55.1	51.4	51.2	47.5	41.3
Requirement	NC~52	73	66	60	56	53	51	50	49

**Data within measurement and analytical tollerace of + 1.0dB. This exceedance of less than 1.0 dB at one octave band frequency has been approved by the NASA JSC Acoustics Working Group.*

- Continuous Noise Exceptions
  - Very difficult to approve if the payload is close to or exceeds the Vehicle + Payload NC~52 requirement
  - Would impact operations of other payloads to meet NC~52
  - Payload noise combines with other payload and vehicle noise into a composite noise level that need to meet NC~52
  - Payloads will need to show how they have performed noise mitigation, performed early testing, etc.
  - Payload developers should determine early-on if they are at risk of exceeding the acoustic requirements
- Intermittent Noise Exceptions depend on operational duration, length of use, crew-operations, etc.

Mufflers to Reduce Noise of "Front-breathers"



ADVASC

MAMS

SAMS-I

CGBA

PCG-STES

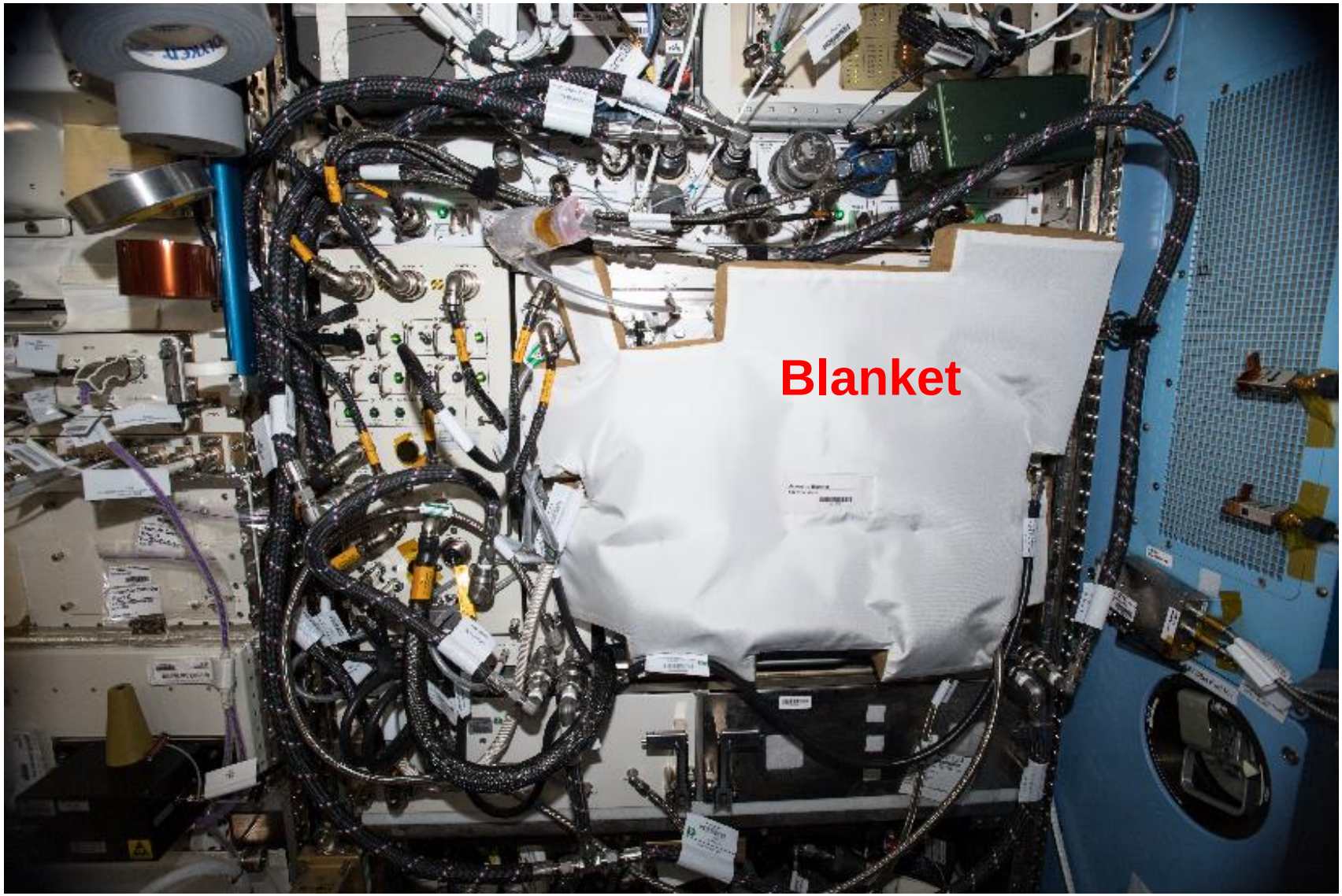
CPCG

PCG-STES

SAMS-II

Mufflers

Acoustic Blanket Example - Plant Habitat



Areas of Development and How Connected

Paths

Noise Sources

Receiver

Areas of Development and How Connected

Paths

Noise Sources

Acoustic Modeling
Statistical Energy Analysis
FEM and BEM

Receiver

Areas of Development and How Connected

Noise Sources

Quiet Fan Design
Quiet Fan Selection
Fan Active Noise Control
Sound Power Measurement

Paths

Acoustic Materials
Development

System Level Noise Controls
Blocking
Sealing
Absorbing

Component Level Noise Controls
Mufflers
Enclosures
Vibration Isolators
Treated Air Ducts

Acoustic Modeling
Statistical Energy Analysis
FEM and BEM

Receiver

Testing and Verification

Acoustic Monitoring
Noise Survey
Noise Exposure
On-orbit Hearing Assessment

Mission Operations
Flight Rules
Operational Constraints
Anomaly Resolution

Hearing Protection

Advanced Acoustic Monitoring
Automated
Remote
Real-Time

Controlling Acoustical Noise

- **Requirements and verification requirements**
  - Allocated requirement depending on system level
- **Hardware design and reviews (SRR, PDR, CDR)**
- **Acoustic Noise Control Plan (ANCP)**
  - Choose quietest sources
  - Acoustic analysis
  - Sub-allocate to components
  - Noise control design
  - Early acoustic testing
  - Component/noise control testing
  - Schedule
  - Recovery
- **Verification by test**
- **System-level analysis**
- **Remedial actions and noise control**
- **Certification of Flight Readiness (CoFR)**
- **On-orbit acoustical monitoring**

Comprehensive Acoustic Emissions Testing and Consulting Services

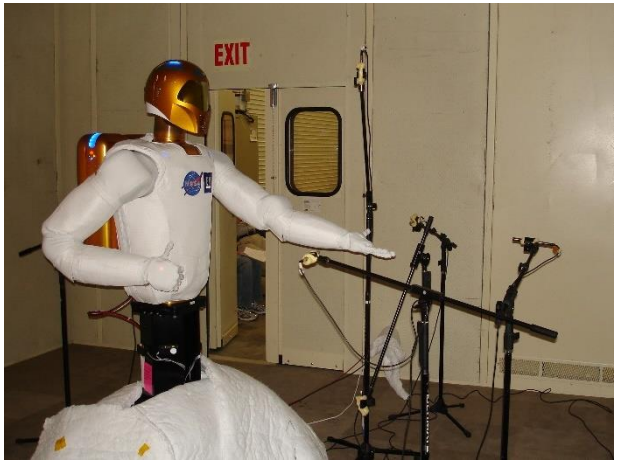
The **Acoustics and Noise Control Laboratory** (ANCL) is part of the JSC Acoustics Office. The Acoustic Office is responsible for ensuring safe, healthy and habitable vehicle acoustic environments, in which astronaut crews can live, communicate, and work. This means ensuring that space vehicle environments are not too noisy, do not have irritating audible sounds (except when trying to get the crew's attention), and do not have startling bursts of acoustic energy.

ANCL Capabilities

The ANCL has funding to provide the following services to ISS hardware projects at ***no cost***:

- Acoustic Requirement Guidance
- Preliminary Acoustic Assessments
- Acoustic Certification/Verification Testing
- Quiet Fan Selection Tool and Fan Selection Guidance
- Acoustic Material Testing and Selection Guidance
- Acoustic Modeling with VAOne

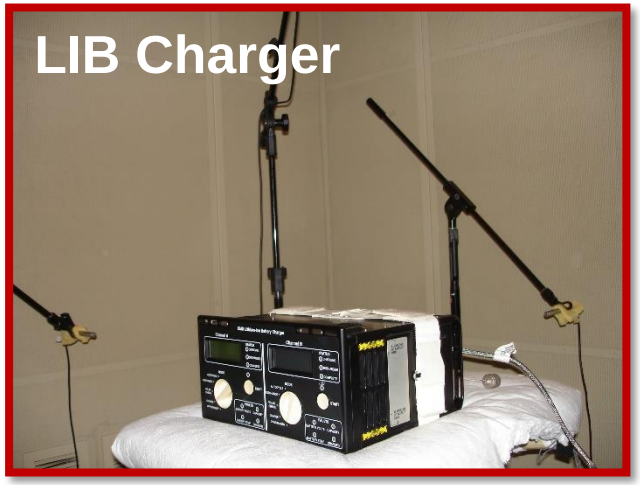
Work that is out-of-scope from nominal acoustics work may require funding from the project. MPCV/Orion and Commercial Crew projects should contact the ANCL to determine if there is funding to support the requested work.



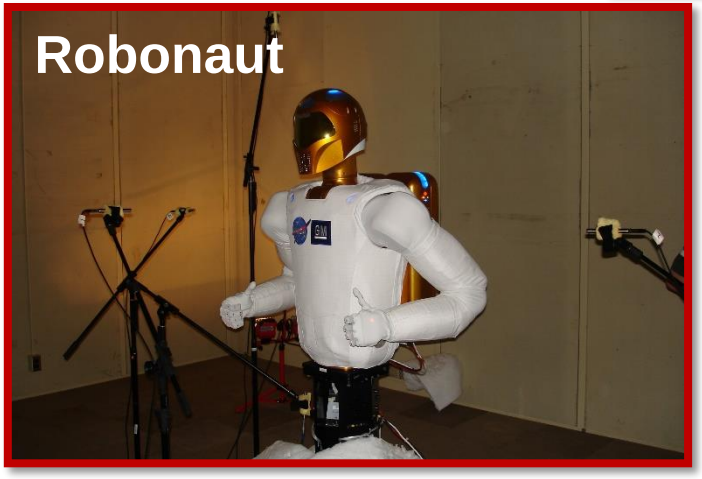
Acoustic Testing in the ANCL

- ANCL is located in Building 241, Room 1000E/F
  - Anechoic chamber
  - Acoustic test chamber
  - Orion mock-up
  - US Lab mock-up
  - Materials testing lab
- Acoustic measurement capabilities include:
  - Hardware certification and verification
  - Reverberation time
  - Sound intensity and sound power
  - Materials testing for acoustic properties
  - Transmission loss and insertion loss
  - Demonstrations and simulations
  - Intelligibility Testing

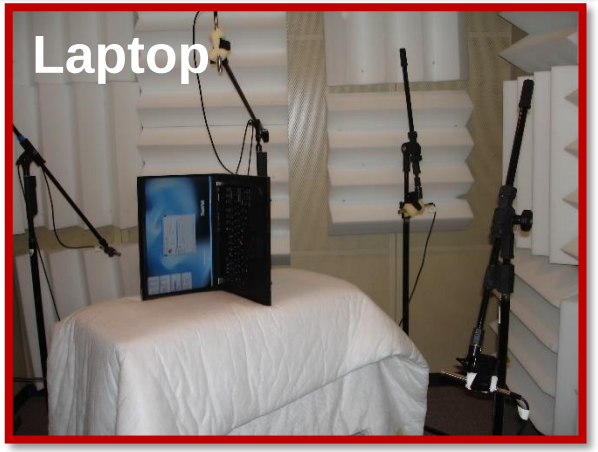

GC-DMS


LIB Charger

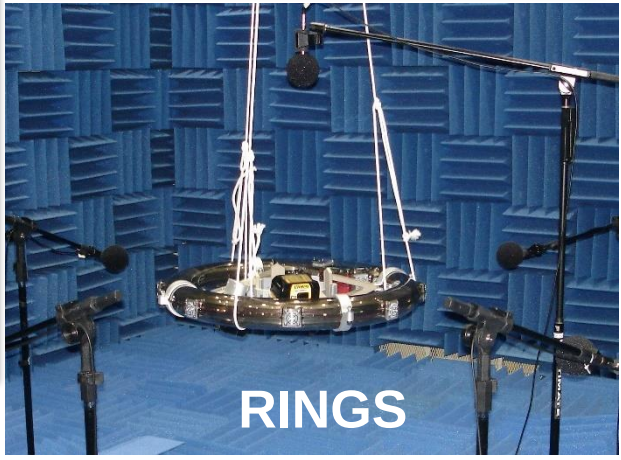

MELFI


Robonaut

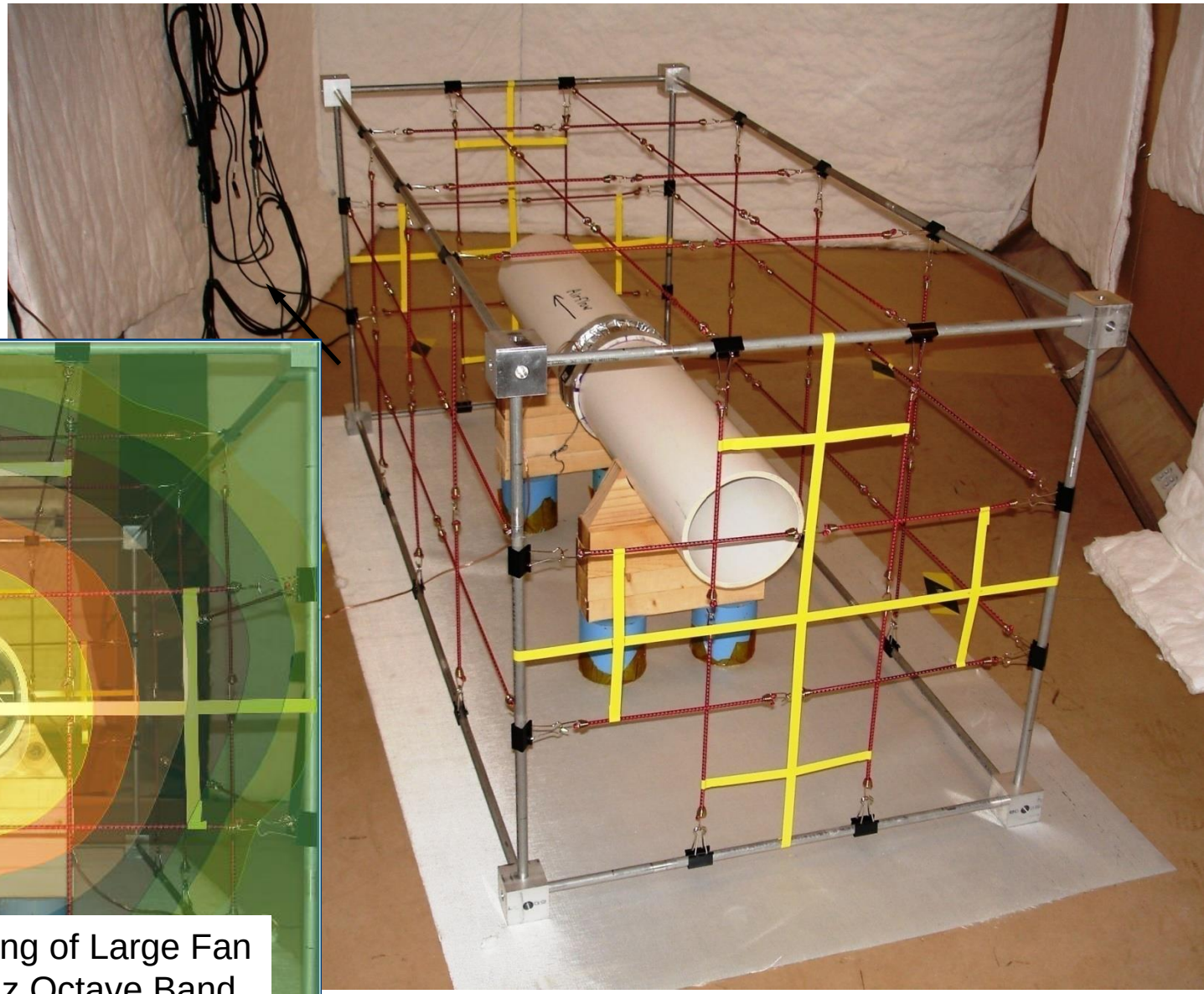

Crew Quarter

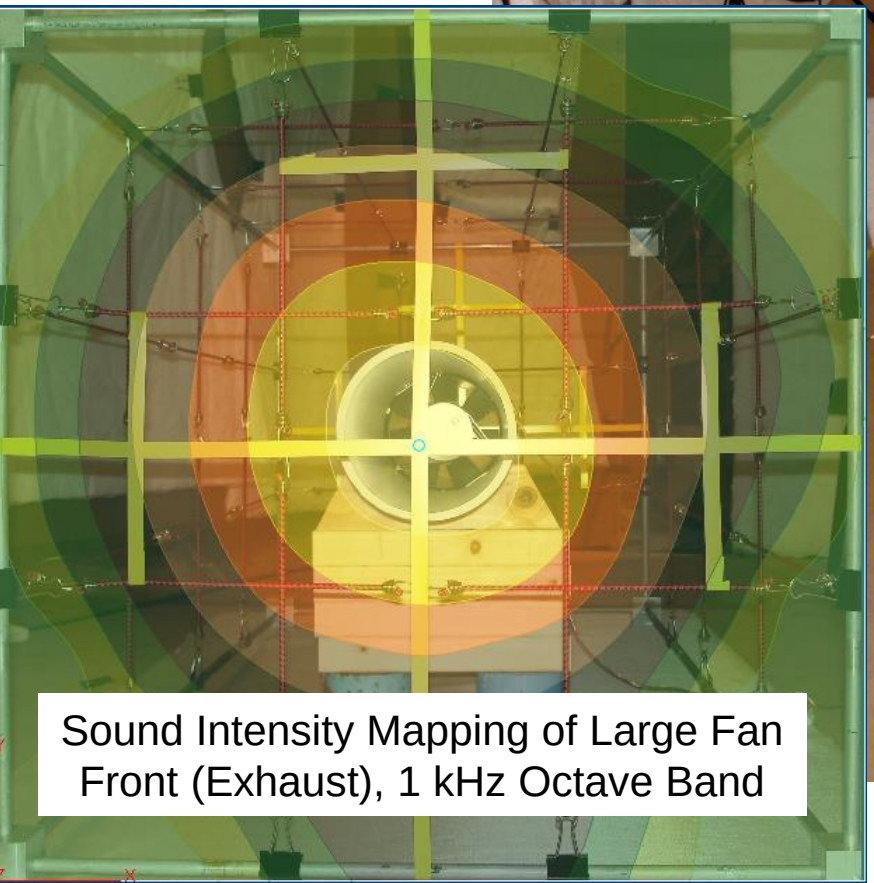

Laptop


TOCA


RINGS

Sound Intensity Measurement





Sound Intensity Mapping of Large Fan Front (Exhaust), 1 kHz Octave Band

Acoustic Material Selection for Hardware

Acoustic material testing capabilities:

- Normal-incidence impedance tube
- T-60 reverberation
- Normal-incidence transmission loss tube
- Large sample transmission loss apparatus

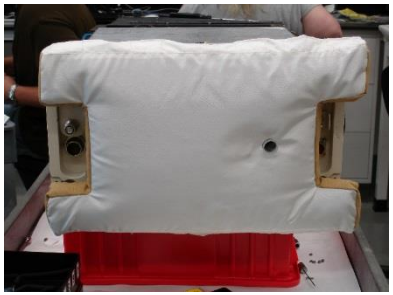
Three types of acoustic materials available:

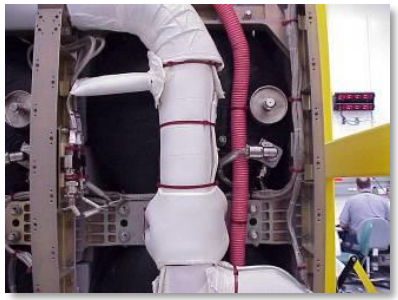
- Absorption (e.g. 3M™ Thinsulate™, DuPont Kevlar®, AcousticFab Inc. Acousti-Flo®)
- Isolation (e.g. Rogers Corporation BISCO® HT-200)
- Vibration isolation (e.g. Saint-Gobain Norseal®, BISCO® HT-800)

Examples of acoustic material usage:

- Acoustic blankets surrounding noisy hardware
- Abatement inside noisy airflow ducts
- Isolation of vibrating hardware including pumps and fans
- Mufflers located at inlet/exhaust ports of noisy hardware
- Covers on exterior duct/pipe walls

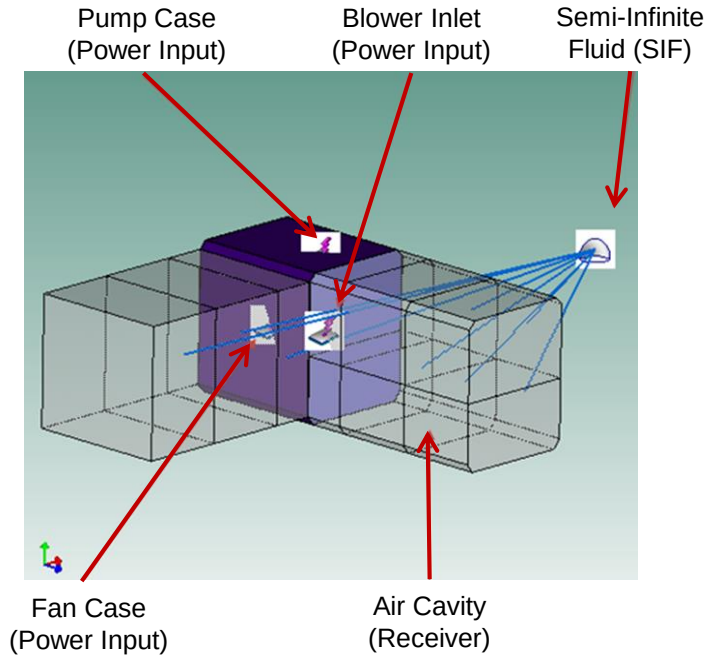
Examples of Acoustic Material Hardware Applications

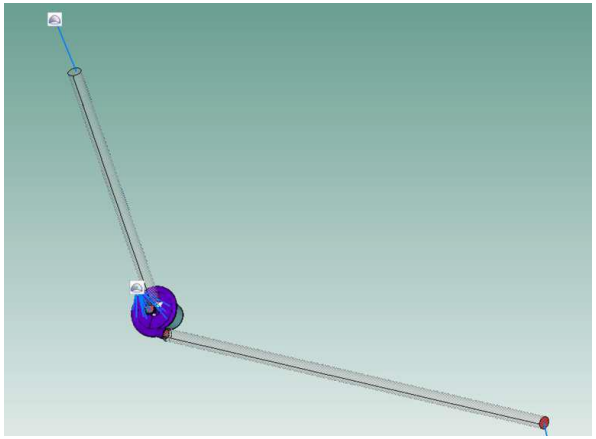


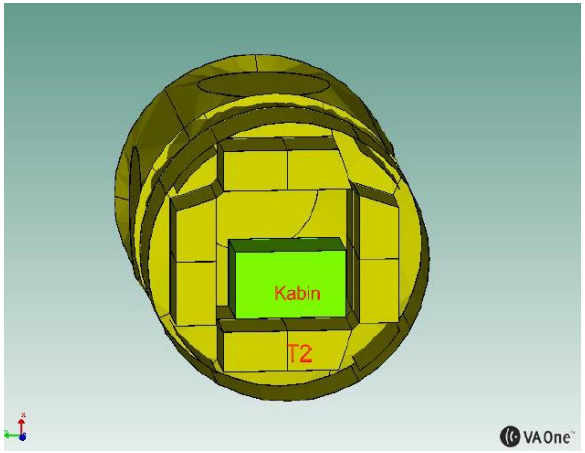


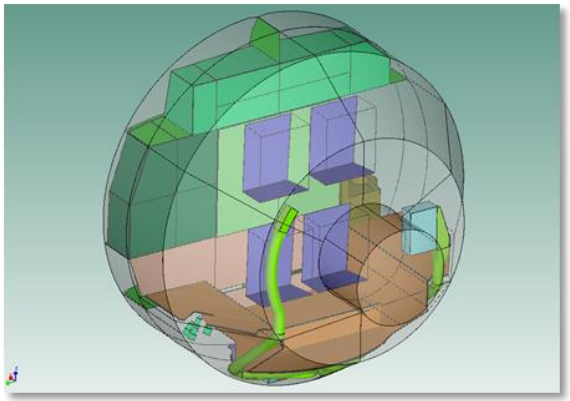
Acoustic Modeling with VAOne

- ANCL uses VA One software from ESI Group to model:
  - Acoustic environments of the ISS, Orion, and commercial vehicles
  - Impact of integrated hardware
  - Impact of materials
  - Insertion loss and transmission loss
  - Reverberation
- Computational analysis methods include:
  - Statistical Energy Analysis (SEA)
  - Finite Element Analysis (FEA)
  - Hybrid SEA-FEA, and
  - Boundary Element Method

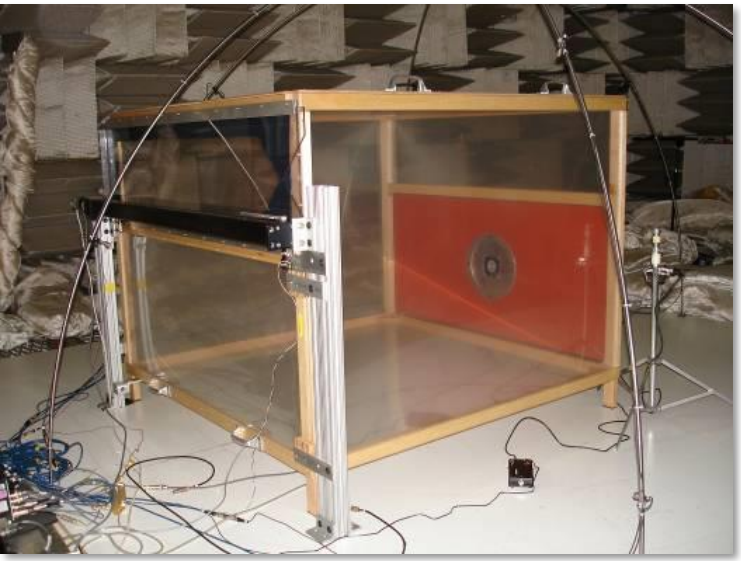








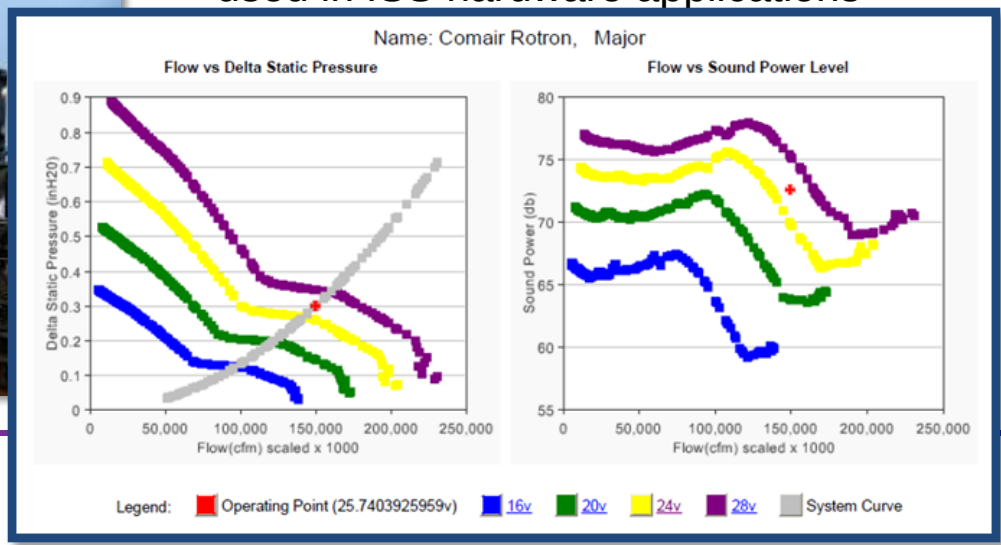
Quiet Fan Selection Tool Database



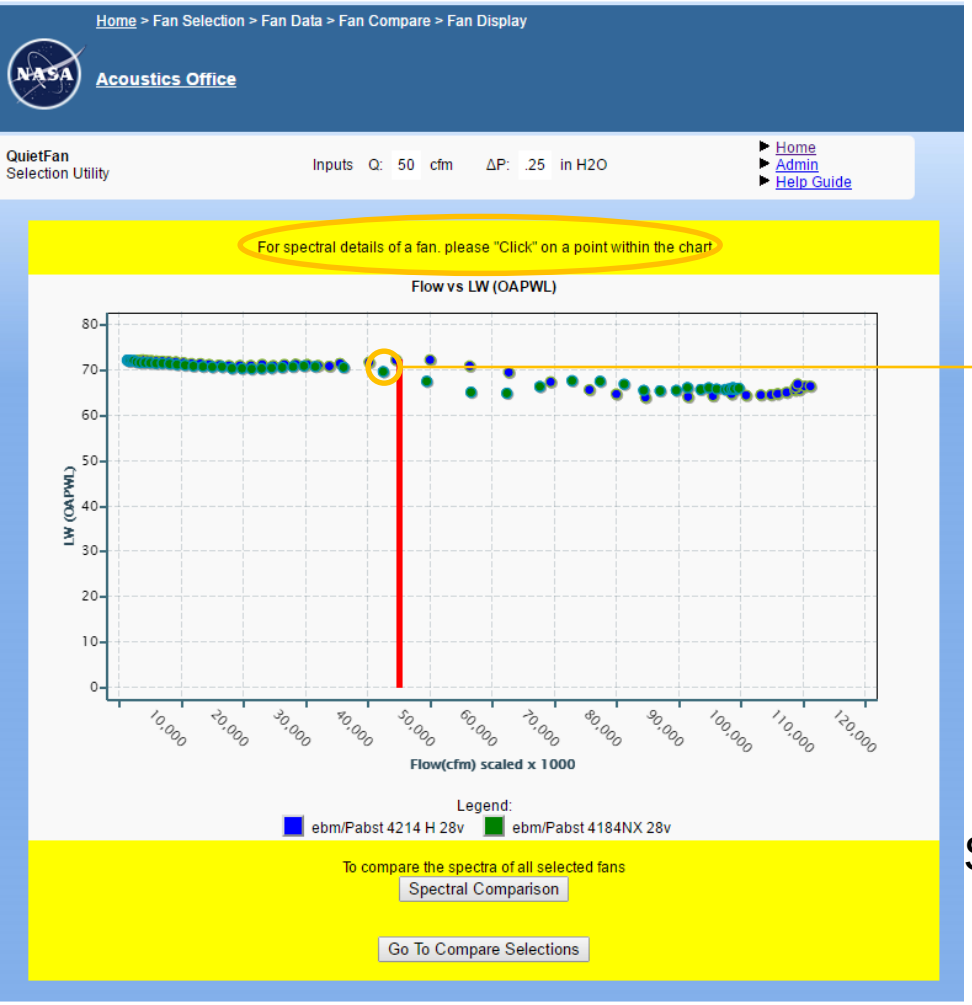
- The Quiet Fan Selection Tool Database is a collaborative effort between ARC and the JSC Acoustics Office to provide hardware developers with the ability to select the quietest, most efficient fan for their applications

- The online database currently contains ~40 fans for comparison but over 100 fans have been tested for performance and acoustics

  - The Quiet Fan Selection Tool Database ***is not*** a collection of quiet fans that have been approved for flight; however, several fans in the database have been used in ISS hardware applications



Using the Quiet Fan Selection Tool Database



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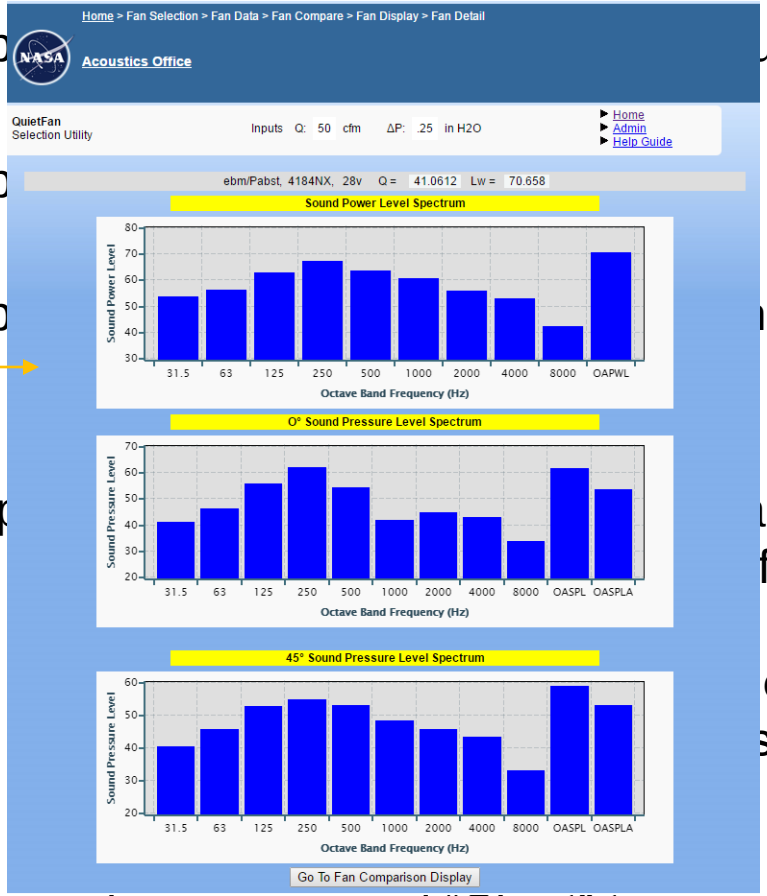


down menu and “Chart” to compare sound power levels.

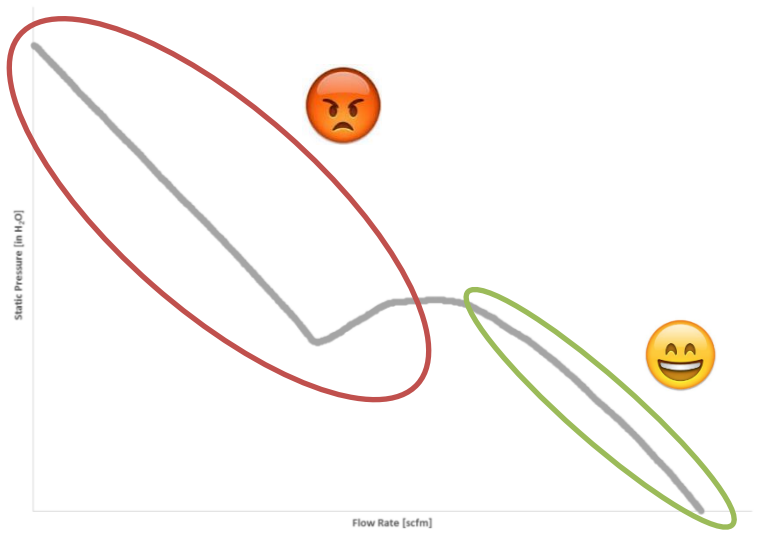
Fan Selection Guidelines for Acoustics

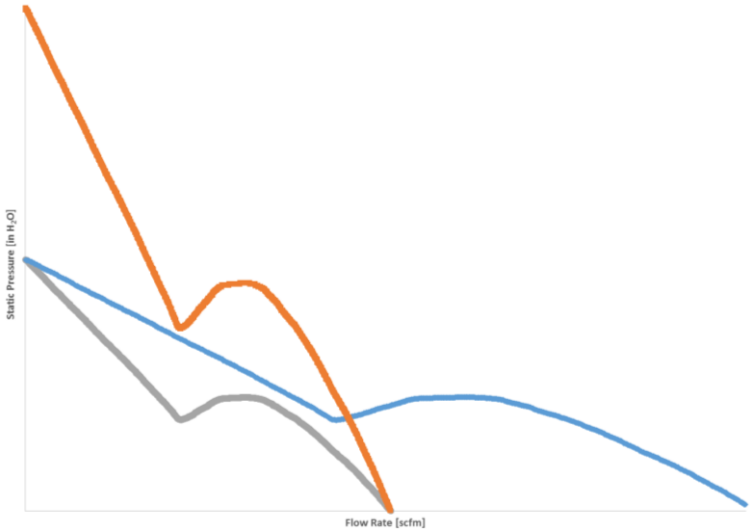
- Do not rely on the sound level reported on the fan's specification sheet to accurately represent how loud the fan will be when integrated into hardware
  - Sound levels on specification sheets are recorded with the fan operating in open air with no back pressure
  - The fan's acoustic emissions will change (usually the fan will get louder) when operating under a back pressure

- Ensure the fan's operating point is on the correct side of its fan curve
  - **Parallel** (side-by-side) fans will theoretically cause the flow rate to double
  - **Series** (one in front of the other; push-pull configuration) fans will theoretically cause the pressure to double

- Operate the fan at the lowest voltage setting and use the minimum number of fans necessary to provide sufficient cooling for system

- Contact the Acoustics Office for fan selection guidance

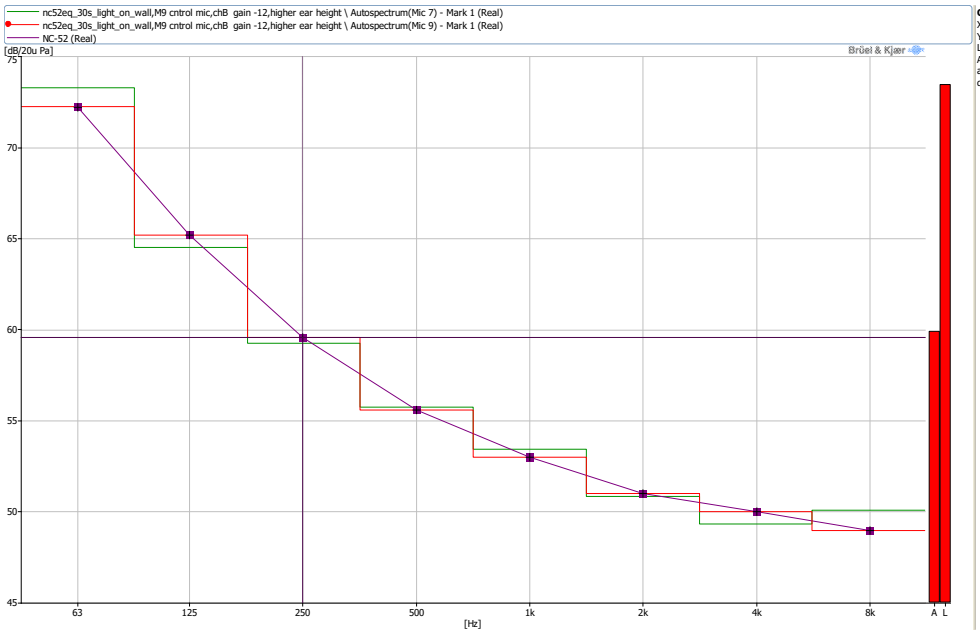




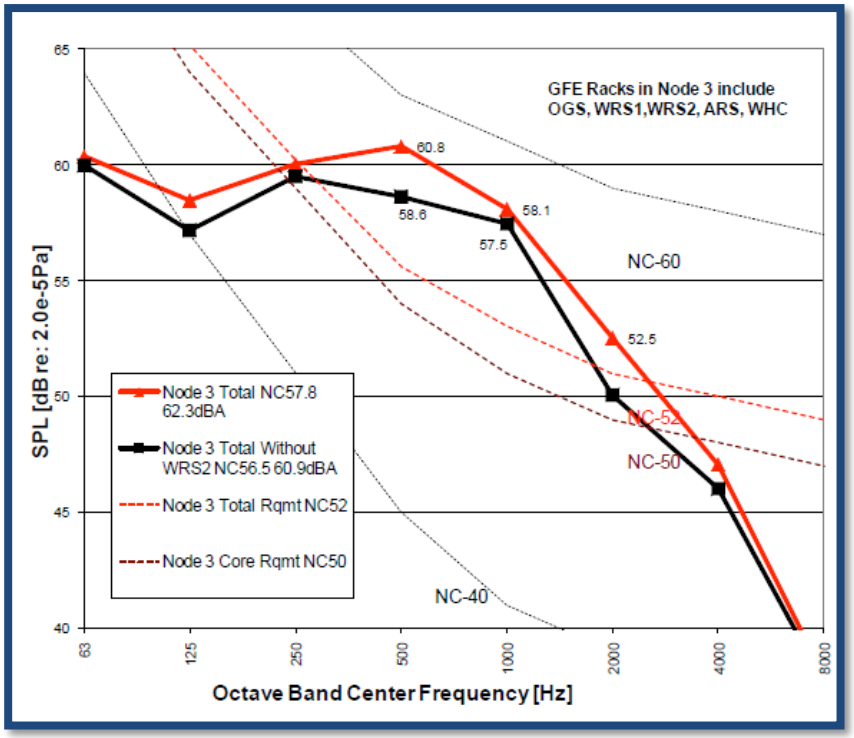
Acoustic Environment Demonstrations

Simulating various noise levels

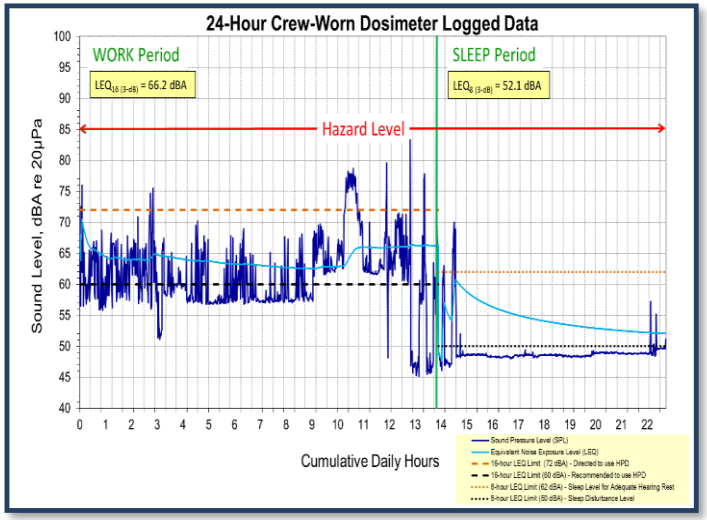
- ANCL can simulate environments experienced by the ISS crewmembers
- The environments are used as background noise for testing
  - Speech recognition
  - Crew speaker testing
- Environmental data can also be recorded and made available for others to use
- Speech interference levels

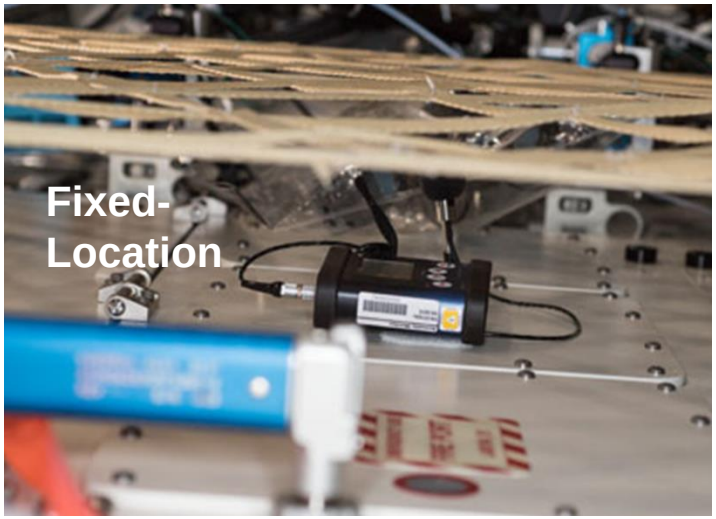


On-orbit Acoustic Monitoring



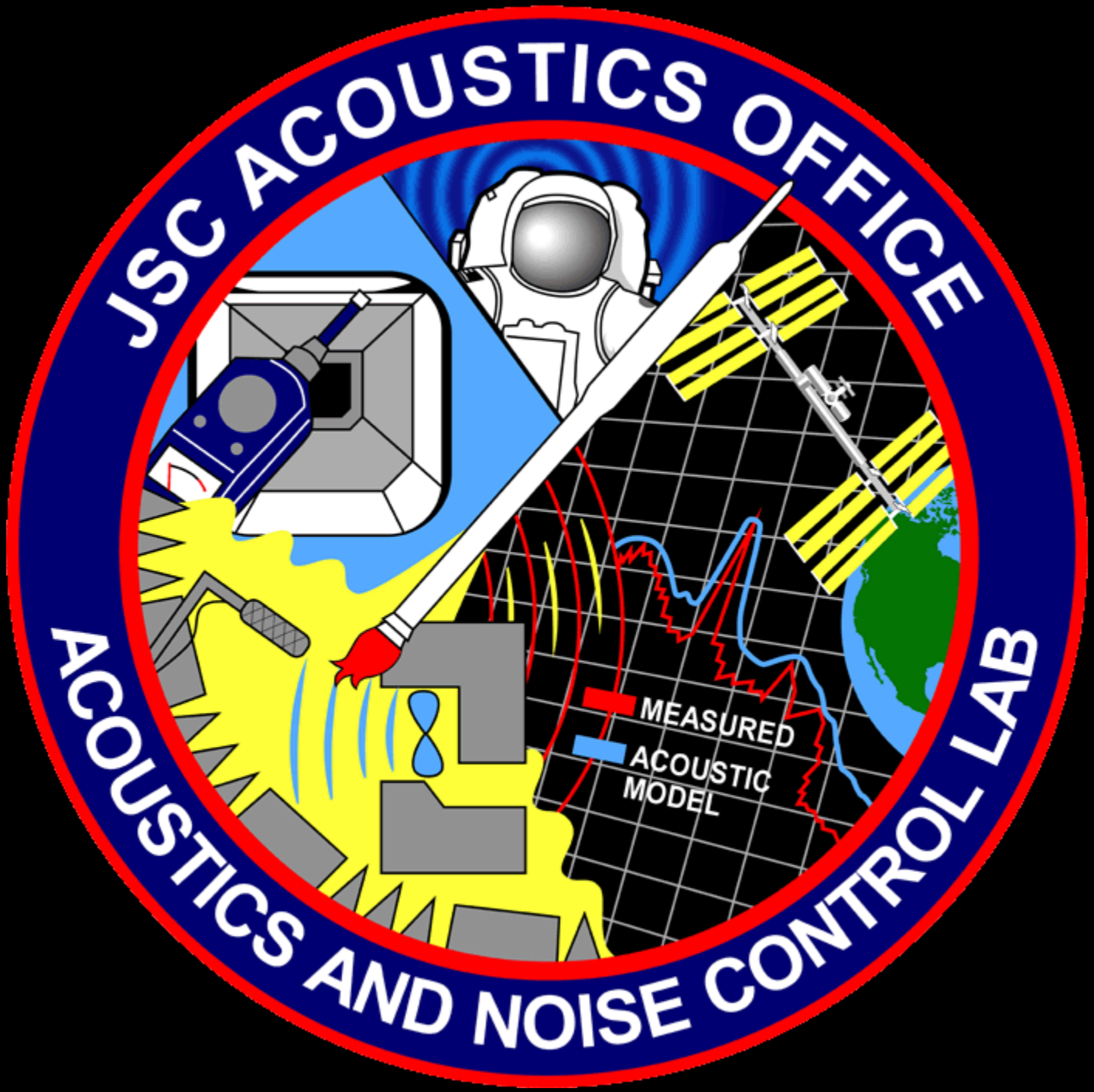
Noise surveys
Noise exposures
Audio recordings
Narrow Band
Time/Frequency
Data downlinked





Summary

- Onboard **NOISE** can interfere with speech, detection of alarms, sleep, and human performance
- Acoustics Office works to maintain/improve noise levels on ISS
- Payloads working to meet acoustic requirements is important to the whole of the ISS acoustic environment
- Noise issues/exceedances are assessed/managed by Acoustics Office, AWG, MMOP Acoustics Sub-working Group
- Please contact the Acoustics Office if you have questions or need assistance


JSC ACOUSTICS OFFICE
ACOUSTICS AND NOISE CONTROL LAB
MEASURED
ACOUSTIC
MODEL

BACKUP