



Survey of Microgravity Vibration Isolation Systems



Section XVIII: Survey of Microgravity Vibration Isolation Systems

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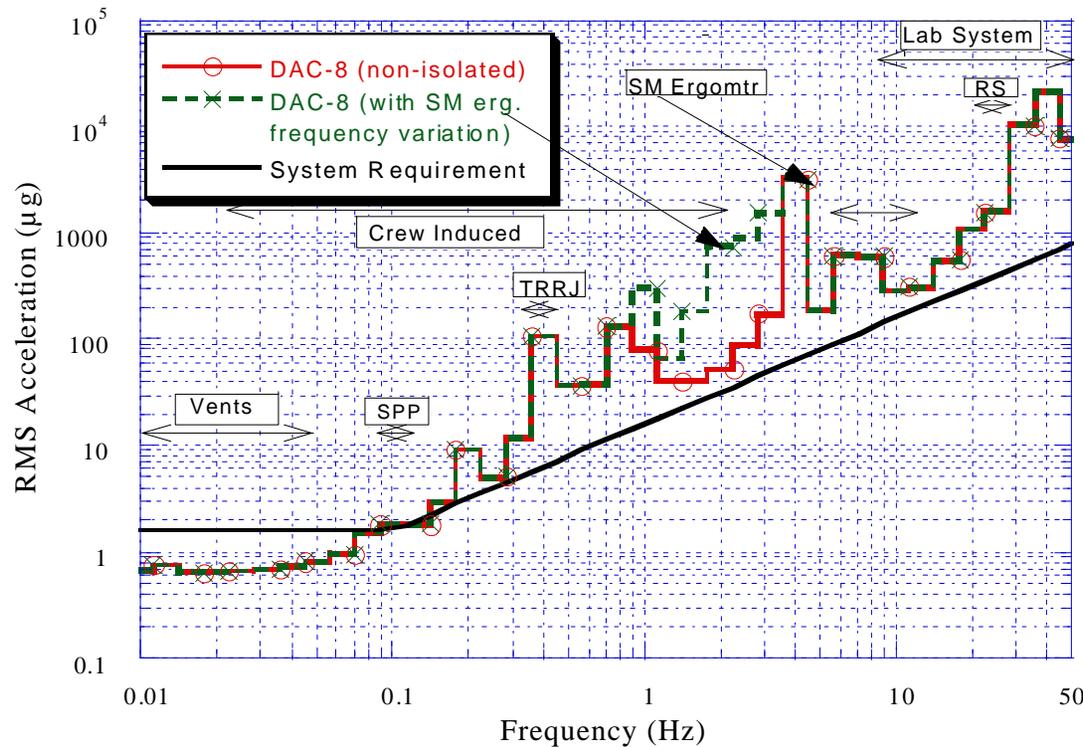
Survey of Microgravity Vibration Isolation Systems



Outline:

- **Review of Vibration Isolation Technology**
- **Survey of Flight Systems**
- **Future Trends**
- **Flight System Availability on ISS**

The ISS will provide a world-class research facility for microgravity science

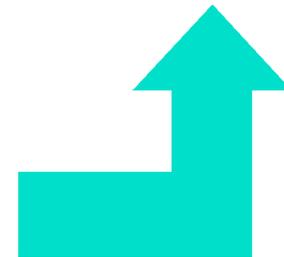
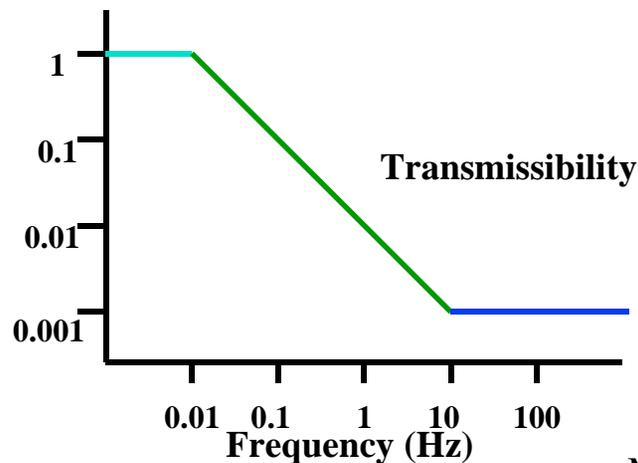
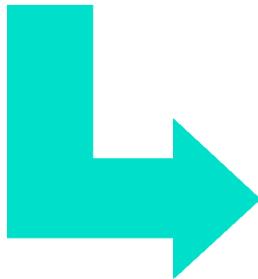
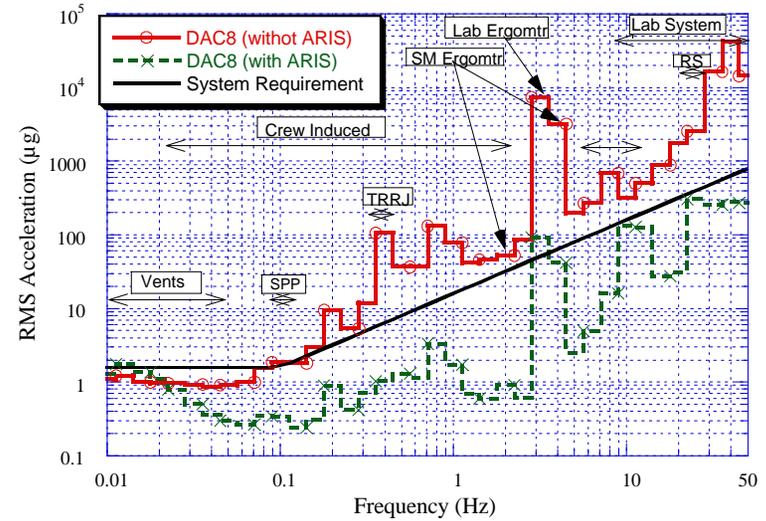
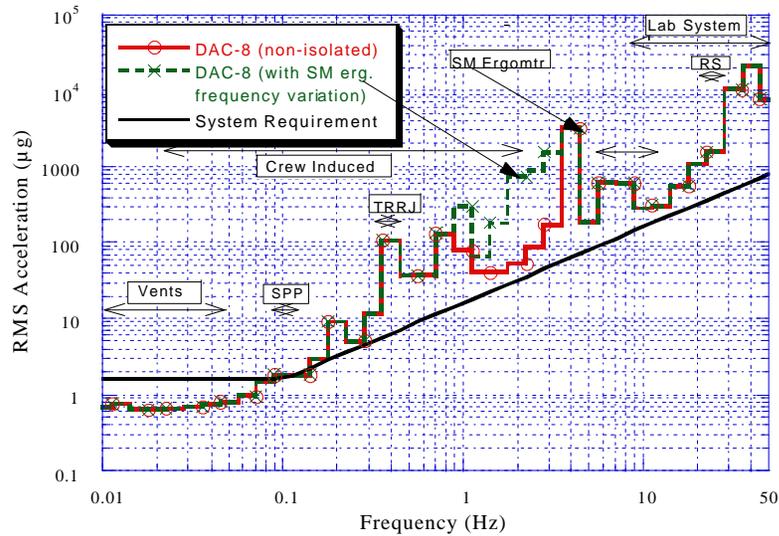


SSP-MG99-074A March 30, 2000

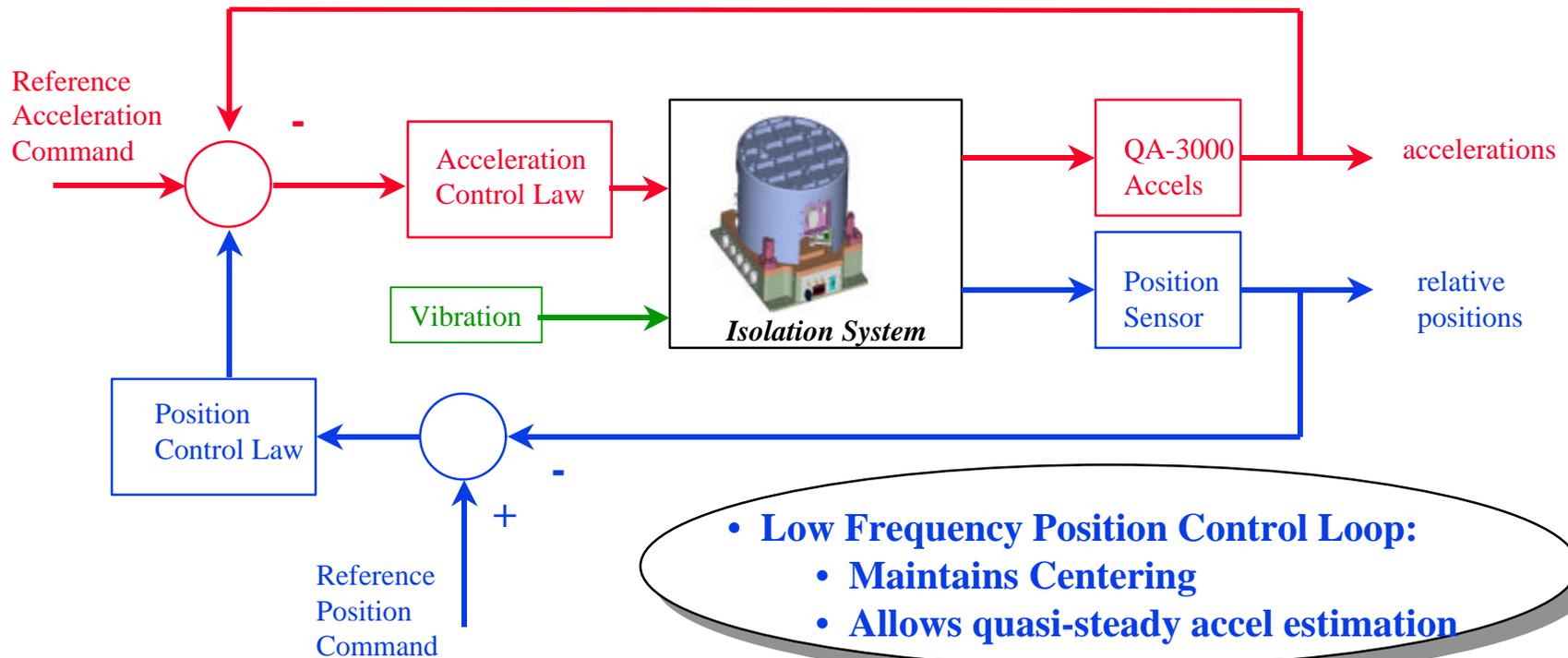
The acceleration environment is expected to significantly exceed acceptable levels

Microgravity vibration isolation systems are required to provide an environment conducive to world-class science research

Why is Vibration Isolation Necessary for ISS?



- **High Frequency Acceleration Control Loop:**
 - Cancels Inertial Motion of the Platform
 - Allows “Good Vibrations”



- **Low Frequency Position Control Loop:**
 - Maintains Centering
 - Allows quasi-steady accel estimation



Comparison of Approaches

Type	Advantages	Disadvantages
Passive	<ul style="list-style-type: none"> •Low Cost •Low Maintenance •Reliable •No Power 	<ul style="list-style-type: none"> •Isolate only higher freq (> 1-10 Hz) •Typically requires large volume •Cannot mitigate payload induced vibrations •Resonance vs attenuation trade
Active Rack Level (ARIS)	<ul style="list-style-type: none"> •Low freq attenuation •Least power & volume (mult. payloads/single unit) •standard user interface 	<ul style="list-style-type: none"> •Cannot mitigate payload induced vibrations •requires payloads to be “good neighbors” •highly sensitive to crew contact •Potential high maintenance
Active Sub-Rack Level (g-LIMIT, STABLE, MIM)	<ul style="list-style-type: none"> •Low freq attenuation •Mitigates payload induced vibration •can be optimized for individual user 	<ul style="list-style-type: none"> •More power & volume than rack-level (single payload/single unit)



Introduction

- To date, three microgravity vibration isolation systems have been flight tested in orbit:
 - STABLE (Suppression of Transient Accelerations By LEvitation)
 - ARIS (Active Rack Isolation System)
 - MIM (Microgravity Vibration Isolation Mount)
- Each system will be surveyed using data provided by each investigation team

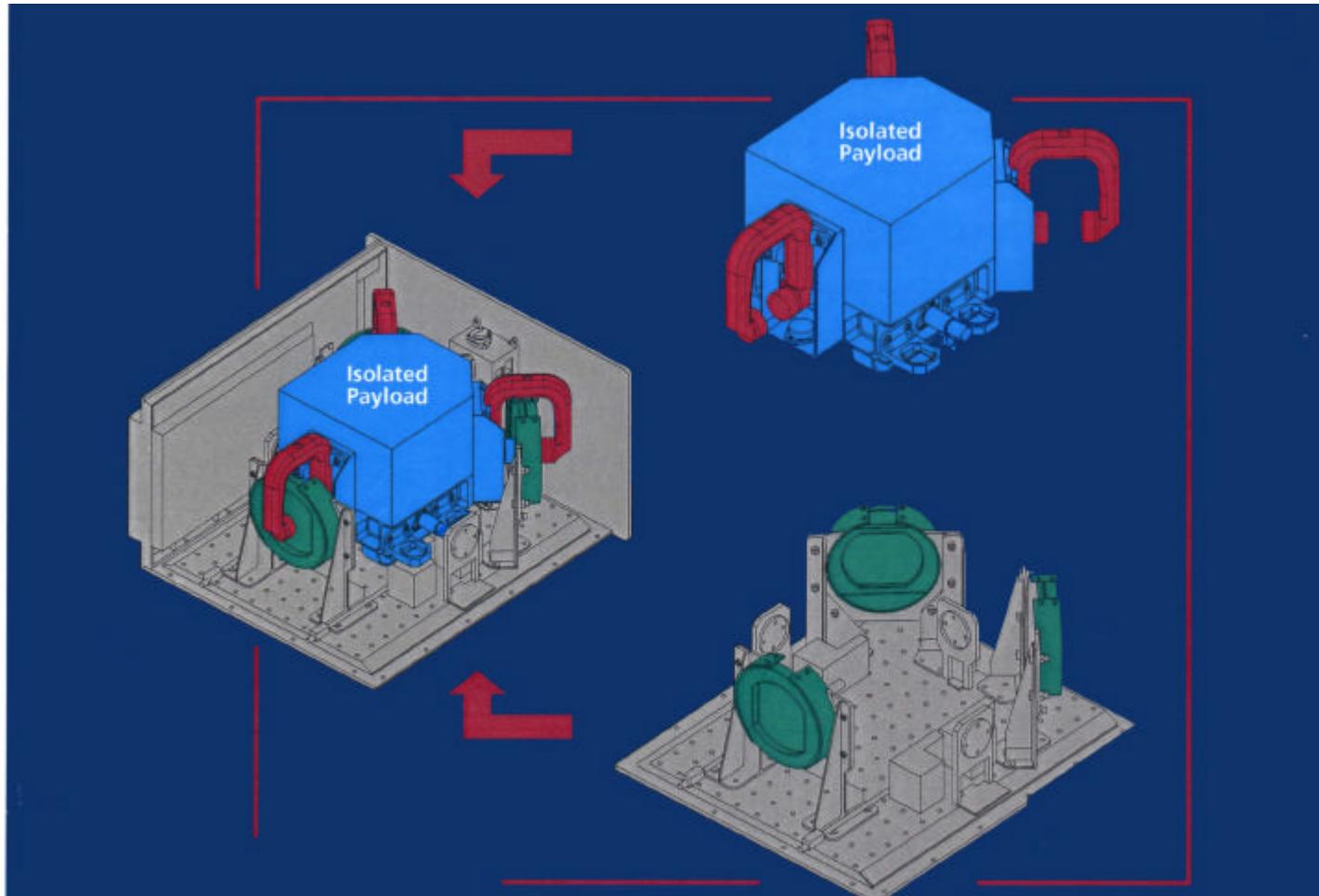


The STABLE Vibration Isolation System

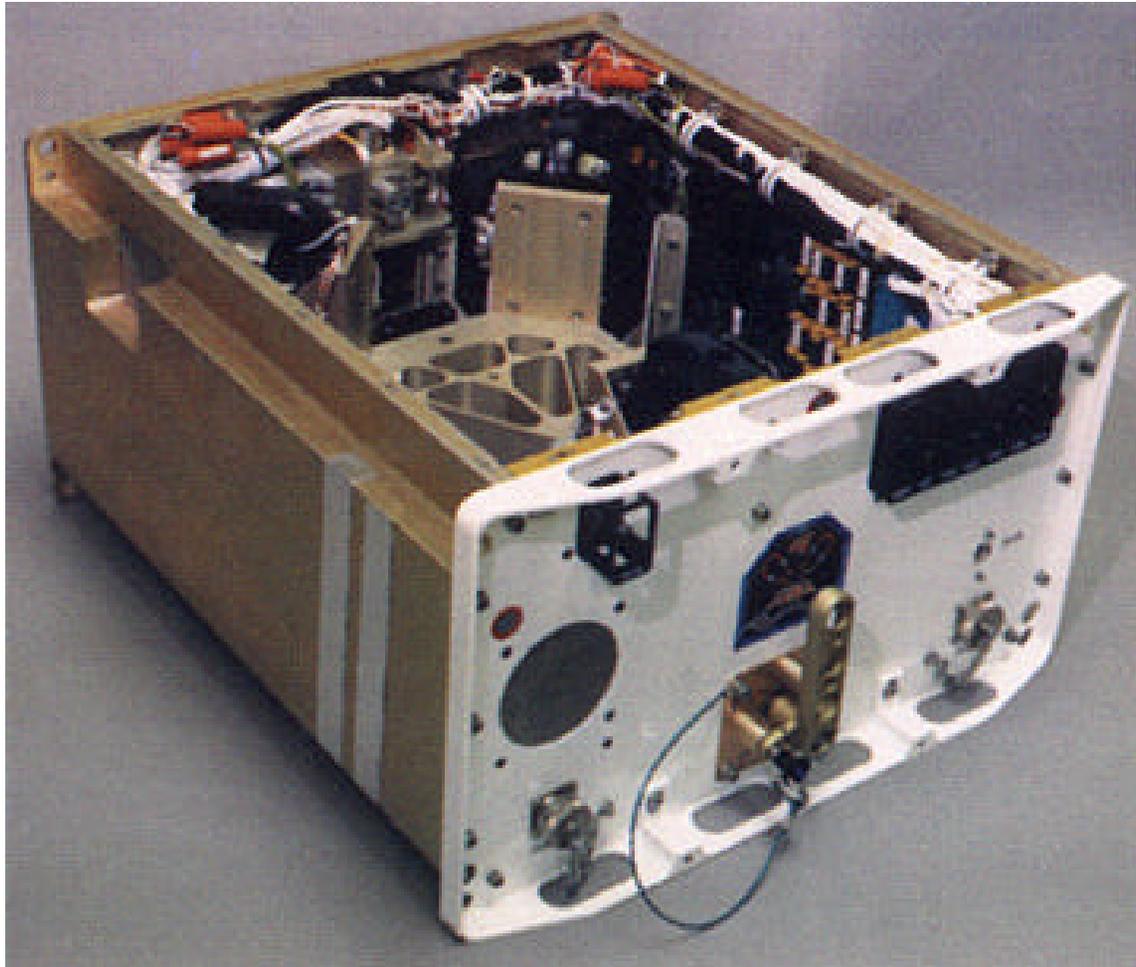
- Payload-level Isolation System
- Developed jointly by NASA MSFC and Boeing (formerly MDAC)
- Flown on STS-73/USML-02, October 1995
- A Faster/Better/Cheaper approach
 - 4.5 months from ATP to delivery
 - Utilized COTS components
 - Necessitated robust control design
 - Supported a fluid physics experiment



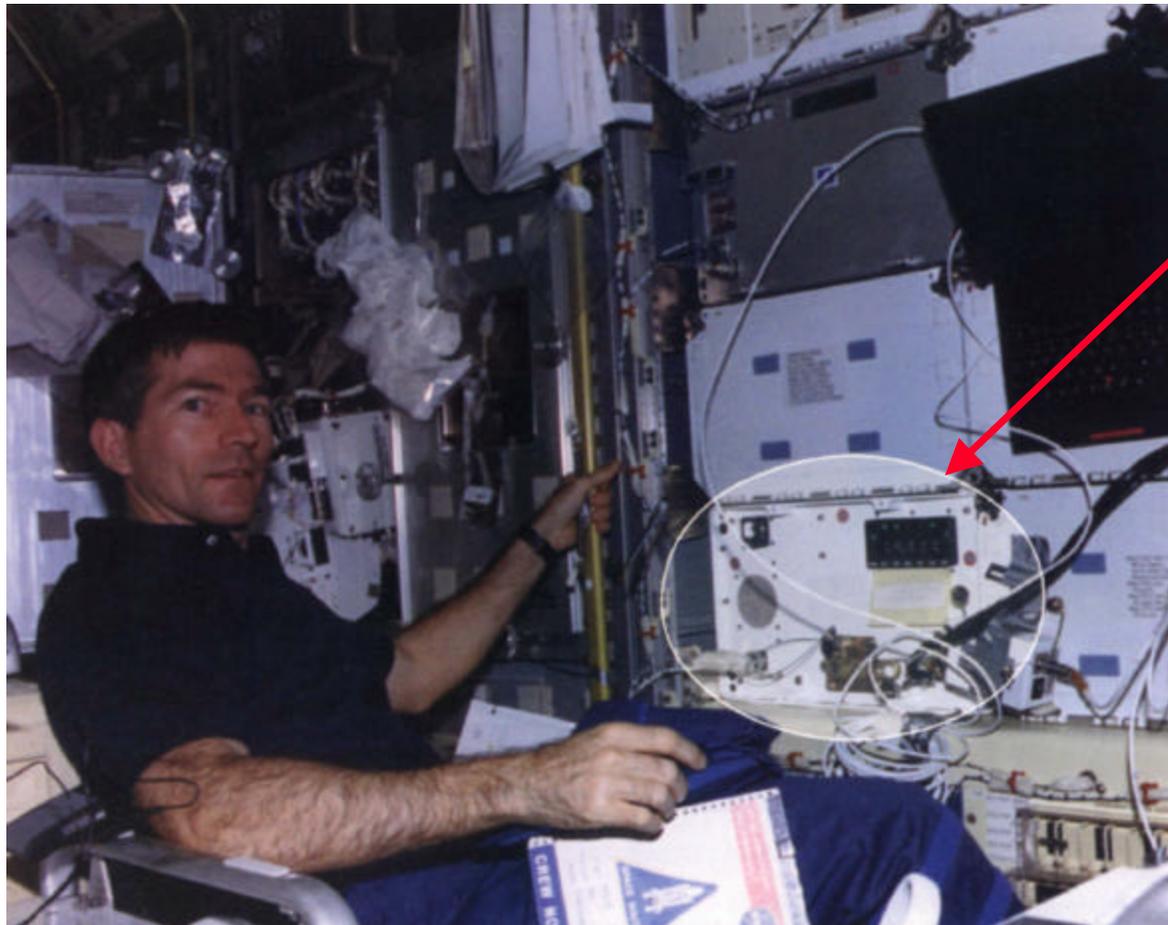
Integration of Payload into STABLE Locker



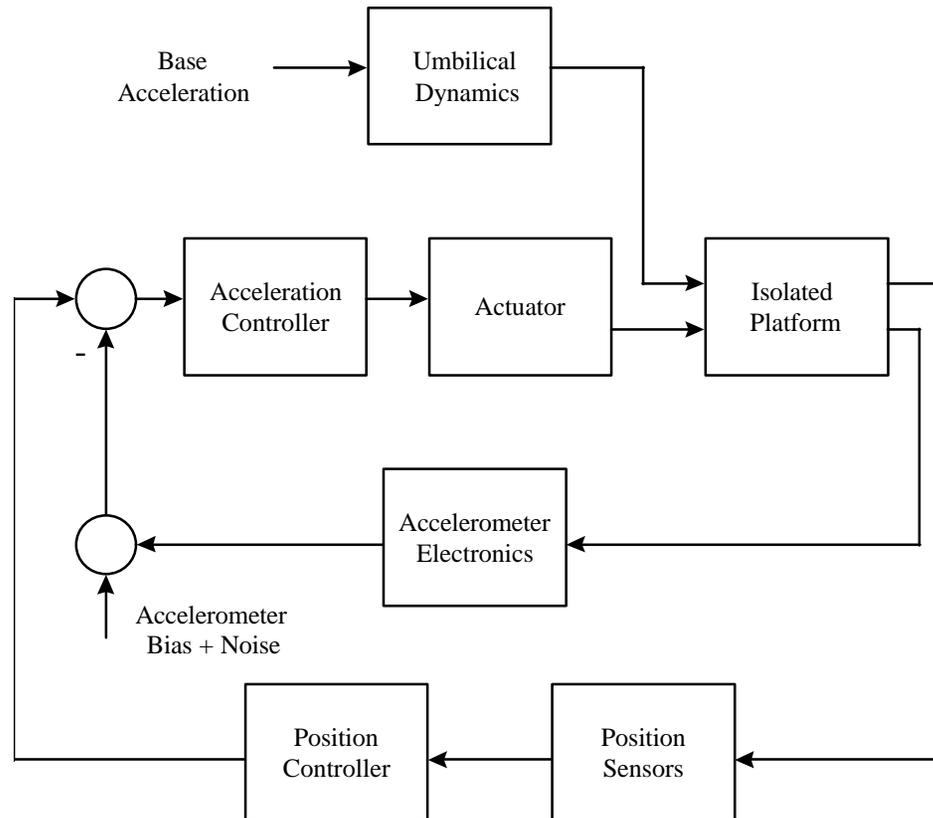
STABLE Flight Unit



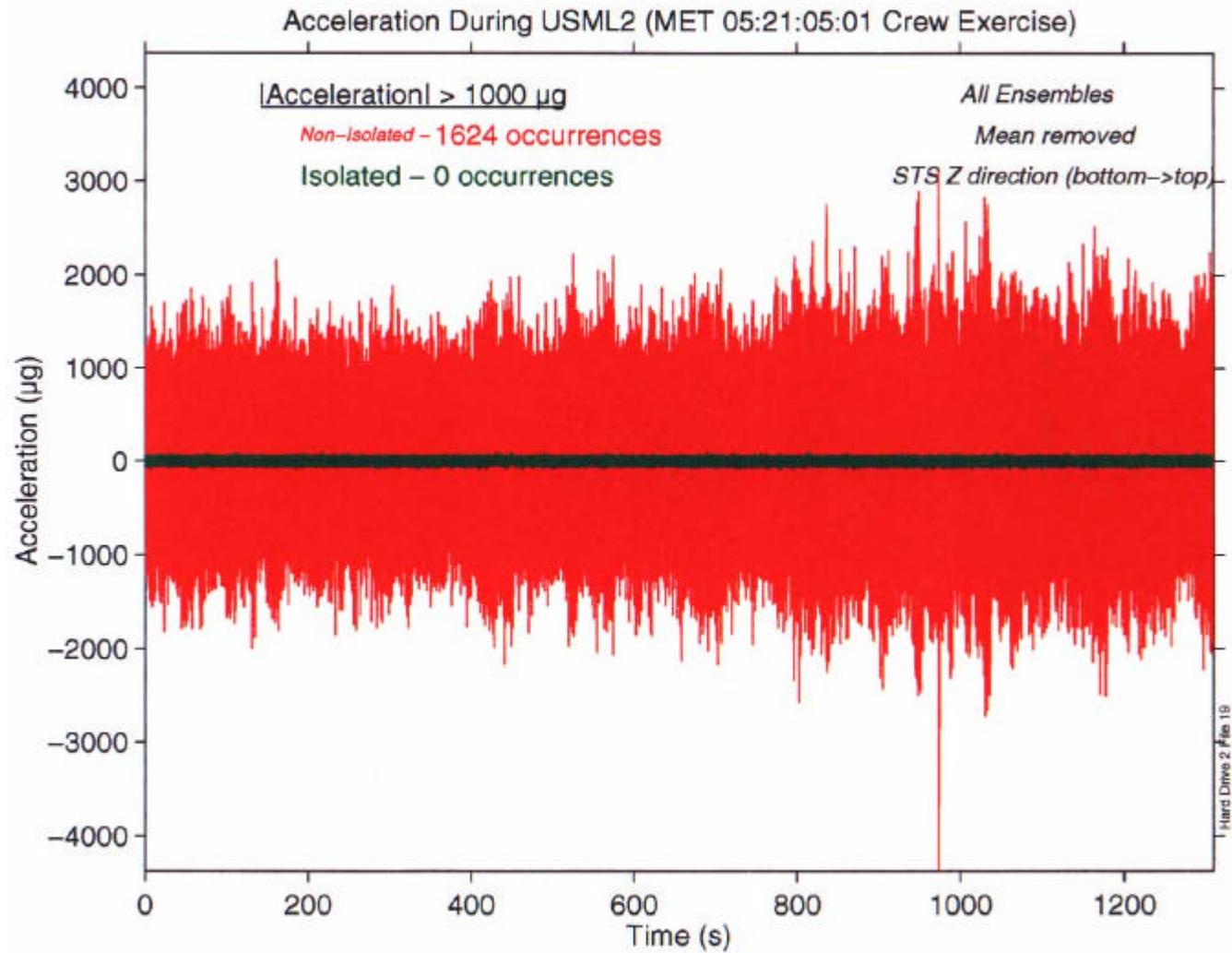
Payload Specialist Dr. Fred Leslie operating STABLE



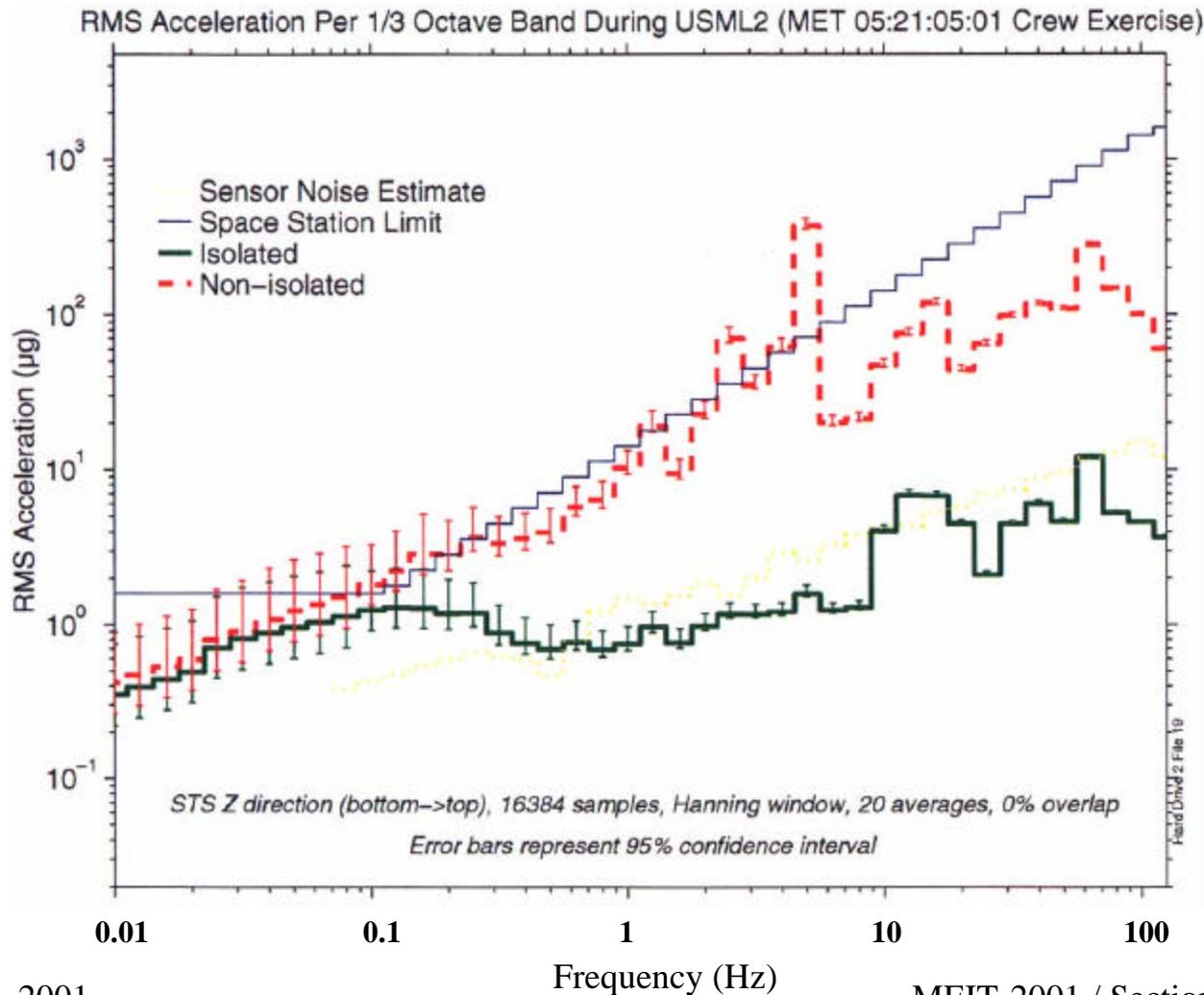
STABLE Control System Block Diagram



STABLE: Typical Active Isolation Time Response



STABLE: Typical Active Isolation Frequency Response

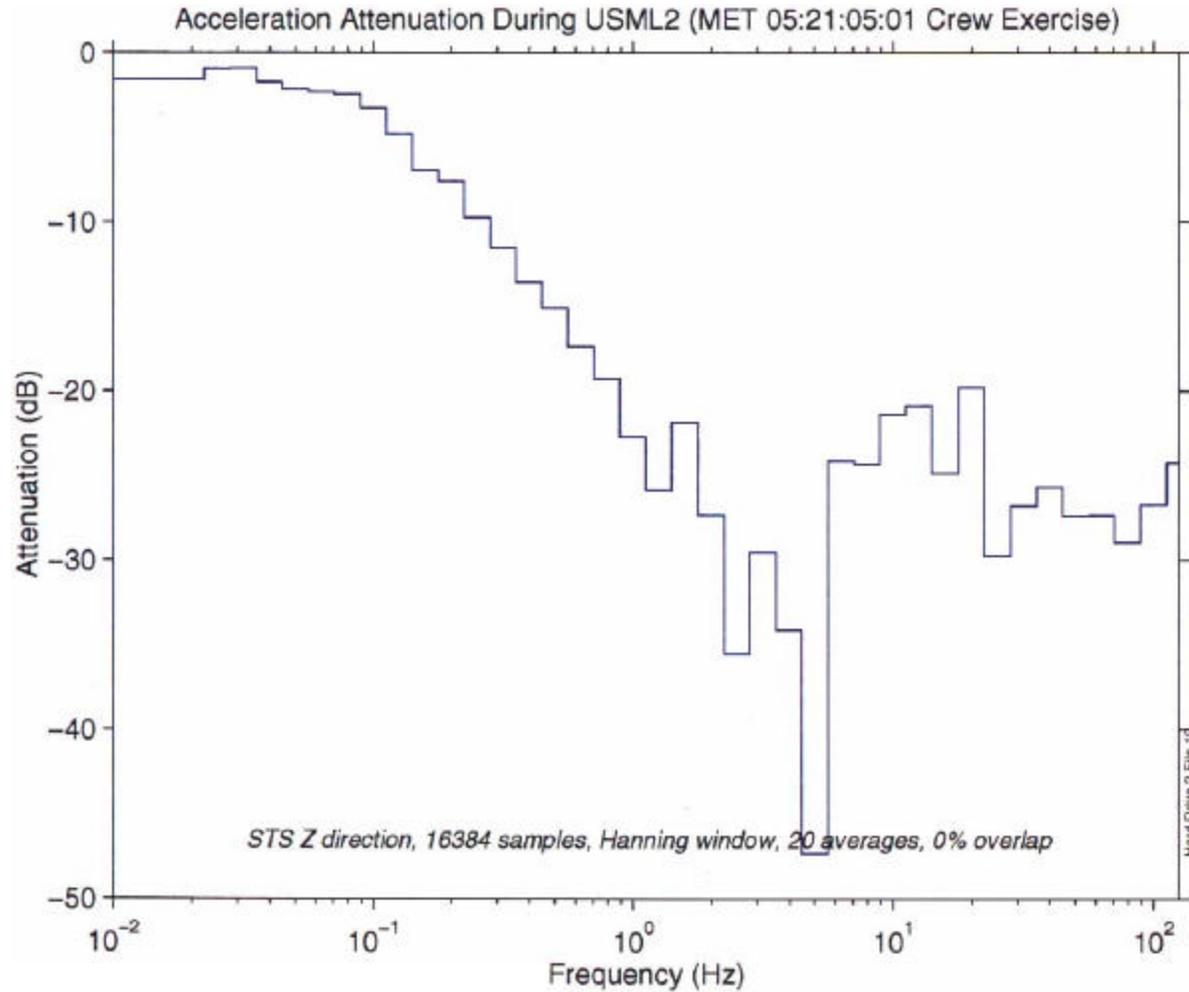




Survey of Microgravity Vibration Isolation Systems



STABLE: Typical Active Isolation Attenuation



MIM Background

- **The Microgravity Vibration Isolation Mount (MIM) has been developed over the past 10 years by CSA under the direction of Bjarni Tryggvason**
- **2 MIM versions have been produced to date:**
 - **First version of MIM is known as MIM-1:**
 - In operation for two years onboard Russian Mir space station since May 1996;
 - accumulating over 3000 hours.



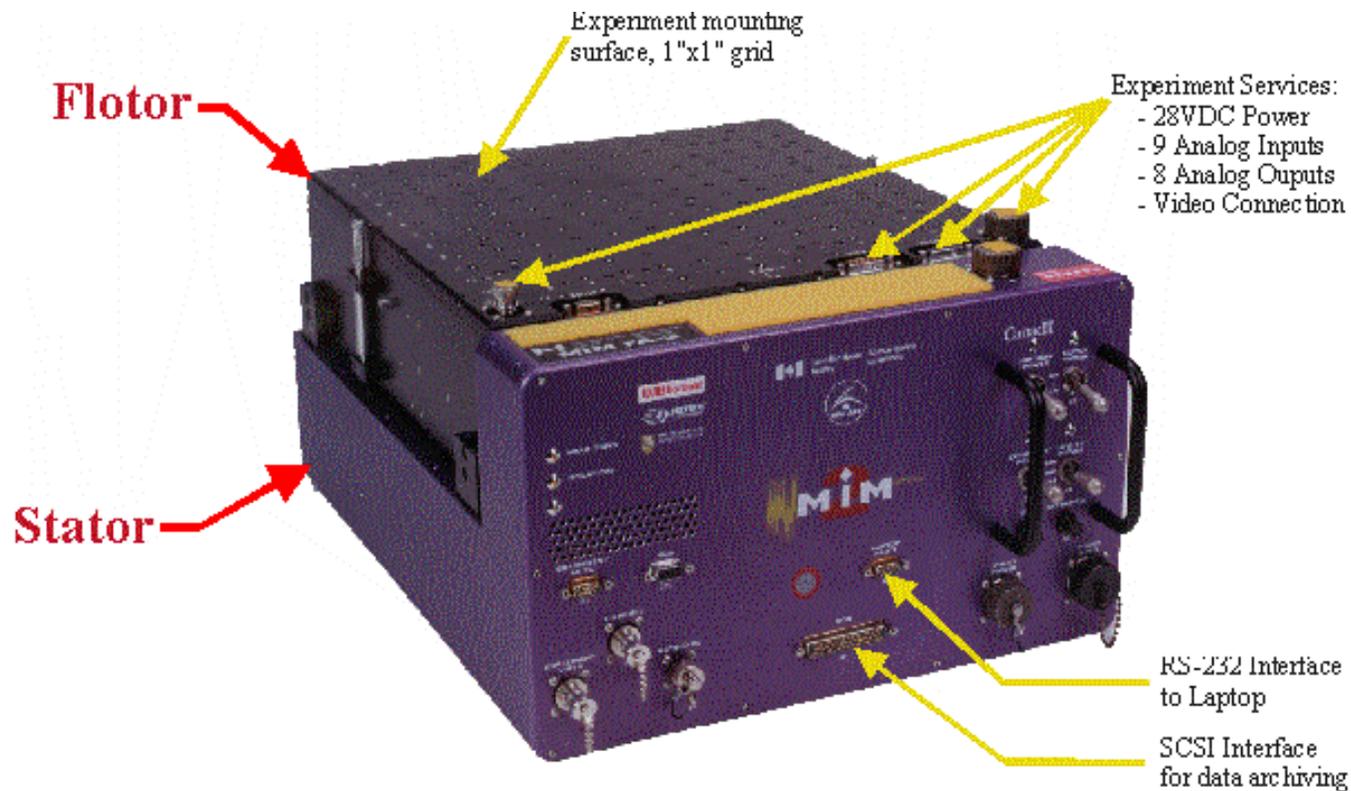
MIM Background

- **Second version of MIM is known as MIM-2:**
 - Flown onboard the Space Shuttle during mission STS-85 with Canadian Astronaut Bjarni Tryggvason;
 - MIM-2 acquired a total of 100 hours of operations.



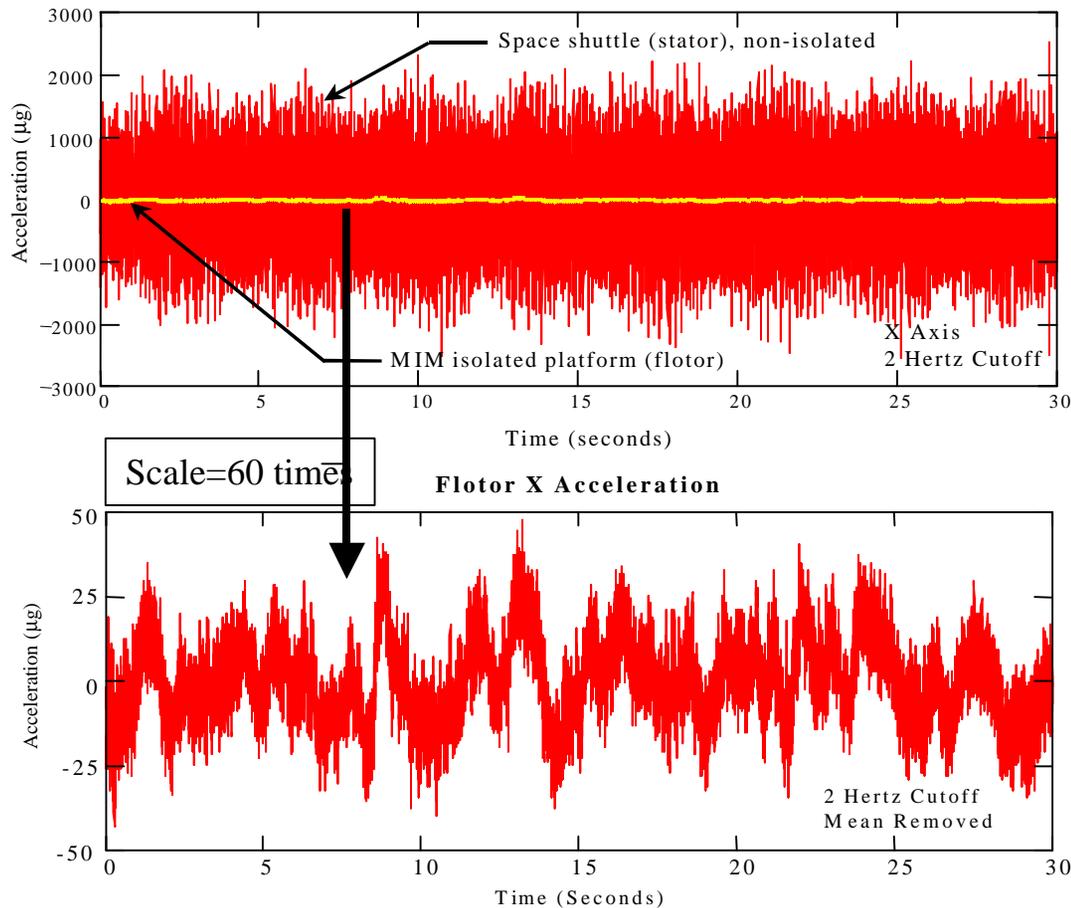
MIM-2 Description:

- 8 wide gap Lorentz force actuators (magnets on flotor & coils on stator);
- 3 light emitting diodes imaged on 3 position sensitive devices (PSD);
- 6 accelerometers for monitoring stator & flotor acceleration



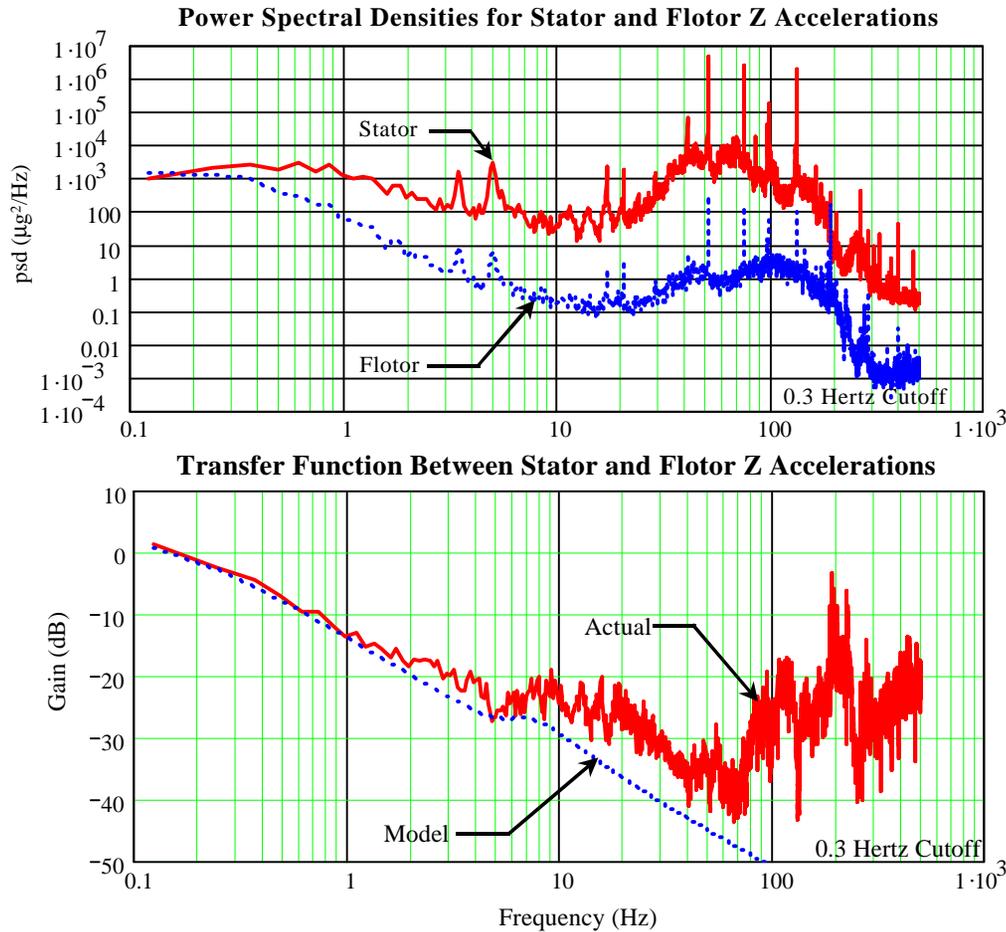
MIM-2 Summary for STS-85

Acceleration Levels of the Space Shuttle and MIM's Isolated Platform



Data filtered by a 100 Hz low-pass filter and sampled at 1000 samples per second

MIM-2 Summary for STS-85



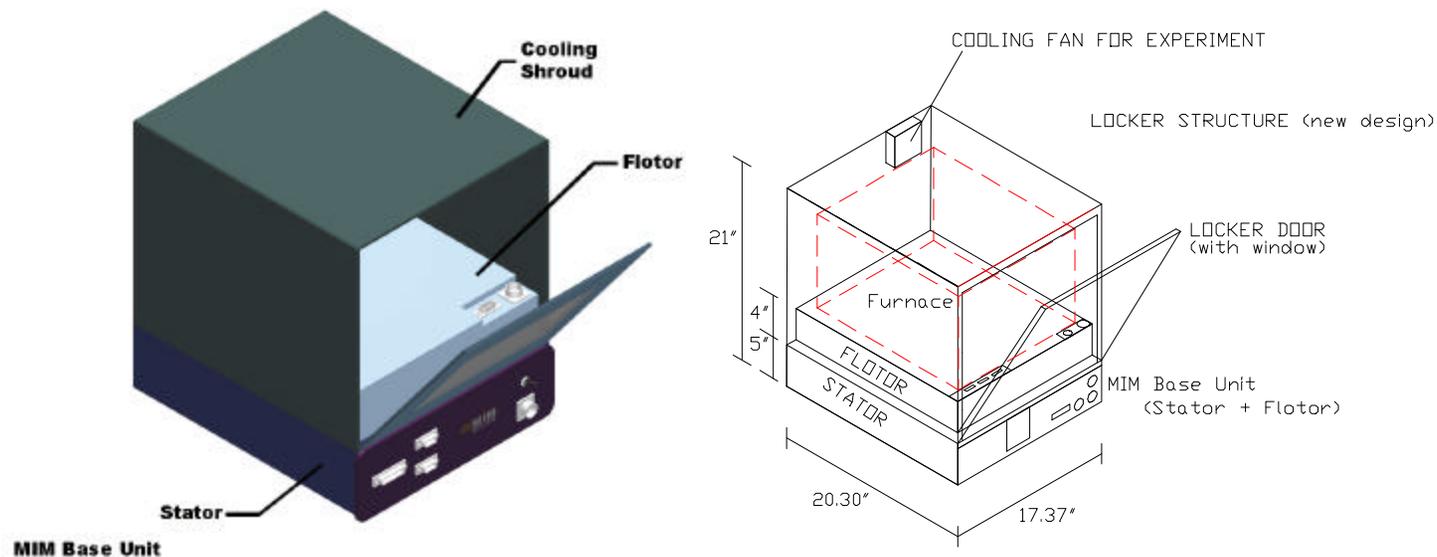
Data filtered by a 100 Hz low-pass filter and sampled at 1000 samples per second



MIM-2 summary for STS-85

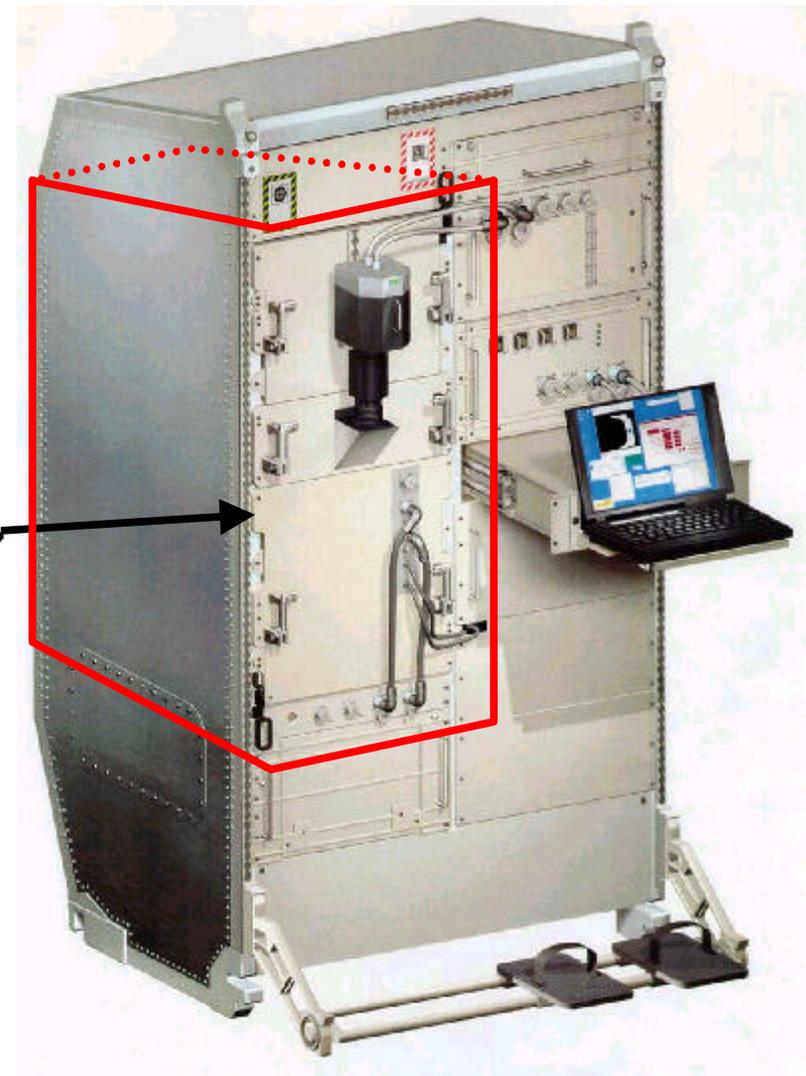
- MIM has shown the capability to isolate down to 0.3 Hertz with that limit related to the PSD case material
- Models indicate that with current umbilical and replacement of PSDs, isolation cutoff frequencies of approximately 0.04 Hertz can be achieved
- To reach 0.01 Hertz, improvements to the umbilical are required

MIM Base Unit Description



- Comprised of Stator, Double Flotor and Flotor Enclosure
- Key support facility for science payloads
- Designed to support small payloads in an EXPRESS rack
- Housed in a double mid-deck locker

MVIS for the ESA Fluid Sciences Lab



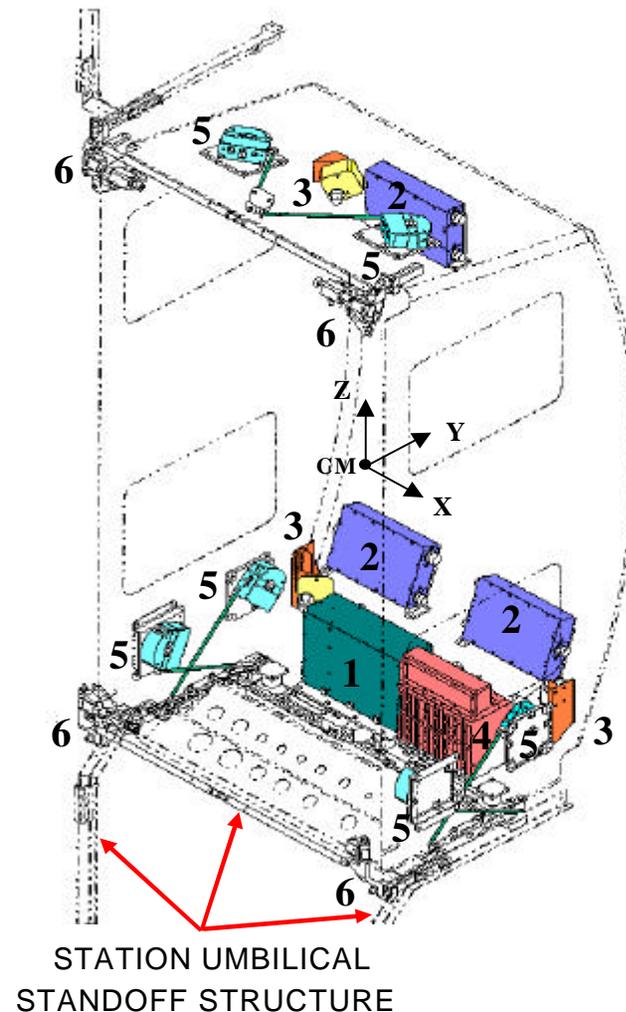


The Active Rack Isolation System (ARIS)

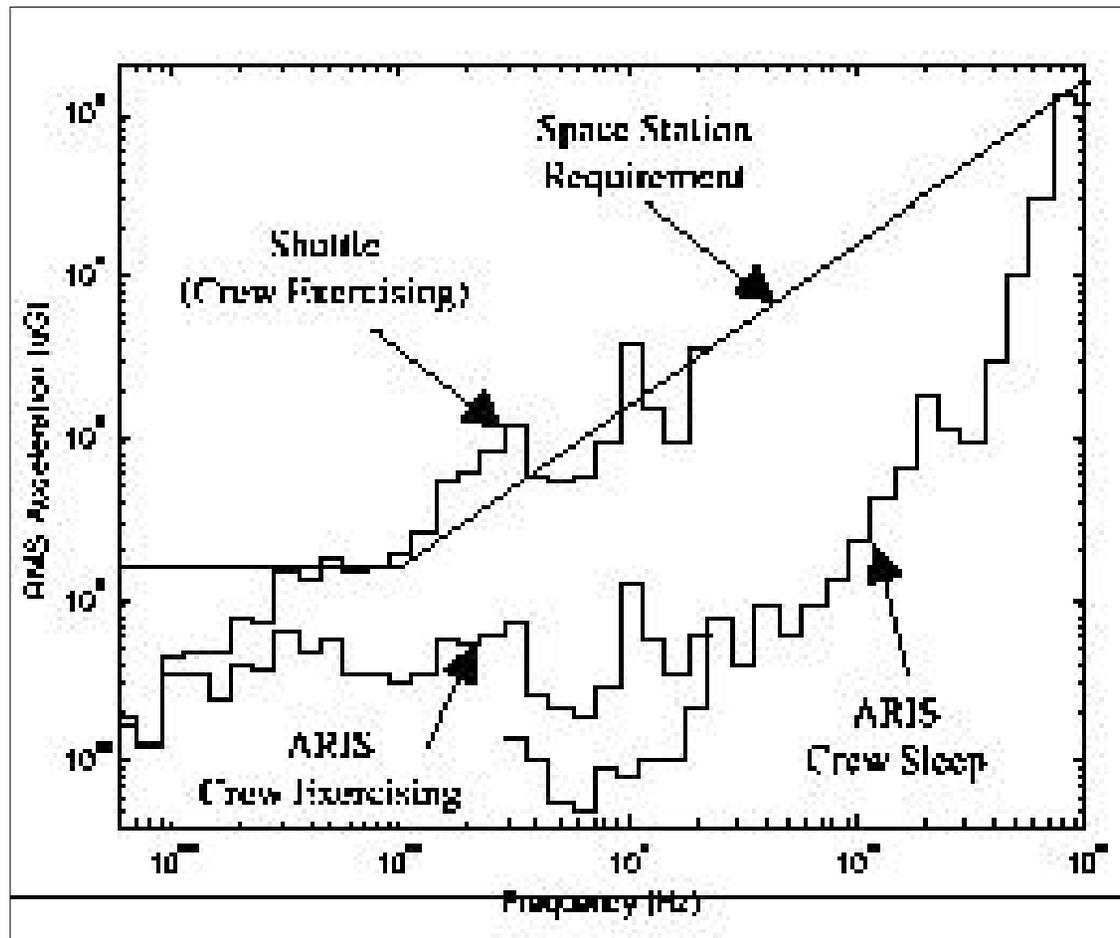
- Rack-level Isolation System
- Developed by Boeing
- Flown on RME 1313 / MIR Spacehab STS-79, August 1996
- ISS baseline solution for acceleration system specification
- Scheduled for Isolation Characterization Experiment, ISS flight 6A

Boeing Active Rack Isolation System (ARIS)

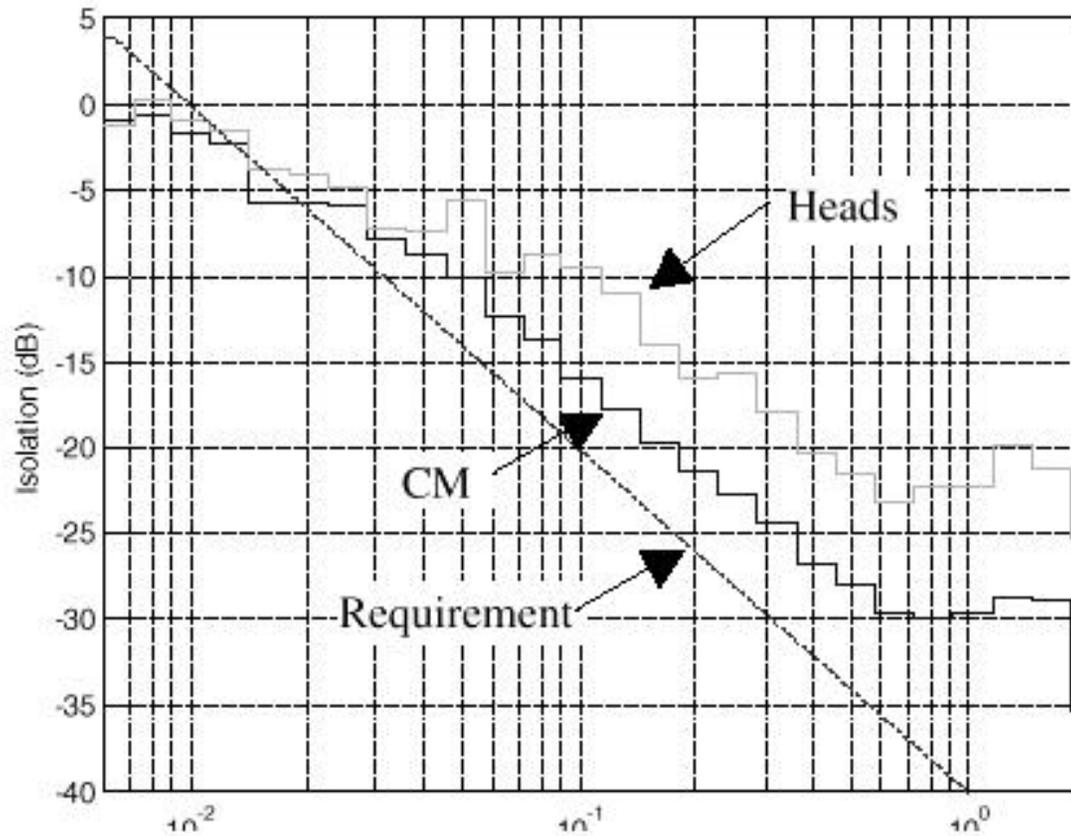
- 1 ➡ Dual Processor : Decoupling implemented in controller allows freedom to place actuators and sensors. Payloads have extensive command, data acquisition, and control options.
- 2 ➡ 3 Sensor Electronic Units : Programmable analog filters & gains & 16 bit analog-to-digital converters.
- 3 ➡ Accelerometer Heads : Built small to fit in rack corners. 2 Tri-axial (Bottom), 1 Bi-axial (Top)
- 4 ➡ 8 Actuator Drivers : Pulse width modulation used to reduce power consumption
- 5 ➡ 8 Actuators : Voice coil rotary actuator used to reduce profile and power consumption.
- 5 ➡ 8 Position Sensors : Integrated with actuators.
- 6 ➡ Hard stop Bumpers



ARIS RME 1/3-Octave Band Acceleration Measurements

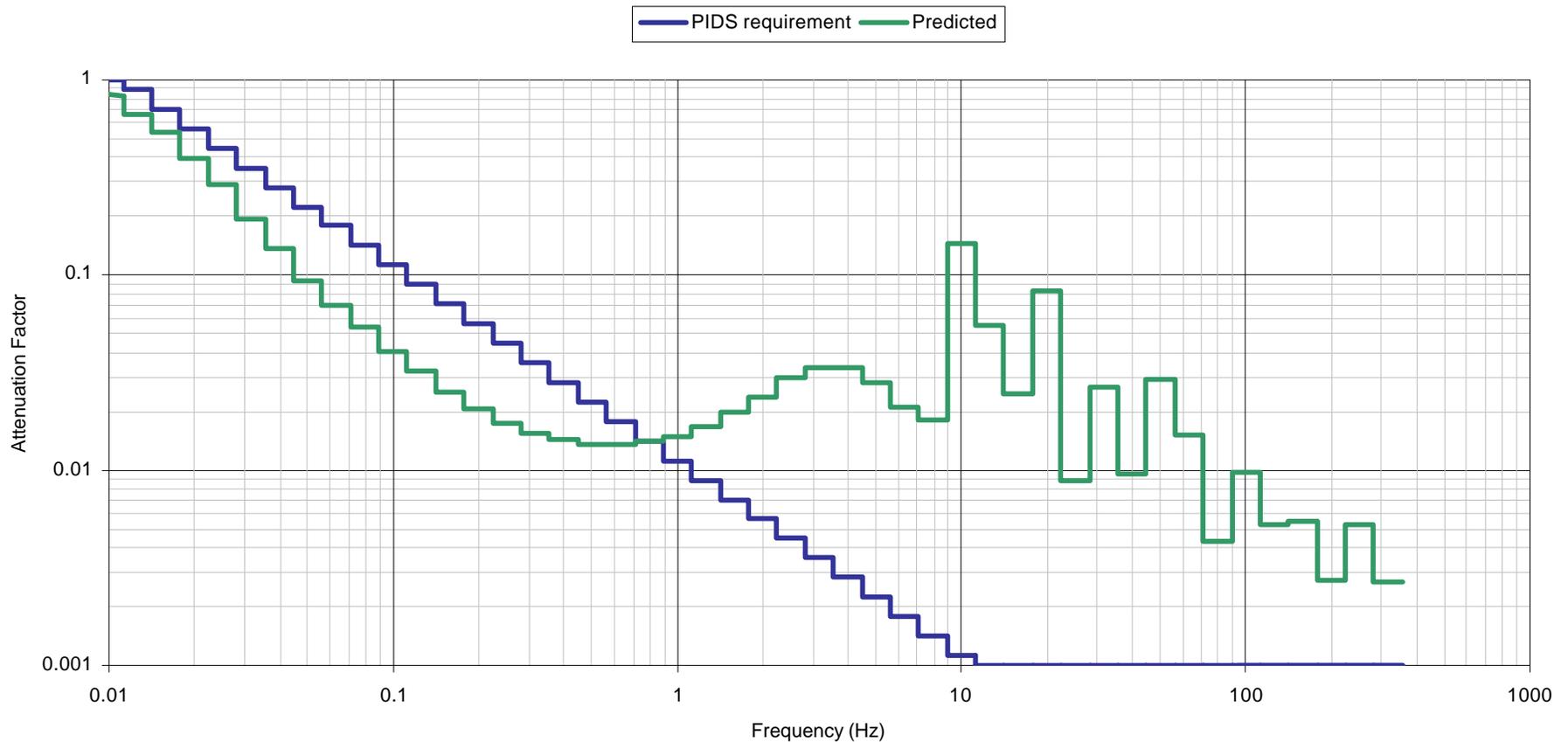


ARIS RME Isolation Performance



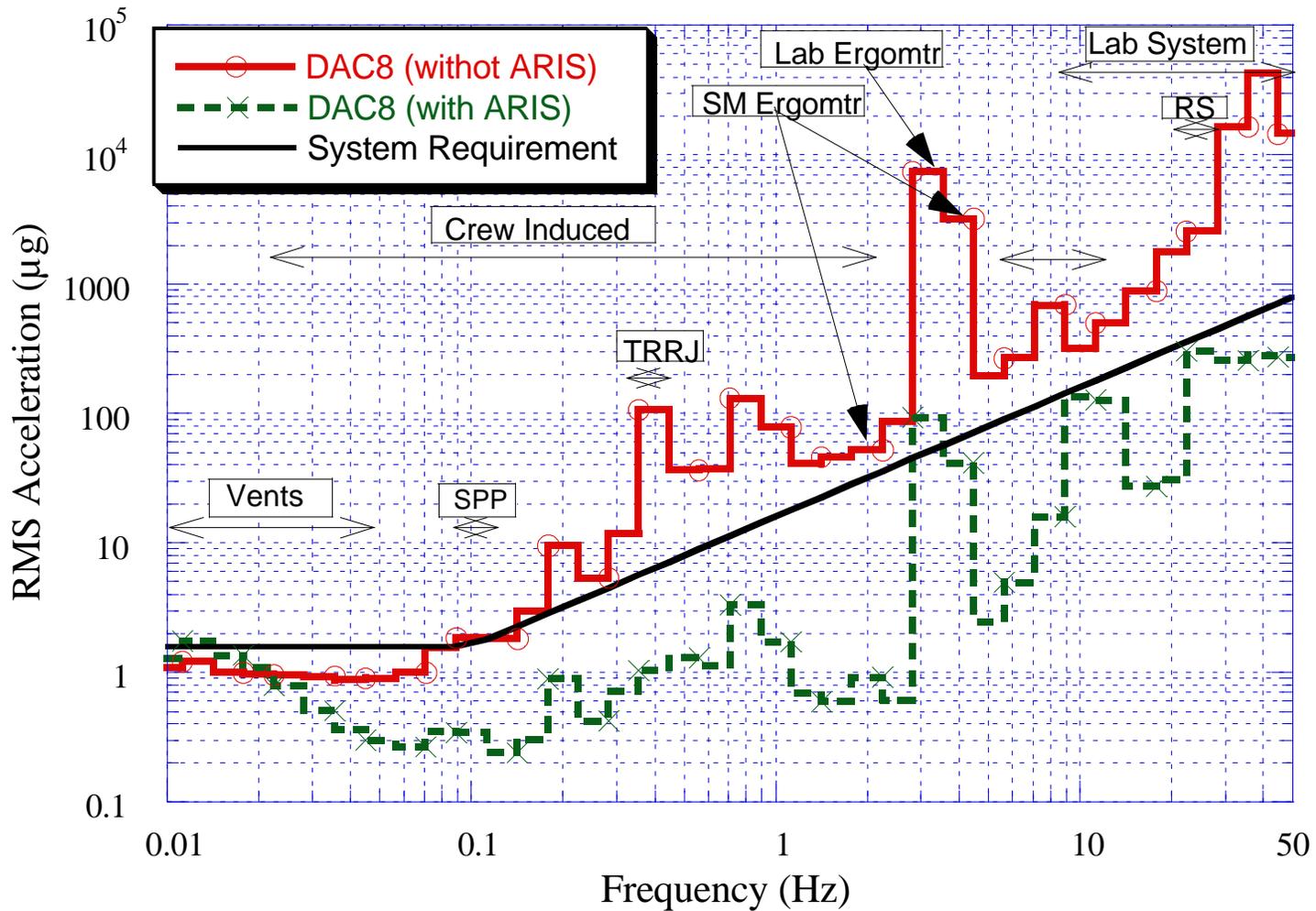


ARIS Isolation Performance: Requirement and Current Prediction (1/00)



Current ARIS isolation prediction without anti-bump invoked

Acceleration Environment with 1/00 ARIS Isolation Prediction





ARIS Forward Work Plan

Focal Points:

- Remove conservatism in models
- Increase control bandwidth
- Improve umbilical design
- Investigate z-panel dynamics
- Investigate rack stiffness and damping enhancements
- Payload scheduled control design



g-LIMIT

A Vibration Isolation System for the Microgravity Science Glovebox (MSG)

- **Small Volume / Low Power**
- **Standard MSG interfaces**
- **Permits multiple experiment operation**
- **Allows crew contact with MSG during ops**
- **Accommodates larger payloads**
- **Modular/reconfigurable design**
- **Scheduled for launch: UF2, Feb. 2002**
- **In-house development by NASA/MSFC**



-L MIT System Assembly

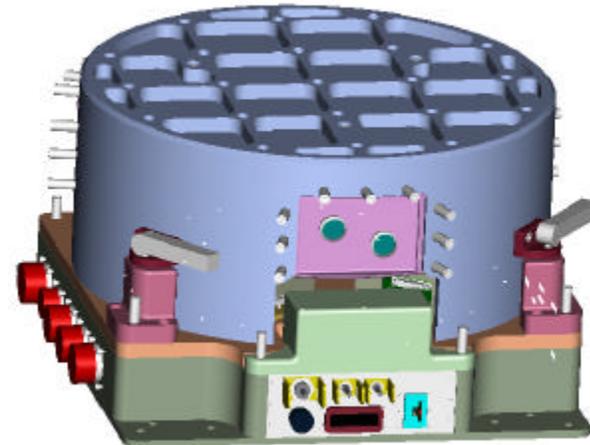
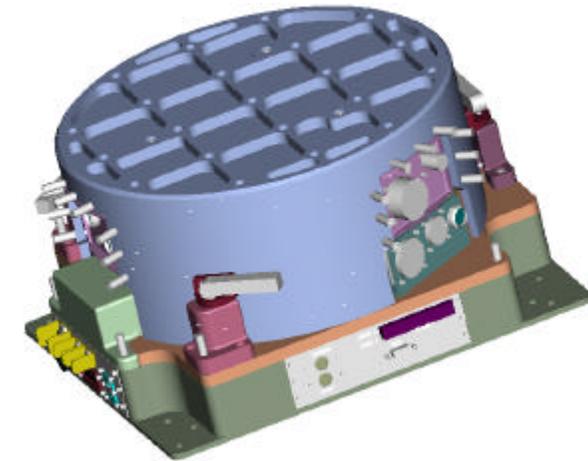
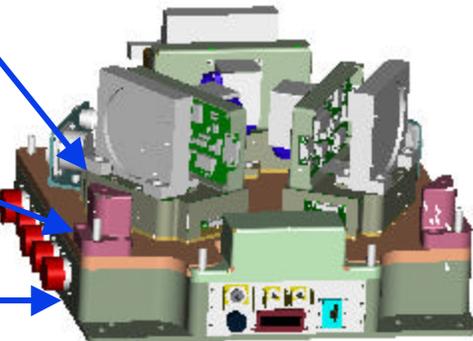
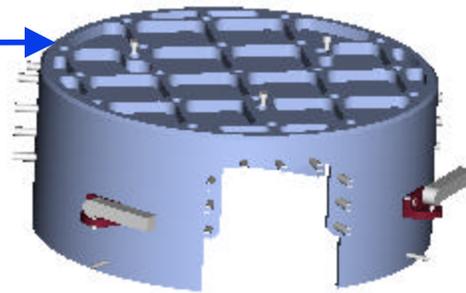
Payload
Mounting
Structure (PMS)

Umbilical
Interface
Plate (UIP)

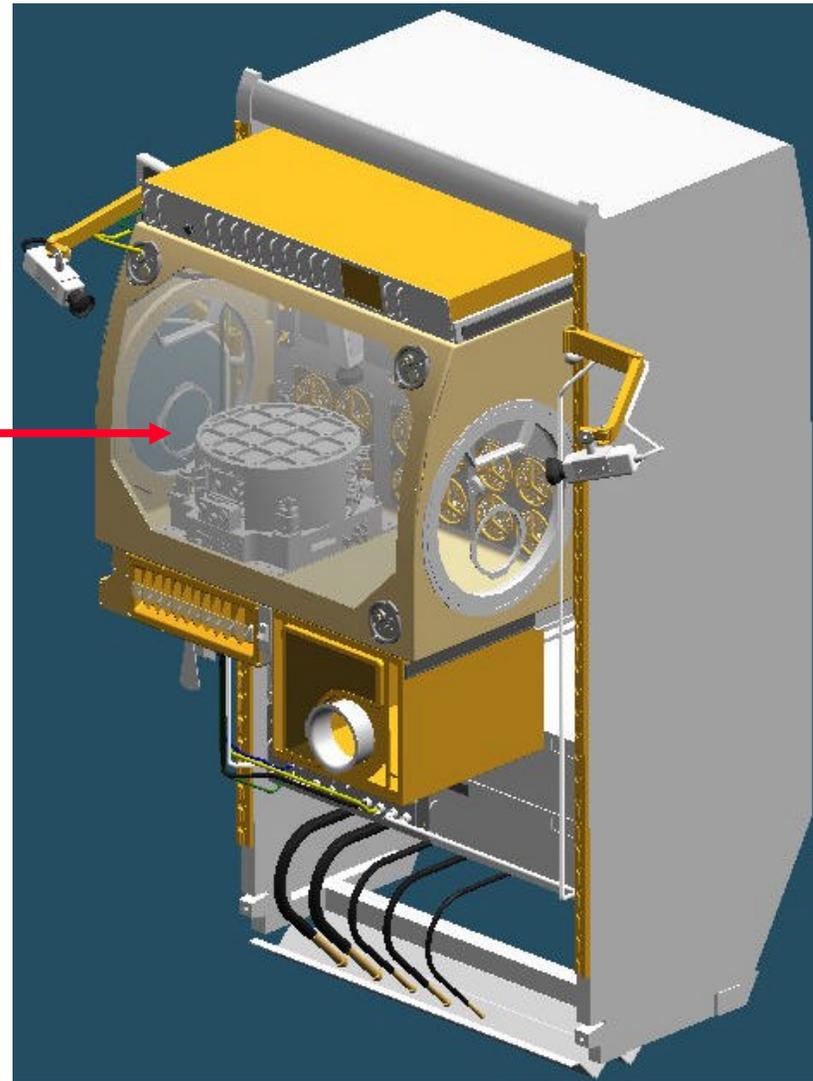
Isolator Module (IM)
•Platform subsystem (TASC*)
•Base subsystem (Base)
•3 units

Bumpers (3)

Power &
Information
Processor (PIP)



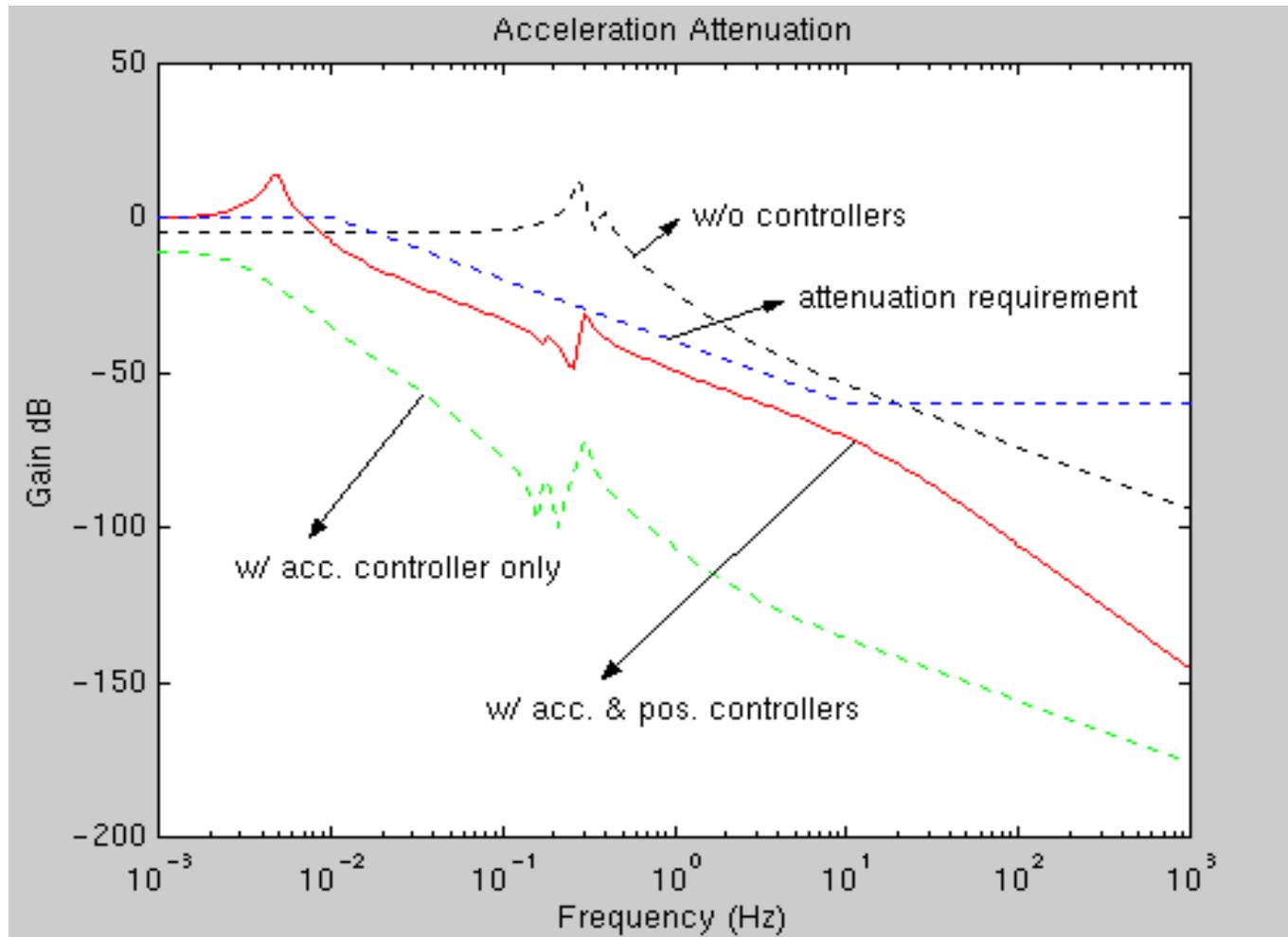
g-LIMIT in MSG



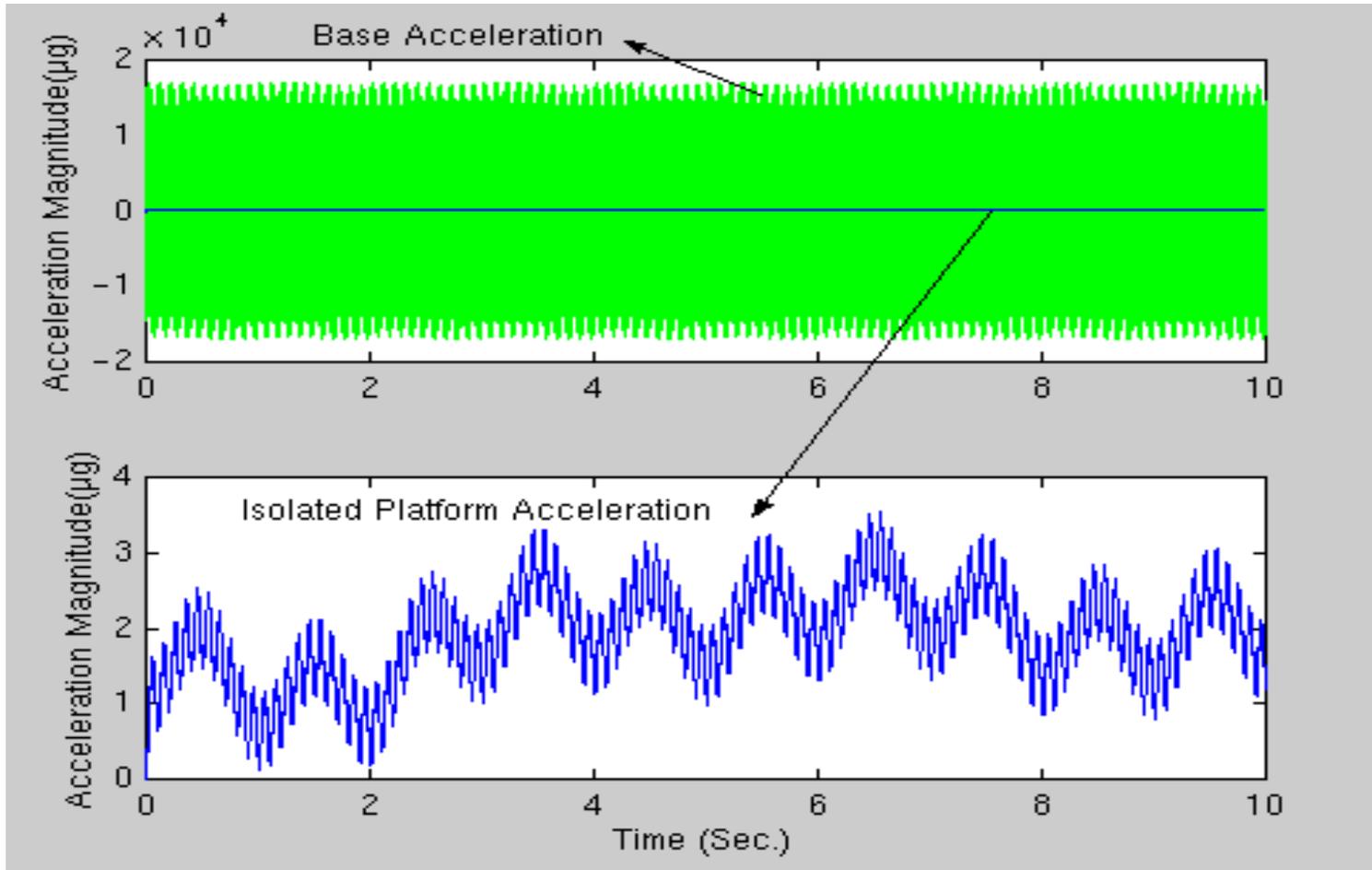
g-LIMIT Trainer in MSG



g-LIMIT 6DOF, Baseline PID Controllers (X-axis)



g-LIMIT 6DOF, Acceleration Time Response (X-axis)



Base acceleration = $1.6 \sin(0.01 \text{ hz} \cdot t) + 16 \sin(0.1 \text{ hz} \cdot t) + 160 \sin(1 \text{ hz} \cdot t) + 1600 \sin(10 \text{ hz} \cdot t) + 16000 \sin(100 \text{ hz} \cdot t)$



Availability of Flight Systems:

STABLE:

- **No plans to fly on ISS, but available**

MIM-2, et.al.:

- **Use on ISS coordinated through CSA**

ARIS:

- **10 units currently to be delivered to ISS**
 - **Express, FCF, MSRF**

g-LIMIT:

- **Employed in MSG**
- **Flight Unit, Spare, & Derivatives applicable elsewhere**



Further Reading:

1. Grodsinsky C. and Whorton, M., "Survey of Active Vibration Isolation Systems for Microgravity Applications," *Journal of Spacecraft and Rockets*, Vol. 37, No. 5, Sept. – Oct. 2000.
2. Bushnell, G. S., and Becraft, M. D., "Microgravity Performance Flight Characterization of an International Space Station Active Rack Isolation Prototype System," Proceedings of The 16th IEEE Instrumentation and Measurement Technology Conference (IMTC/99), Venice, Italy, May 24-26, 1999.
3. Nurre, G. S., Whorton, M. S., Kim, Y., Edberg, D. L., and Boucher, R., "Performance Assessment of the STABLE Microgravity Vibration Isolation Flight Demonstration," submitted for publication to *Journal of Spacecraft and Rockets*.
4. Tryggvason, B. V., Stewart, B. Y., DeCarufel, J., and Vezina, L., "Acceleration Levels and Operation of the Microgravity Vibration Isolation Mount (MIM) on the Shuttle and Mir Space Station", AIAA Paper No. AIAA-99-0578, presented at the 37th AIAA Aerospace Sciences Meeting and Exhibit, Reno, Nevada, January 11-14, 1999.