Section 14:
Fundamentals of Vibration Isolation

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Outline:

- **Vibration Isolation Technology**
  - Dynamics of Systems
  - Active Control Concepts
  - Isolation Performance Measures
- **Flight Hardware Systems**
  - STABLE
  - MIM
  - ARIS
  - g-LIMIT

Introduction

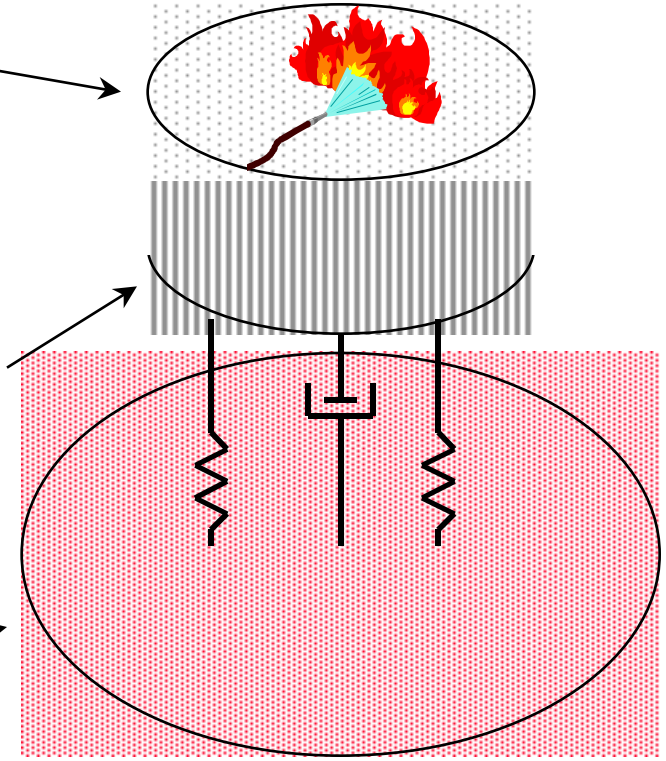
- The ambient spacecraft acceleration levels are often higher than allowable from a science perspective.
- To reduce the acceleration levels to an acceptably quiescent level requires vibration isolation.
- Either passive or active isolation can be used depending on the needs or requirements of a specific application.

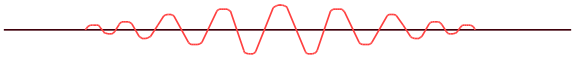
What is Vibration Isolation?

Fluids & Combustion Experiment

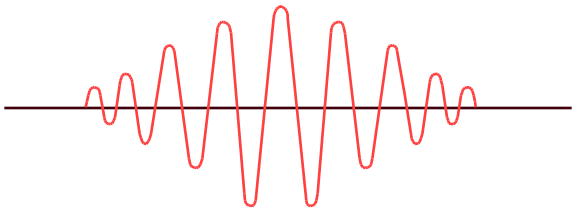
Isolation System Payload Mounting Structure

Vehicle Work Volume Floor





Isolated Experiment Accelerations



Accelerations of Floor

System Dynamics: Transmissibility

- The ***transmissibility*** is the transfer function that relates the acceleration (or position) response of the mass to the base acceleration (or position) input.
- The magnitude of the transmissibility function specifies the attenuation of base motion as a function of frequency.
- Use of springs, masses, and dampers for attenuation is known as "***passive vibration isolation***"

Active Control Concepts

• ***Active vibration isolation*** seeks to minimize the inertial motion of the payload by directly sensing the inertial motion and applying forces to the platform to directly counter the measured motion.

• Using a passive isolation analogy, active control can effectively change the system mass, stiffness and damping and thus change the dynamics -- i.e. the time response of the system.

Active Control Concepts

However, it isn't as easy as it seems --

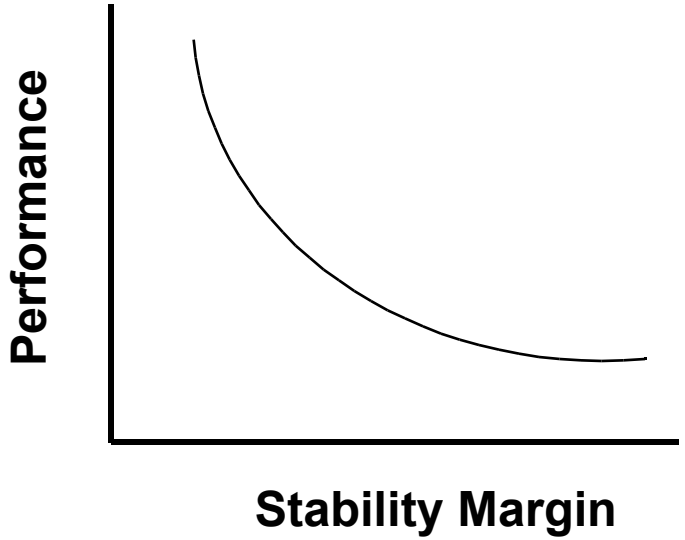
- Real systems aren't simple one degree of freedom lumped masses with discrete springs and dampers.
- Control system design is a function of system properties which typically aren't well known.

The two key control design issues are ***stability*** and ***performance***.

- ***Stability***: will the system return to an equilibrium position when disturbed?
- ***Performance***: how well is isolation achieved?

Active Control Concepts

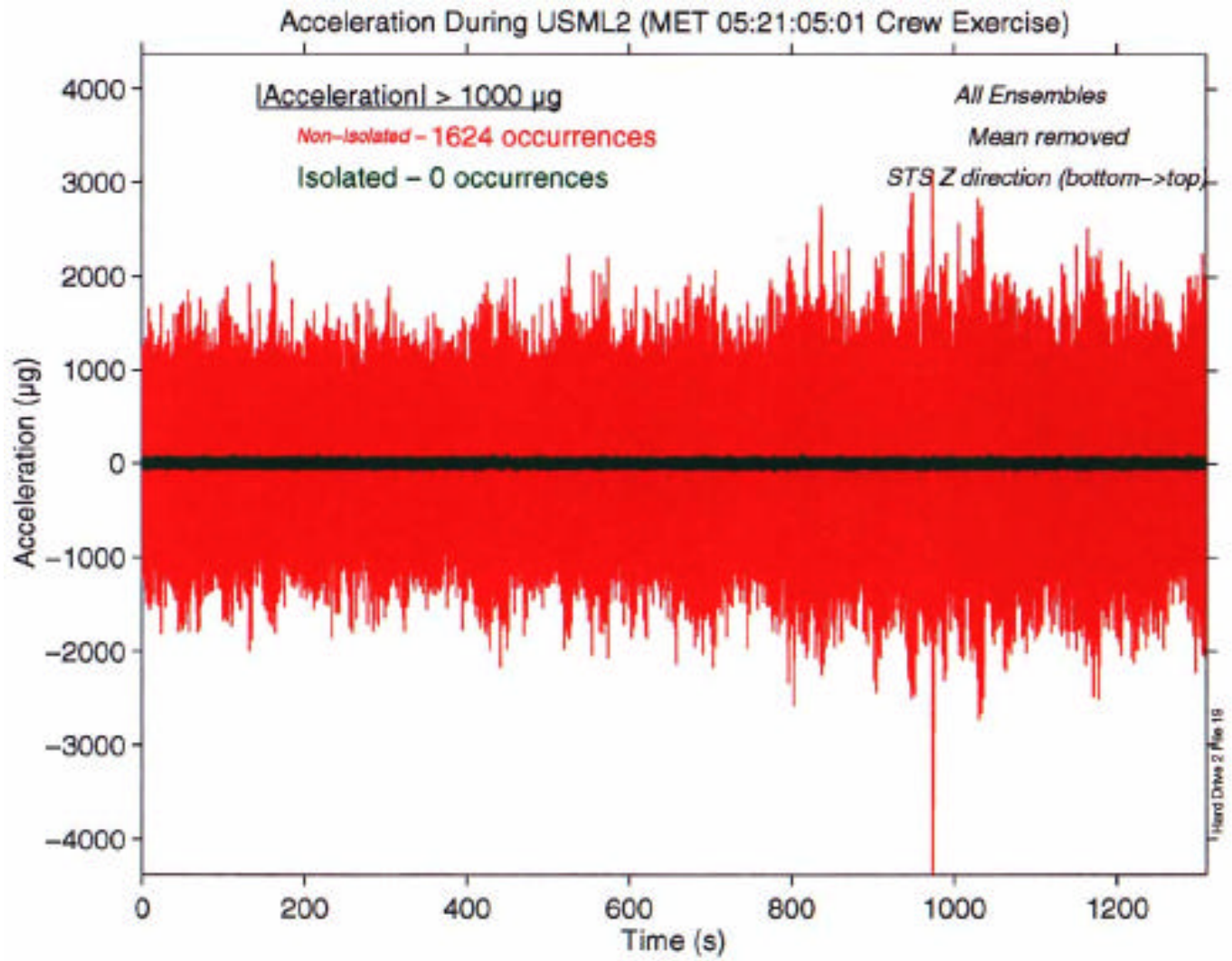
Stability margin and **performance** of a closed loop system are ***always*** in opposition



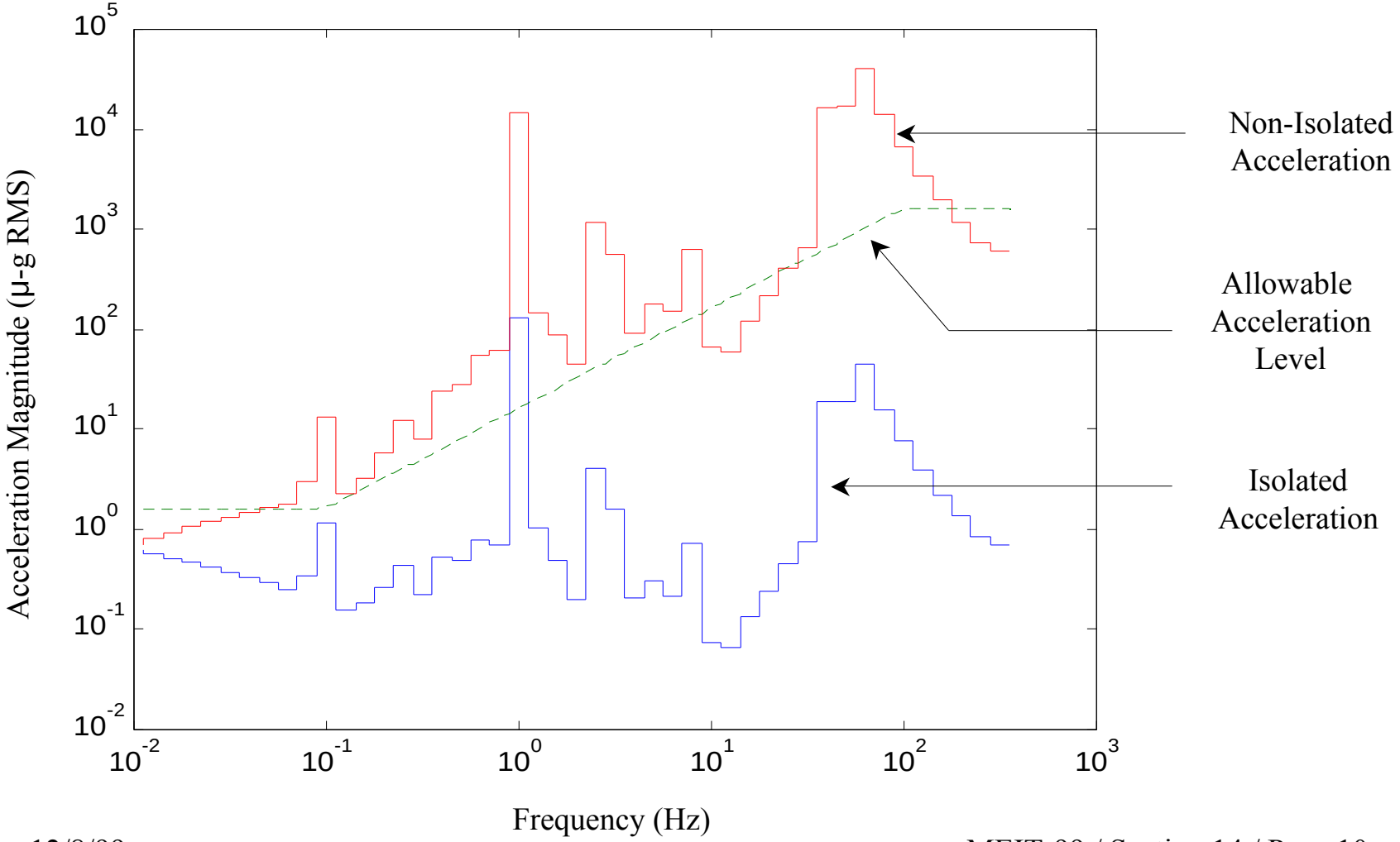
The trade depends on:

- uncertainties in the dynamics of the system:
  - structural stiffness
  - multivariable coupling
  - unmodeled flexible modes
- nonlinearities
- disturbances

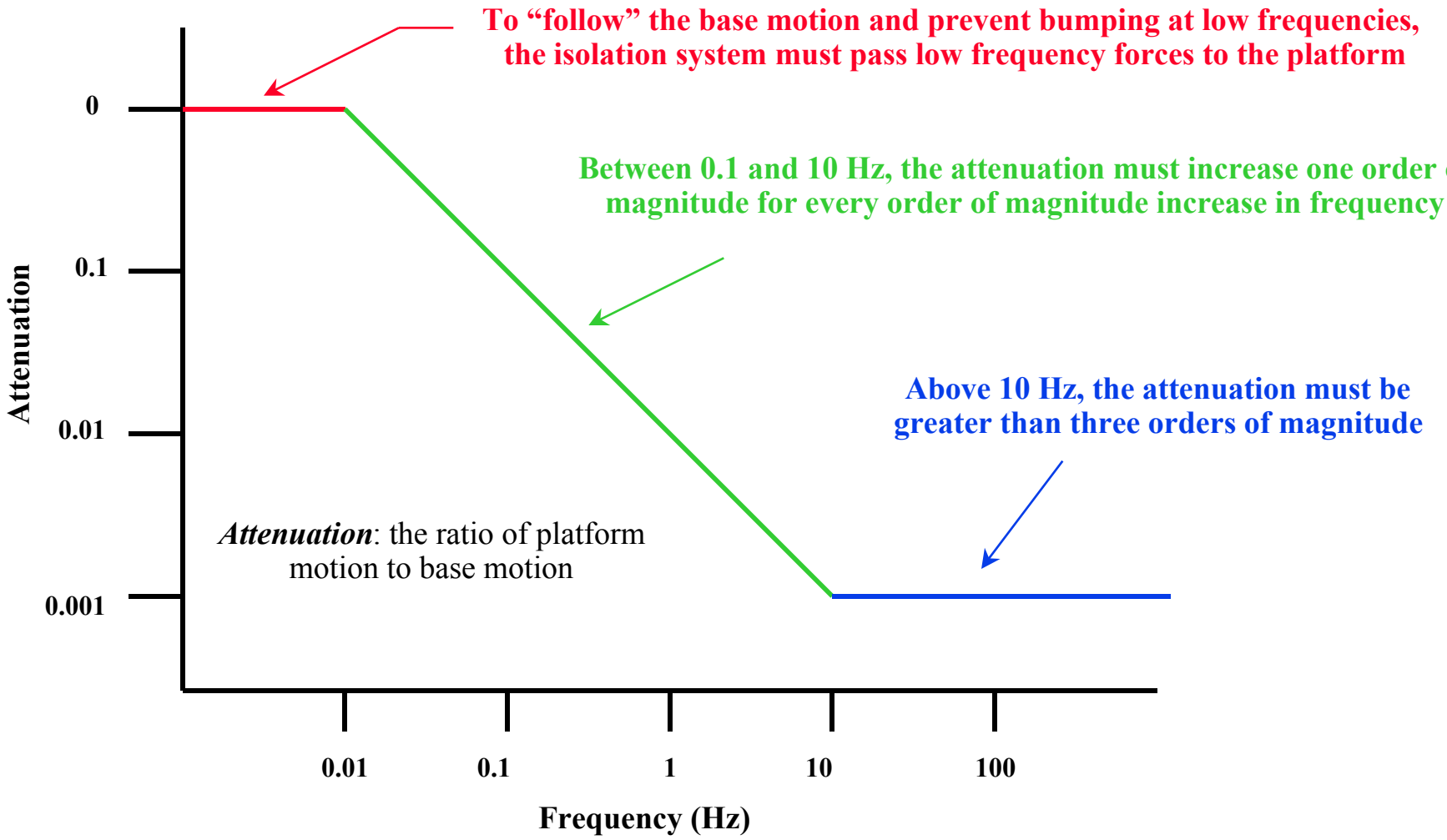
STABLE: Typical Active Isolation Time Response



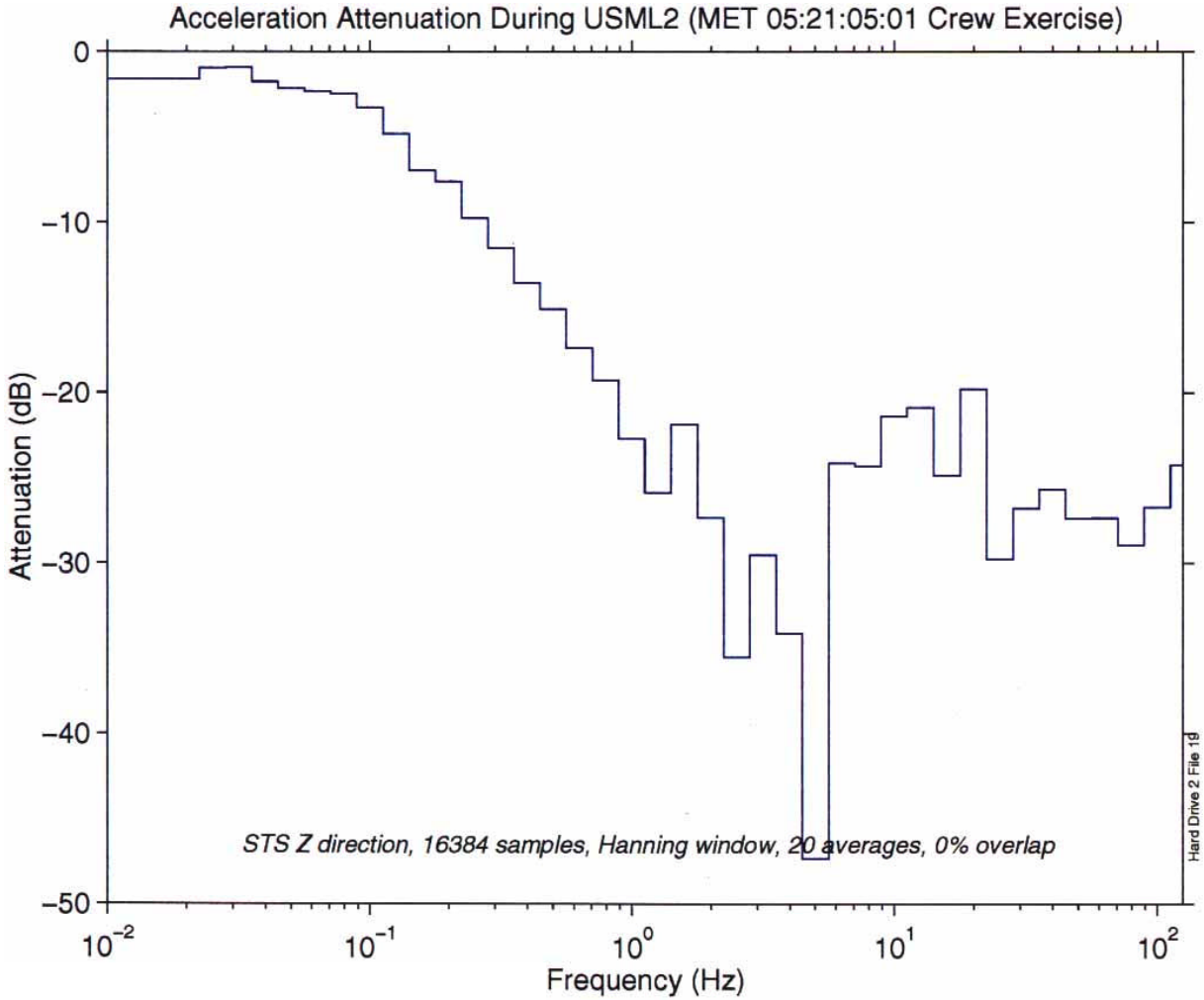
ISS Accelerations



Attenuation Requirement



STABLE: Typical Active Isolation Attenuation

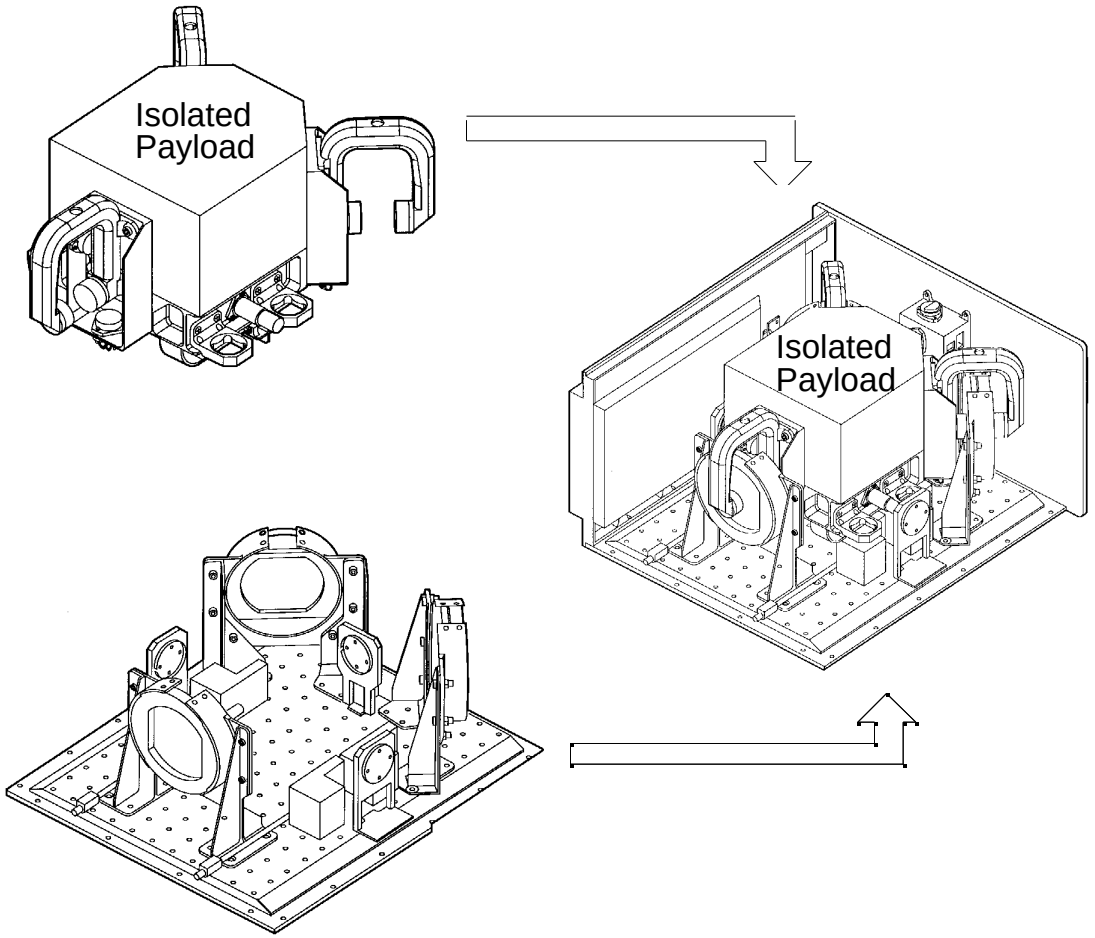


Flight Proven Systems

Isolation System	STABLE (MSFC/MDAC)	MIM (CSA)	ARIS (Boeing)
Application	Individual Experiment Isolation	Individual Experiment Isolation	Full Rack Isolation
Mission/Date	USML-2, STS-73, 10/95	Priroda/Mir, 4/96; STS-	Mir-4, STS-79, 8/96
Volume Used	<50% middeck locker	one full middeck locker	external to user volume
Current Status	Evolved to g-LIMIT; launch on UF-2	Evaluation Testing on UF-1	ARIS-ICE manifested on 6-A

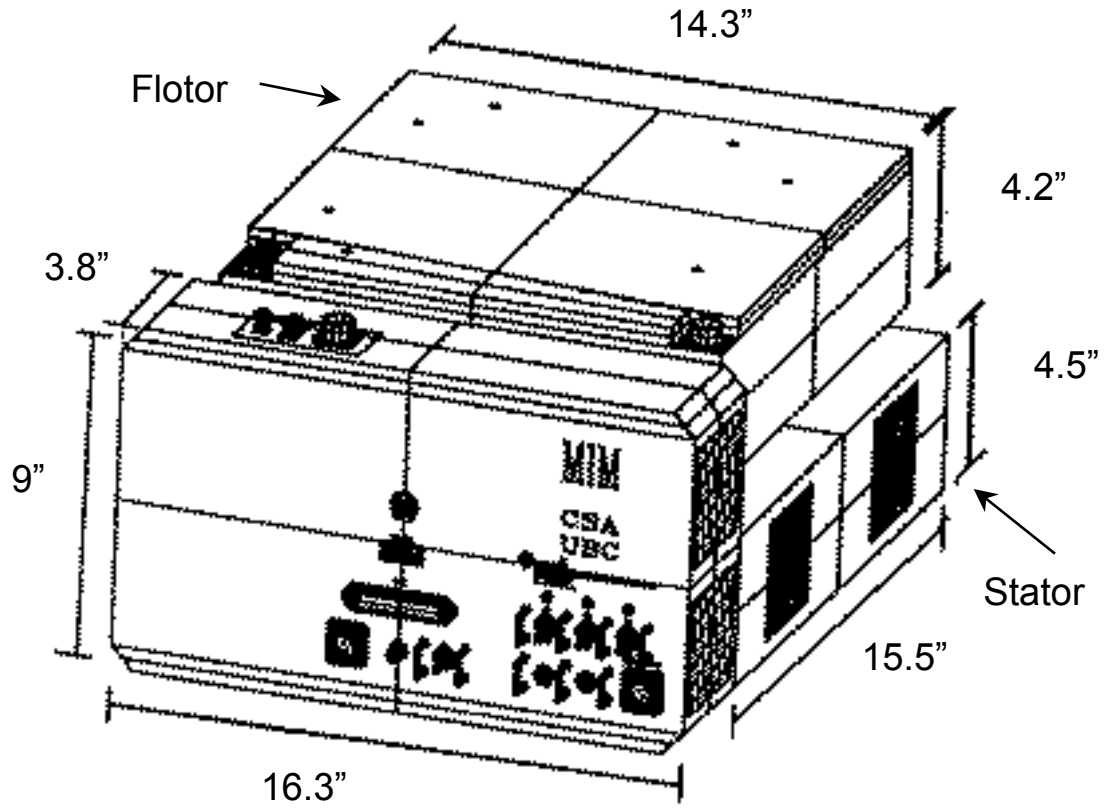
The MSFC/MDAC STABLE Vibration Isolation System

- Sub-rack isolation system
- Requires partial locker for isolation system
- High frequency active control
- Will likely meet attenuation requirement
- Well suited for dynamic payloads



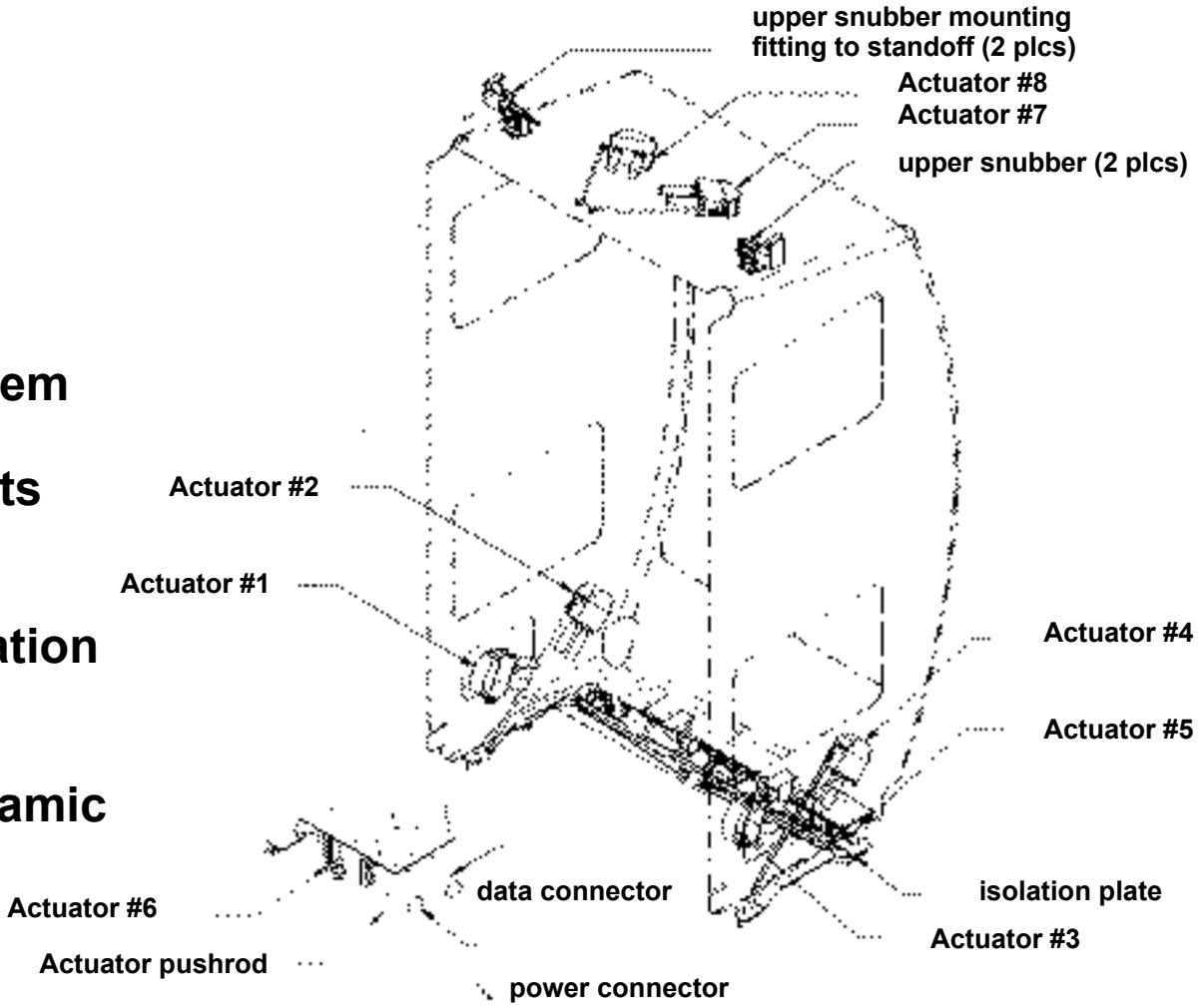
The Canadian Space Agency Microgravity Isolation Mount (MIM)

- **Sub-rack isolation system**
- **Requires full locker for isolation system**
- **High frequency active control**
- **Will likely meet attenuation requirement**
- **Well suited for dynamic payloads**



The Boeing Active Rack Isolation System (ARIS)

- Full rack isolation system
- Active control augments passive isolation
- Will likely meet attenuation req't in nominal cases
- Not well suited for dynamic payloads

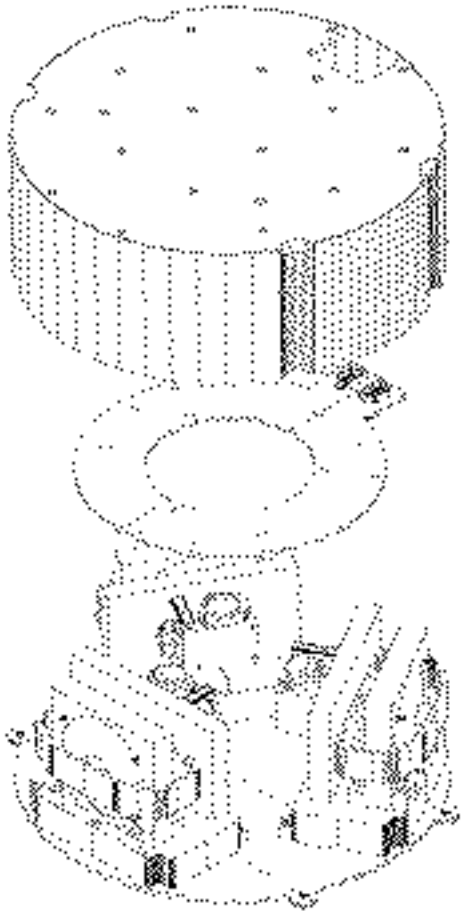


g-LIMIT

A Vibration Isolation System for the Microgravity Science Glovebox

Key Features:

- **Small Volume / Low Power**
- **Standard MSG interfaces**
- **Permits multiple experiment operation**
- **Allows crew contact with MSG during ops**
- **Accomodates larger payloads**
- **Modular/reconfigurable design**
- **Scheduled for launch: UF2/August 2000**
- **In-house development by NASA/MSFC**



Dimensions:
approx. 15” dia. x 5” tall

Comparison of Approaches

Type	Advantages	Disadvantages
Passive	•Low Cost •Low Maintenance •Reliable •No Power	•Isolate only higher freq (> 1-10 Hz) •Typically requires large volume •Cannot mitigate payload induced vibrations •Resonance vs attenuation trade
Active Rack Level (ARIS)	•Low freq attenuation •Least power & volume (mult. payloads/single unit) •standard user interface	•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)	•Low freq attenuation •Mitigates payload induced vibration •can be optimized for individual user	•More power & volume than rack-level (single payload/single unit)