

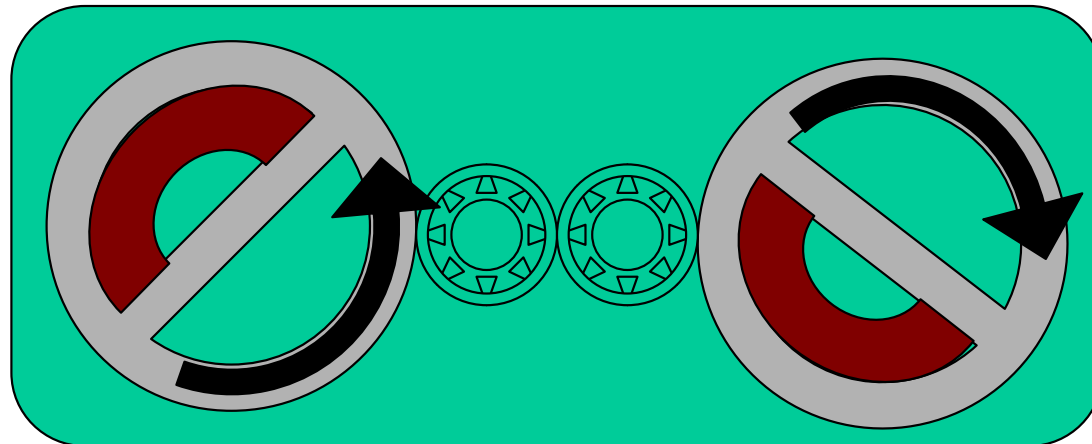
Designing to “Impossible” Vibration Tolerances

**Presented to the August Meeting of the Hospital
Engineers Society of Northern Illinois**

August 15, 2008 – Freeport, Illinois

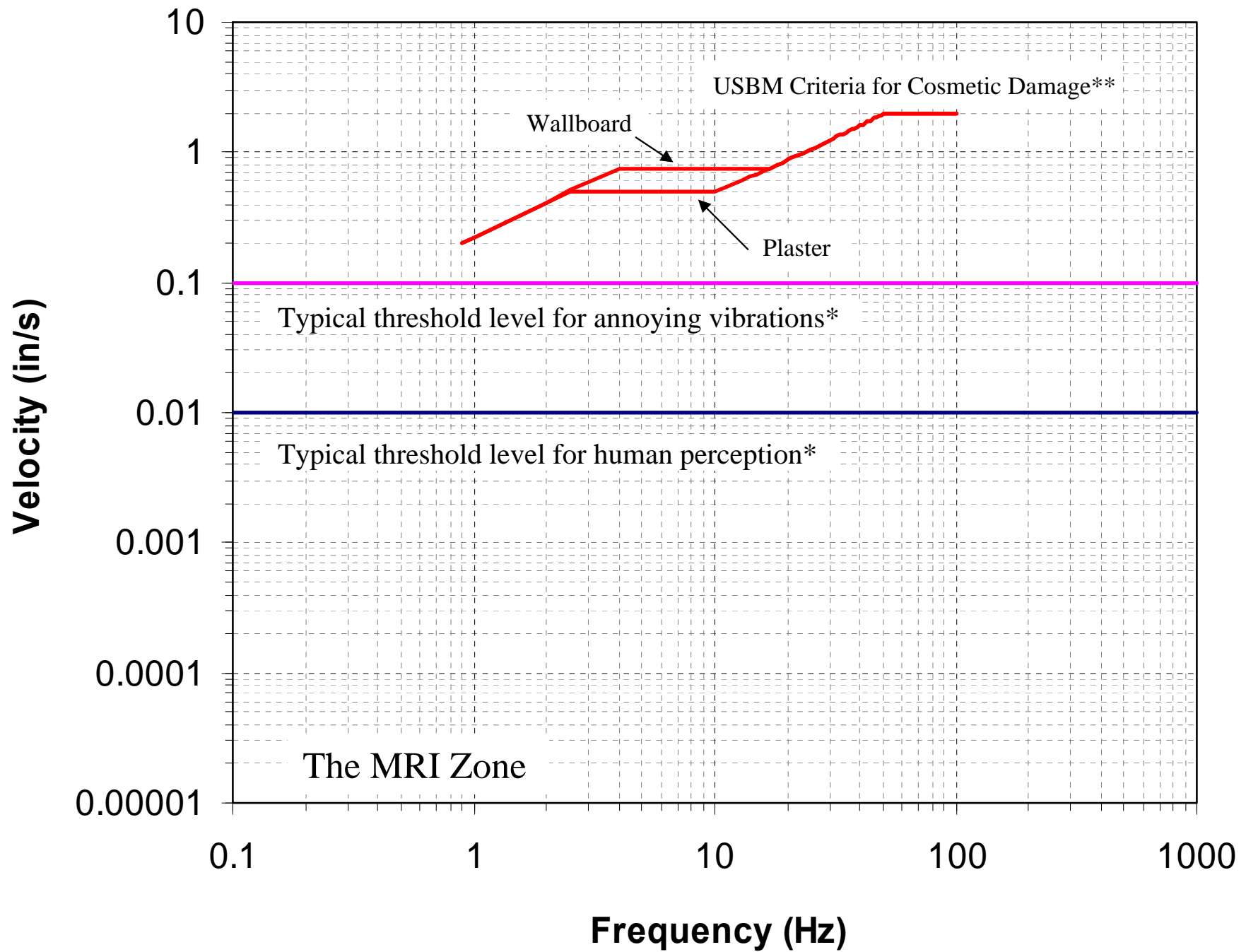
**Bernard H. Hertlein
STS-AECOM**

CEBTP Structure Shaker



Counter-rotating variable speed adjustable weights

Capable of making an 18-story building move 3 feet

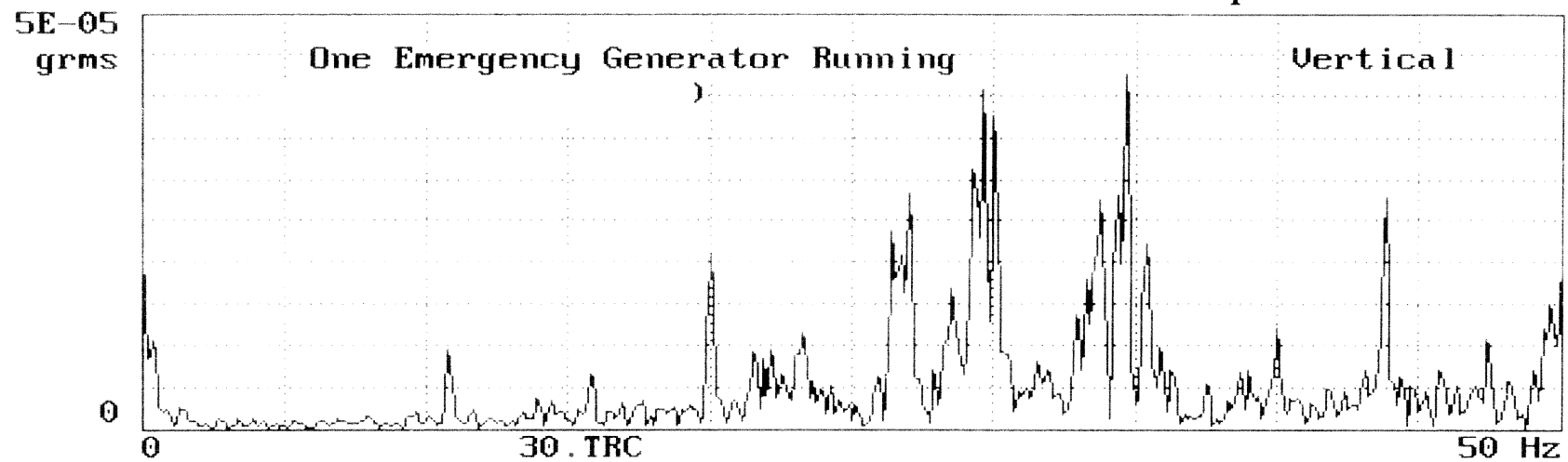


* Reiher-Meister Scale

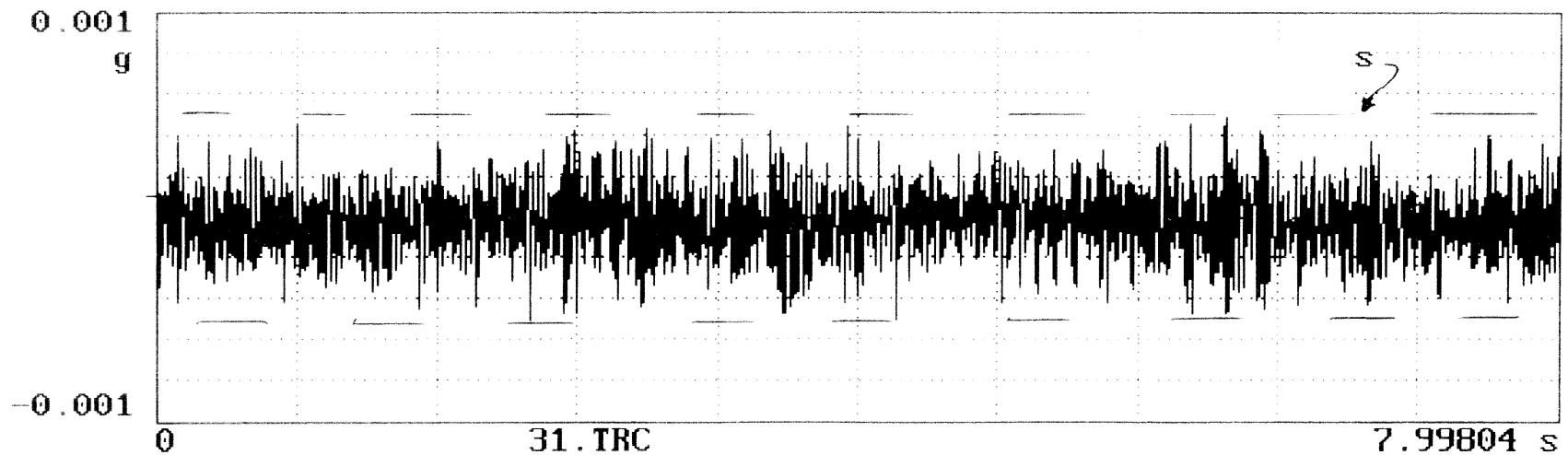
** US Bureau of Mines

Plot of Typical Generator Vibration

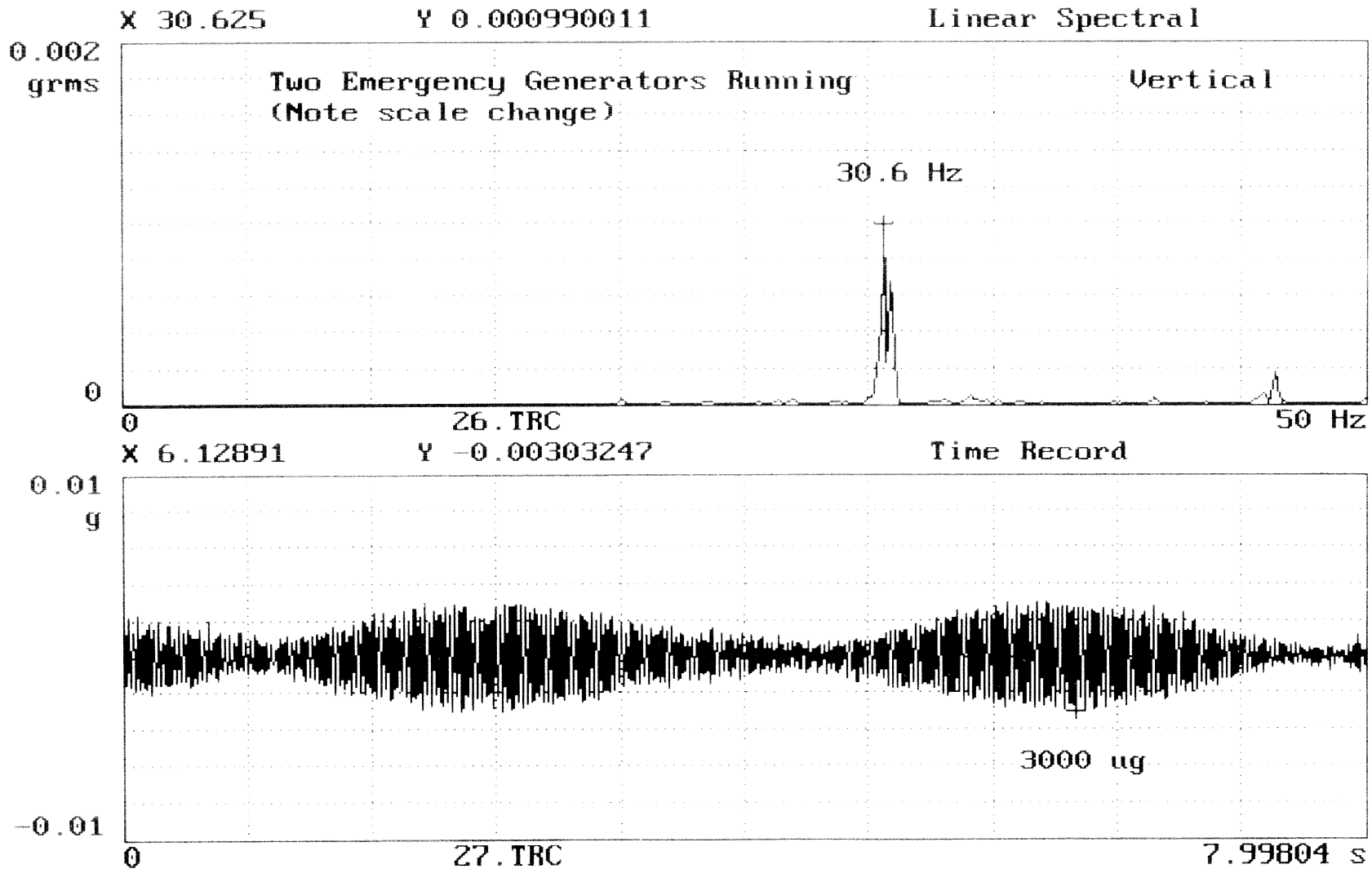
Linear Spectral



Time Record



Beat Frequency Amplification



The Overlooked Equipment



Inadvertent Bypass of Isolation

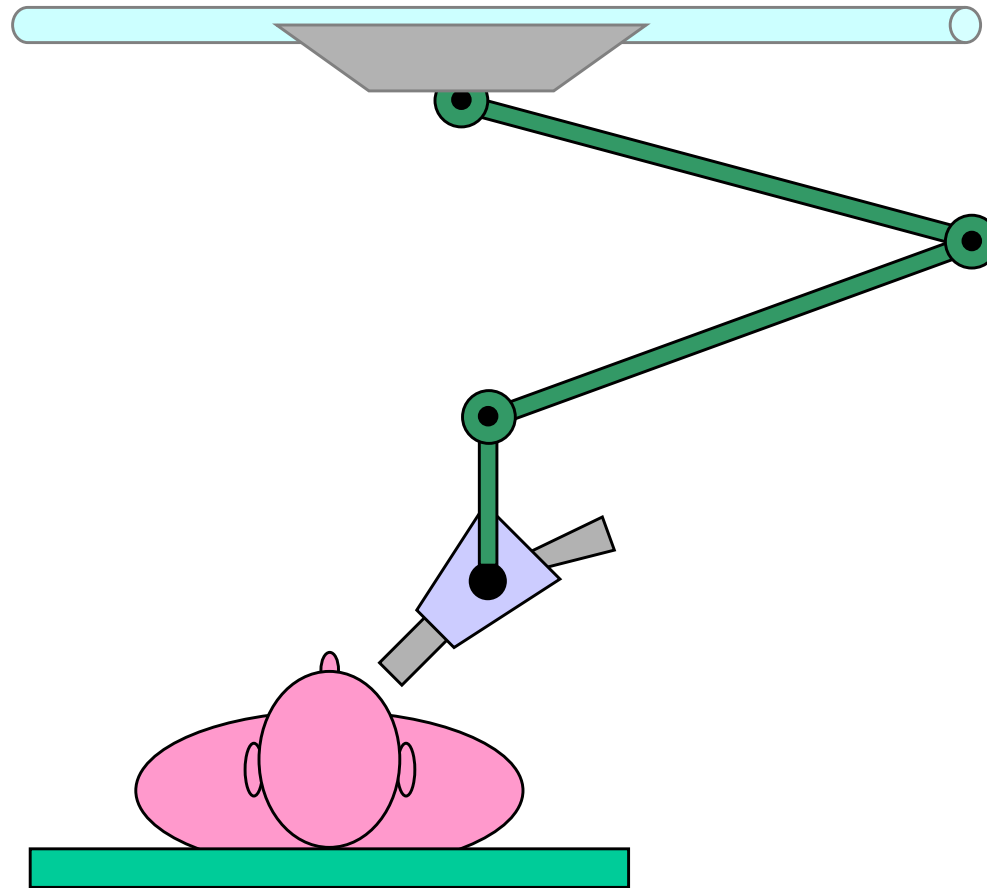


As Resolution improves, Vibration Tolerances Become Tighter.

Comparison:

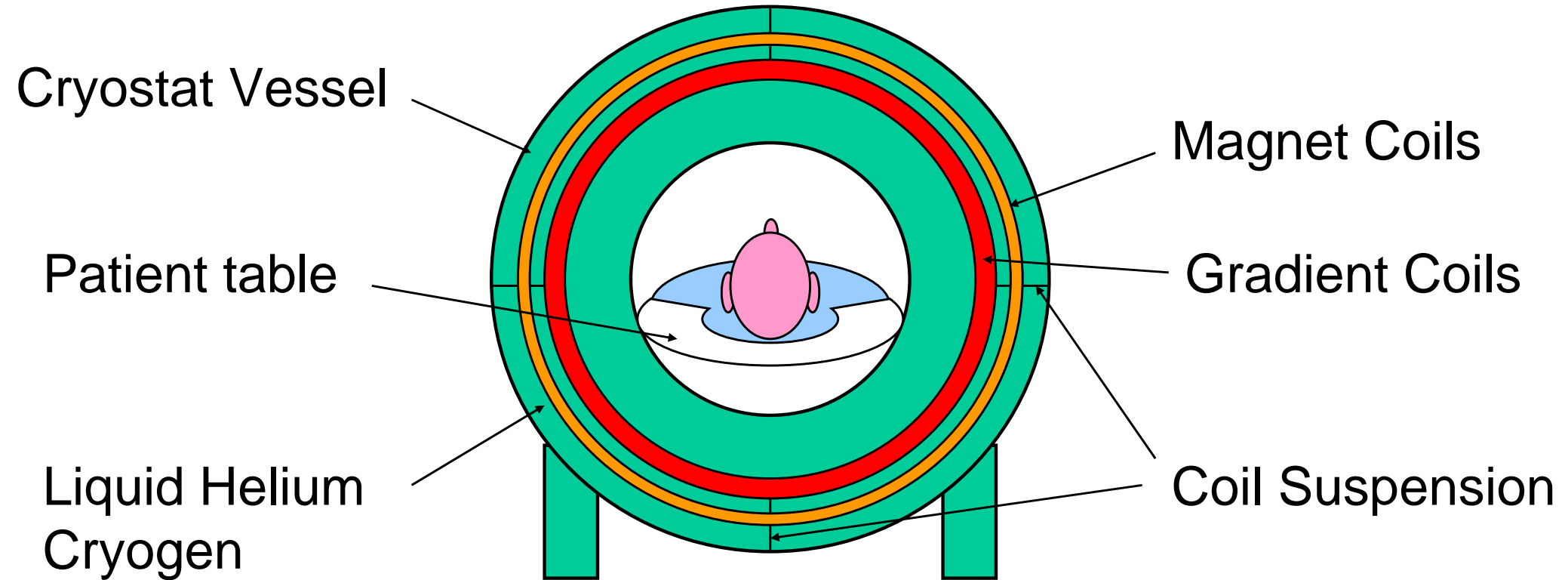
- Semiconductor producers commonly require ground displacement limits of less than 1 μm**
- Precision CMM manufacturers specify a maximum displacement of 10 μm**
- MRI System manufacturers require acceleration due to vibration to be less than 1 μg**
- High-magnification surgical microscopes require displacements to be less than 1 μm**

Vibration Sensitivity of Surgical Microscopes

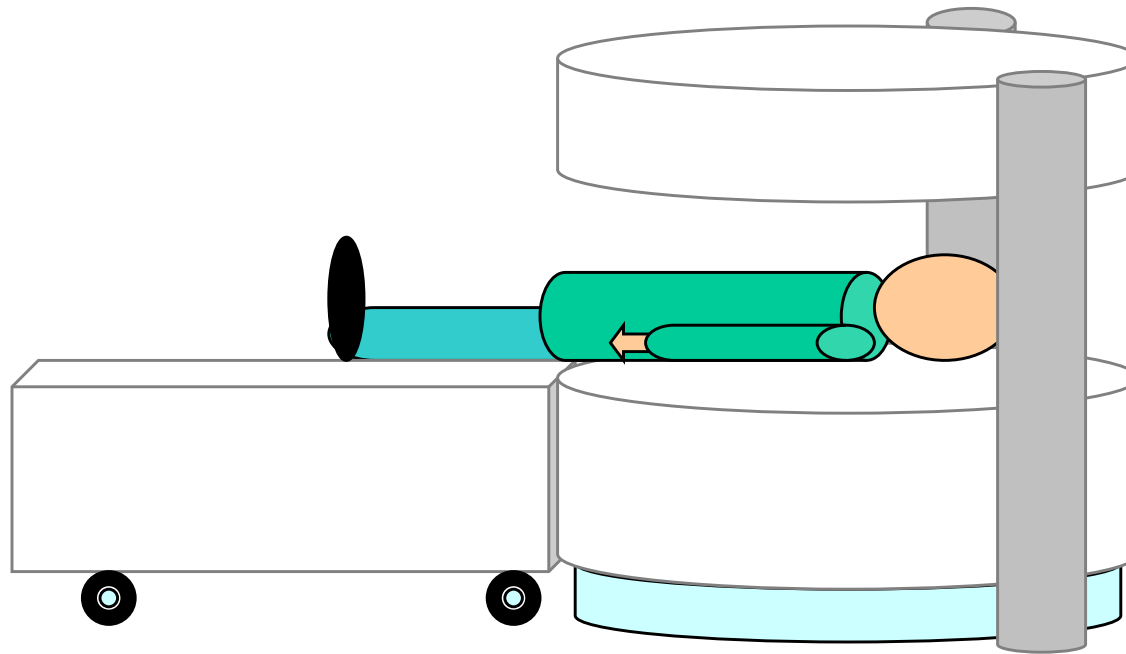


Ceiling mount maximizes maneuverability without obstructing floor, but increases vibration sensitivity

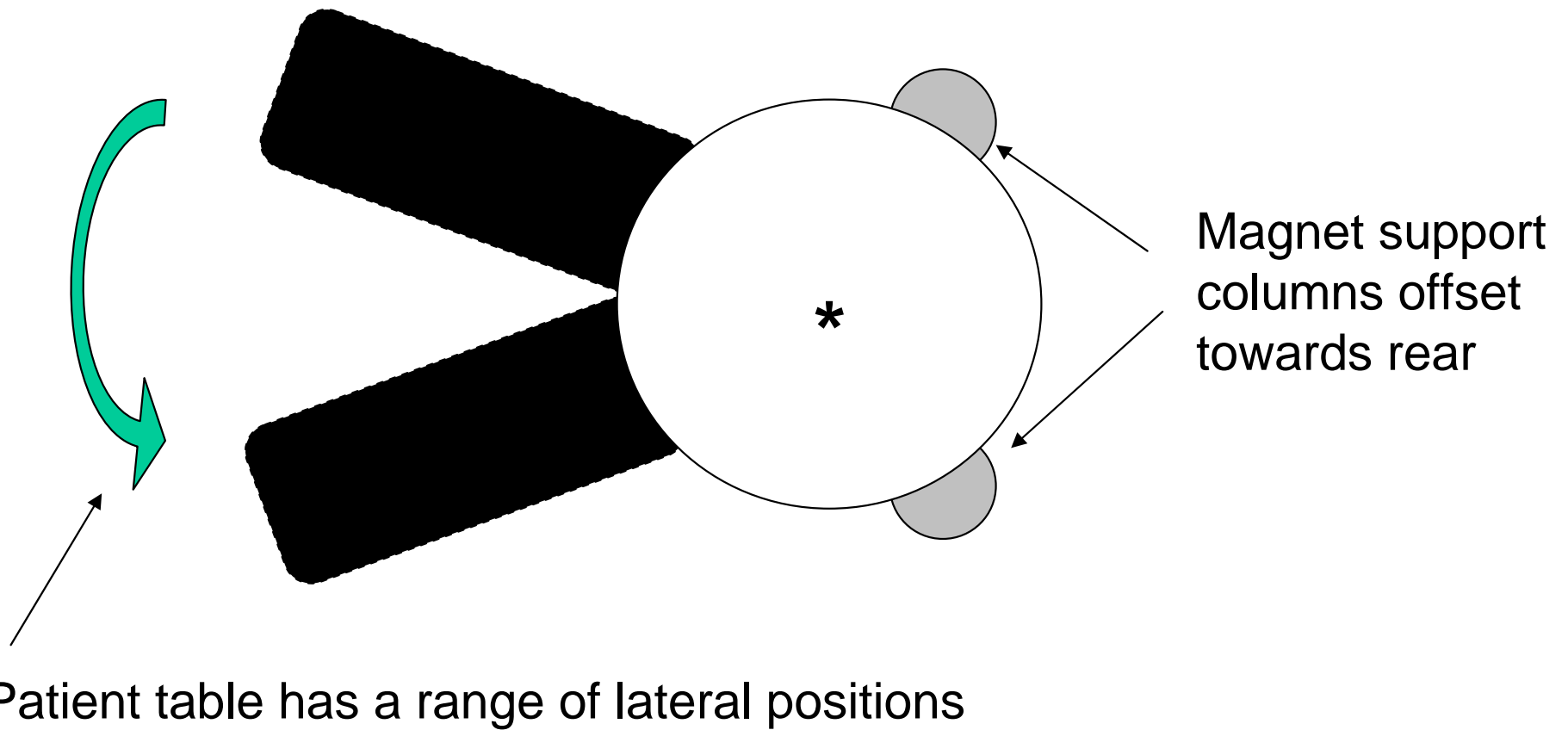
The Cause of MRI Vibration Sensitivity



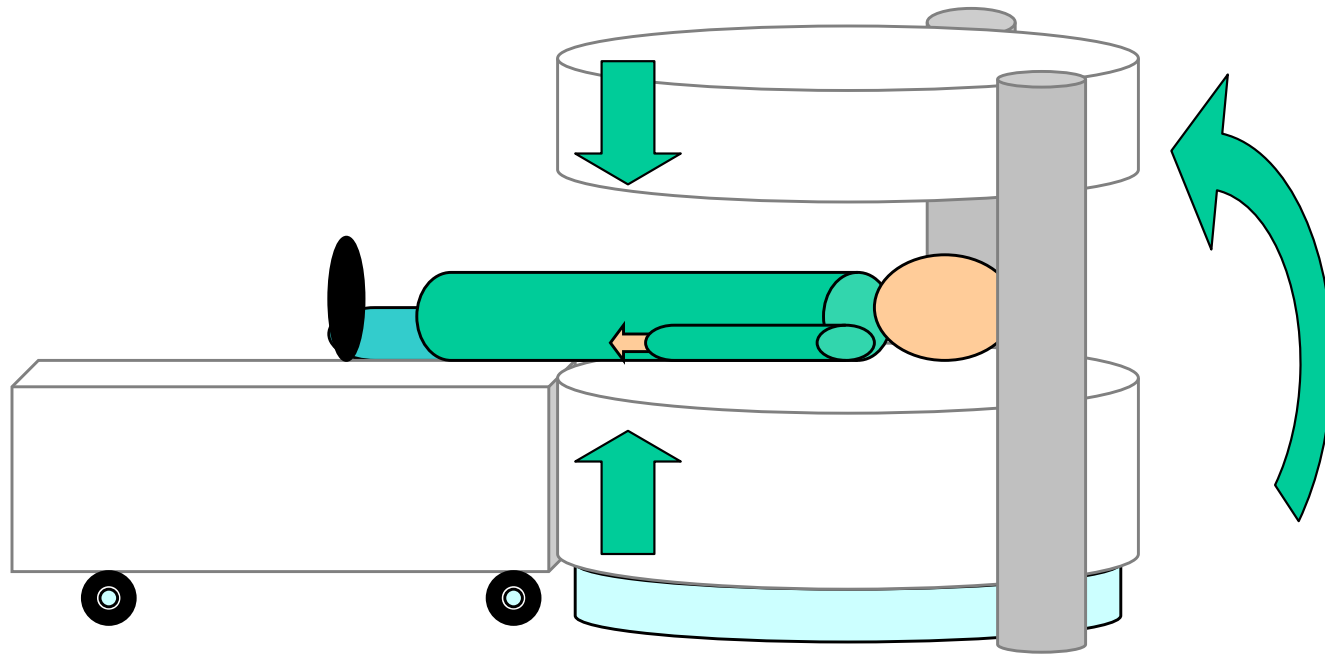
Variation On A Theme - The Open MRI



For Maximum Flexibility In Centering The Patient At The “Sweet-spot”



Battling Magnets.....



If the floor is not thick enough or stiff enough it will be unable to restrain the magnet motion. Uniform support of the floor slab is important.

To optimize the vibration environment for sensitive imaging equipment we must:

- Measure vibrations to levels far below those perceivable by humans**
- Identify the vibration sources**
- Identify the natural frequencies of the structure and the machinery in question**
- Determine maintenance needs**
- Evaluate possible vibration reduction measures**

Hidden Causes of Vibration Problems

Machine wear or imbalance is not always the culprit:

- Turbulent airflow causes plenum chambers and ducts to vibrate.
- Settlement of subgrade can leave machine foundations unevenly supported (“soft foot”).
- Movement of machine foundations can cause misalignment.
- Retrofit, repair or modification by uninformed personnel can result in bypass of isolation mountings.
- Commissioning checks should be performed by personnel that understand the design requirements.

Maintenance problem causes vibration

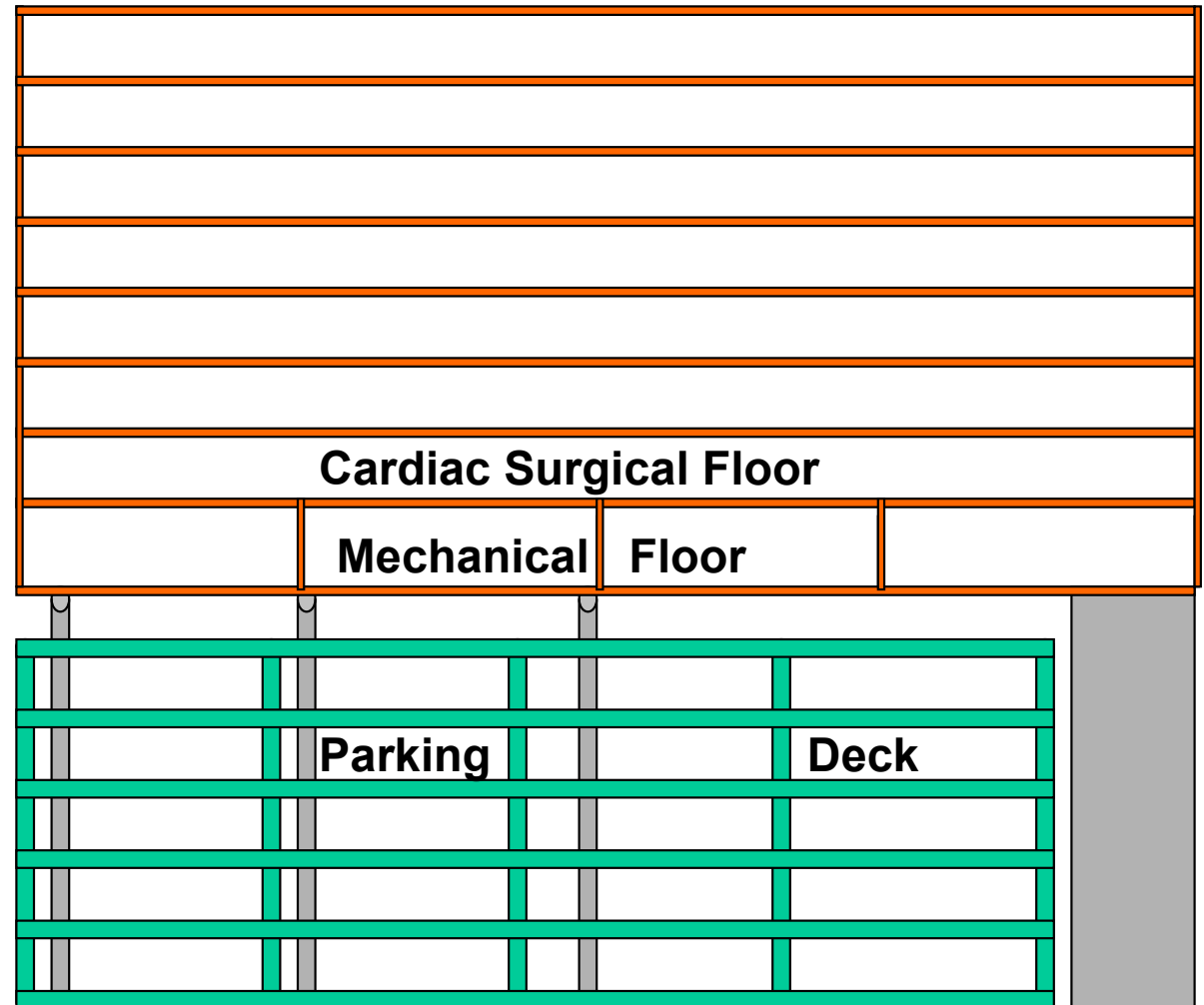
Vibration causes image problems

Repeating scans reduces efficiency and income

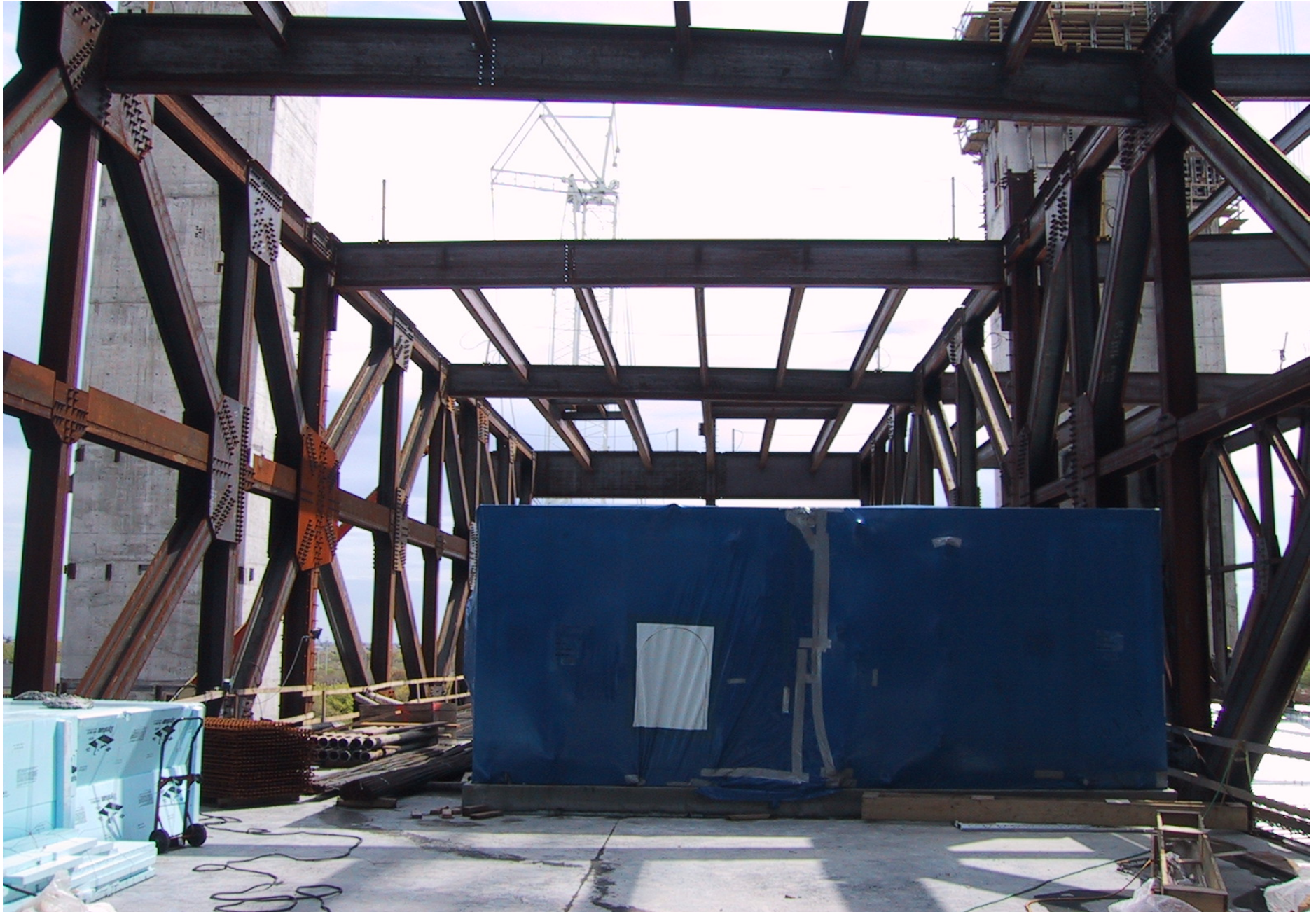
MRI downtime can cost \$25,000/day

New Cardiac Surgery Tower

- Tower must straddle existing parking deck
- Cardiac OR's located over mechanical floor
- Main trusses largest span >130 feet
- Vibrations must meet spec for surgical microscopes



30' Deep Truss Design



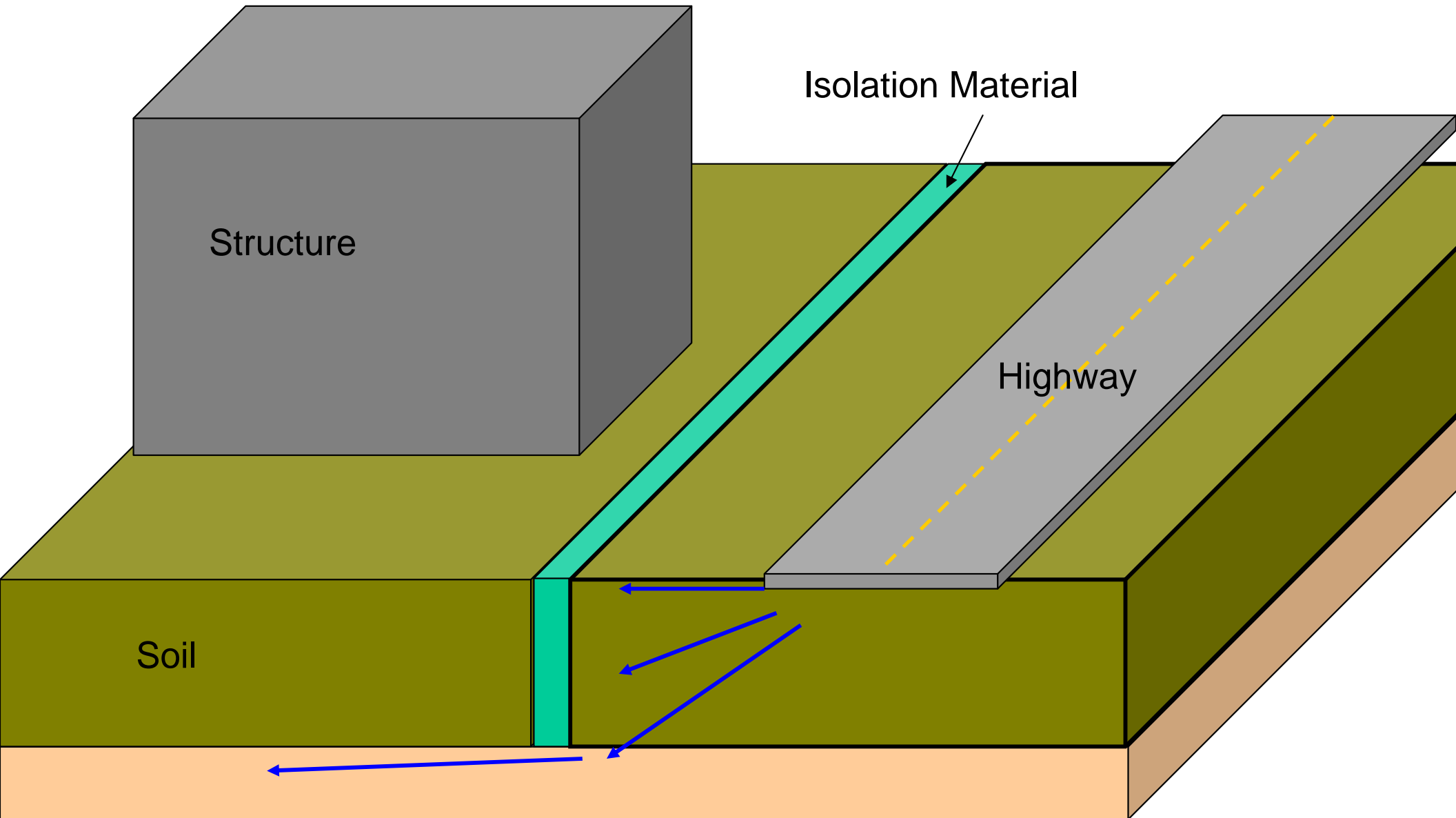
Design Validation by Modeling

- **Finite Element Model (FEM) is constructed**
- **Vibration tests are performed at stages during construction**
- **Test data is used to adjust FEM to approximate the dynamics of the real structure**
- **Structural behavior after the next phase of construction is predicted**

Increasing The Intrinsic Vibration Damping Capability of Structures

- **Injection-grout slab-on-grade**
- **Add beams or trusses to supported slab**
- **Add king trusses to existing beams**
- **Add columns or load-bearing walls beneath slab**
- **Add mass**

Geotechnical Vibration Barrier

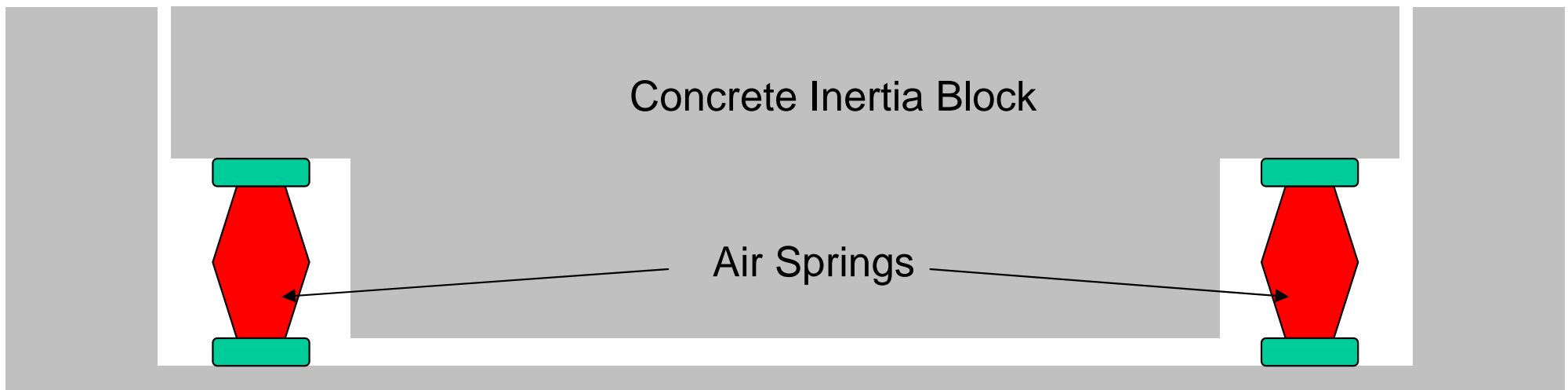


Active Damping Systems (Electromagnetic shaker)

- **Too much mass required – Inertia and hysteresis limit effectiveness to very low frequencies**
- **Typically require too much movement to activate the system**
- **Long-term maintenance issue**

Isolated Foundation Slabs

- Isolate the vibration source – spring isolators are often sufficient
- Isolate the sensitive equipment – inertia mass required



Conclusion

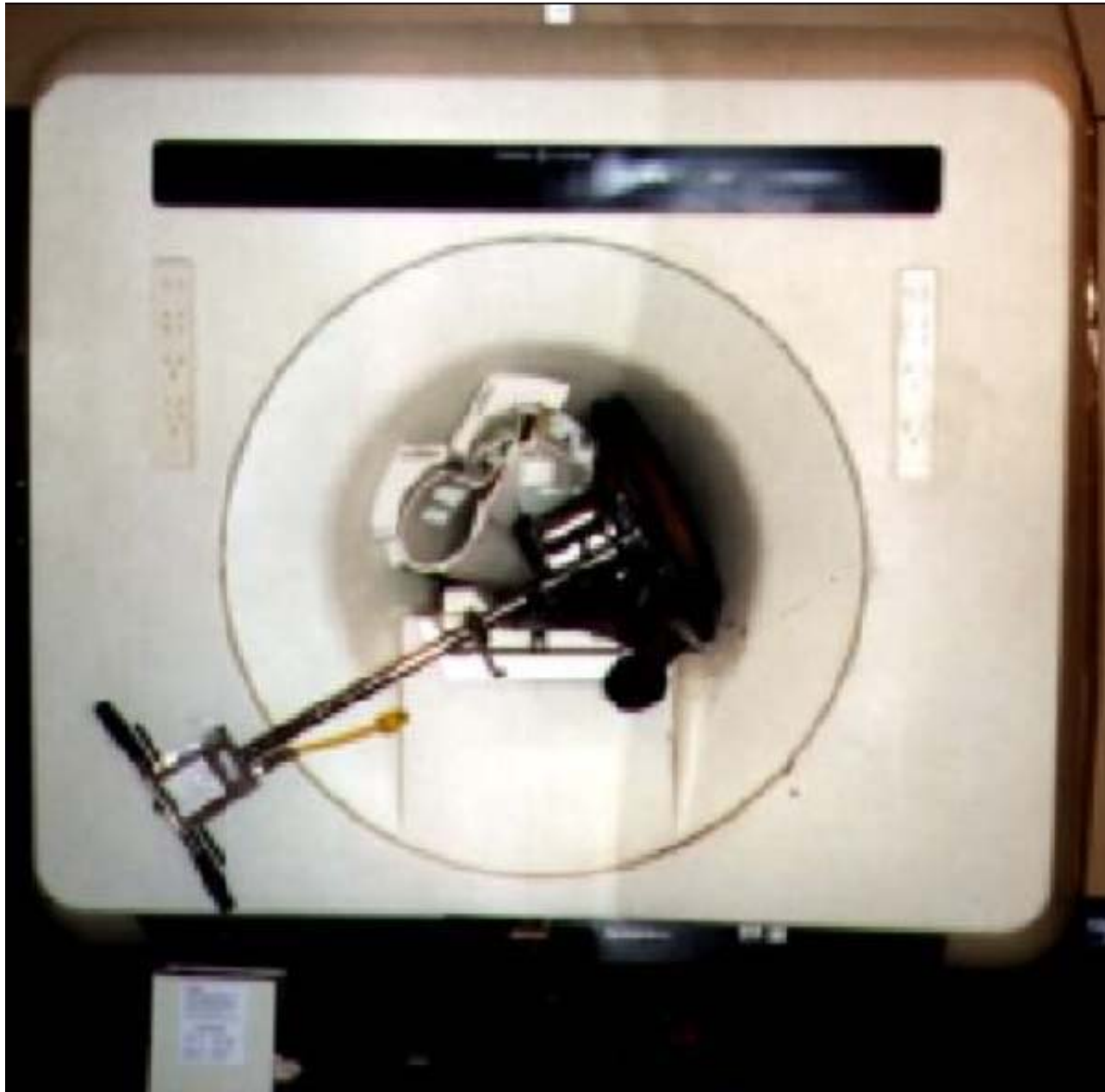
- **Control or elimination of structural vibration is becoming increasingly important.**
- **Computer modeling is enabling structural engineers to “push the envelope”.**
- **NDE and high-resolution vibration measurements provide vital data for the design validation process, and permit design modification “on the fly”.**
- **Maintenance is critical - Annual “Vibration Inventory” aids predictive maintenance programs, and catches potentially costly modification errors.**

Afterword – MRI Safety

DANGER! Flying Objects!

Once you've been in the MRI field for any length of time, you start hearing all of the various horror stories about things that have flown into a scanner. Often, newcomers don't take the real danger of flying objects seriously until they witness an oxygen tank or gurney flying into a magnet themselves. The link below is to a page that contains a collection of pictures and stories of metallic projectiles. Please show this page to all MRI newcomers, for their own safety and the safety of their patients!

http://www.simplyphysics.com/flying_objects.html



Photograph courtesy of www.simplyphysics.com



Photograph courtesy of www.simplyphysics.com

Everyone should do it:

- **Google MRI Safety.**
- **Check out the Joint Commission *Sentinel Event Alert #38* on MRI accidents.**
- **Check out www.MRISafety.com.**
- **Educate facility maintenance and janitorial personnel.**