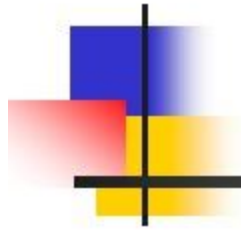


# Successful Implementation of Vibration Control During Museum Construction Projects



Mervin Richard  
National Gallery of Art, Washington DC





# Introduction

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- Introductions
  - **Merv Richard**
    - Chief of Conservation at the National Gallery of Art, Washington
  - **Frank Zuccari**
    - Grainger Executive Director of Conservation at the Art Institute of Chicago
  - **Arne Johnson**
    - Principal Wiss, Janney, Elstner Associates in Northbrook, Illinois
    - Licensed structural engineer
    - Vibration control expert for numerous historic building and museums
  - **W. Robert Hannen**
    - Associate Principal of experience at Wiss, Janney, Elstner Associates in Northbrook, Illinois
    - Licensed structural engineer

# Path Forward



Johan Barthold Jongkind  
The Towpath  
Dutch, 1819 – 1891  
2006.128.22



# Path Forward

---

- Need for vibration control during Museum Construction
  - National Gallery of Art
  - Art Institute of Chicago
- Technical presentation
  - Effects of vibrations
  - Recommended vibration limits
  - Vibration control and monitoring
- Demonstration
- Wrap-up
- Q&A

# National Gallery of Art

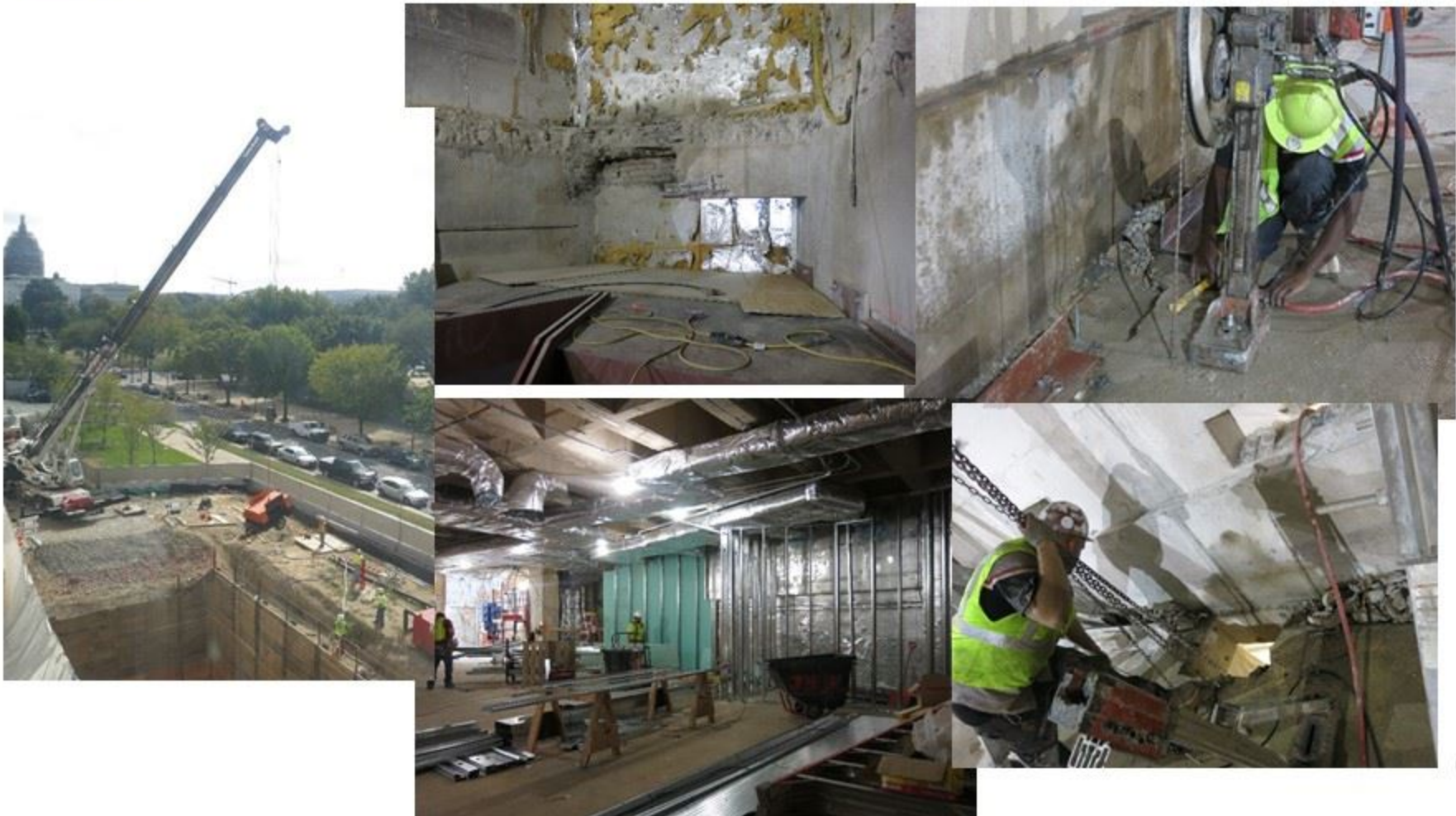


East Building opened 1978



East Building renovation 2013-present

# National Gallery of Art



# National Gallery of Art



Oh My! What a mess!

# National Gallery of Art



Limits (Very conservative)

- 70 decibels adjusted (dBA) for sound
- Peak particle velocity of 0.02 in/sec for vibration





# National Gallery of Art

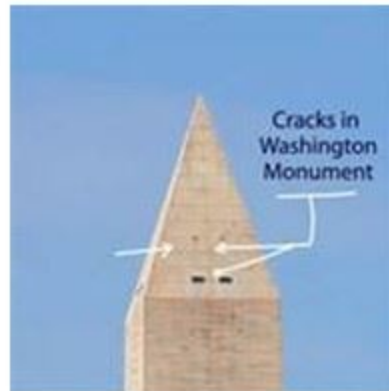
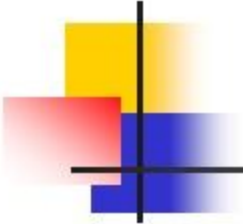
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## Observations

- Outside consultants critical to project
- Rarely exceeded specifications
- Most complaints about sound levels
- Real-time reporting and response critical
- No problems with art

# Earthquake

August 23, 2011



Peak particle velocity at National Gallery

- >1.25 in/sec
- Limit = of 0.02 in/sec

# Thank You for Listening



Rogier van der Weyden  
Portrait of a Lady  
Netherlandish, c. 1460  
Oil on panel  
1937.1.44

ART  
INSTITUTE  
CHICAGO

# The Art Institute of Chicago



The Modern Wing (c. 2009)

[www.wje.com](http://www.wje.com)

**WJE** | ENGINEERS  
ARCHITECTS  
MATERIALS SCIENTISTS

Wiss, Janney, Elstner Associates, Inc.

Frank Zuccari, Art Institute of Chicago  
Arne Johnson and Robert Hannen, WJE



# Planning for Construction of the Modern Wing

Groundbreaking Ceremony  
May 31, 2005



Opening on May 16, 2009

# Predicting the Impact of Vibrations on Artwork

## Object Characteristics

- Size
- Weight
- Shape
- Material
- Construction Method
- Condition
- Treatment History

## Vibration Characteristics

- Amplitude
- Frequency
- Duration



# A Need for Certainty

- Which artworks will need to be de-installed or relocated?
- How much temporary art storage will we need?
- Do any galleries need to be closed to the public?
  
- What would be a safe vibration limit during construction?
- How do we effectively monitor vibrations?
- How do we enforce the agreed upon limit?



# Overriding Goals

- Keeping artwork safe through all phases of construction
- Avoiding costly suspensions of construction once it has begun





# From Ambiguity to Certainty

- Which artworks will need to be de-installed or relocated?
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- 
- What would be a safe vibration limit during construction?
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# References

- *Vibration Control During Museum Construction Projects*, Arne Johnson, Bob Hannen and Frank Zuccari, *Journal of the American Institute for Conservation*, 2013
- *Vibration Limits for Historic Buildings and Art Collections*, Arne Johnson and Bob Hannen, *APT Bulletin - Journal of Preservation Technology*, 2015

## VIBRATION CONTROL DURING MUSEUM CONSTRUCTION PROJECTS

ARNE P. JOHNSON<sup>1</sup>, W. ROBERT HANNEN<sup>1</sup>, AND FRANK ZUCCARI<sup>2</sup>

<sup>1</sup> Wiss, Janney, Elstner Associates, Inc.

<sup>2</sup> Department of Conservation, The Art Institute of Chicago, Chicago, IL, USA

*As vibrations caused by heavy construction at museums are potentially harmful to museum buildings and artwork, the protection of museum objects calls for a reliable method of vibration control. This article provides background information on vibrations and their effects on humans, buildings, and artwork, along with recommending conservative limits for protection of buildings and artwork from construction vibrations. Humans can perceive low levels of vibration before damaging levels are reached, and typical ambient (background) vibrations in museums can approach recommended limits. Research also shows that during transit, art objects are exposed to vibration levels much higher than recommended limits and damage rarely occurs. The greatest risks for damage to art objects during construction are from light objects "walking" on smooth surfaces; from the resonance of objects with natural frequencies similar to construction vibrations; and from vibratory motion of extremely fragile objects or those with serious pre-existing weaknesses. On the basis of research and the authors' experience, a general methodology for vibration control during museum construction projects is introduced—a methodology that reliably protects the museum while not unduly constraining the construction. Two examples of large-scale implementations are described to illustrate this methodology.*

**KEYWORDS:** vibration, shock, construction, museums, artwork, monitoring, vibration limits

### 1. INTRODUCTION

With virtually any kind of construction project, especially with the heavy construction such as selective demolition and foundation installation commonly associated with museum expansions, significant levels of vibrations will be transmitted into the existing buildings. Such vibrations can be damaging to irreplaceable collections as well as to adjacent galleries, which might themselves be aging structures, susceptible to transmitted vibrations.

Artwork left in place near the construction will likely be subjected to greater-than-background levels of vibrations. By their nature, aged and delicate art objects can be very sensitive to damage from vibrations and movement. But while the safety of the art is paramount and the elimination of risk imperative, relocation of artwork poses its own set of risks to collections and is disruptive to the operation of the museum.

Hence, among the difficult questions that museums must address before embarking on major construction projects, the following considerations must be taken into account: what are safe and acceptable vibration levels, what materials should be relocated, what, if any, protective measures should be employed for the artwork that remains in-place near the construction,

and what protective measures should be taken to safeguard the museum buildings themselves?

Approaches taken in response to these difficult questions are:

1. A conservative approach, in which any and all artwork that could possibly be affected by the nearby construction is relocated in advance of the construction. This approach should avert construction-related damage, but it will most likely add unnecessary cost and be disruptive to the operation of the museum.
2. A judgment-based approach, in which the museum staff decides, based on their judgment and experience, what levels of vibration are safe, which artwork can remain, and which artwork must be proactively de-installed. If, based on the staff's judgment, objectionable vibrations occur during the construction, steps are taken to mitigate damage. This approach is not only subjective and risks short-term exposure of artwork to potentially damaging vibrations, but it also risks costly construction stoppages while artwork is relocated. In addition, it fails to provide clear, quantifiable operational limits to which the contractor can be held accountable and

# Technical Presentation (Yes, I'm the engineer 😊)

## References

- **Vibration Control During Museum Construction Projects**, Arne Johnson, Bob Hannen and Frank Zuccari, Journal of the American Institute for Conservation, 2013
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DOI: 10.1111/j.1943-0263.2013.00000.x

## Vibration Limits for Historic Buildings and Art Collections

Arne P. Johnson and W. Robert Hannen

Which vibration limit is right for a particular historic building during a construction project, and how can it be implemented?



Fig. 1. The New York Art Museum, 500 West 125th Street, construction site during the renovation, 2013

Vibration limits to prevent threshold damage to typical buildings are relatively well known. However, there is no commonly accepted standard for vibration limits to protect historic buildings, and vibration limits to protect artwork and other fragile objects within historic buildings are generally not addressed in the literature. The lack of definitive information is problematic for operators of historic buildings, such as museums, that are undertaking rehabilitation or expansion that could expose the building and its collection to vibrations (Fig. 1).

There is a plethora of guidelines for the protection of historic buildings from construction vibrations, but the recommended limits vary widely and are often presented without appropriate explanation or reference to scientific basis. An conservation literature shows that the vibrations that are objects commonly experience during events between museums are several times higher than vibration limits often used to protect museum buildings and collections in situ, yet damage to art during shipment rarely occurs. This disparity suggests that the commonly used vibration limits for the protection of artwork during construction projects are overly conservative. On the other hand, the authors' experience monitoring vibrations during museum construction projects has shown that there are special risks for the artwork that need to be understood.

# Institute of Chicago



Sullivan Arch  
(c. 1893)



Modern Wing (c. 2009)



Original museum  
buildings (c. 1893+)

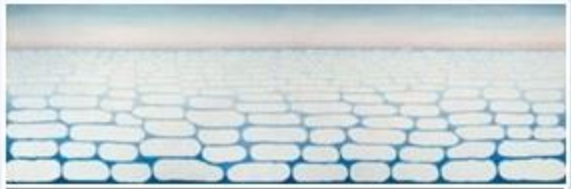
Michigan Avenue



*Old Goodman Theater*

*Mechanical Plant*

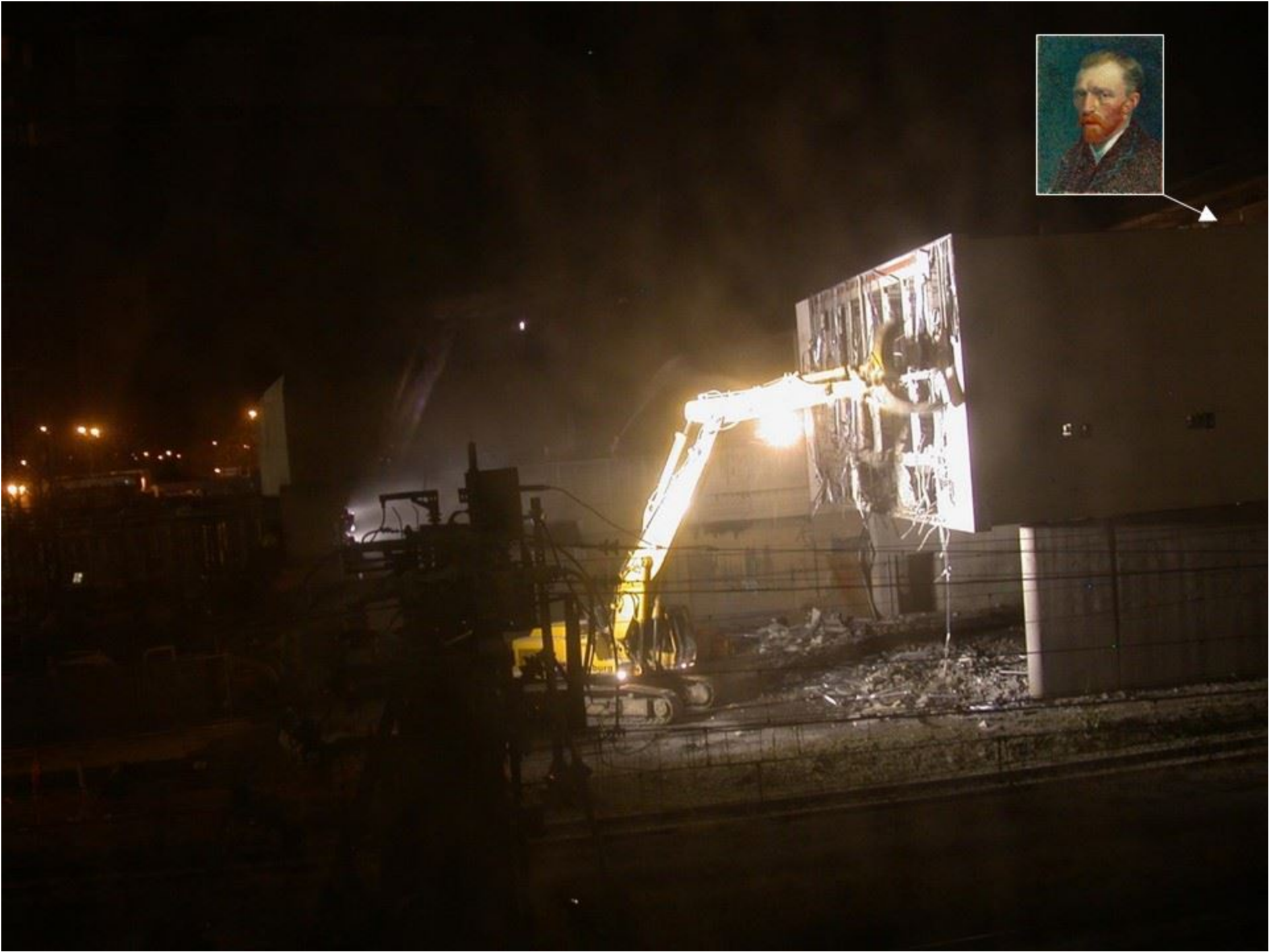
*Cooling Tower*



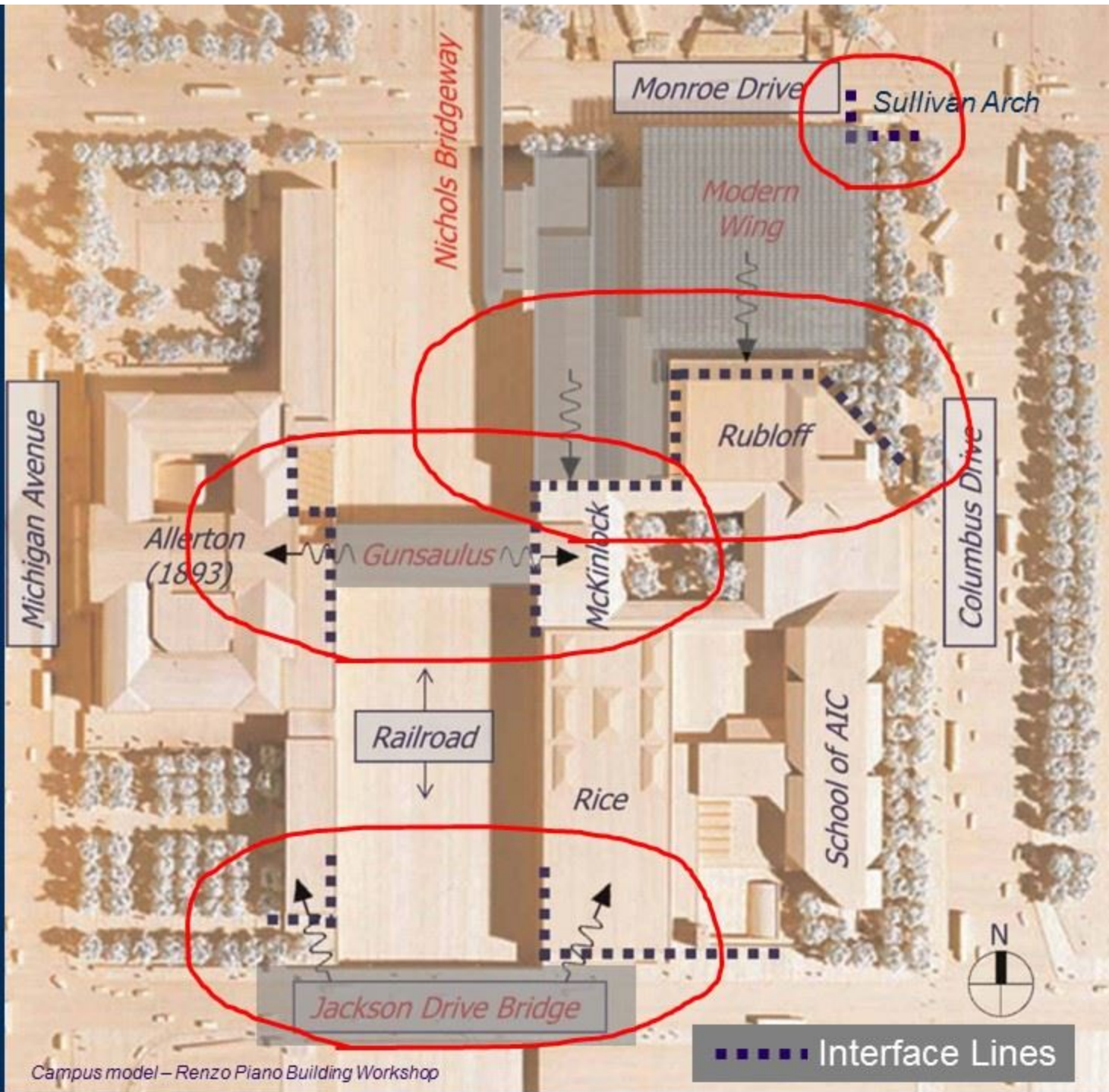
*Active galleries  
(to remain)*











# Goals of Vibration Control in Museum Context

- **Protection of collections** and museum buildings during all stages of construction
- **Guidance** to the museum, before construction starts, **to facilitate advanced planning** (what vibration levels to expect, zones where limits could be exceeded, where/what to de-install, etc.)
- During design/construction process, **reliable enforcement of clear, conservative vibration limits** without unduly encumbering the designers and contractors

Source



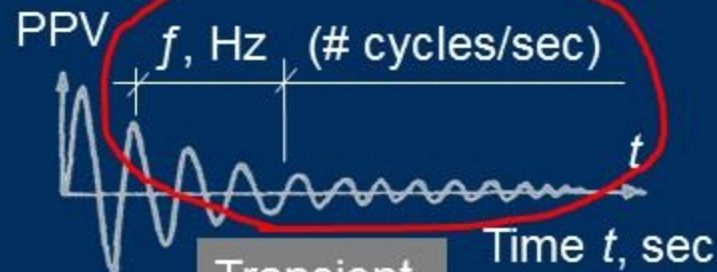
Media (Soil)



Receiver

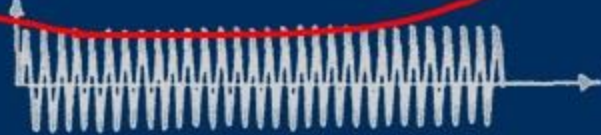


Pile driving

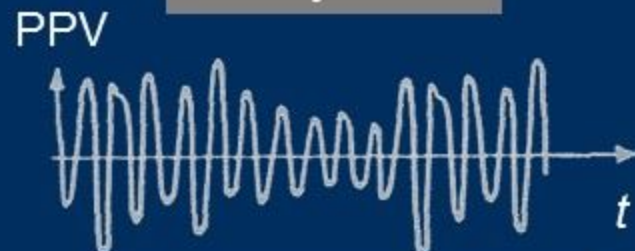


Transient

Velocity (PPV), in/sec



Steady-State



Pseudo Steady-State



Heavy masonry structure

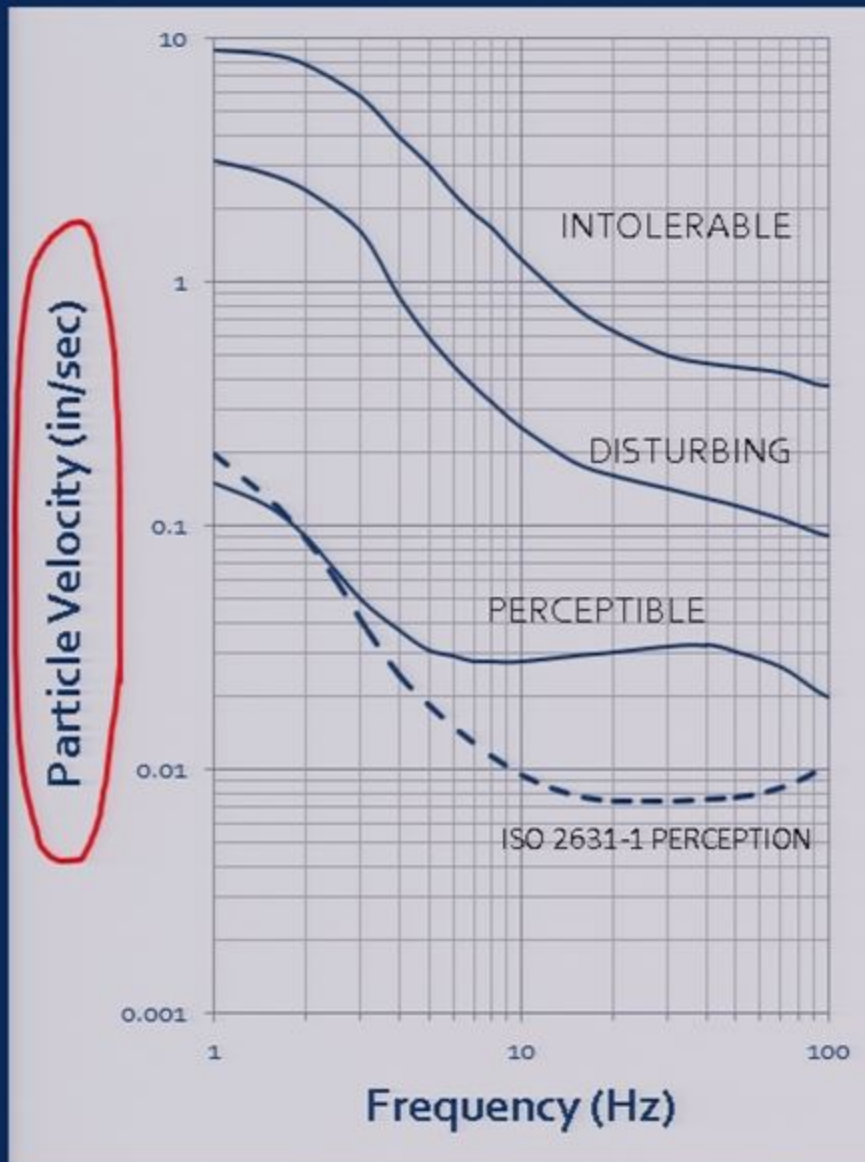


Long span railroad bridge

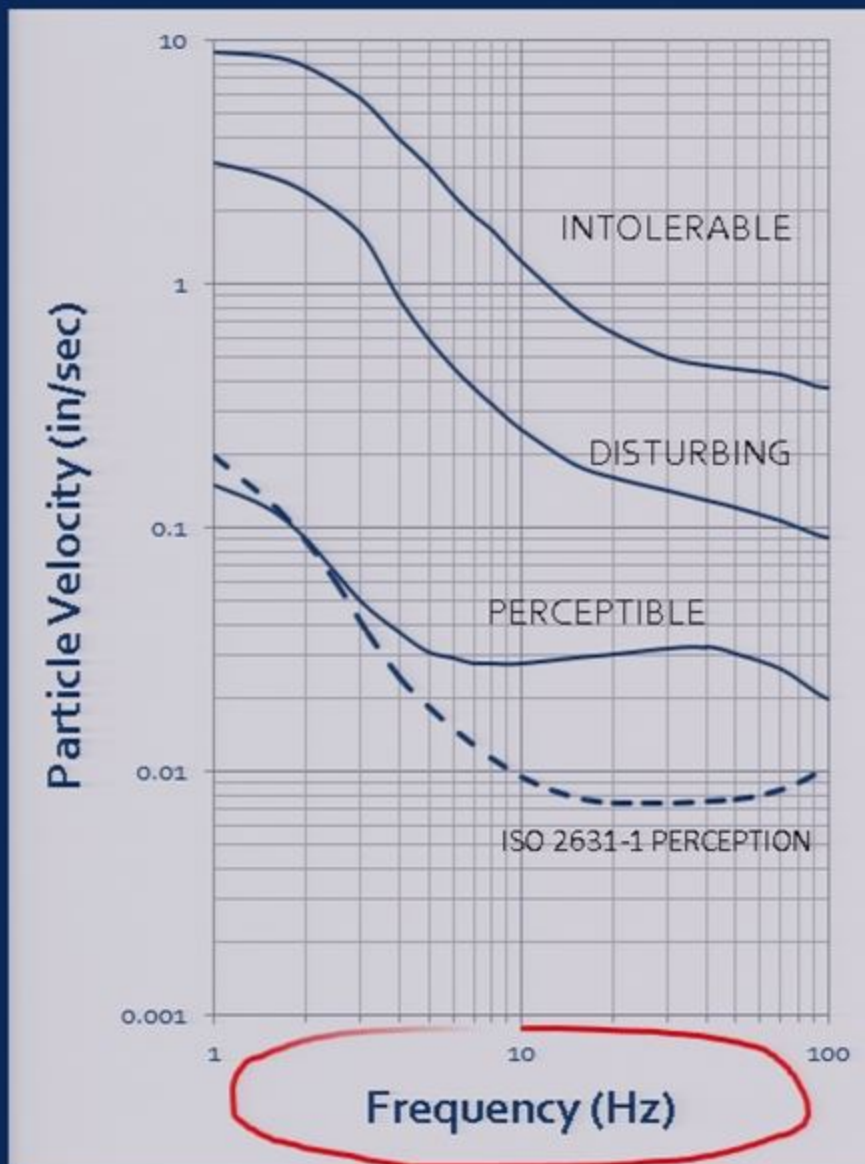


Free-standing art object

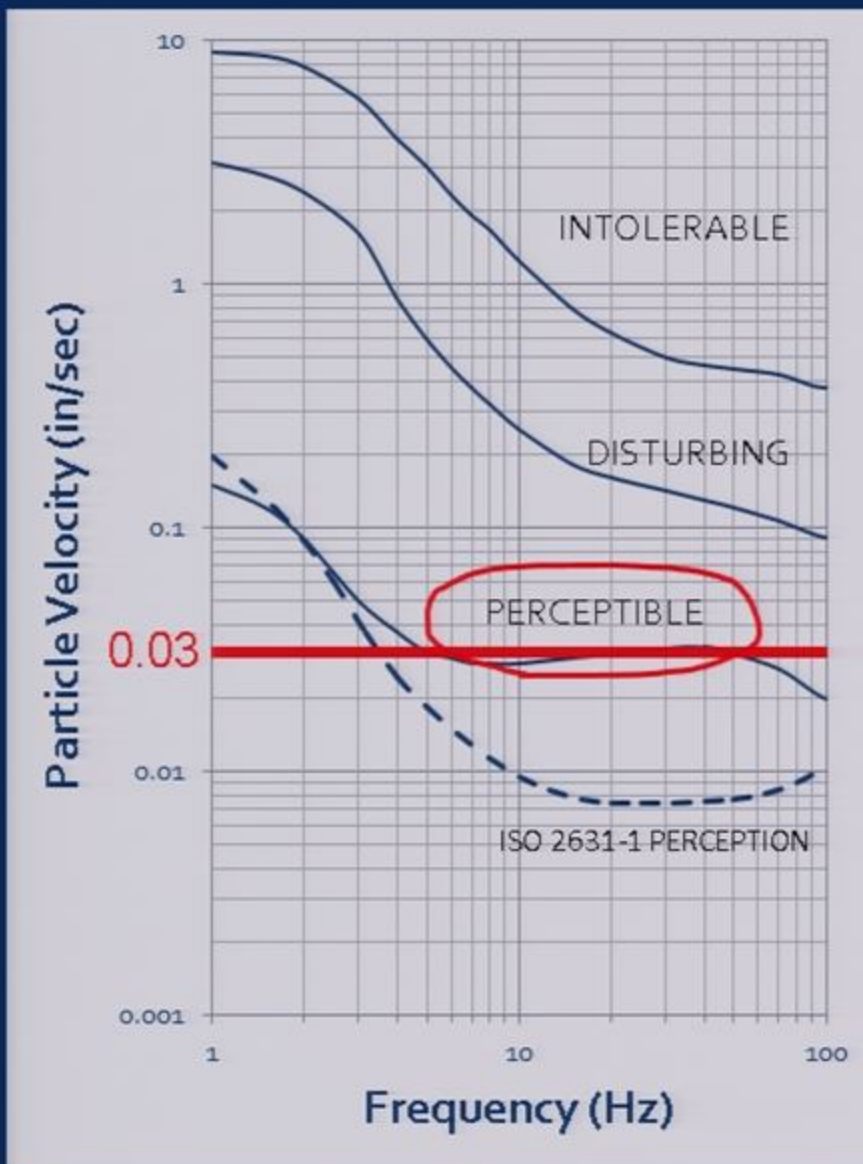
# Human Perception



# Human Perception



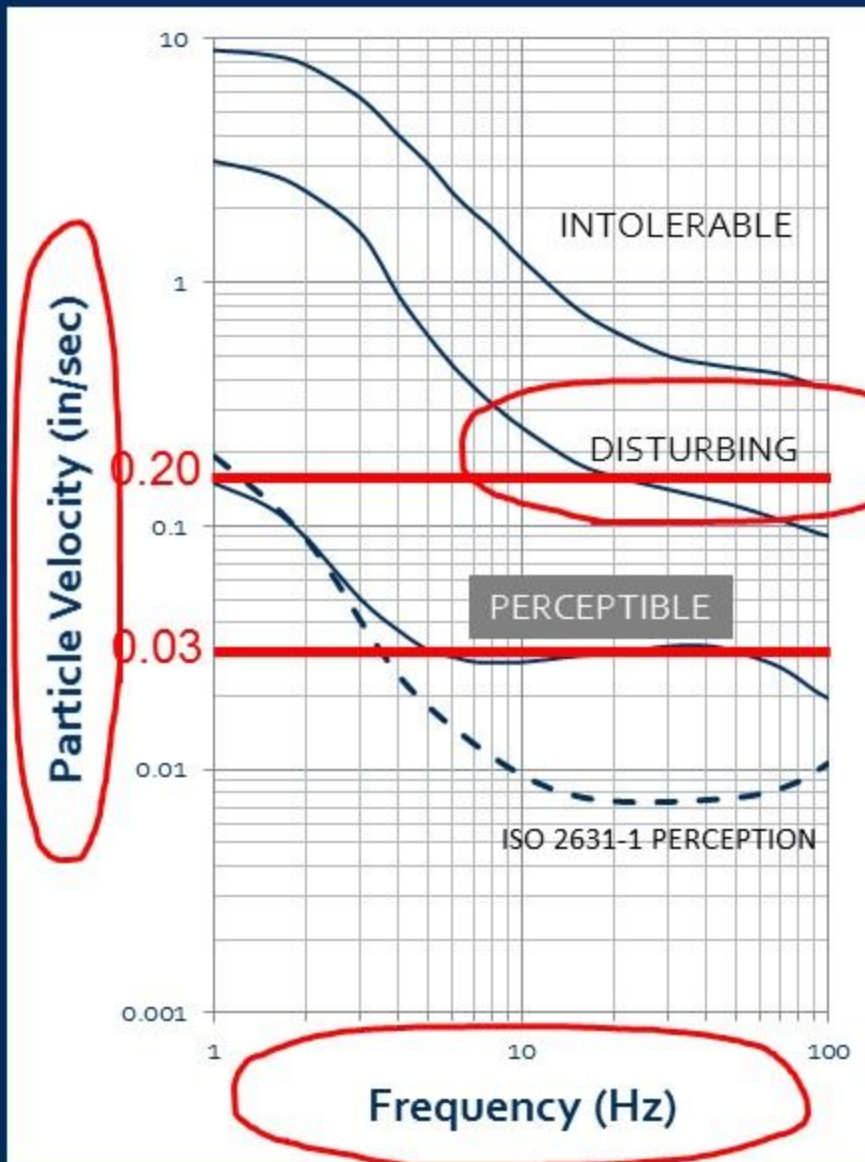
# Human Perception



The human body can **perceive very low levels** of vibrations

Roughly, perception threshold for steady-state vibrations is **0.03 in/sec**

# Human Perception

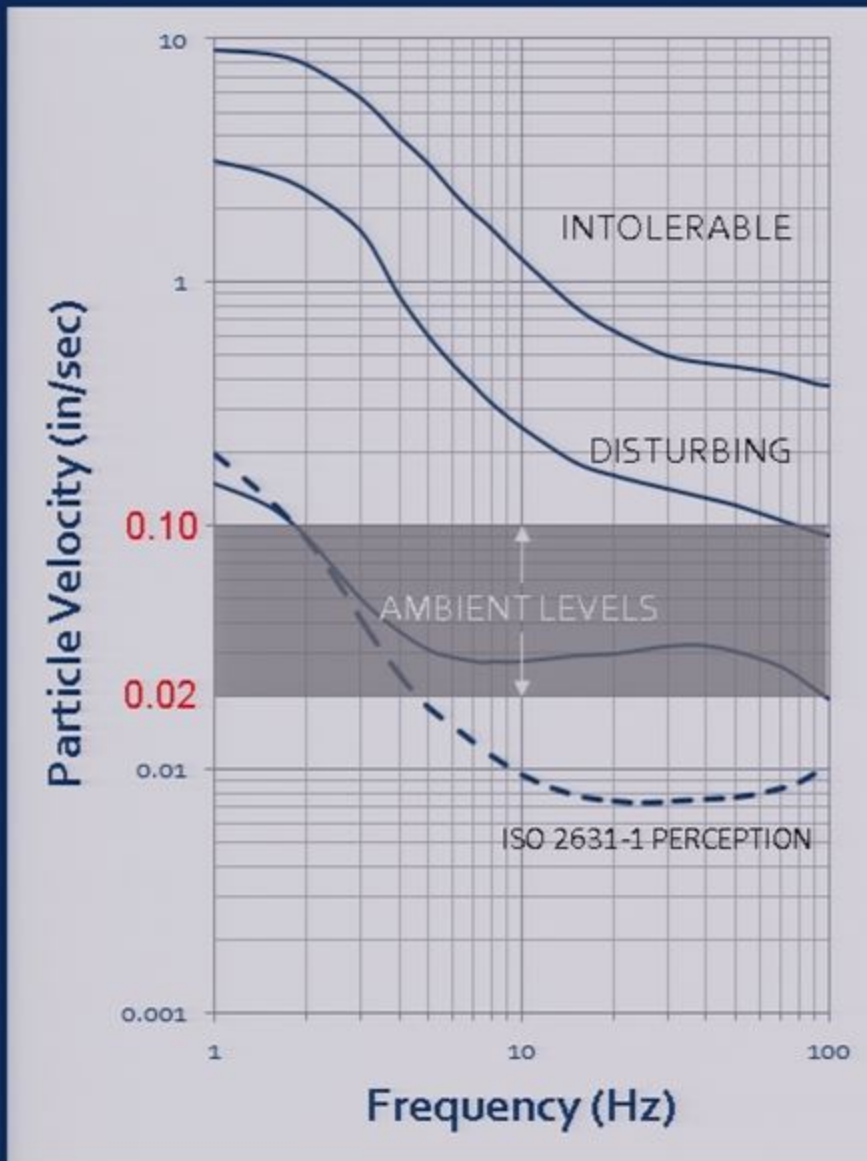


The human body can **perceive very low levels** of vibrations

Roughly, perception threshold for steady-state vibrations is **0.03 in/sec**

Vibrations become disturbing at **0.1-0.2 in/sec**

# Ambient (Background) Levels in Buildings

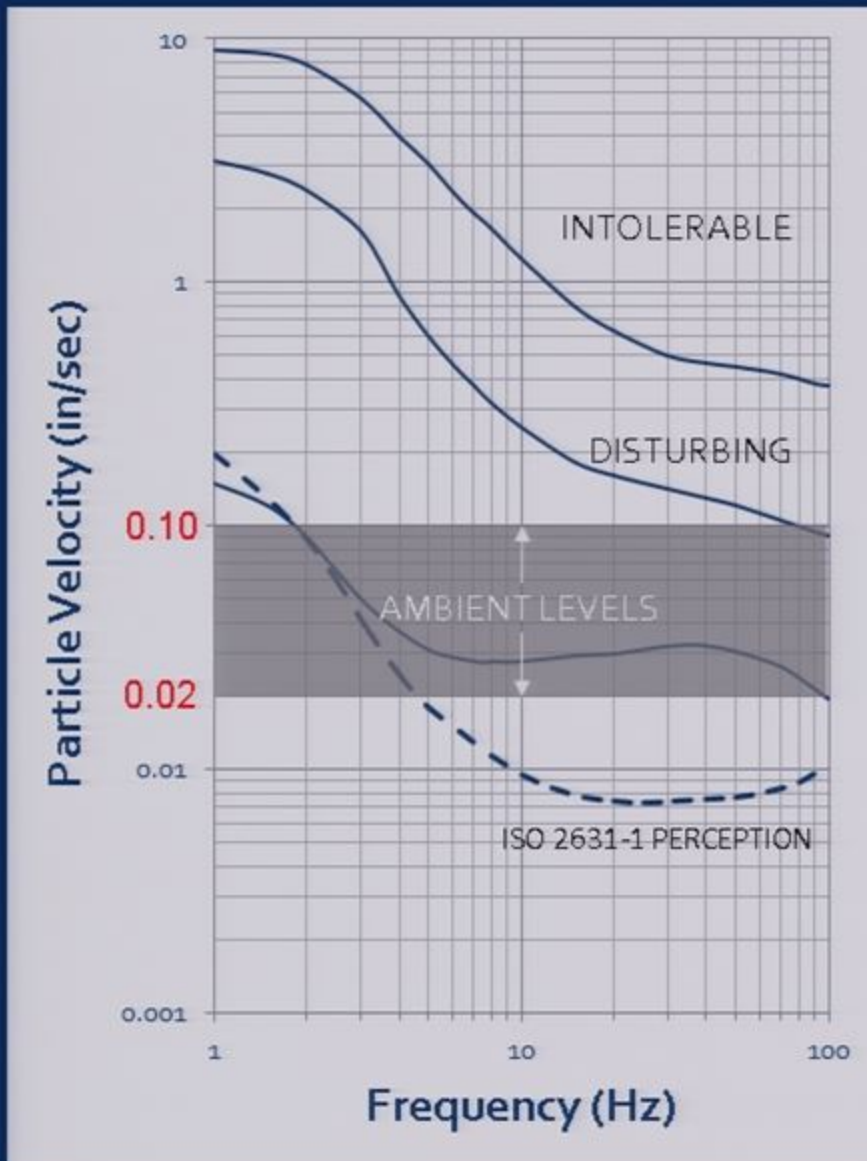


## Common Values:

- Closing doors, crowds walking:  
~0.02 - 0.05 in/sec
- Running, jumping:  
~0.05 - 0.10 in/sec
- Trains next to AIC:  
~0.03 - 0.07 in/sec
- Moving tables and chairs for event:  
~0.10 - 0.15 in/sec



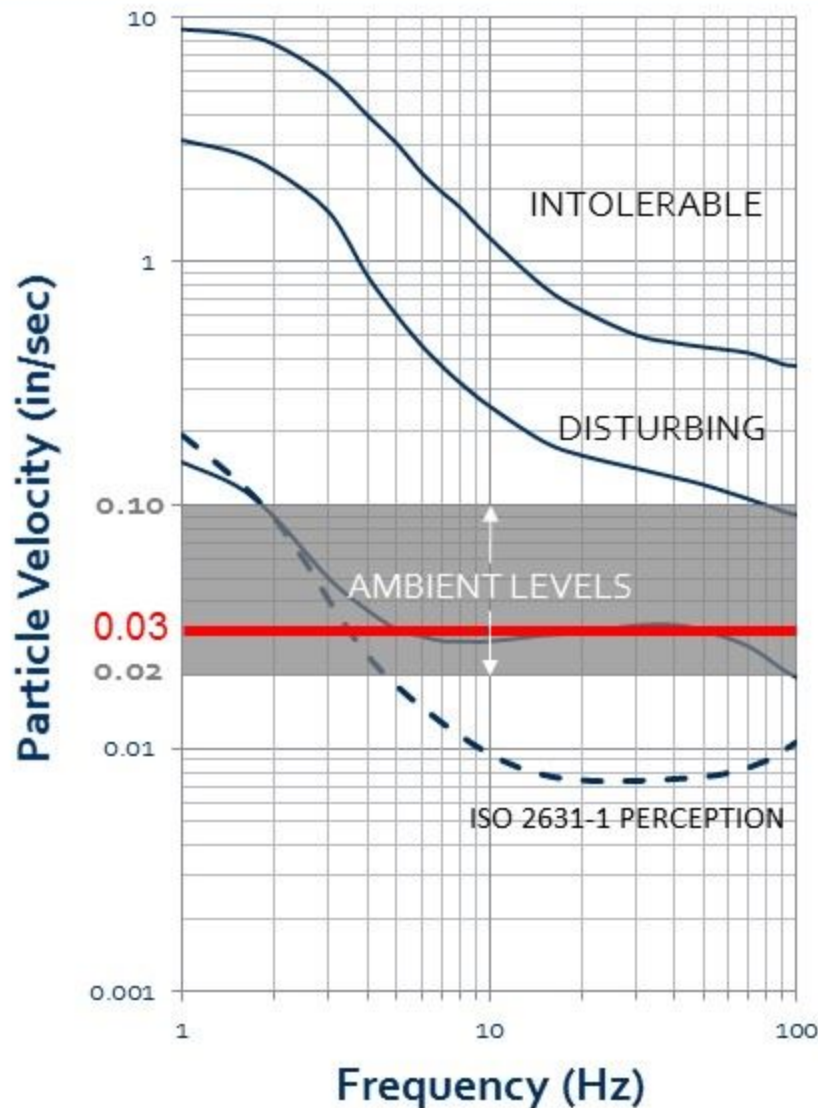
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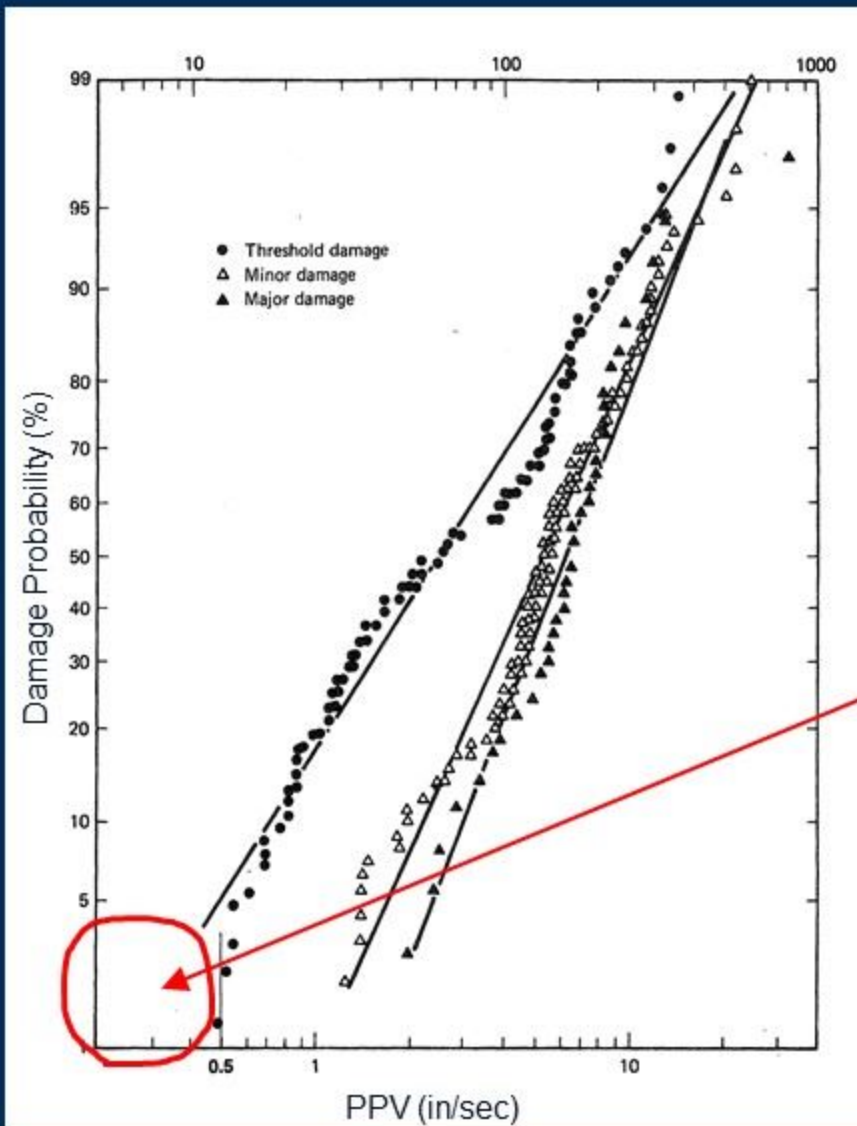
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# Damage Levels for Buildings

U.S. Bureau of Mines testing, 1970s and 1980s



# USBM RI-8507 Damage Levels for Buildings



## Damage Observed

PPV  
(in/sec)

Threshold damage

3.0

(hairline cracking in plaster, opening of old cracks, etc.)

<0.5  
(never)

Minor damage

4.5

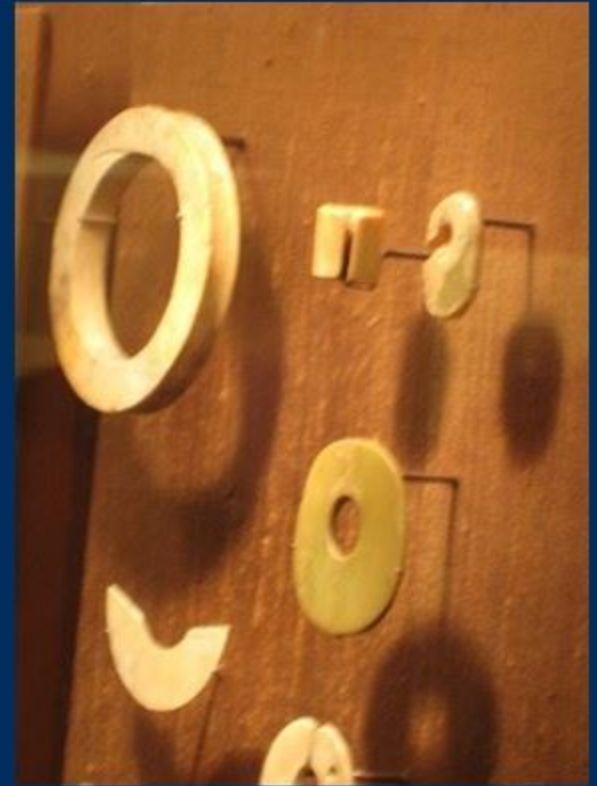
(hairline cracking in masonry, breaking of windows)

Major structural damage

8.0

(cracking or shifting of foundations or bearing walls)

# Artwork and Vibrations



# Artwork in Transit



# Artwork in Transit

- Special vetting, crating, and bracing of objects is performed

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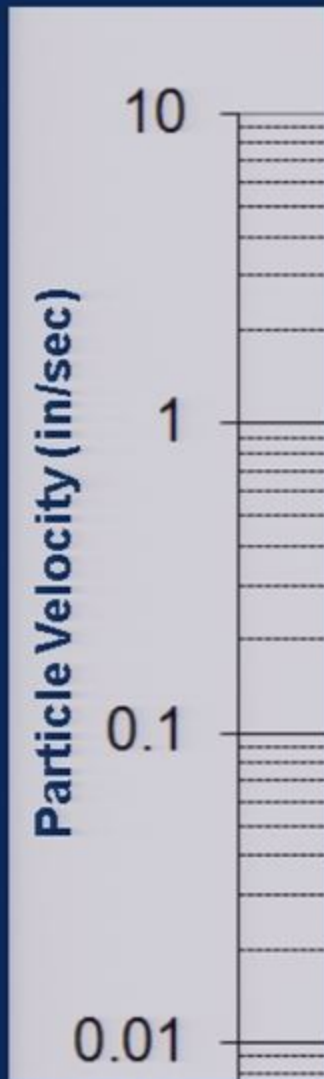
# Artwork Near Construction

- Vibration limits from **0.1 to 1.5 in/sec** have been successfully used to protect artwork during past museum construction projects (i.e. with no damage reported)

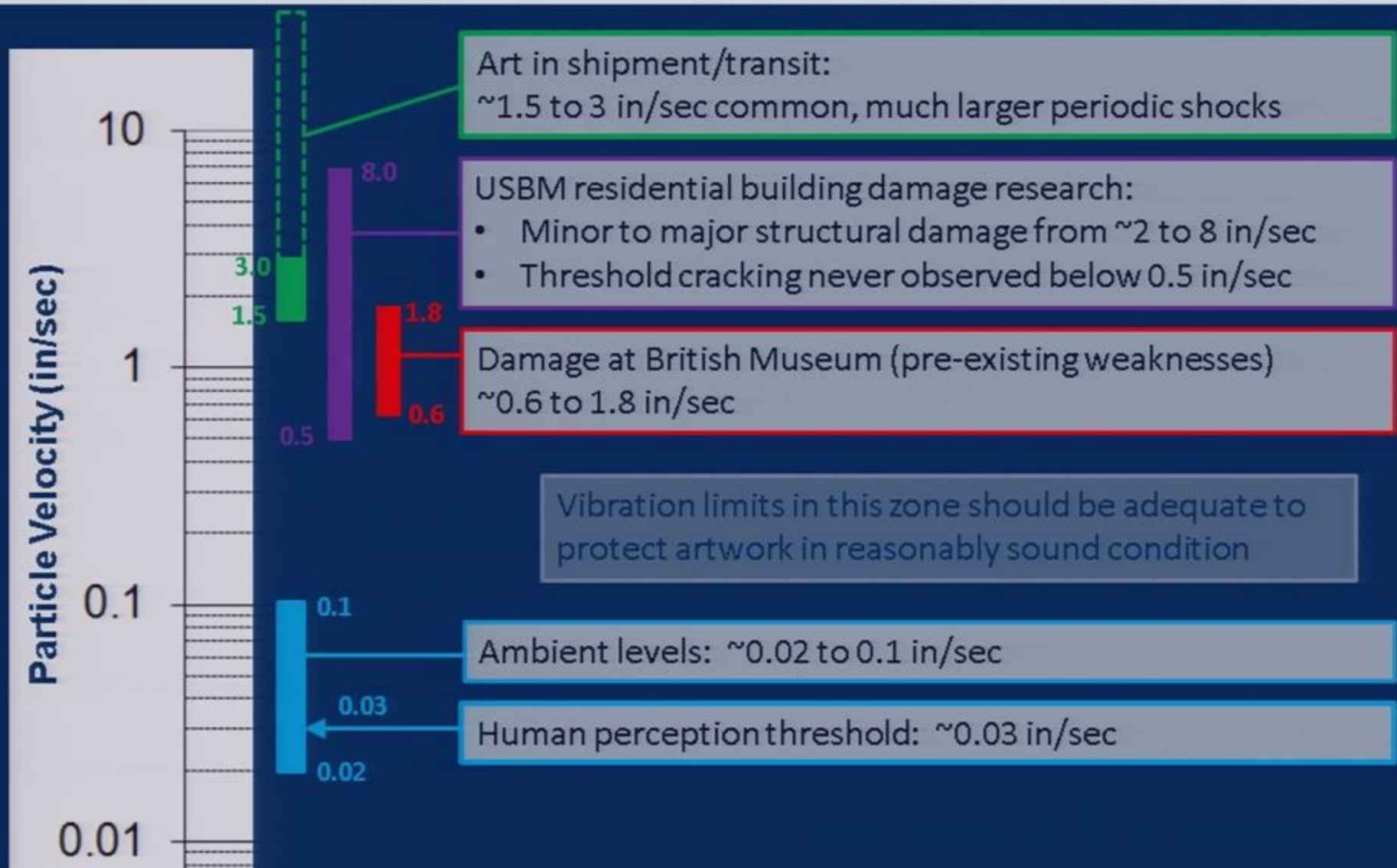
# Artwork Near Construction

- Vibration limits from **0.1 to 1.5 in/sec** have been successfully used to protect artwork during past museum construction projects (i.e. with no damage reported)
- **Very little information** on levels that have caused damage, as this is obviously to be avoided
- One case reported: British Museum, 2000:
  - Damage occurred to 12 art objects at ~0.6 to 1.8 in/sec, all in areas of pre-existing weakness

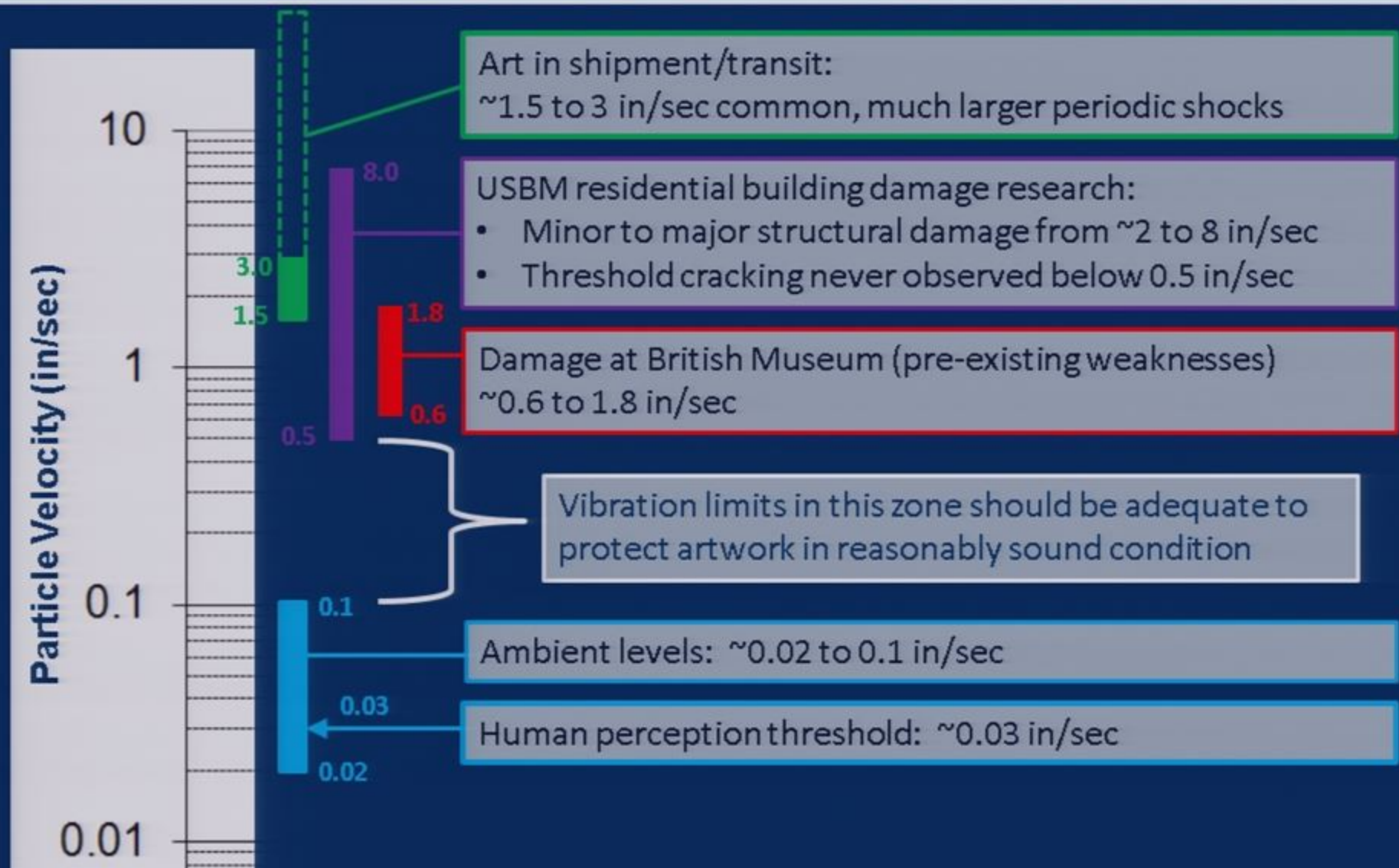
# Superimpose and Simplify...



# Superimpose and Simplify...



# Superimpose and Simplify...





# Limits for Museum Art Collections

- **Limit of 0.1 in/sec** should be conservative to protect most art objects in reasonably sound condition
- Used successfully on several U.S. museum construction projects

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- Used successfully on several U.S. museum construction projects
- **Possible exceptions/caveats:**
  - “Walking” of light objects on smooth surfaces
  - Resonance of objects with natural frequencies similar to continuous construction vibrations
  - Extremely fragile objects or those with serious pre-existing weaknesses

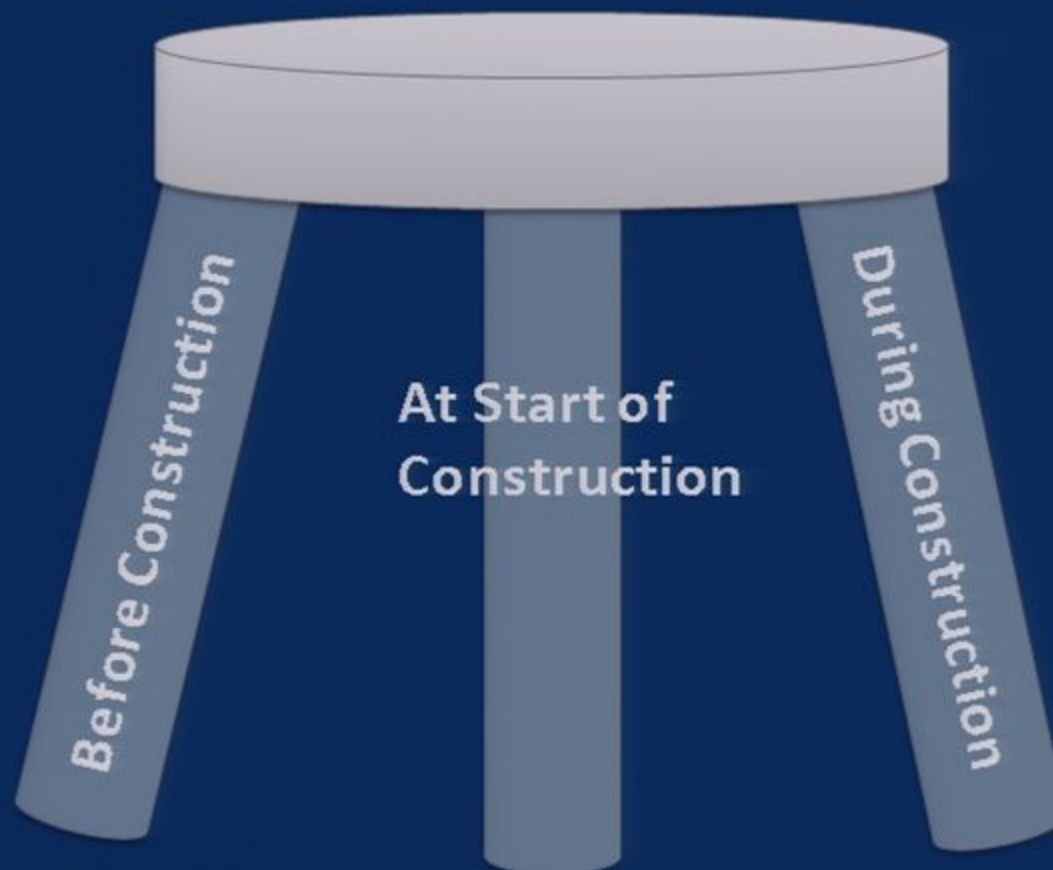
# Vibration Control Methodology



# Vibration Control Methodology

Goals:

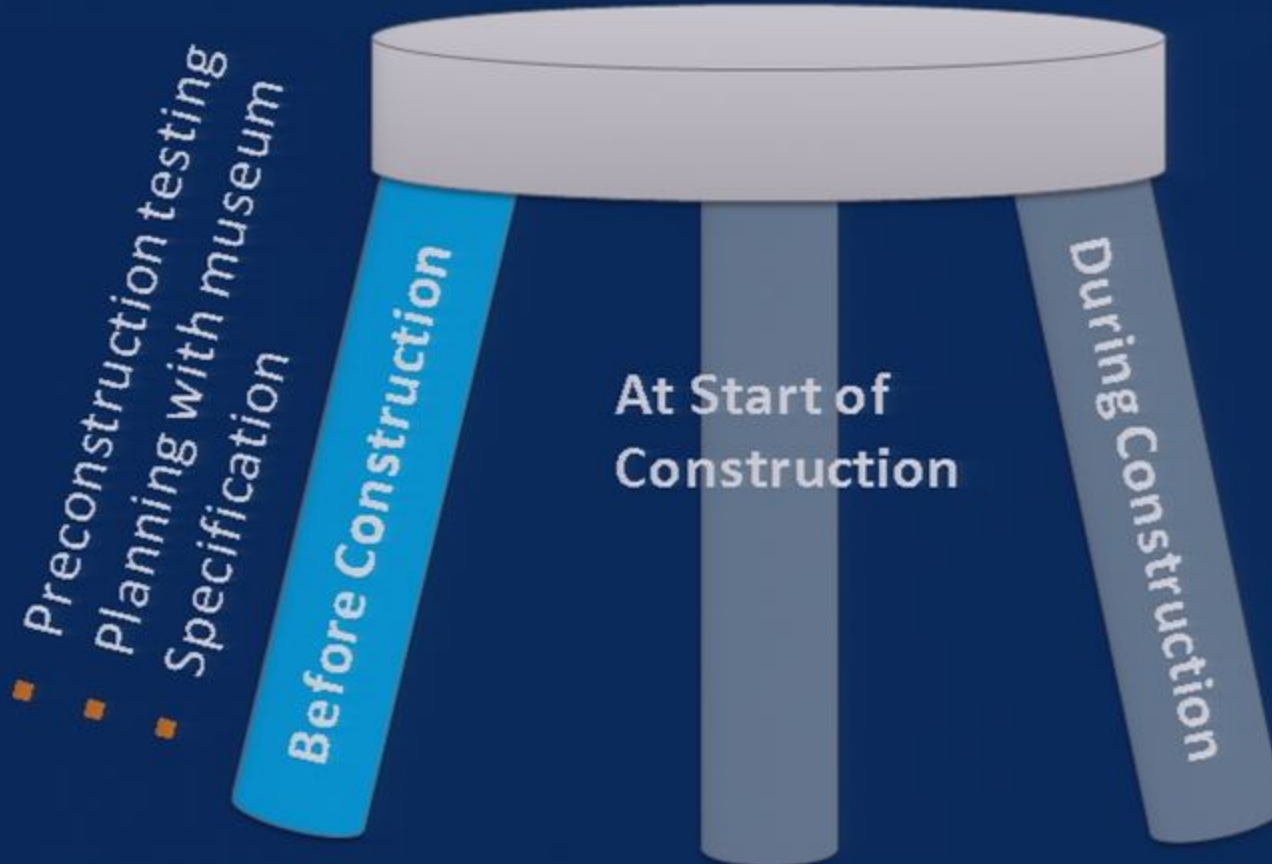
1. Protect collection and building
2. Guidance to museum for advance planning
3. Enforce limits without undue constraints



# Vibration Control Methodology

## Goals:

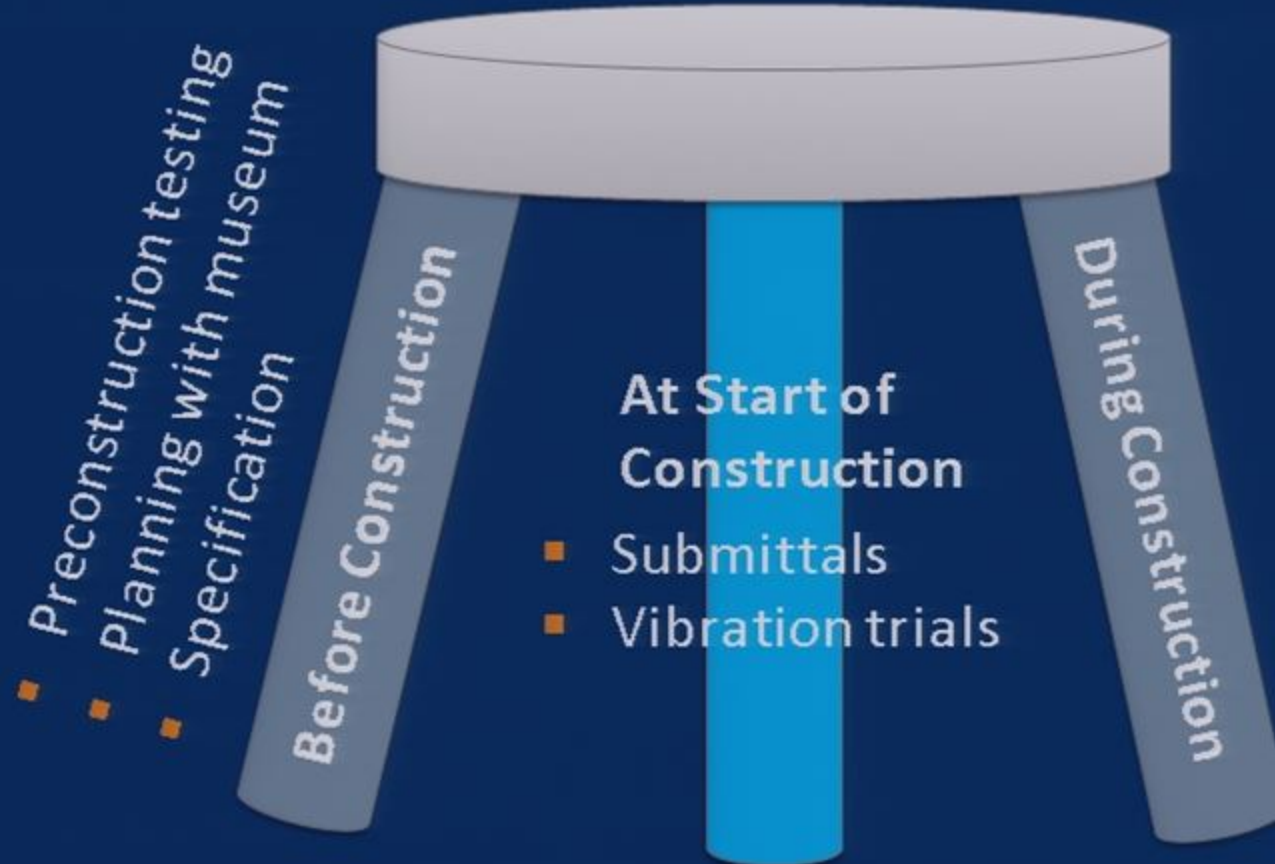
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## Goals:

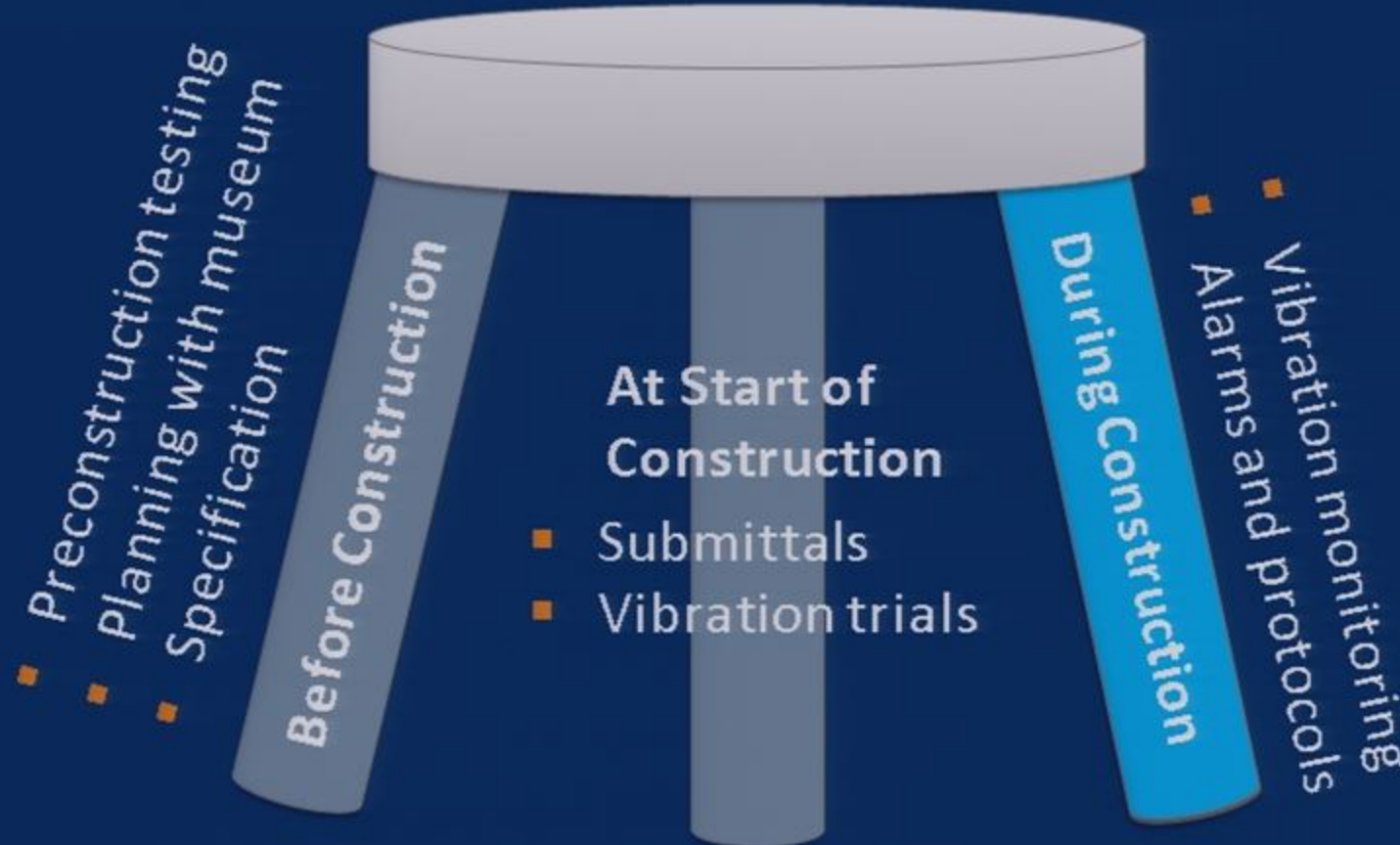
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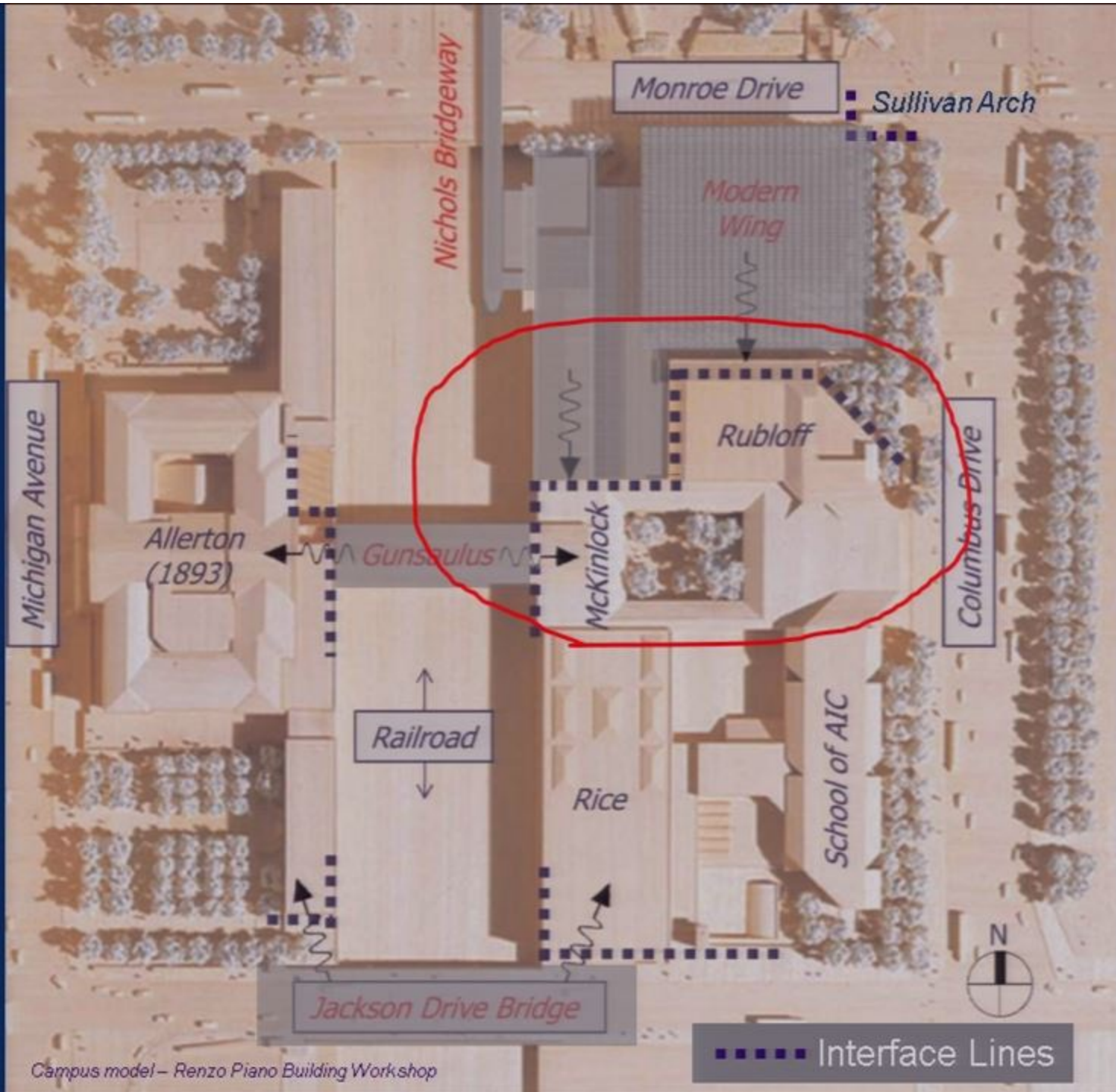
# Vibration Control Methodology

## Goals:

1. Protect collection and building
2. Guidance to museum for advance planning
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# Example - The Modern Wing



Campus model - Renzo Piano Building Workshop

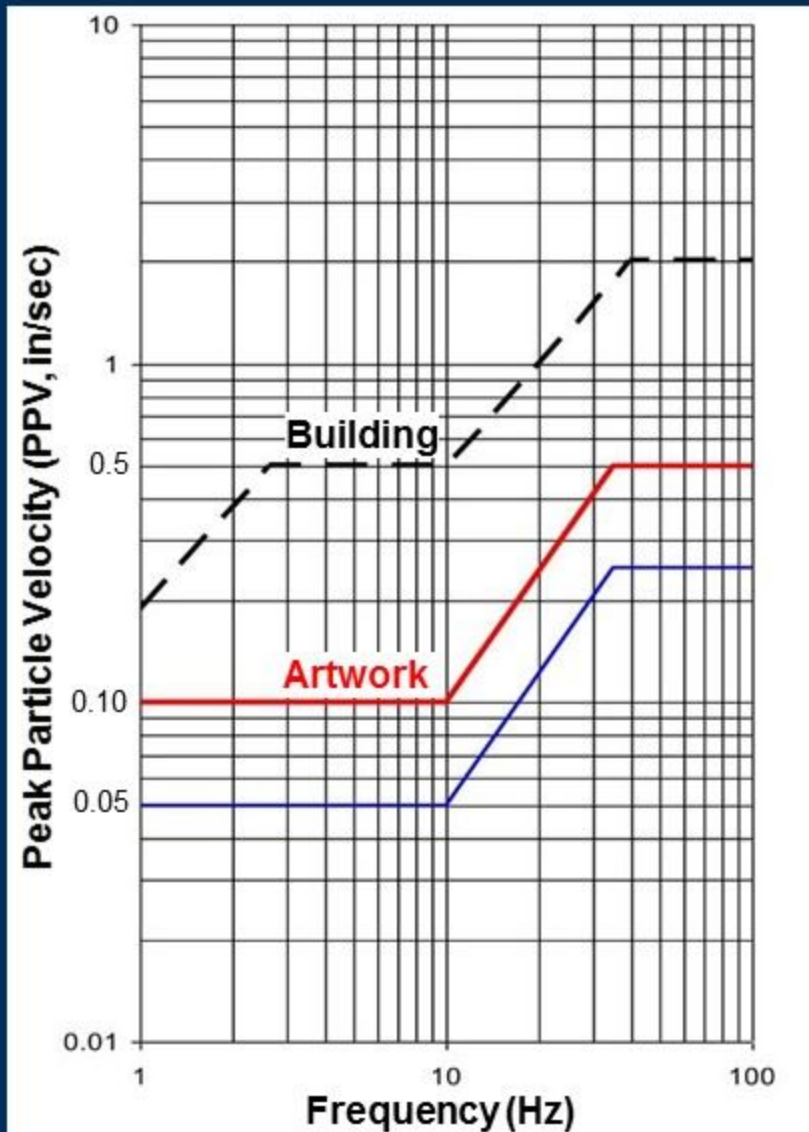




# Before Construction

- Selection of vibration limits
- Preconstruction testing
- Planning with museum
- Vibration control specification

# Preconstruction – Vibration Limits



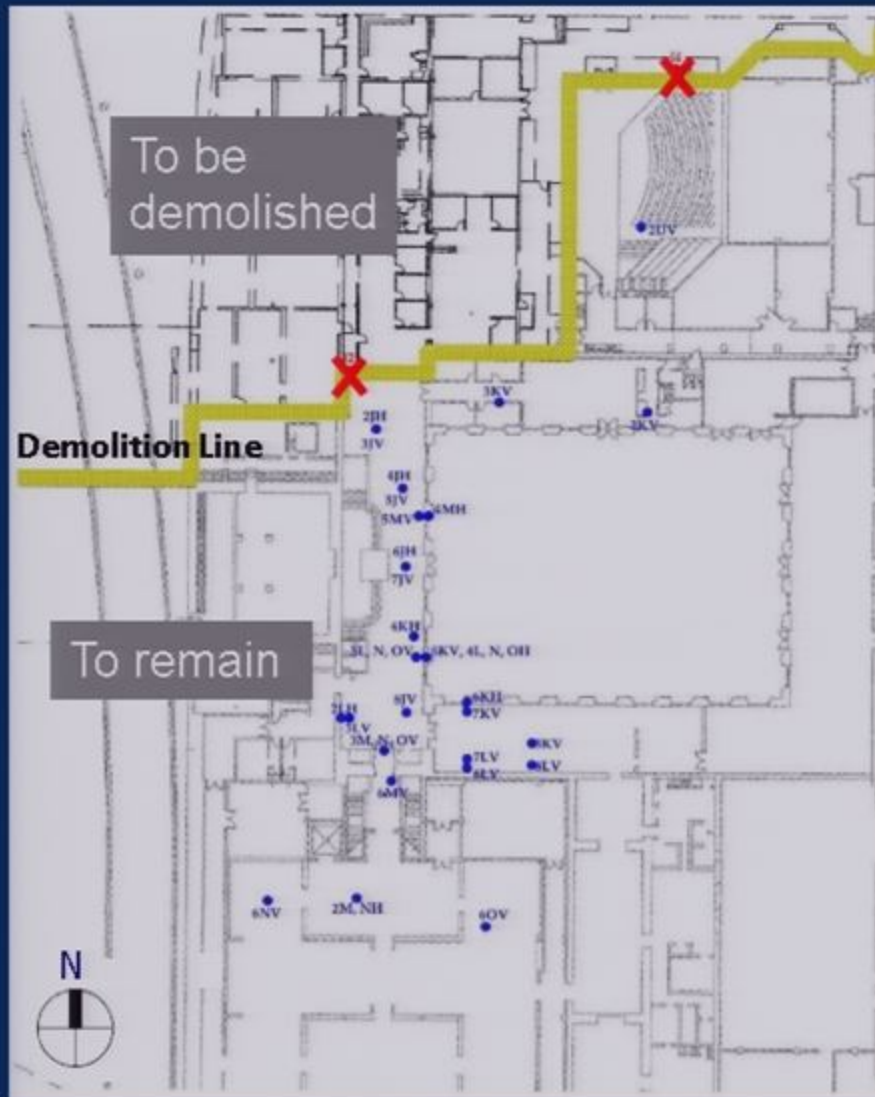
## Building limit:

- 0.5 in/sec baseline (USBM safe limit)

## Artwork limit:

- 0.1 in/sec baseline
- Conservative for objects in reasonably sound condition

# Preconstruction – Site Testing to Predict Levels

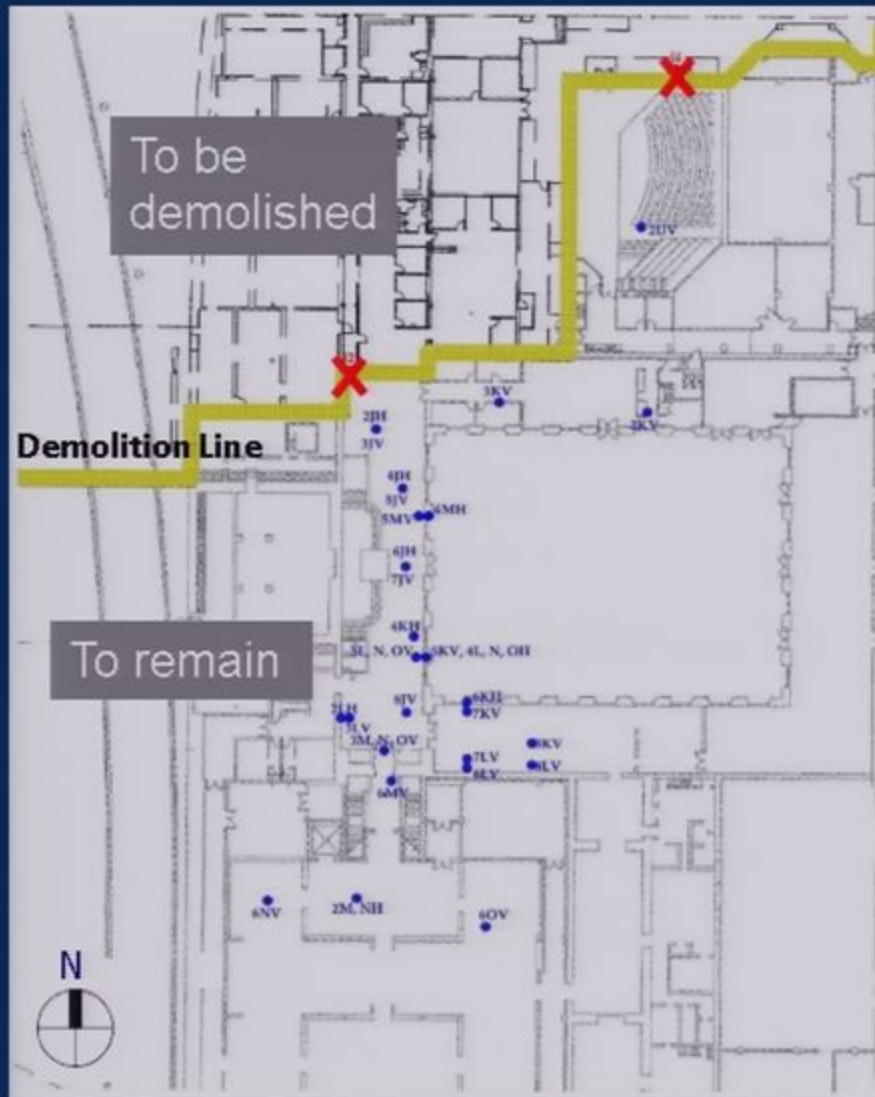


AIC Lower Level

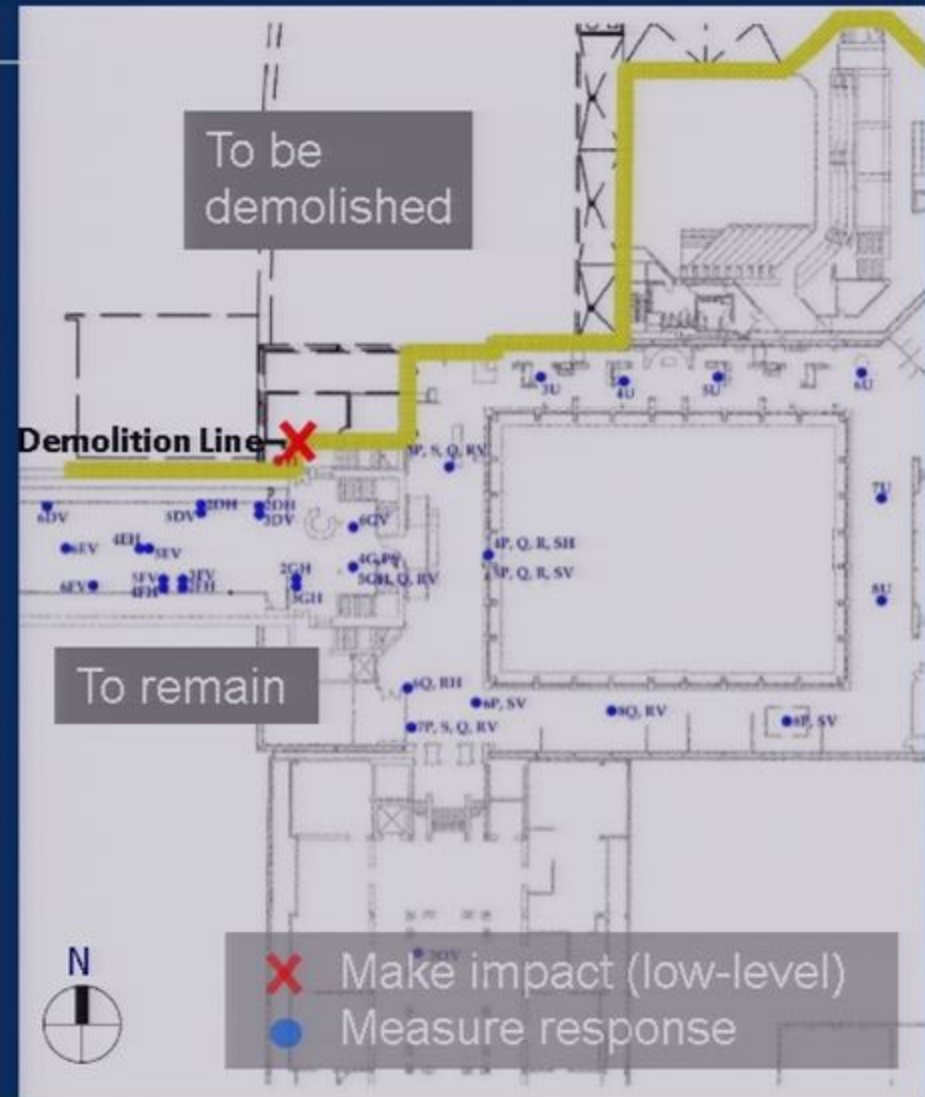


AIC First Level

# Preconstruction – Site Testing to Predict Levels



AIC Lower Level

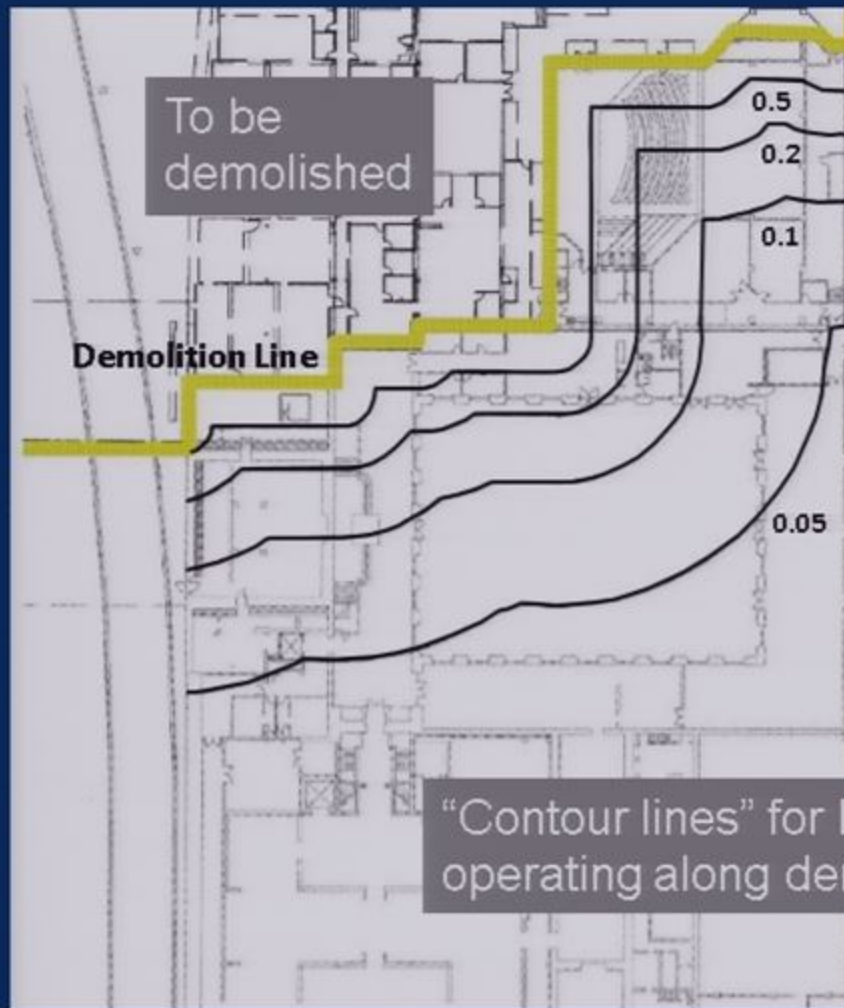


AIC First Level

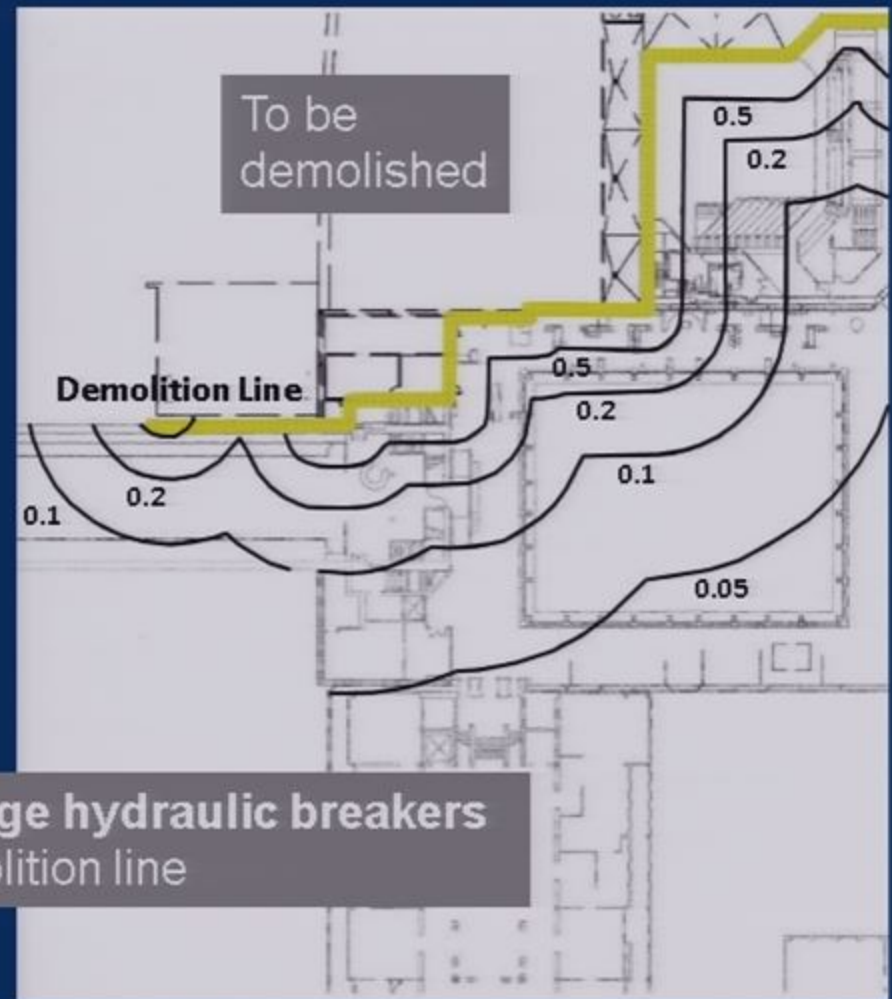
# Preconstruction – Site Testing



# Preconstruction – Vibration Prediction



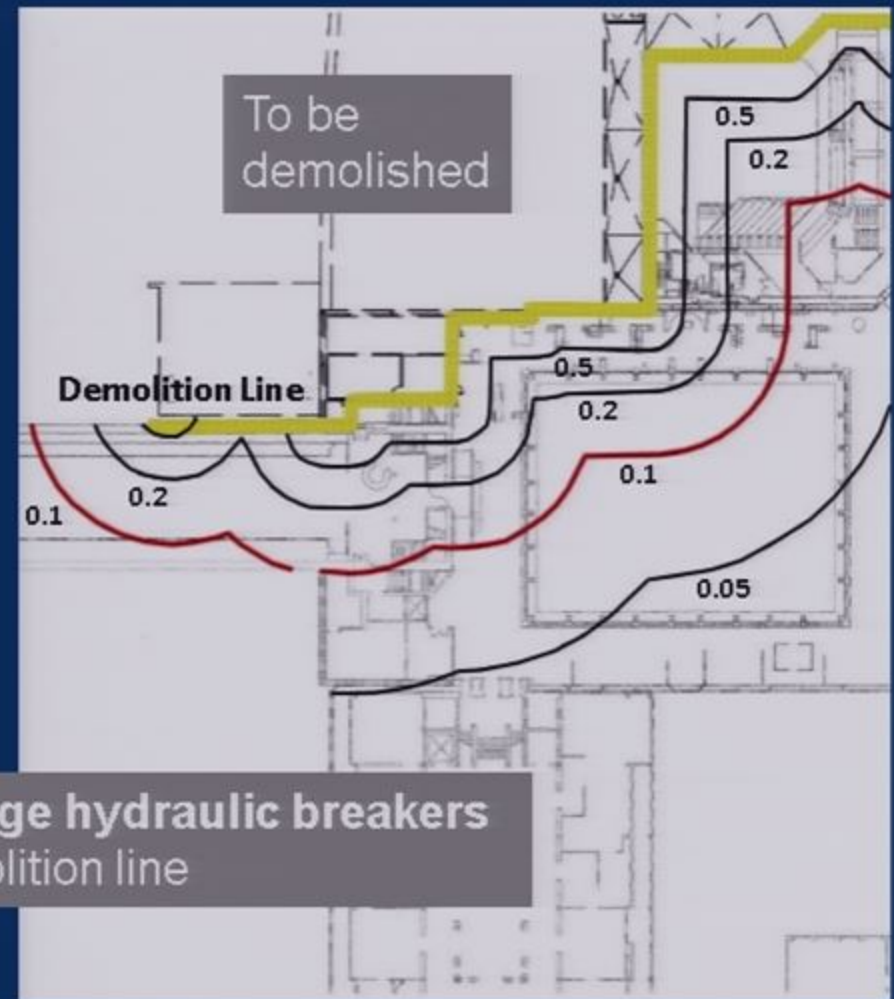
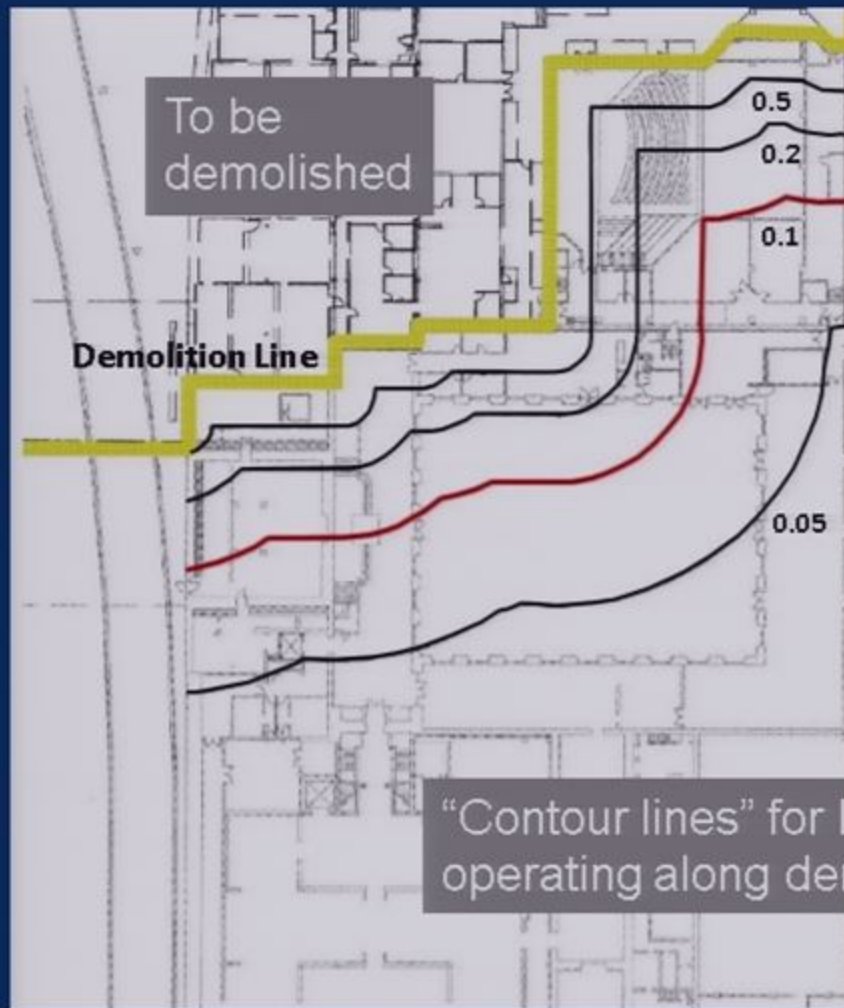
AIC Lower Level



AIC First Level

“Contour lines” for **large hydraulic breakers** operating along demolition line

# Preconstruction – Vibration Prediction

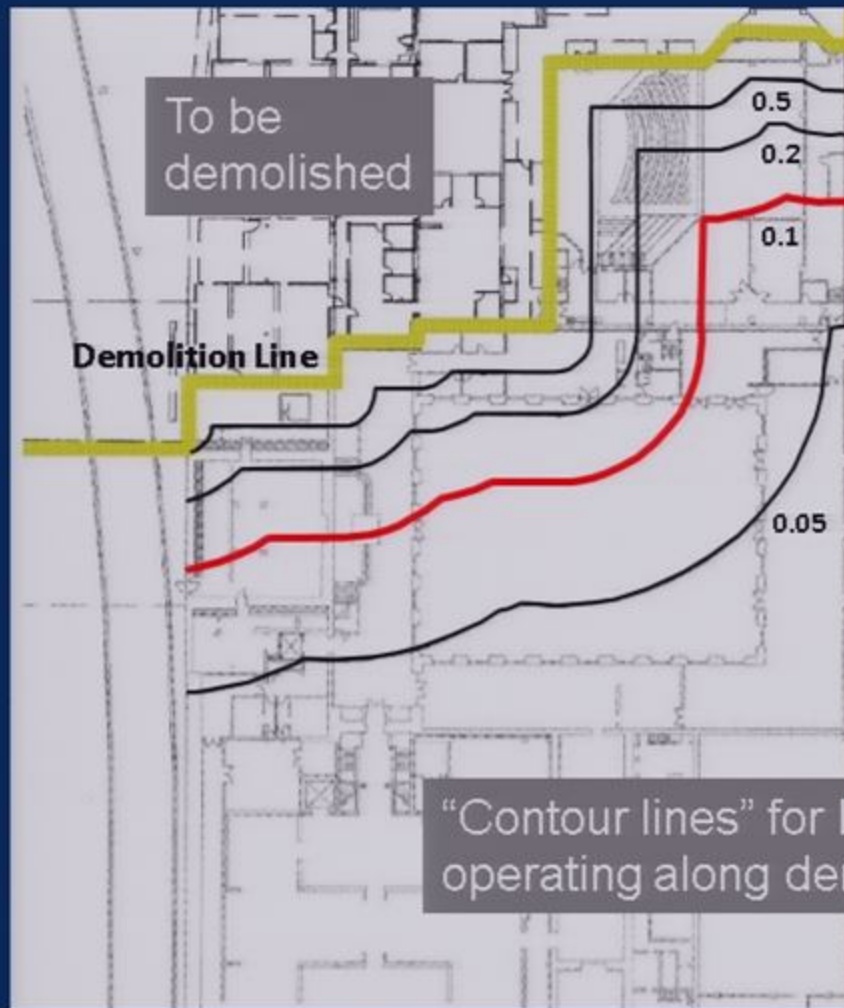


"Contour lines" for **large hydraulic breakers** operating along demolition line

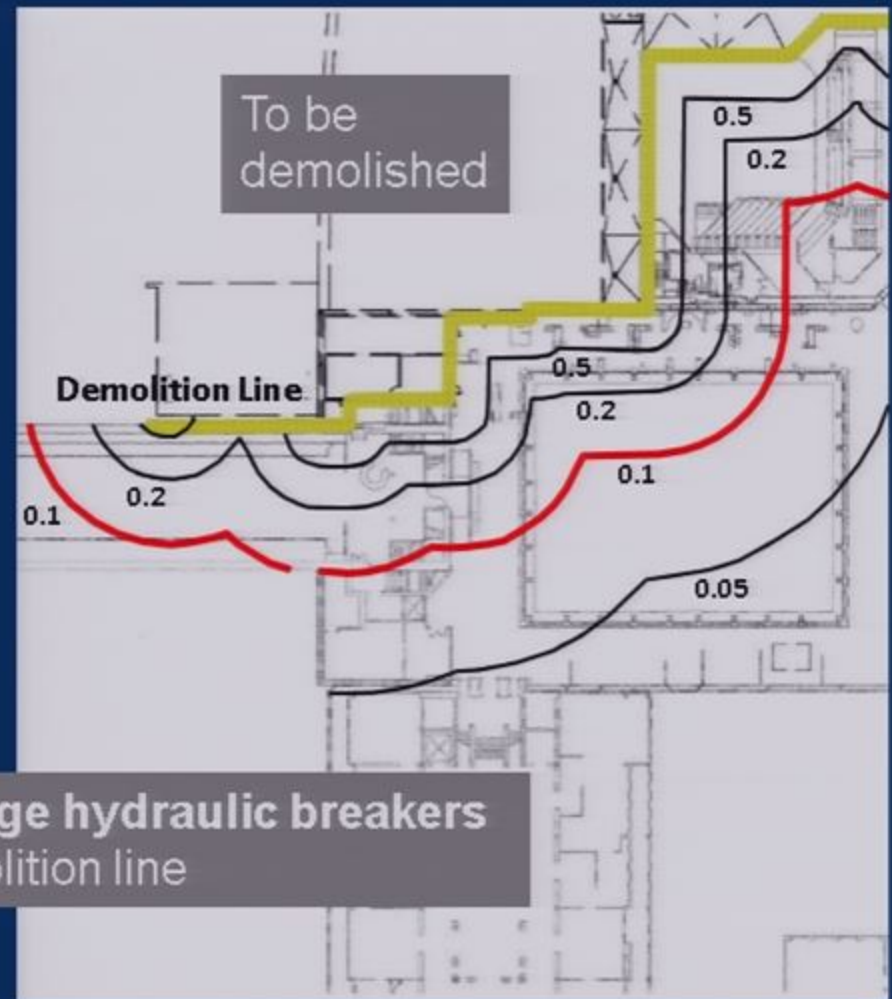
AIC Lower Level

AIC First Level

# Preconstruction – Vibration Prediction



AIC Lower Level



AIC First Level

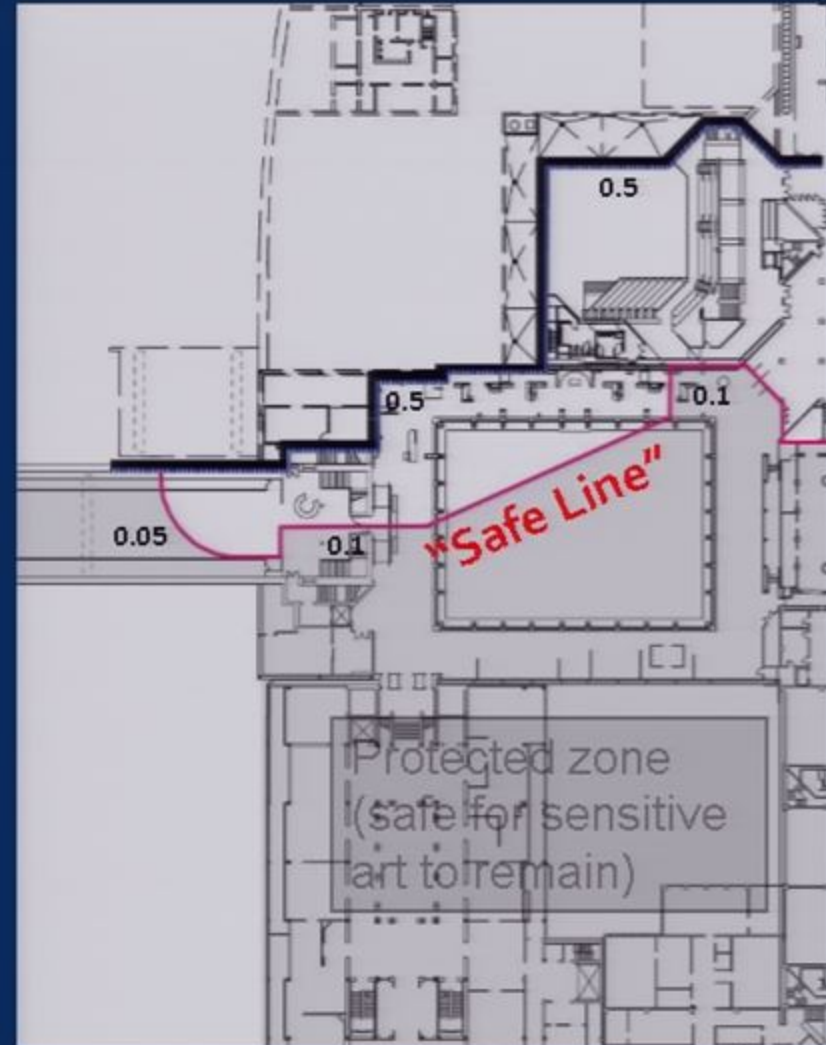
“Contour lines” for **large hydraulic breakers** operating along demolition line



# Preconstruction – Define “Safe Lines”



AIC Lower Level

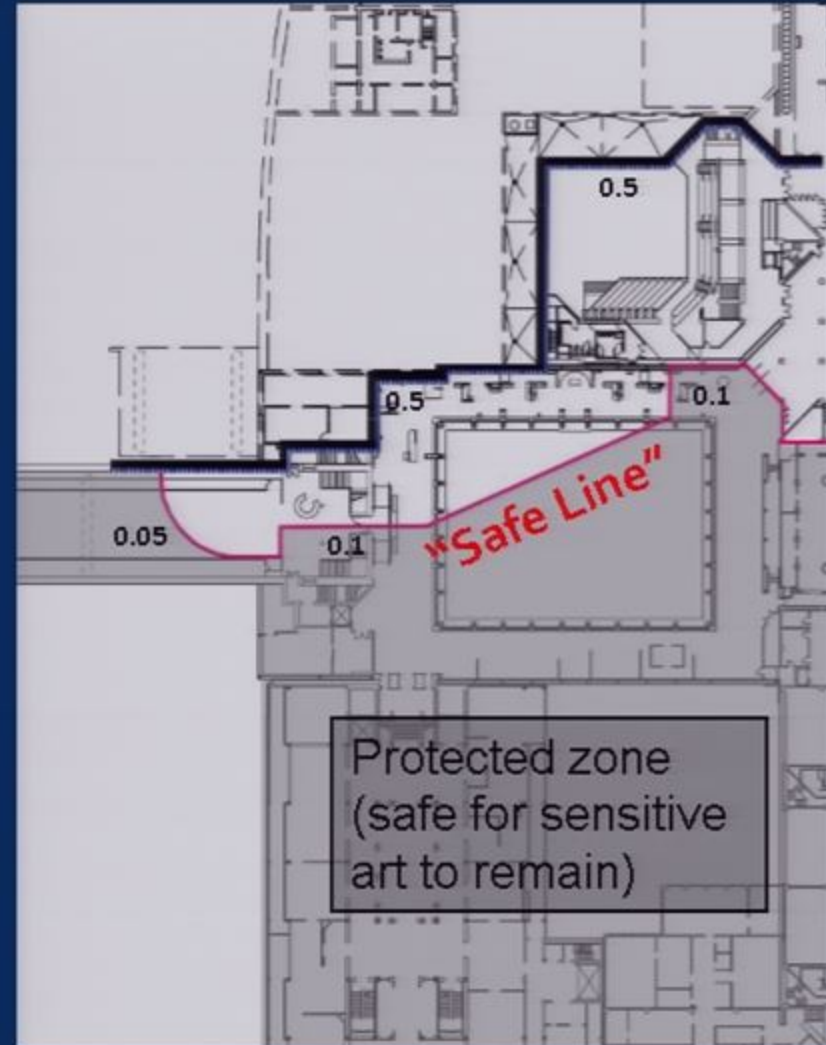


AIC First Level

# Preconstruction – Define “Safe Lines”

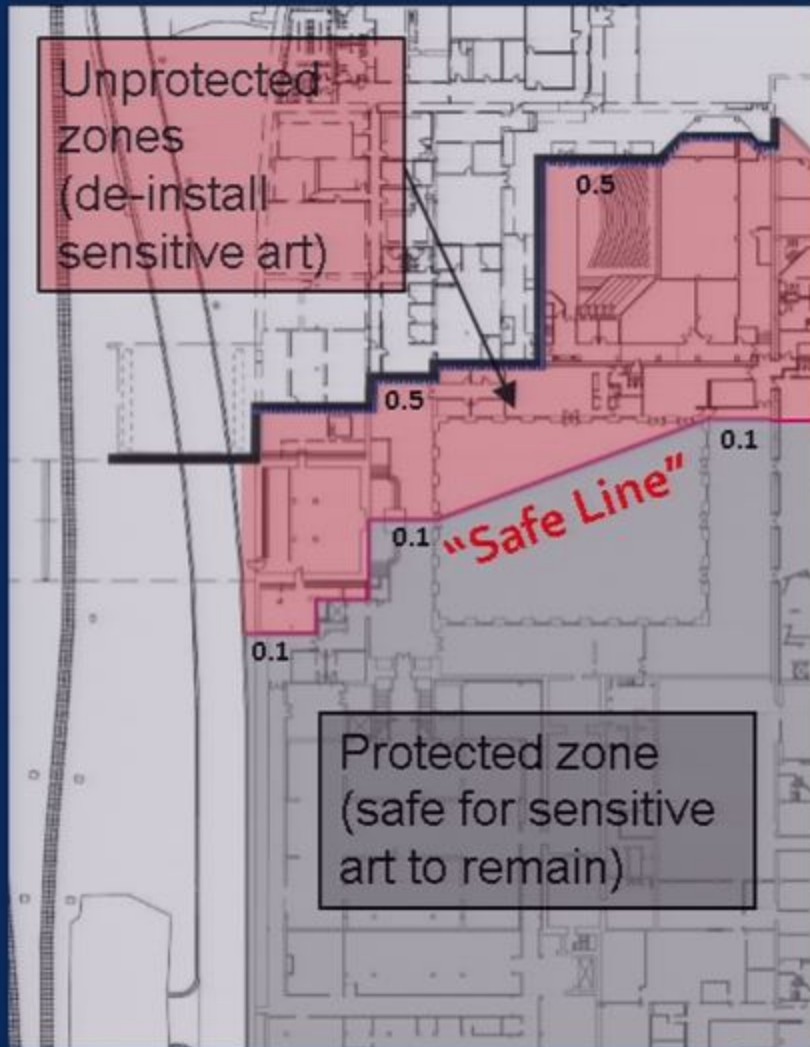


AIC Lower Level

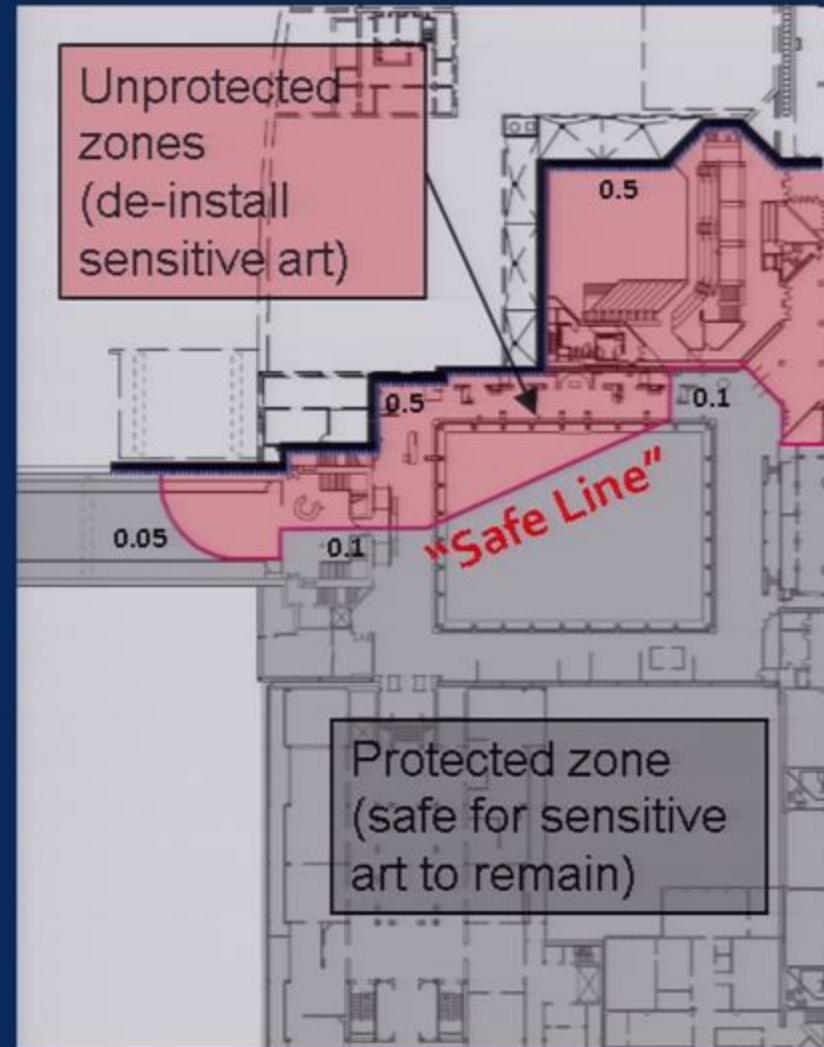


AIC First Level

# Preconstruction – Define “Safe Lines”



AIC Lower Level



AIC First Level

SECTION 01576

VIBRATION PROTECTION REQUIREMENTS  
FOR EXISTING BUILDINGS ALONG INTERFACES  
WITH NEW CONSTRUCTION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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# Vibration Control Specification

- Vibration limits and "safe lines"
- Contractor devise work so as not to exceed limits

SECTION 01576

VIBRATION PROTECTION REQUIREMENTS  
FOR EXISTING BUILDINGS ALONG INTERFACES  
WITH NEW CONSTRUCTION

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# Vibration Control Specification

- Vibration limits and "safe lines"
- Contractor devise work so as not to exceed limits
- Minimum requirements, guidance to contractor
- Require field trials
- Define monitoring system and alarm capabilities
- Define protocols to be followed if above-limit alarm occurs

SECTION 01576

VIBRATION PROTECTION REQUIREMENTS  
FOR EXISTING BUILDINGS ALONG INTERFACES  
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- Define protocols to be followed if above-limit alarm occurs



# At Start of Construction

Contractor means and methods submittals  
Vibration trials

SECTION 01576

VIBRATION PROTECTION REQUIREMENTS  
FOR EXISTING BUILDINGS ALONG INTERFACES  
WITH NEW CONSTRUCTION

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# Field Trials

1. Conduct Field Trials for every vibration-causing activity
  - Actual methods at safe distance from art
  - Monitoring during simulated activities
2. If vibration levels are within limits, proceed
3. If not, change methods and repeat trial



# Vibration Trials



# Field Trials



Large hydraulic breakers



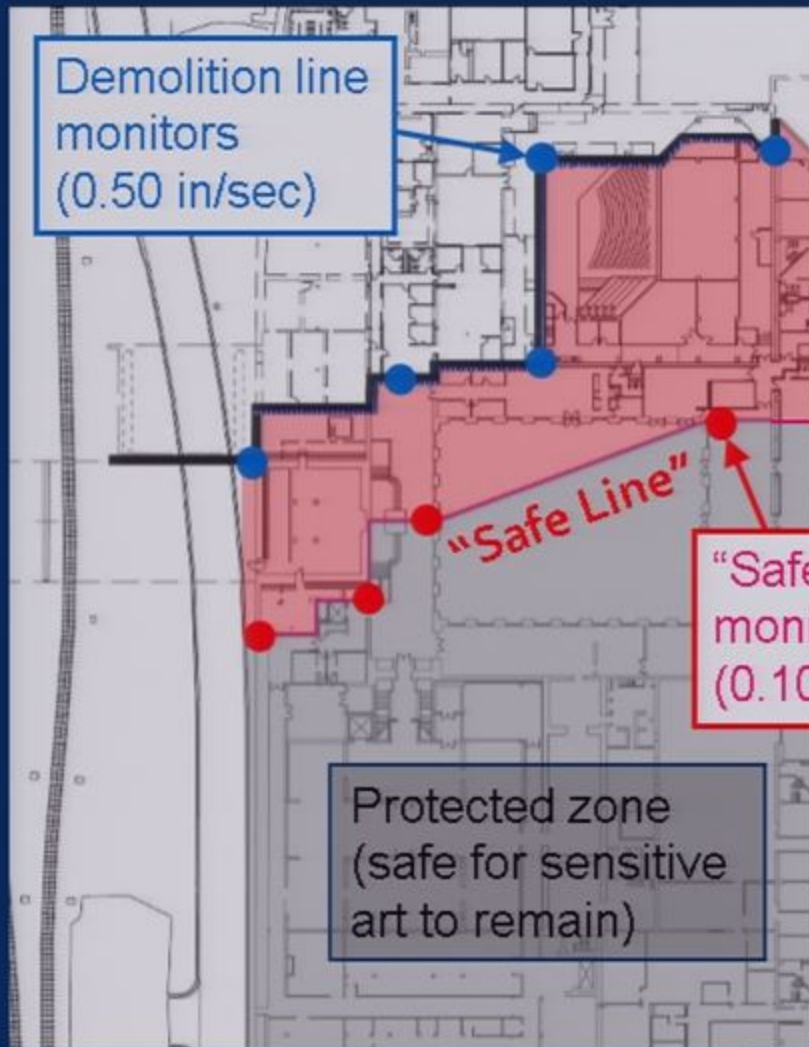
Cooling tower selective demolition



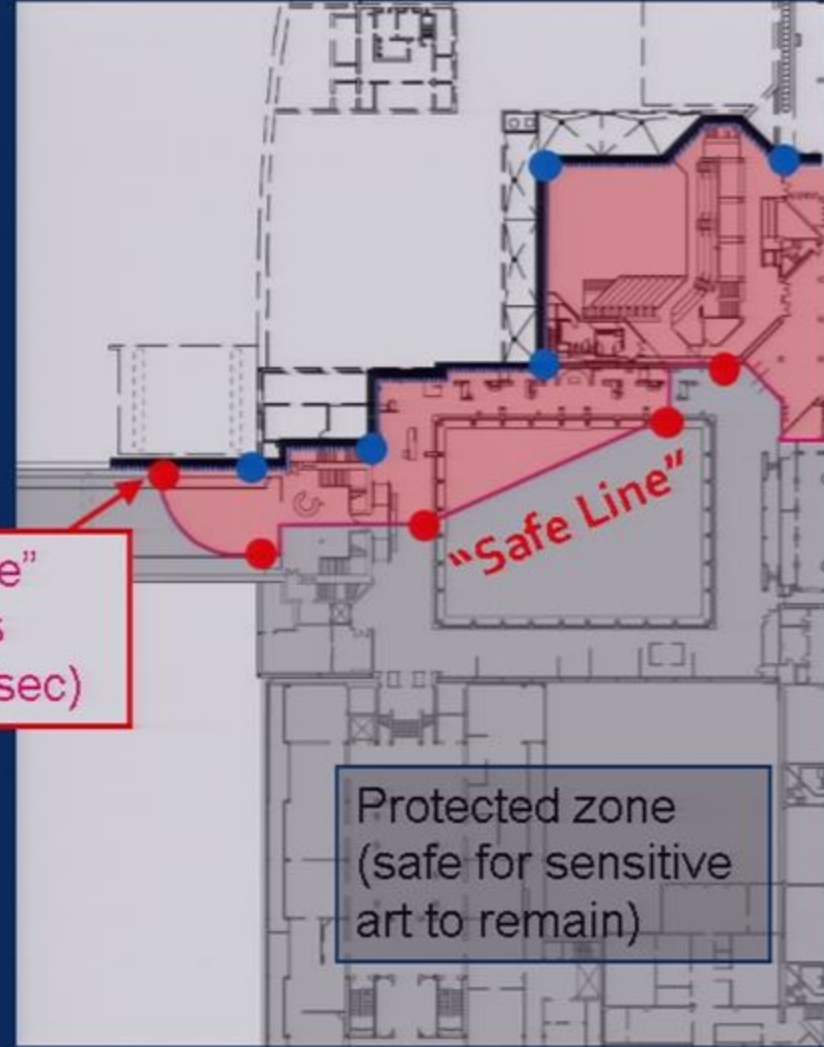
# During Construction

Vibration monitoring  
Alarms and event protocols

# Vibration Monitoring



AIC Lower Level



AIC First Level



SECTION 01576  
VIBRATION PROTECTION REQUIREMENTS  
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# Alarms and Notifications

- Monitoring system capable of immediate email notifications of any above-limit measurements

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FOR EXISTING BUILDINGS ALONG INTERFACES  
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- Construction must stop immediately!

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# Alarms and Notifications

- Monitoring system capable of immediate email notifications of any above-limit measurements
- Construction must stop immediately!
- Review cause, inspect building, change methods



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# Weekly Data Reports



Wis. Janney, Elstner Associates, Inc.  
330 Pfingsten Road  
Northbrook, Illinois 60062  
847.272.7420 W | 847.291.5139 Fax  
www.wje.com

## VIBRATION MONITORING SUMMARY REPORT

REPORT PERIOD: 01/07/2008 - 01/13/2008

Project: AIC Guastavino Hall Renovation  
Client: The Rise Group  
Contractor: Turner Special Projects  
Owner: The Art Institute of Chicago

Report Date: 01/14/2008  
Report Page: 1 of 10  
WJE Proj. No.: 2006.5025

### Vibration Data Summary

	Axis	Peak Measured Response		
		Velocity (in/sec)	Frequency (Hz)	Time of Day (hh:mm)
Mechanical Room Art Storage 181 1119	North-South	0.007	3.3	1/9/08 8:27
	East-West	0.008	11.0	1/7/08 7:36
	Vertical	0.011	12.0	1/7/08 7:36
Gallery Floor Gallery 131A 1264	North-South	0.009	1.4	1/7/08 13:58
	East-West	0.009	21.0	1/10/08 8:34
	Vertical	0.030	30.0	1/10/08 7:28
Storage Gallery 240 1285	North-South	0.010	3.3	1/9/08 9:33
	East-West	0.014	51.0	1/9/08 6:10
	Vertical	0.023	85.0	1/10/08 5:29
Gallery Floor Gallery 243 1230	North-South	0.023	2.6	1/9/08 8:27
	East-West	0.009	4.7	1/11/08 15:27
	Vertical	0.033	51.0	1/11/08 12:09
Gallery Floor Gallery 244 1284	North-South	0.022	2.8	1/9/08 9:34
	East-West	0.011	4.8	1/11/08 15:31
	Vertical	0.123	47.0	1/11/08 8:01
Gallery Floor Gallery 246 1287	North-South	0.019	2.8	1/9/08 9:34
	East-West	0.009	73.0	1/11/08 8:09
	Vertical	0.021	17.0	1/11/08 12:34

- Remarks:
- See Pages 2-7 for comparison of PPV against project threshold levels.
  - See Pages 8-10 for time history chart of PPV.
  - This weekly vibration summary report does not include vibration events occurring at frequencies greater than 100 Hz. High frequency vibrations should not be damaging to artwork or building components and therefore are not included in the project limit. Note that notifications are sent for trigger events occurring at any frequency, including those greater than 100 Hz, to allow for engineering review and to ensure that underlying low-frequency vibrations do not exceed the project limits.

*Nathaniel S. Rend*

Submitted By: Nathaniel S. Rend  
Associate II - Janney Technical Center

Wis., Janney, Elstner Associates, Inc.  
330 Pfingsten Road  
Northbrook, IL 60062

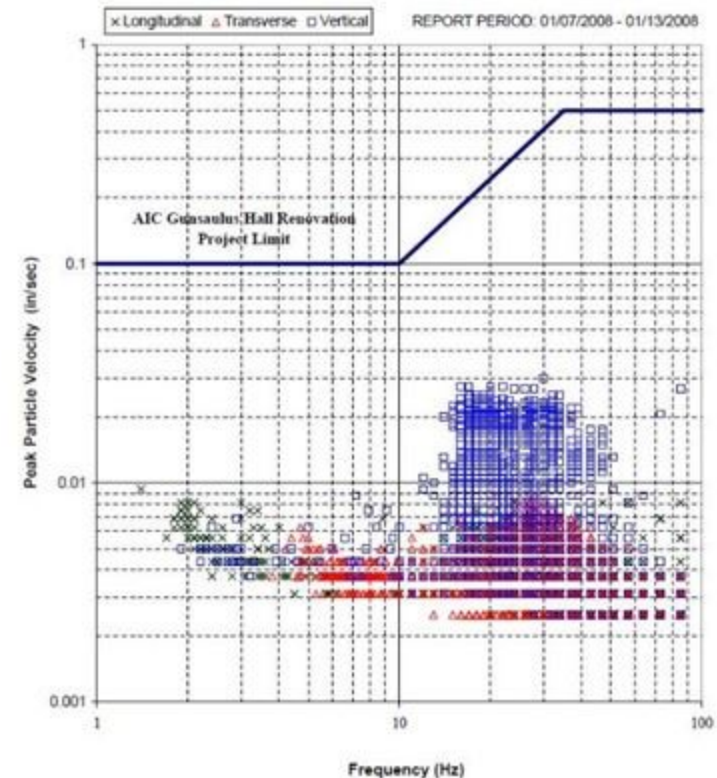


Report Page: 3 of 10  
Report Date: 01/14/2008

## PEAK PARTICLE VELOCITY vs. FREQUENCY

### AIC Gallery 131A: Gallery Floor

Instantel Minimate Plus III  
SERIAL NO.: 12654

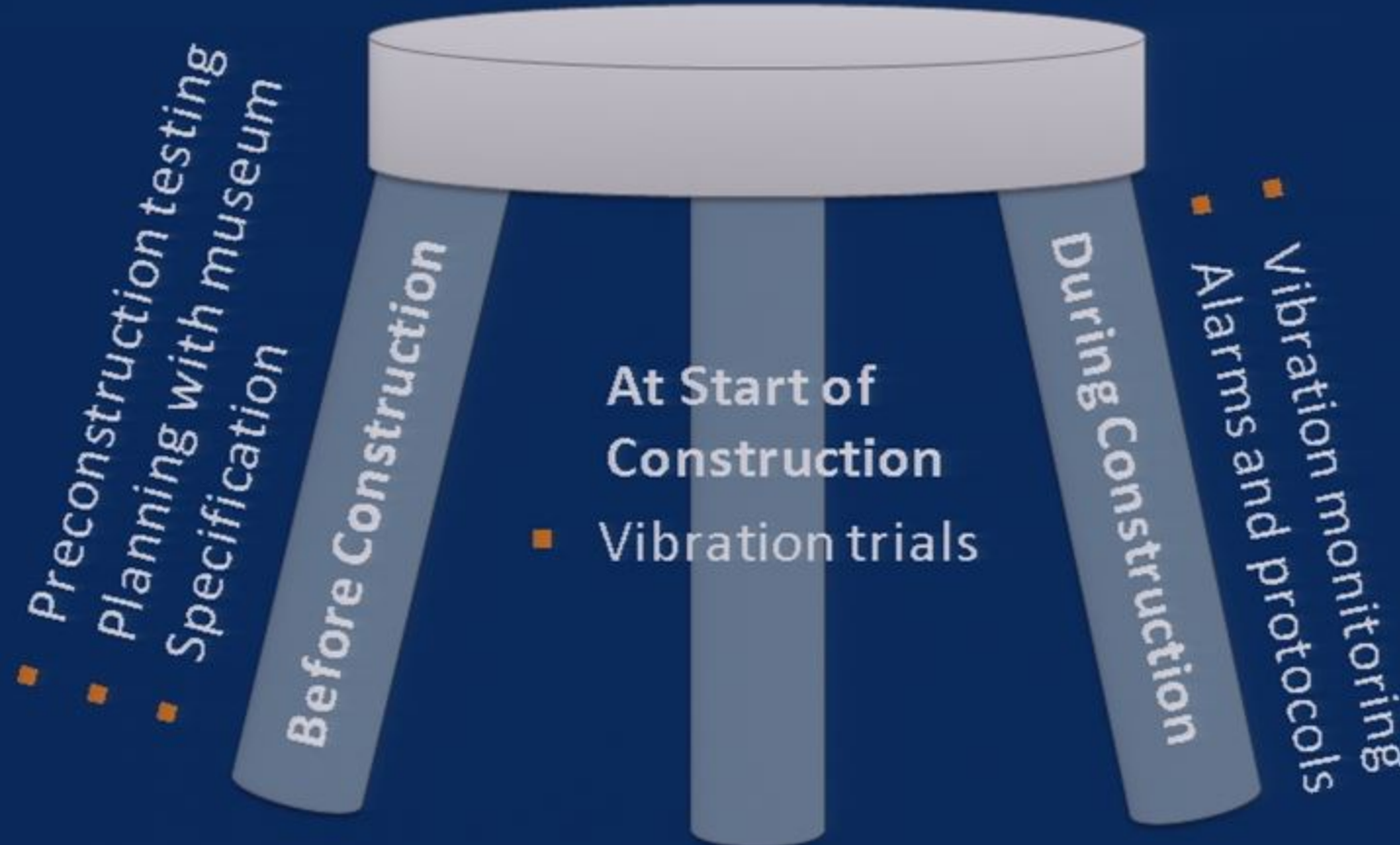


The Rise Group  
WJE No. 2006.5025

# Vibration Control Methodology

## Goals:

1. Protect collection and building
2. Guidance to museum for advance planning
3. Enforce limits without undue constraints



# Vibrations During Normal Operations

## Possible Sources:

- Heavy traffic outside (trains, buses, trucks, etc.)
- Construction on neighboring sites
- Mechanical equipment



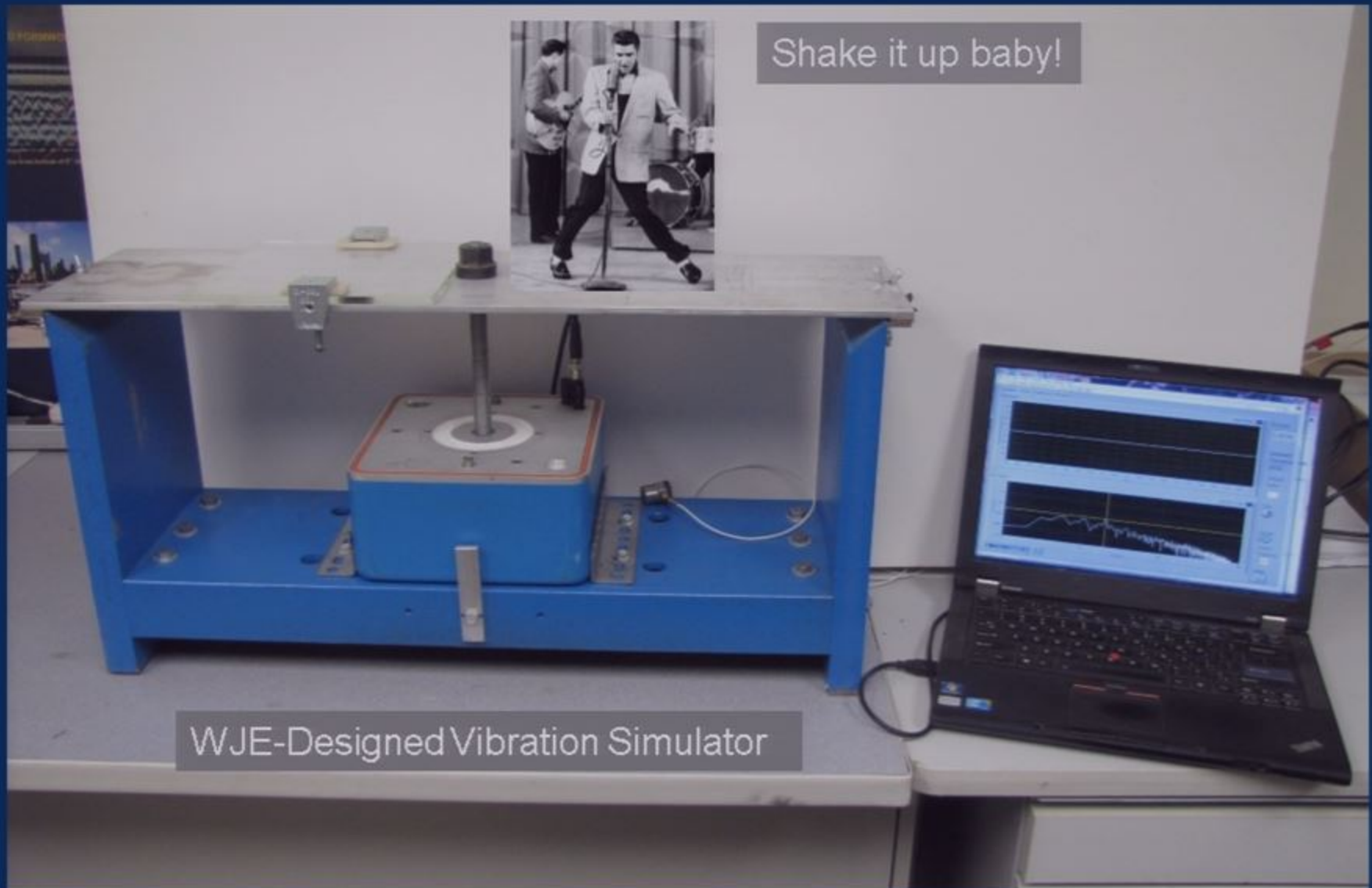
# Vibrations During Normal Operations

## Mitigation:

1. Advocate with entity causing the vibration (reduce or control their activities)
2. Move sensitive artwork away from high vibration zones
3. For non-moveable objects, design vibration isolation mounts or supports



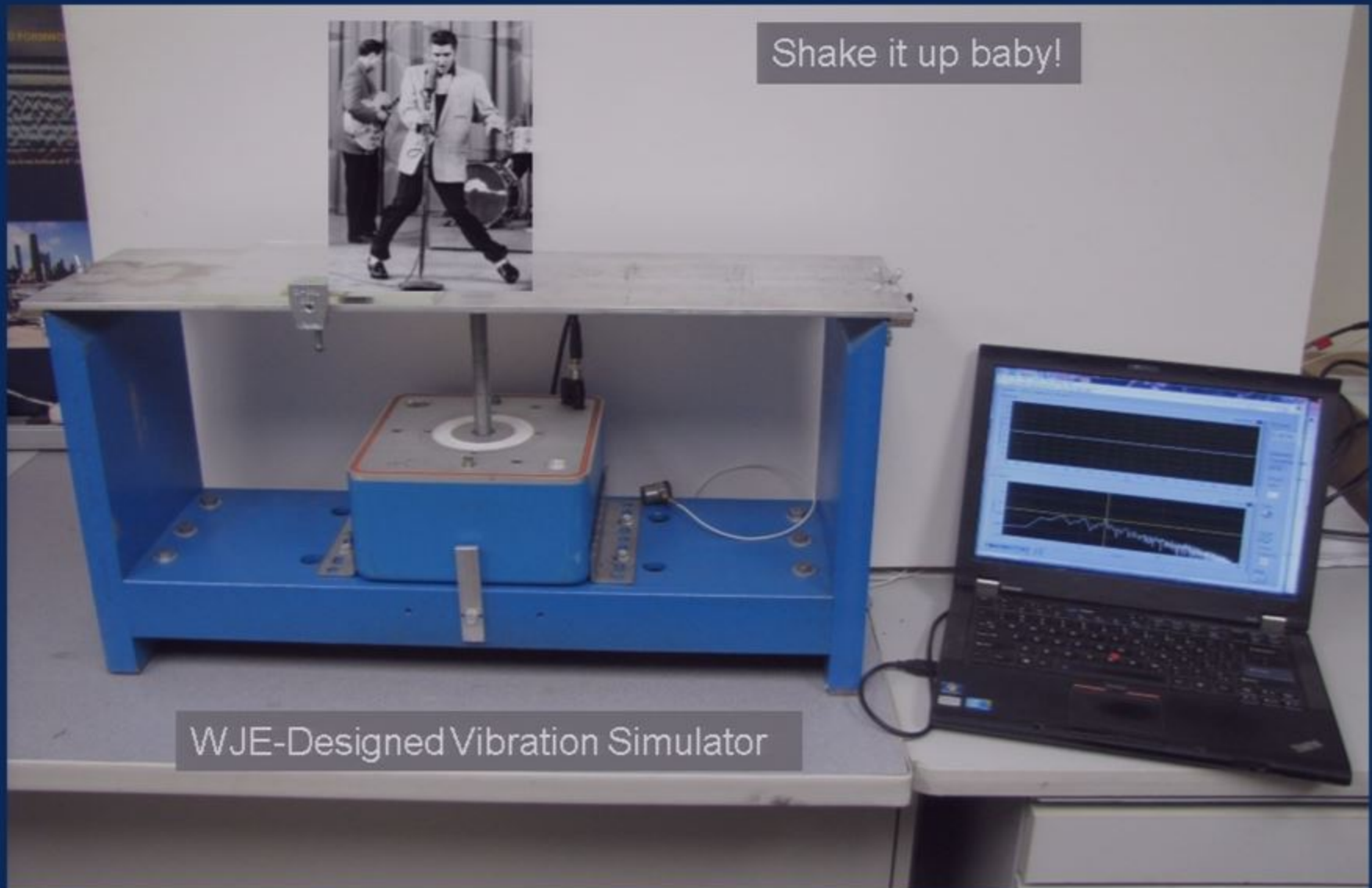
# Vibration Demonstration!



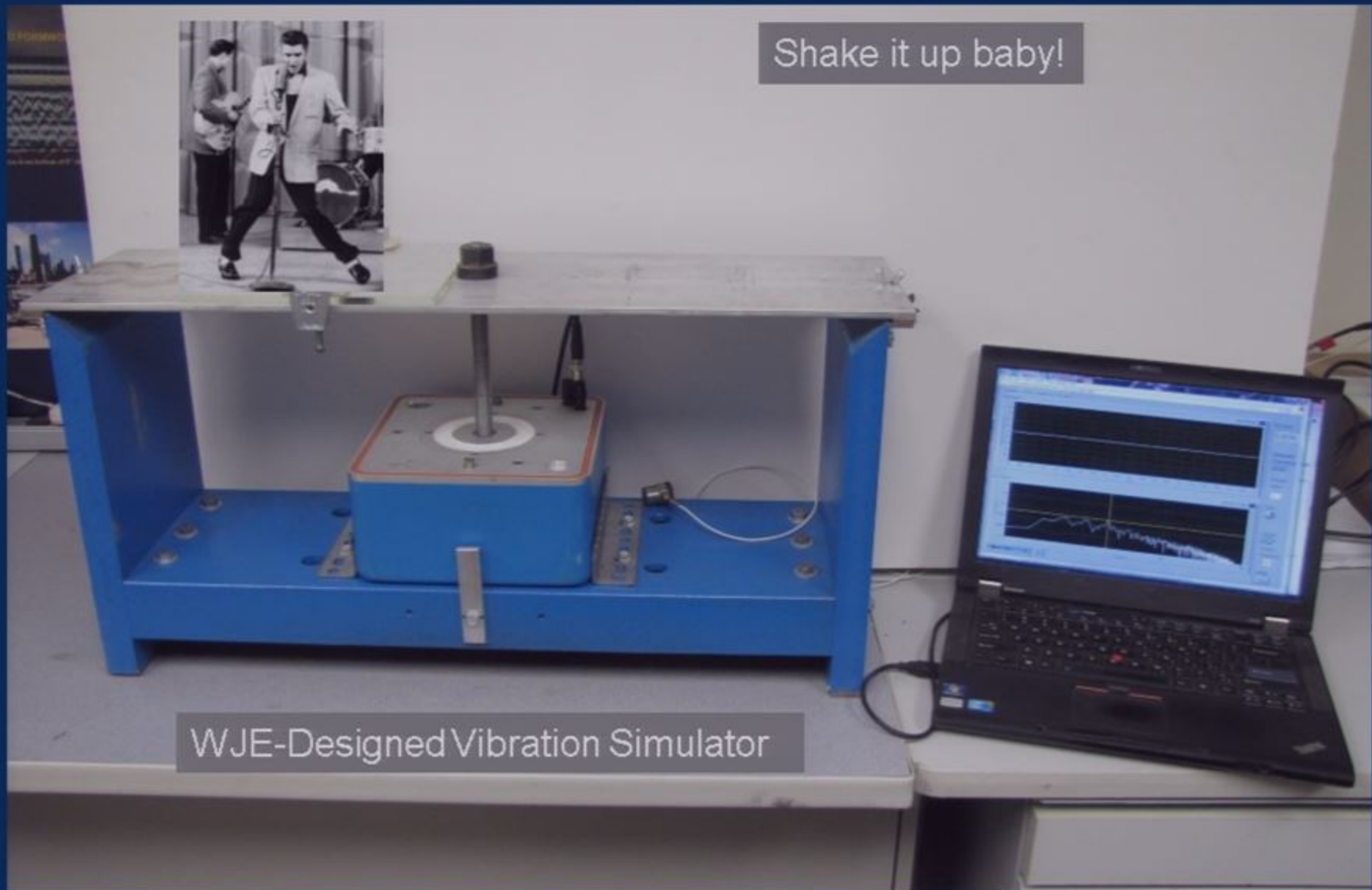
Shake it up baby!

WJE-Designed Vibration Simulator

# Vibration Demonstration!



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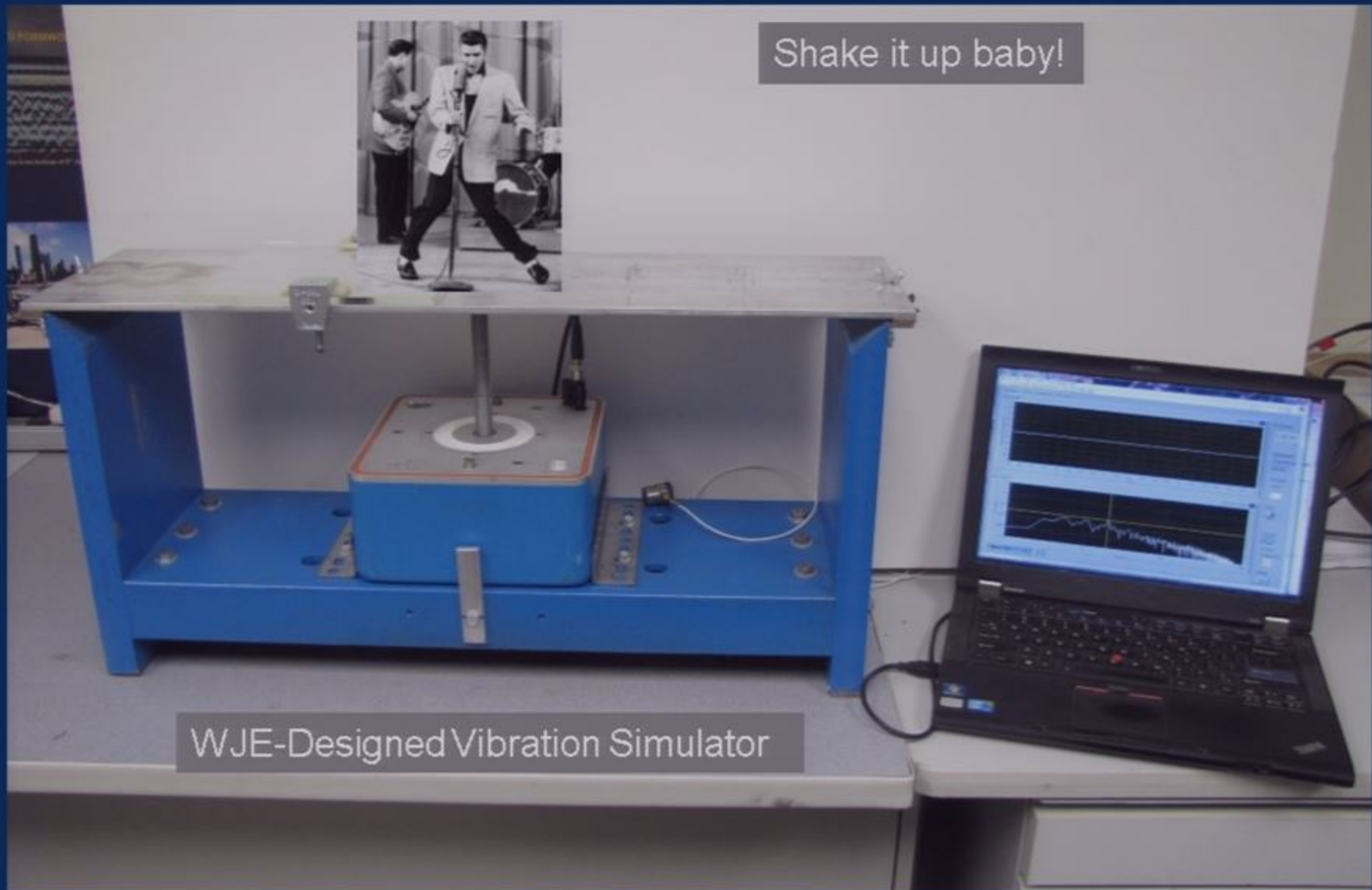


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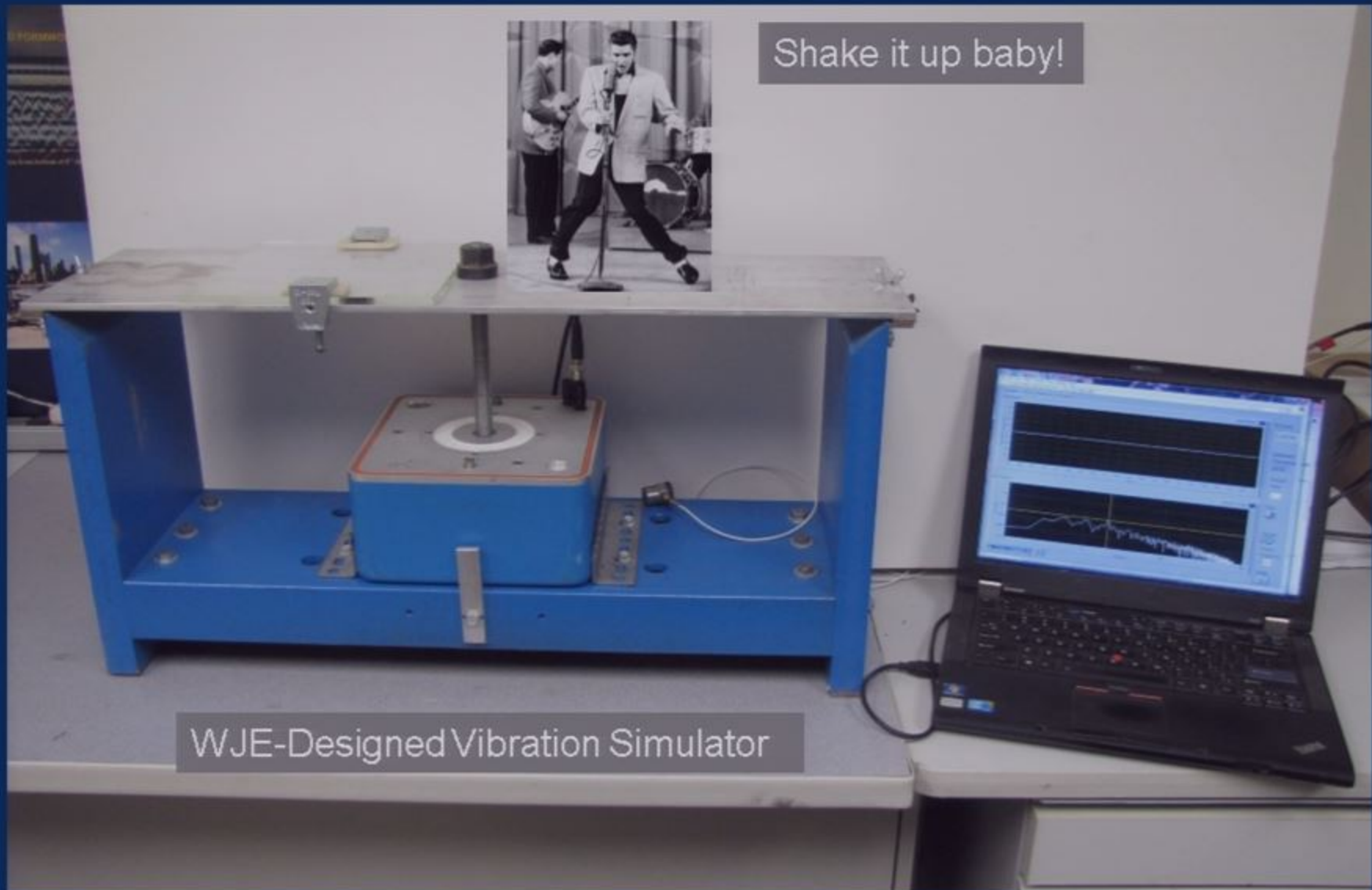
WJE-Designed Vibration Simulator



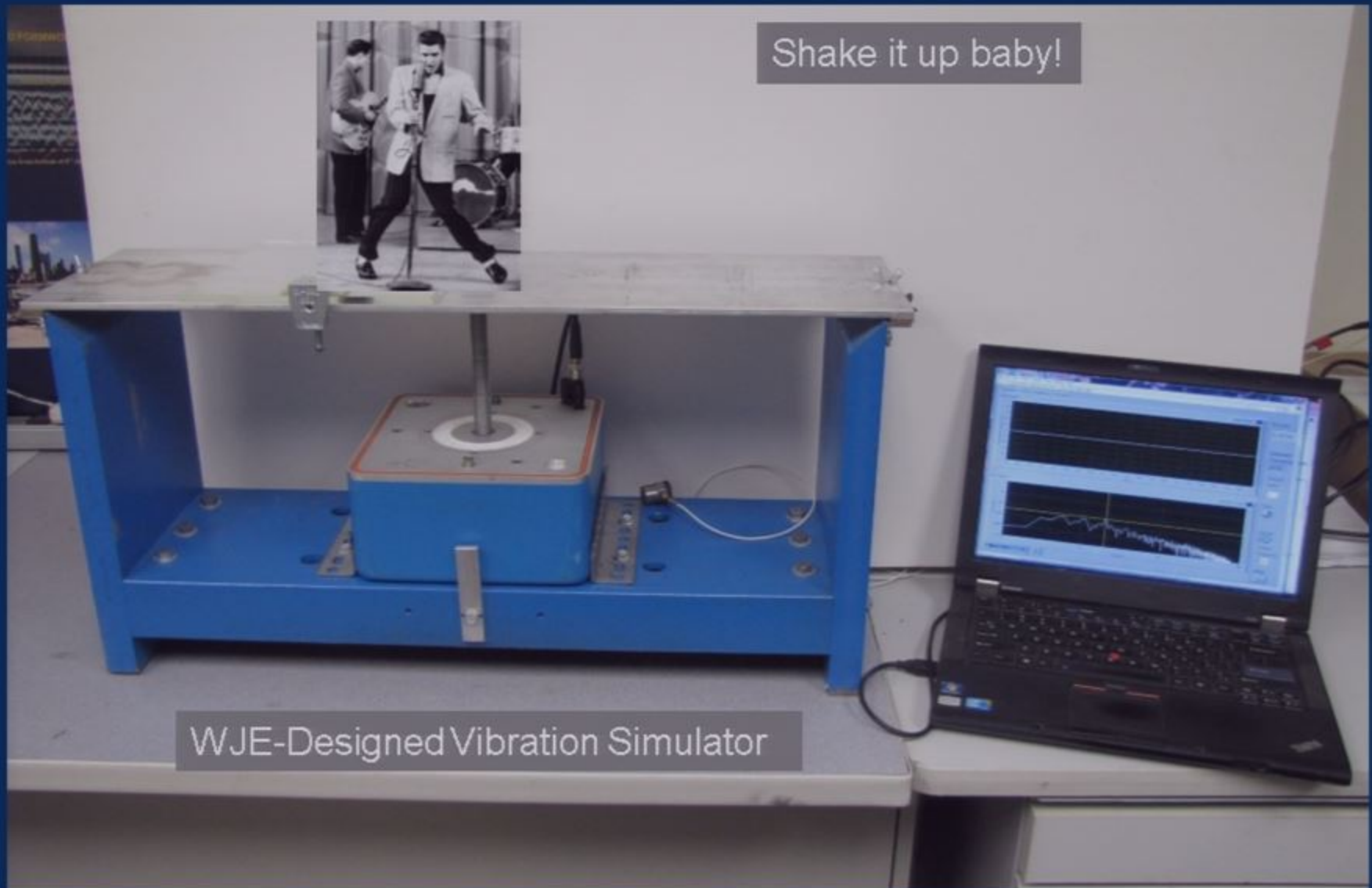
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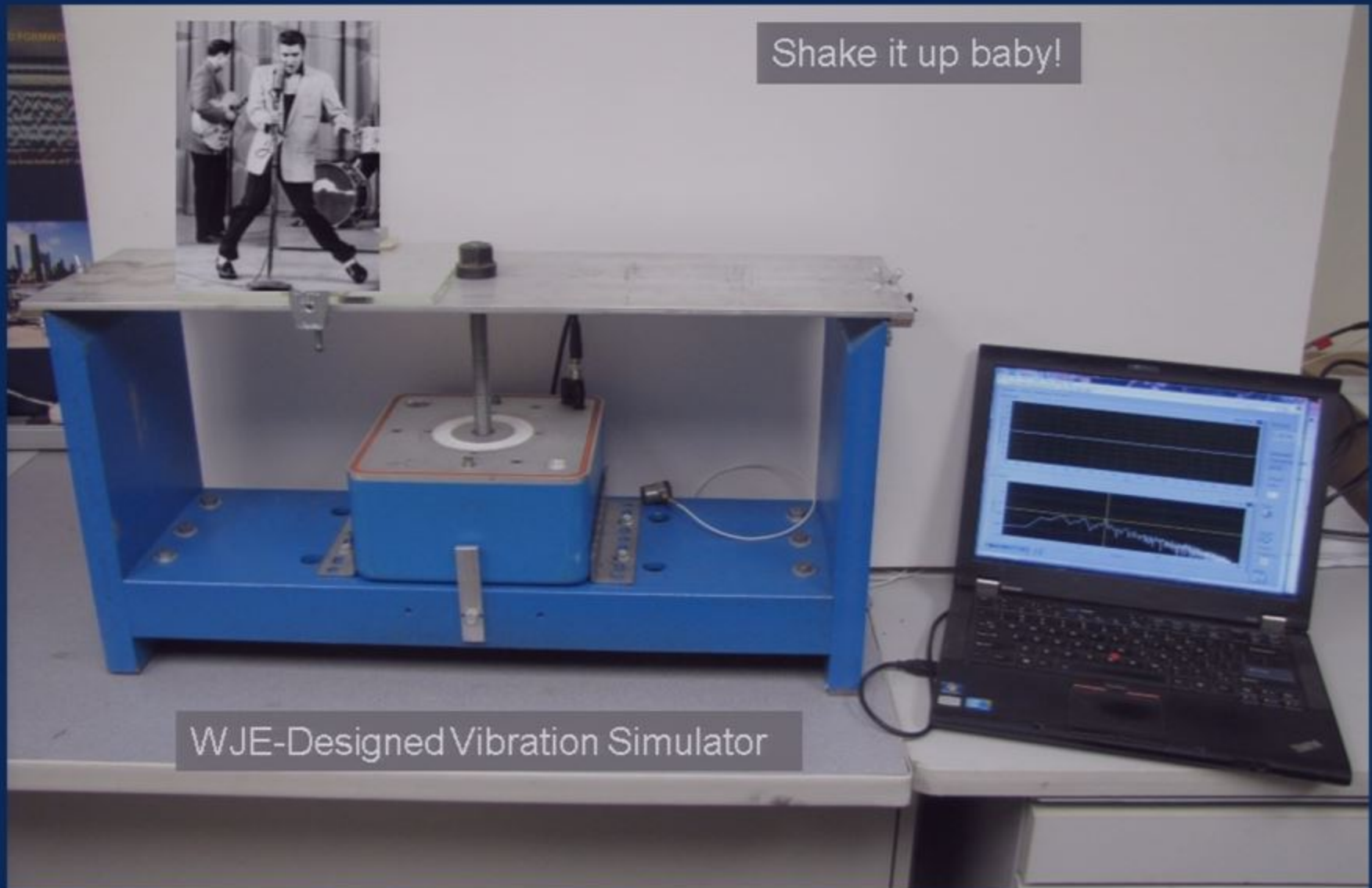
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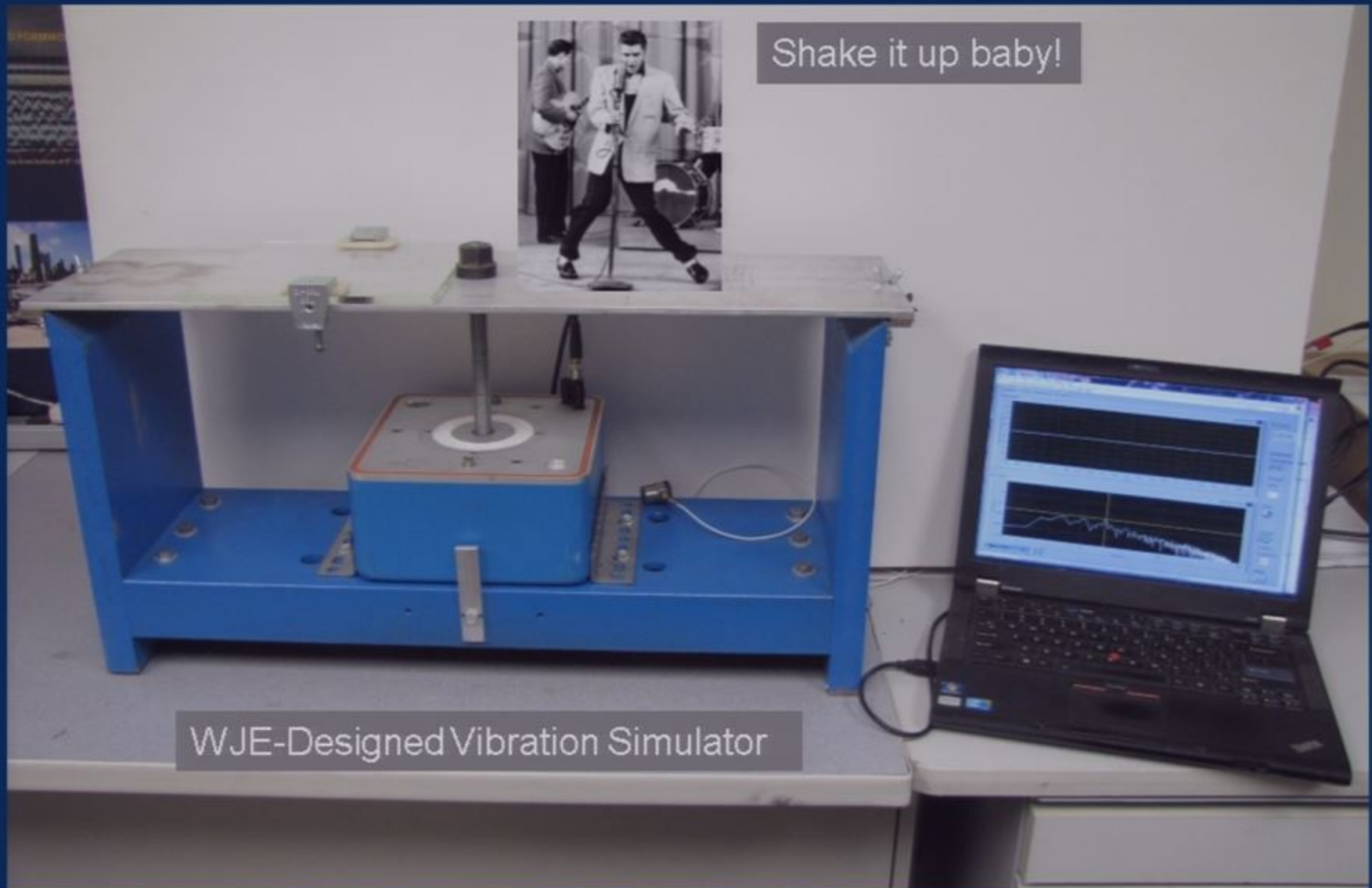
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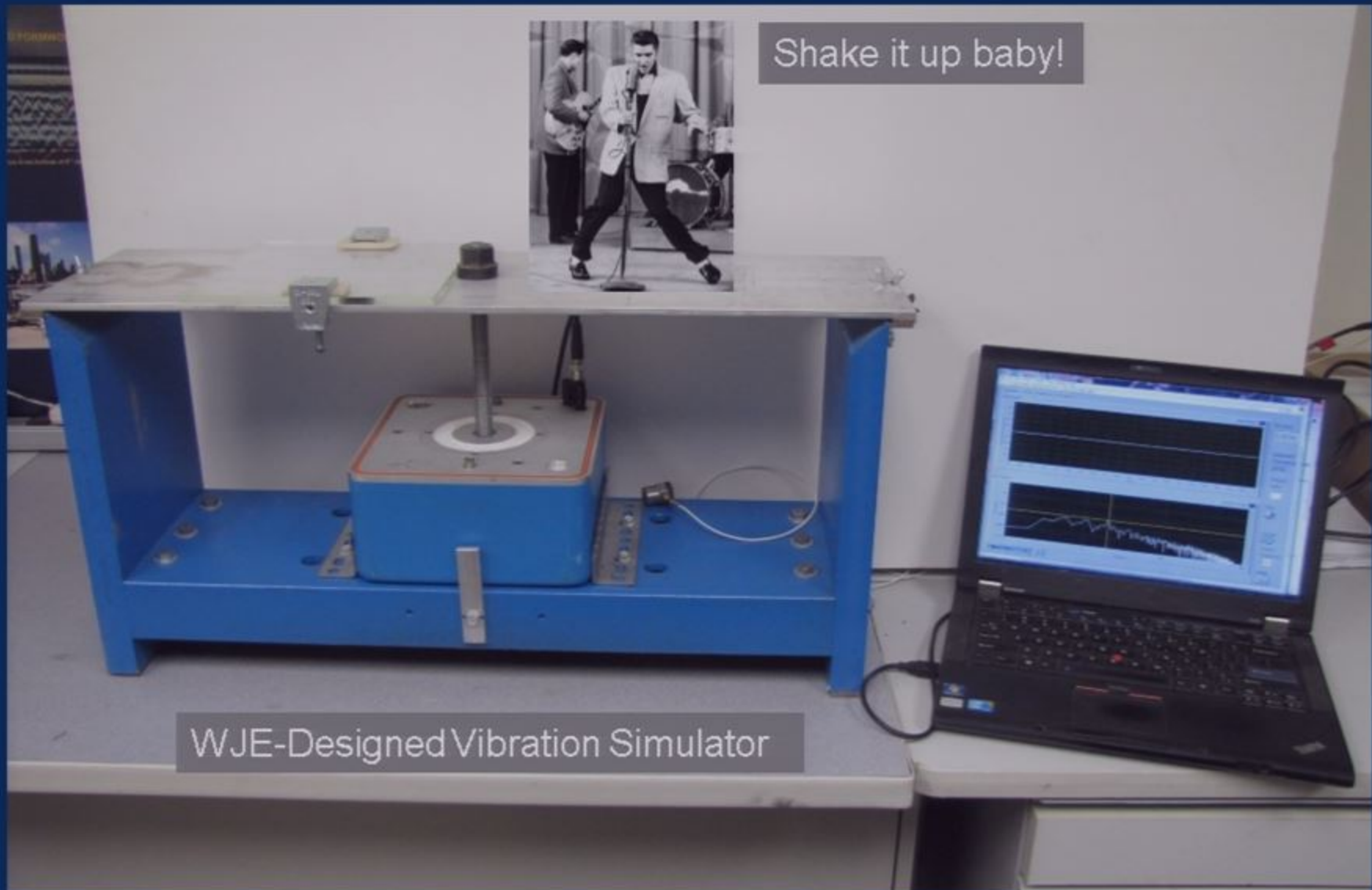
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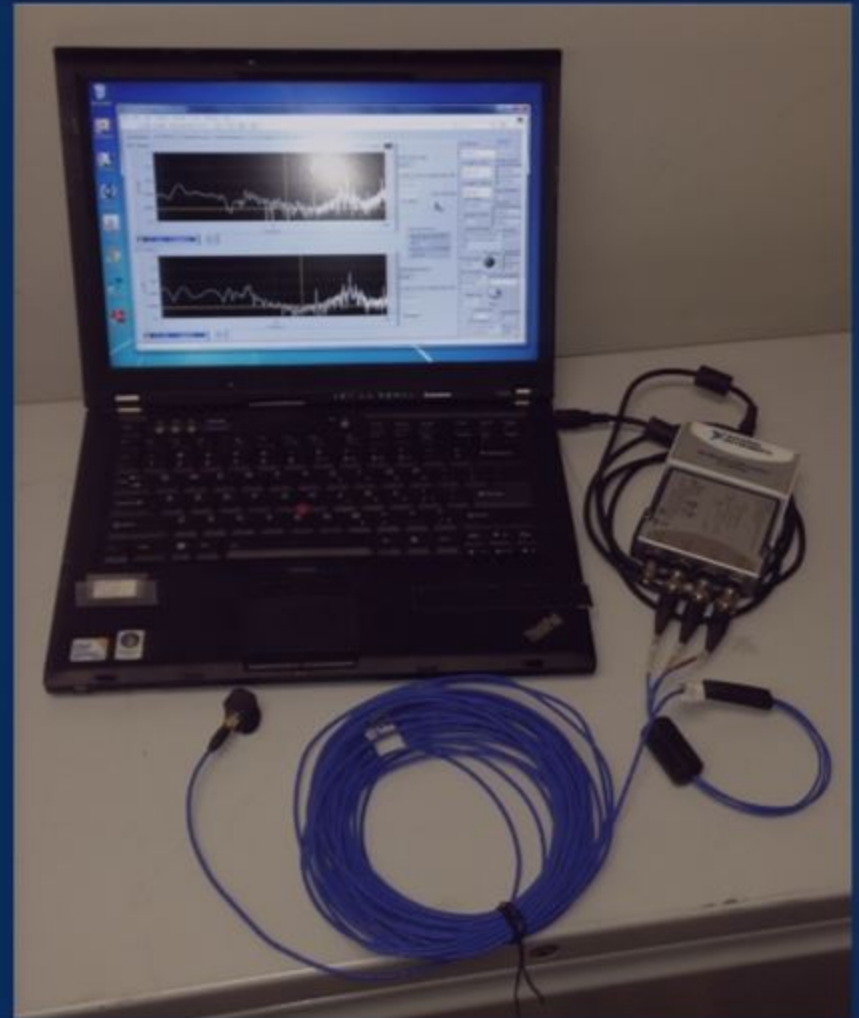
# Vibration Demonstration!



# Typical Vibration Monitoring Equipment



Typical seismograph

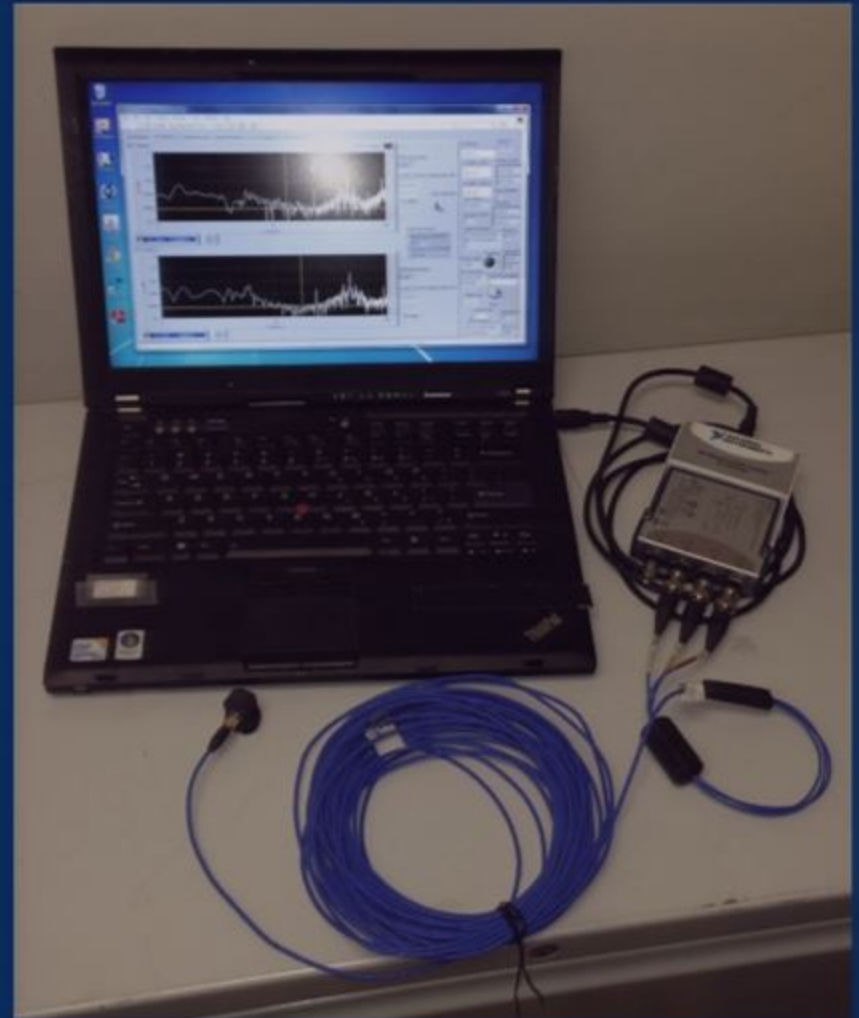


Custom laptop-based system

# Typical Vibration Monitoring Equipment



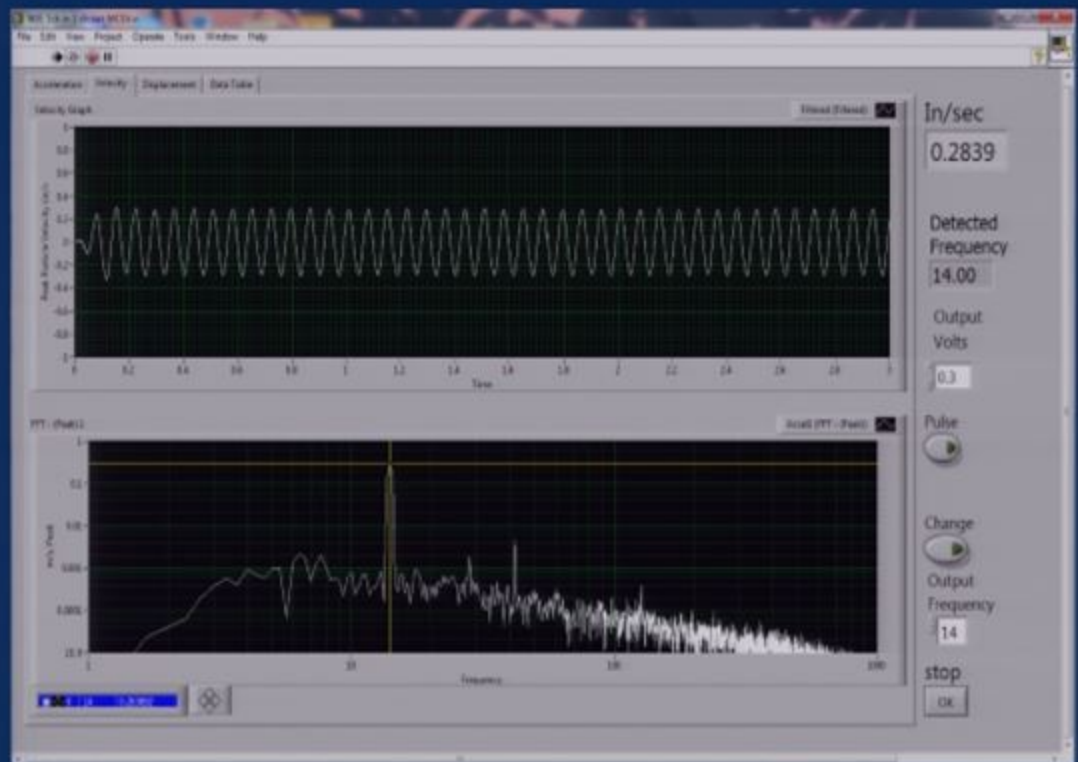
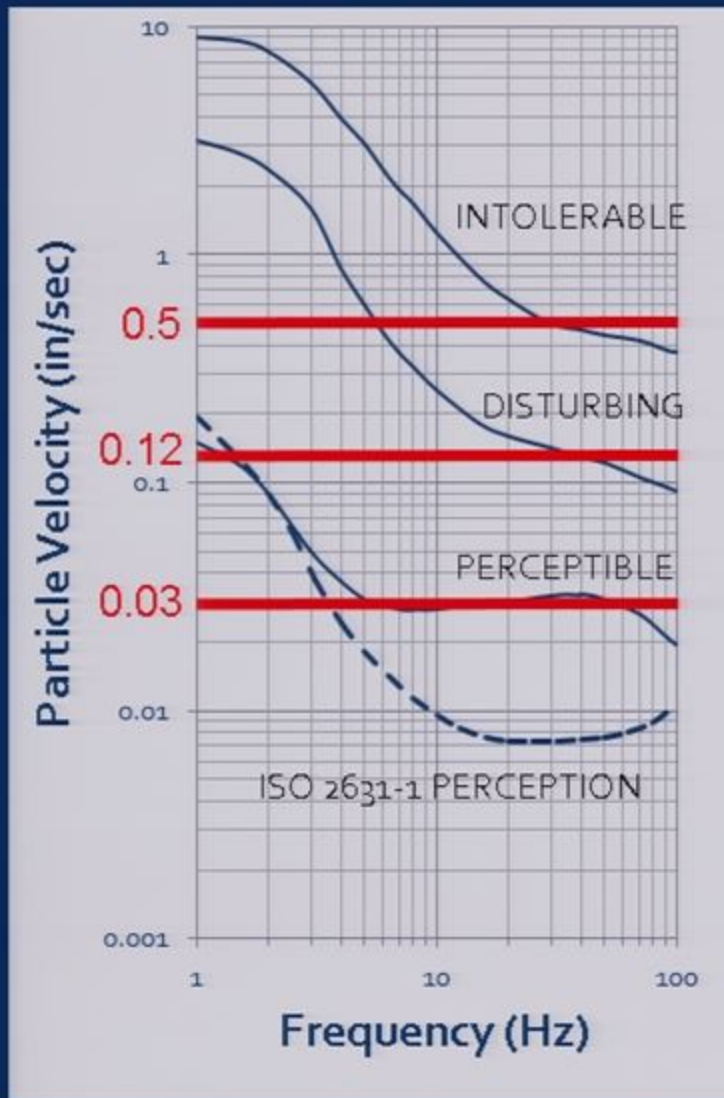
Typical seismograph



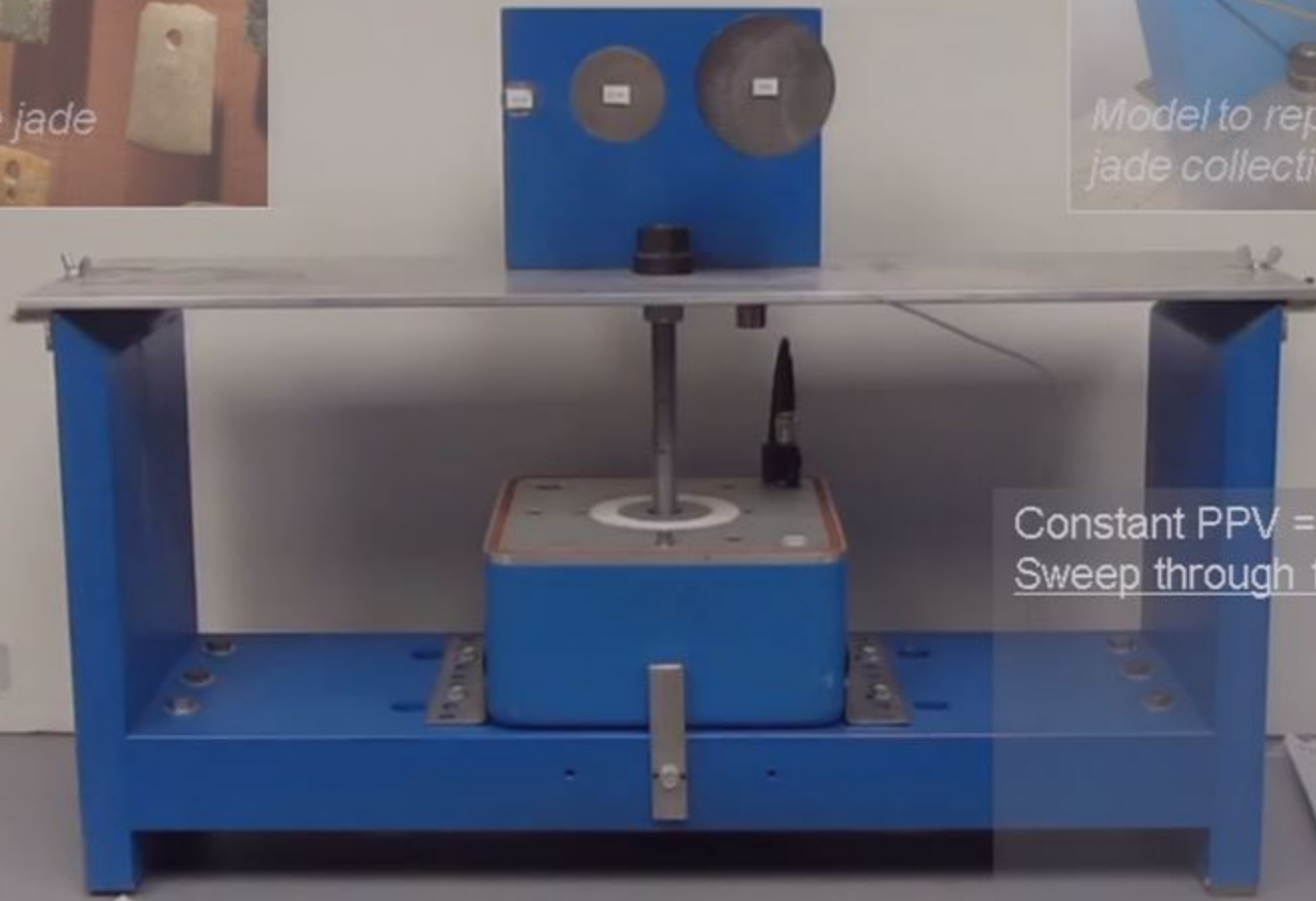
Custom laptop-based system



# Human Perception (2 Volunteers Please! 😊)

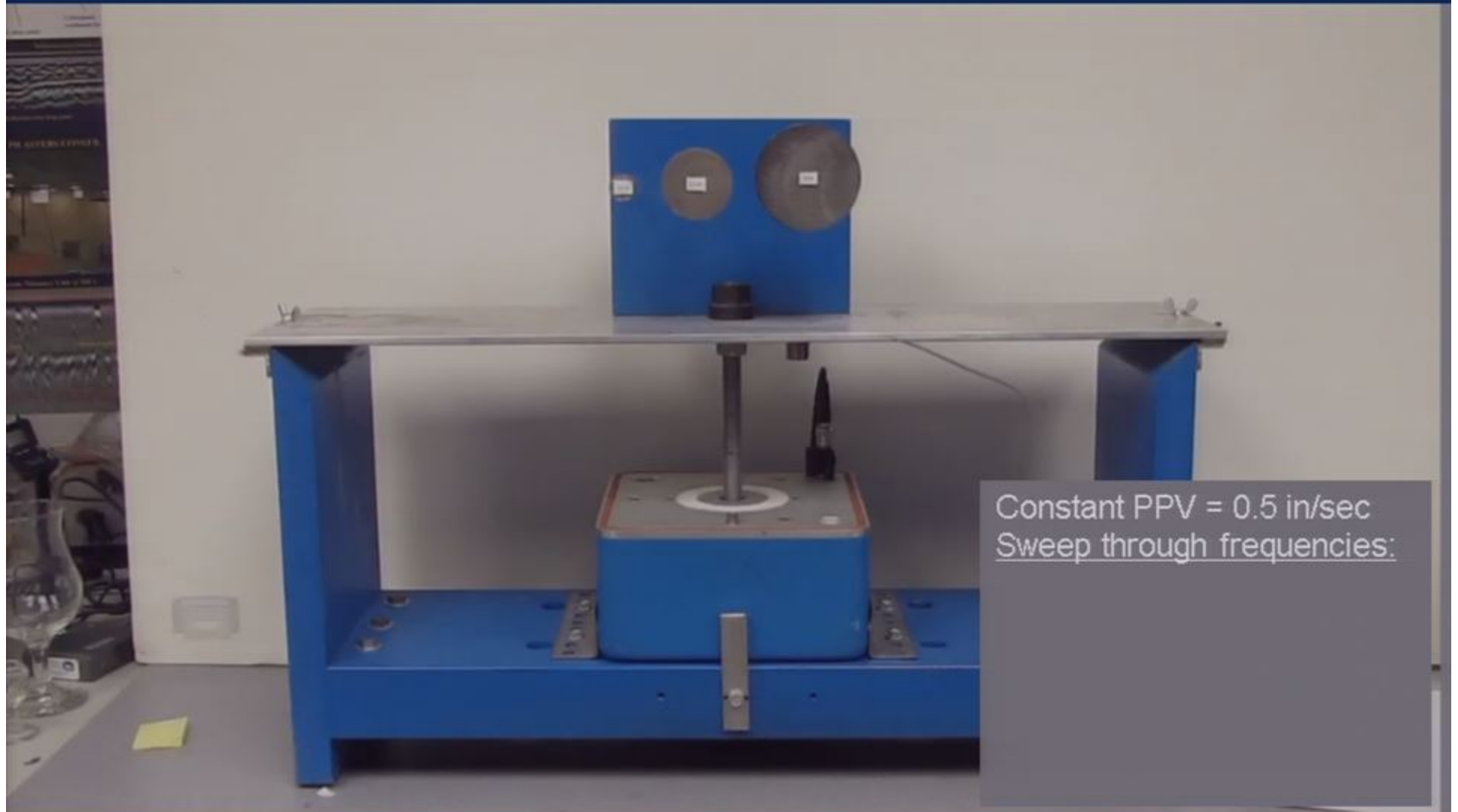


# Potential for Resonance

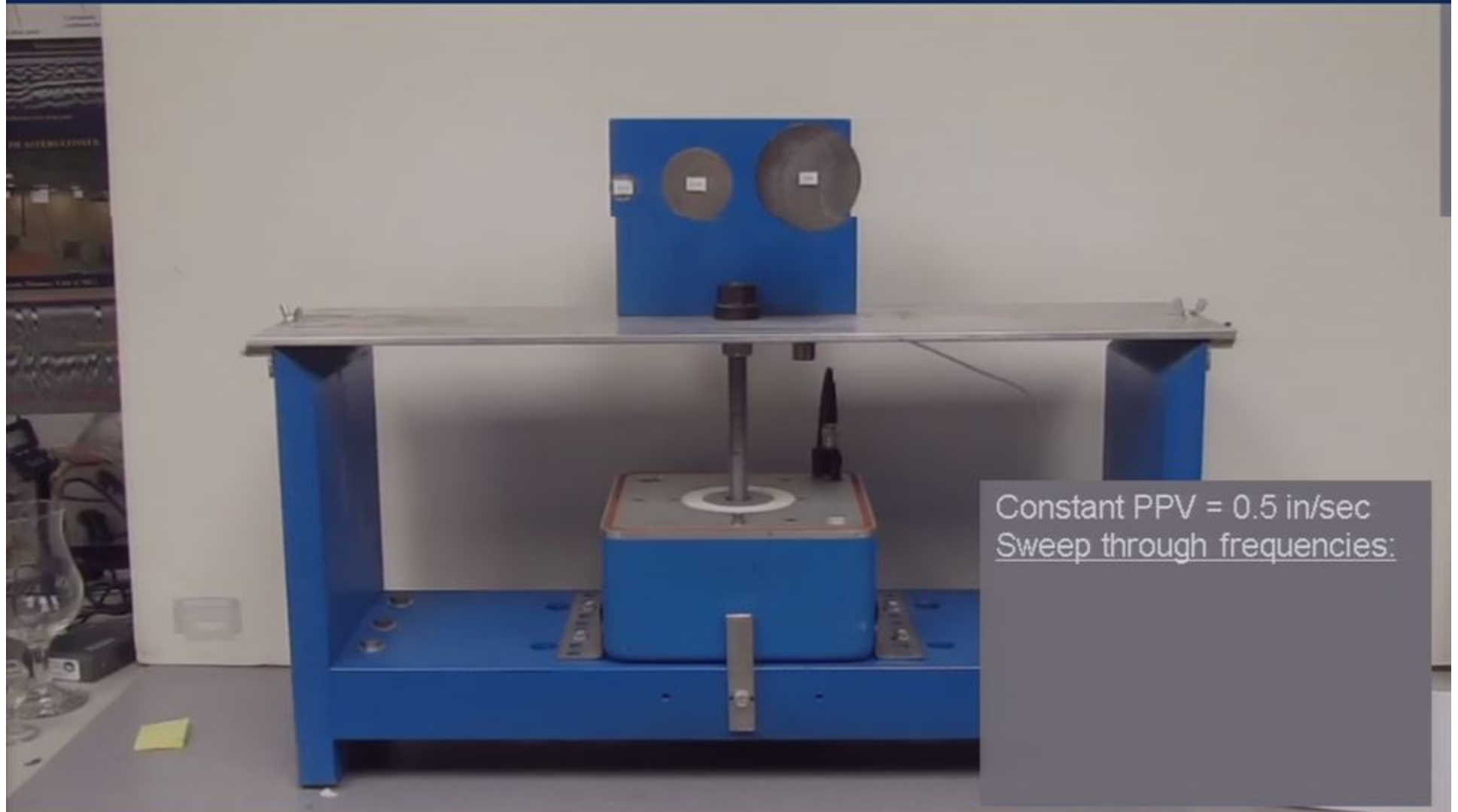


Constant PPV = 0.5 in/sec  
Sweep through frequencies:

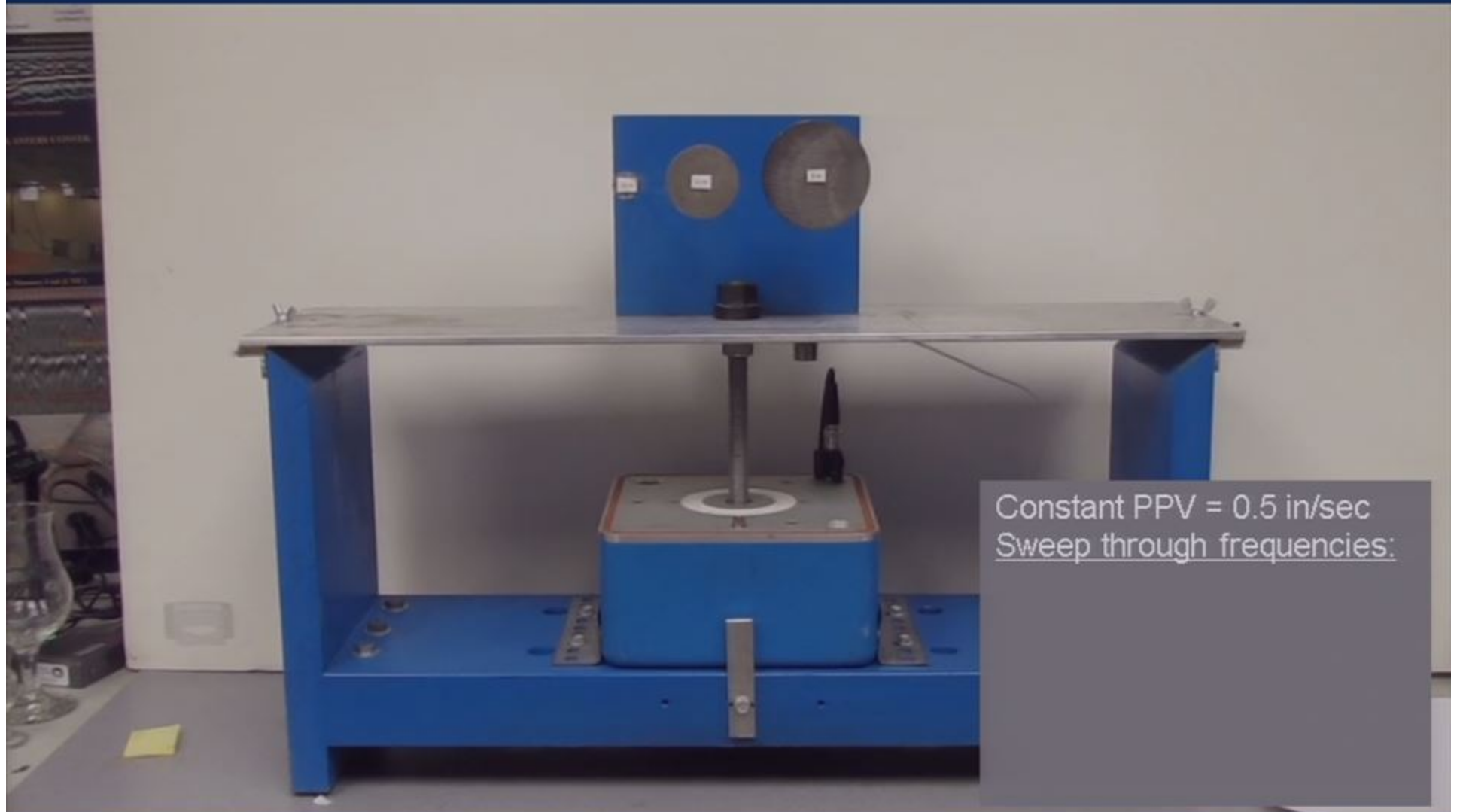
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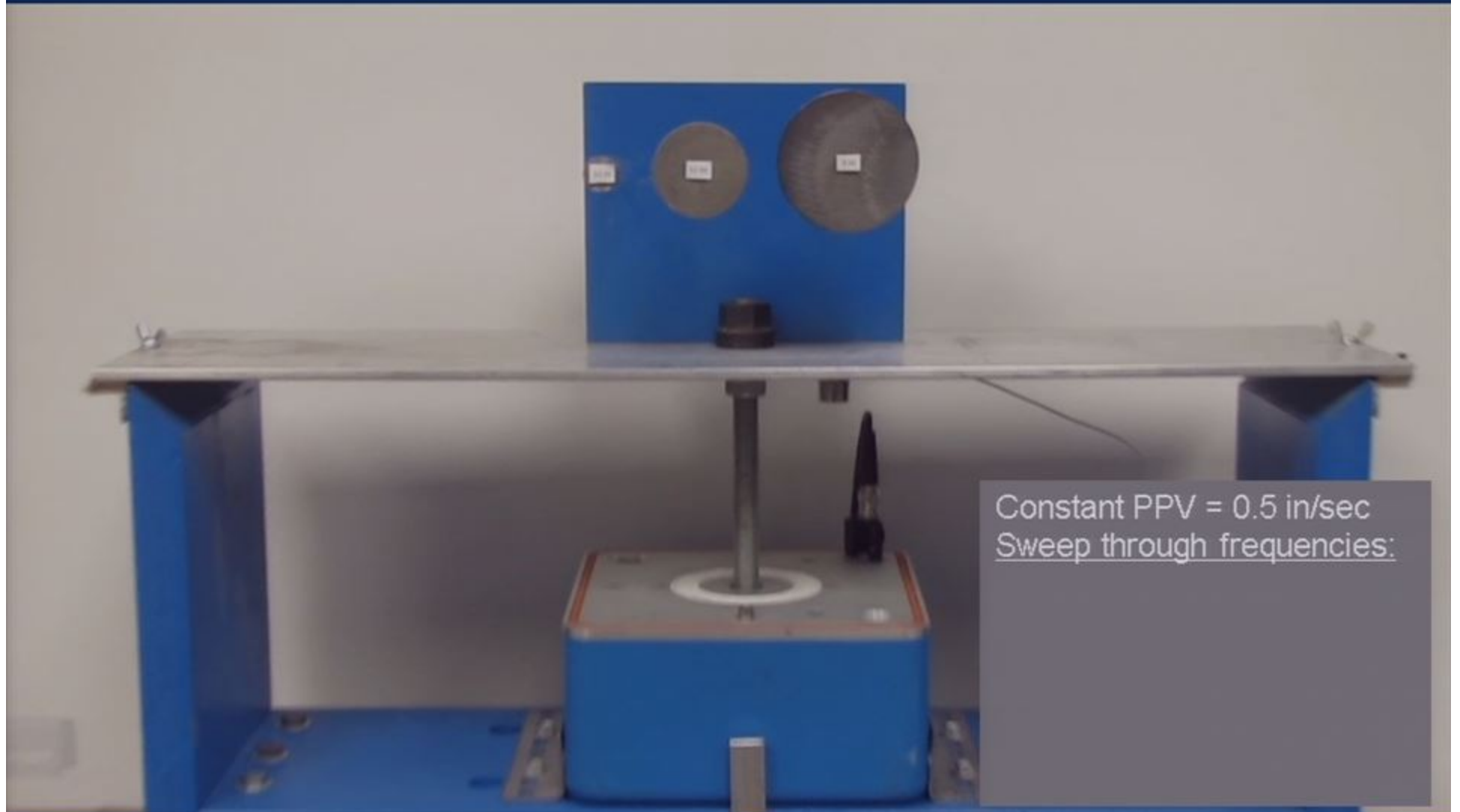


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Constant PPV = 0.5 in/sec  
Sweep through frequencies:

# Potential for Resonance



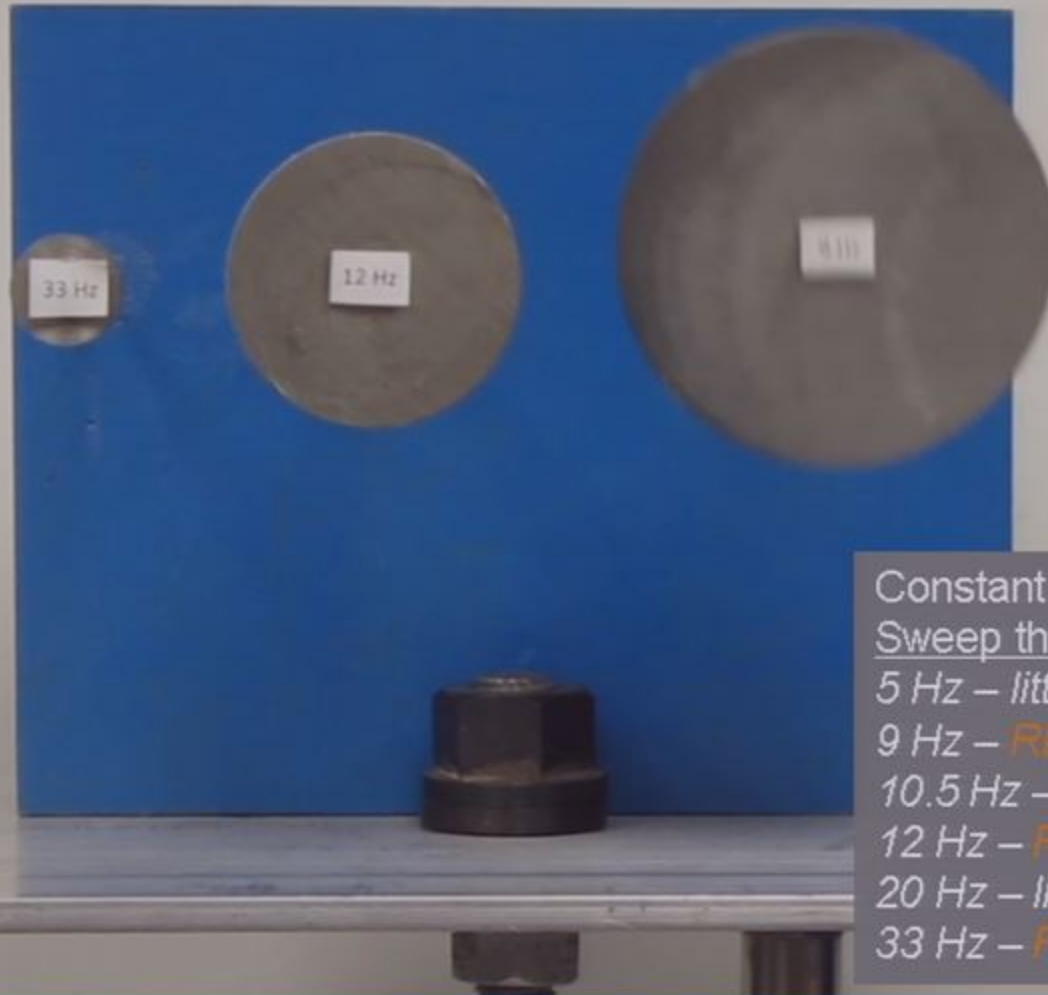
Constant PPV = 0.5 in/sec  
Sweep through frequencies:

# Potential for Resonance



Constant PPV = 0.5 in/sec  
Sweep through frequencies:  
5 Hz – little response  
9 Hz – **RESONANCE** right  
10.5 Hz – little response  
12 Hz – **RESONANCE** center  
20 Hz – little response  
33 Hz – **RESONANCE** left

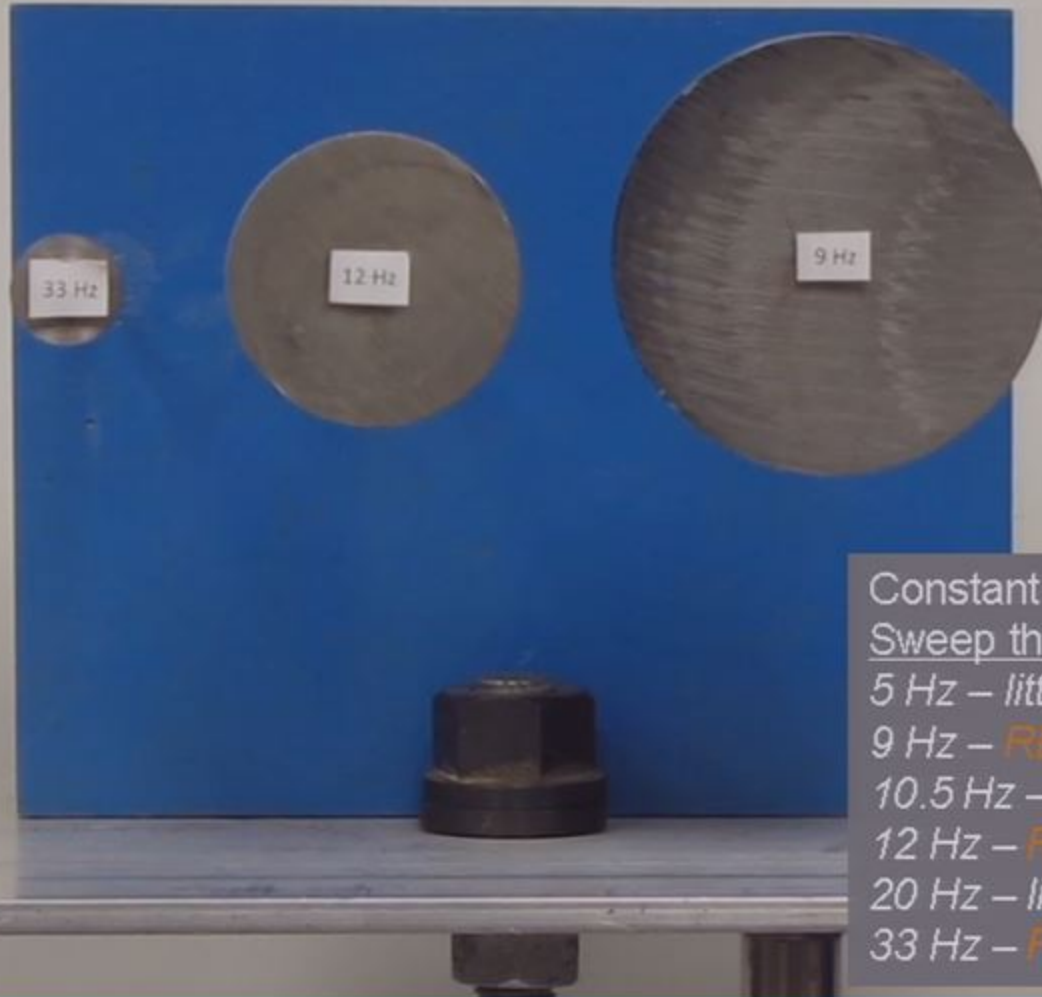
# Potential for Resonance



Constant PPV = 0.5 in/sec  
Sweep through frequencies:  
5 Hz – little response  
9 Hz – **RESONANCE** right  
10.5 Hz – little response  
12 Hz – **RESONANCE** center  
20 Hz – little response  
33 Hz – **RESONANCE** left

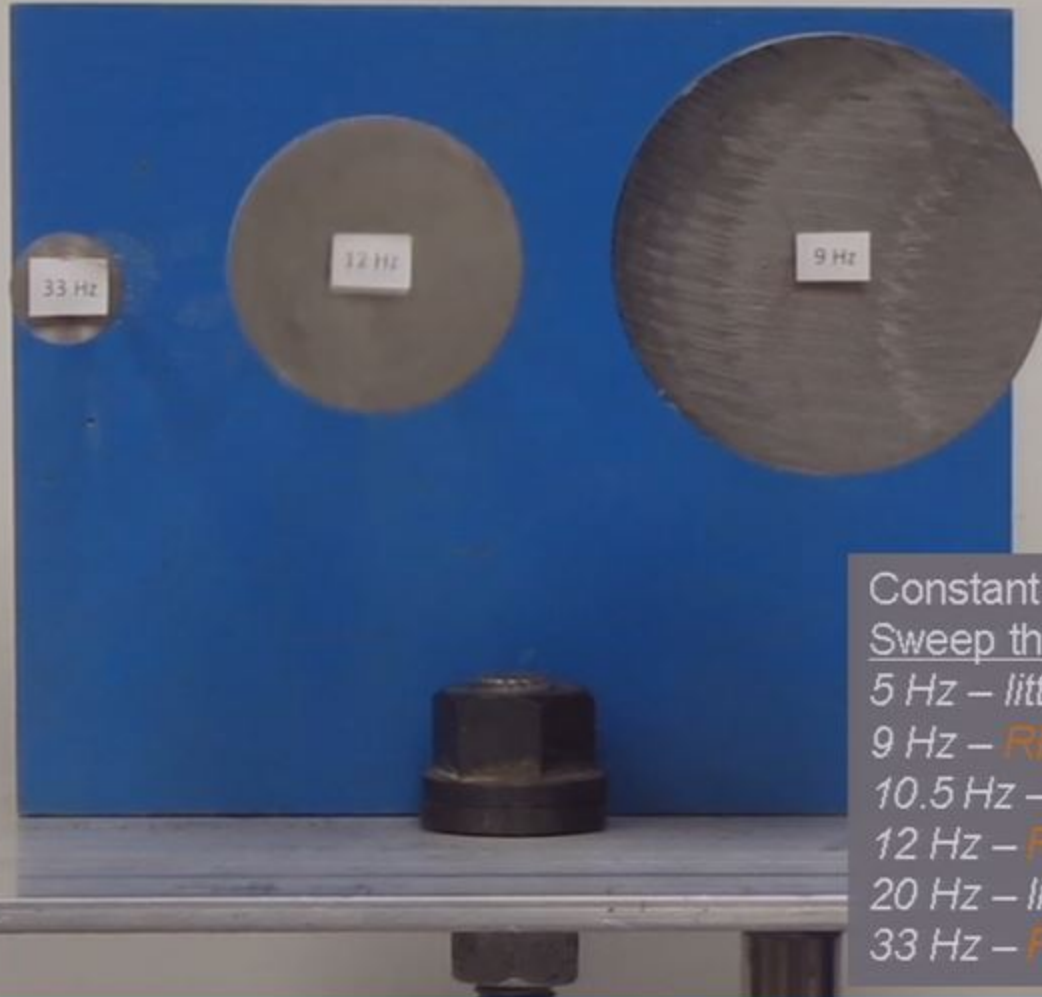


# Potential for Resonance



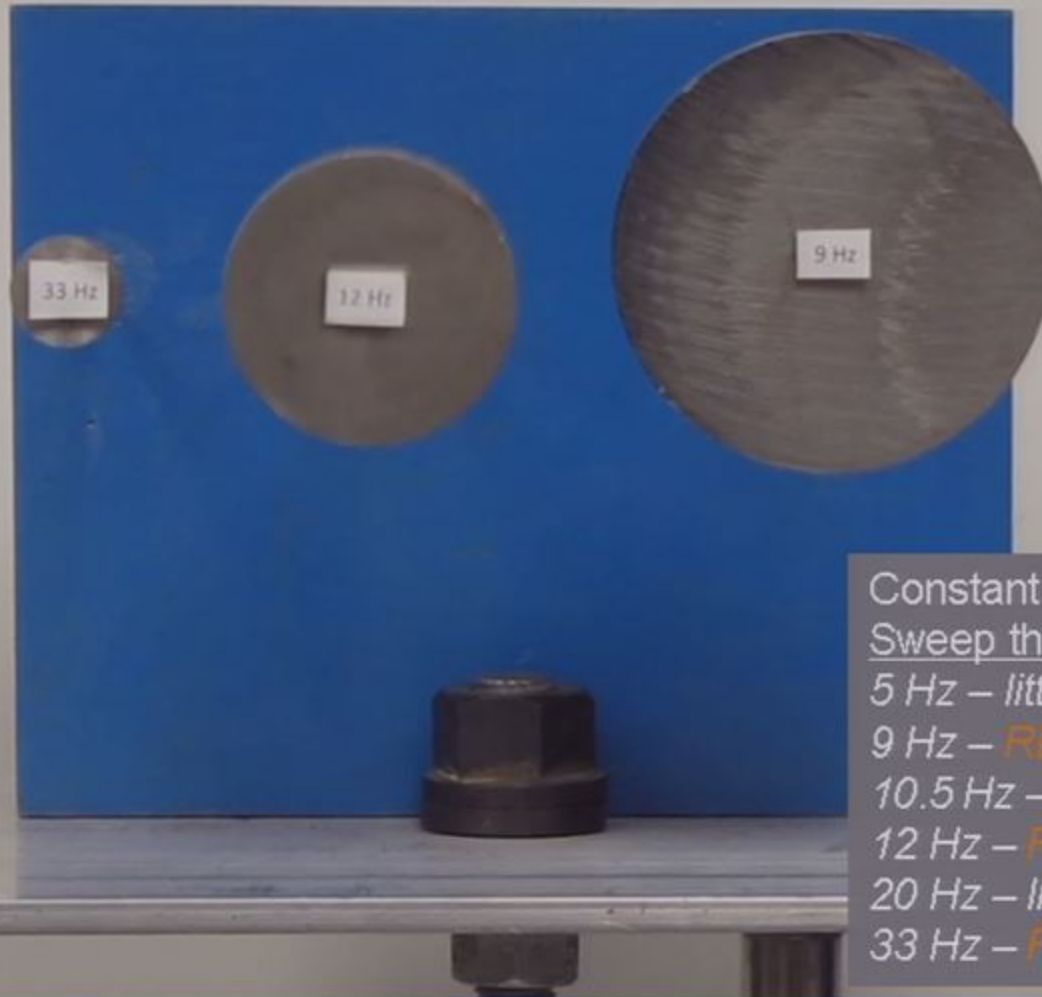
Constant PPV = 0.5 in/sec  
Sweep through frequencies:  
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9 Hz – **RESONANCE** right  
10.5 Hz – little response  
12 Hz – **RESONANCE** center  
20 Hz – little response  
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# Potential for Resonance



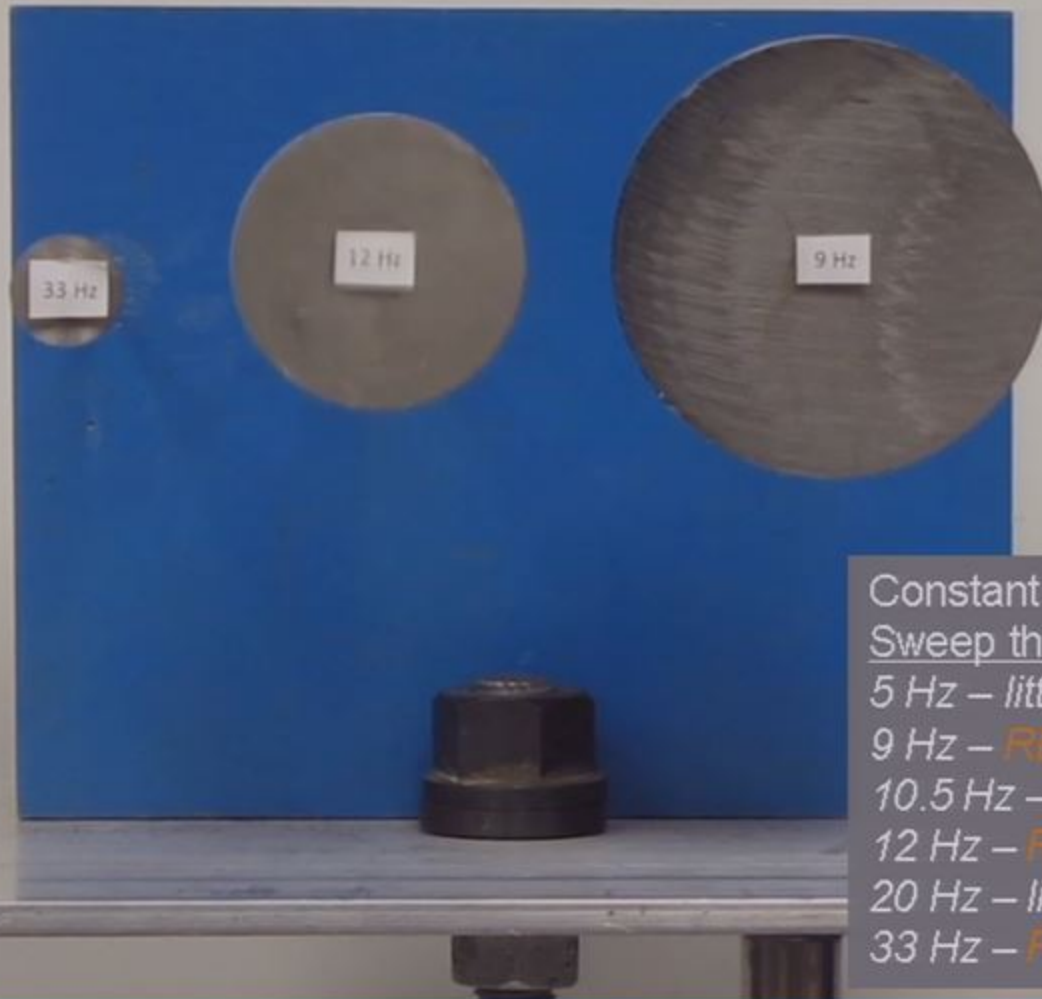
Constant PPV = 0.5 in/sec  
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10.5 Hz – little response  
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20 Hz – little response  
33 Hz – **RESONANCE** left

# Potential for Resonance



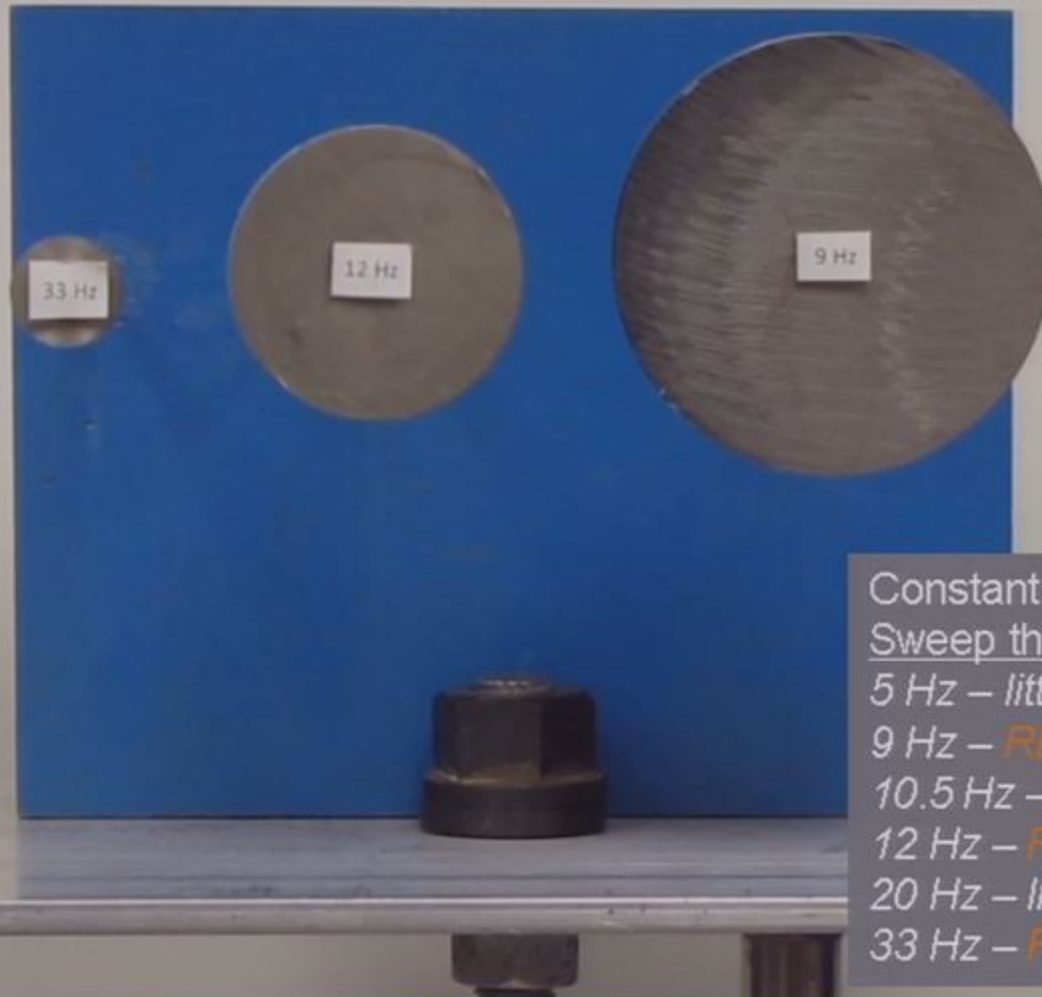
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# Potential for Resonance

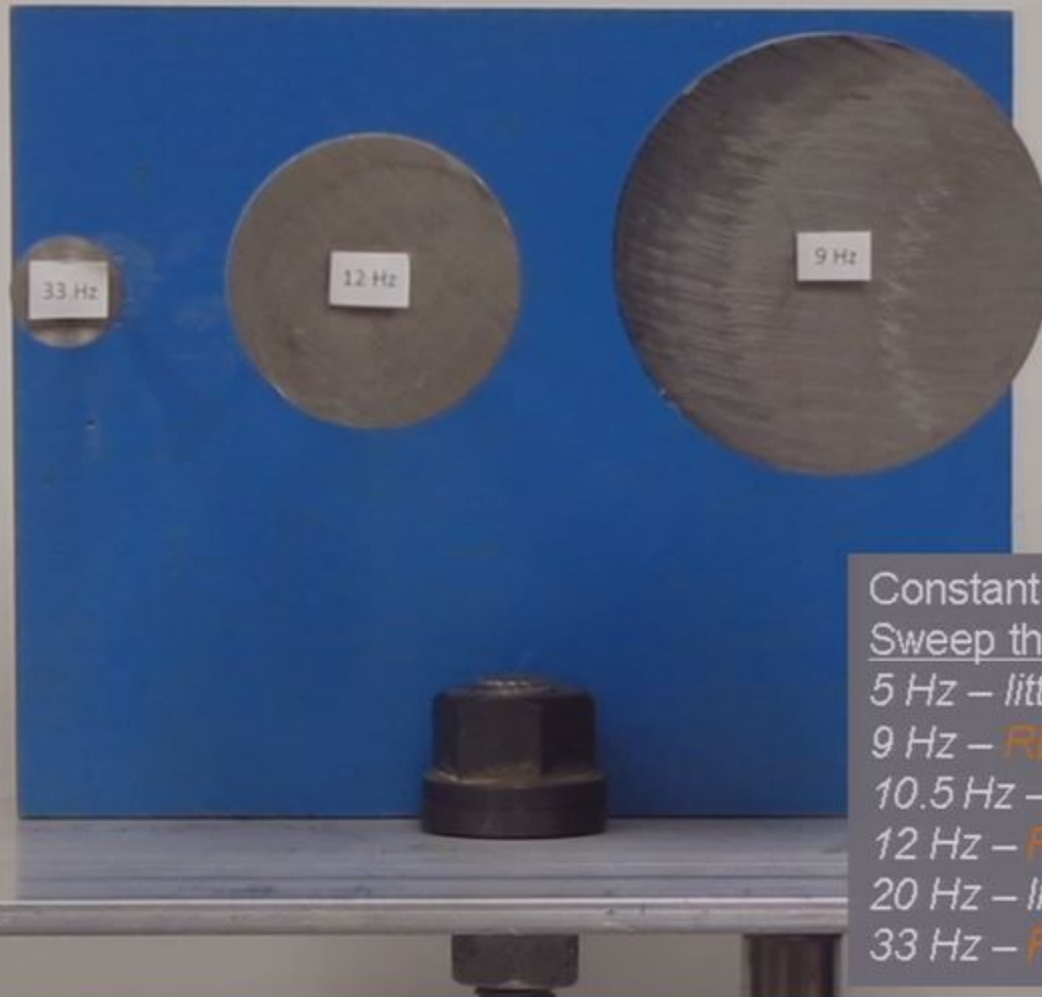


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# “Walking” (light objects, smooth surfaces)



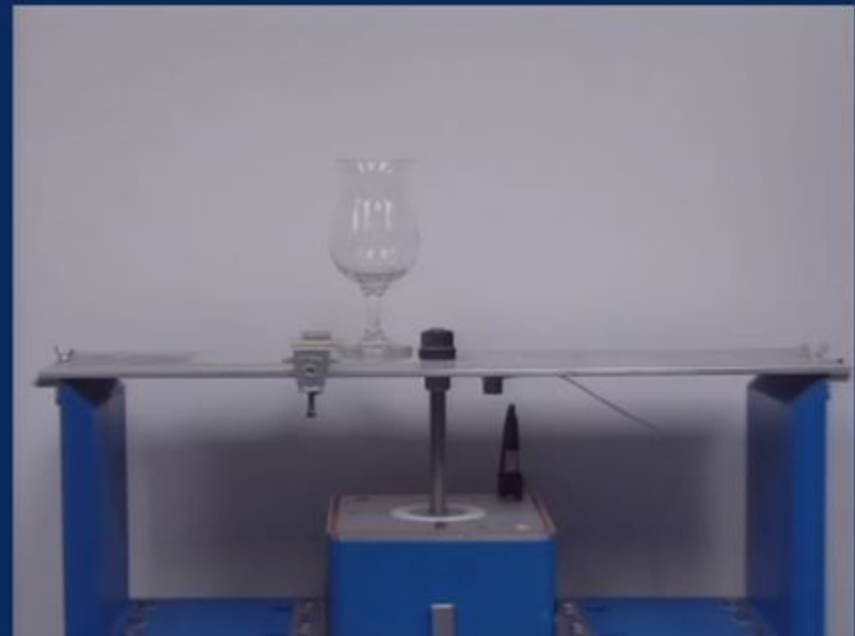
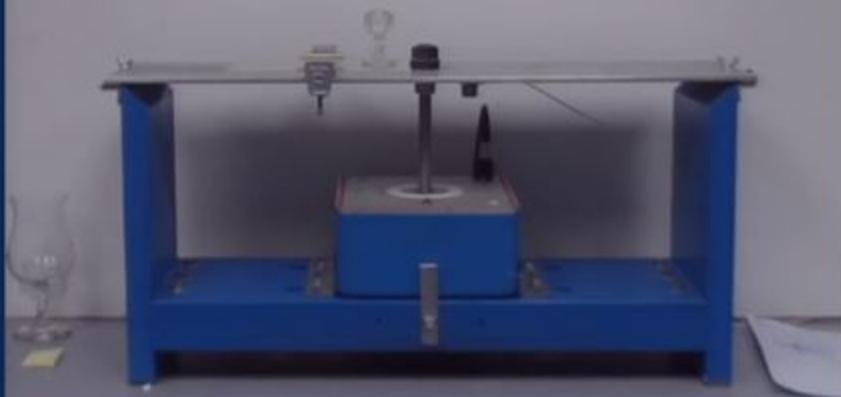
Clark Art Institute – potential for walking



Taft Museum of Art – potential for walking

Simulation...  
Watch cordial walk  
to RIGHT...

Steady-state  
 $f = 32 \text{ Hz}$



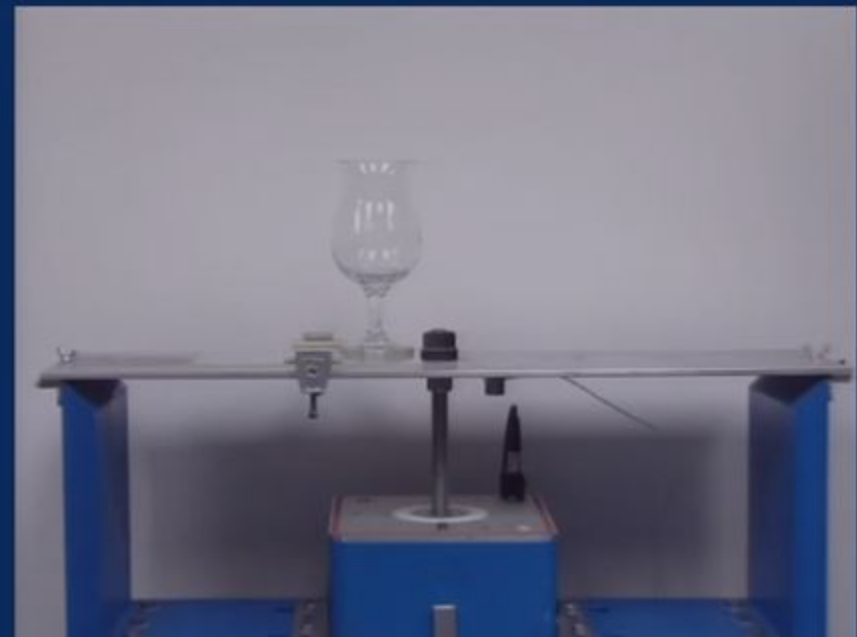
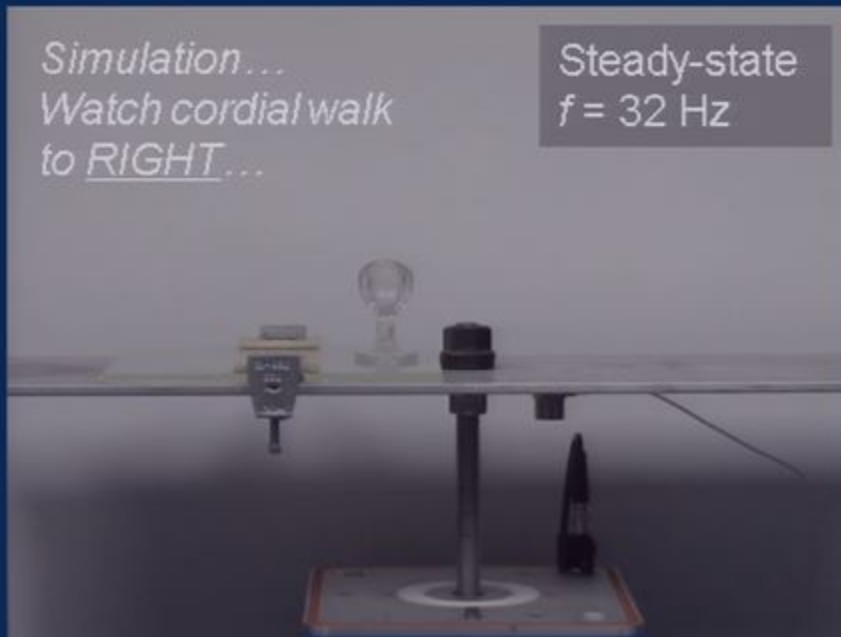
# “Walking” (light objects, smooth surfaces)



Clark Art Institute – potential for walking



Taft Museum of Art – potential for walking





# “Walking” (light objects, smooth surfaces)



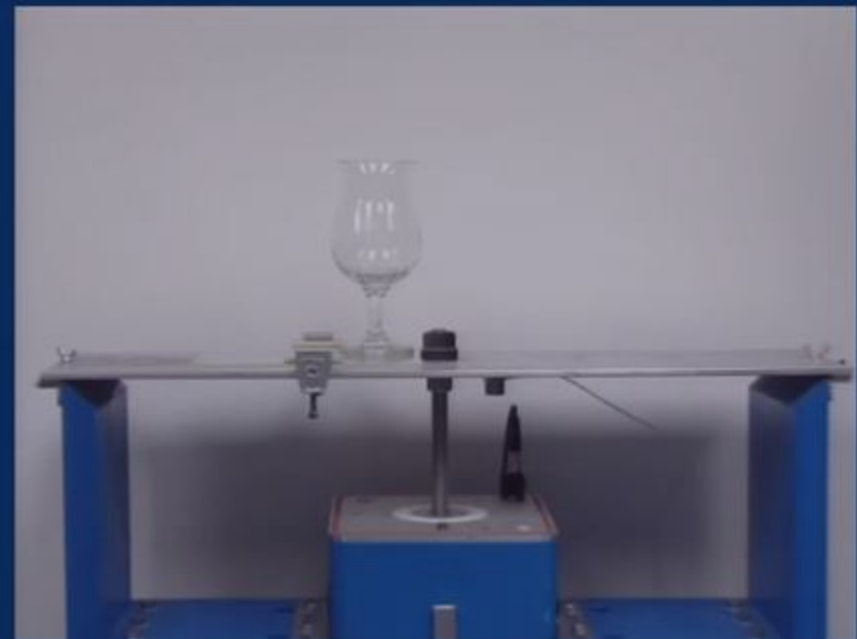
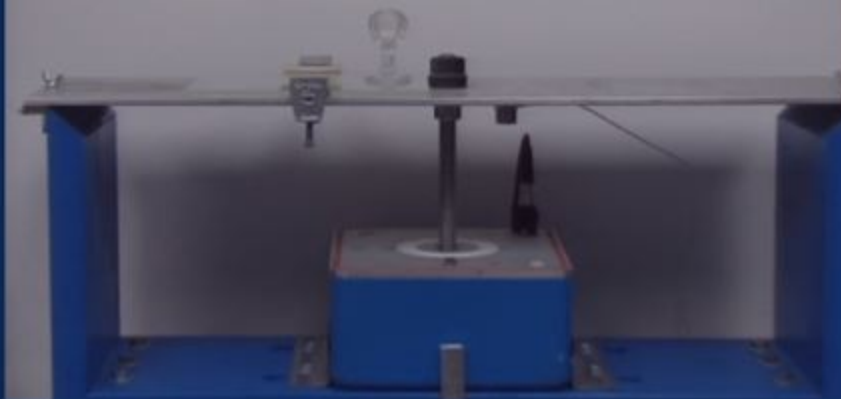
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Watch cordial walk  
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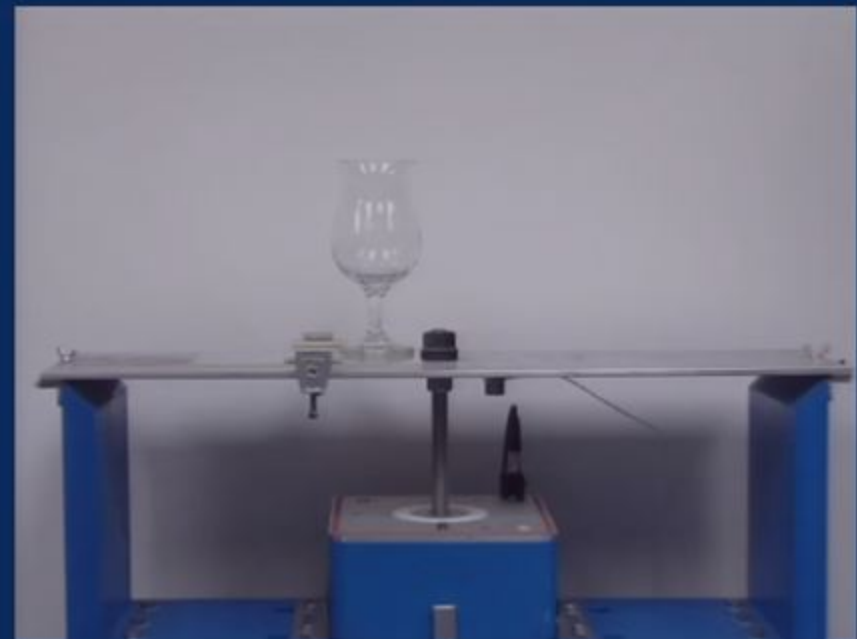
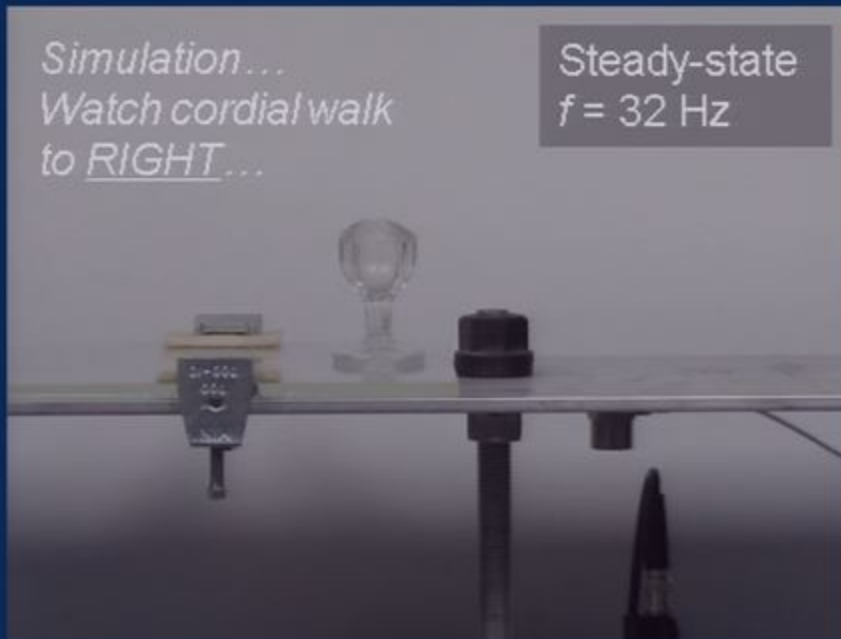
# “Walking” (light objects, smooth surfaces)



Clark Art Institute – potential for walking



Taft Museum of Art – potential for walking



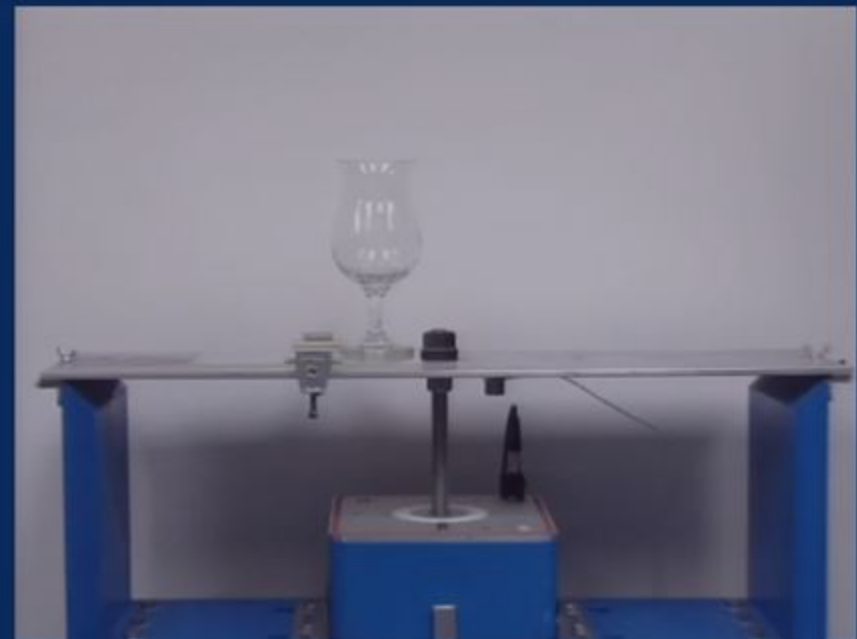
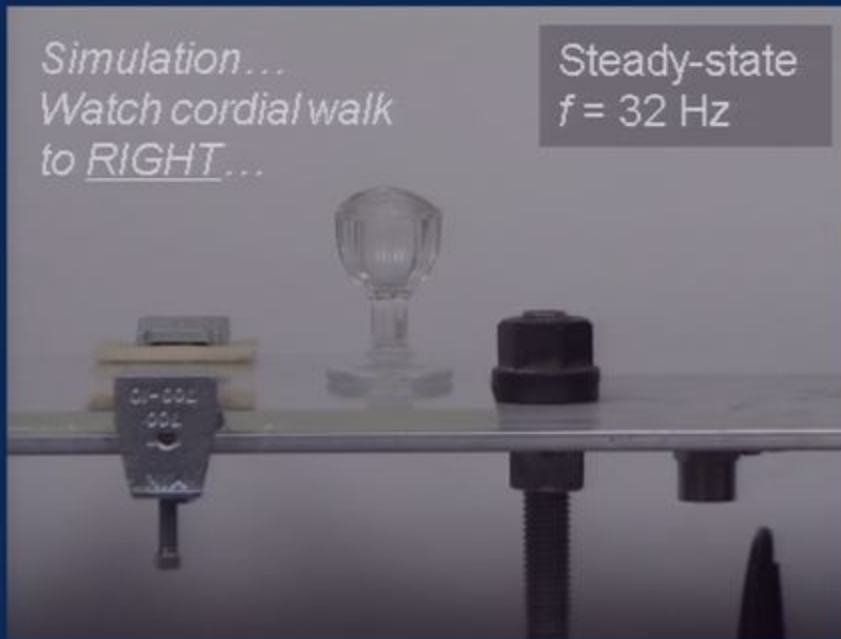
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Taft Museum of Art – potential for walking



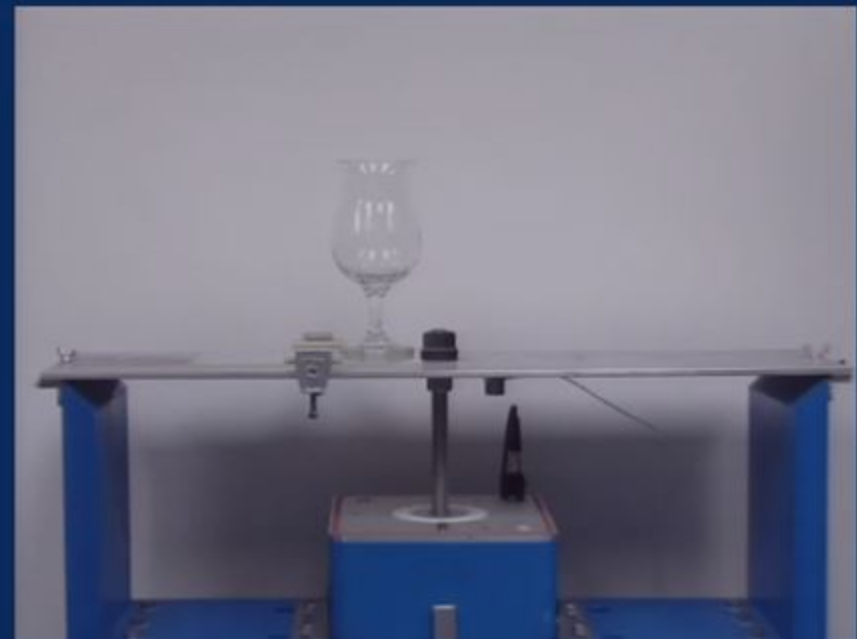
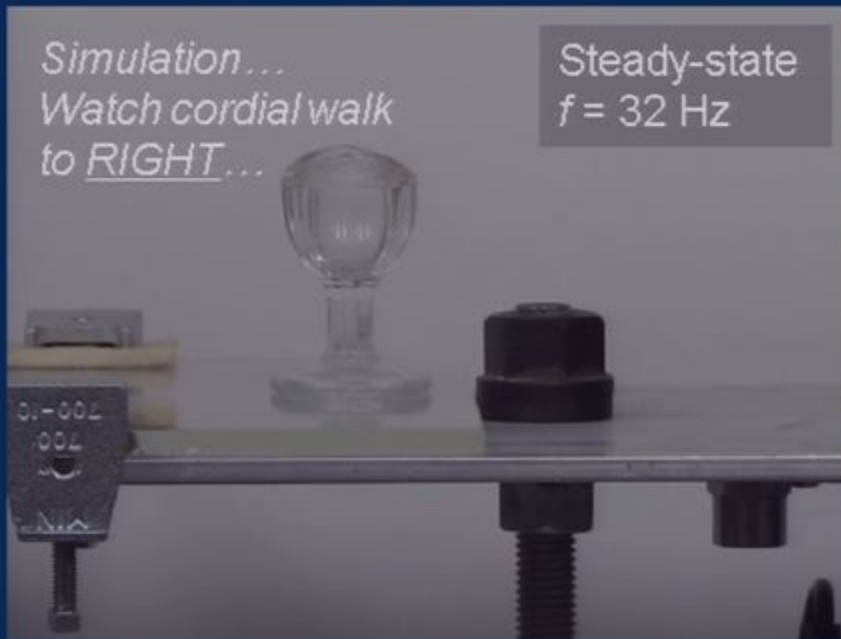
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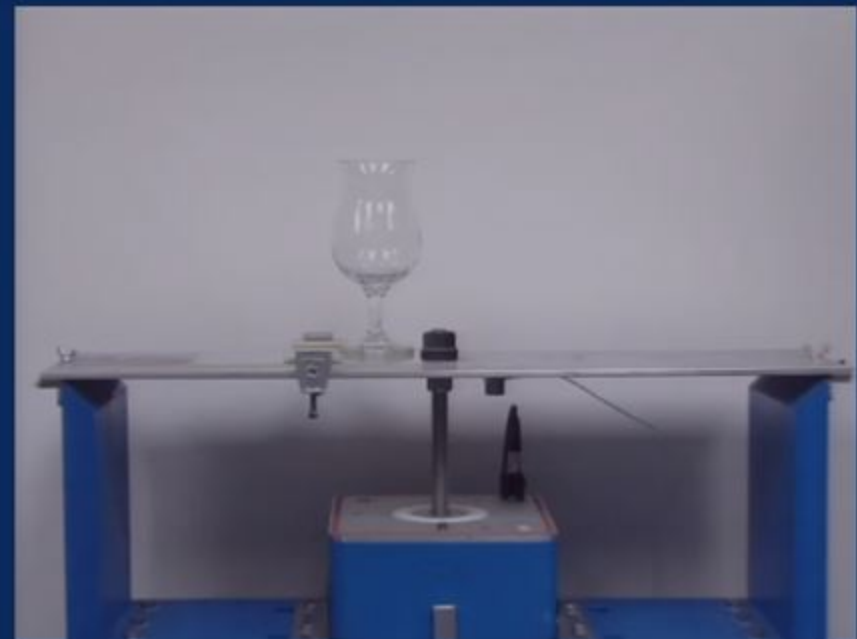
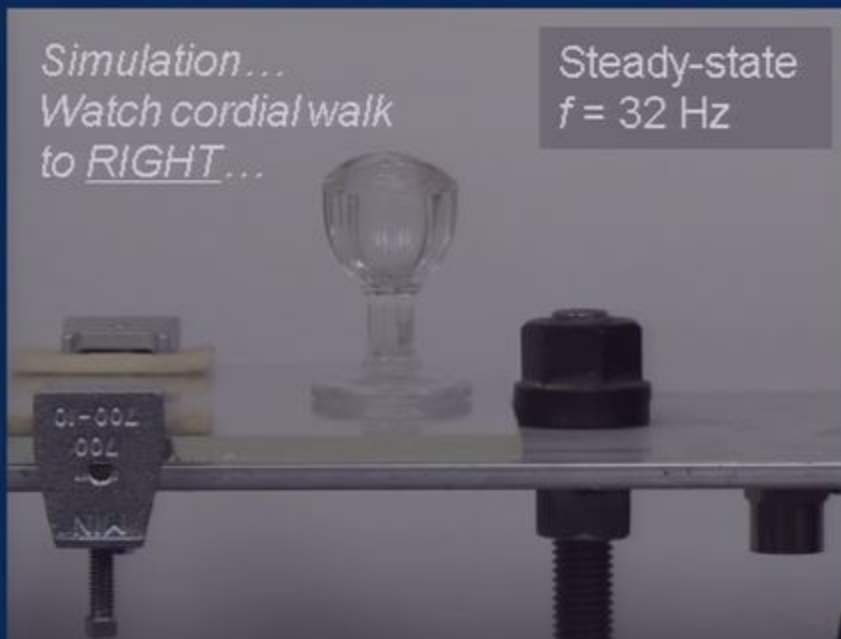
Clark Art Institute – potential for walking



Taft Museum of Art – potential for walking



# “Walking” (light objects, smooth surfaces)



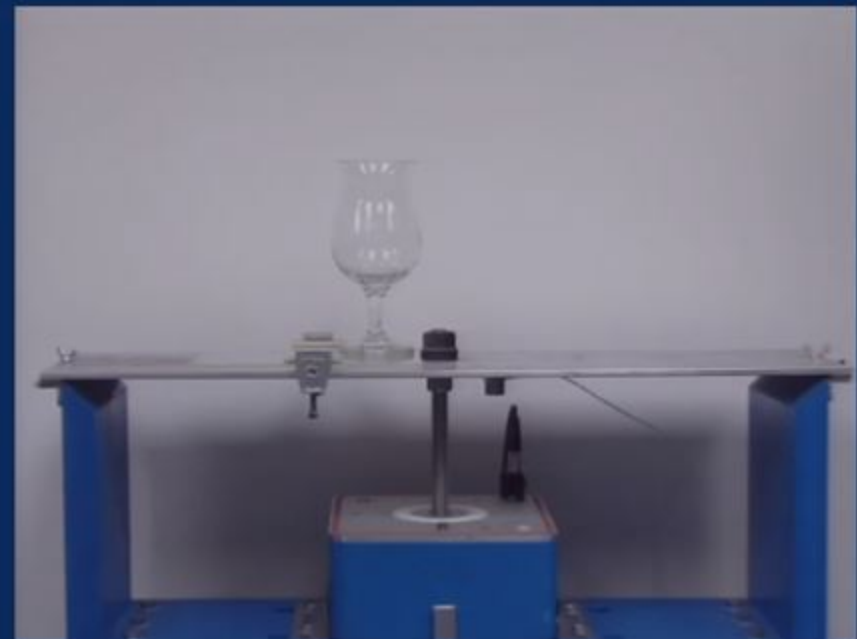
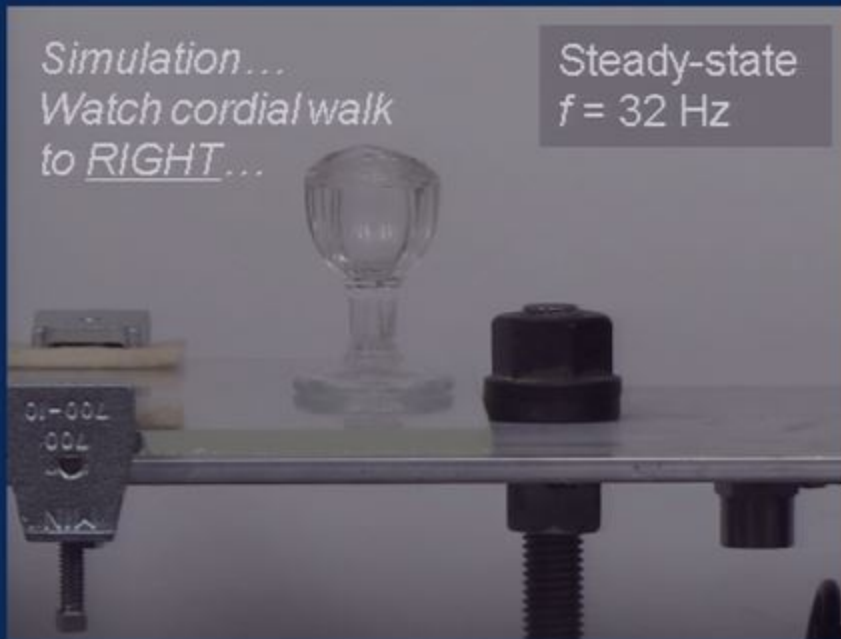
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Clark Art Institute – potential for walking



Taft Museum of Art – potential for walking



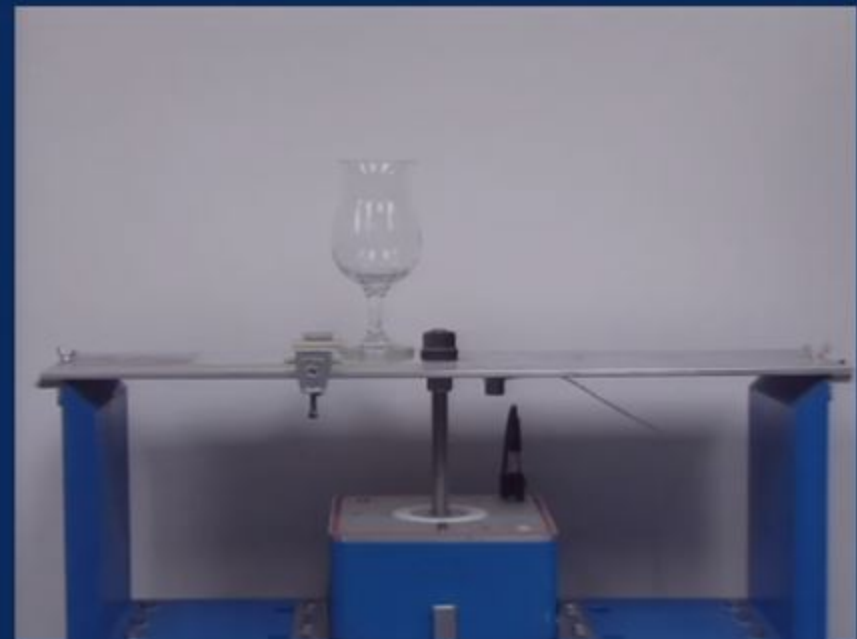
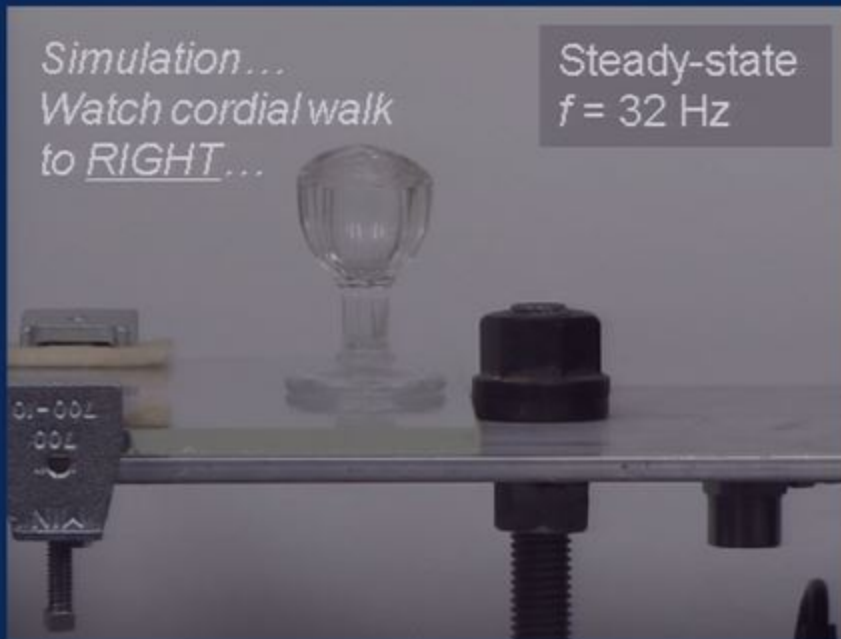
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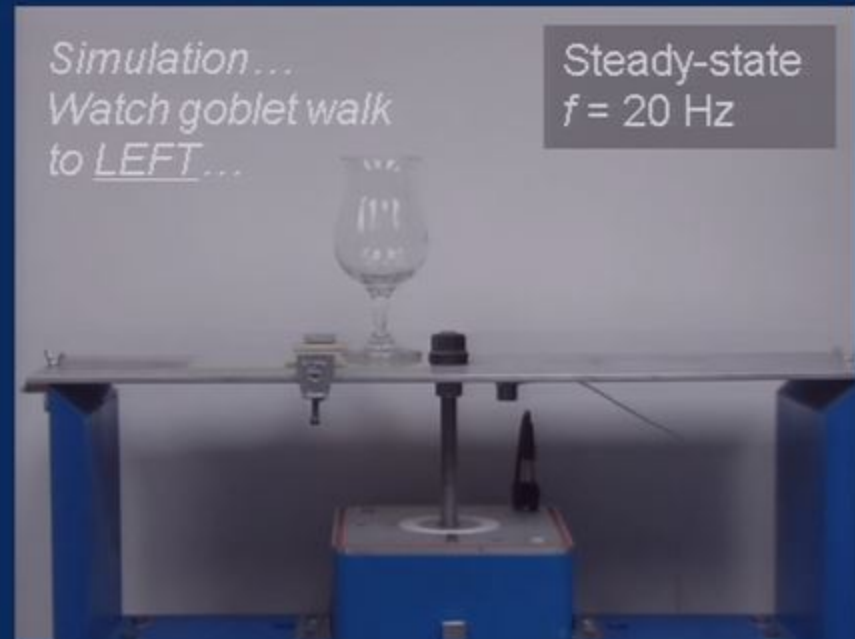
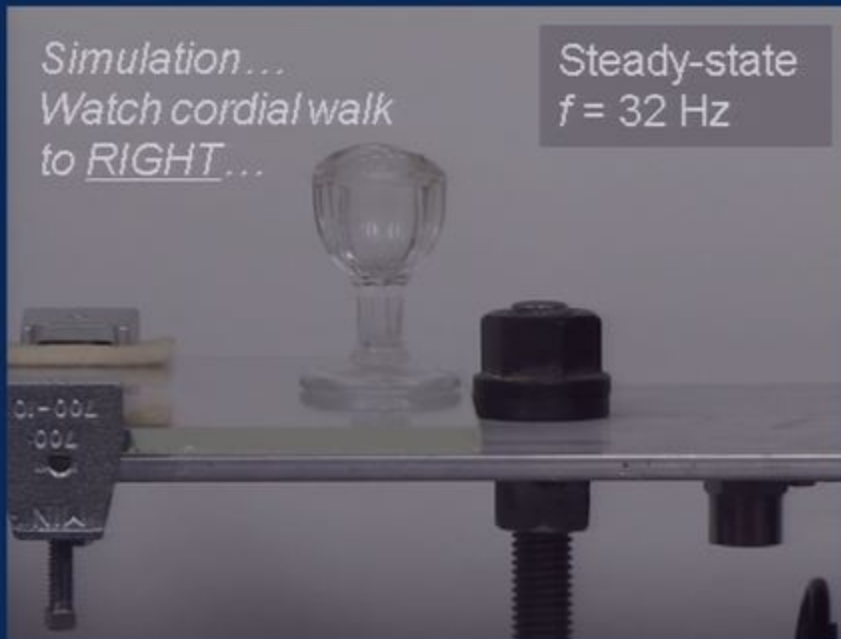
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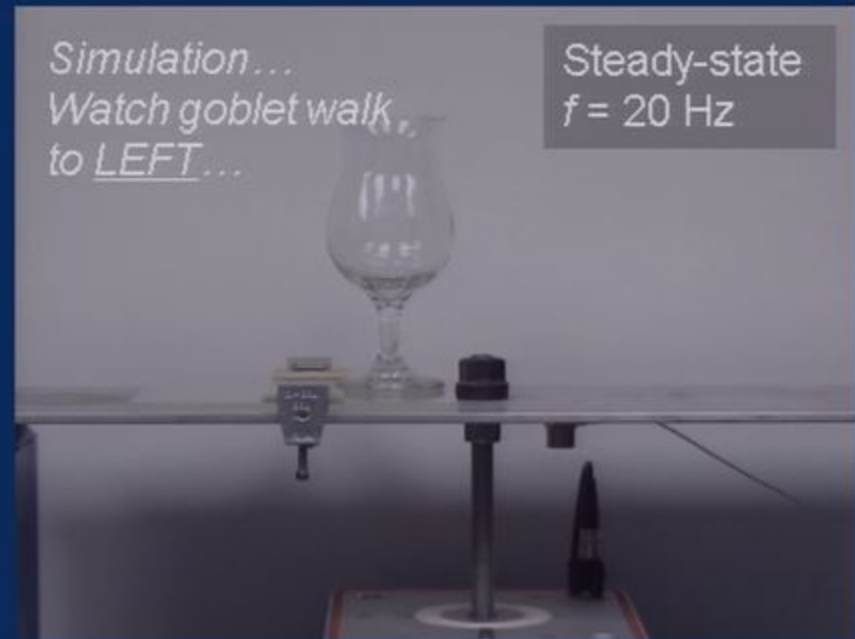
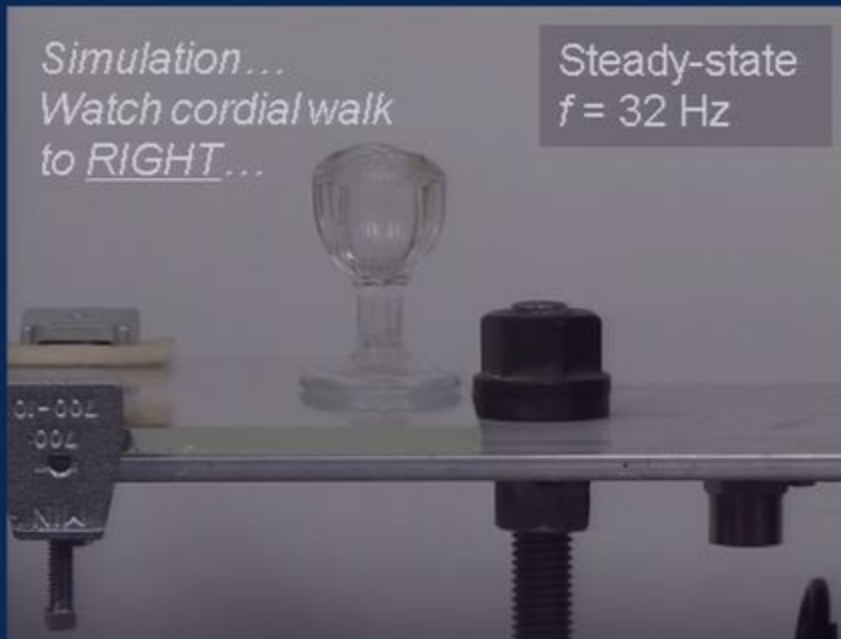
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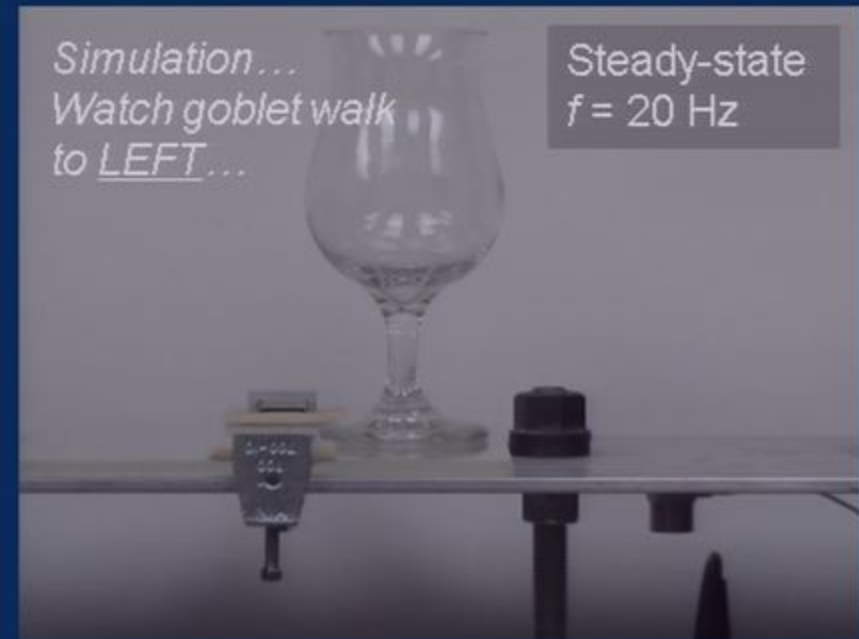
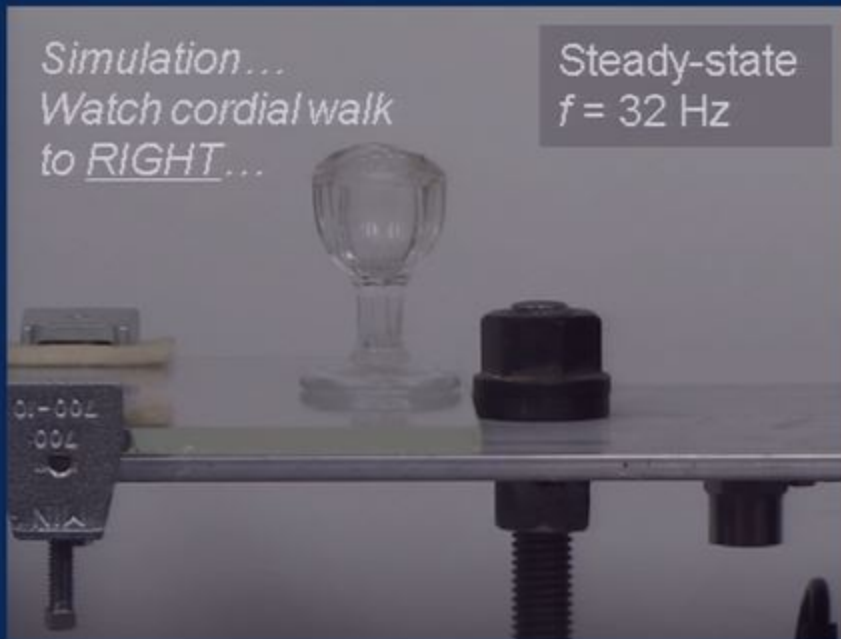
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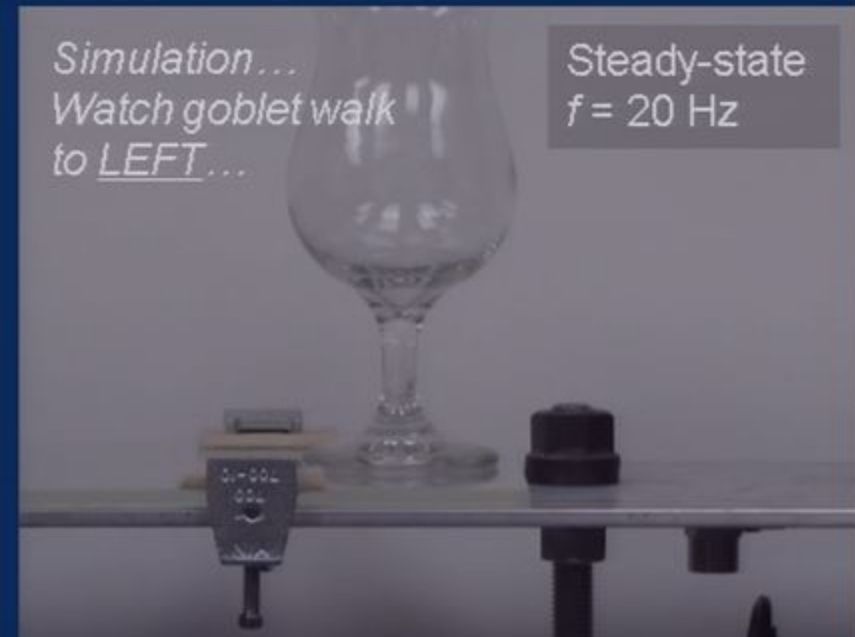
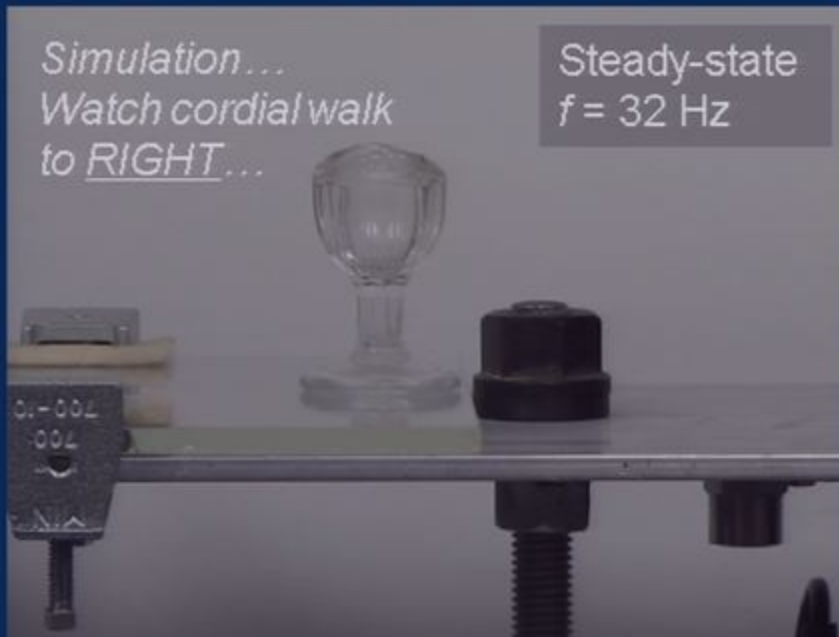
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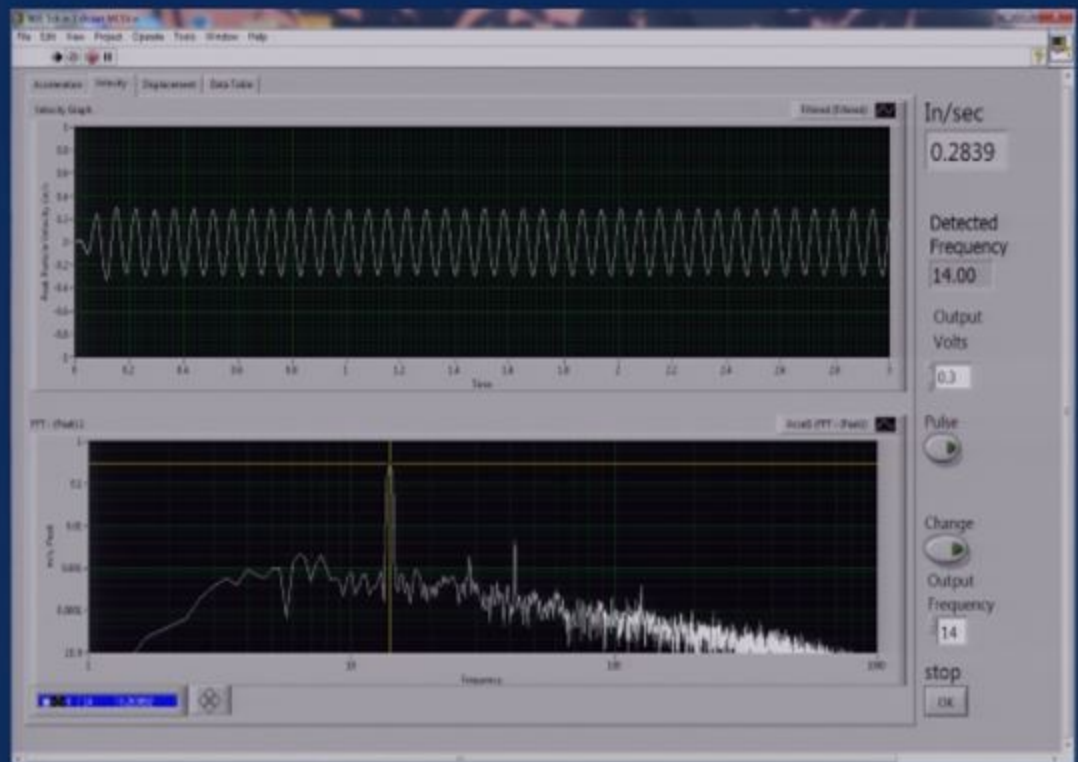
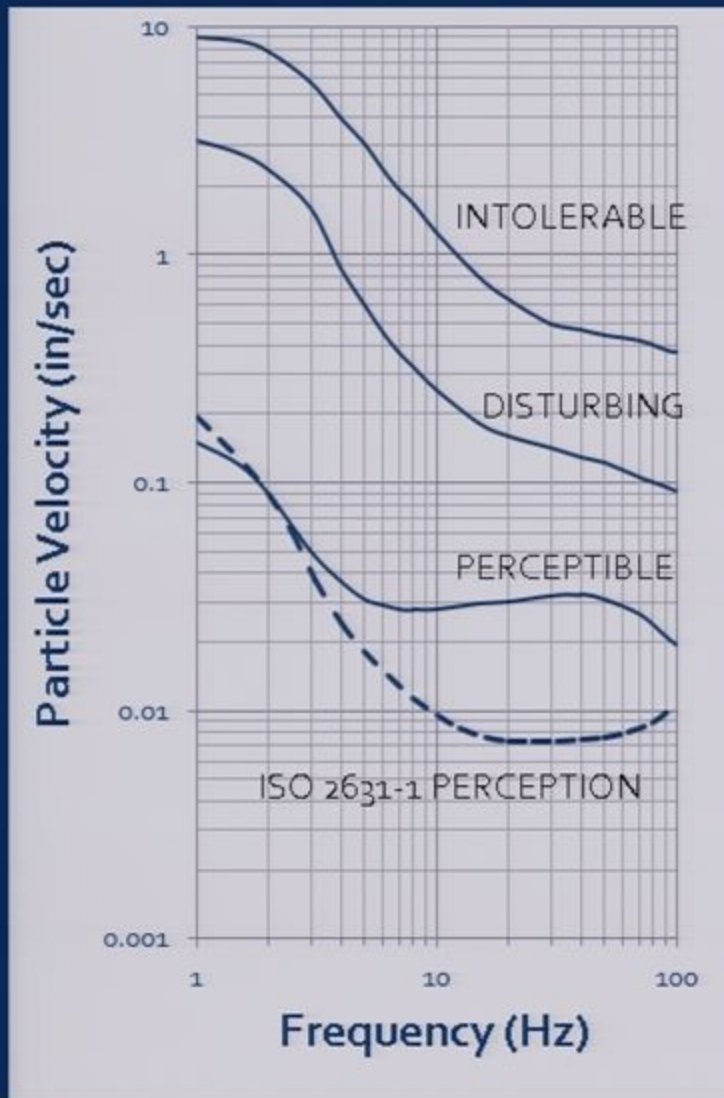
Clark Art Institute – potential for walking



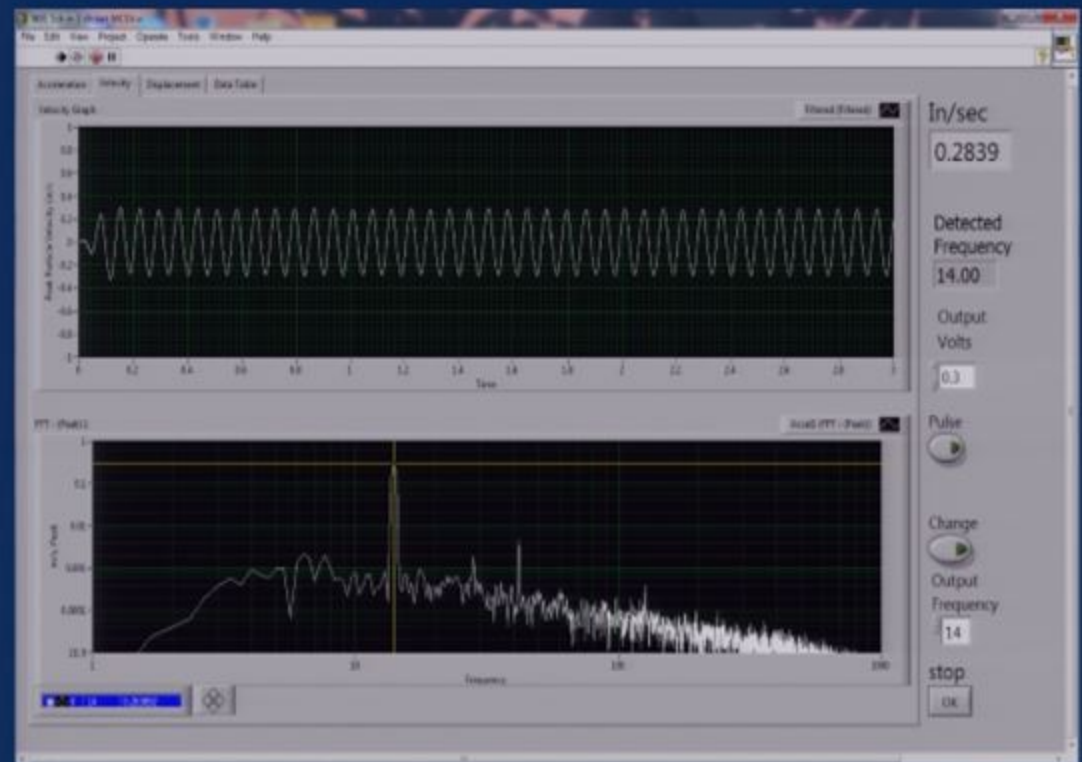
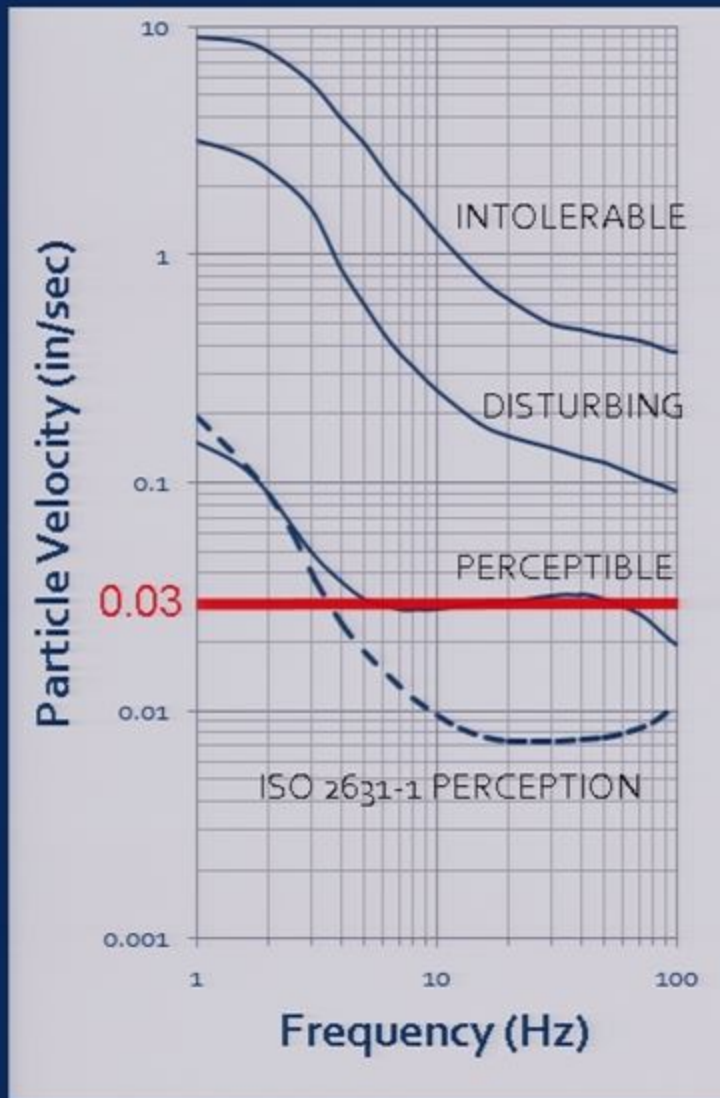
Taft Museum of Art – potential for walking



# Human Perception (Tell us what you feel! 😊)



# Human Perception (Tell us what you feel! 😊)



# Questions



Vibration Control During Museum Construction Projects  
Journal of the AIC 2013, Vol. 52 No. 1, 30-47