Evolution of Energy Contaminant Criteria: Convergence or Divergence?

Presented by:
Hal Amick, Principal, PhD, PE
Steven Lank, Vice President
Colin Gordon Associates
hal.amick@colingordon.com
steven.lank@colingordon.com

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Overview

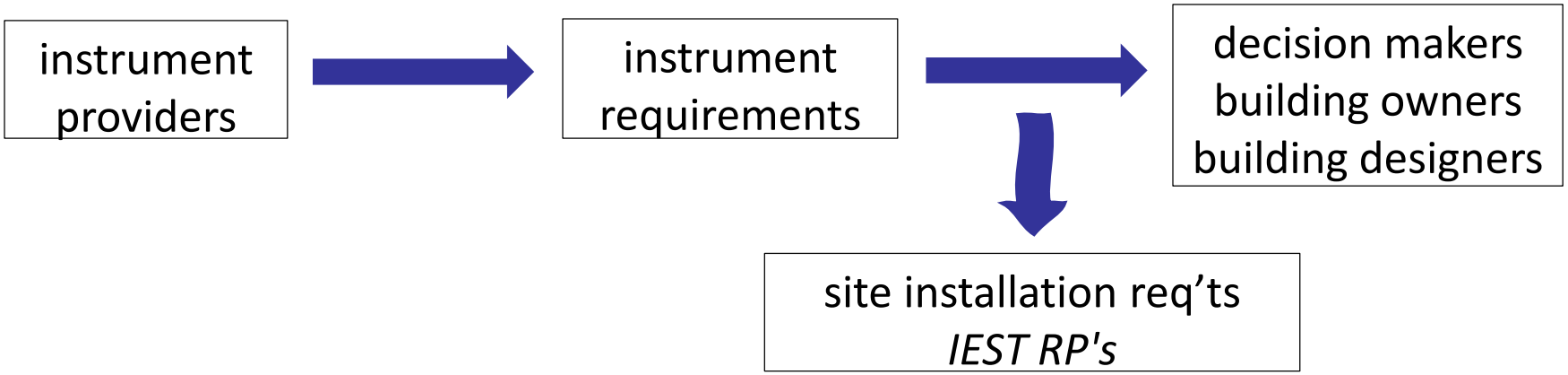
- Energy-Contaminants and their Criteria
  - Vibration, Sound or Acoustic Noise, EMI/RFI, ESD, Thermal Variation
- The *Interface* between instruments and the spaces containing them
- Evolution & ***de***volution
  - What is devolution? (in this context)
  - Is this new?
  - How evolution can lead to devolution
- Examples
- Addressing devolution

Energy-Contaminants and their Criteria

- Exist as energy, not as particulates or molecules
- Vibration, Sound or Acoustic Noise, EMI/RFI, ESD, Thermal Variation

The *Interface*

- The *Interface* between instruments and the spaces containing them
- Instrument providers define the requirements for the *Interface*
  - *Requirements can be interrelated*
- Interface is provided by the owner and design/construction team



Evolution & ***de***volution (1/3)

- Devolution can reduce (or even eliminate) the abilities of lab consultants and building designers to accurately and efficiently provide facility cost estimates or provide designs that will "work the first time"
- What is **devolution**? (in the context of the previous flowchart)
  - We are using this term to represent "Diminishing the quality or quantity of information in the path from left to right in the flowchart"
    - “decrease in ***quality***” means the information available to the end groups has become ***less clear*** or ***less useful*** to the readers
    - “decrease in ***quantity***” implies that some (or all) of the information that was once available ***just disappears***
- Is this new?
  - No, but it is a growing trend

Evolution & ***de***volution (2/3)

- Evolution
  - Increasing throughput by putting tools of different types closer together
  - Increasing site output by using multistory buildings rather than single-story
  - Dramatically increasing the image magnification (or decreasing line width or feature size), effectively increasing sensitivity to environmental contaminants
- Devolution
  - Lack of updates to requirements to respond to the realities and evolution of modern building designs and facility requirements.
  - Overly simplistic or conservative criteria
    - *There is a coveted imaging instrument with a vibration requirement of **VC-J!** **None** of the existing facilities into which it has been installed and is operating well provides an environment this quiet.*
  - A decrease in available information that enables owners to confidently design buildings that are appropriate for sensitive instruments.

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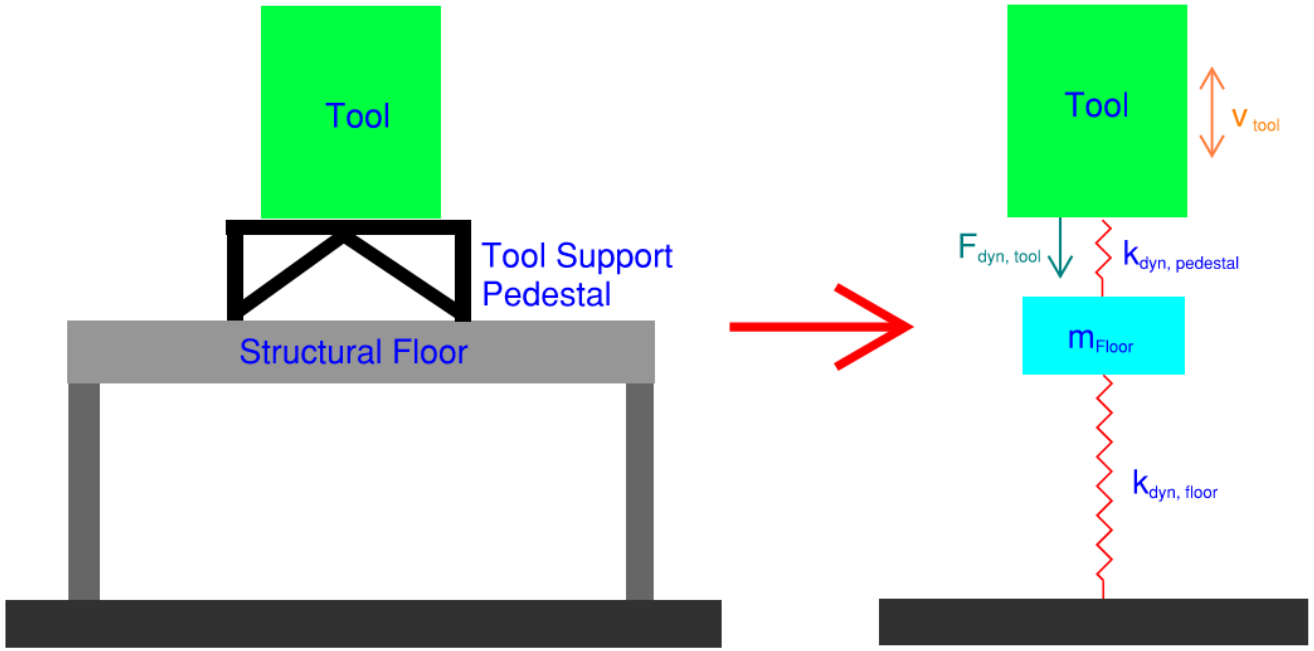
Evolution & ***de***volution (3/3)

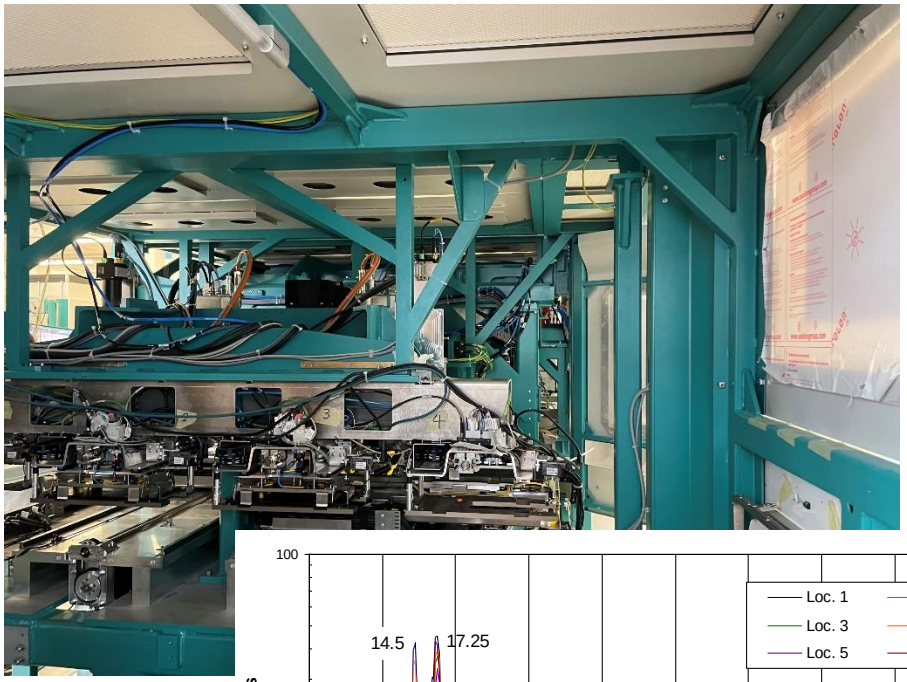
- In these cases, we can see…
  - **evolution** in production technology (e.g., *increase in magnification* or *decrease in line width*) or
  - **evolution** building efficiency (greater output per square foot of building footprint by using multistory buildings)
- **without a corresponding evolution** in the interface (of the earlier slide).
- This disparity is devolution.

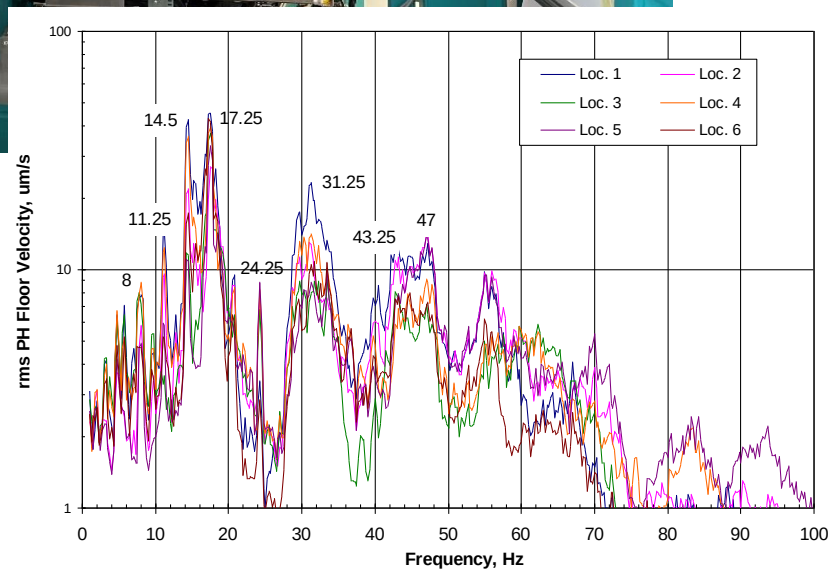
Example #1: Die-prep devices and their move to suspended floors

- Force generated (F_{dyn}) and allowable vibration (v_{tool}) require vendor coordination/info
- Use to define stiffness requirements (k_{dyn}) for pedestal and floor

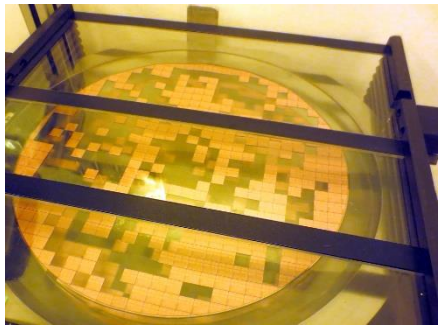


Example #1: Die-prep devices and their move to suspended floors





- In the past, these processes were in single-story buildings (on floors that were slab on grade).
- Quite recently, we have seen a shift toward installation on upper floors of in multistory buildings (these floors being suspended and more prone to vibrate)
- The image to the left shows one of these instruments, which rapidly moves 1 cm x 1 cm pieces of wafer (each one called a die, shown below) as part of a manufacturing process.
- The spectra below show the resulting vibrations when this process is moved from a **slab-on-grade** to a **suspended floor with a resonance frequency around 18 Hz.** (The numbers shown indicate the frequency of individual peaks.)



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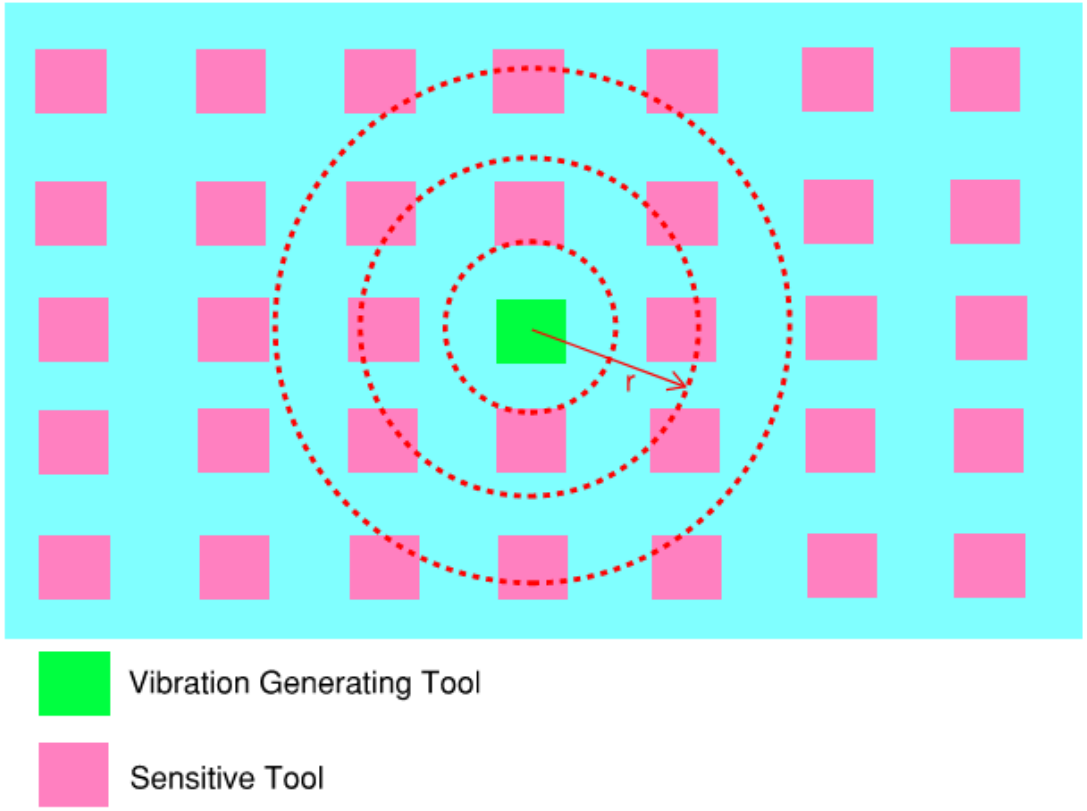
Example #1: Die-prep devices and their move to suspended floors

- Radius of impact, r, dependent upon dynamic force from tool, sensitivity of adjacent tools, and dynamics of supporting structure
- Minimize r
  - Alter supporting structure
  - Reduce force (tool modifications)
  - Isolate adjacent tools

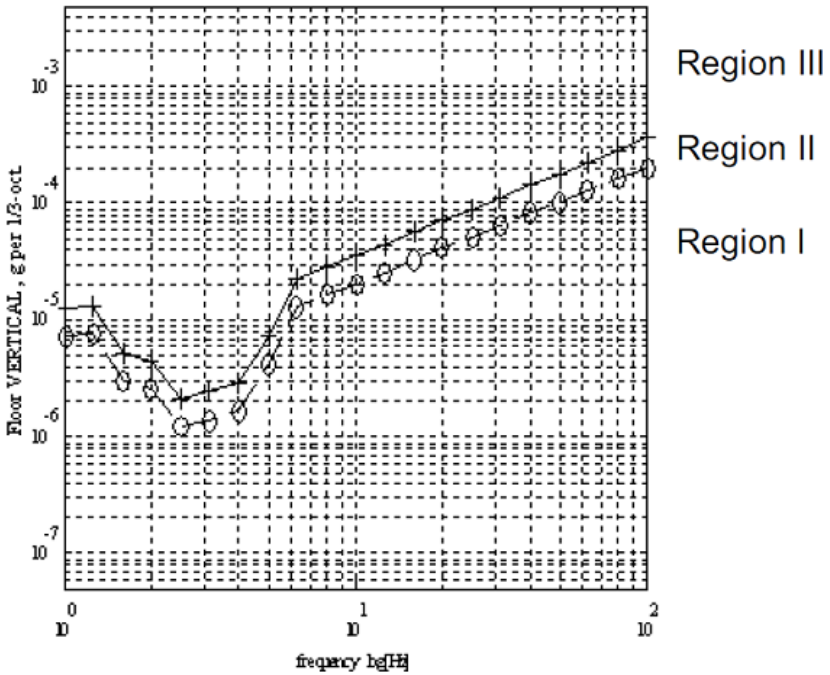


Example #2: Ever-more-powerful imaging devices

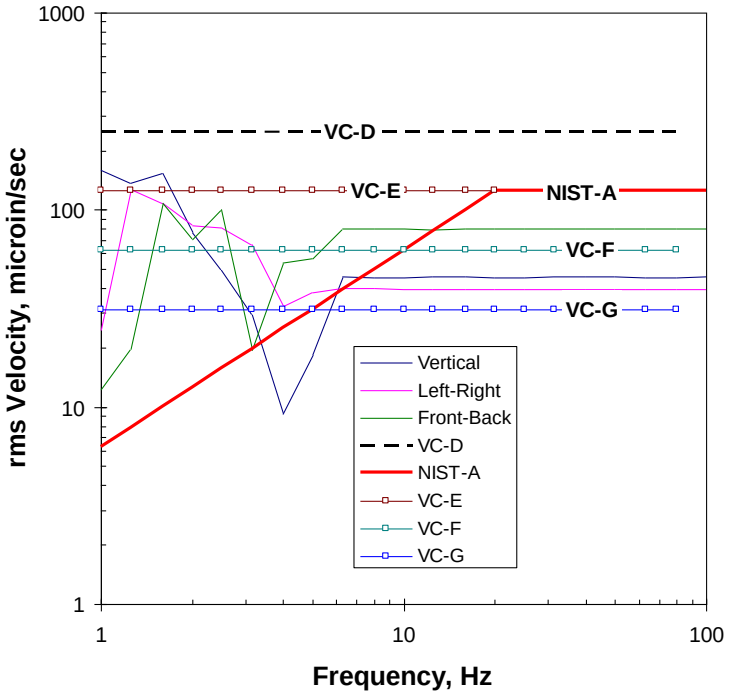
- Vibration requirements for electron microscopes were being stated as early as the early 1980s
- Ungar and Gordon (1983) used VC-B, VC-C and VC-D for electron microscopes, basing the selection upon the magnification and/or the feature size being viewed
- Over the subsequent years, magnification has grown more powerful, and feature size smaller
- It is not unusual for the current generation of EM instruments to require VC-F or VC-G.

Back in the “Good ol’ Days" - Clarity & Precision

From #####’s Site Installation Guide (in acceleration)



Converted by CGA and compared to Generic Criteria (in velocity units)



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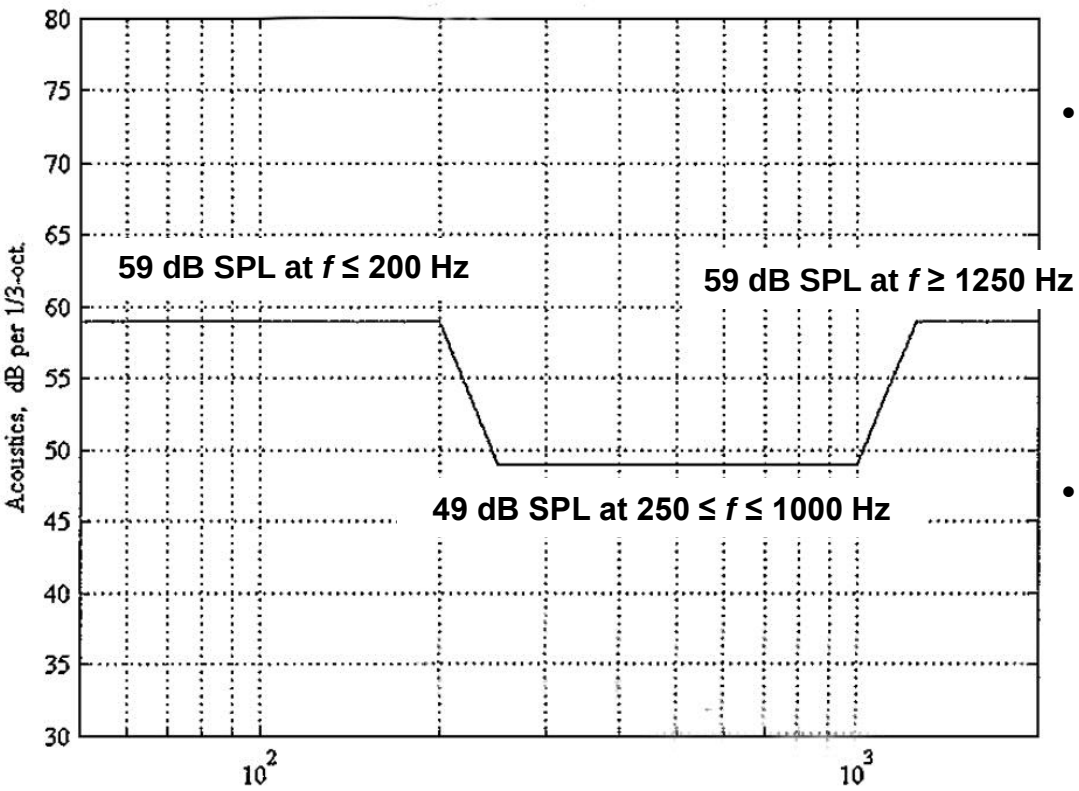
This is typical of how acoustic requirements were defined (back in the “Good ol’ Days")



- Defined as either graphical spectra (as shown at left) or in tabular form, by frequency
- Bandwidths were defined in one third octave bands (as at left) or octave bands, and occasionally PSD
- Very easy to convert any of these to requirements understood by lab planners, architects and HVAC engineers
- Acoustical consultants could work backwards from these requirements to produce sound power level (SPWL) requirements for fans and silencer requirements for ducts

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How it's done now ...

- The following are extracted from a current site installation manual for a current generation microscope produced by the same instrument manufacturer ...

  – *Acoustic noise and floor vibrations can excite resonances in the microscope. The resulting disturbance in high-resolution images is an integral sum of the contributions of the individual disturbing sources. Because these sources are typically interlinked, ######## **intentionally does not provide separate specifications for acoustics and floor vibrations**. To assess how the noise and vibrations in the instrument room may affect the performance of the microscope, a trained ####### engineer will use the* [proprietary] *"***Black Box***"* [site evaluation tool].

  – *The* **Black Box** *tool represents decades of expertise on the dynamics of ####### microscopes and their response modes. The* **Black Box** *tool uses this built-in knowledge to predict how the frequency spectra that are recorded in the instrument room could affect the performance of the microscope.*

NOTE: Words in *Arial italics* are quoted directly. Words in Times Roman are my own, and those in **boldface** or underlined (or **both**) represent emphasis by the authors. The names of the manufacturer (#########) and the instrument are withheld.

Acoustic noise reduction in the Microscope Room

- *An electron microscope typically is sensitive for acoustics in the low frequency range.*
- *To reduce acoustic noise in the Microscope Room:*
  - *It is highly recommended to use sound damping materials and constructions on the floor, ceiling and walls* [**vague design guidance … insulating or absorbent or both? Any specifics?**]. *Make sure that the selected materials do not collect or emit dust and particles and are easy to clean.*
  - *The climate control and ventilation systems* ***must be quiet****, especially in the low frequency range (< 500 Hz).* ["Quiet" is subjective and "in the ear of the beholder"; it differs for a cleanroom or a lab or a conference room or a recording studio.]
    - *Low frequency noise levels could exceed certain instrument requirements by 15+ dB and still be considered "quiet" to the human ear – instruments are more sensitive to low frequency noise than humans!*
- Otherwise, no specifics are given
- Yes, that's it!

A Design Team and Owner Left Guessing

- With no numerical criteria, the design team left to best practices and conservatism
  - Additional expense and less certainty
- Preconstruction site evaluations by the instrument vendor have limited utility – the design of a new lab inherently adds contaminants which much then be controlled.
  - HVAC Noise and Vibration
  - Instrument support equipment
  - Building occupants and facilities activities
  - Neighboring research and instruments
- Design guidelines provided by instrument vendor are typically generic at best and counter-productive at worst

Preventive and corrective counter-measures for floor vibrations in the microscope room

Criteria are no longer given in numerical or spectrum formats. What you see [below] is what you get.

- *For floor vibrations above 10 Hz, ######## microscopes have a built-in air cushion system that provides enough passive isolation for the almost all customer sites.*
  - A typical lab design will include numerous new sources generating vibration at frequencies above 10 Hz
- *For floor vibrations below 10 Hz, ######## recommends the following (next slide):*

recommendations for floor vibrations below 10 Hz

Item	Recommendation
Construction guidelines for the instrument room floor	*Solid concrete block under the microscope base or the entire Microscope Room:* • *Founded directly on the bare ground or sand under the site.* • *Isolated from the surrounding building structure to prevent the transfer of vibrations into the instrument room from equipment or walking persons elsewhere in the building.*
Active vibration isolation	*If a site assessment with the* **Black Box** *tool concludes that the floor vibrations are near or above the limits that allow for system performance within specifications, then the following corrective options are available:* • *A proprietary active vibration isolation system is available* [from #######] *for selected systems.* • *The* **Black Box** *tool can predict if installation of the* [proprietary] *option is sufficient to eliminate excessive floor vibrations.* • *The* **Black Box** *tool cannot predict the effectiveness of third-party systems.* [This removes competing active systems from the table.]

NOTE: Some of the current site installation guides give specific recommendations regarding such things as slab thickness, the use of an "island," and the like. For one instrument, we found three different slab thickness recommendations in three different places.

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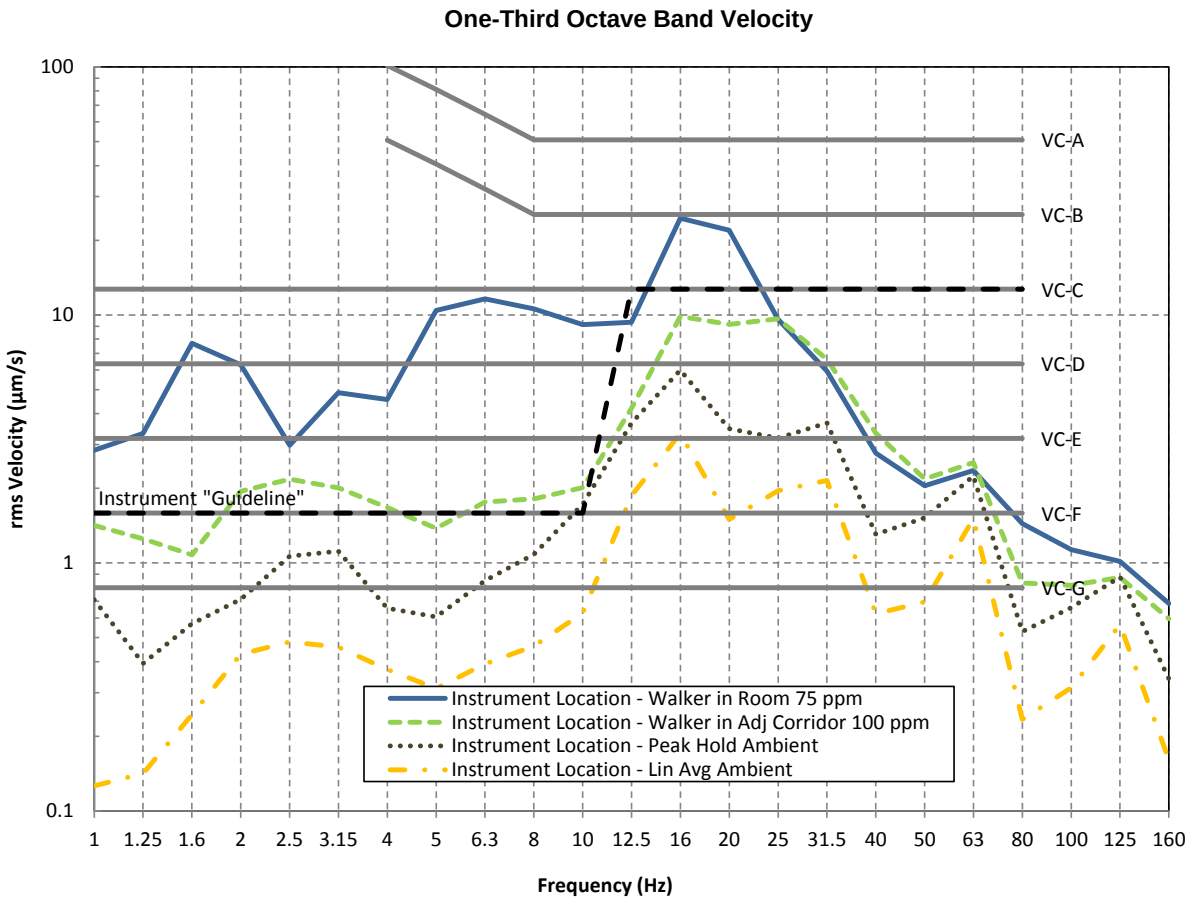
Example Case - Site Evaluation

- Vendor surveys the site, then reports that vibration meets their (proprietary) criterion
- Design team conducts follow up survey.
  - Background amplitudes match closely with vendor measurements
  - Amplitudes due to typical walker are well above vendor results
- Walkers in and around space will be a common occurrence, a significant concern for users
  - Confusion since vendor has already “passed” the site



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A Final Comment

The authors wish to stress that their disagreement with ####### is limited to ...

- The **lack of quantitative information** for vibration and acoustics, while continuing to provide quantitative criteria for EMI, temperature, etc.
- The **apparent removal of the role for a vibration and/or acoustical consultant**, replacing some of the guidance traditionally provided by that consultant by the manufacturer's own somewhat limited design recommendations.
- The **limitation of the ability by otherwise qualified vendors** to provide active or passive vibration control hardware

However, **the authors strongly support the use of a black box in the final acceptance process**, so long as numerical/graphical/tabulated criteria are provided for use by the design team. A black box tool that combines the effects of vibration, EMI, and acoustic noise sound can correctly represent the manner in which the instrument itself combines those contaminants.

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Thank you for listening

Hal Amick, Principal, PhD, PE

Steven Lank, Vice President

Colin Gordon Associates

hal.amick@colingordon.com

steven.lank@colingordon.com