

# The Quest for Stability at NSLS-II

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Andy Broadbent with acknowledgements to many staff at NSLS-II and especially Yong Chu (HXN beamline group leader) and Nick Simos (vibration engineer).

# Why Do We Need Stability?

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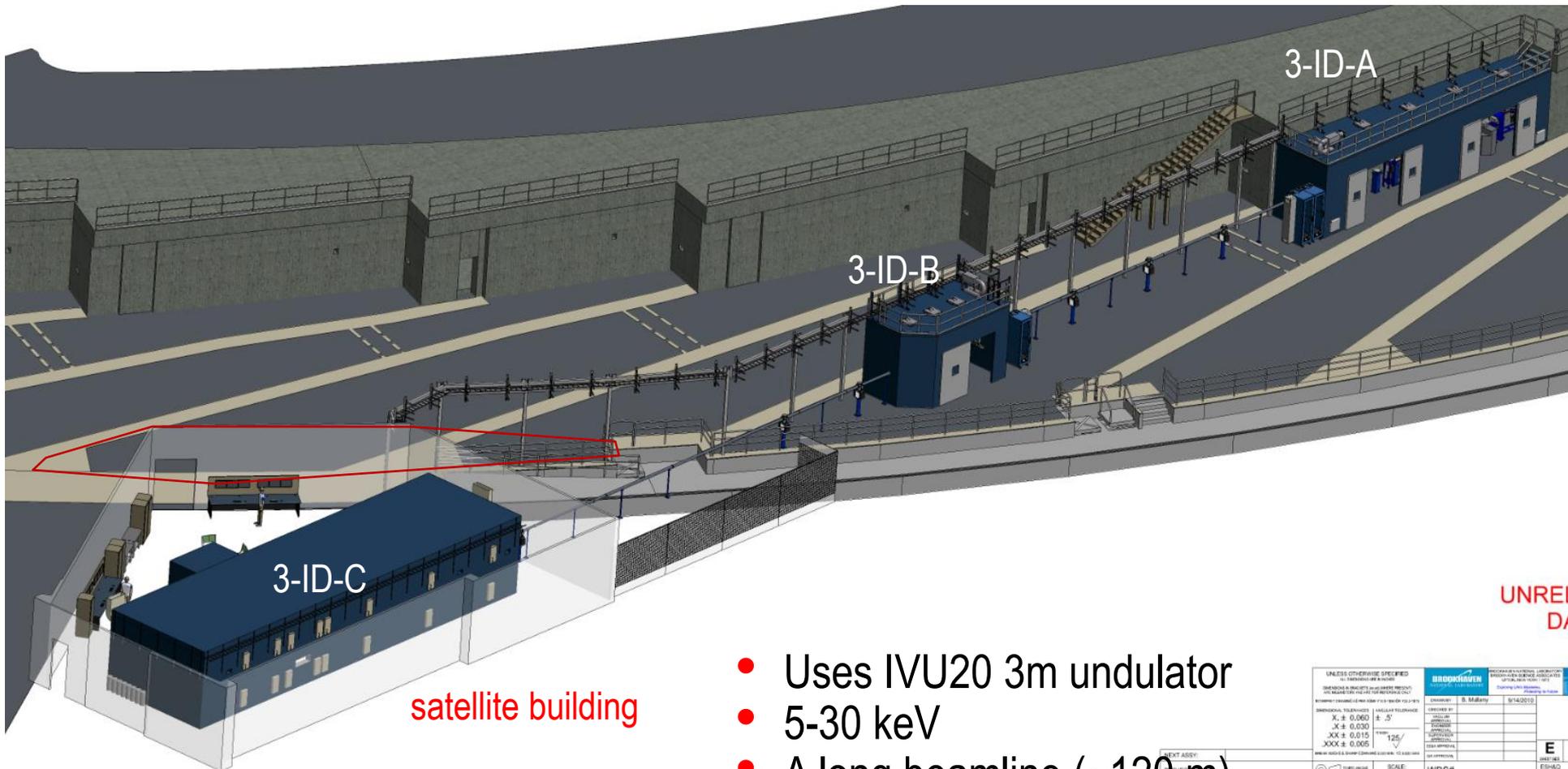
**NSLS-II is a synchrotron source with state of the art brightness.**

- Many beamlines have been constructed which make use of the high brightness, coherence for new applications.

**Take the Hard X-ray Nanoprobe (HXN) as an example:**

- Extreme focusing application requires a long beamline.
- Even with a design using Secondary Source Aperture and horizontal deflections in the optics, to give some immunity to beam movements, the stability of the beam is absolutely critical.
  - We are trying to take a multiply deflected beam  $\sim 100\text{m}$  and pass this through an aperture as small as  $5\ \mu\text{m}$ . (V:  $5\text{-}20\ \mu\text{m}$ , H:  $5\text{-}300\ \mu\text{m}$ ).
  - The SSA, focusing optic and sample are all on the same floor slab.

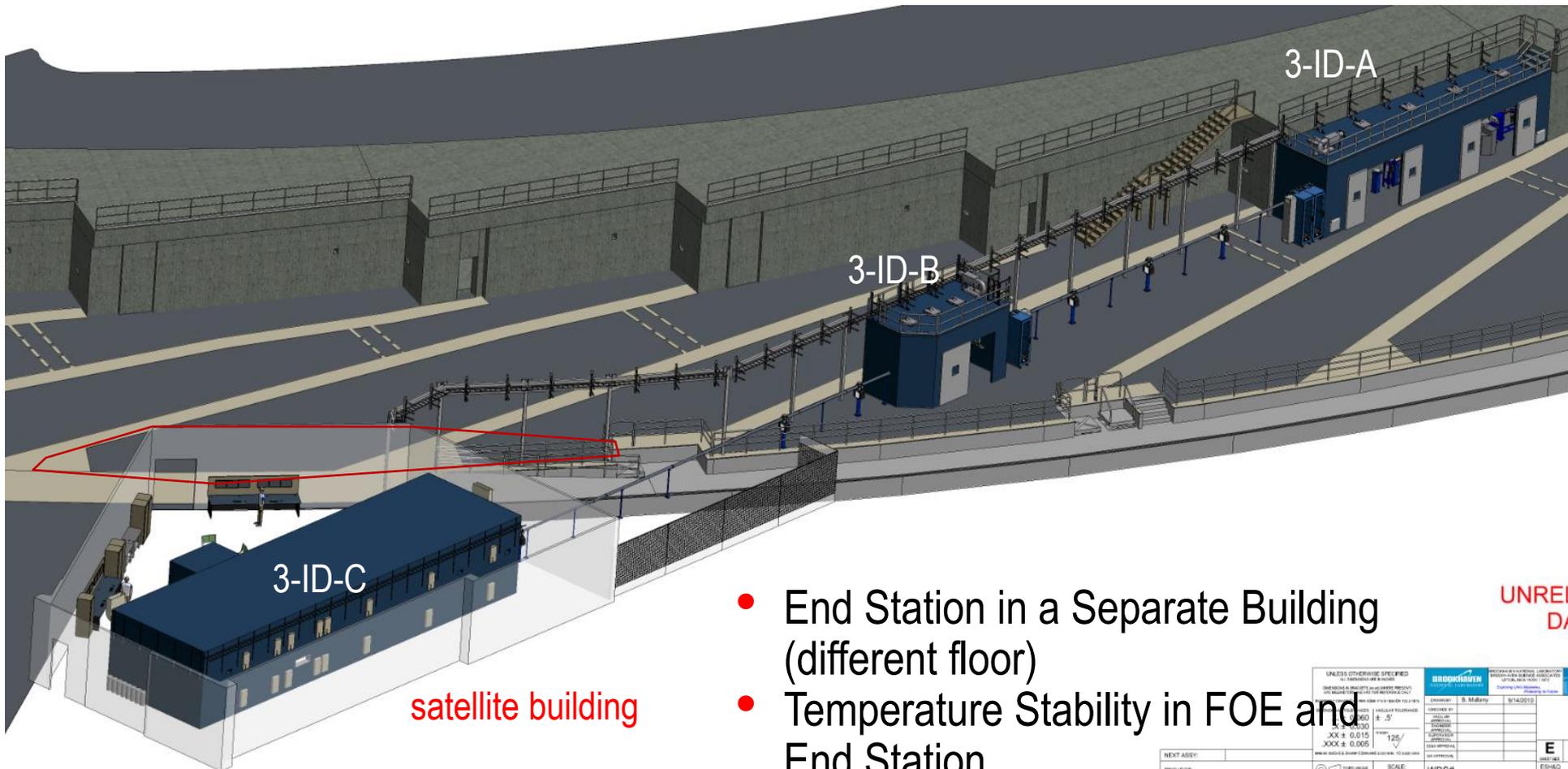
# Beamline Overview



- Uses IVU20 3m undulator
- 5-30 keV
- A long beamline (~120 m)
- 3 Stations (3-ID-C in the satellite building)
- Mono beam outside A-hutch

UNLESS OTHERWISE SPECIFIED SEE DRAWING AND CHANGE		DRAWN BY: S. Maloney		9/14/2010	
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED		CHECKED BY: S. Maloney		DATE: 9/14/2010	
X ± 0.060	± .5°	APPROVED BY: S. Maloney		DATE: 9/14/2010	
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# Some Mechanical Challenges

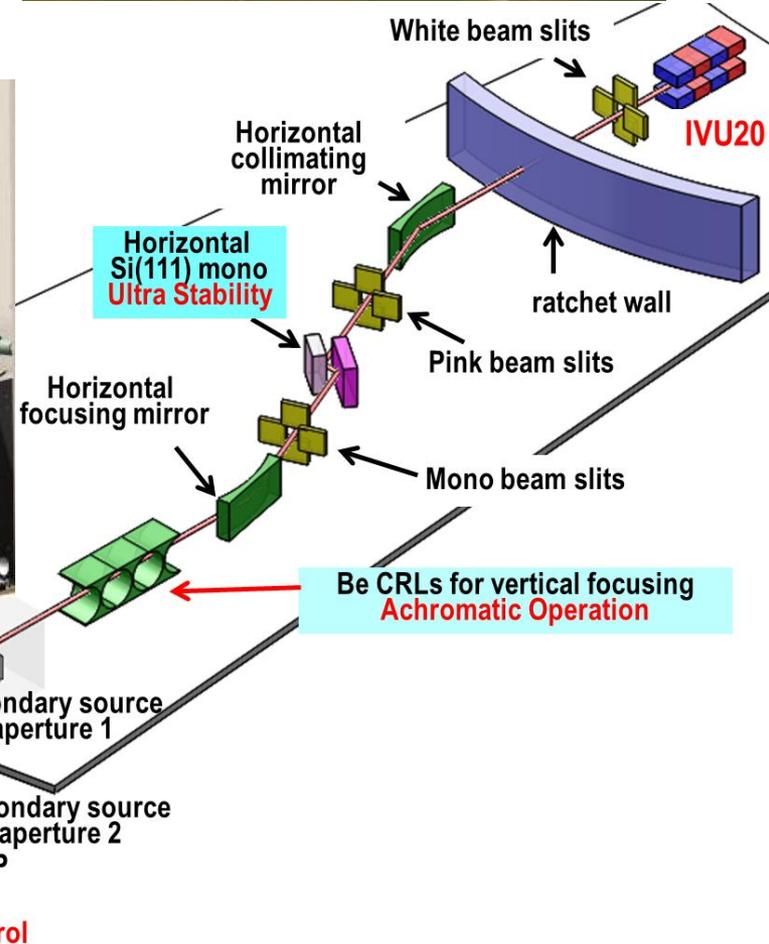
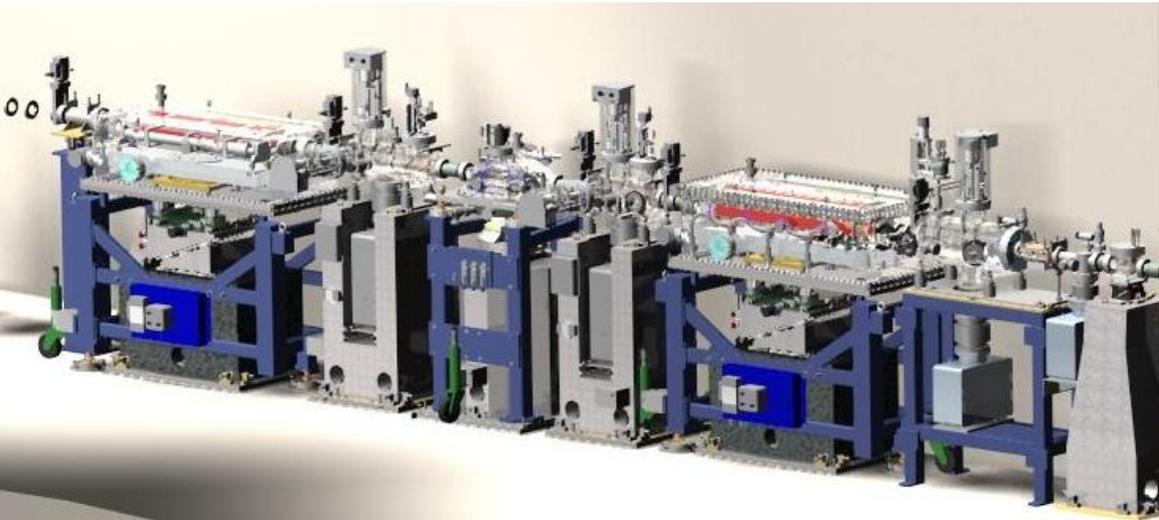


- End Station in a Separate Building (different floor)
- Temperature Stability in FOE and End Station
- Vibrational Stability along full length of Beamline

# Hard X-ray Nanoprobe Beamline

## Unique Capabilities:

- ~110m-long beamline
- Satellite building for vib.& temp. stability
- Extremely stable 2D secondary source and stable beamline optics
- X-ray microscope w/ ~1nm positioning stability
- MLL and ZP optics
- In-situ sample environments



BL energy: 6-25 keV

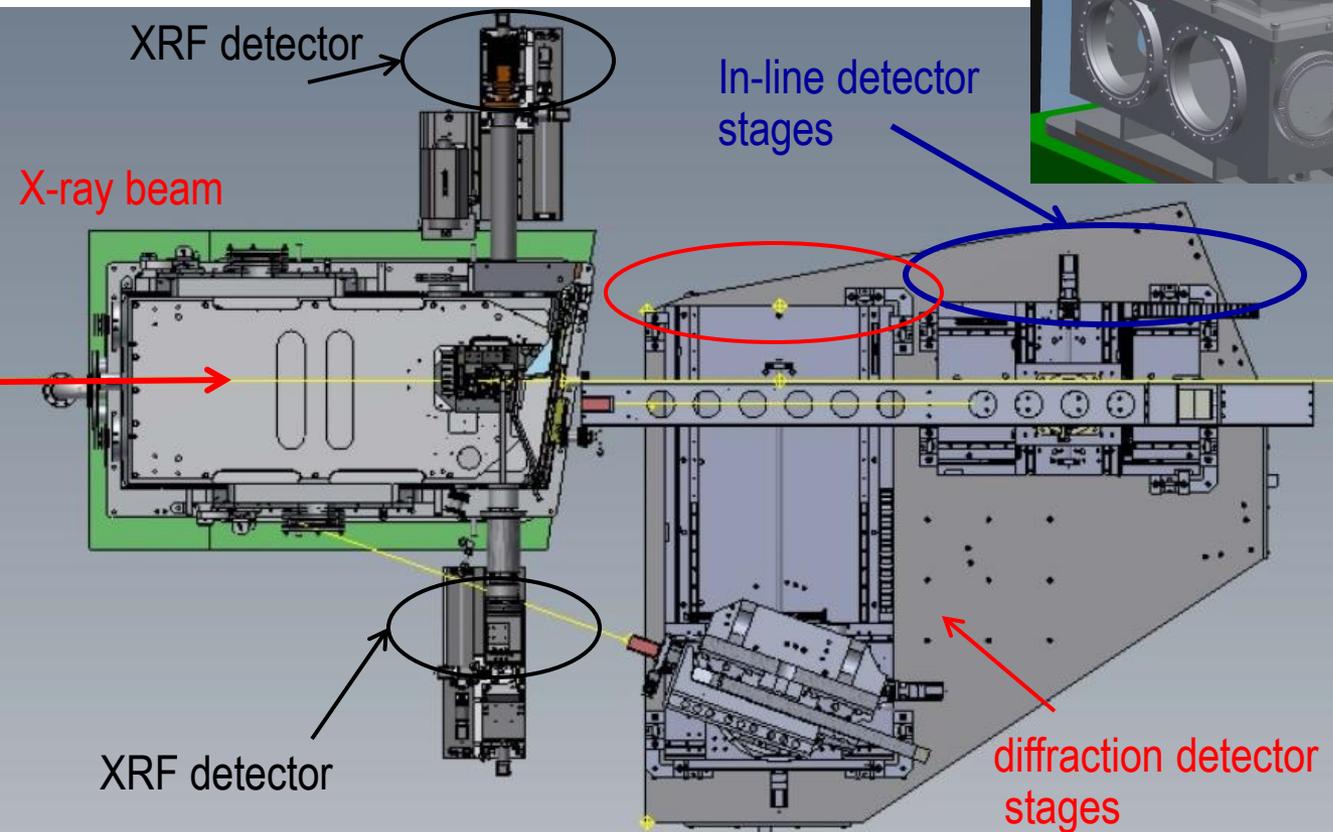
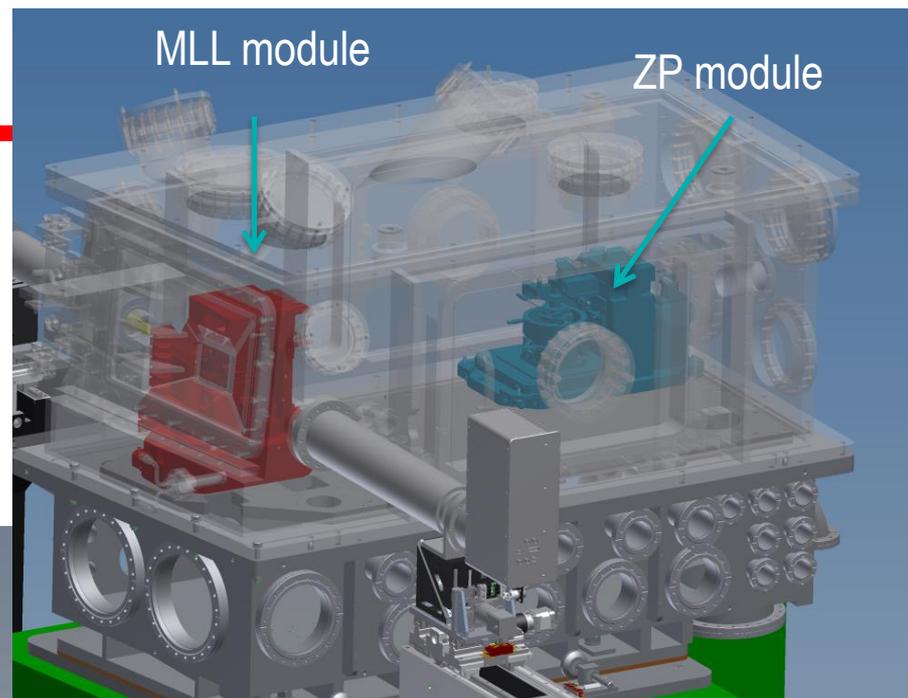


U.S. DEPARTMENT OF  
**ENERGY**

# HXN X-ray Microscope

E. Nazaretski

- 10 nm resolution for fluorescence & diffraction
- phase contrast imaging & ptychography
- MLL and ZP modules, hot-swappable
- sub-1 nm stability w/ laser interferometers
- In-vacuum system
- In-situ sample temperature regulation



Developed over 4 years:  
NSLS-II R&D and collaboration  
with Deming Shu (APS)

# X-ray Performance

at DLS ID13L

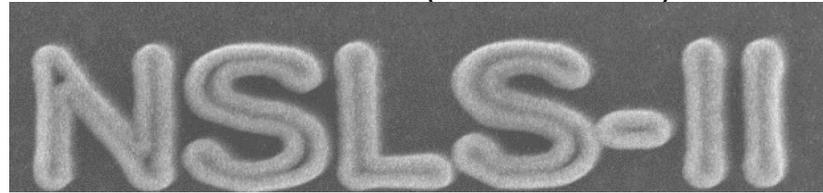
in collaboration with C. Rau team

30 nm Pt lines (200 nm thick)

Focus achieved at 11.8 keV (at Diamond):

- 19 nm (horiz) x 41 nm (vertical) by knife edge scan
- 13.3 nm (horz) x 30.1 nm (vertical) by ptychography

Instrument stability: < 4nm/hr, analysis in progress



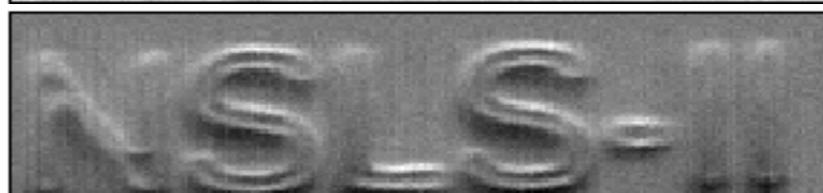
SEM



Pt XRF



Absorption



Vertical  
Phase Contrast

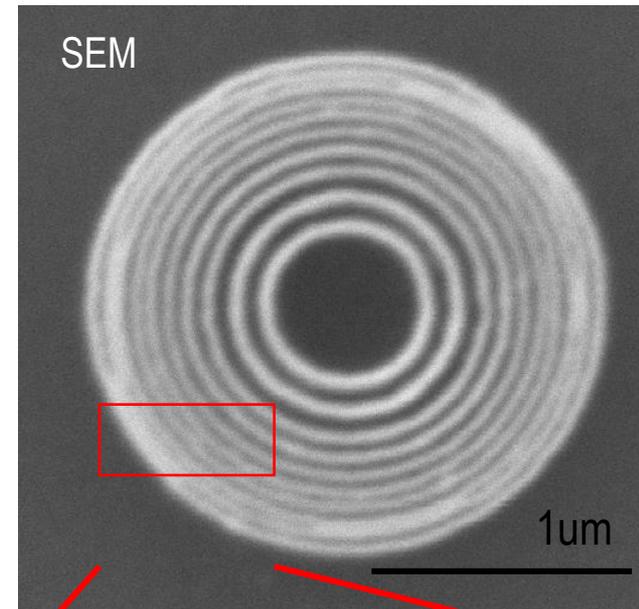


Horizontal  
Phase Contrast



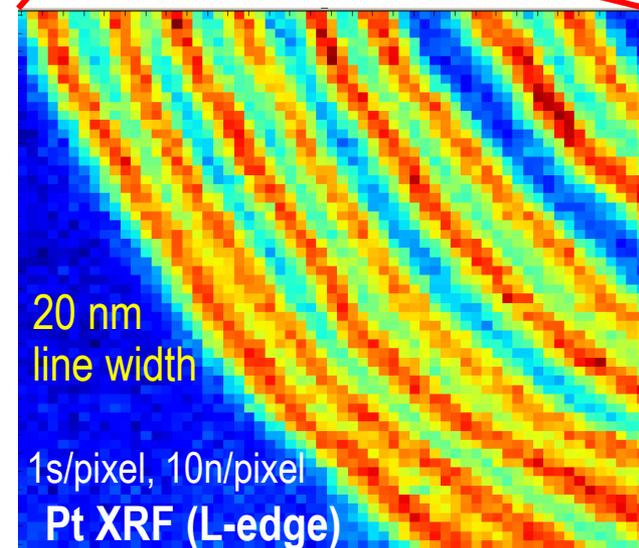
Analyzed  
Phase

7



SEM

1um



20 nm  
line width

1s/pixel, 10n/pixel  
Pt XRF (L-edge)

# Long Transport Pipe to Satellite Building

Crosses sunken bypass corridor  
at building perimeter



Pipe then goes outdoors and is carefully  
protected against the weather and deer.

# Satellite Building: General Design Considerations

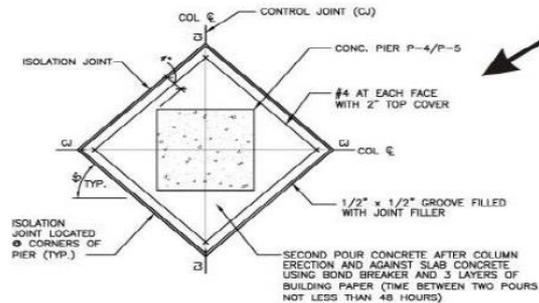
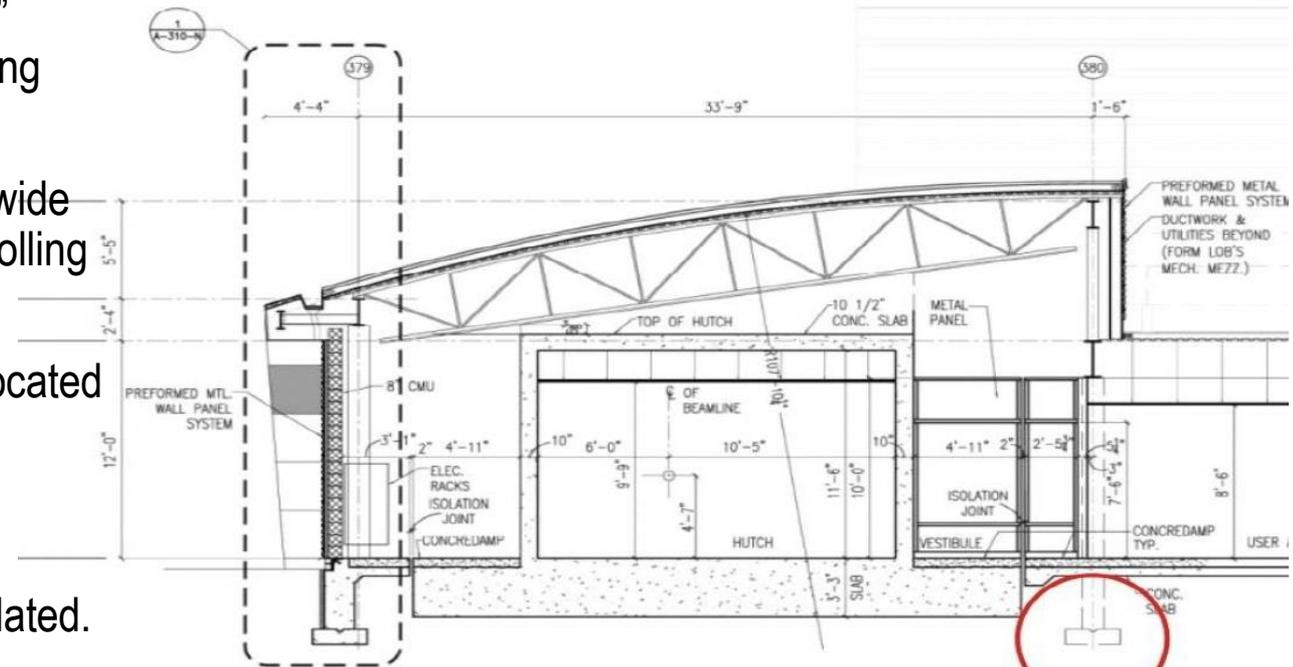
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- We studied electron microscope facilities, opted for the “house within a house” concept and used many ideas common for such modern facilities.
- Used concrete for thermal and seismic mass (~520 Tonnes)
- Minimize vibrations due to;
  - HVAC – equipment located remotely and uses “fanwall unit” not a single large fan
  - Foot traffic - use of Concredamp material on local floors
  - Transmission through structure – minimize direct contact between end station and the remainder of the structure, includes floor and utilities isolation.
- Minimize thermal perturbations by use of;
  - Airlock entry door
  - Special HVAC controls and multiple sensors (use HVAC system for Lab/Office building)
  - Full area “false ceiling” diffuser for creating laminar air flow (not hot spot, or fast air flow)
  - High levels of building insulation and minimization of air ingress – surprisingly difficult to do well: (external temperature range winter to summer of typically -20C to +35C)
  - Water-cooled racks (standard for use at NSLS-II)

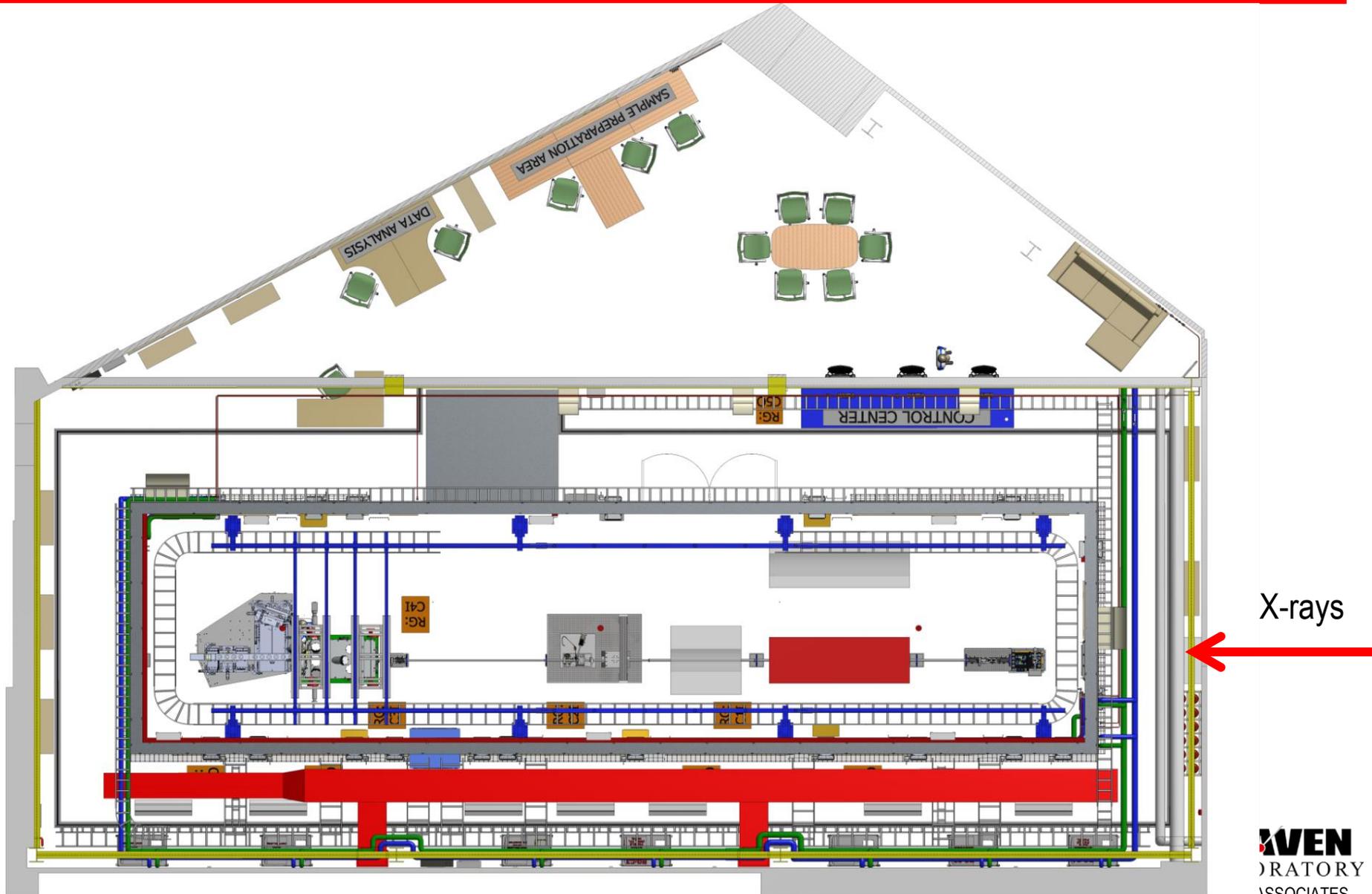
# End Station: Structural Design Considerations

- Careful attention to vibration modelling – many configurations evaluated
- Opted for separate “building” adjacent to Lab Office Building with:

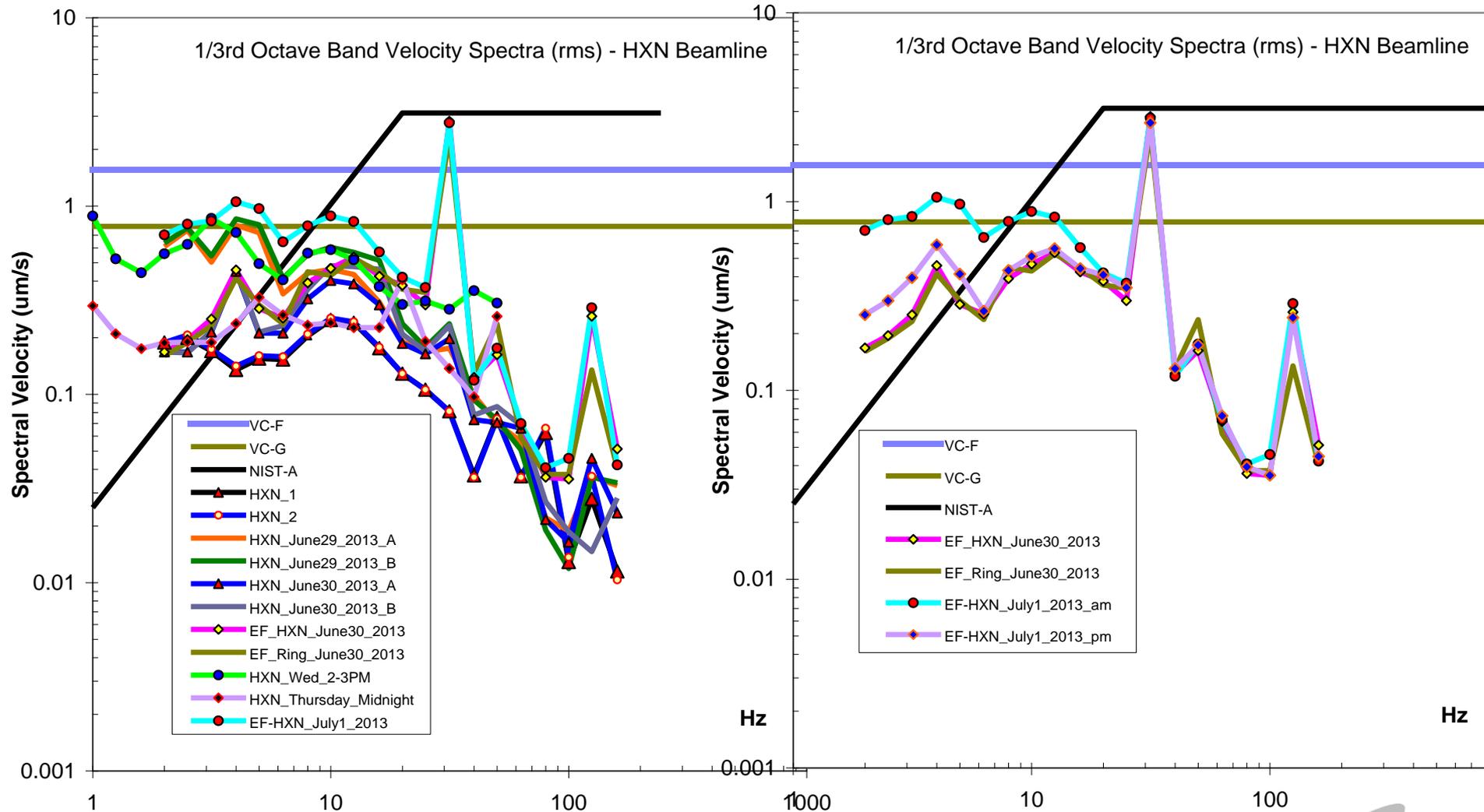
- 1m thick floor with wide “flange” to reduce rolling mode.
- HVAC equipment located in LOB not satellite building.
- Walls and roof are extremely well insulated.
- Concrete hutch gives thermal mass and increases torsional rigidity.



# Final Design of End Station: 20m x 5m Internal Size



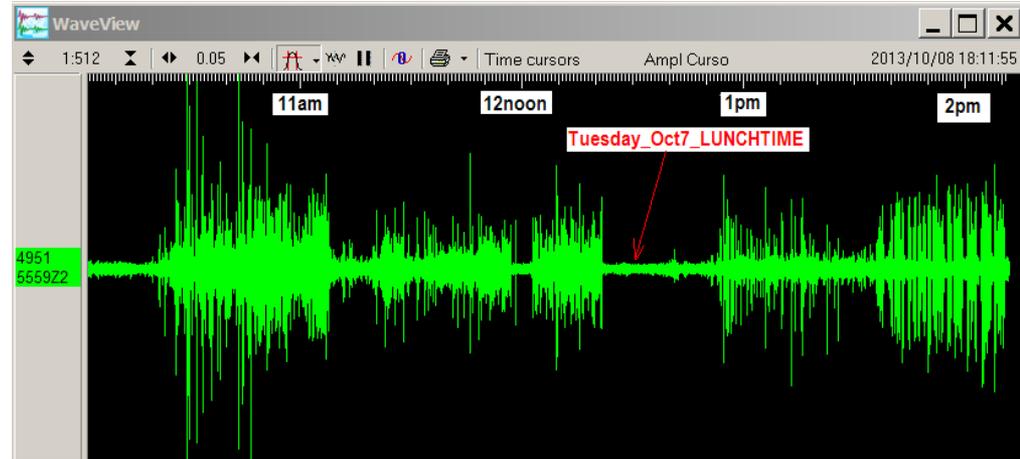
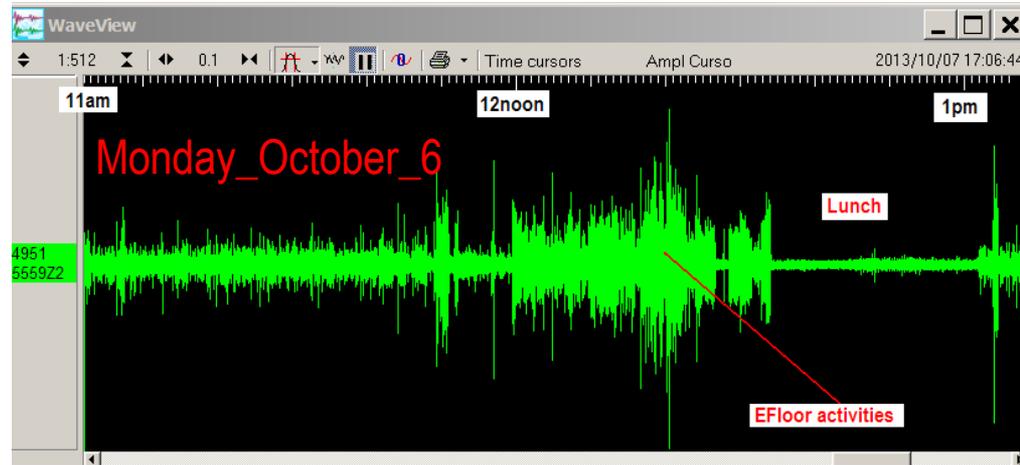
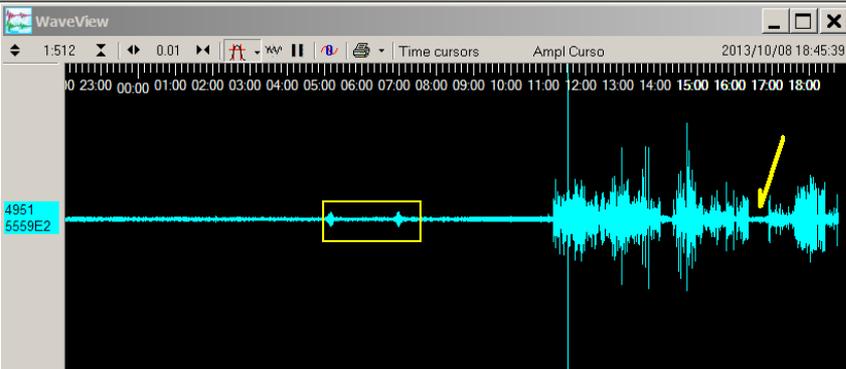
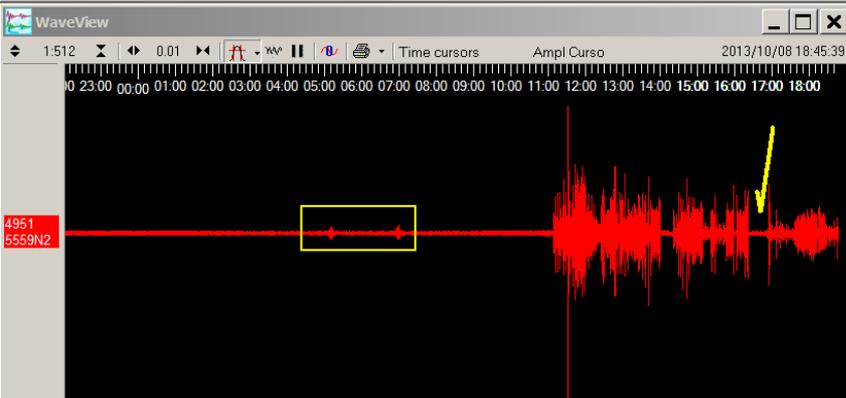
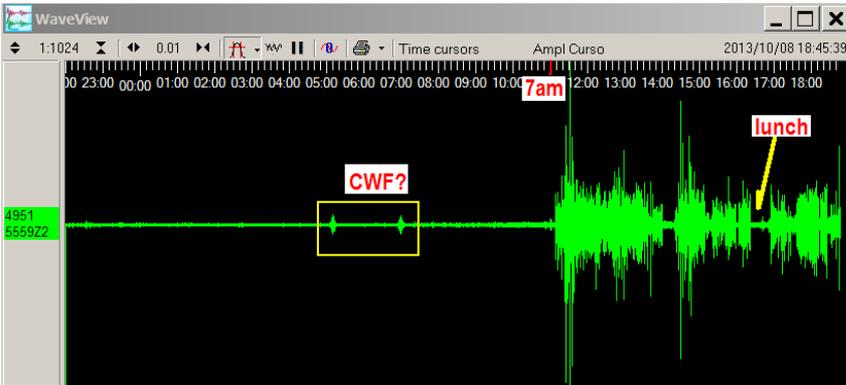
# Vibration Data for HXN End Station and NSLS-II Floor



HXN Stability Summary - October 2013

# Vibration Data over 24 hours

Considerable local construction activity ongoing 7am – 6:30pm, with break for lunch!



# Vibration Data Summary

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Extensive Measurements have been performed on the HXN Endstation Floor and the Experimental Floor Vicinity addressing both the PRIMARY Wide Band Criteria (1/3<sup>rd</sup> Octave Velocity and V-C criteria) and the Narrow Band Criteria (secondary for the HXN)

Attempt to capture different conditions that effect the HXN floor vibration was made (i.e. quietest times over the weekend vs. most active times with heavy installation work on the experimental floor). Because of this continuing INSTALLATION work on the floor, it is still hard to establish the operating environment conditions especially those during the day.

**THE PRIMARY CRITERIA on the HXN (i.e. the wide band VC-based criteria VC-E, and also the VC-F criteria ARE SATISFIED. At off peak periods even the VC-G criteria of 0.78  $\mu\text{m/s}$  spectra in 1/3<sup>rd</sup> octave band are satisfied.**

The narrow band criteria of  $\leq 25 \text{ nm}$  for  $>4 \text{ Hz}$  appear to be exceeded at periods during the day time when local traffic, the LIE and the Chilled Water Facility are on.

**Generally the measurements agree with the modelled data quite well.**

# The Satellite Building for the SIX Beamline



Low Thermal Mass and Very Large.

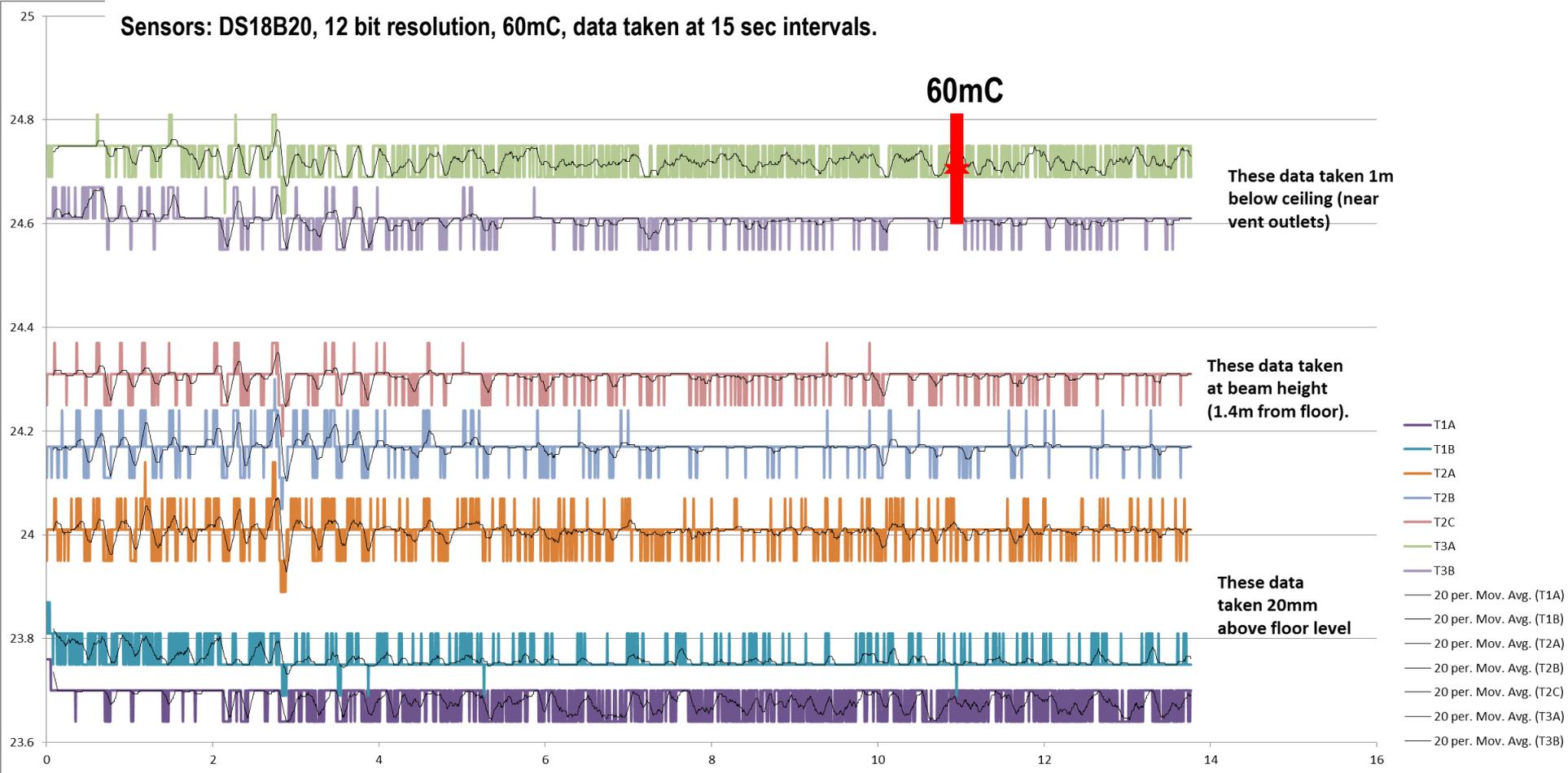
High Temperature Stability ( $\pm 0.01\text{C}$ ) Needed for Scientific Success ( $0.4\ \mu\text{m}$  stability at 4m height)

Sophisticated HVAC and control system – expensive and requires a lot of time to optimize  
– gives excellent performance ( $\pm 0.025\text{C}$ ), but we need to do better.

# Temperature Stability over 12 hours after Closing Door of SIX Satellite Building

Note: absolute values of data adjusted for clarity. Stability  $\sim\pm 0.025\text{C}$  with 5 minute moving average and sensors in free air.

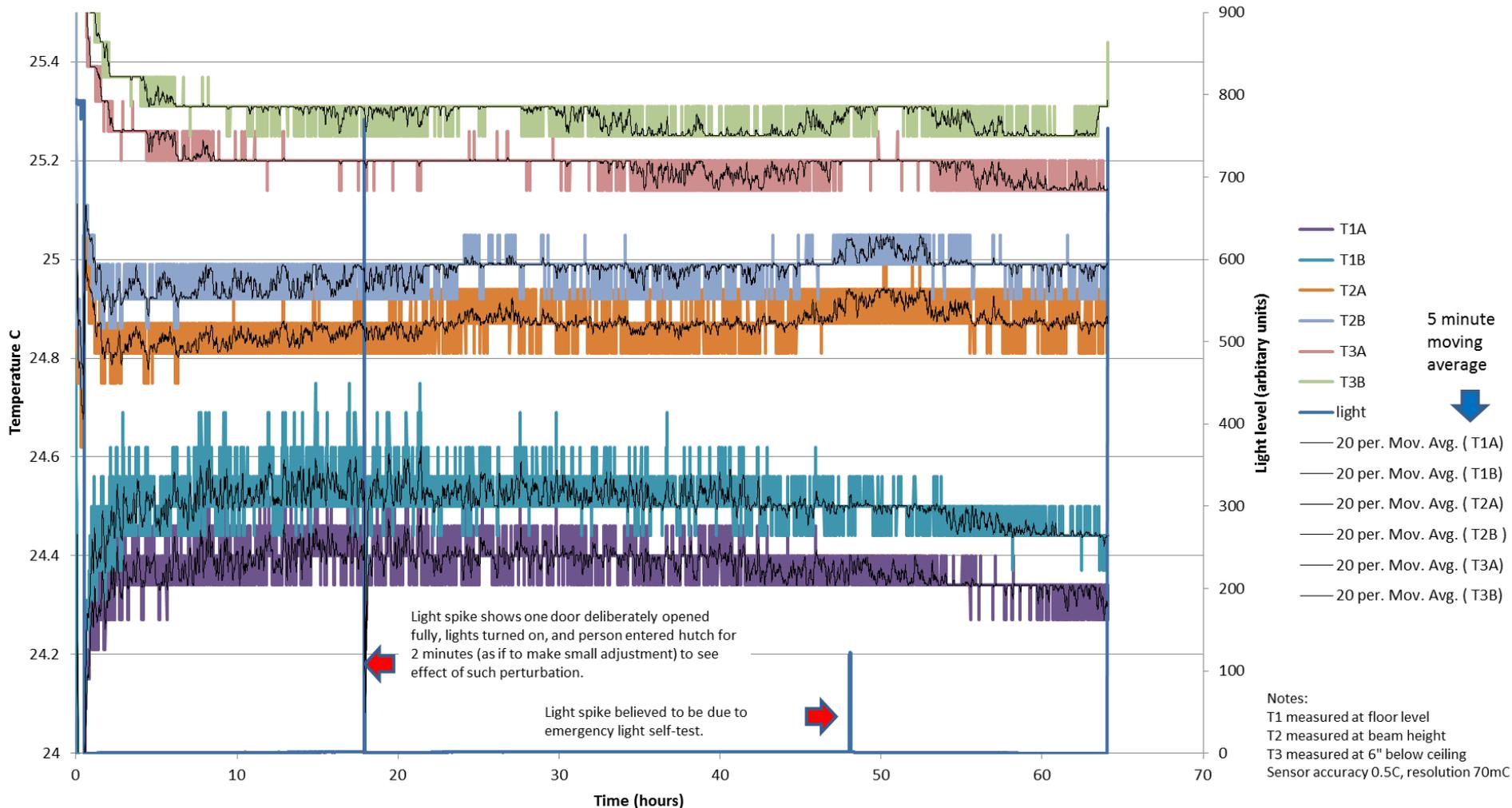
Sensors: DS18B20, 12 bit resolution, 60mC, data taken at 15 sec intervals.



# Temperature Stability over Several Days in a Typical FOE (no special precautions taken)

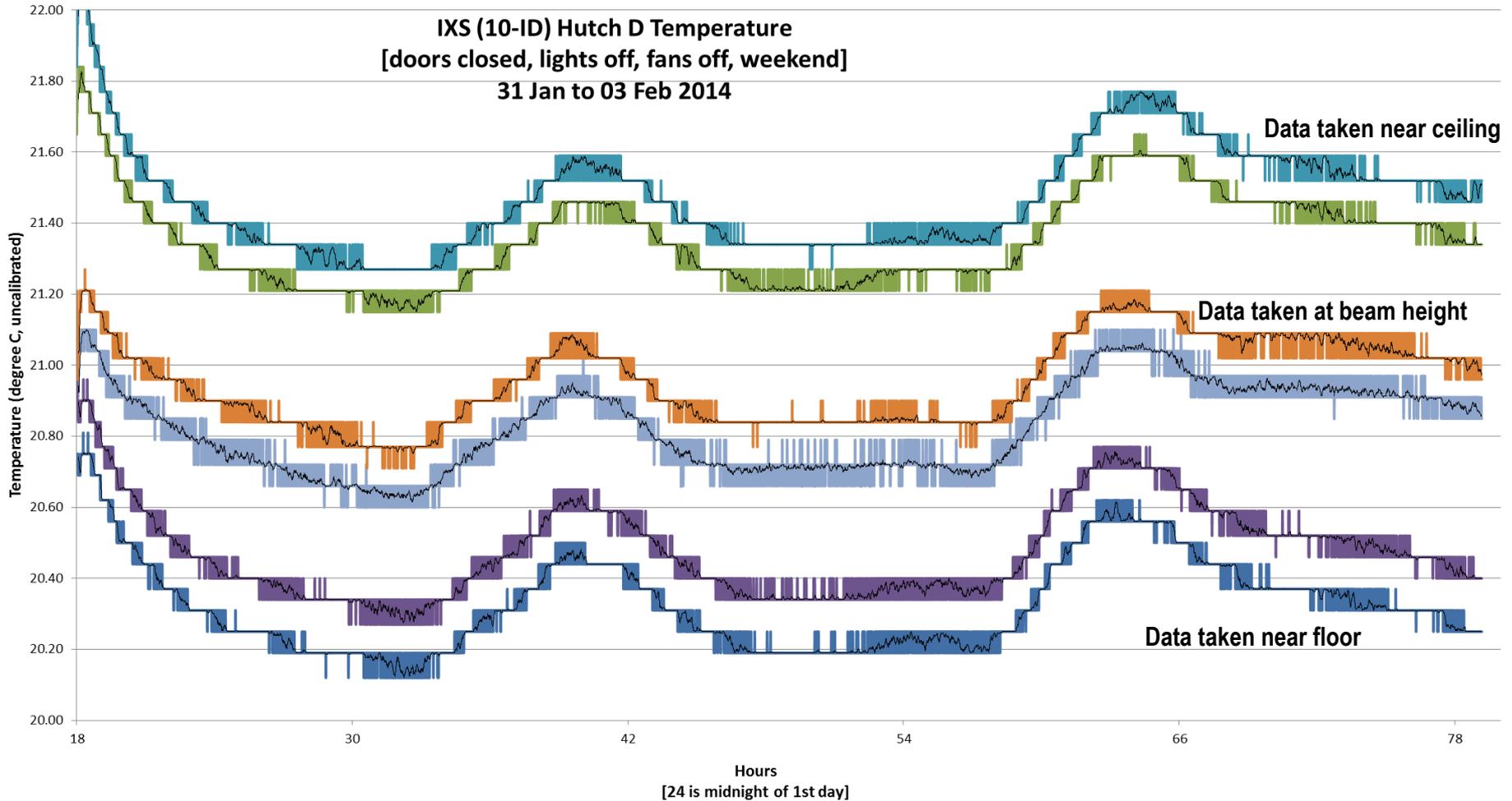
Note: absolute values of data adjusted for clarity. Stability  $\sim \pm 0.06\text{C}$  with 5 minute moving average.

Temperature logged at 15s intervals in CSX FOE 23-ID-A, electronics connected, water flowing (29.5C), doors closed (except when light level spiked), ventilation fan on.



# Temperature Stability over Several Days in a Large Steel Experimental Station

Note: absolute values of data adjusted for clarity. Stability  $\sim \pm 0.25\text{C}$  with 5 minute moving average.



# Summary of Temperature Monitoring Results

Building Temperature Designed for +/-1C, in order to do this cost effectively constraints on how much heat put into the air (ie use water cooled racks). **Requirement achieved.**

We decided not to use active temperature control in hutches on experimental floor (although this could be added later if needed).

Actual temperature stability seen by typical location;

Location	Stability	Notes
On Experimental Floor	+/-0.3C	
In End Station	+/-0.25C	Very large steel hutch, slightly better data: (+/-0.2C) for smaller hutch.
In First Optics Enclosure	~+/-0.06C	Lead hutch attached to 1m thick concrete ratchet wall with +/-0.1C stability on other side.
Satellite building (HXN)	<+/-0.05C	20m x 5m concrete hutch with HVAC taken from adjacent Lab-Office Building.
Satellite building (SIX)	+/-0.025C	Very large volume, expensive and sophisticated HVAC system and controls.

# Further work

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## Vibration.

- Further measurements needed under more controlled conditions (construction completed)
- Areas of concern: traffic / trains / CW plant / **experimental floor equipment (fans etc)**

## Temperature stability

- Continue measurements with additional sensors and sensors located outside hutches and outside building.
- Further evaluation of solar gain (may be more of a problem in winter with low sun angles)
- Continue work with new sensors with 32mC resolution.

Look at using “on-line” monitoring using EPICS available to all beamlines as a useful diagnostic.

# Lessons Learned

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## **Vibration.**

System design important for vibration minimization: eg AHU location / orientation

Unaccounted systems cause problems – much noise very distributed, chilled water facility upgrades not anticipated.

Changing environment – change in highway condition and more traffic

Sand is stable but transmits vibration very well (waveguide) ~300m down to bedrock)

Careful vibration simulation is generally quite accurate and helpful in design choices.

Wave effects measurable, but very low frequency (<1 Hz).

## **Temperature stability**

Basic philosophy to minimize solar gain and internal heat loads is good: allows simpler HVAC system

Thermal mass is good (eg concrete walls of hutch can give stability better than +/-0.1C).

Large building with low thermal mass require a very sophisticated and expensive system but can obtain excellent results (but the air sealing must be excellent)!