Building the Next Generation EM Research Facility

The Sub-Ångstrom Microscopy and Microanalysis Laboratory - SÅMMLab

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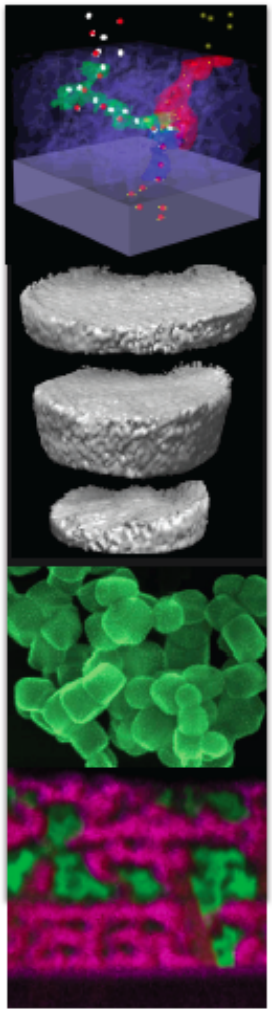
ANL Electron Microscopy Center

The EMC is a BES scientific user facility:

Mission: *High impact science enabled by new instrumentation and methods*

- Conduct and enable science through collaborative and user research
- Maintain unique resources and facilities for scientific research
- Expand the frontiers of electron microscopy through new instrumentation, techniques, and expertise



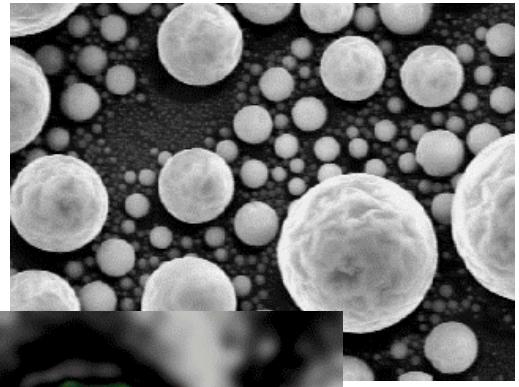
Understanding the Synergistic Relationships Between Structure and Properties

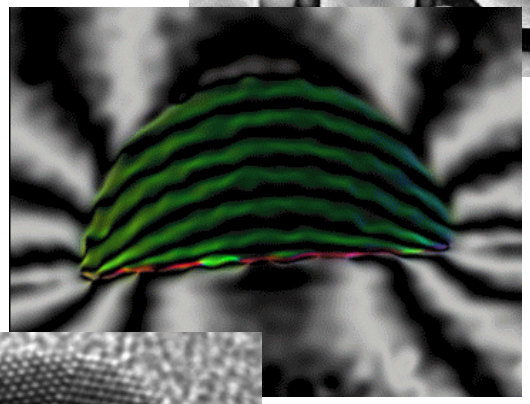
Understanding (New) Materials and Phenomena

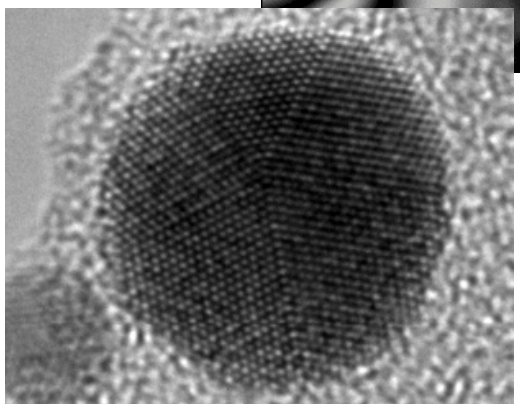
- *Create / Discover*
- *Explore/Understand*
- *Control / Apply*

Motivation:

- *Serve National Strategic Mission*
  - *Energy/ Economy*
  - *Health*
  - *Defense*
- *Enable other Science Breakthroughs*





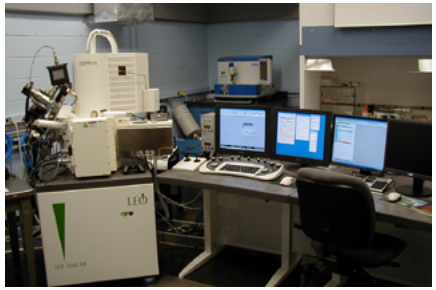


ANL Electron Microscopy Center Instrumentation

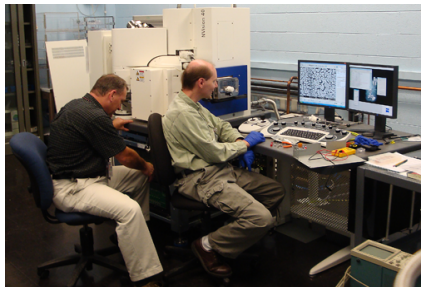
Philips/FEI CM30

Hitachi S4700

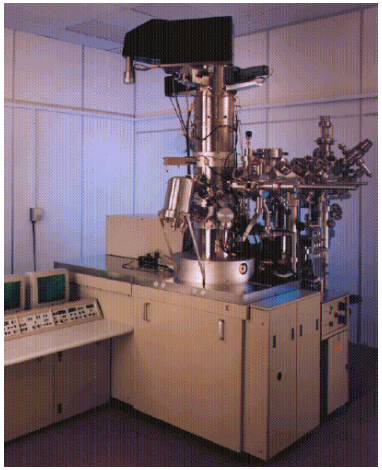
Hitachi H-9000



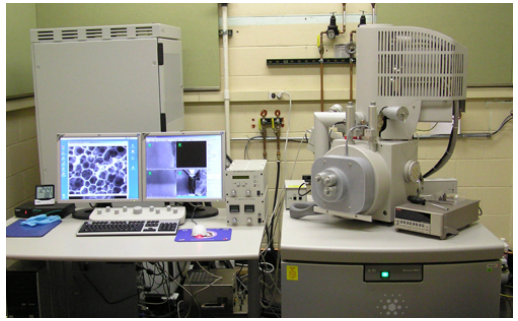
Zeiss 1540 XB SEM/FIB



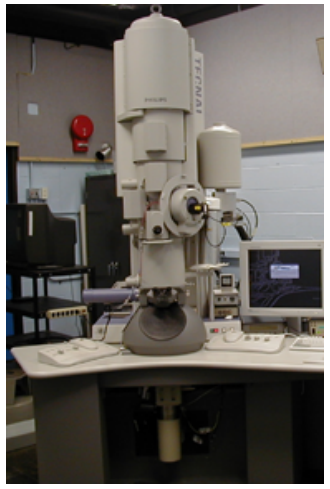
Zeiss NVision SEM/FIB



AAEM
HB603Z



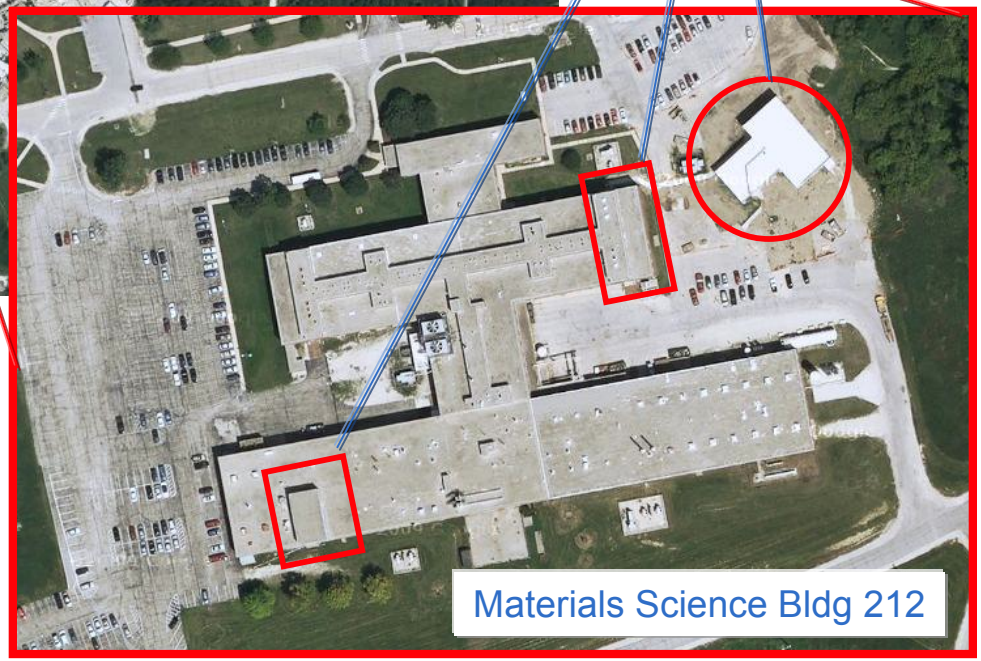
FEI Quanta 400 ESEM



FEI Tecnai F20

ANL EM Center

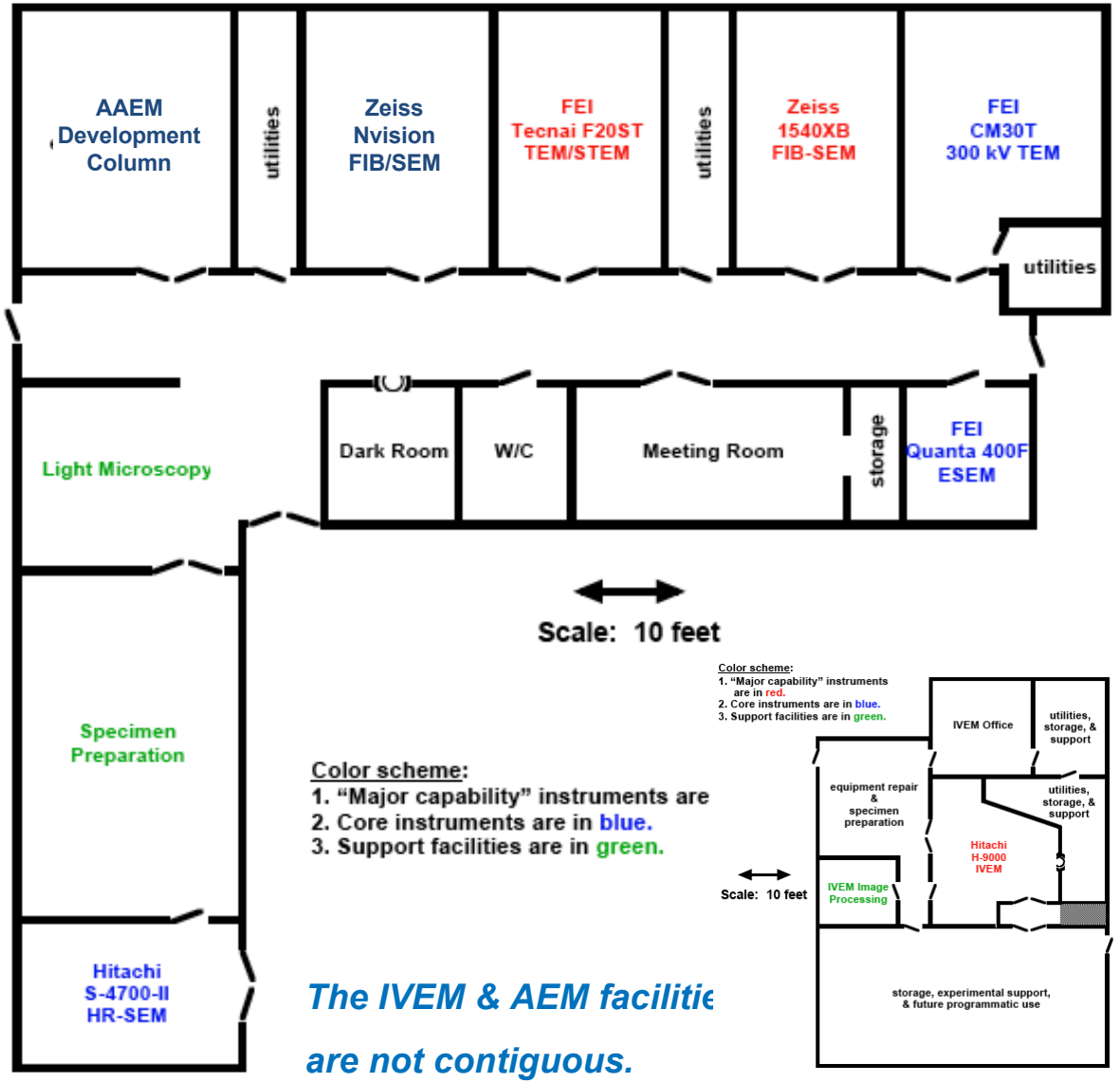
- IVEM Lab
- AEM Lab
- SÅMMLab



Argonne NATIONAL LABORATORY

Existing EMC Facility Floor Plan

- Materials research using:
  - Analytical TEM/STEM
  - Focused ion beam
  - Fluctuation EM
  - HREM
  - Scanning (SEM):
    - High resolution
    - Low voltage
    - Environmental
- Instrumentation and technique development.
- TEM specimen preparation laboratory.



The IVEM & AEM facilitie

are not contiguous.

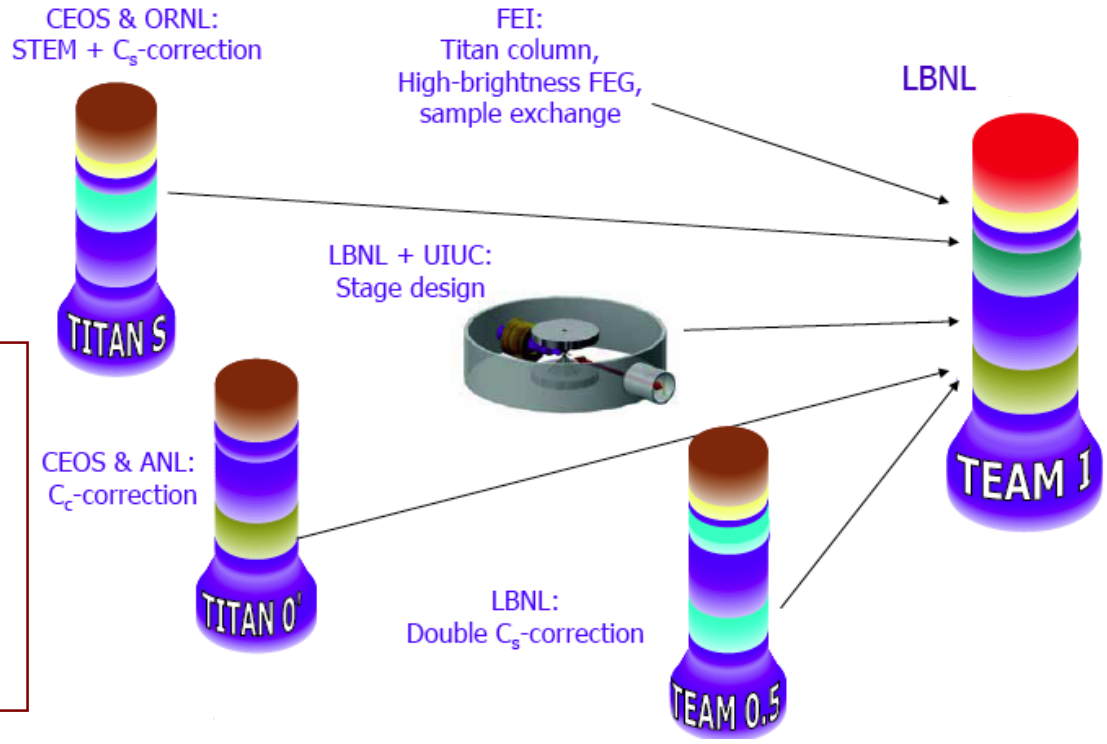
The Transmission Electron Aberration-corrected Microscope (TEAM) project

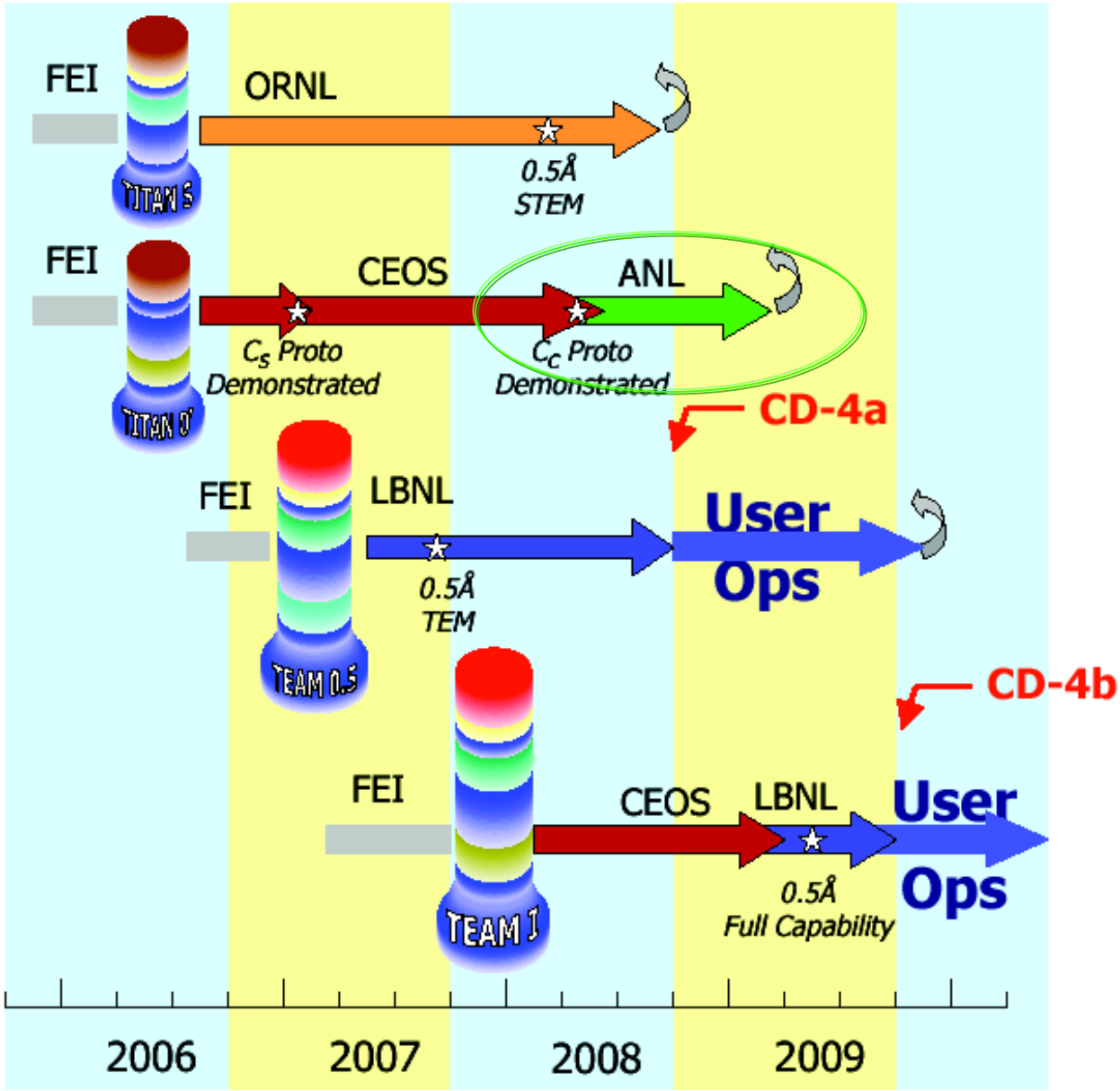
A *DOE* project to develop & build the next-generation microscopes that utilize C_s & C_c aberration correction to revolutionize our capability to characterize materials

Collaborative project between microscopy activities at ANL, LBL, ORNL, BNL, and Frederick Seitz MRL at UIUC

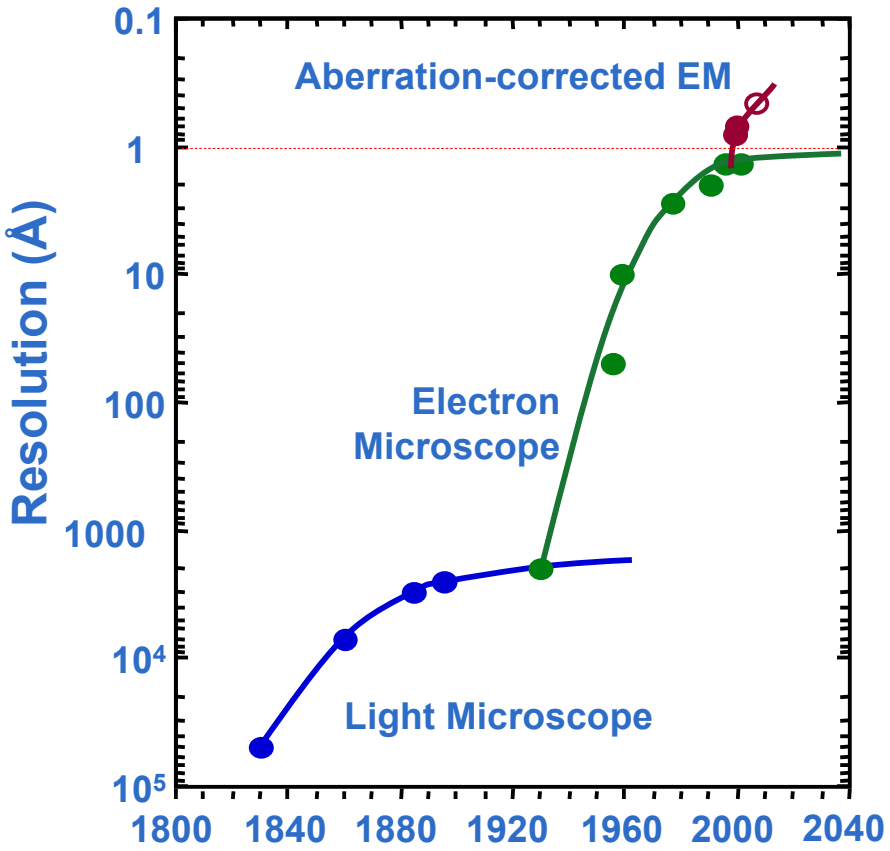
EMC's unique role:
- *develop the C_c-corrector*

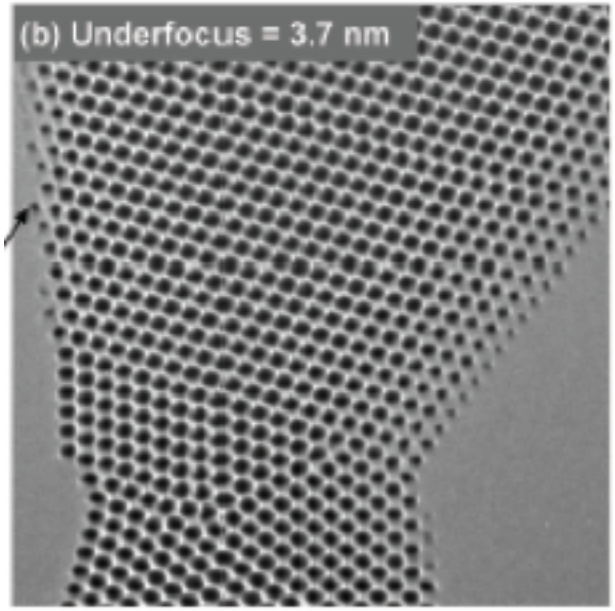
-incorporates both spherical & chromatic aberration correction




FEI
ORNL
TITAN S
0.5Å
STEM
FEI
CEOS
ANL
TITAN 5'
C_S Proto
Demonstrated
C_C Proto
Demonstrated
CD-4a
FEI
LBNL
User
Ops
TEAM 0.5
0.5Å
TEM
CD-4b
FEI
CEOS
LBNL
User
Ops
TEAM I
0.5Å
Full Capability
2006
2007
2008
2009

TEAM Project





TEAM 0.5 @ LBNL

SÅMMLab : Motivation

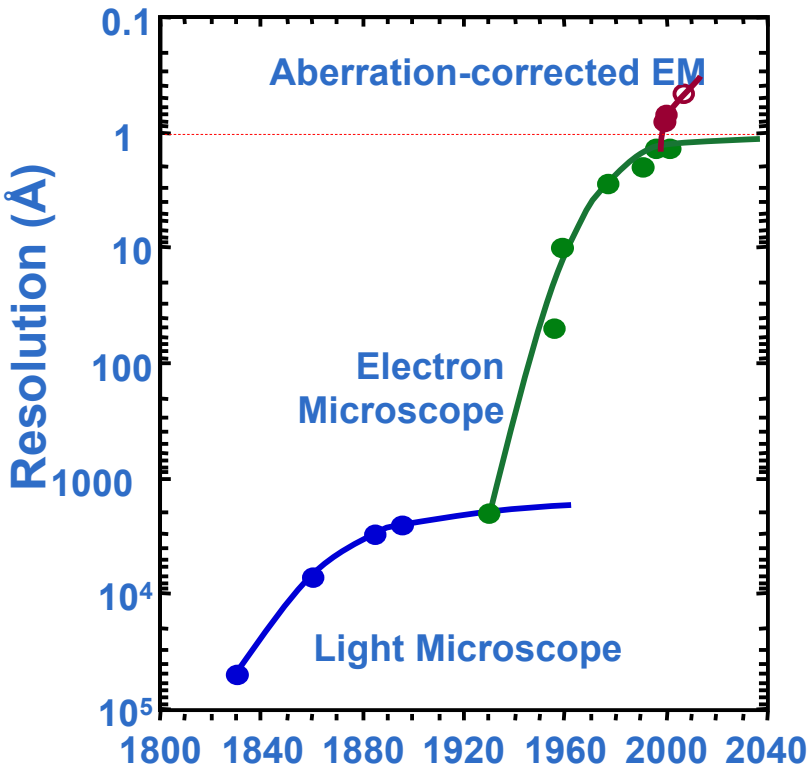
Advances in electron microscopy, driven by scientific need, will enable unprecedented performance …

key technical specifications for TEAM

0.5Å TEM/STEM (vs. ≈ 1Å today)

0.1 eV dE (vs. ≈ 0.5 eV today)

… only if we also provide a laboratory to house such instruments that will not limit their performance.



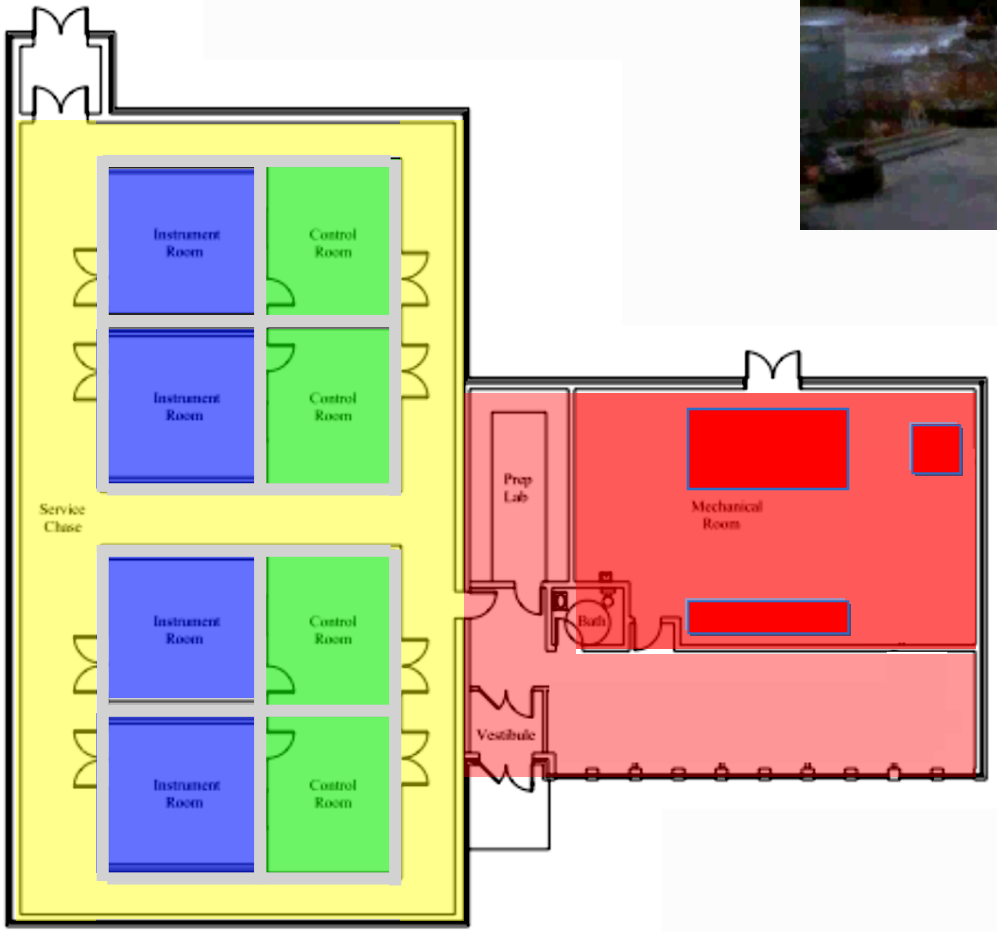
Item	Requirements
Mechanical vibrations	≤ 0.25 µm/sec (rms) at all frequencies and in all directions ≤ 0.25 µm peak-to-peak displacement at 1 Hz in all directions ≤ 0.005 µm peak-to-peak displacement at 10 Hz in all directions ≤ 0.0005 µm peak-to-peak displacement at 100 Hz in all directions EM lab floors must be decoupled from the walls for vibration isolation and minimization.
Stray magnetic fields (AC, in all directions)	≤ 0.1 mG (10 nT) peak-to-peak at frequencies ≥ 60 Hz. At lower frequencies: scaled by f/60. Active elecromagnetic field compensation is not permitted with the EM labs.
Stray magnetic fields (DC)	< 1 mG vertical, < 0.01 mG horizontal above Earth Ambient
Stray electric fields (AC/DC)	All external electric fields must be shielded to produce a Lorentz force which is less than the Magnetic Equivalent above.
Sound levels	≤ 40 dB at all frequencies ≤ 30 kHz
Air flow	< 1 cm/min (0.4 inch/min) vertically; no horizontal air currents permitted.
Air cleanliness	Class 1000 clean room.
Air pressure	+ psi with respect to the corridors and utility rooms to keep out dust.
Temperature and humidity	70˚ F ± 0.1˚ F per minute 24 x 7 40-60% relative humidity at all times.
Electrical power	Power lines to and within the building must be reverse-wound to minimize stray electro-magnetic fields and oriented so that any generated fields will have minimal effect on instrumentation. 208-240 Vac: ≤ 10 kW, single and 3-phase, regulated to 3%, with integrated surge suppression. 110 Vac: 20 A, 4 circuits per room, derived from and in phase with the 208 Vac power. 110 Vac in EM labs must not be in metal raceways, and the receptacles should be computer-grounded.
UPS	≈ 100 kW hour Provides ability to maintain power for one hour in the EM labs to facilitate safe shutdown in the event of power failure.
Isolated instrument grounds	One per microscope. 3-pole permanent to external earth and not connected to main building ground.
In-floor raceways	In-floor raceways for all electrical cabling to electron microscopes.
Recirculating cooling water	≥ 1.5 gpm, 65˚ F ± 2˚ F/hr, ≥ 25 psi differential For cooling dedicated water chillers that will be located in utility rooms.
Nitrogen gas	2-3 psi Free of water vapor and oil. Derive from liquid nitrogen tank boil-off.
Compressed air	100 psi, filtered and free of oil.
SF_6	6 bar (90 psi), distributed to each EM lab from a central room.
Venting systems	1. Passive emergency SF_6 venting for each EM column. 2. Central, filtered, extraction system for exhaust from all vacuum roughing pumps.
Fire suppression	ANL Standard
Room cooling	Heat loads < 3000 W per lab. Passive cooling panels required. Only minimal air currents are allowed. All ducts in the EM labs must be nonmagnetic and, preferably, nonmetallic. Cooling systems must be designed to accommodate periods of time when some instrumentation in the EM lab is powered down, while other units are fully operational.
Floor loading	200 pounds per square foot. All reinforcement bars used in structural construction must be nonmagnetic and electrically isolated.
Room Dimensions	EM labs vary in size from 15 x 21.5 ft to 30 x 31.5ft.
Ceiling height	15 feet, to accommodate column heights, cranes, etc.
Piping systems	All piping (compressed air, cooling water, nitrogen gas, fire suppression etc.) within the EM labs must be non-magnetic.
Room lighting	Lighting must not produce RF or AC fields, which affect detector systems.
Doors	Fabricated of nonmagnetic materials. Double doors: 6 ft-wide opening.

Table 1: SÅMMLab Environmental Specifications

Location

Adjacent to existing EMC resources - minimize additional requirements for new space

Sub-Ångstrom Microscopy and Microanalysis Laboratory



Temp: ± 0.1 F

EMF: < 0.01mG

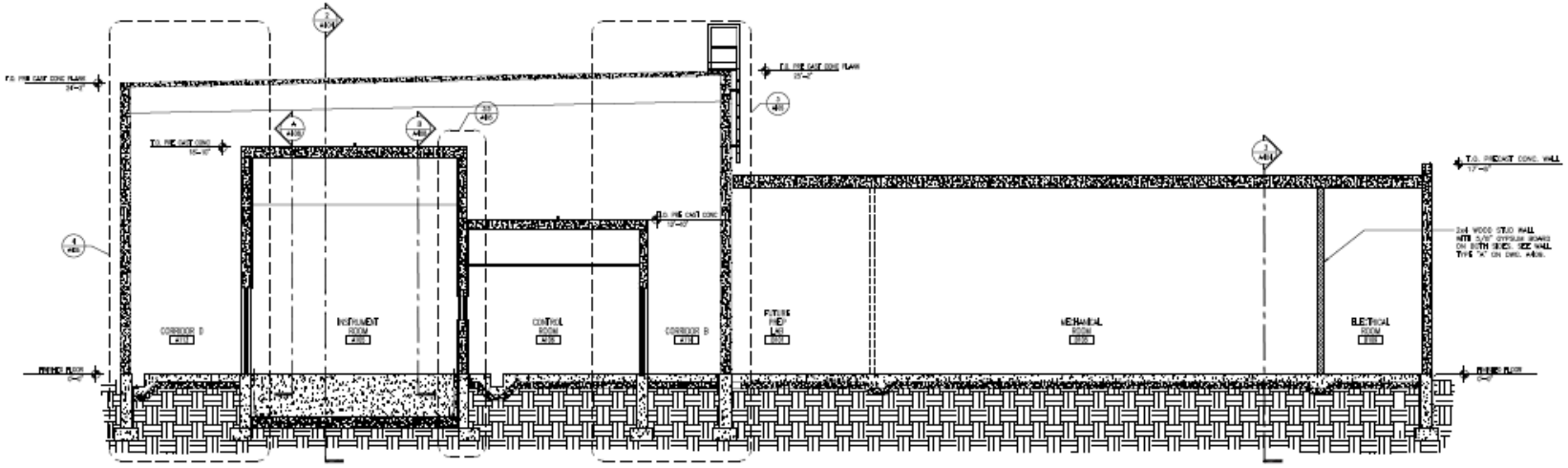
Acoustics: < 40 dB

Air Flow: < 1 cm/min

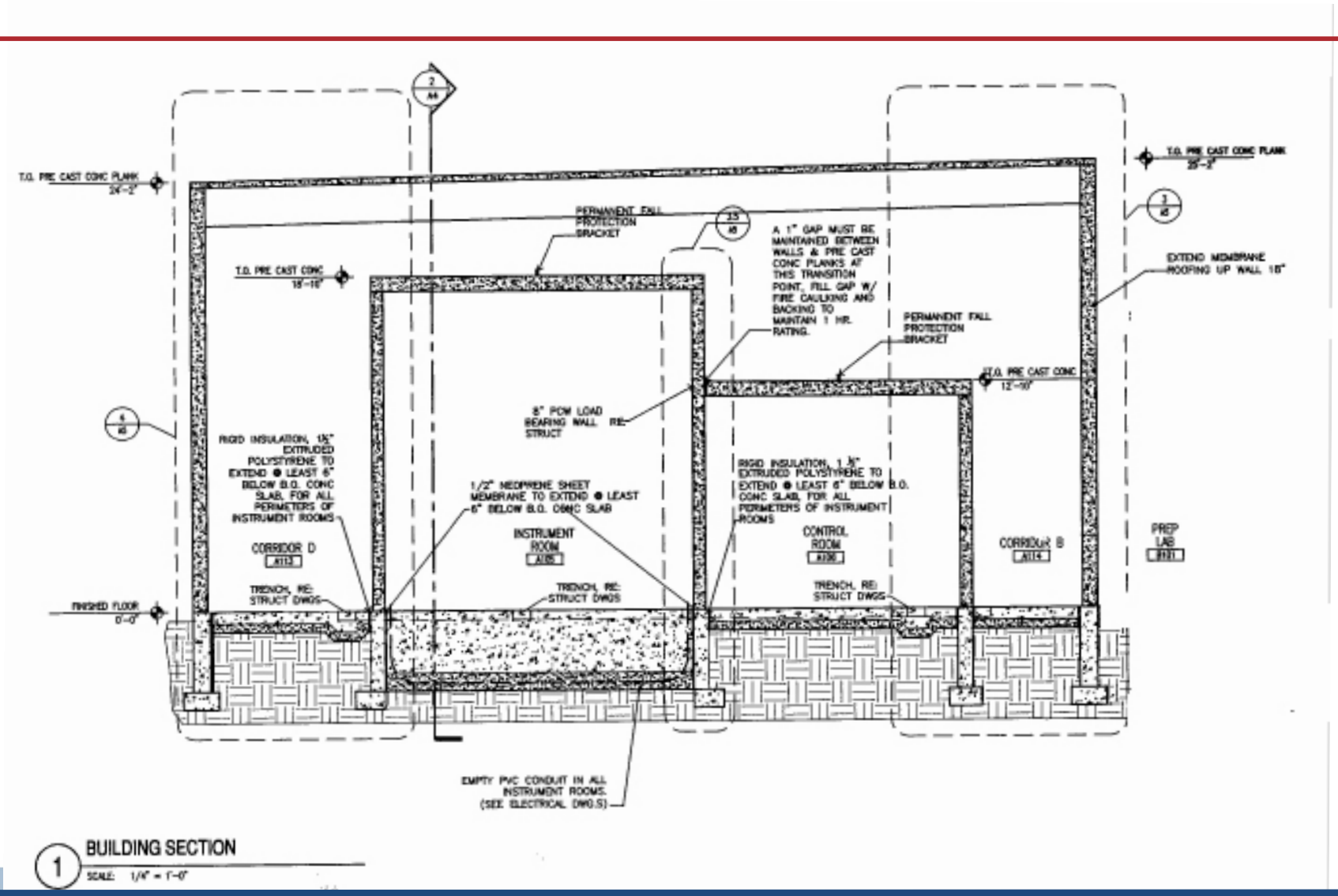
Vibrations: < 0.25 µm/s RMS

Environmental Conditions

Best -> Worse

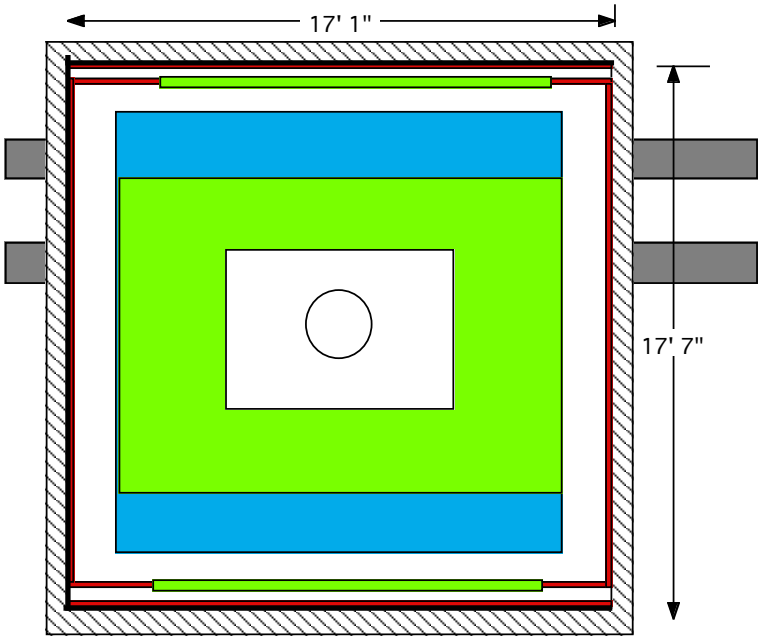

CORRIDOR B
INSTRUMENT ROOM
CONTROL ROOM
CORRIDOR B
FUTURE MECH. EQUIP.
MECHANICAL ROOM
ELECTRICAL ROOM

Design



1 BUILDING SECTION

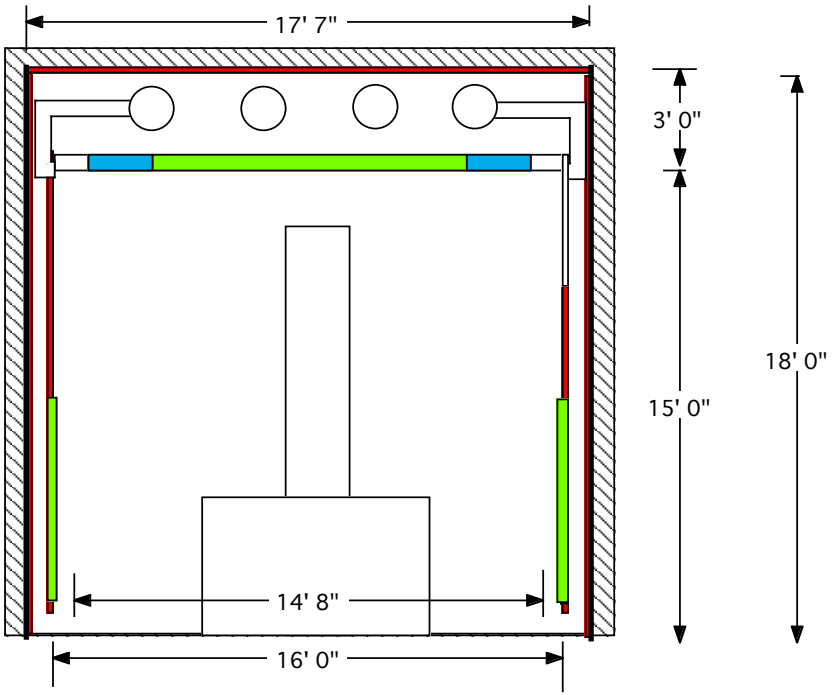
SCALE: 1/4" = 1'-0"



Perforated Cooling Panels No Air Flow & Acoustic Fiber Absorber backing

Perforated Cooling Panels With Air Flow (??? Acoustic Fiber Absorber)

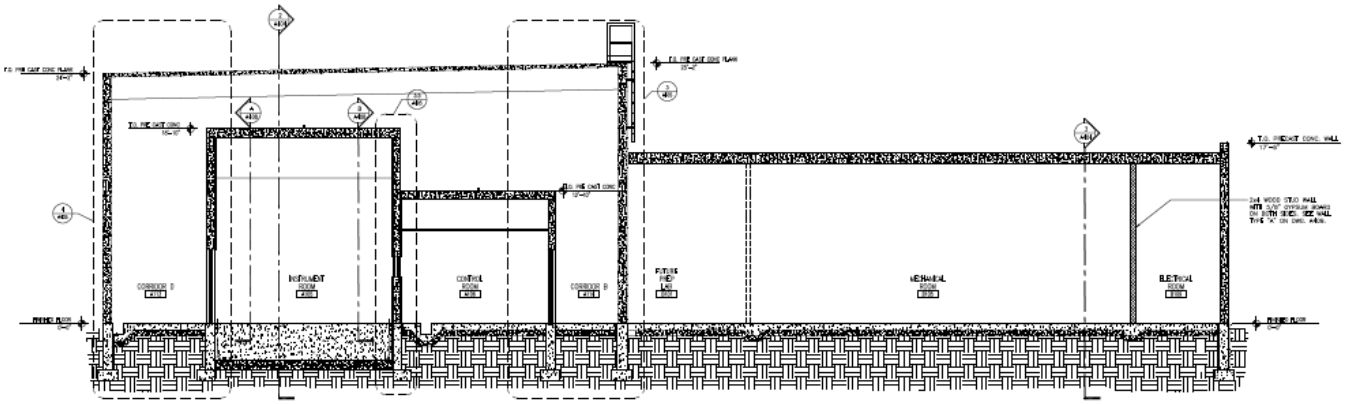
Acoustic Panel Absorber ~ 2"



Acoustic Rubber/Vinyl Block ~ 1/4"

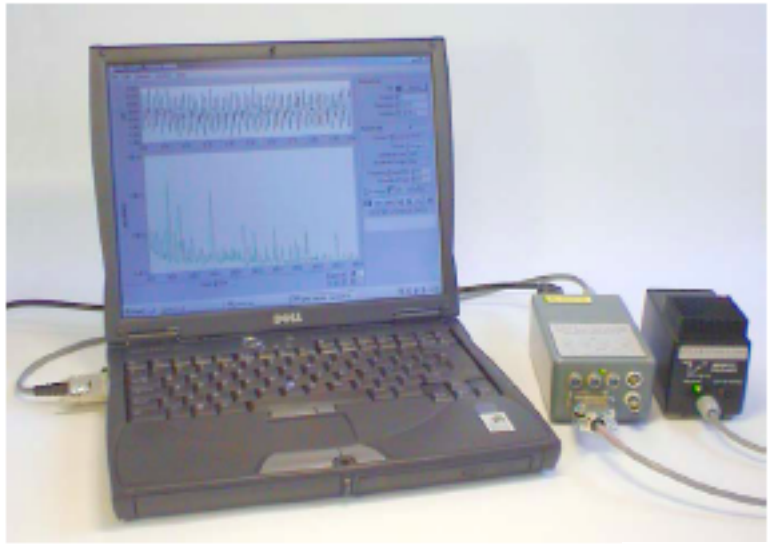
Concrete

Trench in Floor


CORRIDOR B
INSTRUMENT
CONTROL
CORRIDOR B
FUTURE
MECHANICAL
ELECTRICAL

Final Roof Panel Installed

SC11 Analysis System - Sensor Interface



SC11 System in case

SPICER CONSULTING

SAMM Lab performance: mechanical vibrations

Exceeding design specifications and instrument requirements (e.g. TEAM column):

Design Specifications:

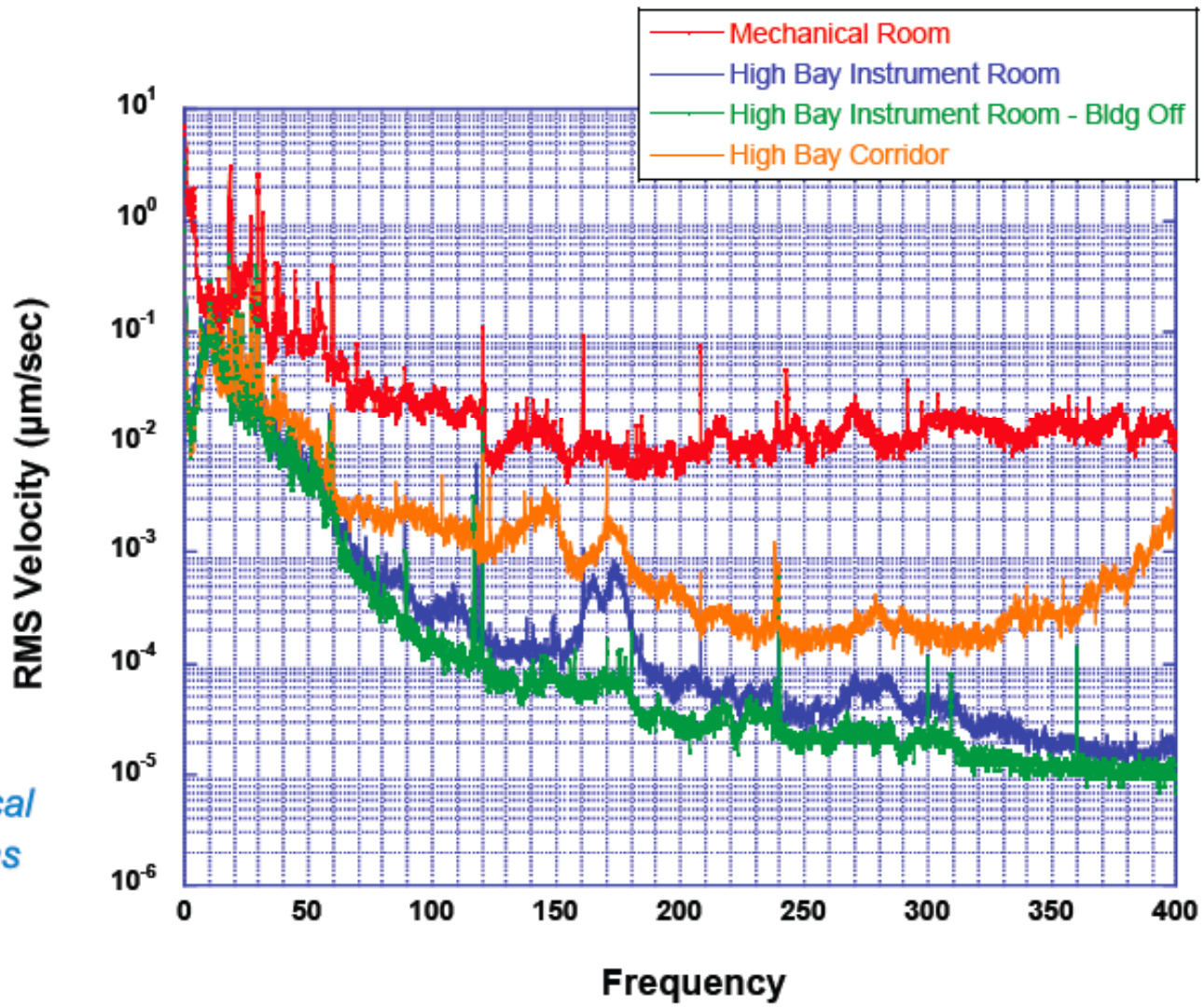
Temp: ± 0.1 F/min

EMF: < 0.1mG p-p

Acoustics: < 40 dB

Air Flow: < 1 cm/min vertical

Vibrations: < 0.25 µm/s rms

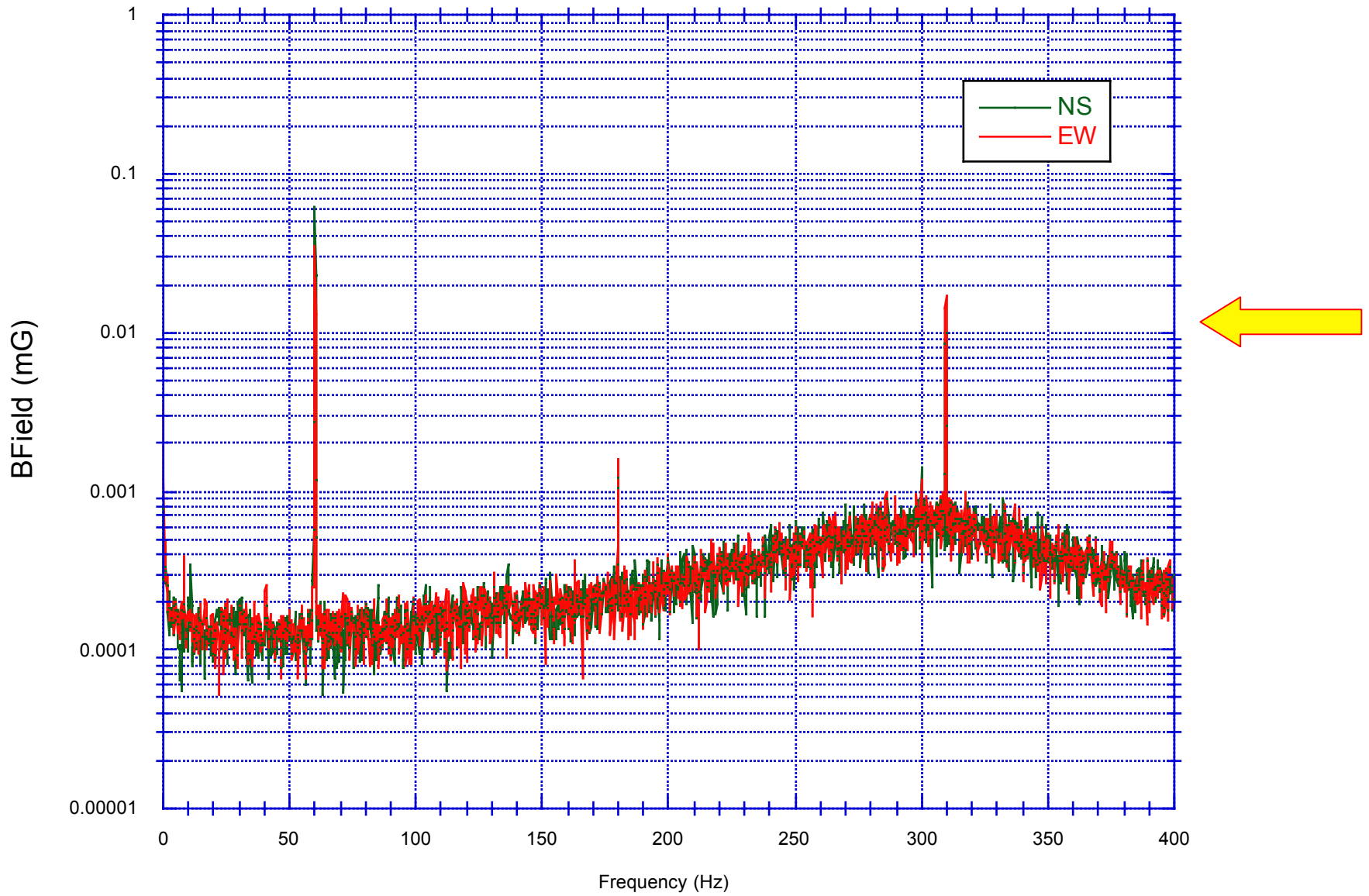


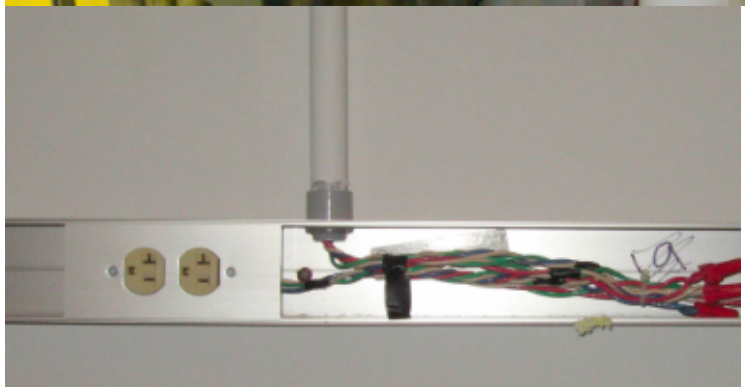
Construction

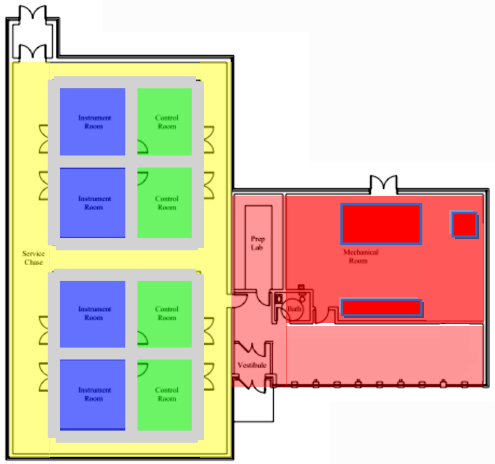
Construction

Fiberglass & Non-Magnetic Rebar

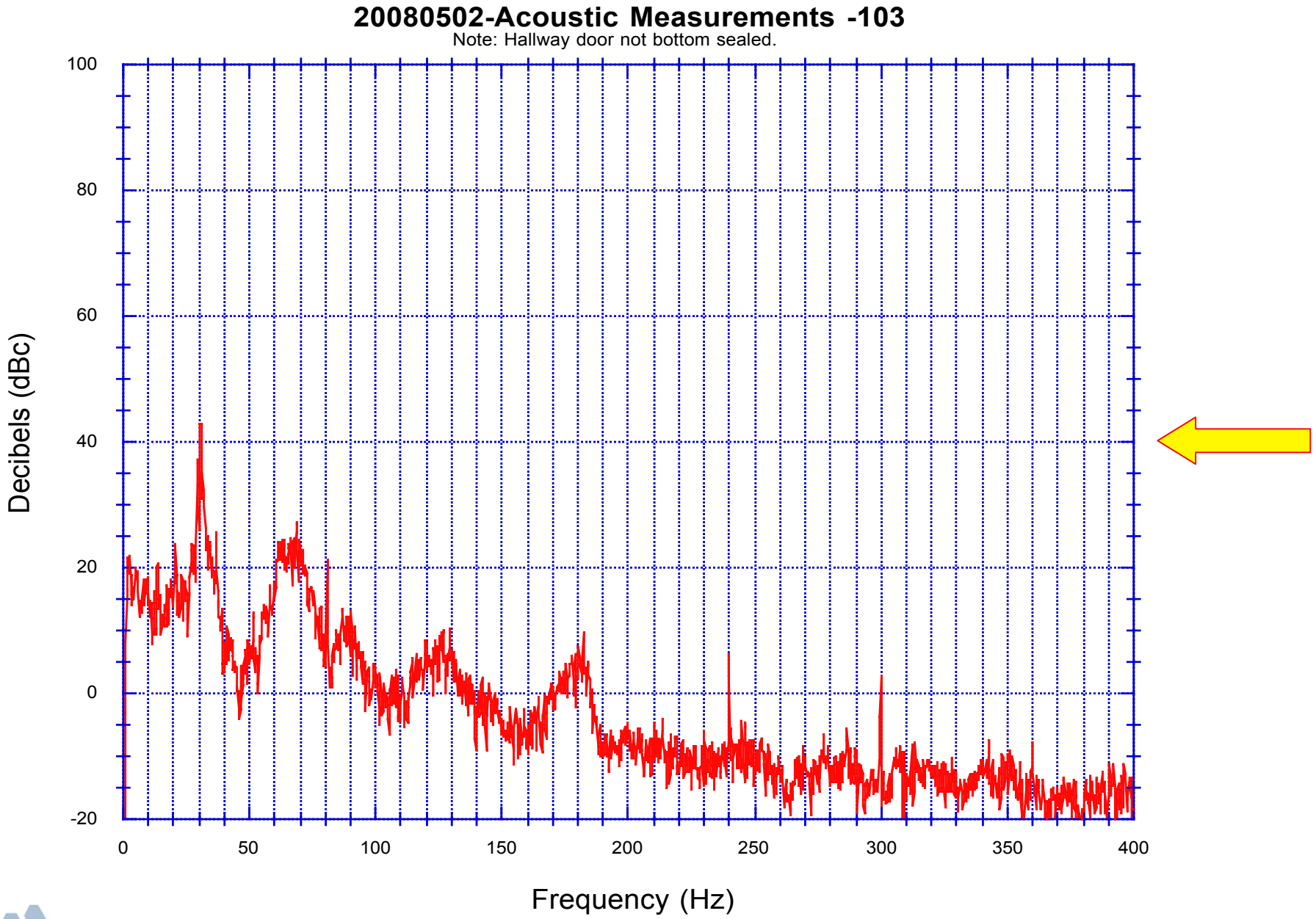
Pre-cast Walls

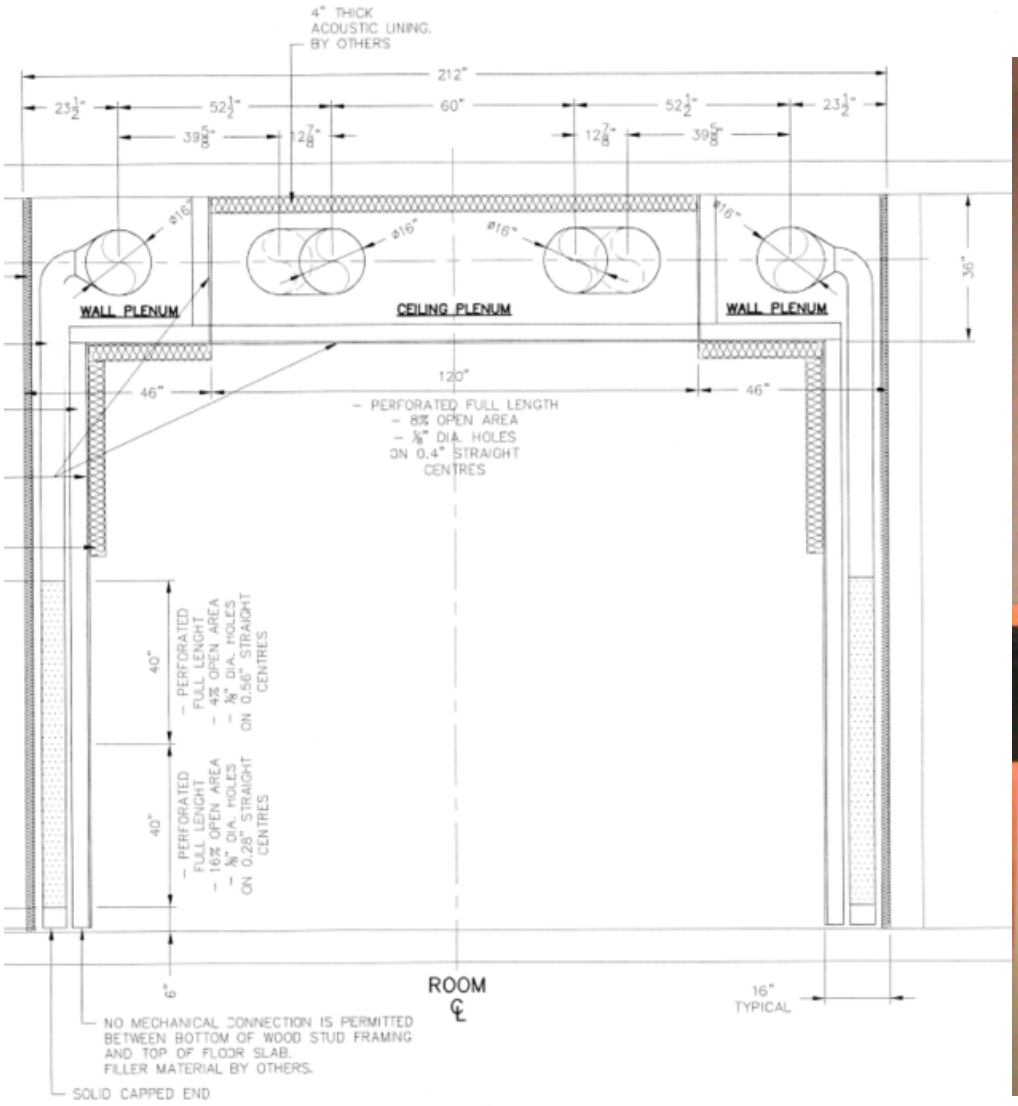

20080505/6 B Field 103 XY Plane
BField (mG)
1
0.1
0.01
0.001
0.0001
0.00001
0
50
100
150
200
250
300
350
400
Frequency (Hz)
NS
EW

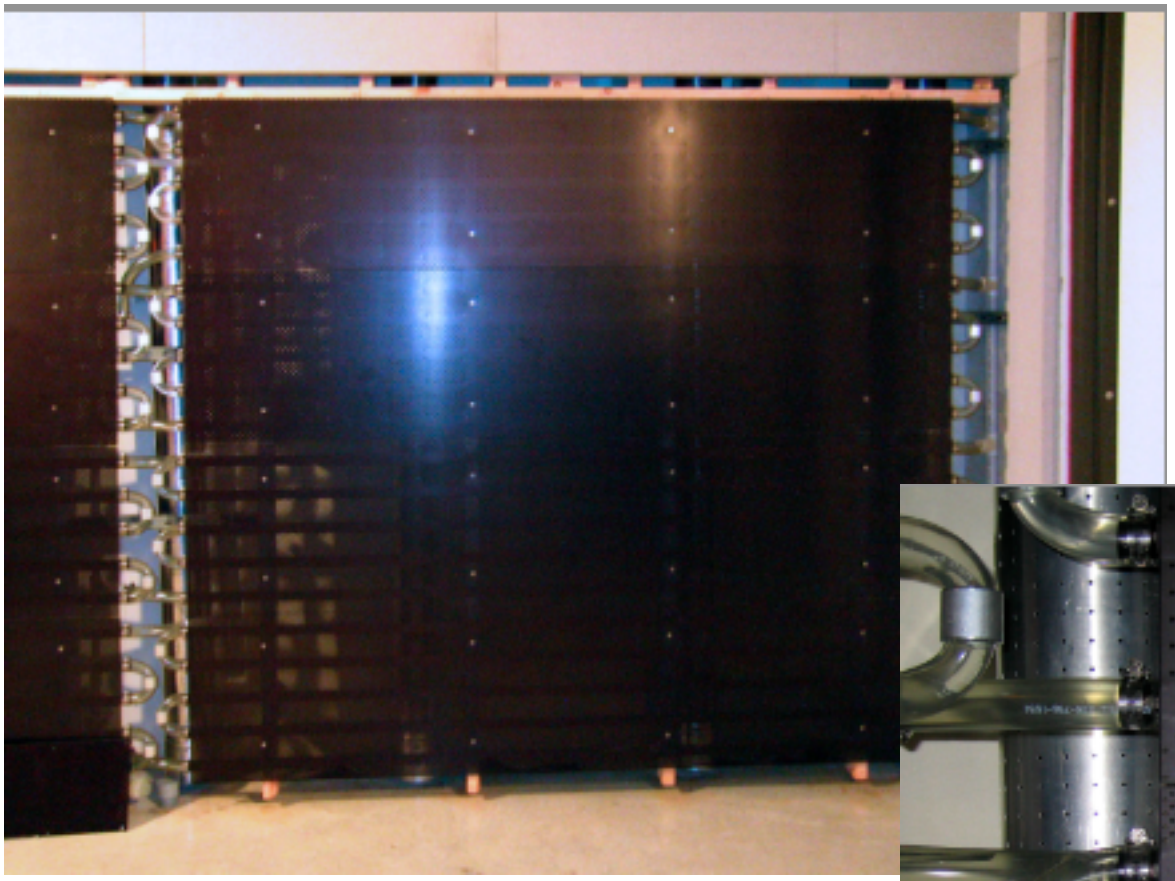


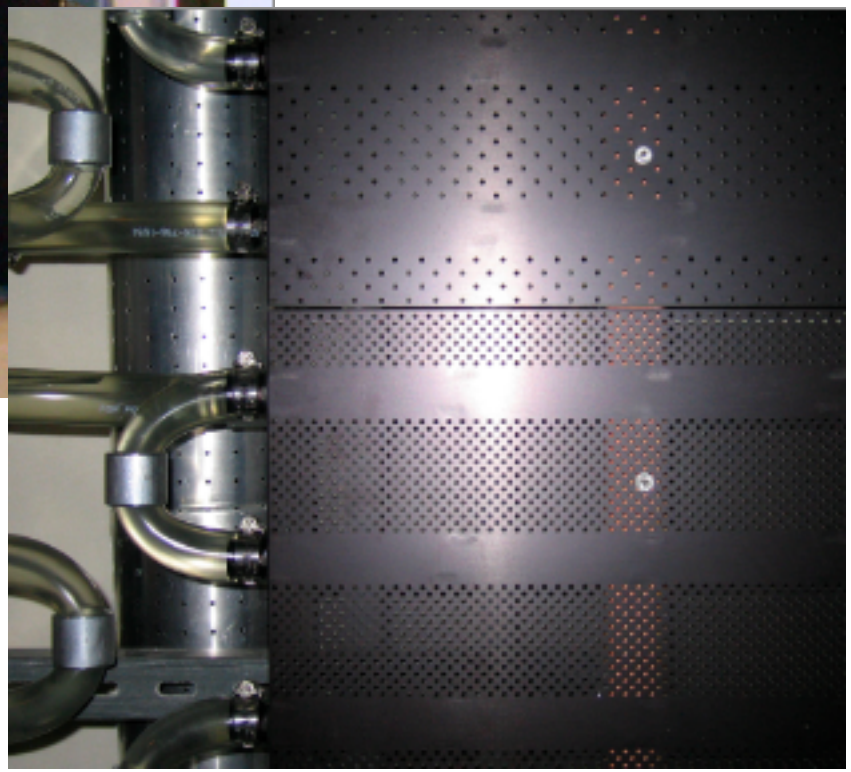


Twisted-pair conductors, & special routing to minimize magnetic fields


20080502-Acoustic Measurements -103
Note: Hallway door not bottom sealed.
Decibels (dBc)
100
80
60
40
20
0
-20
0
50
100
150
200
250
300
350
400
Frequency (Hz)


4" THICK
ACOUSTIC LINING.
BY OTHERS
212"
25½"
52½"
60"
52½"
23½"
39⅝"
12⅞"
12⅞"
39⅝"
ø16"
ø16"
ø16"
ø16"
36"
WALL PLENUM
CEILING PLENUM
WALL PLENUM
120"
46"
46"
- PERFORATED FULL LENGTH
- 8% OPEN AREA
- ⅜" DIA. HOLES
ON 0.4" STRAIGHT
CENTRES
40"
- PERFORATED
FULL LENGHT
- 4% OPEN AREA
- ⅜" DIA. HOLES
ON 0.56" STRAIGHT
CENTRES
40"
- PERFORATED
FULL LENGHT
- 16% OPEN AREA
- ⅜" DIA. HOLES
ON 0.28" STRAIGHT
CENTRES
6"
ROOM
℄
16"
TYPICAL
NO MECHANICAL CONNECTION IS PERMITTED
BETWEEN BOTTOM OF WOOD STUD FRAMING
AND TOP OF FLOOR SLAB.
FILLER MATERIAL BY OTHERS.
SOLID CAPPED END





Passive cooling with laminar flow air in instrument rooms conventional HVAC available to augment if needed.


KELLER

Lights, Cameras,
New photos of completed rooms

Photo Show Here

Performance Features

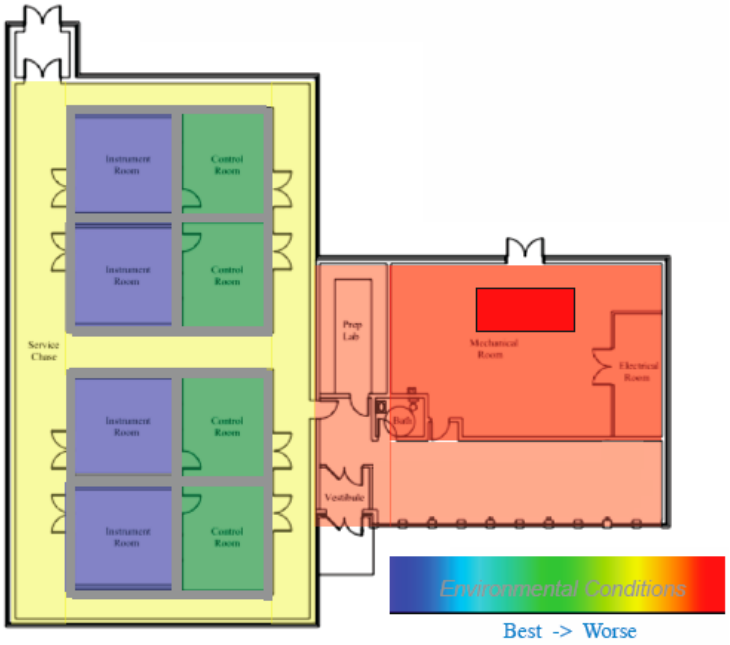
- Architectural and structural isolation of highbay from mechanical equipment lowbay walls and roofs.
- Minimal magnetic and conductive materials in highbay.
- Use of basalt and stainless rebar in highbay control room and instrument walls to eliminate circulating currents.
- Isolated precast tensioning strands in exterior walls to eliminate circulating currents.
- Radiant cooling panels in instrument rooms to minimize airflow.
- Reversible instrument room air flow, to augment cooling panels.
- Neoprene barrier between deep instrument slab and adjacent concrete.
- Foam insulation between highbay slab and foundation walls.
- Twisted electrical wires entire facility.
- Remote duct bank for power supply cables.
- Vacuum pumps located exterior to building.
- Vibration isolation pads for rotating apparatus.

Economic Considerations to Meet Cost Objectives

- Approximately $300k or 20% of apparatus used in the facility is excess new or good condition surplus materials from Argonne and NASA.
- Project broken into seven major contracts with ANL acting as general contractor to reduce cost and allow for greater flexibility in controlling the value engineering and de-scoping required to maintain project budget.
- Rigid controls placed on allowable effort charges to the project.
- Value Engineering cost savings sharing clauses in all major contracts.
- Conversion to precast from brick and block.

Not everything worked = Pink Items were failures

The Sub-Ångstrom Microscopy and Microanalysis Laboratory (SAMM)



-four new state-of-the-art research laboratories to meet the needs of next generation instrumentation

- isolated slabs for instruments and support equipment

- room within a room concept