Acoustics Standard
Fall 2018

272133

Facilities and Campus Services
Facilities Engineering / University Architect / CIT / Engineering &Project Management

Cornell University

Developing an Acoustics Standard

FACILITIES AND CAMPUS SERVICES

- Working Group
  - Matt Reiter, Architectural/Structural Section, FE
  - Liz Kolacki, Senior Mechanical Engineer, FE
  - Andy Page, Manager, Integrated Audio and Video Engineering, CIT
  - Ram Venkat, Senior Project Manager, E & PM
  - J. Shermeta, Associate University Architect, UAO

- Subject Matter Experts
  - Ben Markham, Director, Architectural Acoustics, Acentech
  - Seth Harrison, PE, Senior Associate, Metropolitan Acoustics
  - Mike Tomei, CTS-D/I, Tomei AV Consulting LLC

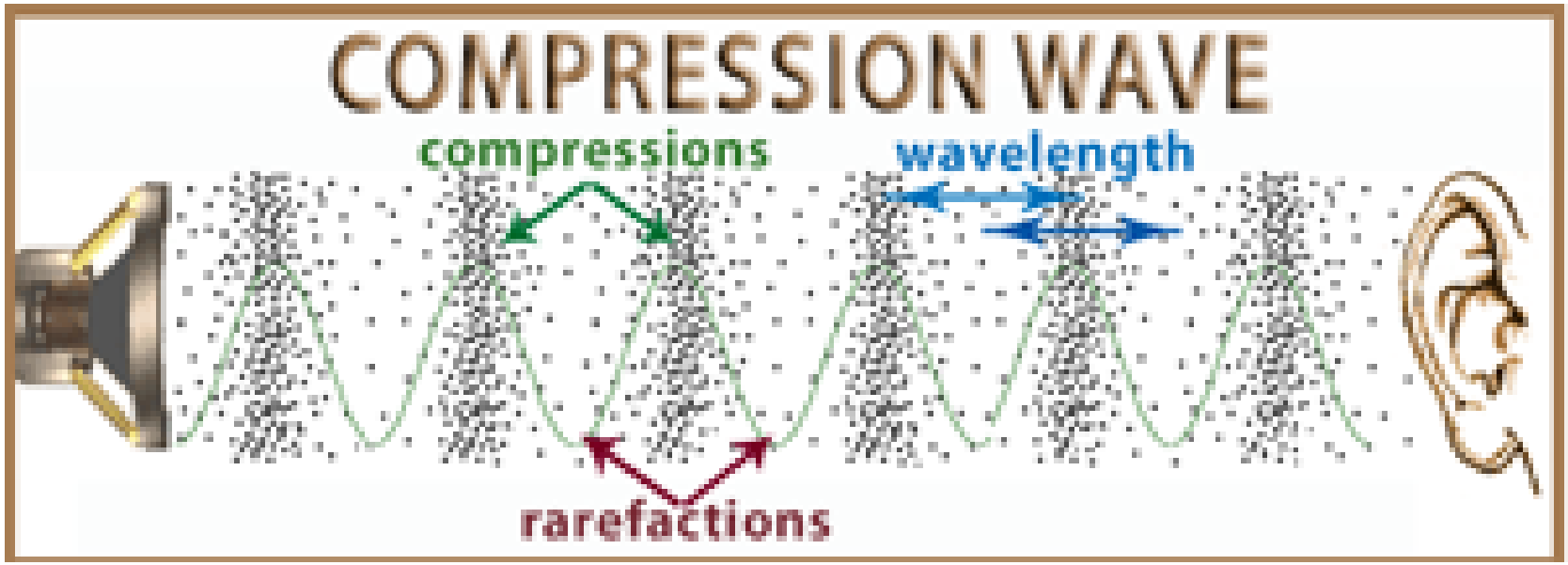
IT@Cornell

ACENTECH ACOUSTICS AV/IT/SECURITY VIBRATION

metropolitan acoustics

TOMEI AV consulting

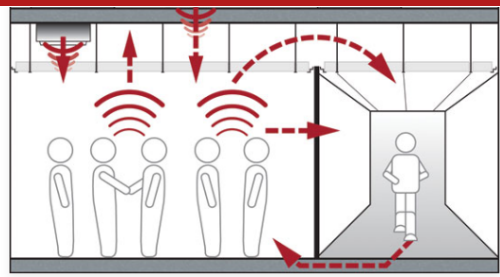
What is sound?



Compression and rarefaction of air from a vibrating source

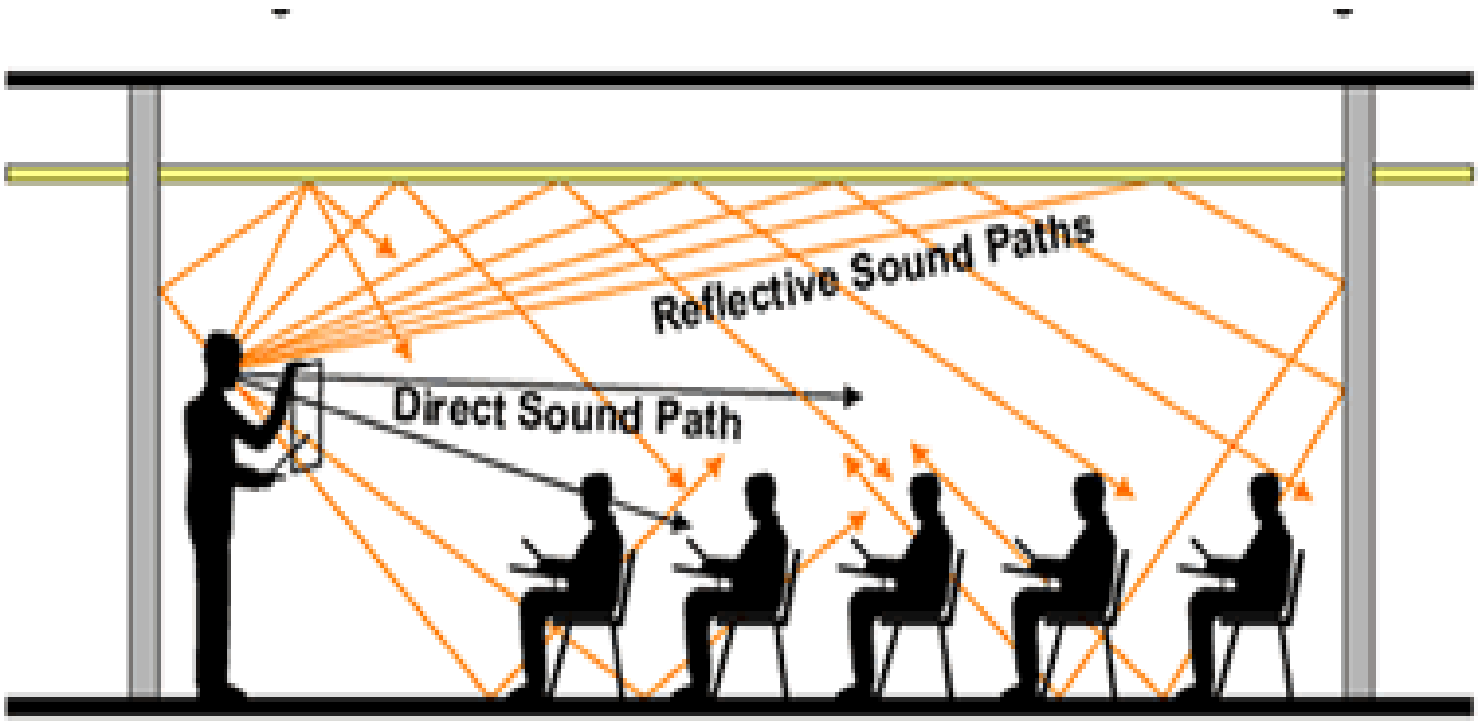
Sound is our psychoacoustic perception of vibrating air molecules.

Fun Facts – Properties of Sound



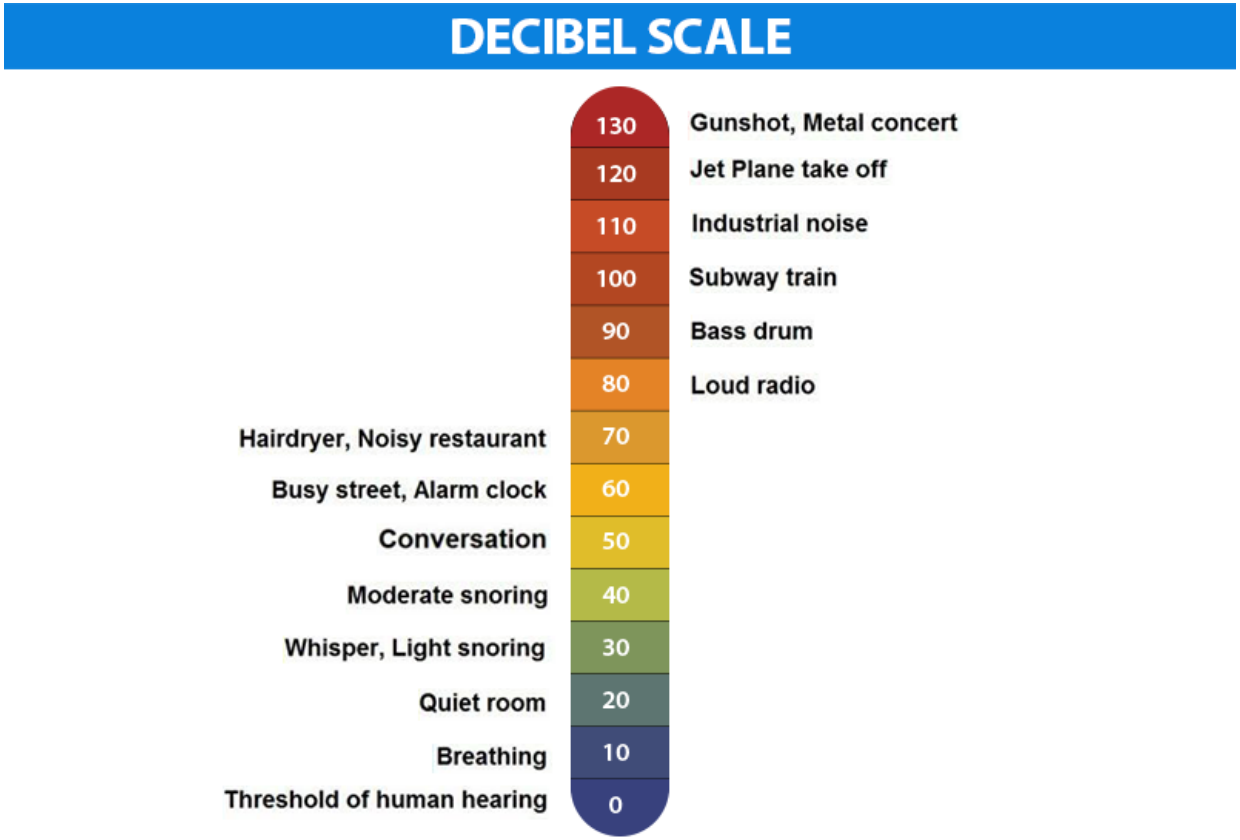
- Sound transmits through air and solids
  - Air tightness of a structure offers better isolation
  - Increased structural mass offers better isolation
- Sound competes with (masks) other sounds
  - Quieter spaces are more intelligible but also offer less speech privacy
- Sound bounces around (reverberates) before it ceases (decays)
  - Spaces with less reverberation offer better intelligibility
  - Larger spaces are generally more reverberant
  - Type of Surface plays a large role
    - hard surfaces increase reverb
    - soft surfaces absorb sound and decrease reverb

Measuring Sound – Reverberation



RT60 measures reverberation time or the time it takes the original sound to decrease (decay) by 60 dB

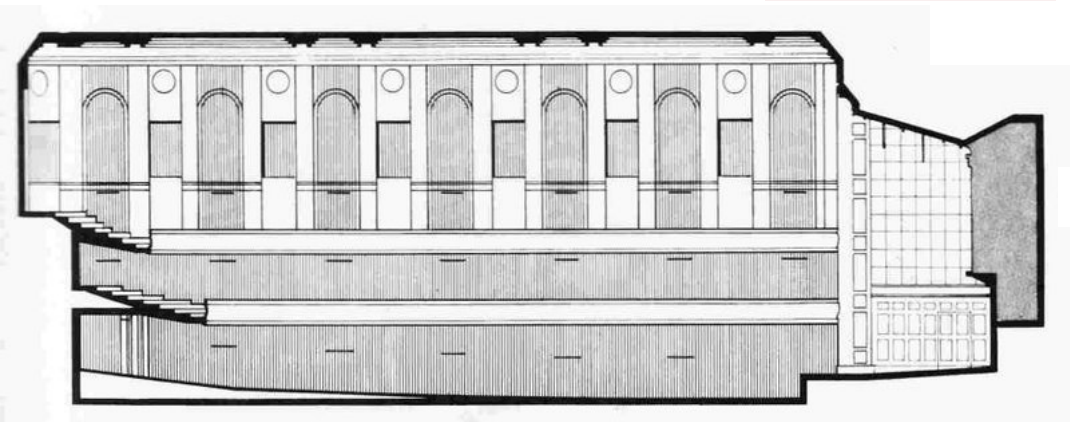
Measuring Sound – Decibels

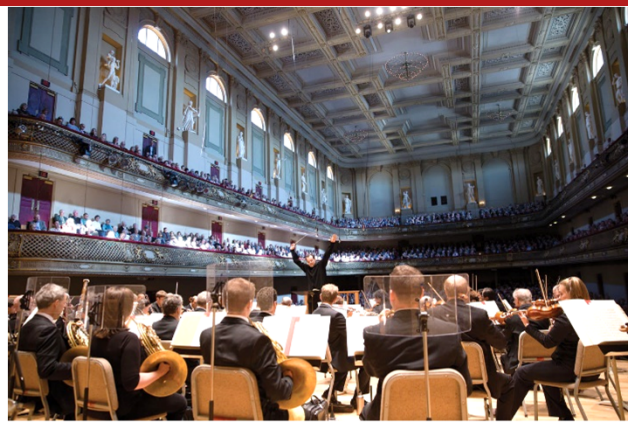


The decibel (dB) is used to measure the relative loudness of sounds

Measuring Sound – Intelligibility

STI measures speech intelligibility or the ability to understand what is being said





Boston Symphony Hall. McKim, Mead, and White 1900

a·cous·tic *noun*

plural noun: acoustics

1.the properties or qualities of a room that determine how sound is transmitted in it.

"Symphony Hall has perfect acoustics"

"Symphony Hall opened on October 15, 1900. Its architects were the distinguished firm of McKim, Mead, and White, who invited a young Harvard physics professor, ***Wallace Clement Sabine***, possibly because of some calculations he had done for Harvard's Fogg Museum, to advise them about acoustics. ***His advice is now considered the first truly "scientific" approach to concert-hall acoustics: the "birth of architectural acoustics."***

Sabine seemed to have figured out what acoustician Robert Berens (who worked on the recent refurbishment of Symphony Hall) calls the "magic formula" for the effective absorption and reverberation of sound: neither too dry (for lack of reverberation) nor too echoey. As he explained it to me, the sound produced on the stage not only goes directly into the hall but also bounces off everything in sight and earshot — side and rear walls and ceiling — at minutely different times. That combination — the magic formula for absorption and reverberation — is what creates the overall hearing experience.

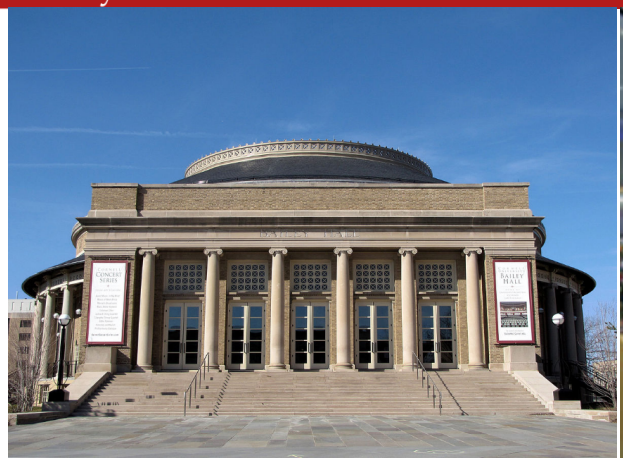
The sound is magical, warm, and vibrant. You can clearly hear the softest pianissimo, the most delicate pizzicato. And its current superb brass section, which for years seemed coarse and blaring, has acquired a new burnished depth along with its familiar power. ***Everything blooms! Everything sounds!*** *Lloyd Schwartz*

Seen and Heard: Boston Symphony Hall

The Birth of Architectural Acoustics

Continuum of Space Types

A building is a musical instrument that can be tuned...



Bailey Hall,1912 - Green & Wicks, Historic landmark & National Register
Renovation 2006 Mitchell/Giurgola Architects. 1,324 seats
State-of-the-art auditorium with comfortable seating, climate control and superb acoustics

Performance — Auditorium — Athletic — Office

Atrium — Conference — Library — Residence

Baker Laboratory, 1921, Gibb & Day

...each space type presents unique acoustical design constraints and criteria.

Case Study : Hughes Hall Renovation

- Design
  - Designer established acoustic performance requirements, confirmed with Cornell
  - Designer developed acoustic design details

- Construction
  - Designer provided construction phase oversight
  - Relied on contractor to construct per drawings

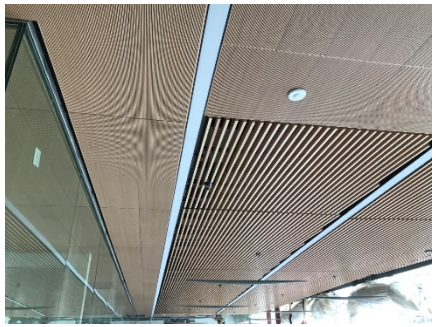
Case Study : Hughes Hall Renovation

- Post-Occupancy
  - Complaints from building occupants
  - Acoustic testing performed; results revealed:
    - Incomplete sealing of wall penetration by contractor
    - Low acoustic design of walls, doors and glazing
    - Low acoustic performance due to recessed toilet accessories and electrical boxes

- Post-Occupancy repairs
  - Wall penetrations are being sealed by contractor
  - Wall construction is being upgraded
  - Glazing is being replaced to acoustic glazing

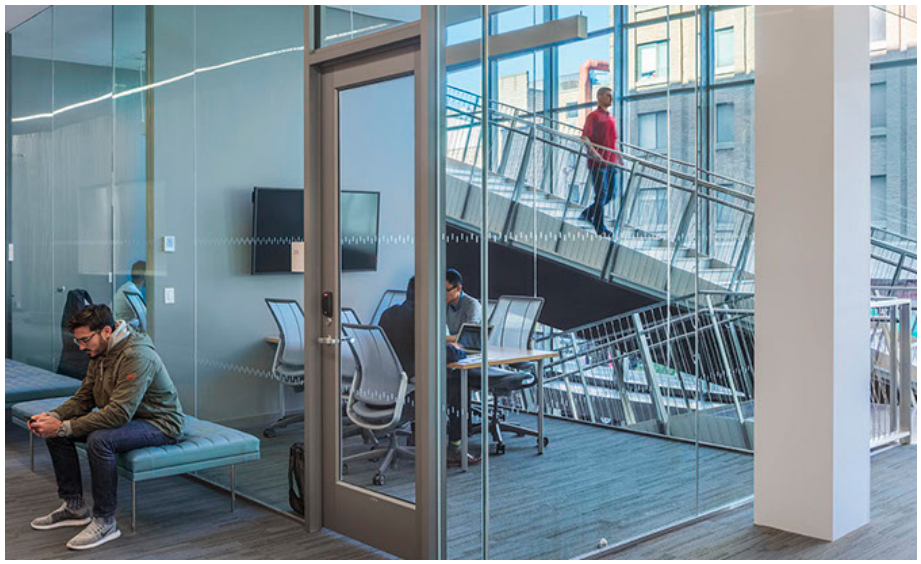
Case Study : Breazzano Family Center for Business Education

- Design
  - Designer established acoustic performance requirements, confirmed with Cornell
  - Designer developed acoustic design details
  - Testing Agent evaluated design, sent feedback to Owner
- Construction
  - Designer and Testing Agent worked together to provide construction oversight – one per month
  - Mockups reviewed, refined and approved
  - Incorrectly constructed walls were re-constructed
  - All wall penetrations were properly sealed
  - Acoustic testing of key spaces like classrooms & conference rooms



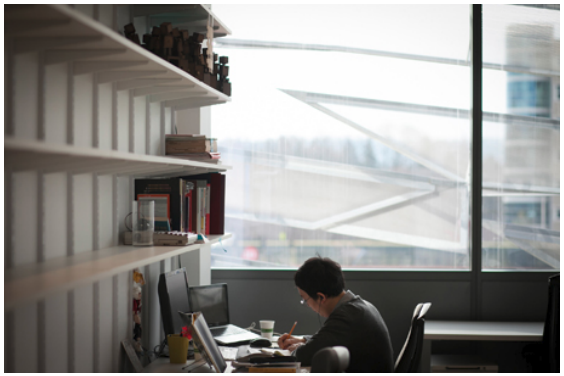
Case Study : Breazzano Family Center for Business Education

- Post-Occupancy
  - None



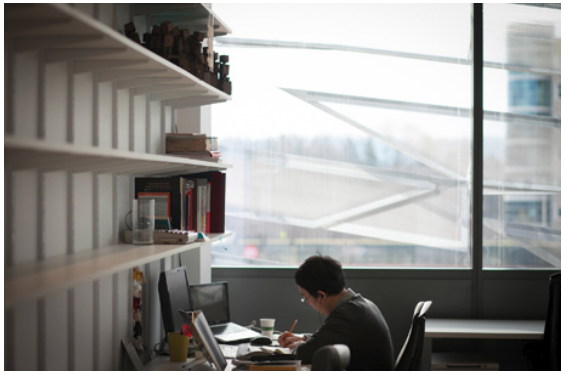
Case Study : Gates Hall

- Design
  - Designer established acoustic performance requirements, confirmed with Cornell
  - Designer developed acoustic design details
- Construction
  - Designer provided construction phase oversight
  - Relied on contractor to construct per drawings



Case Study : Gates Hall

- Post-Occupancy
  - Complaints from building occupants
  - Acoustic testing performed; results revealed:
    - Incomplete sealing of wall penetration by contractor
    - Low acoustic design of walls
    - Video conferencing in office
    - Flanking paths at exterior mullions
    - Quiet mechanical systems like chilled beams
    - Highly reflective surfaces carried sound farther
- Post-Occupancy repairs
  - Wall penetrations are being sealed by contractor
  - Building-wide sound masking system being installed
  - New construction being built to higher standards



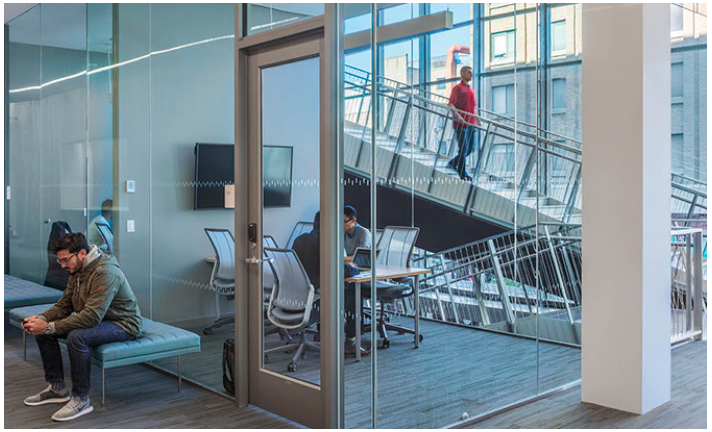
Challenges at Cornell University

Surfaces →

Adjacencies →

Challenges at Cornell University

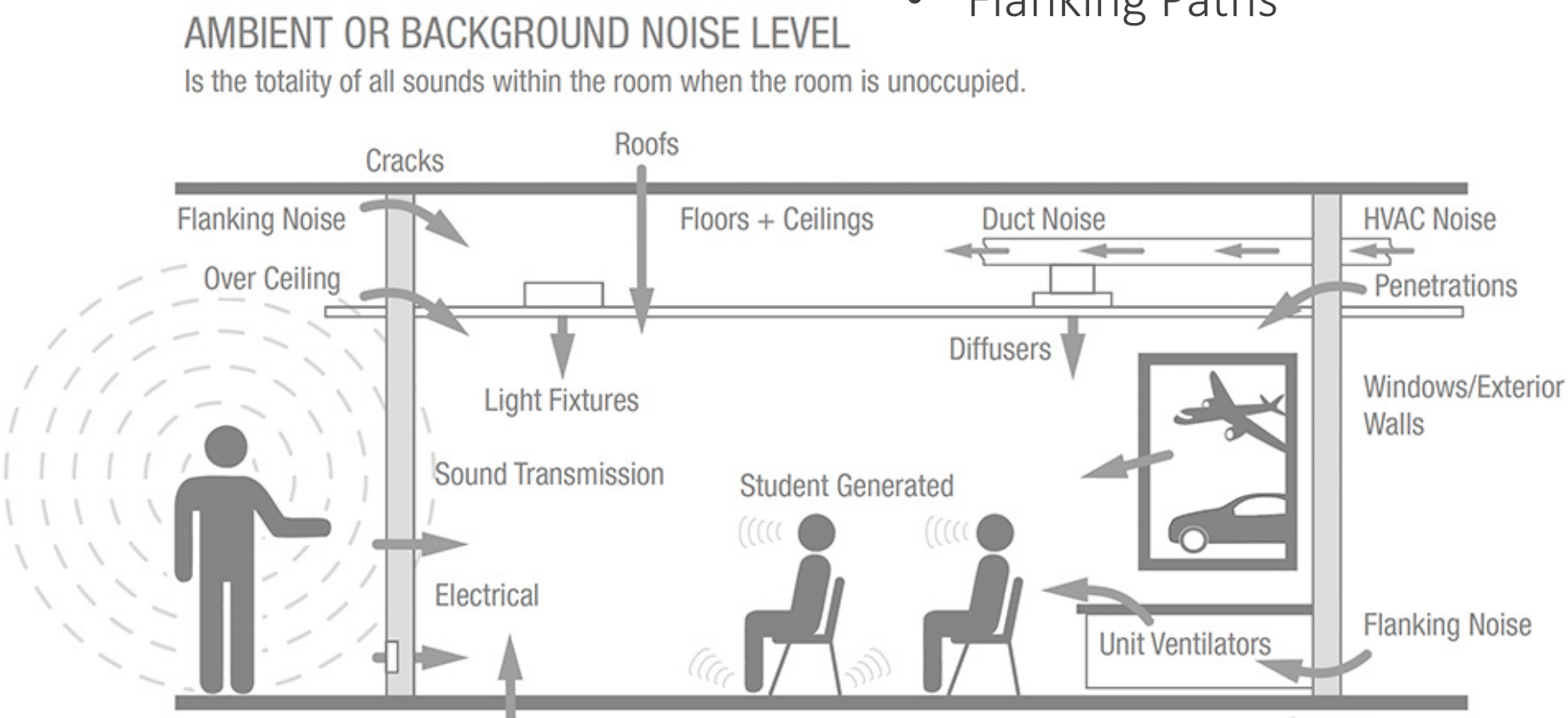
Walls



HVAC

Challenges at Cornell University

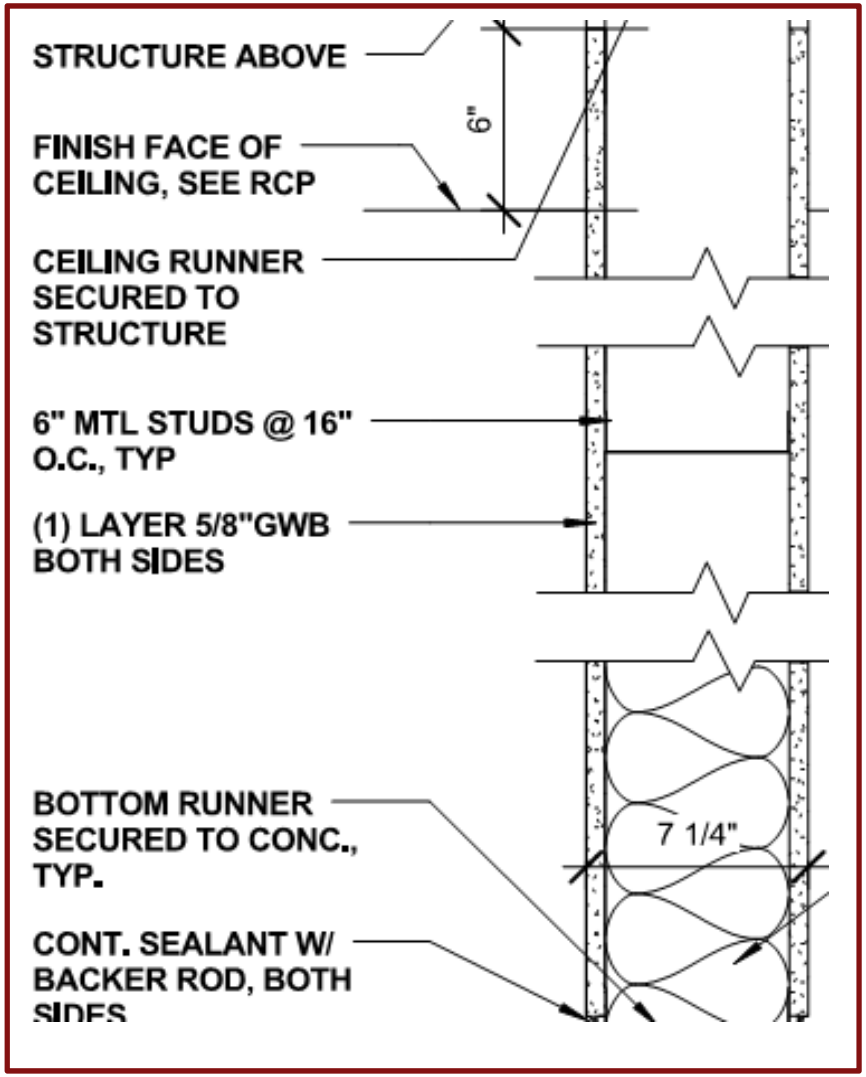
- Room Adjacencies
- Background HVAC Noise
- Privacy
- Partition Detailing
- Sound Transmission
- Sound Absorption
- Low Ambient Noise
- Speech Intelligibility
- Flanking Paths



Acoustics in Practice

Partition Schedules

STC RATING	OTHER CRITERIA
MIN. 50	(1) LAYER 5/8" GWB ON BOTH SIDES; W/ SOUND ATTENUATION BATTS



Precedents & Case Studies

ANSI/ASA S12.60

"American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools"

- "The first and most cost effective step in achieving good noise isolation between learning spaces and other spaces in a school is accomplished in the ***facility planning stage***. This includes optimizing the location of noisy spaces and activities to protect sensitive learning spaces. Where this is not possible, adequate noise isolation is needed."
- Includes Annexes A – F and Tables for Maximum background noise levels and reverberation times and Minimum STC ratings

Yale University Design Standards

- Acoustical consultant required for performing arts spaces, drama theaters, and high performance lecture, conference, and seminar rooms."
- Includes Tables for Noise Control (NC/RC/dbA and for Acoustical Performance NC and NIC)

General Services Administration (GSA) Facilities Standards for the Public Buildings Service (P100) Chapter 3 and GSA Commissioning Guidelines

- Four key concepts:
  1. Speech Privacy
  2. Background Sound
  3. Equipment Vibration and Reverberation
  4. Exterior Noise
- Acoustical performance will be verified during the commissioning of the building.
- Includes Table 3-2:Acoustics with Maximum Mechanical Noise (RC/NC), Minimum Absorption: Ceiling and Walls (SAA/NRC), Minimum Noise Isolation (NIC) and Optimum Reverberation (RT60)

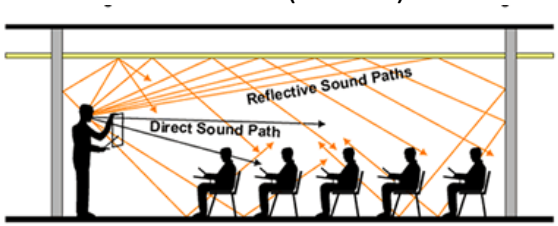
Acoustics Standard 09 8000

- Objective – Establish acoustical standards
- Scope
  - Renovation & New Construction
  - Room Type & Room Adjacency
- Design Criteria
  - Room Acoustics
  - Sound Absorption
  - Sound Isolation
  - Electronic/Mechanical noise
- Design Strategies
- Implementation & Post-Occupancy Testing

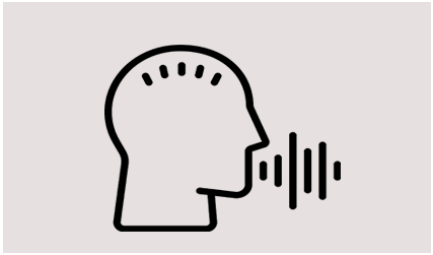
Design Criteria

Noise Criteria (NC)

Reverberation (RT60)



Speech Intelligibility (STI)

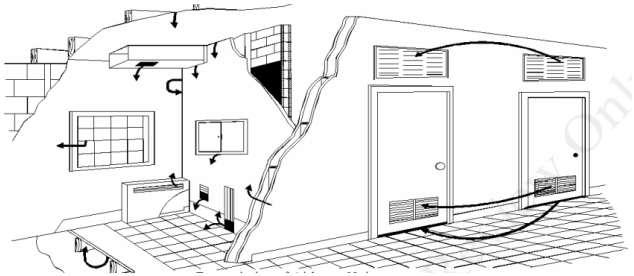


Design Criteria for Spaces

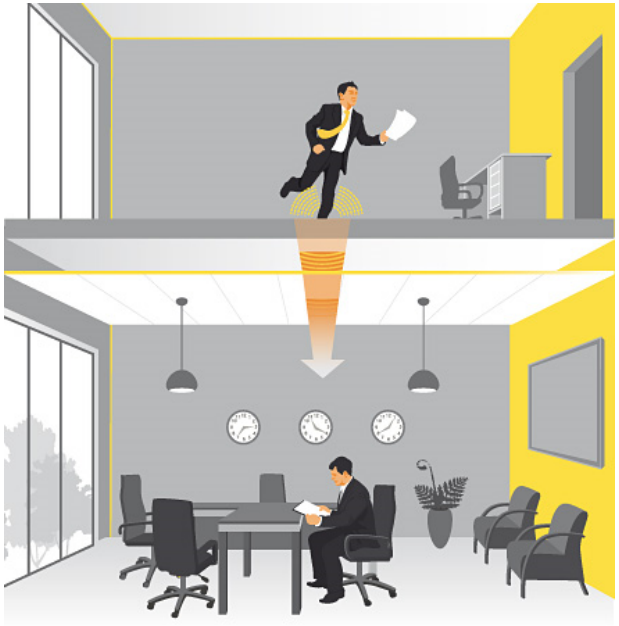
Other Design Criteria

- Exterior equipment noise
- Effective use of sound masking
- Speech privacy

Noise Isolation (NIC)



Impact Insulation (IIC)



Design Criteria for Adjacencies

Design Criteria for Spaces - Table 1

Table 1: Rooms: Acoustic Design Guidelines & Post Occupancy Testing				
Space Type Code	Space Type	Noise Criteria (NC)	RT60 (sec)	STI/STIPA
20	Circulation Area – corridor	40		
20	Circulation Area – atrium	35-40	1.5	
24	Lobby	40-45	1.2	
110	Classroom – flat floor up to 750 ft², 31-90 occupants	30	0.6	0.75
110	Classroom – flat floor over 750 ft², 31-90 occupants	30	0.6	0.75
110	Classroom – stepped/sloped floor 51-90 occupants	30	0.7	0.75
110	Lecture Hall – stepped/sloped floor more than 90 occupants	25	0.1 – 1.1	0.75
110	Seminar Room – flat floor 30 or less occupants	30	0.6	0.85
115, 215, 217	Classroom or Laboratory Service - control room, observation room, translation services	40		

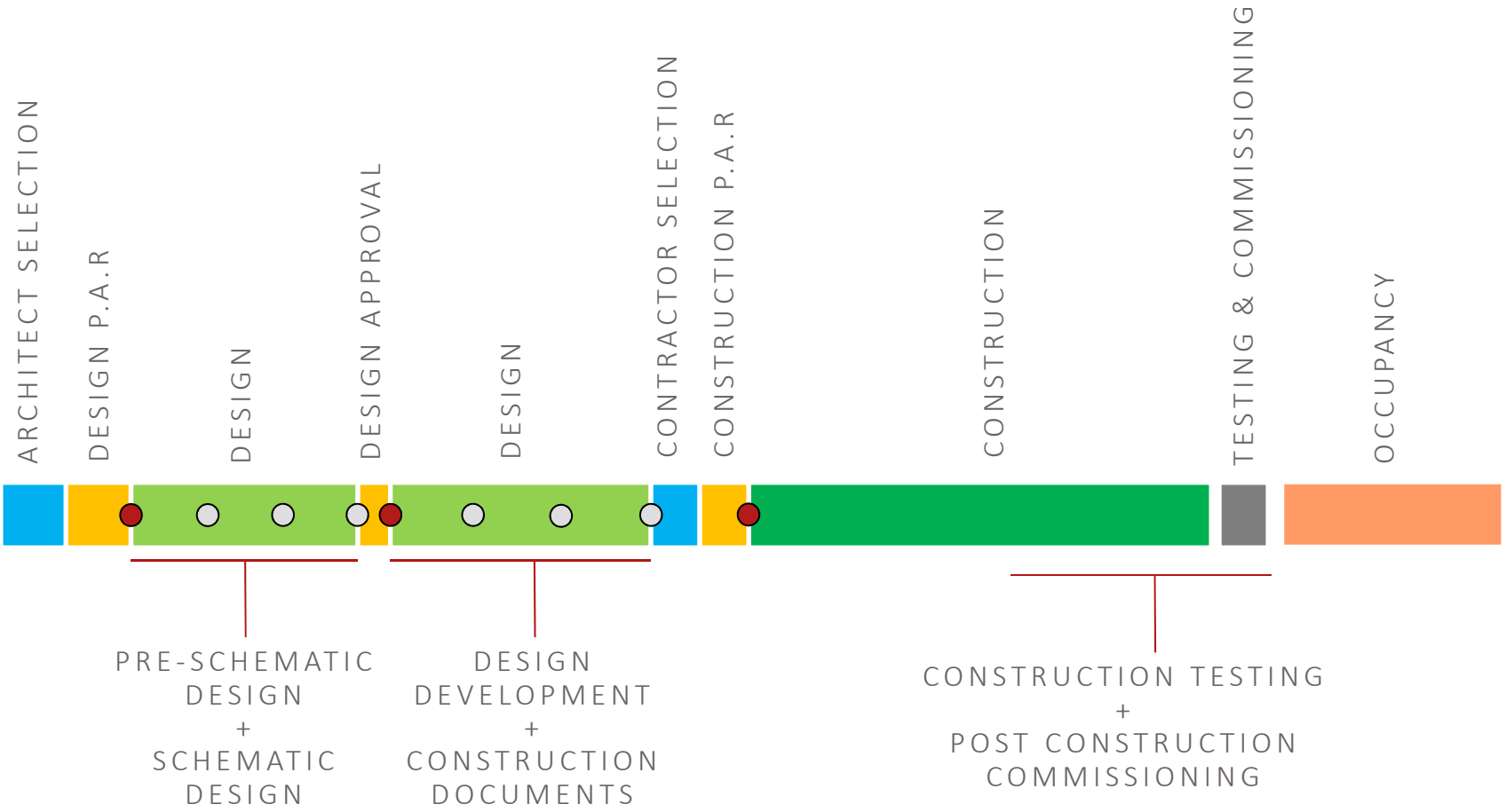
Design Criteria For Adjacencies - Table 2

Table 2: Room Adjacencies: Acoustic Design Guidelines & Post Occupancy Testing					
Space Type Code I	**Space Type Code II**	**Space Type I**	**Space Type II**	**Noise Isolation Class NIC**	**Impact Insulation Class IIC**
110	020	Classroom	Corridor	26	
110	110	Classroom	Classroom	49	45
350	020	Conference Room	Corridor	25	
310	310	Office	Office	44	45
350	350	Conference Room	Conference Room	56	50
310	020	Office	Corridor	26	
935	935	Residence	Residence	46	50
935	020	Residence	Corridor	26	
110	030	Classroom	Mechanical	59	
110	031	Classroom	Toilet	49	

Acoustics Standard - Strategies

- Common Approaches for Consideration
- Partitions and Ceilings – Example from Standard
  - Avoid Undercut Doors
  - Separate Electrical Boxes between Studs
  - Extend Walls to Structure, pack top track
- HVAC - Example from Standard
  - Fan Coil Units providing full capacity when running at 50% Speed
  - Duct Airflow velocity less than 1500 ft/min
  - Avoid Plenum return

DESIGN AND CONSTRUCTION PROCESS



Life Span of project – AE Selection and Design Phase

"Acoustics is a mysterious science; maybe more mystery than science." Lloyd Schwartz

AE Selection : RFP & Contract

- RFP & Contract include Acoustical Engineer as a required sub consultant
- Establish expectation that design team will include acoustical engineering unless architect makes recommendation to opt out IF building type does not require acoustical engineering services such as a storage facility
  "OPT OUT NOT OPT IN"
- Schedule F in Contract includes full scope of acoustical design work per phase
- Contract references and binds consultant to perform work in accordance with Cornell University Design & Construction Standards
- Design & Construction Standards include

098000 ACOUSTICS

D E S I G N

Pre SD / Feasibility Phase

- Identify acoustic requirements by indicating any ***key program spaces*** that may have acoustic and/or vibration requirements, such as auditoriums, classrooms, conference rooms, rooms with sensitive laboratory equipment, open work areas, and large public convening areas.

SD Phase

- Establish and document user expectations
- Develop performance criteria and Adjacency Matrix
- Based on discussions with the client and user group, develop ***a basis of design sound criteria matrix and narrative*** for each discreet space type requested in the program. The matrix as a minimum shall include, as applicable:
  - -NIC ratings between space adjacencies
  - -NC rating
  - -RT60 rating
  - -STIPA rating
- Identify locations where sound masking should be incorporated into the design.
- Existing acoustical conditions should be measured and documented by an acoustical consultant as befits the project acoustical criteria and as is programmatically appropriate for the space.

DD/CD Phase

- Update basis of design sound criteria matrix and narrative.
- Develop a color-coded plan indicating space NC ratings and STC partition types to support the overall NC and NIC ratings in ***Tables 1 and 2.***
- Partition types and detailing. Partition and ceiling schedules shall denote STC ratings and CAC ratings where appropriate as designated by partition/ceiling type.
- Determine types of acoustical interventions to incorporate into the design.
- Where applicable, use RT60 Sabine calculations based on the proposed wall, ceiling, and floor materials, in relation to room size for all spaces with reverberation time criteria in Table 1.
- Provide preliminary layout of sound masking systems including equipment list, conduit and power requirements, and expected heat loads.
- Provide an Acoustical Testing Plan for review by the project team.

D E L I V E R A B L E S

Cornell Facilities and Campus Services – **DESIGN REVIEWS**– confirm consultants' acoustical design work

Life Span of project – Construction/Occupancy Phase

CONSTRUCTION-OCCUPANCY

Construction Administration Phase

- Review and approve Submittals for materials, equipment, and products related to acoustical design scope.
- Review and respond to contractor's questions and proposed product substitutions that affect intended acoustical basis of design.
- Periodically visit the construction site, observe site conditions, confirm documented acoustical details are implemented, and develop a punch list.
- Owner may include 3rd party testing for a specific project component to measure the performance of the component.
- Define scope of work for 3rd party testing and observe testing to confirm test procedures and completeness.

SUBMITTALS

Close Out - Commissioning

- The owner shall retain an acoustic testing consultant to commission systems during construction. The commissioning shall include observing, documenting, and validating the acoustic design requirements during construction to ensure that it is in full accordance with the basis of design and contract documents. Testing shall include confirming the final NC, STIPA, and RT60 as shown in Table 1 and 2. RC Mark II Ratings shall be measured, documented, and submitted with Record Documents. Both background sound measurements with the Audiovisual and mechanical equipment turned off; as well as with the AV/HVAC turned on will be taken. Consider building utilization for increased activities may warrant testing during off peak hours..

- The design consultant shall have the following responsibilities during Construction and Post occupancy testing:
- Perform sufficient site visits during construction to review installation quality of sound partitions, in coordination with the third-party acoustical testing agency. Quantity to be determined on a project by project basis. Provide recommendations for addressing unacceptable field conditions that have the potential to impact compliance with the acoustical design criteria.
- Coordinate with the owner's testing consultant to review compliance with the basis of design; provide recommendations for addressing spaces not in compliance with the basis of design.

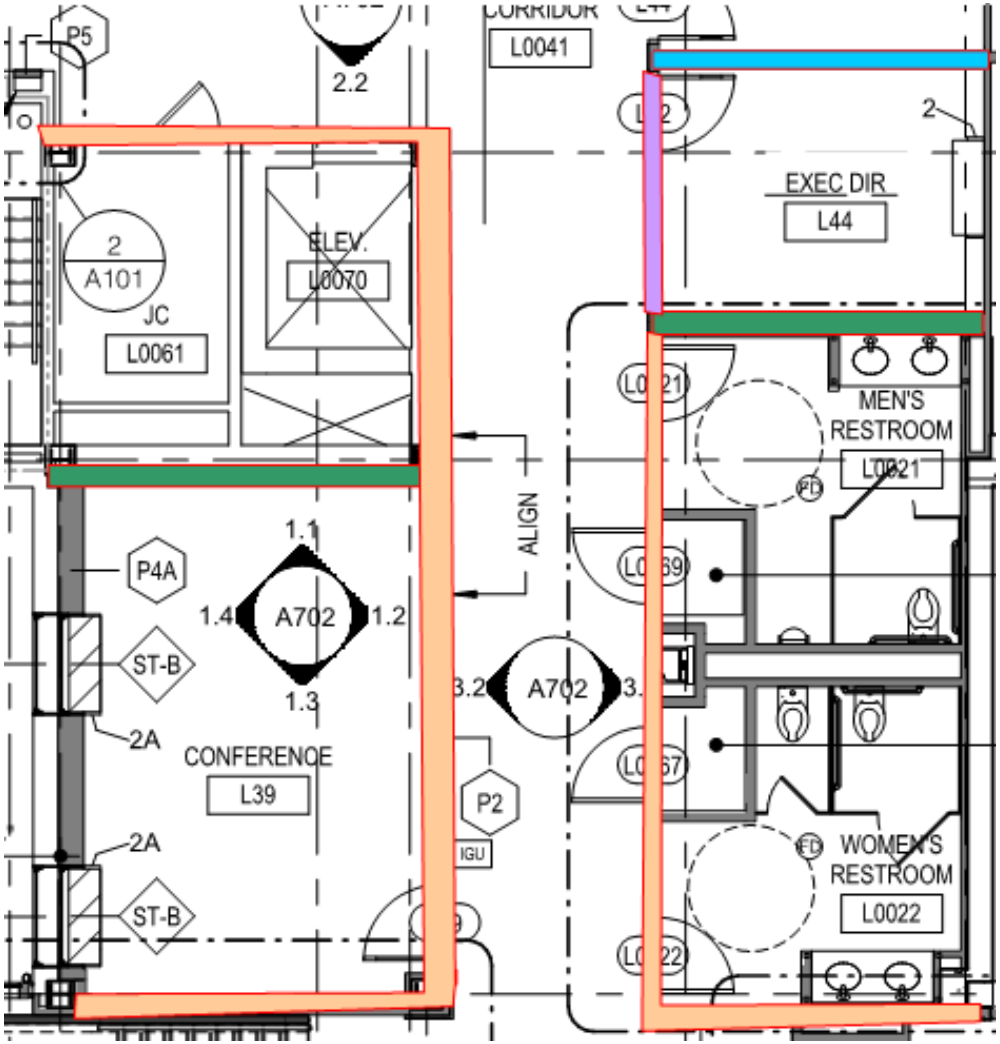
PERFORMANCE TESTING

Occupancy

- Document all acoustical criteria and measurements and distribute to Owner in Record Documents.

Process Improvement

- Identifying Acoustic Requirements in Room Data Sheets
- Color Coded Plans – NC, STC
- Verification Test Results



Questions