

*ARMY RESEARCH LABORATORY*



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**Mission Impact Through Neuro-Inspired Design (MIND)  
Laboratory: Design Principles and Performance  
Characteristics**

**by Christopher C. Stachowiak and Bruce E. Amrein**

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**ARL-TR-6600**

**September 2013**

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Human Research and Engineering Directorate, ARL**

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## **Acknowledgments**

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Based on operational needs outlined by members of the U.S. Army Research Laboratory's Translational Neuroscience Branch, the authors developed the technical requirements, performance characteristics, and scope of work for fabrication and installation of the Mission Impact through Neuro-inspired Design Laboratory space. The primary contractor for this work was TechStar Industries, LLC (a division of Mid-Atlantic Acoustics), of Baltimore, MD; Noise Barriers, LLC, of Libertyville, IL, designed the acoustically treated and electromagnetic interference/radio frequency (EMI/RF) shielded chambers; Kibart, Inc.—Consulting Engineers, of Towson, MD, —designed the heating, ventilation, and air conditioning and electrical systems; Hi-Tech Services, Inc., of Ferndale, WA, installed the shielded chambers and performed the EMI/RF testing; and Brune Consulting, LLC, of Towson, MD, performed the acoustic testing.

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## **1. Introduction**

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The Mission Impact through Neuro-inspired Design (MIND) Laboratory is an environment designed to accommodate the U.S. Army Research Laboratory's (ARL's) neuroscience research. It provides a single flexible space for conducting multiple human research studies in an environment that enables flexible environmental control for scientific experiments; it fosters collaborative work among research personnel and facilitates the efficient use of research space and resources while providing a comfortable environment for researchers and research participants. The MIND Laboratory is located at Aberdeen Proving Ground, MD.

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## **2. Background**

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Funding for the MIND Laboratory was provided by the Director of ARL in response to an infrastructure upgrade proposal submitted by ARL's Human Research and Engineering Directorate (ARL-HRED) for improvements to laboratory spaces in one of ARL-HRED's buildings. This proposal was submitted in September 2010 to address necessary technological advancements and growth in ARL-HRED's research areas and changes to ARL-HRED's research spaces resulting from extensive renovations in the building.

Primarily, two issues caused inadequacies in the former neuroscience research facilities used by ARL-HRED's Translational Neuroscience Branch and ARL's Neuroscience Strategic Research Initiative (SRI). These issues include technological advancement in the state-of-the-art in neuroscience and significant growth in the number of personnel utilizing the research spaces. (There has been an eight-fold increase in on-site neuroscience personnel over the last five years.) The research requirements for the MIND Laboratory have shifted since the former MIND Laboratory facilities were originally developed for computer simulation and not for ARL-HRED's evolving focus on neuroscience as a primary research area. Facility inadequacies included: lack of dedicated space, inadequate sound attenuation and electromagnetic interference/radio frequency interference (EMI/RFI) shielding, necessary to conduct repeatable experiments without the influence of confounding environmental variables, and external signal contamination.

In the long-term, the versatility afforded by the MIND Laboratory provides increased flexibility for adapting to the changing research requirements that are driven by rapid advances in neurotechnology. Advancing these technologies will continue to be the basis of ARL's translational neuroscience efforts and will enable broad-reaching neuro-inspired system designs

that range from computer screen design to robotic control to brain-computer interfaces (BCIs). In the mid-term, this newly installed research facility is the centerpiece for work on fundamental neurocognitive performance and the development of methods and analysis techniques that can be fielded for use in operational environments. The facility supports in-house research as well as collaborations with numerous partners. Most notably, the MIND Laboratory is a primary research facility for work conducted with the Cognition and Neuroergonomics Collaborative Technology Alliance (CaN CTA), which is a collaborative effort between ARL, and private industrial and academic partners (Oie et al. 2012).

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### **3. Research Focus**

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The MIND Laboratory is an all-inclusive environment for neuroscience research designed for studying Soldier-system interactions at multiple levels of inquiry with research paradigms relevant to a range of basic and applied domains.

One of the primary areas of research within the MIND Laboratory is the study of the nature of the interactions between Soldiers and systems within realistic operational environments. A significant effort within this topic area focuses on improving our understanding of relevant cognitive and perceptual processes revealed through the physiology of the nervous system.

With a focus on incorporating neuroscience-based concepts and tools, the research facility is designed to ease subject testing while remaining extremely flexible as research requirements change in the future. This space will be used for studies focusing on, but not limited to:

- Brain-computer interaction technologies,
- Soldier performance prediction,
- Multisensory information processing,
- Stressor effects on neurocognitive task performance,
- Individual differences in neurocognition,
- Visual scanning behavior,
- Adaptive information displays, and
- Cognitive metrics development and validation.

To support these research efforts, it is important to have controlled environments that are acoustically and electronically shielded, and contain logistically suitable facilities for studying participants in a variety of laboratory settings. Specifically, the goal is to move from more

simple, controlled-task environments to more complex simulated operational scenarios. This space is used to conduct a significant portion of on-site ARL-HRED neuroscience research; as such, it must be conducive to a wide spectrum of studies and research methodologies.

### 3.1 MIND Experimental Suite Overview

Because much of the research work focuses on a full spectrum of sensory, perceptual, and cognitive studies, the laboratory spaces are acoustically isolated from each other and from the main building, hallways, and surrounding offices to create environments suitable for conducting repeatable experiments free from external distracters. In addition, the focus on electroencephalography (EEG) and on advanced cognitive metrics, operator state classification, and modeling of neural data requires the ability to limit and control the sources of electrical noise that can interfere with participant EEG data collection.

The MIND Laboratory space is a 952-ft<sup>2</sup> (88.4-m<sup>2</sup>) portion of a suite of research and supporting facilities located in the basement of the building. The partial basement floor plan is shown in figure 1.

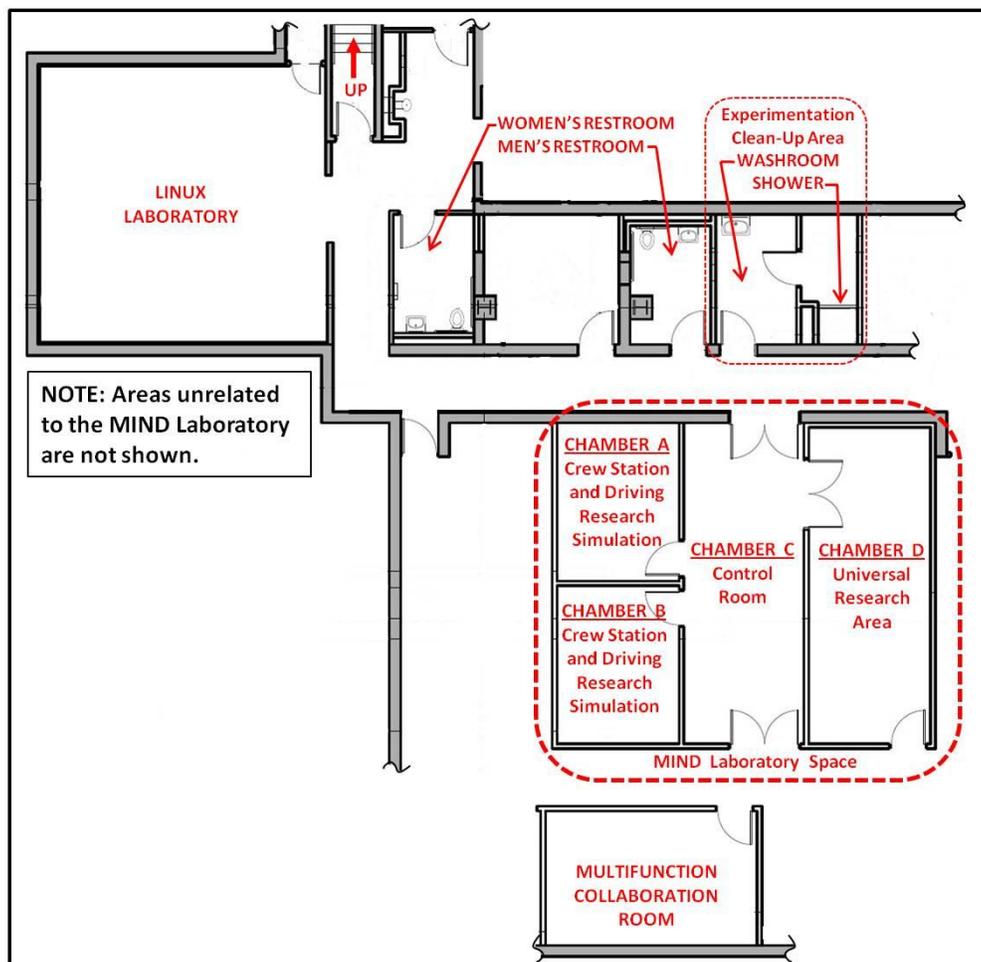


Figure 1. Basement floor plan: MIND Laboratory space and supporting facilities.

The MIND Laboratory space consists of modular acoustically treated and electrically shielded chambers constructed from pre-engineered “QuietMod”<sup>\*</sup> panel systems including wall and ceiling panels, doors, windows, and silenced ventilation systems. These systems are manufactured by Noise Barriers, LLC, of Libertyville, IL.

The MIND Laboratory space is approximately 28 ft (8.5 m) long and 34 ft (10.4 m) wide. The elevation of the roof of the laboratory space is 10.33 ft (3.2 m) above the finished floor. This is the maximum height permitted by the existing building structure.

Ambient lighting in the experimental rooms is provided by ceiling-mounted light-emitting diode (LED) fixtures that are dimmable and digitally controllable from both the individual experimental rooms and from the central control room.

The laboratory includes an independent heating, ventilating, and cooling (HVAC) system for each chamber, sufficient to handle the large amount of personnel, equipment, and computing activity expected in the MIND Laboratory. The systems also allow the heating and cooling cycles to be controlled year-round regardless of outdoor temperature.

Throughout the laboratory, computer network and audio/video connections allow for: (1) easy access to the laboratory intranet, (2) video monitoring of the experimental areas from multiple areas within the control room and separate multifunctional rooms, and (3) audio communications between the experimental areas and the control room.

The chambers are integrated into the life safety systems installed in the building (including sprinkler, fire alarm, and mass-notification systems). Piping required for the sprinkler system uses dielectric couplers at each penetration of the chambers to eliminate electromagnetic fields created by currents in the piping. The entire MIND Laboratory was installed as an “equipment-in-place” system. (Equipment-in-place is defined by the U.S. Army as personal property consisting of capital equipment and other equipment of a movable nature which has been fixed in place or attached to real property, but which may be severed or removed from buildings without destroying the usefulness of the structures [DA PAM 420–11, 2010]).

Prior to installation of the research chambers, the basement space was an unused “fallout shelter.” Figure 2 shows the space prior to installation of the MIND Laboratory space.

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<sup>\*</sup>QuietMod is a trademark of Noise Barriers, LLC, Libertyville, IL.



Figure 2. MIND Laboratory space before installation. (U.S. Army photo by Ron Carty.)

The floor plan of the MIND Laboratory chambers is shown in figure 3. The characteristics of each chamber are described in the following sections.

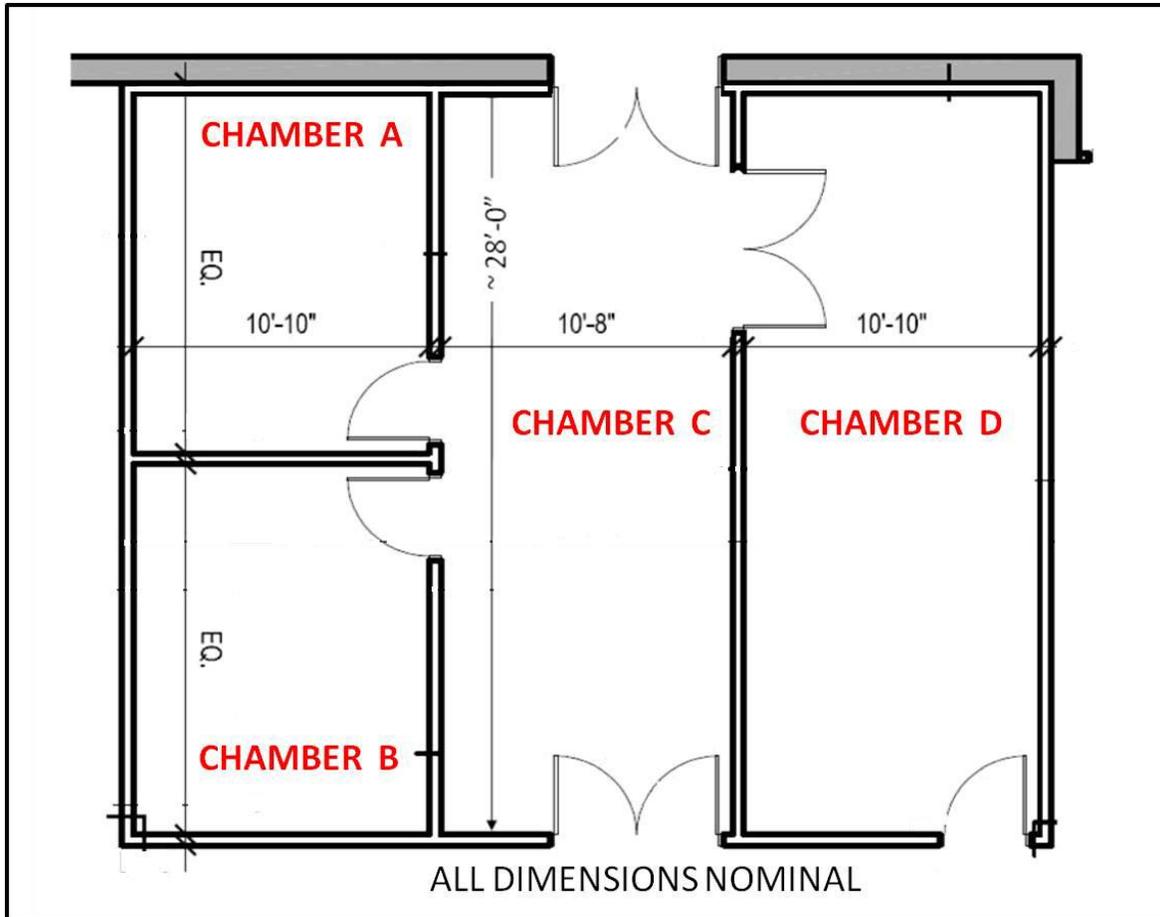


Figure 3. MIND Laboratory chambers.

### 3.1.1 Control Room (Chamber C)

The control room is the primary experiment observation/oversight area for the entire laboratory. It allows for experiment observation and communication within the experimental chambers and houses specialized data acquisition and experiment control equipment (e.g., EEG, eye-trackers, driving simulator). Additionally, this space serves as the primary area for informational tours and VIP visits. The control room contains the hub of the MIND video/audio system. The control room has the following characteristics:

- Dimmable ceiling-mounted recessed LED lighting system
- Double doors installed on each end of the control room provide a minimum sound transmission class\* of STC-50

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\*Sound Transmission Class (or STC) is an integer rating of how well a building partition attenuates airborne sound (ASTM E90, 2009).

- All doors between the chambers provide a minimum of STC-50 isolation and RFI/EMI shielding between spaces when closed
- Four “data drops,” each consisting of four CAT6 cables, are terminated in the control room chamber. All cables are filtered at the entry points to maintain EMI/RFI integrity of the research chambers
- Filtered 120-VAC, 20-A duplex receptacles are placed around the perimeter of the space

### **3.1.2 Crew Station and Driving Research Simulation Chambers (Chambers A and B)**

The primary research capabilities in the MIND Laboratory include the crew-station modules and driving simulators. They each require a separate chamber and areas for computer hardware and experimental control in the control room. The studies conducted in these chambers require the use of neurophysiological measures (e.g., EEG) and other physiological measures (e.g., electromyography [EMG] and electro-oculography [EOG]). These research spaces consist of two sound-attenuated and electrically isolated/shielded chambers each having the following characteristics:

- Dimmable ceiling-mounted recessed LED lighting system
- One filtered-jack panel to the control room
- One filtered-jack panel between the two crew station and simulation chambers
- Filtered 120-VAC, 20-A double-duplex receptacles centered in each wall

### **3.1.3 Universal Research Area (Chamber D)**

The universal research area (URA) is a large reconfigurable area designed to permit experimentation within a large space or for simultaneous experimentation in three portable and reconfigurable sound isolation booths (WhisperRooms)\* that can be installed as needed. Additionally, many studies conducted in the URA require the use of neurophysiological measures (e.g., EEG) and other physiological measures (e.g., EMG, EOG). The URA is a sound and electrically isolated chamber with the following characteristics:

- Dimmable ceiling mounted recessed LED lighting system
- Three filtered-jack panels through to the control room
- Filtered 120 VAC, 20-A double-duplex receptacles every 8 ft around the perimeter of the space

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\*WhisperRooms is a registered trademark of WhisperRoom, Inc., Morristown, TN.

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## **4. Materials and Construction**

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### **4.1 Walls and Roof Panels**

The prefabricated wall sections were assembled on top of the shielded floor. All walls of the MIND Laboratory are constructed of 4-in- (10.2-cm)-thick modular panels rated as STC-50 with 16-gauge solid-steel sheets on both the exterior and interior of each panel. The interior space of each panel is packed with insulation for acoustic attenuation. The roof panels are of the same type of construction as the wall panels. Figure 4 shows an elevation view of typical chamber construction. The space between the suspended ceiling and the underside of the roof panels contains ductwork, electrical wiring, and sprinkler piping.

Panels are connected to each other with steel H-joiners, floor track, and roof channels that provide a U-shaped channel into which each panel is inserted to provide a consistent acoustic and EMI/RF seal between the H-joiner and the edges of the panels. Figures 5–8 show typical joint connections between the various modular components.

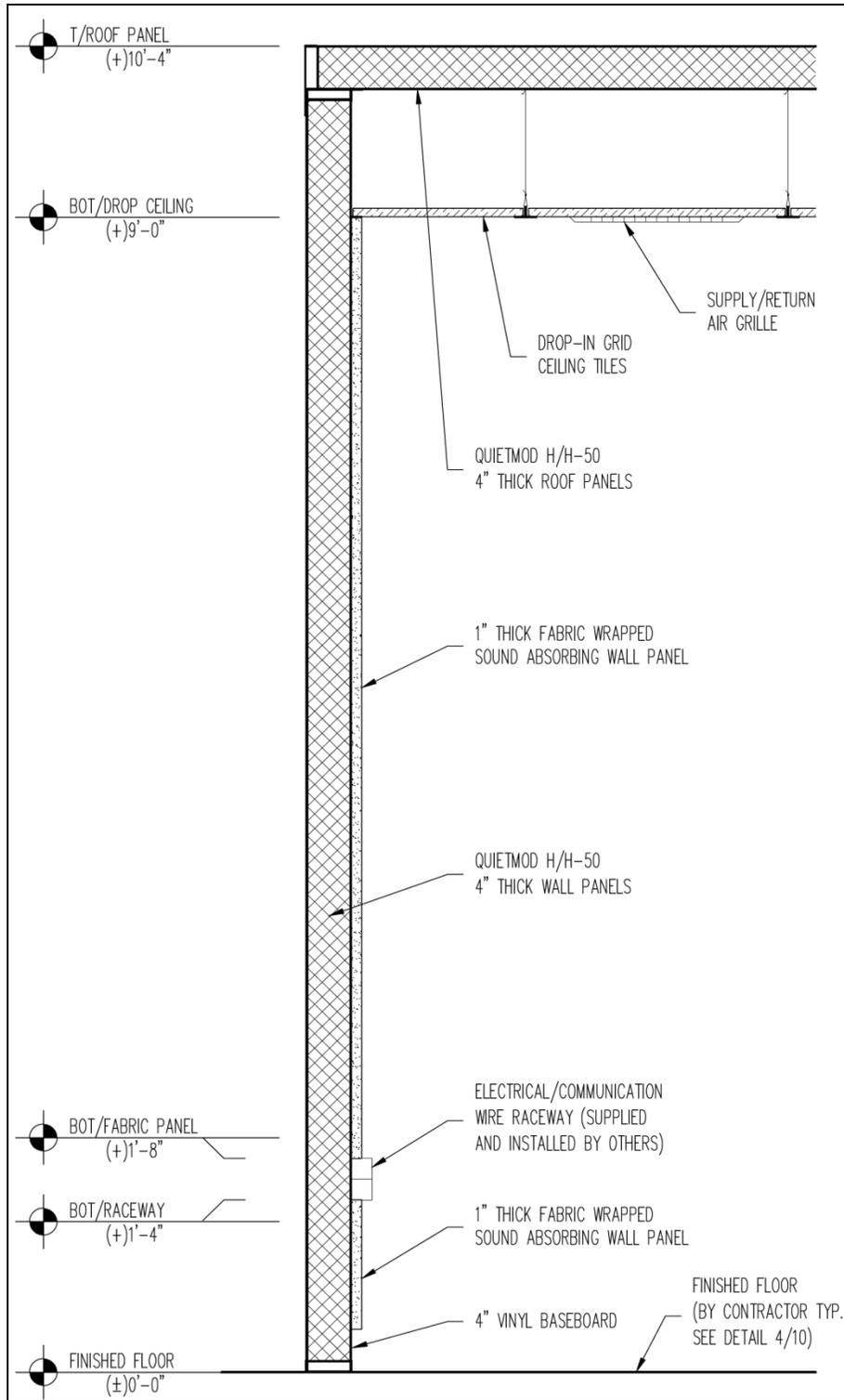


Figure 4. MIND Laboratory: typical elevation view showing electrical and communications raceway, sound-absorbing wall panels, suspended ceiling, and roof. (Adapted from Noise Barriers, LLC, 2011.)

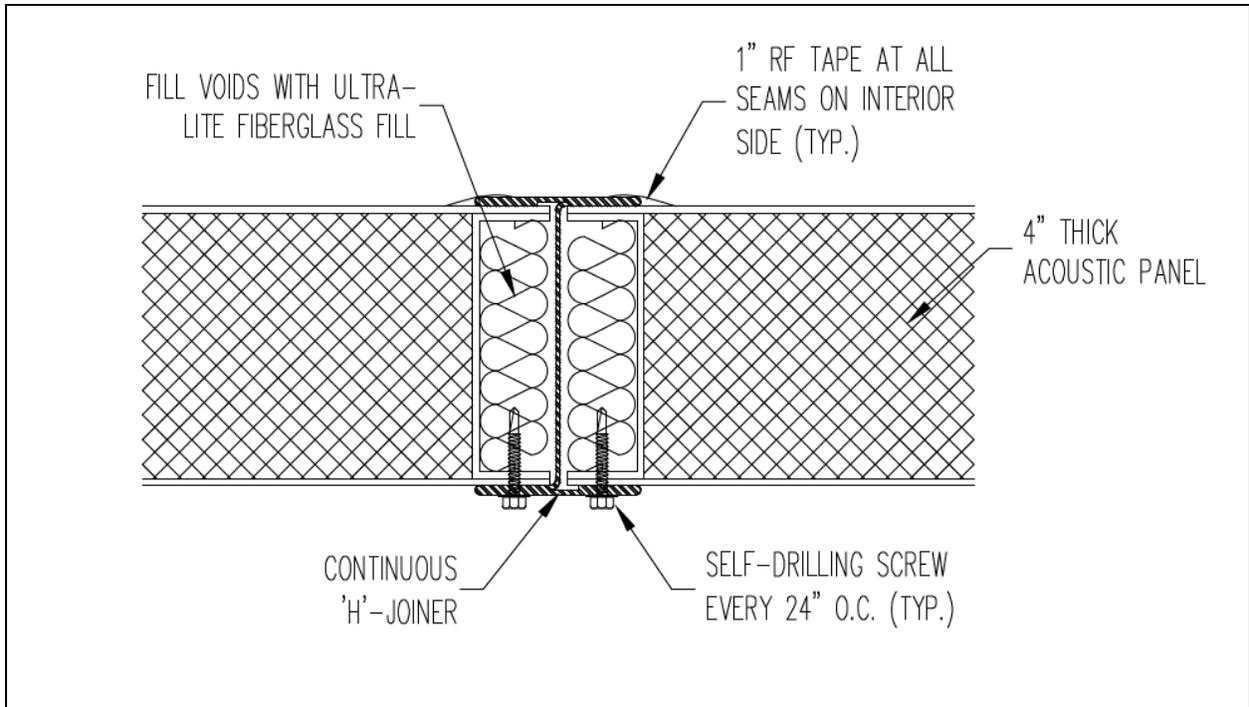


Figure 5. Fabrication details: typical wall panel joint (plan view). (Adapted from Noise Barriers, LLC, 2011.)

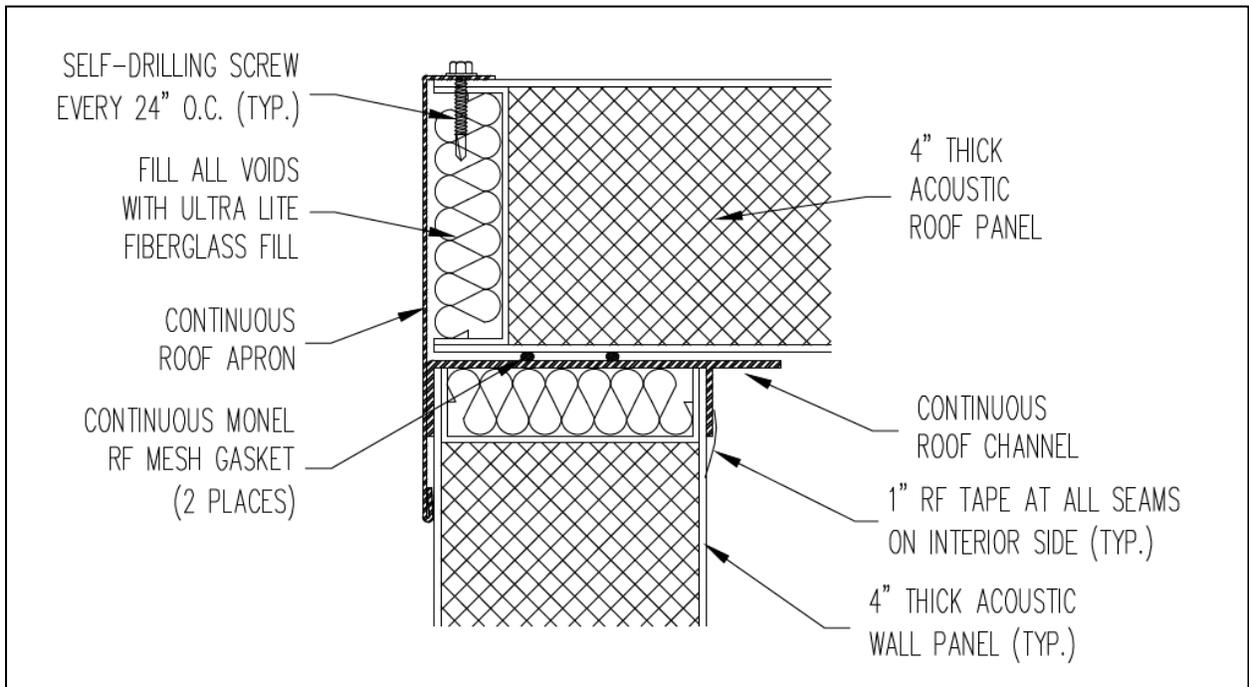


Figure 6. Fabrication details: top of wall. (Adapted from Noise Barriers, LLC, 2011.)

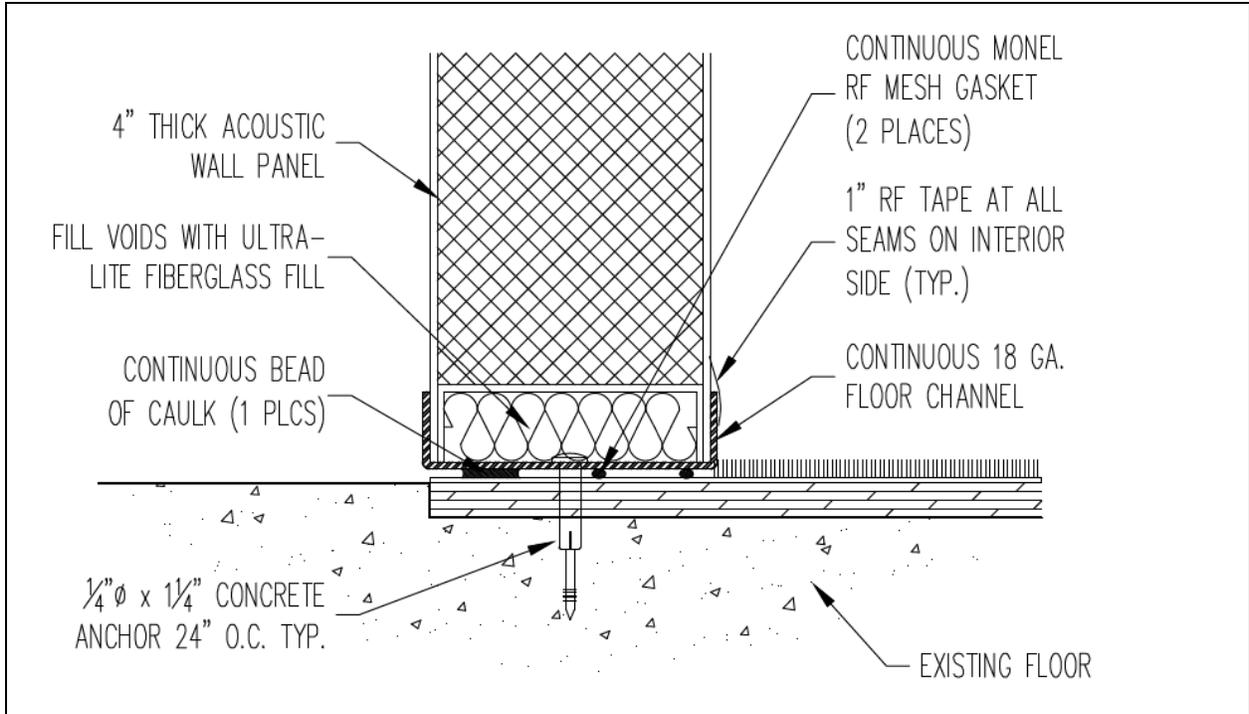


Figure 7. Fabrication details: bottom of wall. (Adapted from Noise Barriers, LLC, 2011.)

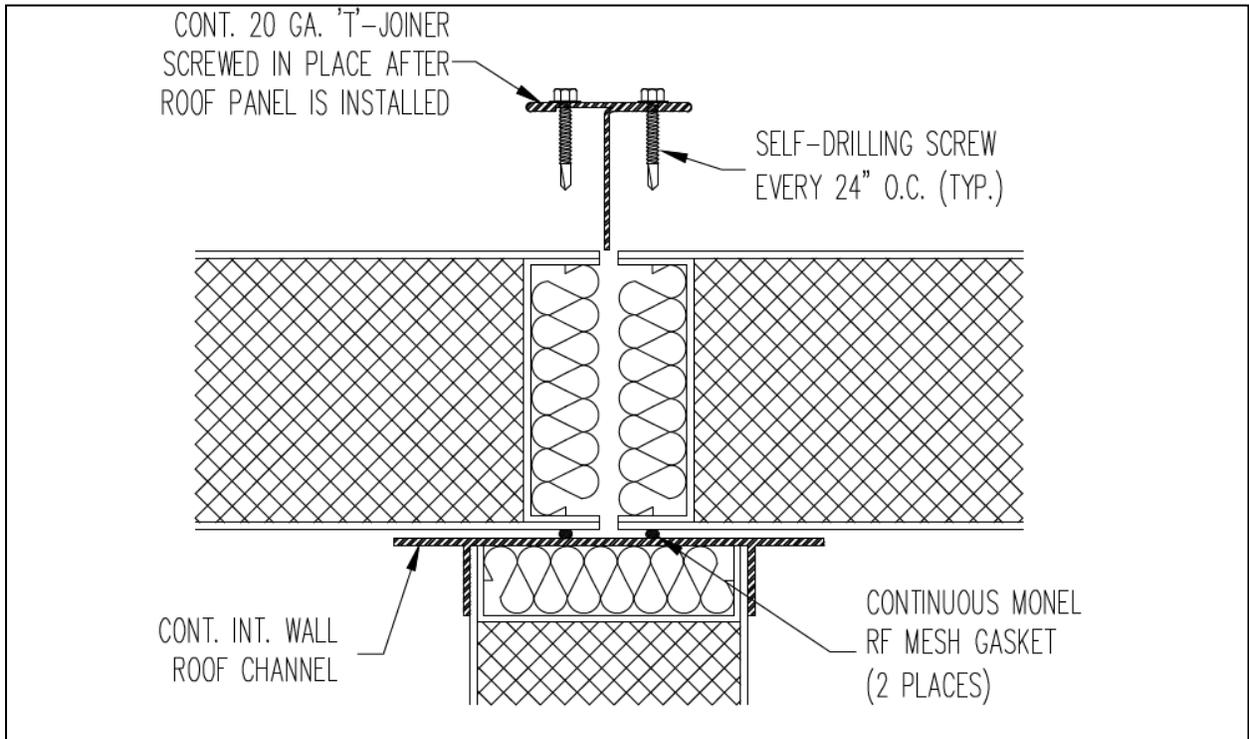


Figure 8. Fabrication details: typical interior wall intersection with roof. (Adapted from Noise Barriers, LLC, 2011.)

The inherent RF isolation characteristics of the steel walls are further enhanced with the use of copper tape with conductive adhesive applied to all joints. RF gaskets were applied under the wall sections and at all two-, three-, and four-way joints.

A suspended ceiling was installed approximately 8 in (20.3 cm) from the underside of the chamber roof in all of the areas except for the first 4 ft (1.2 m) of the laboratory space (nearest the corridor). This 4-ft bulkhead area was necessary to accommodate existing sprinkler and sanitary sewer pipes and spans across chamber A, the control room, and chamber D. The finished ceiling height inside the chambers is 9 ft (2.7 m) above the finished floor.

The interior of all wall surfaces from the floor to the underside of the suspended ceiling are covered in 1-in-thick, cloth-wrapped fiberglass acoustic panels with a density of 6 lb/ft<sup>3</sup> (96.1 kg/m<sup>3</sup>). These panels are attached with hook and loop fasteners and magnets to prevent compromising the RF and acoustic integrity of the chambers. These fiberglass panels are manufactured by Leading Acoustics, LLC, of Libertyville, IL. The acoustic characteristics of a typical panel are shown in appendix A.

## 4.2 Doors

All doors are STC-50 rated and utilize cam-lift butt-type hinges. They include RF-conductive mesh-covered acoustic foam to form a perimeter seal around the door frame. RF copper tape was applied to the door surface making contact with the RF mesh to provide enhanced conductivity and to prevent corrosion. The bottom of each door includes two individually adjustable seals; one is a standard acoustic seal and the second uses RF finger seals to create an EMI/RF seal when the door is closed. Doors from the control room chamber to the corridors each contain lites; the other doors are solid. Door construction and sealing techniques are shown in figures 9 and 10.

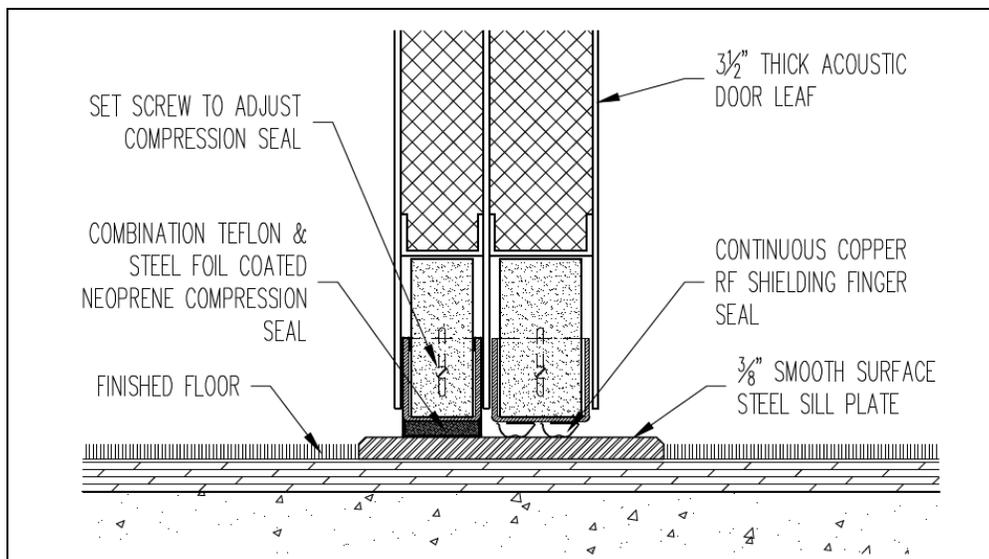


Figure 9. Fabrication details: typical door sill construction. (Adapted from Noise Barriers, LLC, 2011.)

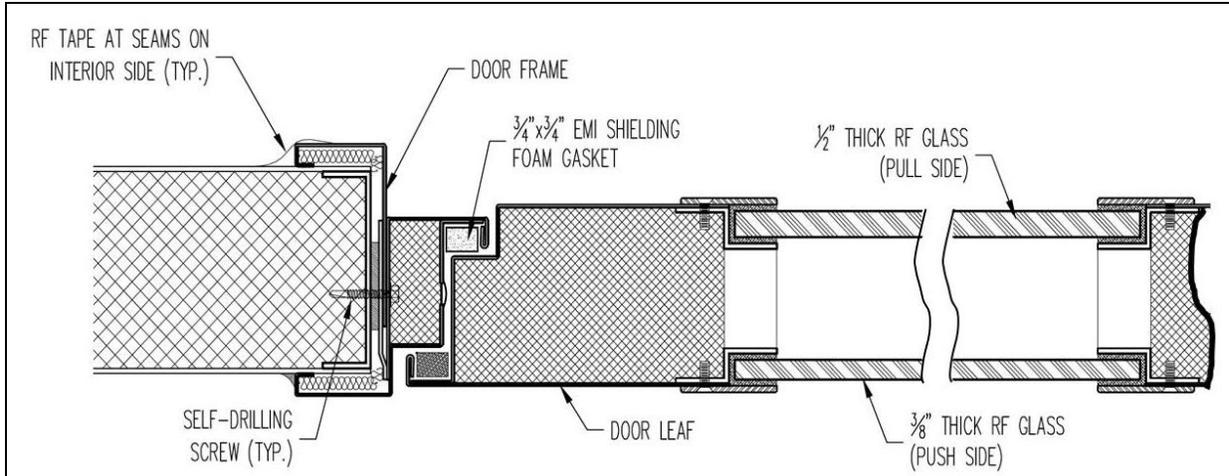


Figure 10. Fabrication details: typical door seals (plan view). (Adapted from Noise Barriers, LLC, 2011.)

### 4.3 Floor

A solid electrically shielded floor was fabricated using plywood underlayment installed over a vapor barrier and fastened to the existing concrete floor with Tapcon\* concrete screws. Fasteners used in the floor were recessed and covered with insulating tape to prevent unwanted contact between the conductive floor panels, rebar, or other conductive paths in the existing concrete floor. The plywood underlayment was covered with 26-gauge galvanized steel sheeting with all seams sealed with copper tape to protect the rooms from any structure-born RF signals. After the chamber construction was complete, all floors were covered with antistatic carpet squares. Figure 11 shows the details of floor fabrication.

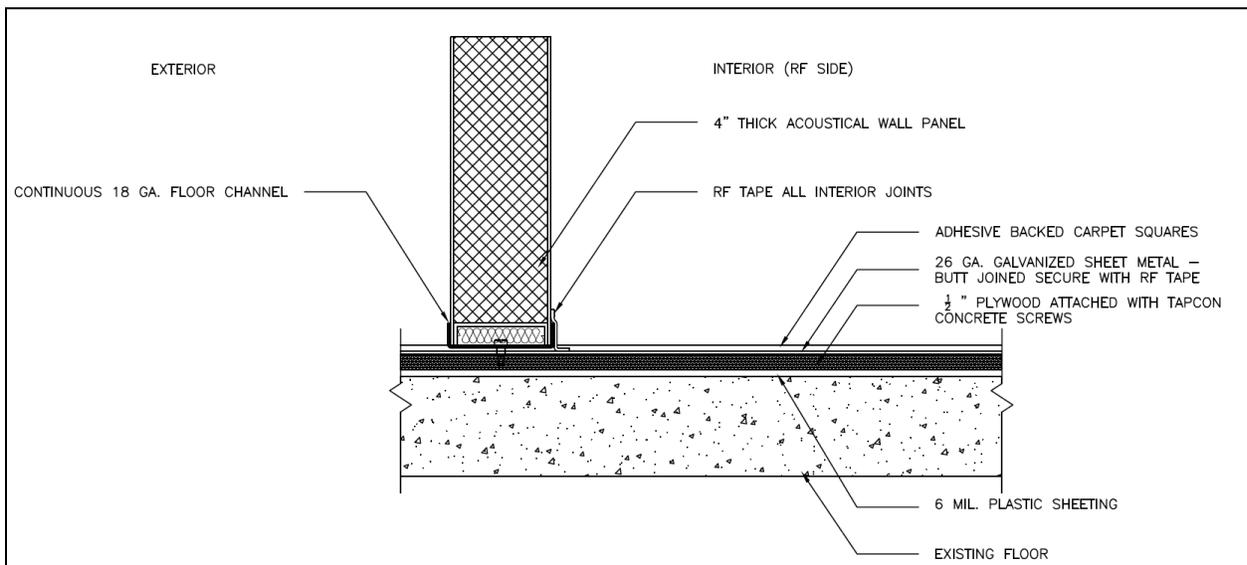


Figure 11. Fabrication details: typical floor isolation fabrication technique. (Adapted from Noise Barriers, LLC, 2011.)

\*Tapcon is a trademark of ITW Brands, Schaumburg, IL.

#### 4.4 AC Power and Communications Circuit Isolation

All electrical power for AC convenience receptacles and lighting is filtered with RF Filters. All communications circuits (CAT6 cable) for network access and telephone circuits enter the chambers through Fiber Optic Isolation Filters (FOILs). These filters are capable of gigabit network speed. Figure 12 shows typical AC power and communications filters. The communications filters are installed in roof panels above the control room, and AC power filters are installed on the exterior of the research spaces in various locations.

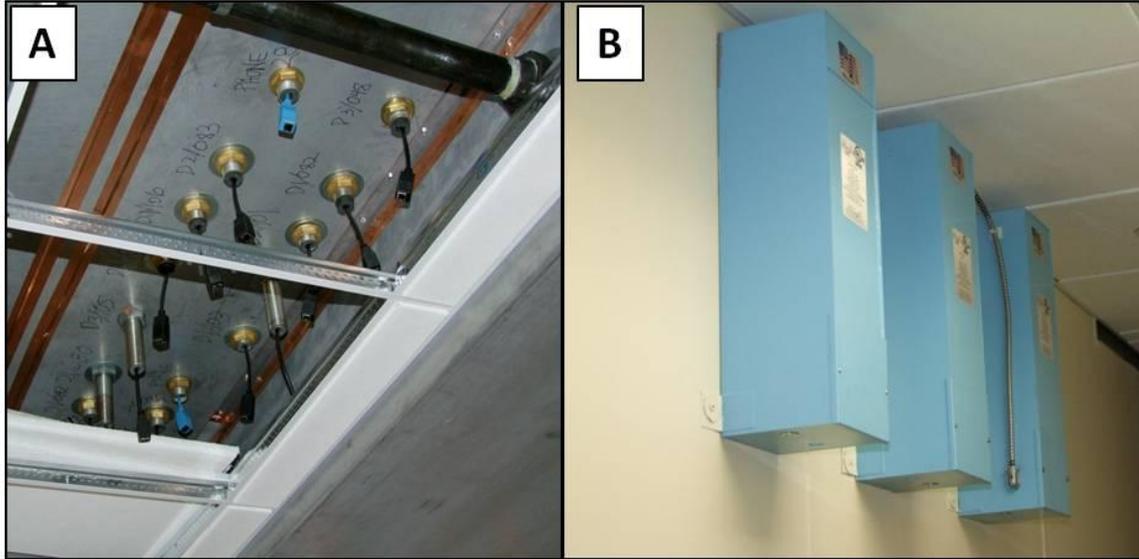


Figure 12. MIND Laboratory RF filters. Panel A: communications filters; panel B: typical AC power filters. (U.S. Army photos by Ron Carty.)

Fire alarm and mass-notification systems wires are fed into the enclosures with RF filters and shielding specifically designed to meet the alarm system requirements.

#### 4.5 HVAC

Each chamber is provided with a dedicated HVAC system consisting of self-contained individual heat pump units. The air handler for each unit is installed in the ceiling spaces above the chambers. The outside condenser units are installed at the rear of the building. Each supply and return duct includes in-line wave guides and acoustic silencers designed to maintain the specified acoustic and EMI/RF integrity of each chamber. The heat pumps utilize “low ambient kits” suitable for operation to 0 °F (−17.8 °C). (Low ambient kits permit the heat pump to operate in cooling mode to remove heat from the interior space when the outside temperature would generally not require interior cooling.)

## 4.6 Lighting

The lighting system consists of Lunera Series 22-G3 recessed LED troffers each delivering up to 3625 lumens. The Lutron GRAFIK Eye\* QS Control Unit is used to operate the lighting system, allowing each chamber independent programmable dimming control. There are wall stations mounted in each chamber with the master control installed in the control room chamber. Computer interface to control or monitor the system is achieved via the Lutron QSE-CI-NWK-E integration access point. This allows lighting control through either RS-232 or TCP/IP interfaces.

## 4.7 Jack Panels

Jack panels provide:

- Eight telephone/data RJ45, CAT6 jacks,
- Six DVI-I connectors,
- Two VGA connectors,
- Eight type A USB 2.0 connectors,
- Four type B USB 3.0 connectors,
- Two 3.5-mm stereo audio ring/tip/sleeve jacks,
- Three 3-pin XLR jacks,
- Three RCA jacks,
- Two DB-25 connectors (parallel),
- Two DB-9 connectors (serial),
- Four BNC connectors, and
- Two female FC fiber optic connectors per panel.

Each connector is insulated from the chamber and from the other connectors. The XLR, USB, and DB connectors in the jack panels are configured with male on one side and female on the other so configuration development can be accomplished in another area then unplugged and run through the jack panel. An open area of  $2 \times 3$  in ( $5.1 \times 7.6$  cm) is provided in each jack panel for future expansion. The panels are designed to preserve the acoustical and EMI/RF integrity of each chamber. Figure 13 shows the configuration of a typical jack panel. Table 1 lists types and quantities of connectors provided in each jack panel.

Figure 14 shows a typical chamber during construction before all fiberglass panels were completely installed. Note the attention to detail in sealing any potential opening with copper RF tape.

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\*Lutron GRAFIK Eye is a trademark of Lutron, Coopersburg, PA.

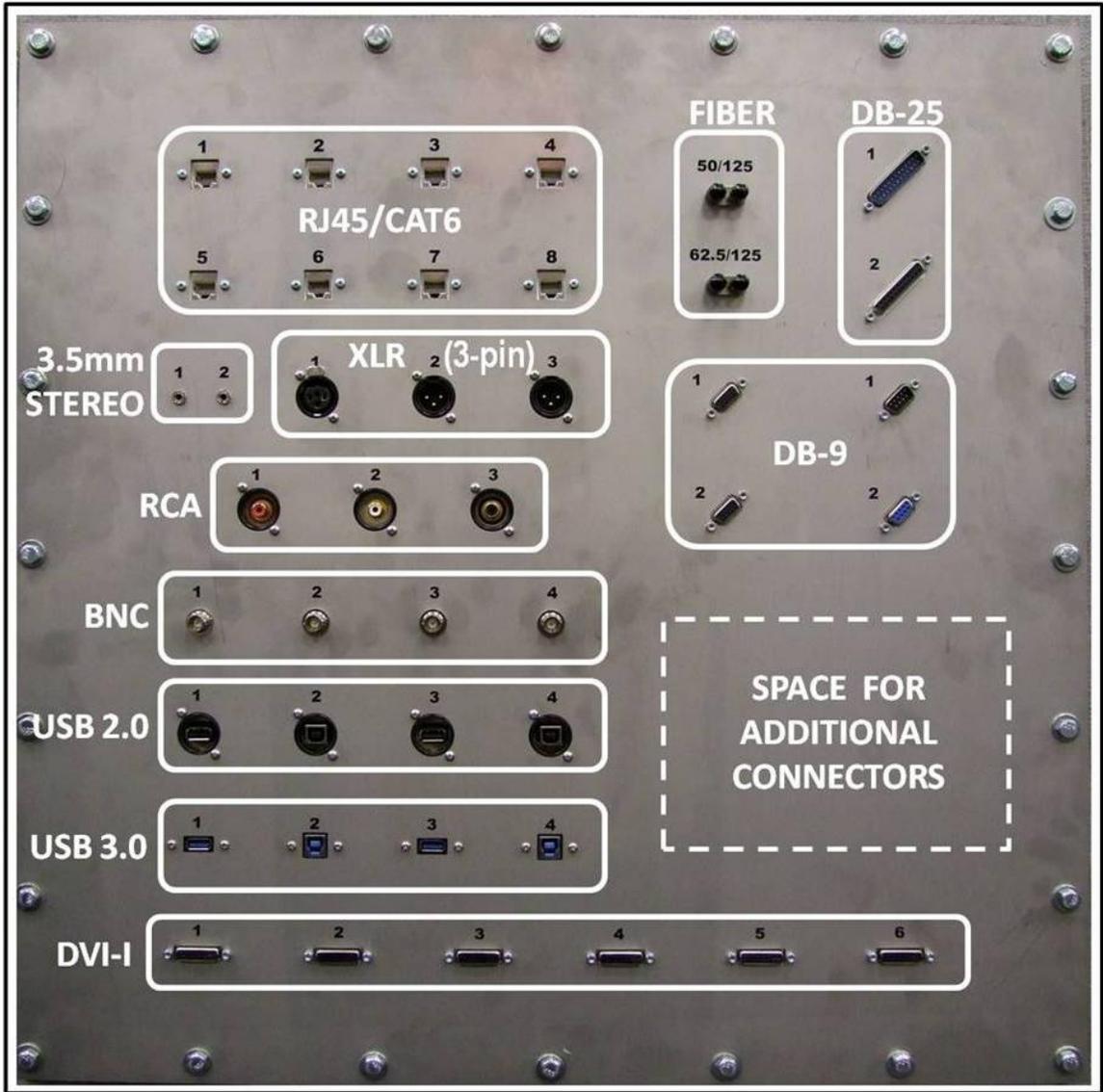


Figure 13. Typical patch panel configuration.

Table 1. Typical patch panel configuration (quantity and type).

JACK	Chambers A to B		Chambers A to C		Chambers B to C		Chambers C to D	
RJ45	8 Female							
DVI-I	6 Female							
VGA	2 Female							
USB 2.0-A	4 Male, 4 female							
USB 3.0 - A	2 Male, 2 Female							
XLR- 3-pin	1 Male, 2 Female							
3.5mm stereo audio (ring/tip/sleeve)	2 Female							
RCA	3 Female							
FC (Fiber optic)	2 Female							
DB-25	1 Male, 1 Female							
DB-9	1 Male, 1 Female							
BNC	4 Female							

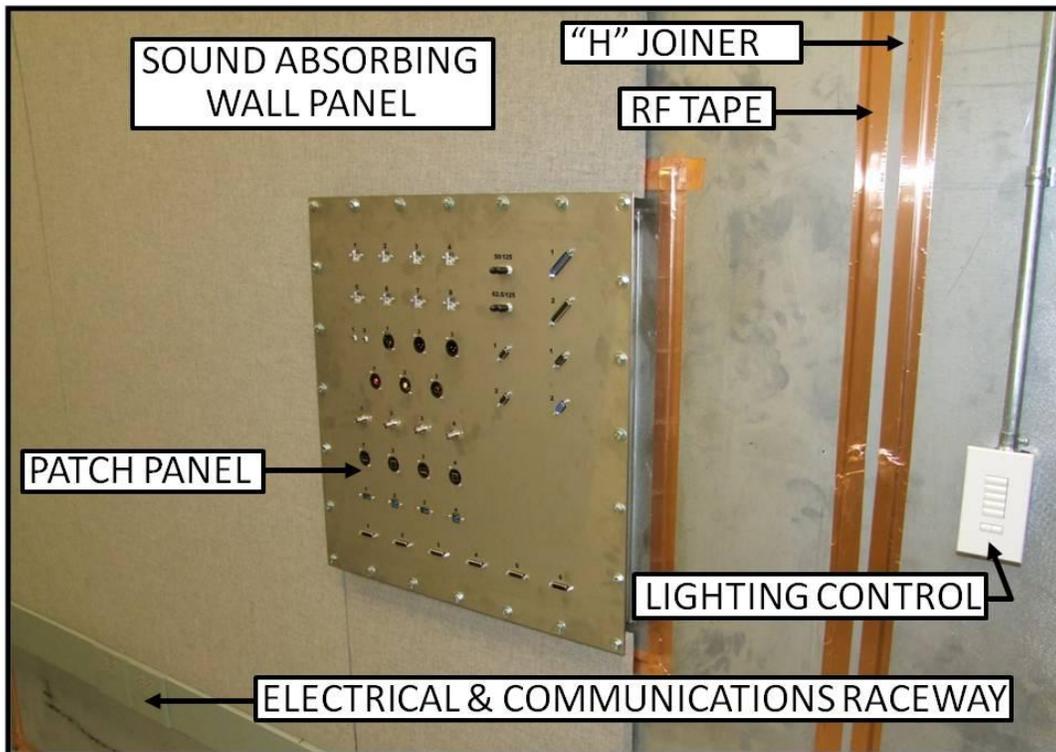


Figure 14. MIND Laboratory: typical RF shielding, lighting controls, and patch panel installation. (U.S. Army photo by Ron Carty.)

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## 5. Testing

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Acceptance tests were conducted using independent testing contractors to verify compliance with specifications. All testing (acoustic and EMI/RF) was conducted with normal building and acoustical chamber HVAC systems operational. All lighting fixtures were “ON” at 75% intensity.

### 5.1 Acoustic Testing

Acoustic testing data were collected with a Norsonic N-140 Real Time Sound Analyzer. The noise source was a Norsonic dodecahedron loudspeaker and amplifier. Typical equipment used for conducting the acoustic tests is shown in figure 15. Each chamber was required to meet or exceed noise isolation class\* 50 (NIC-50).



Figure 15. MIND Laboratory: typical instrumentation for acoustic testing.

---

\*Noise isolation class (NIC) is a single-number rating calculated in accordance with ASTM Standard E413 using measured values of noise reduction. It provides an estimate of the sound isolation between two enclosed spaces that are acoustically connected by one or more paths (ASTM E413, 2010).

Noise levels were measured with the source loudspeaker positioned at 19 locations external to the test chambers. The received noise levels were measured inside the test chambers by moving the sound analyzer within each chamber while the loudspeaker was at each of the locations related to that chamber. Figure 16 shows where measurements were taken in and around the laboratory space.

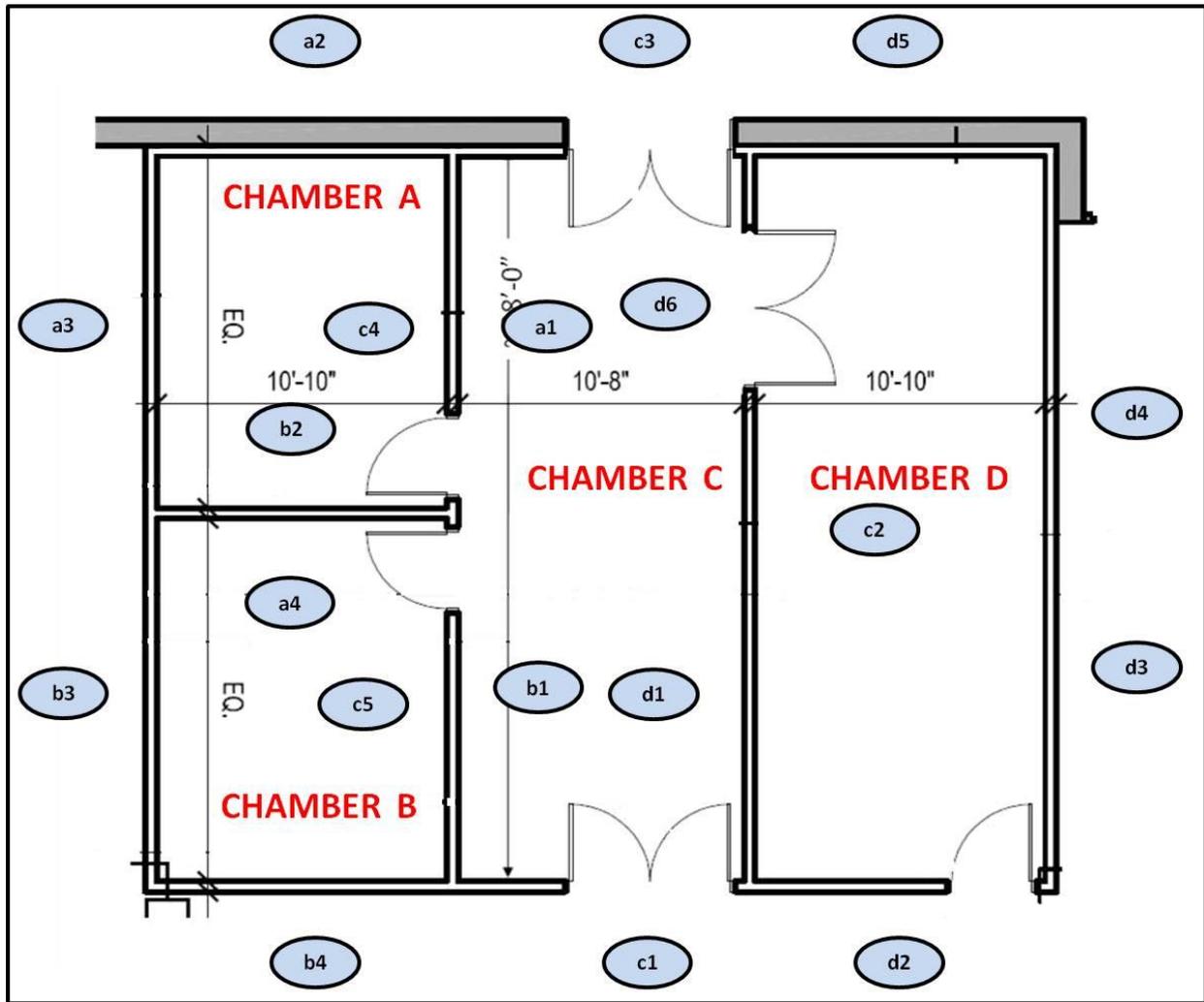


Figure 16. Acoustic test measurement locations.

Figures 17–20 summarize test results for each chamber.

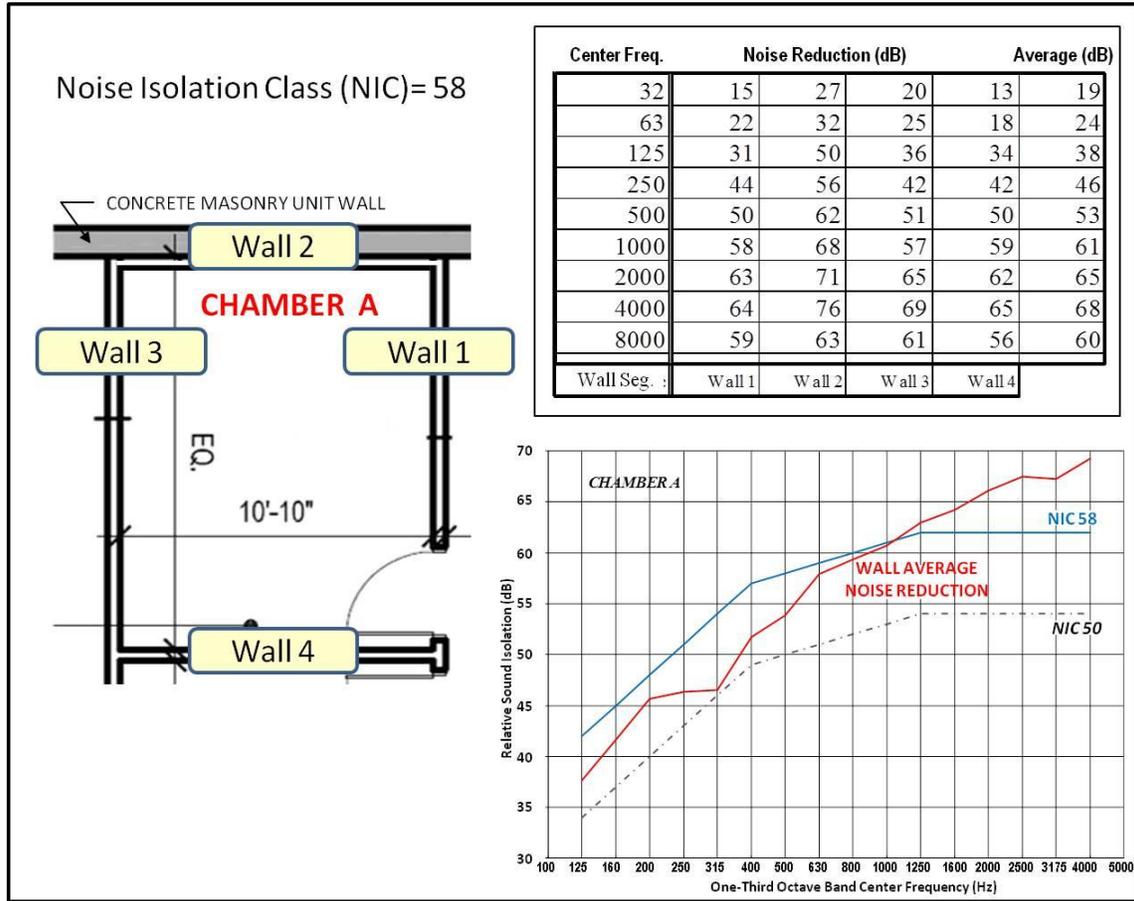


Figure 17.  $L_{eq}^*$  equivalent measured airborne noise reduction (dB re: 20  $\mu$ Pa) in Chamber A. (Chart and graph adapted from Brune, 2013.)

\* $L_{eq}$  = equivalent continuous sound level.

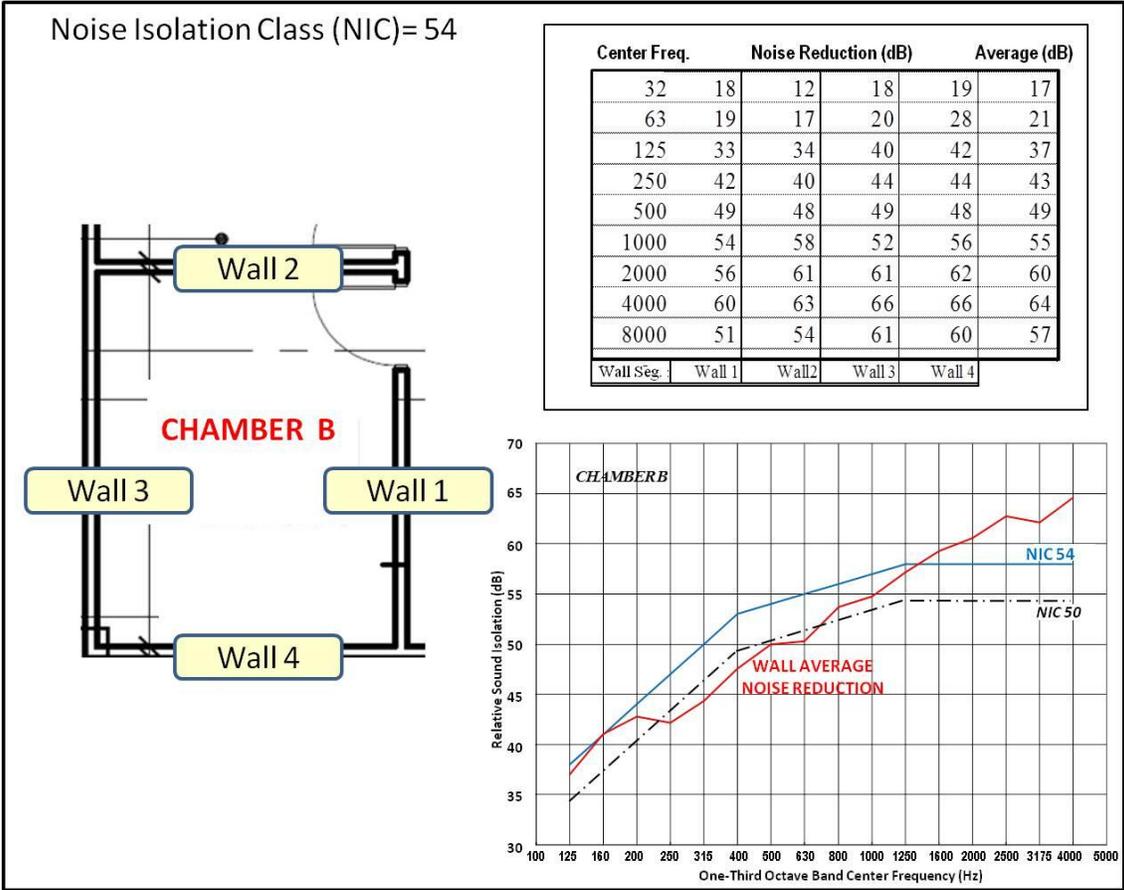


Figure 18. Leq equivalent measured airborne noise reduction (dB re: 20  $\mu$ Pa) in chamber B. (Chart and graph adapted from Brune, 2013.)

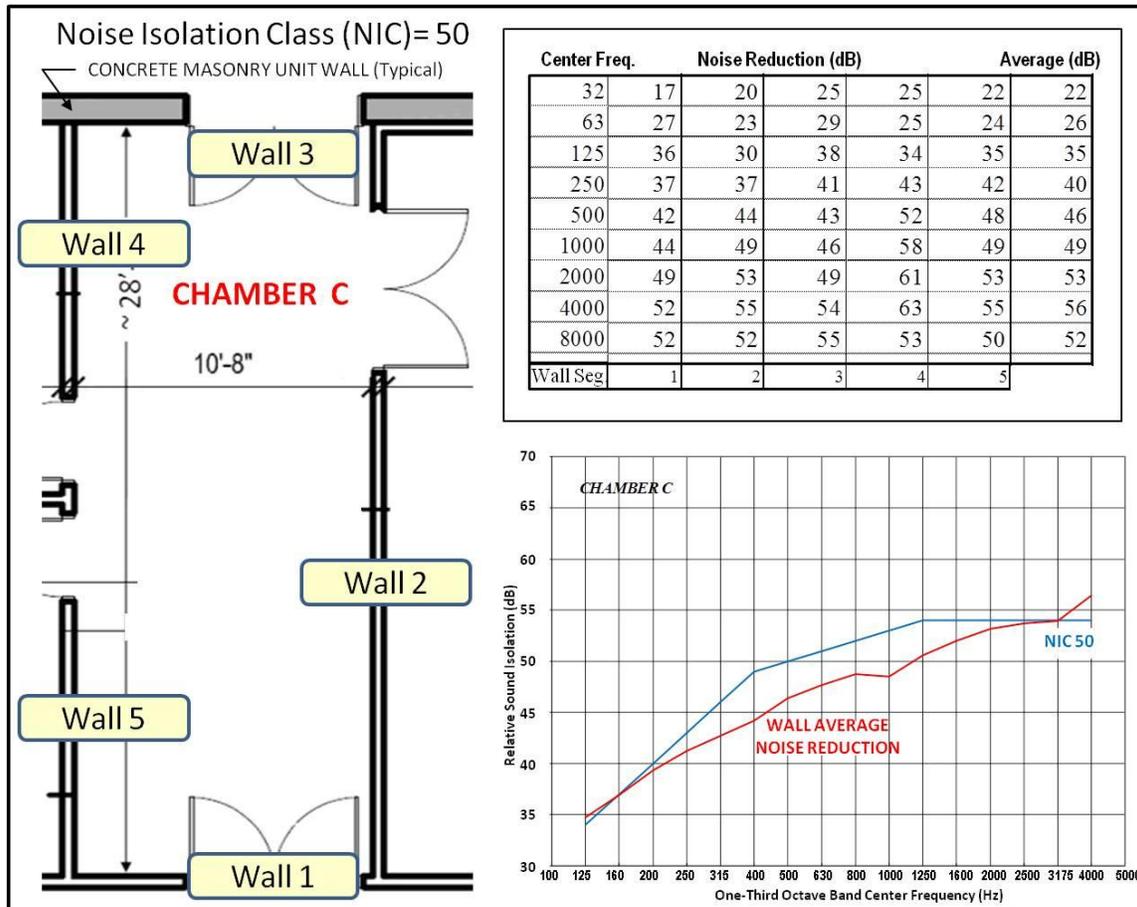


Figure 19. Leq equivalent measured airborne noise reduction (dB re: 20  $\mu$ Pa) in chamber C. (Chart and graph adapted from Brune, 2013.)

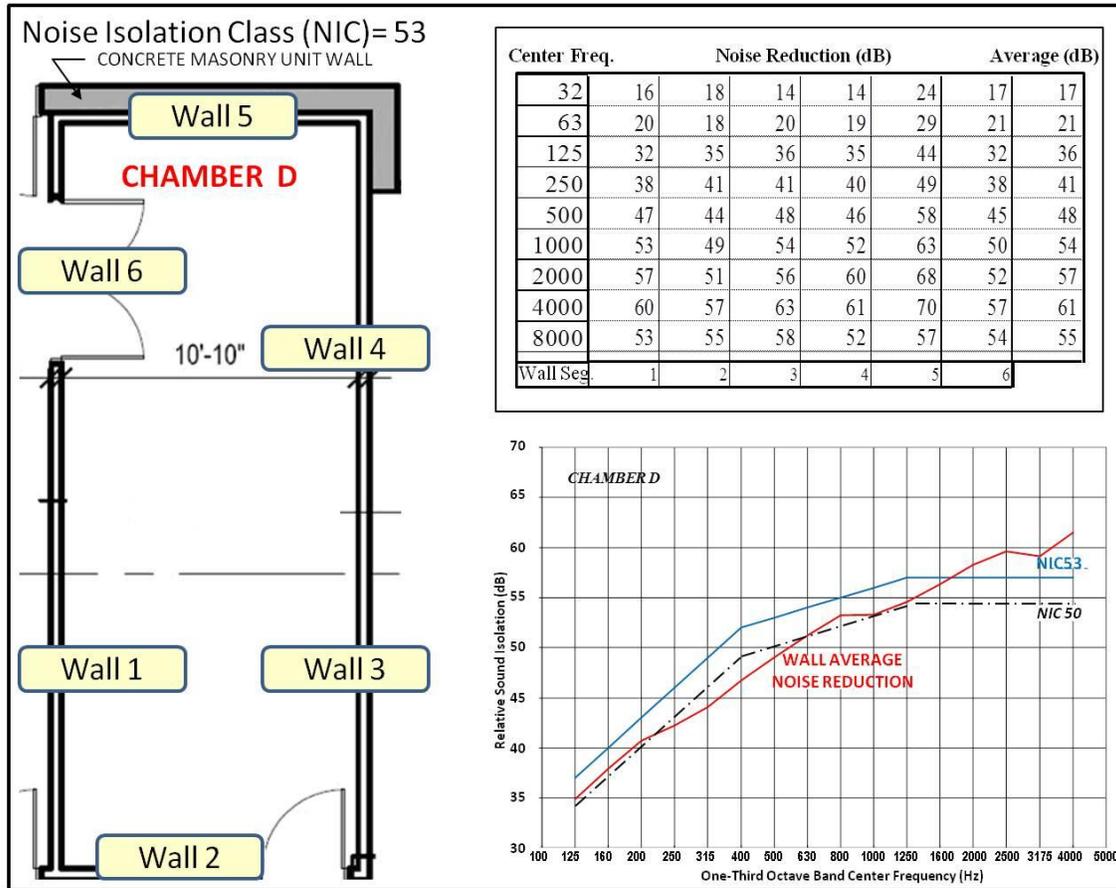


Figure 20. Leq equivalent measured airborne noise reduction (dB re: 20  $\mu$ Pa) in chamber D. (Chart and graph adapted from Brune, 2013.)

Table 2 summarizes the acoustical performance of each chamber and compares results to the specified performance.

Table 2. Acoustic performance: test data, compared to specifications.\*

Octave Center Frequency (Hz)	32	63	125	250	500	1000	2000	4000	8000	NIC
	<b>Noise Reduction dB<sup>a</sup></b>									
<b>Specification</b>	<b>NA</b>	<b>NA</b>	<b>25</b>	<b>37</b>	<b>48</b>	<b>55</b>	<b>59</b>	<b>60</b>	<b>58</b>	<b>50</b>
Chamber A	19	24	38	46	53	61	65	68	60	<b>58</b>
Chamber B	17	21	37	43	49	55	60	64	57	<b>54</b>
Chamber C	22	26	35	40	46	49	53	56	52	<b>50</b>
Chamber D	17	21	36	41	48	54	57	61	61	<b>53</b>

Note: NIC – Noise Isolation Class = single number rating system for noise-reduction characteristics.

<sup>a</sup>Allow  $\pm 3$  dB for field measured performance.

\*NIC calculations are based on center frequencies from 125 to 4000 Hz. Additional data were collected at 32, 63, and 8000 Hz but were not used when calculating NIC in accordance with ASTM Standard E413 (ASTM E413, 2010).

Each MIND Laboratory chamber meets or exceeds the required NIC-50 criterion.

Octave-band reverberation times were measured for each chamber by bursting inflated paper bags and measuring decay times for the acoustic impulse. These data are shown in figure 21.

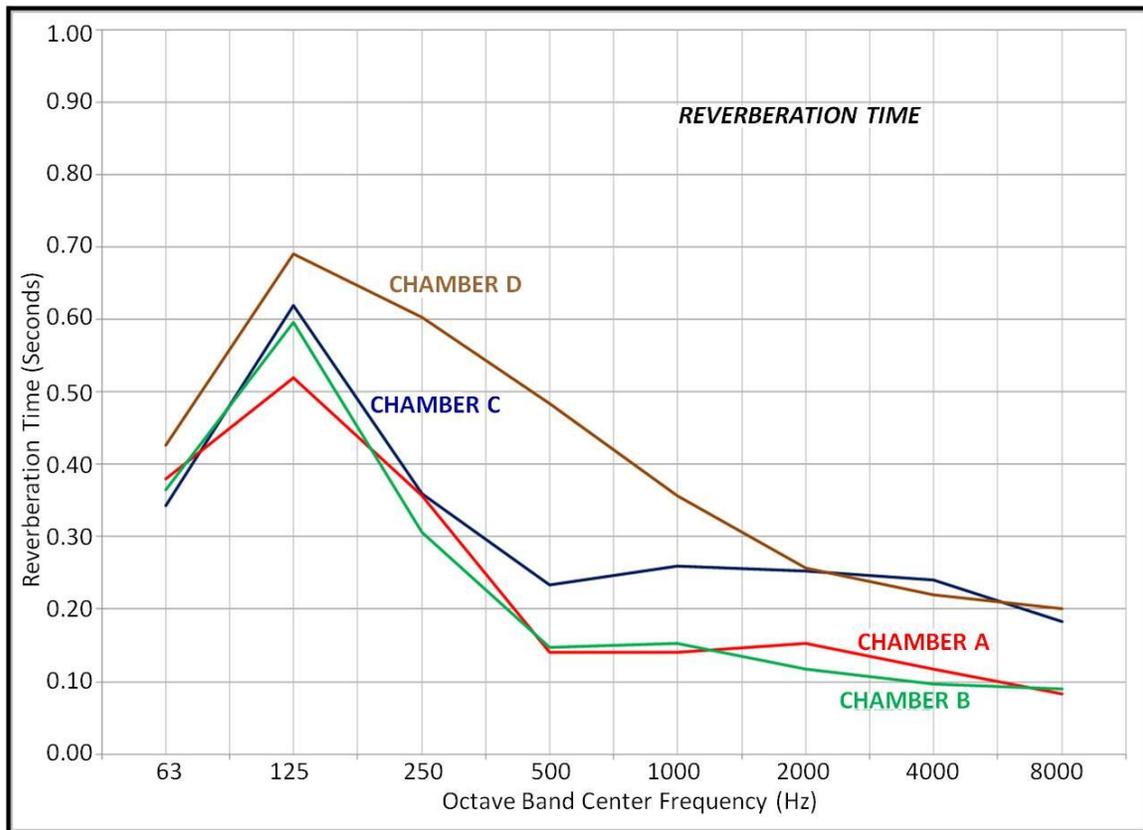


Figure 21. Reverberation times (Brune, 2013).

Complete acoustic test results are provided in appendix B.

## 5.2 Radio Frequency Isolation Testing

The RF isolation testing was conducted in accordance with the intent and general methodology of MIL-STD-285 (1956), which provides the methodology for performing RF isolation tests of RF enclosures. Figure 22 shows typical test configurations and instrumentation for magnetic field and plane wave tests.

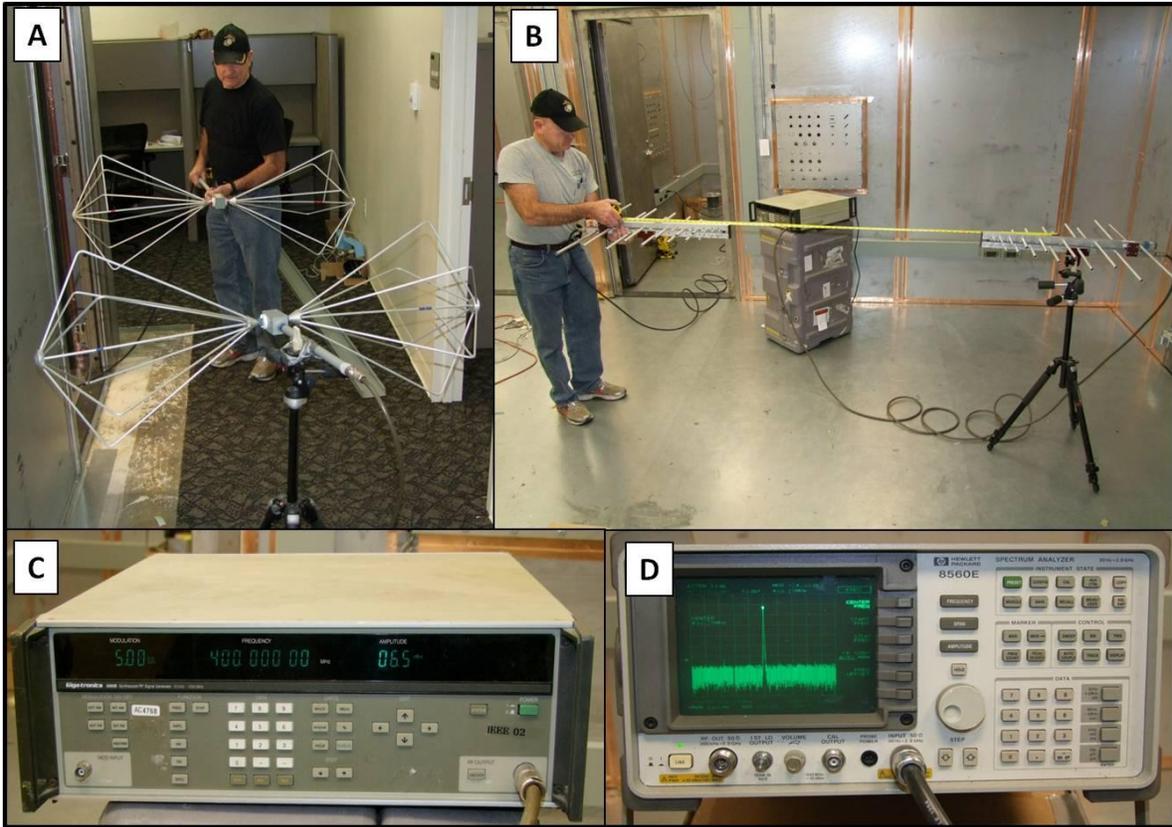


Figure 22. MIND Laboratory: typical RF configurations and instrumentation. Panel A: loop antennas for magnetic field tests; panel B: log periodic antennas for plane wave tests; panel C: Giga-tronics RF signal generator; panel D: Hewlett-Packard spectrum analyzer. (U.S. Army photos by Ron Carty.)

For each frequency tested, a reference signal was established using a signal generator and a matched set of antennas designed for each frequency band. Measurements were obtained with a spectrum analyzer in an open part of the test area. After the reference level was achieved, the transmit antenna and receive antenna were placed on opposite sides of the test point at the prescribed spacing. The signal level received in this position, if any, was subtracted from the reference signal resulting in the signal attenuation value. This procedure was repeated for 28 discrete test points and 6 doors for a total of 34 test locations, each tested at 13 frequencies. These locations are shown in figure 23. All test locations were tested by scanning along the entire wall section, space permitting; all penetrations in the vicinity of a test location were scanned. Doors were tested by scanning around the perimeter of the door and frame.

Figure 24 and table 3 show the results of the RF isolation tests. Data were averaged over the 34 test locations. Complete test results are shown in the test report in appendix C.

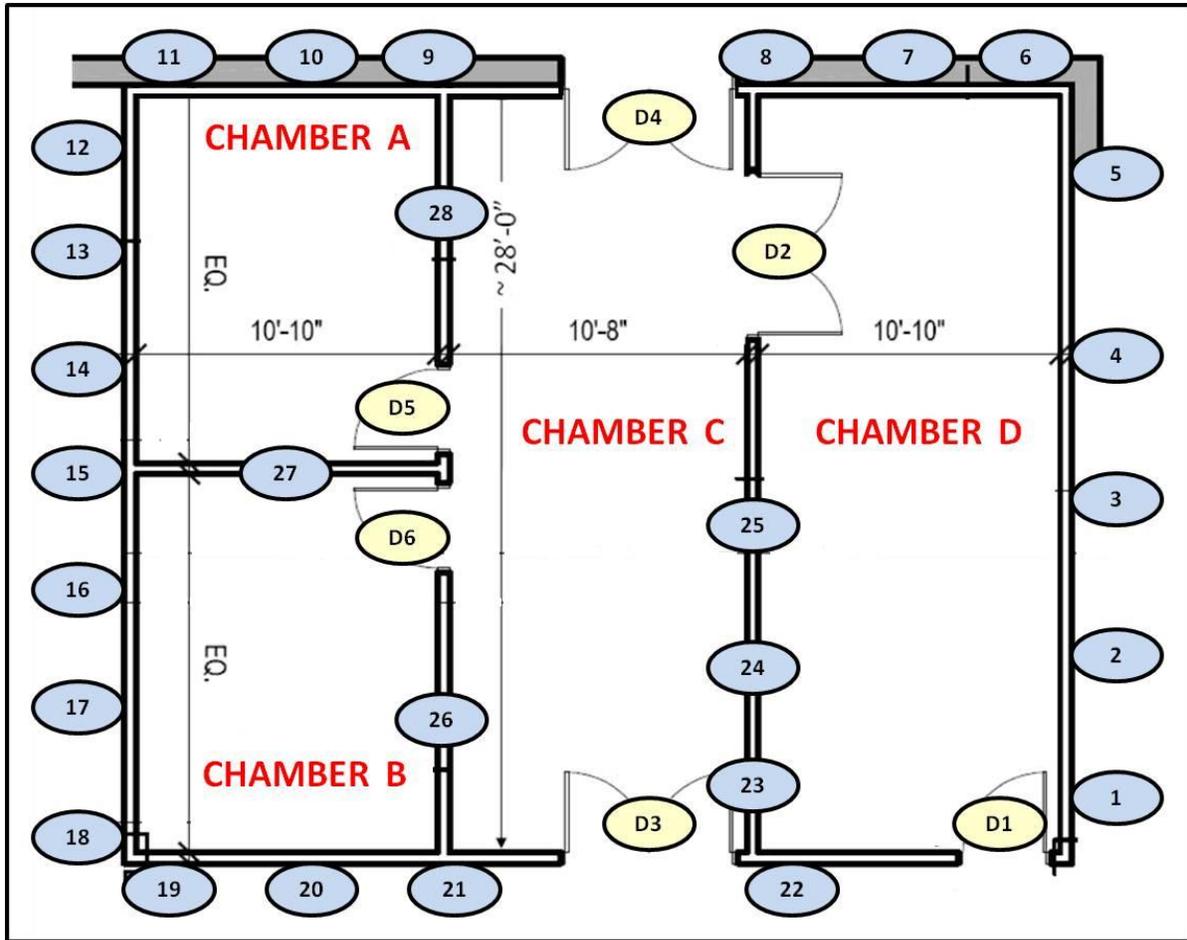


Figure 23. RF test measurement locations.

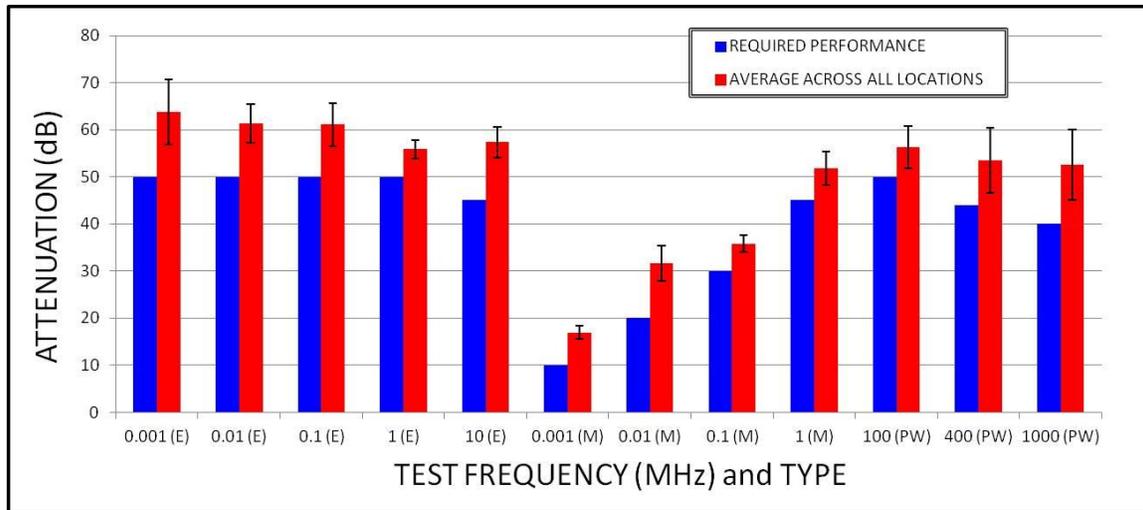


Figure 24. RF isolation test data, compared to required performance. (E = electric field; M = magnetic field; PW = plane wave field.) Error bars = ±1 standard deviation.

Table 3. RF isolation test data, compared to required performance.

Field Type	Frequency		Required Performance (dB)	Average Across All Locations (dB)	Standard Deviation (dB)
	kHz	MHz			
Electric	1	0.001	50	64	6.9
	10	0.01	50	61	4.1
	100	0.1	50	61	4.6
	1,000	1	50	56	1.9
	10,000	10	45	57	3.3
Magnetic	1	0.001	10	17	1.4
	10	0.01	20	32	3.7
	100	0.1	30	36	1.7
	1,000	1	45	52	3.5
Plane Wave	100,000	100	50	56	4.5
	400,000	400	44	53	6.9
	1,000,000	1000	40	53	7.4

The MIND Laboratory met all criteria for EMI/RF isolation at all frequencies for electric, magnetic, and plane wave fields.

## 6. MIND Laboratory Support Areas

In addition to the MIND Laboratory space described previously, the facility includes several supporting functions. These are all located in the basement of the building and are shown in figure 1. These include the following locations:

### 6.1 Experimentation Clean-Up Area

Many studies conducted in the MIND facility incorporate the use of neurophysiological measures such as EEG and other physiological measures such as EMG and EOG. While there have been great technical advances in these methods, state-of-the-art laboratory systems still require the application of electrolytic gels on the skin, scalp, and hair. The MIND facility has a small washroom for participants to wash the gels from their bodies after testing is complete. The experimentation clean-up area, adjacent to the restrooms, contains a shower, changing areas, and basin-style sink.

### 6.2 Multifunction Collaboration Room

Adjacent to the MIND, the multifunction analysis room is the primary collaborative area and serves as a conference, meeting, briefing, and participant waiting and debriefing area.

### 6.3 Linux Laboratory

This space is used for collaborative computing, with multiple Linux-based high-end workstations. These workstations provide a common space for neuroscience researchers and collaborators to share code, data, and analytical methods, and for them to collaborate on data analysis. To facilitate data sharing of large-scale datasets, these Linux-based workstations operate via a central fileserver. Most analyses utilize Mathwork's Matlab\* and other supporting software, with code-sharing, visualization, and collaboration facilitated by the use of large-screen displays.

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## 7. Conclusion

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The MIND Laboratory research space was fabricated and installed over a 20-month period. The research facility meets all specified performance requirements and should fully meet the needs of ARL's neuroscience research for many years to come.

Figure 25 shows the completed research spaces.

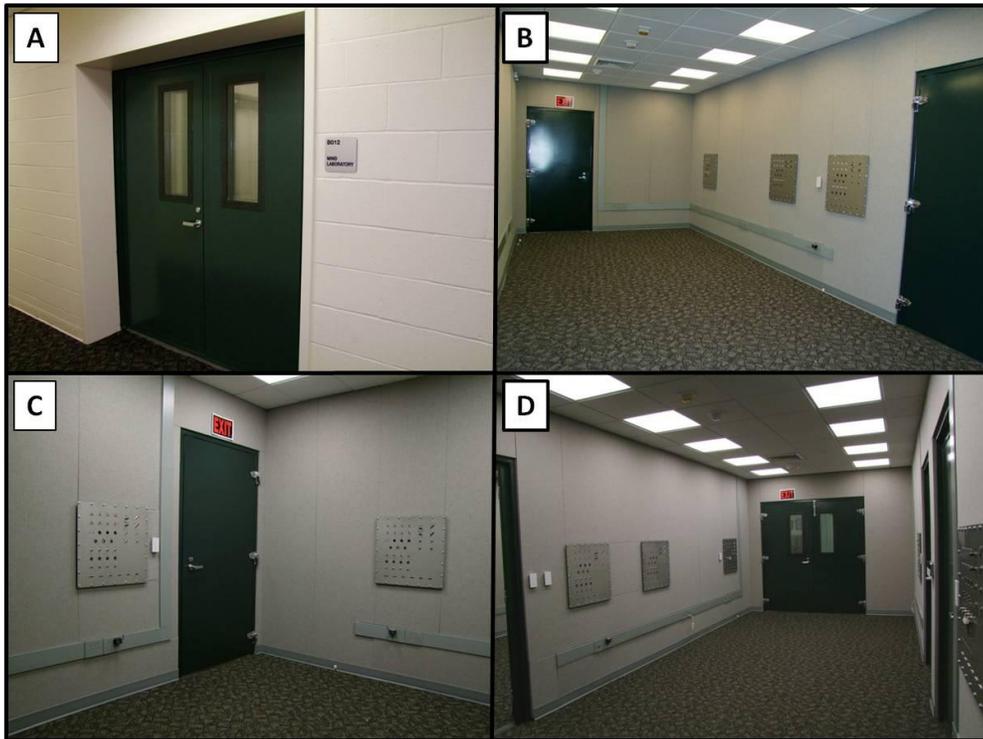


Figure 25. MIND Laboratory. Panel A: main entrance to the control room; panel B: universal research area; panel C: crew station and driving research simulation chamber (typical); panel D: control room. (U.S. Army photo by Ron Carty.)

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\*Mathwork's Matlab is a trademark of Mathworks, Inc., Natick, MA.

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## 8. References

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- ASTM Standard E413. *Classification for Rating Sound Insulation*, ASTM International, West Conshohocken, PA, 2010; DOI: 10.1520/E0413-10.
- ASTM Standard E90. *Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements*, ASTM International, West Conshohocken, PA, 2009; DOI: 10.1520/E90-09.
- Brune, B. G. *MIND Lab Noise Transmission Test Report*; Brune Consulting, LLC.: Towson, MD, 2013.
- DA PAM 420–11. *Facilities Engineering, Project Definition and Work Classification*; Department of the Army: Washington, DC, 2010.
- MIL-STD-285, 1956. *Attenuation Measurements for Enclosures, Electromagnetic Shielding, for Electronic Test Purposes, Method of 1956*.
- Noise Barriers, LLC. Typical Installation Details, Project # 010-7251, Libertyville, IL, 2011.
- Oie, K. S.; McDowell, K.; Metcalfe, J.; Hairston, W. D.; Kerrick, S.; Lee, T.; Makeig, S. *The Cognition and Neuroergonomics (CaN) Collaborative Technology Alliance (CTA): Scientific Vision, Approach, and Translational Paths*; ARL-SR-0252; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2012.

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## **Appendix A. Fiberglass Panel Test Report**

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This appendix appears in its original form, without editorial change.

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1512 S. BATAVIA AVENUE  
GENEVA, ILLINOIS 60134

Alion Science and Technology

630/232-0104  
FOUNDED 1918 BY  
WALLACE CLEMENT SABINE

## TEST REPORT

FOR: Leading Acoustics, LLC  
Waukegan, IL

Sound Absorption Test  
RAL™-A07-120

ON: AWP-1

Page 1 of 4

CONDUCTED: 14 August 2007

### TEST METHOD

The test method conformed explicitly with the requirements of the ASTM Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method: ASTM C423-07a and E795-05. Riverbank Acoustical Laboratories has been accredited by the U.S. Department of Commerce, National Institute of Standards and Technology (NIST) under the National Voluntary Laboratory Accreditation Program (NVLAP) for this test procedure (NVLAP Lab Code: 100227-0). A description of the measuring procedure and room qualifications is available separately.

### DESCRIPTION OF THE SPECIMEN

The test specimen was designated by the manufacturer as AWP-1. The overall dimensions of the specimen as measured were nominally 2.44 m (96 in.) wide by 2.74 m (108 in.) long and 25 mm (1 in.) thick. The specimen consisted of four (4) pieces. Three (3) pieces were nominally 610 mm (24 in.) wide by 2.44 m (96 in.) long and 25 mm (1 in.) thick. One (1) piece was nominally 914 mm (36 in.) wide by 2.44 m (96 in.) long and 25 mm (1 in.) thick. The specimen was tested in the laboratory's 292 m<sup>3</sup> (10,311 ft<sup>3</sup>) test chamber.

The manufacturer's description of the specimen was as follows: AWP-1, 1" thick fabric wrapped panels consisting of 6 pcf fiberglass wrapped with Guilford FR701, Style 2100 Fabric. (Color: Tan) A visual inspection verified the manufacturer's description of the specimen.

The weight of the entire specimen as measured was 18.8 kg (41.5 lbs), an average of 2.8 kg/m<sup>2</sup> (0.58 lbs/ft<sup>2</sup>). The area used in the calculations was 6.69 m<sup>2</sup> (72 ft<sup>2</sup>). The room temperature at the time of the test was 22°C (71°F) and 60±1% relative humidity.

### MOUNTING A

The test specimen was laid directly against the test surface. Perimeter edges were unsealed.

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NVLAP Lab Code 100227-0

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## TEST REPORT

Leading Acoustics, LLC

RAL™-A07-120

14 August 2007

Page 2 of 4

### TEST RESULTS

1/3 Octave Center Frequency (Hz)	Absorption Coefficient	Total Absorption In Sabins
100	0.22	16.18
** 125	0.13	9.52
160	0.14	9.85
200	0.20	14.28
** 250	0.29	20.90
315	0.44	31.84
400	0.58	41.69
** 500	0.75	53.84
630	0.86	62.21
800	0.94	67.38
** 1000	1.00	72.09
1250	1.10	78.87
1600	1.09	78.59
** 2000	1.12	80.38
2500	1.06	76.35
3150	1.01	72.47
** 4000	0.99	71.21
5000	0.95	68.19

SAA = 0.79

NRC = 0.80

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**TEST REPORT**

Leading Acoustics, LLC

RAL™-A07-120

14 August 2007

Page 3 of 4

TEST RESULTS (Continued)

The sound absorption average (SAA) is defined as a single number rating, the average, rounded to the nearest 0.01, of the sound absorption coefficient of a material for the twelve one-third octave bands from 200 through 2500 Hz, inclusive.

The noise reduction coefficient (NRC) is defined from previous versions of this same test method as the average of the coefficients at 250, 500, 1000, and 2000 Hz, expressed to the nearest integral multiple of 0.05.

Tested by Dean Victor Approved by David L. Moyer  
Dean Victor Senior Experimentalist David L. Moyer Laboratory Manager

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**NVLAP**  
NVLAP Lab Code 100227-0

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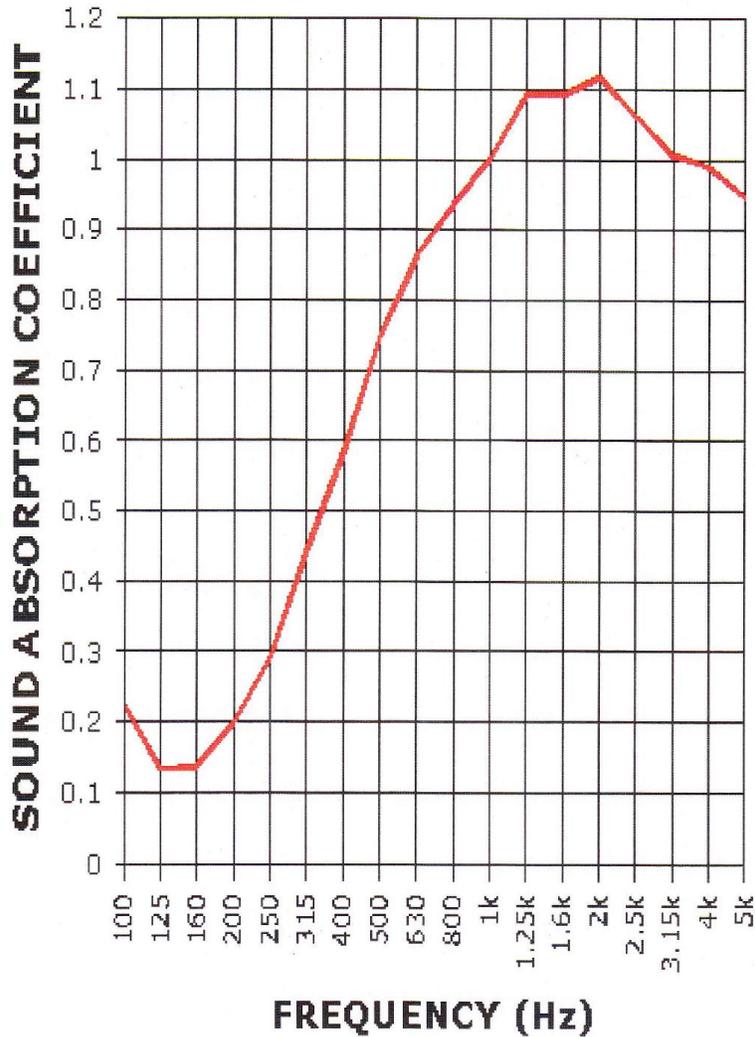
Alion Science and Technology

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## TEST REPORT

Page 4 of 4

### SOUND ABSORPTION REPORT RAL-A07-120



SAA=0.79  
NRC=0.80

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## **Appendix B. APG MIND Lab Noise Transmission Test Report**

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This appendix appears in its original form, without editorial change.

**BRUNE CONSULTING, LLC**  
619 WILTON ROAD  
TOWSON, MARYLAND 21286  
Voice (410) 296-7414  
Fax (410) 583-9659

February 26, 2013

Mr. Richard A. Von Lange  
TechStar Industries  
1124 South Paca Street  
Baltimore, MD 21230

Subject: APG MIND Lab Noise Transmission Test

References: (a) Excerpts from APG MIND Lab Specification (W911QX-11-P-0464, received by email from TechStar on February 6, 2013

Enclosures: (1) APG MIND Lab Noise Transmission Test Documentation, February 12, 2013, Brune Consulting, LLC

Dear Mr. Von Lange:

This letter reports our findings from the February 12, 2013 site visit to the APG MIND Lab for the purpose of collecting noise transmission data between test chambers at the lab. Photo documentation and results from the test are summarized in the Enclosure.

The noise transmission data collected on February 12 were collected with a Norsonic N-140 Real Time Sound Analyzer. The noise source was a Norsonic Dodecahedron loudspeaker. Source noise levels were measured at the 19 speaker locations exterior to the test chambers (Enclosure Figure 2) with the N-140. Space averaged received noise levels were measured inside the four test chambers by traversing each chamber with the N-140 while the speaker was at each of the speaker locations related to that chamber (reference Table 2 in the Enclosure).

Octave band reverberation times were measured for each chamber by bursting inflated paper bags and measuring decay times for the acoustic impulse with the N-140 Sound Analyzer.

The noise data contained in Enclosure (1) reveal the following;

1. All 4 chambers meet or exceed the NIC 50 criterion in Table 5 of Reference (a).
2. Chambers A, B, and D meet the octave-band noise reduction requirements of Table 5 within the +/- 3 dB tolerance.
3. Chamber C has minor noise reduction deficiencies in the four octave bands from 1000 Hz to 8000 Hz.
4. Reverberation times (RT) for the 4 chambers are low. The times for Chambers A and B are in good agreement. This is expected since they are mirror images. The RTs for (B/C),

SOLVING NOISE AND VIBRATION PROBLEMS THROUGH MEASUREMENT ANALYSIS AND DESIGN

Mr. Richard A. Von Lange  
February 26, 2013

D and C increase proportionally to volume, as predicted by the equation for RT.

Our conclusions are:

1. Noise transmission performance (NIC and Octave Band NR) of the 4 chambers meets or exceeds the specification requirements with the exception of noise reduction performance in 4 octave-bands for Chamber C. These deficiencies can likely be corrected by adjustments to the double-door seals at both ends of the chamber.
2. Acoustic reverberation in the chambers has been kept low by the application of sound absorptive panels.

Thanks for the opportunity to consult on your noise issue. Please telephone or email us if you have questions regarding this evaluation

Sincerely,



Bernard G. Brune  
For Brune Consulting, LLC

APG MIND LAB  
NOISE TRANSMISSION TEST DOCUMENTATION  
February 12, 2013

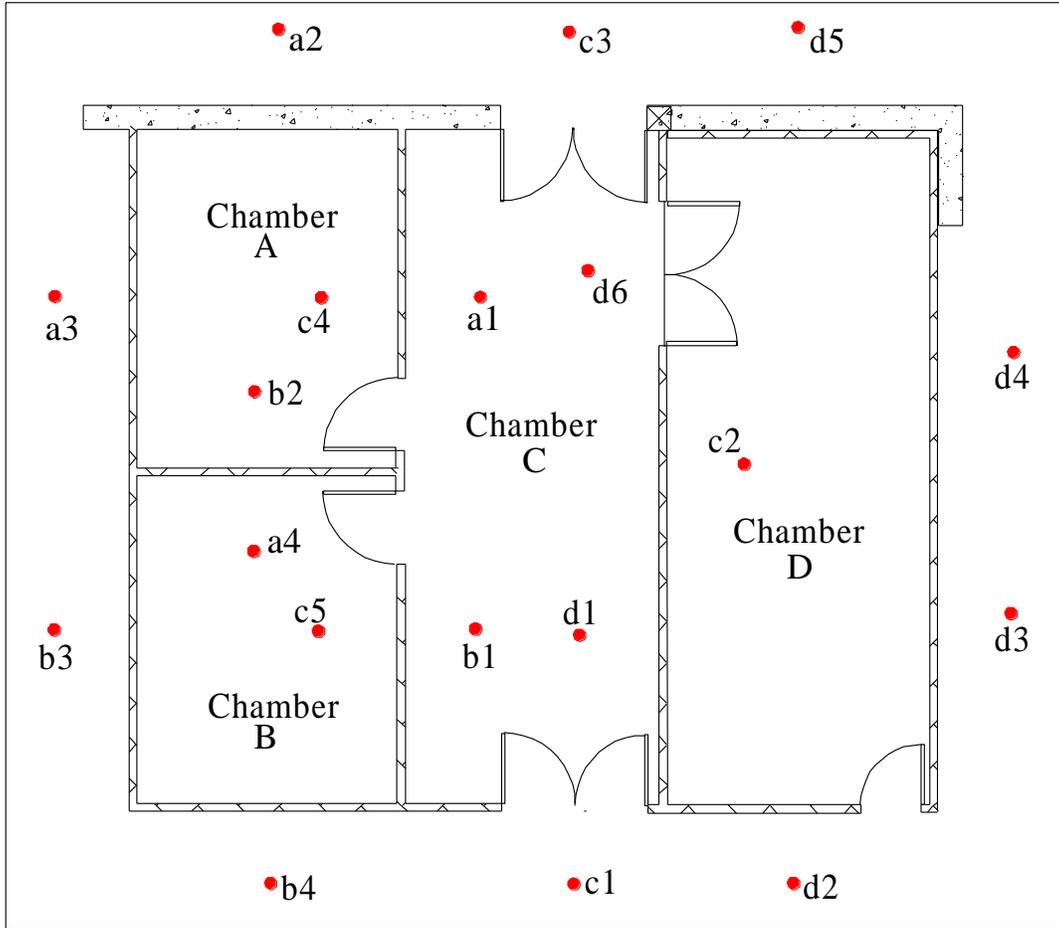
Enclosure 1  
TechStar Industries  
February 26, 2013



Figure 1 – Test Instrumentation in Chamber C

Table 1 – Test Instrumentation Descriptions

Item	Instrument	Manufacturer	Model	Serial	Calibration
1	Sound Analyzer	Norsonic	Type N-140	1403256	12-19-2012
2	Microphone	Norsonic	Type N-1225	96065	12-19-2012
3	Microphone Pre Amp	Norsonic	Type N-1209	13469	12-19-2012
4	Dodecahedron Loudspeaker	Norsonic	N-270	27031833	NA
5	Amplifier	Norsonic	N-260	2803920	NA



Notes:

1. Points a1 through d6 are noise source (speaker) locations
2. Noise response in the chambers is measured for each speaker location by traversing the room with the sound analyzer while the speaker is powered

Figure 2 – MIND Lab Test Locations

Table 2 – MIND Lab Noise Test Sequence

Source Off		Source On		Source On		Source On		Source On	
Location	Run # (Cool/Heat)	Loc	Run #						
A	1/77	A	20	B	54	C	37	D	49
a1		a1	18	b1	53	c1	32	d1	48
a2		a2		b2		c2		d2	
a3		a3		b3		c3		d3	
a4		a4		b4		c4		d4	
B	2/78	A	24	B	56	c5		d5	
b1		a1		b1		C	61	d6	
b2		a2	22	b2	55	c1		D	39
b3		a3		b3		c2	60	d1	
b4		a4		b4		c3		d2	38
C	3/79	A	26	B	28	c4		d3	
c1		a1		b1		c5		d4	
c2		a2		b2		C	51	d5	
c3		a3	25	b3	27	c1		d6	
c4		a4		b4		c2		D	41
c5		A	58	B	30	c3	50	d1	
D	4/80	a1		b1		c4		d2	
d1		a2		b2		c5		d3	40
d2		a3		b3		C	63	d4	
d3		a4	57	b4	29	c1		d5	
d4						c2		d6	
d5						c3		D	43
d6						c4	62	d1	
						c5		d2	
						C	65	d3	
						c1		d4	42
						c2		d5	
						c3		d6	
						c4		D	45
						c5	64	d1	
								d2	
								d3	
								d4	
								d5	44
								d6	
								D	47
								d1	
								d2	
								d3	
								d4	
								d5	
								d6	46

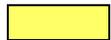
 Denotes Source (Speaker Locations)

Table 3 – Chamber A Noise Reduction

MEASURED AIRBORNE NOISE REDUCTION IN OCTAVE BANDS

PROJECT: APG Mind Lab

Chamber A

DESCRIPTION: Leq, Equivalent Airborne Noise Levels (dB re: 20 microPascals)

OB Cntr Freq	RUN NUMBER								NOISE REDUCTION						
	18	20	22	24	25	26	57	58	18-20	22-24	25-26	57-58	Avg	Spec	
8															
16															
32	72	57	77	50	79	58	81	68	15	27	20	13	19		
63	92	69	91	59	97	71	92	74	22	32	25	18	24		
125	107	76	106	57	108	72	107	72	31	50	36	34	38	25	
250	109	64	108	52	108	66	108	66	44	56	42	42	46	37	
500	97	47	102	40	101	50	97	46	50	62	51	50	53	48	
1000	94	36	97	29	97	39	92	33	58	68	57	59	61	55	
2000	96	33	96	25	98	33	92	30	63	71	65	62	65	59	
4000	94	30	97	21	96	27	94	29	64	76	69	65	68	60	
8000	78	19	80	17	80	19	75	19	59	63	61	56	60	58	
Meas Loc	a1	A	a2	A	a3	A	a4	A	Wall 1	Wall 2	Wall 3	Wall 4			

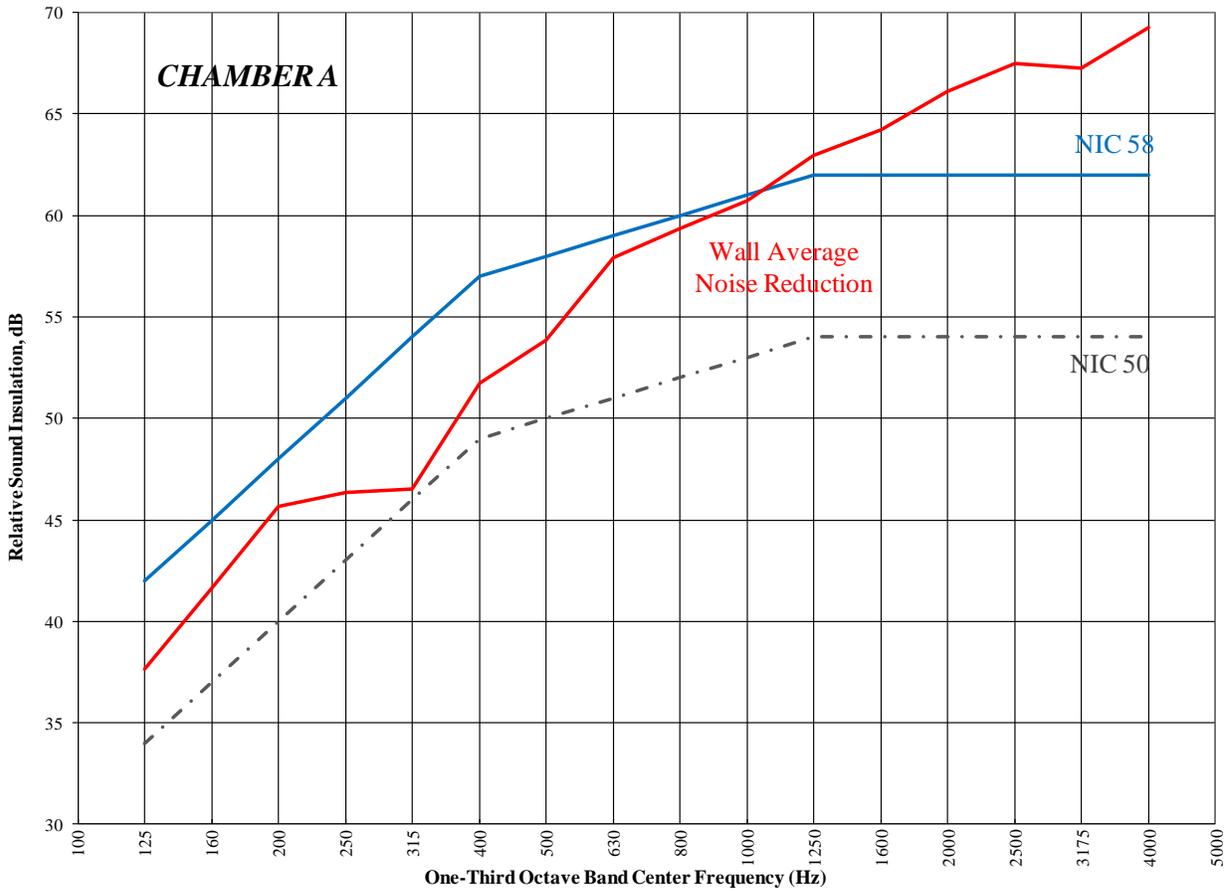


Figure 3 – Chamber A NIC Result

Table 4 – Chamber B Noise Reduction

MEASURED AIRBORNE NOISE REDUCTION IN OCTAVE BANDS

PROJECT: APG Mind Lab

Chamber B

DESCRIPTION: Leq, Equivalent Airborne Noise Levels (dB re: 20 microPascals)

OB Cntr Freq	RUN NUMBER								NOISE REDUCTION						
	53	54	55	56	27	28	29	30	53-54	55-56	27-28	29-30	Avg	Spec	
8															
16															
32	79	60	81	68	79	61	77	58	18	12	18	19	17		
63	88	69	93	76	90	70	92	65	19	17	20	28	21		
125	105	72	105	71	108	68	107	65	33	34	40	42	37	25	
250	106	64	107	66	108	63	108	64	42	40	44	44	43	37	
500	96	47	96	48	98	50	100	52	49	48	49	48	49	48	
1000	91	38	91	33	96	43	96	41	54	58	52	56	55	55	
2000	92	36	92	30	96	35	97	35	56	61	61	62	60	59	
4000	93	33	92	29	97	31	97	31	60	63	66	66	64	60	
8000	74	23	73	19	80	19	79	19	51	54	61	60	57	58	
Meas Loc	b1	B	b2	B	b3	B	b4	B	Wall 1	Wall2	Wall 3	Wall 4			

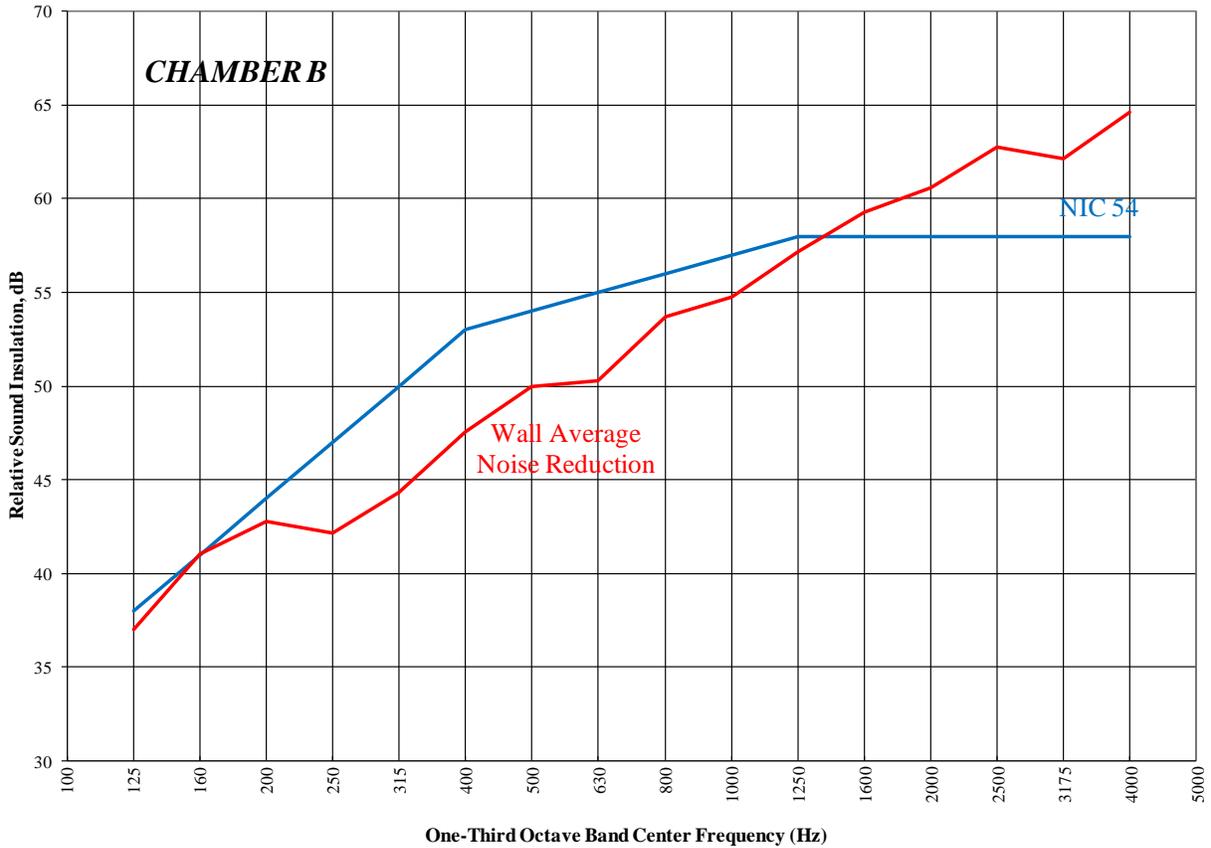


Figure 4 – Chamber B NIC Result

Table 5 – Chamber C Noise Reduction

MEASURED AIRBORNE NOISE REDUCTION IN OCTAVE BANDS

PROJECT: APG Mind Lab

Chamber C

DESCRIPTION: Leq, Equivalent Airborne Noise Levels (dB re: 20 microPascals)

OB Cntr Freq	RUN NUMBER									
	32	37	60	61	50	51	62	63	64	65
8										
16										
32	74	57	78	58	79	54	79	54	79	57
63	92	65	92	69	94	65	95	69	95	71
125	106	70	105	75	108	69	107	73	106	71
250	106	69	106	69	109	69	108	65	106	64
500	97	56	95	52	99	56	97	46	95	48
1000	92	48	91	42	96	50	93	35	90	42
2000	93	45	91	39	97	48	93	33	91	38
4000	94	42	93	38	98	44	94	31	91	36
8000	76	24	74	22	80	25	76	23	72	23
Meas Loc	e1	C	e2	C	e3	C	e4	C	e5	C

NOISE REDUCTION						
32-37	60-61	50-51	62-63	64-65	Avg	Spec
17	20	25	25	22	22	
27	23	29	25	24	26	
36	30	38	34	35	35	25
37	37	41	43	42	40	37
42	44	43	52	48	46	48
44	49	46	58	49	49	55
49	53	49	61	53	53	59
52	55	54	63	55	56	60
52	52	55	53	50	52	58
1	2	3	4	5		
Wall Segment						

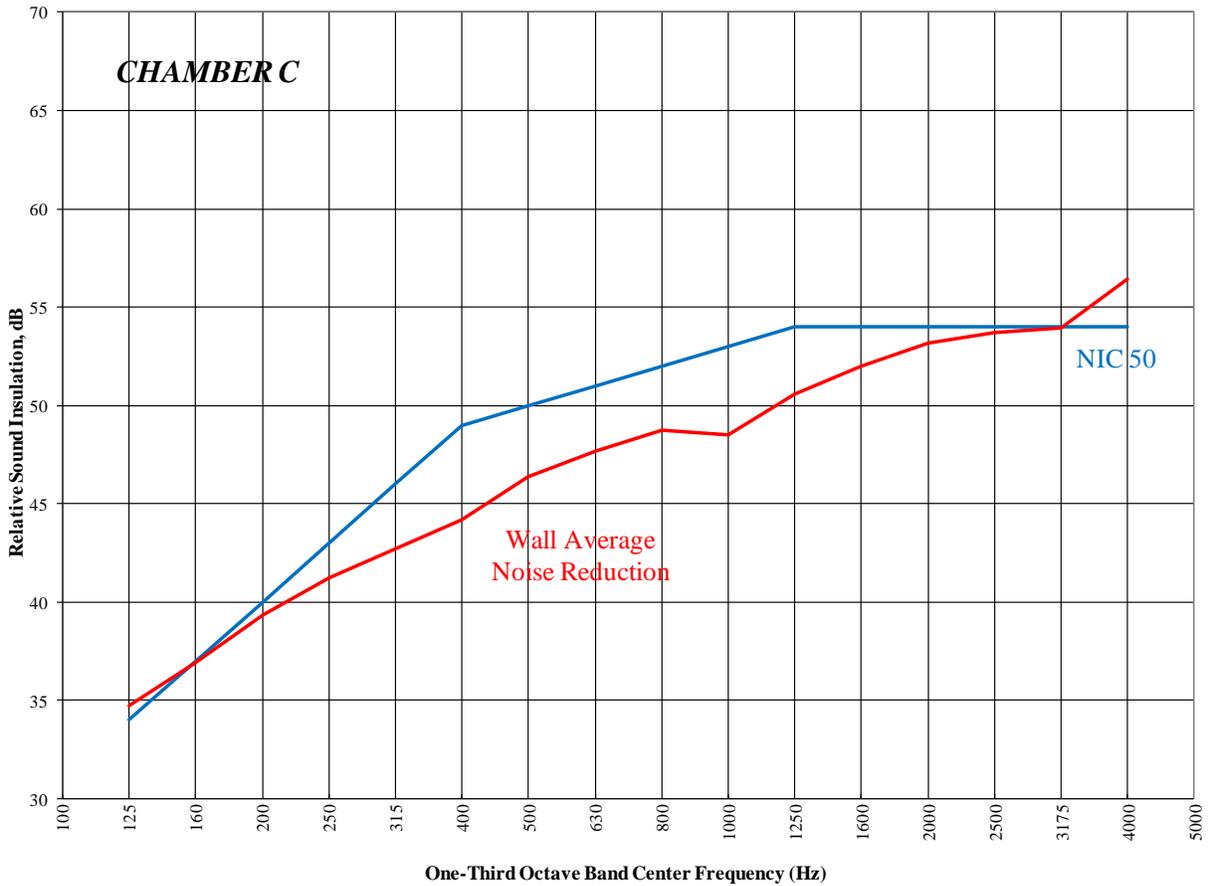


Figure 5 – Chamber C NIC Result

Table 6 – Chamber D Noise Reduction

MEASURED AIRBORNE NOISE REDUCTION IN OCTAVE BANDS

PROJECT: APG Mind Lab

Chamber D

DESCRIPTION: Leq, Equivalent Airborne Noise Levels (dB re: 20 microPascals)

OB Cntr Freq	RUN NUMBER											
	48	49	38	39	40	41	42	43	44	45	46	47
8												
16												
32	80	64	76	57	77	64	77	63	78	53	77	60
63	92	72	92	73	95	75	95	76	94	65	92	71
125	105	73	106	71	107	70	108	72	108	63	105	73
250	106	68	107	66	108	67	106	66	106	57	106	68
500	95	48	99	54	99	51	100	54	101	42	96	50
1000	91	38	95	46	95	40	97	45	96	32	92	42
2000	93	35	95	44	96	39	97	38	97	29	92	40
4000	92	32	96	39	96	33	97	36	96	26	94	36
8000	73	20	78	22	78	20	79	28	77	20	75	21
Meas Loc	d1	D	d2	D	d3	D	d4	D	d5	D	d6	D

NOISE REDUCTION							
48-49	38-39	40-41	42-43	44-45	46-47	Avg	Spec
16	18	14	14	24	17	17	
20	18	20	19	29	21	21	
32	35	36	35	44	32	36	25
38	41	41	40	49	38	41	37
47	44	48	46	58	45	48	48
53	49	54	52	63	50	54	55
57	51	56	60	68	52	57	59
60	57	63	61	70	57	61	60
53	55	58	52	57	54	55	58
1	2	3	4	5	6		
Wall Segment							

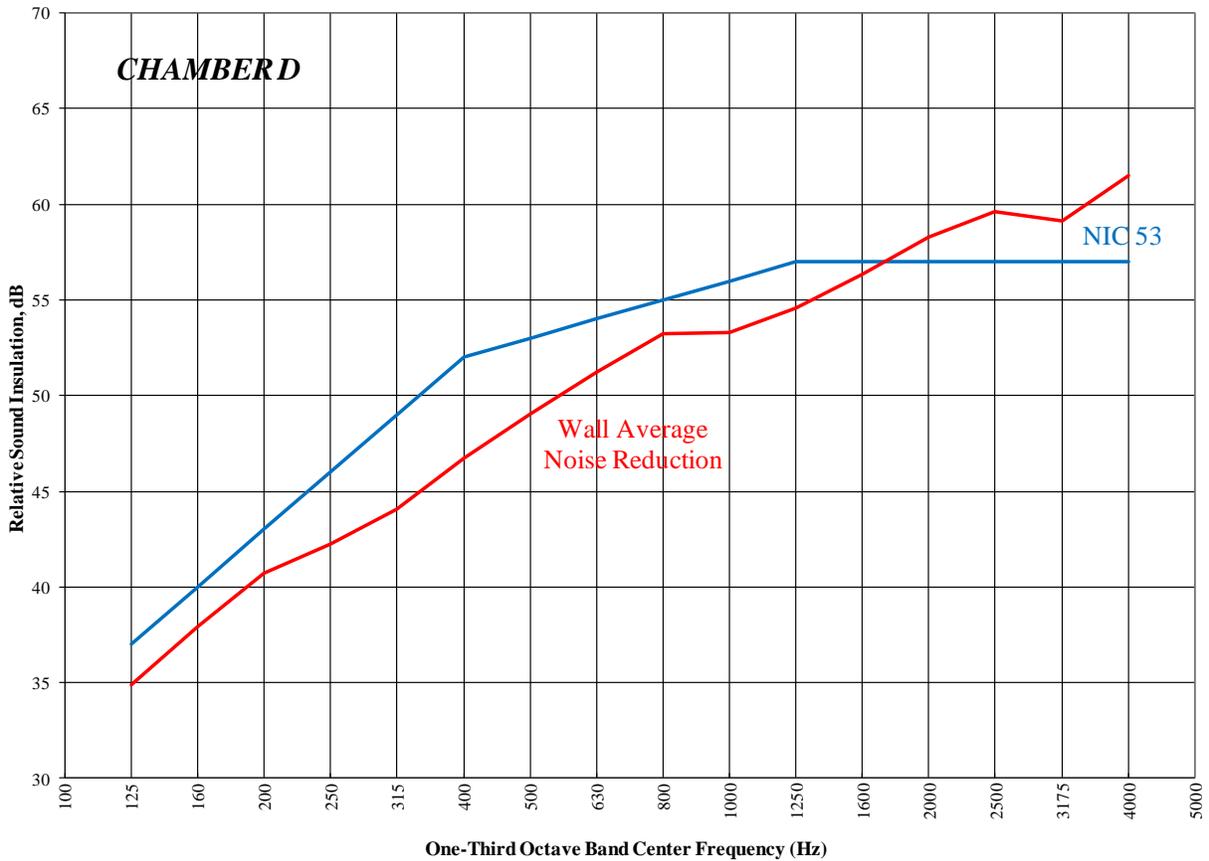


Figure 6 – Chamber D NIC Result

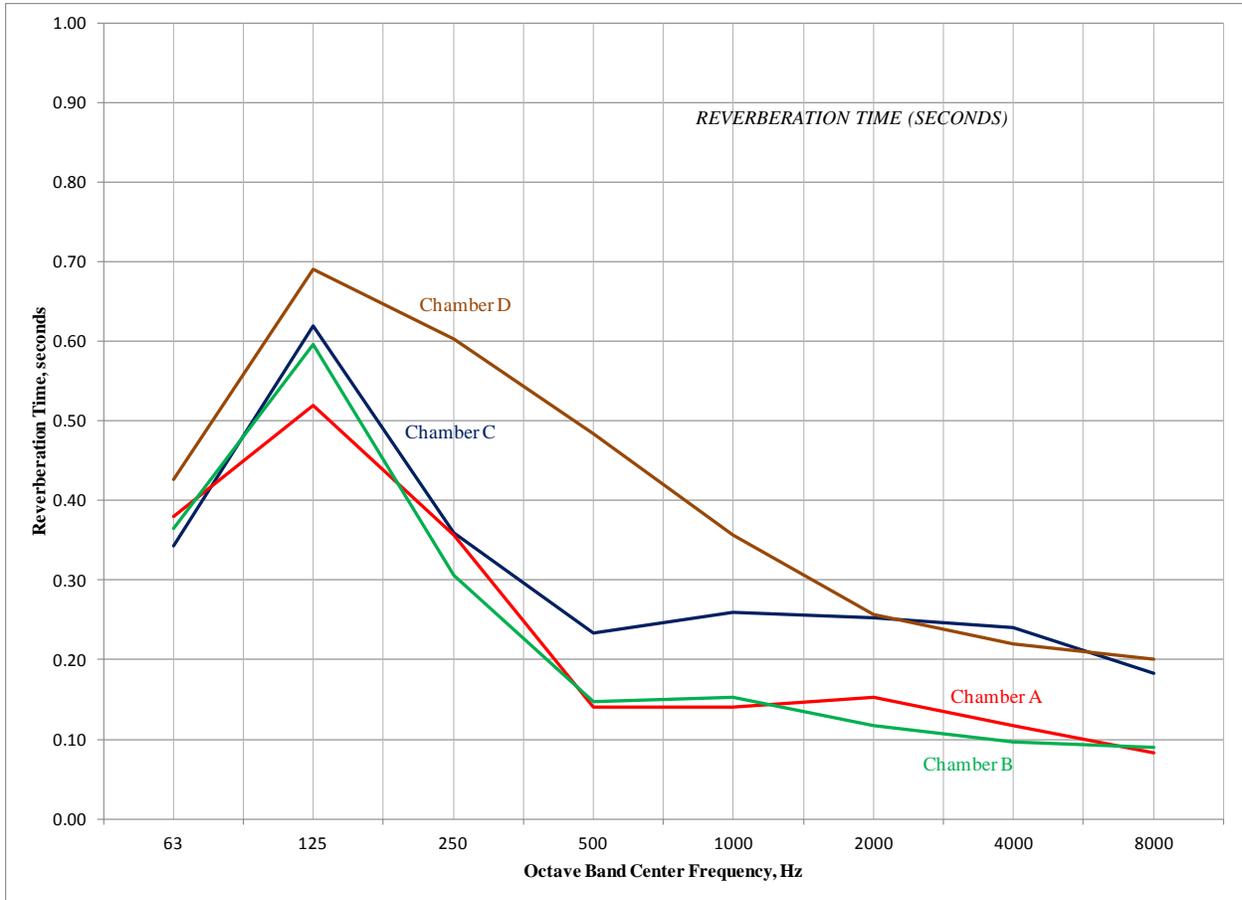


Figure 7 – Chamber Measured Reverberation Times

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## **Appendix C. Radio Frequency Isolation Report**

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The contents of the appendix have been altered only to remove sensitive information.

**RADIO FREQUENCY ISOLATION**

**TEST REPORT**

**(SHIELDING EFFECTIVENESS)**

**OF THE**

**M.I.N.D.**

**RESEARCH LAB**

**HYBRID ACOUSTIC / RF SHIELDED COMPLEX**

**AT**

**ABERDEEN PROVING GROUND**

**MARYLAND**

**PRIME CONTRACTOR**

**Techstar Industries**

**BALTIMORE, MD**

**TESTED BY  
HI-TECH SERVICES, INC  
FERNDAL, WA**

# **Radio Frequency Isolation Test Report**

**M.I.N.D. Research Lab  
Aberdeen Proving Grounds**

## **REFERENCE DOCUMENTS**

Contract Shielding Performance Requirements  
Mil Std 285, Methods for testing Radio Frequency Shielded Enclosures

## **REPORT OF TESTING**

This report documents the Radio Frequency Isolation (shielding effectiveness testing) of the M.I.N.D. Research Lab located in the basement of Building [REDACTED] at the Aberdeen Proving Grounds, Aberdeen, Maryland.

## **DESCRIPTION OF PROJECT**

The project consist of a hybrid acoustic/RF Shielded complex constructed by Tech Star Industries and as manufactured by Noise Barrier, Inc.

The walls and ceiling of the complex is built with 4" thick acoustic panels that are constructed with U channel framing covered on both sides with solid galvanized sheet metal. The interior is packed with insulation for acoustic qualities. The walls and ceiling panel joints are made using a joiner called an 'H' joiner, which provides a 'U' shaped or channel for each panel end to be engaged into. This provides for a uniform meeting of the channel joint and the edges of the panels.

The floor is set on a plywood underlayment fastened to the concrete floor. The plywood is covered with heavy gauge steel and the wall channel is set on the steel floor. Fasteners used in the floor are recessed and taped to prevent fortuitous contact with the fasteners going in to the concrete floor to avoid potential for unwanted spurious contact with rebar or other conductive qualities of the concrete.

## **RF Isolation Provisions**

The metal floor, walls and ceiling provide RF Isolation due to materials and assembly method as described above. The RF isolation characteristics are further enhanced with the implementation of copper tape with conductive adhesive applied to all joints. RF gasket is also installed under the wall channel and at all two, three and four way joints.

Doors are of special construction, implementing an RF mesh covered acoustic foam to form a perimeter seal around the door frame. RF Copper tape is applied to the door surface that makes contact with the frame mesh which provides for better conductivity and prevents corrosion which would degrade the RF Seal performance by covering the edge of the door.

A specially constructed door 'double door' bottom consisting of one section that is a standard acoustic seal and one section with RF fingerstock. Both are individually adjustable.

All electrical is filtered by RF Filters for each use of outlets and lighting.

Ether net cables for network access and phone lines are passed into the chamber with Fiber Optic Isolation Filters (FOIL). The ether net filters are capable of gigabit computer network speed over Cat 5 or 6 cables.

Fire Sprinkler pipes required to penetrate the enclosure walls are dielectrically isolated at the joint just prior to penetration through the walls of the chamber.

Fire alarm system wires are fed into the enclosure with RF Filters with a pass band specific to the alarm system requirements.

### **METHOD OF TESTING**

The RF Isolation test was conducted in accordance with the intent and general methodology of MIL-STD 285. This government test standard is the most widely used guidance in the RF Industry and provides the methodology for performing RF Isolation test of RF enclosures.

### **MEASUREMENT PROCEDURES**

The project RF performance criteria established the field components and frequencies which are to be tested.

In this case the project required testing a wide range of frequencies of three field components consisting of magnetic field, electric field and plane wave field frequencies.

An HP-8593A Spectrum Analyzer which covers all the frequencies in the project requirements was used for signal measurements.

Aberdeen Proving Ground personnel witnessed the test set up and the organization photographer documented each field component measurement set up and is assumed provided to the user under separate cover.

As outlined in Mil Std 285, each field component requires antennas specific to the field for optimal test evaluation and describes the method of performing each field component test.

## **ESTABLISHING TEST SIGNALS and RECORDING TEST RESULTS**

As required by Mil Std 285, for each frequency to be tested, a reference signal is established using equipment specifically designed for the specific test to be performed. The magnetic field requires a matched set of Loop Antennas, the electric field a matched set of both monopole for the lower electric field and bicon antennas for the upper range. The plane wave frequencies of 400 MHz and 1 GHz utilize a pair of log periodic antennas.

For each frequency, a 'reference level' signal is developed by adjusting the amplitude of the signal until a sufficient signal strength is established. This signal strength is 5-10 dB stronger than the required attenuation. Since the noise floor of the analyzer has a very wavy signal, you want a signal stronger than what you are measuring so that the signal can be seen above the noise floor if the RF Isolation shows signs of weakness.

The specific set up for each field component measured is described in detail in the below test set up descriptions.

The reference level is established in an open area of the test area. Once the reference level is achieved and documented on the Test Data Sheet, the transmitting antenna is set outside the test point and the receive antenna place on the other side of the test point at the prescribed spacing. The signal level received, if any, is recorded. The received signal is subtracted from the reference signal, the result being the amount of signal attenuated by the test point of the enclosure wall, door, connector panel or other test point. This recorded measurement is compared to the criteria to determine if the test point meets or exceeds the specified RF Isolation Criteria.

### **MAGNETIC FIELD TEST SET UP**

Magnetic field test set up consist of a pair of Loop antennas, one active and one passive ( receive antenna ). The active loop has a dial to adjust the frequency the loop emanates. The passive loop is connected to a Spectrum Analyzer to measure the strength of the signal being generated.

As per the methodology in the standard, the antennas are placed 25" apart. The signal strength of the active loop is increased with an amplifier until sufficient signal strength level is achieved to perform the test.

### **ELECTRIC FIELD TEST SET UP**

The lower electric field requires the use of monopole antennas. One monopole is on an active base with frequency range adjustments, the other monopole is the receive / passive antenna connected to the spectrum analyzer. The antennas are placed 25" apart to establish the required reference level.

The upper electric field requires a matched pair of Bicon Antennas. These antennas look like large egg beaters. They are placed 6' apart to establish the reference level signal require at each test frequency.

Once the reference level is obtained, space permitting, the radiating antenna is placed 6' from the exterior test point. The receive antenna is located on the opposite side of the wall, door or test point and the entire area from floor to ceiling and joint to joint is scanned. Penetrations and connector panels are scanned as part of a test point if they are in the vicinity of the test point.

### **PLANE WAVE TEST SET UP**

Plane wave measurements for the frequencies of 400 MHz and 1000 MHz (1 GHz) are tested using log periodic antennas which look like old roof top TV antennas. The elements are short at the front and gradually are longer toward the back. This provides an effective antenna matched to the characteristics of the Plane Wave which is a far field measurement as opposed to Magnetic and Electric Field Frequencies which are near field. This graduation in antenna element length allows the use of one antenna for all frequencies from 200 MHz to 1000 MHz.

### **DISCUSSION OF RF FIELD ATTENUATION CHARACTERISTICS**

The magnetic field requires a ferrous metal with mass adequate for the level of attenuation required. In this case, the two layers of galvanized sheet metal separated with a 4" air gap is ideal for the requirements of this project.

The Electric field is still of moderately long wavelength and will not travel through small gaps or holes in an RF Enclosure since the test is conducted in the near field of the wave length.

The electric field does not require mass. It requires a metallic surface of sufficient contact at joints and penetrations. The electric field basically shorts when it impinges on a metallic surface and will not leak through a sufficiently well-constructed grounded enclosure.

The Plane Wave frequencies of 400 MHz and 1000 MHz are the most difficult frequencies in the project specification. These frequencies are tested at approximately two wave lengths based on the antenna used and hence the wavelength is approaching a 'plane wave' in shape.

An RF enclosure must be very well constructed to obtain isolation at these frequencies as these frequencies will penetrate the slightest weakness in an RF Enclosure.

The project isolation criteria is similar to that prescribed in NSA 73-2A and is considered a moderate level of shielding. Given the basement location and the type of activity the enclosure will be utilized for, the specified level of isolation should be more than sufficient to prevent interference with research activities.

## **TEST POINTS**

As per Figure 1\*, enclosed as part of this test report, there were 28 discrete test points and 6 doors for a total of 34 test locations. Each location was tested at the 13 project designated frequencies. All total, 442 measurements were taken. All test points were tested from floor to ceiling and from one joint to the next. Doors were scanned around the entire perimeter of each door and frame unit. Interior rooms were tested from one to the next at all common walls.

Space permitting, all penetrations in the vicinity of a test point were scanned. At each test point on the outside, the transmit antenna was placed pointing above the chamber at the Plane Wave frequencies to look for any weakness in the ceiling or penetration. Due to prescribed antenna spacing, testing magnetic and electric fields in difficult areas to reach is impractical and if a weakness is in the shield construction, it will be seen at 1000 MHz regardless of antenna placement.

## **ENCLOSURES**

Project RF Isolation Performance Criteria  
Figure 1 Test Point Locations  
Field Test Data Sheets

## **PERIOD OF TESTING**

Testing was conducted over the period of 10 January through 23 January 2013. Results are based on the condition of the chamber at the time of testing. Any required modifications in the future will require coordination with the original Prime Contractor to ensure the RF attenuation characteristics of the enclosure are not compromised.

## **RESULTS OF TESTING**

During testing some weaknesses were identified in the enclosure. In each case, corrective action was taken and a re-test performed until the test point achieved the required attenuation or better prior to moving to the next test point. In general, additional gasket material or taping took care of any anomaly found. Door bottom finger seals were adjusted for optimal contact with the metal sill plate.

**As indicated by the Test Data Sheets, the enclosure met all criteria for RF Isolation at all frequencies.**

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\*Figure 1 is not included. See figure 23 in section 5.2 of the report.

<b>Field Component</b>	<b>Frequency</b>	<b>Isolation Required (in dB)</b>
Magnetic Field	1 KHz	10
	10 KHz	20
	100 KHz	30
	1 MHz	45
Electric Field	1 KHz	50
	10 KHz	50
	100 KHz	50
	1 MHz	50
	10 MHz	45
Plane Wave	100 MHz	50
	400 MHz	44
	1000 MHz	40

**TEST DATA SHEET**

Location: Mind Lab APG

Test Engineer: Henry Osgood Assisted by: N/A

Frequency: (PW) 1 GHz/1000MHz Required Attenuation: 40dB

	Test Point	Ref Lvl	Measured Lvl	Attenuation
1	D ext wall	60	5	55
2	D ext wall	60	5	55
3	D ext wall	60	0	60
4	D ext wall	60	0	60
5	D ext wall	60	0	60
6	D ext wall	60	0	60
7	D ext wall	60	5	55
8	D ext wall	60	10	50
9	C-A Ext Joint	60	15	45
10	A Ext wall	60	0	60
11	A Ext wall	60	0	60
12	A Ext wall	60	0	60
13	A Ext wall	60	0	60
14	A Ext wall	60	0	60
15	A Ext wall	60	0	60
16	B outside	60	0	60
17	B outside	60	0	60
18	B outside	60	0	60
19	B outside	60	0	60
20	B outside	60	0	60
21	B outside	60	10	50
22	C-D ext joint	60	15	45
23	C-D Common wall	60	15	45
24	C-D Common wall	60	15	45
25	C-D Common wall	60	15	45
26	B-C wall	60	15	45
27	A-B wall	60	15	45
28	A-C wall	60	15	45
D-1	Chamber D door	60	18	42
D-2	C-D door	60	15	45
D-3	Chamber C door	60	18	42
D-4	Chamber C door	60	17	43
D-5	Chamber A door	60	15	45
D-6	Chamber B door	60	15	45

**TEST DATA SHEET**

Location: Mind Lab APG

Test Engineer: Henry Osgood Assisted by: N/A

Frequency: (PW) 400 MHz Required Attenuation: 44db

	Test Point	Ref Lvl	Measured Lvl	Attenuation
1	D ext wall	60	5	55
2	D ext wall	60	0	60
3	D ext wall	60	0	60
4	D ext wall	60	0	60
5	D ext wall	60	0	60
6	D ext wall	60	0	60
7	D ext wall	60	0	60
8	D ext wall	60	10	50
9	C-A Ext Joint	60	10	50
10	A Ext wall	60	0	60
11	A Ext wall	60	0	60
12	A Ext wall	60	0	60
13	A Ext wall	60	0	60
14	A Ext wall	60	0	60
15	A Ext wall	60	0	60
16	B outside	60	0	60
17	B outside	60	0	60
18	B outside	60	0	60
19	B outside	60	0	60
20	B outside	60	0	60
21	B outside	60	12	48
22	C-D ext joint	60	15	45
23	C-D Common wall	60	15	45
24	C-D Common wall	60	15	45
25	C-D Common wall	60	15	45
26	B-C wall	60	15	45
27	A-B wall	60	15	45
28	A-C wall	60	15	45
D-1	Chamber D door	60	15	45
D-2	C-D door	60	16	44
D-3	Chamber C door	60	15	45
D-4	Chamber C door	60	10	50
D-5	Chamber A door	60	12	48
D-6	Chamber B door	60	12	48

**TEST DATA SHEET**

Location: Mind Lab APG

Test Engineer: Henry Osgood Assisted by: N/A

Frequency: (PW) 100 MHz Required Attenuation: 50db

	Test Point	Ref Lvl	Measured Lvl	Attenuation
1	D ext wall	60	5	55
2	D ext wall	60	0	60
3	D ext wall	60	0	60
4	D ext wall	60	0	60
5	D ext wall	60	0	60
6	D ext wall	60	0	60
7	D ext wall	60	0	60
8	D ext wall	60	0	60
9	C-A Ext Joint	60	5	55
10	A Ext wall	60	0	60
11	A Ext wall	60	0	60
12	A Ext wall	60	0	60
13	A Ext wall	60	0	60
14	A Ext wall	60	0	60
15	A Ext wall	60	0	60
16	B outside	60	0	60
17	B outside	60	0	60
18	B outside	60	0	60
19	B outside	60	0	60
20	B outside	60	0	60
21	B outside	60	0	60
22	C-D ext joint	60	5	55
23	C-D Common wall	60	10	50
24	C-D Common wall	60	10	50
25	C-D Common wall	60	10	50
26	B-C wall	60	10	50
27	A-B wall	60	10	50
28	A-C wall	60	10	50
D-1	Chamber D door	60	10	50
D-2	C-D door	60	10	50
D-3	Chamber C door	60	10	50
D-4	Chamber C door	60	10	50
D-5	Chamber A door	60	5	55
D-6	Chamber B door	60	5	55

**TEST DATA SHEET**

Location: Mind Lab APG

Test Engineer: Henry Osgood Assisted by: N/A

Frequency: (E) 10 MHz Required Attenuation: 45db

	Test Point	Ref Lvl	Measured Lvl	Attenuation
1	D ext wall	60	0	55
2	D ext wall	60	0	60
3	D ext wall	60	0	60
4	D ext wall	60	0	60
5	D ext wall	60	0	60
6	D ext wall	60	0	60
7	D ext wall	60	0	60
8	D ext wall	60	0	60
9	C-A Ext Joint	60	5	55
10	A Ext wall	60	0	60
11	A Ext wall	60	0	60
12	A Ext wall	60	0	60
13	A Ext wall	60	0	60
14	A Ext wall	60	0	60
15	A Ext wall	60	0	60
16	B outside	60	0	60
17	B outside	60	0	60
18	B outside	60	0	60
19	B outside	60	0	60
20	B outside	60	0	60
21	B outside	60	0	60
22	C-D ext joint	60	5	55
23	C-D Common wall	60	5	55
24	C-D Common wall	60	5	55
25	C-D Common wall	60	5	55
26	B-C wall	60	5	55
27	A-B wall	60	5	55
28	A-C wall	60	5	55
D-1	Chamber D door	60	5	55
D-2	C-D door	60	8	52
D-3	Chamber C door	60	10	50
D-4	Chamber C door	60	10	50
D-5	Chamber A door	60	8	52
D-6	Chamber B door	60	5	55

**TEST DATA SHEET**

Location: Mind Lab APG

Test Engineer: Henry Osgood Assisted by: N/A

Frequency: (E) 1 MHz Required Attenuation: 50db

	Test Point	Ref Lvl	Measured Lvl	Attenuation
1	D ext wall	60	0	50+
2	D ext wall	60	0	50+
3	D ext wall	60	0	50+
4	D ext wall	60	0	50+
5	D ext wall	60	0	50+
6	D ext wall	60	0	50+
7	D ext wall	60	0	50+
8	D ext wall	60	0	50+
9	C-A Ext Joint	60	0	50+
10	A Ext wall	60	0	50+
11	A Ext wall	60	0	50+
12	A Ext wall	60	0	50+
13	A Ext wall	60	0	50+
14	A Ext wall	60	0	50+
15	A Ext wall	60	0	50+
16	B outside	60	0	50+
17	B outside	60	0	50+
18	B outside	60	0	50+
19	B outside	60	0	50+
20	B outside	60	0	50+
21	B outside	60	0	50+
22	C-D ext joint	60	0	50+
23	C-D Common wall	60	5	55
24	C-D Common wall	60	5	55
25	C-D Common wall	60	5	55
26	B-C wall	60	5	55
27	A-B wall	60	5	55
28	A-C wall	60	5	55
D-1	Chamber D door	60	5	55
D-2	C-D door	60	5	55
D-3	Chamber C door	60	5	55
D-4	Chamber C door	60	5	55
D-5	Chamber A door	60	0	60
D-6	Chamber B door	60	0	60

**TEST DATA SHEET**

Location: Mind Lab APG

Test Engineer: Henry Osgood Assisted by: N/A

Frequency: (E) 10 KHz Required Attenuation: 50db

	Test Point	Ref Lvl	Measured Lvl	Attenuation
1	D ext wall	65	5	60
2	D ext wall	65	0	65
3	D ext wall	65	0	65
4	D ext wall	65	0	65
5	D ext wall	65	0	65
6	D ext wall	65	0	65
7	D ext wall	65	0	65
8	D ext wall	65	8	57
9	C-A Ext Joint	65	10	55
10	A Ext wall	65	0	65
11	A Ext wall	65	0	65
12	A Ext wall	65	0	65
13	A Ext wall	65	0	65
14	A Ext wall	65	0	65
15	A Ext wall	65	0	65
16	B outside	65	0	65
17	B outside	65	0	65
18	B outside	65	0	65
19	B outside	65	0	65
20	B outside	65	0	65
21	B outside	65	8	57
22	C-D ext joint	65	10	55
23	C-D Common wall	65	5	60
24	C-D Common wall	65	5	60
25	C-D Common wall	65	5	60
26	B-C wall	65	5	60
27	A-B wall	65	5	60
28	A-C wall	65	5	60
D-1	Chamber D door	65	8	57
D-2	C-D door	65	10	55
D-3	Chamber C door	65	12	53
D-4	Chamber C door	65	12	53
D-5	Chamber A door	65	5	60
D-6	Chamber B door	65	5	60

**TEST DATA SHEET**

Location: Mind Lab APG

Test Engineer: Henry Osgood Assisted by: N/A

Frequency: (E) 1 KHz Required Attenuation: 50db

	Test Point	Ref Lvl	Measured Lvl	Attenuation
1	D ext wall	70	10	60
2	D ext wall	70	0	70
3	D ext wall	70	0	70
4	D ext wall	70	0	70
5	D ext wall	70	0	70
6	D ext wall	70	0	70
7	D ext wall	70	0	70
8	D ext wall	70	12	58
9	C-A Ext Joint	70	15	55
10	A Ext wall	70	0	70
11	A Ext wall	70	0	70
12	A Ext wall	70	0	70
13	A Ext wall	70	0	70
14	A Ext wall	70	0	70
15	A Ext wall	70	0	70
16	B outside	70	0	70
17	B outside	70	0	70
18	B outside	70	0	70
19	B outside	70	0	70
20	B outside	70	0	70
21	B outside	70	10	60
22	C-D ext joint	70	10	60
23	C-D Common wall	70	15	55
24	C-D Common wall	70	15	55
25	C-D Common wall	70	15	55
26	B-C wall	70	15	55
27	A-B wall	70	15	55
28	A-C wall	70	15	55
D-1	Chamber D door	70	10	60
D-2	C-D door	70	12	58
D-3	Chamber C door	70	17	53
D-4	Chamber C door	70	17	53
D-5	Chamber A door	70	5	65
D-6	Chamber B door	70	5	65

**TEST DATA SHEET**

Location: Mind Lab APG

Test Engineer: Henry Osgood Assisted by: N/A

Frequency: (M) 1 KHz Required Attenuation: 45db

	Test Point	Ref Lvl	Measured Lvl	Attenuation
1	D ext wall	55	5	50
2	D ext wall	55	0	55
3	D ext wall	55	0	55
4	D ext wall	55	0	55
5	D ext wall	55	0	55
6	D ext wall	55	0	55
7	D ext wall	55	0	55
8	D ext wall	55	5	50
9	C-A Ext Joint	55	5	50
10	A Ext wall	55	0	55
11	A Ext wall	55	0	55
12	A Ext wall	55	0	55
13	A Ext wall	55	0	55
14	A Ext wall	55	0	55
15	A Ext wall	55	0	55
16	B outside	55	0	55
17	B outside	55	0	55
18	B outside	55	0	55
19	B outside	55	0	55
20	B outside	55	0	55
21	B outside	55	3	52
22	C-D ext joint	55	4	51
23	C-D Common wall	55	8	47
24	C-D Common wall	55	6	49
25	C-D Common wall	55	8	47
26	B-C wall	55	7	48
27	A-B wall	55	8	47
28	A-C wall	55	8	47
D-1	Chamber D door	55	5	50
D-2	C-D door	55	8	47
D-3	Chamber C door	55	10	45
D-4	Chamber C door	55	8	47
D-5	Chamber A door	55	5	50
D-6	Chamber B door	55	5	50

**TEST DATA SHEET**

Location: Mind Lab APG

Test Engineer: Henry Osgood Assisted by: N/A

Frequency: (M) 100 KHz Required Attenuation: 30db

	Test Point	Ref Lvl	Measured Lvl	Attenuation
1	D ext wall	40	5	35
2	D ext wall	40	>3	37
3	D ext wall	40	>3	37
4	D ext wall	40	>3	37
5	D ext wall	40	>3	37
6	D ext wall	40	>3	37
7	D ext wall	40	>3	37
8	D ext wall	40	>3	37
9	C-A Ext Joint	40	5	35
10	A Ext wall	40	>3	37
11	A Ext wall	40	>3	37
12	A Ext wall	40	>3	37
13	A Ext wall	40	>3	37
14	A Ext wall	40	>3	37
15	A Ext wall	40	>3	37
16	B outside	40	>3	37
17	B outside	40	>3	37
18	B outside	40	>3	37
19	B outside	40	>3	37
20	B outside	40	>3	37
21	B outside	40	5	40
22	C-D ext joint	40	7	33
23	C-D Common wall	40	>6	34
24	C-D Common wall	40	>6	34
25	C-D Common wall	40	>6	34
26	B-C wall	40	>6	34
27	A-B wall	40	>6	34
28	A-C wall	40	>6	34
D-1	Chamber D door	40	5	35
D-2	C-D door	40	8	32
D-3	Chamber C door	40	7	33
D-4	Chamber C door	40	6	34
D-5	Chamber A door	40	>5	35
D-6	Chamber B door	40	>5	35

**TEST DATA SHEET**

Location: Mind Lab APG

Test Engineer: Henry Osgood Assisted by: N/A

Frequency: (M) 10 KHz Required Attenuation: 20db

	Test Point	Ref Lvl	Measured Lvl	Attenuation
1	D ext wall	35	5	30
2	D ext wall	35	0	35
3	D ext wall	35	0	35
4	D ext wall	35	0	35
5	D ext wall	35	0	35
6	D ext wall	35	0	35
7	D ext wall	35	0	35
8	D ext wall	35	3	32
9	C-A Ext Joint	35	4	31
10	A Ext wall	35	0	35
11	A Ext wall	35	0	35
12	A Ext wall	35	0	35
13	A Ext wall	35	0	35
14	A Ext wall	35	0	35
15	A Ext wall	35	0	35
16	B outside	35	0	35
17	B outside	35	0	35
18	B outside	35	0	35
19	B outside	35	0	35
20	B outside	35	0	35
21	B outside	35	5	30
22	C-D ext joint	35	7	28
23	C-D Common wall	35	10	25
24	C-D Common wall	35	10	25
25	C-D Common wall	35	8	27
26	B-C wall	35	7	28
27	A-B wall	35	5	30
28	A-C wall	35	8	27
D-1	Chamber D door	35	5	30
D-2	C-D door	35	10	25
D-3	Chamber C door	35	8	27
D-4	Chamber C door	35	8	27
D-5	Chamber A door	35	5	30
D-6	Chamber B door	35	5	30

**TEST DATA SHEET**

Location: Mind Lab APG

Test Engineer: Henry Osgood Assisted by: N/A

Frequency: (M) 1 KHz Required Attenuation: 10db

	Test Point	Ref Lvl	Measured Lvl	Attenuation
1	D ext wall	18	3	15
2	D ext wall	18	0	18
3	D ext wall	18	0	18
4	D ext wall	18	0	18
5	D ext wall	18	0	18
6	D ext wall	18	0	18
7	D ext wall	18	0	18
8	D ext wall	18	4	14
9	C-A Ext Joint	18	5	13
10	A Ext wall	18	0	18
11	A Ext wall	18	0	18
12	A Ext wall	18	0	18
13	A Ext wall	18	0	18
14	A Ext wall	18	0	18
15	A Ext wall	18	0	18
16	B outside	18	0	18
17	B outside	18	0	18
18	B outside	18	0	18
19	B outside	18	0	18
20	B outside	18	0	18
21	B outside	18	2	16
22	C-D ext joint	18	0	18
23	C-D Common wall	18	>2	16
24	C-D Common wall	18	>2	16
25	C-D Common wall	18	>2	16
26	B-C wall	18	>2	16
27	A-B wall	18	>2	16
28	A-C wall	18	>2	16
D-1	Chamber D door	18	0	18
D-2	C-D door	18	>3	15
D-3	Chamber C door	18	>3	15
D-4	Chamber C door	18	>3	15
D-5	Chamber A door	18	0	18
D-6	Chamber B door	18	0	18

# **SUPPLEMENTAL TEST REPORT**

## **MIND LAB**

### **ABERDEEN PROVING GROUND, MD**

On Thursday March 28, 2013 additional testing was conducted for the purpose of determining and verifying that the RF Isolation of the MIND LAB enclosure were not compromised by the fire alarm system amber warning and annunciation speaker wiring.

Since the wiring is 'shielded' wire, a test was performed to determine the level of RF Shielding afforded by the shielded wire.

#### Method of Test:

A high gain dual ridge horn antenna was used to radiate a 1 GHz signal with an amplitude of 70 dB directly on to the wiring on the outside of the enclosure at the entry point of the wiring. On the inside of the MIND lab enclosure, a matched dual ridge horn with coax to a spectrum analyzer was placed in close proximity (within 2") of the wiring as it enters the MIND lab interior wall.

No signal was measured with this technique, indicating that the shielded wiring provides a RF Isolation performance which exceeds the required isolation specification of the MIND lab.

Upon determining that the wiring isolation exceeded the performance specification, each point of ingress and egress of the wiring was tested to verify that the method of bonding the wiring on each side of the walls of each entry point was done well enough to maintain the requisite level of RF Isolation.

Based on the above testing, it was determined that the fire alarm shielded wiring and the method of bonding the wiring on both sides of each wall does not compromise the isolation performance of the MIND lab.

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