SCIFs - State of the Art and Future Considerations

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Abstract

This paper will examine the different constructive and technical measures employed by governmental, non-governmental, and corporate actors to protect their secret communications in the physical realm. It will define the target ideal state of "information security", identify information sources that must be controlled to reach this state, set up quantitative limits on these information sources discoverable externally, provide example attack techniques, and propose various passive and active countermeasures to reach these limits and defend against these attacks. Finally it will present an example module that achieves these specifications measurably.

Note, this paper is limited in scope to constructive and technical measures and does not focus on IT or organizational security measures, like encryption, security-related review/monitoring of employees, and classification levels. It also does not dwell on specific countries' bureaucratic protocols, but instead aims to present a unified picture of the global state of the art and an outlook on future improvements.

Contents

1 What is a SCIF?

Sensitive Compartmented Information Facility (SCIF) is a term used by U.S. military and intelligence organizations to describe secure, enclosed areas designed for handling sensitive, classified information. They come in many different shapes and sizes, each designed for a specific mission demand. They can be installed permanently in buildings, aboard aircraft or naval vessels, designed as mobile units or set up temporarily. What unites all SCIF variants is the common goal of creating a designated space with rigorous security practices that thwart all relevant passive outside observers and active attackers.

SCIFs are by no means exclusive to U.S. government institutions. They are used internationally by a wide range of actors, from other governments to international organizations to corporations and NGOs. The term SCIF has become the most commonly used and will also be used in this paper to refer to structures specifically built to protect information processed/discussed inside them.

Most countries keep their specifications for these secure facilities secret. The United States, however, have published comprehensive information on their engineering practices under Intelligence Community Directive (ICD) 705 “Sensitive Compartmented Information Facilities” and its associated technical specifications. ICD 705 will serve as a basis for this paper. It will be supplemented by private contractors’ informational material, documents released under the Freedom of Information Act (FOIA), leaked documents, and scientific literature to create a comprehensive picture of the current state of the art and an outlook on future improvements.

2 Information Security - Ideal State and Practical Tradeoffs

A communication link or room is considered secure if information travelling through it cannot be intercepted by unauthorized parties. This is a theoretical ideal state that *cannot* be reached. However, one can employ various countermeasures to secure a communication link or room to such a degree that it can be practically considered secure against an attacker with certain resources.

Both defenders and attackers are constrained by limited resources. Viewing attack techniques from a resource perspective allows a defender to determine whether they are "in scope", given the threat level, and if countermeasures must be deployed against them. Resources are best expressed in terms of cost, time, and technical skill required. Taking into account these parameters, the defender is able to develop a mission-specific threat model that allows him to employ his *limited* resources effectively to defend against the most likely and serious attacks.

The IC Tech Spec-for ICD/ICS 705 (National Counterintelligence and Security Center 2012, p. 20) bases its threat modelling on country-level threat ratings derived from the Department of State's (DoS) Security Environment Threat List (SETL). Specifically, the ICD establishes appropriate construction criteria based on the host country's SETL technical threat rating. A country-level view is most useful for government organizations, however, other actors, especially corporate actors, may have to rely on different factors to determine threat level. Other possible criteria from which to derive a threat level include value of information handled and named/identified threats.

The fundamental assumption for threat modelling is that it is highly unlikely for an attacker to expend more resources to carry out an attack than the objective value of the attainable information.

3 Passive Attacks

3.1 The Passive Outside Observer

There are various information sources that can leak from the secure facility and be intercepted. These can generally be grouped into visual, acoustic, and electromagnetic information source leaks. A passive observer can use different sensors, like telescopic cameras, directional microphones, and high-sensitivity anntenae, to capture and analyze these information source leaks in order to draw conclusions about the sensitive information processed. A covert location outside the SCIF perimeter is almost impossible to detect and counteract. Therefore, information leaks must be prevented at the source.

3.2 Visual Protection

Visual insights are any direct view of sensitive information or surface whose reverberations can be captured with a laser and then translated into usable information. When speaking, glass panes or mirrors in a room are set into vibration. When there is visual insight into the room (e.g. from the neighboring building), a laser beam can be directed onto these reflecting surfaces and the reflected beam can be received again. The reflected beam is modulated by the oscillations. By demodulation, the conversation can be made audible (Wolfsperger 2008, p. 463). Direct views can also provide valuable insights into information processed and even serve as a basis for other attacks, like lip-reading of sensitive discussions.

Barring holes in the SCIF perimeter, like propped-open doors, visual leaks can only be captured through windows.

Figure 1: Laser Microphone Sptectra M+

Table 1: Passive Attack Techniques Overview - Visual

Capture Technique	Cost	Time	Technical Skill Required
Direct View	medium	low	low
Lip Reading	medium	low	medium
Reverberations Captured by Laser	*high*	low	medium

3.3 Acoustic Leaks

Acoustic leaks are sound waves that escape the enclosed areas, either directly or through structure-borne sound transmission. These can be captured with directional microphones, contact microphones, and well placed conventional microphones. An example of such an advantageous placement would be in an unmuffled ventilation or heating duct.

Acoustic leaks provide some of the most valuable insights. Discussions, conferences, and chatter contain secrets in their purest form. Through them, an attacker not only attains sensitive material, but he also gains insight into underlying priorities and considerations, much more so than from a leaked document. Like Christoph Waltz's character from the 2009 Quentin Tarantino film "Inglourious Basterds" says "I love rumors! Facts can be so misleading, where rumors, true or false, are often revealing."

Figure 2: Parabolic Microphone G-PKS PRO EX

Digital sound processing software can further enhance an outside passive attackers capabilites to reconstruct, clarify, and analyze sound leaks.

Table 2: Passive Attack Techniques Overview - Acoustic

Capture Technique	Cost	Time	Technical Skill Required
Directional Microphones	*medium*	low	low
Contact Microphones	*low*	medium	medium
Conventional Microphones	low	medium	medium

3.4 Electromagnetic/TEMPEST Leaks

Compromising electromagnetic waves unintentionally emitted from information processing equipment, like computers, screens, and even printers are another source for information leaks. These radio or electrical signals, sounds, and vibrations can be captured with antennae, microphones, and other sensors, and allow inferences to be drawn about the information processed, sometimes even allowing its complete reconstruction (Liu, Samwel, Weissbart, Zhao, Lauret, Batina, Larson 2020). They can also serve as a side-channel for attacks on cryptography (Genkin, Pachmanov, Pipman, Tromer 2015). The techniques for extraction and analysis of compromising electromagnetic emanations fall under the commonly used U.S. National Security Agency codename TEMPEST (U.S. National Security Agency 1972).

These attack techniques require high technical skill to develop, however once established are easy and fast to reproduce with *affordable equipment*. Although execution is fast, reconnaissance, planning and setup, especially for well-protected facilities, can entail significant time expenditure.

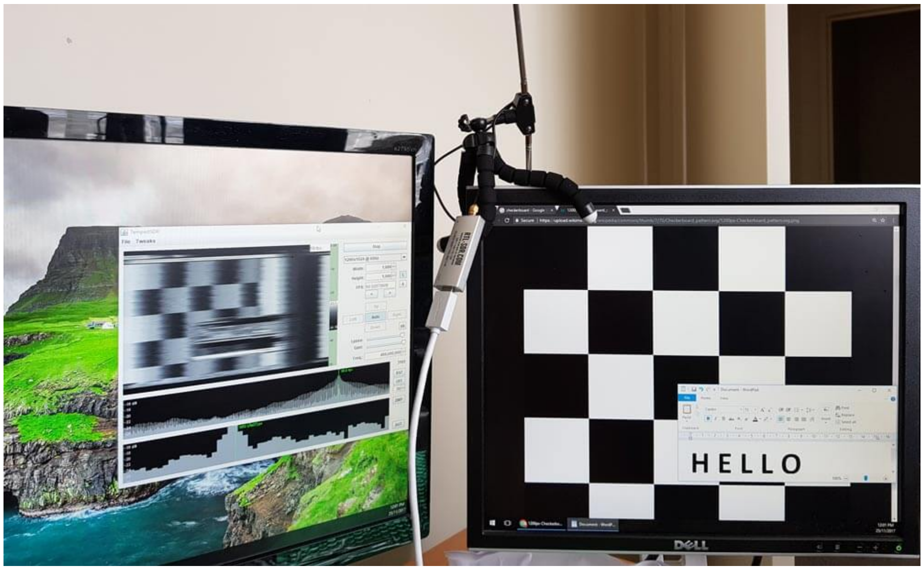


Figure 3: Display of a Monitor Reproduced on another Using its TEMPEST Emanations and a $40 Software Defined Radio + Antenna Setup (RTL-SDR.com 2017)

Table 3: Passive Attack Techniques Overview - Electromagnetic

Capture Technique	Cost	Time	Technical Skill Required
Direct Leaks	low	medium	high
Side-channel on Cryptography	low	medium	high

4 Limits

4.1 Why Set Up Quantitative Limits?

This section will set quantitative limits on information sources available to an outside passive observer. Since information source leaks must be protected at the source, it is important to know the extent of attenuation necessary to ensure adequate protection.

4.2 Visual Insights

No visual information should be accessible to an outside passive observer. Visual information source leaks are the easiest to avoid and should therefore be wholly prevented. Even observation of the entrypoint could provide insights into the comings and goings of authorized personnel and should therefore be obscured as much as possible.

4.3 Acoustic Attenuation

Acoustic emissions must be reduced by at least a weighted sound reduction index of $R'_w = 53$ dB. This measure roughly corresponds to the Sound Transmission Class 50 listed in the IC Tech Spec-for ICD/ICS 705 as an enhanced rating for areas that provide for amplified conversations (National Counterintelligence and Security Center 2012, p. 66). We use this as a general minimum measure, because the IC Tech Spec is geared towards military and other government facilities that provide a large measure of Security in Depth (SID), meaning that only semi-trusted personnel ever get within earshot of the SCIF. Security in Depth is a "multilayered approach, which effectively employs human and other physical security measures (like fences, walls, and guarded entry gates) throughout the installation or facility to create a layered defense against potential threats" (Naval Facilities Engineering Systems Command Northwest 2012, p. 20). Additionally, SID increases the probability of detection of nefarious activity because of continuous friendly-forces presence (National Counterintelligence and Security Center 2012, p. 3). These conditions cannot be guaranteed for all locations, especially in the corporate realm, so the goal is to compensate reduced SID with a higher degree of sound insulation. When possible, $R'_w = 53$ dB should be exceeded.

R'_w represents the resulting sound insulation between two rooms, taking into account all sound transmission paths (Tichelmann, Pfau 2000, p. 26). This explicitly includes not only transmission through dividing components, but also so-called "flank transmission" over adjoining building components. In this phenomenon, sound waves cause vibrations in flanking walls and then linearly travel through them into the other room (Möser 2009, p. 254). R'_w is a cummulative value calculated on the basis of the weighted sound reduction index of each component's R_w (Tichelmann, Pfau 2000, p. 34).

R_w is calculated by measuring sound transmission from one test cabin into another with the test component in between them. The test is carried out in one-third octave or octave steps. White noise, a random signal with equal intensity across different frequencies, with the given bandwidth is used as test sound. A frequency response curve R is thus obtained in the so-called building-acoustics frequency range from 100 Hz and 3.15 kHz. The frequency response curve R is then compared to a reference curve B in order to derive a single comparison value. In the comparison, the reference curve is shifted in 1 dB steps onto the frequency response curve until the sum of the undershoots S_U of the frequency response curve compared to the reference curve is less than 32 dB. (Möser 2009, pp. 256–257)

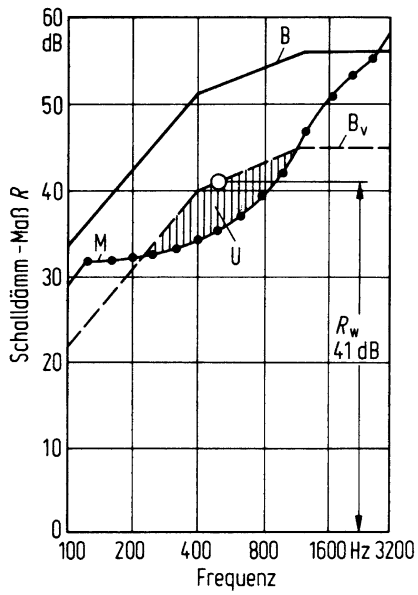


Figure 4: Definition of the Weighted Sound Reduction Index R_w. B = Reference Curve, B_v = Shifted Reference Curve, M = Measured Values, U = Undershoots of M Compared to B_v (Gösele, Schröder 2004)

This diagram also shows that for a R_w = 52 dB (the reference curve) the fundamental frequency of the male voice - 125 Hz - only undergoes a sound attenuation of ca. 35 dB. Given a 60 dB conversation sound-level the sound attenuation is not sufficient to protect from a close proximity attacker. Passive sound-attenuation measures should be specifically evaluated in the 125 Hz to 300 Hz range. There they must significantly exceed the reference curve's performance.

Because of the shortcomings of the standard B reference curve in practical settings, DIN EN ISO 717-1:2013-06 introduced the "Spectrum Adjustment Values" C and C_{tr}. These are used to adjust the B reference curve to different specific model noise spectrums, C for residential activites and C_{tr} for traffic noises. The resulting values are expressed as R_w (C, C_{tr}) in dB and allow quick insight into the components performance in a typical application area.

Airborne sound transmission via ventilation and structure-borne sound transmission via ducts, such as water and ventilation pipes, can significantly reduce sound insulation (Deutsches Institut für Normung 2018, p. 19). In some cases they can even provide direct channels for an outside observer to capture sound on (National Counterintelligence and Security Center 2012, p. 13). Hence, they must be treated with special attention. A mistake on a component penetrating the SCIF perimeter, like a duct or vent, can render all other attenuation useless.

4.4 Electromagnetic/TEMPEST Shielding Requirements

Electromagnetic emissions should be reduced by the values defined in National Security Specification for Shielded Enclosures NSA 94-106. This specification sets forth an attenuation for a 1 kHz - 1 MHz H (Magnetic) Field of 20 dB @ 1KHz, 56 dB @ 10 kHz 90 dB @ 100 kHz, and 100 dB @ 1 MHz. For a 1 kHz - 10 MHz E (Electromagnetic) Field it requires 70 dB @ 1kHz, and 100 dB at 10 kHz, 100 kHz, 1 MHz, and 10 MHz. For a 100 MHz - 10 GHz Plane Wave it also requires 100 dB attenuation.

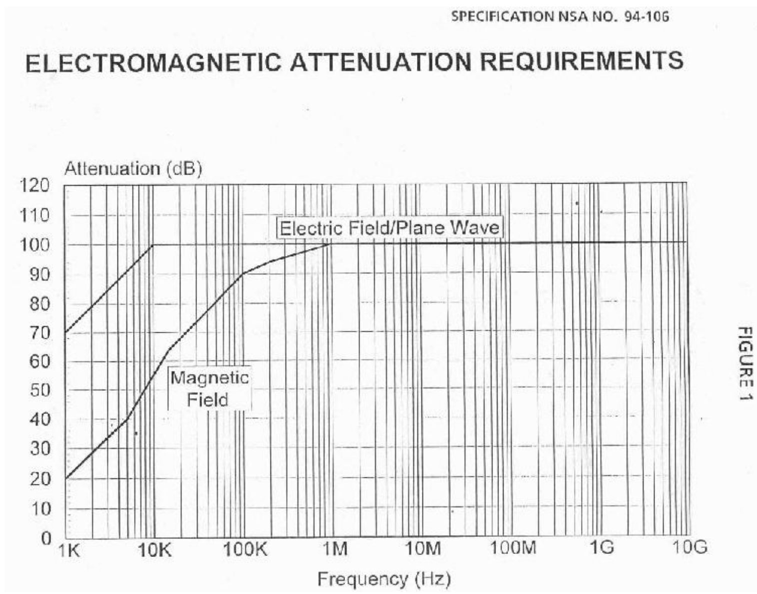


Figure 5: Electromagnetic Attenuation Requirements (U.S. National Security Agency 1994)

The field test is carried out with a parallel setup. A continuous wave source generates a wave in the range of 1 KHz to 10 GHz. Two antennae are placed, one on either side of the shielding. One antenna acts as a transmitting (TX) antenna and the other as a receiving (RX) antenna. The antennae are separated by a distance of 61 centimeters plus the wall thickness. The signal from the RX antenna is fed back into a reciver. Attenuation levels can then be read from a spectrum analyzer. Magnetic field, electronic field, and plane wave attenuations are then measured at various specified frequencies. Attenuation tests are performed around the entire door frame, air ducts, filters and through any accessible joint or penetration. (U.S. National Security Agency 1994)

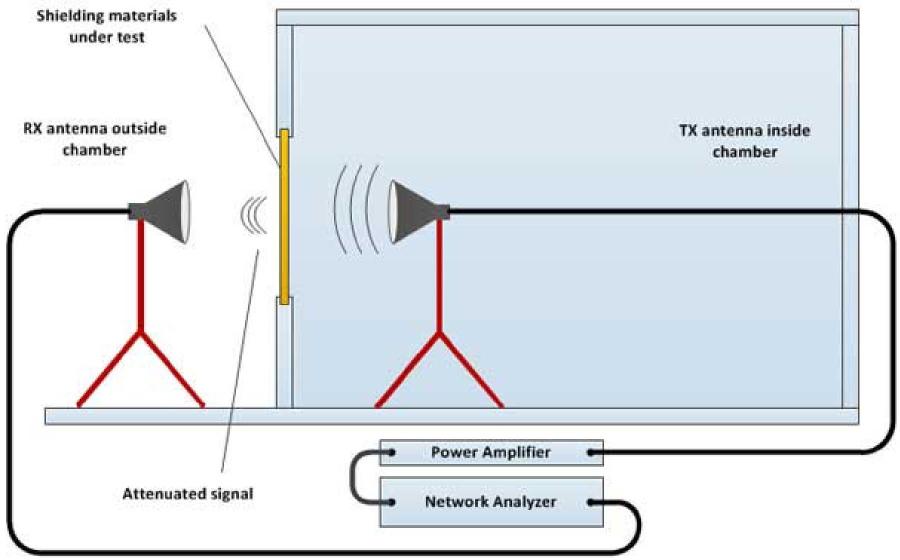


Figure 6: Test Setup for NSA-94-106 (EMCTEST Technologies 2018)

A RF shielding system is only as effective as its weakest component (Krieger Products 2015). Shielding material faults and gaps in the shield should be carefully avoided. These holes become more critical the higher the frequency of the field to be shielded (Wolfsperger 2008, pp. 292–293).

Apart from airborne electromagnetic waves, emanations can also leak from a SCIF on cables and wires. Instead of travelling through the air, unwanted signals can travel along wires out of the SCIF where they induce electromagnetic fields that be captured and turned into usable intelligence (Wolfsperger 2008, p. 210).

With the right electromagnetic shield, supplemented by different filter devices for power, data, and control lines, critical electromagnetic information source leaks can be entirely avoided.

5 Active Attacks

5.1 The Active Attacker

Apart from passively observing information source leaks from outside the secure facility, an attacker can also actively attack the space to place sensors inside the SCIF and transmit sensitive visual, acoustic, or electromagentic information to the outside. He can also seek to weaken the passive attenuation in order to increase the information yield of passive observation.

This chapter intends to give some general ideas about possible attack vectors, not to list out specific attacks and describe their execution. New attack methods are constantly being developed and only few ever get published. Thankfully, most can be prevented by implementing a handful established countersurveillance measures detailed below in *chapter 6*.

5.2 Visual Attacks

The goal of all visual attacks is to place cameras inside the SCIF. These cameras allow an attacker to gain valuable insights into the sensitive information being handled or processed inside the enclosed area. Cameras can be inserted by someone who gains physical access to the space, inserted through HVAC ducts, or drilled through the perimeter.

Another attack avenue is taking over installed CCTV cameras. The video feed from these cameras could allow insights into the SCIF's comings and goings, and, with badly placed cameras, even into the information processed. This attack can also target the built-in cameras of information processing equipment like laptops.

Cameras transmit video feeds to the outside using radio/electromagnetic waves or wired connections. Wired connections could be specially installed for the attack or hijack existing lines, either directly or as emanations along their unshielded exterior.

Table 4: Active Attack Techniques Overview - Visual

Attack Technique	Cost	Time	Technical Skill Required
Inserting Camera	low	low	medium
Hijacking Existing Camera	low	medium	high

5.3 Acoustic Attacks

An attacker may also attempt to place a microphone in the SCIF. To do this, he can either physically insert a new microphone or hijack one of the built-in microphones of devices already located in the room. Acoustic information is usually most sensitive, especially in conference rooms or discussion areas.

Similar to visual attacks, avenues for placing a microphone are physical entry, HVAC ducts, and hole drilling. In order to exfiltrate information, the attacker again utilizes either radio/electromagnetic waves or wired connections, existing or specially placed. Another attack is finding a weak spot in the sound attenuating shell and placing a contact microphone directly on it.

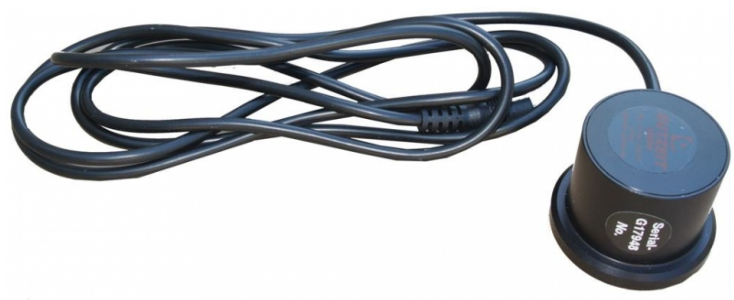


Figure 7: Contact Microphone Gutzeit GmbH

An attacker could also seek to weaken the sound attenuation measures by tampering with the sound masking, destroying insulation or purposely creating sound bridges.

Table 5: Active Attack Techniques Overview - Acoustic

Attack Technique	Cost	Time	Technical Skill Required
Mic over Existing Lines	low	medium	high
Mic over Specially Placed Lines	medium	high	high
Mic Wireless	low	low	medium
Contact Microphone on Weak Spot	low	medium	medium
Hijacking Existing Microphones	low	low	high
Weakening Sound Attenuation	medium	medium	high

5.4 Electromagnetic/TEMPEST Attacks

Instead of passively capturing TEMPEST emanations from outside the SCIF perimter, an attacker could also seek to place an antenna within the SCIF. He could then amplify the signals and thereby overpower the shielding or exfiltrate them on some other channel. He could also seek to weaken the electromagnetic shield by purposely creating holes in it or tampering with protective equipment, like power line filters.

Electromagnetic attacks are possible, but it is more likely that an attacker would place acoustic or visual sensors, which provide more direct insight into sensitive information, given the physical access necessary for these types of attacks.

Another attack is taking over devices present in the room and using their wireless capabilities to capture TEMPEST emanations. If these devices are network-connected, an attacker could exfiltrate data on their normal data connection, without having to setup an additional exfiltration path. However, similar to the insertion of bugging devices it is more likely that he will use this high level of operating system access to hijack the device's microphone or camera.

Table 6: Active Attack Techniques Overview - Electromagnetic

Attack Technique	Cost	Time	Technical Skill Required
Antenna + Amplification	low	medium	low
Antenna + Existing Lines	low	medium	high
Antenna + Placed Lines	medium	medium	high
Weakening Shield	medium	medium	medium
Hijack Existing Device	low	medium	high

6 Countermeasures

6.1 Physical Security

6.1.1 During Construction

Later passive and active countermeasures are ineffective if the SCIF is breached during construction phase. Therefore meticulous preparation of and adherence to a Construction Security Plan (CSP) is required. The CSP covers topics such as construction personnel, site perimeter, site access, and construction materials.

6.1.1.1 Construction Personnel

Construction personnel must be vetted and monitored so that they do not pose an insider threat to the construction site and the resulting facility. The IC Tech Spec-for ICD/ICS 705 (National Counterintelligence and Security Center 2012, pp. 23–27) envisions evaluation of construction workers by their country of origin and U.S. clearance level. For example, it forbids the use of workers from SETL "critical technical threat level" countries. Furthermore, it requires biographical data (full name, current address, Social Security Number, date and place of birth, proof of citizenship, etc.) and fingerprint cards for background checks of all non-cleared construction personnel. It requires finish work in high-threat countries to be carried out by SECRET-cleared U.S. personnel and requires access to the site to be withdrawn if adverse security, counterintelligence, or criminal activity is detected. It also sets various requirements for the monitoring/accompanying of non-cleared workers. As an example, for new facilities it allows non-cleared workers, monitored by Construction Surveillance Technicians (CSTs) - dedicated personnel that supplement site access controls, implement screening and inspection procedures, as well as monitor construction and personnel (National Counterintelligence and Security Center 2012. p. 7) - to perform the installation of major utilities and feeder lines. It requires that all construction personnel receive a security briefing prior to entering the site, so they know which rules to follow and what suspicious activity to report. If a construction worker leaves the project under unusual circumstances, the ICD requires the event be documented and the appropriate officer to be notified (National Counterintelligence and Security Center 2012. p. 26).

Not all the above measures for the security vetting of construction personnel can be implemented by non-government actors. They simply do not have the resources and capabilities to perform in-depth analysis and monitoring of each worker. Therefore, instead of evaluating workers for each project they should try to build a staff of long-term, trustworthy workers or contract a company that is certified to do so, through, for example, the ISO/IEC 27001 standard. Video surveillance during the construction phase can also help supplement monitoring efforts when CSTs are not available. However, video surveillance is not a magic silver bullet. It requires constant attention and responsiveness, just like any non-technological security measure. Threats from construction personnel can also further be mitigated by careful inspection after each construction phase's completion, as well as *bug sweeping* and performance testing before commissioning of the SCIF.

Even with thorough security mitigations and background checking in place, the human factor as an inside threat remains one of the most sensitive areas and the hardest to defend against.

6.1.1.2 Site Perimeter

Without a secure perimeter, access to and movement within the site cannot be controlled. A secure fencing or other form of perimeter should be errected around the site and continuously monitored for unauthorized penetration. For renovation projects, barriers should be installed to segregate construction workers from operational activities, providing protection against unauthorized access and visual observation. When expanding SCIF space into uncontrolled areas, maximum demolition of the uncontrolled areas should be carried out beforehand, ensuring a "clean slate" before the building of a new SCIF. (National Counterintelligence and Security Center 2012, p. 25).

6.1.1.3 Site Access

Access control using badges and other forms of identification should be required for entering the site. Guards should monitor entry points to prevent tampering and penetration attempts. Possible site control measures like identity verification, random searches, signs listing prohibited items, and vehicle inspections should be considered and implemented with the SCIF threat model in mind. (National Counterintelligence and Security Center 2012, p. 27)

The IC Tech Spec also requires the use of cleared American guards (CAGs) to supervise non-U.S. and non-cleared U.S. guards, as well as to directly protect the site in high-threat, SETL Category I countries. No equivalent to CAGs exists in the private sector. Their loyalty is impossible to recreate for a private actor who can't offer the same long-term employment guarantees and ideoligical motivation. However, guards with a similar training level can be sourced from private suppliers and with organizational practices, like close supervision and vetting, an adequate level of security can be ensured.

6.1.1.4 Construction Materials

Construction materials must be procured, transported, and stored in a secure way. If not, the entire security of the finished SCIF can be jeapordized by faulty or compromised materials. Materials are classfied in two categories, inspectable and non-inspectable. Inspectable materials are those that can be reasonably inspected with available measures. All other materials, as well as inspectable materials on which approved test methods were not carried out, are classified as non-inspectable and are subject to higher security requirements. (National Counterintelligence and Security Center 2012, p. 30)

Inspectable materials can be procured from trusted supplyer's without further security restrictions. Inspectable materials from non-trusted suppliers or shipped to the site in an unsecured manner should be inspected using approved methods and then moved to a Secure Storage Area (SSA). If stored outside the SSA, a random selection of these materials should be inspected before use on the site. Non-inspectable materials should be procured from trusted suppliers or other approved channels and securely transported to the SSA. They can also be procured from untrusted suppliers if randomly chosen by trusted personnel from a suppliers shelf-stock without advance notice or indication of their intended use. No discernible purchasing patterns should be established while carrying out this randomized procurement procedure. (National Counterintelligence and Security Center 2012, pp. 27–29)

Secure transporation is not required for inspectable materials if they are inspected and then immediately placed in an SSA. If securely procured, shipped and stored, inspectable materials may even be utilized without inspection. Non-inspectable materials, should be transported securely packaged or containerized and under the 24-hour control of an approved courier or escort officer. If this is not possible they should be securely shipped using approved transit security technical safeguards capable of detecting and displaying tampering or compromise. For government actors it may be interesting to require the transporation by military or flag carrying vessels. (National Counterintelligence and Security Center 2012, p. 30)

A secure storage area is a true floor to true ceiling, slab-to-slab construction of some substantial material, and a solid wood-core or steel-clad door equipped with a security lock. A shipping container located within a secure perimeter that is locked, alarmed, and monitored or a room or outside location enclosed by a secure perimeter that is under direct observation by cleared personnel can also serve as an SSA. All securely shipped and/or inspected materials should be placed in the SSA immediately upon arrival/inspection and stored there until they are required for use. This ensures a secure chain of custody from first arrival/inspection to installation and eliminates the need for possible reinspections. (National Counterintelligence and Security Center 2012, p. 31)

6.1.1.5 Inspection Methods

X-Ray, visual inspection, metal detectors and destructive tests can be used on inspectable materials to ensure their integrity. See Office of the Director of National Intelligence (2020) for a detailed list of inspection methods and their uses.

6.1.1.6 Technical Security Countermeasures

The construction phase involves many different parties and material suppliers. It is almost impossible to defend against threats accross the entire supply chain. Monitoring and inspection measures are only able to completely prevent the most primitive attacks. They merely serve to make advanced attacks more difficult. Therefore, a *Technical Surveillance Countermeasure (TSCM) inspection*, also referred to as “bug sweeping,” should be carried out at all major construction milestones and before commissioning of the SCIF. This can serve to detect and mitigate any attacks that did succeed during the construction phase despite all the above construction security measures.

6.1.2 Intrusion Resistance

A secure perimeter is the foundation of a SCIF’s security. Only a secure outer shell can prevent brute-force entries and make evident entry attempts into the protected space. Without it, no further access control or locking measures are effective because an attacker can simply take the direct way, right through the wall or door.

A multi-layered approach, using security in depth (SID), is most effective in ensuring a SCIF’s physical security. The multiple layers can consist of a controlled perimeter, secure installation, building perimeter, area surrounding the SCIF, and/or the SCIF perimeter itself. It may be possible to compensate for a lower number of total layers with higher security properties in each layer.

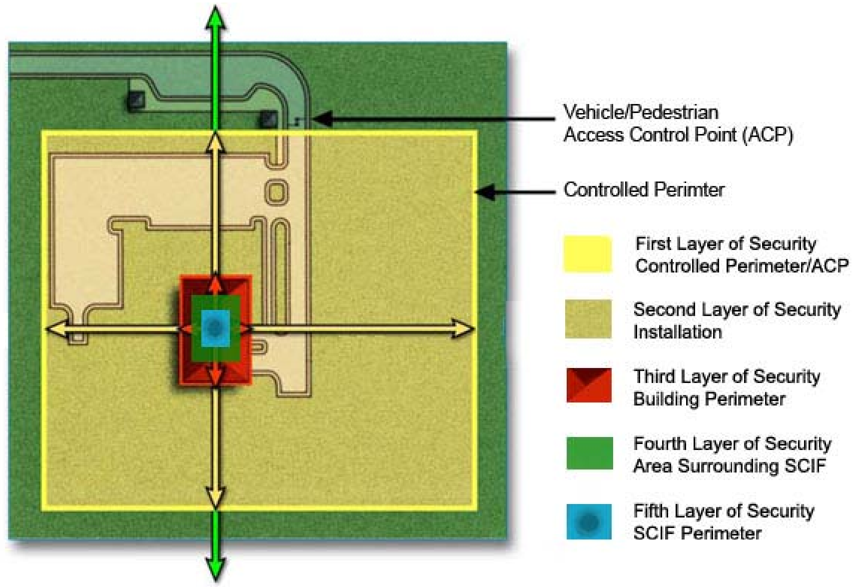


Figure 8: Map for Security in Depth of a Military Installation (Naval Facilities Engineering Systems Command Northwest 2012, p. 20)

The SCIF perimeter itself should be made from a substantial material that is difficult to penetrate in a covert way. The IC Tech Spec-for ICD/ICS 705 (National Counterintelligence and Security Center 2012, pp. 8–10) proposes different wall makeups for different mission demands. For example, an open storage facility, one in which sensitive information is stored in the open, without SID requires a true-floor to true-ceiling wall made up of (from inside to outside) two 5/8" gipsum wall boards (GWB), ¾" mesh from #9 expanded metal spot-welded or screwed every 6" to vertical studs, 16" metal studs and runners, acoustic fill, and another 5/8" GWB. Specifically the combination of multiple GWBs and expanded metal makes for a very sturdy construction. Additionally, sheet metal laminated GWB, like Knauf's Diamant Steel, can be used to further enhance the resistance properties of the GWB. Windows are highly discouraged for security reasons (National Counterintelligence and Security Center 2012, p. 12).

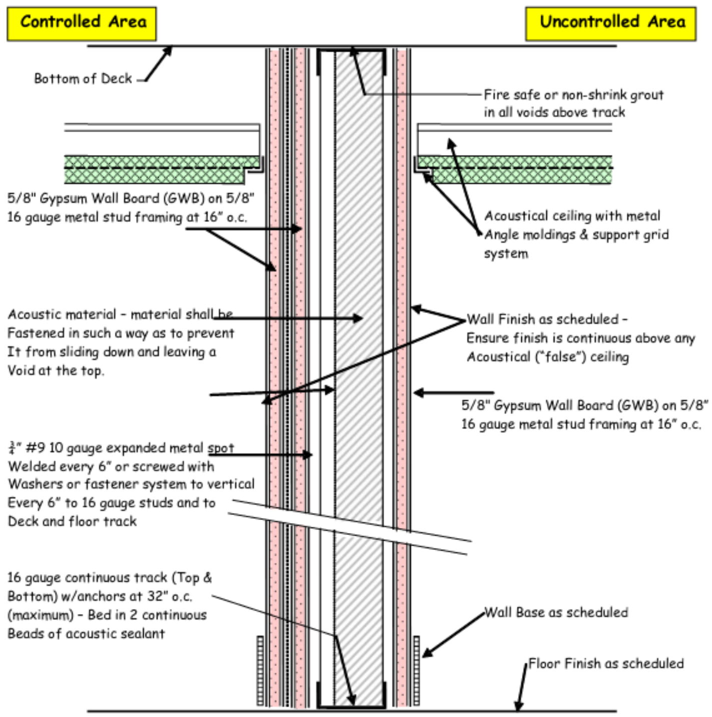


Figure 9: Wall B - Suggested Construction with Expanded Metal (National Counterintelligence and Security Center 2012, p. 17)

There should be only one primary entrance door. This greatly simplifies the controlled entry of personnel and visitors. The door should be of a substantial material, like 1 ¾ inch-thick solid wood core or 1 ¾ inch-thick face steel. Its hinge pins should be located inside the SCIF perimeter or modified to prevent removal of the door, e.g. welded or affixed with set screws. (National Counterintelligence and Security Center 2012, pp. 11–12)

The IC Tech Spec-for ICD/ICS 705 requires a maximum response time of 15 minutes (National Counterintelligence and Security Center 2012, p. 14). Assuming that the door should resist entry for the entire alarm response time, i.e., an attacker should be captured before he breaches the door, this requirement roughly translates to DIN EN 1627 Resistance Class 5. RC 5 entails that an experienced attacker using hand tools, power tools, such as a drill, jigsaw or reciprocating saw and an angle grinder with a maximum disc diameter of 125 mm can't breach the door within 15 minutes. A SCIF door setup should meet or exceed this standard.

Closed storage of sensitive information in a security container is preferrable over open storage when the SCIF is not in use. Even better, sensitive information should be stored in a separate vault when the SCIF is not in use. A security container according to the IC Tech Spec-for ICD/ICS 705 (National Counterintelligence and Security Center 2012, p. 5) must be a General Services Administration (GSA) approved safe, complying to GSA Class 6 for the storage of classified information such as documents, maps, drawings, and plans (Naval Facilities Engineering Systems Command 2021). GSA Class 6 has no forced entry requirements, but requires 30 minutes resistance to covert entry and 20 hours resistance to surreptitious entry. Commercial cabinets meeting EN 14450 Grade S2 also fulfill the requirements of GSA Class 6.

Figure 10: Hamilton GSA Approved Class 6 4 Drawer Security Container

6.1.3 Intrusion Detection System

An intrusion detection system (IDS), also commonly referred to as an alarm system, is essential in securing a SCIF against attackers. It allows quick detection and response to penetrations of the secured area. Multiple sensors are used in conjunction with a monitoring station to ensure round-the-clock alerts to unauthorized entries of any kind.

Mainly, the IDS is used to secure the SCIF when it is unoccupied. All interior areas through which access could be gained, including walls and doors, should be protected by IDS. Special attention should be given to detecting and responding to system outages and tampering. Limiting false alarms to a maximum of one per 30 days further ensures the reliability and effectiveness of the system, as too many false alarms cause fatigue and desensitization of security personnel. The IDS should be stand-alone, i.e., independent of other facilities' alarm systems. It can be supplemented with *audio or video monitoring*, as long as special attention is given not to inadvertently compromise the SCIFs information security as explained later on in *section 6.1.6*. (National Counterintelligence and Security Center 2012, p. 53)

All components, i.e., the monitoring station, movement sensors, high security switches (HSS), premise control unit (PCU), and keypads should meet the internationally recognized Underwriters Laboratories (UL) Standards 2050, 639, 634, 1610 and/or 294, respectively. The UL, being an independent, international organization not complying to the standards of any one country, is most suitable for providing globally recognized and universal security standards for the purposes of this paper.

The IDS should allow for operating in access, secure, maintenance, and shunted/masked mode. Access mode is used during SCIF operation and should allow for normal entry without causing an alarm. Tampering or entry through a secondary point, like emergency exits, should continue to trigger an immediate alarm. Secure mode is used when the SCIF is unoccupied, i.e., the last person departs the SCIF. In secure mode, any unauthorized entry into the SCIF should cause an alarm to be immediately transmitted to the monitoring station. Maintenace mode is used during routine repairs and testing on the system. A signal for this condition should be automatically sent to the monitoring station and verified/recorded there. It might also become necessary to shunt/mask sensors and zones for other reasons, like unforeseen malfunctioning of specific components, however this must be displayed at the monitoring station through the entire period the condition exists and automatically limited in time to the next change from access to secure mode. Generally speaking, for security reasons there should be no remote access for switching modes or performing diagnostics, maintenance or programming. (National Counterintelligence and Security Center 2012, pp. 57–58)

Electrical power supply of the IDS must be redundant, e.g. backed by 24 hours of uninterruptible power supply (UPS). On primary power failure, the IDS should be automatically transferred to emergency electrical power without causing an alarm. An indicator of the power source in use should be given at the PCU and/or monitoring station. (National Counterintelligence and Security Center 2012, p. 58)

The monitoring station must comply to UL 2050, which sets out standards for organizations monitoring, signal processing, investigating, servicing, and operating alarm systems in sensitive facilities (Convergint Technologies 2017). Governments themselves or private contractors can set up monitoring stations that meet these standards. These stations should be staffed by human operators trained in system theory and operation who can effectively interpret system incidents and take appropriate response actions. Any alarm event along with the time of receipt, names of responding personnel, dispatch time, nature of the alarm, and follow up actions taken should be recorded at the monitoring station for at least two years. (National Counterintelligence and Security Center 2012, p. 59)

Sensors are the eyes and ears of an IDS. They detect breaches and trigger alarms. All sensors should be located inside the SCIF to prevent tampering and TEMPEST issues. Interior areas of a SCIF through which reasonable access could be gained should be monitored by motion sensors (UL 639) and high security switches (HSS) (UL 634 level 1 or 2). Motion sensors trigger alarms on detecting movements in their view-field. HSS are split in two components, one mounted on the moving component and the other on its adjacent rigid part. They trigger alarms when they lose internal contact between their two halfs, for example when a door is opened. SCIF perimeter doors should be protected by both an HSS and a motion sensor. Failed sensors should cause continuous alarm until repaired. (National Counterintelligence and Security Center 2012, pp. 54–55) Seismic detectors, sensors that trigger on vibrations such as those resulting from drilling and blasting, can further be used to supplement HSS and motion sensors. There are impressive innovations in the field of motion sensors, like passive infrared detecting attacker's body temperature, doppler radar catching attacker's radar reflections, cloak and camouflage detection against intruders attempting to cover their infrared signal, and anti-masking technology against attempts to obscure the field of view of a detector (Bosch Security 2021).

Premise Control Units (PCU) serve as a first point of control inside the SCIF. They, as well as any associated cabling, should be fully located within the SCIF. PCUs should validate authorized use with an authentication technology, such as a keypad and/or card reader. Cabling between all sensors and PCU should be dedicated to the IDS and contained within the SCIF. Otherwise, "External Transmission Line Security" must be employed. The alarm status as well as power source in use should be continuously displayed at the PCU. A special indicator should alert to changed/failed power supply. The PCU should identify and display all activated sensors. The auto-alarm reset feature, if present, must be disabled as every security incident can only be resolved after an inspection of the SCIF and a determination for the cause of the alarm by trained, dedicated personnel. Because of the sensitive nature of the information displayed, the PCU must be installed in a location that precludes observation by any unauthorized party. (National Counterintelligence and Security Center 2012, p. 55)

Immediate and continuous alarm must be given on any intrusion detection, failed sensor, tamper detection, or enabling of maintenance mode (maintenace message may be used in place of an alarm). Alarms or maintenace messages should be displayed individually for all zones shunted or masked during maintenance mode. (National Counterintelligence and Security Center 2012, p. 55)

Once an IDS is set up to the above specifications, thorough acceptance testing should be carried out before the SCIF is commissioned. Motion sensors should be tested by moving at very slow speeds through the monitored area. This speed should not exceed 800 mm per second. The movements should be repeated throughout the SCIF and from different directions. The alarm must be activated at least three out of every four trials. HSS should be tested to ensure that an alarm activates before the non-hinged side of the door or window opens beyond its own thickness from the closed position. For example, this means that the HSS triggers an alarm before the door opens 5 cm for a 5 cm door. Tamper testing should be carried out by ensuring that alarms are triggered when IDS equipment covers are opened, both in secure and access mode. These test procedures should be repeated at least semi-anually. (National Counterintelligence and Security Center 2012, pp. 60–61)

6.1.4 Access Control

An access control system (ACS) is employed while the SCIF is occupied to control and record personnel entry into the protected space. It is mounted in addition to the SCIF perimeter door lock to regulate access while the SCIF is in use. It does not replace the SCIF perimeter door lock while the SCIF is unoccupied. (National Counterintelligence and Security Center 2012, p. 62)

Visual recognition of persons entering the SCIF by an authorized person at the entrance is the ideal access control. Should this not be possible, an automated system can be used instead. (National Counterintelligence and Security Center 2012, p. 62)

An automated personnel ACS should use two different credentials, such as ID badge/card, PIN, and biometric identifier, to verify authorized personnel. The probability of an unauthorized individual gaining access must be no more than than one in ten thousand. Card readers, keypads, communication interface devices, and other access control equipment located outside the SCIF must be tamper-protected and securely fastened to a wall or other fixed structure. Electrical components, associated wiring, or mechanical links should only be accessible from inside SCIF. Otherwise transmission lines must be FIPS-AES encrypted. Equipment containing access-control software, used to program allowed entry for authorized persons and remove no longer authorized individuals, should be located fully inside the SCIF. Electric door strikes used to unlock the door and "buzz people in" must have a positive engagement, i.e., rest in a locked position and only unlock on entry authorization. The electric door strikes should comply to UL 1034 (Burglary-Resistant Electric Locking Mechanisms). (National Counterintelligence and Security Center 2012, p. 63)

Records should be kept of the active assignment of ID badge/card, PIN, level of access, recent entries, and other similar system-related information. Records of personnel removed from the authorized persons list should be retained for two years. Records of security incidents should be retained for five years from the date of the incident or until the corresponding investigation is resolved. (National Counterintelligence and Security Center 2012, p. 63)

If the number of personnel that require access is low and there is only one entrance, a non-automated access control may be used. This can consist of a mechanical, eletric or electromechanical combination lock with combinations of four or more random digits. Mechanical access control devices should be installed to prevent manipulation or access to mechanisms used for setting the combination from outside the door. The control panel or keypad should be installed to preclude unauthorized observation of the combination entry or the actions of combination change. The control panel for changing combinations should be located inside the SCIF with sufficient physical security to deny unauthorized access to its mechanisms. (National Counterintelligence and Security Center 2012, p. 64)

6.1.5 Locks

When not occupied, SCIFs should be alarmed and secured with a FF-L-2740A compliant combination lock and a pedestrian door deadbolt meeting Federal Specification FF-L-2890 (National Counterintelligence and Security Center 2012, p. 11). The combination lock is used to secure the door when the SCIF is unoccupied and the access control device is used while the SCIF is occupied (National Counterintelligence and Security Center 2012, p. 63). The equivalent international specifications for FF-L-2740A combination locks are UL 768 and DIN EN 1300. The lowest UL 768 rating, Group 2, is essentialy equivalent to FF-L-2740A (Locksmith Reference 2018).

Figure 11: Kaba X-10 Mounted Lock (FF-L-2740)

Combinations to locks installed on perimeter doors should be changed when a combination lock is first installed, when a combination has been compromised, and whenever a person knowing the combination no longer requires access to the SCIF, unless other sufficient controls exist to prevent access to the lock. (National Counterintelligence and Security Center 2012, p. 83)

6.1.6 CCTV

Video surveillance, also known as CCTV, can be used to supplement the monitoring of SCIF entrances for the remote control of doors from within the SCIF. Special attention should be given that a CCTV system presents no additional technical security hazard (National Counterintelligence and Security Center 2012, p. 64). CCTV may be also used to supplement monitoring of the SCIF entrance and record events for later investigation (National Counterintelligence and Security Center 2012, p. 75).

When CCTV is used to monitor a SCIF entrance for ACS purposes, the remote control device should be located within the SCIF and should be monitored/operated by trained personnel. The cameras should provide a clear view of the SCIF entrance without enabling a viewer to observe classified information when the door is open nor external control pads or access control components that would enable them to identify PINs or access procedures. The CCTV communication lines should be fully located within SCIF. Any external communication lines should be installed to prevent tampering. (National Counterintelligence and Security Center 2012, p. 64)

When CCTV is used to monitor a SCIF entrance for security and record-keeping purposes the system and all its components, including communications and control lines, should be exterior to the SCIF perimeter. In this case also, it must not enable a viewer to observe any classified information or authentication procedures.

In both use cases special attention must be given that the cameras present no further technical security risk. Chinese-made video surveillance systems can be reasonably suspected of leaking information back to their Chinese State owned/controlled manufacturers (Lehman-Ludwig 2020). Chinese manufacturers like HikVision and Dahua also suffer from general bad security practices (Cyber & Infrastrucutre Security Agency 2017). Their use has consequently been banned from U.S. government agencies and facilities (U.S. House. 115th Congress 2018). These shortcomings aren't specific to only Chinese-made products. In general, proprietary products suffer from this kind of backdoor-risk and should only be sourced from trustworthy manufacturers. Even better, they should be built in-house with *open hardware* components.

Figure 12: Elphel 10393 Series Free Software and Open Hardware Camera

6.2 Visual Protection

Visual insights into the SCIF space are the easiest attack vector to defend. It suffices to create a "water-tight" outer shell without gaps or holes. Every effort should be made to exclude windows from the SCIF (National Counterintelligence and Security Center 2012, p. 12). If they are unavoidable, they must at least be treated for visual protection, i.e., darkened with external blinds and/or laser protection film (Wolfsperger 2008, p. 463). As noted above, video surveillance systems should be designed with special attention not to provide visual insights into the space. No cameras should be installed inside the SCIF (National Counterintelligence and Security Center 2012, p. 82).

To protect from visual insight into the SCIF during personnel entry, entrance points should incorporate a vestibule to preclude visual observation (National Counterintelligence and Security Center 2012, p. 11). Double doors should have an astragal strip attached to one door to prevent observation through the door crack (National Counterintelligence and Security Center 2012, p. 12).

6.3 Acoustic Countermeasures

6.3.1 Purpose of Acoustic Attenuation

To secure the discussions, information processing, and conferences carried out inside the SCIF it is essential to design an effective acoustic protection system. Sound waves tend to find weakpoints in even the most well-designed systems, escaping through them to the outside where even the faintest emission can be captured and reconstructed with digital means. Therefore, it is necessary to pay meticulous attention to detail, both in the design and construction phase, while building on multiple technologies to prevent capture of usable sound information from the outside.

In most cases, passive sound attenuation, walls with strong sound isolation properties, must be combined with active sound masking, speakers that emit speech-like sounds to render useless escaping sound waves. Both due to room constraints and redundancy considerations, passive sound attenuation most often does not suffice on its own. A sound masking system can reduce the wall thickness needed and mitigate any weakpoints that are inadvertently built into the attenuating shell. Protecting against attackers who manage to smuggle microphones into the SCIF space, as guests or intruders, should also be considered in system design.

6.3.2 Sound Attenuation

Passive sound attenuation is the first step in reducing noise emissions from the SCIF space. Massive single-shell walls or double-shell components can be used to reduce sound transmission on all paths. Both direct transmission, sound forces on a wall → structure-borne sound in the wall → airborne sound outside the SCIF, and indirect transmission, airborne sound within the SCIF → structure-borne sound in the wall → airborne sound outside the SCIF, can be reduced with the right wall design, both on primary and secondary paths. (Möser 2009, p. 253)

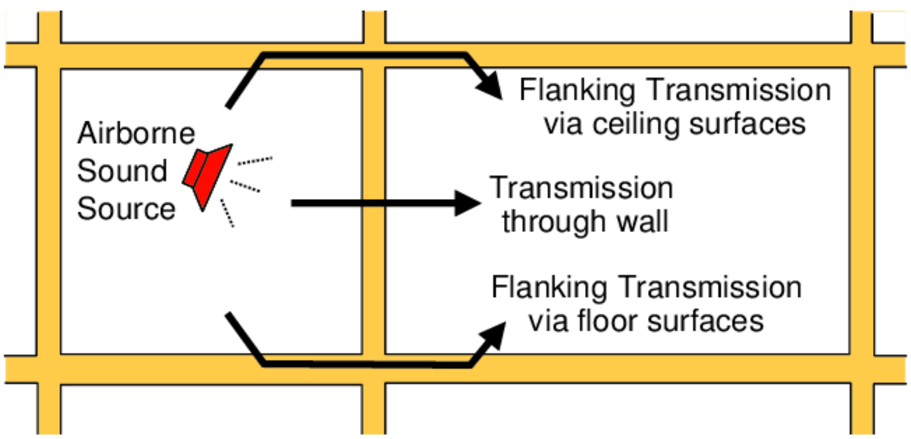


Figure 13: Primary and Secondary, Flanking Sound Transmission through a Wall (Zeitler 2013)

The sound insulation performance of building components is dependent on the frequency of the sound emission. Particularly low-frequency sound waves set walls into vibrations that they readily transmit as airborne sound to the outside. Higher frequencies are of less interest in system evaluation, because the insulation quality of walls for higher frequencies is almost always good. Problematically, the very sound emissions that need to be protected, those of the human voice, are in the low frequency range. (Möser 2009, p. 256)

A clear understanding of cut-off frequencies is essential to properly analyzing the frequency-dependent sound insulation of building components. The cut-off frequency is the frequency at which the wavelength of the airborne sound matches the length of a component's bending wave. In this frequency range, track matching occurs between the incoming airborne sound and the walls internal vibrations. They align and result in poorer airborne sound insulation. For single-shell components, sound attenuation increases with 6 dB/Octave below the cut-off frequency. This is known as Bergers' mass law. At the cut-off frequency the component's sound attenuation suffers a sharp drop and then rises with 7.5 dB/Octave. The drop is also described as the "cut-off slump" and entails significant decreases in sound attenuation at frequencies around the cut-off frequency. The cut-off slump is more drastic the higher on the spectrum the cut-off frequency. Because of the steeper sound attenuation increases above the cut-off frequency and because of the lower cut-off slumps at lower frequencies, it is of interest to design single-shell components with as low a cut-off frequency as possible. This can be accomplished by making the wall as rigid as possible and increasing its thickness. (Möser 2009, pp. 258–270)

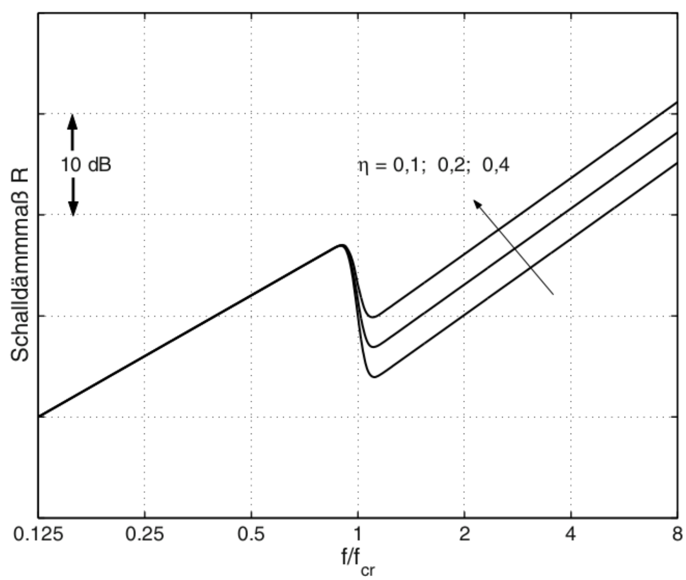


Figure 14: Principle Curve of the Sound Reduction Index Frequency Response of a Single Shell Wall. η = Loss Factor Derived from the Loss Mechanisms at Play, such as Internal Damping and Vibration Energy Dissipation to Adjacent Components, f = Frequency of Emission, f_{cr} = Cut-off Frequency (Möser 2009, p. 267)

Increasing wall rigidity and thickness might not always be possible due to space, weight, and cost constraints. Thankfully, a better method for building attenuating walls exists; double-shell components with flexurally soft facing-shells. These make use of the propensity of the two walls to swing at different frequencies when not connected, making use of the cavity in between to create a mass-spring-mass system. No connections or cross-coupling may exist between the two shells as these defeat the spring function of the hollow space and jeopardize the entire system's effectiveness. (Möser 2009, pp. 270–276)

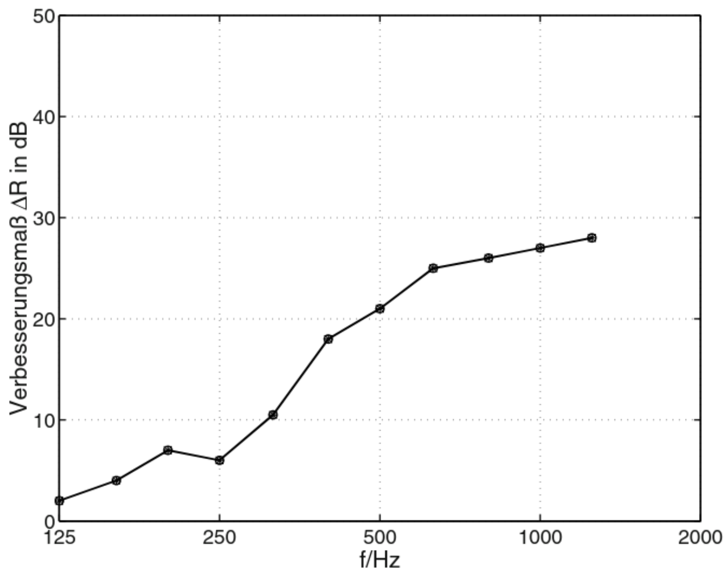


Figure 15: Improvement of the Sound Insulation ΔR of a 80 mm Plaster Wall by a Flexible Facing Shell with $m_2^{''} = 4$ kg/m^2 and Cavity Depth $d = 65$ mm, Filled with Mineral Wool (Möser 2009, p. 274)

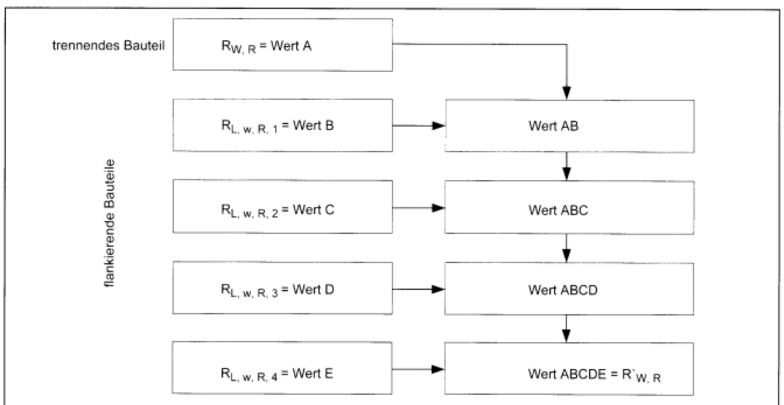
Below the cut-off frequency, the additional shell has no effect, however, above it, the sound attenuation increases with 12 dB/octave. At the cut-off frequency there is again a slump in attenuation performance. The cut-off frequency should be engineered to be as low as possible to make use of the steep attenuation increases. According to

$$f_o \approx \frac{60Hz}{\sqrt{\frac{m_2^{''}}{kg/m^2}\frac{d}{m}}}$$

a cut-off frequency of 60 Hz (well below the building acoustics frequency range beginning at 100 Hz) can be reached with a facing shell with a mass per unit area of $m_2'' = 10$ kg/m^2 (heavy gypsum wall board) and a hollow space of $d =$ 10 cm. Sufficiently low cut-off frequencies can be achieved without excessively heavy facing shells or prohibitively wide hollow spaces. (Möser 2009, p. 273)

To achieve a high sound attenuation level, it is advantageous to use heavy total masses and to distribute them unequally among the shells, if possible avoding shells of equal weight. One should also maximize the distance d between the two shells, dampen the cavity as fully as possible with absorber material, and avoid leaks or structure-borne sound bridges. (Möser 2009, p. 276)

In order to evaluate the solution on a whole system level, including floors and ceilings, one combines the walls R_w value as described in *section 4.3* with the longitudinal sound attenuation $R_{L,w}$ of the four flanking components (two walls, ceiling, and floor) in a stepwise addition scheme specified in DIN 4109-1. The result is a total resulting sound Reduction index $R'_{w,R}$ expressed in dB. (Tichelmann, Pfau 2000, p. 34)



Dabei gilt beispielhaft für alle Stufen:	
wenn Wert A ≥ Wert B: Werte-Differenz = Wert A – Wert B ablesen von ΔR aus Tabelle Wert AB = Wert B – ΔR	wenn Wert B ≥ Wert A: Werte-Differenz = Wert B – Wert A ablesen von ΔR aus Tabelle Wert AB = Wert A – ΔR

Werte-Differenz [dB]	0,0	0,5	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0
ΔR [dB]	3,0	2,8	2,5	2,3	2,1	1,9	1,8	1,6	1,5	1,3	1,2

Werte-Differenz [dB]	5,5	6,0	6,5	7,0	7,5	8,0	9,0	10,0	11,0	13,0	15,0
ΔR [dB]	1,1	1,0	0,9	0,8	0,7	0,6	0,5	0,4	0,3	0,2	0,1

Figure 16: Stepwise Addition Scheme DIN 4109-1 (Tichelmann, Pfau 2000, p. 34)

In accordance with the above scheme, floors and ceilings must also be constructed with sound attenuation in mind to ensure adequate system-level performance. Both longitudinal sound attenuation $R_{L,w}$ and direct sound attenuation R_w should offer adequate protection of escaping sound waves. In general, a designer should seek to constuct floors and ceilings as rigid and heavy as possible. Walls should go from true-floor to true-ceiling, completely interrupting additional longitudional layers like screed, flooring, and false ceilings. Example constructions with their associated attenuation values can be taken from the component catalog in DIN 4109-33 sections 4.3 and 5.3.

Walls and flanking components aren't the only transmission paths for sound out of the SCIF. Air ducts and vents also present a significant challenge in sound attenuation. If untreated they can serve as direct transmission paths for sound waves out of the SCIF and eliminate all benefits gained from a carefully designed double-shell system. In order to treat air ducts and vents it is necessary to insert some type of silencer. These can be reflection mufflers, wall mufflers or active noise cancelling systems. Reflection mufflers work eclusively through reflection. Cross-section changes, branch-offs and inserted chambers reflect sound waves internally and decrease their energy. Wall mufflers work through absorption *and* reflection. Absorbant wall lining or slim absorbant channels are used to reflect sound waves internally. Additionally, these sound waves lose energy into the mufflers absorbant surfaces. (Möser 2009, pp. 285–328)

Active noise cancelling systems produce anti-sound, amplitude inverted sound waves, to cancel out sound. They are limited in frequency range and aereal effectivity. Large levels of sound reduction require very high replication accuracy in the secondary, cancelling field. (Möser 2009, pp. 405–427) Because of their complexity and relative novelty they are not the go-to solution for air vent treatment.

Reflection and wall muflers either achieve high attenuation performance in narrow bands or moderate attenuation in wider bands. Knowing the frequency range of the sound to be cancelled is essential for optimizing the mufflers. Specialized air vent mufflers for the human voice, called cross-talk sound attenuators, are readily available on the market. They achieve relatively high performance values around the frequency spectrum of the human voice and come in a box shape optimized for installation inside drywall. An off-the-shelf product from German manufacturer SHAKO KG, the cross-talk sound attenuator box AUDIX®, achieves a weighted sound reduction index of R_w 38 dB at 508 mm length and 300 mm height. Normalised sound reduction $D_{n,e}$ at the male fundamental frequency 125 Hz is 54 dB. (SCHAKO KG 2021)

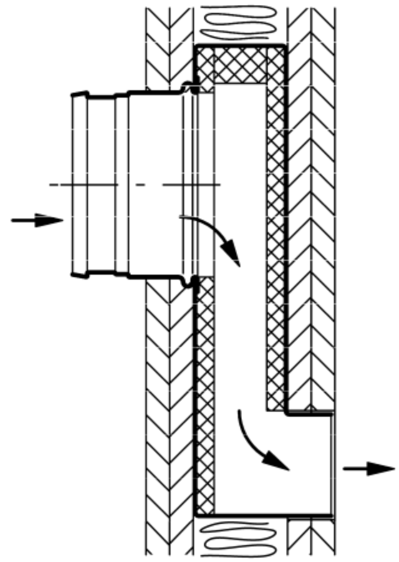


Figure 17: SCHAKO Cross-talk Sound Attenuator Box AUDIX® - Installation Schematic

6.3.3 Sound Masking

When passive measures alone, out of space, weight or costs constraints, can't provide an adequate level of sound attenuation, they can be supplemented by a sound masking system. In such a system, speakers and transudcers are placed on or close to any paths that would allow audio to leave the protected space. In conjunction with a noise generator and amplifier, they generate and distribute vibrations or noise that drown out escaping audio and render it useless. (National Counterintelligence and Security Center 2012, p. 66)

Speakers/transducers must produce sound at a higher level than the audio escaping on the path. They are placed on or close to weak points in the passive sound attenuation, like doors, windows, common perimeter walls, vents/ducts, pipes, as well as raised floors and ceilings. (National Counterintelligence and Security Center 2012, p. 66) For doors and windows, the transducers are placed on the frame to induce vibrations that provide a uniform audio mask and prevent contact/laser microphones from picking up usable emissions. For walls, transducers are placed at specific intervals on the studs to provide uniform protection along the entire length of the perimeter using stud-mount brackets. For vents, ducts, and pipes contact speakers are placed directly on the exterior inducing vibrations directly into the surface. In raised floors and ceilings, as well as all wall cavities, conventional dynamic cone speakers are placed in the hollow space to transmit sound through the air and induce audio interferences into adjoining parts. The speaker placement must be optimized for each room geometry and wall type. (SpeechMasking 2016)

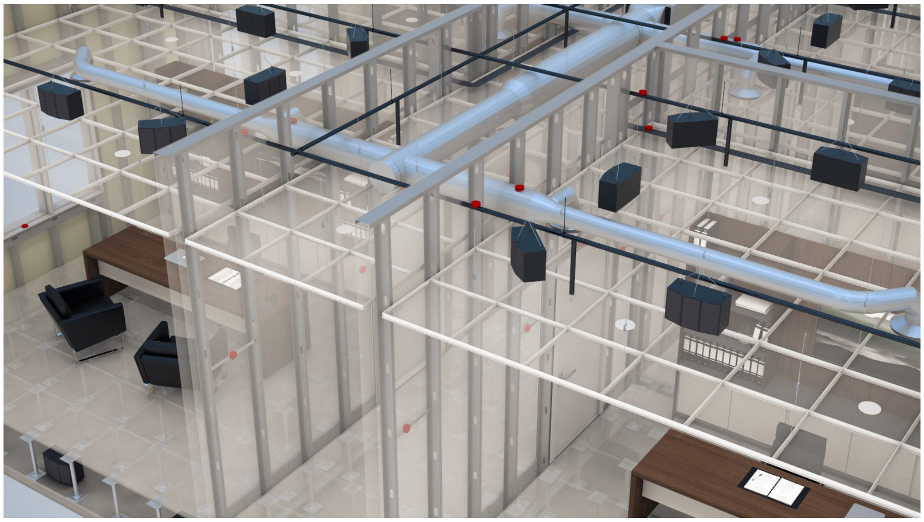


Figure 18: Sound Masking System Speaker Placement (SpeechMasking 2016)

Sound-source generators can be dedicated noise generators, tapes, discs, or digital audio players. They emit some kind of recording, music or randomly generated noise, like pink or white noise. In practice, noise sources with deterministic intensity distribution across the frequency spectrum, also called broadband noises, like pink or white noise, have been proven ineffective to mask the human voice unless used at uncomfortably loud levels (two to five times higher than the voice to be masked). They simply do not replicate the human vocal system and can easily be filtered out by sophisticated speech extraction software. Prerecorded sounds, such as music or tracks, are also easier to isolate and separate digitally from speech. Instead, it is better to use randomly generated noise from an algorithm specifically designed to imitate the spectral density, resonance, periodic pauses and interruptions, tonal and pitch qualities, and other improbable effects of human speech. (SpeechMasking 2016)

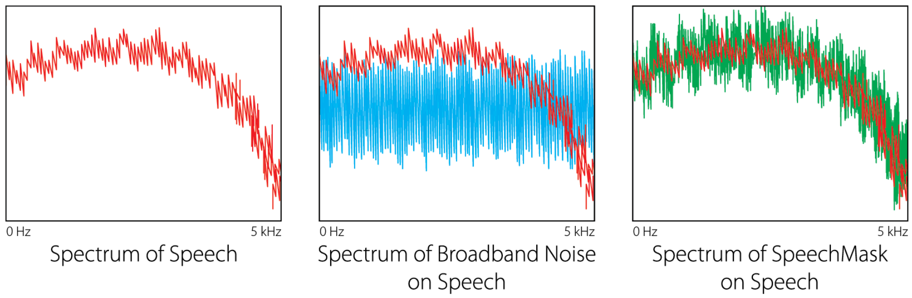


Figure 19: Comparison of Broadband Noise's and SpeechMask® Algorithm's Frequency Spectrum Mapped over the Spectrum of Human Speech (SpeechMasking 2016)

Even more important than the noise source itself, though, is the way the mask is applied and directed inside the protected space. In a properly designed system, the occupants do not hear, or only faintly hear, the mask inside the room. The only way to listen to the mask should be by listening directly against the outside wall. The intended functional area of a sound masking system is not the protected space itself but the exfiltration paths that come from it. There and only there should the sound mask present itself as vibrations and audible noise. (SpeechMasking 2016)

For security reasons, the sound masking systems should be permanently installed and not contain an AM/FM receiver. Its generators, wires and transducers should be located to the greatest extent possible within the SCIF. Generators with any capability to record ambient sound should have that capability disabled. The sound masking system should be subjected to a thorough TSCM inspection to ensure it poses no further technical risk. (National Counterintelligence and Security Center 2012, p. 67)

6.3.4 Microphone Jamming

Microphone jamming can play a special role in protecting the SCIF from inside attackers. A meeting participant who wishes to record the discussions without the knowledge of the other participants could smuggle in a covert recording device, like a modern smartphone. Due to their small form factor, covert recording devices often use micro-electromechanical microphones (MEMS) whose inherent hardware properties can be exploited against them in order to jam and render useless their recordings.

A microphone jammer makes use of the hardware non-linearity of commodity microphones. Linearity is the ability to generate an electrical output proportional to the amplitude of the sound input. Any device, such as a microphone, exhibits non-linearity in some frequency bands, meaning it produces overproportional electrical output for a given input frequency. Ultrasonic signals (centered around 25kHz) can trigger these non-linearities without being noticable by human ears. Inside the microphone, they leak into the audible spectrum and produce jamming signals. (Chen, Li, Nagels, Li, Lopes, Zhao, Zheng 2019)

A 2019 study by University of Chicago researchers showed existing devices to be effective against smartphone microphones, but showed their inability to fully cover potential microphones at different angular positions relative to the masking device. The researchers improved upon existing devices by designing a wearable bracelet with more omni-directional speaker configuration and better angular coverage due to a user's wrist movement. (Chen, Li, Nagels, Li, Lopes, Zhao, Zheng 2019)

Existing microphone jamming devices are most effective against the MEMS microphones found in smartphones and other small-form factor devices. It is unclear how they perform against more sophisticated microphones designed to eliminate hardware non-linearities in the ultrasonic spectrum.

If used at all, microphone jamming systems should function supplementally to a PED policy. A PED policy controls and limits the portable electronic devices allowed in the SCIF. It is especially useful when untrusted individuals are allowed entry to the SCIF to participate in discussions within it. (National Counterintelligence and Security Center 2012, pp. 68–72)

6.4 Electromagnetic/TEMPEST Shielding

6.4.1 Purpose of Electromagnetic Shielding

Electromagnetic shielding is used to prevent inadvertent emissions of sensitive information from the SCIF, and to make information transmission of bugging devices located within it more difficult. These shields take the form of separate enclosures around the entire protected space, and make use of different phyiscal principles to block airborne electromagentic waves. All penetrations of the elctromagentic shield, like pipes, ducts, and cables, are treated separately to prevent the inadvertent or malicious transmission of sensitive information along them. Additionally, a monitoring system can be designed to ensure the continuous performance of the electromagnetic shield over time.

With the proper electromagnetic shield design, otherwise problematic signal processing equipment, like computers, can be operated inside the SCIF without concerns of leaking TEMPEST information to the outside. This saves the operator from having to buy more expensive, shielded equipment with the purpose of blocking emanations at the individual device level.

6.4.2 Functional Principles of Electromagnetic Shielding

There are multiple functional principles which electromagentic shields can utilize to block airborne waves. Faraday cages are the simplest and most well known type of electromagnetic shield. They make use of a conductive material to distribute externally induced electric charges within the material, cancelling the charge's effects in the cage's interior. The cage can be imagined as two metal plates connected by an electric conductor. Because of the higher conductivity within the material than into the surrounding air, the external field causes charges to migrate from one plate to the other instead of being wirelessly transmitted. Migration of charges between plates happens until there is no longer an electric field between the plates that could motivate charges to cross to the opposite side. (Wolfsperger 2008, p. 90)

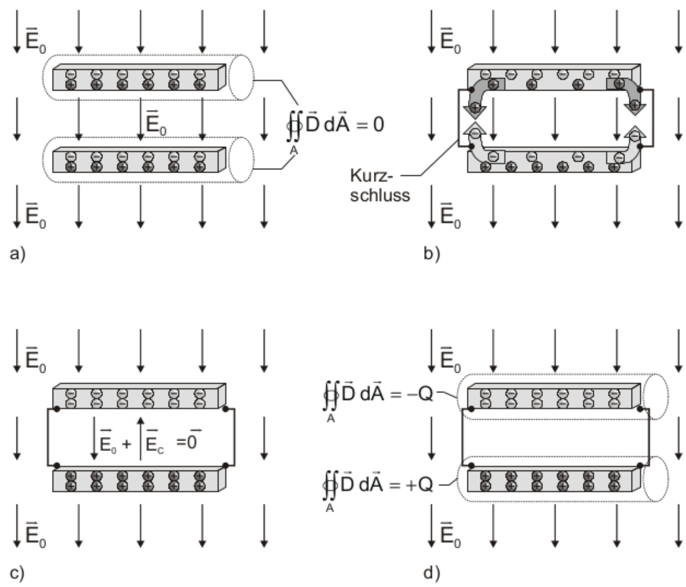


Figure 20: Two Short-Circuited Conductive Plates Functioning as a Faraday Cage (Wolfsperger 2008, p. 89)

Like Faraday cages, dielectric shields are used to block electrostatic fields. They work by refracting electric field lines at the shield's boundary, preventing them from entering the inside. They make use of the fact that an electric field line is "bent" toward the material boundary when transitioning from a material with a low dielectric constant, like air, to a material with a high dielectric constant, like a mineral material. For this effect to take place, a dielectric shield must have thick walls made of a material with high electromagnetic permittivity. For technical shields, the shielding effectiveness of dielectric shields is orders of magnitude lower than that of a Faraday cage at the same cost. Therefore, in normal cases the shielding of electric fields is preferably carried out using the Faraday cage principle. (Wolfsperger 2008, pp. 93–94)

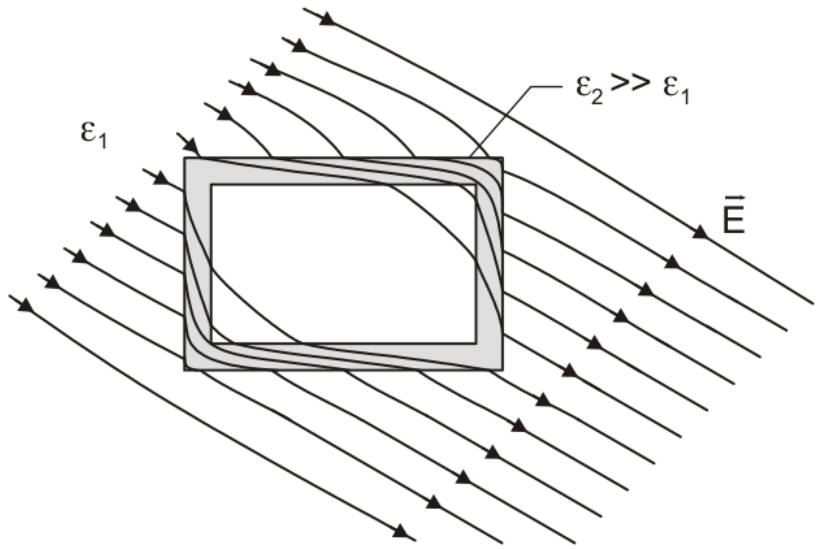


Figure 21: Dielectric Shield, Consisting of a Thick-walled Sheath with a High Dielectric Constant (Permittivity), Refracting Electric Field Lines (Wolfsperger 2008, p. 93)

Dimagentic shields are fully analog to dielectric shields, just that they function in the realm of magnetostatic fields instead of electrostatic fields. Instead of electric field lines, magnetic field lines are refracted at the boundary between materials with different magentic permeability. The high permeability magnetostatic shield is much more important in practice than the dielectric shield. Since there is no physical effect equivalent to the Faraday cage for shielding static magnetic fields, they present the only method of shielding static magnetic fields, like those emanating from electrical conductors carrying a direct current. They must be built from high-permeability materials, such as pure iron, to provide effective shielding of both static and variable magnetic fields. (Wolfsperger 2008, pp. 94–96)

The most useful functional principle for the electromagnetic shielding of SCIFs is the electrodynamic shield. It shields variable magnetic fields while also functioning as a full Faraday cage. In the electrodynamic shield, variable magnetic fields induce electric currents which in turn cause eddy currents to pile up within the conductive material. These eddy currents cause magnetic fields that are directed against the external magnetic field and cancel it out. This effect grows stronger the higher the frequency of the variable magnetic field. The electrodynamic shield must be constructed of a highly conductive material with minimal openings. Therefore it coincidentally also works as a Faraday cage. An electrodynamic shield, made of an ideally conductive shell without openings, shields alternating electric and variable magnetic fields as well as DC electric fields. Forunately, shielding variable magnetic fields is of primary interest in SCIF building. Shielding static magnetic fields, on the other hand, is the absolute exception. (Wolfsperger 2008, pp. 100–102)

Table 7: Types of Electromagnetic Field (Wolfsperger 2008, p. 88)

Type of Field	Example	Shielding Mechanism
Electrostatic field	Separated charges	Dielectric shield, Faraday cage
Magnetostatic field	Magnetization distribution	Dimagnetic shield
Quasi-stationary electromagnetic field	Radio waves, microwaves	Electrodynamic shield
Electromagnetic wave field	Plane wave	Electrodynamic shield

6.4.3 Shielding Materials

Electrodynamic shields are constructed from a wide variety of materials. Aluminium, steel, zinc, stainless steel, copper, brass, and tin are all useful, but come with different tradeoffs that must be evaluated when selecting an ideal material for the mission demand. The different materials with their pros and cons are listed in the table below.

Table 8: Electromagnetic Shielding Materials Overview

Material	Pros	Cons
Aluminium	Low weight, easy to work with, high electrical conductivity	Cannot be magnetized, not so easy to weld, not as rigid as steel, electrically insulating passive corrosion layer forms on the surface (in case of joints remove the passive layer and immediately prevent new formation by applying paint or textiles)
Steel	High magnetic permeability	Corrosive

Material	Pros	Cons
Zinc	Passive layer like aluminium	Low nobility (contact with metals higher on the galvanic series problematic for corrosion)
Stainless steel	Relatively good electrical conductivity, high corrosion resistance (preferred material for electrodynamic shields)	High price, high weight, difficult processing with cutting tools, poor shielding of low frequency fields due to low permeability
Copper	No interfering protective oxidation layers, soft, easy soldering	Very high price
Brass	Good corrosion resistance, harder than copper	Low conductivity, very expensive
Tin	Useful as alloy or corrosion protection	Too soft

For electrodynamic shields, the conductivity of the material is most important. Permeability and dielectricity are secondary. The conductive material must be installed with a minimum thickness, which can be derived mathematically from the penetration depth of the given frequency in the material. The greater the wall clearance between the perimeter walls, the higher the shielding effect. The performance of a larger electrodynamic shield also generally exceeds that of a smaller one, because penetrating energy can be better distributed over a larger volume. Taking these factors into account, an example shield made from stainless steel at the lowest generally usable radio frequency, 100 kHz, can reach 100 dB shielding effectiveness with a thickness of only 2 mm and a 1 m wall clearance. Shielding performance only increases the higher the radio frequency to be shielded. (Wolfsperger 2008, pp. 227–247)

Figure 22: Electrodynamic Shield in the Offices of Finnish IT Security Firm F-Secure (Leyden 2015)

The continuously electrically conductive connection of shielding materials is of utmost importance for the effectivity of the entire shield. Gaps of even half a wavelength in size can nullify the entire shield. Many materials have the propensity to build passive oxidation layers that protect them from further corrosion. These must be carefully removed along the contact area when joining such materials in order to ensure electric conductivity. The stripped surfaces, as well as corrosive materials that not do not form a passive layer, must be immediately covered by a protective coating upon installation as a component of the shield. This prevents the regeneration of the non-conductive passive layer, or further corrosion in the case of corrosive materials that don't form a passive layer. Another factor in the joining of materials, specifically materials with different electrode potential, is contact corrosion. When materials on opposite ends of the galvanic series are joined, they can build a cathode-anode pair that results in the decay of both materials over time. Special care should be given not to combine these materials in use. (Wolfsperger 2008, pp. 249–252)

6.4.4 Joints and Gaskets

The ideal methods for joining shielding components, ensuring consistently high, "watertight" conductivity, are soldering and welding. Riveting or screwing are also effective as long as the distances between surfaces are small relative to the minimum wavelength. However, above methods cannot be applied to connections that need to be opened and closed over time, for example those found in a door. For such joints, there are different types of HF (high-frequency) gaskets that can provide fully electrically conductive connections over long periods of use and many closing cycles. (Wolfsperger 2008, pp. 252–253)

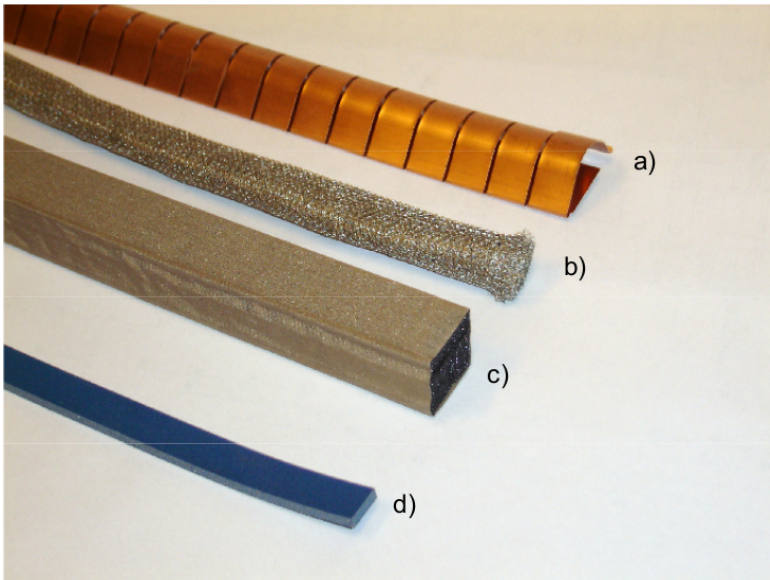


Figure 23: Different Types of Gaskets a) Contact Feather, b) Wire Mesh c) Elastomer Gasket with Conductive Textile Coating d) Conductive Elastomer Gasket (Wolfsperger 2008, p. 267)

Contact feathers consist of stainless steel or copper beryllium, a highly elastic copper alloy, which is pressed against a conductive surface when the moving part is closed. The contact pressure enables excellent contact properties with low electrical resistance over long periods of time and many closing cycles. Contact feathers are self-cleaning. When pressing the contact springs against the conductive surface, the spring grinds over the metal surface and removes any oxide layers or small dirt on both surfaces. On the other hand, they are highly susceptible to mechanical damage, require high contact pressure, have a low tolerance for deviating gap dimensions, offer no insulation against outside air, and come with a high price tag. (Wolfsperger 2008, pp. 254–258)

Wire mesh gaskets are made up of a stainless steel, copper beryllium, aluminum or monel mesh that is pressed against a conductive surface when the component is closed. They have good shielding properties with low electrical resistance over long periods of use. They are very robust, featuring low susceptibility to mechanical damage. Any passive oxidation layers are broken through by the individual wires when the contact pressure is applied. However, they also require very high contact pressures, have a low tolerance for deviating gap dimensions, offer no insulation against outside air, and come at a high price point. Furthermore, they have weaker self cleaning properties than contact feathers and only allow contact pressure to be applied perpendicular to the gasket. (Wolfsperger 2008, pp. 258–261)

Elastomer gaskets, both those consisting entirely of conductive material and those only covered by conductive textile, have generally weaker shielding properties than the above two gasket types. They sit between the moving part and its frame. Due to their elastic properties, they are compressed by the closure and act as a conductor between the two sides. They require lower contact pressures than contact feathers or wire mesh gaskets, have a higher tolerance for deviating gap dimensions, are very resistant to mechanical damage, insulate against outside air, and come at a very low price point. However, they do not have self-cleaning properties, don't counteract passive oxidation layers, and are less durable over time. (Wolfsperger 2008, pp. 261–267)

It is the designers job to weigh the different gaskets' strengths and weaknesses and select the ideal type for the individual SCIF project and component part.

6.4.5 Electromagnetic Shield Penetrations

Electrical lines, data connections and control cables must all pass through the electromagnetic shield without degrading the shields performance or losing connection quality. HVAC vents/ducts, and in some cases water pipes, must carry utilities in and out of the SCIF without degrading shielding performance or incurring excessive throughput losses. Screws for lights and other fixtures must also puncture the shielding without reducing its performance. All these different challenges require individual solutions that must be incorporated in the design from the outset.

Electrical power lines should pass into the SCIF through a power line filter. This filter only allows the 50 Hz frequency of the power grid to pass through while "filtering" out all other transmissions. Their encolsure should be mounted to the wall shielding in order to make its shielding continuous with that of the room. Similar filters also exist for control lines. (Wolfsperger 2008, pp. 271–276)

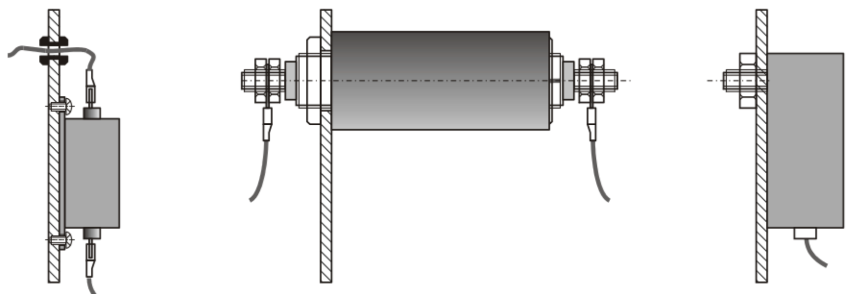


Figure 24: Different Mounting Configurations of Power Line Filters (Wolfsperger 2008, p. 276)

Data lines are best passed through the electromagnetic shield by first converting them onto fiber optic cables using a media converter. Fiber optic cables not only enable very high data transmission rates, but are also beneficial from a shielding perspective, since they are made entirely from non-conductive material. To eliminate electromagnetic leaks through the cable penetration, they should be fed through hollow conductors whose cut-off frequency is sufficiently high or through special fiber optic grommets. The purpose-built grommets wrap tightly around the individual fiber optic cores leaving no gaps for even the highest-frequency emanations to leak. (Wolfsperger 2008, p. 281)

Screws for affixing cable ducts, pipes, facing shells, claddings, suspended ceilings, radiators, etc. should only puncture the electromagnetic shield through special shielding anchor plates. These anchor plates are sheet metal disks that are attached to the room shielding over a large area with an RF gasket or highly conductive adhesive. They ensure a larger contact area between the screw and shield, to couple them with as low an impedance as possible. This helps maintain continuous electrical conductivity, limiting the effect the hole has on the shield's overall performance. (Wolfsperger 2008, pp. 334–335)

Heating, ventilation, and air conditioning vents and ducts should incorporate honey comb panels at the protected space boundary. These make use of the fact that hollow conductors have high attenuation properties below their cut-off frequency. With sufficiently small hollow conductors the cut-off frequency can be raised to a point where almost all waves fall in its highly attenuating spectrum below the cut-off freuqency. (Wolfsperger 2008, pp. 282–284) Due to their small hollow spaces, honeycomb filters restrict air flow. They must be dimensioned with a sufficiently large cross-section area to supply the necessary air for all occupants and discharge the equivalent amount of exhaust air on the other side. Ventilation is absolutely necessary in SCIFs with airtight electromagnetic shields, otherwise there is a serious risk of suffocation for the occupants. As an example, a SCIF with 10 occupants requires ca. 360 m^3/h of fresh air per hour. For a ventilation duct with a cross-section area of 0.1 m^2 (30x30 cm) this results in a necessary air flow velocity of 3600 m/h = 1 m/s. Under these condtions, a 18 GHz honeycomb panel would cause a pressure loss of 0.1 mbar which would have to be compensated by the ventilation system. The same goes for the exhaust air side. (Wolfsperger 2008, pp. 355–358)

Refrigerant lines and water pipes should be fed through purpose-built pipe penetrations as shown in Wolfsperger (2008) Schematic 4.40 and 4.52. These enclose the tubes or pipes and ensure electrical conductivity around the circumference of the penetration.

Controlled heating of the SCIF can be achieved using electrical heating fed from the power line filter. The SCIF can be cooled using a ductless mini-split unit with all refrigerant lines fed through purpose-built pipe penetrations, power lines fed through the power line filter, and control lines fed through a control line filter.

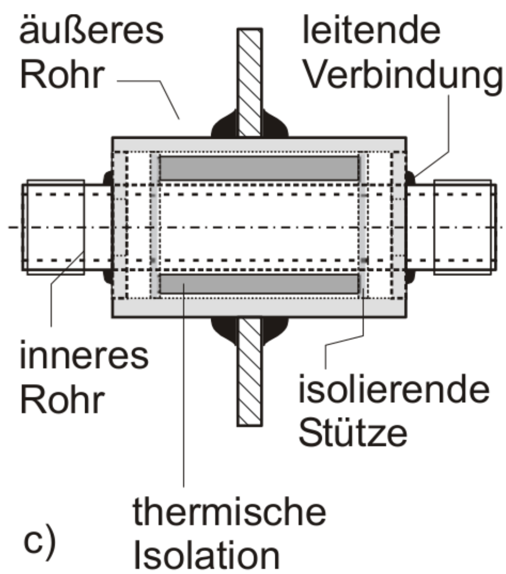


Figure 25: Refrigerant Line Pipe Penetration (Wolfsperger 2008, p. 309)

A vapor barrier should be installed on both sides of the perimeter wall to protect it from moisture penetration by condensate. Especially in a mobile SCIF unit, the vapor pressure gradient can alternate throughout the year. Sometimes transpiration and heating on the inside with simultaneous cold air conditions on the outside will cause moisture to diffuse from the inside to the outside, whereas other times AC on the inside with high temperatures and humidity on the outside (tropical conditions) will cause moisture to diffuse in the other direction. The wall should be protected from both cases. (Wolfsperger 2008, pp. 358–360)

6.4.6 Electrical Safety

A shielded room must never be operated without proper grounding. Otherwise, the leaking currents from the power line filters can flow to the electrical ground in an undefined manner via the high-impedance connections between the power line filter and the shield itself. This would result in the entire line voltage being fed onto the SCIF perimeter walls, presenting a potential danger to the life of the personnel working within the SCIF. A shielded room or area should only be grounded at a single point so that no equalizing currents (usually magnetically induced) can flow through the shielding. In addition, a residual current circuit breaker should be installed to protect occupants from ongoing electric shocks. (Wolfsperger 2008, pp. 351–354)

6.4.7 Shielding System Function Monitoring

Hans Wolfsperger also proposes a system to continuously monitor the function of the room shielding during use. He proposes that the RF output of a spectrum analyzer be fed through an amplifier to a broadband transmitting antenna permanently installed in the room. A receiving antenna, e.g. a leak detector, would also be permanently installed on the outside of the room and connected to the input of the spectrum analyzer. During the first functional tests, when the system is determined to be effective, the spectrum analyzer would determine and store the frequency response of the shielded transmission. Each time the shielding is used, the frequency spectrum would be determined again and compared with the stored values. If clear deviations from the reference are detected, the shielding could be checked for malicious tampering or other damages. (Wolfsperger 2008, pp. 466–467)

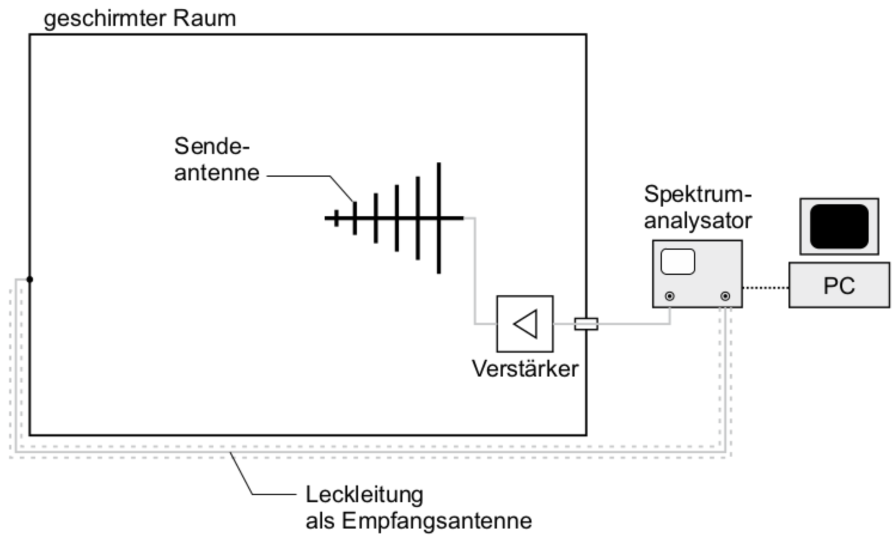


Figure 26: Shield Monitoring System Schematic (Wolfsperger 2008, p. 467)

This system could help mitigate against sabotage and performance losses over time, which would otherwise only be detected by periodic shield attenuation measurements. Because of their high equipment and personnel costs, these are conventionally only conducted anually, if at all. Undetected leaks can therefore persist for long time periods and nullify the large effort that went into the planning and construction of the shield in the first place. Such a system is not yet commercially available and would have to be specially planned and implemented. (Wolfsperger 2008, pp. 466–467)

6.4.8 Signal Jamming

Signal jamming cannot be used as an equivalent to sound masking in electromagnetic shielding. Signal jamming works by deliberately transmitting signals on the same radio frequencies as mobile phones and other wireless devices, disrupting the communication between the devices and their base stations, effectively disabling them within the range of the jammer.

In contrast to sound masking, however, it is not possible to closely target signal jammers' disruptive transmissions. They can interfere with the legitimate functioning of devices inside the SCIF and surrounding it. Because of this, the use of signal jammers is illegal in the EU under Directive 1999/5/EC and in the U.S. under the Communications Act of 1934.

6.5 Bug Sweeping

Active detection of surveillance devices is a precondition to secure SCIF operation. Over time an attacker may manage to infiltrate the protected space and place listening devices that transmit information covertly to the outside. SCIF operators must check both for these devices and their exfiltration channels regularly to limit the effective window of a compromise. Tools for bug sweeping include spectrum analyzers, non-linear junction detectors, line analyzers, and lens finders. By carefully combining the use of these different tools it should be possible to locate any active transmitters, passive transmitters, listening devices' built-in semiconductor components, and compromises of installed lines.

To detect active transmitters in the protected space it is necessary to make use of a spectrum analyzer. These devices are designed to capture and analyze wireless signals over a wide frequency range. They either come as benchtop devices, used to collect the ambient spectrum over longer periods of time, or as hand-held, near field devices to detect signals at their source.

Benchtop devices scan the frequency spectrum within the protected space over hours or even days and then automatically compare them to measurements of the surrounding environment, historical measurements, or reference values for that type of environment. By monitoring the frequency spectrum over long periods of time, they are able to detect even the most sophisticated bugs, like caching bugs that store captured sensitive information temporarily and emit it only at defined intervals all at once.

Figure 27: REI Oscor Blue Spectrum Analyzer

Hand-held, near field devices complement benchtop devices. They make use of different probes to locate surveillance devices at their source, for example when suspicious signals are detected on the benchtop analyzer and require further investigation. The different probes function at different frequency ranges, directional focuses, and sensitivities, each specialized to detect a specific type of bug or exfiltration path. (EMshield GmbH 2019)

Figure 28: REI ANDRE Near-field Detection Receiver Probes and Antennas

Passive transmitters, such as eavesdropping devices that are currently switched-off or not transmitting, and surveillance devices' semiconductor components can be detected using a non-linear-junction detector (NLJD). NLJDs detect the presence of electronics, regardless of whether they are radiating, hard wired, or even turned off. They detect physical properties, and not energy emissions. To do this they make use of semi-conductor's inherent property to return a harmonic signature when radiated with RF energy. By means of a specially polarized antenna, the NLJD emits frequencies in the range of 880 Hz to 2.4 GHz and simultaneously receives their respective harmonics, integer harmonic oscillations of the original frequency. For example, the second harmonic of 880 MHz is 1760 MHz (880 x 2) and the third harmonic is 2640 MHz (880 x 3). If radio waves emitted by the NLJD antenna hit an electronic component, then each semiconductor (transistor, diode, integrated circuit, etc.) causes a strong reflection of the second harmonic. By comparing the reflection of the second and third harmonic one can exclude false positives, like those resulting from non-electronic metal components which tend to also reflect strongly on the third harmonic. NLJDs come in slim, hand-held, telescopic boom designs that allow them to extend to even the most difficult to reach places. The device's head is passed closely over walls, furniture, and other building components and immediately alerts to any electronic components in its range. (EMshield GmbH 2019)

Figure 29: REI ORION 2.4 HX Non-Linear Junction Detector Features

Line analyzers, like the REI TALAN, can be used to inspect and test analog, digital, and VoIP telephone lines and other wiring for taps and eavesdropping devices. Instead of listening to ambient noises in the room, surveillance devices can also be placed directly on legitimate transmission lines to detect sensitive information. They can also hijack installed fixed lines to exfiltrate information without needing to transmit wirelessly or having to set up a custom, covert transmission channel. Line analyzers combine multiple testing capabilities to detect malicious data transmissions over a fixed line or the source and location of any type of device "tapping" the line to capture information travelling on it. Test techniques include a digital multimeter to test lines for voltage, current, resistance, and incapacitance anomalies, frequency domain reflectometry (FDR) to check for impedance anomalies resulting from taps on the line, non-linear junction detection to check for electronics connected to a wire, digital demodulation to confirm that a digital telephone line is not passing audio when it shouldn't, and a high-gain amplifier to detect analog audio being passed on a digital line. (Research Electronics International 2021)

Figure 30: REI TALAN 3.0 in Use

Lens finders emit infrared signals in order to detect reflections coming from hidden camera lenses. When observed through a special view finder, a room will reflect IR signals at a normal rate, however, hidden lenses will concentrate these waves and reflect them particularly strongly. They show up as bright spots on the red backdrop of the room. This allows an analyst to quickly detect cameras in use across an entire room. This technique does not work for camera lenses currently covered by a shutter, like those found in a photo camera not currently taking a picture. (Global TSCM Group, Inc. 2021)

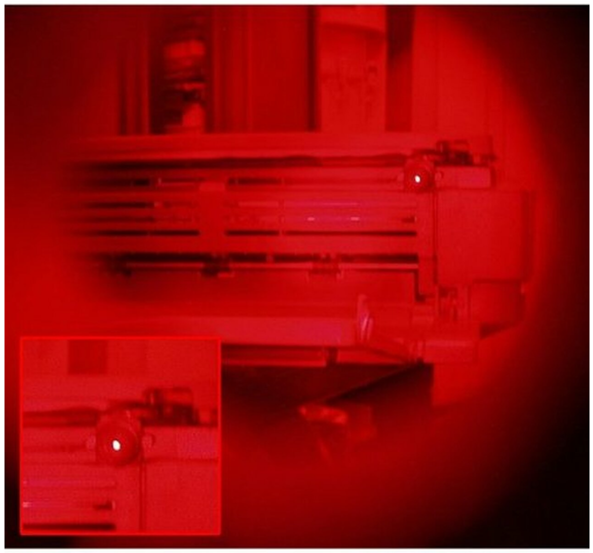


Figure 31: View Through a WEGA-i Hidden Camera Finder

Only through a careful combination of these different tools by trained personnel, can a high detection rate of covert listening devices be guaranteed.

For an initial impression on the equipment costs for these devices see this included price table:

Table 9: Bug Sweeping Devices Overview

Device	Cost
REI OSCOR Blue Spectrum Analyzer	\$39000
REI ANDRE Deluxe Near-field Detection Receiver with probe set	\$8000
REI ORION 2.4 HX Non-Linear Junction Detector	\$19000
REI TALAN 3.0 Telephone & Line Analyzer	\$23000
WEGA-i Hidden Camera Finder	\$500

7 SCIF Container Module

7.1 Why Shipping Containers?

Global logistics infrastructure is designed from the ground up for the 8 x 8.6 x 20 ft dimensions of the standard-size shipping container. Building a SCIF inside these dimensions allows it to be transported to any point on the globe discreetly, cheaply, and quickly. Shipping containers have become commodity hardware, easy to procure and customize. Furthermore, they come with excellent structural properties that allow them to provide a high-level of physical security and load-bearing capacity. So called “high-cube” containers are another foot higher than the standard shipping container dimensions, with 9.6 ft height, providing ample headroom to install proper sound attenuation and ventilation. Using a shipping container to manufacture a standardized SCIF module means building on a stable and highly reliable platform that is easily deployed and reused in any region of the world. (Logan, Braun 2019)

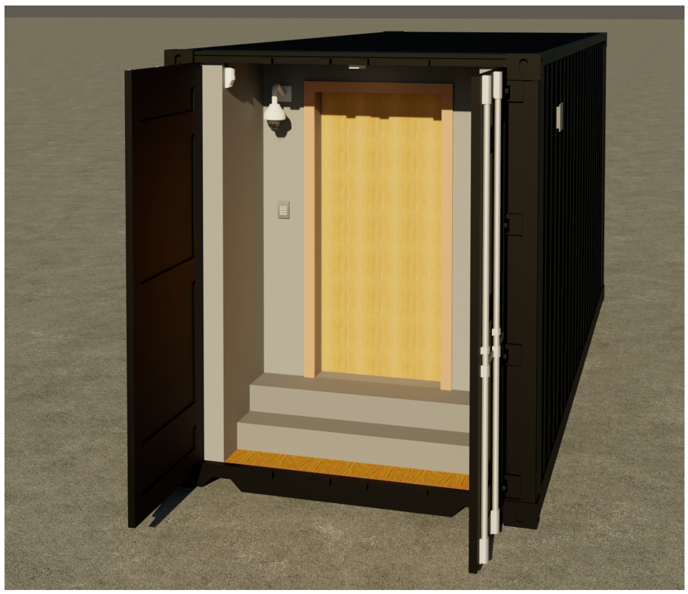


Figure 32: Outside View of SCIF Container Module with Doors Open

7.2 Physical Security

7.2.1 During Construction

The SCIF container modules should be factory-built under constant supervision by trusted personnel and video surveillance. Stationary manufacturing allows for more careful oversight of production premises and personnel access than constantly changing construction sites. The use of long-term employees is also easier in a stationary manufacturing setting than on globally distributed construction projects. The secure procurement, transporation, and storage of construction material is enhanced by long-term stationary manufacturing infrastructure. Investments in thorough material testing equipment and procedures, like X-ray and ultrasonic testing, are made more profitable by the reuse of site infrastructure and higher production quantities. As container modules, SCIFs are no longer bespoke units but mass-produced commodity items, with all the production efficiencies that entails.

7.2.2 Intrusion Resistance

Physical security is provided in multiple layers pursuant to the principle of Security in Depth. The first line of defense is a controlled perimeter around the shipping container. For example, this can be a security fence around the area in which the container SCIF is set up.

The second line of defense is comprised of the shipping container's outer shell made from corrugated steel. This shell provides excellent intrusion resistance. For this reason shipping container's located within a secure perimeter are also authorized as secure storage areas under the IC Tech Spec-for ICD/ICS 705 (National Counterintelligence and Security Center 2012, p. 31). The outer shell is essentially a steel cage around the actual SCIF unit. The container doors are fastened with a Kossie Heavy Duty Container Locking System. The locking system fastens to the container's locking bars, creating a well-anchored connection between the two doors. A padlock is inserted into a bolt-cutter proof steel sleeve to secure the bracket.

Figure 33: Kossie Heavy Duty Container Locking System

The third line of defense is the SCIF module's inner core, referred to in this paper as the "SCIF unit." Its perimeter is made up of Knauf Diamant Steel drywall, a unique drywall solution that features a full steel sheet insert for additional stability and intrusion resistance. A Krieger Products RFI-60-STC-50 pre-engineered door is used to access the SCIF unit. It does not come with special intrusion resistance properties, but instead shields the enclosed area, both acoustically and electromagnetically. In concert, these different layers provide an intrusion resistance that meets and exceeds the requirements of the ICS 705.

7.2.3 Intrusion Detection System

The intrusion detection system is comprised of three Bosch Commercial Series TriTech AM Motion Detectors with Anti-mask, two inside the SCIF area and one in the vestibule, two Bosch RADION contact SM high-security switches, one on the container door and one on the Krieger Products RFI-60-STC-50 door inside the SCIF area, and one Bosch ISN-SM Seismic detector inside the SCIF area hooked up to an *Alertr open-source alarm system*. The power supply is redundant with a designated 12 V 18 Ah battery pack. The alarm system is disarmed from a Bosch B915 keypad located within the SCIF area. The operator has 60 seconds from the triggering of the HSS on the container door to the disarming of the system inside the SCIF space to avoid triggering an immediate alarm. Alarms are sent to client devices on multiple transmission channels (internet, GSM, radio). The Alertr system can also optionally transmit alarms and alerts to an external monitoring station.

It is preferrable to build on the Alertr open-source alarm system over conventional, proprietary solutions because of Alertr's free software licensing. This means source code is publicly available and can be copied, extended, and modified freely. Alertr thereby enjoys a higher degree of trustworthiness and maintenance than many of the commercial, proprietary solutions. It can be easily adapted to the individual project requirements and does not create dependencies on the manufacturer for new functionality and support.

Figure 34: Entrance Door from Inside the SCIF Unit with High-Security Switch, Motion Sensor, and Air Duct

7.2.4 Access Control

Access control, if necessary to control high personnel traffic in and out of the SCIF during use, can best be implemented with an HID® pivCLASS® authentication system. Unlike the conventional Wiegand authentication cards, this system makes use of Personal Identity Verification (PIV) public-key authentication. Unlike Wiegand cards, PIV smartcards can not easily be cloned to perform replay attacks on the card reader (Howson 2013). The HID® pivCLASS® can make use of the FIPS-certified YubiKey 5 with a built-in PIV smart card as one of two authentication factors, the other one being a PIN. Smart card and PIN are used together to authenticate on a HID® pivCLASS® RK40 reader which transmits information to the pivCLASS® Authentication Module, which unlocks and locks the door via a HID® EDGE EVO® Solo ESHRP40-K standalone door controller. The door is equipped with a positive engagement electronic strike lock and a Securitron door contact. (Chapman 2016)

Figure 35: Entrace to SCIF Area with ACS Card Reader, CCTV Camera, Krieger Products RFI-60-STC-50 Door, and Bosch TriTech Motion Sensor

7.2.5 Locks

The second intrusion resistance layer, the shipping container shell, is locked using a Kossie Heavy Duty Container Locking System and an ABLOY PL362 CEN Grade 6 Maximum Security Padlock. The PL362 is commonly considered one of the most secure padlocks in the world (LockPickingLawyer 2017). The third layer of defense, the actual SCIF unit perimeter, is secured by a Krieger RFI-60-STC-50 pre-engineered door equipped with a Kaba Mas DKXL-10 FF-L-2890C locking device.

Figure 36: Kaba Mas DKXL-10 High Security Pedestrian Door Lock FF-L-2890C Type II

7.2.6 CCTV

Video surveillance for security and record-keeping purposes is accomplished with an open-hardware/software system made up of an Elphel NC393-F-CS camera and a ZoneMinder control station. The control station makes use of off-site storage to protect video footage from accidental loss or manipulation. All components are installed external to the SCIF as specified by National Counterintelligence and Security Center (2012), p. 75. The camera is installed without a view of classified information or external control components that would enable the viewer to identify PINs and access procedures.

Alternatively to the Elphel NC393-F-CS, trustworthy commercial camera equipment like a Bosch Flexidome 7000i can also be used, though open software and hardware are preferred for reasons as stated above in *section 7.2.3*.

7.3 Visual Protection

Visual protection of the SCIF unit is achieved by a continuous drywall perimeter without holes or gaps. Windows are excluded from the design. On top of entailing serious information security risks, as detailed in *section 6.2*, they also endanger a container's seaworthiness. This would jeopardize the significant mobility advantages of a SCIF container unit. The container unit also includes a vestibule area to protect from visual insight into the SCIF and access procedures during personnel entry. The entry CCTV camera is mounted so as not to provide direct insight into the SCIF during personnel entry. No other video cameras are installed or allowed inside the SCIF container.

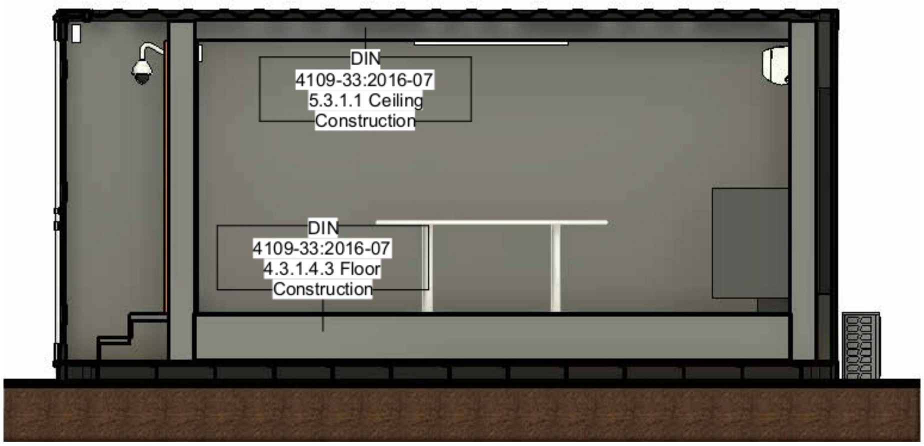


Figure 37: SCIF Container Cross Section Showing Vestibule Access Area

7.4 Acoustic Countermeasures

Sound attenuation is achieved by a three-layer approach, the first layer of defense being a heavily attenuating wall, floor, and ceiling construction with a sound-attenuating door and muffled vents.

The wall, floor, and ceiling constructions draw upon DIN standardized components and Knauf-manufactured, proprietary products. The walls are built with the Knauf W115-75Y6-10 drywall system, which comes with a certified sound attenuation level of $R_w = 73.2$ dB (Knauf Gips KG 2020a, p. 14). All corners and joints are carried out to manfucaturer specifications. According to the manufacturer documentation, this wall system has a slightly weaker sound attenuation performance in the low-frequency range (Knauf Gips KG 2020b, p. 18). This frequency range is especially relvant for the tranmissions of the human voice, as detailed in *section 4.3*. For this reason, a supplemental sound masking system is included as a second layer of defense which specifically addresses this frequency range.

The floor is constructed to the DIN 4109-33 specifications for “wooden beam ceilings with suspended ceilings on spring rails” in section 4.3.1.4.3 (Deutsches Institut für Normung 2016, p. 45). The standard width of ca. 390 mm is slightly reduced to 370 mm in order to leave more headroom for occupants. The width is taken from the cavity between the wood-based panel and the cavity damping. This component comes to a weighted sound reduction index of $R_w = 70$ dB and a horizontal sound transmission attenuation of $D_{n,f,w} = 67$ dB (Deutsches

Institut für Normung 2016, p. 68).

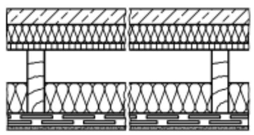
3		≥ 50	Estrich[a]	**50 (0)**	**≥ 70**
		60	Holzfaserdämmplatte WF (2 Lagen 30 mm, $s'_{ges} \leq 10$ MN/m³; Anwendungsgebiet DES-sg)[b]		
		22	Holzwerkstoffplatte HW[c]		
		220	Balken oder Stegträger[d]		
		100	Hohlraumdämpfung[b]		
		27	Federschiene[e]		
		12,5	Gipsplatte GK[f]		

Figure 38: DIN 4109-33 Floor Makeup and R_w

The ceiling is constructed to the DIN 4109-33 specifications for "wooden beam ceilings with suspended ceilings" in section 5.3.1.1. It is made up of a ceiling cladding with a spring rail, a subfloor and planking interrupted by the drywall, and two-layer 12.5 mm GWB, with a full-surface 50 mm mineral wool layer. The partition wall is perpendicular to the ceiling joists. The soft stud compartments are fully insulated. This ceiling makeup has a width of ca. 150 mm and a sound attenuation of $R_w = 67$ dB. (Deutsches Institut für Normung 2016, p. 68) The resulting headroom between ceiling and floor comes out to a relatively comfortable 213 cm.

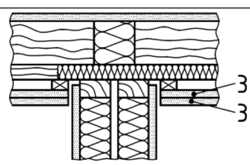
7		3	Bekleidung über Lattung an Decke befestigt	2 x Gipsfaserplatte GF	**61**
8		3	Bekleidung über Federbügel an Decke befestigt	2 x Gipsfaserplatte GF	**67**

Figure 39: DIN 4109-33 Ceiling Makeup and $D_{n,f,w}$

When entering this system into the Knauf online soundproofing calculator, a resulting $R'_{w,R} = 63$ dB is calculated, far exceeding the acoustic requirements set forth in *section 4.3*. See the attached *calculation report* for more information.

The Krieger RFI-60-STC-50 door "only" provides sound attenuation corresponding to STC 50. Although this is on the higher end of the door sound attenuation performance range, it nevertheless degrades the overall performance of the system. The front SCIF unit wall has a relatively small surface area compared to the door, so any performance losses in the door disproportionately affect the overall performance of the wall. For this reason, the entrance door also decreases the overall performance of the system. However, the included vestibule (with sound masking speakers) should reduce the door's overall performance impact, provided the container doors are closed during use.

The air vents constitute another weak point in the sound attenuating shell. They are muffled by SCHAKO AUDIX® cross-talk attenuator boxes on the intake and exhaust side. They use a galvanised sheet steel and an internal lining of special insulating plates to form a deflection labyrinth for sound attenuation. They are best-in-class for form factor relative to performance, however, they still only provide a sound attenuation of $R_w = 38$ dB. Although the inline fans aid in breaking/masking the sound waves, the air vents remain the weakest link in the sound attenuation system. They must be carefully treated with additional sound masking measures.

The second layer of defense is a 12 cm gap between the SCIF perimeter drywall and the container shell. Sound masking speakers are mounted inside this gap, as well as in the front vestibule, to drown out any residual sound waves that escape the SCIF space. Heavy contact emitters are placed on air vent breakthroughs in the gap area to render useless residual sound not attenuated by the cross-talk sound attenuator boxes. The sound masking speakers, as well as the heavy contact emitters, are fed by a SpeechMasking™ 8-channel fixed installation generator using the highly-advanced M2 algorithm. The M2 algorithm uses the natural spectrum of the human voice for maximum effectiveness as detailed in *section 6.3.3*.

The third layer of defense is the container shell itself. It does not factor into the above calculations, but undeniably has a positive impact on overall sound attenuation. Corrugated steel is relatively heavy and has vastly different vibration characteristics than drywall. The double-shell drywall is thus extended from a classic double-shell system, as described in *section 6.3.2*, to a "double-shell-plus" system, with even better acoustic protection.

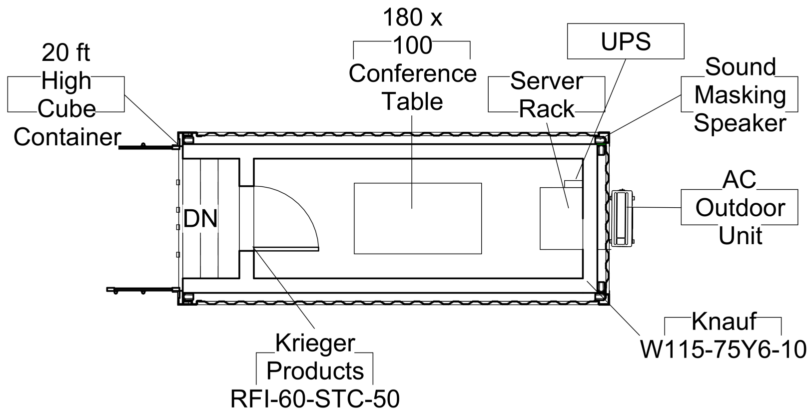


Figure 40: SCIF Floor Plan Showing the Multiple Sound Attenuation Layers

These three layers together provide sound attenuation that far exceeds the provisions of the IC Tech Spec-for ICD/ICS 705 (National Counterintelligence and Security Center 2012). An exact measurement for the sound attenuation performance, however, cannot be calculated theoretically because of the complex and novel nature of this SCIF module. Instead, accurate values must be determined empirically through practical tests on a prototype.

No microphone jamming is used within the SCIF. The technology is not yet fully matured. It can be easily overcome by using specialized microphones without hardware non-linearities in the ultrasonic spectrum. In place of the microphone jamming system, a strict PED policy should be instituted prohibiting the use of all private electronic devices within the SCIF. Compliance with this policy by non-trusted personnel, like visitors, should be checked at the entrance.

7.5 Electromagnetic/TEMPEST Shielding

Electromagnetic shielding is achieved through a 2 mm stainless steel layer functioning as an electrodynamic shield. The stainless steel plate is mounted continously ontop the drywalls interior surface and inside the floor and ceiling superstructures. Stainless steel has good electrical conductivity and high corrosion resistance. It has therefore become the preferred material for electrodynamic shields, and is also used in this SCIF container. At 100 kHz, the lowest usable radio frequency, and 1 m wall clearance this shell provides electromagnetic shielding of 100 dB. Connections between stainless steel plates and floor/ceiling and wall panels are welded exclusively to ensure the best possible electrical conductivity. Stainless steel plates are not treated against corrosion, because this has no added benefit and can worsen electrical conductivity. A paint job is applied atop the wall plates for optical reasons.

The Krieger RFI-60-STC-50 door provides at least 60 dB shielding performance for electric field and plane wave energy between 1 kHz and 18 GHz. It is connected to the wall with an RF Wiremesh seal which also provides at least 60 dB shielding effectiveness. No other moving parts are included in the SCIF design.

Figure 41: Inside SCIF Area with AC Unit, Ventillation Duct, Motion Sensor, and Server Rack

Electric power lines supply the SCIF space through a Holland Shielding Systems compact high performance power line filter model 8020-2-16. It is mounted to the shielding material as specified in *section 6.4.5*. Control lines for the AC unit, access control system, and intrusion detection system are fed through rigid conduit and penetrate the electromagentic shield through a Holland Shielding Systems signal line filter model 8090-2-16-100, also mounted to the attenuating shell. Data lines are converted to optical fibre before passing out of the SCIF space through special hollow conductors. Optionally, data connections are encrypted to a secure exit node over an encrypted VPN uplink. Footage from the surveillance camera is transmitted over an external data uplink to the ZoneMinder system, which is made accessible inside the SCIF over the shielded data uplink. The surveillance camera footage allows constant monitoring of the SCIF's vestibule area during use, allowing SCIF operators to secure its function as a visual and acoustic air lock.

Every effort is taken to keep wiring inside the SCIF unit as much as possible. For all control lines where running outside the SCIF unit is unavoidable, like those of the shield moniotring system and the access control system, lines are FIPS-AES encrypted from end-to-end and fed through rigid conduit. This eliminates interception of usable information or leakage from improperly shielded cables.

Refrigerant lines for the AC unit are fed through purpose-built pipe penetrations as specified in *section 6.4.5*. Screws for affixing cables, ducts, lighting and other components puncture the electromagnetic shield through special shielding anchor plates.

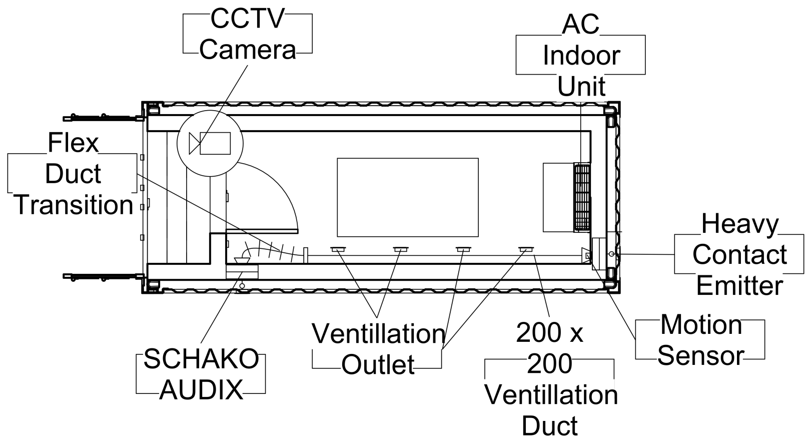


Figure 42: SCIF Floor Plan Showing Ventillation Duct and AC Unit

Air ventilation is accomplished with a 200 x 200 mm duct system with four outlets. Ducts are treated with 18 GHz honeycomb filters on both the intake and exhaust side. These filter panels, along with the cross-talk sound attenuation boxes, cause pressure losses that must be compensated by inline fans. Heating and cooling is achieved with a ductless mini-split AC system, whose inside unit is fed from the power line filter and outside unit is fed from a separate external power connection. Vapor barriers are installed on both sides of the drywall.

An electromagnetic shielding monitoring system according to *section 6.4.7* is designed and manufactured to guarantee adequate electromagnetic shielding at all times.

In combination, these measures should be able to meet and exceed the NSA 94-106 requirements as outlined in *section 4.4*. Empirical tests must be carried out on a prototype to verify that the various design assumptions hold up.

7.6 Bug Sweeping

Thorough bug sweeping using state-of-the-art equipment is conducted on all construction milestones and before SCIF commissioning. Additionally, bug sweeps are carried out quarterly throughout the SCIF's operational lifecycle and when any indications give rise to the suspicion that SCIF security has been breached.

8 Conclusion

This paper has explained the concept of a SCIF and its role in protecting sensitive communications in the physical realm. It has defined the theoretical ideal state of information security and proposed the method of threat modelling for approximating it in practical application. The paper then went on to elaborate the different kinds of passive attacks, those performed by an outside observer without interacting with the physical SCIF space, and set up quantitative limits to prevent them at the source. It also described various types of active attacks, aiming to compromise the SCIF space or weaken its protective measures. It then set forth a handful surveillance countermeasures in physical security, during construction and in operation, visual protection, acoustic attenuation/masking, and electromagnetic/TEMPEST shielding effective at preventing active attacks and meeting the quantitative limits set forth to prevent passive outside observation. It also provided an introduction to technical surveillance countermeasure (TSCM) inspections, also referred to as "bug sweeping," useful for keeping a SCIF secure over its operation lifecycle.

The paper then applied all the above countersurveillance techniques in a shipping-container-based SCIF module that can be serially produced and transported anywhere in the world discreetly, cheaply, and quickly. It demonstrated how such a module can deliver the state of the art, as standardized in the foundational IC Tech Spec-for ICD/ICS 705, even improving upon it with novel features like the shield monitoring system.

The container module delivers standardized performance, high physical security, and novel shielding technologies, all in a form-factor conducive to a SCIFs overall purpose of discreet and seamless information protection. It should be considered as fundamental to future developments in which SCIFs become essential tools for corporate and private security, not just bespoke installations only available to government agencies.

9 References

BOSCH SECURITY, 2021. *Commercial Series TriTech AM Motion Detectors with Anti-mask* [online]. March 2021. [Accessed 1 July 2021]. Available from: https://resources-boschsecurity-cdn.azureedge.net/public/documents/Commercial_Series_Tr_Data_sheet_enUS_75201763083.pdf

CHAPMAN, Ryan, 2016. *Yubikey NEO for Physical Access Control* [online]. June 2016. [Accessed 1 July 2021]. Available from: https://blog.rchapman.org/posts/Yubikey_NEO_for_Physical_Access_Control/

CHEN, Yuxin, LI, Huiying, NAGELS, Steven, LI, Zhijing, LOPES, Pedro, ZHAO, Ben Y. and ZHENG, Haitao, 2019. Understanding the Effectiveness of Ultrasonic Microphone Jammer. *CoRR* [online]. 2019. Vol. abs/1904.08490. Available from: http://arxiv.org/abs/1904.08490

CONVERGINT TECHNOLOGIES, 2017. *Meet UL 2050 Standards for Closed Rooms and SCIFs* [online]. September 2017. [Accessed 1 July 2021]. Available from: https://www.convergint.com/meet-ul-2050-standards-for-closed-rooms-and-scifs/

CYBER & INFRASTRUCUTRE SECURITY AGENCY, 2017. *Hikvision Cameras* [online]. May 2017. ICS Advisory (ICSA-17-124-01). [Accessed 1 July 2021]. Available from: https://us-cert.cisa.gov/ics/advisories/ICSA-17-124-01

DEUTSCHES INSTITUT FÜR NORMUNG, 2016. DIN 4109-1:2016-07: *Sound Insulation in Buildings - Part 33: Data for verification of sound insulation (component catalogue) - Timber construction, lightweight construction and dry walling.* Berlin: Beuth Verlag.

DEUTSCHES INSTITUT FÜR NORMUNG, 2018. DIN 4109-1:2018-01: *Sound Insulation in Buildings - Part 1: Minimum Requirements.* Berlin: Beuth Verlag.

EMCTEST TECHNOLOGIES, 2018. *NSA 94-106 Effectiveness Testing RF Shielded Enclosures* [online]. 2018. [Accessed 1 July 2021]. Available from: https://www.shieldingtests.com/?standard=NSA-94-106

EMSHIELD GMBH, 2019. *Active eavesdropping protection* [online]. 2019. [Accessed 1 July 2021]. Available from: https://emshield.de/en/portfolio/active-eavesdropping-protection/

GENKIN, Daniel, PACHMANOV, Lev, PIPMAN, Itamar and TROMER, Eran, 2015. Stealing Keys from PCs using a Radio: Cheap Electromagnetic Attacks on Windowed Exponentiation. *Tel Aviv University.* February 2015.

GLOBAL TSCM GROUP, INC., 2021. *The Stealth WEGA-i* [online]. 2021. [Accessed 1 July 2021]. Available from: https://www.globaltscmgroup-usa.com/products/covert-lens-detetor/the-stealth-wega-i/

GÖSELE, K. and SCHRÖDER, E., 2004. Schalldämmung in Gebäuden. In: *Taschenbuch der Technischen Akustik.* Berlin, Heidelberg: Springer-Verlag.

HOWSON, Ian, 2013. *Attacks on Proximity Card Systems* [online]. May 2013. [Accessed 1 July 2021]. Available from: https://ianhowson.com/blog/attacks-on-proximity-card-systems/

KNAUF GIPS KG, 2020a. [online]. April 2020. [Accessed 1 July 2021]. Available from: https://www.knauf.de/wmv/?id=1592

KNAUF GIPS KG, 2020b. *Schallschutz und Raumakustik mit Knauf* [online]. March 2020. [Accessed 1 July 2021]. Available from: https://www.knauf.de/wmv/?id=15746

KRIEGER PRODUCTS, 2015. *Radio Frequency Interference (RFI) Shielding Principles* [online]. 2015. [Accessed 1 July 2021]. Available from: https://www.kriegerproducts.com/downloads/general/RFI-Shielding-Principles.pdf

LEHMAN-LUDWIG, Anna, 2020. *Hikvision, Corporate Governance, and the Risks of Chinese Technology* [online]. August 2020. [Accessed 1 July 2021]. Available from: https://www.csis.org/blogs/technology-policy-blog/hikvision-corporate-governance-and-risks-chinese-technology

LEYDEN, John, 2015. Old tech, new battles: Inside F-Secure's formidable Faraday cage. *The Register* [online]. November 2015. Available from: https://www.theregister.com/2015/11/11/f_secure_lab_tour_faraday_cage/

LIU, Zhuoran, SAMWEL, Niels, WEISSBART, Léo, ZHAO, Zhengyu, LAURET, Dirk, BATINA, Lejla and LARSON, Martha, 2020. Screen Gleaning: A Screen Reading TEMPEST Attack on Mobile Devices Exploiting an Electromagnetic Side Channel. *Radboud University*. November 2020.

LOCKPICKINGLAWYER, 2017. *[471] The Top Ten Biggest and Baddest Padlocks* [online]. May 2017. [Accessed 1 July 2021]. Available from: https://www.youtube.com/watch?v=L6iMmCSayBQ

LOCKSMITH REFERENCE, 2018. *Ratings for Safe Locks* [online]. October 2018. [Accessed 1 July 2021]. Available from: https://lockreference.com/ratings-for-safe-locks/

LOGAN, Jonathan and BRAUN, Frank, 2019. *Cypherpunk Bitstream 0x03: TAZ* [online]. November 2019. Available from: https://taz0.org/bitstream/0x03-taz/

MÖSER, Michael, 2009. *Technische Akustik*. Berlin, Heidelberg: Springer-Verlag.

NATIONAL COUNTERINTELLIGENCE AND SECURITY CENTER, 2012. *Technical Specifications for Construction and Management of Sensitive Compartmented Information Facilities Version 1.2 - IC Tech Spec-for ICD/ICS 705* [online]. 2012. [Accessed 1 July 2021]. Available from: https://fas.org/irp/dni/icd/ics-705-ts.pdf

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND, 2021. *Introduction to GSA-approved Security Containers* [online]. January 2021. [Accessed 1 July 2021]. Available from: https://www.navfac.navy.mil/navfac_worldwide/specialty_centers/exwc/products_and_services/capital_improvements/dod_lock/SecurityHardware/SecurityContainers.html

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND NORTHWEST, 2012. *Physical Security of Sensitive Compartmented Information*

Facilities (SCIF) [online]. November 2012. [Accessed 1 July 2021]. Available from: https://www.washingtonpost.com/news/politics/wp-content/uploads/sites/11/2017/02/navfac_scif_ho.pdf

OFFICE OF THE DIRECTOR OF NATIONAL INTELLIGENCE, 2020. *Inspectable Construction Materials Checklist* [online]. July 2020. [Accessed 1 July 2021]. Available from: https://www.dni.gov/files/Governance/Inspectable-Materials-Checklist-V15.pdf

RESEARCH ELECTRONICS INTERNATIONAL, 2021. *Industry Leading TSCM Equipment & Training* [online]. 2021. [Accessed 1 July 2021]. Available from: https://reiusa.net/

RTL-SDR.COM, 2017. *TempestSDR: An SDR tool for Eavesdropping on Computer Screens via Unintentionally Radiated RF* [online]. November 2017. [Accessed 1 July 2021]. Available from: https://www.rtl-sdr.com/tempestsdr-a-sdr-tool-for-eavesdropping-on-computer-screens-via-unintentionally-radiated-rf/

SCHAKO KG, 2021. *Technical Documentation for Cross-talk Sound Attenuator Box AUDIX®* [online]. March 2021. [Accessed 1 July 2021]. Available from: https://schako.com/wp-content/uploads/audix_en.pdf

SPEECHMASKING, 2016. *Industry-Leading Speech Privacy* [online]. 2016. [Accessed 1 July 2021]. Available from: https://www.speechmasking.com

TICHELMANN, Karsten and PFAU, Jochen, 2000. *Entwicklungswandel Wohnungsbau: Neue Gebäudekonzepte in Trocken- und Leichtbauweise*. Wiesbaden: Vieweg+Teubner Verlag.

U.S. HOUSE. 115TH CONGRESS, 2018. *John S. McCain National Defense Authorization Act for Fiscal Year 2019*. August 2018. H.R.5515.

U.S. NATIONAL SECURITY AGENCY, 1972. *TEMPEST: A Signal Problem* [online]. 1972. [Accessed 1 July 2021]. Available from: http://www.jproc.ca/crypto/tempest.pdf

U.S. NATIONAL SECURITY AGENCY, 1994. *NSA 94-106 National Security Agency Specification for Shielded Enclosures* [online]. 1994. [Accessed 1 July 2021]. Available from: http://cryptome.info/0001/nsa-94-106.htm

WOLFSPERGER, Hans A., 2008. *Elektromagnetische Schirmung: Theorie und Praxisbeispiele*. Berlin, Heidelberg: Springer-Verlag.

ZEITLER, Bernd, 2013. *Guide to calculating airborne sound transmission in buildings - Scientific Figure on ResearchGate* [online]. 2013. [Accessed 1 July 2021]. Available from: https://www.researchgate.net/figure/In-reality-there-are-many-paths-for-sound-transmission-between-adjacent-rooms_fig6_262914712

10 Addendum

SCHALLSCHUTZRECHNER

Ihre Konfiguration im Überblick

Anforderungen an den Schallschutz der Trennwand im eingebauten Zustand

Gebäudeauswahl:	**Mehrfamilienhäuser, Bürogebäude, gemischt genutzte Gebäude**
Wandart:	**Wohnungstrennwände und Wände zwischen fremden Arbeitsräumen**
Anforderungsnorm:	**DIN 4109-1:2018**
Schalldämm-Maß (R'w):	**53 dB**

Raumgeometrie

Breite der Räume / der Trennwand:	**1,7 m**
Höhe der Räume / der Trennwand:	**2,1 m**
Tiefe Raum 1:	**0,8 m**
Tiefe Raum 2:	**4,6 m**

Trennwand

Bauweise:	**Trockenbau**		
Systemvariante:	**F90 Metall-Doppelständerwand ≤ 4,85 m, CW 100 (625 mm), Piano GKFI 12,5 mm + Diamant 12,5 mm, d = 255 mm, Rw = 73,2 dB, MW 2x 80 mm (G)**		
Wandart:	**Metallständerwände (W11.de)**	Feuerwiderstandsklasse:	**F90**
Ständer-Profile:	**CW 100**	System:	**Metallständerwand (W115.de)**
Gleitender Deckenanschluss:		**ja**	

SCHALLSCHUTZRECHNER

Ihre Konfiguration im Überblick

Linke Flanke

Bauweise:	**Trockenbau**
Anschlusstyp:	**Anschluss an Metallständerwand**
Wandanschluss:	**Raumseitige Beplankung der flankierenden Wand mit Fuge (5 mm), Unterkonstruktion getrennt, zweilagig, Silentboard ≥ 2x 12,5 mm, CW 100**
Norm-Flankenpegeldifferenz:	**74 dB**

Rechte Flanke

Bauweise:	**Trockenbau**
Anschlusstyp:	**Anschluss an Metallständerwand**
Wandanschluss:	**Raumseitige Beplankung der flankierenden Wand mit Fuge (5 mm), Unterkonstruktion getrennt, zweilagig, Silentboard ≥ 2x 12,5 mm, CW 100**
Norm-Flankenpegeldifferenz:	**74 dB**

SCHALLSCHUTZRECHNER

Ihre Konfiguration im Überblick

Decke

Bauweise:	**Holzbalkendecke mit Unterdecke**
Deckenanschluss:	**Deckenbekleidung mit Federschiene, UK und Beplankung unterbrochen, zweilagig, ≥ 2x 12,5 mm Diamant GKFI, mit vollflächiger Mineralwolleauflage ≥ 50 mm; Trennwand rechtwinkelig zu Deckenbalken, Weichschott oder Gefach vollständig ausgedämmt**
Norm-Flankenpegeldifferenz:	**67 dB**

Boden

Bauweise:	**Wand steht auf Holzbalkendecke**
Bodenanschluss:	**Fertigteilestrich durch Trennwand konstruktiv getrennt Trennwand parallel zu Deckenbalken, mit vollflächiger Mineralwolleauflage ≥ 25 mm**
Norm-Flankenpegeldifferenz:	**67 dB**

SCHALLSCHUTZRECHNER

Ihre Konfiguration im Überblick

Ihr Ergebnis

Ihre Anforderungen:	Schalldämm-Maß (R'w):	**53 dB**
Ihr Ergebnis:	Norm-Schallpegeldifferenz (Dnw):	**63 dB**

Die Anforderungen werden erfüllt!

Rechtliche Nutzungshinweise / Haftungsbegrenzung

Kein Auskunftsvertrag

Durch die Benutzung des Schallschutzrechners kommt kein Vertrag - auch kein Auskunfts- oder Beratungsvertrag - zwischen dem Nutzer des Schallschutzrechners und dem Betreiber dieses Rechners oder solchen Unternehmen zustande, für deren Produkte der Schallschutzrechner genutzt wird.

Haftungsbegrenzung

Der Schallschutzrechner wurde sorgfältig programmiert und die Produktdaten sorgfältig zusammengestellt. Dennoch ist jede Haftung für Schäden (z.B. eine fehlerhafte Planung) ausgeschlossen, die durch Verwendung von Rechnungsergebnissen oder von Daten oder Informationen aus diesem Programm verursacht werden. Der Haftungsausschluss gilt nicht für Schäden aus der Verletzung von Leben, Körper oder Gesundheit sowie für Schäden, die aus einer vorsätzlichen oder grob fahrlässigen Pflichtverletzung der Knauf Gips KG oder vorsätzlichen oder grob fahrlässigen Pflichtverletzung ihrer gesetzlichen Vertreter oder Erfüllungsgehilfen beruhen.