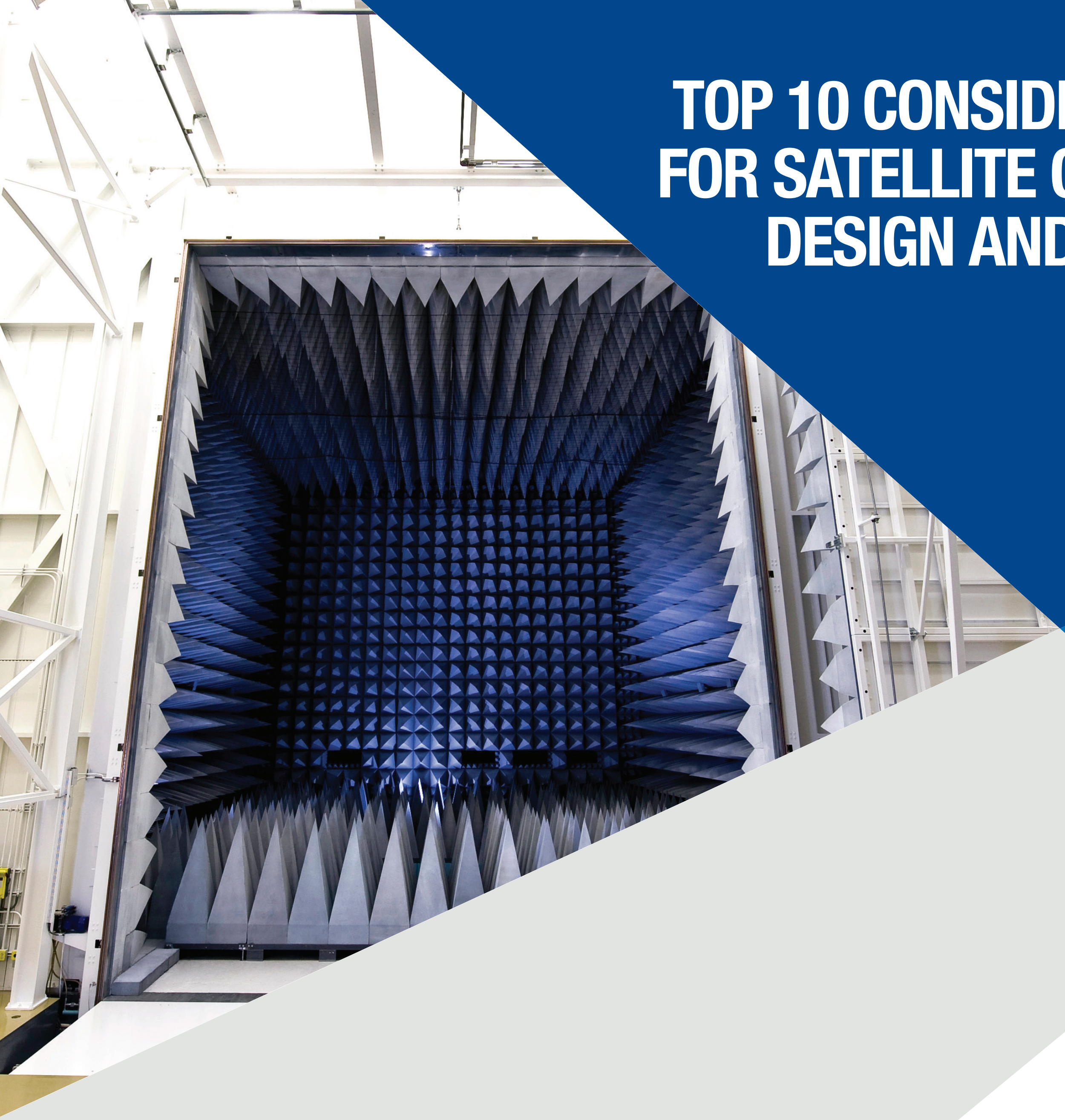
# TOP 10 CONSIDERATIONS FOR SATELLITE CHAMBER DESIGN AND TESTING



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# TOP 10 CONSIDERATIONS FOR SATELLITE CHAMBER DESIGN AND TESTING

Following is our Top 10 list of the most important considerations when developing or refining a satellite test chamber design or specification. This resource identifies the key topics you should address – in advance – to ensure a successful project outcome. With this quick and concise guide, you'll find a convenient review of the different types of satellites, types of testing commonly performed, test system and special handling that may be required for the device under test (DUT), and more! For satellite test chambers, from testing satellite components to full satellites, you'll gain an appreciation for the attention needed to the considerable mechanical engineering inherent in satellite test chambers. A review of these *Top 10 Considerations for Satellite Chamber Design and Testing* will help maximize the return on your investment in a satellite test chamber.

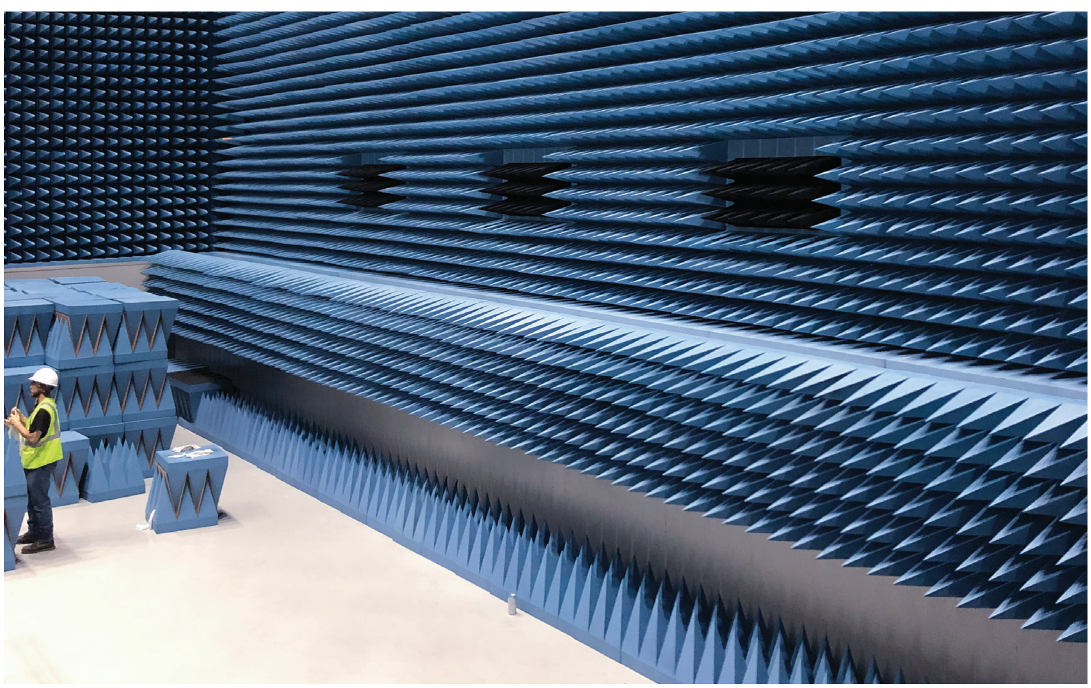
## 1. Identify the Type of Satellite

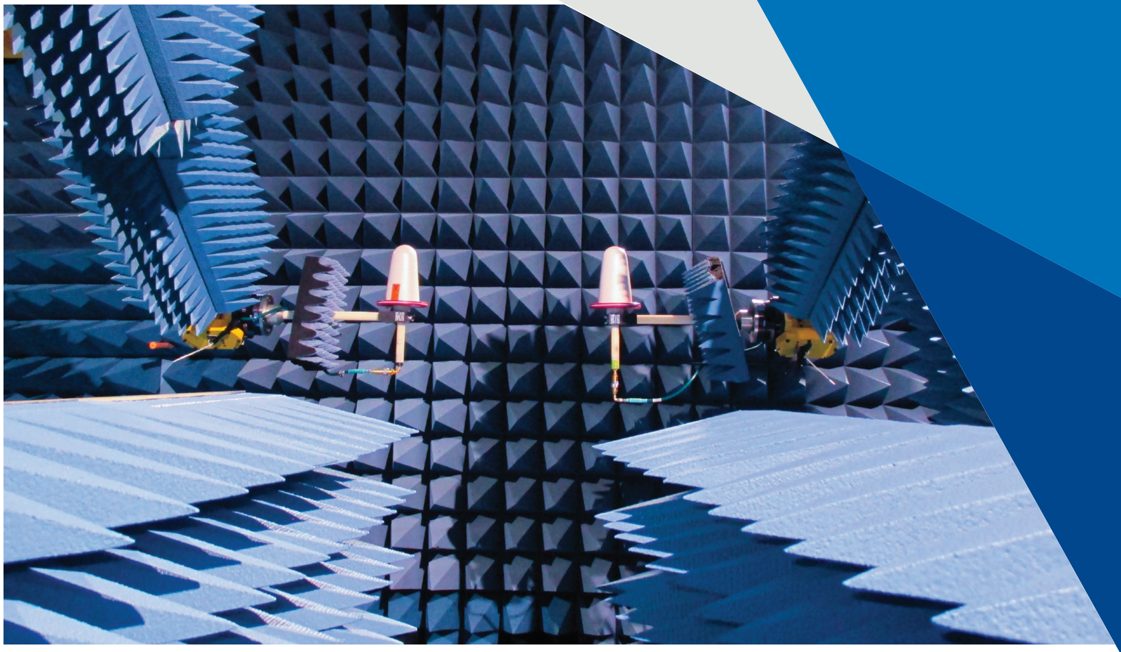
What type of satellite will you be testing? There are five primary types of satellites:

- GEO (Geostationary Earth Orbit)
- MEO (Medium Earth Orbit)
- ICO (Intermediate Circular Orbit)
- LEO (Low Earth Orbit)
- CubeSats (Nanosatellites)

Once the satellite type is confirmed, that will heavily dictate the type of test environment required and the approximate size of the test chamber.

Note satellite component testing also requires a specific test environment. While these chambers are much smaller than those used for testing of full satellites, special care is needed to address shielding levels required and meeting applicable test standards for the given application. This is discussed in further detail under Item 4 on page 4.





## 2. Determine the Primary Use of the Satellite

To further define the appropriate test environment for the DUT, what is the test application? That is, what is the primary use of the satellite? Will it be used for a Commercial, Military, or Civilian application?

Typical applications include Communication (SATCOM), Remote Sensing (ISR), Positioning Navigation (PNT), Space Launch Vehicles (SLVs), as well as Space/Technology Development. The specific application impacts the design of the test environment. For example, for military applications, special design considerations may need to be incorporated into the chamber design to meet security standards and requirements. These requirements will need to be known prior to the design phase. If the purpose is communication in taking or collecting images, determining GPS, or launching another satellite, this further defines the test environment, specifically the types of antennas that will be inherent in the satellite and how the satellite interacts with the system.

With knowledge of the satellite application, this further defines the complexity of the satellite and the robustness of the RF testing required – which dictates the level of mechanical and electrical engineering necessary in the design of the test environment.

## 3. Test System Requirements are Often Pre-Defined and Dictate the Test Environment

You may have a pre-defined test and positioning requirement which may necessitate one of the following common test environments:

- Near Field
- Far Field
- Compact Range
- Vertical Near Field
- Spherical Near Field

Based on the test system required, the complexity of the test environment is defined.

A combination of test system requirements results in a more complex test chamber which requires more sophisticated software, test instrumentation, and positioners that work together as a system.

Test methodology has evolved significantly in recent years due to increasingly sophisticated instrumentation and powerful advances in software capabilities. Costs have increased accordingly so while the possibilities are exciting, test system requirements should be reviewed thoroughly to maximize the return on your investment now and preparedness to meet future test requirements with your chamber.

## 4. Chamber Performance Considerations

What are the performance acceptance test requirements upon chamber completion? Are there specific industry test standards that indicate the chamber performance needed for compliance testing? For shielding performance verification testing, this could be industry standards such as MIL-STD-285 and IEEE 299. For anechoic testing, this could be industry standard ANSI C63.4 for normalized site attenuation (NSA), IEC 61000-4-3 for field uniformity calibration, and/or a SVSWR test per CISPR 16-1-4 for site validation. At a minimum, the chamber RF isolation requirements (RF shielding), the frequency range (bands), and shielding performance (dB) should be defined at the start of satellite test chamber planning as this will influence the basic design and construction of the test chamber.

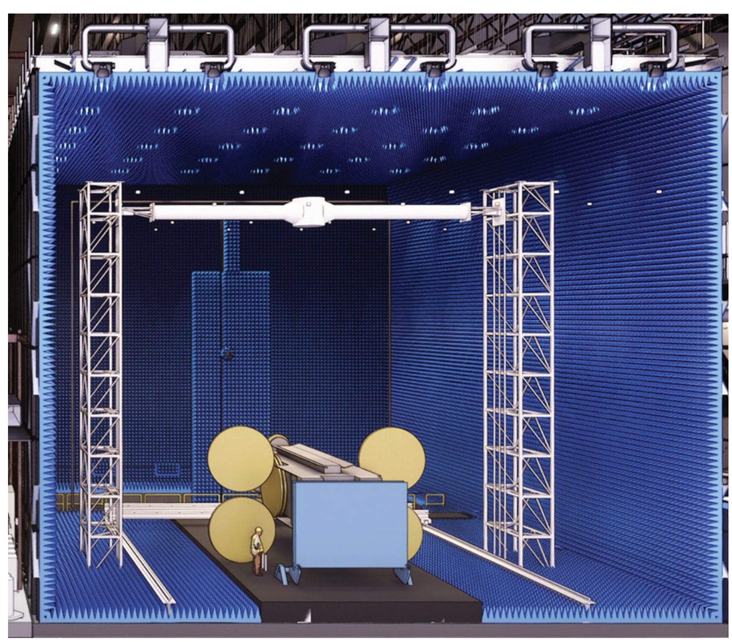
There are many types of test chambers available depending upon the performance requirements. The most common types of test chambers include:

- Fully Anechoic Chamber
- Semi Anechoic Chamber
- Tapered Chamber
- GTEM! Chamber
- Other Chamber – which may be a combination of the above chamber types or a customized chamber design

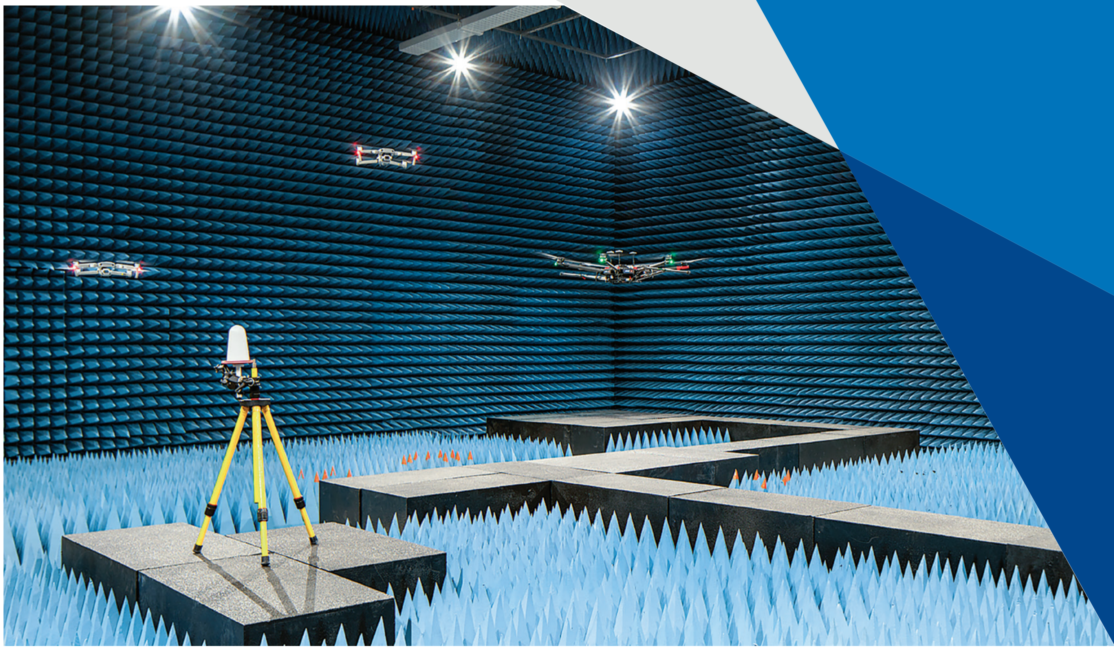
The fully and semi anechoic as well as tapered chamber types are most commonly used for testing full satellites or larger satellite components. GTEM! chambers are most commonly used for testing smaller satellite components.

Based on the applicable industry standard and/or performance acceptance requirements, the test standard determines the optimal chamber construction method. For example, welded chamber construction is used for the most severe shielding requirements while modular chamber construction is suitable for more moderate to low level shielding requirements.

Keep in mind that the RF shielding performance required by the applicable industry standard also impacts the penetrations into and out of the shielded chamber. Special treatment is required of all openings into the chamber, whether it be a large door for personnel and the DUT or smaller penetrations for air, water/cooling fluid, lighting, power, and fire protection, as a few examples. The level of RF shielding performance required dictates not only the overall chamber construction, but also the treatment of penetrations used on the chamber.



In addition, performance acceptance requirements and industry standards specify if anechoic absorber material is required inside the chamber. In this case, considerations must also be given to requirements for absorption, reflectivity, and potential heat loads.



## 5. What Type of Testing is Required?

Will you be testing satellites or components? For example, if you are testing a full satellite, the primary focus would be testing the transmission and reception of the satellite in a real-world environment which requires a larger chamber. If satellite components only are to be tested, such as an antenna, a smaller chamber is sufficient.

When considering the type of testing required, it is helpful to also consider the test instrumentation required to support the test plan as this may have a considerable cost and schedule impact on the overall test chamber project. The most common satellite test applications include:

- RF Emissions and Immunity testing for electromagnetic field response under normal operation, including MIL-STD type testing
- Antenna Power Measurements
- Antenna Pattern Characterizations and Accuracy
- Special Measurements such as Anti-Jamming

Once the testing requirements are defined, the supporting instrumentation necessary and initial footprint of the test chamber can be determined. This is also a good time to review the existing test instrumentation you may have available to support the satellite and new instrumentation you may need to acquire. You might also want to consider automated test software features to efficiently consolidate the various instruments into one convenient software program. Commercial test software packages are available that are instrumentation agnostic and accommodate virtually all manufacturers of test instrumentation. If you have a unique instrument, ask your software provider if a driver can be written to accommodate it in your test protocol.

## 6. Are There Special Requirements for Satellite Handling?

Requirements for handling the satellite directly influence the complexity of getting the satellite into and out of the test chamber as well as define protocol for working in and around the satellite within the chamber. Sensitive components on satellites are not only fragile, but they are costly and not readily available. Therefore, satellites must be treated with the utmost care.

As a primary consideration, the size, weight, and fragility determine the chamber door size and design. It cannot be overstated that satellite sensitivity (fragility) is an import consideration in the chamber and door design regarding the satellite insertion and extraction into/out of the chamber.

The satellite size and weight dictates the door size, type, and threshold required. For example, smaller satellites may be rolled into the chamber on a floor jack through a swing-type personnel door or through a fully automatic sliding door with a flush threshold.

The door threshold design needs to be taken into account to consider not only the weight of the satellite, but the need to seamlessly bring the satellite into and out of the chamber. For example, with very sensitive and fragile satellites, the door threshold must be level to minimize bumps and jarring of the satellite rolled over an elevated door sill.

Many times, the launch provider will dictate the satellite durability design criteria so the optimal door and threshold can be determined.

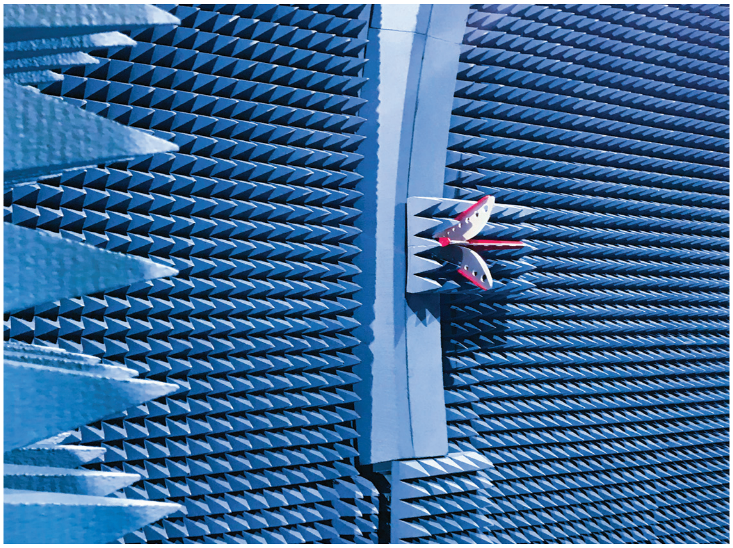
## 7. Test System Positioning Requirements

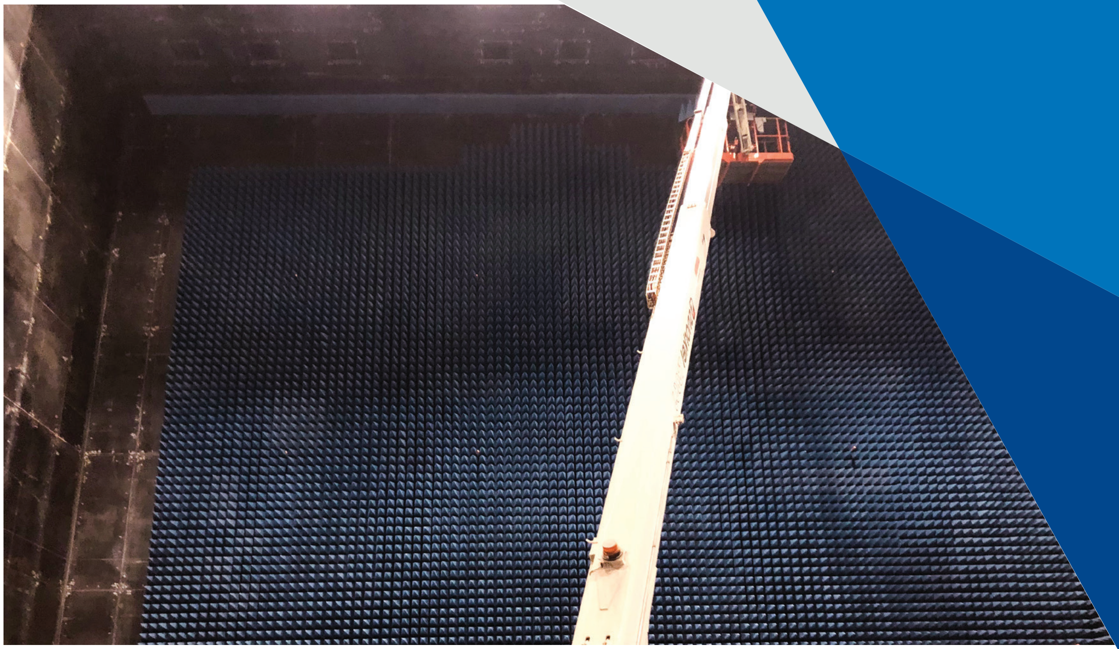
There are many commercially available test positioners for satellite test chambers, including:

- Manual
- Phi Axis
- Azimuth
- Gantry
- "Arch" Type
- Custom

Does your chamber require a special positioning system or do you have a preference? Some positioners are more complex and require a custom solution. Some positioners can be provided for a specific application now, but provided with features to allow for expanded capabilities in the future.

Determining the preferred positioning system in advance is important as that dictates the chamber size needed to accommodate the positioner and may also impact the project completion schedule. Keep in mind that many positioners may have an extended lead time due to the complexity of the design and construction materials used.





## 8. Passive Intermodulation (PIM) Requirements for Satellite Testing

Passive Intermodulation (PIM) occurs when two or more signals are present in a passive device (cable, connector, isolator, switch, etc.) that exhibits a nonlinear response. These unwanted signals could produce intermodulation interference that affect the overall performance of the satellite. Any PIM testing requirements need to be known in the design phase as they will directly influence the design of the chamber, including shielding level requirements. Higher shielding requirements mean more robust construction and special attention to all aspects of the chamber, including all components and penetrations. Utility placement and interface with the parent building are also very important considerations for PIM chambers.

Special design requirements for a PIM chamber may include:

- Chamber construction method and materials used (welded or modular construction)
- Door construction (swing or sliding door opening with special care placed on the door sealing mechanism)
- Connector panel design and interface
- Lighting design, including conduit and interfaces
- Chamber penetrations and connections for water, power, etc. and locations of the penetrations on the chamber
- Fire safety connection design
- Airflow requirements and filtering – when under operation, some testing scenarios generate tremendous heat. To compensate for the high heat levels, the airflow level and filter system design are critical to a PIM chamber. That impacts the number and types of air vents as well as filter foam used that is appropriate to the clean room requirement.

## 9. Is a Clean Room Requirement Applicable to Testing Your Satellite?

Complex satellites often require a clean room environment. This should be confirmed during the initial test chamber planning stages as this will impact the materials used in the chamber design. For example, the anechoic absorber may require a special composition and coating to meet different clean room requirement levels. Airflow and filtering may require special attention to comply with clean room requirements.

First, determine if there are indeed clean room requirements for testing your satellite (example below).

| | | | | | | |
|---|---|---|---|---|---|---|
| Class: US FED 209E | 1 | 10 | 100 | 1,000 | 10,000 | 100,000 |
| ISO Equivalemt: ISO 14644-1 | ISO3 | ISO4 | ISO5 | ISO6 | ISO7 | ISO8 |

Second, be aware there are other clean room capabilities that may be an "intermediate" level between those shown above. Speak with an expert to discuss the options as pricing for different clean room level requirements may be significant.

Clean room requirements affect the overall chamber design and well as the chamber components. Components such as waveguide air vents and doors may undergo special scrutiny to ensure the fabrication method used does not contain particulates that could enter the test environment and adversely degrade the clean room level.

When used in a clean room environment, the anechoic absorber, type, composition, and coating used must be evaluated. For example, traditional absorber requires a special coating to meet certain clean room requirements. The coating seals the absorber so particulates are confined to the absorber. This is especially important around doors and/or on floor walkways where absorber can be bumped, stepped on, and potentially damaged, thus releasing particulates. A specially coated, flexible type absorber is thus ideal for use around the doors and on the floors of a chamber.

## 10. Remember: Quality Project Execution Ensures a Successful Project Outcome

Building Information Modeling (BIM) is an especially helpful tool for the design and construction of large satellite test chambers, including PIM requirements where special rigging and mechanical considerations need to be considered. BIM is useful in visualizing utility placement and interface with the parent building in order to avoid conflict with existing connections. In general, BIM helps in understanding satellite access routes and care needed to move the satellite into and out of the test chamber.

Projects using BIM result in lower expense and risk through reduced construction delays, rework, and/or on site problems. Consider chamber manufacturers who have an in-house Autodesk Certified Professional design team that is proficient in BIM to minimize the inherent risk in your construction project.

*Need additional assistance in selecting a satellite test chamber? ETS-Lindgren can help! Contact your local ETS-Lindgren representative, phone us at +1.512.531.6400, send us an email at info@ets-lindgren.com, or visit our website at www.ets-lindgren.com.*

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