An Introduction to Precision Measurement Laboratories

Course No: D03-005
Credit: 3 PDH

J. Paul Guyer, P.E., R.A., Fellow ASCE, Fellow AEI

Continuing Education and Development, Inc.

P: (877) 322-5800
info@cedengineering.com

This course was adapted from the Unified Facilities Criteria of the United States government, which is in the public domain.

CONTENTS

1. FUNCTIONAL REQUIREMENTS

1.1 DESIGN APPROACH. The design criterion in this discussion simplifies construction or renovation to a wide variety of Precision Measurement Equipment Laboratories (PMELs), including the basic requirements which apply to any PMEL.

1.1.1 STRUCTURAL, MECHANICAL, ELECTRICAL, AND PLUMBING REQUIREMENTS. Using the internal and site layouts, locate interfaces between the facility structure and equipment items. Verify the design contains openings, conduit, and raceways to install cables, equipment, and piping with minimum disruption to finished work. During the pre-design stages of the project, the PMEL supervisor must provide the design agent with technical data for any equipment which requires special connections.

1.1.2 THE COMMISSIONING PROCESS AND VERIFICATION OF OPERATION. The commissioning process ensures that a facility and its components will perform as designed and intended. Optimally, the commissioning process starts during planning and programming prior to design. It continues during design with review of design information, performance data in specifications, and evaluation of submissions. During construction, the commissioning process includes checklists, scheduling of tests, testing and verification, and documentation. Commissioning includes witnessing field tests, adherence to specified performance criteria. Commissioning of building systems is critical to ensuring their expected operation. Commissioning of heating, ventilation, and air conditioning (HVAC) systems must be provided by certified commissioning agents. Performance testing must be conducted during both peak seasons to ensure compliance with functional and performance requirements as described for each space. Certified commissioning agents will have in-depth knowledge of commissioning processes and technical expertise on projects of similar scope, size, and complexity.

1.1.3 ENVIRONMENTALLY SAFE MATERIALS AND INDOOR AIR QUALITY. Ensure that mission and user requirements, as well as occupant health and safety are considered during design, construction and operations for material selection and environmental

systems. Hazardous materials used in the laboratory must be considered in the design. The user will provide the design agent a list of hazardous materials, including quantity, use, and location in the laboratory.

1.2 SPACE REQUIREMENTS. The space requirementsvare based on the typical PMEL. The size of the PMEL varies depending on the inventory and type of facility (Type II or Type III).

1.3 FUNCTIONAL LAYOUT.

1.3.1 FUNCTIONAL LAYOUTS FOR OVERALL BUILDING. Figures 2-1 through 2-4 show the functional layouts for the overall building, and the C/R, support, and administrative areas.

1.3.2 ALTERATIONS TO EXISTING FACILITIES. Figures 2-1 through 2-4 illustrate acceptable layouts for the overall building. These layouts may have to be modified to accommodate alterations to existing structures. However, proposed modifications must be approved by the Owner. Existing buildings being considered for modification should be assessed as to whether they can support all the core and optional spaces and dimensional requirements.

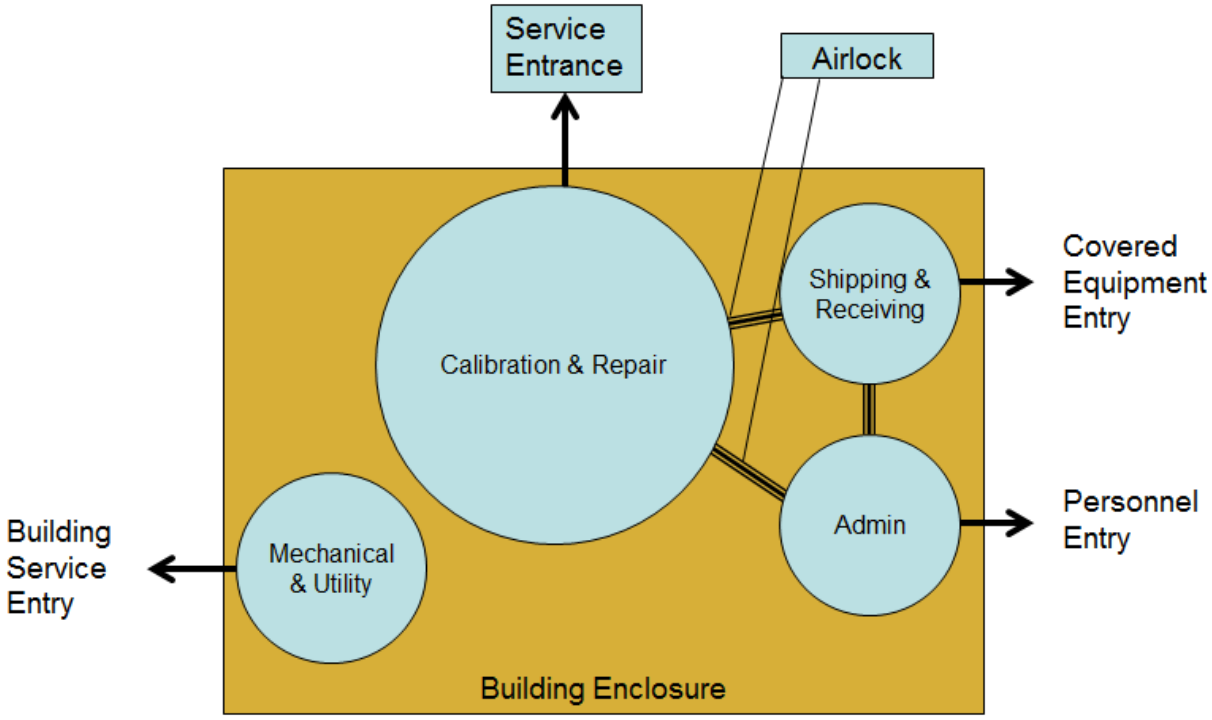

Figure 2-1

Overall Building Functional Layout

1.3.3 OTHER CONSIDERATIONS. Consider the site of the existing facility and its limitations with regard to the PMEL requirements. Only permanent facilities should be considered for conversion to a PMEL facility. Ensure that existing buildings can accommodate the environmental temperature requirements of a PMEL facility. Quantities of workload, physical size of workload, proposed workload, or expansion of workload are the primary factors in determining the design of PMEL support areas. From quantities of equipment that will be received, processed, and stored daily, initial floor space requirements can be estimated. Human engineering and the integration of other PMEL operations must be considered to determine location and layout of the support areas. Equipment storage areas must be isolated from visitors for security and to prevent unauthorized movement of equipment.

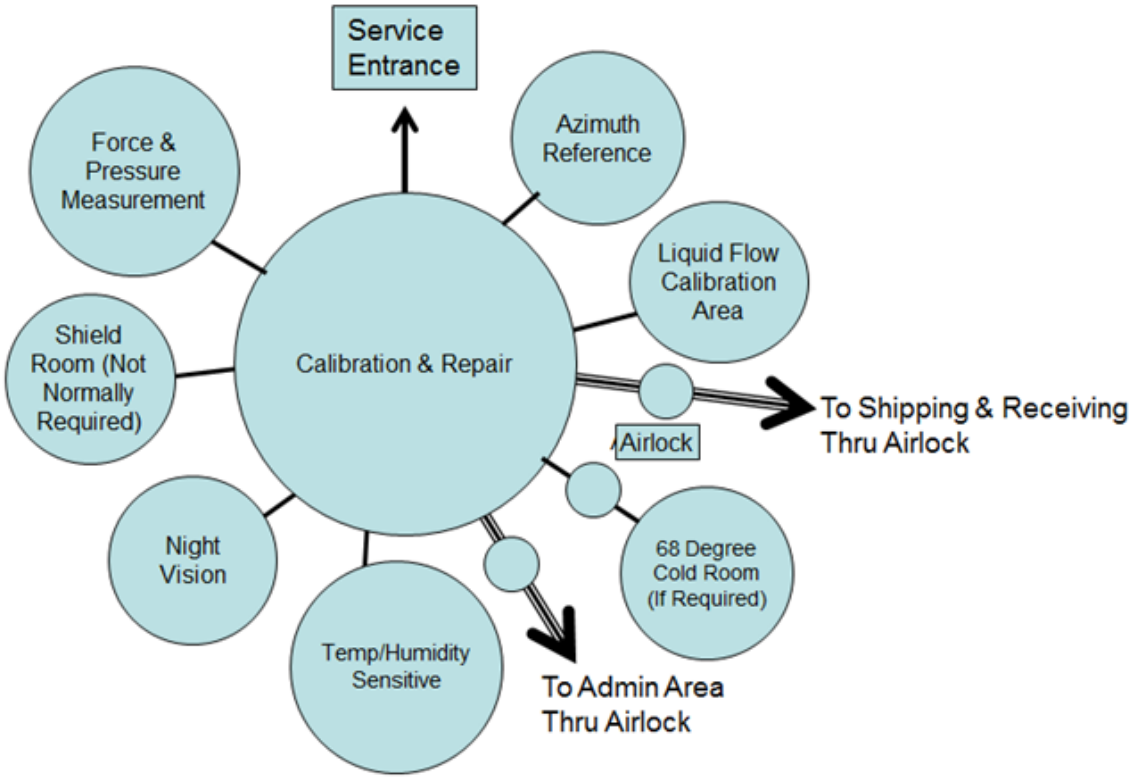

Figure 2-2

Calibration and Repair Area Functional Layout

1.3.4 LOCATION OF ROOMS, SPACES, AND EQUIPMENT. Locate rooms, spaces, and equipment to ensure orderly workflow, and provide security and property management. Incompatible areas should not be in close proximity; e.g., equipment that vibrates should not be near the C/R area when vibration may affect measurements. Moisture-generating areas such as restrooms and break rooms should not be near the C/R area. Limit outside walls in the C/R area as much as possible. North and east exposures are preferred. Ensure traffic from movement of equipment, technicians, and customers are isolated from the C/R area. Where possible, design doors and air locks to allow movement of large PMEL equipment and appropriate material handling equipment within the facility. Whenever practical, locate the C/R area adjacent to other environmentally-conditioned areas.

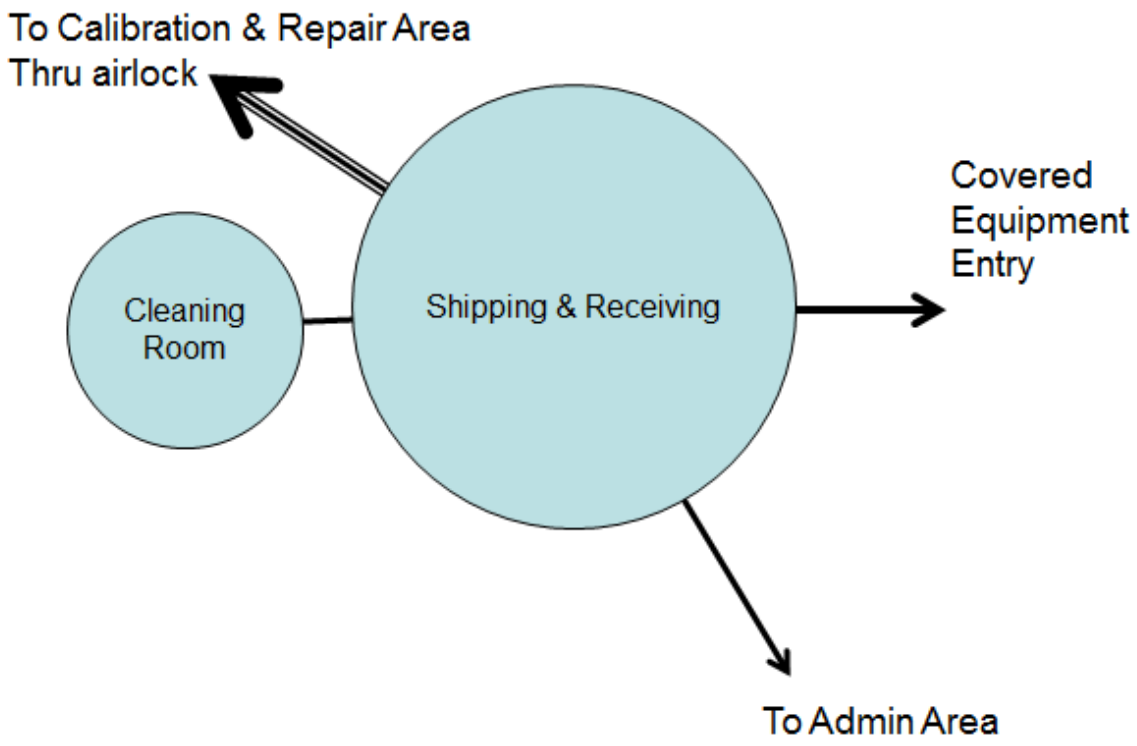

Figure 2-3

Support Area Functional Layout

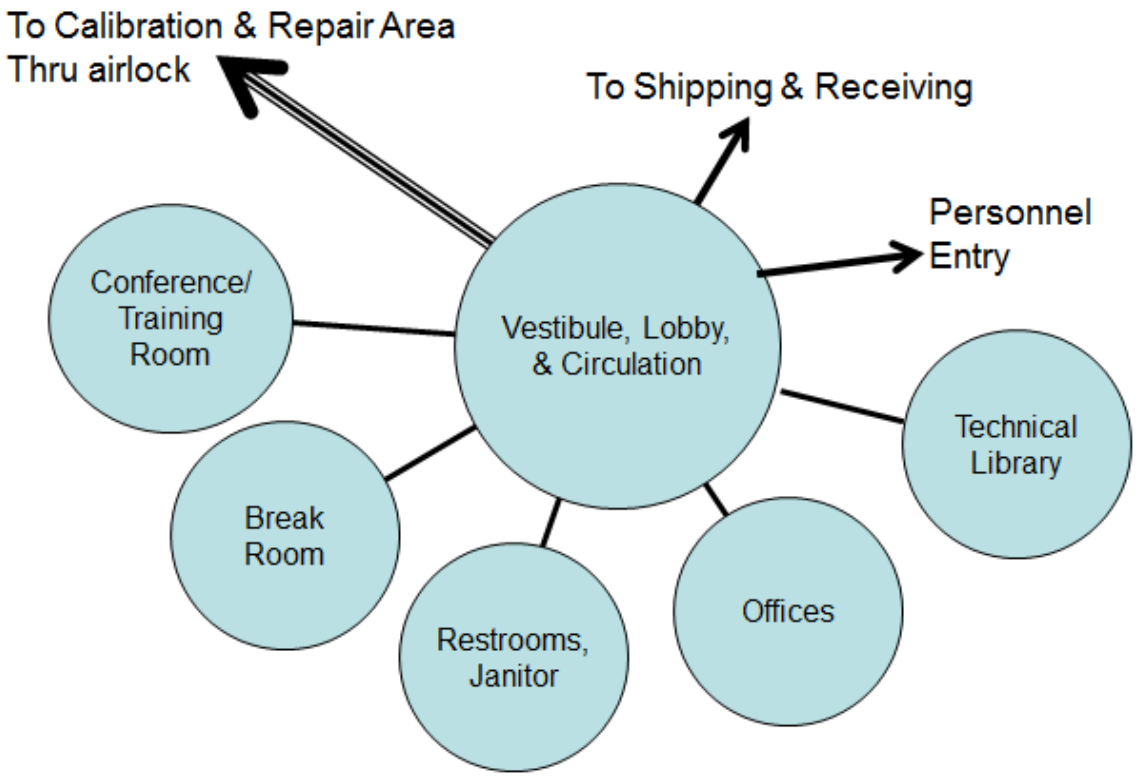

Figure 2-4

Administrative Area Functional Layout

2. GENERAL DESIGN CRITERIA

2.1 GENERAL BUILDING REQUIREMENTS. Comply with model building codes, unique criteria for typical design disciplines and building systems, and guidance regarding accessibility, antiterrorism, security, high performance sustainability requirements, and safety. This discussion provides general criteria only and consists mainly of references to the technical design criteria documents and general considerations. Conform with the specific design requirements for PMEL facilities.

2.2 STRUCTURE.

2.2.1 FOUNDATION. The foundation is site specific and must be designed upon known geotechnical considerations, by an engineer knowledgeable of the local conditions. Facilities must be located to permit laying out unobstructed lines of sight to the target monument, ranging from 45 degrees either side of astronomic north, which is specific to PMELs with Azimuth Reference only.

2.2.2 VIBRATION. The PMEL facility site must be isolated from sources of vibration such as railroads, local heavy vehicle or aircraft traffic, crane or machine operations, foot traffic, or similar disturbances. An infrequently used option is constructing the facility below ground level. An acceptable vibration level for a PMEL is anything less than 10 μin (0.25 μm) displacement peak for frequencies from 0.1 to 30 Hz. The maximum acceleration peak is 0.001 g for frequencies from 30 to 200 Hz. To minimize vibration, apply the guidance herein.

2.2.2.1 EXPANSION AND ISOLATING JOINTS. Use expansion/isolation joints in the concrete floor on the outside toe of the walls defining the conditioned area to isolate the thermal mass of the floor and reduce vibration transmission. Use vibration isolating joints in the utility room where walls and floor adjoin the main structure.

2.2.2.2 VIBRATION EQUIPMENT LOCATION. Locate vibration-generating equipment such as blowers, compressors, heating and air conditioning units, vacuum pumps, and transformers on separate, isolated utility pads. Equipment that vibrates should not be located near the C/R area.

2.2.2.3 SPECIALIZED SHOCK MOUNTS. Use specialized shock mounts, air bag supports, or isolated massive blocks.

2.2.2.4 STEEL SPRING TYPE ISOLATORS. Mount air conditioning equipment (condenser/compressor or fan coil units) to the structure using steel spring type isolators which limit vibration transmission to 0.001 g or less.

2.2.2.5 FLEXIBLE BOOTS. Use flexible boots or connectors to reduce vibration transmission through ductwork, piping, and rigid tubing.

2.2.2.6 RIGID CONDUIT CONTACT. Do not allow rigid conduit such as feeders, subfeeders, and their supports to contact other non-supporting objects.

2.2.2.7 FLEXIBLE NEOPRENE-JACKETED CONDUITS. Use flexible neoprene-jacketed conduits for connections to vibration producing equipment. Install flexible bonding ground straps to ensure continuity of the ground.

2.2.2.8 AIR BEARINGS AND ISOLATORS. Use vibration isolators or air bearings mounted on workbenches and surface plates where extensive isolation techniques cannot be used. This will reduce vibration transmitted to sensitive instrumentation in contact with these surfaces.

2.2.3 STRUCTURAL ELEMENTS IN THE SUPERSTRUCTURE. Use masonry walls, metal studs, steel joists, steel columns, and steel beams in the superstructure. Where possible, locate specially conditioned areas within the structure so the walls are interior partitions. The building must be single-story, ground floor, and concrete slab construction;

exterior doors must not face prevailing winds. Ensure proper floor load bearing design to account for ancillary equipment. Interior partitions must extend above the vapor barrier of the ceiling.

3. EXTERIOR DESIGN. In general, the building's image, theme, and fixtures must be consistent with the functions offered. The building design should reflect the local geographical and cultural environment and comply with the appropriate Service and Installation architectural standards.

3.1 EXTERIOR FINISHES. The exterior color, texture, and design should be consistent with the programs offered and the local environment in accordance with Installation standards. They should also be appropriate for the building type.

3.2 ENTRANCES/EXITS. The main facility entrance to the lobby should serve as a welcome and transition point; elements such as a covered entry are very desirable. In cold climates, provide a canopy (or a recess) at required egress doors to ensure that doors can open completely without obstruction from snow and ice. The number and location of exits must comply with applicable codes to preclude being cut off in the event of a localized fire.

3.2.1 COVERED EQUIPMENT ENTRY. Provide a protected entrance for unloading equipment: either a double-entry door with a drive through canopy; or a service entry with a roll-up door large enough to allow a small truck or van to back into the unloading area. Quantity and size of equipment handled and weather conditions should determine which entry is appropriate.

3.2.2 SERVICE ENTRANCE (OVERSIZED EQUIPMENT ENTRY). Where oversized equipment cannot be moved through the air lock, provide a set of tightly-sealed double doors between the C/R area and the building exterior. Equip doors with low leakage seals to prevent exfiltration from pressurized C/R areas. Provide a canopy to shield equipment and the laboratory from precipitation when moving oversized equipment in and out. Fully enclose the canopy to create an insulated entryway in extreme climates.

3.3 EXTERIOR WALLS AND MOLD. Comply with current industry standards, during design to help prevent the development of mold in exterior walls.

3.4 DOORS AND WINDOWS. Provide windows to allow natural light into the facility, considering antiterrorism and energy conservation/sustainable design issues. All windows and unused doors or other openings shall be sealed to prevent non-conditioned air infiltration and dust contamination from outside. Design and arrange doors opening into the PMEL to maintain effective dust and temperature controls. Minimize the number of doors for personnel passage consistent with fire and safety regulations.

3.5 EXTERIOR SIGNAGE. The main entrance should be equipped with a clearly visible sign that provides the program hours of operation. Ensure that signage complies with Installation requirements. Sign Standards. Sign placement and type are site-specific, but signs must be strategically located, adequately lit, and of sufficient size to permit proper viewing by individuals approaching the facility.

3.6 UTILITY ROOMS. Mechanical equipment is usually housed separately from major electrical equipment, which should be located in a dedicated electrical utility room. It is critical that equipment fits the space without crowding and allows adequate space for maintenance. Designers should plan on equipment utilizing a minimum of 15 percent of the total structure area. Utility rooms must be structurally (seismically) separate from the rest of the PMEL building.

4. INTERIOR DESIGN AND CONSTRUCTION. Interior walls should be Type I or Type II construction as outlined in the International Building Code® using noncombustible materials. Interior walls and ceiling should be insulated and have as much thermal mass on the controlled area side of the wall as possible. If the wall is stud construction, use two layers of 5/8-inch (16-millimeter) gypsum board on the C/R side, with batt insulation, air barrier, and 1/2-inch (13-millimeter) gypsum board on the outside. Tape and seal all gypsum board and seal the sill plate. Good workmanship is essential in finishing each joint and seam of the walls to minimize air infiltration and exfiltration. Refer to UFC 3-101-01 for additional guidance. Interior construction should be extremely durable. Use no hollow core wood doors. All interior glass must be tempered safety glass and mirrors must be made of break-resistant materials. Do not place exterior windows (except for optical windows, as required) in the C/R area; however, sealed glass viewing ports may be installed in calibration areas to permit viewing without entering. Pass-through windows are not permitted.

4.1 INTERIOR WALL AND CEILING CONSTRUCTION.

4.1.1 VAPOR BARRIERS FOR WALLS AND CEILINGS. Vapor barriers usually are placed on the warm side of a wall and ceiling. If the primary method of environmental control is cooling, or if heating and cooling are used about equally, place the vapor barrier away from (outside) the conditioned area. This will reduce the probability of moisture buildup, and result in fewer penetrations of the vapor barrier, since most power outlets will be facing into the conditioned area. Where heating is the primary method of environmental control, place the barrier toward the inside of the wall and the ceiling. On concrete masonry units, use foil-face rigid insulation on the outside of the wall. Fur out and finish the wall. Install a vapor barrier underneath new floor slabs. Seal all penetrations in walls, ceilings, and floors.

4.1.2 AIR BARRIER SYSTEMS FOR WALLS AND CEILINGS. Provide a continuous air barrier system to control air infiltration and exfiltration in environmentally-controlled areas. The purpose of the air barrier is to make the walls and ceiling airtight with materials having

a low air permeance or resistance to air flow, to seal the joints and penetrations, and to control air pressure relationships within the building. An air barrier must be provided between spaces that have either significantly
different temperature or humidity requirements. Provide excess ventilation air for pressurization and a continuous air barrier system to control infiltration and exfiltration to maintain air tightness. Avoid selecting materials that are too air-permeable, such as fiberboard, perlite board, and uncoated concrete block in air barrier systems.

4.2 CLEAN CONSTRUCTION PROTOCOL. Cleanliness within a PMEL facility is necessary to: (1) protect precise measurement surfaces from abrasive damage caused by dust particles; (2) prevent contamination of fluids, chemicals, and metals used during the calibration process; although cleanliness and particle filtration requirements for most PMELS are not as stringent as for clean rooms, incorporating clean construction protocol (CCP) in design and construction contracts is recommended.

4.3 INTERIOR FINISHES. Finishes should take into account the intended uses, be appropriately durable, and be low maintenance. Finishes should have good acoustical, noise reducing characteristics. Prepare surfaces to prevent, or at least reduce, dust accumulation. Clean concrete masonry thoroughly to remove dirt, fungus, grease, oil, glaze, loose particles, and scale. Fill voids to give a smooth surface without pits or holes. Repair joints, cracks, holes, and other surface defects in gypsum wallboard so the surface is flush and smooth. Where there are painted surfaces, use a smooth, non-chalking, mildew-resistant semi-gloss finish which will stand up to frequent cleaning. Use light neutral tints, such as light blue or beige, to prevent eye fatigue, increase light reflectivity, and improve lighting efficiency.

4.4 COUNTERS AND CABINETS. Counters, casework, and workbenches should be of high-quality and durable construction. Specify Architectural Woodwork Institute (AWI) Premium or Custom for finishes per AWI Architectural Woodwork Standards. Workbenches and surface plates mounted on vibration isolators or air bearings should be

used in PMELs where extensive isolation techniques cannot be used. This will reduce vibration transmitted to sensitive instrumentation in contact with these surfaces.

4.5 NON-CONDUCTIVE FLOOR COVERING. Non-conductive floor covering has a minimum resistance of 1 x 10^9 ohms (1 giga-ohm). Non-conductive flooring is required to protect personnel servicing equipment where voltages up to 3,000 volts may be present. [Note: Vinyl flooring is inherently non-conductive, provided conductive materials (such as carbon, graphite, etc.) have not been added to reduce the resistance to modify it as either conductive (2.5 x 10^4 to 1 x 10^6 ohms) or static-dissipative (1 x 10^6 to 1 x 10^9 ohms)]. Sheet vinyl is recommended because its smooth, continuous surface simplifies daily cleanup, including chemical and mercury spills. Epoxy resin flooring is a suitable alternative, provided it is non-conductive.

5. SITE DESIGN AND ORGANIZATION. The site design and all exterior features must comply with the antiterrorism standards.

5.1 LANDSCAPING. Refer to landscaping requirements and any agency design standards.

5.2 PARKING AND ACCESS DRIVES. Provide adequate parking for both staff and patrons with the appropriate access drives.

5.3 GENERAL SITE LIGHTING. Ensure that parking areas and the facility have adequate lighting for safety, evacuation, and security measures. Include parking and lighting requirements in final site plan.

5.4 SERVICE DRIVE. The size of required service vehicles should be verified by the designer prior to planning the service access areas. Provide a service vehicle apron and consolidate service access when possible.

6. ANTITERRORISM. Provide controlled access, including protection from unauthorized entry, and security for maintaining classified equipment and documents.

7. SERVICES.

7.1 DESIGN DOMESTIC HOT and cold water, sanitary and storm drainage, propane, fuel oil, and natural gas systems to meet the requirements of applicable codes and local Installation standards.

7.2 FIRE PROTECTION. The PMEL facility must have a complete automatic sprinkler system and a fire alarm evacuation system conforming to NFPA and ICC codes.

7.3 LIGHTING. Provide lighting and control systems throughout the facility in accordance with UFC 3-530-01. Refer to specific lighting design criteria for each functional area.

7.3.1 ILLUMINANCE. Facilities require a minimum uniform illumination, depending on the task requirement, calculated at the midlife of the tubes, as measured at bench level in the various areas. Light shall be evenly distributed to minimize glare, spectral reflection, and radiant heat to the extent that measurements are nominally unaffected by any of these parameters. The following areas should have a minimum 50 foot-candles (538 lux) design level: equipment storage, restrooms/toilets, janitor's closet, bench stock, stairways, corridors, halls, airlocks, elevators, shipping docks, and utility/storage rooms. Other areas in the PMEL not listed above will have a minimum 100 foot-candles (1076 lux) design lighting level. Additional general lighting shall be used for tasks that are difficult to perform within the ambient light level. Provide zone lighting by work area when required, and locate switches near the air lock entrances. Motion sensor lighting is prohibited in the C/R areas. Provide lighting controls per ASHRAE Standard 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings, in areas not involved with the calibration process.

7.3.2 EMERGENCY LIGHTING. Provide emergency lighting in accordance with NFPA 101, Section 7.9. Evaluate the standard carefully, as its requirements may not include considerations for the unique layout and equipment configurations in a metrology facility. Installed emergency lights are recommended. Ensure emergency lights have a battery

backup installed. If portable lights are mounted on the wall, locate an electrical receptacle near the light.

7.3.3 HAZARDOUS (CLASSIFIED) AREA LIGHTING. Class 1 Division 2 hazardous area light fixtures should be used in hazardous (classified) areas housing pressurized flammable liquids. Protect luminaries located above hazardous classified areas as required in NFPA 70, Article 501, Section 130, (B)(1) through (B)(3).

7.4 ELECTRICAL. Provide electric service, distribution equipment, wiring receptacles, grounding, interior and exterior lighting, control, emergency lighting, telephone, communication systems, fire alarm, other health and safety alarms, and intrusion systems in accordance with NFPA 70 and the latest Installation design requirements. Service grounding system and all wiring methods must meet the current NFPA 70 requirements. All service equipment must be Underwriters Laboratories (UL) listed. Alternately, published proof from an approved independent testing laboratory may be provided.

7.4.1 VOLTAGE REGULATION. Voltage drop of the building wiring system will not exceed 3% to any outlet. Provide outlets for technical testing with regulating equipment to maintain voltage within ±2 percent of the basic voltage, except 28 Vdc, which will be regulated to ±3%. Time constant (response time) of the voltage regulators should not exceed 0.3 seconds, and total harmonic distortion must not exceed 5%. Power conditioning and continuation interface equipment (PCCIE) must be supplied by the using agency.

7.4.2 TYPES OF ELECTRICAL POWER. Normally, electric service will be provided at 480 Vac, 3-phase, 60 Hz. Table 3-1 lists possible PMEL power requirements for testing. This list does not include lighting and air conditioning requirements. Power demand varies depending on the workload of the individual PMEL. The PMEL superintendent will assist the Base Civil Engineer in determining power requirements and equipment heat loads, and identifying any special mission requirements. Design 400 Hz distribution systems to the requirements of 400 Hertz Medium Voltage Conversion/Distribution and Low Voltage

Utilization Systems (note: motor generator is not real property installed equipment [RPIE]).

Nominal System Voltage	Phase	Frequency
277/480	1 & 3	50/60 ± 1 Hz
120/240	1 & 3	50/60 ± 1 Hz
120/208	1 & 3	50/60 ± 1 Hz
208 or 240	1	50/60 ± 1 Hz
120/240	1 & 3	400 ± 10 Hz
120/208	1 & 3	400 ± 10 Hz
28	DC	N/A
220/240	1 & 3	50/60 ± 1 Hz

Table 3-1

Power Requirements for PMEL Facilities Testing

7.4.3 TAGGING AND LABELING. Tag or label electrical power outlets, connectors, or receptacles with a technical description of the type or amplitude of a voltage source, the power rating, and phase or connection scheme, and indicate the breaker servicing them.

7.4.4 WIRING INSTALLATION. Install electrical wiring in metal raceways, concealed but accessible, in attics, plenums, or utility housings. Install wiring for frequencies greater than 60 Hz in nonferrous raceways and label with the correct frequency. Extend utilities into the C/R area within utility chases concealed in walls and partitions. Do not use under-the-ceiling utility services. Direct overhead utility connections to workbenches and stations are permitted if the most feasible and economical and if the design minimizes dust collection. Use gaskets and seals to maintain room pressure and prevent dust infiltration where ducts, pipes, and conduit penetrate walls.

7.4.5 GROUNDING. Install grounding in accordance with the National Electrical Code. The resistance to ground of the service ground must be 10 ohms or less. Where 10 ohms cannot be obtained with basic electrode configuration due to high soil resistivity, rock formations, or other terrain features, consider alternate methods for reducing the resistance to earth. Power the C/R area from (an) isolation transformer(s) with an

electrostatic shield between the primary and secondary windings installed as a separately derived system as close as practical to the loads. A table, bonded at each end to a static bus bar, may be used in place of the equipotential plane, as appropriate.

7.4.6 ELECTROMAGNETIC INTERFERENCE/RADIO FREQUENCY INTERFERENCE (EMI/RFI). The amount of EMI/RFI generated by nearby overhead high voltage lines, radio and TV transmitters, and microwave antennas determines the suitability of a site, and the extent of internal facility shielding required. Most building sites not close to sources of EMI/RFI will meet the electromagnetic requirements for PMELs, since average magnetic field in the vicinity of overhead electrical distribution lines drops off rapidly with distance. However, EMI from overhead high voltage power lines, radio/TV transmitters and aircraft operations may introduce calibration errors. With maximum currents of up to 243 amperes, average maximum field exposure is approximately 13.53 milligauses at zero feet (zero meters) and 2.48 milligauses at 100 feet (30.5 meters). These levels of exposure would be acceptable for most laboratories. EMI/RFI levels should be reevaluated whenever generators are installed after a PMEL is operational. If excessive EMI/RFI is suspected, contact AFMETCAL.

7.4.7 INTERNAL ELECTROMAGNETIC INTERFERENCE (EMI/RFI) CONTROL. Within the laboratory itself, interference suppression should include RF-shielded lenses, ballast RF suppressors, and power line filters for fluorescent lighting. EMI/RFI is best controlled by following the guidance in Military Standard (MIL STD) 188-124B, Grounding, Bonding, and Shielding for Common Long Haul Tactical Communication Systems Including Ground Based Communications - Electronics Facilities and Equipments; MIL STD 188-125-1, Department of Defense Interface Standard: High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Based C4I Facilities Performing Critical, Time-Urgent Missions, Part 1, Fixed Facilities; Military Handbook (MIL HDBK) 419, Grounding, Bonding, and Shielding for Electronic Equipment and Facilities; and MIL HDBK 423, High-Altitude Electromagnetic Pulse (HEMP) Protection for Fixed and Transportable Ground-Based C4I Facilities.

7.4.8 ELECTRICAL OUTLETS AND CABLING. Computer network, intercom, and telephone conduits and outlets should be installed during construction at enough locations to meet current layout and future expansion needs. Cabling should be installed in conduit in the walls, and in metal raceways above suspended ceilings. A doorbell should be installed on the customer entry door. Electrical power loads should not be on the same circuits providing electricity to the calibration areas.

7.4.9 EMERGENCY ELECTRICAL POWER DISCONNECTS. Emergency electrical power switches or disconnects are recommended at a central location in every room of the calibration area. They should be well-marked, unobstructed, and have a lockout feature. Electrical power switches should not turn off the overhead lights.

7.4.10 ELECTRICAL RECEPTACLES. Location and type of electrical receptacles must match the purpose of the equipment served and comply with the National Electrical Code (NEC). It is recommended to locate electrical receptacle high on the wall for portable emergency lights and at mid-wall level for connecting to work benches located along the walls. Do not use the common 60 Hz, 120 Vac receptacles for 28 Vdc, 50 Hz, or 400 Hz services. Install receptacles in accordance with NEC Articles 406, 501, 502, 503, and 647 as shown below:

- Install sufficient number of receptacles and circuits to allow for future changes in layout due to relocation or addition of new measurement systems.
- Install general-use receptacles so that they are accessible every four feet. Do not install a general purpose receptacle in the center of a wall where large equipment or furniture is typically located. Do not install more than six duplex receptacles on a single circuit and situate circuits so that each room has access to at least two circuits.
- Install and mark receptacles in hazardous locations in accordance with NEC Articles 501, 502, and 503.
- Determine placement of special-use receptacles by the location of equipment to be supported. Provide one additional circuit above work benches to allow for future

expansion of work bench or services. Mark special-use receptacles in accordance with NEC Article 647.7.

7.4.11 MAIN POWER PANELS OR SERVICES. If possible, especially in locations having frequent inclement weather, no two adjacent receptacles should be on a single circuit.

7.4.12 BACKUP POWER. Provide a means for connecting a portable backup power unit to serve critical circuits within the PMEL. Use a double-throw switch; and, if feasible, provide a matching plug and receptacle. Locate the switch for easy access by a power unit. Comply with isolated neutral requirements in NEC 250-5(d), Alternating-Current Circuits and Systems to be Grounded, Separately Derived Systems.

7.4.13 ELECTRICAL UTILITY ROOM. Install electrical facility equipment such as transformers, power distribution systems, frequency converters, rectifiers, and voltage regulators in the utility room. The 28 Vdc power supply and the 400 Hz motor-generator or frequency converter will be provided by the using agency and installed by the contractor. Follow applicable portions of the NEC and Occupational Safety and Health Administration (OSHA) standards. Provide PCCIE for testing and powering sensitive electronic equipment.

7.4.14 ANTENNA PORTS. An antenna port must be installed in a PMEL facility during construction. Port location is dependent on the location of certain instruments (e.g., precise time (GPS) receivers). Antenna port penetrations through the walls in the C/R area should be properly finished and sealed to prevent loss of positive pressure.

7.5 COMMUNICATIONS AND DATA. A phone and intercom system is required to allow two-way conversation between rooms in the PMEL facility. Provide conduit runs and terminal boxes to support the intercom, telephone, and computer systems as part of facility design. Include data outlets in walls, recessed floor boxes, and offices to provide internet connection for work areas. Confirm the technical design requirements for the phone and intercom system with the Laboratory Manager. Provide local area network

(LAN) internet connections to work benches for access to technical manuals and maintenance procedures as required.

7.6 ALARM SYSTEM. Provide an alarm system for intrusion detection to protect equipment and assets. The calibration area environment shall have an alarm system which will relay an alarm when the temperature or humidity is out of tolerance. Provisions for an alarm system must be identified during the planning/programming process.

7.7 HEATING, VENTILATING, AND AIR CONDITIONING (HVAC).

7.7.1 HVAC DESIGN CRITERIA. Systems will be designed and sized to maintain space temperature and humidity requirements at the following ambient load conditions:

- The 0.4% dry bulb temperature and the corresponding mean coincident wet bulb temperature.
- The 1% humidity ratio and the corresponding mean coincident dry bulb temperature.
- The 99% dry bulb temperature and the corresponding mean coincident wet bulb temperature.

7.7.2 HVAC SYSTEMS REQUIRED. Provide separate HVAC zone controls to meet the environmental requirements of the following areas: C/R, administration, support, and shipping and receiving. Provide HVAC system(s) specific to the building (i.e., NOT connected to a central system servicing other buildings). Where a 68 degree room is required, a modular environmental enclosure system can be considered as an option.

7.8 HVAC DESIGN CONSIDERATIONS.

7.8.1 EQUIPMENT HEAT GAIN. The using agency must provide the test and measurement equipment specifications, approximate equipment location, and use patterns so that heat gains can be accurately estimated during the predesign stages of the project.

7.8.2 DESIGN ANALYSIS. The HVAC design analysis for new facilities or renovation of existing facilities must include a psychometric analysis documenting that the system meets the PMEL design criteria. The analysis must provide calculations of system cooling load, energy/mass transfer through conditioning equipment and fans, and a system schematic indicating the dry bulb and wet bulb temperatures (or humidity ratios) of outside air, mixed air, supply air, and return air flow streams. The cooling load for this analysis must be based on the load conditions as previously identified. Provide capability to tie into the Energy Management Control System (EMCS), if available.

7.8.3 VENTILATION AIR. Supply ventilation air to satisfy the number of occupants and to provide for air exhausted from hoods, etc., to meet the positive pressure requirements for the rooms and the building as a whole. Integrate static pressure monitoring of individual rooms to ensure proper control of ventilation air.

7.8.4 VENTILATION FILTERING. Filter ventilation air before it enters an air handler, heat recovery equipment, or preconditioning equipment. Use extended media filters with a Minimum Efficiency Reporting Value (MERV) of 8 or greater, in accordance with ASHRAE 52.2-2012, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size.

7.8.5 HVAC ZONE DESIGN. Provide single zone controls to isolate environmental requirements for each major PMEL area. Size the cooling coils for each space to maintain the required temperature and relative humidity under the location design conditions listed in UFC 3-400-02. Determine the minimum acceptable room air change rate. The design requirement is to provide an even temperature, consistent with required temperature gradients, throughout the controlled spaces.

7.8.6 AIR DISTRIBUTION. Design the air distribution system to circulate air throughout the facility to prevent stratification. Use non-unidirectional air flow pattern control. Specifications apply within the space 3 feet to 4.9 feet (0.9 meter to 1.5 meters) above the floor (working area); air velocity in the working area must be 25 ± 9.8 fpm (7.6 ± 3

meters per minute). Keep noise level below 45 dB as measured by a meter meeting ANSI/ASA S1.4, American National Standard Electroacoustics – Sound Level Meters. Locate heat-generating equipment (such as temperature baths) to prevent heat buildup; also isolate high-heat-generating equipment to maintain temperature within required limits. Localized exhaust may be used for this purpose, provided makeup air requirements do not adversely affect system operation. Locate and select supply air diffusers to ensure even-conditioning of the space. Locate return air grills above heat producing equipment to quickly remove excess heat and minimize temperature fluctuations.

7.8.7 HVAC SYSTEM RESPONSE. The system must heat, cool, humidify, and dehumidify as required at all anticipated flow rates. Design and construction documents must specify: the maximum difference in temperature and humidity between supply air and room air (to establish the rate of change of the room environment); and the number, type, and location of room thermostats and humidistats and how the environmental system should respond to their signals. Duct design should not rely on adjusting dampers on diffusers or grills for control because of the effect on air distribution patterns. Where required, provide dampers inside ducts and install access panels.

7.8.8 AIR LOCKS FOR CALIBRATION AND REPAIR (C/R) AREA. Access into the C/R area is only through air locks. Provide a shoe cleaner at the entrance to the air lock, including a grounded touch pad to dissipate electricity. Use a minimum 6-foot (1.8-meter) -wide air lock at the entrance to the C/R area, with a door opening at least 5 feet (1.5 meters) wide to accommodate large equipment. The air lock must be at least 9 feet (2.7 meters) long to ensure both sets of doors are not open at the same time. Door interlocking systems are not necessary. Double doors are preferred (exception: a sliding door may be used). If double doors are used, install a pair of 3-foot (0.9-meter) -wide double doors to allow movement of large pieces of equipment when necessary. Do not position air lock doors in-line with building entry doors. Air lock doors must have 24- by 30-inch (610- by 760-millimeter) shatterproof glass vision panels (or the closest standard size that fits) and bumpers to prevent equipment and cart damage. Air will flow from the C/R area through the air lock toward the administrative or shipping and receiving areas. Install gasket-type

stops, astragals, automatic door bottoms on air lock doors located closest to the C/R areas, and a properly sized grille above the inside air lock doors to permit air flow through the air lock. Seal joints between doors and frames with gaskets.

7.8.9 MODULAR ENVIRONMENTAL ENCLOSURE CONSIDERATIONS. Provide an off-the-shelf, self-contained, environmentally-controlled module where a 68 degree room is required, as an option. Typically, they are more cost effective and provide better environmental control for the stringent environmental requirements. Their self-contained environmental system provides temperature and relative humidity control, and dust particle filtration. The modular structure is normally installed inside the PMEL, but separate from the C/R area. Before contracting construction of a modular environmental enclosure, consider: (1) size (fits the space); (2) possible vibration and electromagnetic interference; and (3) volume and type of work to be processed. The environmental enclosure system should include the following line items as shown in Table 3.2.

Design Features
External duct work, plumbing, wiring, painting, and testing as part of the installation
An electrical supply system providing protection from voltage surges, spikes, or transient noise.
Control equipment with good earth ground.
A suitable drain for condensate disposal in the fan-coil area.
A smooth concrete floor for the enclosure installation, with maximum deviation in the horizontal plane of 3/8 in (9.5 mm).
Non-conductive vinyl floor covering.
If required for the humidification system, a year-round supply of potable water operating at a flow rate and pressure required by the system.

Table 3-2

Modular Environmental Enclosure Design Considerations

7.9 HVAC EQUIPMENT SELECTION.

7.9.1 MAINTAINABILITY. To ensure maintainability, select and locate equipment to provide adequate access for servicing, filter replacements, and coil removal.

7.9.2 MOISTURE CARRYOVER. To preclude moisture carryover, coil face velocities must not exceed 550 fpm (167.6 m/min).

7.9.3 COOLING COIL CHARACTERISTICS AND PERFORMANCE REQUIREMENTS. Specify cooling coil characteristics and performance requirements in the construction bid documents. These requirements include total cooling capacity, sensible capacity, coil design entering and leaving air conditions (wet and dry bulb temperatures), design airflow rate, face velocities, coil sensible heat ratio, and entering chill water temperature.

7.9.4 DEHUMIDIFICATION AND ENERGY CONSUMPTION. Select equipment that will meet the design requirements for dehumidification and provide the lowest life cycle cost and energy consumption.

7.9.5 DEDICATED OUTDOOR AIR SYSTEM (DOAS). DOAS systems should be considered, with other options, for humidity control and supplying ventilation air, especially in high-humidity areas. The DOAS supplies a volume of preconditioned makeup/outside ventilation air to the calibration areas of the PMEL. The system must be equipped with heating and cooling (chilled water/glycol) coils and controls to temper outside air to a neutral dry bulb temperature and regulate humidity levels. In some climates, an air-to-air heat exchanger may be beneficial to precondition makeup air. Humidity in non-administrative areas will be controlled by regulating the humidity in the outside/makeup air system. Coils must meet 99% design conditions. Ensure that DOAS systems are designed to handle both the ventilation and zone-generated latent loads. In humid areas, the amount of conditioned outside air required to dehumidify the calibration areas (see Figure 2-2) may exceed the amount required for ventilation and makeup. In these cases, a portion of the return air can be drawn through this system and dehumidified with the outside air stream. To facilitate inspection and cleaning of coils, install access doors between coils, and ensure coils are no more than eight rows deep. Also consider using desiccants in areas of high humidity.

7.9.6 DUCTED RETURN AIR SYSTEM. Provide a fully-ducted return air system. Use of the space above the ceiling as a plenum is not allowed.

7.9.7 PIPING INSULATION. Insulate piping with an operating temperature below dew point with jacketed insulation meeting the cold piping requirements. The insulation jacket must be sealed to provide an exterior vapor barrier.

7.9.8 MAINTENANCE ACCESS. Sufficiently safe access space must be provided for the maintenance of valves, variable air volume (VAV) boxes, dampers, controls, and other HVAC components.

7.9.9 EQUIPMENT COMPLIANCE WITH DESIGN. Construction specifications must provide documentation that HVAC equipment submittals for proposed equipment are in compliance with the design specifications. Design calculations should recognize the effect

of brief deviations in outside temperature and humidity beyond those listed. Careful application of the weather data is essential to develop designs that meet critical environmental control requirements. The designer should optimize the selection of cooling equipment to take into account all aspects of performance, reliability, maintainability, and capital and maintenance costs.

7.9.10 CHILLED WATER EQUIPMENT SELECTION. A chilled water system with reheat is the recommended option to maintain required temperature tolerances in PMELs. A central building chilled water system with modulating control is most satisfactory for the required 40 to 42 °F (4.4 to 5.5 °C) water. The optimum supply and return water temperature differential must be determined by life cycle cost analysis. Select compressors that are the most efficient over the range of anticipated loads.

7.9.11 RECORDING DEVICES, MONITORING AND ALARMS. Temperature and humidity must be monitored and recorded continuously, and pressure must be monitored. The recording system must be continuous, and use self-contained sensors/recorders, or remote sensors with centrally-located recorders. Sensors are required in each separate room in the calibration area, and a minimum of one set of sensors for every 2000 ft2 (186 m2) of calibration area. When selecting recording devices, consider accuracy and response time; critical environments require immediate response and high accuracy. Mount sensors in the center of the room away from walls, vibration, sunlight, and supply air diffusers, as near as possible to the most critical area of measurement. If the PMEL facility is monitored by a base-wide EMCS system, the system will transmit an alarm when any space goes out of tolerance for temperature, humidity, or pressure. Notice of the alarm will be communicated by automatic notification back to PMEL staff. Both the recording device and the alarm system will indicate real time. All sensors, including wall-mounted assemblies, will be removable for calibration.

7.9.12 ACCURACY OF RECORDING DEVICES.

The following requirements apply to temperature and humidity recorders:

- Recording devices monitoring 68 °F (20 °C) C/R areas must be accurate to a minimum of ± 0.5 °F (± 0.28 °C), ± 5% RH.
- Recording devices monitoring 73 °F (22.8 °C) C/R areas must be accurate to a minimum of ± 2.0 °F (± 1.11 °C), ± 5% RH.
- Recording devices must be calibrated across the full range for the area being monitored.
- If a computerized system is used to record environmental data, the time between data samples shall not exceed 15 minutes.
- Daily or weekly charts must be used when not using computerized or roll type recording devices.

7.9.13 ROOM FILTRATION. The 68 degree room must have a filtration system which satisfies a particle count not exceeding 700 particles per ft3 (24,700 particles per m3) of atmosphere, 5 microns and larger; and 100,000 particles per ft3 (3,530,000 particles per m3) of atmosphere, 0.5 microns and larger. Accurately describe filter installation to ensure easy access and quick changing of filters, minimizing air system shutdown. Install diaphragm-activated draft gages with remote audible alarms across all filter banks to signal when filter replacement is required. (Reference UFC 3-410-01 for details on filter requirements.)

For all other spaces, air filters will have a MERV of 8 when tested by an acceptable atmospheric dust spot test. (Reference ANSI/ASHRAE 52.2-2012.) Add filter specification and installation requirements to the maintenance manual for the building.

7.10 COMPRESSED AIR AND NITROGEN SYSTEMS.

7.10.1 COMPRESSED AIR AND NITROGEN SUPPLY. Compressed air and nitrogen must be supplied considering the requirements for the type and number of flow calibrators necessary to accommodate the workload. Compressed air delivered to flow calibrators must be of instrument quality. Service must be adequate to support the simultaneous operation of all major systems in the facility. Refer to NFPA 55, Compressed Gases and Cryogenic Fluids Code, for safety considerations for compressed air and nitrogen gas.

7.10.2 COMPRESSED AIR QUALITY. Use oil-free, dry, compressed air for technical use in the C/R area. Compressed air for the equipment cleaning room must be supplied from an oil-free compressor. The compressed air supplied to the cleaning stations must have an adjustable regulator with a 0-35 psig range at the stations. Compressed air must conform to ANSI/ISA S7.0.01, with minimum pressure of 120 psig (827 kPa). The pressure of compressed air used at work benches should be reduced with a precision valve and a 0-827 kPa gauge. Compressed air quality for technical use in the C/R area or for operating TMDE must satisfy operating manuals for the TMDE to be serviced. In no case will the oil content of compressed air be greater than 24 ppm (wt) and the compressed air no greater than -40 °F (-40 ºC) atmospheric dew point. (For more information on atmospheric dew point, refer to the latest version of ASHRAE's Fundamentals Handbook, chapter on psychrometrics). Reduce the line pressure at the work stations, generally to 15 psig (103 kPa), depending on mission requirements. This quality may be achieved using dryers fitted with appropriate pre-filters or coalescent air filters that remove oil and particulates. Provide an in-line oil monitor to check quality. Supply a refrigerated dryer for high flow requirements. Minimum filter requirement for equipment cleaning areas for the incoming airline is 75 microns. All air lines into the laboratory must have an automatic blow-down valve ahead of each filter. Each top connection and line tie must lead off the top of the line. The number of outlets and total capacity may vary by individual laboratory; but normally, a minimum 20 scfm (9.4 L/s) is needed. Each PMEL organization will determine specific requirements and incorporate them into the design criteria. Install the air compressor in the utility room as real property and size it to satisfy total facility requirements. Mark compressed air lines to show pressure and appropriate piping color code for the service.

7.10.3 DRY NITROGEN. Water-pumped dry nitrogen (oil free) is required for technical use. Install dry nitrogen cylinders in the utility room. Piping run to the C/R area must be rated at 1600 psig (11032 kPa). Mark nitrogen lines to show pressure. Review design requirements to determine the number of lines required.

8. SUSTAINABLE DESIGN. Use an integrated approach to the planning and design of PMEL Facilities that minimizes energy consumption and optimizes life cycle cost renewable energy possibilities.

9. SPECIFIC DESIGN CRITERIA

9.1 PMEL FUNCTIONAL AREA DESIGN CRITERIA.

This section identifies the specific design requirements for each functional area. Tables 4-1 through 4-13 provide this data in a standard Functional Data Sheet format.

Description/ Usage	The administrative offices consist of a mix of private and open office space. Locate the site manager's office and the administrative staff near the main laboratory entrance to control building access and to receive visitors. Generally speaking, the following office spaces are provided: Flight Chief or Site Manager, Laboratory Chief, Administrative and support staff, and Quality Assurance Supervisor. The main laboratory entrance is usually combined with a waiting and equipment check-in and pickup area. Refer to AFMAN 32-1084 for office space sizes and requirements.
Min. Ceiling Ht.	9 ft (2.74 m) finished ceilings to provide a finished surface and to conceal conduits
Finishes	**Walls.** Painted gypsum wall board with flush and smooth surface to reduce dust. **Floor.** Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. Static dissipative carpet may be added for offices. **Ceiling.** Acoustical Ceiling Panels (ACP). Provide air-tight, dust-tight ceiling access panels for environmental system balancing and required maintenance. **Windows.** Where possible, locate offices on exterior wall and provide windows for natural light admission.
Plumbing	Drinking fountain.
HVAC	Reference the most recent Air Force or installation policy on temperature set points for HVAC systems.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Ensure an adequate number of circuits to power all equipment. Provide standard duplex outlets in closed offices as required. Install additional outlets for data, telephones and to operate shared equipment such as printers, fax, etc.
Lighting	100 foot-candles (1076 lux) ambient lighting.
Communication	**CCTV.** None required. **CATV/Internal Video:** None required. **PA/Audio.** One speaker, with controls in the Flight Chief's/Site Manager's office. **Telephone.** One line per staff plus one additional line for fax and copier. **Data.** One outlet per staff plus one outlet for each printer, copier, scanner, etc. **Security.** None required.
Casework/Built-in Equipment	A custom-built customer service counter to separate customer incoming equipment storage from the completed equipment storage and calibration areas.
Furnishings Fixtures & Equipment (FF&E)	**Private Offices**—Furniture for 120 ft^2 (11 m^2) or 100 ft^2 (9.3 m^2) office: desk, credenza, filing cabinet, desk chair, and two side chairs. **Workstations**—Furniture for 64 ft^2 (6 m^2) workstation: desk chair and side chair for open offices. Workstation systems furniture must provide adequate space for filing and overhead storage.
Special Requirements	Side lights next to the office doors for supervision and security.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers
Min. net ft^2 (m^2)	

Table 4-1

Administrative Offices

Description/ Usage	This space is used as a conference and training room for related PMEL business. In sizing the room, consider number of personnel that will use the room; and training aids and furnishings required. Locate near the Flight Chief's/Site Manager's office and provide space for special PMEL projects.
Min. Ceiling Ht.	9 ft (2.74 m)
Finishes	**Walls.** Painted gypsum wall board with flush and smooth surface to reduce dust. **Floor.** Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. Static dissipative carpet may be added. **Ceiling.** ACP; air-tight, dust-tight ceiling access panels for environmental system balancing and required maintenance.
Plumbing	None required.
HVAC	Reference the most recent Air Force or installation policy on temperature set points for HVAC systems.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Ensure an adequate number of circuits to power all equipment. Provide standard duplex outlets in closed offices as required. Install additional outlets for data, telephones and to operate equipment such as printers, fax.
Lighting	100 foot-candles (1076 lux) ambient lighting. Provide dimmable recessed lighting for training purposes.
Communication	**CCTV.** Outlets as required for coverage. **CATV/Internal Video.** One outlet as required. **PA/Audio.** One speaker. **Telephone.** One line with conference room capability. **Data.** Minimum of one outlet. Consider providing additional outlets for training purposes for internet data connection. **Security.** None required.
Casework/Built-in Equipment	Storage closet for training materials and audio-visual cart. Provide an electrically operated retractable screen, a built-in computer projector, and conference call capability.
Furnishings Fixtures & Equipment (FF&E)	CCTV cameras per the outlet count. Tables, chairs, bulletin board with tack surface and dry-erase board. Consider providing overhead projector, printer, and TV, VCR, and DVD player.
Special Requirements	Consider the acoustics of the space and features to eliminate potential distractions. Provide a minimum sound transmission coefficient (STC) rating of 50 to 55. Provide a vision panel in the door.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers
Min. net ft^2 (m^2)	

Table 4-2

Conference Room/Training Room

Description/ Usage	Shipping and receiving area dedicated to customer support for test items. Includes control counter to receive and pickup test items. Install equipment storage area in conjunction with shipping and receiving.
Min. Ceiling Ht.	10 ft (3.05 m)
Finishes	**Walls.** Painted gypsum wall board with flush and smooth surface to reduce dust. **Floor.** Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. **Ceiling.** ACP; air-tight, dust-tight ceiling access panels for environmental system balancing and required maintenance.
Plumbing	Work sink with hot and cold water connections and a floor drain.
HVAC	Reference the most recent Air Force or installation policy on temperature set points for HVAC systems
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code and additional outlets as necessary to operate any dedicated equipment.
Lighting	100 foot-candles (1076 lux) ambient lighting.
Communication	**CCTV.** None required. **CATV/Internal Video.** None required. **PA/Audio.** One speaker. **Telephone.** One line with internal two-way communication. **Data.** One outlet per staff member, plus one outlet for each printer, copier, scanner, etc. **Security.** None required.
Casework/Built-in Equipment	Work bench(s) within the storage area for equipment inspection and review. Secure storage area for equipment, tools, supplies, and test items. Include adequate shelving, bins, and open end cubicles to store equipment. Install additional areas as required for storage, depending on volume of workflow.
Furnishings Fixtures & Equipment (FF&E)	None required.
Special Requirements (Covered Equipment Area)	A protected entrance for unloading equipment: either a double-entry door with a drive-thru canopy; or a service entry with a roll-up door large enough to allow a small truck or van to back into the unloading area. The quantity and size of equipment handled and weather conditions should determine which entry is appropriate.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers
Min. net ft^2 (m^2)	

Table 4-3

Shipping, Receiving, and Equipment Storage

Description/ Usage	Where a 68 degree room is required, provide an area in the PMEL, with utilities, to install an off the shelf modular environmental control module. The 68 degree room is used to maintain a closely-controlled environmental area for calibration and use of higher accuracy dimensional TMDE.
Min. Ceiling Ht.	10 ft (3.05 m)
Finishes	**Walls.** Painted gypsum wall board with flush and smooth surface to reduce dust. **Floor.** Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. **Ceiling.** ACP; air-tight, dust-tight ceiling panels for environmental system balancing and required maintenance.
Plumbing	None required.
HVAC	68 ± 1 °F (20 ± 0. 6 °C) and an optimum RH of 35, +10/-15%. The temperature may not vary more than 1 °F (0.6 °C) in any one hour period during normal system operation. Maximum temperature gradient across the room is 2 °F (1.1 °C). A minimum positive static pressure of 0.05 inch of water (12.5 pascals) compared to ambient pressure is required to prevent infiltration of dust-laden air.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code and additional outlets as necessary to operate any dedicated equipment.
Lighting	100 foot-candles (1076 lux) ambient lighting using permanent overhead-recessed vapor-proof/dust-resistant fixtures sealed with gaskets to prevent air or moisture leakage and dust accumulation/intrusion from the interstitial area.
Communication	**CCTV.** None required. **CATV/Internal Video.** None required. **PA/Audio.** One speaker. **Telephone.** One line with internal two-way communication. **Data.** One LAN Internet connection per work bench, and a WLAN signal, if required. **Security.** None required.
Casework/Built-In Equipment	Work bench(s) within the storage area for equipment inspection and repair.
Furnishings Fixtures & Equipment (FF&E)	Modular environmental enclosure system will be provided, per user requirements, to meet environmental requirements. The modular structure is normally erected inside the building, along with the environmental control system, electrical system, laboratory equipment, and furniture. Typically, the modular system is more cost effective based on life cycle cost.
Special Requirements	The 68 degree room must have a filtration system which satisfies a particle count not exceeding 700 particles per ft^3 (24,700 particles per m^3) of atmosphere, 5 microns and larger; and 100,000 particles per ft^3 (3,530,000 particles per m^3) of atmosphere, 0.5 microns and larger. Design the filter installation to ensure easy access and quick changing of filters, minimizing air system shutdown. Install diaphragm-activated draft gages with remote audible alarms across all filter banks to signal when filter replacement is required.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers
Min. net ft^2 (m^2)	

Table 4-4

68 Degree Room

Description/ Usage	This area is maintained under a positive pressure at specified temperature and humidity levels. Air locks are required for entry into the C/R area. Locate the C/R area adjacent to other conditioned areas. Use only oil-free, dry, compressed air.
Min. Ceiling Ht.	10 ft (3.05 m)
Finishes	**Walls.** Painted gypsum wall board with flush and smooth surface to reduce dust. **Floor.** Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. **Ceiling.** ACP; air-tight, dust-tight ceiling panels for environmental system balancing and required maintenance.
Plumbing	None required.
HVAC	73 ± 6°F (22.8 ± 3.3 °C) for Type II and Type III PMELs. Size cooling coils to maintain an optimum operational RH level of 35, +10/-15%. Refer to UFC 3-400-02. A minimum positive static pressure of 0.05 inch of water (12.5 pascals) compared to ambient pressure is required to prevent infiltration of dust-laden air. Exhaust ventilation systems must accommodate the fume hoods over the temperature calibration baths.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code and additional outlets as necessary to operate any dedicated equipment, such as printers, fax, etc.
Lighting	100 foot-candles (1076 lux) ambient lighting using permanent overhead-recessed vapor-proof/dust-resistant fixtures sealed with gaskets to prevent air or moisture leakage and dust accumulation/intrusion from the interstitial area.
Communication	**CCTV.** None required. **CATV/Internal Video.** None required. **PA/Audio.** One speaker. **Telephone.** One line with internal two-way communication. **Data.** One LAN Internet connection per work bench plus an outlet for printer/copier/ scanner. Ensure WLAN signal is available, if required. **Security.** None required.
Casework/Built-In Equipment	Work bench(s) within the storage area for equipment inspection and repair.
Furnishings Fixtures & Equipment (FF&E)	A monolithic surface of gypsum or plaster construction with finished joints between the walls and ceiling. If the wall is stud construction, use two layers of 5/8-in (16-mm) gypsum board. Install compressive base sill plate seals under all walls enclosing this area. Tape and seal all wall and ceiling penetrations (conduit, pipe, duct and light fixtures, etc.) to ensure positive pressure in the area.
Special Requirements	Air locks: Use a minimum 6 ft- (1.8 m-) wide air lock at the entrance to the C/R area, with a door opening at least 5 ft (1.5 m) wide to accommodate large equipment. Install gasket-type stops, astragals, and automatic door bottoms on airlock doors located closest to the C/R Area. Seal joints between doors and frames with gaskets.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers.
Min. net ft² (m²)	

Table 4-5

Calibration and Repair (C/R) Area

Description/ Usage	This is a special temperature/humidity sensitive (T/H S) controlled area for PMELs that do not have a requirement for a 68 degree room.
Min. Ceiling Ht.	10 ft (3.05 m)
Finishes	**Walls.** Painted gypsum wall board with flush and smooth surface to reduce dust. **Floor.** Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. **Ceiling.** ACP; air-tight, dust-tight ceiling panels for environmental system balancing and required maintenance.
Plumbing	None required.
HVAC	The temperature and humidity requirements for this area are 73 ± 2 °F (22.8 ± 1.1 °C) and an RH of 35, +10/-15%. Though room temperature may vary by 4 °F (2.2 °C), the temperature may not vary more than 1 °F (0.5 °C) in any one hour period during normal system operation. Maximum temperature gradient across the room is 2 °F (1.1 °C). A minimum positive static pressure of 0.05 inch of water (12.5 pascals) compared to ambient pressure is required to prevent infiltration of dust-laden air.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code and additional outlets as necessary to operate any dedicated equipment.
Lighting	100 foot-candles (1076 lux) ambient lighting using permanent overhead-recessed vapor-proof/dust-resistant fixtures sealed with gaskets to prevent air or moisture leakage and dust accumulation/intrusion from the interstitial area.
Communication	**CCTV.** None required. **CATV/Internal Video.** None required. **PA/Audio.** One speaker. **Telephone.** One line with internal two-way communication. **Data.** One LAN internet connection per work bench plus an outlet for a printer, copier, and scanner. Ensure WLAN signal is available, if required. **Security.** None required.
Casework/Built-in Equipment	Work bench(s) within the storage area for equipment inspection and repair.
Furnishings Fixtures & Equipment (FF&E)	A modular clean room may be provided to meet these requirements. Modular environmental enclosure systems are available as controlled laboratories for high precision metrology. The self-contained environmental system provides temperature and relative humidity control, and dust particle filtration. The modular structure is normally erected inside a building, along with the environmental control system, the electrical system, laboratory equipment, and furniture.
Special Requirements	None required.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers.
Min. net ft^2 (m^2)	

Table 4-6

Temperature/Humidity Sensitive Area

Description/ Usage	A specially-equipped, isolated area required in PMELs to perform liquid flow meter calibration using propylene glycol. Ensure that doors swing out in the direction of egress per the NFPA 101. Determine floor space by considering the type and number of flow calibrators necessary for the mission. Include space for work benches, tool storage, and systems furniture as required.
Min. Ceiling Ht.	10 ft (3.05 m), or high enough to reasonably clean mission equipment.
Finishes	**Walls.** Painted gypsum wall board with flush and smooth surface to reduce dust. **Floor.** Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. **Ceiling.** ACP; air-tight, dust-tight ceiling panels for environmental system balancing and required maintenance.
Plumbing	Supply chilled water considering the requirements of flow calibrator heat exchangers. Minimum service consists of 20 gpm (75.7 L/min) of 40 ± 5 °F (4.4 ± 2.7 °C) water for a low flow liquid flow calibrator and 25 gpm (94.6 L/min) of chilled water for a high flow liquid flow calibrator supplied using 1.5 inch tubing.
HVAC	Ventilate the area according to the requirements of 29 CFR 1910, *Occupational Safety and Health Standards*. Provide a ventilation rate of not less than 1 cfm per square foot of solid floor area. Temperature requirement is 73 ± 6 °F (22.8 ± 3.3 °C) and an RH of 35, +10/-15%. A minimum positive static pressure of 0.05 inch of water (12.5 pascals) as compared to ambient pressure is required to prevent infiltration of dust-laden air.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code and additional outlets as necessary to operate any dedicated equipment. Each liquid flow calibrator requires a 3-phase, 208V, 20 amp outlet.
Lighting	100 foot-candles (1076 lux) recessed vapor-proof/dust-resistant fixtures.
Communication	**CCTV.** None required. **CATV/Internal Video.** None required. **PA/Audio.** One speaker. Provide an emergency call/alarm in the liquid flow calibration area. **Telephone.** One line per staff. **Data.** LAN internet connections and ensure WLAN signal is available, if required. **Security.** None required.
Casework/Built-in Equipment	Install double doors to facilitate installation of large liquid flow calibration units and test equipment. Two sizes of liquid flow calibrators may be installed: low flow liquid flow calibrator footprint: 1.9 ft x 6.3 ft (0.6 m x 1.9 m); high flow liquid flow calibrator footprint: 2.17 ft x 13.9 ft (0.67 m x 4.24 m). The number of calibrators may vary from one to four, depending on mission.
Furnishings Fixtures & Equip. (FF&E)	Furniture for 64 ft^2 (6 m^2) workstation: desk chair and side chair for open offices. Workstation systems furniture must provide adequate space for filing and overhead storage.
Special Req.	Supply utilities, services, furnishings, tools, and equipment, including the following: Compressed air, cleaning system, exhaust system, work bench with lipped stainless steel top that drains into the sink, and a vacuum port. Supply oil-free dry compressed air at 80 psig (552 kPa) and 75 gpm (284 L/min) for a low flow liquid flow calibrator and 80 psig (552 kPa) and 150 gpm (568 L/min) for a high flow liquid flow calibrator.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers.
Min. net ft^2 (m^2)	

Table 4-7

Liquid Flow Calibration Area

Description/ Usage	A specially-equipped and isolated area required for cleaning and washing of mechanical, electrical, and electronic equipment. Install a drying oven meeting the requirements of the standard PMEL cleaning room. Install a bench type slot hood or canopy hood to remove fumes from calibration baths and gas monitors
Min. Ceiling Ht.	10 ft (3.05 m), or high enough to reasonably clean mission equipment.
Finishes	**Walls.** Ceramic wall tile or other hard surfaces approved for the cleaning room. **Floor.** Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. **Ceiling.** ACP; air-tight, dust-tight ceiling panels for environmental system balancing and required maintenance.
Plumbing	Hot and cold water supply piping and floor drain with mercury trap to be connected to the government supplied cleaning system and utility sink..
HVAC	Reference most recent Air Force or installation policy on temperature set points for HVAC systems. Exhaust ventilation systems must accommodate the fume hoods over temperature calibration baths. Install a bench style slot hood to pull fumes away from the breathing zone where a canopy type hood would allow fumes into the breathing zone. The drying oven requires 212 cfm (6 m^3/min) of room air for the purge blower intake and exhaust.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Dedicated 120/240 Vac single-phase 20 amp circuit hard-wired to a government- or contractor-supplied electronic drying oven with disconnect switch. This circuit should not be connected to the electrical distribution system serving the calibration area.
Lighting	100 foot-candles (1076 lux) ambient lighting using permanent overhead-recessed vapor-proof/dust-resistant fixtures sealed with gaskets to prevent air or moisture leakage and dust accumulation/intrusion from the interstitial area.
Communication	**CCTV.** None required. **CATV/Internal Video.** None required. **PA/Audio.** One speaker and an emergency call/alarm in the equipment cleaning room that sounds at the control counter in the event of an emergency. **Telephone.** None required. **Data.** None required. **Security.** None required.
Casework/Built-in Equipment	Install a cleaning unit and drying oven in the equipment cleaning room. Each cleaning unit or drying oven requires 15 ft^2 (1.4 m^2) of floor space. See the Power and HVAC sections above for electrical and exhaust requirements.
Furnishings Fixtures & Equip. (FF&E)	Install a built-in eye-wash system for safety requirements. A vacuum port will be provided in the equipment cleaning room. Install a deep industrial sink and work bench with lipped stainless steel top that drains into the sink.
Special Req.	Locate the cleaning and washing area outside the calibration area. Supply utilities, services, furnishings, tools, and equipment, including the following: compressed air with oil-free compressor, cleaning system, drying oven, and exhaust vent system. Install a vacuum port in the equipment cleaning room.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers.
Min. net ft^2 (m^2)	

Table 4-8

Equipment Cleaning Room

Description/ Usage	This space is used as a staff workroom for copying, meetings, breaks, and lunches.
Min. Ceiling Ht.	9 ft (2.74 m)
Finishes	**Walls.** Painted gypsum wall board with flush and smooth surface to reduce dust. **Floor.** Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. Static dissipative carpet may be added for copy/ work/break room. **Ceiling.** ACP; air-tight, dust-tight ceiling panels for environmental system balancing and required maintenance.
Plumbing	Two-compartment countertop sinks with hot and cold water supply. Floor drain. If an icemaker is desired, provide a cold water connection.
HVAC	Reference the most recent Air Force or installation policy on temperature set points for HVAC systems
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code; one additional outlet at counter height for convenience; additional outlets necessary to operate dedicated equipment such as the copier, fax machine, printers, coffee machine, refrigerator, time clocks, microwave, and various other office machines.
Lighting	100 foot-candles (1076 lux) lighting fixtures with dimmable lights.
Communication	**CCTV.** None required. **CATV/Internal Video.** None required. **PA/Audio.** One speaker. **Telephone.** One line. **Data.** Outlets as required for equipment. **Security.** None required.
Casework/Built-in Equipment	Two separate solid-surface countertops: one for food/break functions and one for administrative functions as required
Furnishings Fixtures & Equipment (FF&E)	Copier, fax machine, printers, table, chairs, microwave, coffee machine, refrigerator, bulletin board with tack surface, dry-erase board, and other office equipment as required.
Special Requirements	Locate copy/work/break room on exterior wall and provide windows for natural light admission. Provide a vision panel in the door.
For use during project execution by the appropriate Service agency	
Occupancy	Staff. Customers.
Min. net ft² (m²)	

Table 4-9

Copy/Work/Break Room

Description/ Usage	These toilet rooms are used primarily by visitors, PMEL staff, and customers checking in or picking up equipment. They should be located near the main laboratory entrance in the waiting room and equipment check-in and pickup area.
Min. Ceiling Ht.	9 ft (2.74 m)
Finishes	**Walls.** Epoxy or enamel painted moisture-resistant gypsum wall board with a ceramic tile wainscot. Consider full ceramic tile walls with integral patterns. Use a dark-colored epoxy grout. **Floor.** Ceramic tile with integral patterns. Use a dark-colored epoxy grout. **Ceiling.** Epoxy or enamel painted moisture-resistant gypsum board. None needed for janitor's closet.
Plumbing	Wall-hung water closets, wall-hung urinals and lavatories based on the applicable code for the calculated occupancy of the laboratory. Floor drain and a keyed hose bib.
HVAC	Ventilate exhaust to the outside per code. Provide 8 to 12 air changes per hour.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code.
Lighting	50 foot-candles (538 lux) lighting fixtures
Communication	**CCTV.** None required. **CATV/Internal Video.** None required. **PA/Audio.** One speaker. **Telephone.** None required. **Data.** None required. **Security.** None required.
Casework/Built-in Equipment	Solid-surface countertop with either underhung or integral sink. Solid composite toilet and urinal partitions. Consider permanent ceramic-tile partitions. Toilet accessories: toilet paper dispensers, paper towel dispenser with integral trash receptacle, robe hooks, grab bars, sanitary napkin disposal (female water closet stalls), seat cover dispensers, and soap dispensers. Mirror.
Furnishings Fixtures & Equipment (FF&E)	None required.
Special Req.	Janitor's closet associated with or in proximity of these toilets. This closet includes a floor mop sink with hot and cold water and a hose connection, a floor drain, and storage for pails, mops, vacuums, and related cleaning supplies and equipment. Include a lockable door (which can be opened from the inside) with a vision panel. Lockable cabinets for cleaning supplies. Exhaust ventilation in janitor's closet to remove chemical fumes.
For use during project execution by the appropriate Service agency	
Occupancy	Staff. Customers.
Min. net ft^2 (m^2)	

Table 4-10

Public Toilets/Janitor's Closet

Description/ Usage	Night vision calibration area for testing under controlled conditions of lighting, temperature, and humidity. The night vision ANV-126 NVD Infinity Focus System should be calibrated in a room with ambient lighting levels of less than 0.1 foot-candles in the general area of the test set. The ANV-20/20, field deployable, low light level calibration system requires total darkness during the adjustment procedures for the night vision test to accomplish calibration.
Min. Ceiling Ht.	10 ft (3.05 m)
Finishes	**Walls.** Painted gypsum wall board with flush and smooth surface to reduce dust. **Floor.** Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. **Ceiling.** ACP; air-tight, dust-tight ceiling panels for environmental system balancing and required maintenance.
Plumbing	None required.
HVAC	73 ± 6 °F (22.8 ± 3.3 °C) and a RH of 35, +10/-15%. A minimum positive static pressure of 0.05 inch of water (12.5 pascals) compared to ambient pressure is required to prevent infiltration of dust-laden air.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code and additional outlets as necessary to operate any dedicated equipment.
Lighting	During non-test conditions, provide 100 foot-candles (1076 lux) ambient lighting. Night vision calibration lighting levels must meet minimum requirements of the test set being calibrated.
Communication	**CCTV.** None required. **CATV/Internal Video.** None required. **PA/Audio.** One speaker. **Telephone.** One line with internal two-way communication. **Data.** LAN internet connections and ensure WLAN signal is available, if required. **Security.** None required.
Casework/Built-in Equipment	Work bench(s) within the night vision area for equipment inspection and review. Secure storage area for equipment, tools, supplies, and test items. Include adequate shelving, bins, and open end cubicles to store equipment. Install additional areas as required for storage, depending on volume of workflow.
Furnishings Fixtures & Equipment (FF&E)	None required.
Special Requirements	None required.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers.
Min. net ft^2 (m^2)	

Table 4-11

Night Vision Area

Description/ Usage	The Force and Pressure Measurement area may require safety screens in the immediate vicinity of the force and calibration equipment to protect operators and other personnel from flying projectiles, high pressure gas, or fluids. This area is part of the C/R area, but can be part of the Dimensional Measurement lab.
Min. Ceiling Ht.	10 ft (3.05 m)
Finishes	**Walls.** Painted gypsum wall board with flush and smooth surface to reduce dust. **Floor.** Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. **Ceiling.** ACP; air-tight, dust-tight ceiling panels for environmental system balancing and required maintenance.
Plumbing	None required.
HVAC	73 ± 6 °F (22.8 ± 3.3 °C) for Type II and Type III PMELs. An optimum operational RH level is 35, +10/-15%. A minimum positive static pressure of 0.05 inch of water (12.5 pascals) compared to ambient pressure is required to prevent infiltration of dust-laden air.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code and additional outlets as necessary to operate any dedicated equipment.
Lighting	100 foot-candles (1076 lux) ambient lighting using permanent overhead-recessed vapor-proof/dust-resistant fixtures sealed with gaskets to prevent air or moisture leakage and dust accumulation/intrusion from the interstitial area.
Communication	**CCTV.** None required. **CATV/Internal Video.** None required. **PA/Audio.** One speaker. **Telephone.** One line with internal two-way communication. **Data.** One outlet per work bench. Ensure WLAN signal is available, if required. **Security.** None required.
Casework/ Built-in Equipment	Work bench(s) for equipment inspection and repair.
Furnishings Fixtures & Equipment (FF&E)	Safety screens to protect personnel, as required.
Special Requirements	If double doors are used, install a pair of 3-ft-wide double doors to allow movement of large pieces of equipment when necessary. Consider placing force and pressure measuring equipment in isolated parts of the room or space as an added measure for personnel and equipment protection.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers.
Min. net ft^2 (m^2)	

Table 4-12

Force and Pressure Measurement Area

Description/ Usage	The library contains TOs, equipment descriptions, maintenance manuals, Air Force Manuals and Instructions. It is used by PMEL technicians, supervisors, and staff to provide data for precision measurement calibration activities, including library research and internet downloads of technical manuals.
Min. Ceiling Ht.	9 ft (2.74 m)
Finishes	**Walls.** Painted gypsum wall board with flush and smooth surface to reduce dust. **Floor.** Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. Static dissipative carpet may be added to the technical library if located outside the C/R area.
Plumbing	None required.
HVAC	Reference the most recent Air Force or installation policy on temperature set points for HVAC systems.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code; one additional outlet at counter height for convenience; additional outlets necessary to operate dedicated equipment such as a copier, fax machine, printer, and various other office machines.
Lighting	100 foot-candles (1076 lux). Consider dimmable lights.
Communication	**CCTV.** None required. **CATV/Internal Video.** None required. **PA/Audio.** One speaker. **Telephone.** One line. **Data.** Minimum of four LAN internet outlets for library research. **Security.** None required.
Casework/Built-in Equipment	Bookshelves to house technical library collection
Furnishings Fixtures & Equipment (FF&E)	Copier, fax machine, printers, table, chairs, bulletin board with tack surface, dry-erase board, and other office equipment as required.
Special Requirements	None required.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers.
Min. net ft^2 (m^2)	

Table 4-13

Technical Library