LABORATORY GUIDELINES

Research Laboratories

The following guidelines are to be incorporated into the planning, design, construction and maintenance of Arizona State University's (ASU) laboratory facilities.

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Arizona State University

Laboratory Guidelines

A. Introduction

The following guidelines are to be incorporated into the planning, design, construction and maintenance of Arizona State University's (ASU) laboratory facilities. As research technology continues to develop, these documents will be periodically updated to reflect the latest requirements. Design Professionals shall visit this site regularly to confirm they are utilizing the latest edition for the updated Laboratory Guidelines.

It is the responsibility of design professionals to use these guidelines to complement their design knowledge and experience by providing contemporary, "state-of-the-art", sustainable and energy efficient laboratory facilities that will assist ASU to effectively and successfully compete with its peer organizations for the best students, faculty and staff; and for available public and private research funding.

Lab Planners and Design Professionals should also keep in mind that laboratory design is a highly specialized field. Comprehensive research, programmatic development and due diligence are essential to the successful development of these facilities through programming, design and construction. Codes and guidelines referred to in this (or any other) section of these Design Guidelines are not to be assumed as comprehensive. It is incumbent upon the Design Professionals to properly investigate the specific requirements of the lab to ensure compliance with all local, state and national codes and regulations, as well as established ASU Fire Marshall (FMO) requirements, CPMG Design Guidelines and Environmental Health and Safety (EHS) best practices.

B. Guidelines for Research Laboratory Design

1. Definition of a "Laboratory" at ASU

   ASU defines a "Laboratory" as a facility or room where the use of potentially hazardous chemicals, biological agents or sources of energy (i.e. lasers, high voltage, radiation, etc.) are used for scientific experimentation, research, or education.

2. "Wet Lab" versus "Dry Lab" at ASU

   a) Wet Labs

      A wet lab is a type of laboratory in which a wide range of experiments are performed, for example, characterizing of enzymes in biology, titration in chemistry, etc., all of which may involve dealing with hazardous substances.

      Even though scientific equipment has advanced, the importance of wet labs has not fundamentally changed. These types of labs handle a range of biological specimens, chemicals, drugs, gases and other materials for use in experiments. In order to support this scientific research effectively and safely, wet labs need a range of tools, equipment, and services at hand, such as:

      - Lab bench countertops and sinks which can be cleaned easily and are resistant to bacteria and chemicals
      - Piped in water, often including reverse osmosis (RO) or deionized water (DI)
      - Chemical fume hoods and biosafety cabinets (BSCs)
      - Facilities for handling live test specimens (animal housing aka vivariums) or proximity to clinics for human subjects

- Specialized refrigerators and freezers for storing tissue and other specimens
- Controlled environment areas (warm or cold rooms)
- Autoclaves and other sterilization equipment
- Glass washing and drying area
- Piped in compressed air and vacuum as well as a range of other gasses like natural gas, oxygen, etc.
- Radioactive work area for radiological materials, including safe storage facilities
- Safety showers, eye wash stations, and hand washing stations
- Climate control of ambient air and ventilation (HVAC)
- 100% outside air and exhaust to outside the building
- Vibration controls for sensitive experiments, such as DNA sequencing.

Wet Lab Examples:

- Organic Chemistry Labs
- Physical Chemistry Labs
- Cell Biology Labs
- Fermenter Labs
- Molecular Biology Labs
- Pathology Labs
- Tissue Culture Labs
- Anaerobic Chamber Labs

b) Dry Labs

Over the years, the role of the dry lab has expanded from providing a space for working with dry stored chemicals to a lab space with a network of powerful computing systems.
In dry labs, computers are used to carry out analysis, modeling, and simulations. A dry lab is a place where analysis of data is conducted with computers and mathematical analysis. The design of these labs is as critical as wet labs, but the requirements are very different.

Dry laboratory spaces will have fewer requirements for piped services than wet labs, but that doesn't mean they don't have their own unique requirements. Increasingly, dry labs need these types of services:

- Extensive cooling and humidity controls to support computer labs (HVAC)
- Clean power systems for sensitive computers, research instruments, and network communications
- Occasional clean room system installations are required for certain processes and experiments
- Vibration controls for sensitive instruments that need to maintain calibration

Dry Lab Examples:

- Computer Labs (Mainframe, Workstation, and PCs)
- Confocal Microscope Labs
- Electromagnetic Instrument Labs
- Electron Microscope (EM) Labs
- Electrophysiology and Biophysics Labs
- Flow Cytometry Labs
- Laser Labs
- Robotic Equipment Labs
- X-Ray Crystallography Labs

Basis of Comparison	Wet Lab	Dry Lab
Analysis	Primarily chemicals and gases are used in analysis.	Primarily electronic equipment such as computers and instruments are used in analyzing and evaluation of data.
Examples of Experiments	Examples of experiments done in wet labs include: characterizing enzymes in biology, titration in chemistry and diffraction of light in physics.	Examples of computer assisted experiments done in dry labs include: quantum state analysis, ground theory methodology, and coding and text interpretation, mapping or networking.
Lab Design	The lab is mostly designed with Biosafety cabinets, fume hoods specialized refrigerators and freezers.	The labs are normally designed with HVAC controls to support cooling and humidity levels.
Major Consideration	Because of the nature of the work and the handling of chemicals and gases, wet labs require benches, sinks, hoods and safety equipment.	Because of the nature of the work, dry labs require clean power systems for sensitive computers, research instruments and network communication and HVAC controls to support cooling and humidity levels.
Lab Ventilation	100% outside air and exhaust to outside the building.	Ventilation requirements vary depending on the type of lab.

3. Open labs versus closed labs

   Today's "open lab" concept is significantly different from that of the "closed lab" of the past, which was based solely on accommodating the individual principle investigators. In open labs, researchers share not only the open space itself, but also equipment, bench space, and support staff. At Arizona State University, the majority of new laboratory research projects that are built are open type labs which encourage "Interdisciplinary Research."

   "Interdisciplinary Research" at ASU is defined as a mode of research by teams or individuals that integrate information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research.

   In order to create successful Interdisciplinary Research labs at ASU, Laboratory Planners and Design Professionals must understand the latest trends in interdisciplinary research, the needs of the defined users, the different ways the laboratories will be utilized today and the ways they might be used in the future, the technical needs of the departments involved, appropriate health and safety standards of practice and the technical requirements of the lab support spaces required to support the types of research planned for the project. Critical to the success of the project will be the early involvement of the Office of the University Architect (OUA), Capital Programs Management Group (CPMG), Environmental Health and Safety (EHS), University Technologies Organization (ET) and Facilities Management (FACMAN).

ASU continues to develop closed labs for special research requirements and for the renovation of existing labs to either expand or update them in keeping with our goal to create contemporary, "state-of-the-art", sustainable and energy efficient laboratory facilities. Even for these lab facilities, ASU strives to develop interactive opportunities to encourage the sharing of equipment, personnel and research collaboration.

4. General Approach

Because a facility (site + building) is meant to house and support human activities, research facilities at ASU will need to accommodate the physical, social, behavioral and psychological needs of the occupants while also providing cost effective and high performance and sustainable facilities. To this end, the following are desirable characteristics of ASU research facilities:

a) Protects occupants from general and specialized chemical, biological, radiological and physical force hazards.

b) Provides a flexible and adaptable facility to accommodate changes in research technology, methods, equipment, staffing and maintenance.

c) Designed to effectively use resources (energy, water, materials, equipment, etc.) to establish and maintain a sustainable campus and local community environment.

d) Designed to meet (and possibly exceed) the Sustainability Guidelines established for ASU buildings. Refer to http://www.asu.edu/fm/documents/project_guidelines/Sustainable-Design-Guidelines.pdf

e) Adherence to the “Best Practices Guide” developed for sustainable laboratories by the International Institute for Sustainable Laboratories (I2SL): https://www.i2sl.org/documents/i2sl_pi_best-practices-guide.pdf.

f) For additional requirements for the deign and construction of Research Laboratories, refer to the National Institute of Health (NIH); https://www.nih.gov; and the National Science Foundation (NSF), https://www.nsf.gov.

g) Provides a secure exterior and interior environment to protect ASU’s critical assets of its people, intellectual property, and physical facilities.

There are many different requirements for research laboratories at ASU, depending on the research approach to be used in the laboratory.

New lab buildings or lab renovation projects must be planned and designed to provide flexibility and adaptability to keep pace with the rapid changes continually occurring in laboratory research, grant funding cycles and recruitment of new researchers. It is essential that the design allow research space to be converted and/or renovated with minimal disruption.

The most important aspect of the "state-of-the-art" research facility at ASU is the ease and simplicity with which any part of the facility can respond to change. For example:

a) Change in focus of research (e.g.: response to new types of research)

b) Change in personnel (e.g.: size or makeup of group or team).

c) Change in environment (e.g.: open space vs. enclosed space).

d) Change in procedure (e.g.: wet chemistry to automated processes).

e) Change in technology (e.g.: for new equipment)

Laboratory research at ASU is advancing rapidly, and therefore the newly planned facilities must be designed to anticipate these advances. High bay/maker's spaces, highly sophisticated instrumentation, including robotics, and the use of virtual reality; and 3-D printers (which require additional power and cooling) is the wave of the future in all research laboratories and should be considered in the initial planning and design particularly for future space requirements.

Wet laboratories house functions that include working with chemicals or biological materials and utilize benches, sinks, chemical fume hoods, and/or biosafety cabinets. Generally, a wet lab is fitted out with a full range of piped services such as reverse osmosis (RO) or deionized (DI) water, lab cold and hot water, lab waste/vents, carbon dioxide (CO_2), vacuum, compressed air, nitrogen, hand washing sinks, eyewashes, safety showers, telecom, data, security, WiFi, AV, lighting, and power.

Today's trend in laboratory design at ASU is toward larger, denser, shared laboratory support rooms such as equipment rooms and special function support rooms. The use of fume hoods for biomedical research has decreased dramatically in recent years due to researchers replacing many volatile and carcinogenic reagents with less toxic chemicals and procedures. However, there is an ever-increasing need for developing core facilities and temperature-controlled storage (e.g., controlled environmental cold and warm rooms).

To support these larger lab areas generally will require a central administrative unit along with larger open office areas and larger offices that may include up to (3) individuals. As a result this can create larger sensible latent heat loads for this portion of the building that needs to be considered when sizing the HVAC system for the building.

Local computer user rooms are also required for the "state-of-the-art" laboratory at ASU. The computer user room should be designed into laboratory neighborhoods as shared space where all the equipment needed for the current state-of-the-art communication technology can be brought together and shared. Equipment in the computer user room may include scanners, microprocessors, personal computers, plotters, laser printers, 35 mm slide makers, and so on.

New laboratories at ASU shall also be designed to be adaptable for the rapidly changing environment and shall be capable of supporting new and emerging scientific disciplines. Thought should be given to planning new lab buildings for the ability to renovate/convert floors or building zones to special purpose uses such as CXFEL vaults, a semiconductor fab, a high-bay clean room, etc.

5. Types of Research at ASU

At ASU, the predominance of research studied is in the fields of the Life Sciences, Physical Sciences, Geological Sciences and Engineering.

Life Science laboratories include, but are not limited to: Biology, Biomedical, Biochemistry, Bioinformatics, Cell Biology, Microscopy, Molecular Biology, Virology, Immunology, Physiology, Pathology, Synthetic Biology, and Clinical Research.

Physical Science laboratories include, but are not limited to: Chemistry, Organic Chemistry, Analytical Chemistry, Physical Chemistry, Inorganic Chemistry, Nuclear Chemistry, Polymer Chemistry, Biophysical Chemistry, Bioinorganic Chemistry, Electron Microscopy and Environmental Chemistry.

Geological Science laboratories include, but are not limited to: Geology, Astrogeology, Engineering Geology, Paleontology, Petrology, Geochronology, Sedimentology, Geophysics, Geochemistry, Hydrogeology, Mineralogy and Petroleum Geology.

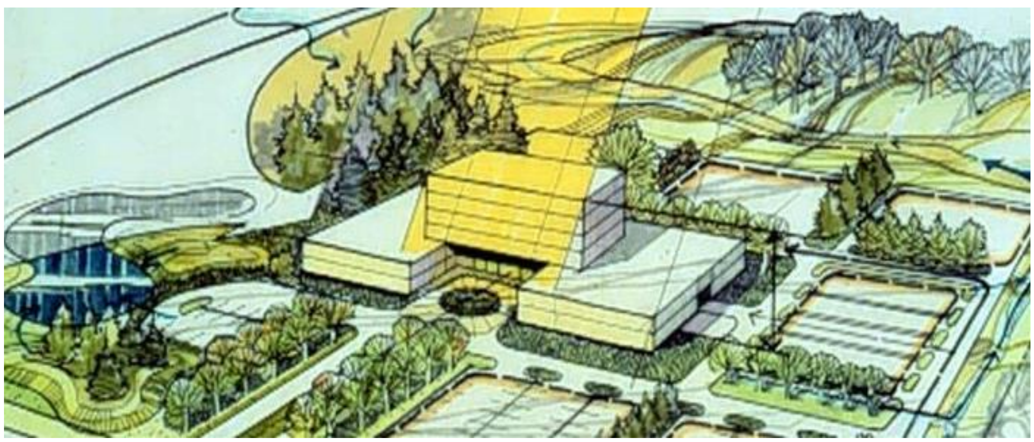
Engineering laboratories are very diverse and field specific; some are specialized, single-purpose spaces with large fixed equipment, while others may be indistinguishable from the sciences above. Engineering laboratories may include, but are not limited to, materials testing, robotics development, material growth and characterization, biomedical device prototyping, machining and fabrication shops and bio-chemical reactor construction and operation.

6. Laboratory Design Approach

One factor to keep in mind when designing research laboratories is the zoning of the building between lab and non-lab spaces. Labs and lab support areas require 100% outside air while non-lab spaces can be designed with re-circulated air, such as an office building. Through proper zoning, lab flexibility is increased by limiting the potential obstacle of offices "inside" the laboratory. The desired connectivity can be maintained between the lab and office zones by designing for proper proximities in conjunction with a networked lab management system.

a) Orientation

1. Laboratories should be oriented to take advantage of natural lighting (with consideration for controlling sunlight and glare). Generally, labs are located on the north side of the building to help control direct sun exposure.



2. They should also be oriented such that the organization of the building elements are harmoniously integrated with the site to create an inviting yet secure environment to encourage interaction of researchers.

b) Location of the Building Fresh Air Intakes and the Lab Exhaust Stacks

1. Another key planning element is the location of the building fresh air intakes and the lab exhaust stacks. A wind study should be developed to determine the prevailing winds direction for lab exhausts; and how the geometry of surrounding buildings can create wind currents and various pressure zones. This can cause undesirable exhaust plume drifting and nuisance odors or chemical concentrations with negative health impacts entering these fresh air intakes or occupied zones outside of the building, or for other surrounding buildings. Laboratory exhaust stacks shall terminate on the roof both downward and as far away from building air intakes as possible to preclude re-circulation of laboratory exhaust emissions within a building. Exhaust systems shall discharge at a point where it will not cause a nuisance and from which it cannot be readily drawn in by a ventilating system. For specific minimum distances between exhaust stacks and building fresh air intakes reference applicable building and safety codes and standards. Refer to the CPMG Project Guidelines webpage at:

https://cfo.asu.edu/design-professionals and the EHS Laboratory Standards & Design Guidelines webpage at: https://cfo.asu.edu/ehs for additional requirements.

c) Location of the Building Loading Dock(s)

1. The placement and location of loading dock(s) must be coordinated with the outside fresh air intakes and shall be located no less than 30 feet horizontally away from the building fresh air intakes. Also, the direction of the prevailing winds needs to be considered when siting the loading dock(s) such that the exhaust of idling trucks at the loading dock(s) is not blown into the fresh air intakes.

d) Flexible and Adaptable Laboratory Facilities

1. When designing research facilities at ASU Design Professionals need to incorporate the following four main principles in their design concepts:

    a) Modular space planning

    b) Modular laboratory building systems design

    c) Accessibility and connectivity of modular building systems

    d) Determine required vertical chase(s) size(s) and then oversize by 20%.

2. By successfully utilizing these four main principles, it provides ASU the ability to remodel laboratory space in the future with minimal disruption which is essential for extending the effective life of ASU's laboratory facilities.

    a) Modular Space Planning

        1. The first and most fundamental concept of laboratory planning is the application of modular design. This approach maintains the highest level of flexibility by allowing the functional requirements of the lab to influence the form such that the laboratory is designed from the inside out.

        2. Modular planning, carefully executed, also allows for future flexible and adaptable renovation. The concept of repetitiveness, regularity in size, shape, and arrangement of space provides the ability to convert and/or renovate space with a minimum of disruption.

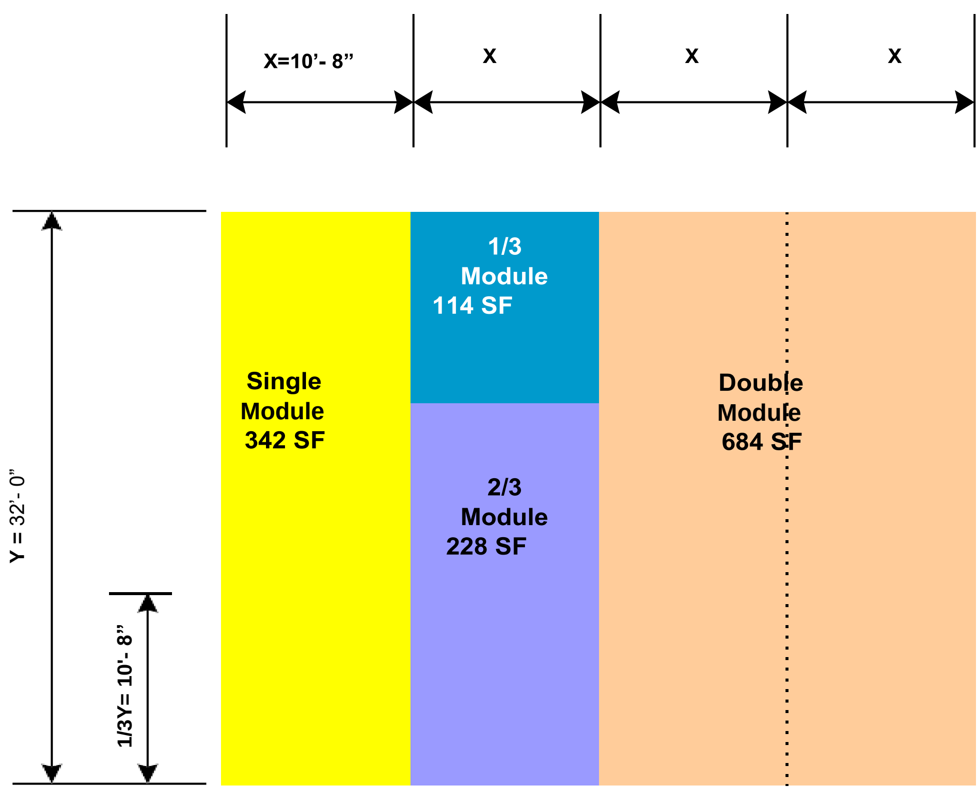
        3. A carefully developed modular planning approach allows for renovation of partitions and doors, and the expansion, subdivision, or reconfiguration of rooms with minimal disruption to adjacent laboratories; and with minimal altering or shutting down of central building utility systems.

        4. In order to achieve successful modular laboratory design at ASU, the laboratory must be developed utilizing laboratory modules. The laboratory module serves as a fundamental unit, that when combined with other modules, is utilized to create a flexible laboratory building. The laboratory module serves as the basic laboratory building block, and it must be properly sized so that assembling a number of modules can create a variety of laboratory areas.

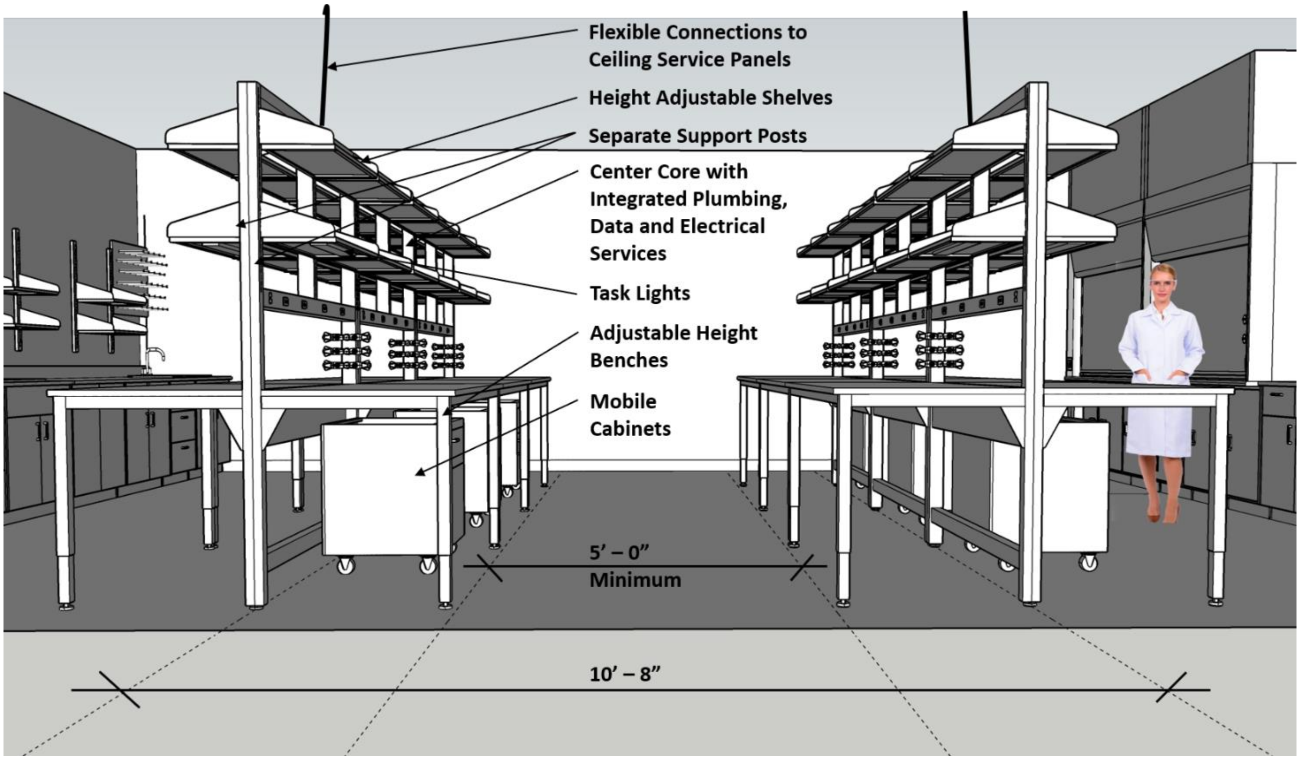
5. For design purposes, the laboratory module at ASU is comprised of Net Square Feet (NSF) and is determined by establishing a centerline to centerline of the width of the module multiplied by inside face to inside face of walls in the length to determine the depth of the module (which is usually two times or three times the module width depending upon whether or not office space is included in the overall module.) (Refer to the diagram below). Certain dimensions work better in the laboratory environment than others. For most ASU lab projects, we have determined that the appropriate minimum module width dimension should be planned at 10’- 8” wide.

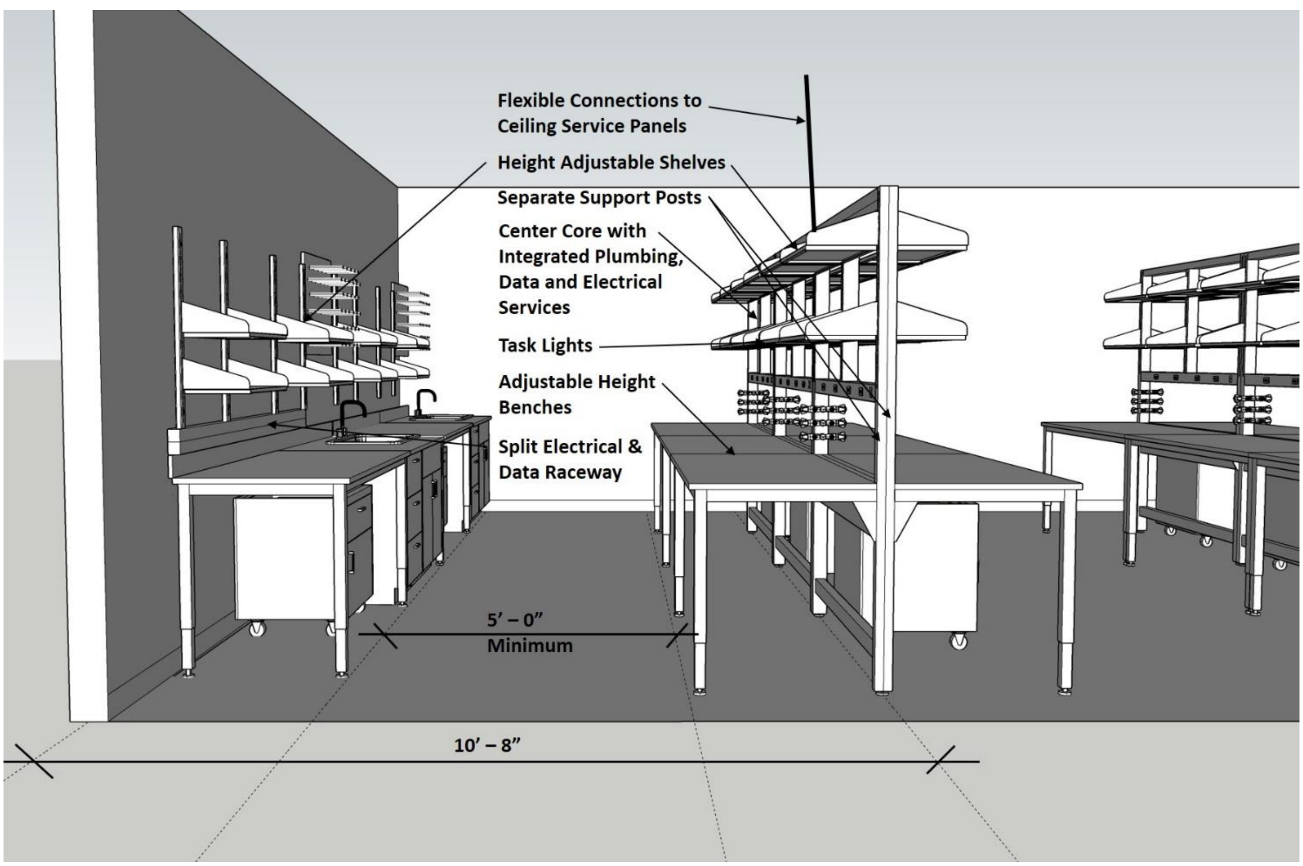
6. The 10' - 8" dimension is based on the following analysis and design considerations:

   a. Two rows of laboratory casework and equipment (each row minimally 2' - 6" deep on each module line, a 5' – 0” minimum aisle, and 6" for potential wall thickness separating one lab from another when designed as single labs. For open labs, the planning module is repeated such that it helps to create an overall building grid that can be developed as the structural grid for the building. (Refer to diagram below.)



Possible Laboratory Module Configurations


Flexible Connections to Ceiling Service Panels
Height Adjustable Shelves
Separate Support Posts
Center Core with Integrated Plumbing, Data and Electrical Services
Task Lights
Adjustable Height Benches
Mobile Cabinets
5' – 0" Minimum
10' – 8"


Flexible Connections to Ceiling Service Panels
Height Adjustable Shelves
Separate Support Posts
Center Core with Integrated Plumbing, Data and Electrical Services
Task Lights
Adjustable Height Benches
Split Electrical & Data Raceway
5' – 0" Minimum
10' – 8"

b. Laboratory buildings at ASU are designed to last for minimally 50 years or more. As such, durable materials must be used to construct these buildings. One material that is commonly used successfully for laboratories is masonry products which generally use an 8 inch module size both horizontally and vertically. By combining the masonry module with the planning requirements above, the most efficient lab module becomes 10’ – 8”.

7. From our experience at ASU, we have determined that the most cost effective and efficient structural grid is 21’ – 4” wide x 32’ – 0” deep. This structural grid also helps to minimize the issues associated with vibration for lab equipment.

8. Note, although the 10’ – 8” module is the preferred ASU size, each lab needs to be evaluated based upon the user and lab requirements; and may be required to be a larger size. Any deviation from the 10’ – 8” module must be reviewed and approved by the Office of the University Architect.

9. In addition to the lab module, the height between floor to floors for labs also becomes an important element for flexible and adaptable lab projects. At ASU, we have determined that for floors above Level One, that 14’ – 8” is the minimum accepted floor to floor height for new lab buildings; however, 16’ – 0” between floor to floor height is the preferred height for labs at ASU. This allows the lab ceilings to be established at 10’ – 0” above the finished floor; and allows 6’ – 0”” for structure and the routing of the building systems that support the labs and lab support areas. (Refer to Diagram below).

10. When designing the height for special labs including, but not limited to, Engineering Labs, Physics Labs, Material Sciences Labs, Vivariums and Maker’s Spaces, a minimum floor to floor height of 18’ – 0” is required.

Laboratory Cross Section

11. The lab module also may be sub-divided to accommodate core support or office spaces as needed. To the extent possible, organization of the laboratory modules in strings, uninterrupted by toilet rooms, shafts or other fixed elements helps to maximize flexibility and adaptability.

12. Lab support spaces also should be developed based upon the laboratory module and include such spaces as: Environmental Rooms, Instrumentation Rooms, Microscopy Rooms, Fume Hood Alcoves, Sterilization and Glass Washing Rooms, Tissue Culture Rooms and Computer Rooms.

13. The offices and conference rooms are also developed from multiples of, or fractions of, a standard module when they occur in a new facility.

b) Modular Laboratory Building Systems Design

1. Modular design should also extend to building systems as well. It must be thought of as “Integrated Systems Design”, where all spatial and systems elements are carefully organized in a repetitive modular approach. Points of connection to each building system must be located at consistent, predetermined, and recurring positions based upon the laboratory module, so that services can be easily extended into any module with minimal systems shutdown and minimal disruption of research in adjacent spaces. Thus, as the requirements of lab programs change, the individual spaces can be readily modified with a minimum of cost, effort, and disruption.

2. Modular laboratory systems design also provides greater adaptability for future renovations by distributing primary building systems (HVAC, piping, electrical power, I.T. and communications) from consistent, recurring points of connection relative to the laboratory module. These points of connection provide each laboratory module access to all laboratory systems. In this way, additional services can be added as simple extensions from the distribution loop into the laboratory without disruption of service to adjacent modules. Design professionals need to organize all utilities, including communication and information systems, into zones, both horizontally and vertically, to provide a consistent and accessible systems distribution concept.

3. An accessible modular systems approach to design also simplifies and facilitates maintenance of building systems and the construction process. Repetitive modular systems components allow some systems components to be factory assembled for delivery and installation at the project site reducing construction time.

4. In coordination with building modules, design loads for each building system must be based on an evaluation of modular systems demand, where each module represents a unit of capacity, watts of power, supply and exhaust cfm, gallons of water, etc. The size of this “unit” shall consider both present and anticipated future use. However, a balance between adequate reserve capacity and too much capacity must also be considered. A system with too much capacity increases both initial construction cost and operational cost; and has an adverse effect for energy efficiency for sustainability.

5. From the initial planning stage of design, mechanical systems need to be designed for a maximum number of fume hoods per floor and for the total building. This will vary based upon the type of research planned as the basis of design for the building, ie, chemistry versus biology versus engineering based research.

6. Also to increase the flexibility for future lab renovations, the vertical shafts shall be oversized by 20%; and the mechanical and electrical rooms, MDF and IDF rooms and building equipment rooms shall be oversized accordingly to accommodate future renovations or additional equipment.

7. Ductwork shall be sized to allow for change and vertical exhaust risers provided for future fume hoods in the initial stage of construction. When a fume hood is required in the future, a duct can be run from the fume hood to the installed vertical duct riser.

c) Accessibility and Connectivity of Modular Building Systems

1. Ceiling service panels and overhead service carriers are options that provide systems connectivity when hung from the ceiling. They can include utilities such as piping, electric, data, light fixtures, and snorkel exhausts. They also afford maximum flexibility as services are lifted off the floor, allowing free floor space to be configured as needed.

2. Providing adequate building systems capacity at ASU is also essential when planning research laboratories to accommodate future levels of use and/or shifting loads. Criteria for the design of central systems shall be based on careful evaluation of the anticipated range of systems demand for the facility. Building systems with adequate capacity will allow changes in facility utilization without modification of primary systems components including primary distribution systems, pumps, chillers, fans, etc.

3. Also, building systems components must be easily accessible for maintenance and servicing. Components that require regular maintenance shall be located in the corridor ceiling spaces or other spaces outside the perimeter of the laboratory module. This facilitates maintenance access without service personnel entering primary laboratory spaces. Servicing inside the laboratory disrupts research and is difficult because of the scientific apparatus and instrumentation that must be protected. In addition, facilities service staff must be aware of, and concern themselves with, the inherently hazardous nature of the work conducted inside the laboratories.

4. To adequately plan for accessible building systems, space shall be reserved in the utility corridors, ceilings outside the lab and lab support areas, and vertical chases for future HVAC, plumbing, and electrical needs.

e) Laboratory Density

1. Providing each investigator with an adequate amount of laboratory work space, laboratory support space, office space and administrative support space is essential to establishing an efficient, flexible and usable laboratory environment. When Investigators are not provided adequate amounts of space in which to work, they invent creative solutions to their laboratory workspace deficiencies, generally sacrificing both safety and efficiency.

2. To help solve this issue at ASU, we have developed our own average Net Assignable Square Feet (NASF) metrics for developing space requirements for wet and dry laboratories as follows:

3. For **new** laboratory buildings at ASU, there are (3) basic team size models that are used for research laboratories:

a) Typical research team #1 (for Physical Sciences and Biosciences) includes (1) PI and (5) post doctorates/graduate assistants

1. NASF for this team has been determined to be between 750 – 800 SF depending upon the type of research.

    a) This NASF only includes lab and lab support space

    b) The ratio of lab space to lab support space averages between 1:1 depending upon the type of research.

    c) It also is based upon the PI being assigned 90 – 120 lineal feet of bench space (LFB).

2. This research team module also includes an additional 400 NASF for office and administrative space which is assigned as follows:

    a) 100 NASF for the PI

    b) 48 NASF for each post doctorates/graduate assistants = 240 NASF

    c) 60 NASF for administrative support

b) Typical research team #2 (for High Hood Density) includes (1) PI and (6) post doctorates/graduate assistants

1. NASF for this team has been determined to be between 900 – 950 SF depending upon the type of research.

    a) This NASF only includes lab and lab support space

    b) The ratio of lab space to lab support space averages between 1:1 depending upon the type of research.

    c) It also is based upon the PI being assigned 90 – 120 lineal feet of bench space (LFB).

2. This research team module also includes an additional 460 NASF for office and administrative space which is assigned as follows:

    a) 100 NASF for the PI

    b) 48 NASF for each post doctorates/graduate assistants = 288 NASF

    c) 72 NASF for administrative support

c) Typical research team #3 for Engineering (Computer Science, Electronics & Electrical Engineering) includes (1) PI and (5) post doctorates/graduate assistants

1. NASF for this team has been determined to be between 600 – 650 SF depending upon the type of research.

   a) This NASF only includes lab and lab support space, although this group often uses shared Core facilities to supplement their lab support functions.

   b) It also is based upon the PI being assigned 80 – 100 lineal feet of bench space (LFB).

2. This research team module also includes an additional 400 NASF for office and administrative space which is assigned as follows:

   a) 100 NASF for the PI

   b) 48 NASF for each post doctorates/graduate assistants = 240 NASF

   c) 60 NASF for administrative support

4. For laboratory renovation projects at ASU, each project is unique and must be designed to meet the requirements of the research team or the type of research being developed.

f) Laboratory Separations

1. A laboratory at ASU is defined as a facility or room where the use of potentially hazardous chemicals, biological agents or sources of energy (i.e. lasers, high voltage, radiation, etc.) are used for scientific experimentation, research, or education. As such, in order to keep from classifying these areas as high-hazardous Group "H" occupancies, the IBC and IFC codes allow Higher Education laboratories to be constructed as either "Control Areas" or "Laboratory Suites".

2. Control Areas are defined as areas within a building where quantities of hazardous materials not exceeding the maximum allowable quantities (MAQ) per control area (as defined in the IBC and IFC) are stored, dispensed, used or handled.

3. In Higher Education laboratories, the IBC and IFC allows for moderate increases in hazardous materials storage and use over the MAQ for Control Areas by providing an option for "Laboratory Suites" with construction as per IFC 2018 Chapter 38 Higher Education Laboratories.

4. Laboratory Suites provide a much higher level of fire and hazardous materials protection than Control Areas, but impose additional construction and operational controls in exchange for the increased allowances.

5. In either option, in order to successfully plan and design laboratory facilities at ASU, the Design Professional must determine the MAQ required for each laboratory area and design the areas in accordance with the IBC and IFC MAQ requirements.

g) Interaction and Collaboration

1. Research is enhanced by communication, interaction and collaboration amongst researchers. At ASU, fostering interaction is a priority and must be an integral component of the design solution.

2. The Design Professional must develop a planning concept which encourages casual encounters through strategic location of common facilities. This will create an opportunity for meaningful interaction which is designed to draw researchers out of their labs and offices from time to time. Careful consideration must be given to developing circulation patterns that can significantly contribute to the potential for this type of interchange between faculty, students, researchers and their staff.

3. A single corridor scheme with offices opposite labs reinforces interaction and collaboration.

4. Experience shows that proximity to coffee stations, break areas, copy centers, meeting rooms, toilet rooms, and main corridors makes interaction areas successful. Interaction spaces also provide a place to safely consume food and drink outside the laboratory.

5. Also, for laboratories at ASU, consideration should be given to foster interaction outside of the building. Outdoor building amenities shall be developed to provide opportunities for interaction which will help draw researchers out of their labs and offices from time to time when the weather is appropriate.

6. Both indoor and outdoor spaces, remote from the routine of laboratory life, shall be designed to promote interaction and collaboration as part of the overall laboratory program.

h) Vibration Control

1. Laboratories house a variety of vibration sensitive equipment used for research and production in fields such as Laser based research, high-resolution imaging, and biotechnology. Inserting electrical probes into nuclei of living cells, etching sub-micron lines in nanostructures, or taking SEM images requires laboratory environments to have vibration levels well below human perception thresholds.

2. Floor vibrations can cause imaging components, specimens, lasers, or substrates to move relative to each other, causing blurry images, low yields, and erroneous results. The degree to which this relative motion affects results depends on the amplitude and frequency of the environmental vibrations as well as the sensitivity of the experiment.

3. Also, ambient vibrations are constantly encountered in lab facilities and can be grouped into two sources: internal and external sources. Common internal sources of vibration include foot traffic, duct velocity of air handling systems, unbalanced fans, vacuum pumps, and chillers. These sources can typically generate higher vibration levels than external ones. External vibration sources are those coupled into the building structure itself and include elevators, ventilation motors, road and rail traffic, construction activity, and nearby heavy industry. Airports also can generate significant levels of low-frequency vibration issues.

4. In order to properly design the structural system for laboratory facilities at ASU, the Design Professional must determine the vibration criteria required for the specific lab needs. Refer to the chart below for specific vibration requirements. At ASU, a vibration rating of ISO – 4000 micro-inches per second is sufficient for the majority of our research labs, however, VC-A - 2000 micro-inches per second is the preferred level for our laboratory projects.

Octave criterion curve/environmental rating

Criterion curve/ (Environment rating)	Max level[1] micro-in./s (dB)	Detail size[2] achievable/ (Application need rating) (μm)	Description of area
Workshop	32,000 (90)	500	Distinctly felt vibration. Significant audible noise present from adjacent machinery, roads, elevators, or overhead doors. Typical of manufacturing areas, workshops, and warehouses. Adequate for heavy manufacturing and assembly.
ISO Office	16,000 (84)	250	Noticeable vibration. Noticeable audible noise from machinery, pumps, air handlers, and external disturbances. Typical of centrally located office areas, hallways, and upper floor laboratories. Adequate for basic component assembly stations, basic sample preparation areas, and break rooms.
ISO Residential Day	8000 (74)	75	Barely felt vibration. Low-level audible noise from air handlers, small machinery, water lines, and external road noise. Typical of perimeter offices, laboratories, and buildings in seismic zones. Would be possible to sleep in this environment. Adequate for computer equipment, probe test and precision assembly equipment, lower-power (to 20X) microscopes, scatterometers, and sensitive sample preparation.

ISO Operating Theatre	4000 (72)	25	Very slight vibration felt. Very low-level audible noise from air handlers or lighting. Adequate in most instances for microscopes to 100X and for other equipment and applications of mild sensitivity including optical/visual inspection, multiphoton microscopy, electrophysiology, fluorescence imaging, and optical profilometry.
VC-A	2000 (66)	8	No vibration felt. Minimal audible noise for environmental control equipment. Adequate in most instances for sensitive equipment and applications including optical microscopes to 400X, microbalances, optical balances, proximity and projection aligners, optical trapping, fluid dynamics, and high-resolution laser imaging.
VC-B	1000 (60)	3	No vibration felt and less than 40 dB audible noise. An appropriate standard for optical microscopes to 1000X, inspection and lithography equipment (including steppers) to 3 μm linewidths.
VC-C	500 (54)	1	No vibration and less than 25 dB audible noise. A good standard for most lithography and inspection equipment to 1 μm detail size.
VC-D	250 (48)	0.3	No vibration felt and less than 15 dB audible noise. Suitable in most instances for the most demanding equipment including electron microscopes (TEMs and SEMs) and E-Beam systems, operation to the limits of their capacity.
VC-E (1)	125 (42)	0.1	A difficult criterion to achieve in most instances. Assumed to be adequate for the most demanding of sensitive systems including long path, laser-based, small target systems, and other systems.

The information given in this table is for guidance only. In most instances, it is recommended that the advice of someone knowledgeable about applications and vibration requirements of the equipment and process be sought.

[1] As measured in one-third octave bands of frequency over the frequency range 8–100 Hz. The dB scale is referenced to 1 micro-in./s.

[2] The detail size refers to the linewidths for microelectronics fabrication, the particle (cell) size for medical and pharmaceutical research, etc. The values given take into account the observation that the vibration requirements of many items depend upon the detail size of the process.

5. Vibration is alleviated by increasing the stiffness of the floor slab. This stiffness can be increased by providing a combination of mass and/or depth for above grade slabs. Instruments that are extremely sensitive to vibration (SEMs, TEMs, NMRs, etc.) shall be located on isolated slab-on-grade construction to minimize transient structure-borne vibration.

i) Graphics and Signage

1. Graphics and signage are extremely important for labs to help employees and visitors find their way through a laboratory building. Directional graphics and signage should be functional and designed based upon ASU Signage Guidelines. Refer to the following website: https://www.asu.edu/fm/documents/project_guidelines/ASU-Signage-Design-Standard.pdf

2. Signs are also important for the identification of the hazardous waste and biohazard level of areas where hazardous work is performed. All new signage for labs shall be coordinated through OUA/CPMG to confirm that ASU signage standards are utilized and coordinated with EHS Standards. Refer to the following website for specific lab signage hazardous standards: https://cfo.asu.edu/chemicals

j) Safety

1. A critical aspect of creating a successful working environment in the laboratory is creating a safe work environment. In addition to providing an adequate amount of workspace, laboratories must be well ventilated, have proper chemical and biological containment devices, adequate means of egress, clear aisle space inside the laboratory, and must be equipped with all necessary safety devices.

2. Lab safety is increased with organized pathways for egress and materials handling, alcoves for fume hoods, and functional zones for efficient wet-bench work.

3. For information regarding laboratory safety, the Design Professional shall refer to the ASU EHS Guidelines: Chemical Hygiene Plan, CHP", July 2019 edition at: https://cfo.asu.edu/design-professionals

k) Environmental Interference Management (EIM)

1. Some types of research are sensitive to interferences. Interference may occur in many forms including; vibration, either structural borne or acoustical, radio frequency (RF), magnetic fields, dust, odors, air velocity in ducts and fume hoods or electrical power.

2. Another form of concern for laboratories is (EMI) Electromagnetic Interference which is caused by electromagnetic emissions that can disrupt the function of electronic devices and (RF) Radio Frequency systems.

3. The types of labs that are subject to EMI include labs that work with sensitive electronic equipment such as medical devices, military/aerospace hardware, high-speed data processing systems, scientific research instruments, and any lab where precise measurements are critical as even small levels of interference can significantly impact the accuracy of their results.

4. To address these issues above, a site survey to quantify the existing vibration, noise, and EMI conditions at the site needs to be implemented. This survey needs to include particular emphasis to quantify the impact from surrounding sites as well as pedestrian and vehicular traffic.

5. This survey also needs to measure ground triaxial vibrations on the surface at multiple locations within the project boundary. Measurements should be in the form of spot measurements (60 to 90 second averages) to quantify typical ambient conditions. Longer measurements also need to be carried out to quantify the impact from pedestrians and vehicles as needed.

6. If a basement is to be included, measurements need to be taken at different depths to determine the vibration attenuation properties of the sub-grade soils. If practical, this can be done by measuring at the bottom of a borehole drilled down to the proposed basement depth. Alternatively, measurements can be taken at an existing basement if it is located nearby and at a similar depth. Conservative assumptions can be made in lieu of borehole data if measurements are taken at grade. (Note that this will result in a more conservative design that can add to building construction costs.)

7. Also, short-term background noise "spot" measurements of the site need to be taken.

8. At the conclusion of this survey, and after suitable data processing and analysis time, a report documenting all the assumptions, methodology, results, and recommendations needs to be provided. These recommendations need to address setback distances for vibration and EMI, and layout of vibration sensitive spaces with respect to the site.

8. New lab facilities at ASU must include the development of an appropriate environmental interference management concept which includes identifying and then isolating sensitive instrumentation from sources of interference.

l) Chemical and Hazardous Waste Distribution/Collection

1. Consideration must be given to how materials will be delivered, moved through the facility and removed. Materials will include chemicals, gas cylinders, supplies, and equipment.

2. Chemical and Hazardous waste and debris from the laboratories will be collected in the labs and disposed of through EHS. EHS has strict guidelines for handling and disposing of Chemical and Hazardous waste and debris. For specific information, refer to: https://cfo.asu.edu/waste-mgmt-and-shipping

m) Accessibility for Persons with Disabilities

1. Providing accessibility for persons with disabilities requires special design considerations. New and renovated lab facilities must conform to applicable local, state and federal regulations regarding accessibility. Special consideration must be given to how accessibility will be addressed within the laboratory spaces including work areas, fume hoods and sink locations within the labs and lab support areas.

2. For information regarding Laboratory Accessibility, the Design Professional shall refer to "Section 2: Design Guidelines, Accessibility Standards" at https://cfo.asu.edu/design-professionals

n) Noise

1. Noise in laboratories can be difficult to control and is a serious issue that must be addressed during the design phase. Laboratory supply and exhaust systems, centrifuges, vacuum pumps, elevator equipment, hydraulic pumps and other equipment are noise generators. Room finishes in laboratories are generally hard and acoustically nonabsorbent, contributing further to the noise problem.

2. Proper design of the laboratory supply and exhaust systems is especially important at ASU and requires careful consideration of several factors that may significantly contribute to noise inside the laboratory including: high duct velocity, air turbulence, mixing boxes, air valves, fan noise, elbows or abrupt duct transitions close to the fume hood connection, and short distance from the exhaust fans to the fume hoods or exhaust grilles.

3. Therefore, the design of the lab facilities at ASU must isolate noise sensitive areas from noise sources or provide noise control systems. Design professionals must separate noise sensitive areas such as meeting rooms, conference rooms or interaction spaces from noise producing areas with non-sensitive buffer zones.

o) Laboratory Finishes and Materials

Design features and materials selected for the construction of laboratories shall be durable, smooth and cleanable, provide ease of maintenance and minimize pest access, and contribute to the creation of a comfortable, productive, and safe work environment.

Materials for laboratory finishes shall be as resistant as possible to the corrosive effects of chemicals and other reagents used in the laboratory.

Also, sound transmission classification (STC) ratings of building components and finishes shall be considered when selecting materials and systems to help mitigate noise within the lab areas.

Selection of finish materials also must be coordinated for compatibility with the sealants and caulks used for penetrations through walls and floors to maintain the required separations and fire ratings to comply with the codes for fire safety in buildings.

1. Walls

    a) Wall surfaces shall be free from cracks, unsealed penetrations, and imperfect junctions with ceilings and floors.

    b) There is no 'standard' wall material or finish, but the Design Professional must utilize products that are capable of withstanding washing with strong detergents and disinfectants and be capable of withstanding the impact of normal traffic.

    c) In lab and lab support areas, the Design Professional must use a white color finish (Snowbound, Semi-gloss) throughout. (Off-white color is not acceptable). In large open lab areas, an accent color on select wall(s) is acceptable provided the color and location(s) are approved by OUA in advance.

2. Floors

    a) Floors shall be designed to accommodate different types of wheeled conveyances and shall be devoid of abrupt changes in elevation. Avoid raised thresholds, steps, and ramps in circulation areas including Environmental Controlled Rooms.

    b) Floor materials shall be nonabsorbent, slip resistant, skid-proof, resistant to wear, easily cleanable and provide minimal cost for maintainability; and resistant to the adverse effects of acids, solvents, and detergents.

    c) Minimally, flooring for new laboratories shall be as follows:

        1. Chemistry and biological labs: seamless resinous epoxy flooring (not sealer) (either Dur-a-flex Accelera "C" or Key Chip 100 YRMC) with integral epoxy base that is proven to have excellent chemical and stain resistance, outstanding wear resistance and low maintenance requirements; and is slip resistant.

        2. Electronics Labs: Electronic Static Dissipation (ESD) vinyl with welded seams.

        3. Instrumentation labs: Confirm static electrical requirements for equipment first; and, if not required, then sheet vinyl or linoleum may be used, otherwise use Electronic Static Dissipation (ESD) vinyl with welded seams.

        4. Dry engineering labs: vinyl composition tiles or sealed concrete.

    d) The Design Professional shall consult with OUA/CPMG personnel in establishing the final design criteria for lab flooring finish in any lab renovation or new lab construction project.

    e) In temporary lab relocations, sealed concrete, vinyl composition tiles or sheet linoleum may be used provided that they are not installed in life sciences labs.

f) Finished flooring shall be installed throughout the laboratory and laboratory support areas completely to accommodate flexible laboratory reconfigurations and room modifications.

g) Floor materials shall be installed to allow for decontamination with liquid disinfectants and to minimize the potential spread of spills.

3. Ceilings

a) Concern for proper acoustics shall prevail in selection of ceiling materials. Minimally, acoustic ceilings are to be provided for lab and lab support areas. The Design Professional shall design a removable square non-tegular edge tile system.

b) Ceilings such as washable lay-in acoustical tiles (mylar face with smooth surface, vinyl face or equivalent) with a square edge (non-tegular) on a non-concealed spline shall be provided for Biosafety Level 2, 3 or 4 laboratory spaces.

c) Ceiling heights shall be a minimum 9' – 6" (10' – 0" is preferred) for the majority of laboratories and laboratory support spaces at ASU. For specialty labs including, but not limited to, Engineering Labs, Physics Labs, Material Sciences Labs, Vivariums and Maker's Spaces, a minimum ceiling height of 12' – 0" is recommended. Office ceiling heights shall be a minimum 8' – 0".

d) Mold resistant gypsum wall board with epoxy paint ceilings, equipped with access panels, shall be provided in vivariums, glassware washing and autoclave rooms, and other areas where the potential for high moisture levels exists. These access panels shall be fitted with gaskets that seal the door when closed and also the flange around the panel lip where it meets the ceiling.

e) Open ceilings are acceptable in certain applications for Specialty Labs provided that minimal ducting and piping are present and all exposed surfaces are smooth, sealed and cleanable. The Design Professionals must analyze the overall impact that open ceilings will have for energy efficiency, indoor air quality and LEED Certification; and discuss with OUA/CPMG staff for approval prior to implementing in the lab project. Note for Life Sciences labs and BSL-2 and above labs, ceilings shall be provided.

f) Concealed-spline ceilings shall not be specified.

g) The Design Professional shall consult with OUA/CPMG personnel in establishing the final design criteria for ceiling finish in any renovation or new lab construction project.

h) All penetrations through ceilings must be sealed with caulking or other sealant. Fire rated assemblies shall meet the fire rated assembly requirements set forth in the IBC and IFC.

p) Window treatment

1. Light-tight treatments shall be provided in conference rooms, special laboratories, and other spaces that may need to be darkened such as microscopy.

2. The Design Professional shall review the need for sunlight filtering in all laboratories.

3. Consistent visual appearance on the exterior of the building shall be maintained by the type of window treatment selected.

q) Doors

1. Main doors leading into laboratories shall be a minimum of 3’-6” wide, but the preferred door opening is a combined width of 4’ – 0” wide with a minimum 3’ – 0” active leaf and a 1’ – 0” inactive leaf.

2. Doors leading into laboratory support areas and doors into specialty lab spaces shall be a minimum of 3’ – 6” wide.

3. Vision panels shall be provided in the active leaf of all laboratory and lab support doors.

4. Doors into laboratories and lab support spaces shall be a minimum of 7’ – 6” high and in special labs may be required to be 8’ – 0” (Animal Research Labs) to 8’ – 6” (Laser Labs) high.

5. Laboratory door material shall be determined based upon the type of laboratory and consideration for areas subject to impact or abuse from carts, equipment, materials and personnel; and shall meet the fire rated requirements set forth by the IBC and IFC.

6. If wood doors are selected, the finished wood species shall be a common species and not an exotic wood species such that replacement of or additional doors to match the selected wood door becomes problematic. This also applies to the stain finishes for the wood doors.

r) Lab Casework

1. Generally, all laboratory casework shall be adjustable height painted metal casework. Refer to **Section “12 35 53 Laboratory Casework and Benchtops”** for specific design requirements.

2. Minimally, work surfaces for lab casework shall be as follows:

   a) Chemistry and biochemistry labs: epoxy tops

   b) Biological labs: phenolic or epoxy tops

   c) Electronics and instrumentation labs with chemicals and low heat: phenolic tops

   d) Electronics and instrumentation labs without chemicals: plastic laminate tops

   e) Dry labs: phenolic or chemical resistant plastic laminate tops

   f) Heavy materials labs: concrete or hardwood butcher-block wood tops

   g) Industrial and fabrication labs: hardwood butcher-block wood tops

   h) Prior to final work surface material selection, the Design Professional must review and gain approval from the offices of OUA and CPMG.

3. Work surfaces, including computer areas, shall incorporate task and daylighting considerations, equipment layout, and ergonomic features such as adjustability.

4. Benchwork areas shall have knee space to allow room for chairs and stools near fixed instruments, equipment, or for procedures requiring prolonged operation.

5. Mobile cabinets shall include work surfaces that are chemical resistant, smooth, and readily cleanable. In chemistry labs, include epoxy tops for mobile cabinets.

6. Data Cables for lab benches shall be provided and coordinated as identified in the diagram below: Note. Provide a minimum of (1) data cable per bench.

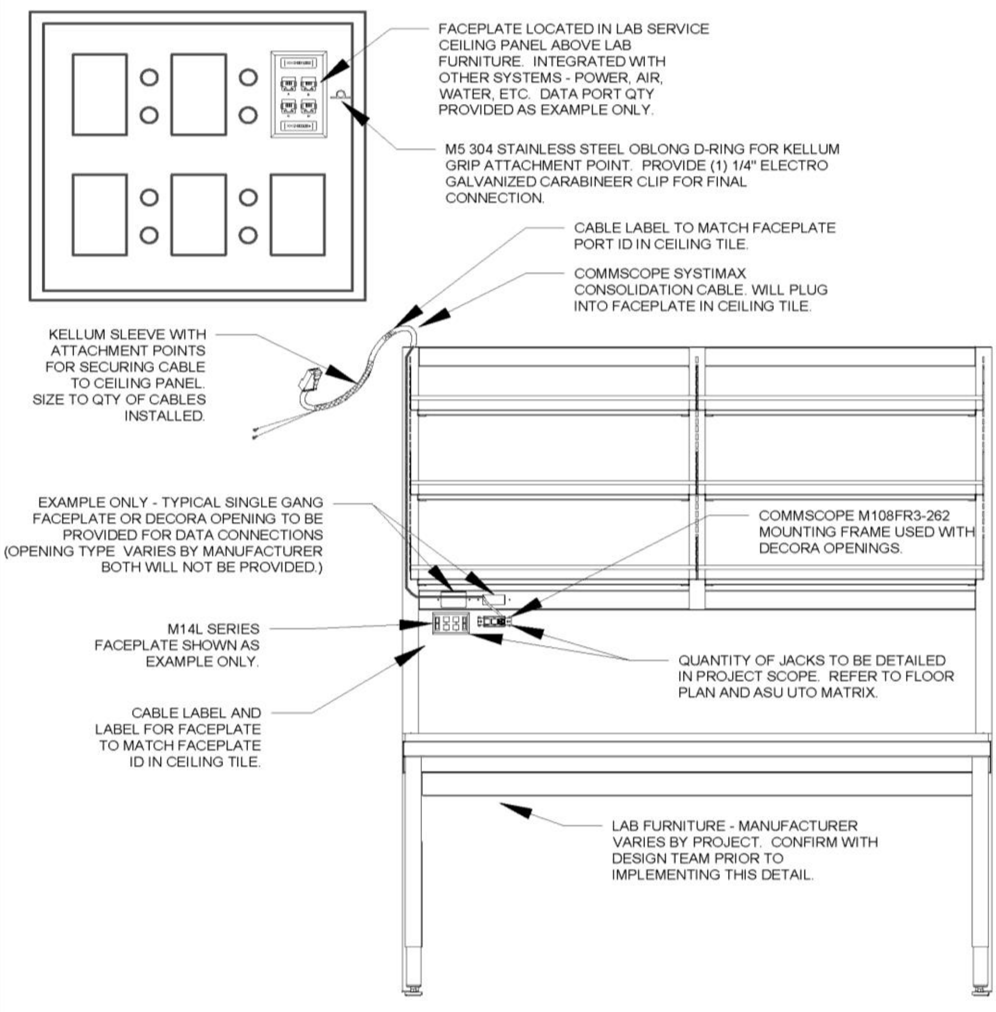
SCOPE OVERVIEW

ASU PROJECTS WILL NEED THE GC TO SHIFT ANY CABLING SCOPE FROM THE FURNITURE VENDOR TO THE SCS CONTRACTOR IN ORDER TO MAINTAIN THE CABLE INFRASTRUCTURE WARRANTY. ASU WILL REQUIRE THE SCS CONTRACTOR TO BUILD "CONSOLIDATION CABLES" FROM SOLID CONDUCTOR PATCH CABLES ORDERED IN CUSTOM LENGTHS, FROM COMMSCOPE SYSTIMAX, DOUBLED IN LENGTH OF WHAT IS REQUIRED, THEN CUT IN HALF, SO THEY CAN BE INSTALLED FROM THE OPENING AT THE TOP OF THE LAB FURNITURE, THRU THE FURNITURE TO THE TELECOMM OUTLETS PER THE DESIRED QTY. ENSURE UNTERMINATED END IS TERMINATED WITH A JACK AT THE OUTLET OPENING IN THE FURNITURE (IN THE FIELD BY THE SCS CONTRACTOR). AT THE TOP OF THE FURNITURE LEAVE 6'-10' OF SLACK WITH THE MALE CONNECTION (PRE-TERMINATED FROM THE FACTORY) TO PLUG INTO THE SERVICE PANEL IN THE CEILING. *NOTE THAT LENGTH WILL DEPEND ON DISTANCE FROM CEILING. A KELLUM GRIP (IDENTIFIED IN KEY NOTES ON THE TECHNOLOGY FLOOR PLANS, HOPEFULLY) WILL BE ADDED FOR STRAIN RELIEF.

A CABLE LABEL WITH UNIQUE IDENTIFIER INFO IS REQUIRED AT EACH END OF THE CABLE TO MATCH THE ASU MATRIX THAT COINCIDES WITH THE SERVICE PANEL OUTLET (IN CEILING) AND THE WORKSTATION OUTLET (AT THE LAB BENCH).

THE SCS CONTRACTOR WILL NEED TO COORDINATE THEIR EFFORTS WITH THE FURNITURE INSTALLER MUCH LIKE TYPICAL MODULAR SYSTEMS FURNITURE, IN ORDER TO PLACE CABLES AS THE LAB FURNITURE IS BEING ASSEMBLED.

TESTING WILL BE DIFFERENT IN THESE INSTANCES. FOR THESE LOCATIONS, THE CHANNEL TEST METHOD IN ADDITION TO THE PERMANENT LINK WILL BE UTILIZED. MEANING ONCE THE LAB FURNITURE IS IN PLACE WE WILL WANT A TEST FROM THE FACEPLATE OF THE LAB BENCH THRU TO THE PATCH PANEL. THE PATCH CABLES WILL NOT BE LEFT IN PLACE AS IS TYPICAL WITH THIS METHOD.



1 UTO ASU LAB BENCH DATA CABLE TO CEILING SERVICE PANEL TERMINATION DETAIL
SCALE: N.T.S.

7. Mobile tables shall be adjustable height and include tops from the same material as adjacent lab benches at a minimum.

8. Lab casework in all Research Labs shall conform to ADA requirements.

s) Lighting

1. General

a) Laboratories requires adequate lighting for precise work. Lighting is to be bright, uniform in nature, and glare free.

b) The Design Professional shall consider the location of overhead lighting and the position of the users in the room when developing the lighting layouts. Light levels on the bench/work surfaces are to be designed to meet the researcher's lighting requirements without shadows being cast by occupants or shelving at the bench.

c) The introduction of natural light into the laboratory shall also be incorporated into new laboratory projects to provide an opportunity for visual relief and help create a comfortable work environment. Whenever possible, the main laboratory spaces and offices are to be located to maximize natural daylight into the labs while ensuring that excessive glare does not result.

d) Minimum ambient light levels shall be established based upon the type of research performed in each lab.

e) Also supplemental under shelf and standalone task lighting is to be supplied to support proposed research programs and meet energy requirements.

2. Special Lighting Features

a) At ASU, lighting shall be controlled by occupancy sensors. As such, Design Professionals shall provide occupancy sensors in all labs and lab support areas and they shall be wired such that they can be bypassed with a conventional light switch when occupants are working in these areas.

b) Occupancy sensors also shall include additional contacts for integration with HVAC systems to allow for occupied and unoccupied conditions.

3. Lighting Types

a) To develop a comfortable work environment in the labs, Indirect/direct lighting is preferred for its even quality and sustainability. For any required downlighting or highlighting, LED energy efficient fixtures shall be provided. LED light fixtures shall be provided as the basis of design for general lighting of all labs, however, there are specialty labs that may require other types of lighting such as halogen lighting for Insectary Labs.

b) To minimize the need for storing a large variety of replacement lamps, Design Professionals shall minimize the different types of lighting to be designed for labs and lab support areas.

t) Hazardous Material Storage

1. Hazardous material storage refers to the storage of controlled chemicals and other hazardous items including biological, radiological and/or physical which has the potential to cause harm to humans or the environment.

2. Typically, hazardous materials are stored in flammable storage cabinets, corrosives cabinets and gas cabinets at ASU. Refer to EHS Guidelines: “Flammable Liquid Storage” at: https://cfo.asu.edu/design-professionals

   a. Combustible/Flammable storage cabinets are used to store flammable or combustible liquids exceeding the maximum allowable quantity (MAQ) for a laboratory occupancy or not stored in a specific type of container within the lab. These cabinets **shall** be designed in accordance with ASU Fire Marshal (FMO) and EHS requirements and with current code requirements.

   b. Corrosives cabinets are used to store corrosive liquids that are capable of corroding steel at a rate of more than 0.250 inches per year at a test temperature of 55 degrees Celsius. These cabinets **shall** be designed in accordance with FMO and EHS requirements and with current code requirements.

   c. Gas cabinets shall be used in the use and storage of all flammable, corrosive, toxic and highly toxic compressed gas containers. These cabinets **shall** be designed in accordance with FMO and EHS requirements; and with current code requirements. Refer to EHS Guidelines at: https://www.asu.edu/ehs/design-guidelines/pressure-vessels-and-compressed-gas-cylinders.pdf

3. Laboratories using cylinders for compressed gases shall have areas designated for cylinder storage and be equipped with devices to secure cylinders in place. Appropriate signage at remote cylinder storage shall note via text and/or plan areas being served. In addition, gas turrets should indicate source location of remote cylinder storage.

4. Design Professionals also need to plan for dedicated space in the labs for chemical waste collection containers in areas other than in fume hoods and below sinks. For specific information, refer to: https://cfo.asu.edu/waste-mgmt-and-shipping

u) Laboratory HVAC

1. All lab and lab support areas shall have mechanically generated supply air and exhaust air. There shall be no return of fume hood and laboratory exhaust back into the building for wet labs and lab support areas, however, the HVAC system design shall incorporate an energy recovery system. For specific laboratory HVAC design requirements for labs, the Design Professional shall contact CPMG and refer to “Engineering Design Guidelines” at https://cfo.asu.edu/design-professionals

2. For ASU labs, a Variable Air Volume (VAV) system is preferred for energy efficiency of laboratories.

   a) Unless otherwise specified (e.g., clean rooms), air pressure in the laboratory and laboratory support areas shall be negative with respect to the outer hallways and non-laboratory areas.

3. Refer to https://www.asu.edu/ehs/design-guidelines/laboratory-ventilation.pdf “Laboratory Ventilation” section for the minimum Air Changes per Hour (ACH) for wet labs. Any deviations from these requirements shall be reviewed and approved with EHS prior to including in the overall design.

4. For Laboratory Renovation projects, a Pre-TAB (Testing and Balancing) Report shall be provided to determine the actual HVAC system performance prior to developing the Design Documents for this project.

5. At the completion of the lab construction, a Post-TAB Report shall be provided to confirm that the HVAC system is operating within the design intent.

v) Fume Hoods

1. Fume hoods work by extracting air and noxious fumes away from the user and out of the fume hood where the air is exhausted to the outside environment by means of a laboratory exhaust duct system. User protection is enhanced by a movable sash that can be raised or lowered based on the needs of the user.

2. Types of Fume Hoods

    a) General Purpose, Bench Top Chemical Fume Hood

        1. A Bench Top Chemical fume hood is a cabinet with a moveable front sash (window) made out of safety glass set on a work surface approximately 36" above the floor which provides a convenient work area for the standing position. The device is enclosed except for necessary exhaust purposes on three sides and top and bottom, designed to draw air inward by means of mechanical ventilation, operated with insertion of only the hands and arms of the user, and used to control exposure to hazardous substances. Air is drawn into the hood under and through the opened sash and is exhausted through openings in the rear and top of the cabinet to a remote point such as an exhaust stack on the roof of the building.

    b) Radioisotope Fume Hood

        1. Radioisotope fume hoods are constructed specifically to protect users from radioactive materials. They have specially constructed worktops to withstand the weight of lead shielding plates, and may also have lead laced sashes. Interiors are made of stainless steel with coved corners to aid in decontamination.

    c) Distillation Fume Hood

        1. A distillation hood is characterized by a low worktop height which results in a large working height for the operator. This allows tall distillation equipment to be installed and mounted in the work chamber. Otherwise, it has similar features to that of a standard fume hood.

    d) Perchloric Acid Fume Hood

        1. Perchloric Acid hoods are required when acid is heated above ambient temperature. Perchloric acid reacts violently with organic materials. Dried perchloric acid is also highly explosive. Therefore, perchloric fume hoods require built-in water wash down systems in order to prevent perchlorate salt deposits. Interior liners are made of acid resistant materials like stainless steel. Interior corners are coved to aid in cleaning. All procedures that use perchloric acid must be confined to a perchloric fume hood, to prevent dangerous reactions with other chemicals.

e) Acid Digestion Fume Hood

1. Acid digestion fume hoods have special liners manufactured of acid resistant materials such as unplasticized PVC. For acid digestion applications involving high service temperatures, other materials such as PVDF may be used. Sashes shall be made of polycarbonate to resist hydrofluoric acid etching.

f) Floor Mounted Fume Hood

1. Floor mounted fume hoods are used for applications which require large apparatus. As the name implies, these hoods are floor mounted with or without any work surface. This facilitates the transfer of equipment and materials into, and out from the hood. Floor mounted hoods are sometimes referred to as walk-in fume hoods.

g) Demonstration/Observation Fume Hood

1. A demonstration hood has all 4 sides made of safety glass, and this hood is commonly used in educational institutions to allow students to easily view the instructor's demonstrations inside the fume hood from all angles, enhancing efficiency in teaching laboratories.

h) ADA Fume Hoods

1. ADA fume hoods are designed in accordance with the guidelines for the Americans with Disabilities Act. These hoods are also used when a sitting position is desired for work at the hood. They provide the same size work area as the corresponding bench hoods.

i) Canopy Hoods

1. Custom fabricated stainless steel canopy hoods are used over work areas or equipment to capture heat, odors or steam. Refer to Section 12 35 53: Laboratory Casework and Benchtops.

j) Ductless Fume Hood (These hoods are **NOT** allowed at Arizona State University.)

1. Ductless fume hoods utilize activated carbon filtration to adsorb chemical vapors and fumes. These hoods recirculate air to the laboratory, and are growing in popularity because of energy savings and the green movement.

k) Not Fume Hoods

1. Biological safety cabinets, glove boxes, laminar flow clean benches, downdraft tables, slot hoods, fume extractors, isolators and snorkels are sometimes mistaken for fume hoods. They have specific use (depending upon their design) and shall not be used to filter or remove chemicals.

3. Fume hoods shall be set back against the walls in locations that are out of the normal daily user circulation and are to be provided with infill panels above to match the fume hood finish, to cover up the exhaust ductwork and minimize dust collection. Fume hoods should not be located near a point of egress or along a path of egress from the lab.

4. Because of their recessed shape fume hoods are generally poorly illuminated by general room lighting, therefore internal lights with vapor-proof covers shall be included.

5. Fume hoods also must not be located directly opposite occupied work stations. Materials splattered or forced out of a hood could injure anyone seated across from it.

6. Fume hoods shall be so located within the laboratory to avoid cross currents at the fume hood face due to heating, cooling, or ventilation supply or exhaust diffusers. Cross currents outside a fume hood can nullify or divert air flow onto a hood, negatively affecting its capture ability.

7. Fume hoods shall also be placed away from doors and not located where they would face each other across a narrow aisle. Air velocity caused by supply vents should not exceed 25 feet per minute at the face of the hood. Locate supply diffusers far enough away from the fume hood to avoid draft disturbances at the face of the fume hoods.

8. At ASU fume hoods shall be located more than 10 feet from any door or doorway.

9. At ASU the preference is to use high performance low flow VAV fume hoods that allow for lower face velocities.

10. For information regarding the design of Fume Hoods refer to Section 11 53 13 “Fume Hoods and Other Air Containment Units”; and for exhaust requirements, refer to EHS Guidelines: “Laboratory Ventilation” at: https://cfo.asu.edu/design-professionals

w) Biological Safety Cabinets

1. A biosafety cabinet (BSC) also called a biological safety cabinet is an enclosed, ventilated laboratory workspace for safely working with materials contaminated with (or potentially contaminated with) pathogens requiring a defined biosafety level. Several different types of BSCs exist, differentiated by the degree of biocontainment required.

2. The primary purpose of a BSC is to serve as a means to protect the laboratory worker and the surrounding environment from pathogens. All exhaust air is HEPA-filtered as it exits the biosafety cabinet, removing harmful bacteria and viruses. This is in contrast to a laminar flow clean bench, which blows unfiltered exhaust air towards the user and is not safe for work with pathogenic agents. BSCs are not to be substituted for use as fume hoods. Likewise, a fume hood fails to provide the environmental protection that HEPA filtration provides in a BSC.

3. The U.S. Centers for Disease Control and Prevention (CDC) classifies BSCs into three classes. These classes and the types of BSCs within them are distinguished in two ways: the level of personnel and environmental protection provided and the level of product protection provided. Refer to chart below for Biosafety cabinets uses and requirements.

    a) Class I cabinets provide personnel and environmental protection but no product protection. The inward flow of air can contribute to contamination of samples. Inward airflow is maintained at a minimum velocity of 75 ft/min. These BSCs are commonly used to enclose specific equipment (e.g. centrifuges) or procedures (e.g. aerating cultures) that potentially generate aerosols. BSCs of this class are either ducted (connected to the building exhaust system) or unducted (recirculating filtered exhaust back into the laboratory). **Note, Class I hoods are not used at ASU.**

    b) Class II cabinets provide both kinds of protection (of the samples and of the environment) since makeup air is also HEPA-filtered. There are five types of Class II cabinets: Type A1, Type A2, Type B1, Type B2 and Type C1.

c) The Type A1 cabinet has a minimum inflow velocity of 75 ft/min. The downflow air, considered contaminated, splits just above the work surface and mixes with the inflow. This air is drawn in, through internal ductwork, up the back of the cabinet where it is then blown into a positive pressure, contaminated plenum. Here, the air is either recirculated, through a HEPA filter, back down over the work zone, or exhausted out of the cabinet (also through a HEPA filter). Sizing of HEPA filters and an internal damper are used to balance these air volumes. This type is not safe for work with hazardous chemicals even when exhausted with a "thimble" or canopy to avoid disturbing internal air flow. **Note, Type A1 hoods are not used at ASU.**

1. The Type A2 cabinet has a minimum inflow velocity of 100 ft/min. A negative air pressure plenum surrounds all contaminated positive pressure plenums. In other respects, the specifications are identical to those of a Type A1 cabinet.

2. Type B1 and B2 cabinets have a minimum inflow velocity of 100 ft/min, and these cabinets must be hard-ducted to an exhaust system rather than exhausted through a thimble connection. Their exhaust systems must also be dedicated (one BSC per duct run, per blower). In contrast to the type A1 and A2 cabinets, Type B BSCs use single pass airflow in order to also control hazardous chemical vapors. Type B1 cabinets split the airflow so that the air behind the smoke-split is directed to the exhaust system, while air between the operator and the smoke-split mixes with inflow air and is recirculated as downflow.

3. The Type B2 cabinet is expensive to operate because no air is recirculated within. Therefore, this type is mainly found in such applications as toxicology laboratories, where the ability to safely use hazardous chemistry is critical.

4. The Type C1 BSC was borne out of necessity to control infectious material, chemical hazards, reduce operating costs and add flexibility in modern laboratories. The Type C1 moves air by mixing inflow air with the air in the columns of downflow air marked for recirculation. Air above a clearly delineated section of the work surface is drawn in by a second internal fan where it is exhausted through a HEPA filter.

d) The Class III cabinet, generally only installed in maximum containment laboratories, is specifically designed for work with BSL-4 pathogenic agents, providing maximum protection for the worker, the environment and the sample from contamination. The enclosure is gas-tight, and all materials enter and leave through a double-door autoclave. Gloves attached to the front prevent direct contact with hazardous materials (Class III cabinets are sometimes called glove boxes).

Outside air is filtered through a HEPA filter prior to entry, and air leaving the class III biological safety cabinet is filtered through two HEPA filters before being vented to the outside.

4. Biological safety cabinets shall be installed in such a manner that fluctuations of the room supply and exhaust air do not cause the biological safety cabinets to operate outside their parameters for containment. Locate biological safety cabinets away from doors, from heavily traveled laboratory areas, and from other potentially disruptive equipment so as to maintain the biological safety cabinets' air flow parameters for containment.

SIDE-BY-SIDE BSC CLASS COMPARISON				
Classes of Biosafety Cabinets	Personnel Protection	Product Protection	Environmental Protection	Use
Class I	Yes Inward air flow through sash opening	No Unfiltered room air is drawn across work surface	Yes Exhaust air is HEPA-filtered	• Not in use today for bioagents • May be used to enclose equipment or procedures with aerosol potential
Class II A1, A2, B1, B2	Yes Inward air flow through sash opening	Yes By HEPA filtered air drawn down onto work surface & room air kept away	Yes Exhaust air is HEPA-filtered	• *Most common class of BSC used today, esp. Type A2* • Used to handle specimen material, biological toxins, cell tissue culture, biohazardous agents
Class III (Glove Box)	Yes Complete containment of interior work area	Yes HEPA filtered air is supplied to work surface; total containment keeps room air out	Yes Exhaust air is double HEPA-filtered	• Provides the highest level of containment for handling the most dangerous microorganisms

x) Gloveboxes

1. For exceptionally hazardous materials, an enclosed glovebox shall be used, which completely isolates the operator from all direct physical contact with the work material and tools.

2. A glove box is a sealed container used to manipulate materials where a separate atmosphere is desired. They are commonly used to protect workers from hazardous materials or to protect chemicals and materials that may be sensitive to air or water vapor.

3. Glove boxes may be used under either positive or negative pressure. Glove boxes operated under positive pressure usually contain materials sensitive to outside contaminates such as air or water vapor. Exposure to outside contaminates can lead to degradation or a violent reaction with these compounds. Negative pressure glove boxes are used to protect workers and are used for hazardous materials such as toxic gases or pathogens.

y) Laminar Flow Clean Benches

1. A clean bench is a laminar flow work cabinet that provides filtered air across the work surface to protect against contamination. The clean bench was originally created to supplement clean room technology and today is used across a broad spectrum of industries including research, manufacturing, aerospace, bioscience, pharmaceutical production and food processing.

2. The clean bench is recommended for work with non-hazardous materials where clean, particle-free air is necessary to avoid contamination. The clean bench ensures that the work surface is constantly flooded with HEPA-filtered air in a laminar flow. Unlike a biological safety cabinet, the clean bench protects the work on the work surface, but not personnel or the surrounding environment from aerosols created on the work surface.

3. Clean benches are equipped with either vertical or horizontal laminar flow. Both of these configurations provide a unidirectional velocity along parallel flow lines. Proper enclosure design helps prevent backwash and ensures that the vertical or horizontal laminar air flow continues to protect work on the surface of the clean bench.

z) Downdraft Tables

1. A downdraft table is a workbench with built-in ventilation to capture dust, smoke, and fumes; and draw them away from the material being worked on.

2. They typically consist of a perforated surface whose underside is connected to a ventilation or dust collection system, to draw material through the holes and away from the work.

aa) Slot Hoods

1. A slot hood is a collection hood across whose face several thin baffles are placed separated by narrow gaps to create the slots through which the air must flow. Such baffles are usually made of sheet metal placed 1 to 2 inches apart. The open slots are usually horizontal and run the full width of the unit. Collectively, the slots create a more uniform face velocity than would be achieved without the slots.

2. Slot hoods are generally used in conjunction with sinks used for glass washing and preparation. They should never be used to remove contaminates and other hazardous substances.

bb) Fume Extractors

1. Fume extractors are used to extract and filtrate toxic fumes and dust from work environments.

2. A fume extractor is a system utilizing a fan to pull fumes and particulates into a filtration system cleaning the air of these harmful chemicals and particulates. Industrial processes create fumes or particles such as welding, sanding, grinding, spraying, powder filling, and chemical applications. Fume extractors use a variety of filters for their applications.

3. The combination of a powerful fan and high-quality filtration media creates a recirculating air pattern for ductless units. Because of the air flow, ductwork or costly replacement air is not required. These units take up less space, weigh less, are more energy efficient, and have easy access to change filters.

cc) Snorkels

1. A snorkel is a flexible duct or hose connected to an exhaust system. It can only capture contaminants that are very close to the inlet of the hose, typically less than a distance equal to one half of the diameter of the duct.

2. Due to its poor capture ability, snorkels shall not be used to exhaust hazardous materials.

3. The average capture velocity for snorkels taken at the face of access ports shall be 100-150 feet per minute (fpm); recommended air flow for these connections is 100 cubic feet per minute (cfm), unless otherwise specified by the manufacturer.

4. Snorkels shall only be used to dissipate heat, remove small particulates on the bench surfaces or to dissipate smells and odors in a laboratory.

dd) Isolators

1. An isolator is a decontaminated unit, supplied with Class 100 (ISO 5) or higher air quality that provides uncompromised, continuous isolation of its interior from the external. There are two major types of isolators:

a) Closed Isolator operation

1. "Closed isolator" systems exclude external contamination from the isolator's interior by accomplishing material transfer via aseptic connection to auxiliary equipment, rather than use of openings to the surrounding environment. Closed systems remain sealed throughout operations.

b) Open Isolator

1. "Open Isolator" systems are designed to allow for the continuous or semi-continuous ingress and/or egress of materials during operations through one or more openings. Openings are engineered to exclude external contamination from entering the isolator chamber.

2. Isolators are designed to provide continuous and complete isolation of the inside of the unit from the external room environment (including its operators). Only installed gloves or robotic arms are used to manipulate the product. This ensures that the environment is maintained as contamination-free.

3. Isolators are primarily utilized in the pharmaceutical industry and research industry for pharmacy aseptic compounding applications and other research applications.

ee) Safety Showers and Eyewash

All Safety Showers and Eyewash locations must be reviewed and approved by OUA/CPMG and meet the requirements established by EHS. Refer to “Eyewash and Safety Showers” included in the EHS Guidelines at: https://cfo.asu.edu/design-professionals

1. Laboratories using hazardous materials must have a safety shower and eyewash located within 10 seconds travel time from the chemical use areas.

2. ASU’s standard for a combination safety shower and eye wash unit shall be a recessed safety station with drain pan and exposed shower head and shall meet the requirements of ANSI Z358.1.

3. Safety shower and eye wash combination units shall not have floor drains below units.

4. Safety showers and eye wash units shall be standardized within a laboratory building.

5. Flooring under safety showers shall be slip-resistant and marked.

6. Safety shower markings include signs and floor tape. The goal of these markings is to make safety showers easy to find in an emergency.

7. Modesty curtain assemblies shall be provided around all safety showers mounted at 80 inches AFF.

8. Each emergency shower and/or eyewash unit shall have a separate shutoff valve located within easy access for the maintenance staff.

ff) Laboratory Utility Distribution

1. When utilizing modular laboratory planning at ASU for laboratories, there is also the need to distribute laboratory utilities uniformly throughout the labs to support long term flexibility for future lab renovations or expansions.

2. Water Systems:

    a) A water supply distribution approach shall be developed that meets all the program requirements of the facility. The use of three segregated distribution systems shall be required for laboratory facilities.

    b) A domestic potable cold water system shall be distributed to emergency showers, emergency eyewashes and other non-laboratory areas. If hot domestic water is requested, it shall be provided by point of use instant hot units.

    c) An industrial non-potable cold water system shall be distributed to general laboratory and laboratory support areas. If hot industrial water is requested, it shall be provided by point of use instant hot units.

    d) In general, a type II reverse osmosis (RO) purified water system loop shall be provided to select locations throughout the lab and lab support areas. The purity level for the RO system must be confirmed with the users and with OUA/CPMG prior to incorporating into the laboratory project.

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    e) Individual sinks in laboratories may require additional high purity water requirements. The Design Professional shall determine these requirements with the lab users and if required, shall plan for high purity water polishers at select locations that shall be provided by the lab user.

3. Laboratory Waste:

    a) A hard piped Laboratory waste and vent system shall be provided for laboratory waste producing fixtures and equipment.

    b) All fixtures will be individually trapped and vented to the atmosphere.

    c) No floor drains shall be provided in laboratory areas. Floor sinks shall be provided for ice machines, autoclaves and other equipment that requires drainage.

    d) No hazardous waste or hazardous materials shall be flushed down the sink drains in the laboratory and lab support areas. Therefore, chemical and solvent collection containers must be included in the laboratory and lab support areas and be disposed of properly by EHS. Refer to: https://cfo.asu.edu/waste-mgmt-and-shipping.

4. Laboratory Piped Gases:

    a) Compressed Air: A complete central oil-free instrument grade laboratory compressed air system shall be provided throughout the laboratory and lab support areas.

    b) Laboratory Vacuum: A complete central laboratory vacuum system shall be provided throughout the laboratory and lab support areas.

    c) Specialty Gases: Specialty Gases shall be provided to laboratory and lab support areas as required with local cylinders.

        1. Support blocking inside the walls must be provided for the gas cylinder restraints at the gas cylinder locations; and shall be sized to support the proposed gas cylinder size(s) and quantities planned for that location.

d) For additional requirements regarding the design for piped gases, refer to EHS Guidelines: https://cfo.asu.edu/design-professionals

gg) Power

1. Laboratories shall have a sufficient number of electrical receptacles to eliminate the need for extension cords and multi-plug adapters. Provide wall mounted electrical raceways in all lab support areas with 120 v, 20 amp duplex outlets located maximally at 4' – 0" O.C.

2. Each laboratory shall have a dedicated panelboard located in an unobstructed accessible area. Install ground fault circuit interrupters near sinks and wet areas.

3. Laboratories with high voltage lasers and/or high voltage equipment shall have an emergency power-off switch installed near the laboratory exit and not over the laser table.

4. Some laboratories will require special considerations for mitigation of stray electromagnetic EM fields or for fields produced by research equipment, such as non-ferrous materials, twisted and/or shielded wiring or shielded power distribution rooms. Equipment requiring these measures will usually be accompanied by a pre-installation manual from the manufacturer stating allowable field levels. The presence of this equipment in any project must be determined through program interviews by the Design Professional.

5. Some laboratories will require a reference earth ground for precise electrical measurements. This will have to be determined through programming interviews by the Design Professional with users or their representatives at ASU.

hh) Emergency Power

1. For laboratory projects, life safety emergency power shall be provided by the campus central plant or a separate stand-alone fuel operated emergency generator.

2. Critical standby power shall be provided for critical research lab equipment, lab support equipment (including select refrigerators, -20 degree freezers and -80 degree freezers); and vivarium HVAC and lighting systems.

3. Chemical Fume Hood exhaust fans should be connected to an emergency power system in the event of a power failure.

4. This backup power source will ensure that chemicals continue to be exhausted. EHS recognizes that it may not be practical to provide emergency power sufficient to maintain fume hood functioning at normal levels but recommends an emergency supply of at least half of the normal airflow.

5. Emergency power circuits should be provided for fan service so that fans will automatically restart upon restoration after a power outage and supply at least half of the normal airflow.

6. Momentary or extended losses of power shall not change or affect any of the control system's setpoints, calibration settings, or emergency status. After power returns, the system shall continue operation, exactly as before, without the need for any manual intervention. Alarms shall require manual reset, should they indicate a potentially hazardous condition.

7. If laboratory suite(s) are provided, there are emergency power requirements for fume hoods one story below grade or above the sixth story above grade.

8. For additional requirements regarding the planning and design of emergency power system(s) the Design Professional shall refer to the "ASU Electrical Reliability Standard" revised: December 2009 and meet with the Office of the University Architect to confirm the Emergency Power requirements for each project. https://www.asu.edu/fm/documents/project_guidelines/Electrical-Reliability.

ii) Laboratory Gases Monitoring

1. Gas monitoring shall be required when highly toxic, toxic, flammable, or pyrophoric (spontaneously combustible in air) gas use is planned. Under some conditions, oxygen monitoring is required in locations with compressed and liquefied inert gases and LEL (Lower Explosive Limit) monitoring in locations such as storage areas for flammable gases and chemicals.

2. All monitoring systems must report alarm details back to a continuously monitored station.

3. Fume hoods shall include low flow monitoring alarms.

4. A visual and audible alarm must be present inside and outside of the lab with the ability by emergency responders to silence the alarm. Alarm details in a display panel must be available inside and immediately outside of the monitored area.

5. A remote monitor is required near the main building Fire Alarm Panel.

6. The location of gas sensors will be based on the properties of the gas and potential leak points. Sensors shall be located within 12 inches of the floor for gases heavier than air and near the ceiling for gases lighter than air. Ambient air sensors for toxic gas monitoring will be located near breathing zone height.

7. Gas monitoring equipment make/models shall be standardized as much as possible to facilitate maintenance requirements. The Design Professional shall contact CPMG and EHS to ensure that an acceptable monitor is provided.

jj) Fire Protection

1. Fire Alarm: All new laboratory buildings or lab renovation projects shall be provided with a fully addressable, speaker type fire alarm system. The system will provide audible and visual occupant notification, air-handling unit shutdown, fire suppression system monitoring, and off-site monitoring. Refer to section "21 10 00 – Fire Protection Systems" for ASU requirements.

2. Sprinkler Protection: All new laboratory buildings or lab renovation projects shall be provided with an approved sprinkler fire protection system in accordance with NFPA 13. Refer to section "21 10 00 – Fire Protection Systems" for ASU requirements.

kk) Security

1. Since events such as the attacks on the World Trade Center, the world has become more security conscious, and that awareness extends to laboratories. As a result, laboratories need to take specific actions in order to provide security against theft of highly hazardous materials, valuable equipment, and to ensure compliance with state and federal regulations.

2. There are four integrated domains to consider when developing the security of a laboratory:

    a. Physical or architectural security—doors, walls, fences, locks, barriers, controlled roof access, and cables and locks on equipment;

    b. Electronic security—access control systems, alarm systems, password protection procedures, and video surveillance systems;

    c. Operational security—sign-in sheets or logs, control of keys and access cards, authorization procedures, background checks, and security guards; and

    d. Information security—passwords, backup systems, shredding of sensitive information.

3. For the purpose of these Guidelines, ASU will only address the physical and electronic laboratory security. The choice and implementation depends on the level of security needed and resources available.

4. When developing a security plan, it is important to establish levels of security that correspond to the security needs of a particular laboratory or portion of a laboratory.

    a) Normal (Security Level 1):

        1. A laboratory characterized as Security Level 1 poses low risk for extraordinary chemical, biological, or radioactive hazards; and shall include the following:

            - Provide lockable doors and windows.

    b) Elevated (Security Level 2):

        1. A laboratory characterized as Security Level 2 poses moderate risk for potential chemical, biological, or radioactive hazards. The laboratory may contain equipment or material that could be misused or threaten the public; and shall include the following:

            - Provide Lockable doors, windows and other passageways.
            - Provide access control systems such as key pads and/or card readers.
            - Perimeter walls shall extend above ceilings and prevent access from one area to other areas; and shall include the following.
            - Intrusion Alarm System recommended.
            - Closed-circuit television cameras for entrance and exit points, materials storage, and special equipment recommended.

    c) High (Security Level 3):

        1. A laboratory characterized as Security Level 3 can pose serious or potentially lethal biological, chemical, or radioactive risks to students, employees, or the environment. Equipment or material loss to theft, malicious pranks, or sabotage would have serious health and safety impacts and consequences to the research programs and the facilities; and shall include the following:

            - Provide Lockable doors, windows and other passageways.
            - Hardened doors, frames and locks.
            - Provide access control systems such as key pads and/or card readers that records the transaction history of all authorized individuals.
            - Double Door vestibule entry

- Perimeter walls shall extend to underside of floors above and prevent access from one area to other areas.
- Perimeter walls and ceilings shall also include steel mesh reinforcing to prevent anyone from breaking through the walls and ceilings.
- Biometric personal verification technology recommended
- Intrusion Alarm System.
- Closed-circuit television cameras for entrance and exit points, materials storage, and special equipment.

5. Also, many ASU researchers receive federally funded grants from the National Science Foundation (NSA) and the National Institute of Health (NIH); and as such are subject to the policies and regulations regarding security contained within the following publication: Public Policy Requirements and Objectives-Federal Information Security Management Act.

6. ASU also develops laboratory projects for Federal agencies. As such for these facilities, security requirements for safeguarding Controlled Unclassified Information (CUI) in nonfederal systems, particularly for federal agency contracts and partnerships with nonfederal entities, need to be developed based upon the requirements identified in the National Institute of Standards and Technology (NIST) publication SP 800-171r3.

7. Therefore, Security of research laboratories and lab support spaces at ASU is extremely important. The Design Professional must involve OUA/CPMG and ET (Enterprise Technologies) in the security system design for all laboratory projects at ASU.

8. For all security requirements for laboratories, the Design Professional shall refer to the ASU ET and Design Standards V3.0.: https://asu.service-now.com/sp?id=kb_article_view&sysparm_article=KB0010867&sys_kb_id=bbaf58c71b3a95508078766e034bcbcc&spa=1

ll) IT and Communications

1. The Design Professional must involve OUA/CPMG and ET in the IT and Communications systems design for all laboratory projects at ASU.

2. For IT and Communications requirements for laboratories, the Design Professional shall refer to the ASU ET and Design Standards V3.0.: https://asu.service-now.com/sp?id=kb_article_view&sysparm_article=KB0010867&sys_kb_id=bbaf58c71b3a95508078766e034bcbcc&spa=1

mm) Audio Visual

1. The Design Professional must involve OUA/CPMG and ET in the Audio Visual systems design for all laboratory projects at ASU.

2. For Audio Visual requirements for laboratories, the Design Professional shall refer to the ASU ET and Design Standards V3.0.: https://asu.service-now.com/sp?id=kb_article_view&sysparm_article=KB0010867&sys_kb_id=bbaf58c71b3a95508078766e034bcbcc&spa=1

nn) Laboratory Equipment

1. A wide variety of laboratory equipment is used in laboratories. The goal is to create adaptability in laboratory space so that instruments can be relocated within the laboratory without altering the space or attendant utility systems and without compromising the operation of the instruments or safety of the users.

2. Some instrumentation rooms, electron microscopy suites, MRI spectroscopy suites, x-ray crystallography suites, and mass spectrometry rooms require special utilities and environmental controls. Based upon these special requirements, the Design Professional must determine these requirements during the early planning phase of the project; and must involve OUA/CPMG for final Concept approval.

oo) Lab Ventilation Design Levels (LVDL)

1. At the beginning of each laboratory project, a risk assessment needs to be conducted to determine the level(s) of hazardous use and the MAQ for Hazardous Materials.

2. As part of this process, the DP needs to determine (along with input from ASU) the Laboratory Ventilation Design Levels (LVDL) for each lab.

3. To help determine the LVDL for each lab, the DP shall refer to the 2018 ASRAE "Classification of Laboratory Ventilation Design Levels" and develop lab diagrams that illustrate the LVDL and risk assessment for each lab similar to the examples below:

LABORATORY VENTILATION DESIGN LEVELS (LVDL)

CLASSIFICATION + GENERAL CHARACTERISTICS

LVDL-0
- Hazardous Materials
  - Quantities of Materials: Negligible
  - Potential Airborne Generation: Negligible
  - Severity: Negligible (No GHS chemicals)
  - Control Strategy: Dilution Only (Recirculation OK)
- Types of Laboratories
  - Classroom + Computer Laboratories

LVDL-1
- Hazardous Materials
  - Quantities of Materials: Small
  - Potential Airborne Generation: Negligible
  - Severity: Low (Consumer Chemicals)
  - Control Strategy: Dilution, Removal, Local Exhaust
  - Types of Laboratories
  - Quality Control, Secondary Teaching Laboratories

LVDL-2
- Hazardous Materials
  - Quantities of Materials: Moderate
  - Potential Airborne Generation: Low
  - Severity: Low to Moderate (H226-227, H333-H335)
  - Control Strategy: Dilution, Removal, Local Exhaust, and Fume Hoods
  - Types of Laboratories
  - Undergraduate Teaching, Research Laboratories

LVDL-3
- Hazardous Materials
  - Quantities of Materials: Large
  - Potential Airborne Generation: High
  - Severity: High (H226-227, H229, H333-H336, H242)
  - Control Strategy: Dilution, Removal, Local Exhaust, Fume Hoods, Specialized Exhaust (ECD Isolators?)
  - Types of Laboratories
  - Inorganic/Organic Synthesis, Typical Research Labs

LABORATORY CLASSIFICATIONS + VENTILATION

ISTB12 LEVEL 1

LVDL-0 VENTILATION
- Unoccupied: ASHRAE 62.1
- Occupied Minimum: ASHRAE 62.1
- Design Ventilation: ASHRAE 62.1

LVDL-1 VENTILATION
- Unoccupied: ASHRAE 62.1
- Occupied Minimum: 4 ACH
- Design Ventilation: 6 ACH

LVDL-2 VENTILATION
- Unoccupied: 4 ACH
- Occupied Minimum: 6 ACH
- Design Ventilation: 8 ACH

LVDL-3 VENTILATION
- Unoccupied: 6 ACH
- Occupied Minimum: 8 ACH
- Design Ventilation: 10 ACH

Note Listed ACH is for the Occupied Lower 10 Feet of the Laboratory and Assumes that Primary Air is Delivered to the Zone

pp) Room Data Sheets

1. To assist the Design Professionals and Contractors for applying the information above to different lab types, ASU has developed lab specific Room Data Sheets.

2. These Room Data Sheets contain detailed attributes of a room's interior elements including finishes, fixtures, mechanical, electrical and other requirements.

3. For additional information regarding ASU Room Data Sheets, the DP shall refer to the "ASU Room Data Sheets Design Guidelines" at: https://www.asu.edu/fm/documents/project_guidelines/room-data-sheets.pdf

qq) Sustainable Design for Laboratories

1. A typical wet laboratory uses approximately five times as much energy and water per square foot compared to a typical office building.

2. In addition, wet laboratory facilities have intensive ventilation requirements including "once through" air; and must meet other health and safety codes, which also add to energy use.

3. Based upon these requirements, sustainability opportunities for laboratories must be studied on a project-by-project basis. To determine the best sustainable options for a laboratory project, factors such as the project specific goals, the type of lab being designed and its position on the site will lead to different solutions for sustainability.

4. The Design Professional shall also utilize the "Best Practice Guide" developed for sustainable laboratories by the International Institute for Sustainable Laboratories (I2SL) for ASU laboratory projects. https://www.i2sl.org/documents/i2sl_pi_best-practices-guide.pdf

   a) One example of a sustainable design solution for a lab at ASU is to use Chilled Beams in lieu of mechanical diffusers to possibly reduce air change rates and air flow, but not jeopardize safety.

5. For additional information regarding sustainable design, the DP shall refer to the "ASU Sustainable Design Guidelines" at: https://cfo.asu.edu/design-professionals

rr) ADA / Accessibility:

1. Since ASU is classified as a Title II Institution that also receives federally funded programs and grants, ASU is required to adhere to the Americans with Disabilities Act (ADA) for Day 1 Occupancy of all research laboratory projects.

2. As such, ASU has established the minimum requirements specifically for research laboratories to include but not be limited to the following:

   a) All Laboratory benches and tables shall be adjustable height.

   b) At Least one ADA compliant Fume Hood shall be included in a laboratory.

   c) At least one ADA compliant sink shall be located in a laboratory.

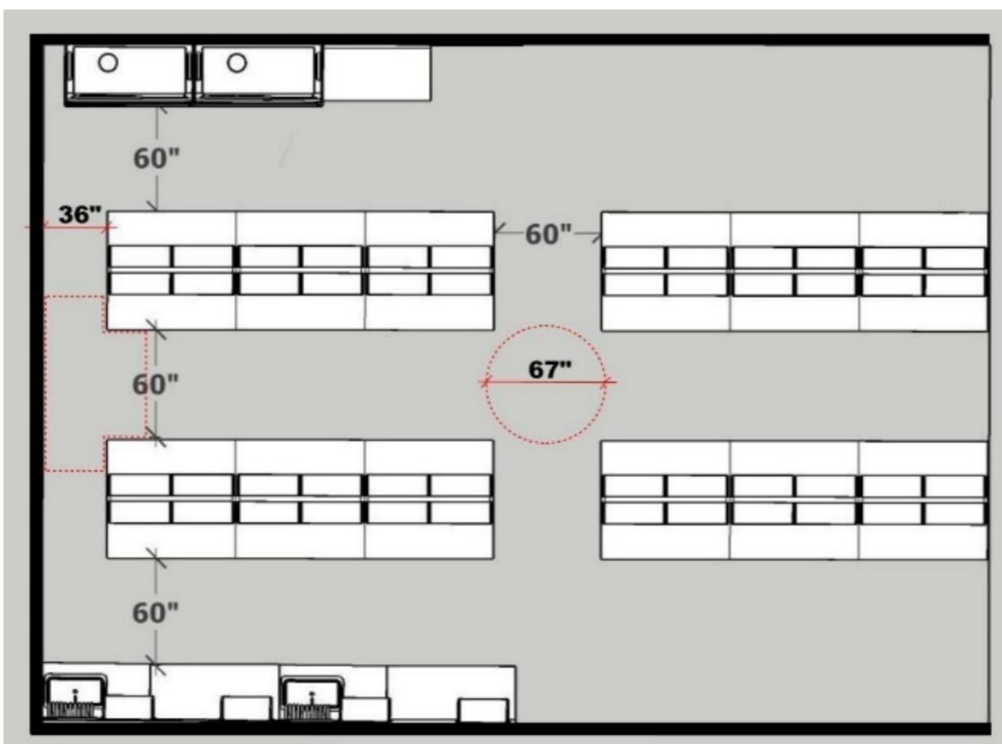
   d) All Eyewash units shall have the sink unit located at 34 inches AFF.

   e) Minimum clearance between front edges of lab countertops that are located front to front shall not be less than 60 inches.

   f) Minimum clearance between the side edges of lab countertops that are located next to a wall, column or other non-occupied item shall not be less than 36 inches.

   g) All lab gas turrets located at walls, lab benches, glove boxes, fume hoods and any other locations shall have lever controls in lieu of knobs; and shall be mounted no higher than 48 inches AFF.

   h) In order to address Accessibility Compliance for laboratories, please refer to the diagram below for minimum clearances and turn around spaces.



ss) Clean Rooms

1. A **cleanroom** or **clean room** is a facility that is utilized as part of certain scientific research at ASU. Clean rooms shall be designed to maintain extremely low levels of particulates, such as dust, airborne organisms, or vaporized particles. As such, cleanrooms have a cleanliness level quantified by the number of particles per cubic meter at a predetermined molecule measure.

2. Clean rooms are classified according to the number and size of particles permitted per volume of air. (Refer to the chart below.)

Class	maximum particles/m^3						FED STD 209E equivalent
	>=0.1 µm	>=0.2 µm	>=0.3 µm	>=0.5 µm	>=1 µm	>=5 µm	
ISO 1	10	2					
ISO 2	100	24	10	4			
ISO 3	1,000	237	102	35	8		Class 1
ISO 4	10,000	2,370	1,020	352	83		Class 10
ISO 5	100,000	23,700	10,200	3,520	832	29	Class 100
ISO 6	1,000,000	237,000	102,000	35,200	8,320	293	Class 1,000
ISO 7				352,000	83,200	2,930	Class 10,000
ISO 8				3,520,000	832,000	29,300	Class 100,000
ISO 9				35,200,000	8,320,000	293,000	Room Air

ISO 14644-1 Cleanroom Standards

3. The air entering a clean room from the outside shall be filtered to exclude dust, and the air inside shall be constantly recirculated through high-efficiency particulate air (HEPA) and/or ultra-low particulate air (ULPA) filters to remove internally generated contaminants.

4. For additional information regarding Cleanrooms and Semiconductor requirements, the DP shall refer to the "ASU Semiconductor Cleanroom Design Guidelines" at: https://www.asu.edu/fm/documents/project_guidelines/Semiconductor-Cleanroom-Facility-Guidelines.pdf

C. Biosafety Level Laboratory Facilities

Biosafety Level Laboratories at ASU are used to study and research contagious materials safely and effectively. These state-of-the-art labs are designed not only to protect researchers from contamination, but also to prevent microorganisms from entering the environment.

There are four biosafety levels (BSLs) that define proper laboratory practices and techniques, safety equipment and facilities that deal with biohazards (an infectious agent, or part thereof, presenting a real or potential risk to the well-being of man, animals and / or plants, directly through infection or indirectly through disruption of the environment) posed by the agents used and for the laboratory activity.

The Biosafety Levels 1 through 4 were established by the Centers for Disease Control (CDC) and the National Institutes of Health (NIH); and were developed to designate laboratories according to their design features, construction and containment facilities. Biosafety Levels 1 and 2 (BSL-1) and (BSL-2) labs are basic labs, Biosafety Level 3 (BSL-3) labs are called containment labs, and a Biosafety Level 4 (BSL-4) lab is a maximum containment lab. These biosafety levels are described below.

1. Biosafety Level 1:

    a) BSL-1 represents a basic level of containment that relies on standard microbiological practices with no special primary or secondary barriers recommended, other than a sink for hand washing.

    b) Biosafety Level 1 practices, safety equipment, and facility design and construction are appropriate for undergraduate and secondary educational training and teaching laboratories, and for other laboratories in which work is done with defined and characterized strains of viable microorganisms not known to consistently cause disease in healthy adult humans.

c) A BSL-1 laboratory shall be designed so that it can be easily cleaned with spaces between benches, cabinets, and equipment easily accessible.

d) Walls, ceilings, and floors shall be smooth, impermeable to liquids and resistant to the chemicals and disinfectants normally used in the laboratory.

e) Floors shall be monolithic, seamless or with welded seams and slip-resistant with integral coved bases.

f) All penetrations in floors, walls, and ceiling surfaces shall be sealed to facilitate decontamination.

g) All bench countertops shall be impervious to water and resistant to acids, alkalis, organic solvents, and moderate heat.

2. Biosafety Level 2:

a) Biosafety Level 2 practices, equipment, and facility design and construction are applicable to clinical, diagnostic, teaching, and other laboratories in which work is done with the broad spectrum of indigenous moderate-risk agents that are present in the community and associated with human disease of varying severity.

b) BSL-2 differs from BSL-1 in that (1) laboratory personnel have specific training in handling pathogenic agents and are directed by competent scientists; (2) access to the laboratory is limited when work is being conducted; (3) extreme precautions are taken with contaminated sharp items; and (4) certain procedures in which infectious aerosols or splashes may be created are conducted in biological safety cabinets or other physical containment equipment.

c) BSL-2 is appropriate when work is done with any human-derived blood, body fluids, tissues, or primary human cell lines where the presence of an infectious agent may be unknown.

d) Each BSL-2 laboratory shall contain a sink for handwashing.

e) A BSL-2 laboratory shall be designed so that it can be easily cleaned with spaces between benches, cabinets, and equipment easily accessible.

f) Walls, ceilings, and floors shall be smooth, impermeable to liquids and resistant to the chemicals and disinfectants normally used in the laboratory.

g) Floors shall be monolithic, seamless or with welded seams and slip-resistant with integral coved bases.

h) All penetrations in floors, walls, and ceiling surfaces shall be sealed to facilitate decontamination.

i) All bench countertops shall be impervious to water and resistant to acids, alkalis, organic solvents, and moderate heat.

j) A safety shower and eyewash station shall be installed in BSL-2 labs.

k) Properly maintained biological safety cabinets, preferably Class II, or other appropriate personal protective equipment or physical containment devices shall be used in BSL-2 laboratories.

3. Biosafety Level 3:

    a) Biosafety Level 3 is applicable to clinical, diagnostic, teaching, research, or production facilities in which work is done with indigenous or exotic agents which may cause serious or potentially lethal disease as a result of exposure by the inhalation route. Laboratory personnel have specific training in handling pathogenic and potentially lethal agents, and are supervised by competent scientists who are experienced in working with these agents.

    b) All procedures involving the manipulation of infectious materials are conducted within biological safety cabinets or other physical containment devices, or by personnel wearing appropriate personal protective clothing and equipment.

    c) BSL-3 laboratories shall be separated from areas that are open to unrestricted traffic flow within the building, and access to these laboratories are restricted. Passage through a series of two self-closing doors creating an anteroom is the basic requirement for entry into the laboratory from access corridors. Doors shall be lockable. Depending upon the type of BSL-3 lab, a clothes change room may be required in the passageway.

    d) The anteroom shall be designed to accommodate at a minimum a sink, autoclave, and shelves for protective equipment and lockers.

    e) Each BSL-3 laboratory room shall contain a sink for handwashing. The sink shall be hands-free or automatically operated and shall be located near the room exit door.

    f) The interior surfaces of walls, floors, and ceilings of areas where BSL-3 agents are handled shall be constructed for easy cleaning and decontamination.

        1. Walls, ceilings, and floors shall be smooth, impermeable to liquids and resistant to the chemicals and disinfectants normally used in the laboratory.

        2. Floors shall be monolithic, seamless or with welded seams and slip-resistant with integral coved bases.

        3. All penetrations in floors, walls, and ceiling surfaces shall be sealed to facilitate decontamination.

        4. Openings such as around ducts and the spaces between doors and frames shall be sealed to facilitate decontamination.

    g) All BSL-3 laboratories shall be designed so that they can be easily cleaned with spaces between benches, cabinets, and equipment easily accessible.

    h) All bench countertops shall be impervious to water and resistant to acids, alkalis, organic solvents, chemicals and moderate heat.

    i) A safety shower and eyewash station shall be installed in BSL-3 labs.

    j) Properly maintained biological safety cabinets, Class II or greater, or other appropriate personal protective equipment or physical containment devices shall be used in BSL-3 laboratories and shall be located away from doors, from room supply louvers, and from heavily-traveled laboratory areas.

    k) All Biological Safety Cabinets shall be HEPA filtered prior to exhaust either by direct ducting or room exhaust.

l) All BSL-3 labs shall have mechanically generated supply air and exhaust air and shall use 100% outside air and 100% exhaust shall be to the outside of the building. There shall be no return of laboratory exhaust back into the building.

m) All BSL-3 labs shall also be designed such that the mechanically generated supply air creates directional airflow which draws air into the laboratory from "clean" areas and exhausts directly to the outside creating a negative pressure system.

n) An air pressure status panel shall be provided in the anteroom to confirm upon entry that all rooms are under negative pressure.

4. Biosafety Level 4:

a) Biosafety level 4 (BSL-4) is the highest level of biosafety precautions, and is appropriate for work with agents that could easily be aerosol-transmitted within the laboratory and cause severe to fatal disease in humans for which there are no available vaccines or treatments.

b) Biosafety level 4 laboratories are used for diagnostic work and research on easily transmitted pathogens which can cause fatal disease.

c) As with BSL-3 laboratories, BSL-4 laboratories must be separated from areas that receive unrestricted traffic.

d) In order to exit the BSL-4 laboratory, personnel must pass through a chemical shower for decontamination, then a room for removing the positive-pressure suit, followed by a personal shower.

e) Additionally, airflow is tightly controlled to ensure that air always flows from "clean" areas of the lab to areas where work with infectious agents is being performed.

f) The entrance to the BSL-4 lab must also employ airlocks to minimize the possibility that aerosols from the lab could be removed from the lab.

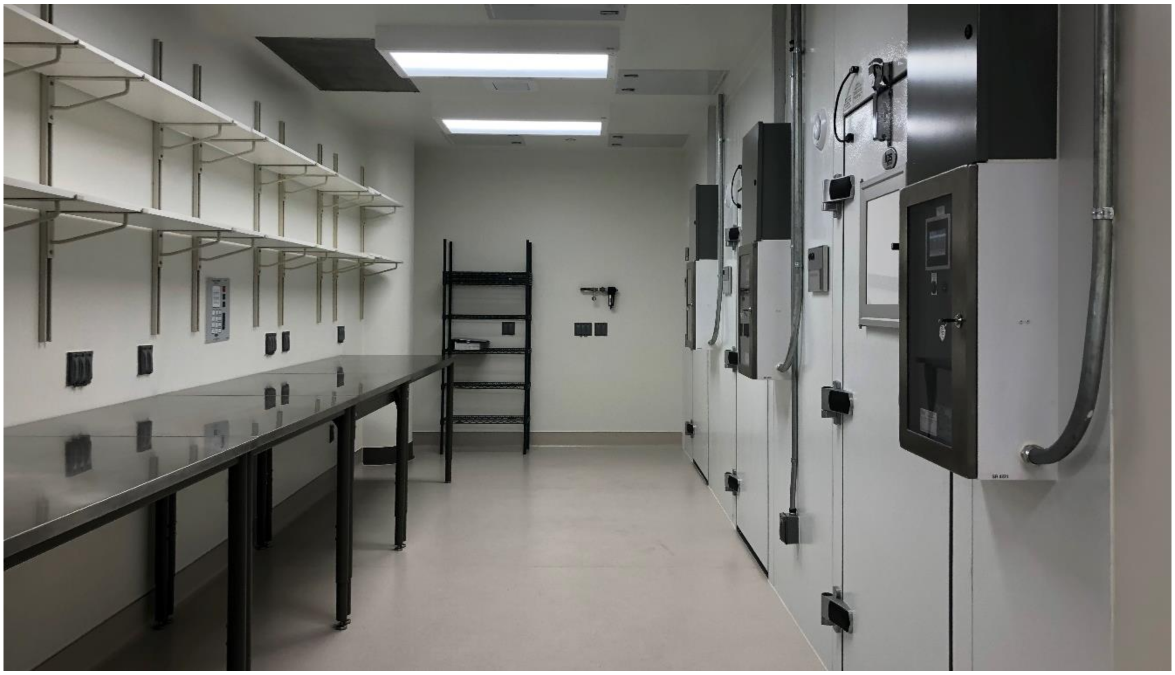
g) All laboratory waste, including filtered air, water, and trash must also be decontaminated before it can leave the facility.

h) BSL-4 laboratories are generally set up to be either cabinet laboratories or protective-suit laboratories.

i) Due to the highly specialized requirements for BSL-4 laboratories, there currently are only 13 operational or planned facilities within the United States. If a BSL-4 laboratory facility is being planned at ASU, it must be designed in accordance with the Center for Disease Control (CDC) requirements for BSL-4 laboratories.

j) For additional information regarding Biosafety in Microbiological and Biomedical Laboratories (BMBL) please refer to: https://www.cdc.gov/labs/bmbl/?CDC_AAref_Val=https://www.cdc.gov/labs/BMBL.html

D. Arthropod Laboratory Facilities:



1. When arthropods are used for research at ASU, facilities, trained staff and established practices must be in place to ensure appropriate safety, and the protection of health and well-being of workers and the environment.

2. Also for Arthropod facilities, all other laboratory design requirements are still required, ACL guidelines are in addition to biological lab requirements.

3. In order to provide safe laboratory facilities for Arthropod research, Arthropod Containment Levels or (ACLs) are evaluated by EHS in collaboration with the end users to determine the level at which a facility may operate.

4. Arthropod Containment Level 1 (ACL-1):

   a) Arthropod Containment Level 1 (ACL-1) is suitable for work with uninfected arthropod vectors or those infected with a non-pathogen including: 1) arthropods that are already present in the local geographic region regardless of whether there is active vector borne disease transmission in the locale, and 2) exotic arthropods that upon escape would be inviable or become only temporarily established in areas not having active vector borne disease transmission. This category would include most educational use of arthropods.

   b) For ACL-1 facilities the insectary area shall be separated from areas that are used for general traffic within the building.

   c) Doors openings, whether covered by rigid panels, glass, screens, plastic sheets or cloth, shall be designed to prevent escape and entrance of arthropods.

   d) Windows, if present, shall be designed to prevent escape of the smallest arthropods contained within.

5. Arthropod Containment Level 2 (ACL-2):

   a) Arthropod Containment Level 2 (ACL-2) must be followed if working with exotic and indigenous arthropods infected with BSL-2 agents, or that are suspected of being infected with such agents. Uninfected genetically modified arthropod vectors also fall under this level provided the modification has no, or only negative effects on viability, survivorship, host range, or vector capacity.

   b) ACL-2 requirements will also apply to Arthropods infected with plant pests not native to Arizona.

   c) For ACL-2 facilities, the insectary shall be separated from areas that are open to unrestricted personnel traffic within the building. It is recommended that this be accomplished by at least two self-closing doors that prevent passage of the arthropods. Increased levels of physical isolation are recommended, e.g., separate buildings, wings, suites.

   d) Entrances to the insectary shall be via a double-door vestibule that prevents flying and crawling arthropod escape. For example, the two contiguous doors must not be opened simultaneously. Internal doors may open outwards or be sliding, but are self-closing, and are kept closed when arthropods are present. Additional barriers (e.g., screened partitions, mirrors being hung to aid in the personnel identifying potential escapees) may be required by a local risk assessment.

   e) Windows are not recommended, but if present shall not be opened and are well sealed. Windows must be resistant to breakage (e.g., double paned or wire-reinforced).

   f) The insectary shall be designed, constructed, and maintained to facilitate cleaning and housekeeping as follows:

      1. The interior walls are light-colored so that a loose arthropod can be easily located, recaptured, or killed.

      2. Gloss finishes, ideally resistant to chemical disinfectants and fumigants, shall be provided.

      3. Floors shall be light colored, monolithic, smooth and uncovered with integral base.

      4. Floor drains are not generally allowed at ASU, but if an existing space proposed for an ACL-2 facility has floor drains, they need to be modified to prevent accidental release of arthropods and agents. If present, traps must be filled with an appropriate chemical treatment to prevent survival of all arthropod stages (e.g., mosquito larvae).

   g) Internal facility appurtenances (e.g., light fixtures, pipes, ducting) shall be minimal since these items provide hiding places for loose arthropods. Penetrations of walls, floors, and ceilings shall be minimal and sealed/caulked. Ideally, light fixtures shall be flush with the ceiling, sealed, and accessed from above.

   h) Ventilation for Arthropod facilities shall be negative pressure and shall be 100% outside air and 100% exhaust to the outside with containment screening without being recirculated to other rooms. Appropriate filter/barriers shall be installed to prevent escape of arthropods including fans located in the vestibule and internal corridor which help prevent escape of flying arthropods Also, air curtains can be located in vestibules and doorways to help provide containment.

   i) An autoclave shall be conveniently located to rooms containing arthropods within the insectary building.

j) The facility shall include a hand-washing sink with hot water and with suitable plumbing to prevent arthropod escape.

k) Appropriate illumination for arthropod maintenance shall be provided that does not compromise arthropod containment, impede vision, or adversely influence the safety of procedures within the insectary. Lighted (or dark) openings that attract escaped arthropods shall be avoided.

6. Arthropod Containment Level 3 (ACL-3):

a) Arthropod containment level 3 (ACL-3) involves practices suitable for work with potential or known vectors that are, or may be infected with, BSL-3 agents associated with human or animal disease. Arthropods that are infected or potentially infected with BSL-3 pathogens may pose an additional hazard if the insectary is located in an area where the species is indigenous, or if alternative suitable vectors are present, as an escaped arthropod may introduce the pathogen into the local population.

b) ACL-3 builds upon the practices, procedures, containment equipment, and facility requirements of ACL-2. It differs in that access is more restricted, and the microbiological containment takes a more prominent role in determining the practices and facilities.

c) For ACL-3 facilities, biological safety cabinets shall be used for all BSL-3 pathogens.

d) To prevent arthropod escape, arthropod work is performed in a designated area, preferably small and self-contained within the laboratory.

e) Furniture and incubators containing arthropods shall be located in such a way that accidental contact and release by laboratorians, custodians, and service persons does not occur. This is usually achieved by locating arthropods in dedicated rooms, wings or suites in incubators located out of the traffic flow in areas of the building dedicated to BSL-3/ACL-3 activities.

f) For ACL-3 facilities, the insectary shall be strictly separated from areas that are open to unauthorized, untrained personnel within the building by locked doors. These shall be controlled, for example, by key lock, proximity reader, or card key.

g) Access to the facility is limited to trained, approved personnel by a selfclosing and self-locking door.

h) Entry into the insectary shall be via a double-door entry that includes a change room and shower(s). The external insectary entry doors shall be controlled by a key lock, card key, or proximity reader.

i) A shower(s) shall be provided within the suite and shall be plumbed to prevent arthropod escape.

j) An additional double-door access (air lock) or double-door autoclave shall be provided for movement of supplies and wastes into and out of the facility respectively. The two contiguous doors must be designed to be interlocked such that one door can not be opened until the other door is completely closed.

k) Internal doors shall open outward and shall be self-closing; and shall be kept closed when arthropods are present.

l) Additional barriers (e.g., hanging curtains) are recommended.

m) Windows are not recommended. Any windows present shall be resistant to breakage (e.g., double paned or wire-reinforced) and well sealed. If present, fixed light windows are recommended.

n) In addition to the recommendations for ACL-2, spaces around doors shall be sealed to facilitate decontamination or troughs surrounding door frames can be installed and filled with sticky or greasy material that will trap crawling arthropods.

o) Floor drains connected directly to the sanitary sewer are not permitted. Floor drains connected to effluent decontamination systems are allowable. If present, traps must be filled with an appropriate treatment to prevent survival of any arthropod stage (e.g., mosquito larvae). Ideally, all drains are plumbed to a holding tank to facilitate heat or chemical treatment to kill all stages of arthropod prior to disposal into the waste system.

p) Internal facility appurtenances (e.g., light fixtures, pipes, ducting) shall be minimal since these items provide hiding places for loose arthropods. Penetrations of walls, floors, and ceilings shall be minimal and sealed/caulked with approved sealants based upon the activities of the space. Ideally, light fixtures shall be flush with the ceiling, sealed, and accessed from above.

q) Ventilation for Arthropod facilities shall be negative pressure and shall be 100% outside air and 100% exhaust to the outside with containment screening without being recirculated to other rooms. Exhaust air must be HEPA filtered. Appropriate filter/barriers shall be installed in fume hoods, hard ducted Bio-Safety cabinets, exhaust registers, light fixtures, etc. to prevent escape of arthropods including fans located in the vestibule and internal corridor which help prevent escape of flying arthropods Also, air curtains can be located in vestibules and doorways to help provide containment. Visual air pressure monitoring devices shall be provided to confirm negative pressure of different areas with audible alarm to identify system failure.

r) An autoclave shall be conveniently located to rooms containing arthropods within the suite of rooms containing arthropods.

s) The facility shall include a hand-washing sink with hot water and with suitable plumbing to prevent arthropod escape.

t) Appropriate illumination for arthropod maintenance shall be provided that does not compromise arthropod containment, impede vision, or adversely influence the safety of procedures within the insectary. Lighted (or dark) openings that attract escaped arthropods shall be avoided.

7. Arthropod Containment Level 4 (ACL-4):

a) ACL-4 safety guidelines are for the most dangerous pathogen-infected arthropods. No compromise is acceptable at this level of work. BSL-4 agents are associated with a high risk of infection from aerosol exposure, and cause life-threatening disease. Certain other pathogens such as those listed as “restricted animal pathogens” may also necessitate BSL-4 containment if used in vectors. For vector work, production of aerosols is a potential risk when preparing infectious meals or inocula, and can also result from analytical practices involved in virus isolation. If work with vectors must be performed in a BSL-4 facility, then BSL-4 requirements must be strictly followed.

b) ACL-4 Arthropod facilities shall strictly follow the requirements identified for BSL-4 facilities; and currently are not permitted at ASU.

c) For additional information and requirements for Arthropod facilities please refer to: Arthropod Containment Guidelines, version 3.2

E. Radioactive Materials Laboratories

1. Radioactive materials are material composed of unstable radioactive atoms which spontaneously decay to reach a more stable state. During the decay process they release excess energy in the form of radioactive particles (beta, alpha, neutrons) or electromagnetic waves/photons (gamma rays, X-rays).

2. A facility for handling radioactive materials shall be located and designed so that the radiation doses to persons outside the facility can be maintained below applicable limits and are as low as Reasonably Achievable (ALARA).

3. Sinks shall be constructed of impervious material such as stainless steel. Faucets shall be foot, elbow or knee-operated. Plumbing shall be smooth and easily cleaned.

4. When required, radiation shielding shall be approved in advance by EHS. This applies to high-energy gamma and x-ray emitters. Facility-designed shielding is not usually needed for alpha- or beta-emitters.

5. EHS shall determine whether High, Very High or Airborne radiation areas exist and specify requirements that may result from these unusual levels of radioactive materials.

6. Floors shall be smooth, nonporous, easily cleaned surfaces. Appropriate floor materials include sheet vinyl and sealed concrete.

7. Laboratory benches must have nonporous, easily decontaminated surfaces. Epoxy or high-quality chemical resistant plastic laminate or 316 stainless steel shall be specified.

8. To reduce unnecessary exposure, radioactive waste shall be stored in areas separate from work places. However, it is recommended that the transfer route of radionuclide to waste areas be as short a distance as possible.

9. Stock Storage such as cabinets, drawers, refrigerators, freezers, etc. shall be equipped with a locking mechanism to prevent unauthorized access to radioactive materials.

10. Interlocks are required on movable shielding components or access doors to rooms containing high energy radiation producing machines or large sources of radioactive material. The interlocks must disable the production of radiation or shield the radioactive source if doors are not closed or if shielding is not positioned as required to provide adequate protection to controlled or uncontrolled areas. Such interlocks shall be failsafe and tamper resistant.

11. Shielding: Radiation shielding may need to be incorporated into the lab design depending on the quantity and isotopes used. The radiation dosage can affect radiation users if unshielded and may extend into adjacent spaces affecting other facility occupants. The following examples of shielding equipment shall be discussed and determined during design as necessary:

    a) Alpha Emitting Isotopes:

        1. Because alpha particles cannot penetrate the outer layer of human skin, shielding for external exposure is usually not required.

        2. The main hazard with alpha emitters is when they are ingested or inhaled, allowing them to directly damage internal tissues due to their high ionizing power.

        3. Proper handling procedures, such as glove boxes and sealed containers, are crucial to prevent inhalation or ingestion of alpha-emitting material.

        4. In cases where minimal external shielding is needed, materials like plastic or thin layers of metal can be used depending on the application.

    b) Beta Emitting Isotopes:

        1. Plexiglas shields for bench tops to protect radiation user

        2. Plexiglas shields to shield between adjacent lab spaces

        3. Plexiglas waste container shields for high activity waste

        4. Plexiglas stock storage containers (lock boxes)

    c) Gamma/X-ray Emitting Isotopes

        1. Leaded Gypsum (Leaded drywall)

        2. Lead Stock Storage containers

        3. Fume hoods with leaded walls

        4. Lead bricks

    d) Neutron Emitting Isotopes

        1. Consult EHS for neutron shielding requirements.

    e) Radioactive Materials Laboratory Safety Equipment

        1. Various types of laboratory safety equipment need to be incorporated into a facility's design to keep occupants safe and mitigate radiation contamination, injury or other emergency events.

f) Personal Protective Equipment (PPE) Storage shall be located by the entrance to the facility so that it can be worn prior to entering a potentially hazardous area. Adequate space should be allotted for laboratory coats so that they are easily accessible, and the possibility of cross contamination is minimized.

g) Radiation Survey Equipment Space shall be allotted for the storage of this equipment to avoid damage and contamination.

h) A lab signage holder shall be provided at the entrance to each facility for required regulatory warning postings and emergency response information. Refer to Lab Signage Standard.

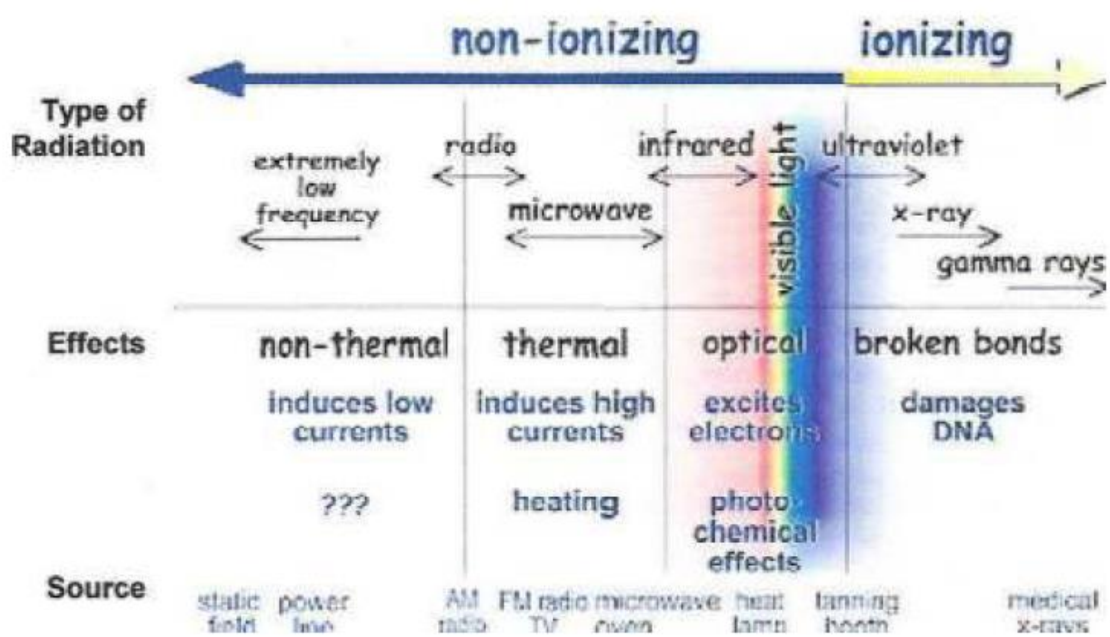
12. Radiation is classified as being either non-ionizing or ionizing. Non-ionizing radiation is longer wavelength/lower frequency lower energy. While ionizing radiation is short wavelength/high frequency higher energy.

13. Ionizing radiation has enough energy to remove electrons from atoms, creating ions, while non-ionizing radiation does not have enough energy to do so, meaning it cannot create ions; examples of ionizing radiation include X-rays and gamma rays, while non-ionizing radiation includes visible light, infrared radiation, and radio waves.

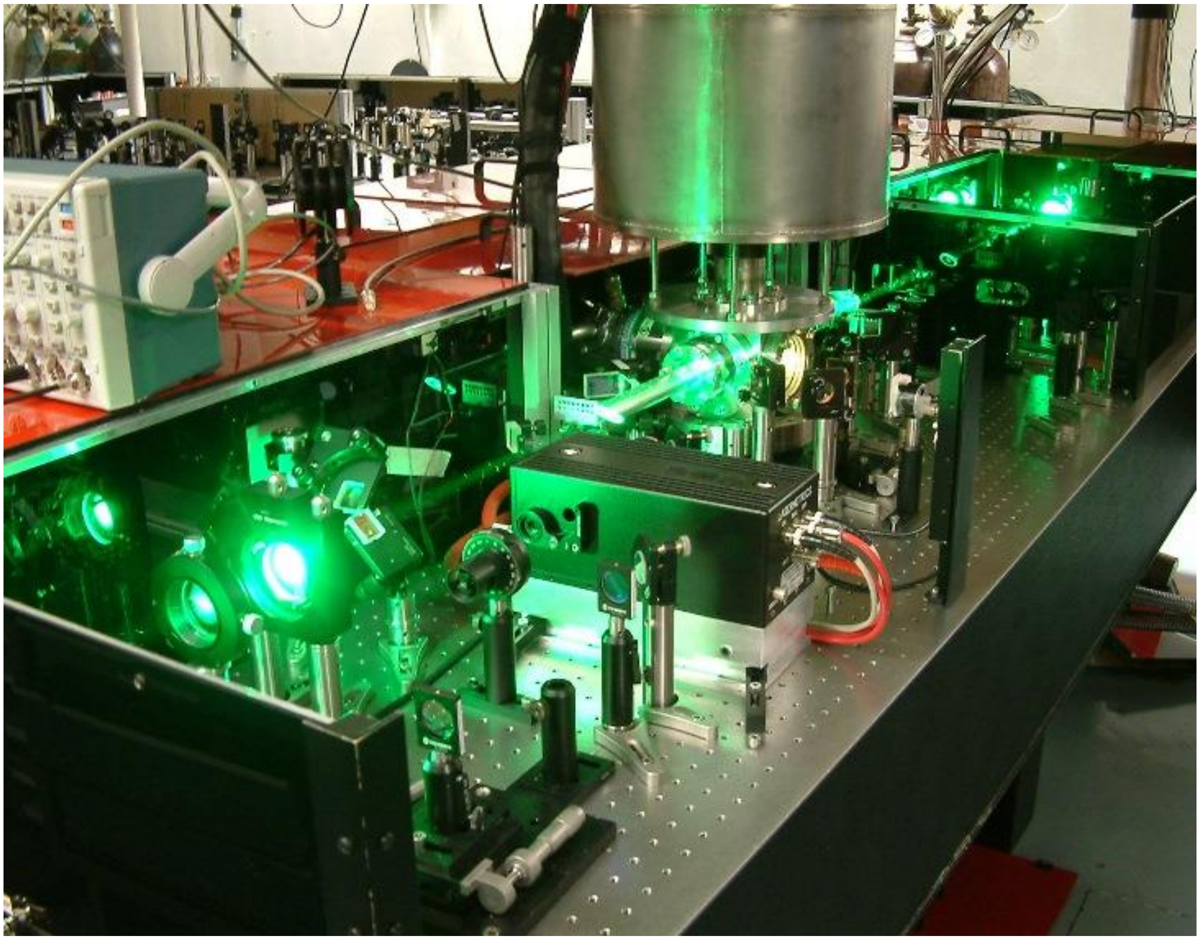
14. Non-ionizing radiation differs from ionizing radiation in the way it acts on materials like air, water, and living tissue.

15. Refer to the chart below for an overall illustration identifying the differences between ionizing and non-ionizing radiation.

16. Most devices containing radioactive material already contain shielding and normally do not require additional shielding. However, EHS must be consulted to perform an evaluation and make a determination as to whether additional shielding is required prior to any construction or renovation. Refer to “Section 6.0 Radiation Materials” at https://cfo.asu.edu/design-professionals



F. Laser Laboratories



1. The term LASER is an acronym for Light Amplification by Stimulated Emission of Radiation. Light can be produced by atomic processes which generate laser light. A laser consists of an optical cavity, a pumping system, and an appropriate lasing medium.

    a) The optical cavity contains the media to be excited with mirrors to redirect the produced photons back along the same general path.

    b) The pumping system uses photons from another source such as a xenon gas flash tube (optical pumping) to transfer energy to the media, electrical discharge within the pure gas or gas mixture media (collision pumping), or relies upon the binding energy released in chemical reactions to raise the media to the metastable or lasing state. This also includes a stimulated emission process where a spontaneously emitted photon from the excitation source collides with a higher energy orbit (further away from the atom) metastable electron producing two photons in phase temporally and/or spatially (coherence). These in turn collide with other metastable electrons aided by reflective mirrors on either side of the optical resonator cavity until a population inversion occurs where metastable electrons are the most abundant within the cavity. This is the lasing process. One mirror at the end of the optical resonator cavity is highly reflective and the other is partially reflective allowing the non-ionizing coherent laser radiation to pass through.

    c) The laser medium can be a solid (state), gas, dye (in liquid), or semiconductor. Lasers are commonly designated by the type of lasing material employed.

2. Laser laboratories are classified into four major hazard categories called the laser hazard classifications. The classes are based upon a scheme of graded risk. They are also based upon the ability of a beam to cause biological damage to the eye or skin.

   a) Class 1: a special designation that is based upon a 1000-second exposure and applies only to lasers that are "not intended for viewing" such as a supermarket laser scanner. The emission from a Class 1A laser is defined such that the emission does not exceed the Class 1 limit for an emission duration of 1000 seconds.

   b) Class 1: cannot emit laser radiation at known hazard levels (typically continuous wave: cw 0.4 mW at visible wavelengths). Users of Class 1 laser labs are generally exempt from radiation hazard controls during operation and maintenance (but not necessarily during service).

   c) Since lasers are not classified on beam access during service, most Class 1 industrial lasers will consist of a higher class (high power) laser enclosed in a properly interlocked and labeled protective enclosure. In some cases, the enclosure may be a room (walk-in protective housing) which requires a means to prevent operation when operators are inside the room.

   d) Class 1M: Class 1M lasers produce large-diameter beams, or beams that are divergent. A laser can be classified as Class 1M if the power that can pass through the pupil of the naked eye is less than the AEL for Class 1, but the power that can be collected into the eye by typical magnifying optics (as defined in the standard) is higher than the AEL for Class 1 and lower than the AEL for Class 3B.

   e) Class 2: low-power visible lasers that emit above Class 1 levels but at a radiant power not above 1 mW. The concept is that the human dislike reaction to bright light will protect a person. Only limited controls are specified.

   f) Class 2M: These are visible lasers. This class is safe for accidental viewing with the naked eye, as long as the natural aversion response is not overcome as with Class 2, but may be hazardous (even for accidental viewing) when viewed with the aid of optical instruments.

   g) Class 3A / 3R: intermediate power lasers (cw: 1-5 mW). A Class 3R laser is a continuous wave laser, which may produce up to five times the emission limit for Class 1, or Class 2 lasers. Although the maximum permissible exposure (MPE) can be exceeded, the risk of injury is low. Some limited controls are usually recommended.

   h) Class 3B: moderate power lasers (cw: 5-500 mW, pulsed: 10 J/cm2 or the diffuse reflection limit, whichever is lower). A Class 3B laser produces light of intensity such that the MPE for eye exposure may be exceeded and direct viewing of the beam is potentially serious. In general Class 3B lasers will not be a fire hazard, nor are they generally capable of producing a hazardous diffuse reflection. Specific controls are recommended.

   i) Class 4: High power lasers (cw: 500 mW, pulsed: 10 J/cm2 or the diffuse reflection limit) are hazardous to view under any condition (directly or diffusely scattered) and are a potential fire hazard and a skin/eye hazard. Significant controls are required of Class 4 laser facilities.

3. Laser Laboratories using non-ionizing radiation sources shall be designed to minimize radiation exposure to personnel and the environment. Laser Laboratory designs shall be forwarded to EHS for safety review and approval during the Design Phase and prior to being released for bid or beginning construction.

4. Class 3B & Class 4 laser labs require access control. The door to the laser laboratory shall be equipped with a self-closing device and be secured at all times. The ANSI standard (Z136.1 & Z136.8) allows for a wide range of access controls. The three most common are: door interlock systems; an electronic lock; and/or posting. The system that should be chosen for laser labs at ASU depends on how well the laser beams are contained. EHS needs to be consulted to help make this determination.

5. Entryways into Class 3B & 4 laser labs shall have signs that alert personnel to the type(s) of laser(s) that may be encountered within that particular lab. A list of authorized users and emergency contact numbers should also be provided on this sign.

6. Immediately inside the entrance to a Class 3B & 4 laser lab, a laser beam containment curtain shall be hung on a track with rollers which, when closed, fully protects the doorway from stray beams that might otherwise be reflected out the door. The curtain attaches to the walls by a Velcro strip. The curtain material must be nonflammable and capable of stopping laser radiation from the ultraviolet to the infrared and comply with ANSI: Z136.1- Section 7.5. An overlap of ~ 12 inches of two vertical curtain pieces shall provide access for persons desiring to enter the laser usage area.

7. These containment curtains shall be designed to coordinate with a sprinkler coverage on either side of the curtain not disrupting the spray pattern, shall have a NFPA 701 rating and have the rating listed on the laser rated curtains.

8. The Design Professional needs to understand the differences between blackout curtains and laser rated curtains as they are different. The blackout curtain is used just to block out light, but it is not laser rated and should not be used to protect against lasers.

9. For laser safety curtain placement, a fire protection engineer may require a certain arrangement such as an L-shape with sufficient clearance to allow for emergency egress.

10. Depending upon the type of laser project being designed, the Design Professional may be able to develop an equivalent system to the laser beam containment curtain. EHS shall be contacted during the Design Phase to determine if and how this can be accomplished.

11. Also, some labs are large open spaces with curtains around each table or across sections of the lab. EHS shall be contacted during the Design Phase to determine the vertical dimension for the height of the top of the curtain and how far from the floor the curtain can start.

12. An electrical control circuit shall be installed in Class 3B & 4 laser labs for the primary purpose of shutting down laser operation in the event that one or more of the following occurs:

    a. Curtain interlock opened

    b. Door interlock opened

    c. An emergency "laser off" switch activated

    d. "Stop" switch activated

    e. Power lost to control circuit

13. Illuminated "Laser On" warning signs shall be posted at the entrances of Class 3B & 4 laser laboratories which is activated automatically when the laser is emitting light.

14. The use of eye protection when operating lasers of classes 2B, 3B and 4 in a manner that may result in eye exposure above the MPE is required in the workplace by the US Occupational Safety and Health Administration.

15. Eyewear must be selected for the specific type of laser, to block or attenuate in the appropriate wavelength range. For example, eyewear absorbing 532 nm typically has an orange appearance (although one should never rely solely on the lens color when selecting laser eye protection), transmitting wavelengths larger than 550 nm. Such eyewear would be useless as protection against a laser emitting at 800 nm. Furthermore, some lasers emit more than one wavelength of light, and this may be a particular problem with some less expensive frequency-doubled lasers, such as 532 nm "green laser pointers" which are commonly pumped by 808 nm infrared laser diodes, and also generate the fundamental 1064 nm laser beam which is used to produce the final 532 nm output. If the IR radiation is allowed into the beam, which happens in some green laser pointers, it will in general not be blocked by regular red or orange-colored protective eyewear designed for pure green or already IR-filtered beam.

16. A protective eyewear station shall be provided inside Class 3B & 4 laser labs near the main entrance, and within the curtained enclosure, so that personnel may put on appropriate protective eyewear before proceeding into the laser area.

17. Doors into Class 3B & 4 laser labs shall not have windows.

18. Provisions shall be made to enclose Class 3b or 4 laser beams whenever possible. Class 3b or 4 laser beam paths that cross between optical tables/equipment benches or pass through barriers shall be properly enclosed and marked identifying the hazard. All enclosures shall be compatible with the laser wavelength and beam power. All laser beam paths shall be maintained at a height either above or below the eye level of standing/sitting persons who may be exposed.

19. Laser enclosures, beam stops, beam barriers and other exposed surfaces shall be diffusely reflective at the laser wavelength used. Surfaces that may create a specular reflection at the laser wavelength shall not be used.

20. Provisions shall be made for the safe storage of laser dye solutions, solvents, and other flammable materials.

21. Appropriate grounding connections shall be provided for laser power supplies and other electrical components. All optical tables shall be properly grounded. To facilitate use, all grounding connections should be properly marked.

22. In Class 4 Laser labs, red mushroom-type room/area emergency shutoffs (to deactivate or reduce laser power below the Maximum Permissible Exposure, or MPE) shall be installed in a conspicuous location that is easily accessible from the laboratory entrances. The switch shall be clearly and conspicuously marked with the words "Notice - In emergency, push button to shut down laser".

23. When designing the HVAC for Laser labs, the engineer needs to design a non-directional air flow system.

24. Typical finishes for Laser labs shall include the following:

    a. Floors shall be epoxy with integral epoxy base
    b. Walls shall be painted per laboratory finishes included in this document
    c. Ceilings shall be lay-in non-tegular ceiling tiles integrated with the equipment Unistrut system.

25. For more information regarding the safe use of lasers for research labs, refer to the "ANSI Z136.1" standard, published by the American National Standards Institute,

ANSI and IEC laser classification	Class 1		Class 2		Class 3		Class 4	Notes
Sub-class	Class 1	Class 1M	Class 2	Class 2M	Class 3R	Class 3B	Class 4	
U.S. FDA laser classification	Class I	No special FDA class	Class II	No special FDA class	Class IIIa (definition is different but results are similar)	Class IIIb	Class IV	Newer ANSI/IEC number classes are now preferred over older FDA Roman numeral classes
Human-accessible laser power (for visible light)	For visible light, emits beam less than 0.39 milliwatts, or beam of any power is inside device and is not accessible during operation.		Emits visible beam of less than 1 milliwatt.		For visible light, emits beam between 1 and 4.99 milliwatts.	For visible light, emits beam between Class 3R limit (e.g. 5 milliwatts) and 499.9 milliwatts	For visible light, emits beam of 500 milliwatts (1/2 Watt) or more	Non-visible lasers emitting infrared or ultraviolet are not included in this chart. Only visible lasers are discussed.
Caution/warning indication	No special caution/ warning indication		No special caution/ warning indication		CAUTION	WARNING	DANGER	
Label descriptive text		DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS	DO NOT STARE INTO BEAM	DO NOT STARE INTO BEAM OR EXPOSE USERS OF TELESCOPIC OPTICS	AVOID DIRECT EYE EXPOSURE	AVOID EXPOSURE TO BEAM	AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION	For visible-light lasers, the word "light" can be used instead of "radiation". The latter is more accurate for lasers emitting infrared and ultraviolet radiation.
EYE AND SKIN HAZARDS								
Eye hazard for intraocular exposure (having a direct or reflected beam enter the eye)	Safe, even for long-term intentional viewing. For visible light, usually applies when the laser is enclosed inside a device (ex: CD or DVD player) with no human access to laser light.	Safe for unaided eye exposure. May be hazardous if viewed with optical instruments such as binoculars or eye loupe.	Safe for unintentional exposure less than 1/4 second. Do not stare into beam.	Safe for unintentional (< 1/4 sec) unaided eye exposure. May be hazardous if viewed with optical instruments such as binoculars or eye loupe.	Unintentional or accidental exposure to direct or reflected beam has a low risk. Avoid intentional exposure to direct or reflected beam.	Eye hazard; avoid exposure to direct or reflected beam.	Severe eye hazard; avoid exposure to direct or reflected beam.	
Maximum or typical Nominal Ocular Hazard Distance (for 1 milliradian beam, exposure time less than 1/4 second)	Not an eye hazard -- does not apply	Consult an LSO as described in the Technical Note below	**NOHD of 0.99 mW beam:** 23 ft (7 m)	Consult an LSO as described in the Technical Note below	**NOHD of 4.99 mW beam:** 52 ft (16 m)	**NOHD of 499.9 mW beam:** 520 ft (160 m)	**NOHD of 1000 mW (1 Watt) beam:** 733 ft (224 m). **NOHD of 10 W beam:** 2320 ft (710 m)	Avoid eye exposure to a direct or reflected laser beam, within the NOHD. The closer you are to the laser, the greater the chance of hazard and the more serious the injury potential.
Eye hazard for diffuse reflection exposure (looking at the laser "dot" scattered off a surface)	None	Consult an LSO	None	Consult an LSO	None	Generally safe. Avoid staring at the laser "dot" on a surface for many seconds at close range.	To avoid injury, do not stare at laser "dot" on a surface. The light is too bright if you see a sustained afterimage, lasting more than about 10 seconds.	
Skin burn hazard	None	Consult an LSO	None	Consult an LSO	None	Can heat skin if beam is held long enough on skin at close range	Can instantly burn skin. Avoid direct exposure to the beam.	
Materials burn hazard	None	Consult an LSO	None	Consult an LSO	None	Can burn materials if beam is held long enough on substance at close range	Can instantly burn materials. Avoid direct exposure to the beam, for materials susceptible to burning.	Dark materials which absorb heat, and lightweight materials such as paper and fabric, are most easily burned by visible laser light.
VISUAL INTERFERENCE DISTANCES								
Maximum or typical flashblindness distance (FAA 100 μW/cm², for 1 milliradian beam, 555 nm green light)	Not applicable; beam is usually contained inside a device such as a CD or DVD player	Consult an LSO	**For a 0.99 mW beam:** 117 ft 36 m	Consult an LSO	**For a 4.99 mW beam:** 261 ft 80 m	**For a 499 mW beam:** 2.614 ft (1/2 mile) 797 m (0.8 km)	**For a 1 Watt beam:** 3,696 ft (0.7 mile) 1,127 m (1.1 km) **For a 10 W beam:** 11,689 ft (2.2 miles) 3,563 m (3.5 km)	Value given is for 555 nm, the green wavelength that appears brightest to the light-adapted human eye. This gives the longest hazard distance. To approximate for red laser light, divide the distance by about 5; for blue, divide by 20.
Maximum or typical glare distance (FAA 5 μW/cm², for 1 milliradian beam, 555 nm green light)	See above	Consult an LSO	523 ft 159 m	Consult an LSO	1,169 ft 356 m	11,689 ft (2.2 miles) 3,563 m (3.5 km)	**For a 1 Watt beam:** 16,531 ft (3.1 miles) 5,039 m (5 km) **For a 10 W beam:** 52,275 ft (9.9 miles) 15,933 m (16 km)	See above
Maximum or typical distraction distance (FAA 0.05 μW/cm² or 50 nanowatts/cm², for 1 milliradian beam, 555 nm green light)	See above	Consult an LSO	5,227 ft (1 mile) 1,593 m (1.6 km)	Consult an LSO	11,689 ft (2.2 miles) 3,563 m (3.5 km)	116,890 ft (22 miles) 35,628 m (35.6 km)	**For a 1 Watt beam:** 165,307 ft (31 miles) 50,386 m (50 km) **For a 10 W beam:** 522,746 ft (99 miles) 159,333 m (160 km)	See above
Technical Notes	For a 1/4 second exposure to accessible visible-light beams, Class 1 limits are the same as Class 2, and such lasers are usually labeled as Class 2.	We are unaware of any Class 1M laser devices intended for consumer use. If you do have such a laser, consult a qualified Laser Safety Officer for more detailed analysis.	Class 2 (and 2M) only applies to visible lasers. Infrared and ultraviolet lasers cannot be Class 2 (or 2M).	We are unaware of any Class 2M laser devices intended for consumer use. If you do have such a laser, consult a qualified Laser Safety Officer for more detailed analysis.	Class 3R is either: (1) From 1 to 4.99 mW into a 7mm aperture (e.g., pupil of the eye) or (2) five times the Class 2 limit of 2.5 mW/cm², which works out to be 12.5 mW/cm². The second method is used by LaserSafetyFacts to determine NOHD.			
	Class 1	Class 1M	Class 2	Class 2M	Class 3R	Class 3B	Class 4	
	Class 1		Class 2		Class 3		Class 4	

26. For additional requirements from EHS, refer to "Section 6.0 Radiation Materials" at https://cfo.asu.edu/design-professionals.

G. Nuclear Magnetic Resonance (NMR) Laboratories

1. Nuclear Magnetic Resonance (NMR) uses strong magnetic fields to induce resonance at the nuclear (atomic) level. As the orientation of the magnetic field is manipulated and atoms are knocked off-axis, they emit faint radio frequency energy as they return to their polar orientation. These emissions are measured and allow a computer image to be created by the analysis of the frequencies emitted by resonating atoms comprising cell structures. The image is electronically enhanced, recorded on video, stored on tape or optical disk and reproduced as a laser image.

2. NMR electronics are sensitive to distortions in the electromagnetic field. The proximity to high-amperage power lines, electrical switchgear and transformers, are crucial siting considerations when planning the space for NMR equipment. Consult with the NMR equipment manufacturers for the effective distances required between NMR equipment and potential sources of electromagnetic interferences.

3. As NMR measures radiofrequency responses at the atomic level, vibration can be profoundly disruptive to NMR processes. Disruptive vibration can be telegraphed through a building's structure from either external (vehicle traffic, construction or trains, etc.) or internal sources (pumps, motors or fans, etc.) to the NMR equipment. As a result, the NMR equipment must be structurally isolated from the rest of the building. In elevated floors, structural systems shall be designed with the expressed intention of minimizing vibration in the frequency and amplitude ranges defined by the NMR vendor that are known to be disruptive. For retrofits of NMR equipment in existing structures, it is advisable to obtain site vibration testing early in the design phase. Many NMR vendors offer vibration mitigating solutions to help alleviate these issues.

4. NMR equipment and computer equipment also have stringent parameters for maximum and minimum temperature; and relative humidity levels, as well as maximum hourly air change requirements. These thresholds are more restrictive than requirements for surrounding areas. Supplemental cooling, humidification or de-humidification will be required for these areas. Consult with the NMR vendor's environmental criteria for specific requirements for temperature and humidity control.

5. NMR installation and replacement also will require crane access and a direct route for magnet passage. These magnets are very heavy so the route of travel through the building must be designed to support the weight of these magnets. NMR magnets also require periodic cryogen service. Cryogen replenishment is accomplished via cryogen dewars typically brought to the site by third-party contractors. As a result, access is required around and above the magnet for cryogen service.

6. When planning and designing a NMR suite, the following technical space requirements shall be considered which will impose special constraints on the location and design of NMR facilities:

    a. The size and weight of the magnet(s)

    b. Venting / exhaust requirements

    c. Total magnetic field of the magnet(s) – (3-dimensional)

    d. Sensitivity to radio frequency interference

    e. Cryogen service / liquid helium; (coordinate with ASU Gas Services)

    f. Interference from the magnetic field generated by the NMR magnet(s)

    g. Sound and vibration isolation

    h. Future equipment upgrade / replacement including clear pathway(s).

7. The height of the ceiling (or that part of the ceiling located directly above the magnet) shall not have obstructions, such as lighting and HVAC ducts; and must be equal to or greater than 10' – 6" for magnet sizes 300 to 500. Ceiling heights for magnets greater than 500 must be coordinated with the NMR vendor for proper height and clearance requirements.

8. Air ventilation must be designed to displace the liquid helium gas during a quench, especially when using any type of volatile liquid for variable temperature experiments. Gaseous helium or nitrogen exhausted from the magnet will displace oxygen and cause asphyxiation if not properly ventilated. During a magnet quench, the evaporated helium is exhausted from the manifold by the pressure relief valves. The amount of gas exhausted depends on the amount of liquid helium held by the magnet at the time of the quench.

9. In order to properly ventilate the NMR area during a quench, a dedicated cryogen vent pipe (quench pipe) must be provided starting from the NMR area and run as directly as possible through the building and to the outdoors.

    a. The vent pipe must meet the pressure and diameter requirements of the NMR system manufacturer and is to be fully insulated to the point of discharge.

    b. At the discharge, the vent pipe must provide a weather-head to prevent the introduction of horizontally driven precipitation.

    c. Discharge direction should be downward.

    d. Cryogenic gas vent discharge should be located a minimum of 25 feet from any air intake and located a minimum of 36 inches above the roof with a safety warning sign.

    e. A 25 foot radius exclusion zone shall be located around the vent pipe and be clearly marked such that staff and contractor personnel shall be restricted from working in this area until they have been educated to the risks of cryogenic gasses escaping from the vent pipe.

H. Electron Microscope Laboratories

Electron microscopy (EM) is a technique for obtaining high resolution images of biological and non-biological specimens. It is used in biomedical research to investigate the detailed structure of tissues, cells, organelles and macromolecular complexes. The high resolution of EM images results from the use of electrons (which have very short wavelengths) as the source of illuminating radiation.

1. There are two main types of electron microscopes: transmission electron microscope (TEM) and scanning electron microscope (SEM).

   a) The transmission electron microscope (TEM) is used to view thin specimens (tissue sections, molecules, etc) which electrons can pass through generating a projection image. The TEM is analogous in many ways to the conventional (compound) light microscope. TEM is used, among other things, to image the interior of cells, the structure of protein molecules, the organization of molecules in viruses and cytoskeletal filaments, the arrangement of protein molecules in cell membranes and the viewing of atomic planes to single atoms.

   b) Scanning electron microscopy (SEM) depends on the emission of secondary electrons from the surface of a specimen. It provides detailed images of the surfaces of cells and whole organisms that are not possible by TEM. It can also be used for particle counting and size determination, and for process control. It is termed a scanning electron microscope because the image is formed by scanning a focused electron beam onto the surface of the specimen in a raster pattern.

2. Due to the complexity of the design and high sensitivity of the electron microscope (EM), it is important that a comprehensive evaluation of the intended location for the facility be performed.

3. There are several factors that must be investigated to determine whether the overall environment meets the equipment operating conditions, such as:

    a) Vibration: Vibration can reach the EM through the floor (background vibration from vehicular traffic, movement of heavy equipment, from its own ancillary equipment), through the HVAC system (acoustic vibration), footfalls and other sources. Also, some of the vibration may be coming from the building's natural frequency.

    b) Noise: The impact of noise in EMs may be from residual noise sources from alternating current fields or HVAC sources.

    c) Temperature Control: The removal of heat from an EM room requires air devices that may produce noise and drafty conditions that should be avoided.

    d) Pressure Differential: Significant pressure differential impacting the EM room can cause variations in the vacuum chamber and its controls.

    e) Magnetic Field: Alternating-current electromagnetic interference (AC-EMI) is a common source of scan noise. Determining whether the observed noise is from EMI or coupled through vibrations or acoustics is required.

    f) Radio Frequencies Noise: Although electron microscopes may be designed to shield radio frequency noise, they may not be very effective with frequencies of 3000 Hz or lower.

4. Each electron microscope room layout will vary depending on the type and sensitivity of equipment specified and the site constraints.

5. At ASU, electron microscope suites shall include the following at a minimum:

    a) Separate room for heat, vibration or noise generating equipment associated with the electron microscope that has sound and vibration attenuating internal walls.

    b) 18" to 24" thick vibration isolation slab on grade for electron microscope.

    c) Appropriate shielding. Electromagnetic (EM) interference cancellation may require EM cancelling systems or shielding depending on the requirements of the microscope and building conditions. However, no copper shielding or faraday cages shall be used to provide shielding.

    d) The suite shall contain no windows or wall penetrations to the exterior.

    e) Physical separation from busy corridors and other sound and vibration generating areas.

    f) Electron microscope suites shall be designed to achieve a minimum Noise Criteria NC-25 rating.

    g) Non-directional air diffusers shall be provided for air distribution in electron microscope suites.

I. Guidelines for Animal Research Facilities (Reserved for Future)

1. Animal care and use areas must meet Association for Assessment and Accreditation of Laboratory Animal Care (AAALAC) International guidelines. This includes guidance on materials of construction, ventilation design, security and more.

2. Vivarium design must also provide for the care of the research animals and shall comply with the requirements identified in the “Guide for the Care and Use of Laboratory Animals”, Eighth Edition.

3. Any renovation or new construction to house or study animals used in research needs to be planned with the research and the animals in mind. Principal Investigators (PI’s), the Attending Veterinarian, the Director of Laboratory Animal Resources (LAR) and their staff need to be involved from the earliest concepts through the detailed planning. Depending on the species, multiple regulations and/or guidelines may apply.

4. Additional concerns when designing animal research facilities are for occupational health and safety of animal care staff and research personnel, as well as different levels of bio-containment or bio-exclusion of the species and type of research being conducted.

5. Special consideration needs to be given to space for storage and logistics and separation of clean and dirty traffic flows and impact on the surrounding activities.

Additional Laboratory Guidelines have been established by ASU Environmental Health and Safety (EHS) and are to be utilized for new laboratory and lab renovation projects. They include the following sections: Section 1.0: Lab Ventilation; Section 2.0: Emergency Eyewash and Safety Shower Equipment; Section 3.0: Pressure Vessels and Compressed Gas Cylinders; Section 4: Flammable Liquid Storage Cabinets; Section 5.0: Hazardous Material Storage; Section 6.0: Radiative Materials; and Decommissioning of Laboratories.

The **ASU EHS Laboratory Standards & Design Guidelines** are located online at: https://cfo.asu.edu/design-professionals