SAND2013-4213P

Laboratory Building Systems

Instructor Guide

Sandia National Laboratories

International

BIOLOGICAL THREAT REDUCTION

Note to printer

The majority of this document is intended for printing double sided on 8 ½” x 11” or A4 paper however there are drawings at the end which should be printed at 11”x 17” single sided.

Also note that the 11”x17” portion includes both vertical and horizontal layouts.

Welcome & Introductions

Slide 1

Introduce Instructor(s):

[Introduce others associated with the training, as appropriate]

Name

Affiliation

Representation (I'm here on behalf of. . .)

Quick Experience Glimpse

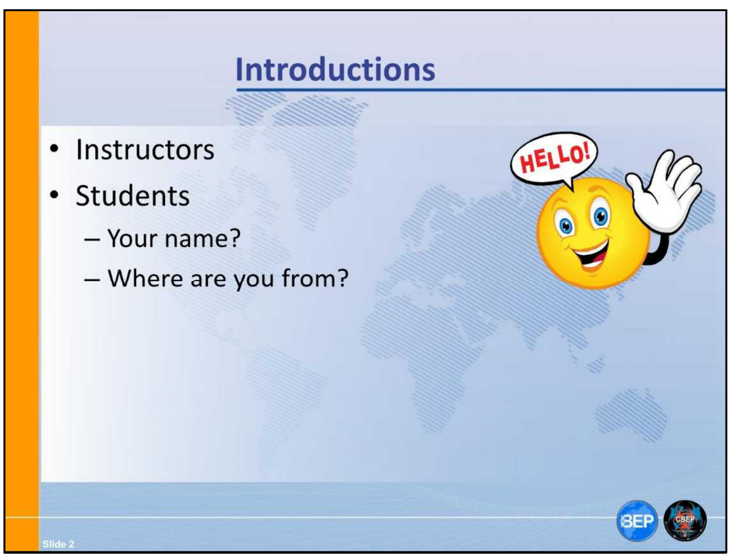
Relevancy of the Course to your experience

Welcome & Introductions

Before you introduce yourselves, I'd like to provide some reminders about this facility and the training:

1. Restrooms are . . .
2. Exits are . . .
3. Evacuation procedures are . . .
4. [any escort or restricted access procedures]
5. We will have intermittent breaks during the course, but please feel free (or not) to take a quick break if you need to at other times during the course
6. Beverages and snacks will be available at (time) and at (location). You may/may not eat and drink in this room
7. Please silence any cell phones or other noise-making devices.
8. Others . . .

Slide 2



Welcome & Introductions

Let's go around the room and let each of you introduce yourself. Please tell us your name, where you work (organization and/or title, as appropriate), and what you hope to gain from the course.

Ground rules

This will be a very interactive session and you will learn the most if you participate fully. We will not intentionally force any one to speak or to do an activity that embarrasses them – if you are uncomfortable, please speak to one of the leaders. For those of you who like to talk, please share your expertise but be aware of those around you who may be quieter and give them time to share their opinion as well. We ask that everyone respect the break times and report back promptly when asked to do so. But most of all, we want to make this a fun time to learn, so remember to smile and enjoy yourself!

Transition to Objectives

Goal

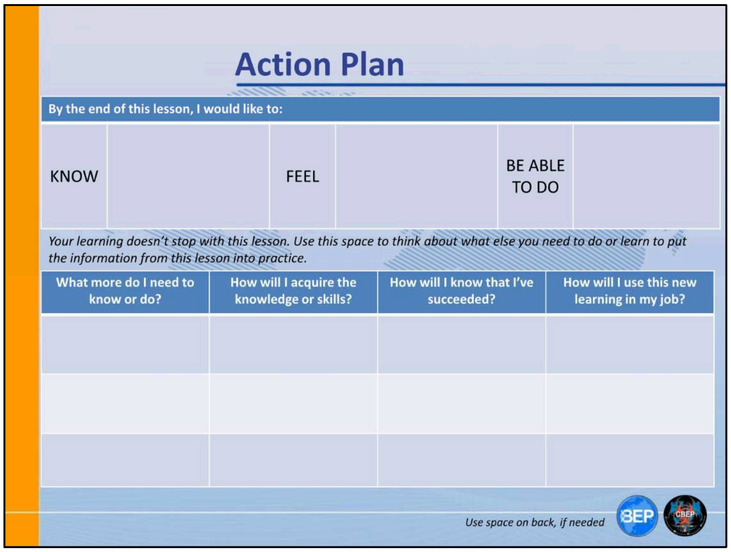
To review the Action Plan and Learning Objectives for the course and to solicit any additional learning goals from the participants.

Time

5 minutes (timing assumes this is an afternoon course and introductions have been made in morning session)

Welcome & Introductions

Slide 3

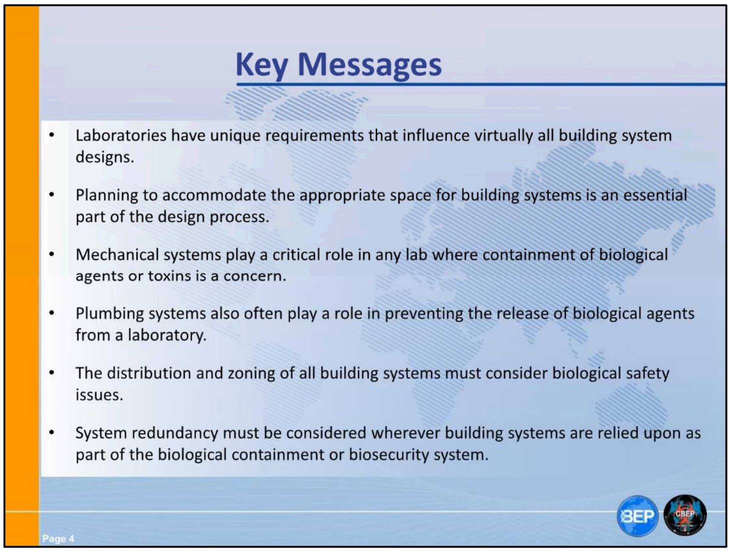


Instructions for the Action Plan handout:

- The Action Plan handout is on page __ of the student guide.
- It is designed to help you assess your learning of the material as we go through the course. It is also referred to as a learning contract.
- Go over each section of the Action Plan. . .
- The sections KNOW, FEEL and DO are designed to help outline personal learning objectives for this course.
- Ask each participant to think about what they would like to be able to KNOW, FEEL, and DO once this course is completed
- Tell the students that this is their own Action Plan. It does not need to be shared with anyone. It can be used during the course and after the course to help continually reach learning goals.
- Allow 5 minutes

Welcome & Introductions

Slide 4



Key Messages

1. Laboratories have unique requirements that influence virtually all building system designs.
2. Planning to accommodate the appropriate space for building systems is an essential part of the design process.
3. Mechanical systems play a critical role in any lab where containment of biological agents or toxins is a concern.
4. Plumbing systems also often play a role in preventing the release of biological agents from a laboratory.
5. The distribution and zoning of all building systems must consider biological safety issues.
6. System redundancy must be considered wherever building systems are relied upon as part of the biological containment or biosecurity system.

Welcome & Introductions

Lecture

This course is intended to offer a basic understanding of the systems required to support a typical laboratory, how these influence facility design and how specialized systems enhance biosafety and biosecurity.

The goals of this course are: To prepare you to discuss building systems with architects, builders and engineers and enable you to provide the type of information needed to design these systems. To help you assist in the accommodation, selection, organization and layout of building systems. And to give you a well rounded understanding of how building systems enhance biosafety and biosecurity.

Question: What would you like to take home from this course?

Background Information for Instructor

Review the course objectives (key messages), these can be read from the slide. Check for understanding and verify that these objectives are consistent with student expectations.

Capture any additional KNOW, FEEL, or DO or other learning goals

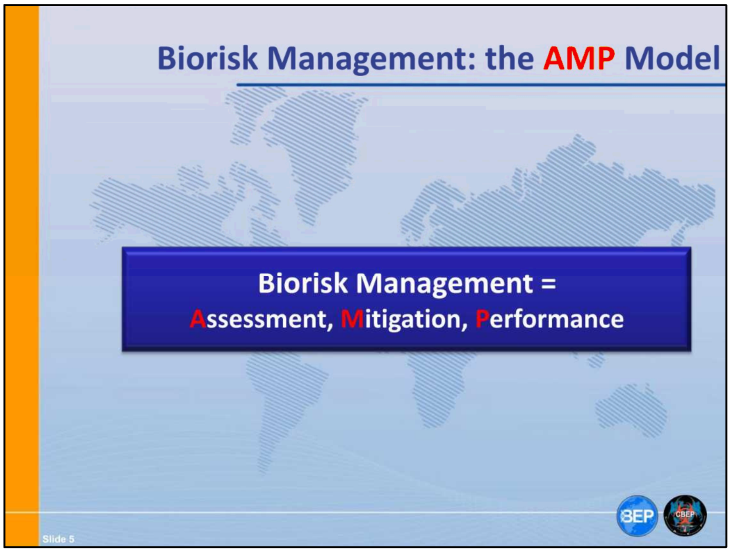
Capture any learning goals that will supplement course objectives and address any that are outside the scope of the course.

This course is flexible in nature. If there is a learning goal that is easily incorporated into the course, feel free to add it. Please note successful additions and consistently requested learning goals in the evaluation portion of this course and/or to GBRMC administrators.

Transition to Biorisk Management Touchstone

Biorisk Management

Slide 5

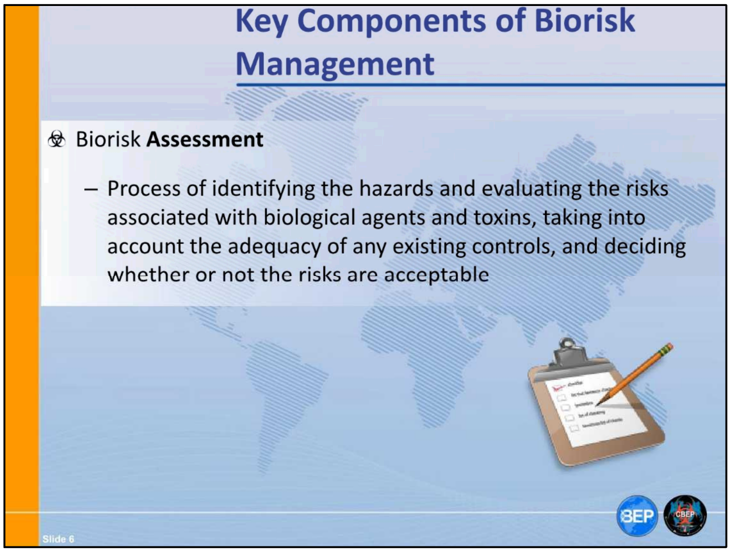


Background Information for Instructor

- Review the AMP model of Biorisk Management with the participants.
- The following three slides provide specific definitions for A, M, and P.
- Integration of laboratory biosafety (protect people from pathogens) and laboratory biosecurity (protect pathogens from people)

Biorisk Management

Slide 6



Background Information for Instructor

The instructor uses the following three slides: Biorisk Assessment; Biorisk Mitigation; and Performance to define key components of biorisk management

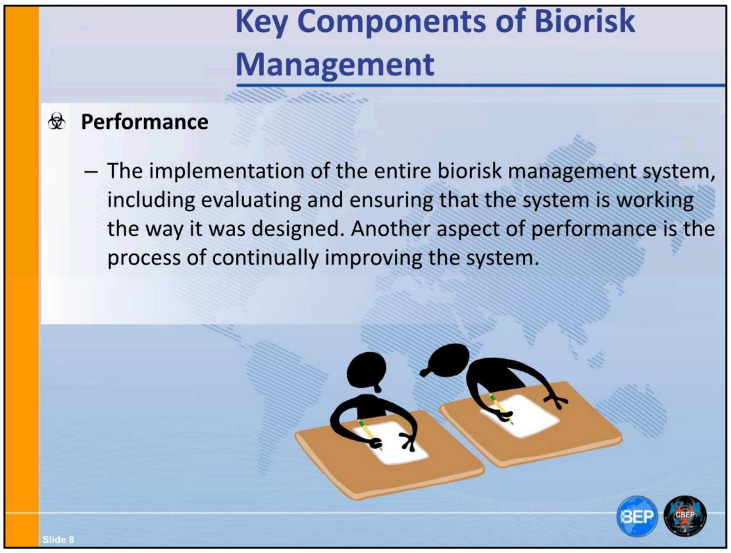
Slide 7

Biorisk Management

Background Information for Instructor

The instructor uses this slide and following slide (Performance) to define key components of biorisk management

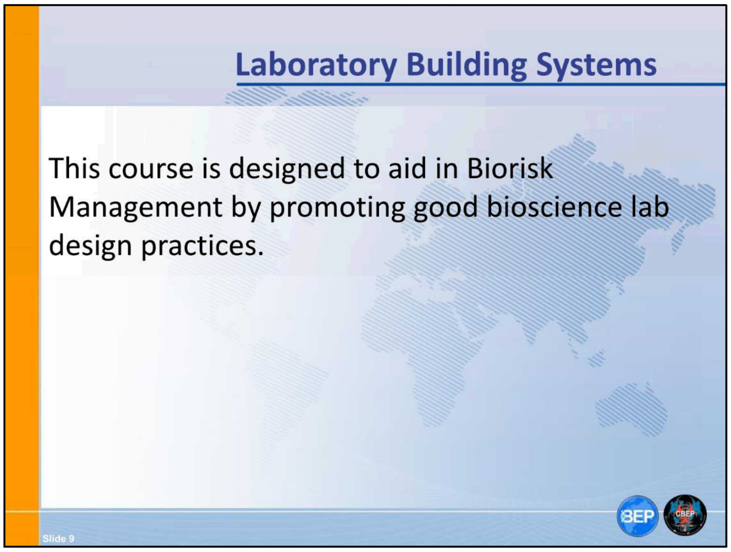
Slide 8



Lecture

Taken together, the three elements of AMP constitute a complete biorisk management system. The elements of the AMP model also underpin CWA 15793:2011 – Laboratory Biorisk Management Standard

Slide 9



Lecture

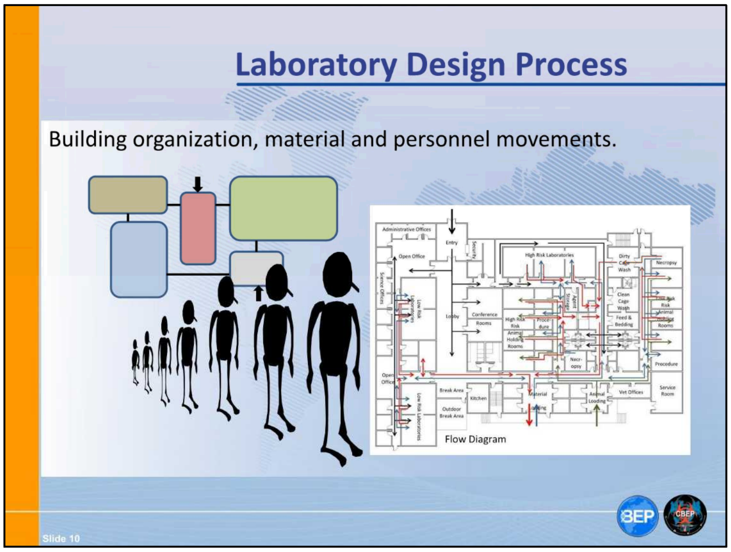
This course is intended to aid in managing biorisk around the world by promoting good bioscience lab design practices. If the facilities in which biological agents and toxins are held and studied are well designed the risks of accidental or intentional releases of these materials can be reduced.

Transition to Laboratory Design Touchstone

Background Information for Instructor

The instructor uses these slides to remind students of the lessons learned in the *Laboratory Design* course (if taken prior to this course)

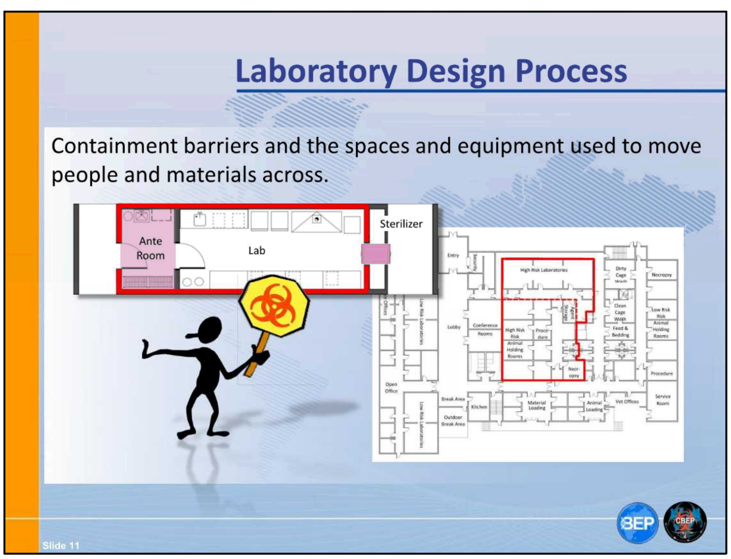
Slide 10



Lecture

Through the 'Laboratory Design Process' and 'Laboratory Design Best Practices' courses we have learned about organizing laboratory spaces to create efficient and functional environments. We looked the 'big picture' concepts that give the overall shape to the building, and we looked at analyzing the flows of materials and personnel as a way of refining our designs.

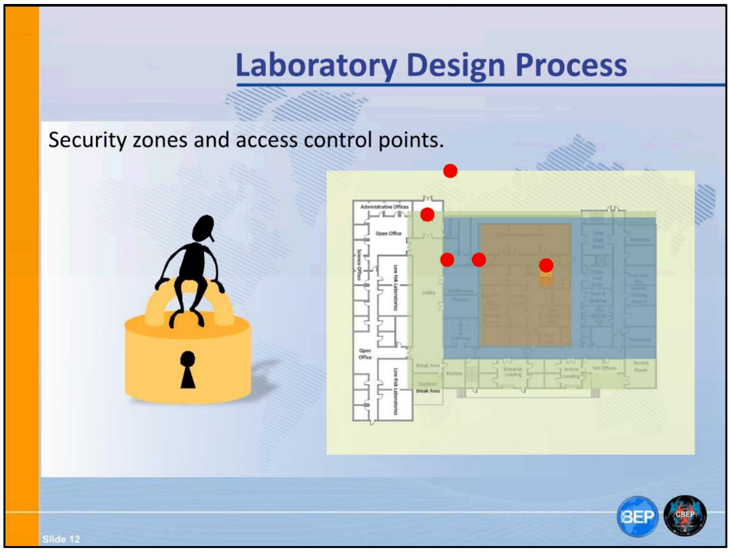
Slide 11



Lecture

We looked at defining biocontainment barriers, and the spaces, equipment and protocols that allow personnel and materials to cross these barriers.

Slide 12



Lecture

We also looked at defining security zones and access points to help ensure that the layout of the building goes hand in hand with the operations needed to secure the biological agents or toxins held within the labs.

Transition to Laboratory Building Systems

Laboratory Building Systems

Slide 13

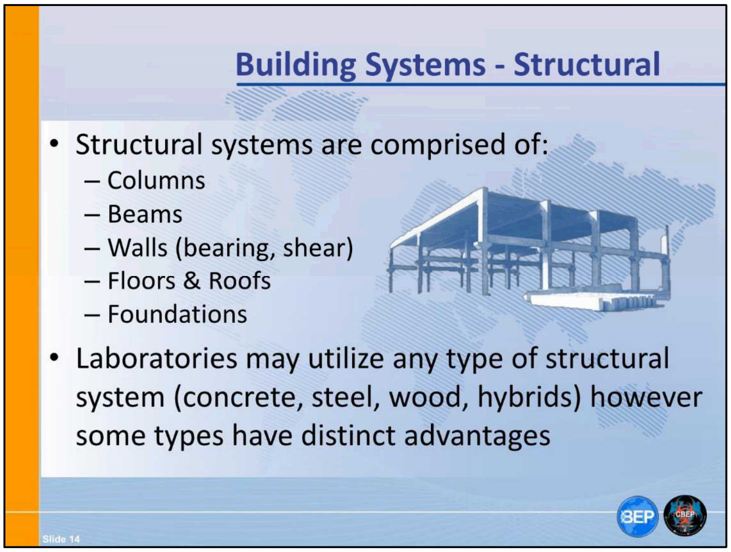
Lecture

Up until now we have been exploring ideas about design from the perspective of determining the best way to arrange the spaces to satisfy the needs of function, safety and security. Now we are going to talk about the physical matter that makes up the laboratory building. The architectural and engineering components and materials that satisfy these functional, safety and security needs.

As there is a lot of material there to cover, we will focus more on understanding the design drivers for each of these building systems, rather than looking at specific solutions. Talking about what needs to be considered when designing a mechanical system, for instance, rather than looking at a specific mechanical system design.

Laboratory Building Systems

Slide 14



Lecture

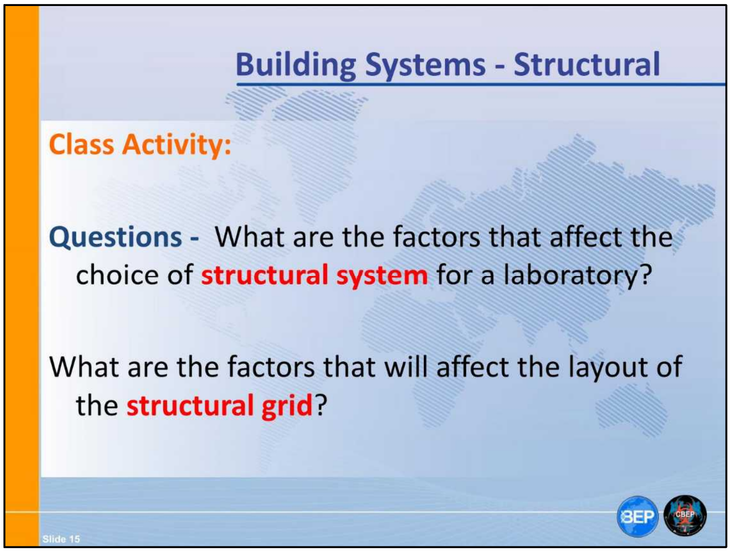
We will begin with a discussion of structural systems for laboratories. The structural systems are comprised of the columns, beams, walls, floors, roofs and foundations that are required to make the building stand, to hold up the floors, the equipment and the occupants that make up the laboratory facility.

As with any building the structural system has a significant influence on the laboratory building layout, and in turn the desired laboratory layout will influence the structural design.

This back and forth between structure and architecture is common for many types of projects, however laboratories exert some unique influences on structural design which we should be aware of.

Class Activity - Structural Design

Slide 15



In plenary ask students the questions on the slide.

What are the factors that affect the choice of structural system for a laboratory?

What are the factors that will affect the layout of the structural grid?

Record the student's answers on a flip chart.

Expected Responses

Factors affecting choice of structural system.

- Laboratory type
- Containment level
- Seismic zone
- Number of floors
- Vibration criteria (for equipment, animals)
- Spans required
- Cost
- Compatibility with containment barrier construction
- Rigidity required for lab finishes/containment barrier
- Local availability
- Resistance to damage from attacks
- Need for maintaining operations & security after an attack or natural disasters
- Fire resistance

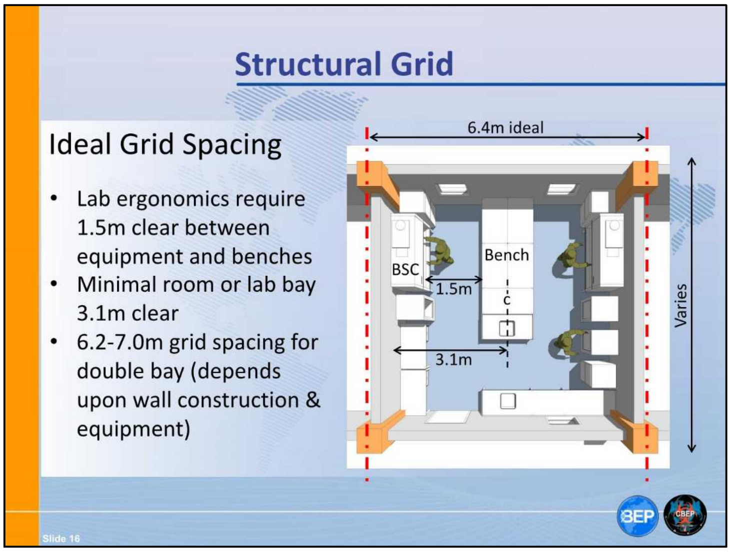
Factors affecting structural grid layout.

- Laboratory function
- Required clearances between columns
- Capacity of structural system for large spans

Background information for Instructor

Instructor should try to highlight any responses that are unique to laboratory designs, particularly those affecting biosafety/biocontainment or biosecurity. Sensitivity to vibrations, for animals and for microscopes or specialized imaging equipment is often overlooked. Compatibility with the containment barrier system is usually better achieved with more massive systems such as concrete frames or heavy masonry/concrete bearing walls as they don't inherently create open spaces that need to be sealed (as a steel structure might) and are usually quite rigid, making them compatible with containment barrier coatings which can sometimes be very brittle and need a stable substrate. Steel structures can however be a successful solution for many types of labs.

Slide 16


Structural Grid
Ideal Grid Spacing
• Lab ergonomics require 1.5m clear between equipment and benches
• Minimal room or lab bay 3.1m clear
• 6.2-7.0m grid spacing for double bay (depends upon wall construction & equipment)
6.4m ideal
BSC
Bench
1.5m
3.1m
Varies
Slide 16

Lecture

Developing a structural grid that works well with laboratory layouts is critical for making functional labs and can help to save costs by ensuring an efficient layout that does not waste space.

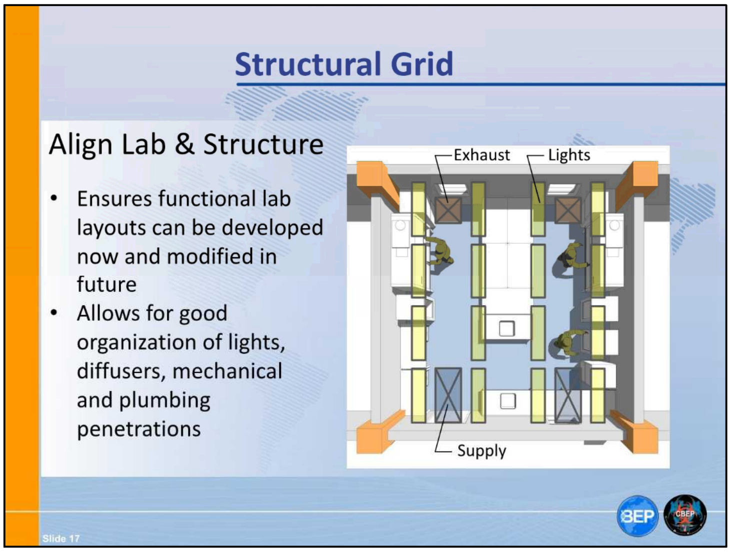
A wide variety of labs have the same basic ergonomic criteria of providing a space, approximately 1.5 meters wide between two rows of benches, or equipment or alternating rows of benches and equipment. Lab benches are generally around .75 meters wide and so is a lot of equipment. Providing a space that is 3.1 meters clear allows for the required clear area for users to move around, plus benching and equipment. This in turn usually generates a grid based multiples of 3.2 meters (allowing for some wall construction). As most structural systems can span much more that 3.2 meters the structure for a lab will very often be somewhere around 6.4 meters which provides a very nice space for a double bay lab.

Wider structural grids, around 9.6 meters can also be used, however these sometimes begin to push the limits of efficient material spans.

Variations on the 6.4 meter width will depend upon the exact type of equipment and benching used, the desire of the users for more or less space, and the number of walls constructed. A lab with very large open spaces can usually get by with a smaller grid spacing, whereas one with walls between each lab bay will need a little more space.

Another factor that can change the grid spacing for some labs is the type of personnel protective equipment (PPE) the users are wearing. For instance if users are wearing fully body, inflatable suits, they may require a little more clear area to maneuver without bumping into one another.

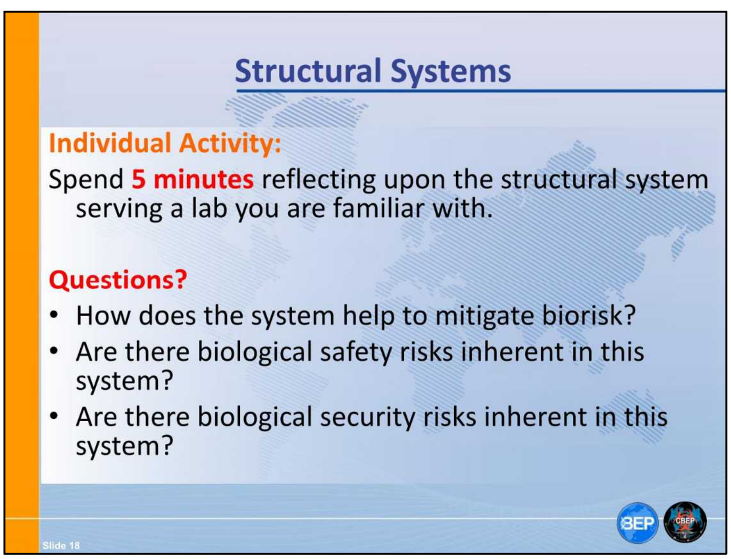
Slide 17



Lecture

Aligning the lab with the structural grid may not seem like it is essential, and indeed it is possible to design around a grid that doesn't match the spacing of the labs. It is however much easier when the two align, not only to allow for ease of working around columns or bearing walls, but also to help align other elements such as lights and duct penetrations. When the lab aligns with the structure, inherently the spaces and openings required for mechanical, electrical and plumbing elements will align as well, making the layouts of these items simpler and more consistent.

Slide 18

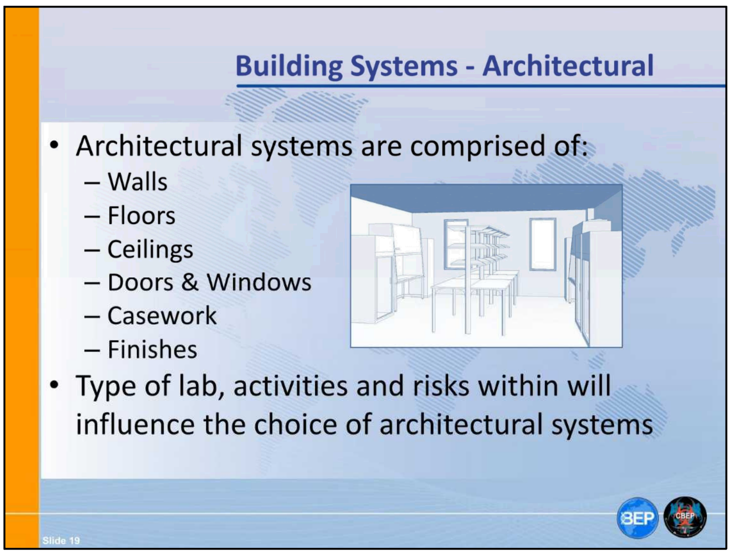


Take a few minutes now to think about a laboratory building you are familiar with, or another building type if you aren't familiar with any labs.

Think about how the structural system might relate to issues of biorisk, are there inherent safety or security risks, or inherent benefits that come along with that particular structural system?

Transition to Architectural Building Systems

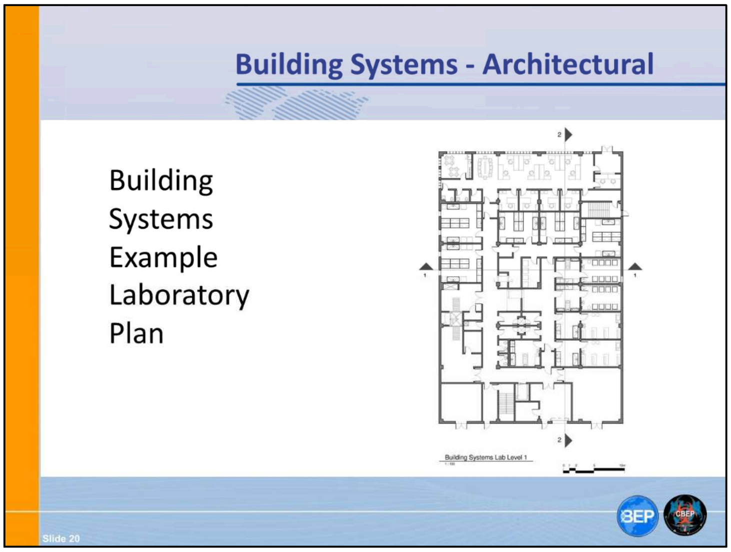
Slide 19



Lecture

Next we are going to talk about the architectural systems required for laboratories. By systems we mean the physical elements used to create the spaces and support the functions. The walls, floors and ceilings that create the rooms, the finishes that go on those surfaces, which in some cases form containment barriers, and even the materials and finish of the casework and equipment used in the labs.

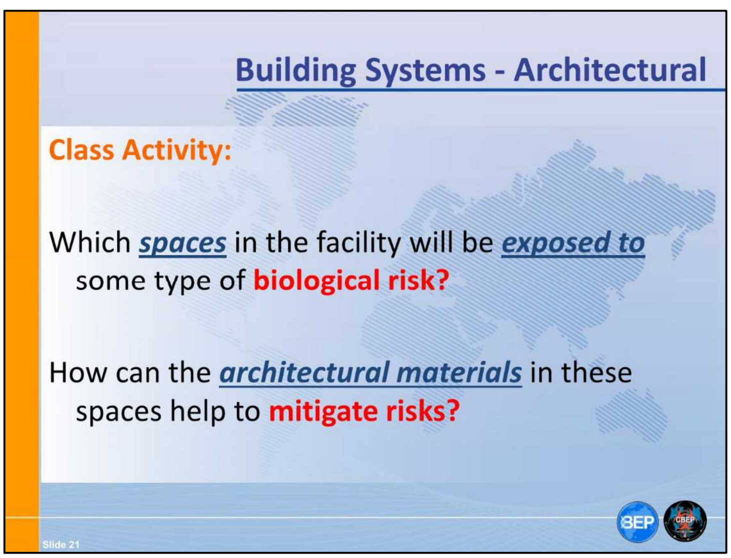
Slide 20



Lecture

We are going to talk about these architectural systems in the context of an example laboratory design. Locate the plan shown on the slide at the back of your student guides. You will see that this building includes some different types of labs, office spaces, animal areas and supporting functions as well.

Slide 21



Class Activity Instructions (to students)

1. So first let us talk about which spaces in the facility might be exposed to some type of biological risk.
2. Next let's talk about how the architectural materials in these spaces help to mitigate biorisk.

You have 10 minutes each to complete this activity

Directions for Instructor:

- Encourage students to all participate as much as possible.
- List on the flipchart all the spaces students indicate as being exposed to biorisk.
- Make note of general ideas about how materials mitigate risk on the flipchart as well.

Expected Responses

Which spaces in the facility might be exposed to biological risk?

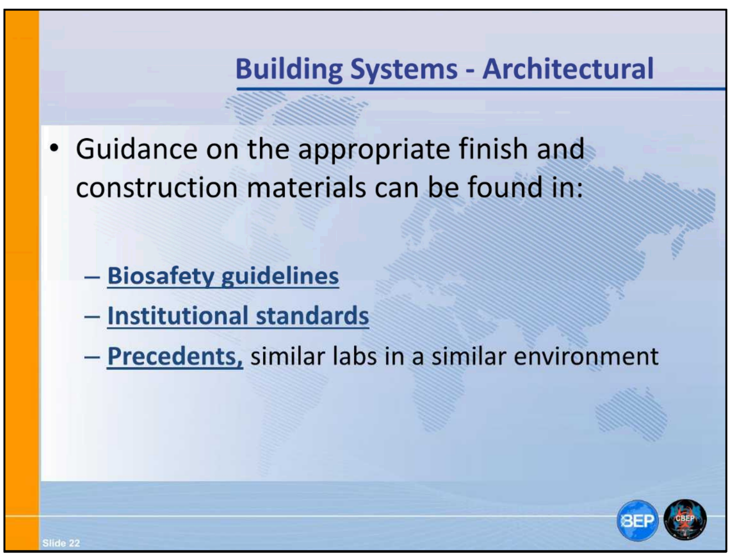
- Containment Labs
- General Labs
- Lab Corridor
- Agent Storage
- Primate/Rodent Holding
- Procedure Rooms
- Necropsy
- Inner Change Rooms, Showers
- Sterilizer Alcoves
- Dirty Cage Wash
- Vestibules
- Corridor
- Loading area

Expected Responses

How can the architectural materials in these spaces help to mitigate biorisk?

- Use materials that don’t harbor biological agents
- Use materials that don’t absorb biological materials or toxins
- Non-slip floors to prevent falls/spills
- Locate equipment & benching to create safe working spaces to reduce accidents/spills
- Use materials that allow for disinfection/decontamination of labs
- Use materials and forms that are easy to clean and disinfect
- Locate windows to help lab users see where others are to avoid accidents (ie windows in doors, along corridors can prevent bumps and spills).
- Design shelving and bench tops to help prevent spills (rails at front of shelves for instance can prevent objects from falling)
- Design shelving or bench tops to contain spills (back splashes, marine edges)
- Use coatings & sealants to make walls, floors and ceilings air tight to prevent escape of biological agents

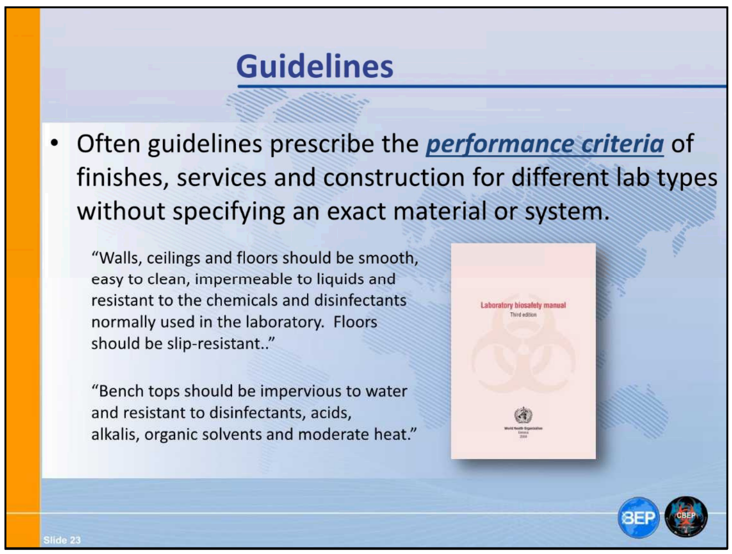
Slide 22



Lecture

Guidance on what materials are right for different labs can be garnered from biosafety guidelines. Many institutions have standards for the materials they want to use, and where more guidance is required it is always good to look at precedents of similar labs built for similar functions, ideally in a similar construction environment at the one you are working in. You will find that lab managers and operators are often very willing to share information about the success or lack of success they may have had with different flooring materials etc.

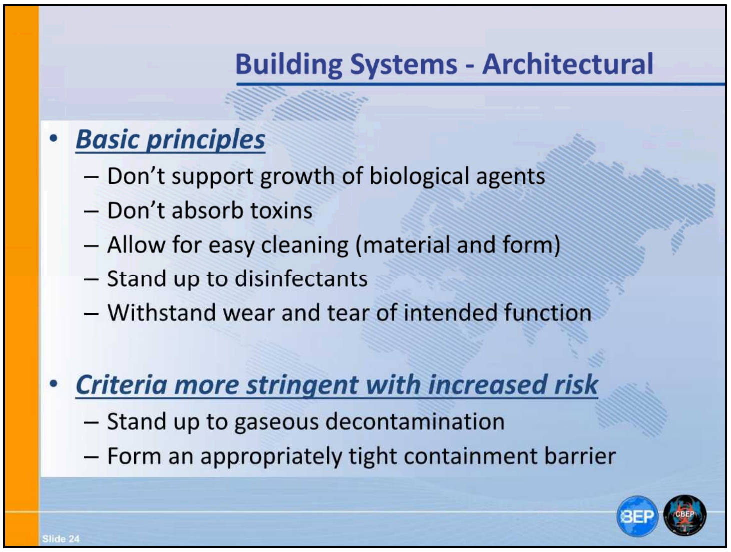
Slide 23



Lecture

Guidelines don't tend to require specific materials, but rather spell out the performance criteria for the materials and systems to be used.

Slide 24


Building Systems - Architectural
• Basic principles
– Don't support growth of biological agents
– Don't absorb toxins
– Allow for easy cleaning (material and form)
– Stand up to disinfectants
– Withstand wear and tear of intended function
• Criteria more stringent with increased risk
– Stand up to gaseous decontamination
– Form an appropriately tight containment barrier
Slide 24

Lecture

There are some basic principles to keep in mind when determining the appropriate materials for a lab which may be utilizing biological agents or toxins.

- The materials of the lab should not support the growth of biological agents or absorb toxins. While good lab protocols generally keep lab spaces clean, there are inevitably going to be accidents and spills and therefore the walls, floors, ceiling of the lab, the benches and chairs in the lab, shouldn't be made from materials that would allow an unnoticed bit of material to grow and spread.

- The materials should all be easily cleanable. This applies not only to the surface of the materials which should generally be smooth and non-absorbent, but also to the forms and shapes of the materials. An adjustable chair for instance, with complex shapes and levers and wheels, will be much harder to clean than a simple stool with smooth round legs.

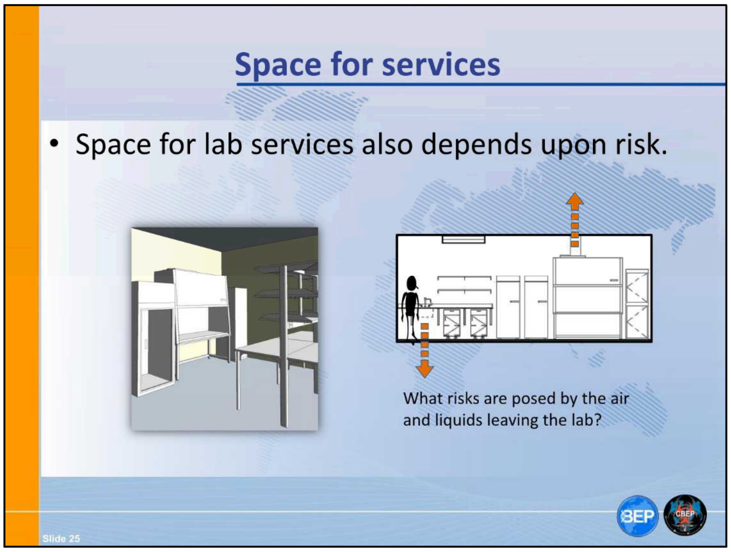
- The materials should stand up to the intended disinfectants as well. It is best if the lab users can provide a list of disinfectants and chemicals to be used then you can specify materials that will stand up to these. It's important to have a discussion with the users about how these are used as well. It might be unreasonable to assume that the walls and ceiling would have to stand up to a certain chemical, but it might be very reasonable to assume that the floor and of course the bench top would.

- It is of course important to anticipate the type of wear and tear on the materials. While a lab and animal room may have the same biological risk, and use the same disinfectants, one will be exposed to soft shoes and occasional cleaning the other may be exposed to animal hoofs and daily wash down with a high pressure hose.

- For certain types of labs it is also necessary to decontaminate with gases. Again it is important to know the type of decontaminant to be used.

- And finally, some of the materials used will need to form a part of the containment barrier. Knowing the level of air tightness needed, how stable the walls, floors and ceiling are assumed to be, and knowing what materials need to be joined together to form the barrier, will all help in determining the right solution.

Slide 25



Lecture

The space required for supporting lab sevices is very closely related to the biological risks present within the lab. Higher biorisk will usually mean greater space required to support the lab.

The majority of this space is needed for properly dealing with the air and the liquids leaving the lab.

The air leaving the lab may just need to be exhausted away from the building, or it may need to be passed through a HEPA filter before being dispersed into the atmosphere. In the highest risk situations the air may need to pass through two sets of HEPA filters, and there may even need to be HEPA filters on the supply side of the air systems just to be extra sure that no contaminants can escape if a failure in the mechanical systems causes the normal pattern of airflow to be reversed.

The liquids leaving the lab may be disinfected in the sink before they go down the drain and so may not pose a significant risk, however in many situations it is not possible to treat liquids before they leave the lab, and in some cases the risks associated with the agents being used is too great to rely solely on chemical disinfectants used in the sink. So it may be necessary to have some type of treatment system below the lab for dealing with contaminated liquids. In some instances the risks may be perceived to be so high that even the piping leading from the lab to the treatment system needs to be kept within an isolated space.

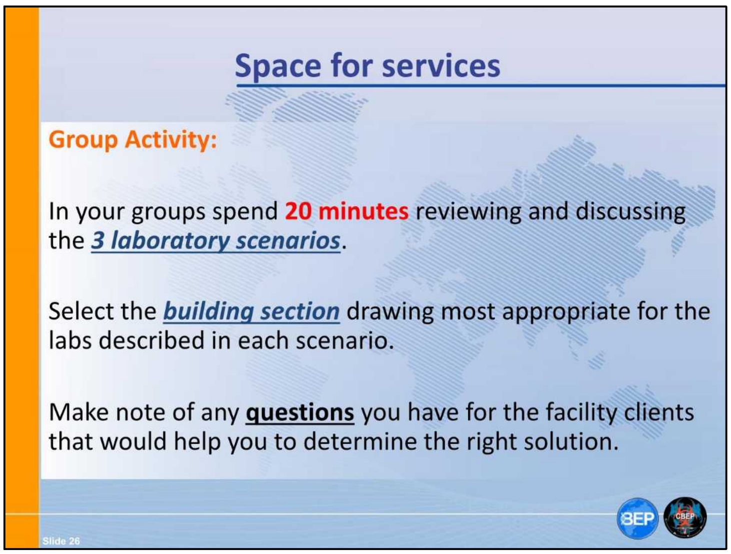
Time Check

You should be approximately **45 minutes** into the course at this point. You have approximately **3 hours 15 minutes remaining**.

Transition to Description of Group Exercise 1

Group Activity 1 - Exercise

Slide 26



Small group activity 1 (30 minutes).

Activity Instructions (to students)

1. In your student guides you will find 3 brief laboratory scenarios. Read these individually.
2. When you have read the scenarios you should begin to discuss, as a group, the services that might need to be above and below the labs in each scenario.
3. Next look through the 3 building section options & choose the one your group thinks is best suited for each of the labs described in the scenarios.
4. Note that while there are 3 scenarios & 3 different building section options, this in not necessarily an indication that there is a unique section for each lab. Your group may decide that the same building section is right for two or even all 3 of the labs
5. Also, if there are questions you would need answered in order to make the right choice, make note of these.

You have 20 minutes to complete this activity

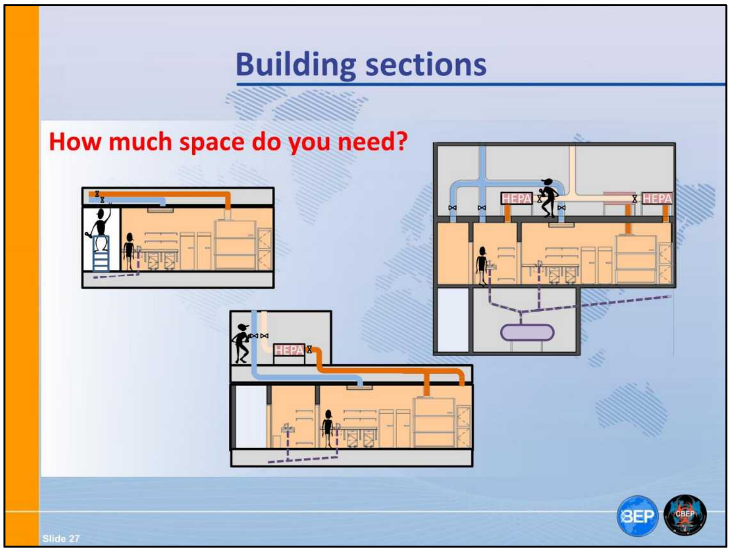
Directions for Instructor:

- Instructor should go through these instructions, then quickly describe the next few slides (up to slide 31) to help the students understand the exercise.
- Once the students are done, allow an additional **5 minutes** for the groups to discuss their answers with the class.

Background information for instructor

Descriptions of the 3 laboratory scenarios can be found at the end of this document.

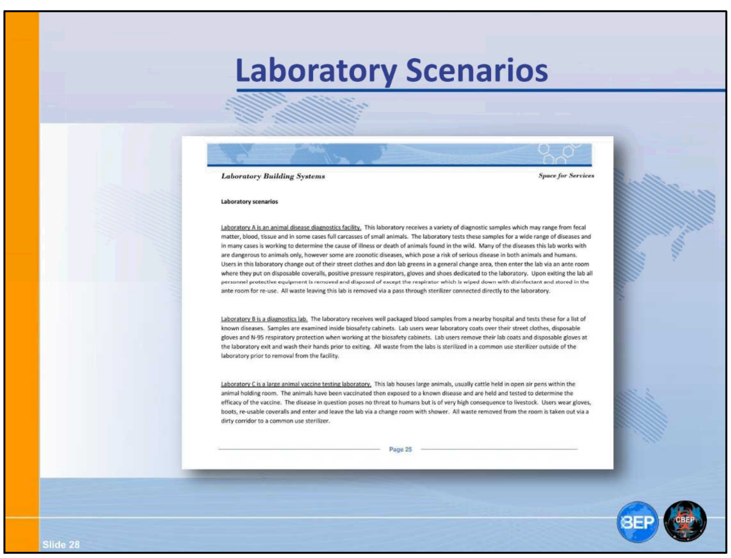
Slide 27



Lecture

This exercise is something that needs to be carried out early on in the design process. You need to have a pretty clear idea about the type and scale of services required to support the lab functions, in order to determine how much space, and what type building configuration, is needed to support the labs with the infrastructure they require.

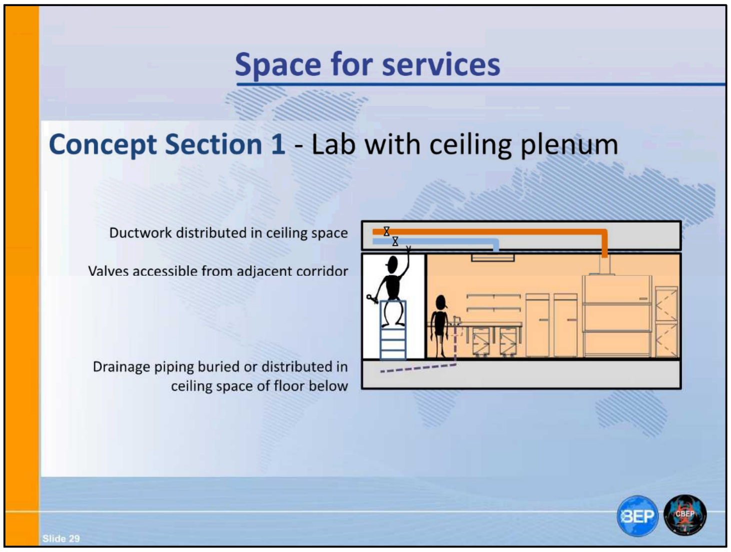
Slide 28



Lecture

These are the lab scenarios that can be found in your student guides.

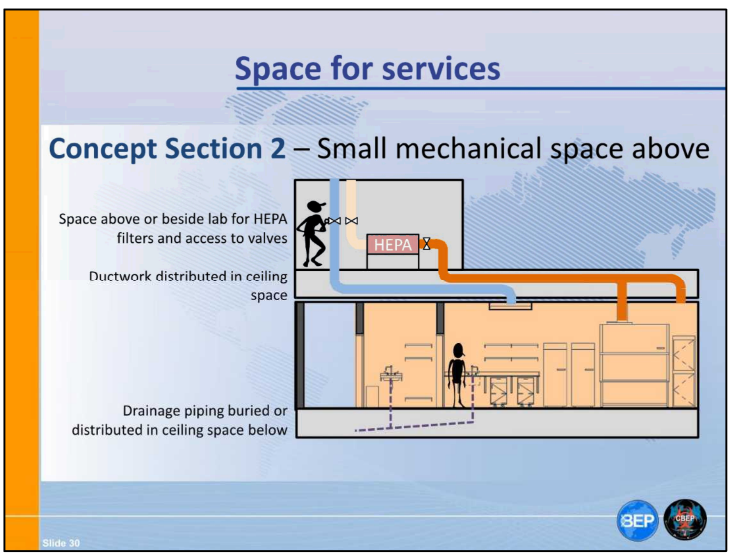
Slide 29



Lecture

And these are the building section options. The first is quite simple.

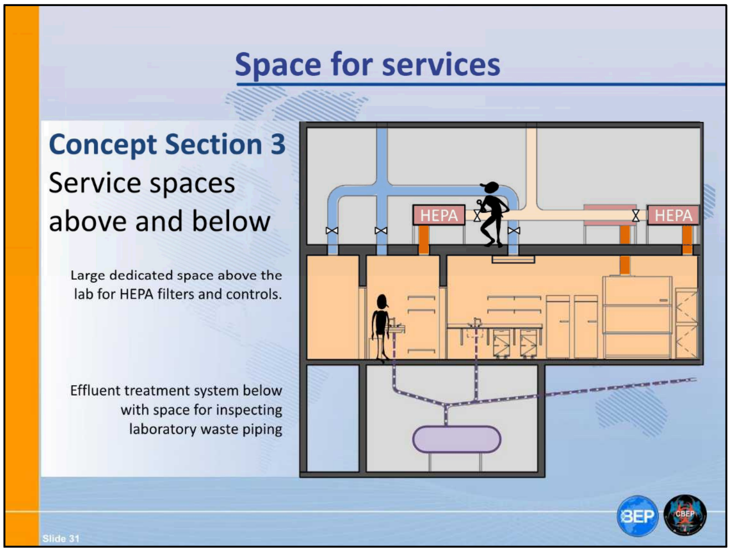
Slide 30



Lecture

The second adds a little bit of space for dealing with contaminated air.

Slide 31



Lecture

The third has even more space for dealing with contaminated air as well as space below the lab for dealing with contaminated liquids coming from the lab.

Expected Responses

Which concept building section is most appropriate for each of the labs described in the 3 scenarios?

Laboratory A – this laboratory might be served by concept section 2 or 3. The description that the users will wear positive pressure respirators is an indication that there is a risk of dangerous agents becoming airborne within the lab, therefore HEPA filters would likely be appropriate. Students may indicate section 3 as this section places HEPA filters closest to the lab, minimizing the extent of contaminated ductwork. Students may also indicate Section 2 however as this does not show a space for effluent treatment. It is difficult to infer from the scenario whether or not effluent treatment would be required for this lab. A good question for students to note would be to enquire how liquids in the lab are disinfected.

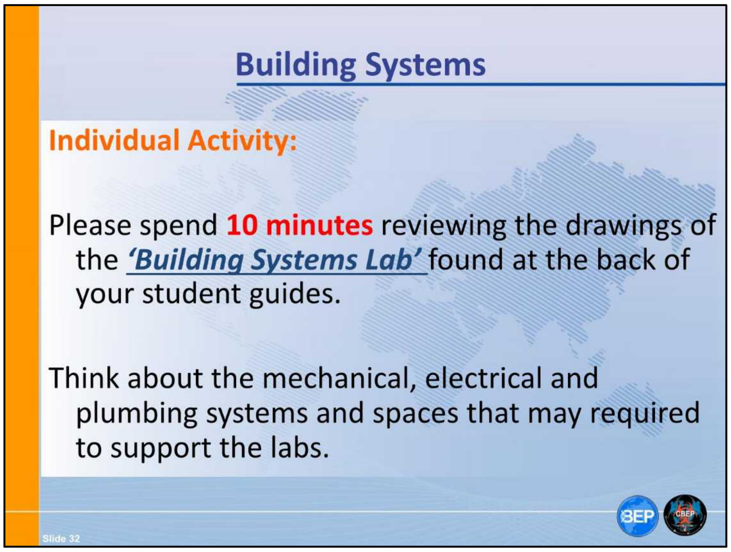
Laboratory B – this laboratory would be best served by concept section 1. From the scenario description it is clear that there is relatively little risk in this lab except where users are working at their biosafety cabinets. As the cabinets themselves can be fitted with HEPA filters, it would likely not be necessary to provide HEPA filters on the room.

Laboratory C – this laboratory would likely be best served by concept section 3. The fact that large animals are housed loose in the room makes it very likely that there may be infectious agents in the air and in any liquids going down the drain when rooms are cleaned. Therefore a building section that allows space for both HEPA filtration and effluent treatment would be most appropriate.

Questions - Students may come up with many questions to ask the client(s) in these scenarios. Some good questions might be:

- What is/are the agent(s) being studied in these labs?
- What diseases are caused by these agents?
- Are the diseases mild or dangerous? Potentially fatal?
- Are users protected by vaccinations for work in the labs?
- How close is the facility to other buildings/populated areas?
- Are any of the agents under study easily aerosolized?
- Do any of the lab processes have a risk of generating aerosols?
- Can all liquids be disinfected prior to release to the drains?

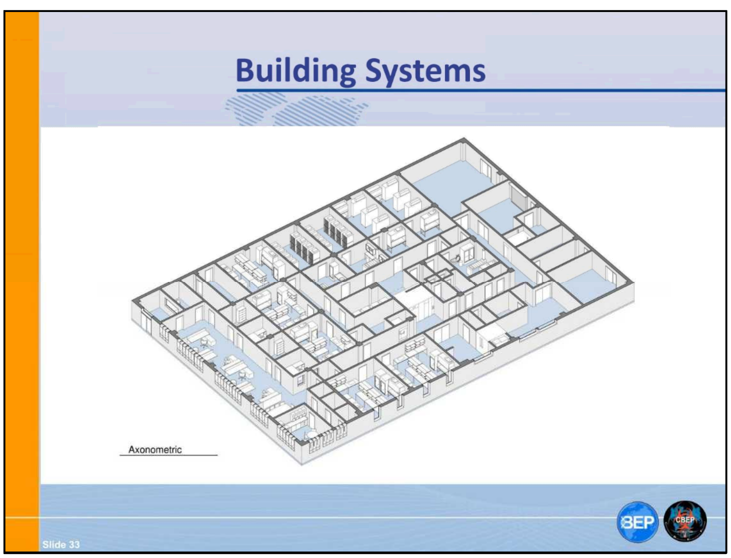
Slide 32



Reflection Activity

Take 10 minutes to individually review the drawings for the example laboratory and think about the building systems, and the spaces to house them, that might be required to support the laboratories and animal spaces.

Slide 33



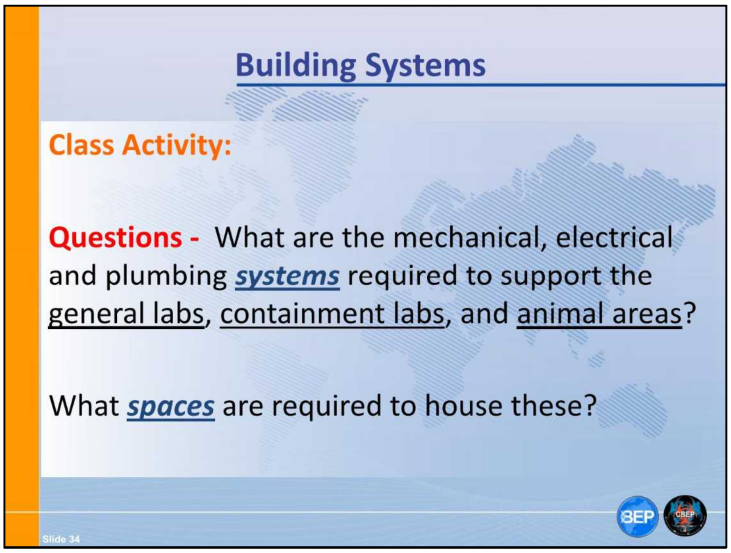
(instructor should leave this slide up while students are reviewing drawings)

Take a 10 minute break at this time if appropriate

Time Check

You should be approximately **1 hour 20 minutes** into the course at the start of the break. You have approximately **2 hours 30 minutes remaining** after the break.

Slide 34



In plenary ask students the questions on the slide.

What are the mechanical, electrical and plumbing systems required to support the example laboratory and animal areas?

What spaces are required to house these?

Record the student's answers on a flip chart.

Expected Responses

Systems and spaces required to support the labs

Mechanical

- Air Handling Units / Supply Air Units
- Exhaust Fans
- HEPA Filters
- Heating/Cooling
- Heat recovery
- Building Automation System (BAS)

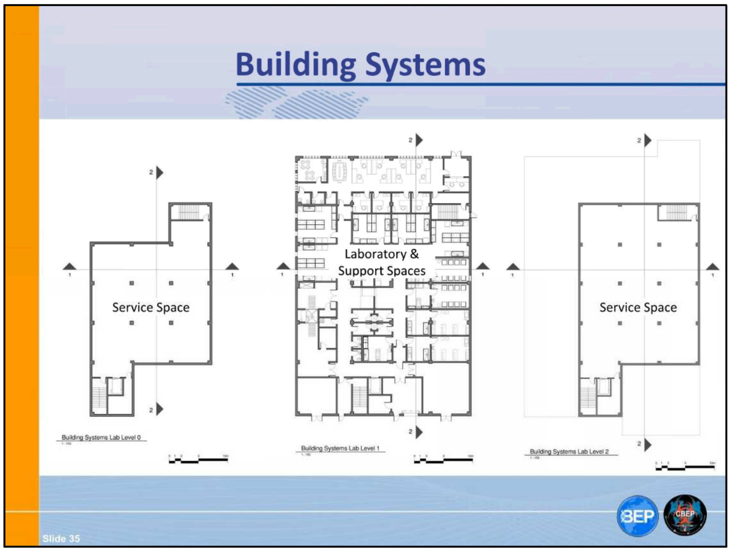
Electrical

- Power distribution
- Lighting
- Emergency Power
- UPS (Uninterrupted Power System)
- Video surveillance
- Access control system

Plumbing

- Hot & Cold water (Lab/non-Lab)
- Waste piping
- Effluent treatment
- RO water/DI water
- Animal Watering
- Laboratory gases (CO2, others)

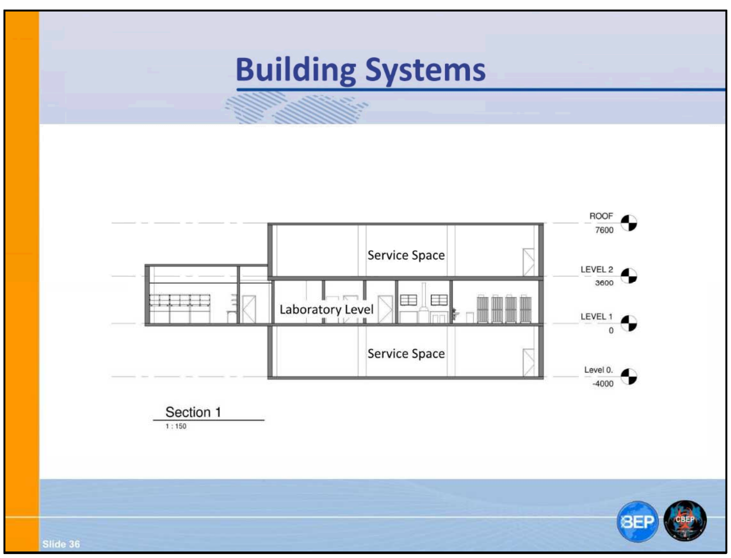
Slide 35



Lecture

You will have noticed in your review of the drawings that the laboratory design we have been discussing has a relatively large service space above the containment laboratory and animal spaces.

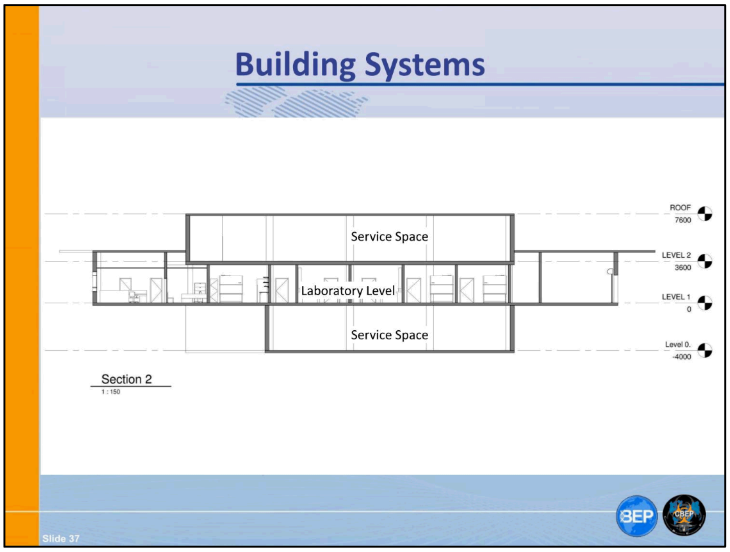
Slide 36



Lecture

In contrast there is only a ceiling plenum area above the general laboratories.

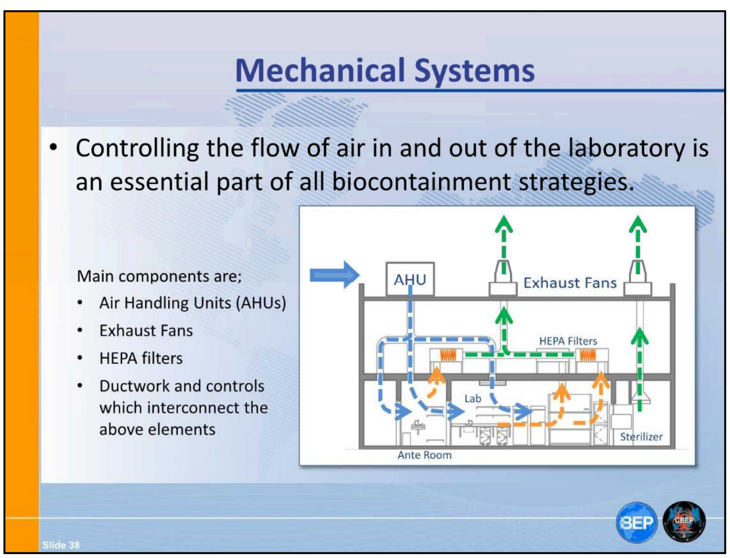
Slide 37



Lecture

Our next group activity will be to utilize the second level and perhaps the roof areas of this building to create a quick conceptual design for the basic components of the mechanical systems serving the general labs and the containment labs. Of all the engineering systems, the mechanical systems generally occupy the most space in a laboratory facility. It is therefore important to develop an understanding of the type and configuration of spaces required to house them.

Slide 38

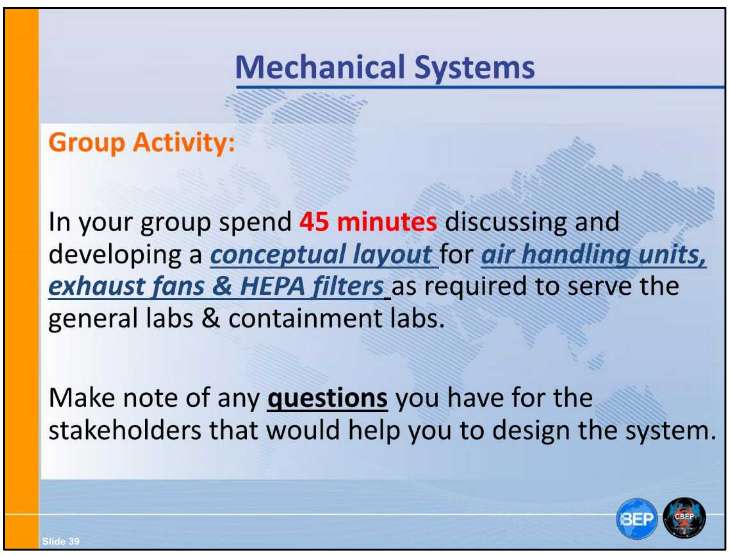


Lecture

As we have seen in our previous courses, controlling the flow of air in and out of a laboratory is an essential part of most biocontainment strategies. The main components of the mechanical system, the ones that take up most of the space, are the air handling units, the exhaust fans, the HEPA filters where needed, and the ductwork that interconnects these elements.

Group Activity 2 – Mechanical concept layout

Slide 39



Lecture

For this exercise we want you to decide how many air handling units, HEPA filters and exhaust fans you might need for this building, and to locate these components in the available spaces (you may use rooftops as well if you like) and to provide an idea of how the ductwork would connect these elements.

Each group should have at least 2 large scale (1:100) copies of the floor plans and sections printed to scale for this exercise. (Include the roof plan)

Small group activity 2 (45 minutes).

Activity Instructions (to students)

1. Think about where you would need to supply air to and exhaust air from the general labs and the containment labs.
2. Think about how many air handling units would be appropriate, and how many exhaust fans, and how many HEPA filters.
3. Try to locate all the components on the plans.
4. Try to create a simple diagram showing the basic idea of where the ductwork required to connect these elements would be run.

You have 45 minutes to complete this activity we will then spend 15 minutes reviewing one another's work.

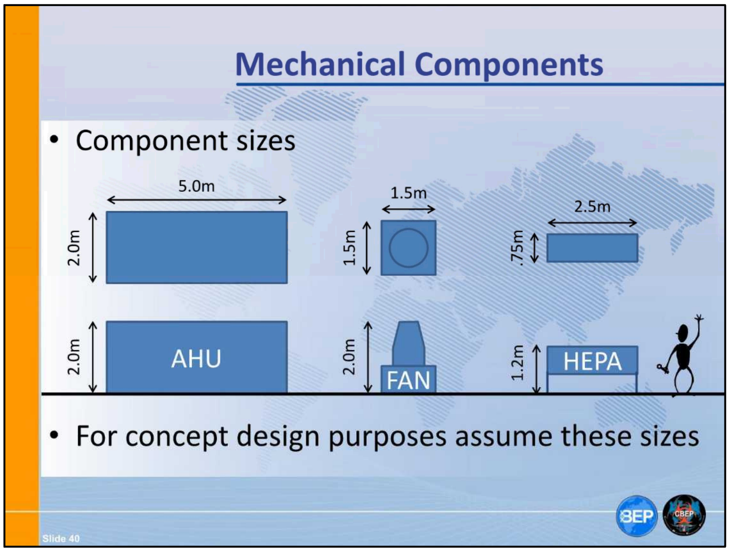
Directions for Instructor:

- Ensure students are working both in plan and section to develop their designs.
- Ensure students are working to develop general ideas of how the system will be designed and not getting too involved in detailed design.
- You may wish to give the students an extra 15 minutes to develop their design in lieu of presenting their designs to the class.

Diagram Demonstration

Course materials will include a large scale copy of the plans & section, laminated for use with dry erase markers. Utilize these to show students how to diagram the mechanical system concept. See the end of this document for sample illustration diagrams, showing what the instructor might draw to guide students.

Slide 40

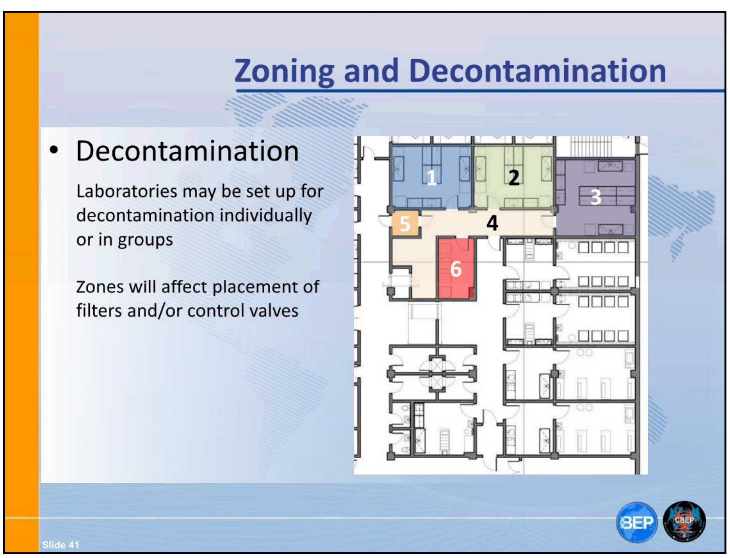


Lecture

This drawing, which you can find in your student guides, gives a general idea of the size of the components you need to locate. Do not worry too much about the sizes as the intent is to develop a conceptual idea of how the layout would work, these are just to give a general idea of scale.

Transition to zoning and decontamination strategies

Slide 41



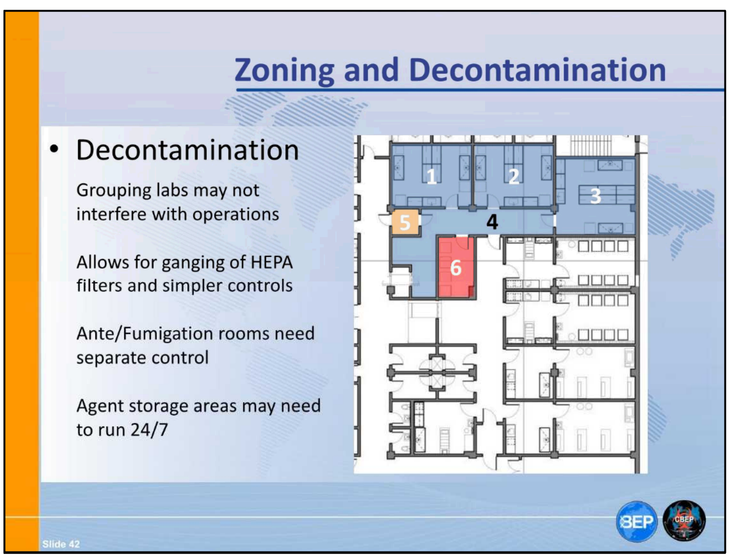
Lecture

One important thing to keep in mind when developing the layout of laboratory services is the strategy for maintenance of the facility. This is particularly important for containment labs where it may be necessary to use gaseous decontamination methods prior to performing any maintenance. It may also be necessary to decontaminate the laboratories between program changes. Many institutions decontaminate their labs on a yearly or other periodic basis as a part of their biological safety program or for certification purposes.

Looking at the containment lab areas of our design we see that there are 6 different spaces; the 3 labs, the corridor, the ante room and the agent storage room. The mechanical systems may be set up to allow all of these spaces to be shut down individually or in groups.

It is important that the laboratory designers discuss how the labs will operate with those who will be operating the facility. In general terms, more spaces that need to be individually controlled and shut down will mean a more complex and more costly system. Laboratory operations are expensive however so in some cases a design with more capacity for individual control can save on operating costs. This can happen in two ways; Firstly it can mean less downtime so those working in the lab can be more productive, Secondly it may allow areas not in use for long periods be shut down to save energy.

Slide 42

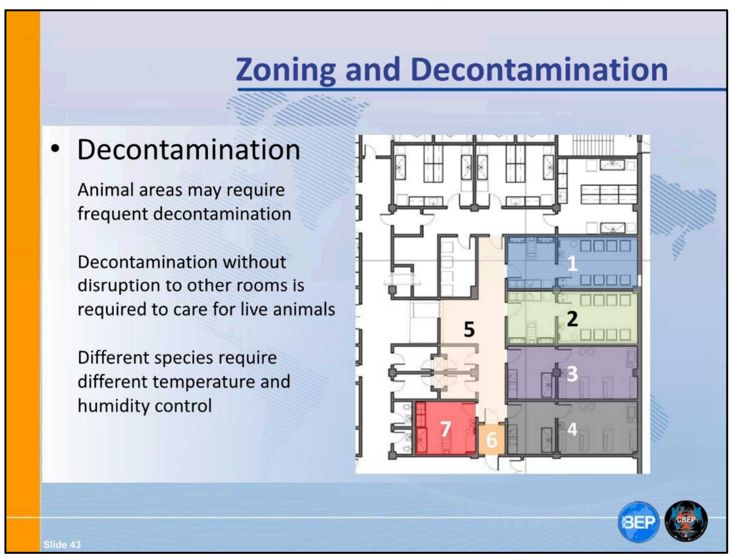


Lecture

In this particular lab it would likely not inhibit operations too much to group all of the laboratories together. Since the labs are relatively small it would not affect a large number of people if one lab needed to be shut down on short notice. Additionally it would be relatively easy to coordinate a yearly shut down between 3 groups using these labs. This might allow for some ganging of HEPA filters and simplification of controls.

There are some spaces that might need the capacity for individual control however. The ante room, if intended to be used for decontaminating materials or equipment, might need to have the supply and exhaust air shut off frequently during gaseous decontamination procedures. Conversely the agent storage area might be a space that the owners want to keep operational year round, regardless of the maintenance, certification, or program change activities taking place in the labs.

Slide 43



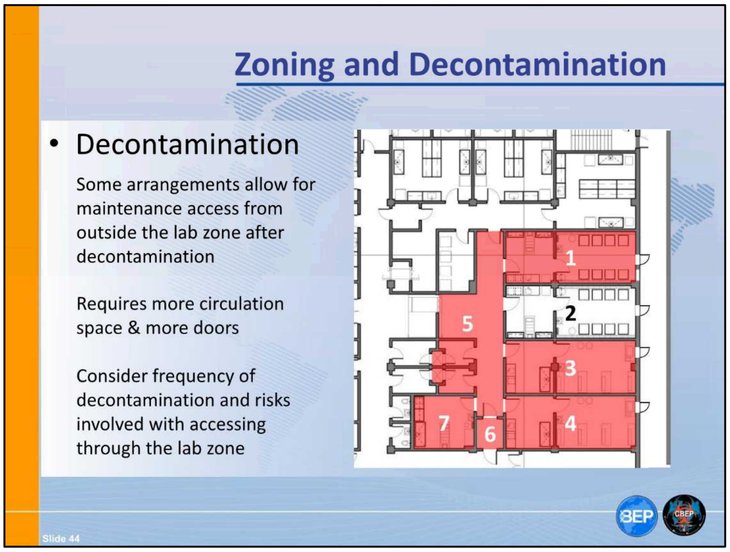
Lecture

Animal holding areas pose different challenges for mechanical systems design. The presence of live animals makes it difficult to shut down all spaces simultaneously. If there was to be a spill or other incident that necessitated decontaminating one of the rooms, it wouldn't be possible in this laboratory to move the animals to another area while the decontamination takes place. Even for yearly certification purposes it may not be possible to coordinate programs to have all rooms empty at once, and some long term animal studies may even last longer than the certification period. Some animal facilities may even require redundant HEPA filters on a single room, to allow these filters to be changed, or tested without shutting down the room. The controls on animal experiments are such that even a short term shut down, where temperature and humidity levels in the room cannot be maintained could render the results of the study invalid.

The need to control temperature and humidity can also affect the layout of mechanical systems for animal areas. Unless the facility you are working with only houses one type of animal, it will almost always be necessary to allow the temperature and humidity to be controlled for each room individually. Rabbits, mice and non-human primates all have unique requirements.

A good solution for our facility would likely be to provide the capacity to shut down and decontaminate each holding room, the necropsy area, and the air lock or fumigation room individually. It would also be good to provide the capacity for the corridor and change rooms to operate 24/7 regardless of the activities going on in the other areas so that the animal care staff can always have access.

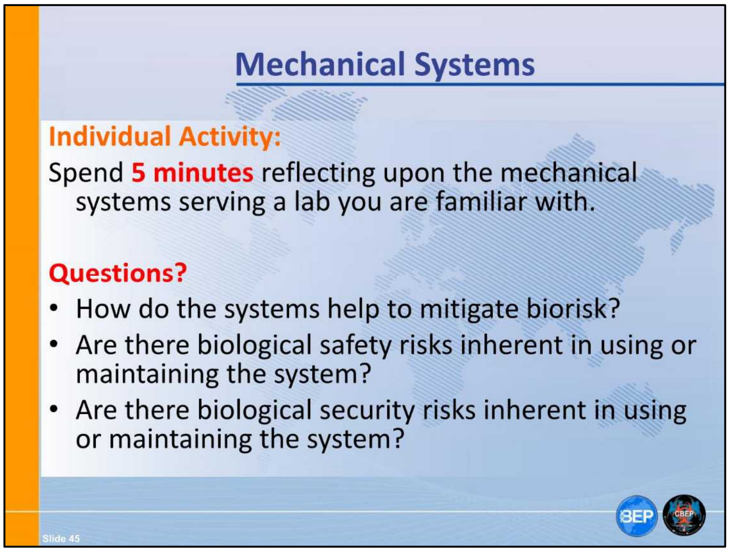
Slide 44



Lecture

Some animal facility arrangements, with clean and dirty corridors or contained/non-contained corridors, will allow for maintenance access from a safer area after decontamination. This type of setup obviously requires more corridor space and more doors which may not be merited. It is however important to discuss the frequency of decontamination expected and the risks involved with allowing maintenance personnel to enter into the animal area to perform any maintenance or equipment changing activities required. This can also depend largely on how the facilities are maintained. When outside contractors are used the facility may be uncertain of the training level of the personnel so there may be more risk. When the facility utilizes their own trained maintenance staff, who can be educated about the agents under study and any vaccination or health monitoring requirements, it may be perfectly acceptable to have the maintenance staff enter via the same route as the scientists and animal care staff.

Slide 45



Take a few minutes now to think about a laboratory building you are familiar with.

Think about how the mechanical system helps, or maybe how it should help, to mitigate biorisk. Are there inherent safety or security risks, or inherent benefits that come along with that particular system?

Note to instructor – It may be best to allow the students quiet contemplation time for these questions however you may wish to have class discuss these questions in plenary depending upon available time and the level of understanding the class may have. If necessary you may also wish to give the students some relatively standard answers to the questions such as:

Mechanical systems mitigate biorisk by:

- Creating directional airflow from low risk to high risk areas.
- Exhausting potentially contaminated air away from the building and away from air intake points.
- Filtering contaminated air when required.

Biosafety risks in inherent in using and maintaining the system may be:

- Valves in contaminated ductwork may leak, creating a contamination risk in the mechanical area.
- Changing of HEPA filters may create a risk of exposure if filters are not decontaminated first and handled properly.
- Failures in systems might cause a reversal of directional airflow causing contaminants to spread to non-lab areas.

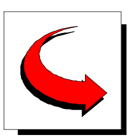
Biosecurity risks might include:

- Roof mounted mechanical equipment may be subject to damage.
- Mechanical openings may inadvertently create access points into secure areas.
- Service personnel may create a security breach, particularly if the systems cannot be maintained by the institutes own maintenance team.

Take a 10 minute break at this time if appropriate

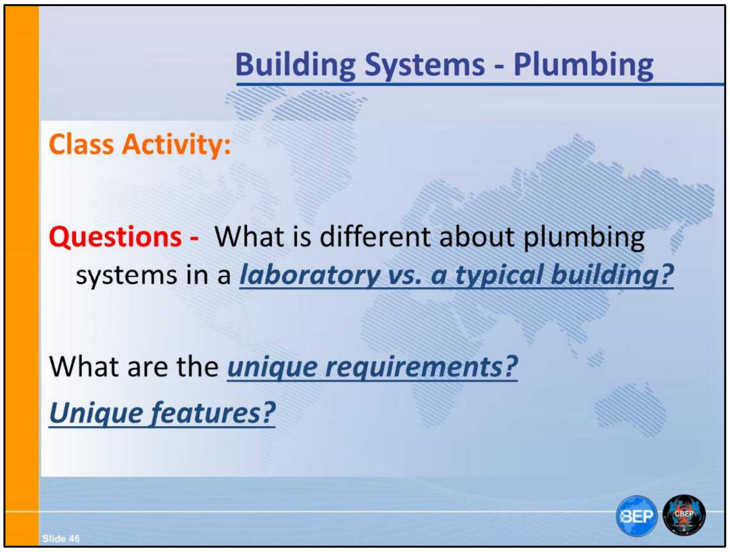
Time Check

You should be approximately **2 hours 50 minutes** into the course at the start of the break. You have approximately **60 minutes remaining** after the break.



Transition to Plumbing Systems

Slide 46



In plenary ask students the questions on the slide.

What is different about the plumbing systems in a laboratory versus a typical building?

What are the unique requirements and the unique features?

Record the student's answers on a flip chart.

Expected Responses

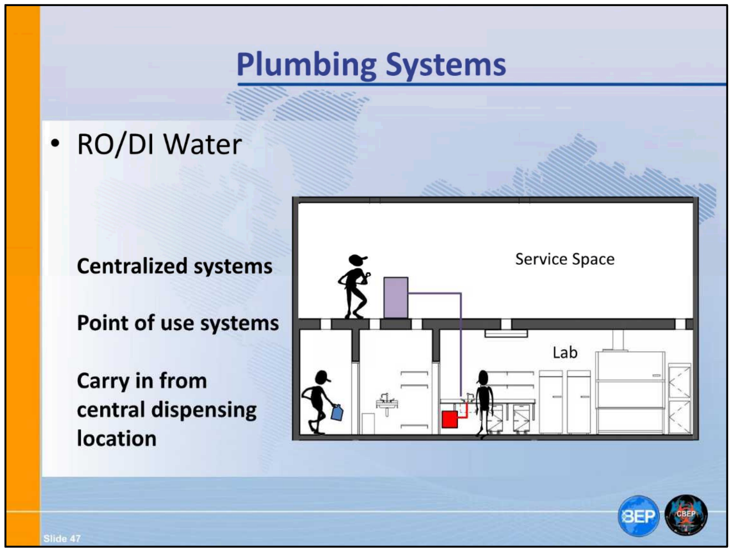
Unique plumbing requirements

- Special types of water required, DI, RO, animal watering systems
- CO_2 and other gases required
- Biological waste treatment required in some cases
- High pressure/High temperature wash down required in animal areas
- Trench drains may be required in animal areas and in cage washing areas
- Sterilizers may require high pressure steam supply
- Some laboratory equipment may require chilled water
- Body showers required in some areas
- Chemical showers required in some lab types
- Emergency showers & emergency eyewash units required
- A vacuum system may be required for some equipment and processes

Unique features

- Piping materials need to withstand decontamination
- Drainage piping may have to be resistant to many types of chemicals
- Chemical use may necessitate a neutralization system
- Drainage piping may be subject to steam decontamination
- Some services may require backflow prevention where crossing through containment barriers
- Plumbing vents may require HEPA filters where crossing through containment barriers
- Piping may need to be exposed for inspection
- Plumbing traps may be deeper due to pressure differences between labs and other spaces
- Vacuum lines need to be protected with HEPA filters for some lab types

Slide 47



Lecture

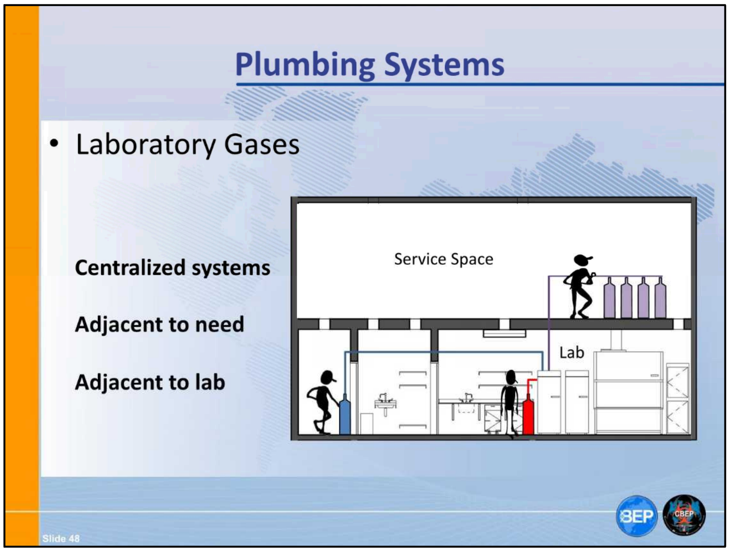
One unique requirement found in a wide variety of lab types is the need for purified water which may be created through a deionization (DI) process or through reverse osmosis (RO). An important question to ask the lab users is the type of water they need, how much they need, and where they need it. Depending upon the answers to these questions this water can be provided by a centralized system, a point of use system installed adjacent the lab sink, or it can even be carried in from a system located outside the lab area. There are pros and cons to each approach which need to be discussed with the buildings operators as well as the users.

Centralized systems usually need to recirculate and in some cases you won't want to recirculate water in and out of the lab so you will end up designing a system with a 'dead leg' a portion of piping that drops down from a recirculating loop above. The users will then run the water to clear out the dead leg and get to the fresh supply. This approach may waste water, but may save resources in other ways.

A point of use system can be very efficient as it just takes the regular water piped to the sink and treats it as needed right in the lab. The downside to this is you may end up with multiple systems to maintain. And there may be some types of labs where you don't want maintenance personnel to enter the lab to change filters on the system.

A central dispensing location can be a good approach if the volume of need is not great but this puts an extra burden on the lab users.

Slide 48



Lecture

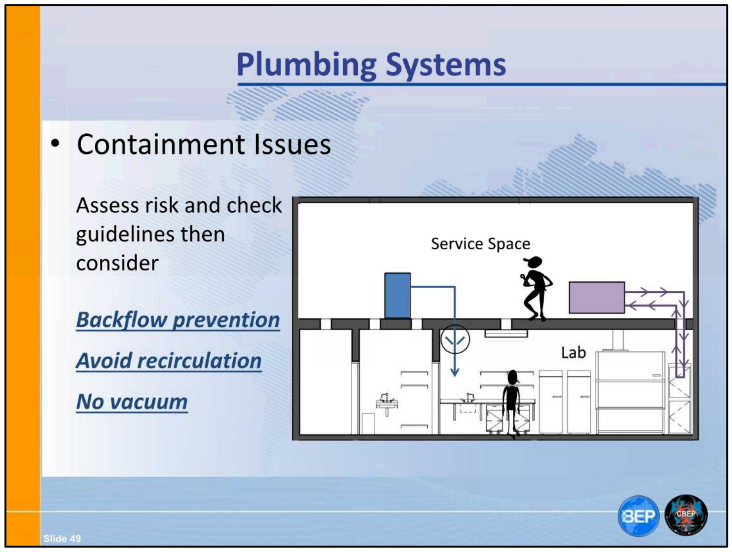
There are similar options for delivering laboratory gases. A centralized set of tanks can provide a reliable supply to multiple locations.   A series of tanks can be connected through a manifold in such a way that one tank running out does not cause the supply to any lab to diminish. Tanks can be replaced in a location outside the lab so user's work is never disrupted.

For gases that are only required in a few locations it may be more economical to locate the tanks directly adjacent to where the gases are being used. The type and volume of gas being used needs to be assessed from a safety perspective. In some cases a gas cabinet may be required and in other cases you may find that it is safest to keep the tanks outside the lab.

In containment areas you may need to keep the tanks outside the lab to avoid the issue of how tanks would be decontaminated and removed from the lab once they are empty. Even if the surface can be safely cleaned the gas suppliers may be hesitant about refilling the tank if they don't have certainty that no contaminants have gotten inside.

A good solution can be to locate the required tanks in a small closet directly adjacent the lab. This approach can minimize piping while avoiding safety and containment problems that may come with placing the tanks inside a lab.

Slide 49



Lecture

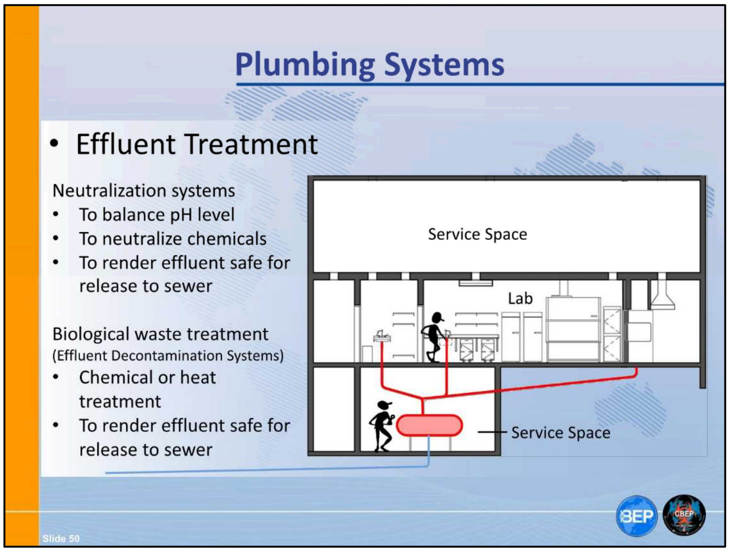
In higher containment labs it may be necessary to provide all plumbing lines with backflow prevention devices. This is to protect against contaminants escaping via the piping system should the service flow become reversed or the pipes become empty as the result of some type of failure.

In higher containment labs you may also wish to avoid the installation of any system that requires a recirculating loop that goes into then out of the lab. While these systems often operate with a 'closed loop' there is still risk involved with purposefully drawing liquid out of a lab that may be contaminated. This may be specially treated water, chilled water or some type of coolant.

Similarly in higher containment labs you may wish to avoid utilizing vacuum systems.

In any case referring to the applicable guidelines and discussing the risks with your client is essential.

Slide 50



Lecture

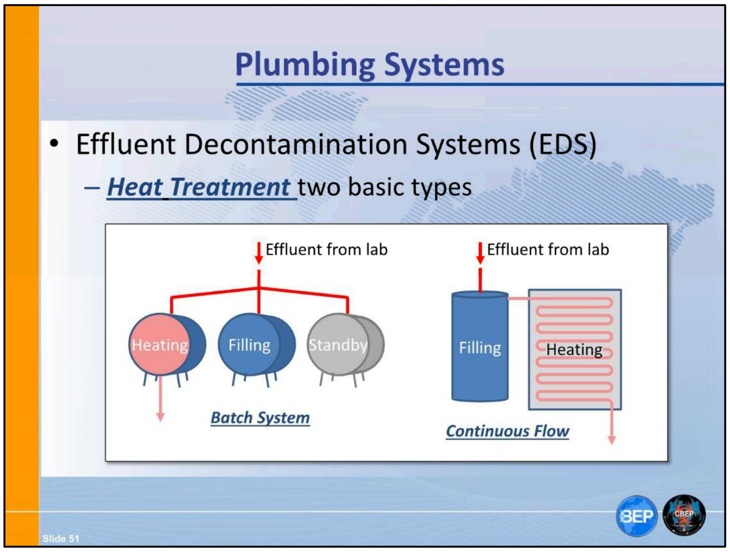
Treatment of the waste water coming out of the lab area, from sinks, floor drains, showers and equipment always requires careful consideration. It is often critical to discuss the project with local authorities to ensure that the effluent leaving the lab will not put undue strain on the local sewage treatment plant.

Treatment of effluent may be required to balance the pH level, to neutralize chemicals or to decontaminate biological materials. In every case the goal is to render the waste from the lab safe for release to the sanitary sewer system.

Biological waste treatment can be done via chemical treatment or heat treatment. Many labs operate without an effluent decontamination system by having users chemically disinfect liquids right in the lab sink, prior to releasing this material to the drain.

Chemical treatment can be done in a large tank outside the lab, however often heat treatment is preferred. If there are likely to be any solid infectious materials (such as animal waste) in the liquid then a heat treatment process is a much better approach.

Slide 51



Lecture

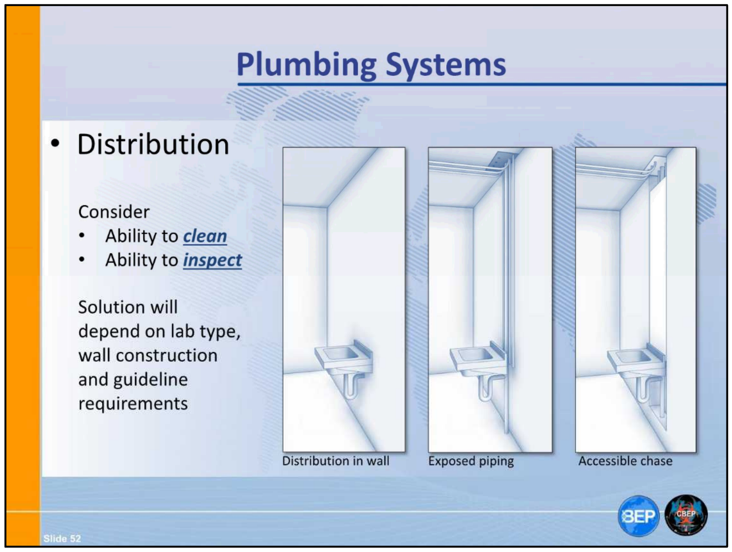
Effluent decontamination systems using heat to sterilize biological contaminants come in two basic types; batch systems and continuous flow systems.

Batch systems are often comprised of multiple tanks. During the operation of a batch system you would find one tank already filled and heating the effluent for a prescribed time and temperature, another tank collecting the waste currently flowing out of the lab, and perhaps a third tank standing by to be used if the second tank is full before the first is finished its sterilization process. The standby tank may also be utilized to allow continued operations while one tank is undergoing maintenance work or repairs.

A heat treatment system can be operated with two tanks, or even just one, (filling during the day and cooking overnight) however this will require coordination with the users and operators.

The other type of system utilized is a flow through system. This type of system is usually comprised of a filling tank, and a long heated pipe system which sterilizes the liquid as it flows through. The filling tank is required to ensure a steady flow through the heating system. This type of system can be very effective but is not so good if there will be solids in the effluent.

Slide 52



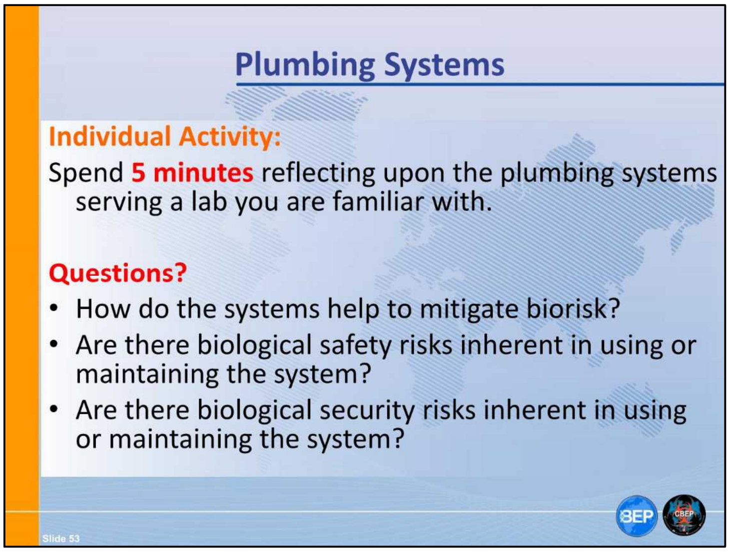
Lecture

Piping distribution in the labs should be considered with respect to the ability to keep the lab clean and the ability to maintain and inspect piping systems.

With some types of labs, and with some types of walls it may be perfectly acceptable to bury the piping within the walls, in other cases you may need to run the piping exposed, or organize pipes into accessible wall chases to allow for maintenance access. Consulting the appropriate guidelines for the type of lab you are constructing, and discussing this with those who will maintain the labs is necessary to determine the best solution.

Pipe surfaces can collect dirt and potential create difficult to clean areas that could harbor infectious agents so the need for access should be balanced with a consideration of how the lab will be cleaned and decontaminated.

Slide 53



Take a few minutes now to think about a laboratory building you are familiar with.

Think about how the plumbing system helps, or maybe how it should help, to mitigate biorisk. Are there inherent safety or security risks, or inherent benefits that come along with that particular system?

Note to instructor – It may be best to allow the students quiet contemplation time for these questions, however you may wish to have class discuss these questions in plenary depending upon available time and the level of understanding the class may have. If necessary you may also wish to give the students some relatively standard answers to the questions such as:

Plumbing systems mitigate biorisk by:

- Treating contaminated effluent.

Biosafety risks in inherent in using and maintaining the system may be:

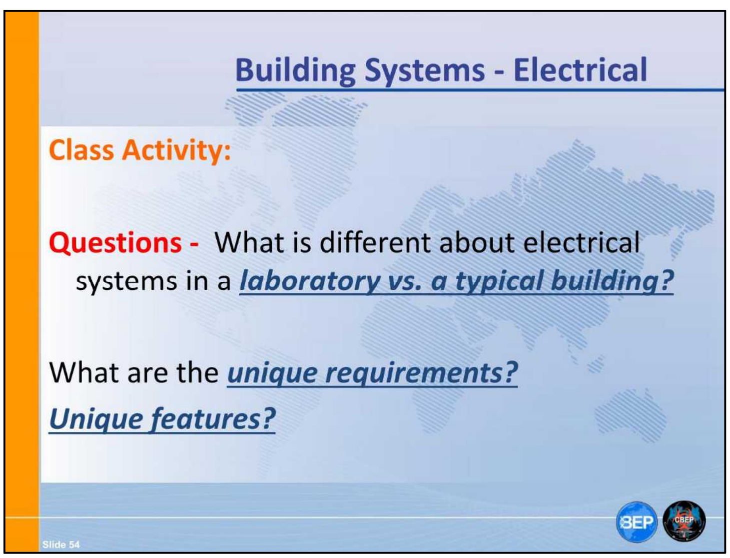
- Contaminated piping may leak, creating a contamination risk in service areas or spaces below the labs.
- If pumps are required in the contaminated waste stream there can be a risk of contaminants being aerosolized.
- If piping is interconnected between high and low risk areas there may be a potential that contaminated effluent backs up into a low risk or non lab area.
- Piping penetrations can be source of air leakage between labs or between labs and non-lab areas.

Biosecurity risks might include:

- Service personnel may create a security breach, particularly if the systems cannot be maintained by the institutes own maintenance team.
- Laboratory gas systems could be damaged to create risks to the building occupants.

Transition to Electrical Systems

Slide 54



In plenary ask students the questions on the slide.

What is different about the electrical systems in a laboratory versus a typical building?

What are the unique requirements and the unique features?

Record the student's answers on a flip chart.

Expected Responses

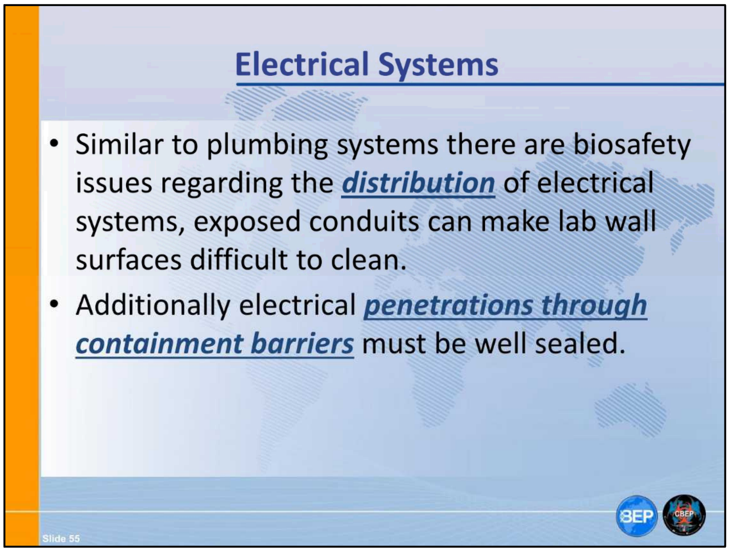
Unique Electrical requirements

- High power levels required to support mechanical equipment
- Brighter, more intense light levels for labs vs. typical functions
- Large freezers and other equipment that require substantial power
- Lots of equipment that needs backup power (freezers, biosafety cabinets, air handling equipment)
- Emergency systems have to work for longer than other building types, need to operate with sufficient time for cleaning up infectious materials and leaving the lab utilizing safe protocols, maybe showering
- Significant amount of electronic access controls, cameras, monitors
- Diurnal lighting for animal rooms

Unique features

- Backup power systems, emergency generators, UPS systems
- Special lighting controls for animal areas
- Protective covers on outlets in animal areas subject to wash down

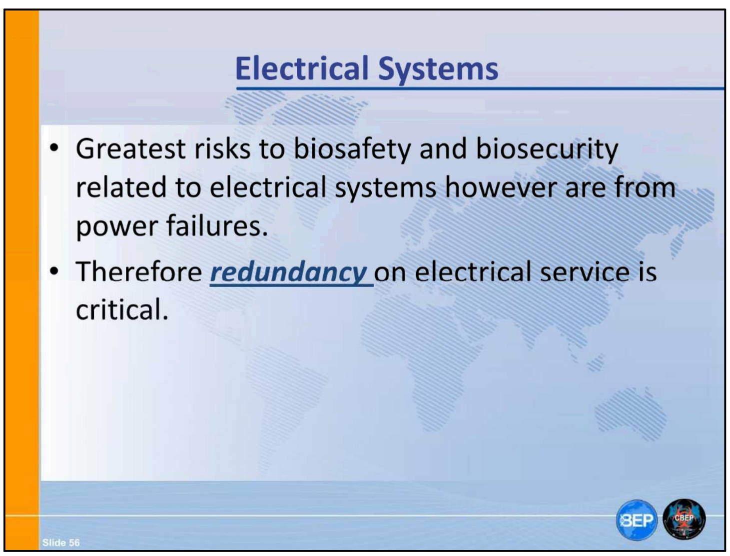
Slide 55



Lecture

Read Slide

Slide 56



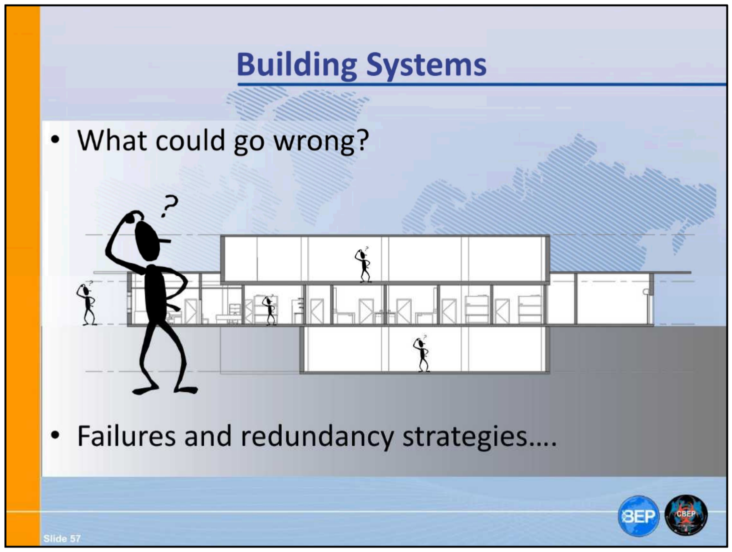
Lecture

While there are some biocontainment risks associated with how electrical services are distributed and how outlets and lights are detailed, the greatest risks to biosafety and biosecurity related to electrical systems have to do with the potential for power services to fail.

So the electrical systems make a nice transition to our next topic which is systems redundancy.

Transition to Systems Redundancy

Slide 57

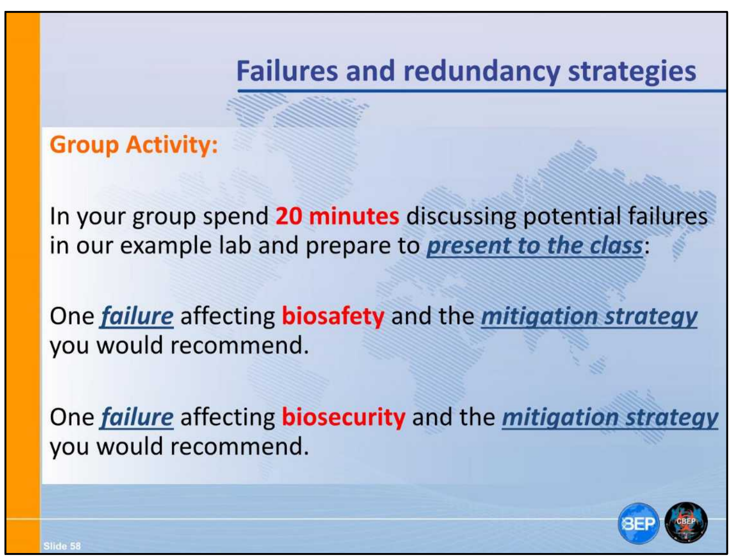


Lecture

Our next exercise will be to think about what could possibly go wrong in the example lab we have been reviewing.

Group Activity 3 – Redundancy Strategies

Slide 58



Small group activity 3 (20 minutes plus 10 minutes presentation).

Activity Instructions (to students)

1. Think about all of the systems we have discussed today, structural, architectural, mechanical, plumbing and electrical.
2. Think about how these systems support the biosafety and biosecurity needs of the building.
3. Then try to think about all the things that go wrong.
4. As a group you should choose one failure issue which would compromise biosafety and one which would compromise biosecurity and discuss the possible ways you could mitigate the risks of these failures.

You have 20 minutes to complete this activity.

Directions for Instructor:

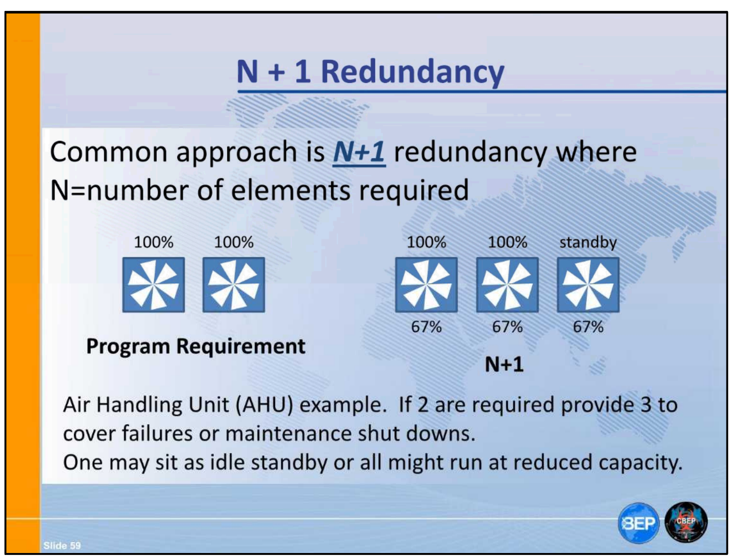
- Ensure students are discussing mitigation strategies as well as failures.
- Encourage students to be original in their thinking particularly if you notice two groups examining the same potential failure.
- After 20 minutes have the groups present their thoughts to the class.
- The students may use their flip charts for the presentation portion or just describe their ideas verbally.

Expected Responses

Possible Failures and mitigation strategies might include:

- Power failure – mitigate by providing UPS system and diesel or natural gas powered generator. This could affect both biosafety and biosecurity. Challenge to biosafety is to maintain directional airflow if fans lose power, challenge to biosecurity is to maintain control of biological agents and toxins without electronic security devices.
- Failure of supply air handling unit or exhaust fan. Losing directional airflow to labs would compromise biosafety. Mitigation strategy could be to provide extra units in an N+1 arrangement.
- Failure of structural columns due to explosion or attack. Mitigation strategies could be is to provide hardening for the structure, to keep vehicles and other items that could carry large amounts of explosives away from the structure or to design the structure to avoid progressive collapse.
- Leak in effluent decontamination system. Mitigation strategy could be to provide secondary containment in the space containing the EDS equipment.
- Leak in biocontainment barrier. Mitigation strategies could be to provide periodic checks of the barrier, to provide alarms when airflow is affected.

Slide 59

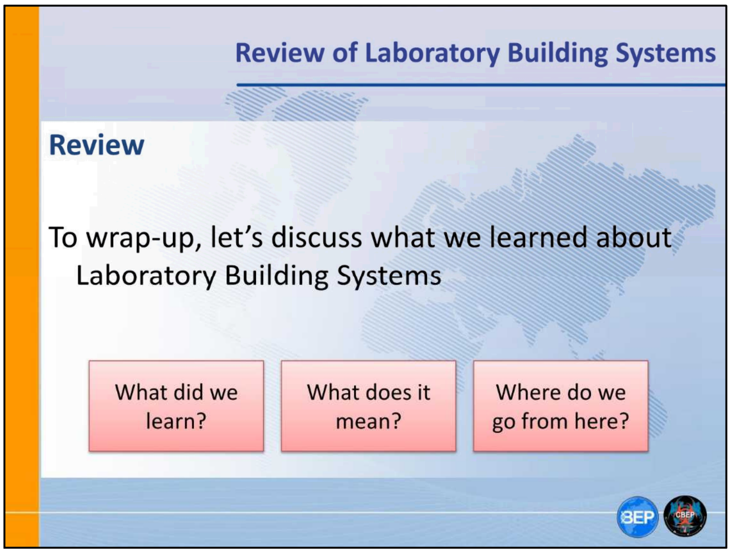


Lecture

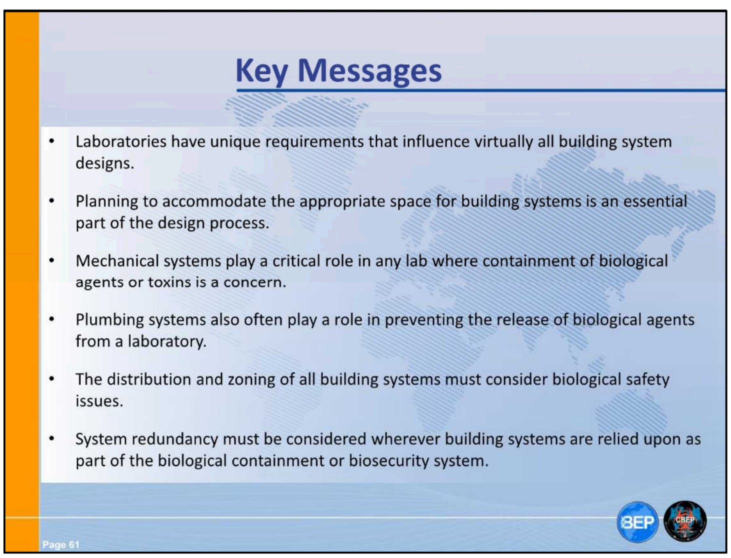
Read slide

Transition to Review and Wrap up

Slide 60



Slide 61

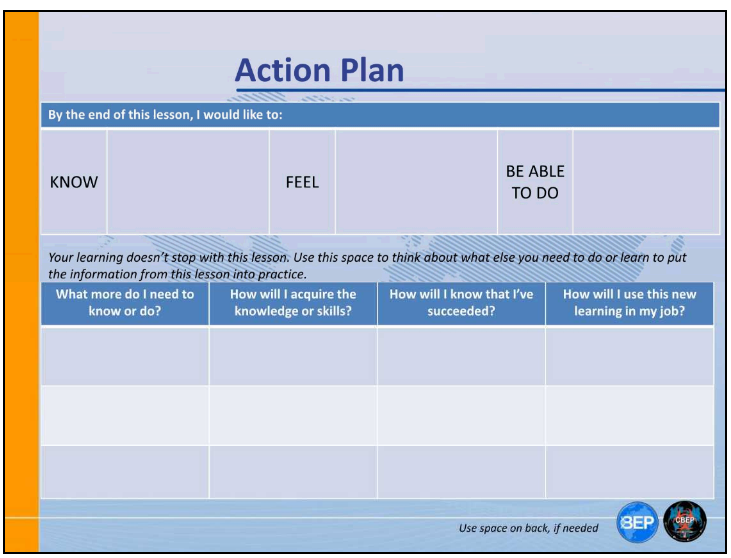


Review Key Messages

Include discussion on how activities/examples relate to the Key Messages of the course and how the messages can be applied.

1. Laboratories have unique requirements that influence virtually all building system designs.
2. Planning to accommodate the appropriate space for building systems is an essential part of the design process.
3. Mechanical systems play a critical role in any lab where containment of biological agents or toxins is a concern.
4. Plumbing systems also often play a role in preventing the release of biological agents from a laboratory.
5. The distribution and zoning of all building systems must consider biological safety issues.
6. System redundancy must be considered wherever building systems are relied upon as part of the biological containment or biosecurity system.

Slide 62



Ask students to spend a few minutes reviewing and completing their action plan.

Slide 63

Level 1 Evaluation

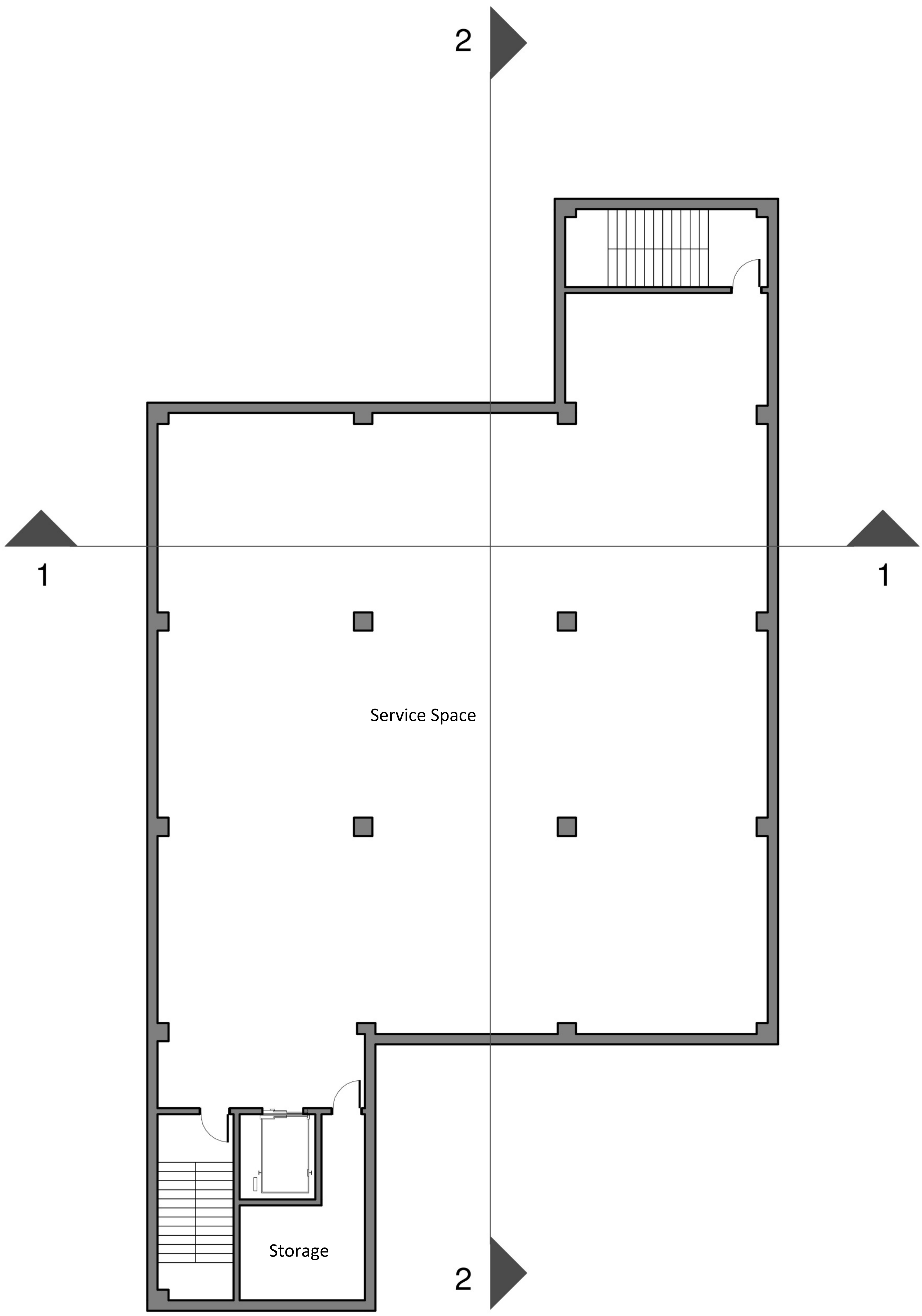
- Ask students to complete the course evaluation and to put it in the evaluation box (alternately, give students instructions for completing the evaluation on-line).

Laboratory scenarios for student Group Activity 1

Laboratory A is an animal disease diagnostics facility. This laboratory receives a variety of diagnostic samples which may range from fecal matter, blood, tissue and in some cases full carcasses of small animals. The laboratory tests these samples for a wide range of diseases and in many cases is working to determine the cause of illness or death of animals found in the wild. Many of the diseases this lab works with are dangerous to animals only, however some are zoonotic diseases, which pose a risk of serious disease in both animals and humans. Users in this laboratory change out of their street clothes and don lab greens in a general change area, then enter the lab via an ante room where they put on disposable coveralls, positive pressure respirators, gloves and shoes dedicated to the laboratory. Upon exiting the lab all personnel protective equipment is removed and disposed of except the respirator which is wiped down with disinfectant and stored in the ante room for re-use. All waste leaving this lab is removed via a pass through sterilizer connected directly to the laboratory.

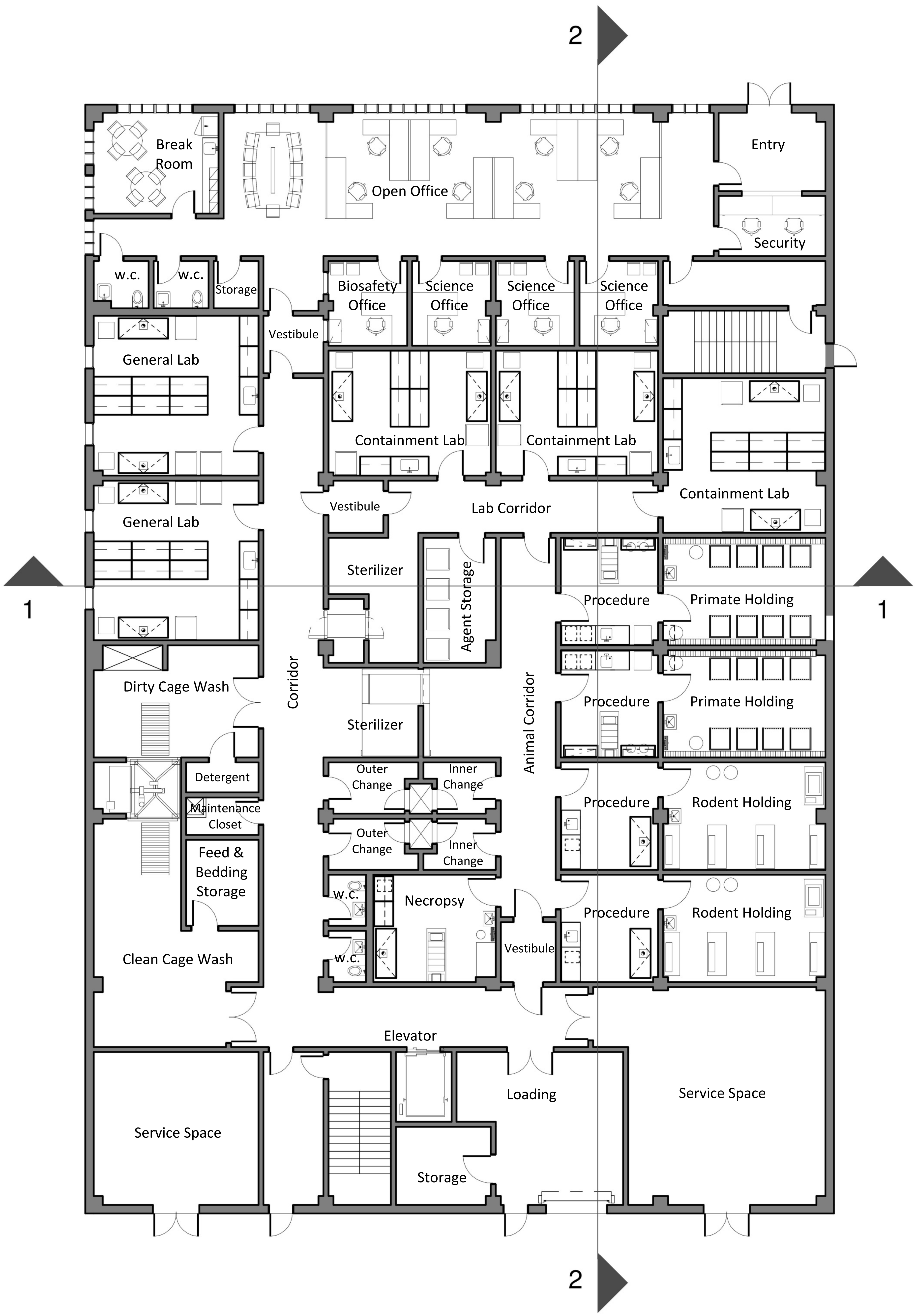
Laboratory B is a diagnostics lab. The laboratory receives well packaged blood samples from a nearby hospital and tests these for a list of known diseases. Samples are examined inside biosafety cabinets. Lab users wear laboratory coats over their street clothes, disposable gloves and N-95 respiratory protection when working at the biosafety cabinets. Lab users remove their lab coats and disposable gloves at the laboratory exit and wash their hands prior to exiting. All waste from the labs is sterilized in a common use sterilizer outside of the laboratory prior to removal from the facility.

Laboratory C is a large animal vaccine testing laboratory. This lab houses large animals, usually cattle held in open air pens within the animal holding room. The animals have been vaccinated then exposed to a known disease and are held and tested to determine the efficacy of the vaccine. The disease in question poses no threat to humans but is of very high consequence to livestock. Users wear gloves, boots, re-usable coveralls and enter and leave the lab via a change room with shower. All waste removed from the room is taken out via a dirty corridor to a common use sterilizer.



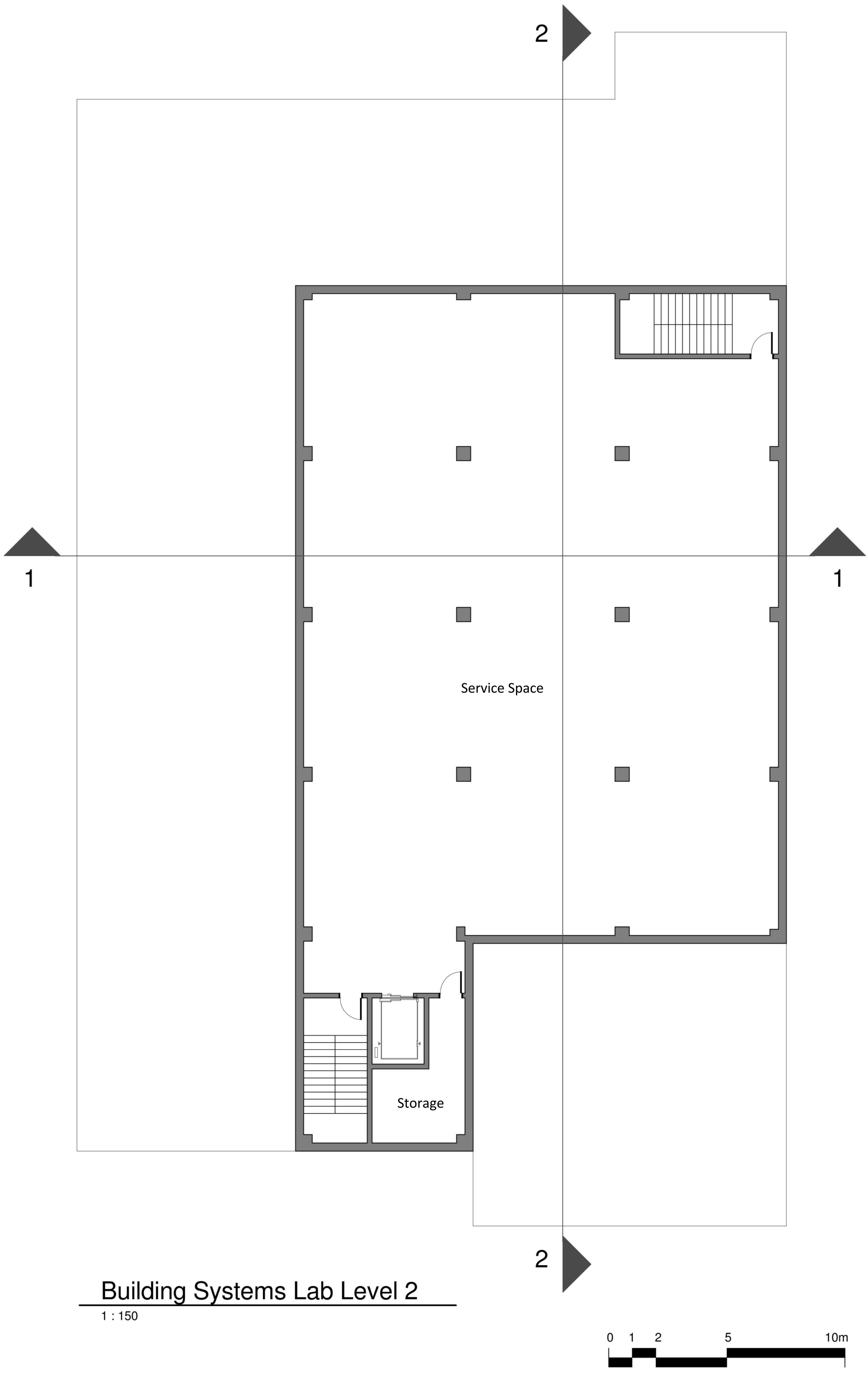
Building Systems Lab Level 0

1 : 150



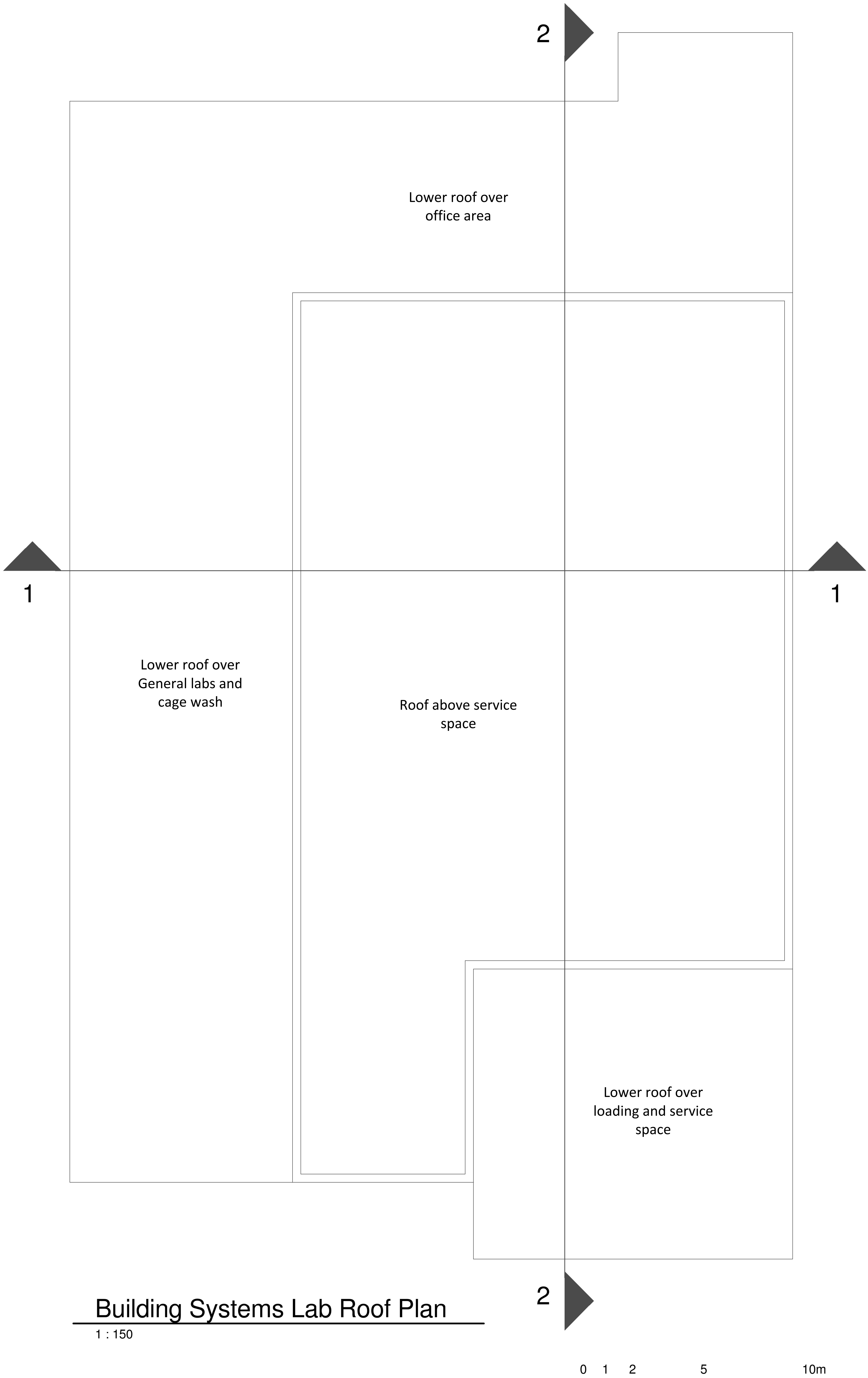
Building Systems Lab Level 1

1 : 150



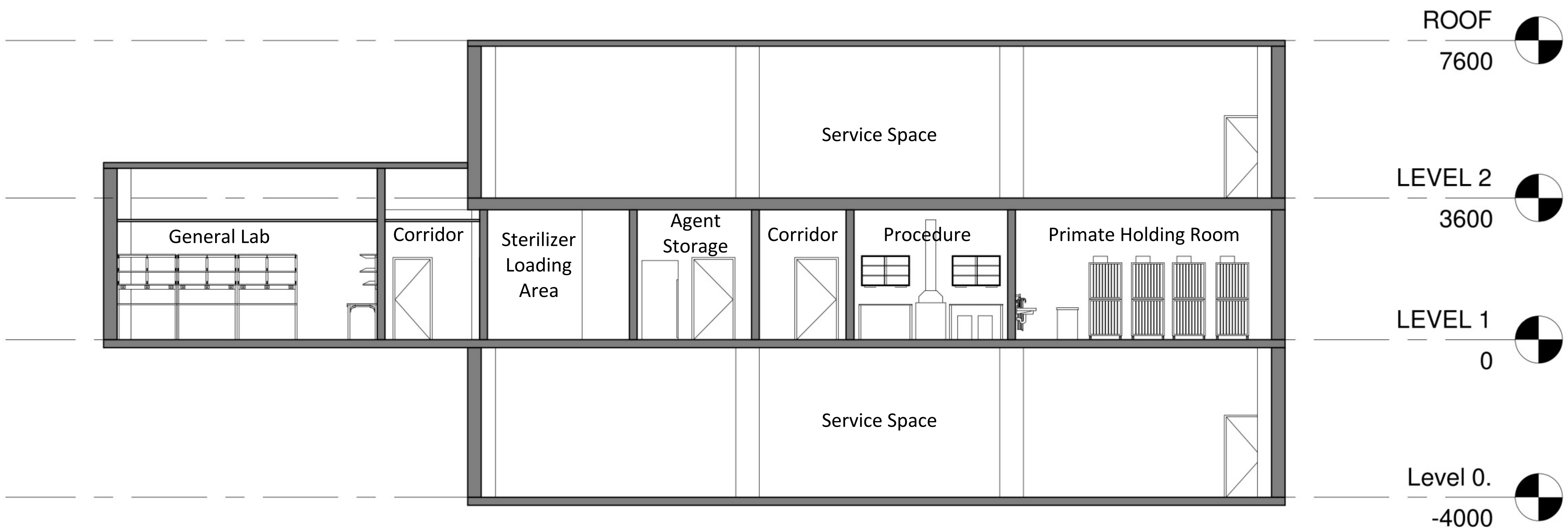
Building Systems Lab Level 2

1 : 150

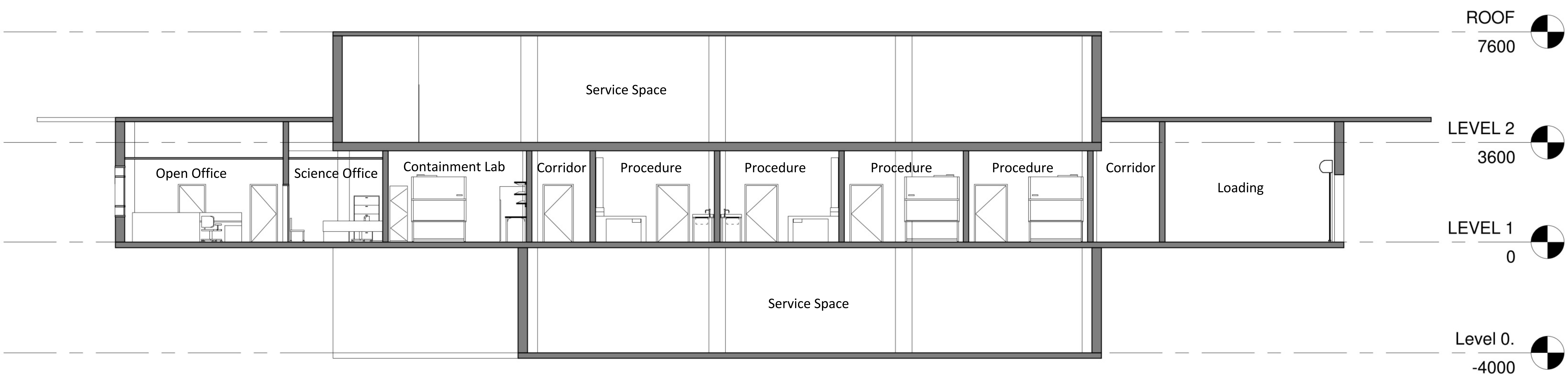


Building Systems Lab Roof Plan

1 : 150

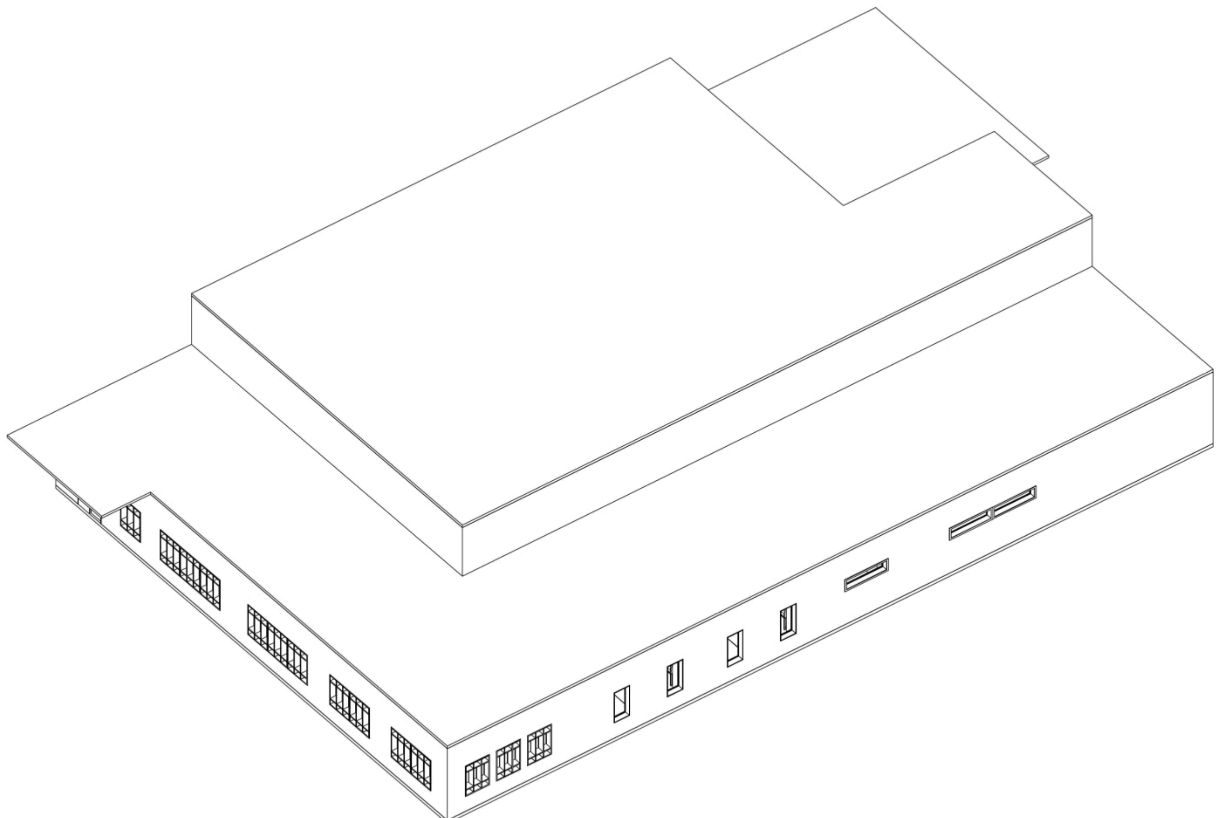


Section 1
1 : 150

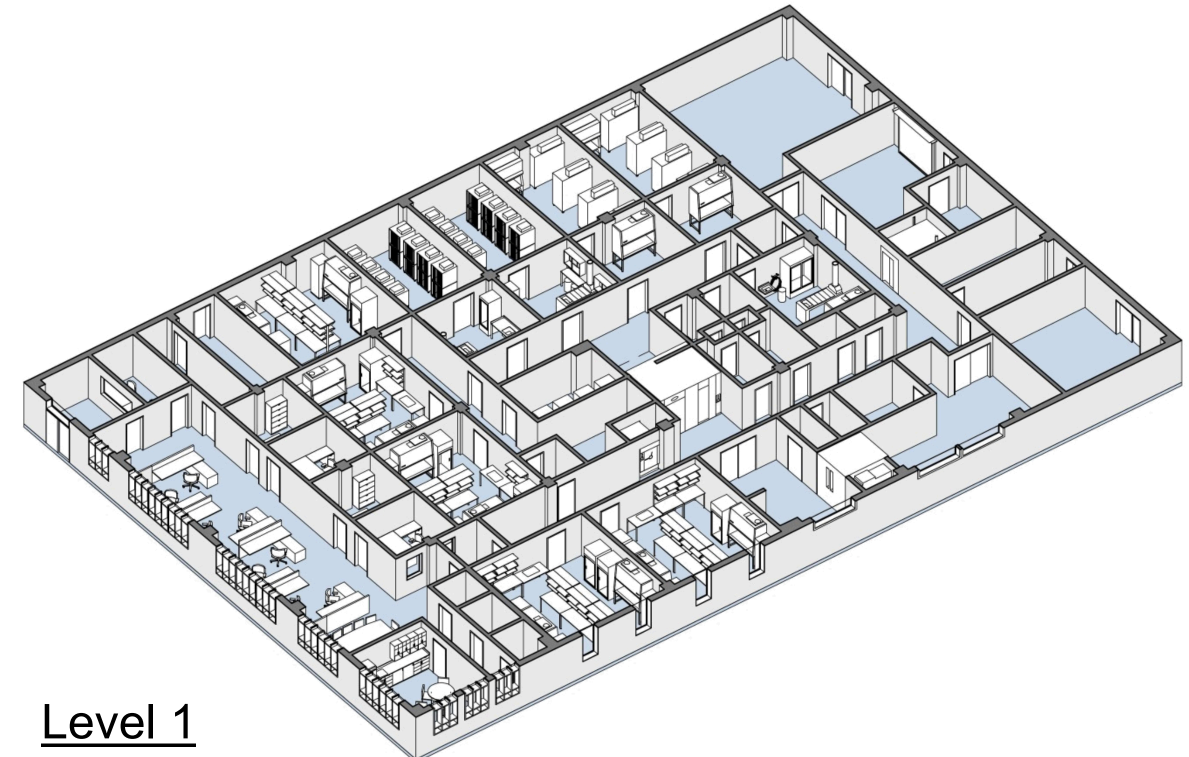


Section 2

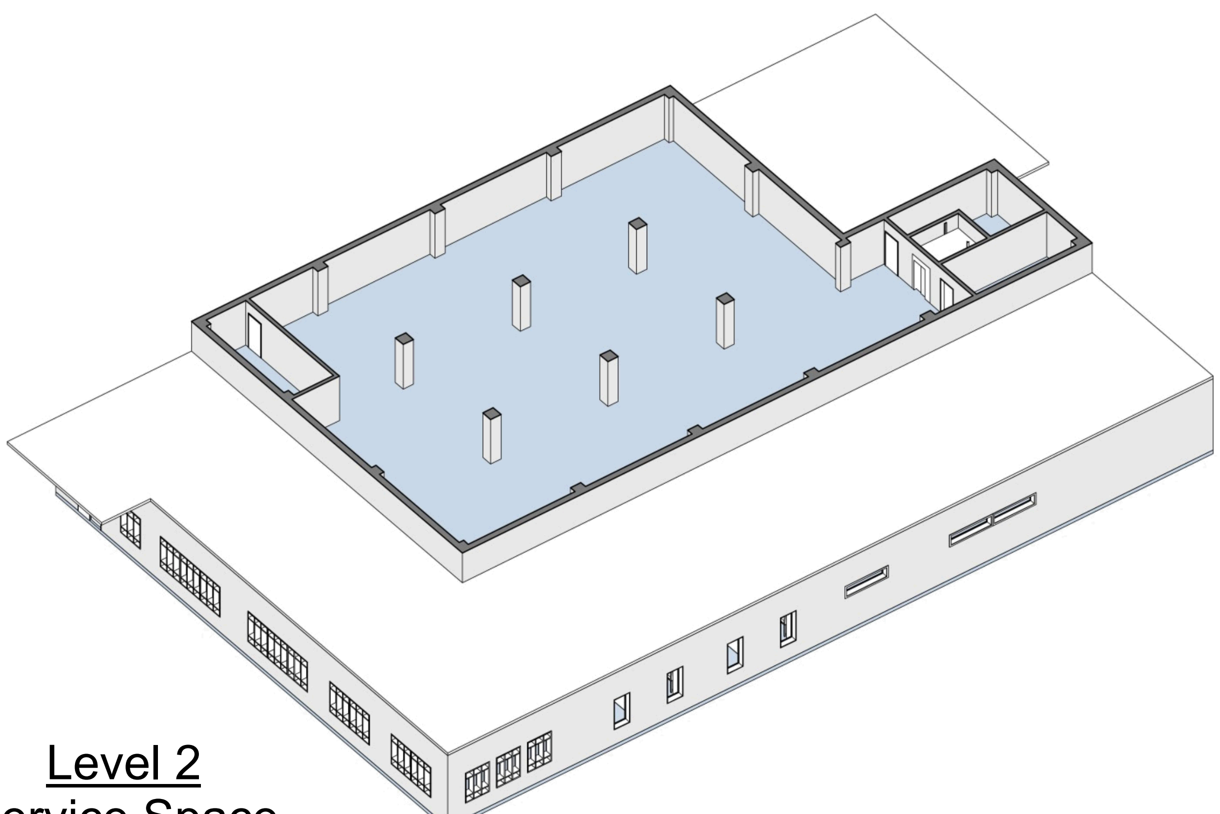
1 : 150



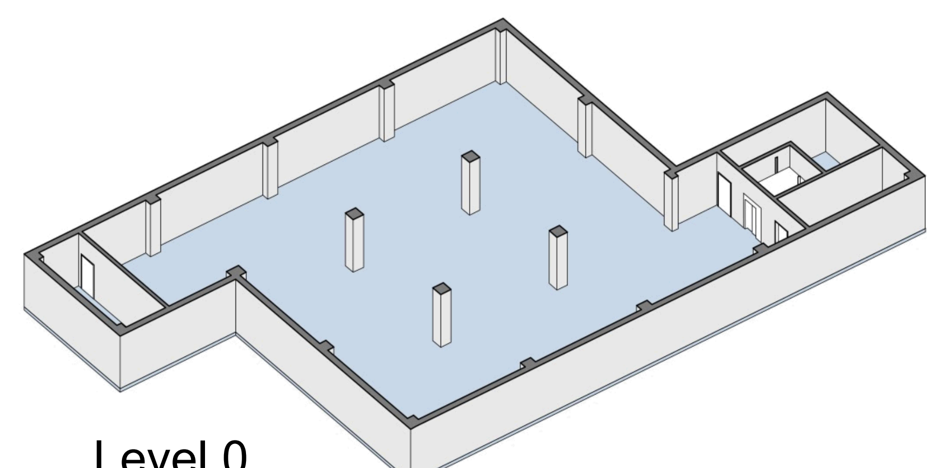
Building Exterior



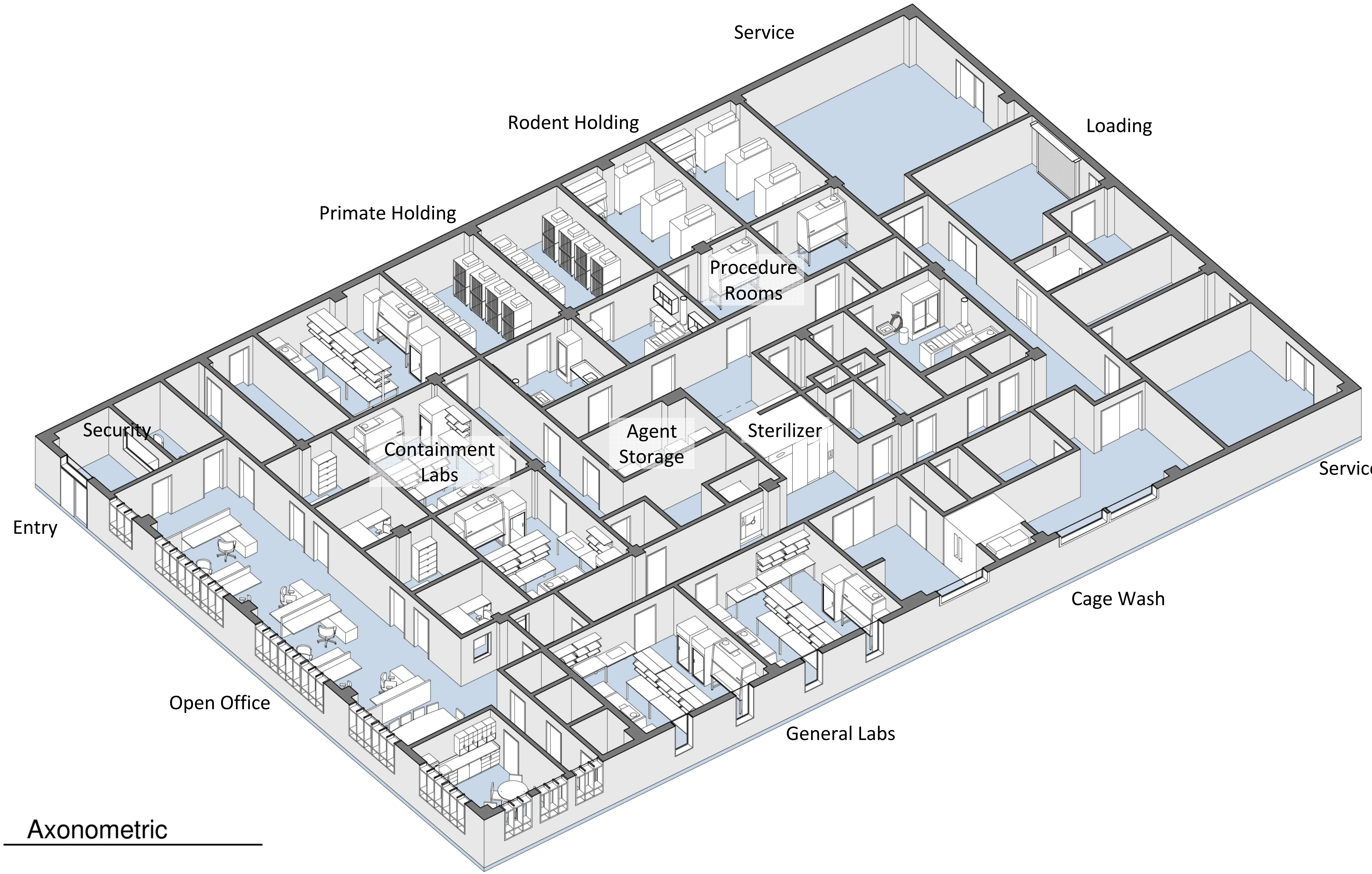
Level 1
Lab & Office Floor



Level 2
Service Space



Level 0
Service Space



Axonometric

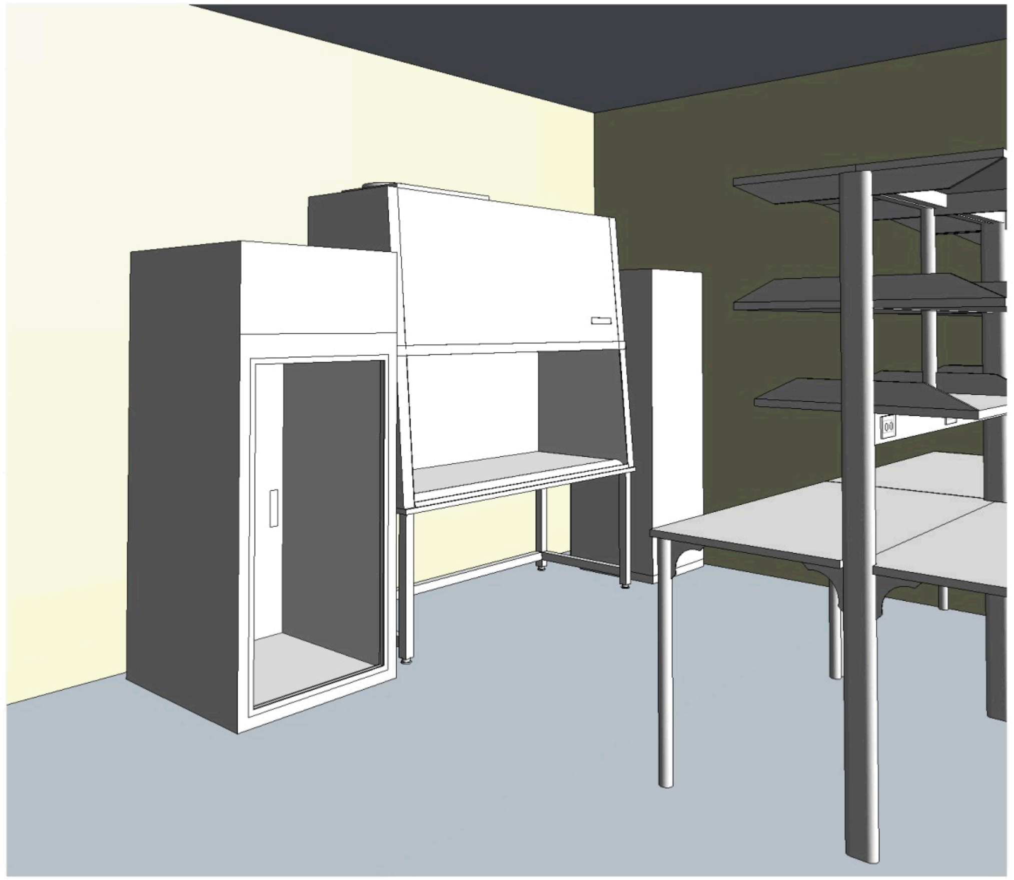

Open Office Area


Break Room

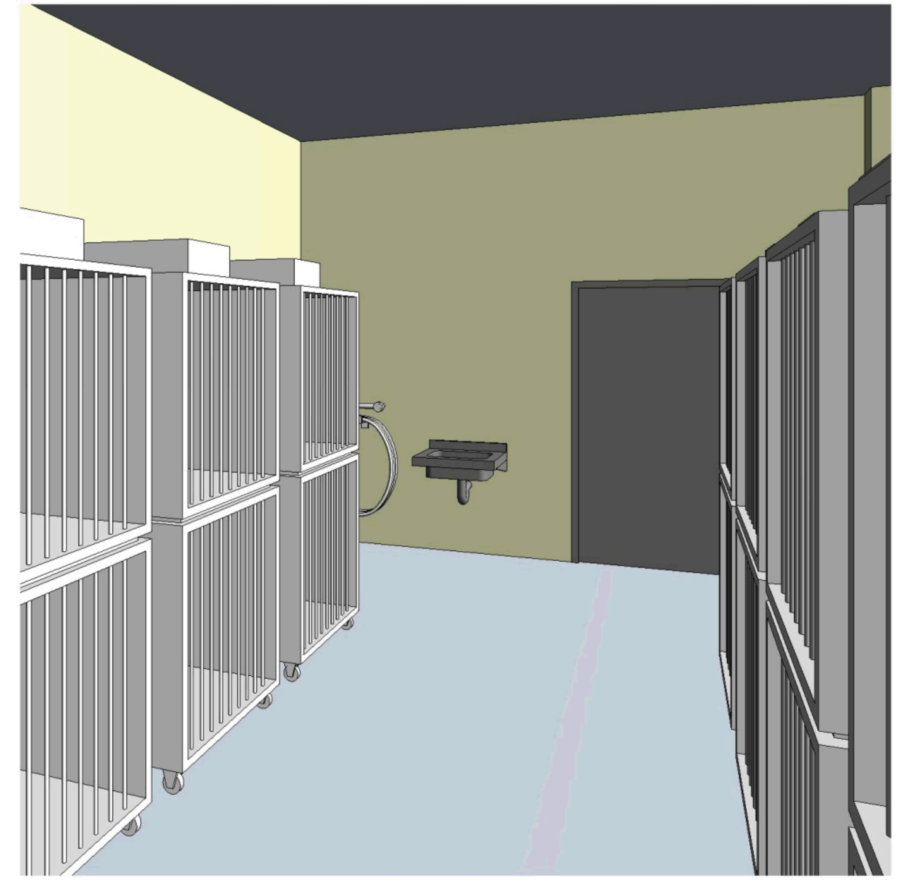

General Laboratory

Interior Views

Interior Views



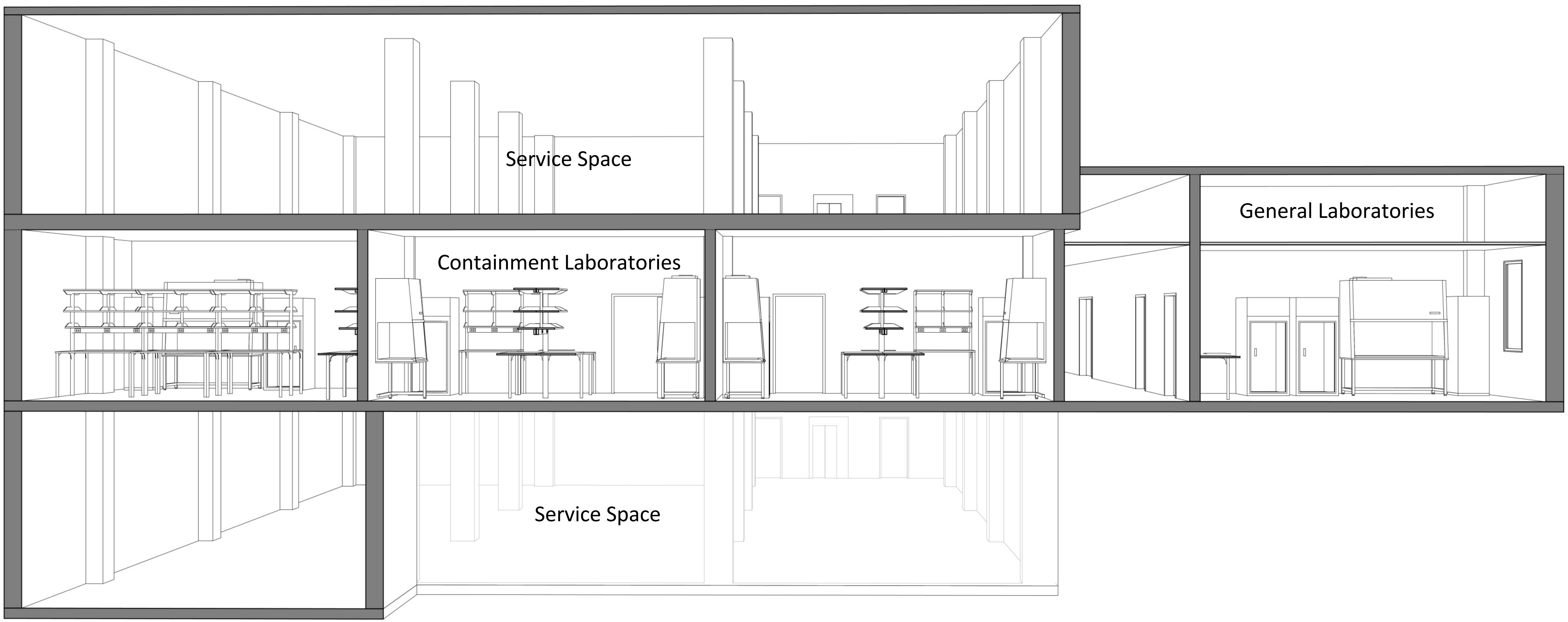
Containment Laboratory



Primate Holding Room

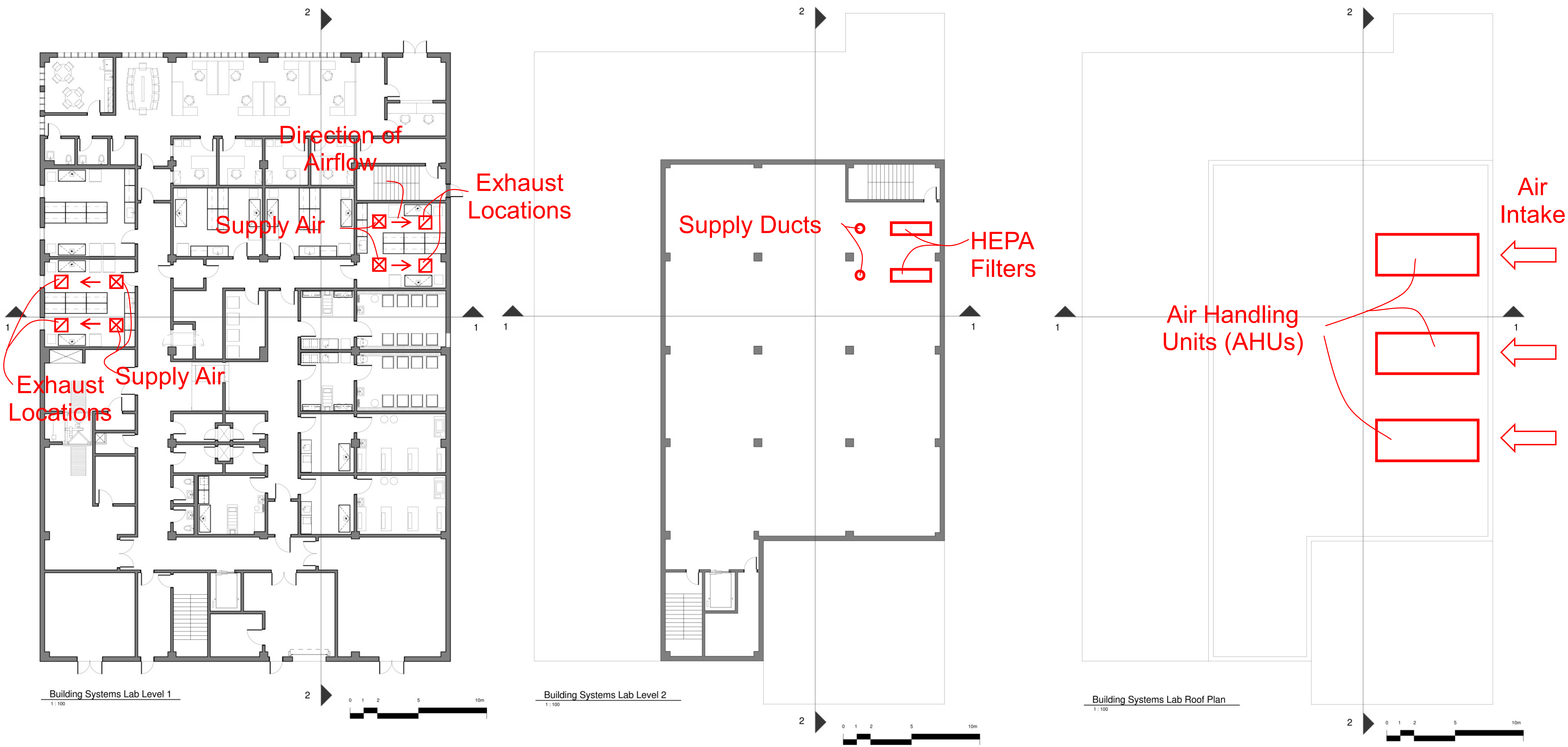
Rodent Holding Room

Cage Wash Area



Section View

Drawing Demonstration Examples for Group Activity 2 – Mechanical concept layout



Drawing Demonstration Examples for Group Activity 2 – Mechanical concept layout