Design Considerations for Healthcare Simulation Facilities

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The number of simulation facilities across the United States and internationally is growing rapidly. The capital investment required can be substantive regardless of size. This article focuses on ways to optimize expenditures and maximize utility. Several key factors will play decisive roles in the successful launch of a new simulation facility. Mission/vision, budget, functional need, and space are partners in determining the final design of the simulation facility. Ideally, the budget is based on the functional requirements and desired capacity; but when this is not the case, of course, the owner must prioritize the needs of the new center. The type of space allocated for the facility is also critical and can seriously impact the budget because renovating a space that is fitted for another purpose versus constructing the center in an open shell space can add considerable cost. A well-balanced design team led by a diligent and knowledgeable project manager who can keep the team focused is integral to the success of designing and constructing a new facility. Users should inform themselves about each of the issues that a design team may consider to ensure that the issues are resolved in a way that meets the needs and vision of the program(s). A simulation facility, such as any education facility, should be built around the concepts of the overall mission, vision, and values of the institution(s) and stakeholder(s). For any new educational facility to be a success, the thoughts, ideas, and creativity of the owner, users, and stakeholders must find its way into the ultimate built environment. The experience base of simulation facility design is fragmented and not standardized. Therefore, we live at a time where the risk of ineffective design is higher than one would like given the costs involved. It behooves the owner to set parameters with the planning and design team that they want a balanced, controlled, collaborative, and inclusive design process.
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The number of simulation facilities across the United States and internationally is growing rapidly. The capital investment required can be substantive regardless of size. This article focuses on ways to optimize expenditures and maximize utility and is based on collectively being involved in over twenty simulation facility designs. There is no current single resource that defines best practice in simulation facility design. The dialog of best practice in simulation facility design is beginning. This article seeks to further the conversation as undoubtedly varying opinions will be published as the field continues to develop. The scope of the article covers the more common forms of simulation facilities being built that have the ability to provide services and infrastructure using simple and complex task/skill trainers, mannequins, standardized patients (SPs), and hybrid simulation. Traditional nursing skills laboratories and advanced surgical training centers using tools such as cadaveric simulation are not addressed.

Several key factors will play decisive roles in the successful launch of a new simulation facility. Mission/vision, budget, functional need, and space are partners in determining the final design of the simulation facility. Ideally, the budget is based on the functional requirements and desired capacity; but when this is not the case, the owner must prioritize the needs of the new center. The type of space allocated for the facility is also critical and can seriously impact the budget because renovating a space that is fitted for another purpose rather than constructing the center in an open shell space can add considerable cost.[1] A well-balanced design team (Table 1) led by a diligent and knowledgeable project manager who can keep the team focused is integral to the success of designing and constructing a new facility. Finally, and likely most importantly, a simulation facility, such as any education facility, should be built around the concepts of the overall mission, vision, and values (Table 2) of the institution(s) and stakeholder(s).[2] These concepts should be defined early and with clarity. Regrettably experience suggests that this is a step that is frequently omitted until late in the process, much to the detriment of the stakeholder. The facility must bring to life the mission and vision of the stakeholder(s). For any new educational facility to be a success, the thoughts, ideas, and

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Table 1. Suggested Design Team Members and Function*†

Member	Partial Functional Description
Architect	Provides architectural consultation, expertise, and design. The architect works with the various project groups to lead the project from conceptual planning and design, through to construction and eventual completion of the project. They leverage their specific knowledge of design to translate the vision of the stakeholder into actual form, while integrating the various technical details required of such a technologically advanced facility.
Owner representative	This may be a person or group of people who often represent the financial stakeholders of the facility. This representative may be an executive or their designee.
Owner's simulation experts	If the institution is fortunate to have people with simulation proficiency or expertise, then these individuals play a key role in informing the process with respect to the application (simulation) and requirements for successful simulation. They are the subject matter experts (SME) in simulation. They should also (theoretically) ensure that the vision for the facility is properly translated by the design team into function and form.
Simulation design consultants	If meaningful simulation expertise does not exist within the institution, the utilization of a Simulation Design Consultant can help directly impact the planning stages of a project. Simulation Design Consultants can act as surrogates for the role of owner's simulation expert if such expertise does not already exist within the institution. They often bring a wealth of information from a broader context. They should also (theoretically) ensure that the vision for the facility is properly translated by the design team into function and form.
Project manager	This individual keeps things on time and on budget. They should also (theoretically) ensure that the vision for the facility is properly translated by the design team into function and form. The project manager interfaces with most groups and may at times find themselves having to juggle budgetary, time, and stakeholder needs. The project manager can either be someone within the institution's employee resources or they may be a firm selected as a consultant to provide the services of project management.
IT and AV consultants	This may be an in-house or external resource that serves to ensure the proper AV and IT systems are in place to serve the needs of the equipment and the end users. They should also (theoretically) ensure that the vision for the facility, from an AV context, is properly translated by the design team into function and form.
Contractor	Once designs and permits are obtained/issued, the contractor builds the facility. Having the contractor involved early is important to ensure that they are in alignment with some of the unique aspects related to a simulation facility. There are nuances (eg, electrical and plumbing) that veer from common practice in traditional buildings.
Faculty/instructors—user group	This group represents the individuals who have the ability to inform the process with respect to the curricular, political, and quantitative requirements for the facility. These individuals may or may not be simulation instructors but will be those that utilize the space once completed. Their input and participation in the planning and design process are critical to the success of the project.
Facilities management	Depending on the institution, representatives from facilities management are often involved to ensure that the project runs smoothly and follows institutional requirements. They are in essence owner representatives but with particular focus on the process, project management, and construction. These individuals may replace, or compliment, the project managers noted earlier in this table.

*The descriptions are intended to provide basic context of individual roles. The actual job descriptions are much more complex and will vary by location and project.

†The term stakeholder has not been included in the table as it represents many things and may have different meanings in different institutions and organizational structures. Stakeholders may refer to the actual participant, faculty, and financial decision maker(s), to name a few.

IT, information technology; AV, audiovisual.

creativity of the owner, users, and stakeholders must find its way into the ultimate built environment. It behooves the owner and project manager to set parameters with the planning and design team that they want a balanced, controlled, collaborative, and inclusive design process. The members of the design team have both overlapping and defined roles (Table 1). Members of the design team are diverse and will vary by project. Although roles are usually clearly defined, they may change at different times in the project process. Ground rules and proper management are important for the team. This includes what the accepted process is, what the expected communication channels are, and understanding how decisions are made. A sample abbreviated project time line is illustrated in Figure 1. It is important that stakeholders, simulation experts, and users note that space programming and schematic design phases are the most important time to impact the project. Subsequent to these phases, design teams are more focused on refining a vision as developed in the early stages of the project.

Table 2. Mission and Vision Statement Description

Mission statement	A brief description of the facilities' purpose that answers the question "what do we do and why do we exist?"
	Articulates the purpose both for those internal and external to the organization
Vision statement	A statement that answers the question: "where do we want to go?" or "what do we want to look like moving forward?"
	It sets the direction of where an organization may want to go. It does not say how an institution/facility is going to get there

DESIGN MEETS FUNCTION

A simulation environment is built to accommodate the needs of its program(s) and learners. The temptation in simulation—especially mannequin-based simulation—is to replicate the clinical environment. The notion of a physical virtual hospital (not screen or image based) is appealing and hard to resist. However, the hospital and clinical environment are designed for the primary purpose of serving patients, and education is at best a secondary and more likely a tertiary objective. The primary objective of simulation, on the other hand, is education; and therefore, replicating the clinical environment does not necessarily produce a facility conducive for education.[3–5] Successful simulation environments find ways to integrate three different space types: clinical environments, educational environments, and theatrical environments (front stage and back stage concept). It is at the

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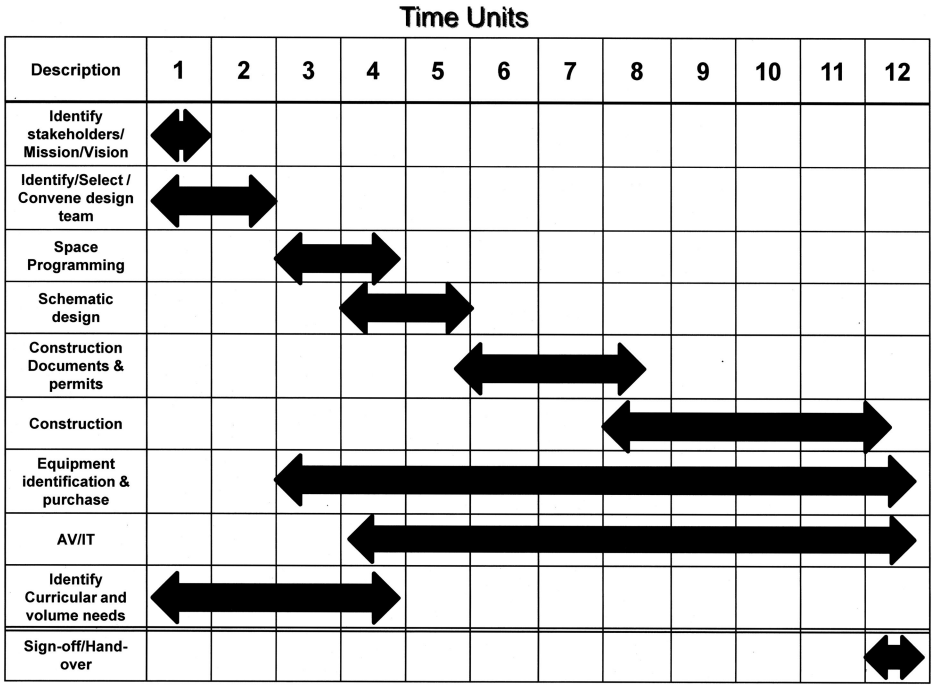

Figure 1. Sample project time line.

intersection of these environments that we likely find the most successful learning spaces.

With this in mind we must ask "does a physical virtual environment meet the functional requirements of the simulation program(s)." To answer this it must be acknowledged that simulation's primary and core objective is educational (summative or formative).[3,4] To achieve an optimal setting for simulation training, the facility must:

- Replicate the clinical environment sufficiently to meet the educational objectives.
- Have the control infrastructure needed to support and run the simulations.
- Be flexible in design to accommodate the myriad of possible situations/environments.
- Allow participants to focus on specific educational objectives. (Mixing classes with different objectives is a substantive educational distracter in most cases.)
- Ensure that participant flow patterns in the facility accommodate the demands of the methodology being used.

Before design can really occur in a meaningful way, the user must identify specific program needs. For example,

- How do you expect to use the space and how often?
- How many people do you expect to use the space in a given time period?
- What, if any, are the special needs that should be met for the desired activities?
- Are there any regulations governing design to accommodate users with disabilities?
- What type of simulation and equipment is most likely to be used for specific activities?
- If feedback is to be given: what type and in what format?

To answer these questions, the curricular/educational expectations must be carefully defined during the initial stages of design. An experienced design team will be essential to this process. Furthermore, visiting other simulation facilities, reading texts with facility design chapters, and talking with consultants can be invaluable.

Defining the number of people who will use a space during a given time period is one of the more vexing issues in the design process, but it is very important for determining how much space is needed for the curricular requirements. Similarly, the "maximum capacity" of the space is important. For example, a space used 100% of the time will provide little downtime to accommodate such issues as scheduling changes, repairs, and upgrades.[6] Given the relative lack of published utilization data, facility design teams should determine the realistic target utilization rate for the space. The absolute hours of occupancy this may represent will vary depending on the intended hours of operation of the facility.

Several other pieces of information will be needed as distribution of learning may be asymmetric through the year. For example, it is not atypical for programs to have heavier use in specific months. This has to do with the structure of the overall curriculum. It does cause inefficiencies because there are other months where utilization may be quite low. The key in the calculation, however, is defining the element that is the biggest bottleneck, such as curricular demand, type of simulation, or equipment. As courses are added, the complexity can grow exponentially as we have to consider other factors such as flow, additional amenities needed, and any required flexibility.

ROOM ADJACENCIES, FLOW, AND CONFIGURATIONS

Simulation facilities try to be many things at once: (1) clinical environment; (2) educational environment; and (3) theatrical environment. It is the last item that poses special challenges in design. It is important to consider the notion of the front stage where students and participants experience

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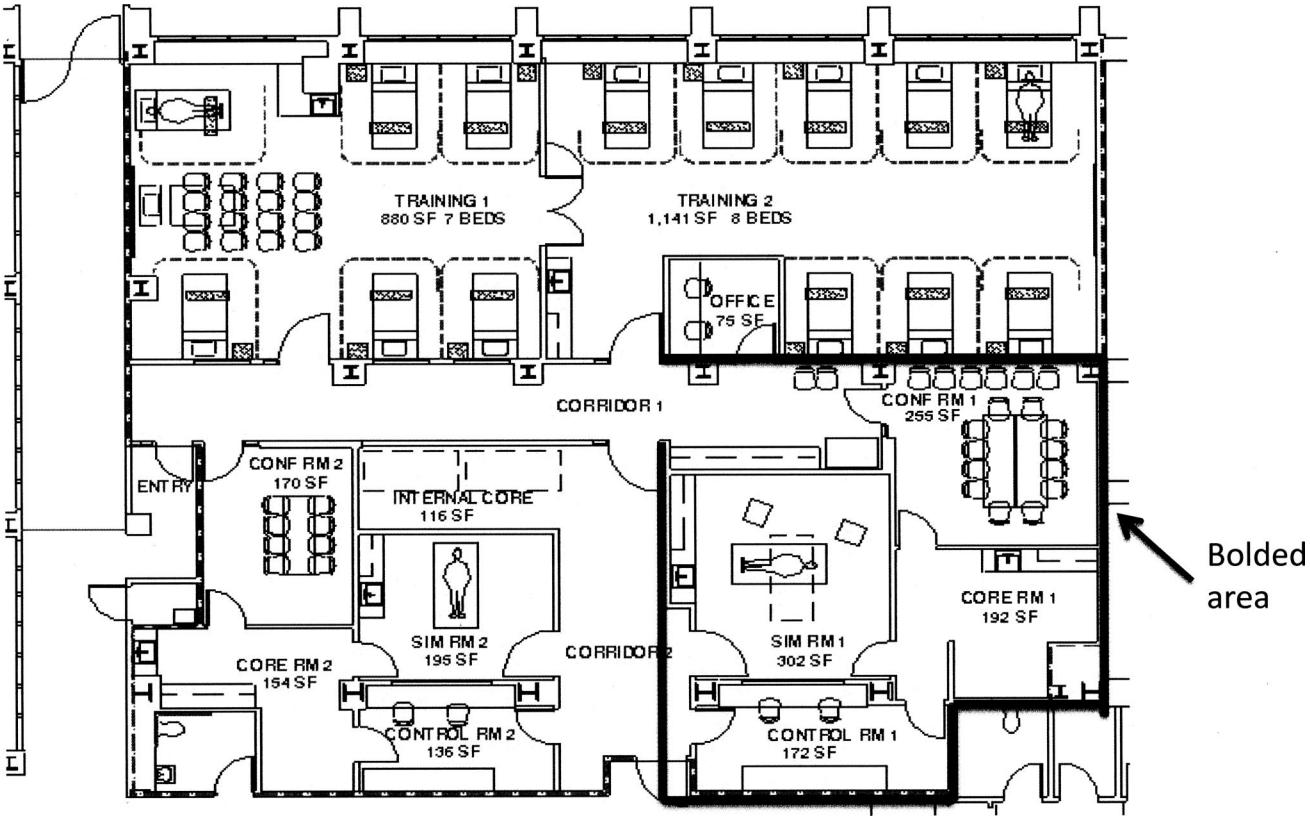

Figure 2. Simulation apartment (in bolded area).

the simulation education and backstage where the staging and preparation of the simulation environment is done. The design of the facility should include these concepts, because there are spaces and rooms that will be used by instructors and staff solely (backstage), versus students (front stage). Because simulation in healthcare has an educational focus, it is important to design room adjacencies, so that participants can learn without distraction from other classes engaged in unrelated activities. The flow of participants, operations personnel, instructors, and staff is also critical. Therefore, the proximity of learning and staging spaces to support areas must be carefully designed with appropriate adjacencies, hallways, and doors.[7–10]

Formats for simulation training can range from a single open-room design to apartments/suites with a clustering of a debrief room, control room, simulation theater, core supply area, and circulation space (Fig. 2). The simulation apartment while providing educational "isolation" may be space consuming. Conceptually, however, it provides design teams with a framework from which to work. Each format has unique challenges that must be addressed to optimize learning.[3,8–10] For example, in the single open-room design, the room should be large enough to allow free flow of students and to accommodate multiple teaching formats including group lecture and station-based training (Fig. 2, training room 1 or 2). Adequate sound treatments must also be installed to optimize sound delivery and capture, while minimizing unwanted sound transmission and reverberation. In the compartmentalized apartment design, free access between rooms for participants and for faculty and staff is a primary consideration.

ROOM TYPES

There are many forms of simulation. By their very nature, they will have specific requirements. One may, however, apply common questions for each major space (Table 3).

Open Learning Area

The single open-room format can be very appealing because it presents the ultimate in flexibility. Some key design elements are listed in Table 4. These rooms are typically large (900–1500 square feet) and can accommodate 25 to 50 people. They can be set up with stations for multimodal teaching or in a more traditional classroom seating arrangement.[10] The possibilities are considerable. To support the intended activities, the room must be configured with appropriate information technology and electrical infrastructure, which may include audio and video equipment; cameras for high-stakes examinations, distance learning, or for security reasons; and laptops or computers on wheels for computer-based sessions. (For programs that rely on computer-based simulation, a dedicated computer room may be warranted.) Also, because biologic materials may be used in stations (eg, for suture practice), the flooring material should be

Table 3. Examples of Initial Questions

Are there appropriate spatial and acoustical controls/treatments that support learning?
Is the room the appropriate size for its desired function(s)?
Has all the required plumbing (gases and water) been considered?
Is there all the required audiovisual components for optimal capture?
Is there the required information technology infrastructure to run computers, electronic health records, mannequins, and other low voltage systems?
Is there an associated control infrastructure or system for each activity?

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Table 4. Open Area Considerations

Large enough to allow for free flow of students in the class
Adequate sound treatments to allow for multiple groups to work while minimizing sound levels
Flow of students/trainees not associated with the class should be diverted away from the area
Large enough to accommodate multiple teaching formats including group/lecture/station based
Infrastructure to support multiple simulation methodologies

resistant to spills and be easy to clean. If biologic or biohazardous material is used then specific building and regulatory code considerations will need to be considered and addressed because this may have impact not only on flooring but also drainage, ventilation, plumbing, and storage. The code requirements will vary by region and country.

This room format can also be used for virtual reality, task, procedural, and surgical training. The best configuration for these training units depends on the curricular and capacity needs. For example, units can be arranged in rows in the open area or they may be placed along the perimeter of the room with wall-mounted screens, leaving an open center space.

Simulation Theater

In planning the design of a simulation theater, the function and flexibility of the space must be carefully considered. Many people have used the word fidelity in the past but are now shying away from it as it has many crossover implications (do you mean the fidelity of the simulation or the fidelity of the simulator or surrounding equipments/people/space?).[11–13] The room setup and configuration should achieve its front stage objectives of immersing the participant in the learning activity. The trick is to recognize that participants enter into a room with a certain sense of "their own reality." This reality is not the same as the operator's reality. Similar to theater and the movies, we need to provide the participant with sufficient sensory inputs that make cognitive sense to them. Will the space need to simulate an ICU, a labor and delivery suite, an operating room, or an in-patient room, or will it be used to provide training in multiple scenarios? The level of immersion necessary for the participant is another important consideration. For example, how real should a given activity be? Does the headwall need to be identical to that in the hospital? Is functioning oxygen a requirement? Of course, the more specialized the room, the less flexible it becomes; therefore, to optimize use of the space, it is essential to design it according to the percentage of time that it will be used for given training scenarios.

Control Room

The control room is a unique environment that allows the instructor and operator to observe (see and hear) and control a simulation. This is particularly true for mannequin-based simulation. When a facility has more than one simulation room, the ratio of simulation rooms to control rooms becomes an important design factor. As the ratio increases, the complexity of the control room increases, and considerations of flow, noise, and setup in the control room become important. A fundamental issue in the control room is the ability to "see and hear" what is happening in the simulation room.[14–16] The operator and control room occupant have a very different visual need than the learner. They must be able to see what is occurring with sufficient detail to allow for proper operation of the simulation and must be able to gather sufficient meaningful and accurate data (information) to use as part of the education process postscenario. Three different solutions to this challenge are as follows:

1. Use audio-visual equipment only. With this setup, it is not necessary for the control room to be adjacent to the simulation theater. However, this solution can be quite expensive because it requires robust audiovisual (AV) systems that can truly act as the "eyes and ears" of the controller. It also adds complexity because either the operator or someone else must control the cameras. Finally, even advanced AV systems may not give the operator the same "feel" for the room as looking through a window. Although not formally studied within healthcare simulation, there does seem to be an intuitive tangible difference between seeing a series of two-dimensional screen-based images and seeing actual three-dimensional images directly. This is a point of continued controversy, but no simulation-specific study has been published in this area.
2. Use a one-way mirror only. Although this option does give the operator a direct three-dimensional view of the simulation room, the limited angle/line of sight and any obstruction can limit observation. Audio will still be required with this option.
3. Use a combination of solutions 1. and 2. This is the most versatile option and optimizes the view for the operator. Many simulation facilities use this option.

Debrief/Observation/Conference Room

The debrief room is a multipurpose meeting room where instructors can distribute materials and content about a training session and where groups can observe live simulations as well gather to engage in postscenario discussion (debrief). The setup for this room should be conducive to free-flowing group discussion and is typically a central table with chairs. Alternative setups can be accommodated if the room furniture is flexible and moveable. The debrief room should also have the necessary equipment to view simulations (live or recorded) and other presentation materials. Cameras should also be considered to record debriefings and other activities for distance applications and for quality assurance. The ability to transmit and share debrief sessions with remote locations can be a very rich and efficient educational experience. Similarly, the ability for debriefers to have access to recordings of debrief sessions for quality and learning purposes is helpful. The number of debrief rooms is another important consideration and ultimately depends on the format of simulation being used most commonly. If the number of debrief rooms is less than the number of simulation rooms, there may be circumstances when the instructors will conduct debriefings (if needed) in the simulation room. Instructors can be creative by doing debriefs in the simulation rooms themselves or (if the capability exists) streaming video to a remote location beyond the facility. The flexibility gained by having debriefings/observation in a separate room comes at the expense of additional space and infrastructure requirements.

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Storage/Supply

This area is essential for storing consumables, equipment, and other items but is perhaps the most underestimated space and often gets reduced as planning continues. The amount of storage space needed is based on (1) the size of the center and the number of rooms, (2) the type and variety of simulation training, (3) the volume of use that requires consumables, and (4) the flexibility of the rooms—the more flexible the rooms, the more equipment is likely to be stored. Storage rooms should be furnished for optimal flexibility and organization. Because fixed shelving may reduce flexibility, for example, wire shelving on castors may be ideal. Design teams should also consider whether storage space will be needed for in situ (point of care) simulation or mobile simulation at a distant location outside the facility.

Preparation Area

The preparation area is used by faculty/instructors/staff to prepare items for a given scenario or simulation activity. It requires a sink and counter space and should also have a freezer/refrigerator to store such items as prepared fake blood and biologic materials.

Medication Room

Although this room is not a requirement, it does add a "reality" factor by forcing participants to make decisions regarding who should get medications and when it is reasonable to leave the bedside. If a center is fortunate to have a medication or supply dispensing device (eg, Pyxis), trainees can also use the inventory function to track restocking needs.

Standardized Patient Area

Standardized Patient (SP) areas are unique environments. There are four types of individuals involved: (1) the student; (2) the faculty; (3) operations personnel; and (4) the SP. Depending on budget, the setup can be elaborate where flow of students is separated from that of instructors, operations personnel, and SPs. Providing the SP dedicated areas in which to view previous sessions or current sessions (in the case where one SP is relieving another) can be invaluable to allow session consistency. Seeing previous sessions can help in standardizing the experience for students. The SP area should also have the following:

- A change room
- A faculty area
- A control/monitoring room to monitor all the clinic rooms through the AV infrastructure
- Office space for operations personnel

Many institutions and programs may not have the budget or space to allow for the separation of learners and operations. A common setup is that of a standard clinic with all involved individuals intermingling. This is not ideal but has worked for years. Ultimately, the ability to incorporate many of the features mentioned will depend on the scale of the SP operation, budget, and available space.

The patient rooms are typically fashioned after standard clinic examination rooms, although this need not be an absolute. Including a minor room for minor procedures (eg, suture placement) may be desirable. The AV requirements of this area are more basic in that the rooms tend to be smaller than your typical simulation theater (which makes acoustics easier), and the cameras generally have a passive function to record/observe what is occurring. The operator does not typically need to actively control anything in real time. There may be some circumstances where the camera view and microphone gain may need to be adjusted. There are some centers that are using mannequin simulators in SP areas which does add the need to have similar control infrastructure as described for simulation theaters.

Server Room

If the facility has professional grade audio-visual and learning management systems of sufficient size, a dedicated server room may be necessary. This space will have specific electrical and ventilation requirements and should be air conditioned because the equipment generates considerable heat. Failure to cool this space can lead to equipment failure and pose a fire hazard. This room should ideally be located on the same floor as the facility, and access should be limited because the equipment is expensive and delicate, and the servers may contain sensitive/confidential information.

Restrooms and Change Areas

Including a restroom is largely subject to building and regulatory code requirements for a given space and may not be mandatory. Depending on the country and location, regulations such as the American with Disabilities Act must be followed. Although change areas and lockers can be useful to personnel and students, they take up valuable space. Requiring participants to arrive in their clinical attire can partially relieve this requirement. A change area or oversized restroom would be helpful for situations such as when operations personnel, actors, or faculty need to change clothes between sessions.

Offices and Reception Area

Reserving office space for instructors and operations personnel will depend on the size of the facility. However, offices or work spaces for operations personnel should be a priority and should be positioned, when possible, in close proximity to the day-to-day activities. In medium to large centers, an area for managing the flow of guests and participants is important. This reception area would ideally include the following:

- An administrative person to help with questions and directions and to act as a "gatekeeper"
- An electronic (preferred) board with the location and time of scheduled activities
- A waiting area
- A space for pamphlets about the center and for information about rules and regulations, general expectations, and other important information.

The larger the facility, the more important office and reception space becomes as management of flow, and activities can quickly overrun a center.

DETAILS…

Doors, Hallways, and Flooring

Doorways and hallways must be large enough for oversized equipment. For example, a hospital bed requires 42″ to 48″ (approximately 1.07–1.22 m) to pass through a door easily. Furthermore, if a bed is brought into a room from the

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hallway, the door size and the width of the hallway must be adequate to accommodate the turning radius of the bed.

The flooring material used for each room will depend on the purpose of the room, what materials may be used (eg, liquids), and the amount of traffic. Many facilities use materials similar to those found in a hospital. If carpeting is used, it should be reserved for debriefing rooms and offices. All flooring should have good sound dampening qualities and be durable and easy to clean.

Light, Sound, and Electrical

The considerations for lighting are very important and include temperature, positioning, and type of lighting, ie, artificial versus natural sources. Table 5 summarizes some of the concerns that impact these considerations.

The control of sound levels in a simulation facility is a very complex design issue and, depending on the size of a facility and the budget, is best handled by a sound engineer. Sound can come from a number of sources within the room, including voices, equipment, ventilation systems, and electronic paging systems, and from adjacent rooms and hallways. Full height walls, acoustic ceiling tiles, sound-absorbing wall treatments, and appropriate flooring can mitigate the sound levels. Another issue to consider is the size and shape of a room. A perfectly square room has very different sound qualities than an asymmetric room. When sound waves bounce off the walls of a square room, they can collide and create "dead zones." This can be a problem especially for capturing sound on a recording, for example. In addition, although the science of capturing sound is beyond the scope of this article, the choice and position of the right microphones are critical. Microphones come in varying qualities and may be omnidirectional or directional. They can be ceiling or wall mounted. Other alternatives include lapel or lavalier microphones, which work very well to pick up a personal conversation. Sound processors with noise cancellation capabilities have improved greatly because they were introduced and may also be useful for optimizing the quality of recorded sound.

Table 5. Lighting Considerations

Issue	
Temperature	Exposure problems on camera
	Unnatural light perceived by participant
	Brightness
	"Warmth" or "coolness" of room
	The choice of appropriate light temperature is an easy fix for these issues
Position of the lighting	May impede location of cameras
	May impede location of ceiling mounted projectors
	May cause undue glare if camera is too close to the light
Artificial lighting	Fluorescent lights produce less heat but may cause IR interference
	Fluorescent lights generally cannot be dimmed
	Recessed incandescent lights can be dimmed but produce heat
	Fluorescent lights can cause a "hum," although this is less of a problem with modern bulbs.
Natural lighting	May cause glare that impedes camera capture quality and may impede viewing of materials on flat panels and projectors

Electrical considerations for a simulation facility will vary by room, size, and equipment type. Electrical engineers will need to understand the equipment being used and the corresponding power requirements. The overall design of the electrical system must take into account the total electrical load requirements, the need for dedicated circuits, and local electrical and building code requirements. Additionally, it is important that the user convey to the responsible parties the quantity and location of electrical outlets to service the equipment they are likely to use (eg, mannequins, monitors, and virtual-reality trainers). Although many simulation units (eg, mannequin or virtual reality trainers) are now battery operated, contingencies related to battery failure should be considered. If special wiring is needed to emulate such events as isolated power failures then this often requires a thorough functional description, so that the electrical engineer may translate the requested functional requirement into their design documents. These special wiring requirements when viewed by the electrical engineer and electrical contractor may be viewed and questioned as nontraditional. Being very clear of what is functionally expected is critical to avoid confusion.

Low-voltage wiring requirements related to the simulation equipment, routers, and other equipment (eg, cameras and microphones) can be substantive and should be clearly articulated. Enumerating and specifying the type and location of equipment (source and destination) will help to ensure that the proper conduits are installed to accommodate the wiring. The information technology and AV consultants/contractors should be involved early in the process, so that they can specify the low voltage needs and conduit locations. It is much more challenging for low-voltage wiring to be placed after the walls are up.

Ventilation and Gases

The ventilation system must meet building code specifications based on the maximum occupancy of the room and the composition of the gases in the room, ie, oxygen and volatile anesthetics. If supplemental oxygen will be used (>21%), ventilation must meet code to avoid a fire/explosion hazard. Volatile anesthetics also have specific regulations regarding scavenging and removing the gases.

Careful consideration must be given to engineering the distribution of gases, eg, oxygen, air, nitrous oxide, and vacuum, from where they originate to where the manifolds terminate at the wall plates, headwall, or boom.

- Shut-off valves must meet building and plumbing codes but must also meet the needs of the center, eg, emulate an oxygen failure in one room but not another.
- Tank farms or other sources of gases must be defined and engineered to meet regulatory code requirements. In the case of tank farms, tanks must be secured, easily replaced, and monitored.
- The capacity of vacuum generators must be sufficient to meet the needs of the whole center. However, vacuum generators can be quite noisy and should, therefore, be appropriately isolated.

There are circumstances when compressed air may be used rather than oxygen or other gases (eg, nitrous oxide). This may avoid regulatory and building code requirements and fire haz-

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ard issues. There are a variety of considerations when compressed air is used in lieu of oxygen or other odorless gases:

- There are certain devices such as ventilators, anesthesia machines, and even simulators that specifically look at oxygen concentration from pipeline sources. In these circumstances, the use of compressed air in lieu of oxygen will likely trigger an alarm or report that what is being used is 21% oxygen.
- In the case where a wall or ceiling source is labeled as oxygen but is in fact only compressed air, then proper precautions should be taken to prevent safety issues such as inadvertent human use (eg, labeling). This practice of substitution and mislabeling must also be in compliance with building and regulatory requirements. Additionally, if gases are to be used with human subjects (eg, SPs being given oxygen) then the plumbing will need to meet regulatory code for human use.

Audio-Visual Capabilities

An in-depth discussion of audio-visual needs is beyond the scope of this article, but suffice it to say that planning and budget must include a robust AV system. Audio-visual systems act as the eyes, ears, and voice of operators; serve to broadcast information to learners; and archive information in real time.[12,14–16] As the process of choosing the system begins, it is imperative that knowledgeable members of the design team consult with vendors who understand the application (in this case, simulation) and the vision for the facility. A similar strategy should be applied for choosing user-friendly information management system and learning management system to facilitate scheduling, inventory, and scenario archiving.

Security

Security is a high priority in a simulation facility. First and foremost, confidential information, both electronic and paper, must be protected. Equipment, especially smaller more portable pieces, is also a target for theft. Finally, gases and medications, even those that are not real, may be subject to theft or abuse, and strict policies must be in place to prevent this. All medications (real or not) should be clearly labeled "Not for Human Use" and locked securely according to institutional and regulatory requirements. Ideally, each room would have a card reader to ensure authorized access and serve to create a record of who entered the area at particular times during the day and night. This, however, is costly, and less expensive alternatives are available. The room type should determine the level of security that is required. If cameras are present in the facility then they may be a valuable security resource. Additional cameras, beyond those used to further the educational mission of the facility, may be required (eg, cameras in office areas).

SUMMARY

Designing a simulation facility can be complex and very costly. Budgets will vary depending on the size and scope of the project. A well-balanced design team (Table 1) with a thorough understanding of the functional and capacity needs of the new facility is essential. Thoughtful process and deliberate cross-checks over the span of design and construction will help to produce a simulation facility that meets the needs of its stakeholders. There have been many different areas that have been covered. Although many will apply to most, some will not. The intent in discussing all the areas is to allow those embarking on facility design to be deliberate and to appreciate the questions that may be pertinent. The purpose-built simulation environment is unusual, and the simulation community is yet to establish standards of what a good simulation environment is. This will almost certainly occur in the next 5 to 15 years. Standards will provide consultants, architects, and users materials to work from that define best practice/evidence rather than anecdote.

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