Project ER One

Technical Report
Phase II

A Design Study for an
"All Risks, Scalable"
Emergency Department

March 31, 2003

Project *ER One*
Phase II

A Design Study for an All-Risks, Scalable Emergency Department in the Nation's Capital

March 2003

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Executive Summary

EXECUTIVE SUMMARY

The tragedy of the attacks on the Pentagon and World Trade Centers in 2001 highlighted the importance of medical response capability and the need to protect our nation's critical medical infrastructure. The medical system plays a key role in our national security framework that extends beyond providing clinical services to those that are ill in peaceful times. The medical system is needed and, in these times, expected to be at its best when disaster strikes.

Our hospitals must be able to provide the specialized clinical services for those that present with injuries or illness in the advent of disasters, epidemics, or terrorism. Implied with that responsibility is the fact that the system must still be standing and operational after a disaster strikes. Because of its critical role in consequence management, it is essential that the medical infrastructure not be part of the consequence. Further, it must not only remain standing and functional, it must be able to scale up to meet the increased demand brought on by these events. Surge capacity is essential for disaster management. Hospitals and especially emergency departments within hospitals will need to be able to protect themselves, have the special medical capabilities to manage the medical consequences of these events, and have the ability to meet the surge demand. Thus, the need for threat mitigation, specialized medical consequence management capabilities, and surge capacity are core to Project *ER One*.

Project *ER One* originated at Washington Hospital Center in 1999 with the intent to assemble the best available thought in emergency department design to meet the needs of these emerging threats. Even before the events of September 11, 2001, it was felt that most emergency facilities were ill-equipped to deal with mass casualties, epidemics, and emerging diseases. Even the flu epidemics of the late 1990s proved to overwhelm the medical capacity of our cities' emergency departments. The specter of terrorism placed further emphasis on the fact that the emergency medical infrastructure was not just a medical issue—it was a public health and national security issue as well. The Washington Hospital Center was awarded a contract from the Office of Emergency Preparedness, HHS September 29, 2001, to develop a design study for the all-risks, scalable emergency department.

Project *ER One* was founded on the premise that careful thought during the initial design can improve specialized medical consequence capability. Careful planning can result in greater capacity and better outcomes in time of disasters and epidemics without creating excessive contingency space or cost requirements. Further, many of the features that enable the emergency department to function in these critical situations can also enhance capabilities during normal operations. The *ER One* concept recognizes that a civilian hospital's principal mission is not preparedness for disaster. Thus, design decisions will involve a careful analysis of the facility's predicted role in the community disaster response, the likely threats to be managed, and the limits of resources available.

Project *ER One* further recognizes that simply designing better and more effective emergency departments is only one element of a complex set of solutions needed for overall medical system improvement. However, if all facilities took these matters into consideration at the initiation of the design process, the system could have significantly more capability and surge capacity, as well as better survivability. The logical conclusion establishes the principal objectives of Project *ER One*:

- Improved medical consequence management capability
- Surge capacity through facility scalability
- Enhanced protection of the physical facility and its occupants through threat mitigation features

An extensive search was undertaken in Phase I to develop various concepts, features, and specifications that could make such a facility possible. The design compendium of Phase I provided the 'menu' for the design team of Phase II to develop a demonstration prototype on the Washington Hospital Center campus. The Phase I design compendium addressed both new and retrofit construction. The results of the design study incorporate many features that provide threat mitigation for medical facilities and enhance medical consequence management. These features are detailed in the technical report.

Phase II focused on the design of a demonstration prototype on the existing medical campus at Washington Hospital Center. This involved exploring and analyzing the processes and the tools necessary to achieve a design that would meet the Project *ER One* goals and objectives. An understanding of this process and the application of the appropriate tools are essential for successful design efforts. Designers have established successful processes for design of emergency departments and hospitals over the years. They focused on the program requirements, budget constraints, and the esthetic requirements of the client. For the all-risks emergency department, the appropriate protective features needed to be incorporated.

The selection of such features needs to be based on a careful analysis of the threats that may present to the facility, as well as any vulnerability the projected/existing structures may have to such threats. Thus, the concept of including hazard/vulnerability analysis to the design process is forwarded. Such facilities may also have increased operational requirements during emergency or contingency situations, so the standard design space program needs to be reassessed with an understanding of these requirements.

Establishing the contingency requirements of an individual emergency department is challenging. Generally, a community will involve multiple facilities to absorb the casualties from major events. Further, it makes little sense to develop a large amount of receiving capacity that cannot be either supported by the in-patient capacity of the hospital or somehow rapidly and safely distributed to other facilities.

An understanding of the facility's projected mission and role in the community or regional disaster plan—as well as an understanding of the volume of casualties to be expected in various scenarios—can provide a logical framework for design decisions. Projections based on casualty modeling may be useful but also have limitations. While typically a government agency or regional planning authority would be best suited to provide casualty estimates resulting from unusual events, the Project *ER One* team accomplished casualty modeling using computerized modeling software developed by the Defense Threat Reduction Agency.

An additional valuable aspect of the design process is validating the effectiveness of the design for the stated operational requirements. A systematic analysis—based on such elements as square footage, number of treatment rooms and personnel—should be conducted to determine whether the proposed design will perform as expected during normal operations and contingency situations. The Phase II design process of Project *ER One* includes the above elements.

In its basic form, the design process includes the following steps:

1. Definition of the facility's mission and role in normal and contingency operations
2. Operational needs assessment (also known as facility space program)
3. Establishment of the esthetic goals and requirements
4. Threat assessment
5. Vulnerability analysis
6. Definition of constraints (site, zoning, financial)
7. Definition of the critical axis of the hospital or more specifically the emergency department
8. Selection of solutions via multi-objective optimization
9. Model testing, validation, and design refinement

This study focused on threat mitigation, medical consequence management, and scalability, but many of the proposed features would support the daily hospital requirements of infection control and patient flow. It has been demonstrated that a protective hospital design is compatible with maintaining a healing environment. The original premise that such features could be incorporated more effectively at the time of original design seems to be affirmed. While it is most efficient to provide these features at the time of original design, many of these features can be considered in retrofit application, and some can be applied at very little cost.

Any architectural design for a medical facility should be guided by a formal process that includes threat assessment and modeling. The mission and role of the facility in the

community response also plays as key role in determining the extent of the development of these capabilities. There is a cost premium to design and develop an all-risks, scalable emergency department. However, many of the changes and features do not actually increase cost, but they do require a reconfiguration or rethinking of hospital design to allow for better function during contingency events. Nevertheless, there are additional costs to design and build facilities that have capabilities beyond routine medical care. Both the cost/benefit of such design and construction and identification of appropriate funding sources are valid issues for discussion and policy development.

Phase III will begin by disseminating the Phase II results at a conference to be held on April 30th in Washington, DC. However, much development remains to be accomplished. While the Phase II design study incorporated the concepts and features into a workable design in a real setting of site constraints, detailed engineering specifications for the ventilation systems and structures need to be further developed in order to fully understand the feasibility of such a facility.

Phase I of Project *ER One* assembled a unique multi-disciplinary team of professionals from around the nation and developed a design compendium that reflects the current state of design knowledge. Since science and applied technology are developing more rapidly than ever, the design compendium will require continuous update and development. The efforts of Project *ER One* have established an infrastructure and platform from which an institute can be established to continue these activities for the national benefit. The *ER One* Institute will continue to pursue the knowledge needed to make hospital design better for the future.

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SECTION 1

PROJECT INTRODUCTION

1.1 BACKGROUND

The tragedy of the attacks on the Pentagon and World Trade Centers in 2001 highlighted the importance of medical response capability and the need to protect our nation's critical medical infrastructure. The medical system plays a key role in our national security framework that extends beyond providing services to those that are ill in normal times. The medical system is needed and, in these times, expected to be at its best when disaster strikes.

Our hospitals must be able to provide the specialized clinical services for those that present with injuries or illness in the advent of disasters, epidemics, or terrorism. Implied with that responsibility is the fact that the system must still be standing and operational after a disaster strikes. Because of its critical role in consequence management, it is essential that the medical infrastructure not be part of the consequence. Further, it must not only remain standing and functional, it must be able to scale up to meet the increased demand brought on by these events. Surge capacity is essential for disaster management. Hospitals and especially emergency departments within hospitals will need to be able to protect themselves, have the special medical capabilities to manage the medical consequences of these events, and have the ability to meet the surge demand. Thus, the need for threat mitigation, specialized medical consequence management capabilities, and surge capacity are core to Project *ER One*.

Project *ER One* originated at Washington Hospital Center in 1999 with the intent to assemble the best available thought in emergency department design to meet the needs of these emerging threats. Even before the events of September 11, 2001, it was felt that most emergency facilities were ill-equipped to deal with mass casualties, epidemics, and emerging diseases. Even the flu epidemics of the late 1990s proved to overwhelm the medical capacity of our cities' emergency departments. The specter of terrorism placed further emphasis on the fact that the emergency medical infrastructure was not just a medical issue—it was a public health and national security issue as well. The Washington Hospital Center was awarded a contract from the Office of Emergency Preparedness, HHS September 29, 2001, to develop a design study for the all-risks, scalable emergency department.

1.2 THE *ER ONE* CONCEPT

Emergency departments are routinely designed to meet standard operations requirements. Many medical facilities have included disaster and contingency preparation in their operational plans. The Joint Commission for Accreditation of Healthcare Organization places some emphasis on this by requiring facilities to have a disaster plan. While there are no specific requirements for any physical features or capabilities, some hospitals have taken

initiatives to develop a certain amount of medical consequence management capability. In most cases, however, this involves the development of disaster plans after the hospital has been designed, which often equates to which parking lot will host certain functions such as triage, casualty reception, and decontamination.

Project *ER One* was founded on the premise that careful thought during the initial design could improve specialized medical consequence capability. Careful planning can result in greater capacity and better outcomes in time of disasters and epidemics without creating excessive contingency space or cost requirements. Further, many of the features that enable the emergency department to function in these critical situations can also enhance capabilities during normal operations. The *ER One* concept recognizes that a civilian hospital's principal mission is not preparedness for disaster. Thus, design decisions will involve a careful analysis of the facility's predicted role in the community disaster response, the likely threats to be managed, and the limits of resources available.

Project *ER One* further recognizes that simply designing better and more effective emergency departments is only one element of a complex set of solutions needed for overall medical system improvement. However, if all facilities took these matters into consideration at the initiation of the design process, the system could have significantly more capability and surge capacity, as well as better survivability. The logical conclusion leads to the principal objectives of Project *ER One*: improved medical consequence management capability, surge capacity through facility scalability, and enhanced protection of the physical facility and its occupants through threat mitigation features.

1.3 PROJECT PURPOSE AND PRINCIPAL OBJECTIVES

The purpose of Project *ER One* is to develop and demonstrate the feasibility of design concepts, features, and specifications that will improve the performance of emergency medical facilities in three major areas: threat mitigation, medical consequence management, and scalability. Threat mitigation refers to the protection of the facility, its assets, and most importantly its occupants. Since medical facilities will need to remain functional and most likely become hyper-functional during a contingency, they will need to have reasonable protective features incorporated into their design. Medical consequence management refers to the specialized medical capabilities to deal with epidemics, disasters, and terrorist activity. Scalability refers to the physical facility's ability to respond to the potential surge demand on the medical system. In general, excess bed capacity across the country has been minimized due to fiscal pressures, so the nation's medical infrastructure generally lacks surge capacity. Design features improving scalability will provide significant benefit in disaster management.

1.4 GENERAL OVERVIEW OF PROJECT *ER ONE* TO DATE

Project *ER One* was planned in three phases. Phase I of Project *ER One* emphasized knowledge acquisition and creation for the development of design concepts, features, and

specifications that could be applied in the all-risks emergency department. Phase I of Project *ER One* included over 150 participants from multiple institutions, backgrounds, and disciplines. The final technical report of Phase I was the '*ER One Design Compendium 1.0'*. This compendium of several hundred pages includes numerous design concepts, features, or specifications. This compendium was also produced as a CD-ROM with full search capability. Phase II of the project—the design study—is the application of the knowledge accumulated and developed in Phase I to produce design studies of an emergency facility in a real setting of a major urban emergency department (Washington Hospital Center in the National Capital Region). Phase III will begin to disseminate the information and knowledge collected in Phase II through a conference/forum scheduled to be held in Washington, DC, in April 2003.

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Section 2 *Phase II*

SECTION 2
PHASE II

2.1 DELIVERABLES AND GOALS

The principal deliverable of Phase II is the actual design study for the *ER One* prototype sited on the Washington Hospital Center campus in Washington, DC. In the process of accomplishing the design study, a number of intermediate products were also developed to ensure that the goals of the project were effectively met. It was not the project's intent to merely design a facility for Washington Hospital Center but rather to develop an appropriate approach and logic to arrive at design solutions. It was clearly recognized that no single solution would be applicable at all facilities. Thus, a commentary accompanying the design was developed to describe the logic for that particular solution, as well as some potential alternatives in some cases. Such an approach brings broader applicability to other facilities. Designers and facility managers can use materials contained in the *Phase I Design Compendium 1.0* and apply them to their own situation (new construction or retrofit) using methods and logic of the Phase II Design Study. The design approach and processes are for universal application.

2.2 SCOPE AND EXCLUSIONS

The design study for Project *ER One* includes the development of some theoretical ideal or green-field solutions, as well as the actual design solution chosen specifically for the Washington Hospital Center. It describes the key features and details that affect the performance of the emergency department. While specifications of materials or their performance characteristics are included when appropriate to illustrate potential solutions, it must be noted that these do not constitute engineering specifications and should not be construed as specific construction recommendations. For example, the narrative may specify the use of heavy concrete on certain walls capable of shielding from a certain level of radiation, but it will not specify the actual mixture of the concrete or the exact thickness required. Such engineering specifications are outside the scope of the design study. As a study design of the built environment, the project intensely reviewed and considered the various technologies—detectors, filters, diagnostic equipment, etc.—that may be utilized in this type of facility and adapted the design to accommodate such technologies. However, the Phase II design study does not include the specific selection or recommendations of such technologies. Project *ER One* does not include the design of a community or regional response to disasters or contingencies, but it clearly recognizes that an individual facility is a contributing element to the response and the design effort should be sensitive to that fact. Project *ER One* addresses the design issues regarding the interaction of first responders with the fixed medical facility such as communications and casualty arrivals to the facility, but it

does not address emergency medical services issues outside the emergency department environment.

2.3 GENERAL PROJECT GUIDING PRINCIPLES

A limited number of general principles were forwarded to guide team members toward the same end. The general guiding principles used in Phase I for design recommendation development were carried over to Phase II:

a) *Dual-Use* – The facility should function as a day-to-day emergency department and trauma center but should have special capability to handle the consequences of a terrorist attack. Large empty spaces reserved specifically for contingency operations will not be cost-effective.

b) *Scalability* – The facility should have the capability of handling large surges in the number of patients presenting for care. How can this be accomplished without having large empty spaces, rarely used expensive equipment, and excessively large medical staffs?

c) *Modularity and Flexibility* – The design should be such that a specific functionality could be altered without disrupting the integrity of the whole structure or process. A modular approach allows reproducibility and efficiency.

d) *Daily Routine* – Numerous studies and experiences have demonstrated that individuals function most effectively in stressful or unusual situations when their tasks approximate their daily routine. The capabilities designed into this facility should serve equally well—and even enhance—day-to-day emergency department and trauma center operations as they do a mass casualty or biological terrorist incident.

e) *Knowledge Management* – Knowledge specific to the management of a given condition must be available at point of use. Individual personnel cannot be counted on to know beforehand or recall fully and immediately what to do in all given situations. The pertinent corporate knowledge should be built into systems or facility design. Examples of knowledge built into facility design include architectural way-finding strategies.

2.4 DESIGN GUIDANCE

Phase II of Project *ER One* included a smaller cohesive design team. The project-guiding principles were expanded and modified to become the General Design Principles. The design team would use the following principles in the creative and decision process for all design execution:

a) *Universality* – Whenever appropriate, the design should support the broadest scope of users and uses. For example, entry portals should allow access to individuals with any range of disabilities as opposed to having a separate handicapped entrance.

b) *Simplicity* –Less can be more; simplicity of design will be sought. Simplicity reduces complication and in many cases reduces the potential points of failure. Adherence to this principle will allow for ease of standardization and reduce knowledge requirements for users.

c) *Intuitive Obviousness, Usability* – The design should support ease of use by individuals regardless of their training or background. The design should lead to obviousness for use and way finding. Shapes, icons, or other symbols should lead to the intended usage. This will reduce training and familiarization requirements. There should be minimal dependence on secret or compartmentalized knowledge.

d) *Flexibility* – The design can accommodate a large range of potential applications and users.

e) *Multi-use* – The dual-use principle of Phase I was expanded to multi-use since more than two uses could be envisioned in many cases. It is clearly understood that medical facilities cannot have dedicated specialized space and resources exclusively for contingency use. All opportunities will be explored to utilize space and resources needed for normal daily operations to meet the needs of various contingencies. This multi-use concept extends not only to contingencies but also to convertibility of treatment rooms for normal operations. The typical variation of patient flow in terms of types of patients suggest that efficiencies can be achieved through having patient rooms that can convert to accommodate different types of patients—for example trauma versus cardiac.

f) *Functionality* – Design should include features to ensure that emergency department clinical processes and logistics are facilitated.

g) *Late Binding* – Late binding refers to the ability to defer decisions until the last possible moment. The facility is designed in a fashion that will allow for upgrades of the facility and its technology at a later date, which means that the facility can add specific functionality at the time needed. The late binding provides increased flexibility in design while deferring the cost to a later timeframe, thus requiring less spending initially.

h) *Design Totality* – Promote an end-to-end design process with the understanding that the finishes are part of the core design that ultimately determine the effectiveness and functionality of the design.

i) *Commodity Threshold* – Selecting widely available commodity products as opposed to having products custom-designed. Staying within this threshold will allow the

purchase of items at lower cost. An example would be the use of standard-size girders rather than custom girders.

j) *Encapsulation* – Encapsulation expedites modularity. Functional objects regularly have a set of clearly defined inputs and clearly defined outputs from those inputs. This is their only means of communicating with the external environment. How the outputs are created from the inputs is the magic of the object. If another object comes along that does a better/faster/cheaper job of converting those inputs to outputs, the old object can be discarded and the new one inserted without worrying about disturbing the rest of the system. The new object must be able to accept the same inputs as the old object and produce outputs that follow the same parameters as the outputs of the old object. The self-contained mobile DECON units or radiation operating rooms with a standard docking capability are an example of an encapsulated object.

2.4.1 Design Directives

General instructions or rules of engagement for design team members when facing a design issue or challenge were as follows:

a) *Invent When Necessary* – Create new design solutions or devices when proper solutions are not available from the current options.

b) *Be Ready To Break Rules* – Conventional wisdom should not constrain the design process. Truisms will be challenged.

c) *Recognize Cultural Expectations* – Design must be sensitive to the cultural needs of the users. Environments that are discomforting to individuals will decrease performance among providers and aggravate anxiety for patients and providers.

d) *Design for Future Change* – Minimize dependence on permanence. Technology is evolving at a rapid pace. The facility must be able to accommodate new technology as it develops. There is no way to predict with any certainty what the requirements or mission of an emergency department will be in the future. Over the years, if preventive medicine measures are successful, the need for emergent cardiac care may decrease. The emergency department that is expected to function for the next 30-40 years will need to be designed to accommodate change. The technologies and processes of today will not necessarily be those used in the future. Our experience indicates that hospitals and emergency departments frequently require change in their physical structure. Further, when such change is undertaken it is often costly and time-consuming. The design team will explore design features that will make the remodeling of a room possible in a single day.

2.4.2 Design Objectives

The following overall design objectives of project were identified:

a) *Scalability* – Ability of a system to adjust to a broad window of variation of load relative to normal load. In terms of scalability, the design should be able to easily accommodate double capacity during the expected surges of influenza season and potentially four times normal capacity during surges required by mass casualty events.

b) Flexibility – Flexibility through the Therapeutic Range – Typically, emergency departments have specialized rooms for various acuity levels and patient types. While approximation of needs may work most of the time, it is not possible to predict the number of all patient types that would present on any given day. Rooms that provide latitude for acuity levels would be advantageous.

c) *Convertibility* – Rooms should be able to convert from cardiac to trauma without significant delay or effort.

d) *Minimal Maintenance* – Clearly, maintenance consumes human resources and finances. In contingency situations, inability to use equipment, rooms, or areas because of maintenance requirements could lead to failure of operations. Design features of *ER One* should support the ease and speed of facility maintenance.

e) *Ubiquitous Access to Information* – Information is key to patient care and disaster management. The ability to have access to the right information at the right time and place is fundamental to improved quality of care and efficiency. The design must allow for availability of information at all places in the department. This capability can enhance the scalability by reducing the time needed to acquire critical information. Furthermore, medical consequence management capability is enhanced through providing just-in-time knowledge.

f) *Modularity* – Modularity provides repeated patterns with easy recognition. These repeated patterns allow staff to operate in familiar environments with minimal learning requirements. Additionally, modularity usually provides the ability to economically reproduce the individual units.

g) Graceful Degradation

- Not on or off
- Conversion of space quickly
- Scalability
- Self-assembling

h) *Provide Adequate Supportive Spaces* – Supportive spaces are critical to operational success. Storage is often overlooked or reduced to keep design costs lower.

2.4.3 Design Priorities

Early in the design and planning process, it was recognized that there would be a number of competing objectives that would occasionally lead to conflict. Some understanding or prioritization for the various objectives was necessary. Such prioritization did not imply hard-and-fast rules but rather a general approach to looking at the competing priorities.

a) *Give Preference To Daily Operations* – The hospital is first and foremost a healthcare environment.

b) *Give Preference To Mobility & Portability* – Built-in solutions decrease flexibility and adaptability to different situations.

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Section 3 *Methodology*

SECTION 3

METHODOLOGY

Given the previously outlined guidance, principles, and directives, the design study was formally executed as outlined by the process below. The activities of Phase II of Project *ER One* extend beyond the execution of the design prototype.

3.1 DESIGN PROCESS

Phase II explored and analyzed the processes and the tools necessary to achieve a design that would meet the Project *ER One* goals and objectives. An understanding of this process and the application of the appropriate tools are essential for successful design efforts. Designers have established successful processes for design of emergency departments and hospitals over the years. They focused on the program requirements, budget constraints, and the esthetic requirements of the client. For the all-risks emergency department, the appropriate protective features needed to be incorporated.

The selection of such features needs to be based on a careful analysis of the threats that may present to the facility, as well as any vulnerability the projected/existing structures may have to such threats. Thus, the concept of including hazard/vulnerability analysis to the design process is forwarded. Such facilities may also have increased operational requirements during emergency or contingency situations, so the standard design space program needs to be reassessed with an understanding of these requirements.

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elements as square footage, number of treatment rooms, and number of personnel—should be accomplished to determine whether the proposed design will perform as expected during normal operations and contingency situations. The Phase II design process of Project *ER One* includes the above elements.

In its basic form, the design process includes the following steps:

1. Definition of the facility's mission and role in normal and contingency operations
2. Operational needs assessment (also known as facility space program)
3. Establishment of the esthetic goals and requirements
4. Threat assessment
5. Vulnerability analysis
6. Definition of constraints (site, zoning, financial)
7. Definition of the critical axis of the hospital or more specifically the emergency department
8. Selection of solutions via multi-objective optimization
9. Model testing, validation, and design refinement

During the execution of Phase II, it became evident that the elements of the process may not always occur in a sequential fashion. For instance, testing of a single element of the design with computerized modeling software may have occurred before the element was incorporated into the total design, or cost considerations could preempt a solution at any time.

3.2 MISSION AND ROLES

Ultimately, a facility's normal operating capability will determine much of its expected roles and responsibilities during a crisis. While not entirely rigid, the general expectation of the community and policy makers is that larger facilities will be expected to do more. Clearly, government-owned institutions may have unique requirements. Usually, some type of regional planning effort is necessary to determine the specific role of any particular medical facility during a contingency situation. Prior to undertaking any design or redesign effort, the medical facility should clearly understand its role and the community's expectations. Likewise, the community must understand the limitations of the facility's resources.

3.3 SPACE PROGRAM REQUIREMENTS/CASUALTY MODELING

The projected operational (clinical) needs assessment includes the definition of the procedures and practices likely to be executed, the projected volume, and the current technologies and equipment needed to achieve the mission. This is a typical facility space program, which is considered essential in any design process. For the design study, a normal

operations space program was established on the basis of an 80,000-visit per year emergency department.

Project *ER One* was tasked to analyze the possibility of designing a department that could surge to meet the requirements of contingency situations. In order to program such a department, it was necessary to estimate the number of expected casualties. Casualty modeling was undertaken to determine estimated demand during contingency scenarios. One of the desired outcomes was to understand what premium in terms of additional space and construction cost would be needed to achieve the needed surge capacity. An initial premise of the project was that with careful initial planning, it would be possible to include significant augmentation of surge capacity without excessive financial premiums.

3.4 CASUALTY MODELING

The Defense Threat Reduction Agency has developed a suite of specialized software—the Consequence Assessment Tool Set (CATS)—to estimate the consequences of different types of natural and manmade threats, including deployment of nuclear, chemical, and biological weapons, in a specific location and under specific weather conditions. Project *ER One* applied a basic version of CATS software to different scenarios in the Washington Metropolitan area to estimate potential casualty numbers and to take a reasonable approach to scalability decisions.

To accomplish this task, several scenarios were considered. In the version of the software used by the *ER One* team, several limitations were noted. First, this model only estimates the number of real casualties, which can severely underestimate the actual requirements for the facility. For example, if anthrax is released, relatively few people will actually die or become severely ill. However, thousands may perceive the need to be evaluated and tested, greatly stressing medical resources. Further, the software only accounted for known residents of the area involved and did not include transients who actually are the majority of the Washington, DC, population during an average workday. Despite these limitations, the general results of the casualty modeling (see Appendix C) indicated that some scenarios (such as nuclear) could easily overwhelm any conceivable medical capability. However, many scenarios—including chemical and biological—could be managed if the medical system had the ability to scale to three- to fourfold capacity during a surge period. This fourfold surge capacity was determined after analyzing the various potential casualty scenarios and evaluating the expected role and contribution of Washington Hospital Center to the regional response to mass casualty events.

It is fully understood that providing additional space and physical capacity does not directly equate to surge capability. Additional factors involving manpower, supplies, logistics, transportation, and actual processes used will play major roles in determining the ultimate surge capability of an emergency department. Further, the emergency department

must be able to rapidly process patients to home, hospital, or other facilities to prevent gridlock. The multiple of creating four times the number of beds in the emergency department will not affect the desired solution. For this reason, Project *ER One* used computerized simulations to evaluate the physical layout design under various manpower and logistical assumptions (see Section 3.11).

Ultimately, if all hospitals were efficiently designed with some degree of integral surge capacity, the entire system would be significantly more robust. It is clearly understood that most hospitals are already built and that retrofit solutions would be logistically difficult and expensive.

3.5 ESTHETIC OBJECTIVES

At different times in history, the view towards esthetic objectives varied from being viewed as unnecessary luxuries to being considered essential elements. Recent studies have determined the importance of the building environment in the healing process. Esthetic features are now among the clinical tools of the medical facility.

3.6 HAZARD AND VULNERABILITY ANALYSIS

Today's world environment has many threats**:** natural, accidental, or deliberate (such as acts of terrorism). Hazard Vulnerability Analysis (HVA) tools have been developed by a number of entities to provide medical facilities with a systematic and comprehensive approach to evaluating and prioritizing the various risks posed to a facility by its natural and manmade threats. Early hazard vulnerability analysis tools focused on natural threats and industrial hazards, as well as potential security concerns based on such factors as local crime. More recently, the terrorism threats posed to facilities have been considered. While most facilities would not consider themselves as likely primary targets for a terrorism attack, many are located near potential targets and could suffer considerable collateral damage or contamination as a result of the attack. This is of particular concern because the community will likely be relying on the medical facility to be operational after the event has occurred. This concept has been well established in California where experience with seismic activity has led to an understanding that medical facilities are critical infrastructure and must remain operational after an earthquake. The same logic should apply for other potential events, including terrorism. The Hazard Vulnerability Assessment Matrix of the American Society of Healthcare Engineers and American Hospital Association provides a useful tool to this end and was used in this particular project. Several other such assessment tools exist and may be equally effective.

It may be of some value to distinguish the difference between a hazard assessment and a vulnerability analysis. In the simplest form, the hazard assessment evaluates the various extrinsic (hurricane winds, terrorist activity) and intrinsic (fire from electrical wiring within the facility, employee workplace violence) threats to a facility, its assets, and its occupants. A vulnerability

analysis evaluates the facility's ability to withstand such an event. A vulnerability analysis cannot be accomplished unless an actual facility or facility design elements exist to evaluate. However, the two are very closely linked and can usually be accomplished simultaneously.

In Project *ER One,* a hazard assessment and a vulnerability analysis of the current facility were performed. During the design study process, the architectural team reviewed the hazard and current vulnerabilities. As the design proceeded, the various components and features of the design were evaluated in terms of their ability to mitigate the principal threats. Thus, the vulnerability analysis was a continuous process throughout the design effort.

HVAs should be accomplished by a multidisciplinary team, including hospital management, relevant clinical staff, facility managers, engineers, security personnel, and perhaps consultants expert in the HVA process. Inter-rater variability should be expected in any HVA given the various disciplines and experiences represented. Each participant should be allowed the opportunity to offer persuasive discussion to justify his or her rating.

Depending on the tool used, the amount of weight placed, and the scoring option for each factor (probability, magnitude of consequence, and preparedness), a small change in one domain could mean a significant change in the final scoring. For example, if one gives a 33 percent weight factor to each of the three categories mentioned above and then has only three possible values for the domain of probability of the event (high, medium, and low), then it follows mathematically that an event that was considered close between high or medium probability would jump or drop 11 points in the final score just based on whether it was considered high or medium. Obviously, this is a major move in a scoring system that could potentially create prioritization errors.

It should be recognized that such rating systems are only first indicators to assist in the task of identification of priorities and should not be viewed as an absolute decision matrix. Some low-probability incidents with tremendous negative public confidence impact (such as infant abduction) may warrant a reprioritization beyond that indicated in the rating system. In addition, items that need minimal effort or cost to provide preparedness and could potentially enhance the organization's readiness capability can be considered as action items (the low-hanging fruit concept). See Appendix D for the HVA Results for Washington Hospital Center.

3.7 VULNERABILITY ANALYSIS

After completing the threat assessment, a vulnerability analysis should be undertaken. To which threats are the hospital or emergency department most vulnerable? Are there threats to which the hospital does not deem itself vulnerable? For example, the hospital threat analysis may identify a high crime rate in the community, but the hospital itself does not feel vulnerable due to the number of police in the neighborhood. Which parts of the emergency department are most vulnerable to the identified threats? Most state licensing authorities have standards that require a level of security; for instance, reception, triage, and a control station

shall be located to permit staff observation and control of access to the treatment area, the pedestrian and ambulance entrances, and the public waiting area. The triage area also requires special consideration. As the point of entry and assessment for patients with undiagnosed and untreated airborne infections, the triage area shall be designed and ventilated to reduce exposure of staff, patients, and families to airborne infectious diseases.

3.8 CONSTRAINTS

The external and financial constraints will need to be defined. External constraints include the building site, zoning, codes, accrediting bodies, and even local cultural acceptance. Some communities will object to a highly secure facility in their vicinity. Financial constraints are ever-present. All of these factors will need to be considered in the design solution.

3.9 DEFINING THE CRITICAL AXIS

It is useful for a medical facility to determine its critical axis in order to prioritize decisions on where to incorporate specific features. Large medical centers are complex and often sprawling facilities with numerous functions and capabilities. Within any hospital, there exist critical areas and infrastructure essential to maintain the mission-effectiveness of the hospital. Basic mission-effectiveness would be expected to continue providing essential services during contingencies. This concept is referred to as the critical axis of the hospital. The elements of the critical axis of a hospital generally include the following:

- Emergency Department
- Operating Suites
- Intensive Care and other Designated Special Care Units
- Imaging, Lab, and Pharmacy capabilities (essential elements only)
- Critical Facility Resources
- Water, Gases, Power, Ventilation Systems
- Connectivity
- Communications, Informatics
- Command and Control Center

These are the elements that permit the continued operability of the medical facility. Depending on the mission, operations, and values of a given facility, the elements of this axis will differ. For instance, a cardiac care facility may determine that a cardiac catheterization suite is critical due to the number of patients in the facility with cardiac conditions that might require intervention. Ultimately, only the facility management can determine what is critical to their operations. Even within the emergency department, a critical axis for optimal protection applies. The planning staff should carefully assess which elements of the emergency department are most vulnerable and most critical to protect. Examples include the entry, the communications center, the triage area, and the critical care/trauma bays.

Administrative offices, break rooms, and lecture rooms are generally not considered critical infrastructure unless they are designated to have a specific role in contingency situations, such as casualty receiving area, command center, or safe-room functions.

Once the critical axis is established, it can be followed by the prioritization of the security recommendations. A practical example would be the decisions to provide blast mitigation features. Higher priority could be the emergency department entrance (assuming it was determined to be critical) as opposed to the administration offices. This would be affected by other factors such as the vulnerability of the particular area. In some cases, the critical infrastructure may already be relatively safe from threats. However, if all other factors are equal, the critical axis as determined by the facility should have the priority for security improvements. Some high-value resources such as ultra–high-cost medical equipment may also require priority for protection (even though not part of the critical operating axis).

3.10 MULTI-OBJECTIVE OPTIMIZATION

The process of choosing which design features would ultimately be included in the design study is complex. Even if threat is determined to exist and the mitigation solution is affordable and acceptable, it could potentially sub-optimize hospital operations. A deliberate decision will need to be made weighing the variables and advantages. The various design objective and priorities were outlined previously. Multi-objective optimization is a process that is useful in reconciling a number of different objectives. In some cases, this process can be formalized to provide additional objectivity. A matrix and scoring system can be established providing values to the various priorities. In Project *ER One,* it was determined that the multi-objective optimization process would be best served by continuous reinforcement of the design principles and priorities while attempting to achieve the objectives. Each design feature selected was discussed in this framework. The principal features are included in this report, along with the logic for their selection. This effort considered the issues of costs, goals, and other concerns, which can be formally done with a matrix with some type of assigned-value scoring system. Despite scoring systems, the process ultimately involves subjective decision making.

3.11 DESIGN VALIDATION – MODELING AND REFINEMENT

The development of a realistic and workable plan for any emergency services facility requires more than an architectural design. In fact, the architectural design of any given emergency department is only a part of that department’s ability to function properly. While the position of rooms, beds, and spaces is important, more important still are the actual processes that occur that allow patients and staff to flow within a given space. Without effective processes, no emergency department can function well, regardless of the circumstances or the spatial environments. However, the processes can be enhanced by the design and the two are interrelated.

The process requirements of the *ER One* concept demand that it function effectively both under normal circumstances and during an event scenario. Creating a space that functions under both conditions requires a deep understanding of the processes and patient flows that go into that function. This demands the ability to somehow map and model the flow of processes as patients would move through the facility. Under normal circumstances, an Emergency Services facility must function effectively as a normal emergency department. However, under an event scenario, the *ER One* facility must quickly transform and be able to handle huge increases in patient arrivals, rapid and concentrated patient acuity changes, and increased overall demands on the facility's systems.

Static tools such as flow charts and spreadsheets are often used to analyze process flow. However, these static analytical tools fail to capture the dynamic and stochastic nature of a system such as an emergency department, particularly a department in an event scenario. Tools that can capture the rapidly and ever-changing conditions of a dynamic environment are required to fully and deeply understand the effects of changes on the system.

Therefore, a stochastically driven discrete event simulation was chosen as the tool for understanding the processes that would be necessary to allow the *ER One* facility to function properly. This process simulation allows an accurate and realistic model of a dynamic environment such as the *ER One* facility and provides developers a detailed understanding of the specifics of process, staffing, flow, and overall system requirements.

Process simulation allows one to accurately model or mimic a complex process environment for the purpose of analysis. Imagine tearing the roof off an emergency department and looking down to see all the patients, staff, and physicians moving in real time; this is essentially what a simulation is. By accurately mimicking the actual processes that take place, we can thereby accurately model the entire system and predict the effects of changes to the system by changing the parameters of our model. We can then quickly analyze the results of those changes in the risk-free environment of the model. Simulations are used in many environments where testing new processes is difficult or expensive or where systems are not yet created, such as the *ER One* facility. By simulating the systems first, we can accurately predict how a system will function once it is in place.

The *ER One* simulation model focuses on the throughput and capacity of the system in order to determine critical breakdowns in process flow, process bottlenecks, staff requirements, and resource utilization. In doing so, the simulation can help one determine specifically what certain event scenarios will mean to the patient flow and function of the system. The simulation will also accomplish the following:

- Help determine the effects of bottlenecks in the system, and the subsequent effects of correcting them.

- Help optimize spatial requirements, equipment and storage requirements, and other spatial considerations.
- Help determine proper staffing levels and the effects of various staff mixes on process and patient flow.
- Help determine the effects of various patient types, arrival patterns, acuities, and the impacts of their overall demands on the system.
- Assist in determining overall process changes necessary to implement event scenario management.

Through the use of simulation, the planners and staff will be better able to judge the impacts of the events on the system, the space, the staff, and most importantly the patients. Based on these simulations, either the design of the facility can be modified prior to construction or processes can be modified. The ultimate goal is to optimize the relation of the design to the processes. For further details on simulation modeling in Project *ER One*, see Appendix H.

ER*One*

Section 4 *Design Study Findings*

SECTION 4
DESIGN STUDY FINDINGS

The principal deliverable for Phase II of Project *ER One* is the design study at the site at Washington Hospital Center. This specific design includes site and zoning constraints that may not be present in other facilities. In the execution of the design study, ideal or prototypical solutions were considered prior to the selection of what would work on-site. Several of these prototypical solutions are included in the design study narratives.

The design process carried forward the design principles, concepts, features, and specifications developed and assembled in Phase I to formulate a prototype plan for *ER One* on the Washington Hospital Center Campus. The basis of the design program was to include mass casualty and emergency situations, as well as normal operations (discussed in Appendix C, Casualty Modeling). Material will be presented specifically addressing the three principal goals of the project: threat mitigation, medical consequence management, and scalability. In some cases, information will be presented regarding general concepts that support good emergency department design. Many features and concepts will have applicability to more than one goal or have more than one area of impact and may be discussed in more than one section.

4.1 GENERAL DESIGN CONCEPTS AND SOLUTIONS

4.1.1 General Emergency Department Layout

Emergency department design lends itself to unidirectional flow. That is patients enter, register, triage, wait, etc. It is desirable to have the design of the facility support these processes. Typically, emergency departments have a one entry and one triage area that represent potential choke points for flow. If these functions were allowed to gracefully expand horizontally, choke points would be less of an issue. This is the general design scheme of *ER One*. A long arrival concourse with multiple entries is needed. Only as many entries as are needed would be operational at one time.

The emergency department flow can subsequently be arranged into zones representing elemental functional areas. This level of organization is called the Module. Five zones were identified and color-coded:

Zone 1 – out-door drop-off/plaza, no color

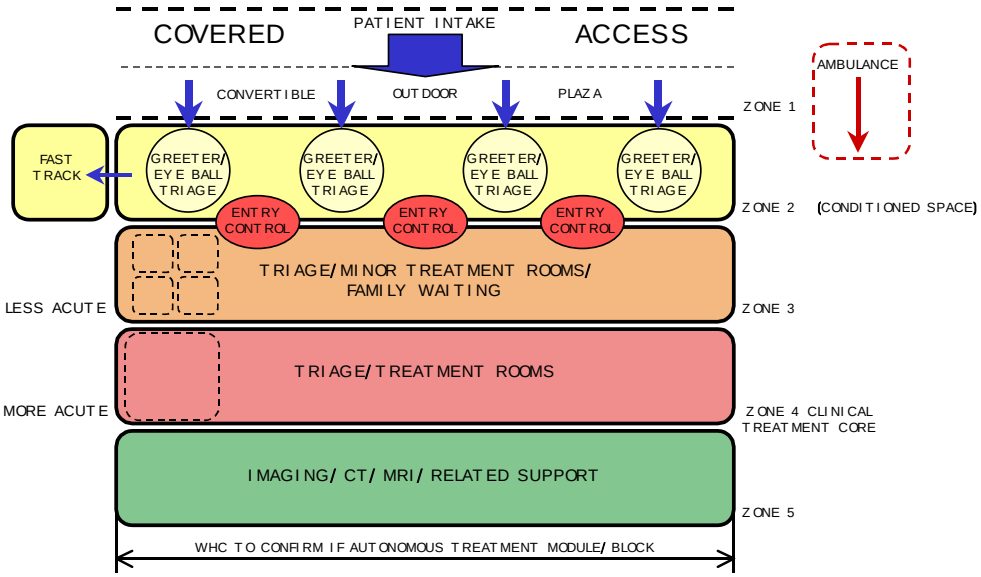
Zone 2 - public circulation, conditioned space, yellow.

Zone 3 - triage/minor treatment/family waiting, peach

Zone 4 - clinical treatment, red

Zone 5 - support/imaging, green

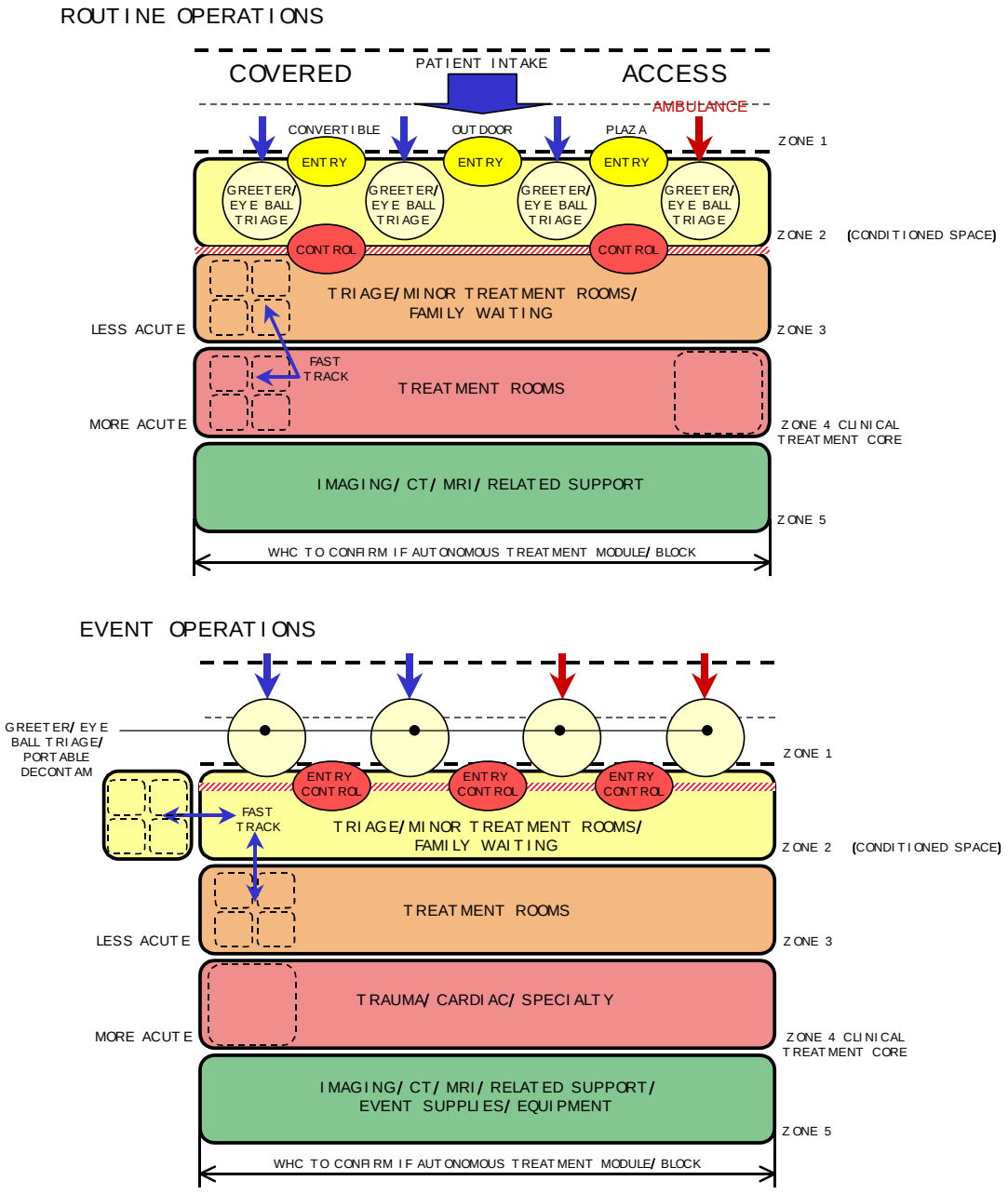
An additional element of the program, administration, was not considered during module development.



Zone Concept

This zone concept also has significant security implications. Based on the principle of concentric rings of security, with higher security to the inner rings the zones provide a natural architectural security division. Zone one is essentially public under normal operating conditions-vehicles and pedestrians arriving to front of the facility after minimal screening at the campus entry portals. During higher threat scenarios the campus entry portals may do extensive screening of all individuals and materials attempting to enter. Individuals enter Zone 2 (now inside the public part of the building only after security identification is accomplished. This is still a public area but all individuals are identified. Zone 3 is an area of

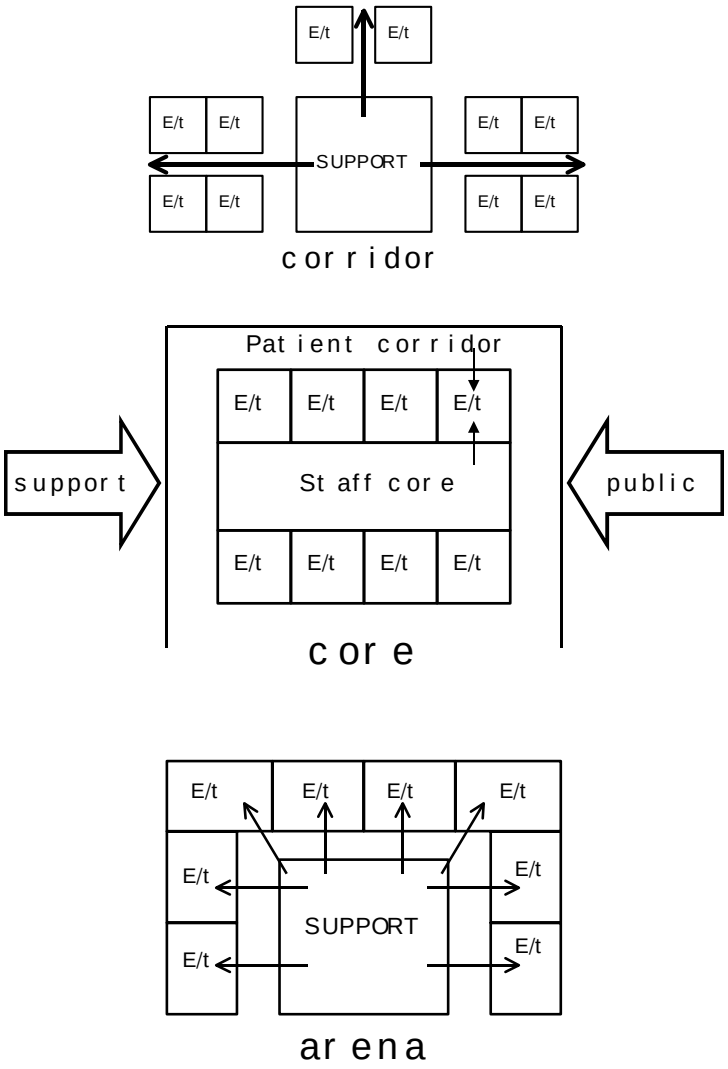
triage, minor treatment and disposition and is accessible only by those that have a need for access. No longer a public circulation area, individuals entering this area can be checked for weapons, etc. During high alert situations increased security can move to the outer zones as needed. During high casualty scenarios the clinical treatment can also move to the outer zones. Designated portals exist between the zone to allow control and access.



Zone Flexibility

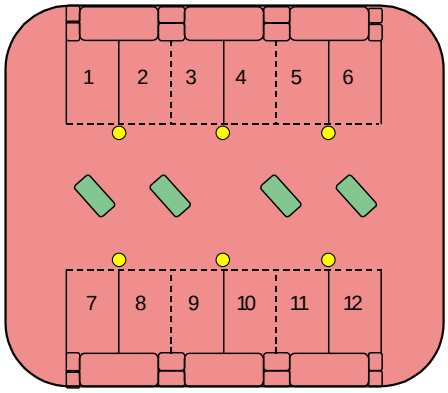
4.1.2 The Core Operational Area or Engine

The Engine is a term developed by the *ER One* team identifying the core operational area that does the patient care. It is composed of the clinical area and support zones. The area for the support core between rows of exam/treatment rooms was particularly important because of the projected need for expansion during contingency operations.

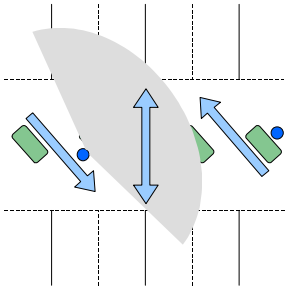


Hypothetical Core Configuration Options

This configuration was evaluated in normal and threefold capacity to judge the minimum amount of support area needed to function properly. The support area widths reviewed were 44 feet, 38 feet, 29 feet, and 16 feet. For optimum scalability and to create a threefold capacity, a 12-foot corridor was established.



The staff workstations were of particular interest. Because the modules were arranged with rooms in parallel facing each other, access across the central support area was critical. One could not accept a longitudinal counter over the expanse of the module. This would require a significant walk get to the other side. Frequent three-foot walk through gaps in the counter would significantly limit the counter space. A diagonal arrangement maintains total length and allows walk through at multiple points. It also allows for easy visual monitoring of patients in treatment rooms on both sides of the corridor.

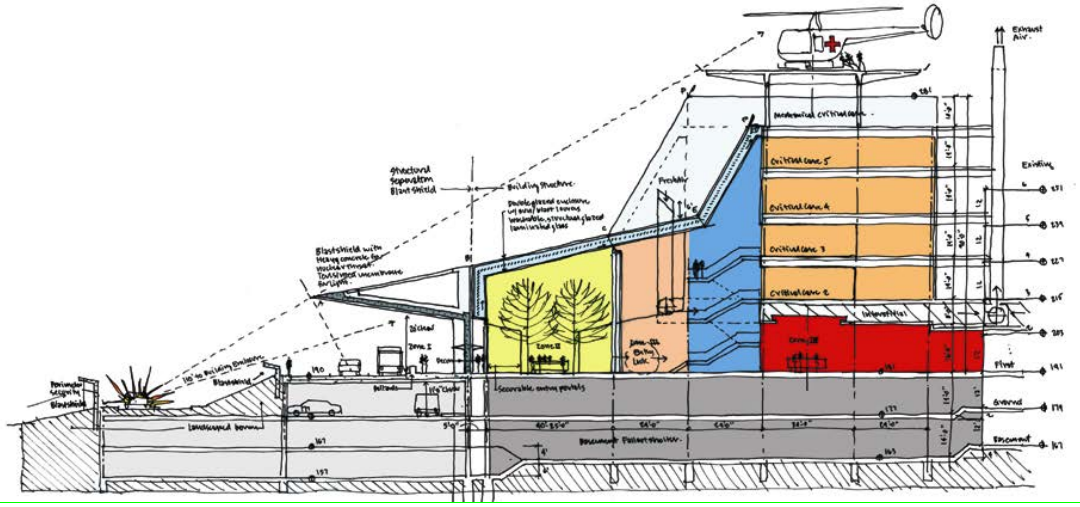


Staff Workstation Configuration

4.1.3 Vertical Proximity Concept

In order to keep the distances to needed services and support at a minimum, the *ER One* design exploited the potential of vertical proximity. Many support functions that required only the movement of equipment, supplies, or other objects could be located immediately

below or above the department. Immediately above, a 6-foot clearance interstitial space allows for lighting, electrical, HVAC, communications and other services to be easily accessed and reconfigured as needed without disruption of the clinical space.



Vertical Proximity of Support to Core Functions

The lower levels are multi-use and are fully integrated into the *ER One* design concept. Specialized labs, power generators, water supply and purification, shelter, storage and equipment service are all located immediately below. Most daily interaction between the levels takes place with a series of strategically located clean and dirty lifts. The dirty lifts are used to transport items to the lower level for cleaning, repair or disposal. Clean lifts are used to supply the emergency department with what is needed at the time of service.

Special services will be provided in the levels immediately below the emergency department engine. Water purification systems capable of providing potable water at all times will be available. Potential energy generation via pyrolytic gasification will use hospital and contaminated waste for energy generation without incineration. A Class III isolation lab will be on the lower level. Servicing of all equipment as well as contingency/mobilization equipment and supply storage will be accommodated. As described in the section on radiation mitigation, these areas naturally serve as a fall-out shelter. Additionally, this level is

Lower-Level Passages for Rapid Access

also gridded for power allowing patient care during times requiring maximum capacity or increased security from external threats. Tunnels from one area to another provide rapid, secure passage of patients and staff.

4.1.4 Concept of Dual Use of Public Spaces

The initial interior lobby area of *ER One* consists of facility connective functions such as escalators, elevators and stairs complemented with art, seating, and retail kiosks. In contingency modes, this area functions as initial triage, ambulatory indoor decontamination or even extended treatment zones depending on the requirement at the time.

The mezzanine provides seating with scenic views of landscape and city beyond. This mezzanine provides comfortable and peaceful surroundings filled with natural light from expansive overhead protected glazing. Light wells extend this natural light to the lower levels.

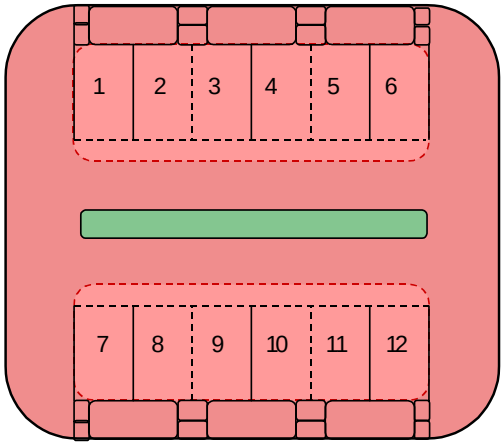
4.1.5 The Module Concept

Given the challenge to develop a functional emergency department that has the inherent capability for scalability to meet the demands of unexpected surges and additionally has the potential for expansion as steady state demand increases over the long term, Project *ER One* undertook an analysis of current usage, projected growth and casualty modeling of various contingency scenarios representing the most likely threats (see Threat Assessment and Casualty Modeling sections). To achieve the goals of scalability while maintaining functional practicality and cost containment, it was felt that an organization of the entire program into modules would be advantageous. The concept was that each section or module could be sized to an optimal scale, allowing staff to function as a team in a relatively self-sufficient unit. Further, this modular unit organization could allow the facility to be built in phases. Modules could be added when demand warranted the construction.

Determining the size of each module is dependent on several assumptions. The most important assumption is the size and make up of the clinical team serving the module. In most clinical situations the treatment team sizes and makeup are determined by the configuration of the facility. For example, a particular emergency department may have 8 rooms on the minor side, 22 in the emergency department, 4 critical care and 2 trauma rooms. These may be geographically separated in a way that determines the team makeup; for instance, one physician, four nurses, and four technicians would be assigned to the critical care area. Different team makeup is determined for the other areas. The *ER One* concept was to determine the optimal clinical team to be led and managed by a trained emergency physician and then subsequently what would be the optimal number and mix of rooms for that team to service. In its simplest terms, the architecture must support the optimally configured clinical team rather than configuring the team to match the architecture. Considerable academic debate will continue regarding the size and make up of the ideal clinical team. No doubt, there

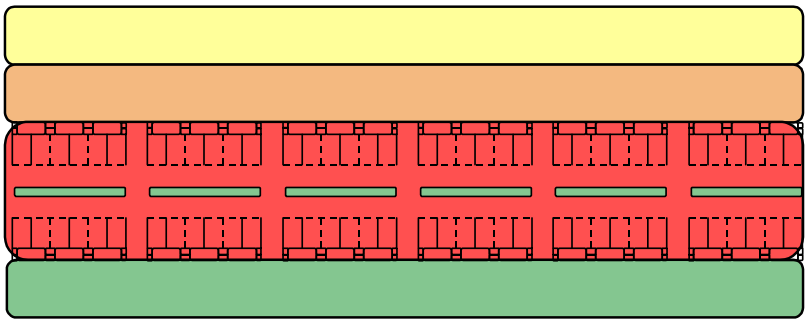
will be variations on this even based on the capabilities of individuals, as clinicians some are more capable than others. Regardless, the *ER One* concept is that facilities should be designed to accommodate and support the clinical team and the size of that team could be determined by the facility prior to initiating the design. In this case, based on experience and data accumulated at the Washington Hospital Center, the assumed optimal emergency department clinical treatment team consisted of a fully trained emergency physician, three nurses, and one technician. It was felt that such a team could manage up to 12 emergency department rooms simultaneously. Thus the 12 room module was established. In some cases the module would include a trauma bay. Based on the 11x16 room configuration and the number of rooms in the module, the dimensions of each module would remain relatively small providing short travel distances for clinical and support staff to any room from any point in the module**.**

The initial program analysis led to a design that eventually could support 80-120,000 annual emergency department visits. It was determined that 96 treatment spaces—92 exam/treatment spaces and 4 trauma spaces—would be adequate. The team considered six geometric ways to organize 6 modules. The number of exam/treatment spaces initially used was 16 per module (16 x 6 = 96). All multi-module diagrams indicate the entire 96-space design.



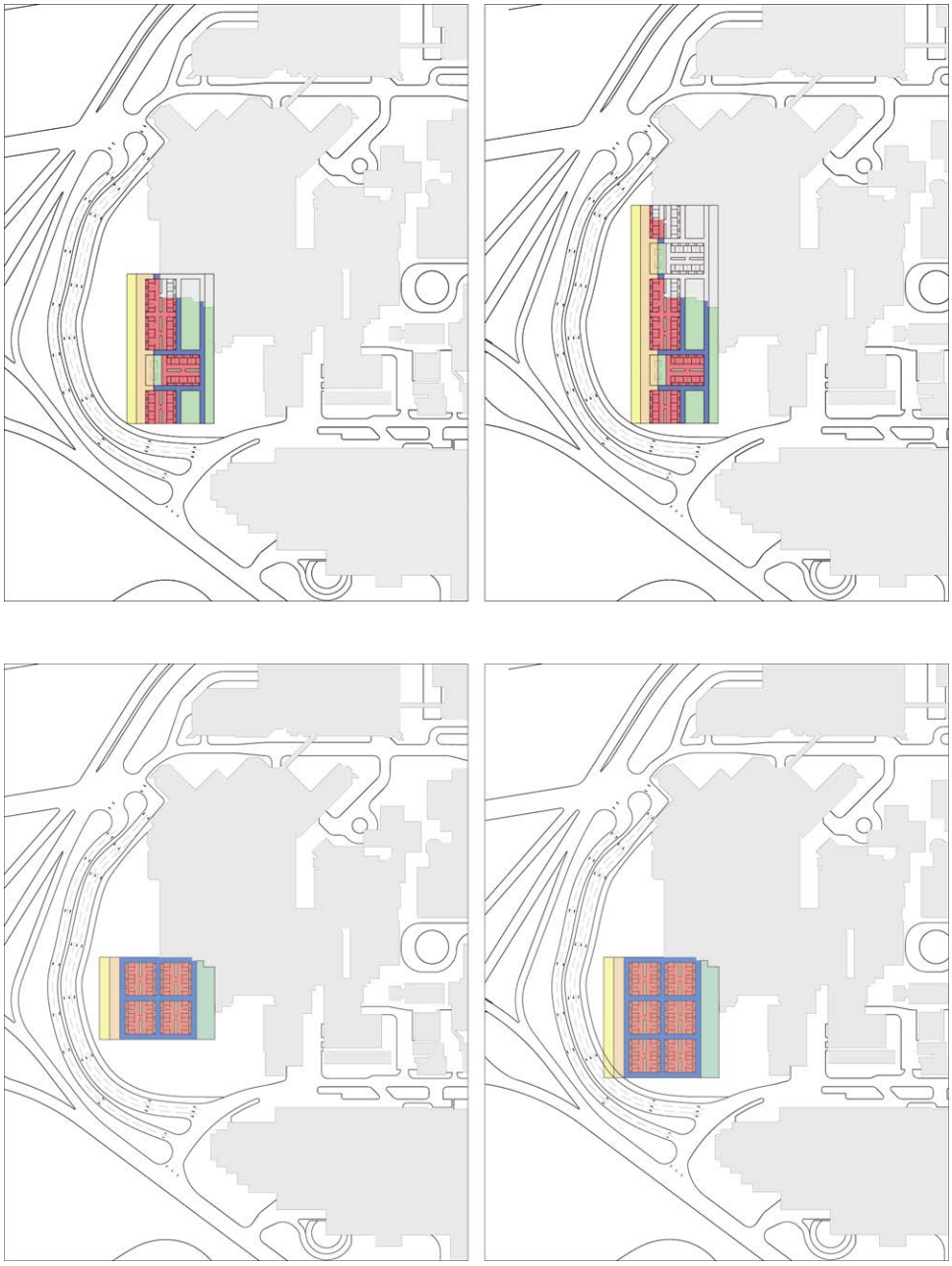
Basic Module Concept

The space program is broken into current and future portions. There are 4 modules in the current program and 2 modules in the future. The four modules were deemed to be sufficient for current and near future demand. Future expansion was integrated to the module diagram master demonstrating the 6-module potential.

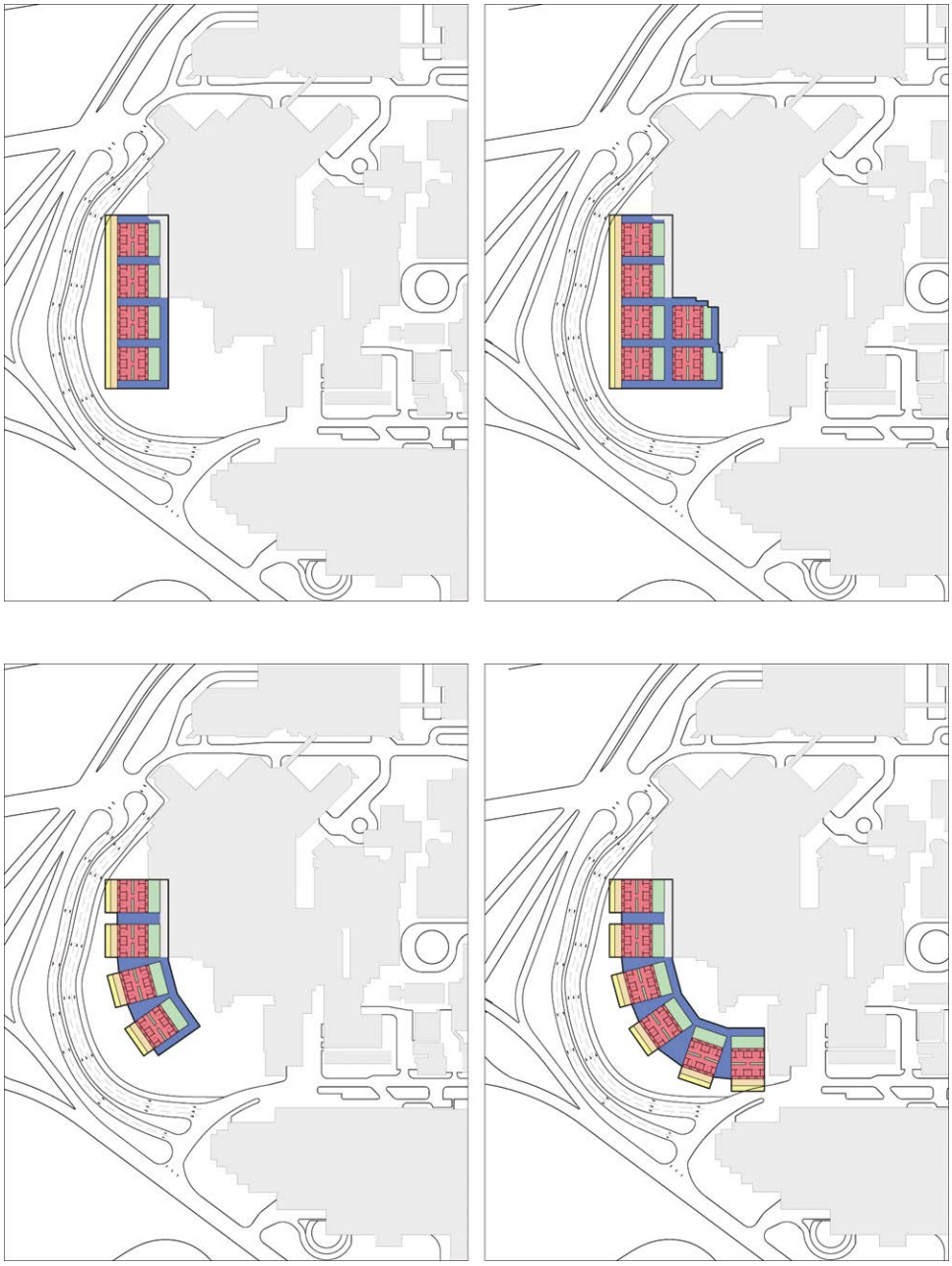


Linear Arrangement of Modules

Three basic organizational concepts were used to replicate the module. These generated four options: the necklace, the hub, the grid, and the necklace with spur. Each of these had particular advantages from a clinical and construction standpoint. However, when the diagrams were drawn to scale and overlaid on the site, the grid and necklace with spur did not fit. Thus site limitations and restrictions immediately eliminated those options. The necklace and hub needed to be curved to fit. See images on following pages.



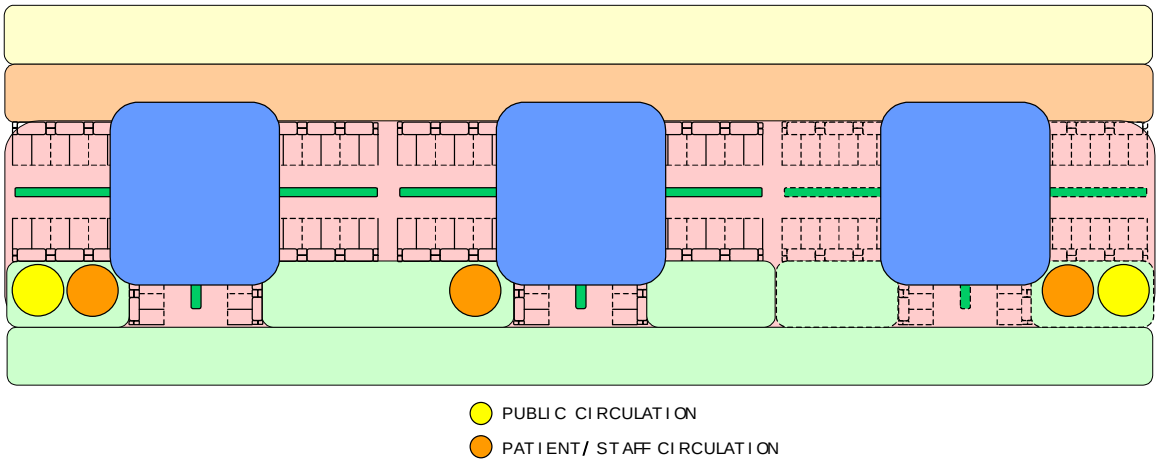
Potential Module Configurations on Site



Potential Module Configurations on Site

A high capacity scalable emergency department cannot provide effective services unless the supporting services and adjoining medical facility can support and accommodate the increased demand. There are three basic approaches to address this issue: Augment the hospital to match the predicted capabilities of the emergency department. Augment the capabilities of

the emergency department to support itself in terms of lab, radiology, food, etc. Provide external support from sources outside the hospital or by distributing demand via rapid transfer of inpatient or surgical candidates to other facilities. The use of any one of these strategies may be limited through space, cost, personnel, or other restrictions. Thus a careful evaluation of a combination of these strategies is desirable. For project *ER One* it was determined that the program also would require intensive care unit towers and additional surgical capacity in proximity to the emergency department to complement the surge capability of *ER One*. Additionally, augmented multimode transportation systems allowing more rapid distribution of casualties were incorporated. The following diagrams explored the relationship between the tower massing and the organizational concepts underneath. They were further developed to explore the effects of separating the public and patient/staff circulation.



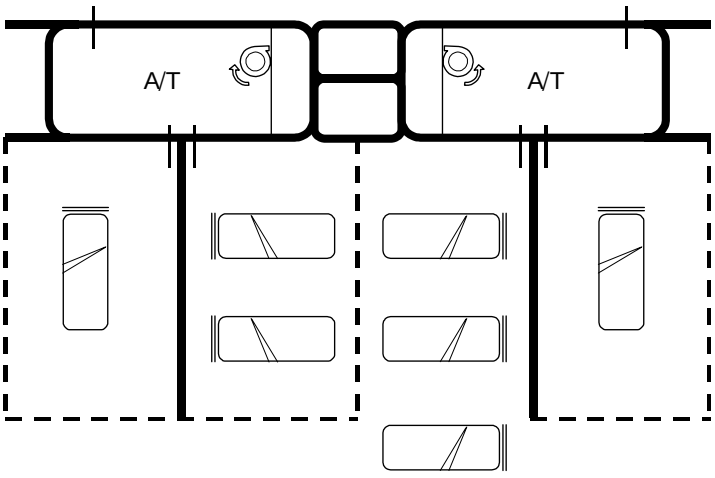
4.1.6 The Universal Treatment Room Concept

Among the most difficult challenges in designing an emergency department is determining how many of each type of room is required. Most major emergency departments find it difficult to predict and accommodate the exact mix of patient types that will present at a given time. The result is often that there is cueing for certain types of rooms while others cannot be used because they are not appropriate for that patient type. A number of formulas have been devised to determine how many minor-treatment, major-treatment, orthopedic, cardiac, and other rooms will specifically be needed. Invariably these estimates cannot predict the ebb and flow of each patient type and over time patient populations can change. A universal treatment room that could accommodate all types of patients would be operationally advantageous. A universal treatment room needs to have the appropriate dimensions, equipment and environment to provide a variety of services. Flexibility in terms of the equipping the room will be key. First, the treatment rooms should have use flexibility. To the greatest extent possible, *ER One* intended to develop a flexible universal treatment room to allow treatment of various categories of patients from minor illness to major trauma.

In addition to flexibility for types of patients, the rooms should have the flexibility to accommodate additional patients for scalability.

4.1.7 The Sizing of the Universal Treatment Room

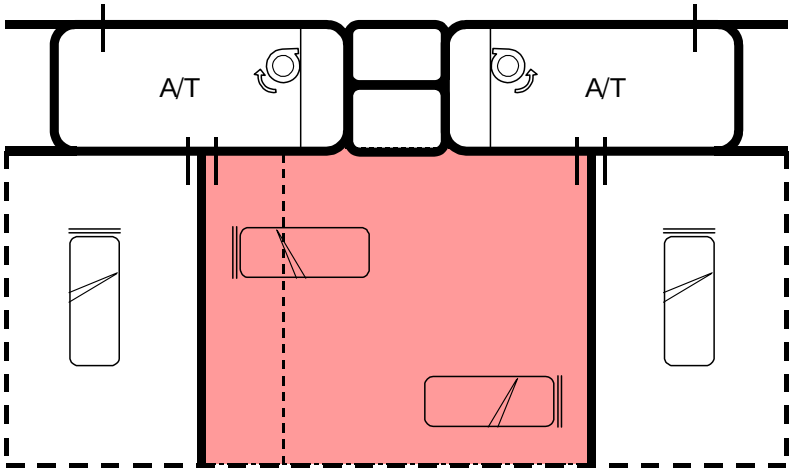
Traditional emergency department design depends on compartmentalization of levels of clinical acuity. Typically, smaller rooms are used for ambulatory care and larger rooms for trauma etc. This strategy attempts to save in terms of square footage needed for the department. The sizing of a universal treatment room was a critical element to be determined. An oversized exam room is not only costly but may create an uncomfortable environment for ambulatory patients. Rooms that are too small could not function for critical care. While most design efforts accept the 110 sq ft standard for examination and treatment rooms (American Institute of Architects guidelines). It became immediately clear that this room size was not optimal for flexibility or scalability. On the other hand, doubling the size of the room to allow the placement of an additional treatment bed would create a significant square footage premium when not being used for two patients and would eliminate desirable privacy if used in that mode consistently. Various options of room sizes and configurations were evaluated to determine a room size that would allow the addition of a treatment gurney during contingency operations while minimizing the square footage premium required. While various size configurations provide different advantages, ultimately, the 6x11 (front x depth) configuration was determined to be the most useful for application in the *ER One* project. This represents about a 55 percent premium for exam room square footage per room. Approximately 175 square feet was deemed to be sufficient for major trauma cases if appropriate equipment were chosen to support the operation. This initially appears to be a large premium for one additional gurney space. However the proposed wide opening doors to the staff work area allows a third gurney placement in an open bay configuration. Thus a three-fold capacity is now possible entirely within the normal emergency department space.



Room Size Analysis for Scalability

The room orientation to the corridor was studied. The team selected the long axis perpendicular to the corridor. Moreover because the 11-foot frontal dimension is not unlike the standard 120 square-foot exam room, there is minimal additional distance for staff to walk.

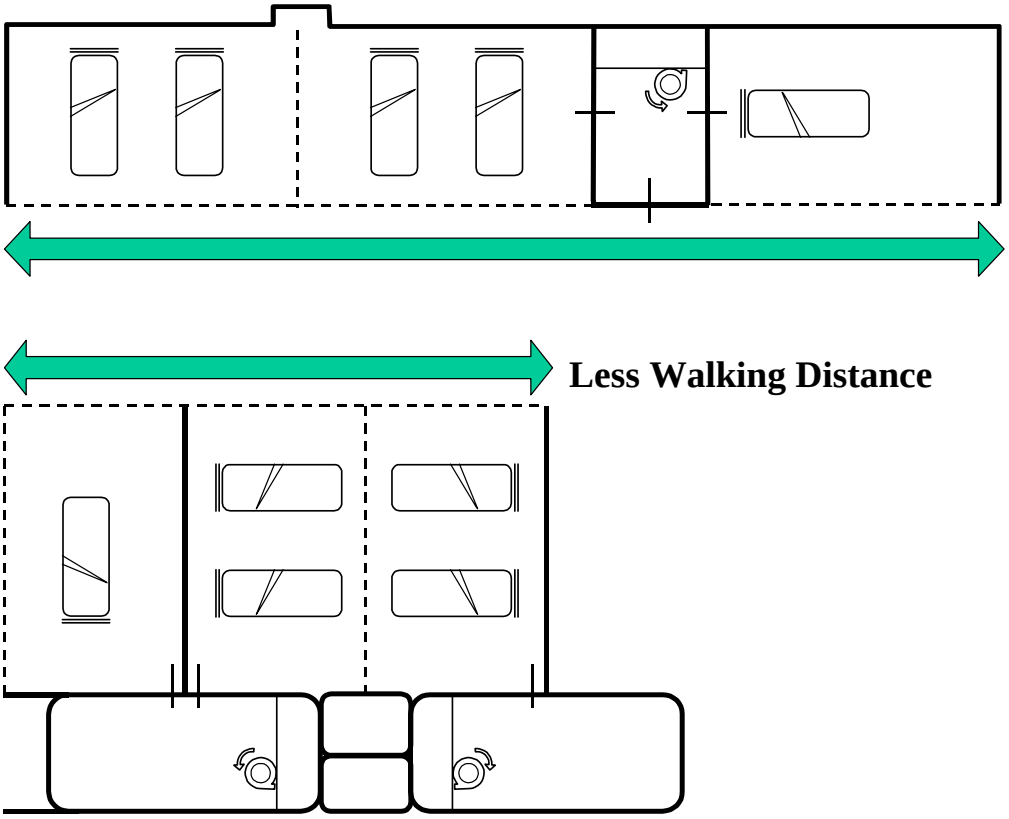
While 175 square feet was determined to be adequate for trauma cases in a contingency situation it was recognized that the standards for trauma rooms calls for greater square footage allowance. The American Institute of Architects guideline for trauma rooms is currently 250 square feet. One of the *ER One* design principles calls for repeatable modularity. Thus the designated trauma rooms would be two of the 11x16 treatment modules. While this 350 square foot trauma room is larger than the standard trauma room, it can also accommodate an additional trauma treatment gurney and team if needed during mass casualty operations.



Scalability in Trauma Rooms

4.1.8 Orientation of the Universal Treatment Rooms

The horizontal orientation provides easy access to all parts of the room from the central provider's station but also requires significant frontage requiring longer walking distances for staff during regular operations. The deep axis configuration offers a high concentration of rooms and less distances for staff to travel as well as enhance isolation capabilities in time of contingency.



Advantages of Deep Axis Configuration

4.1.9 Ancillary Support Positioning – Radiological Imaging and Laboratory

To the greatest extent possible support services were to be provided in or near the modules. All efforts were made to optimize the use of point of service laboratory and imaging with in the modules. Certain support services such as CT and MRI that were frequently used by the emergency department and required patient transport were to be positioned adjacent to the emergency department with easy access from all emergency department modules as well as easy access from the critical care towers. Further, this controlled access support zone needed to separate the emergency department from other public access areas in the hospital.

4.2 THREAT MITIGATION DESIGN SOLUTIONS

Threat mitigation is directly related to consequence management. No facility can engage in a constructive role in consequence management if it has suffered severe damage during the event. In such cases the facility becomes part of the consequences needed to be managed. A general premise of project *ER One* is the mitigation of threat to maintain functionality of the facility in times of need. Key threat mitigation concepts for Project *ER One* are presented below. An in-depth discussion of threat mitigation in medical facility design is provided in Appendix E.

4.2.1 Protected Building Concept

The original concept of the built environment was shelter from the elements. As time developed, structures took on additional features of esthetics, privacy, and functionality that were not assumed in its original role. In fact, we now speak of environmental 'control' functions in buildings rather than protection. The protected building concept expands the original function of shelter to a built environment that can withstand natural, accidental and deliberate events of various types. Protection from natural causes such as flooding, wind forces, combustion and seismic activity have been underdevelopment for years. As would be expected, features that protect from these types of events are only added to buildings if the natural threat is present in that area. For years most buildings erected in the United States did not need to address the issue of deliberate attack. However, this does not hold true today- especially for those buildings that are considered part of the critical infrastructure. This protection is not limited to 'fortification' which implies strengthening the building to withstand physical forces but also requires addressing the more insidious threats such as contamination form biological or chemical events- thus the immune building concept is a subset of the protected building concept. Further protection can be achieved not just with fortification but also by positioning structures in a way that they are less likely to be threatened. Finally, when speaking of the critical infrastructure, especially hospitals, it is implied that the capabilities housed by those facilities are needed during any crisis or event, establishing the need that such facilities can rapidly rehabilitate if attacked or damaged.

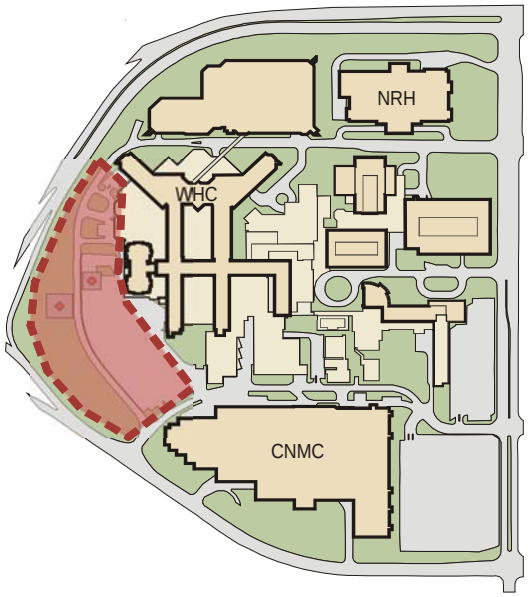
4.2.2 Strategic Location Concepts for Threat Mitigation

Theoretically, the ideal location for a facility that is to participate in the response of an event generating a large number of casualties is difficult to establish because one cannot predict where an event will occur. The driving principles are to be close enough to be useful as a receiving facility yet far enough away so as not be significantly effected or damaged by the event itself. While defining this location for all potential scenarios is impossible, thoughtful consideration can address the issue. For instance, it makes little sense to place a hospital immediately next door to a petroleum refinery, chemical plant or nuclear facility. It also makes little sense to place a facility in a remote area too far to be of immediate use. Besides distance, other factors such as traffic access and protection from flooding or other natural events should be considered.

Emergency department planners are generally not given much choice in determining the location of their hospital. However, they may be given input as to the location of the emergency department within a medical campus or facility. Standoff distance is one of the most useful mitigation strategies for blast, radiation and chemical. The emergency department planners should attempt to choose their location on campus with sufficient standoff distance from uncontrolled public access such as highways or a nearby government building. Emergency departments should be positioned to minimize the effects of traffic congestion that occurs in rush hours or perhaps during contingencies. Additionally, open green space can provide a security setback. While limited to the choice of orientation and configuration on a predetermined site, applying the same principles should allow for a more secure emergency department.

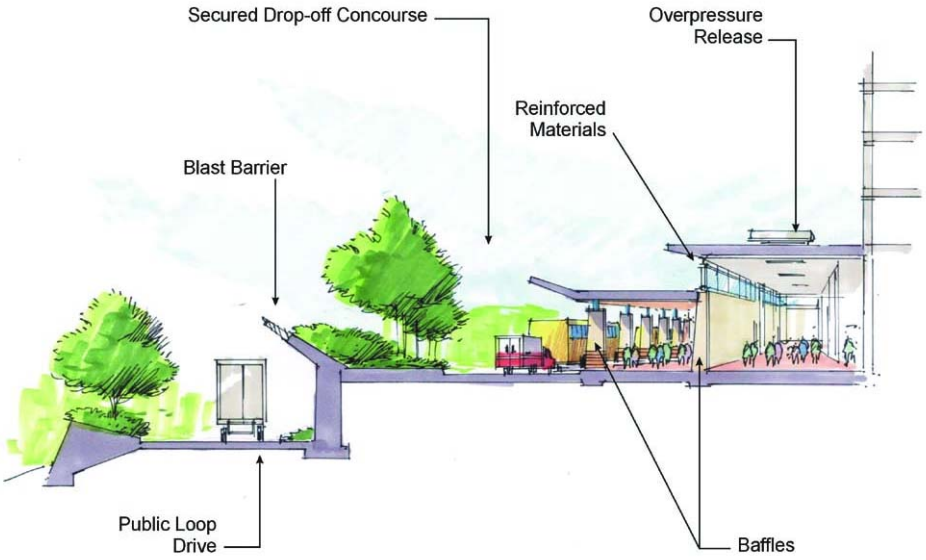
The study site (Washington Hospital Center) is located one minute from the U.S. Capitol building by helicopter and only two miles by ambulance. This proximity to the Capitol and other key government agencies infers a role for disaster preparedness. It is proximal to a high threat area yet far enough away from the center so that it is less likely to suffer collateral damage from a terrorist attack. Additionally, the facility's distance from the epicenter can mitigate the traffic congestion that occurs during contingencies. Washington Hospital Center shares a campus with Children's Hospital, the Washington VA Medical Center, and National Rehabilitation Hospital. The campus perimeter is surrounded by public roads, creating perimeter security challenges. However, other advantages exist. Open areas are available on campus and nearby for vehicle reception and operations expansion; and the resources of all four hospitals could potentially be shared.

Based on the study of the master plan, the western face of the campus was chosen for the design study.

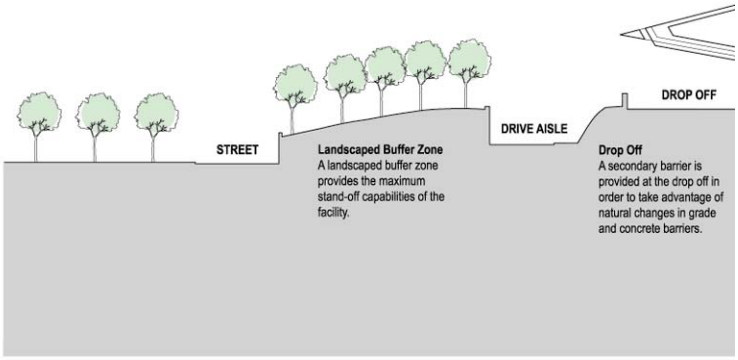


Site Plan Analysis for Strategic Location

This site was chosen because of the proximity to key services in the hospital that would be required to support the emergency department in contingency situations as well as the best location for traffic access and control. The threat posed by proximity to public roads near to perimeter could be mitigated by hardscape and landscape berms.



Landscape Strategy for Protection



Protective Landscape Berms

4.2.3 Portal Concepts

People, vehicles, packages, food, water, air, and information all enter and exit major medical centers in large volumes daily. Any of these modes may provide a means for intrusion into the facility with undesired consequences. The portal concept implies functionality beyond

simple ingress and egress. It involves determining all the processing that one would desire at the time of entrance and egress. First, identifying and categorizing all that enters or leaves the facility will need to be accomplished. Estimates of throughput requirements during normal and surge requirements will need to be defined. Next, one needs to decide specifically what needs to be accomplished in each type of portal. For instance, irradiation used to mail/package handling portals should are not necessary in the personnel portals. Likewise, biometric identification is not necessary for a package. The portal should, to the greatest extent possible, provide all the identification, control, security and mitigation interventions needed before anything enters the facility. An appropriate threat and vulnerability analysis will determine the specific measures needed to be accomplished. Projected volumes will determine the number of portals needed.

The specific design, appearance, configuration, number and location of portals will vary from facility to facility. However, several general principles will apply. The first principle is standoff distance. Most threats other than informatics threats are significantly decreased with distance. This is true of blast, radiation and chemical. Therefore designers/planners should give attempt to place entry control point or traffic portals at sufficient distances from critical infrastructure of the facility such as the power supply or communications center. The definition of those critical areas will vary from facility to facility. In most cases, portals for emergency departments will, by necessity, be adjacent to the operational areas of the department. However, standoff distance for mailrooms, loading docks and vehicle control may be achievable depending on site constraints. Whatever the design configuration of the portal, it should have the flexibility to accommodate additional capabilities or newer technologies as they become feasible.

Ideally, the portal interiors for human use will appear pleasing and non-threatening. Any security, surveillance and monitoring should be non-intrusive. The portals themselves should have surfaces that can be easily decontaminated. The technologies applied should be automated with little labor requirement and allow rapid throughput with high reliability. In some cases these technologies do not yet exist with acceptable efficacy to achieve the desired level of throughput and reliability.

Portals that can be relocated would be desirable in addition to fixed-site solutions. This would allow for adaptability and some scalability in contingency situations. Fixed-site solutions should consider significant blast and other threat mitigation features for the portal itself.

In order for the portals to be effective they must be integrated with other features in the master plan. Secure portals are of little use if perimeter barriers are inadequate or other access points cannot be secured. Effective measures to prevent entry via any method other than the designated portal will be necessary. The monitoring and detection technologies in the portals would need to be connected and integrated with an overall security/monitoring system. Appropriate data collected from proposed screening systems need to be transmitted

to a control site separated from the portal site for interpretation and archival. Finally, the portal concept addresses external threats but not internal threats such a patient to patient violence or workplace violence. Appropriate internal security measures are needed.

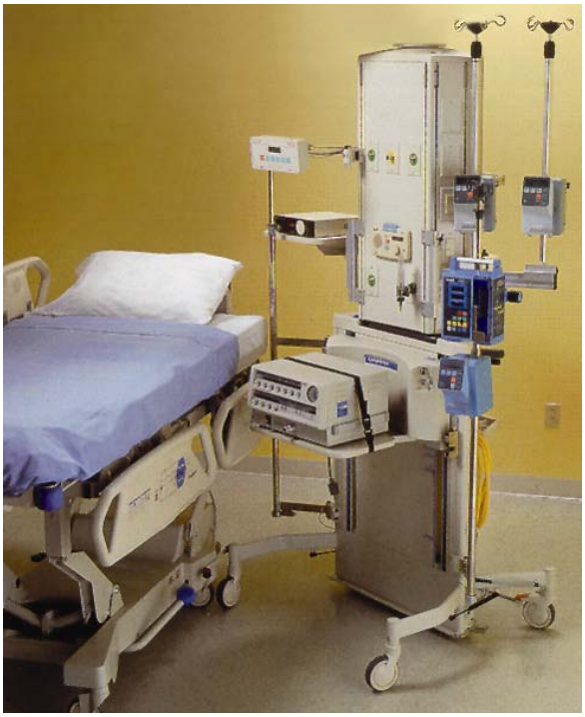
The portal concept is not limited to visible physical structures. In designing an informatics and communication systems for the emergency departments and medical facilities in general, the same concept/approach can be used.

4.2.4 Immune Building Concepts for Threat Mitigation

The "Immune Building" is a concept that a building can protect and rapidly rehabilitate itself when presented with substances that could be toxic to the facility or its inhabitants.

Hospitals have long struggled with the challenge of treating infected patients and keeping the facility clean and safe for other patients. Some biological and toxic agents of terrorism appear to be able to resist repeated decontamination attempts. Hospital rooms have surfaces, seams, equipment, and outlets that pose serious decontamination challenges. There are innumerable cracks and crevices for organisms to hide.

ER One's immune building enhancements include compartmentalized air handling systems with high efficiency, specialized filters that ensure clean air in and clean air out. These systems are designed to accommodate new detection and filtering technologies easily.



Headwall Service Portability

Each surface crack, perforation crevice or corner provides a potential nidus for contamination. Hospital rooms and emergency department treatment rooms typically have numerous perforations for fixtures, lights, power etc. The Project *ER One* Phase II team analyzed currently available technologies to determine what was fundamentally necessary to provide the necessary resources to a room. The first area that was evaluated was the headwall. The treatment room headwall usually has oxygen, suction and air. Each of these creates perforations in the wall and requires an extensive plumbing system. The suction is of particular concern because it is consistently used to aspirate contaminated material. This material is suctioned through tubes that are difficult to clean and perhaps can leak. If this apparatus were not required, a smooth,

cleanable wall would be possible. Portable suction and air are easy solutions. Oxygen generators capable of providing an adequate supply of O2 (scavenged from ambient air) are under development. If deployed such a system would not only allow easier cleaning of the room but also reduce the cost of hospital construction and allow more flexibility of room use. The functions of the headwall could be replaced with portable columns with similar utility.

Furniture systems do not need to be permanently attached to the walls. Most cabinetry could be secured in place but easily removed if cleaning were required. Even a wall sink could have snap on water hook ups. Power cells in the stretchers may eventually eliminate the need for power sources in the wall. Communications can be accomplished in a wireless manner. Typical hospital ceilings with acoustic tiles could be replaced with a seamless translucent membrane. Light sources would be behind the membrane and accessible through the interstitial space above the treatment rooms. In the end, a water supply, ventilation access (discussed below) and the door appear to be the only necessary permanent perforations required in the immune room.

Seamless surfaces of non-porous materials will be ubiquitous allowing ease of cleaning and preventing the sequestration of spores, bio-agents or chemicals in cracks. Self-decontaminating materials and surfaces are selectively applied to walls and floors. These surfaces will be able to withstand degradation from repeated decontamination. Where seams are necessary welding of the seams will further enhance the surface integrity. The use of self-decontaminating materials in the duct and water fixtures will add to the protection. Blister switches and controls will replace standard toggles for ease of decontamination. Smooth covers with gasket seals for any outlets or perforations that may be present but not in use are provided. All corners are coved for easy cleaning. Even keyboards used for data entry would be smooth surfaced blister type keyboards that could be cleaned and sterilized or holographic keyboards could also be used. The end result is a membrane surfacing the room that is readily and rapidly cleanable after any event.

4.2.5 Advanced Ventilation Systems Technology

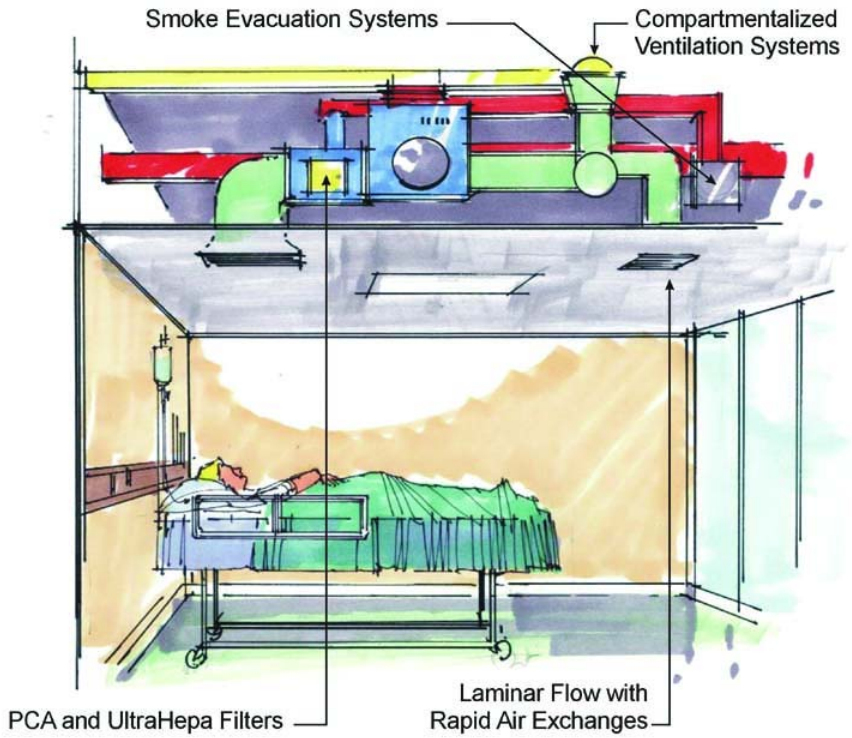
Ventilation systems have been an important aspect of the immune building concept for several years. Hospitals have long struggled with the challenges of providing clean air for their clients. Pathogens such as *Legionella* spread through ductwork. Many facilities have adopted HEPA-filters and ‘shut down’ strategies to ensure a safer ventilation system. However, additional protection can be achieved with careful forethought of ventilation requirements in contingency situations. During normal operations hospitals need to provide isolation capability and clean air environments for procedures. In contingency operations, hospitals will be faced with two basic challenges: preventing contaminated air from entering the facility and preventing infectious or contaminated patients from spreading airborne agents within the facility. Several strategies can be adopted to achieve these ends. These include use of pressure gradients, laminar flow strategies and sealed re-circulation strategies. Each of

these has advantages and disadvantages. Pressure gradients are most commonly employed in hospital environments. Infectious isolated patients are placed in negative pressure areas and immune compromised patients can be placed in a positive pressure environment to prevent infectious agent from entering the area. Only small amounts of pressure gradient are needed to effectively provide effective protection as long as the openings to the area are not too large and traffic in and out does not created too much turbulence. Laminar flow systems continue to send air in one direction. A laminar flow system allows the upstream area to be cleanest. Downstream air can be discarded or re-circulated and purified. Sealing a room is very effective protection but prevents entry and exit. Additionally, it requires oxygen replenishment and CO2 scavenging.

Whatever isolation strategy is employed, the issue of compartmentalized versus smart systems is continuously debated. Sophisticated smart ventilation systems have been developed with capabilities to detect and then to isolate hazards. Such systems have impressive capability but also have a few draw backs. These systems rely on appropriate and properly running detectors, actuators and digital information systems—all known to malfunction. This would be especially true if the building had been comprised by a blast attack. There are a series of seals and actuators that will constantly need to be monitored for functionality and competence. On the other hand, a less complicated solution involves the use less sophisticated, compartmentalized systems. If one breaks, it does not affect the others. Each one of these compartmentalized modules could also have the capability to detect and pressurize automatically or manually. While initial concerns regarding the cost of such a compartmentalized system may be an issue, the hotel industry has favored these types of individual systems for individual rooms for the reasons outlined above and have found such systems to be cost effective. Both pressurized and laminar flow modular ventilation systems have been developed commercially.

In addition to protective isolation strategies, the decontamination of air can occur with a number of strategies including filtration, dilution, physical alteration, neutralization and others. Filters are best understood and play a key role in hospital ventilation strategies. HEPA filtration is accepted technology and commercially available. Catalytic filters for specific types of agents are under development. Physical agents such as ultraviolet light can be added to ventilation ducts and overhead in the rooms to decontaminate the air. To some extent exhausting contaminated air can be considered a dilution strategy as it is assumed its dispersal and dilution in the environment will render it harmless. More radical approaches include aerosolizing rooms with 3 percent hydrogen peroxide mists to rid the air of biological agents.

Although the engineering specifications and detailed design of the ventilation systems are beyond the scope of Phase II of Project *ER One*, the concepts and basic architecture of the systems have been conceived. *ER One* will rely on a combination of the strategies above to optimize protection, operations and medical consequence management. Air intakes will be disguised and inaccessible.



Modular Compartmentalized Ventilation System

The *ER One* design principle of modularity favors the selection of smaller compartmentalized systems over sophisticated smart unified systems. Positive and negative pressure will be possible in all rooms allowing the effective isolation of any room or small section of the facility. The modular-compartmentalized ventilation system allows rooms and areas to act independently. Each unit operates individually removing the risk of system wide failure.

A slight over-pressure coupled with laminar flow strategies will be used in the public areas to force any contaminant outside the facility. Advanced filters using photo-catalytic processes as well as passive HEPA-filtration will be applied where appropriate. The filters will be bathed in UV light to further reduce the risk of live contaminant remaining on the

filters. Furthermore, the ducts can be equipped with UV lights and ultimately lined with a self-decontaminating coating. In non-compartmentalized areas, technology used for smoke evacuation systems will provide protection against inhalation injuries in fire and will provide additional protection if a contaminant is released in the facility.

Fully deployed, the immune building concept will greatly enhance the ability of a facility to protect itself from biological and chemical attack as well as greatly improve the hospital's daily quest to combat contamination and hospital acquired infection. In addition the solutions demonstrated in *ER One* will have substantial extra-healthcare applications. Better air handling systems in private homes and public buildings will result in the reduction of molds and other pathogens known to cause respiratory illness. Self-cleaning and decontaminating technologies could be applied to public restrooms and food preparation facilities.

4.2.6 Blast Mitigation

Any major facility serving the public is a potential terrorist target. Hospitals could be strategically targeted as part of the critical community infrastructure or suffer collateral damage as a result of high yield explosive detonation targeted elsewhere. The integrity of hospital function after a major incident will be key not only to managing the medical consequences of such an attack, but also to maintaining public calm and order. The public expects that hospitals will be safe havens for those who have suffered injury or illness. While the first line of defense will always remain vigilant security and prevention, the best measures can only reduce—not completely eliminate—the risk. Therefore, *ER One* will incorporate features that mitigate the consequences of blast effects, as well as other direct threats on the facility, its personnel, and its patients. Careful attention is applied to provide these features only where needed.

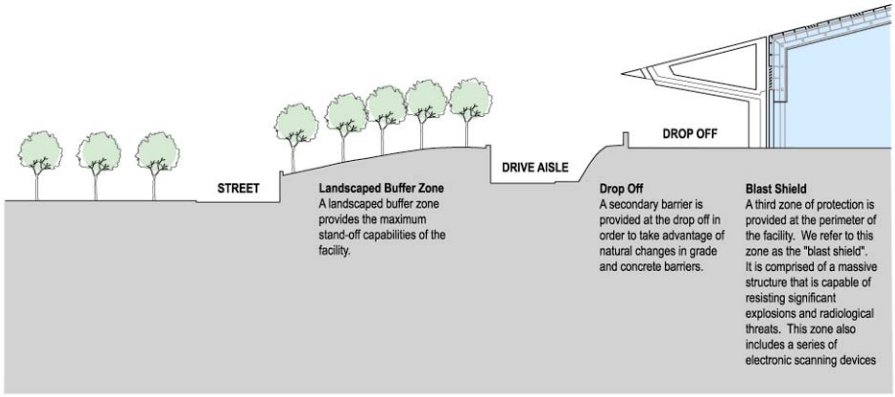
The primary mission of an emergency facility is to provide an environment for effective medical care. It must be a welcoming and healing place; it cannot be built only as a blast-proof bunker. Fortunately, creative engineering solutions and innovative safe-building technologies exist and can be incorporated into hospital design. *ER One* incorporates the strategies of deterrence, prevention, mitigation, and recovery to optimize protection. It fully exploits landscape and facility structures to control traffic as well as to protect against blast propagation.

Blast can be dealt with in several ways: strengthen to withstand it, provide standoff distance, deflect the blast wave, absorb the blast wave, or release the blast wave through vents. Further, it has been demonstrated that most injuries and damage result from the consequences of fragmentation rather than from the blast wave itself. Strategies that can reduce fragment projectiles would be very useful. While standoff distance an effective tool for blast mitigation, hospitals by their very nature must allow vehicles close proximity to the facility.

The best results are obtained by protecting the most critical infrastructure in the most vulnerable areas. Again a careful threat assessment and vulnerability analysis of the critical axis

of the facility will lead to appropriate decisions. The Hazard Vulnerability Analysis for the design study included potential blast from proximal vehicles and potentially a nuclear blast to government facilities near the U.S. Capitol. Considerations for the magnitude of blast resistance for the facility included a 22 PSI load to the building façade. This is the approximate load one would expect from a one megaton detonation two miles away (the approximate distance from the Capitol). The blast wave from a nuclear detonation differs in character from the blast wave of a conventional weapon not only in magnitude but also in the length of time that the blast wave is in effect. This "time load" must be factored in to the blast resistance requirements. Some level of flex will be necessary to prevent structural failure. The blast wave will be followed by high velocity winds carrying significant debris that can pose shrapnel threat as well as depositing radioactive material. Additionally, the facility should be able to withstand a large car bomb blast (unknown load) from the perimeter road outside of any of the *ER One* security checkpoints or perimeter. The most vulnerable areas were considered to be the south portion of the facility near loading docks and the walls nearest traffic.

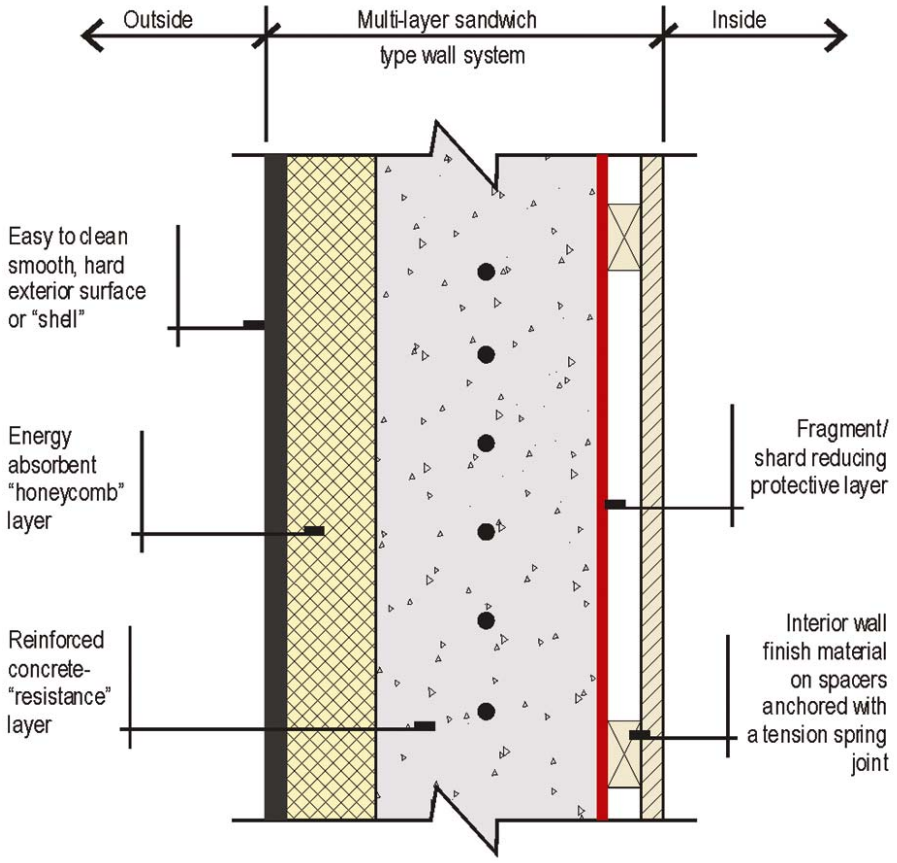
For the *ER One* design study, multiple strategies for blast mitigation were employed. The approach begins in the outer perimeter featuring landscape berms, as well as constructed barriers. The berms serve triple duty by providing natural blast mitigation, traffic way finding and as a natural component to a healing environment.



Protective Landscape Berms

Vehicles are able to enter only through designated portals that act as entry control points and processing areas further preventing the risk that unwanted vehicles will threaten the facility. The entire front of the first level of the facility is constructed as a blast wall. This is the level where vehicles arrive. There are few windows on this level and when present they are appropriately glazed with polymer sheets anchored into the wall structure.

The general scheme of the blast walls includes a multi-layered sandwich. The front blast wall is this type of multiple layer strategy.

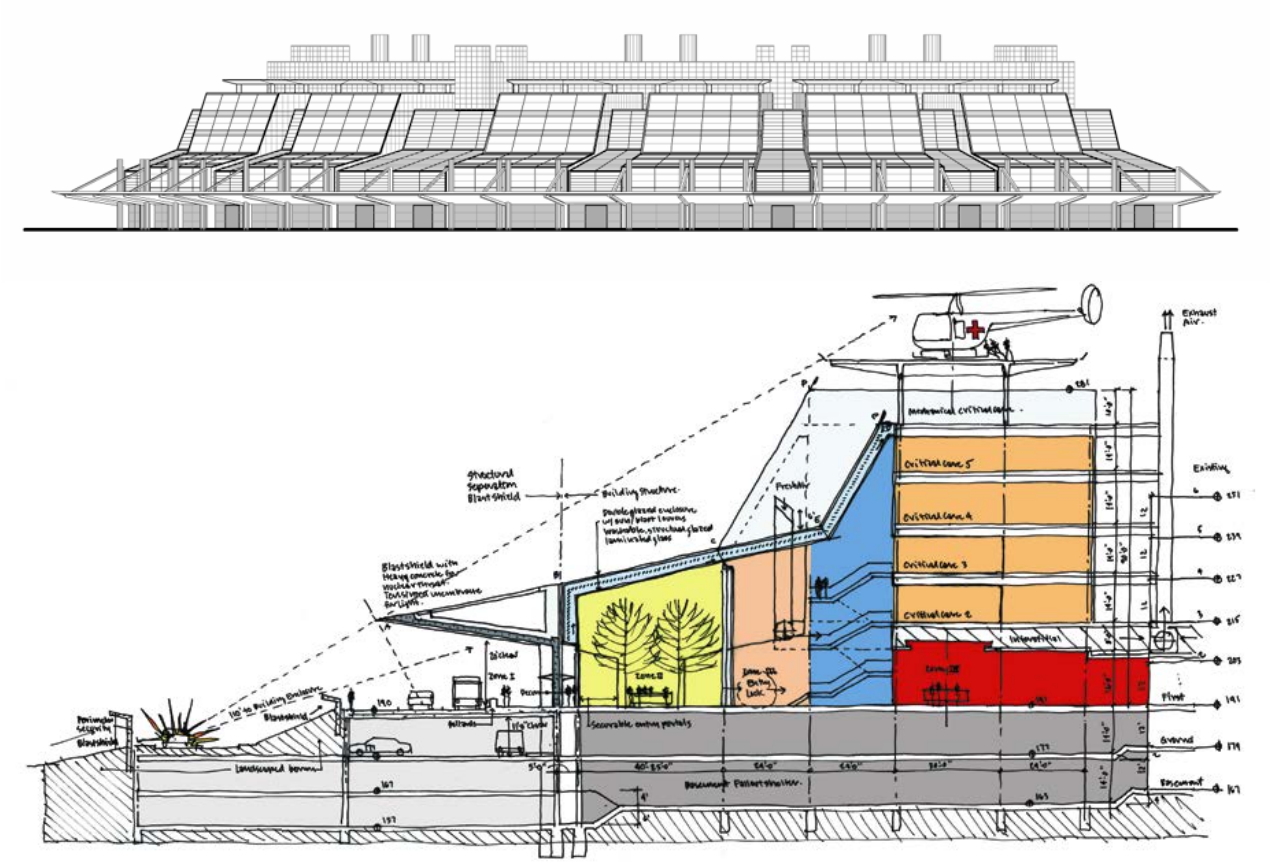


Blast Protection Wall

This includes an external smooth skin that is a sacrificial façade. This smooth external skin provides an attractive façade and at the same time can be easily decontaminated. This external sacrificial façade is followed by an absorptive layer. This can be a number of materials such as high density foam or honeycomb. This layer absorbs blast energy. The reinforced concrete core provides the strength. In those areas were radiation is also a concern the concrete is a specialized mixture with heavy elements known as heavy concrete. This material is able to prevent radiation penetration. The next layer is a polymer or fiber coating that prevents fragmentation. Finally, an appropriate cosmetic interior surface is provided. It is very important to note that this particular arrangement is used only in key areas that are determined to be high threat and critical to remain operational. The arrangement of the doors provides additional blast shielding for the building. A blast canopy extending over two traffic

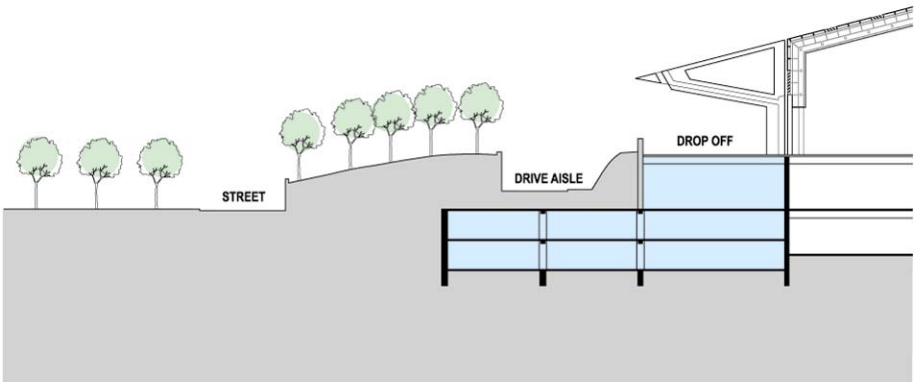
lanes of the arrival concourse and Zone 1 provides protection from explosives to upper levels of the facility. The roof structure selected for *ER One* includes stainless steel with glazing protected by active louvers. Another strategy could have been utilizing a tension membrane type structure with overlapping vented pressure release can provide needed protection while minimizing the risk of structural collapse and related crush injuries.

The building front leans away from the ground rather than presenting a vertical plane of brick and mortar. In the event a blast was to get past the initial shield, the angles created by the frontal design would provide blast deflection for the protected inner zones.



Blast Deflection Strategies

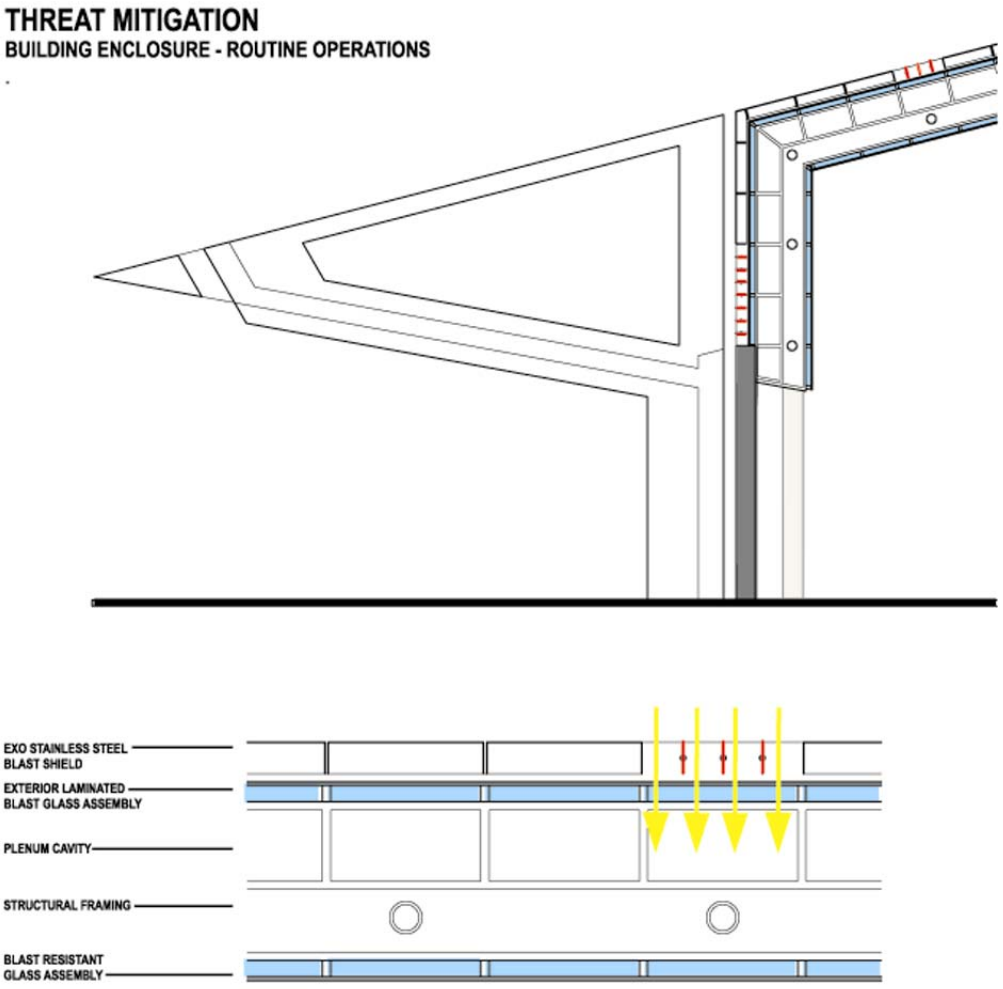
The reinforced blast walls with blast absorbing materials extend to the lower levels providing separation and protection from the parking areas underneath the access road.



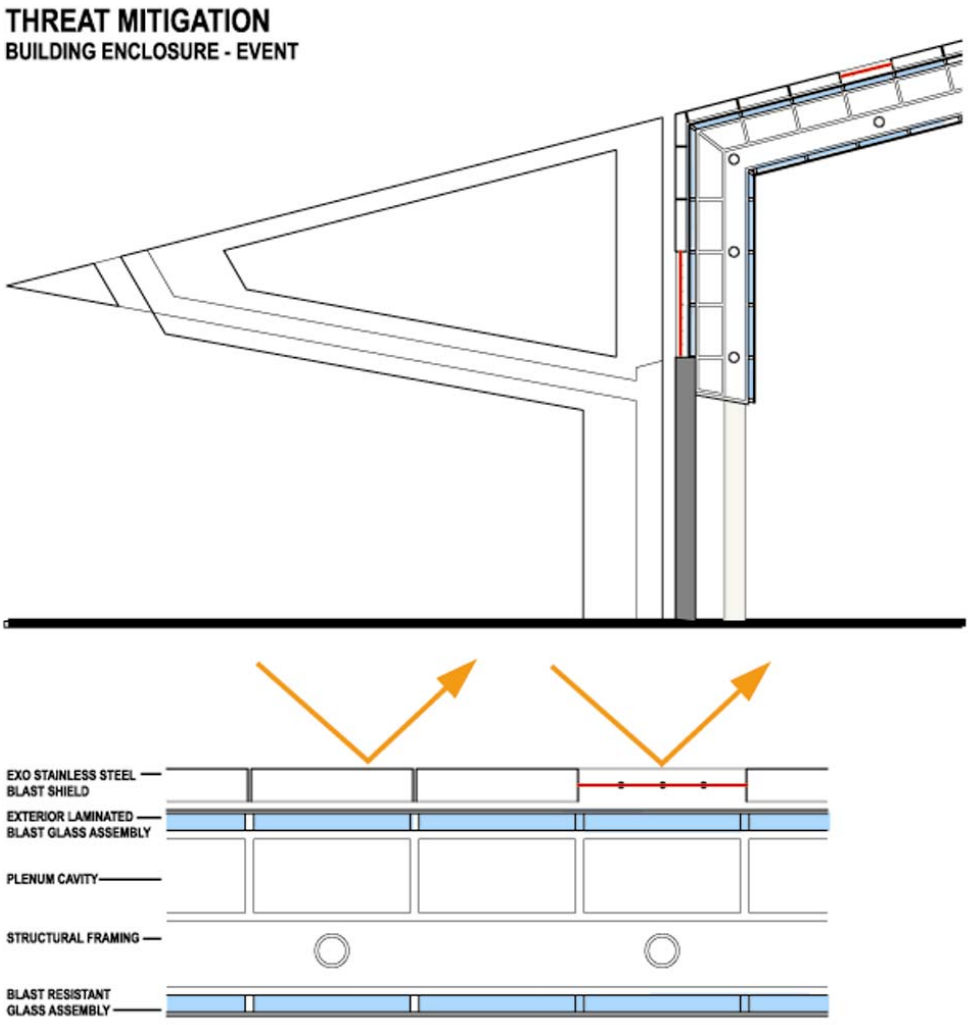
Underground Parking (*Blue*) Outside Building Footprint

Other heavily protected areas include the ambulance garage and the loading docks. These are both located on the periphery of the facility to minimize any damage to the working engine in case a blast does occur.

Natural light is key to the healing environment. Blast mitigation features improperly employed may create a bunker environment. As part of the overall esthetics and healing environment of the hospital's emergency department design will incorporate the use of large expanses of windows. Keeping blast mitigation concerns in mind, the design will incorporate a sloped double glazed integral louvered wall system over Zone 2 in selected areas to provide light. Actuating sensors positioned at key distances on the site (and around the city) will signal early closure of the louvers for blast protection. This early detection technology, similar actuates if an abnormal signal occurs or if signals are lost. During routine usage the louvered wall system will provide natural lighting and solar radiation control. See images on following pages.



Glazing Protection



Glazing Protection Activated

4.2.7 Radiation Protection

Due to its mission and location, the *ER One* facility has the additional requirement of nuclear threat mitigation. This involves blast, radiation and contamination from radioactive particulate matter. The blast performance parameters are addressed in the section on blast mitigation. Radiation protection is provided through the use of heavy concrete in selected areas of the facility. Heavy concrete contains matter such as depleted uranium or other substances that dramatically increase the density of the concrete and thus attenuate the penetration with radiation. Such materials are used in the construction of hospital nuclear medicine areas. Heavy concrete provides a broader spectrum of radiation protection than lead and is considerably less costly. It is roughly 4 times more expensive than standard concrete.

The use of heavy concrete is limited to the lower levels on the western and southern exposures of the facility. This is based on the likely direction of radiation threat. Assuming the facility is able to withstand the initial blast and radiation, protection from particulate matter will be important for continued operations. The pitched roof with wash-down nozzles rapidly removes radioactive particulate matter from the overhead surfaces. Ventilation ducts are positioned to minimize particulate aspiration and the ventilation system filters protect the interior environment from particulate contamination. Standard decontamination procedures are used on individuals entering the facility. The lowest level of the *ER One* facility provides a large hardened fallout shelter for all hospital personnel not working in protected areas.

In addition to radiation protection significant thermal loads will be addressed with high performance insulation materials. Critical electrical infrastructure will need protection from electromagnetic pulse, but the engineering aspects of this are outside the scope of the Project.

4.2.8 Advanced Security Technologies

Hospitals are by nature open facilities. They must allow visitors, patients, staff, suppliers, contractors and others to enter and leave multiple times. During high security scenarios, ingress and egress limitations may impede hospital operations. Intrusive security measures would make a facility undesirable from a customer standpoint. *ER One* employs non-intrusive technologies to enhance security and safety for all staff, patients, family and other stakeholders.

Multiple entry/exit ports for individuals arriving to the facility will feature non-intrusive walk-through screening. These portals will be architecturally integrated into the facility and have the ability to employ various screening and detection technologies as well as the ability to accommodate new technologies. Detection sensors in the ports will check for explosives and toxic materials. Metal detection capability will exist. Advanced biometric identification such as iris scans will be used for all individuals entering the facility and will uniquely identify each individual. The most promising biometric identification for hospital use is iris scanning. With the ability to rapidly, non-intrusively, and accurately identify individuals, iris scanners have several advantages over other biometric identification strategies. The iris scanners will be located at all security portals. Even if an individual has presented false credentials, the iris scan will permanently connect the individual with those credentials. An identification/access band will be attached to all entering the facility when higher security levels are in effect. The band will have the ability to track all movements of the individual. Additionally, patients will have bands that will include vital sign monitoring**.** Despite all these measures, the experience for the individual will be non-intrusive.

In addition to security, such technologies and design solutions can also improve the clinical functions of a hospital. Biometric identification can reduce incorrect blood transfusions or surgery on the incorrect patient. Patients the have been moved to other areas can be tracked for rapid location if needed.

For an in-depth discussion of blast mitigation, see Appendix B.

4.3 MEDICAL CONSEQUENCE MANAGEMENT

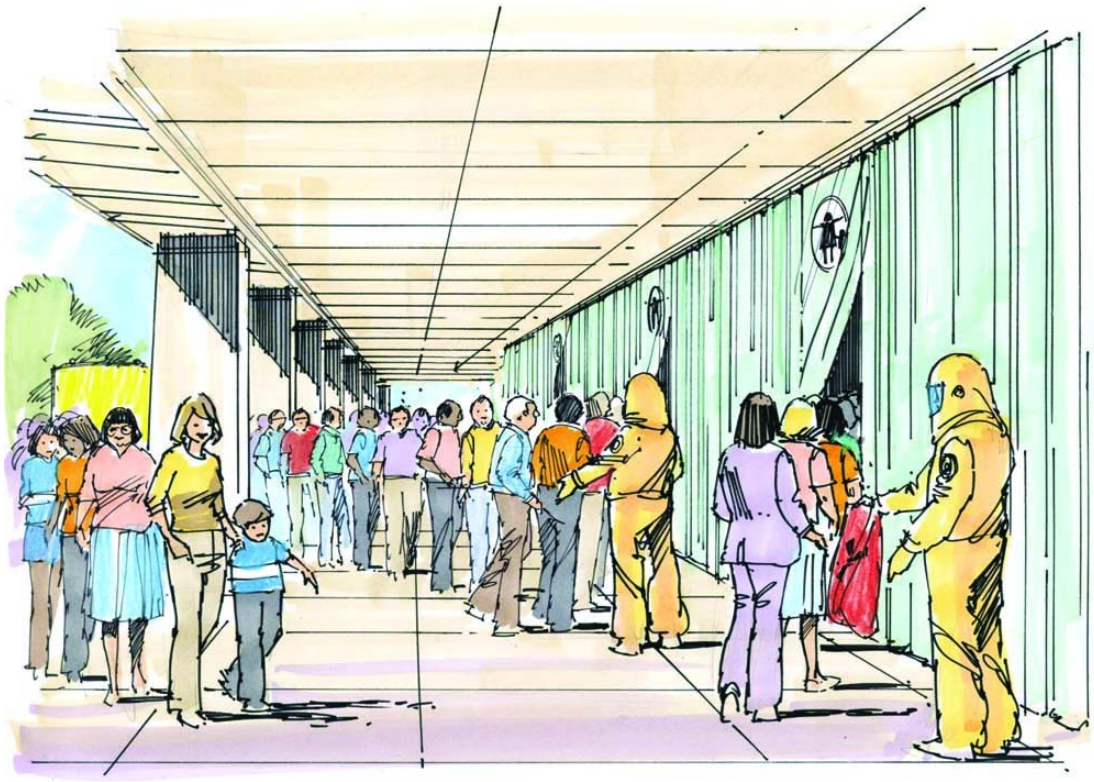
In the event of a disaster or terrorist event, the principal role for the hospital and emergency department is medical consequence management. That is taking care of all the patients that may present as a result of the event. Medical consequence management implies the ability to take care of larger numbers of patients- scalability. For convenience medical consequence management in the design study refers to specialized features or capabilities needed to take care of the types of patients that will be presenting. Scalability will be addressed in a separate section with the full understanding that one affects the other.

4.3.1 Multi-Mode Decontamination

The multi-mode decontamination concept simply means that decontamination should be available at places or points where patients present or wherever it is discovered that they are contaminated. Decontamination capability will need to be present at multiple points including the access points and entry points of the facility, in or near treatment rooms as well as on the grounds of the facility.

While most hospitals have a contingency plan for decontamination and may actually have a single DECON room in their facility, few are equipped for the unexpected presentation of multiple contaminated patients. Planners cannot be ensured that all contaminated individuals will be secured and decontaminated at the event site. Historically, during such events many patients self-refer. A hospital must be prepared to decontaminate the single patient, multiple ambulatory patients, multiple injured patients, and large numbers of victims; furthermore, hospitals might need to be able to provide decontamination at a distance from the facility.

The multi-mode decontamination concept will address the possible various presenting contingencies. The entire entry concourse will have exterior shower-heads under the arrival canopy. This will provide an extensive capability to decontaminate ambulatory patients that have self-referred. The canopy and blown warm air will provide environmental control while curtains will improve privacy.



Ambulatory Decontamination

Drains in the pavement surface will ensure that contaminated effluent is properly managed. Contaminated clothing will be removed and processed onsite. All water for decontamination service will be heated to 88-94 degrees Fahrenheit for comfort and to prevent hypothermia during operations and improving patient cooperation. These features allow for the management of multiple ambulatory casualties presenting unexpectedly to the emergency department entrance.

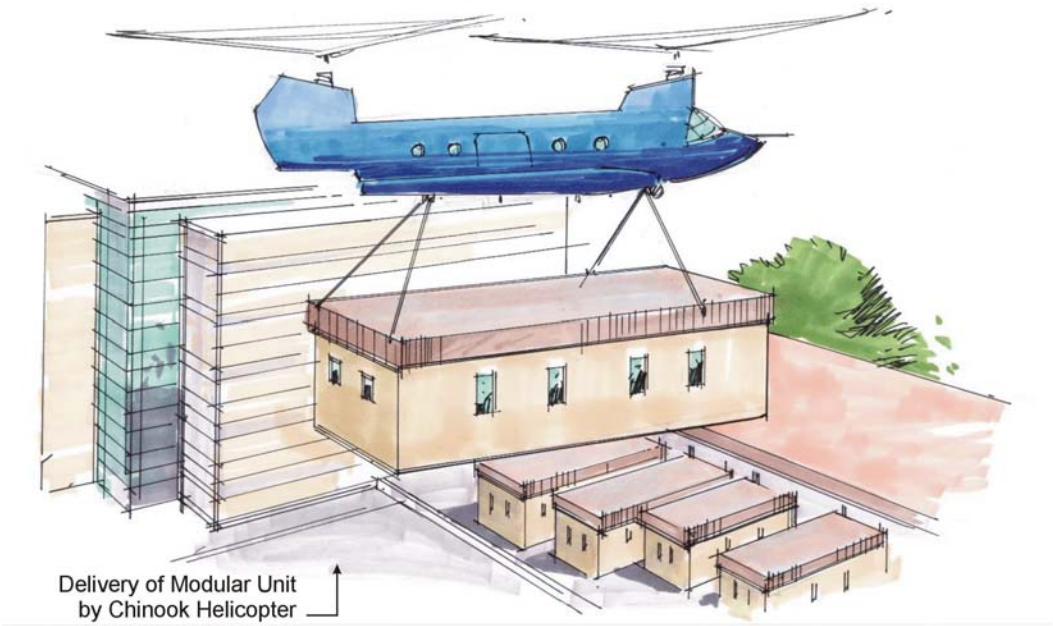
Each entry portal will have more formal decontamination rooms for heavily contaminated and non-ambulatory patients. These rooms are oriented in a fashion allowing unidirectional patient flow, maintaining the decontamination process precepts of warm and cold zones.

Portals with Decontamination Capability

Additionally, each exam room will have integral decontamination capability. In some cases, patients may not state or it may not be discovered that they are potentially contaminated until they are in the treatment room. The exam rooms will have extendible water faucets that will allow decontamination on the examination gurney. Floor drains will allow proper contaminant disposal. For more mundane clinical requirements, the bathrooms adjacent to each

exam room will have shower capability. The decontamination strategies outlined above do not rely on set-up of facilities and provide extensive environmental protection. More importantly they do not alter the intuitive ‘daily routine’ of patient arrivals. It does not require re-routing of vehicles and patients to areas that they do not normally drive to.

There will be approximately 60 ambulatory and 12 litter stations available without any set-up or preparation latency. If the number of casualties becomes even larger, other areas have been identified that can be recruited to assist with mass decontamination. The ambulance garage will be fully equipped for decontamination. In controlled scenarios this may be the arrival point of choice as it could keep the regular main entrances clean. Additionally, modular mobile units with decontamination capability will provide the ability for remote decontamination in the event it is advantageous and possible to do decontamination remote from the facility.



Portable Modular Decontamination Units

The overall effect will be a scalable decontamination capability that will be able to conveniently handle the single patient, several patients, or large numbers of patients, and provide remote decontamination or assist the community at the decontamination site.

4.3.2 Consistent Universal Isolation

4.3.2.1 Universal Isolation

It is impossible to prevent potentially contagious individuals who require evaluation and care from entering medical facilities. Many contaminated or infectious patients will not be identified as such until they have progressed well into the facility. *ER One* will incorporate the design specification that any room or section of the hospital is automatically contained and isolated from contiguous rooms and sections *all of the time*, during normal operations as well as during the time of a disaster. Furthermore, every room will have the capability for in-room decontamination and disposal of toxic or infectious material.

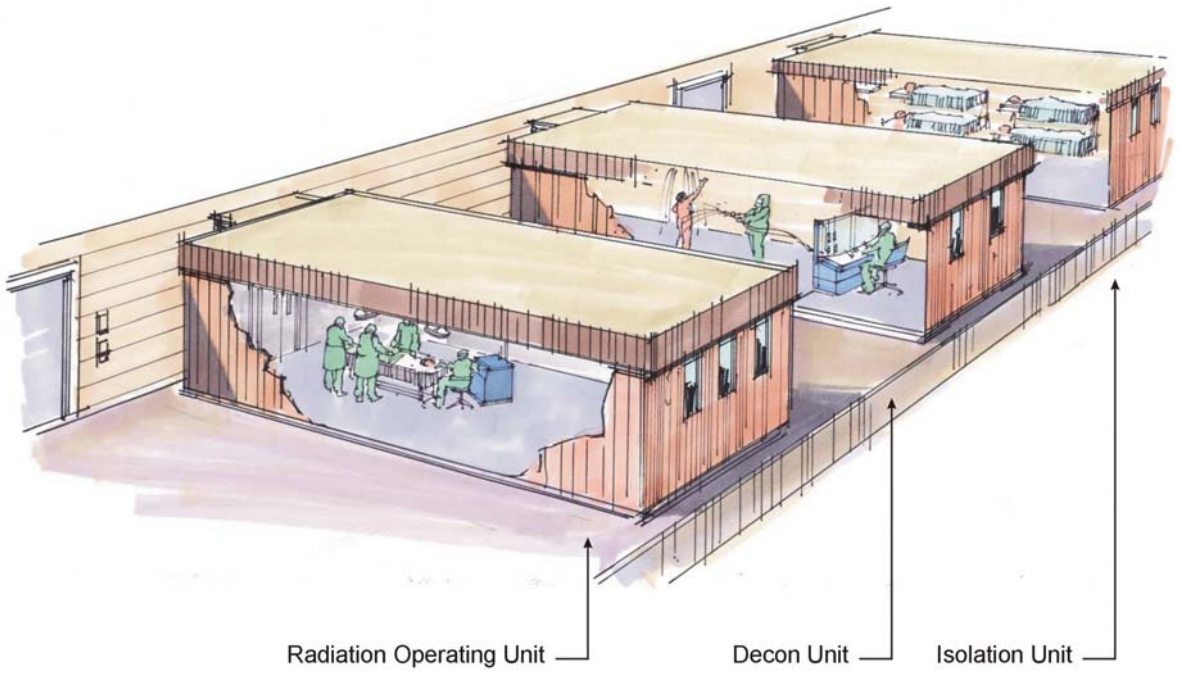
Design features will include rapid air exchanges through advanced filtration systems. The air handling systems will be compartmentalized to relatively small areas (in some cases one room) allowing isolation as well as filtered air in and out. The ventilation systems will be designed for easy access for cleaning and incorporation of new purification technologies. Each room will have the capability to do a rapid decontamination through the availability of warmed water outlets and drains systems. Protective gowns and respiratory devices will be readily available to care providers.

The concept of consistent universal isolation incorporated into hospital design will reduce the risk of transmission of dangerous diseases likely to be used in bio-terrorism. This is classic dual use technology, because the day-to-day benefit will be even greater. The in-hospital transmission of tuberculosis as well as other resistant, potentially epidemic diseases will be greatly reduced.

4.3.3 Specialized Modular Mobile Units with Docking Stations

No facility can be prepared in an optimal configuration for every possible contingency. *ER One* will test a concept of modular units that can be docked to the permanent existing facility to provide the specialized capabilities for contingency situations. For example, the need for an operating suite that has radiation shielding rarely would be required. An ideal design would be to employ a mobile modular docking unit could be attached to the facility when needed but at other times be removed. This specialized resource mobile unit could share among several facilities on an as needed basis. Another use of the module concept would be for scale-up or augmentation of existing capabilities. Decontamination modules could dock to the DECON area providing expanded service. Similarly, they could be moved to a satellite location if it were determined that decontamination would be executed better at some distance from the facility.

Occasionally, some infectious processes may be of such concern that hospitals would not be capable of handling such patients even in standard isolation rooms. An example would be a patient infected with Ebola virus. In such cases, specialized isolation modules could be employed without any direct connection to the main facility. In summary, modules can provide both scale-up and specialization capabilities.

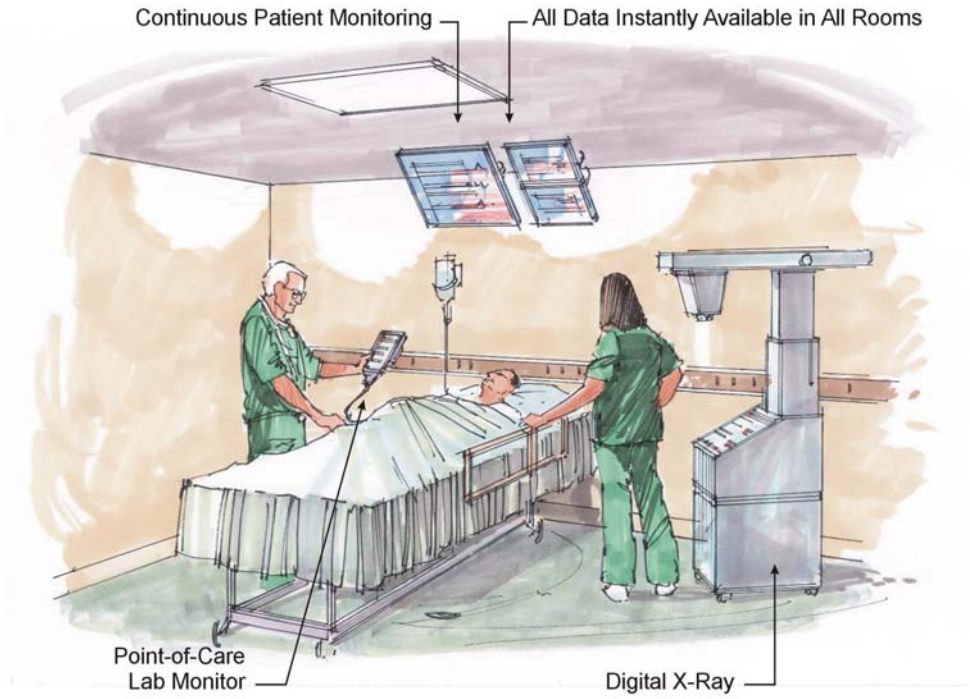


Portable Specialized Modular Medical Consequence Management Units

4.3.4 Point of Service Capabilities

Patients are inconvenienced with repeated movement requirements for laboratory and other ancillary tests. Long delays waiting for returned labs or patients sent to X-ray have for years been rate-limiting steps in emergency departments. These delays will become even more critical during contingency scenarios. Furthermore, the patient movement requires valuable manpower that will be very limited during disasters. *ER One* will maximize point of service capabilities for lab/registration, X-ray, continuous patient monitoring and informatics. Delays will be avoided with X-ray and lab being accomplished in the exam room with equipment usable by emergency department staff rather than technicians from other departments.

Equipment such as portable point of service lab and breathalyzers for rapid diagnosis of respiratory infections potentially eliminate the requirement for patients to be repeatedly moved.



Point of Care Services

4.4 SCALABILITY

The Project developed design concepts and features for medical facilities in the multi-threat environment were developed for the three primary focus areas: threat mitigation, medical consequence management and scalability. The features selected for threat mitigation are largely determined by the hazard assessment and vulnerability analysis provided in the section entitled "Project *ER One* Threat Assessment". Likewise, the medical consequence management features one chooses to apply in the facility are largely determined by the potential medical entities one would be faced with. Scalability is of a different nature. This addresses how large the facility may need to be in order to provide adequate surge capacity during contingency events. It makes little sense to build something larger than could ever be needed. On the other hand, it is essential that the medical system have a robust surge capacity to manage the volumes of patients that could be generated as a result of today's threats from terrorism, epidemics and disasters. Scalability, unlike the other elements, requires some quantitative understanding of the magnitude of casualties that could be expected from the potential scenarios. As these events are not common and little hard historical data is

available, casualty modeling becomes a useful tool to estimate potential casualty numbers. The determination of scalability requirements is more useful if coordinated through regional authorities rather than by individual hospitals. Each medical facility must know its role in the various scenarios before making adjustments to their design.

Casualty modeling estimates resulting from a nuclear event would have required a design that could accommodate up to 10,000 casualties in the first 24 hours. A rapid analysis of this determined that the scope of such a facility was beyond financial realities. Moreover, the site itself was limited and could not accommodate a facility of this size. Thus the program strategy became to determine operational needs under normal conditions for the emergency department and the supporting services of the Washington Hospital Center. This was followed by reasonable projections of future needs based on predicted growth. Finally, given this program, what type of surge capacity could be practically built within reasonable cost parameters. Thus the objective may not be to build a facility that has adequate capacity to absorb and conceivable number of casualties but rather one that would be adequate for most events and a reasonable capacity for the worst events. The reasonable goal agreed upon was to develop a four-fold surge capacity within the built facility while maintaining a functional healing environment for every day use. Based on the casualty modeling scenarios such a fourfold surge capacity would be adequate capacity for most contingency events.

4.4.1 General Comments on Designing for Surge Capability

Central to *ER One* goals is the development of and emergency department with significant surge capacity for mass casualties and disasters as well as the ability to accommodate the expected variations in patient volume from events such as influenza outbreaks. Achieving large-scale surge capability has been challenging. Simply making a larger facility that sits idle during most of its existence is not cost effective. Further, even if space is provided one most also have the staff and logistical support to effectively provide the care and services.

If surge capability is redefined as output, one can analyze the elements that can be modified to temporarily increase the output. First, personnel can simply work faster; in fact, this is expected behavior in many critical situations. However, it is a limited strategy as it leads to errors and fatigue over time. Second, the processes used by personnel to create the output can be modified via streamlining or even omitting steps that are not considered necessary in emergency situations. Third, personnel can be added as long as the facility can accommodate the additional personnel. Including additional physical capacity to respond to a surge is only practical if the space would not be idle and non-productive during normal operations. Therefore, an effective design should be able to efficiently leverage all of the above-mentioned strategies.

To achieve a true surge capability the combination and integration of facility, personnel, supply, logistics and processes is needed. These elements are tightly inter-related. While

beyond the charter of Project *ER One*, a brief discussion of manpower is warranted as it is critically related to surge capability. Essential to this discussion is whether manpower can be augmented and any particular facility or whether an attempt should be made to simply distribute the patients to other facilities as rapidly as possible. The arguments for either philosophy are both compelling and flawed. Depending on the particular situation and circumstances it may be advantageous to have both capabilities. The moving of large numbers of casualties is very labor and logistic intensive as well as creating inherent clinical risk to the patient. The moving of providers is faster, cheaper, and less risky. The challenge is whether local licensing and privileging concerns can be met. These are issues that are being resolved by policy makers. Among the solutions is the use of National Guard medical personnel from other regions on a temporary basis. Once providers are available they must have an appropriate environment to work in. The set up of a contingency hospital consumes time and rarely provides and an optimal clinical environment. The emergency department and medical facility that is rapidly scalable and could accommodate the additional personnel is advantageous in circumstances where immediacy is paramount. Assuming that a scalable emergency department is useful, the design should employ simplicity and intuitive obviousness so that providers not familiar with the facility can function effectively with minimal orientation.

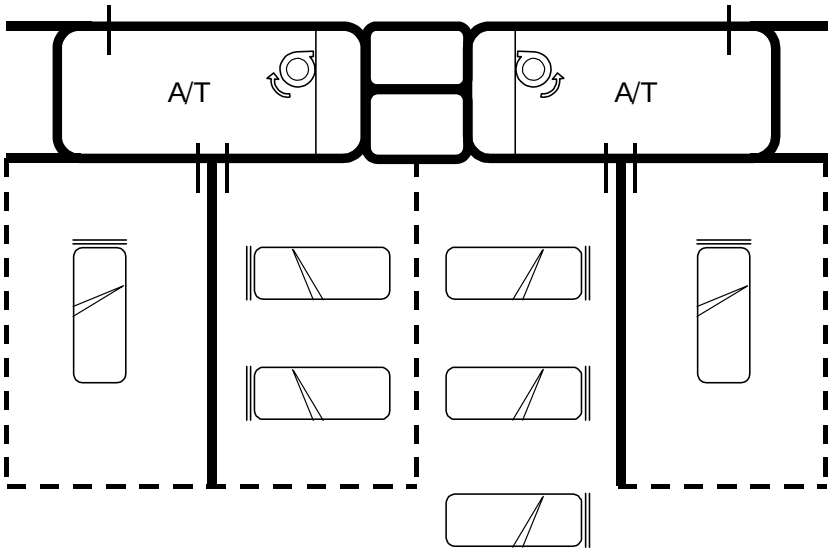
The design itself can also support logistics and supply functions. The design should support the processes and not require work-a-rounds. An effective design can even reduce personnel requirements if distances members of the clinical staff need to walk are minimized, etc.

Emergency departments should be designed within the constraints of operational normalcy. Stated another way, the general facility size should be determined by expected operational needs under relatively normal conditions. The square footage premium for additional contingency capacity should be carefully added to provide the most benefit for the least additional cost. An evaluation of medical facility physical layout reveals that there are numerous spaces with sufficient square footage to provide large-scale patient care. Examples of this include hallways, auditoriums, atriums, public spaces, conference rooms etc. Each of these areas is usually large enough to accommodate patients. Unfortunately, in most cases these areas remain unsuitable for patient care because of inappropriate surfaces, lack of power supply, water and other services or they are simply in a location that cannot be effectively supported by the personnel. Advance thought to these spaces could provide the opportunity to orient the space and incorporate the appropriate features to render such space as usable and effective in times of emergency without excessively increasing the square footage of the facility.

From the design standpoint this equates to increasing potential bed capacity without dramatically increasing square footage. Further this bed capacity needs to be in a configuration easily serviced by the staff and convenient to logistical support. This can be

accomplished in two general ways; increasing the bed capacity of the standard treatment rooms and providing for bed capacity in areas not usually used for treatment.

Semi-private rooms have long been the standard for inpatient facilities. The principal driver for this has been the lower cost of putting two beds into one room. This semi-private arrangement is highly preferred by third-party payers. Emergency departments typically require private exam and treatment areas. However, in contingency situations demand may dramatically increase. By adding an incremental margin of square footage, one could provide sufficient space for an additional treatment gurney if needed. Much like a semi-private room, this would be far less in cost than constructing and additional room. Furthermore, an additional gurney space can be gained if an entire side to a room could be opened to a hallway or common space area. This can be accomplished through a full-face entry to an exam room. While sacrificing privacy during major contingencies, such a configuration can minimize the additional square footage requirements.



Treatment Room Scalability

It is also feasible think vertically within a room and provides additional capacity through bunking. In fact a triple-tiered configuration has been used on military aircraft for air evacuation and previously on army hospital trains. There are, of course, disadvantages with bunking patients in terms of accessibility for clinical interventions. Nevertheless, the potential of vertical capacity should not be dismissed, especially for holding areas of stable patients unlikely to require immediate interventions.

The triage or patient reception areas can also be converted into a treatment area if needed. Convertible chairs that can be used for standard seating during normal use become recliners or even patient stretchers in a contingency situation. Additional capacity can be obtained by moving outdoors.

Scalability by Expansion into Available Space

Once all the potential of the exam/treatment rooms and standard clinical spaces has been exhausted, additional contingency bed capacity can be gained in other spaces of opportunity. As mentioned above, these include but are not limited to hallways, auditoriums, atriums, conference rooms, administrative space, etc. There are three keys to making such space usable for patient care in contingencies. First, the appropriate utilities such as water, oxygen, and power must be available. Second, the physical environment must be appropriate. For example, surfaces must be cleanable, carpeted surfaces are not appropriate for care areas. Finally, the orientation and location of these areas must be accessible and in reasonable proximity of personnel, ancillary services and support facilities such as restrooms. These are all achievable if considered at the outset of a new facility design. Retrofitting existing facilities provides additional challenges and cost barriers. For example, attempting to route power and water supplies to an atrium that is remote from any existing patient care area is an expensive undertaking and may ultimately not be logistically or clinically supportable because of the location.

Nevertheless, existing facilities may find that certain areas of their hospital are amenable to some modifications that will allow retrofit of contingency bed capacity. This is more feasible with of the development of the integrated critical care gurneys that provide the ICU headwall services in the gurney.

Adopted from military field critical care stretchers, the *ER One* treatment gurneys are designed to be self-sufficient. All capability previously available on the headwall such as oxygen, suction and air are now integrated into the gurney. Further these units accept modular components such as cardiac monitors, ventilators and IV pumps for quick swap needs specific to the patient. Breakaway power cords and internal battery power provide significant mobility, eliminating the requirement to disconnect and then reconnect monitor wires and IV tubing. The result allow for rapid patient movement of the patient to the operating room, critical care unit or to the radiology area for MRI or CT scan.

Portable Modular Critical Care Capability

In the *ER One* design, the cleaning and staging of such gurneys is located in level immediately below the emergency department. As series of appropriately positioned lifts efficiently move the used and serviced gurneys between the two levels. Trained technicians (as opposed to standard janitorial services) ensure the quality of cleaning services and equipment function.

Position of Service Lifts (*Orange*)

Finally, these gurneys are moved elsewhere for cleaning and servicing during changes of patients. Immediately replacing the used gurney with a fully cleaned and serviced unit will lead to more rapid room turnover and less patient waiting.

Traditionally, a treatment room requires 20 minutes or more to clean and set up for the next patient. Cleaning of the room and exchange with a clean stretcher with the specific components needed for the next patient can now be accomplished in approximately 2 minutes.

In addition to providing bed capacity and space for additional personnel, the design of the facility should enhance and support processes such as triage, decontamination, patient registration, security as well as clinical procedures. Efforts should be made to analyze staff and patient movement distances for care and ancillary procedures such as X-ray. All time spent in movement is time not spent in clinical care. The general layout of the *ER One* design study attempted to optimize the arrangement to meet this end. Details are demonstrated in Section 5.

Contingency equipment storage should be logically placed for rapid and easy access. If the design requires excessive walking distance for providers to wash their hands in mass casualty scenarios then the care process will be unnecessarily slowed or, most likely, hand washing will not take place. Infection complications will increase. Therefore, design efforts should carefully evaluate the typical processes to be required in both normal clinical and contingency operations. In the *ER One* design, hand-washing sinks are placed near the entry/exit of each treatment room.

In summary, the design development of a scalable emergency department is an effort not only to increase physical capacity but a consideration the relationship of the physical design to personnel and processes likely to be involved in both contingency and normal operations. Such scalability needs to be accomplished within budgetary constraints and still maintain an appropriate healing environment. Project *ER One* approached the scalability goal with these issues in mind. Some of the scalability concepts and features applied to *ER One* are described below additional details are displayed and discussed in the architectural narratives in Section 5.

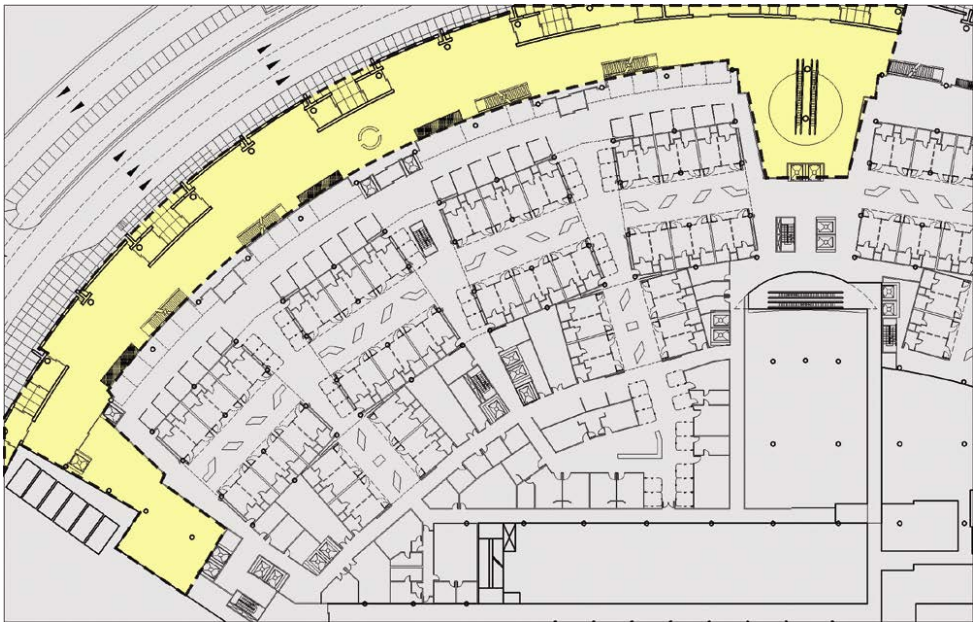
4.4.2 Flexible Configuration of Treatment Areas

A state of the art emergency room receives four trauma casualties but has only three trauma bays. Where does that fourth patient receive care?

Any hospital can face this problem. Although there may be a sufficient number of emergency treatment rooms, typically hospitals design emergency departments with only a few major rooms. The *ER One* prototype uses not only the concept of the universal treatment rooms but also allows for reconfiguration or removal of a wall between two standard rooms to double the size if that is desirable. With the universal treatment room concept critical care, trauma and acute care rooms have significant interchangeability. Any room can be used for any function. However, it is recognized that the 176 square foot universal treatment room may be smaller than desired for routine trauma care. This flexible wall configuration allows the emergency department to adapt to its changing demands without expensive remodeling requirements. Similar principles can be applied to in-patient rooms where intensive care unit beds will have the ability to convert to burn beds in the event that multiple burn casualties must be admitted. The use of the portable headwall and self-contained gurneys ensure treatment areas will have sufficient space, power, lighting and hookups to adapt quickly to a new configuration in minutes.

4.4.3 Dual Use of Non-Clinical Space

ER One will strategically place power and water outlets in the hallways and public spaces to accommodate multiple modular patient units. In the prototype numerous opportunities were exploited. The entirety of Zone 2 which functions as public space during normal operations can is pre-grid for power and water.



Public Space for Surge Capacity (*Yellow*)

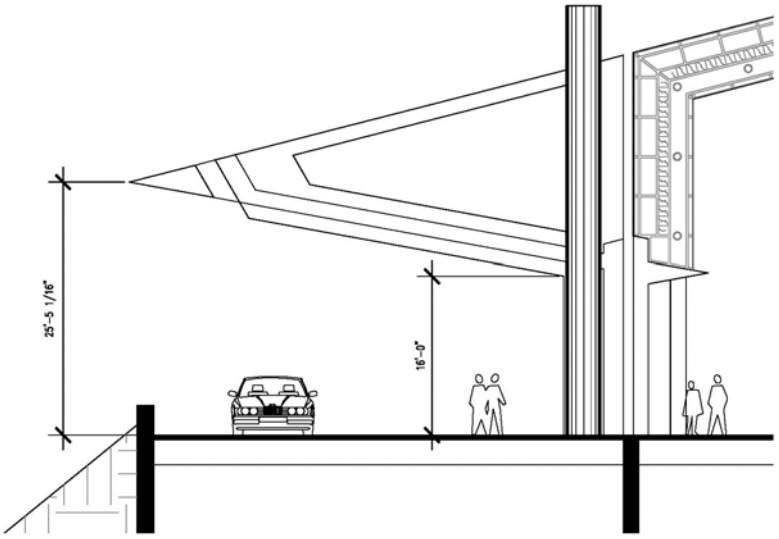
The portable headwalls columns and self-contained gurneys will allow for massive expansion. In the prototype it is calculated that a least 200 treatment stations can be easily established in this space. In addition to Zone 2 connecting hallways were designed with sufficient width to accommodate holding beds. The lower levels normally used for maintenance and support functions also have spaces and hallways that are protected, ventilated and powered to accommodate more patients if need. In the extreme case even conference rooms and auditoriums will be added to the capability. The *ER One* portable headwall concept eliminates the dependency on fixed utilities. Properly ventilated space, power and water are the only requirements. With the development of long life power cells even the power requirements may be virtually eliminated.

4.5 ACCESS AND TRANSPORTATION SOLUTIONS SUPPORTING SCALABILITY AND THREAT MITIGATION

Most hospitals have limited vehicular access for emergencies; they were designed to handle standard ambulance traffic based on the expected number of simultaneous ambulance arrivals. In most cases this is only a few positions for ambulances arrival. The typical

ambulance arrival area is a concave area with ‘back-in’ unloading access for ambulances. These arrival canopies typically have sufficient clearance for ambulances but not higher vehicles. If a hospital has a helipad, there usually is only one landing site. The result is the number and type of vehicles that can effectively transport critical casualties to the hospital is limited. During mass casualty events, most hospitals revert to makeshift reception areas in parking lots. Weather can make consistent operations unreliable. Ambulance and private vehicle drivers unfamiliar with a hospital’s traffic patterns may cause additional problems.

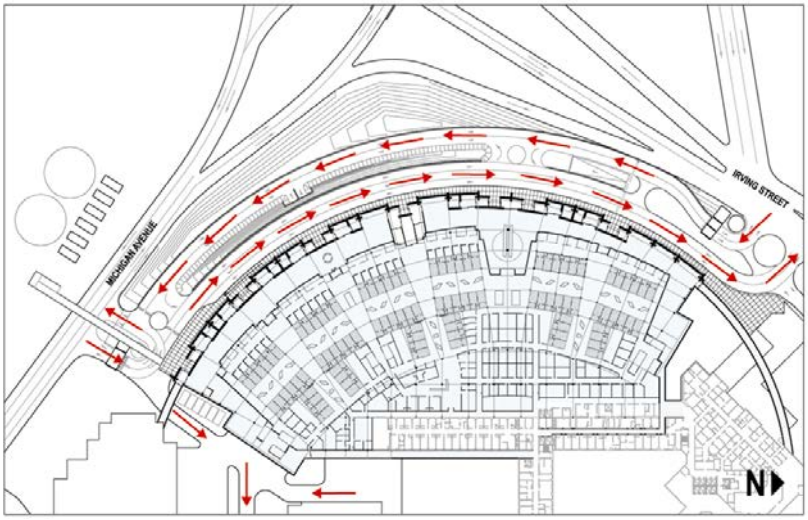
The *ER One* traffic management concept will employ several innovative solutions proven in other venues to dramatically enhance the capability to scale-up traffic flow during surge requirements. Patterned after efficient airport configurations, multi-lane access ramps at departure terminals provide a long frontage for immediate vehicle access through numerous doors along the length of the facility. The canopy height is sufficient for larger vehicles such as buses.



Canopy Height Clearance for Oversize Vehicles

This configuration provides several advantages over the current typical hospital design. First, this type of vehicle arrival and unloading is intuitive. It does not require instructions or directions for even nonprofessional drivers. The elimination of back-in requirements for ambulances will make unloading faster and safer. Manpower requirements will be reduced as ‘spotters’ for back-in will not be needed. Most importantly the extensive length of the arrival concourse will allow many vehicles to simultaneously unload. The multi-lane configuration

will allow drive by capability maintaining flow. Drive-through access checkpoints (portals) will exist. These checkpoints will be vehicle portals able to employ a variety of screening technologies as well as offer rapid external vehicle decontamination. Ambulances will be given priority, and private vehicles will be directed to appropriate portals with digital traffic management signs. Landscape barriers will prevent vehicle operators from attempting aberrant routes. Smart pop-up barriers will control and divert traffic flow as needed.



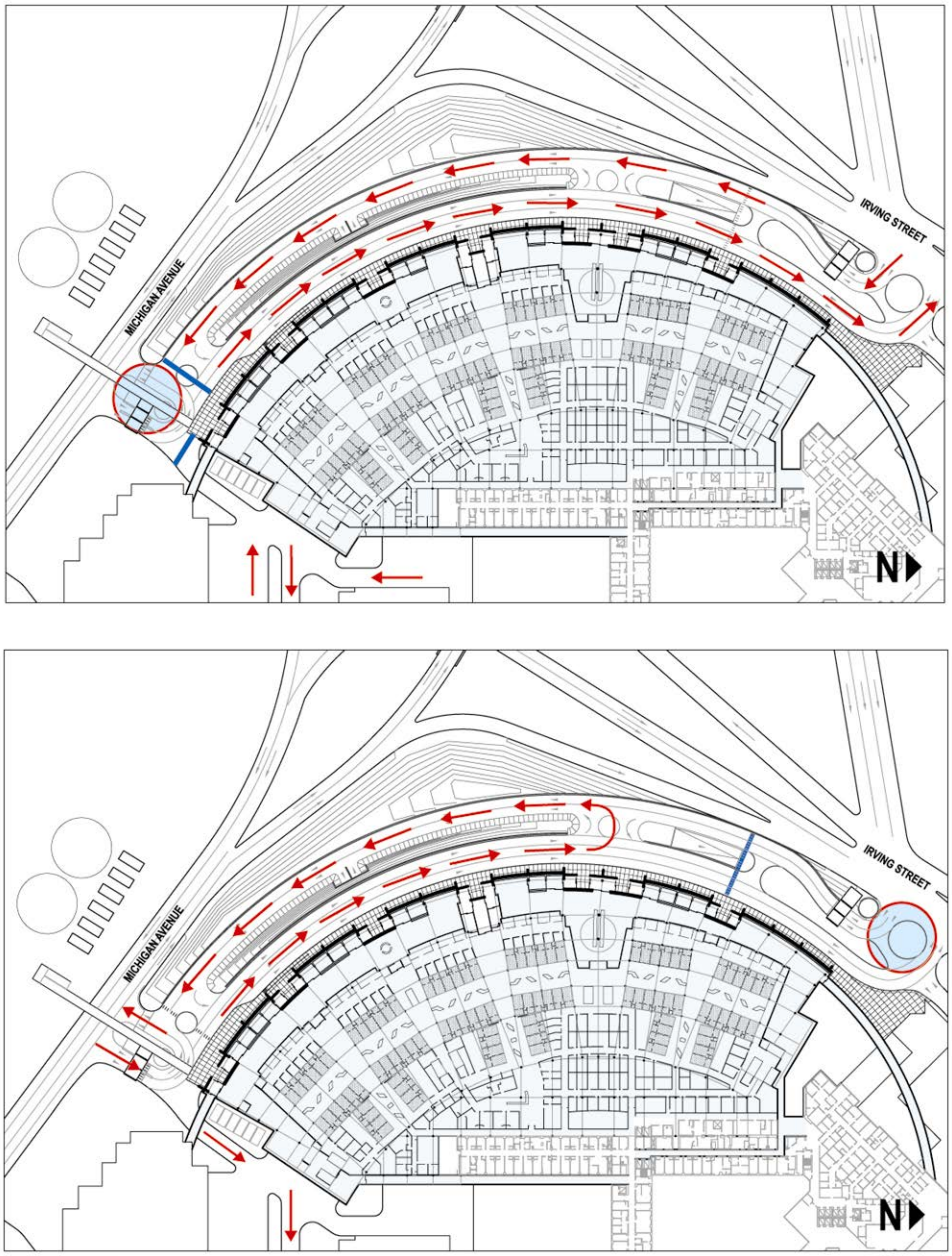
High-Volume Airport-Style Traffic Scheme

4.5.1 Vehicle Traffic Management and Control

During normal operations, public vehicles utilize the first floor concourse/drop-off area on the south end and ambulance traffic stages on the north end of the first floor concourse. Incorporating the portal concept for access control, all vehicles entering the *ER One* traffic pattern, including vehicles heading to the loading docks and hospital, will drive thru a vehicle portal. The portal having scanners, capable of detecting explosives and toxic/hazardous materials, also have the capability to provide gross surface decontamination for a vehicle noted to have radiological or chemical surface contamination. At any time, the security staff can divert vehicles that pose a safety concern away from the building through the use of active bollards and turnarounds.

During contingency operations, the concourse readily adapts to several configurations depending on need. Passive traffic management features such as berms, barriers and signage remain but are enhanced by active traffic features such as pop-up bollards which can close off turnarounds and re-direct traffic flow away from critical areas of *ER One* and surrounding facilities. The vehicular lane immediately adjacent to the plaza (patient drop-off area) can quickly become designated as ambulance only. It can also close entirely to provide additional

plaza depth for outdoor triage and treatment if needed during an event. Ambulances that are heavily contaminated or with seriously contaminated patients may also be directed to the basement level decontamination facility (adaptable ambulance garage), to the ground floor parking ramp and secondary drop-off, or to an additional unloading zone created on the main concourse. Unsecured public vehicles, during a contingency event, may also be directed to more distant levels depending upon the particular circumstances and security needs.



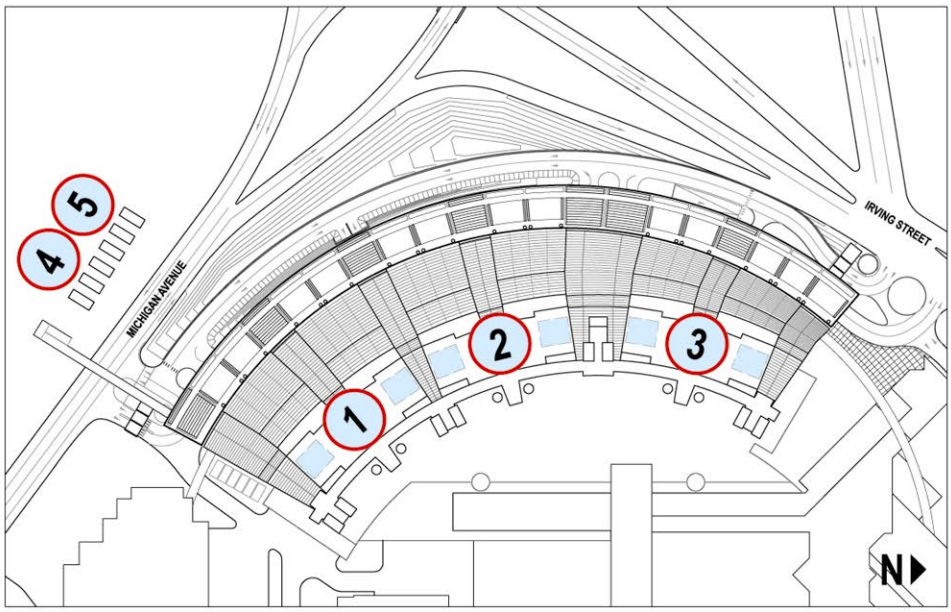
North and South Traffic Control Portals and Traffic Flow Management

A critical feature of any secure medical facility is to minimize the threat posed by parked empty vehicles. Parking under the hospital structure is eliminated. These below grade levels will be used for support functions, storage, and shelter. Parking that is closest to the facility is for vehicles with designated security clearance; this includes full-time emergency department staff. General parking will be maintained at a sufficient standoff distance for security but still close enough for client convenience. Patient drop-off areas will remain close to the facility.

It is ideal that all motor-vehicle traffic surfaces have minimal incline. In the prototype site this was not possible. The arrival drive ramp on the south will maintain approximately 8 percent grade until it reaches the patient drop-off area. This ramp will be heated to prevent ice buildup in the winter months and will have a special traction surface. All stopping and unloading will be on flat surfaces. The high clearance overhang allows oversize vehicles such as busses and trucks to arrive. The lower deck (ground level) provides an additional arrivals area during contingencies, even for the larger vehicles. This lower arrival area can remain open to general public arrivals during high security times because the stand off distance and barriers between it and the facility is sufficient. Secure portals will screen arrivals as they enter through the lower level. The landscaped berms and lighting scheme will help with the direction of traffic and pedestrians. The berms will ensure that the pedestrians proceed in the correct direction because it will be easiest to do so. Incorporation of lighting features provides way finding that is intuitively obvious and pleasing to the eye.

4.5.2 Augmented Air Traffic Capacity

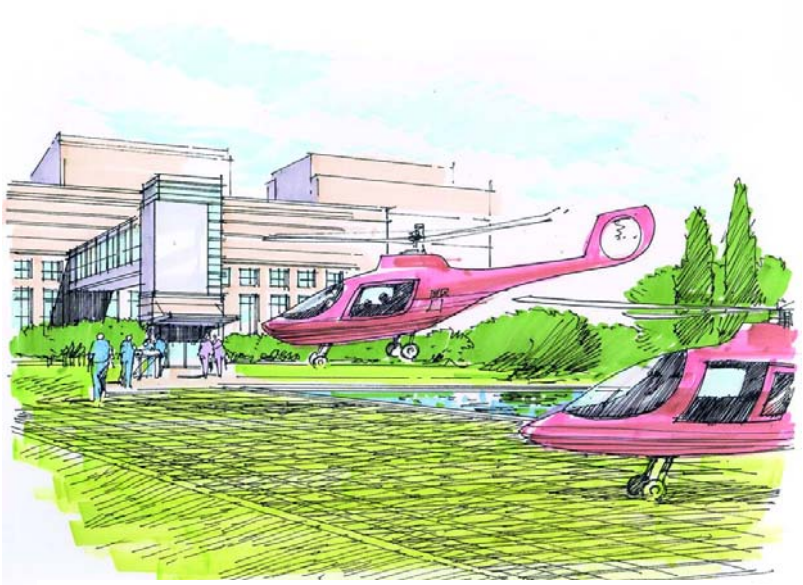
Major receiving hospitals and trauma centers rely on rotary wing aircraft for patient arrivals. During disaster or contingency operations a single landing pad creates a rate limiting choke point for air-evacuation operations. Multiple rooftop heliports provide one landing and two helicopter parking zones each. Incorporation of a visual air/land traffic observation tower into the critical care tower facilitates operations oversight of the *ER One* rooftop and ground helipads.



Helipads

Under circumstances where rooftop operations are deemed unfeasible or additional landing sites are required, special “stealth” ground helipads can become operational. Ground helipads can be developed on flat areas with sufficient overhead air clearance. This can be achieved on grass a well as solid pavement. Utilization of reinforced eco-pavers provides a solid all-weather foundation for landing while maintaining the appearance of a grassy knoll. This solution provides several advantages. Maintaining green space is important to both the urban and healing environment. Further, these areas do not appear as operational sites and therefore as less subject to targeting. The reservoir area remains grassy and park-like to the passer-by. An enclosed or partially enclosed pedestrian bridge from the ground heliport site

facilitates movement of patients from that area safely and securely while providing staff and visitors straightforward access to enjoy the park setting. Similar solutions can be used for alternative or contingency vehicle routes when primary routes are disabled or overwhelmed.

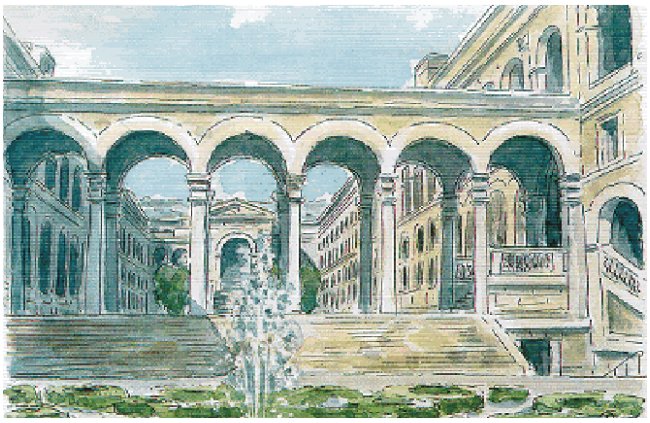


Contingency Helipad Space

These solutions will allow for graceful scaling of patient access transportation to the emergency care site during a mass casualty event. These traffic management concepts have been well tested in other venues. The demonstration of this in the hospital setting will provide valuable information to other major medical facilities around the nation.

4.6 HEALING ENVIRONMENT CONCEPTS

Above all else hospitals and medical facilities are to be a place of healing. The importance of environment was understood in ancient times as the Greeks often sent the infirmed to temples in bucolic settings. In the middle-ages hotel like structures were created as hospitals.



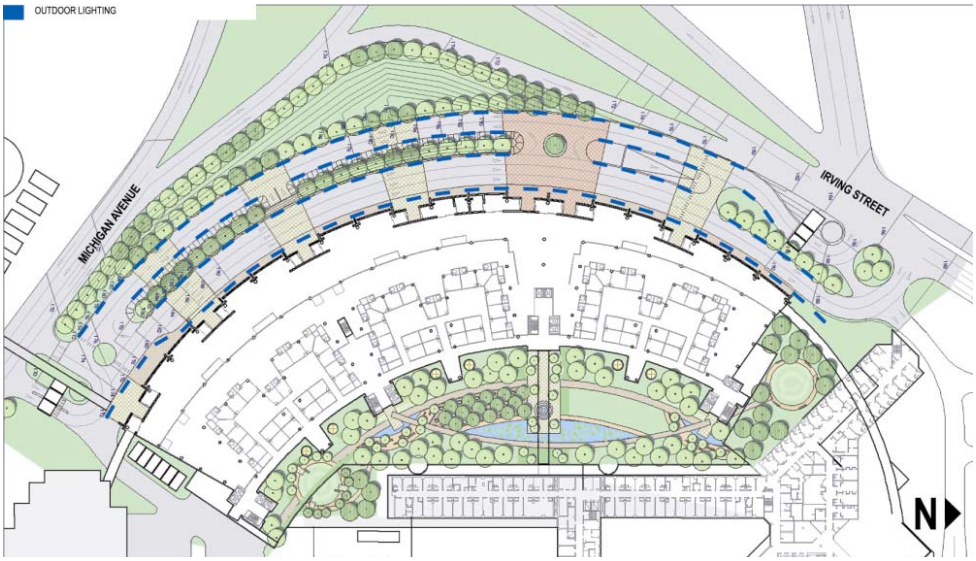
Hotel Dieu (Medieval Hospital–Paris)

The impact of environment on health and healing is now being investigated. Research has shown the power of the environment and surroundings effecting positive outcomes in chronic disease. In the emergency department setting the exposure to the environment is short term and most likely will not affect the outcome of chronic disease. However, emergency department environments can have significant effects on the anxiety level of individuals. This, in-turn, will effect how patients cooperate and even the amount of pain medication that is required. The *ER One* emphasis on threat mitigation and medical consequence management should be accomplished in the context of the healing environment. Many examples of architecture and landscape indicate that both protection and beauty can be achieved.

The *ER One* prototype includes many features to enhance the healing environment. These include elements that are visual, auditory and other sensory inputs. The competing priorities of providing light versus protection can be resolved. Liberal glazing of edifices provides natural light with positive impact on the visual environment. However, glass is prone to fragmentation under blast force. Appropriate strategies in placement of glass, coating glass or choosing alternative ways to provide natural light can achieve both objectives—natural light and protection. The most vulnerable areas are the ground levels near heavy traffic. Windows place above ground level can provide light sources for the ground level. Indirect lighting from light well can also be effective. Tensioned membrane structures can be translucent allowing light passage but do not fragment on failure. The scale of the space also has effects on the patient. Too large of an exam room will create a sense of insecurity. Too small will may also increase anxiety. Details of the various features that can be employed to enhance a healing environment are contained in the Phase I technical report. In addition to the attention

to light appropriate sound strategies are employed in the different areas depending on the need at the time. Surface colors and textures also play a key role. The *ER One* prototype design employs a series of strategies to allow ample natural light while providing protection. Details of this are contained in the architectural narratives in Section 5.

Landscape plays a key role in establishing a healing environment at a medical facility. Natural landscape can provide pleasing views to patients. Water features provide not only visual effect but also provide sound enhancements that can be calming and mask undesirable noise. Such landscaped areas are not only healing and pleasing for patients but also provide staff similar advantages. While the impact or the esthetic features of landscaping are obvious, many protective and operational features are also possible. Landscaped areas can provide standoff distance from the edifice. Berms can be protective barriers can also serve to intuitively direct traffic. Water features can be used for beauty, barriers, sound mitigation and even as an operational source for decontamination capability.



Landscape for Protection Healing Environment and Operations Support

The lighting features associated with the exterior and landscaping will create not only esthetic advantage but improve night-time security. Further lighting can be used to identify areas and provide direction.

4.7 SPECIAL INTEREST AREAS

4.7.1 General Hospital Configuration

Overall hospital design is outside the scope of the Project. However, clearly many of the suggested features such as large public spaces near the emergency department and extended

patient arrival concourses/ramps will affect the overall design of a medical facility. In the past hospitals considered the emergency department as a 'back entrance' and segregated the emergency department from any public entrances to the hospital. While this may have provided an element of privacy for emergency department arrivals, it usually created a situation where access was limited and there was little ability to expand into public spaces during a contingency event. If a medical facility indeed determines that it has a significant role in the community or regional response to major contingency events this configuration should be rethought. If one analyzes the area of the foot print of a large medical facility it will often be larger then the footprint of the main terminal at a large airport. Yet the airport terminal is configured to receive many more vehicles per hour than any hospital. This is understandable, as hospitals have not been design with high volume traffic reception in mind. Nevertheless,given the need for the high volume traffic arrival during major events, one could configure hospitals with a longer traffic frontage. The public spaces and atriums could be adjacent and contiguous with emergency department spaces allowing graceful expansion when needed. These design alterations do not add significant costs to hospital construction. They simply represent reconfiguration of square footage usually included in hospital design.

4.7.2 Universal Treatment Room Design Features

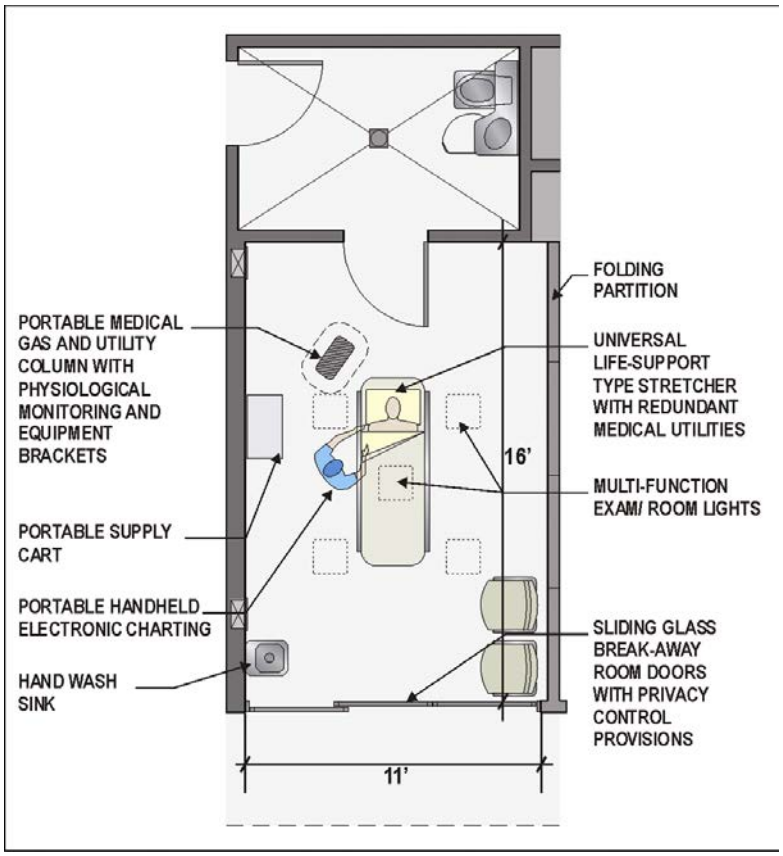
The universal treatment rooms are designed slightly larger than typical emergency department treatment area. This increase in square footage provides the sufficient area to easily accommodate a second treatment gurney. The relation of the room to the circulation area allows the addition of a third treatment gurney. Thus a scalable three fold capacity exists within the treatment room configurations. Areas designated as gurney holding areas can also accommodate an additional six patients. In the event even additional treatment space is needed, *ER One* is designed for additional expansion into Zones 3, 2 and further towards the building periphery

The walls of each treatment room are designed as an immune membrane. Utilizing non-permeable materials, the room walls and ceiling are seamless without corners. Surface penetrations of the wall, ceiling and floors are minimized. Any penetration, perforation, seam or fixture provides a nidus for contamination that is difficult to clean or decontaminate. Flat surface luminescent screens provide ambient overhead room illumination. The light source is replaced from the interstitial area above the treatment room. Additionally ultraviolet light sources in the room's ceiling decontaminate the room's air and surfaces when the room is not in use.

Wireless access points for communications are house in the ceiling interstitial space. All needed equipment including cabinetry is portable in nature, enhancing rapid room re-arrangement and decontamination processes. The sink can be portable or seamlessly fixed to the wall surface. Sink faucet design incorporates a hose from the sink neck, which can be used to wash down the room or a patient if needed. A central floor drain facilitates rapid

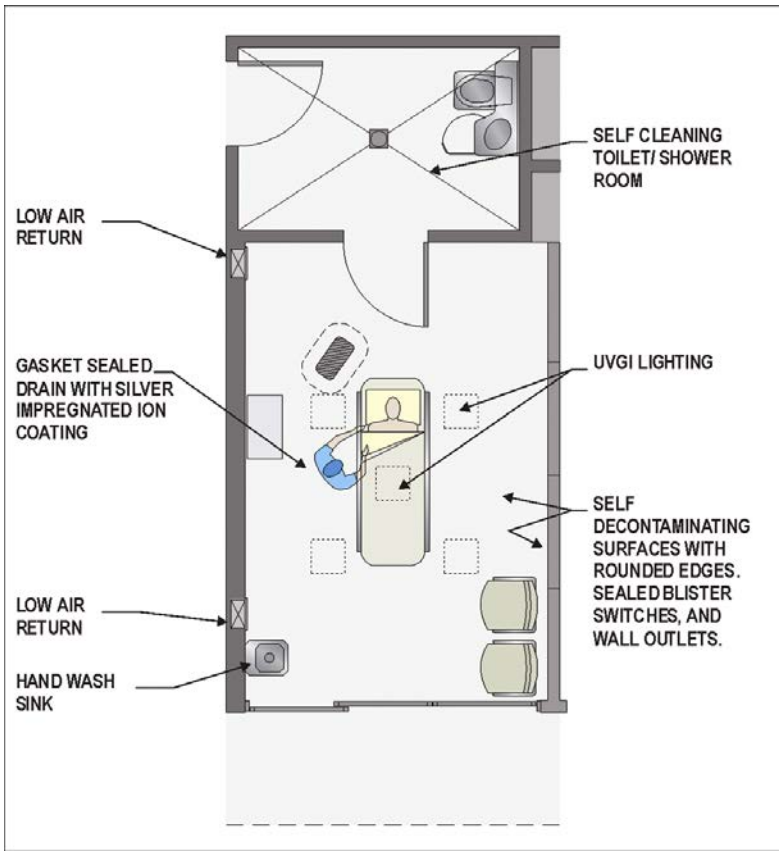
wash down. Using inexpensive coatings such as N-halamine compounds on most surfaces and silver ion on metal items, the surfaces and components become self-decontaminating. Specially designed wall mounts with seamless easily cleanable surfaces allow any needed items to be fixed in place as needed but quickly removed when necessary.

Thus the room surfaces have become a virtual immune membrane. The only penetrations include the drain, power outlet, and water source. The drain and power outlets are covered with a sealing gasket when not in use. All services such as oxygen and suction previously provided by the headwall are now either contained in the litter or portable headwall service columns that simply plug into the power source and generate their own oxygen. Each column can service single or multiple patients.



To further minimize surface contamination, holographic or blister-type keyboards for data entry and inductive light switches reduce cross contamination from surface contact.

The development of oxygen generation technology and lightweight power cells may eventually remove the need for any fixed utilities in the universal treatment room with the exception of water supply. The potential for this is significant in several ways. First, a dramatic reduction in construction cost is possible as plumbing and gridding of these utilities will no longer be necessary. Second there will be greater flexibility in room usage one will not be confined to spaces that had services supplied. Additionally, infection control will be enhanced. Suction fixtures, outlets, other headwall utilities or perforation in the walls create areas that harbor pathogens and are difficult to clean.



ER*One*

Section 5 *Architectural Design and Narrations*

SECTION 5

ARCHITECTURAL DESIGN AND NARRATIONS

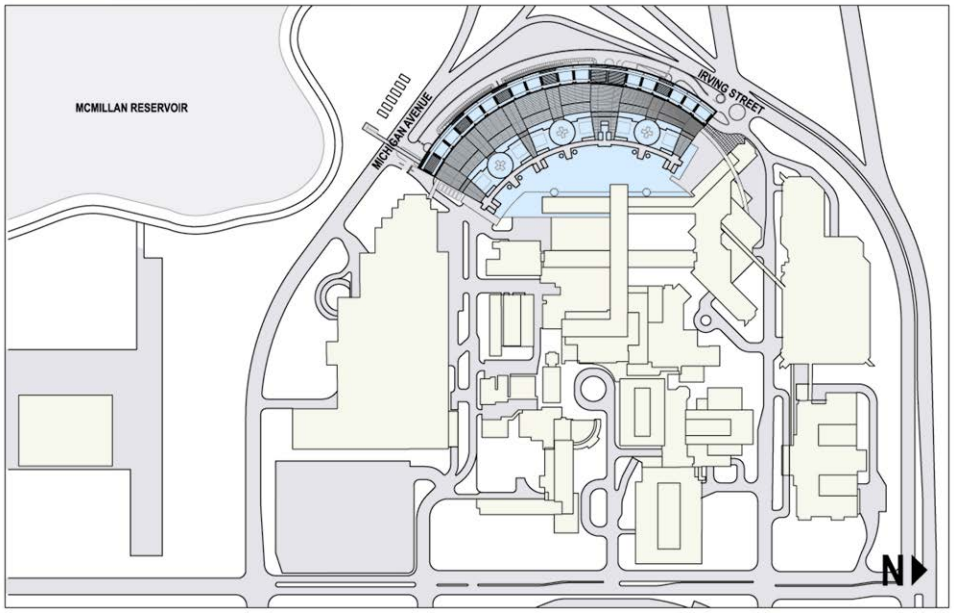
The planning of ER One incorporates the various types of access that can occur during both routine and event operations. These include pedestrian, vehicular, and air access to the building's exterior, as well as access to multiple zones within the facility. Because access drives scalability and flexibility, these features were key factors in shaping the design of ER One and its positioning within the site constraints of Washington Hospital Center. After extensive study, the location of the building footprint was strategically placed to maximize site access from various vantage points in the fashion of an airport 's design for vehicular, pedestrian and air traffic. To that end, ER One has a unidirectional traffic flow that directs all traffic in an orderly fashion that easily adapts during an event situation. Pedestrians are directed to and around ER One via a large public drop off plaza along the entire western façade and the interior public concourse. Multiple access points to the facility are located along this drop off plaza and can be appropriately activated depending upon the scale of an event.

Security is factored into all levels of access to the facility. Vehicles are scanned at various security checkpoints, and those posing a threat are directed to an alternate location. If a checkpoint is forced to close due to a security threat, the site has multiple entrance locations that can handle redirected traffic. If the main drop off is closed, the ground floor drop off and parking can become a drop off location or additional contingency space.

Multiple building entrance portals have been included in the building exterior, allowing for flexible and scalable entrance options. Each entrance portal is capable of effectively identifying individuals by employing biometric scanning, providing access control, detecting unwanted material (chemical, biological, explosive), temporarily detaining an individual, and in some cases, providing decontamination. Upon entering the facility, patients and staff are provided with several circulation options to all levels of the complex.

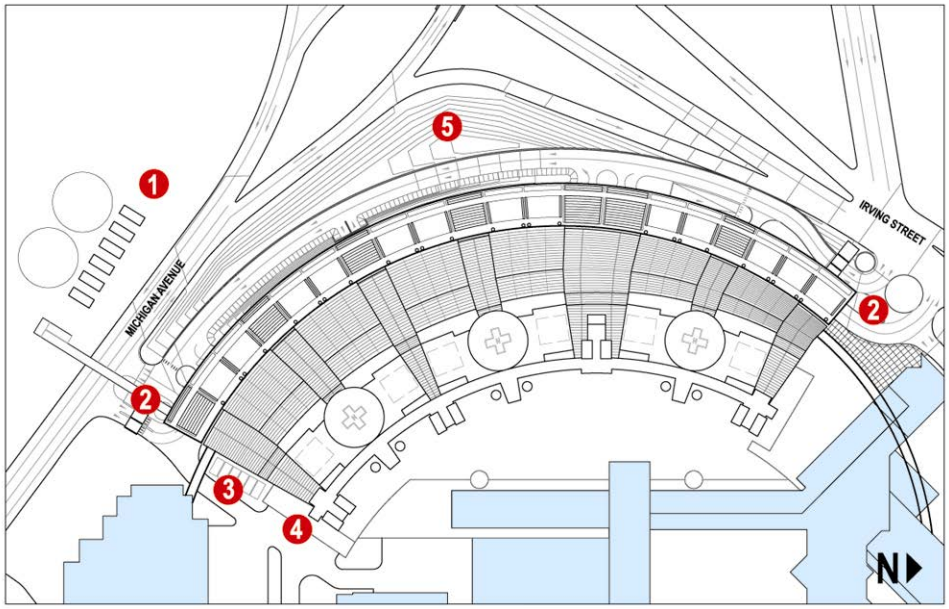
Air access is supported with three helipad landing zones that are located on the roof of the complex and are vertically connected to the emergency department and critical care towers via a circulation spine. Two additional landing pads are located adjacent to the facility at McMillan Reservoir and can aid in the transport of casualties to and from the complex. A more in depth explanation of site and building access design and how it functions during both routine and event situations is discussed further in this section.

5.1 STRATEGIC LOCATION – SITE PLAN



The *ER One* study site, Washington Hospital Center, is located in Washington, DC, approximately two miles north of the nation's capital. *ER One* is situated one-minute by air and two minutes by ambulance from the capital. Its proximity to key buildings and locations in the Washington, DC area dictates that *ER One* will treat many casualties in case of an event.

The *ER One* facility is located in the western precinct of the Washington Hospital Center campus at the intersection of Irving Street and Michigan Avenue. This location is consistent with the Washington Hospital Center official Master Plan and can accommodate relationships with critical medical departments within the existing medical facility. It also provides for an advanced vehicular, pedestrian and air access system. A key element of *ER One*'s placement is that it affords space for a bermed landscape stand-off area in front of the facility, creating a natural protective barrier from surrounding uncontrolled streets.



1. Remote Treatment Area

Green space at McMillan Reservoir could convert to a remote treatment area. This area can accommodate portable treatment modules and two helipad landing zones for additional air support. This contingency space allows for flexible treatment options during an event. The remote treatment area is connected to the facility via a partially enclosed pedestrian bridge that facilitates the safe movement of patients during an event. This bridge also provides a connection for staff and visitors to the grassy area during routine operations.

2. Controlled Access

Secure checkpoints are incorporated into each end of the complex similar to an airport concourse drop-off that allows multiple vehicles to enter the facility. Traffic flow is designed to allow for multiple drop-off and traffic-flow options during an event so the facility can remain operational. The lower-level drop-off location can accommodate emergency vehicle clearance. The vehicle entrance portals have scanners capable of detecting hazardous materials. Vehicles determined to pose a threat to the facility are easily diverted from the complex via the use of active bollards and barriers.

3. Contingency Treatment Area

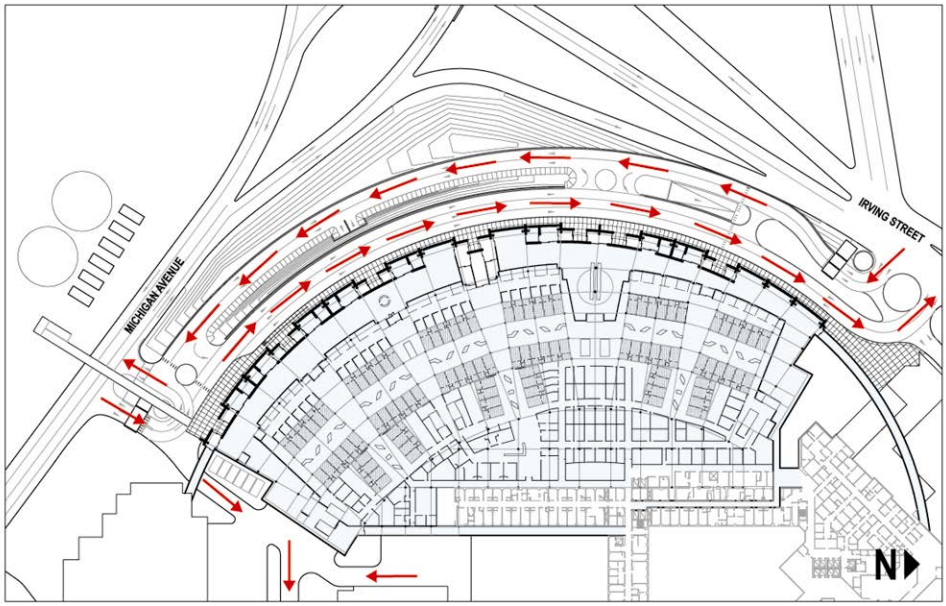
Portable treatment units that are placed adjacent to *ER One* permit direct access for incoming ambulance traffic and serve as additional treatment locations during an event.

4. Ambulance / Large Scale Decontamination

The ambulance garage that is located at the building's perimeter can become a large-scale decontamination facility during an event. Emergency vehicles can be washed at controlled entry portals and other available points before bringing patients to the facility. This will reduce the chance of contaminating the complex and hindering traffic flow.

5. Protective Barrier

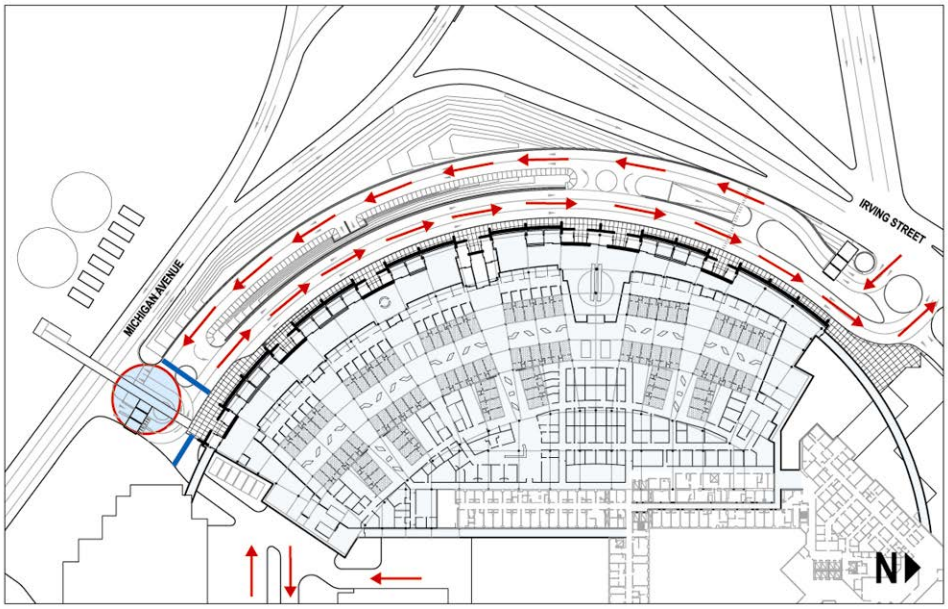
A bermed landscape area is incorporated into the site plan and provides additional stand-off distance and a barrier to prevent uncontrolled access to the *ER One* facility. This green space functions in conjunction with the berm to create a protective barrier while concurrently providing the facility with an inviting and healing environment, which promotes the healing nature of *ER One*.



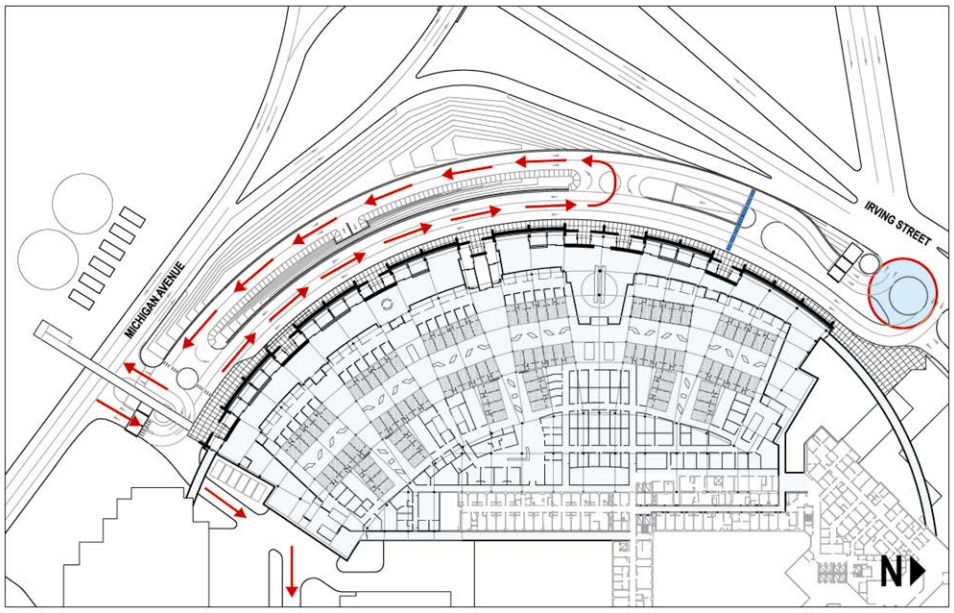
Site access is designed to provide for controlled access to *ER One*. In order to accommodate scalability and graceful degradation, the design of the *ER One* drop-off has taken other facilities that accommodate large volumes of traffic into account. Both ends of the complex have multi-lane drive aisles that pass through access portals that can function as checkpoints in order to search vehicles before entering the complex. This directional traffic flow accommodates large numbers of vehicles and can easily adapt during an event. During an event, ambulances are channeled closest to the *ER One* receiving area, while higher security risk and less vital vehicles are channeled farthest away. Directional traffic flow

allows vehicles to pass in one direction, stop as needed, and continue without affecting traffic flow.

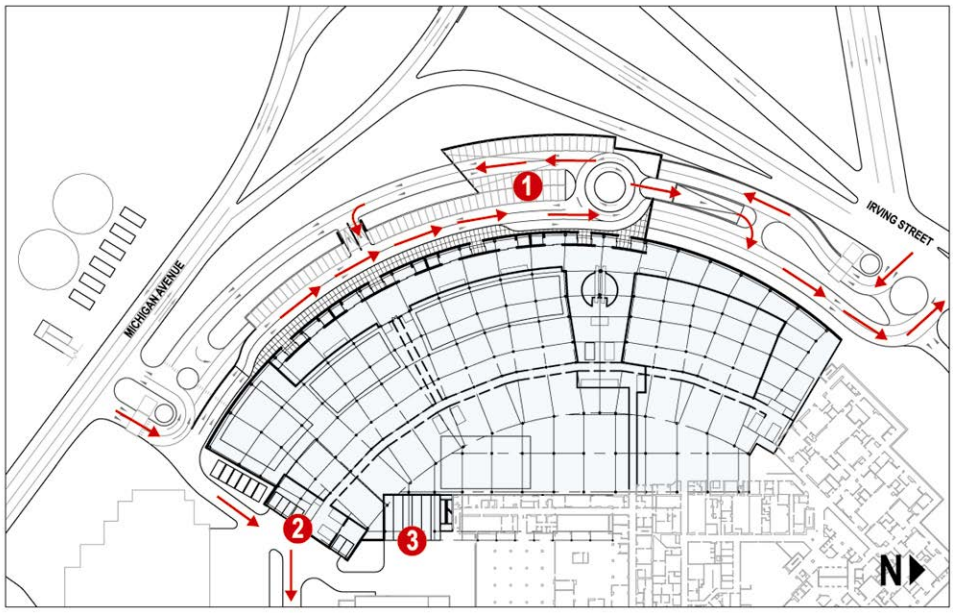
Special features include the use of pop-up bollards, which allow for security and the segmentation of traffic when needed. Heated drive aisles keep the roads free of ice and snow during winter months. General parking for *ER One* is located elsewhere on the campus, as all parking located near the facility is for hospital staff and personnel only.



When the south-controlled access point is closed, the facility remains functional using the north controlled access. This allows traffic to enter the facility and circulate back without impeding routine operations.



When the north controlled access point is closed the facility remains functional using the south controlled access. When this occurs, traffic enters the facility and circulates back without impeding routine operations.



1. Traffic Flow / Drop-Off

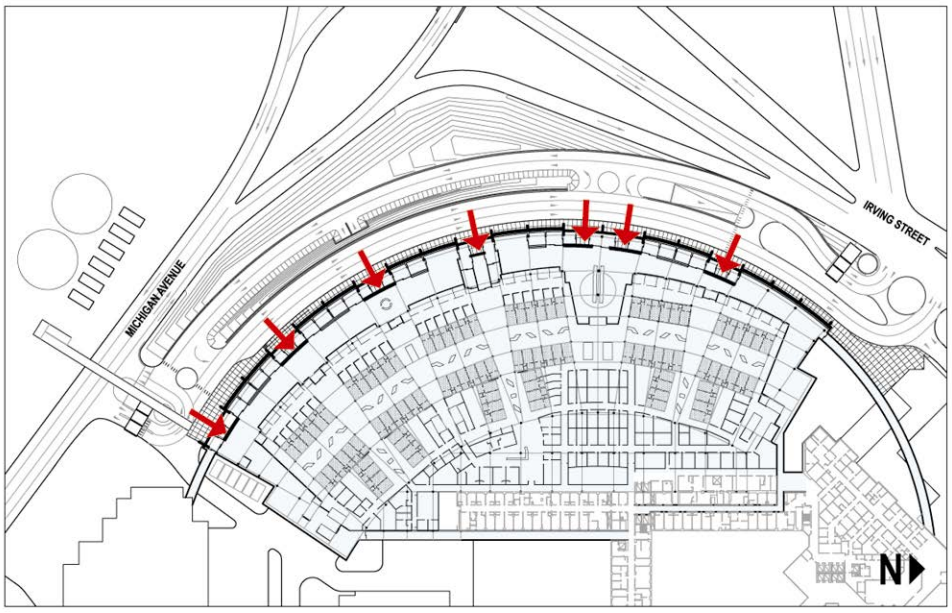
The flexibility of traffic flow allows for various drop-off scenarios. During regular operations, the ground floor serves as a secure parking area for staff and personnel of the facility. During an event, the ground floor can easily become a drop-off location. This includes multiple entrance portals and drive aisles that can adapt to direct traffic to reduce confusion and congestion.

2. Ambulance Garage / Large Scale Decontamination

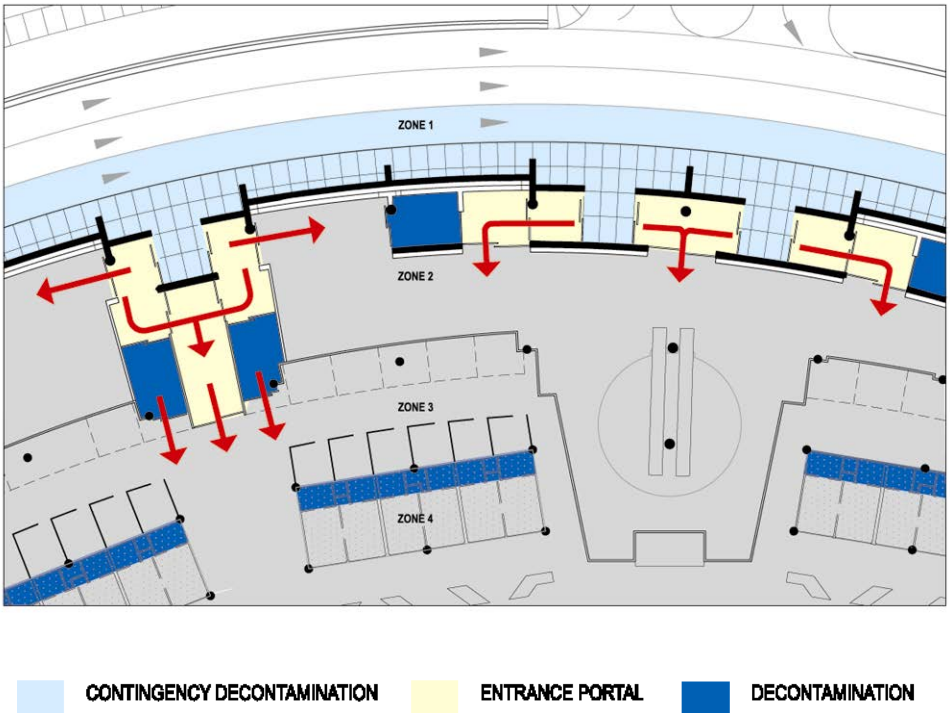
The ambulance garage is located at the perimeter of the building in order to eliminate the possibility of unscreened traffic circulating beneath the complex. The ambulance storage area can become a large-scale decontamination area during an event in order to handle mass numbers of contaminated individuals.

3. Loading Dock / Large Scale Decontamination

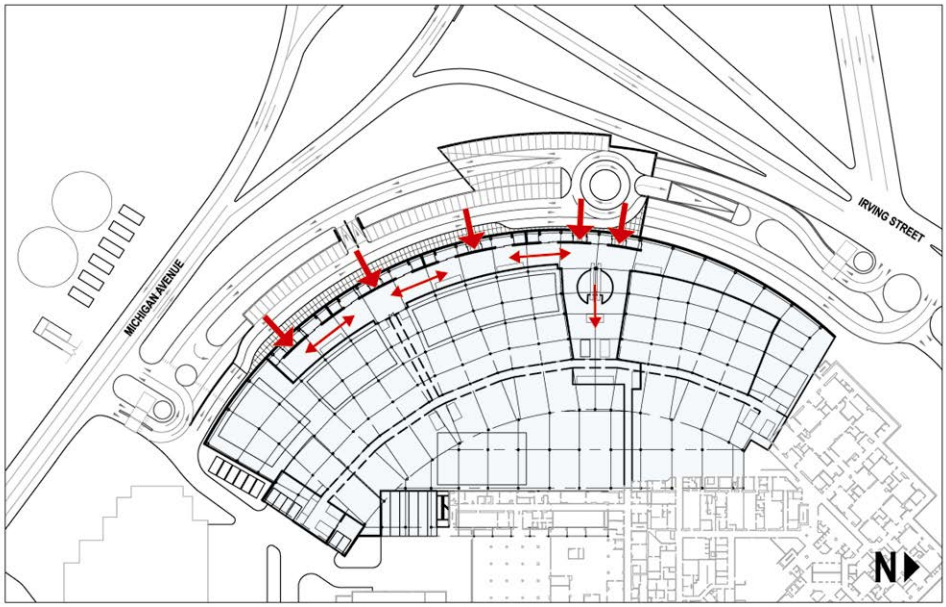
The ground-level loading dock has a secure checkpoint where delivery trucks are scanned. Its proximity to the ambulance garage / large-scale decontamination area enables it to double as a remote treatment area or decontamination location.



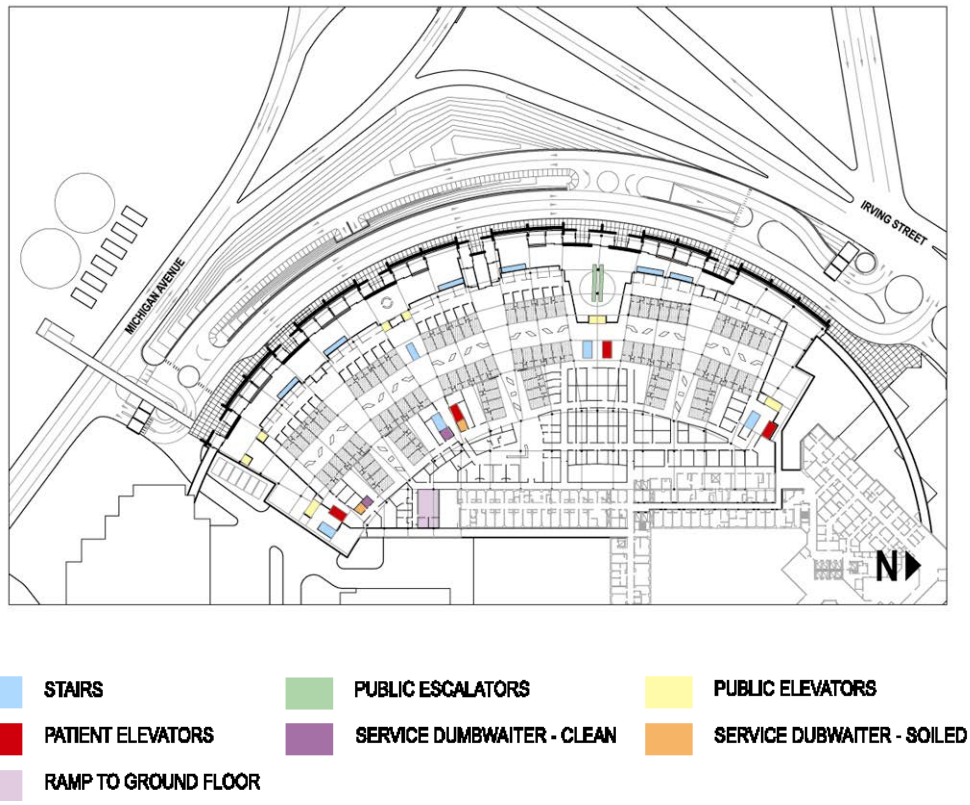
ER One is designed to provide flexibility and universality. To that end we have configured multiple entrances. The number of operational entrances can be manipulated depending upon the demands of a situation. In normal mode, approximately half of the entries are operational. When the complex is in high mode, all of the entrances can potentially become operational. Each entrance portal is capable of effectively identifying menacing individuals by employing biometric scanning, providing access control, detecting unwanted material (chemical, biological, explosive), temporarily detaining an individual, and in some cases, providing decontamination. New detection and scanning technologies are accurate, highly effective, non-intrusive, and non-invasive to provide maximum privacy. The entrance portals are placed away from the core treatment area to create stand-off distance, adding an additional level of security to the facility by applying the concept of rings of security—the most secure zone is the core.



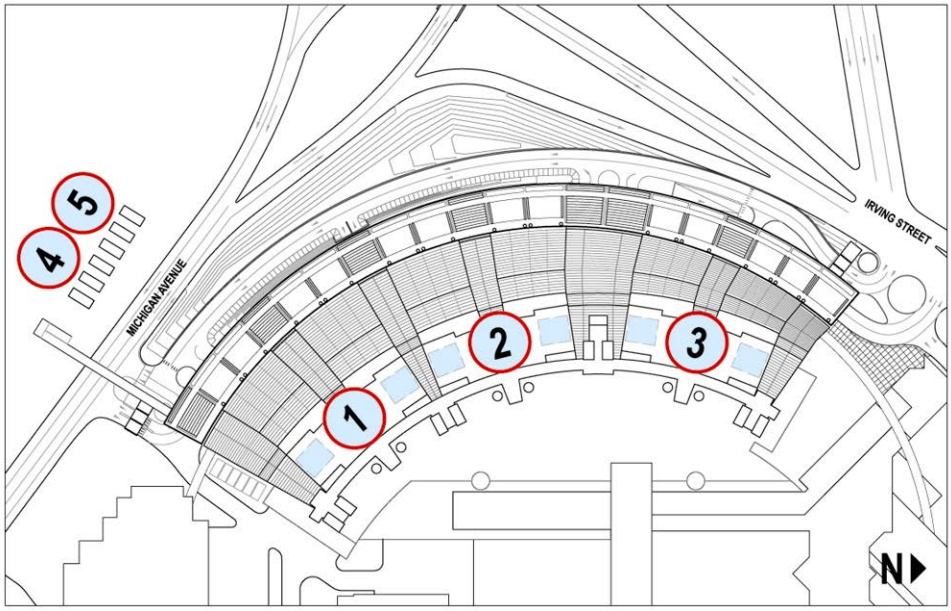
ER One provides multiple points for decontamination. Unlike conventional medical facilities, which typically require the establishment of decontamination facilities or location of permanent decontamination facilities away from entrances, *ER One* is designed to accommodate large numbers of people where they are most likely to arrive—the front entrance. Located in Zone 1 are hundreds of decontamination stations. A fully covered overhead canopy, warmed heating coils in the ground plane, infrared heaters, and special protective privacy screens can provide additional weather protection for these stations when needed. In addition, ambulatory patient showers with multiple formal decontamination chambers are located adjacent to each of the portals, as indicated in the diagram. Although it is not illustrated here, it is significant that each treatment room can also be used as decontamination space. Each treatment room has a dedicated toilet room that is equipped with showers for the daily requirements of Emergency Medicine.



The ground (lower) floor entry and egress concepts replicate that of the first floor. Multiple entrance portals allow for various entry points to the facility during both routine and event operations. This arrangement reduces congestion at any one entrance. The entrance sequence repeats this portal configuration and is equipped with the same technology to effectively identify an individual by employing biometric scanning, providing access control, detecting unwanted material (chemical, biological, explosive), temporarily detaining an individual, and in some cases, providing decontamination.



ER One is designed to provide multiple convenient points of horizontal and vertical circulation. Patients and staff are moved throughout the facility in dedicated elevators (red). Guests and the public are provided with several circulation options. Stairs, elevators, and escalators provide access to the ground floor and the mezzanine. Public elevators (yellow) are located at key intersections within *ER One* and connect to the administrative floor and critical care towers above.



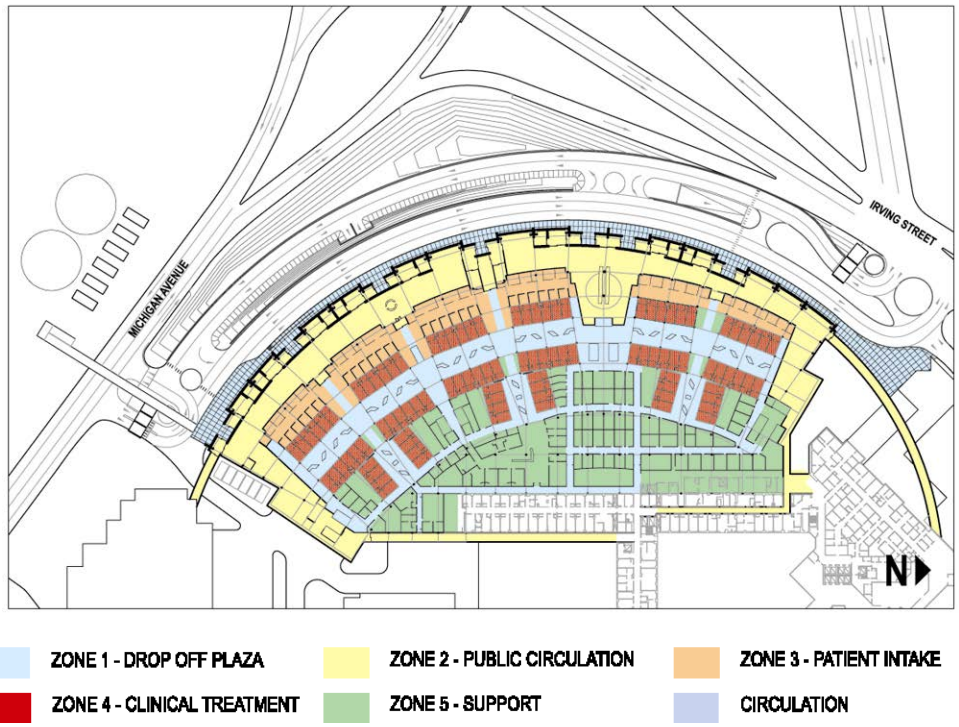
ER One provides five fully capable helipads. Three are located above the facility and have direct access to the emergency department and critical care towers via stairs and

elevators, which are located in a rear circulation spine. The remaining two helipads are situated at the nearby extra-facility treatment area adjacent to McMillan Reservoir. The multiple helipad locations can efficiently transport casualties to and from the complex.

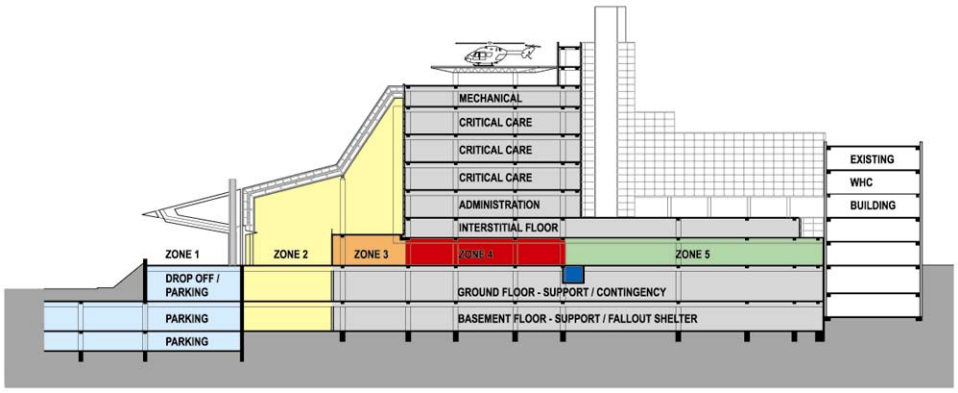
5.2 BUILDING ORGANIZATION – FIRST FLOOR

The essence of the building organization for *ER One* prototype is both a horizontally and vertically integrated architecture. In the WHC site-specific case application, very much of this model has been accomplished. Approaching vehicular traffic and parking, as previously mentioned, is positioned away from the footprint of the occupied building. The first floor is the main emergency services level that is supported by the two lower levels of dual-use contingency functions, ground floor and basement, the interstitial building support services level just above, and the level two administrative support functions. Critical care towers are positioned above, levels 3-5, and are strategically tied via elevators into the functional flow at all levels. The various types of vertical circulation such as public, patient, and clean and soiled service are intentionally segregated to better control and disperse elevator traffic.

Horizontally, the emergency services are organized in concentric functional zones that are ordered in such a way that reflects the patient flow. This concentric zone concept is consistent with the early conceptual prototype. Additionally, access, infection control, and security measures are layered seamlessly into and between these zones. The upcoming exhibits will convey the overall planning organization level by level, building massing, and detail regarding the function in each of the zones. Zone 2 is the only zone that connects two levels (first floor and mezzanine) together, and is open to all levels of the towers in an atrium setting.



The organization of the first floor is based upon increasing levels of security, modularity of treatment areas, and scalability of the facility. The design is based upon the full phase development of six treatment pods and three additional treatment modules, which are located in a formation that allows for the flexible use of space and increased scalability of resources during both routine and event operations.



ER One is organized as follows: the public concourse, treatment areas, and supportive function are located on the first floor; interstitial space is placed between the first and third floors; the third floor houses administrative space; and the critical care towers occupy floors four to six. The lower levels support clinical treatment areas such as a Class III isolation lab,

a pyrolytic gasification system, storage, large–scale decontamination areas, a fall out shelter, and potable water storage. Vehicular parking is not located under the structure in order to reduce vehicular threats to the building.

This plan represents a schematic level of detail of the initial construction. The various functional areas are organized in flexible concentric rings that provide increasing levels of security from the main entrances to the inner clinical and treatment areas.

The outdoor zone 1 offers multiple access points and provisions for mass ambulatory decontamination. Due to the WHC site-specific plan constraints, we have a somewhat reduced plaza depth from the pure model prototype. Ideally, the plaza depth from curb to the entrance doors would be approximately forty feet. Our plan is indicating approximately 10 feet for this dimension, so the inclusion of the right hand vehicular traffic lane will be absorbed into this space during the an event where mass ambulatory staging and decontamination is needed. Medical utility provisions and heated air will available as needed during outdoor contingency operations.

Zone 2 is the public connectivity, and could be additionally used for event medical consequence management. The potential for medical utility rough-ins exist.

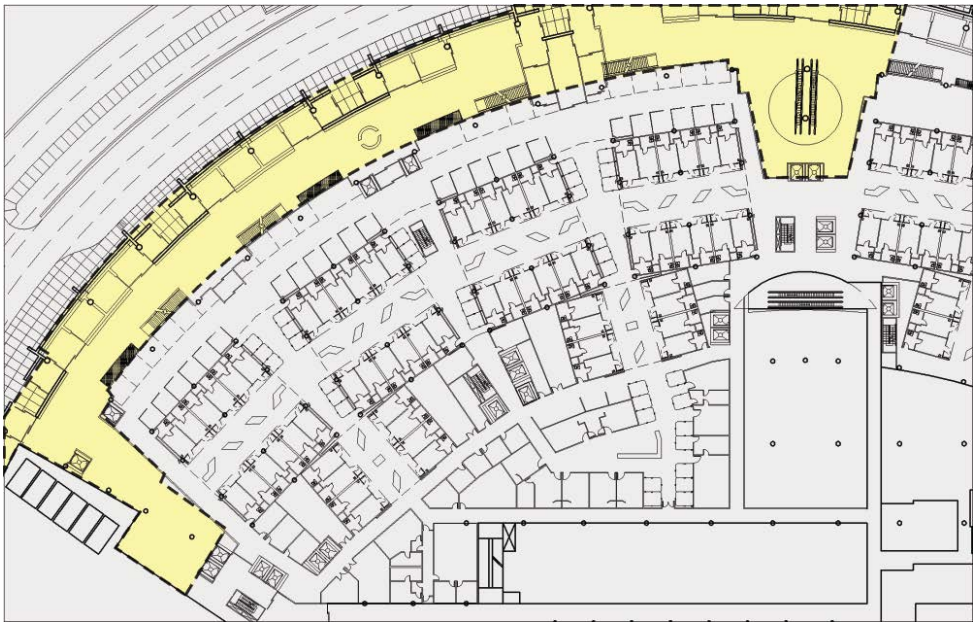
Zone 3 is composed of flexible patient and family intake modules composed of prefabricated and quickly demountable panels. Another deviation from the model to the

plan, again driven by available depth across zones, shows up in there not being a corridor behind the triage /registration positions that directly allows for a unidirectional patient flow into the exam/treatment zone (zone 4).

Zone 4 has worked out very consistent with the modeling, as it reflects planning based upon an efficient clinical staff workgroup. A note here is the flexible integration of clinical support functions such as patient informatics, medicines and supplies that are indicated (dark blue and green) in the middle of the pods. Further detailed discussion of the organization of these modules is up coming in this section.

Zone 5 consist of the balance of clinical support functions, diagnostic imaging, some staff support functions, and building support functions such as utility and telecom services strategically located to maximize efficiency. Administrative support functions are located on the floor above.

Zone 1 is the unidirectional, multi-lane vehicular drop-off concourse and outdoor staging area. The linear concourse design (similar to airports) offers significant drop-off capacity, multiple entrance points, and flexibility to designate specific arrival types. It is protected from the elements by a canopy. Provisions for controlled mass ambulatory decontamination are also incorporated here.



Zone 2 is the main public connector, allowing accessibility to emergency services and other hospital services. Entrances into this space are controlled via multi-function screening portals that have the ability to identify, detect, detain, and decontaminate. Internal way-finding and information devices such as digital flat panels and electronic messaging boards will be present and obvious.

Zone 3 is where the main patient intake functions can occur. Triage, registration, family waiting, and other patient-assistance functions are available. Multi-function portals are adding an additional level of protection also integrated into the entrances of this zone.

Zone 4 is the main exam/ treatment block of space. It is composed of 12-room pods, with each 2 pods connected by an 8-room spur. The center of each pod is composed of a flexible

staff work core with a direct sight line to the patients and associated clinical support functions/ equipment immediately available. Flexible space is provided along the main circulation pathways into the pods. Some of the patient intake functions from Zone 3 and clinical support functions from Zone 5 may be included here as operational systems are further defined and modified over time.

Zone 5 serves as the main support block for clinical functions and is composed of functions such as:

- Clean Supplies
- Equipment Storage
- Utility Support Functions
- MEP/Telecom Support

Additionally, diagnostic imaging area, indicated by the lighter shade of green, is integrated into and dedicated for use by emergency services.

5.3 MEDICAL CONSEQUENCE MANAGEMENT – FIRST FLOOR

Within this context, we will distinguish the essential root attribute as a contingency response to a mass event. Scalability may be inherent to some of the Medical Consequence Management (MCM) responses, however, it can also be exercised relative to normal daily operations.

The incorporation of medical consequence management (MCM) features in the architectural plans is achieved in a variety of ways.

Multiple horizontal and vertical entrance points to distribute immediate significant volume increases to the magnitude of three to four, and possibly as high as five, times normal daily peaks. These entrances are distributed throughout three levels of the facility.

Functional zone expansion and contraction, and redistribution of tasks is an integral aspect to the planning. The concentric ring approach represents an ordered and logical patient and staff flow and throughput.

Multiple decontamination locations distributed throughout the plan that allow for a hazardous material response by patient mobility type and point of identification. These provisions are incorporated prior to building entrances, ambulatory and non ambulatory entrances, intermediate points of travel along the patient processing path, and within the patient treatment room setting.

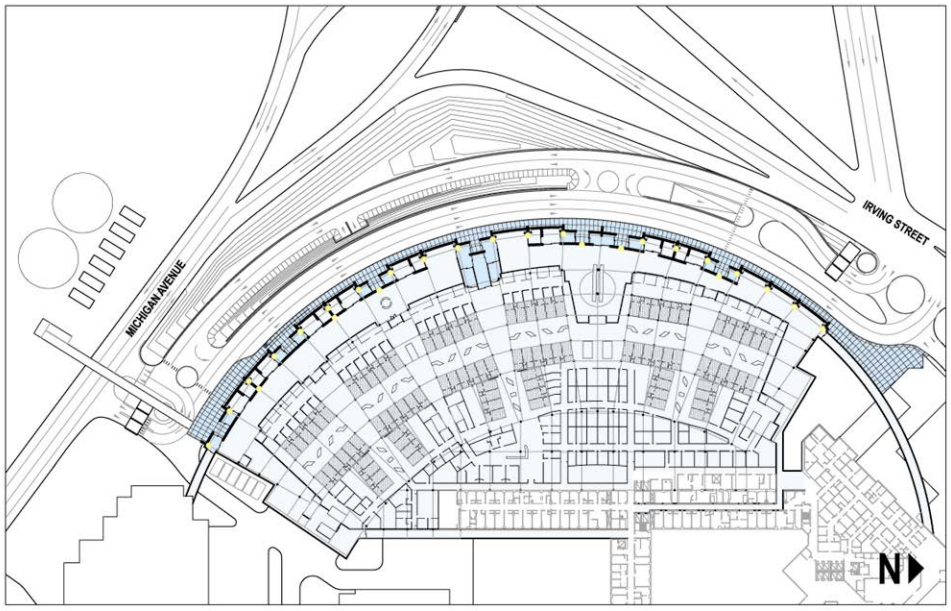
Multifunctional portals are incorporated to the plan at key levels of access and employ both high and low technology devices such as hazardous material, weapon, and personal identification and detection. Additionally, the portals offer a level of detention and decontamination if needed.

Flexibility is achieved several ways. The most significant being the incorporation of an interstitial mechanical /electrical and plumbing floor just one level above emergency services. Flexible open, soft modular, and fixed convertible space is included throughout the plan so that a variety of functions can easily be accommodated. Additionally, the integration of moveable, or portable services and supplies via self-contained packaging will play a contributing role. As clinical operations and technology evolves over time, the architecture will adapt with minimal disruption to ongoing care and related services

Contingency space is sprinkled throughout several areas of the plan and offers dual-use potential. The objective here is to utilize all the available space during routine operations, but facilitate a higher and best use during contingency events. This adaptation can be accomplished to a high degree since contingency planning is incorporated throughout multiple levels.

Infection control and the flexible creation of sectors are provided, again, in a multi-solution fashion. Reducing the risk of infection is addressed within the portals as previously mentioned, reconfigure-able sectors with adjustable pressure gradients, self-decontaminating surfaces, and sealed penetrations. Preventing airborne contaminants from entering the building envelope is fundamentally solved by redundant testing and conditioning of inaccessible fresh air intakes. In addition, exhaust air ducts are located an ample distance away from the intakes.

In all, the multi-faceted integration and incorporation of these ideas and concepts provide a comprehensive environment that responds to the demands of managing mass medical consequences. The following exhibits will illustrate the incorporation of these strategic planning concepts.



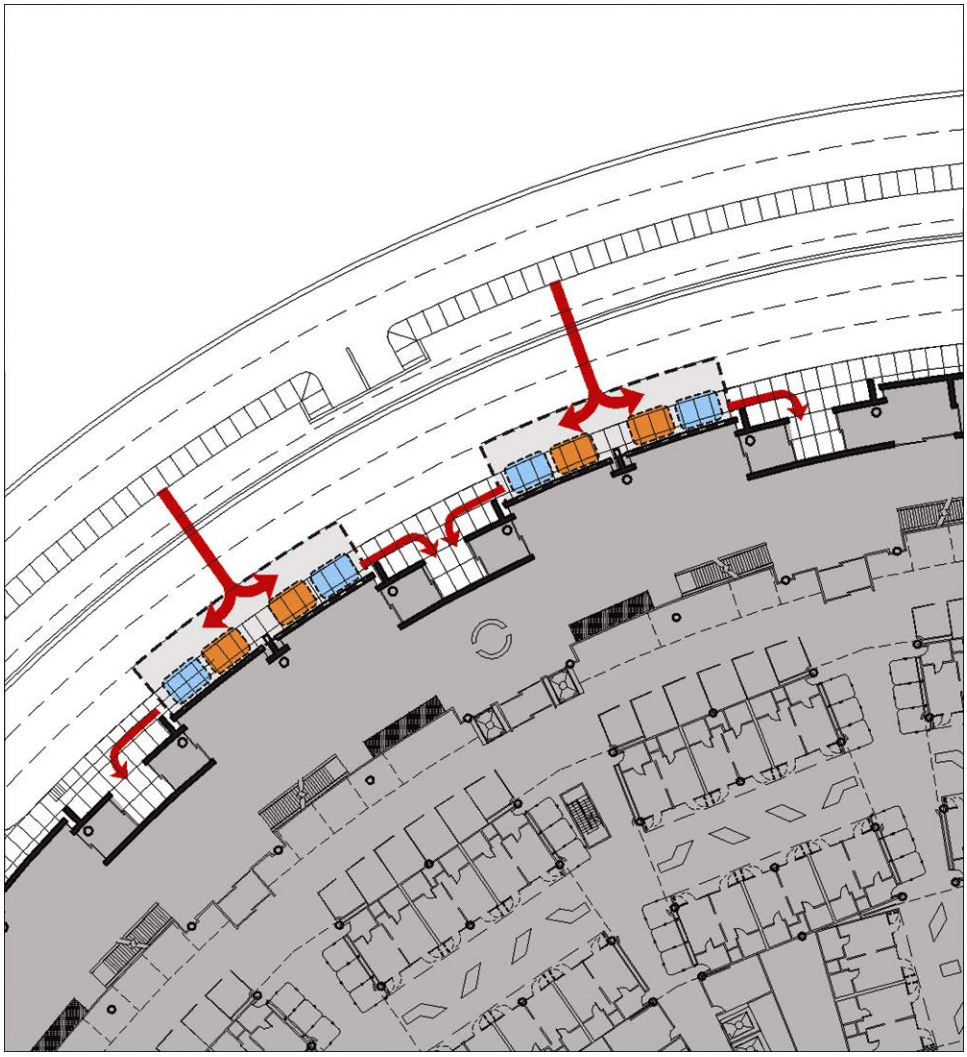
The first floor of *ER One* is designed with medical consequence management and scalability features that effectively utilize the entire potential of the complex during a major event.

The exterior public drop-off plaza (darker blue) can accommodate large numbers of people as a contingency treatment location during an event. Additionally, the ground floor and mezzanine can support the overflow of people.

The public concourse is equipped with exterior showerheads (yellow) available to provide service on arrival for contaminated patients. This permits multiple ambulatory casualties to pass through the entrance portals and into the facility in a fully decontaminated state.

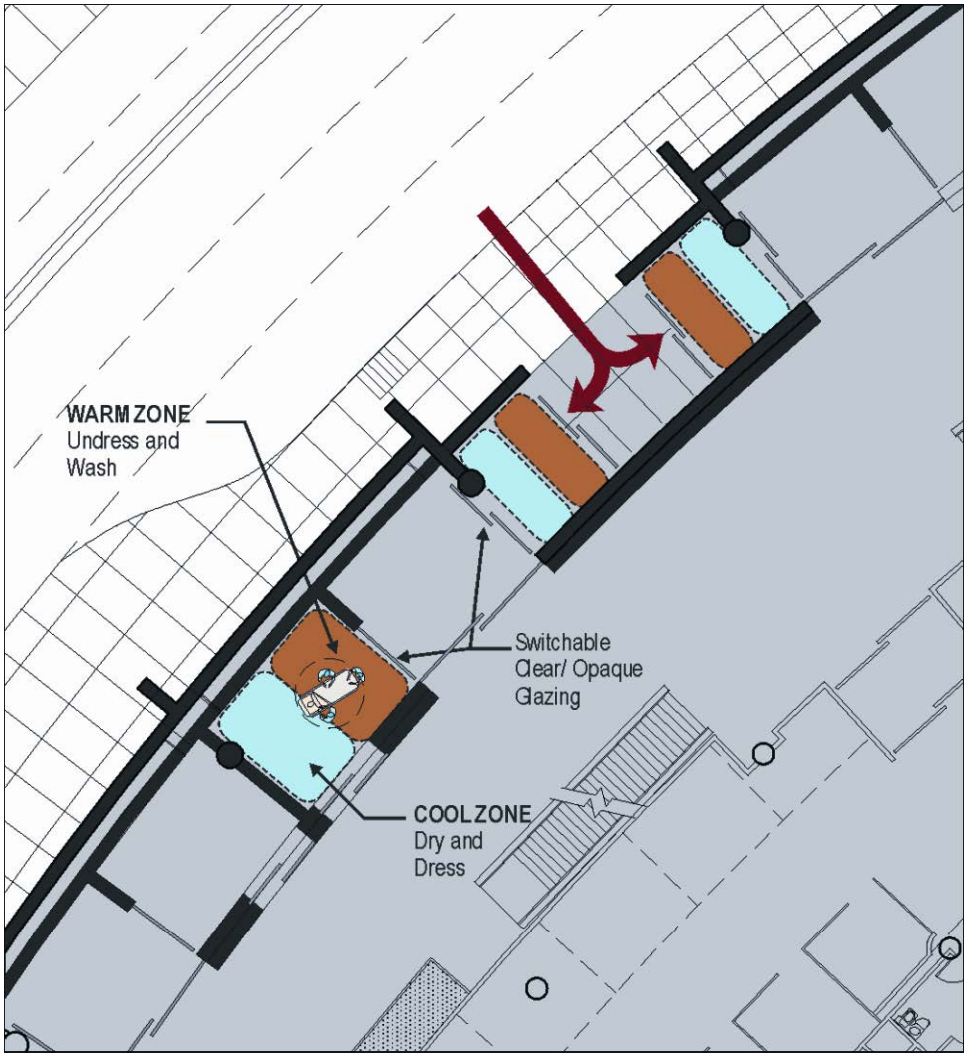
During event conditions the functional zones must adapt to meet demands. We have partly achieved this through the concept of expanding peripherally. This exhibit indicates

how the functional zones move out towards the front of the curvilinear form. The main exam/ treatment area grows into the former patient intake area. The patient intake function moves into the former public connector. The public connector effectively becomes merged with patient intake.

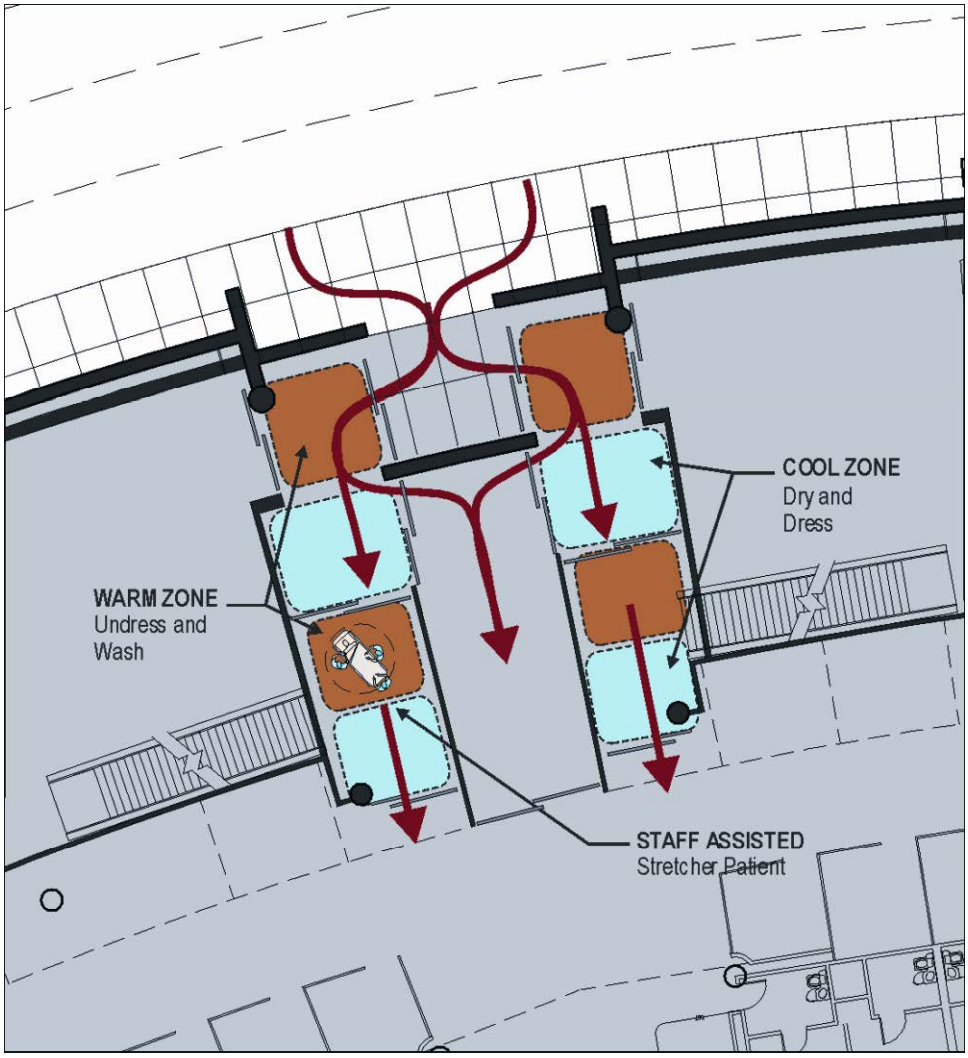


Mass ambulatory decontamination provisions are located all along the exterior wall in Zone 1, and are protected from the elements of weather.

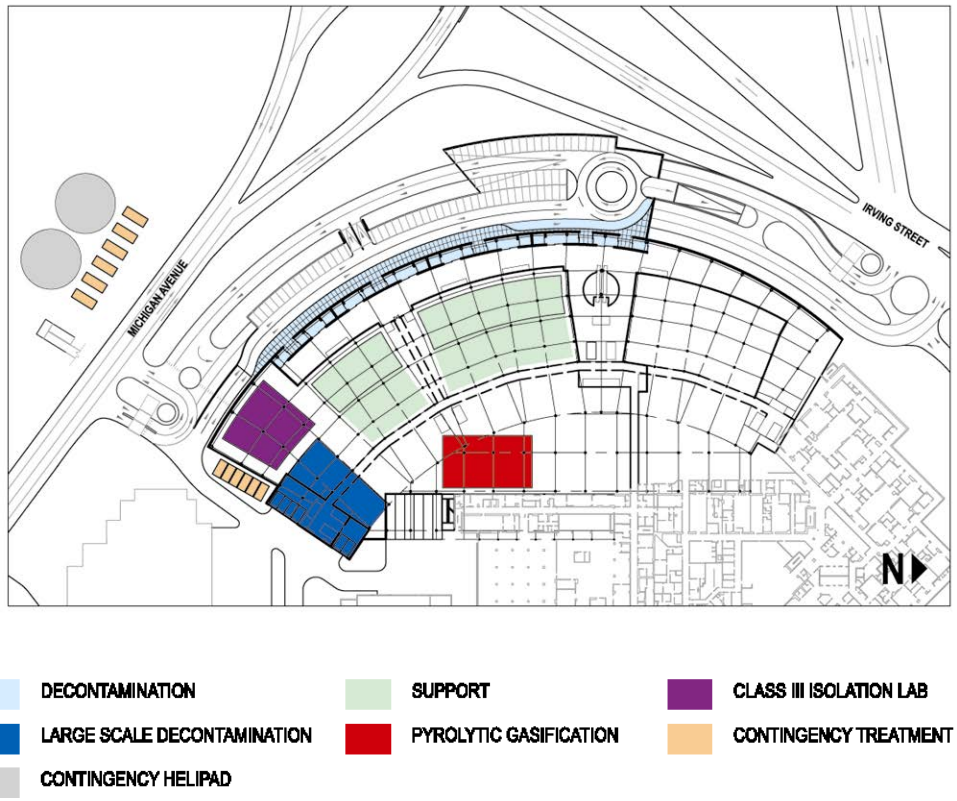
Multiple entrance points will allow for greater vehicular staging and reduce congestion. Flexibility for designated specialty entrances such as urgent care or chest pain, if so desired, is inherent. Additionally, multiple entrance points will allow greater flexibility as needed in conjunction with security or decontamination. These decisions can be determined in a late binding fashion as needed.



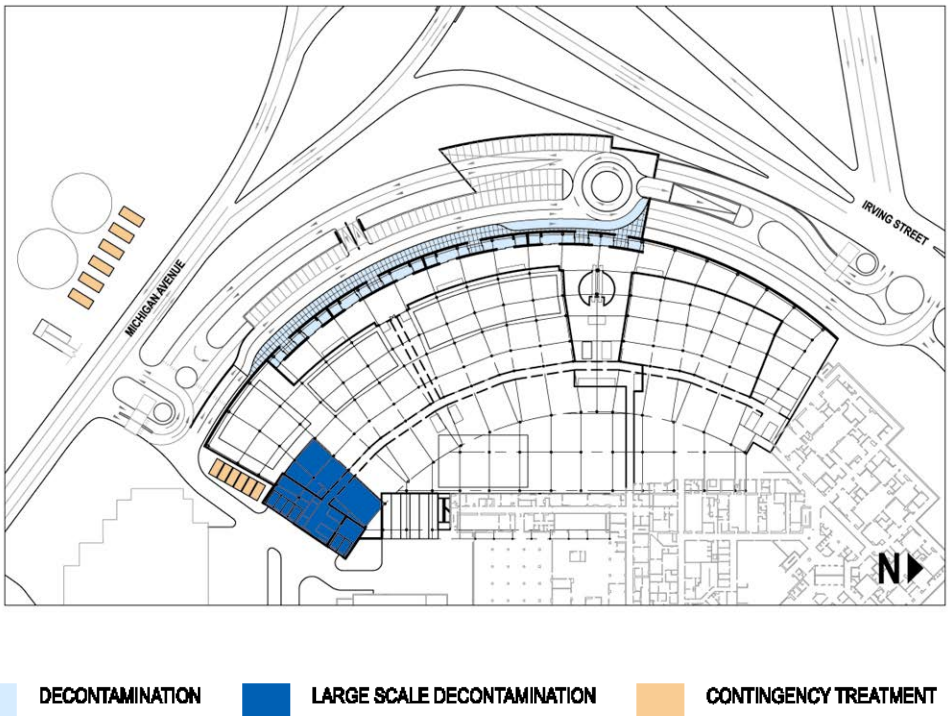
Entrance portals provide non-obtrusive screening for chemical and biological agents, radiation, and other hazardous materials. Decontamination capability is fully incorporated in the portals, as this is the most likely place for contaminated patients to present.



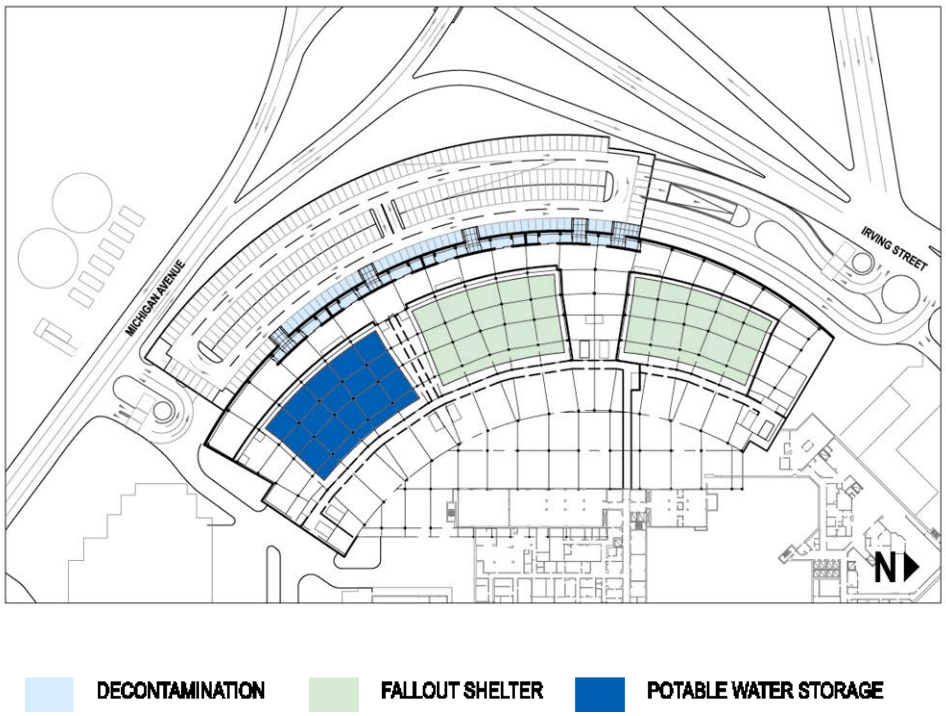
During routine use, staff assisted formal decontamination chambers will be available for use by ambulance delivered patients on stretchers. In major event conditions, staff-assisted mass decontamination can also occur in large ambulance garage on the ground level.



The ground floor provides the support spaces that are necessary to maintain efficiency and the function of the emergency department. This includes items such as storage facilities that provide gurneys to the emergency department floor. The gurney cleaning zones that are located directly below the first floor will be connected to the first floor emergency department via dedicated elevators. Additionally, support spaces, a Class III isolation lab, and a pyrolytic gasification system that uses hospital and contaminated waste for energy generation without incineration will be located on the ground floor. The ground floor is also equipped with the utilities and support services necessary to act as an additional treatment space during an event.

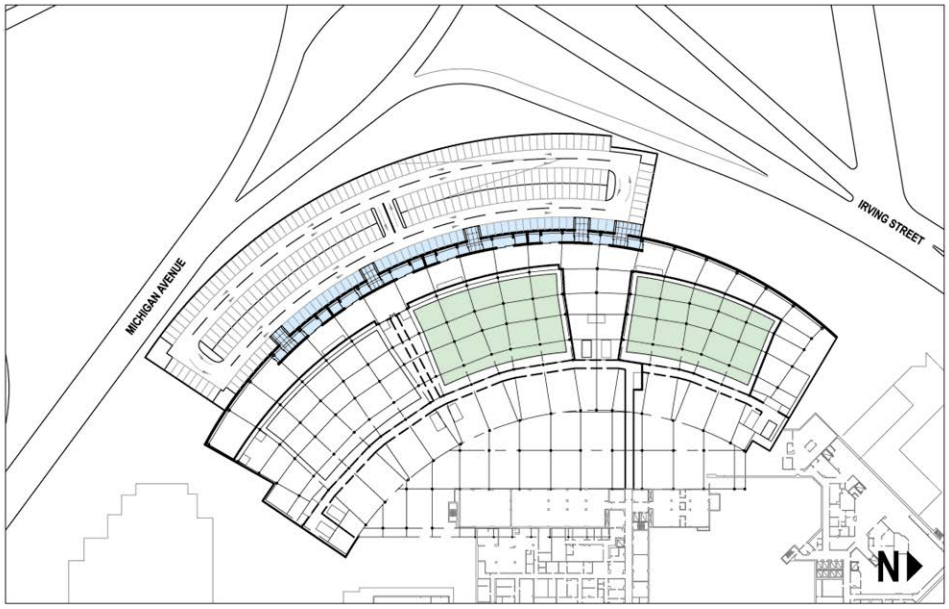


ER One is designed to accommodate some of the specialized treatment facilities that might be required during multifarious events. The modular units can be airlifted in order to provide for the unique facilities that *ER One* cannot justify providing on a permanent full-time basis. These facilities include uniquely designed radiation-protected surgical suites and high level isolation facilities that can be flown in during an emergency and located in a series of standardized docking stations as indicated in the plan.



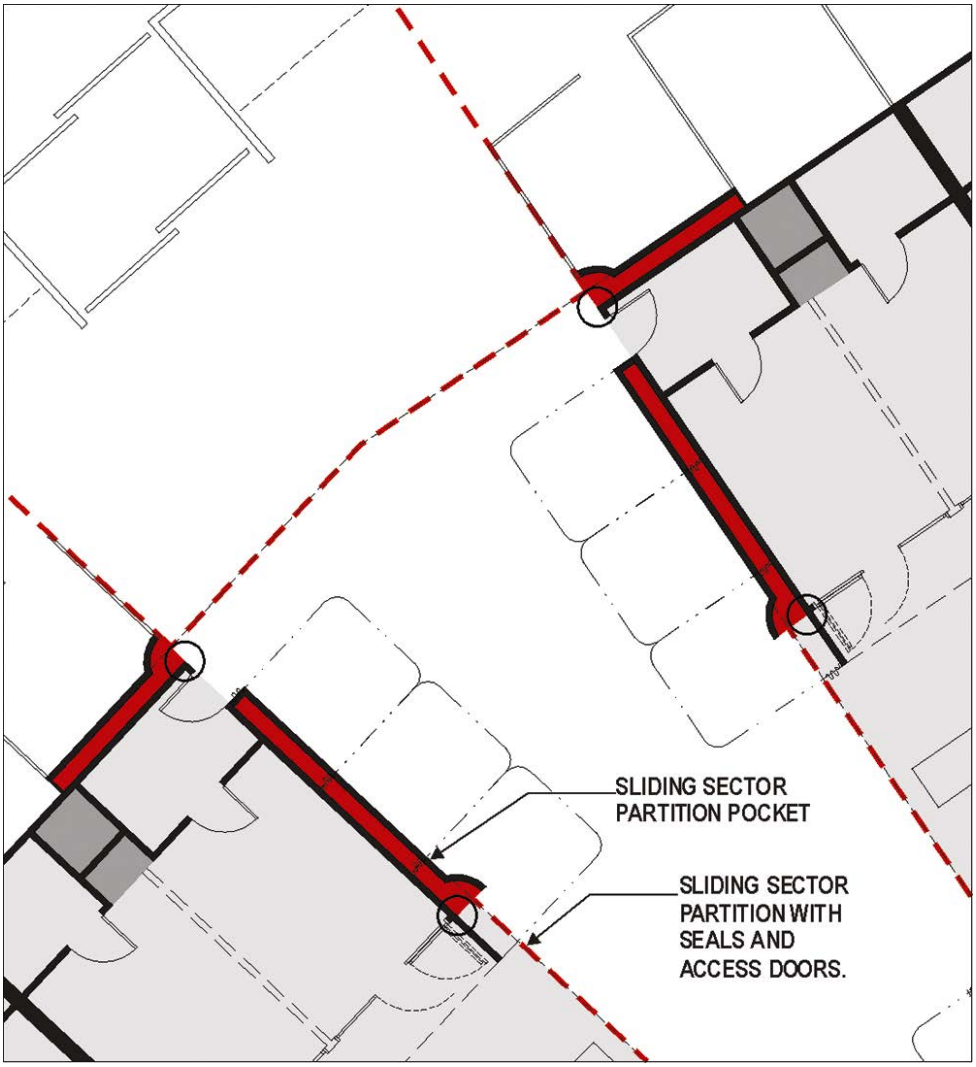
Entrance portals from the parking garage can also be used as decontamination areas during an event, while the first drive aisle can become a decontamination staging area.

A potable water storage facility that is located on the basement level can provide a secure water source during an event.



A fall out shelter is situated in the basement of the facility in order to house large numbers of people seeking refuge during an event. The basement is an ideal location for this function because it has the advantage of being below grade and therefore provides additional defense during an event.

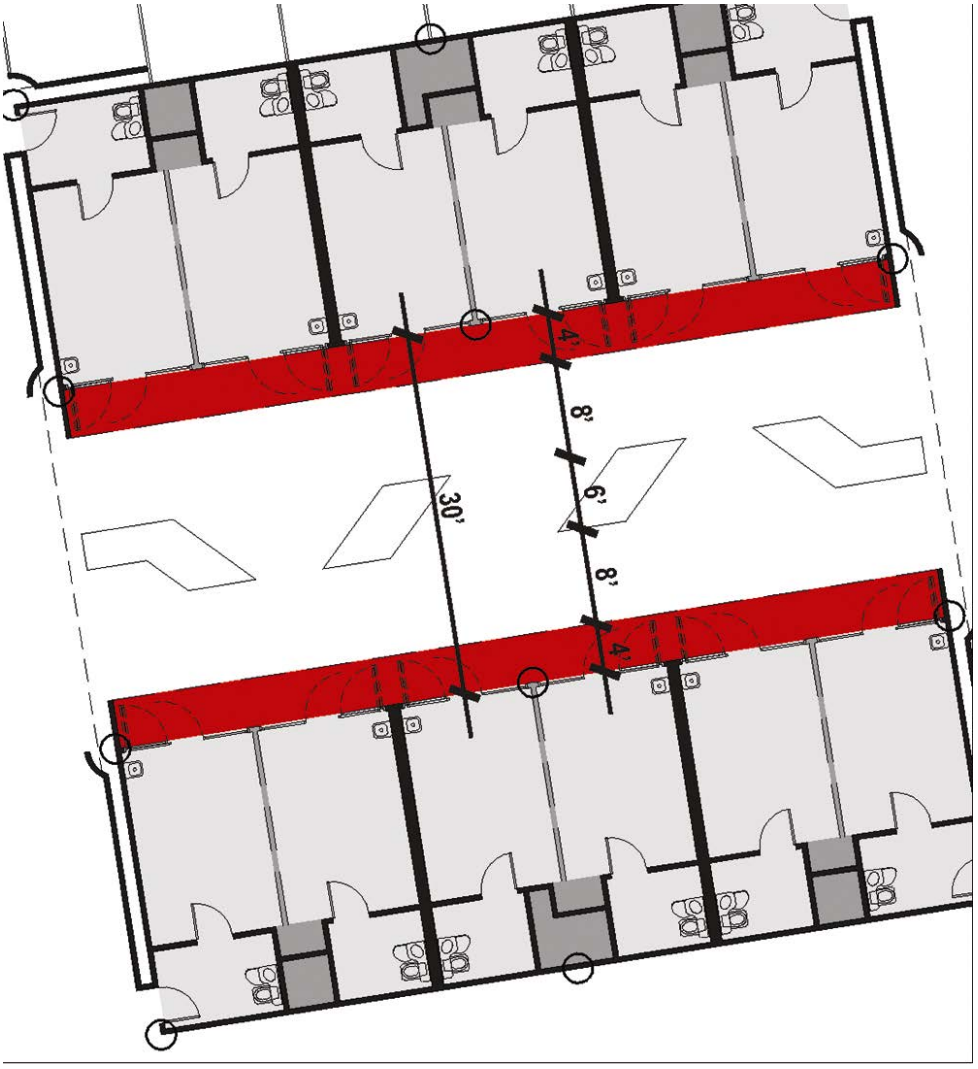
The concept of sliding sector partitions is employed to facilitate the isolation of specific areas as needed in a multi-configurational manner.



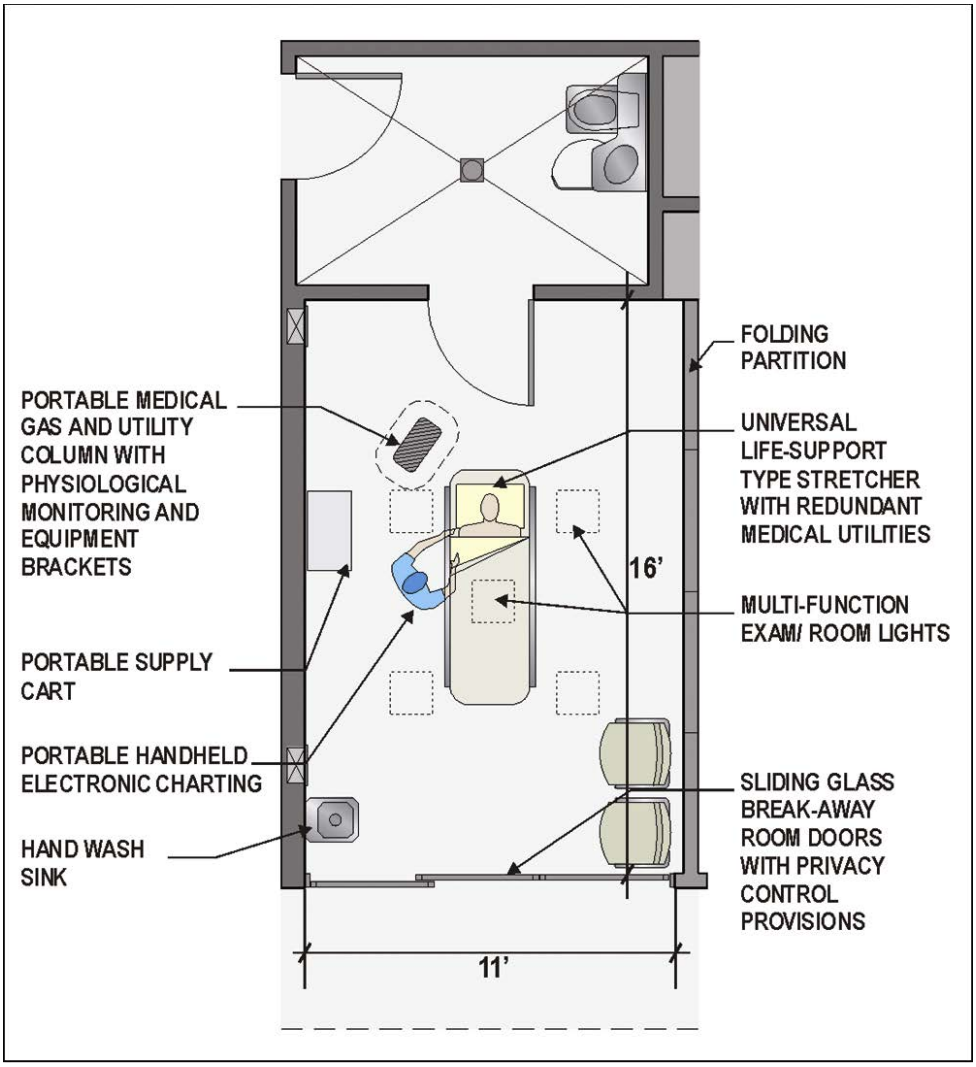
This exhibit indicates various potential uses for flexible spaces provided in the design. They can be used for multi- functions as needed during routine or contingency events.

On an aggregate basis, the soft area incorporated into the overall plan allows for significant adaptation as needed.

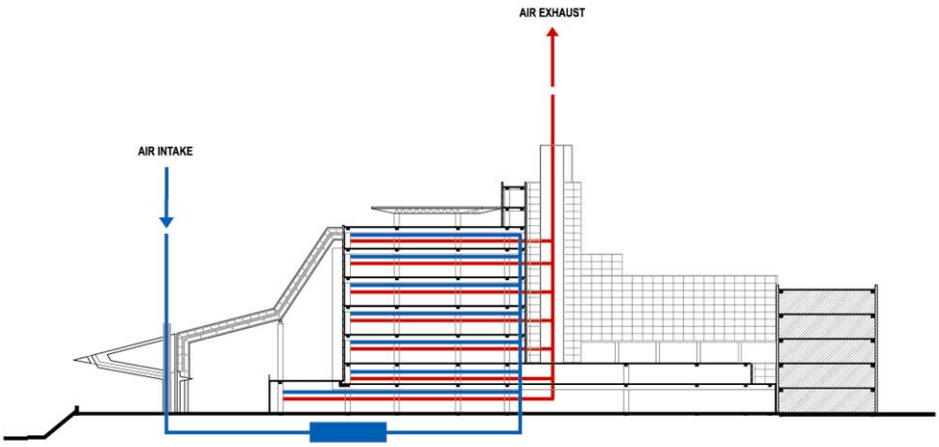
The 3rd stretcher position results by utilizing a portion of the open space in the center of the exam/ treatment pod on one side, and the remaining area in the exam room that becomes open.



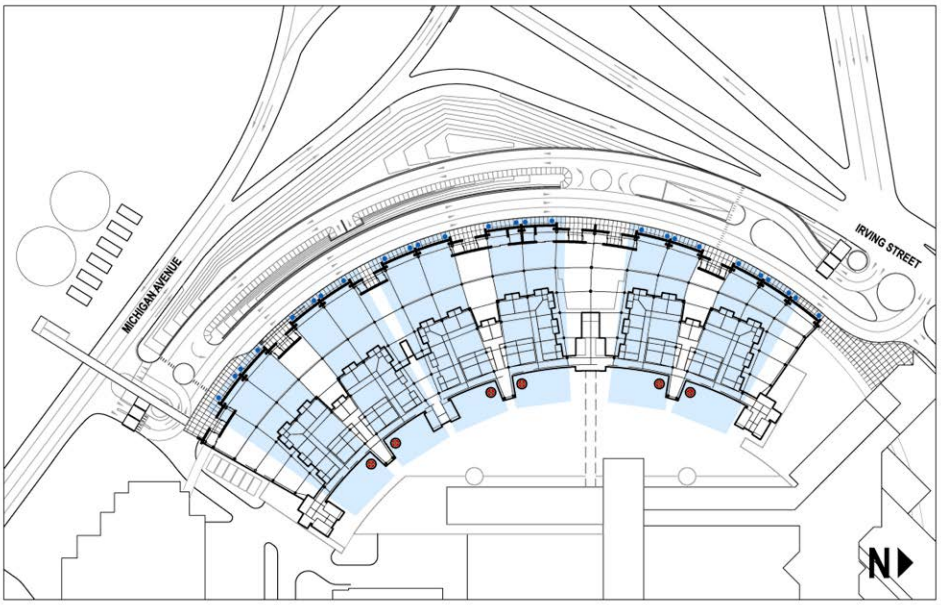
The 30 Ft dimension between exam room groupings consists of a 4-foot–wide strip of space on each side that allows for the 3rd stretcher position.



The plan above exemplifies a single position exam/treatment room layout.



ER One is exposed to many threats ranging from chemical contamination to diseases such as tuberculosis or smallpox. We have designed a facility that will provide constantly filtered fresh air. Fresh air is taken into the facility through intake shafts that are located behind the blast shield on the western façade. The air is then processed through filtered systems to a series of compartmentalized fan units that service zones that are arranged on a room-by-room basis. Processed air is exhausted to the outside at the highest level of the facility. Although the proposed system is not the most energy efficient, we believe it provides for a high measure of safety in the event of contamination.



The Zones can be controlled at progressively smaller levels—not only room-by-room, but also pod-by-pod. Compartmentalized air handling systems have high efficiency and specialized filters that ensure that clean air enters and exits the facility. These systems are designed to easily accommodate new detection, filtering, and biological technologies. The air intake shafts (blue) are an architecturally integral part of the building exterior and are similarly protected with blast resistant materials and air exhaust (red), which is located at the rear of the facility.

5.4 SCALABILITY – FIRST FLOOR

As scalability was previously discussed in depth in 4.4, related factors such as personnel, adjustments in clinical operations, utilization or dual usage of existing space, and supply and equipment management must all be considered when developing a scalable plan. Vehicular circulation and site scalability related issues, as well as the overall related building areas on other levels for staging of patient intake, supplies and equipment have also been addressed earlier in this section.

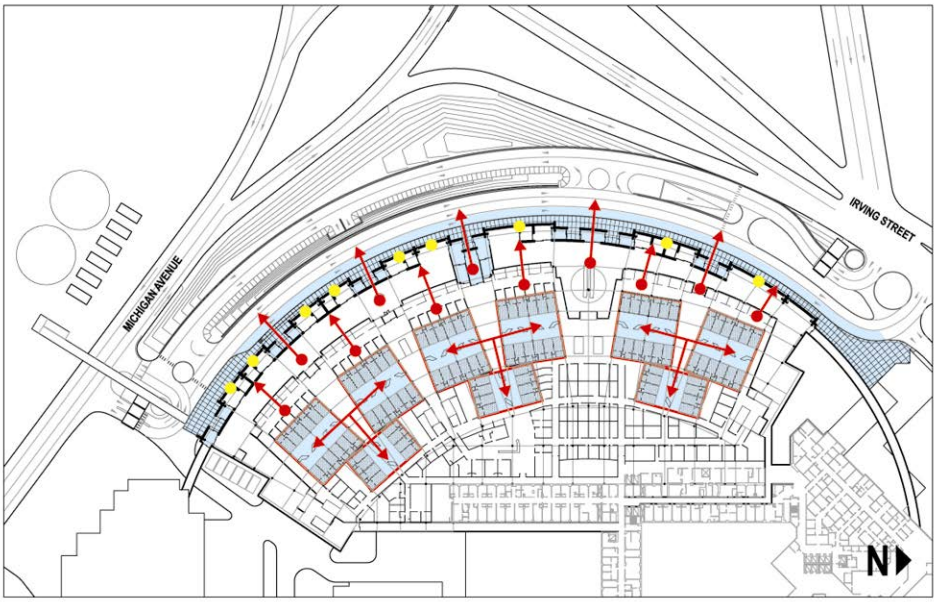
The concept of scalability in the broad or global sense is very much related to, or even a subset of medical consequence management. Another strongly related attribute is that of flexibility. In architectural terms as space becomes scalable flexibility must also be inherent.

Scalability as represented in the following exhibits is related to the re-configurable options that the plan offers at the room, pod, and zone levels of magnitude or scale. The expansion and, equally important, contraction capability of these areas of magnitude can be

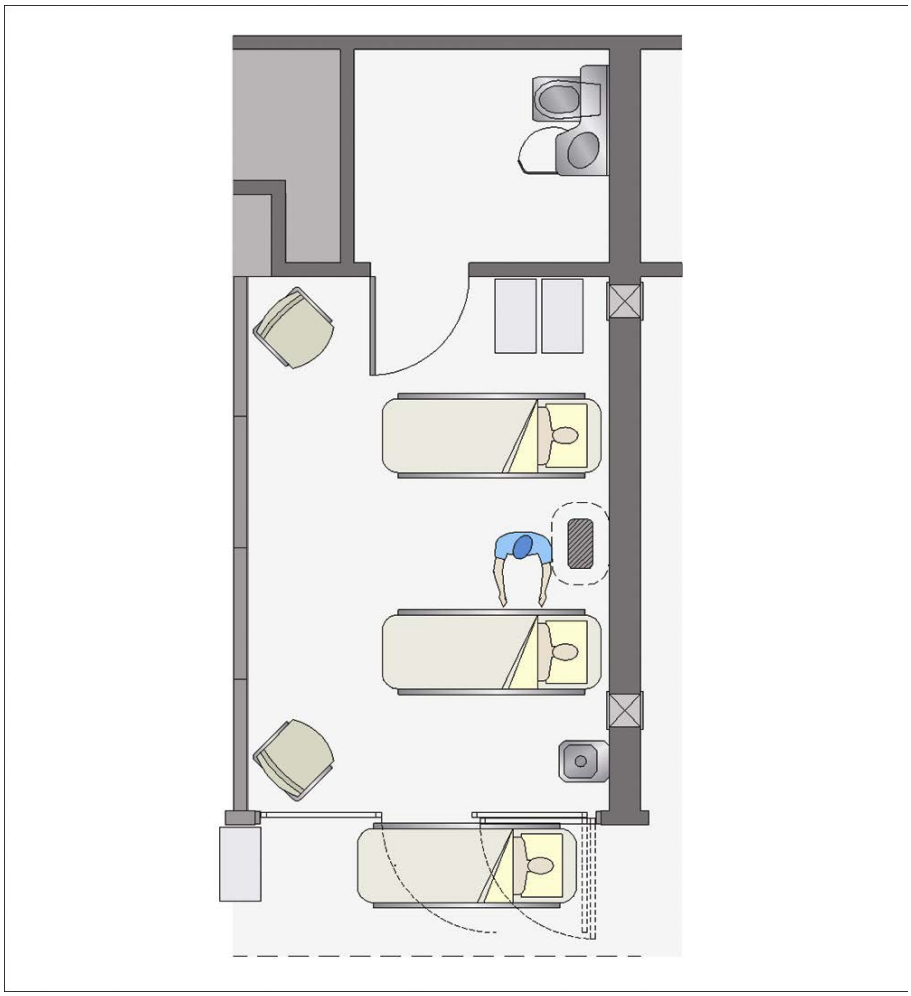
implemented or adjusted independently or collectively to meet dynamic volumes on demand. Providing scalability in this manner even allows the ratio or mix of clinical case types to also be easily adjusted instantaneously. The scalability of these areas on the up side will allow a three fold (3X) of normal daily patient volumes in the exam/treatment room space, an additional (1X) by utilizing the flexible pod space and exercising one step contingency zone expansion, and potentially an additional (1X) by two step zone expansion. In all four to five times expansion of routine patient volumes can be achieved. It is interesting to note that achieving the (3X) scalability within the exam/treatment room module and the associated 4-foot–wide contingency space in front of it is achieved by only adding a marginal 57 percent increase in space. The difference in this scenario is calculated by comparing a traditional 140 SF private exam room to that of our 220 SF extended exam module.

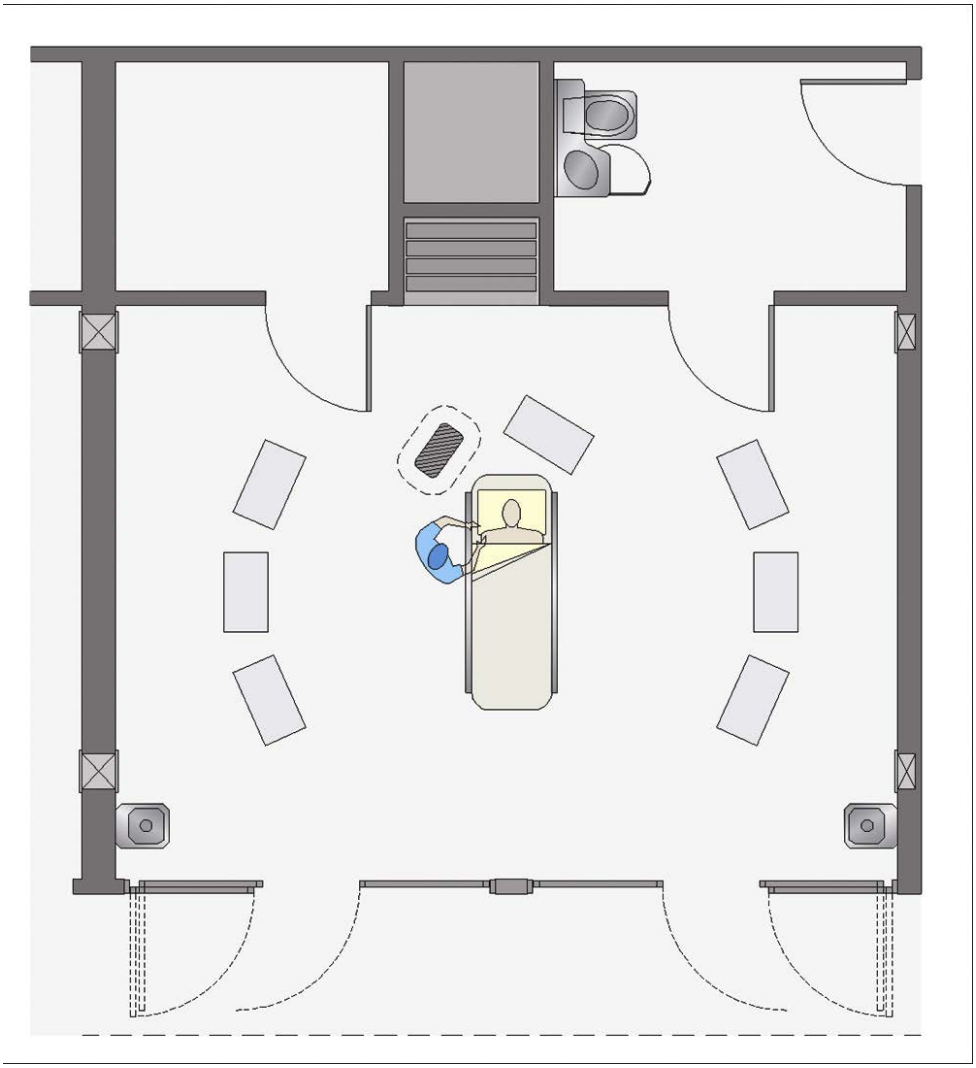
One final mention regarding the flexible use of the space as it relates specifically to the scalable context of the exam/treatment room. To a certain extent, the diversity of the clinical caseload and throughput capability can affect the scalable potential. We have substantially addressed these issues in three ways. Firstly, all the medical equipment and supply support is mobile. Secondly, paired exam/treatment rooms can be combined into a double sized room module for critical and trauma care. Thirdly, the immune room concept will facilitate quicker room decontamination, if needed, affecting turnover between cases.

In all, the combined synergy of these features will provide a very good level of scalability that is unique in emergency care to date.



The treatment pods and other treatment zones are laid out in a flexible manner in order to increase in scale during an event. This is achieved by moving outward to occupy additional areas as shown in the diagram. The drop-off area under the canopy is turned into an ambulatory decontamination zone. The previous interior public circulation area (Zone 2) now functions as a treatment space or holding area.





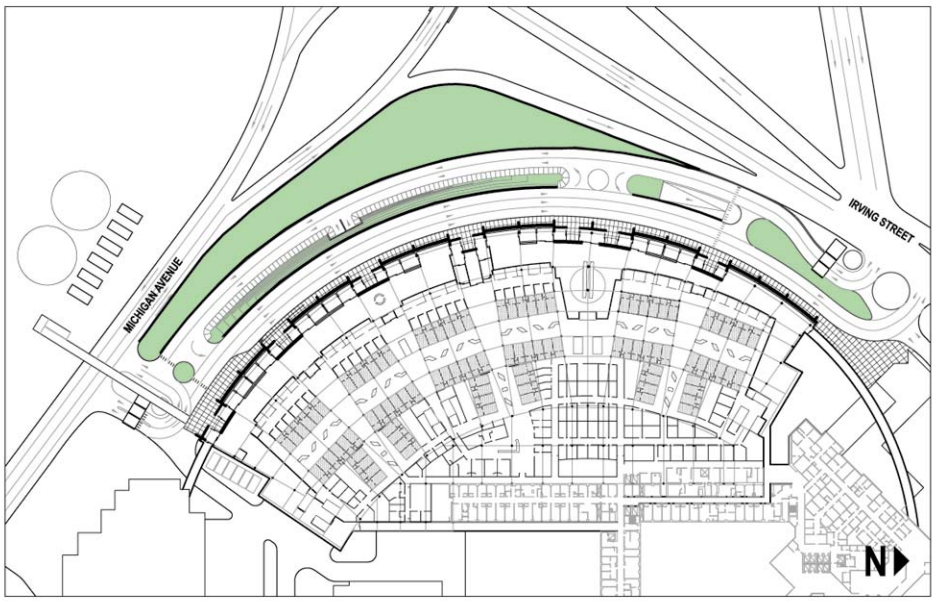
This plan shows, on a composite basis, the planning flexibility for both the Zone 3 patient intake modules, and the Zone 4 exam/ treatment module. Walls in Zone 3 are all modular, and can be quickly reconfigured as needed. Every other wall in the E/T pods can be eliminated to allow instantaneous room expansion for trauma use.

5.5 THREAT MITIGATION – PROTECTIVE BARRIER

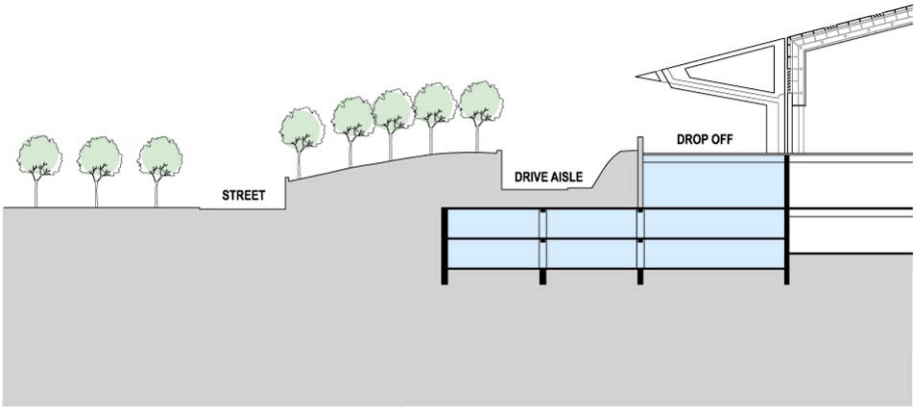
The concept of threat mitigation is incorporated into multiple aspects of ER One such as placement of the complex within the site, blast shield and building enclosure design, as well as other design considerations. The site design incorporates a landscaped buffer zone, which provides maximum stand-off capability for the facility. Retaining walls, which flank the drive aisles, also provide added protection. The next level of threat mitigation is the canopy,

which provides cover for the drop off plaza and three drive aisles of the facility. The canopy also protects personnel and patients when the drop off plaza is used as contingency treatment space during an event. The canopy is a highly engineered concrete blast shield that is capable of resisting the force of an adjacent explosion. It also serves to mitigate the effects of a blast on the critical care towers and the interior public concourse.

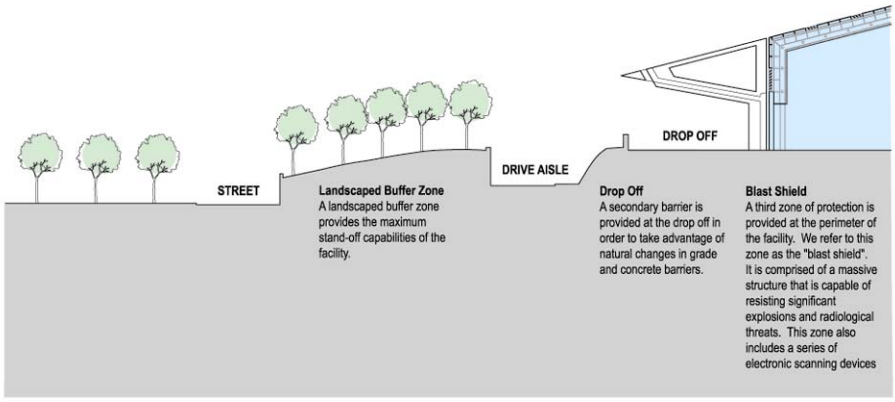
Entrance portals to the interior of the facility are located in vestibules and are constructed of the engineered concrete used in the blast shield. This precaution will diminish the effects of a blast on the interior public concourse and the rest of the facility. Each entrance portal is capable of effectively identifying menacing individuals by employing biometric scanning, providing access control, detecting unwanted material (chemical, biological, explosive), temporarily detaining an individual, and in some cases, providing decontamination. New detection and scanning technologies are accurate, highly effective, non-intrusive, and non-invasive to provide maximum privacy. The entrance portals are placed away from the core treatment in order to create stand-off distance, adding an additional level of security to the facility.



A bermed stand-off area and retaining walls will provide a protected environment and effective stand-off distance from threats from vehicles driving the perimeter of the property.



Project *ER One* will provide limited secure parking for residents, staff and personnel of Washington Hospital Center. The parking (blue) is located outside of the footprint of *ER One* with no vehicles allowed to enter directly under the structure. *ER One* is fully protected from this parking area by a significant blast wall that extends from ground level to the basement level parking. The facility has multiple drop-off points on the first floor as well as on the ground floor level.



1. Landscaped Buffer Zone

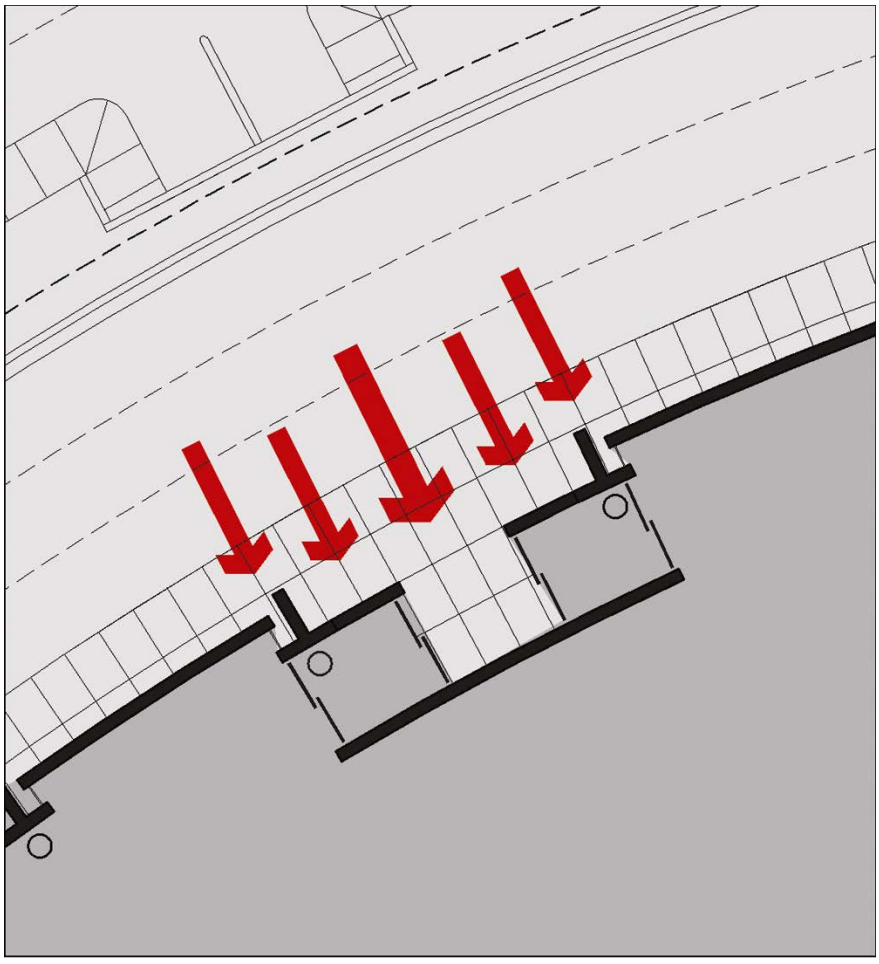
A landscaped buffer zone provides the maximum stand-off capabilities of the facility.

2. Drop-Off

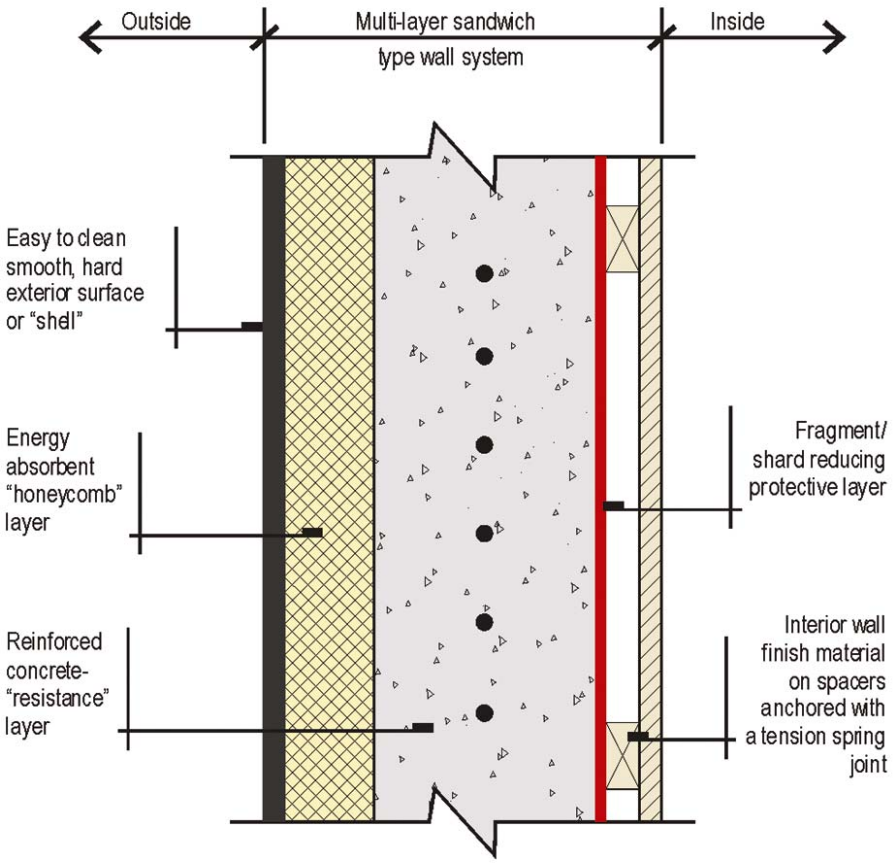
A secondary barrier is provided at the drop-off in order to take advantage of natural changes in grade and concrete barriers.

3. Blast Shield

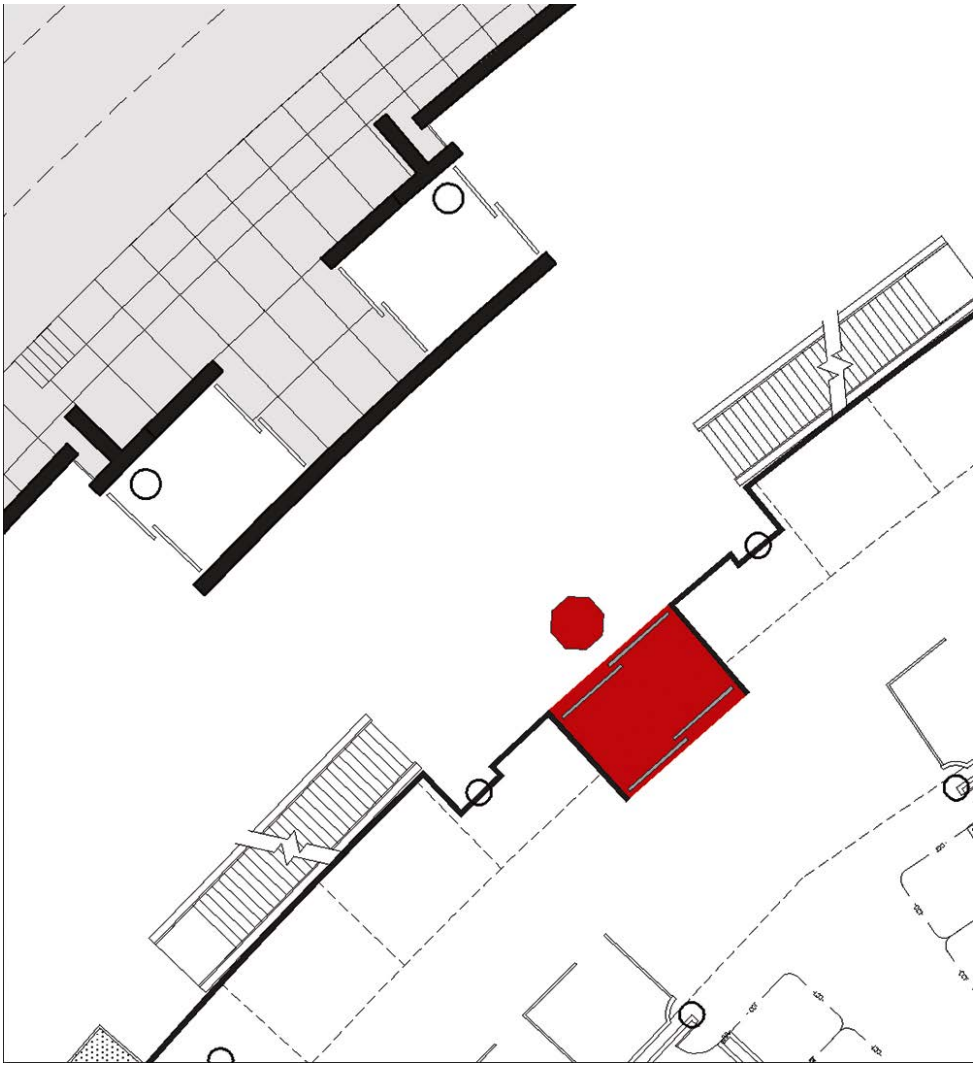
A third zone of protection is provided at the perimeter of the facility. We refer to this zone as the blast shield. It is comprised of a massive structure that is capable of resisting significant explosions and radiological threats. This zone also includes a series of electronic scanning devices.



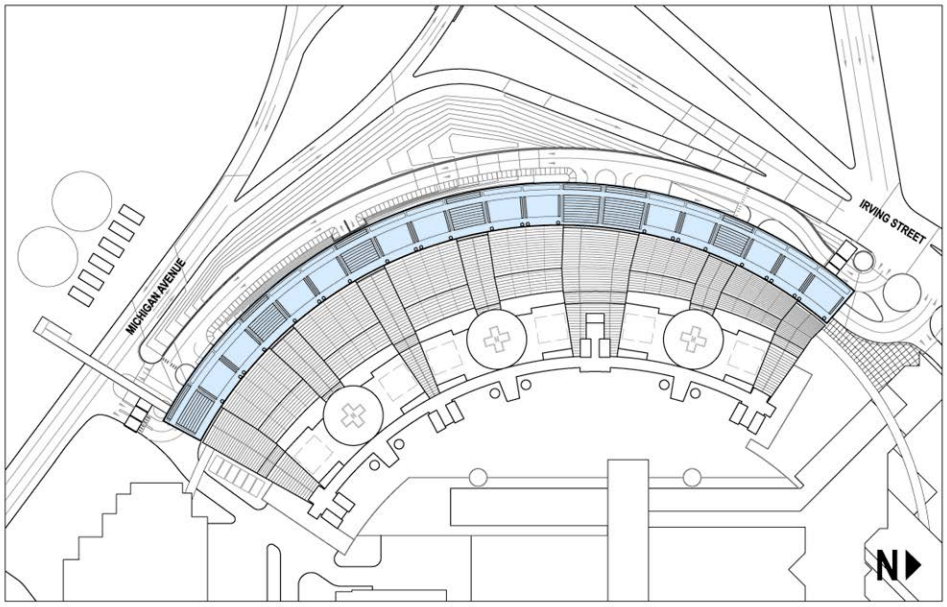
Entrance doors are positioned perpendicular to the exterior facade to mitigate potential blast forces. The exterior wall is composed of multi-layered, blast mitigation type, energy-absorbing material.



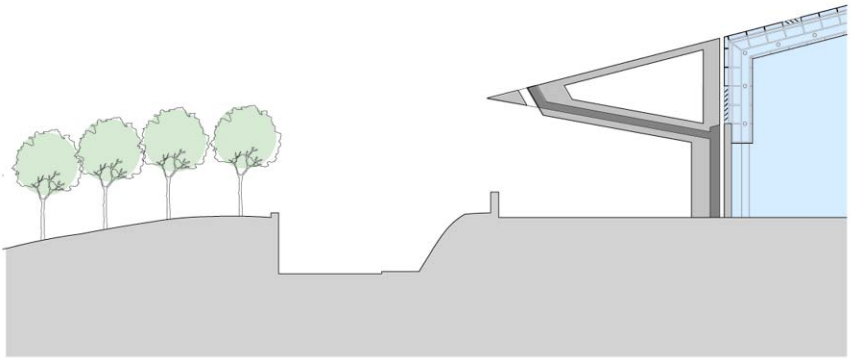
The blast mitigation exterior wall section above indicates a multi-layered sandwich system.



Non-obtrusive security technology used to protect the inner clinical and staff zones.

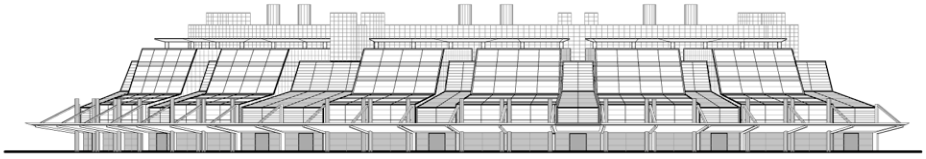


ER One will be protected from most blast threats by a highly engineered concrete and steel blast shield. This blast shield extends the entire length of the facility. An integral part of the blast shield concept is a projecting canopy. This canopy offers cover for vehicular loading and unloading as well as personnel that may be required to assist in decontamination. In addition to its weather protective function, the canopy also serves as a blast shield to resist the forces of an adjacent explosion to the critical care towers.

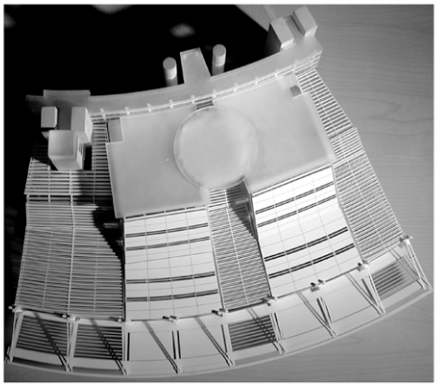


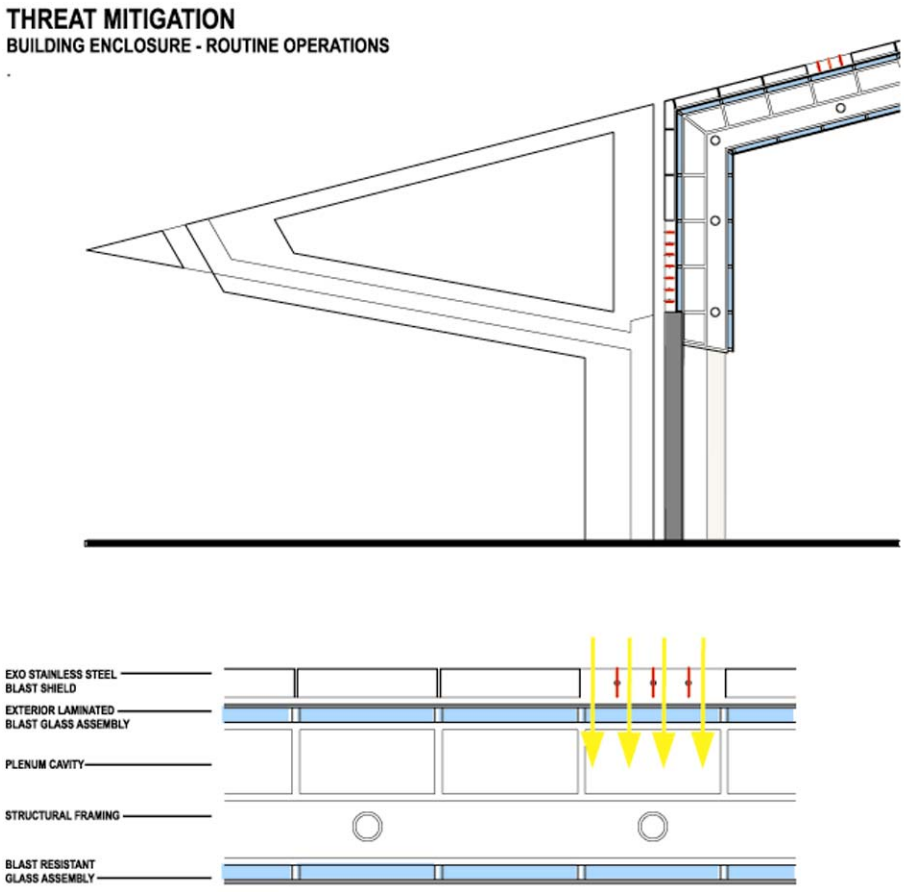
The blast shield is comprised of an exterior surface that can be easily cleaned and decontaminated. There will be an energy absorbent layer behind the outer surface followed

by a reinforced concrete and structural wall. On the specifically designated exposures (south and west) the concrete will be specially compounded to offer resistance to radiation. This concrete is frequently referred to as heavy concrete. Behind the concrete will be a gap that will serve as an expansion joint between the blast shield structure and the actual structure of *ER One*. It also allows for the recoil impact of any explosion to not touch the inner structure of *ER One*. Inner surfaces will be lined with materials that will mitigate fragmentation effects. In addition to its weather protection function, the canopy is also designed to be a blast shield. This shielding primarily protects the upper levels from a street-level blast. The upper levels that include critical care towers will not have the same blast walls as envisioned on the ground levels. There will be a series of slots perforated through these exterior walls to allow sunlight to enter. That light will be admitted through either tension membrane systems or a laminated engineered glass assembly.

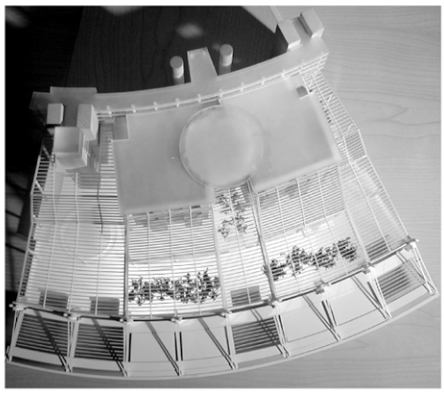


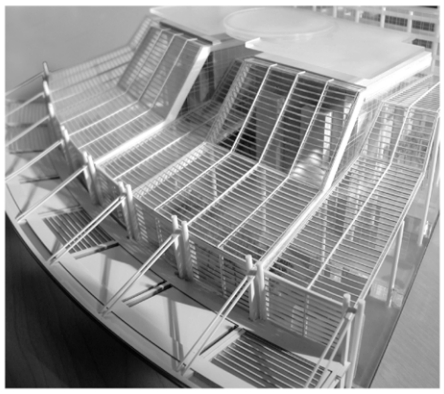
ER One is designed to mitigate serious threats and yet provide for the creation of a humane and healing environment. The first layer of defense is the highly fortified blast shield. The outer layer would be made of a very dense steel, perhaps stainless steel or even titanium. It would be comprised of a series of panels and louvers. The combination of stainless steel louvers and stainless steel panels provides the most critical protective screen and still allows filtered light to enter the facility.

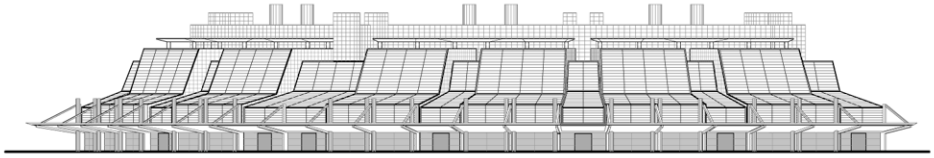




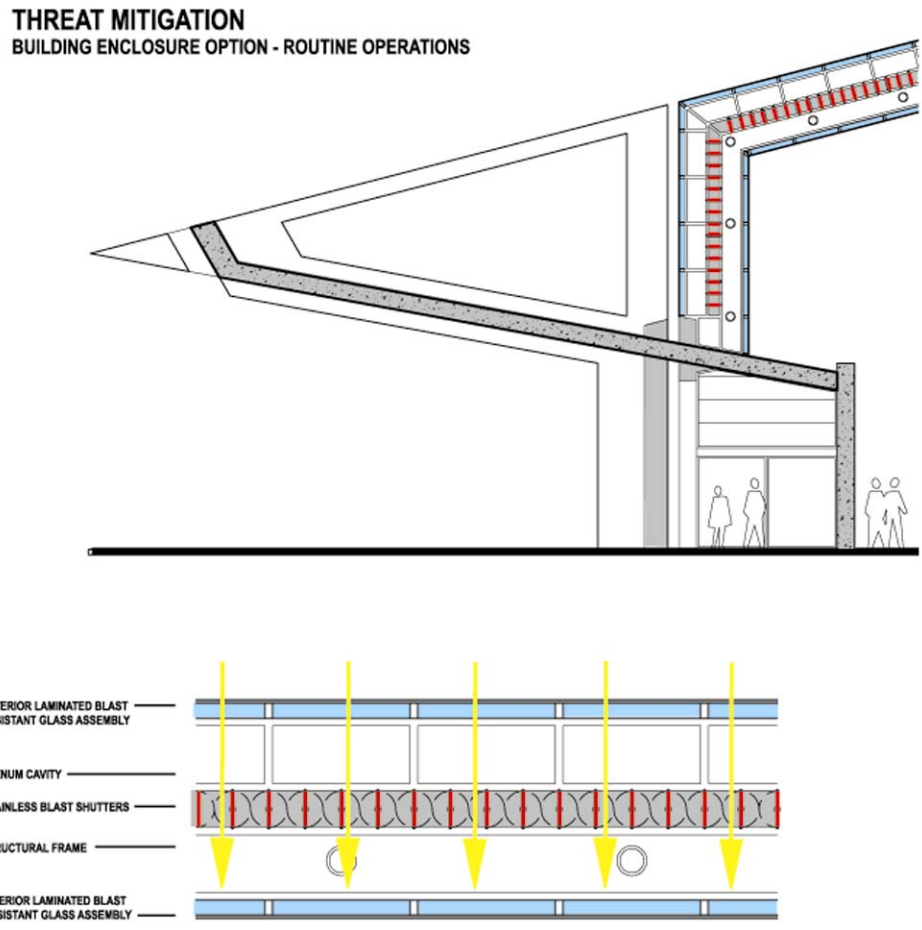
The first layer of defense is the highly fortified blast shield. A second layer of defense is the enclosing surface that defines and encapsulates Zone 2 or the atrium. The enclosing system is comprised of a series of panels and louvers. The second layer directly behind would be highly engineered laminated glass. There would be an interstitial space between the second and the inner most layer which would accommodate the structure and with that would be fully protected. Also this interstitial space allows for the passage of air and can provide for a more energy efficient and comfortable environment. Finally, there is a third and inner layer of an engineered glass system. The outer layer can be designed to meet or exceed any designated forces that are anticipated to act upon it. The current criteria is discussing the resistance of a one mega tone blast located approximately two miles away which will result in a 22 psi load force. If the criteria should be increased, the system can be correspondingly engineered to accommodate that load.



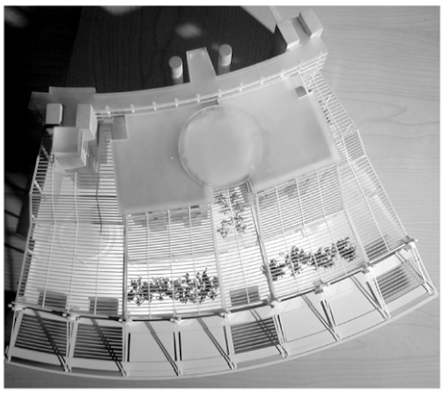


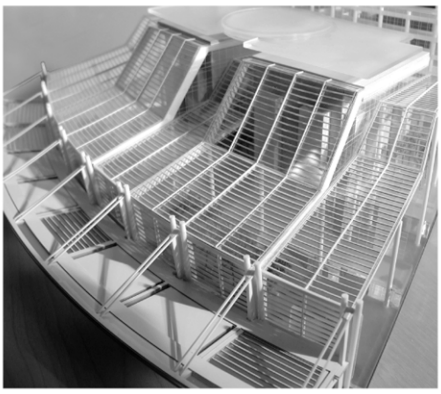


The system proposed to protect Zone 2 or the public atrium from the potentials of blast is a predominately closed exterior enclosure comprised of stainless steel. The advantage of this system is its ability to protect the occupants from potential danger. The stainless steel shroud will mitigate the amount of natural light that will be allowed into the facility. The *ER One* design team developed an alternative enclosure strategy that may equally meet the need for threat mitigation and provide for humane environment. The alternative strategy would be to have a triple layered enclosure system. The outer layer would be a highly engineered glass assembly that is layers of glass sandwiched between layers of special plastics that together would form a surface composite approaching 1-1/2 to 2 inches thick. There would be an inner air space within which would be a series of stainless steel louvers. Finally, beyond the inner space would be another laminated glass assembly defining the inner most layer.



During normal operations, the stainless steel louvers that are encapsulated within this cavity would be in an open mode permitting filtered sunlight to enter the space. During an event, situation remote sensors, which will be located approximately one mile around the facility and coordinated to likely threat inducing vibrations, would be linked to activated louvers. As those sensors detect a potential threat to the facility, they would provide a signal and the louvers would shutdown, forming yet another layer of blast protection. The primary protective membrane, however, is the XO glass assembly designed to meet whatever the criteria is determined to be. Currently, the discussion is 22 psi. If the load exceeds the determined criteria, that layer will act as a sacrificial façade. The louvers will close and will receive most of the shards from the XO glass. Finally, the innermost layer of glass will prevent any shards from entering the facility.

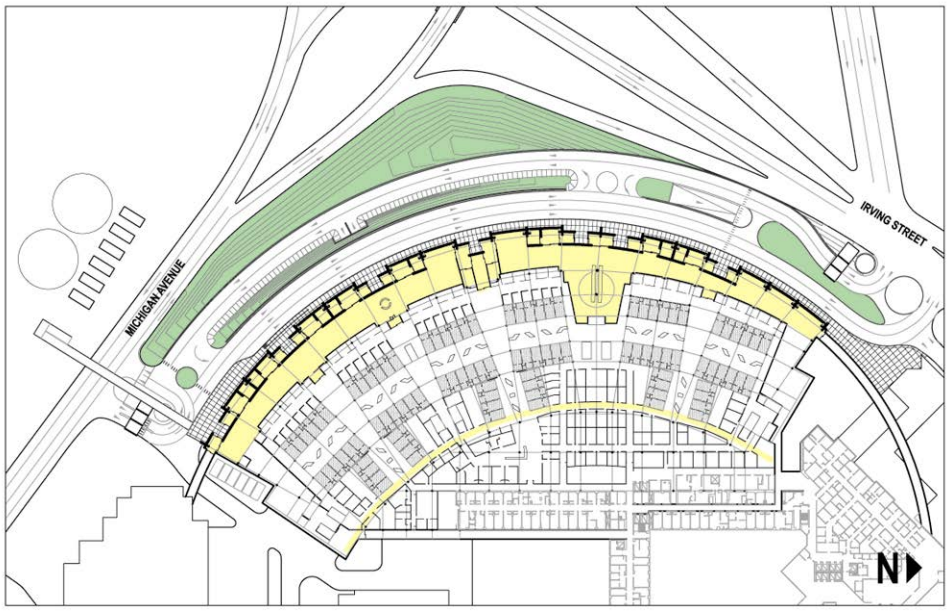




5.6 HEALING ENVIRONMENT – FIRST FLOOR

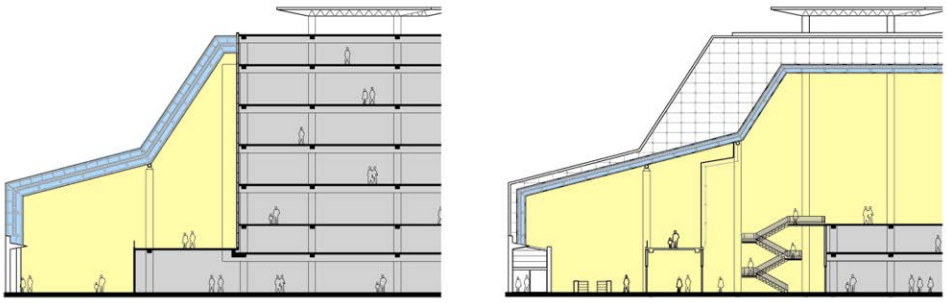
The creation of a healing environment is important not only to the patients and guests of ER One, but also to the professional staff that is serving those patients. The design of ER One supports this belief and incorporates humane spaces without compromising the facility's security. At the perimeter, the landscape embraces the site by supporting the established earthwork and providing a generous buffer from the street. The interior concourse and mezzanine space is designed to be an anxiety reducing environment with views to the exterior, incorporation for areas to rest.

Between ER One and the existing Washington Hospital Center, a healing garden courtyard has been included that can serve as a space for individuals and groups, with an emphasis on diverse environments. Inside ER One, the public atrium of Zone 2 is an open and inviting public concourse very much in the spirit of the main concourse at Reagan National Airport. The atrium also includes an upper level mezzanine that supports the public concourse and entire facility and offers beautiful and open views to the outdoors. The public concourse may also provide some limited use of water or perhaps even plant materials. The concept of a healing environment is also brought deeply into the professional spaces and Zone 3. Professional staff will have access to controlled courtyards and secondary atria so that they have an opportunity to get away from their critical work



The creation of a healing environment is important not only to the patients and guests at *ER One* but also to the professional staff that is serving those patients. It is commonly recognized that the natural environment helps to mitigate stress. Simply the presence of flowering plants, trees, grass, and the sound of running water help to calm individuals and reduce heart rate. We have recognized the power of a healing environment in the design of *ER One* and have proposed a beautiful tranquil garden courtyard between the existing Washington Hospital Center and the new *ER One* facility. This garden is accessible to patients and staff and provides places for people to sit, to read, to think, to be alone or to be together. Trees and shrubs are chosen carefully not to be brittle as this may cause additional fragmentation during explosions.

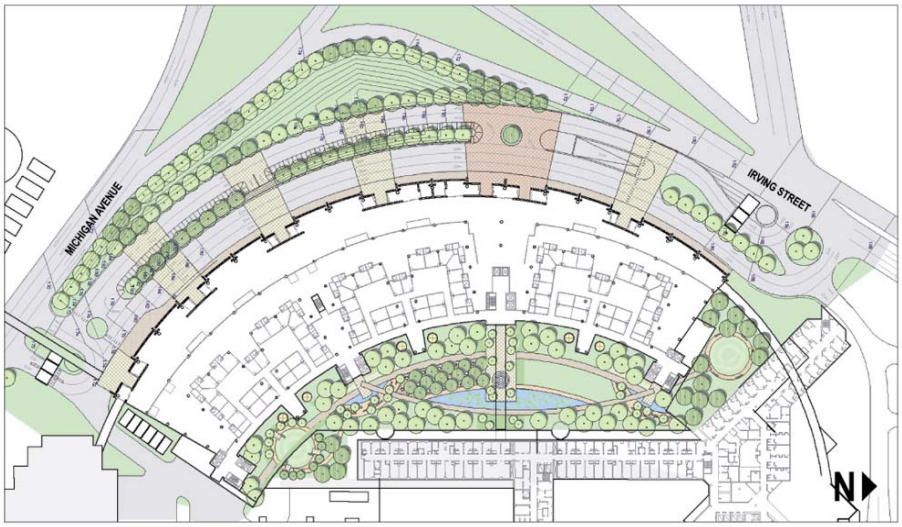
The garden in the forecourt of the project along Irving Street and the drop-off will have a very different function. Although it is not a destination point, the forecourt garden will provide a graceful introduction to the project and help mitigate potential threats in conjunction with the landscape.



The designers of *ER One* believe that the creation of a humane environment is perhaps as important as the ability to provide an environment that offers protection against any threats. It is recognized that for the majority of the time that *ER One* is in operation it will operate in a normal pattern of activity. It is imperative the facility be designed to support the productive life of its inhabitants. We have introduced natural light throughout the facility. Research has shown that the introduction of natural light, views to the outside, gardens, and to the sky promote healing and a faster recovery.

We envision the public atrium or Zone 2 as an open and inviting public concourse very much in the spirit of the main concourse at the Reagan National Airport. This space will offer a space for people seeking respite from work and a place to relax. There is an upper-level mezzanine that allows for beautiful and open views to the outdoors. There also would be places for people to have a cup of coffee, buy a magazine, and read a newspaper away from the hustle and bustle of the actual emergency department. We envision that the public concourse may also provide some limited use of water or perhaps even plant materials.

The concept of a healing environment is brought deeply into the professional spaces as well into Zone 3. Professional staff will have access to controlled courtyards and secondary atria so that they will have an opportunity to get away and to recharge their batteries prior to returning to their critical work. The garden courtyard will be located directly above the interstitial space between the existing Washington Hospital Center and the new facility. The courtyard will be accessible to staff and guests of *ER One*.



The approach to the landscape is one that accommodates the safety and security goals of the program while creating thoughtful, flexible, well-planned environments for the staff, patients, and visitors. The landscape supports the idea of creating a humane and restorative environment for one of the most sophisticated and complex healthcare facilities. Stress reduction and relief from the intense medical environment was a primary goal for the design team, and therefore the project reflects a strong emphasis on daylight, connection to nature, and generous outdoor spaces for gathering.

At the perimeter, the landscape embraces the site by supporting the established earthwork and providing a generous buffer from the street. The canopy trees provide seasonal color and shade, creating an informal edge that makes a great addition to the park-like setting of this area of the city. Special paving in the auto court identifies the entry points to the building and lighting will be incorporated in the plaza to help support orientation and way finding.

The third floor garden is created as a space for groups and individuals, with an emphasis on diverse environments. The main gathering space adjacent to the connection link is a large terrace with ornamental flowering trees, ornamental plants, special paving, moveable furniture, and a living pool that features koi and aquatic plantings. The main path that mirrors the arc of the building serves as a connector to a variety of other more intimate spaces that allow for personal reflection and decompression. Seating along the path offers one a choice of shade or sun, lawn or perennial garden, and two important water features are located at either end of the path. This path connects to the entry points to the building and ties the garden together.

On the first floor, a simple gathering space in a concentric form allows for larger gatherings to occur in the garden. The space has seating and perimeter shade trees along with blooming plants along the edges.

ER*One*

Section 6 *How ER One Will Work*

SECTION 6

HOW *ER ONE* WILL WORK

Creating the all-risks facility is a complex endeavor. In the end, many different concepts and features must function as a coordinated and integrated whole. To illustrate *ER One* concepts in action, two challenge scenarios—a chemical and a nuclear event—will be presented and the *ER One* response will be described. The details of the scalability aspects of these responses are described in the modeling and scalability sections of this document. This section will focus on the qualitative responses and only describe the general aspects of the scale-up response.

6.1 A CHEMICAL EVENT AT THE NEW CONVENTION CENTER

Consider the release of a potent chemical agent at the new convention center. Thousands of individuals begin to flee the scene despite efforts by the authorities to contain them and establish decontamination capability at the event site. Hundreds of individuals without apparent illness of injury arrive at the facility. *ER One* personnel already alerted to the event have prepared by donning protective equipment and securing the exterior portals. The positive pressure within the facility prevents entry of contamination. There are 70 exterior decontamination stations that are immediately available without set up requirements at the entrances of the facility. Warmed blown air keeps the patients warm as they begin to undress for decontamination. Privacy curtains are unveiled, and ambulatory patients begin to wash themselves under supervision of *ER One* personnel. Family members are allowed to remain as a unit. All effluent material drains as planned by the slight grade engineering into the pavement surfaces. Contaminated clothing is bagged and sent for handling and destruction via processes such as pyrolytic gasification. This process will not only destroy the contaminant, but it will provide energy production for electrical needs. There will be no requirement to send the material to a special handling facility. As the first survivors finish decontamination, the interior of *ER One* has already rapidly scaled up to a three-fold capacity by moving its stored gurneys into position. This three-fold capacity is planned to require less than 20 minutes for deployment.

More serious casualties arrive and are provided decontamination on litters in the decontamination zones adjacent to the portals. After these casualties are decontaminated, they enter the engine area (patient care area) of the ED. They are placed in one of the many treatment rooms and receive therapy appropriate to their symptoms and eventual disposition to inpatient status, transfer or release.

All vehicles arriving to the facility receive a rapid 10-second wash-down in the vehicle security portal prior to arrival at the entrance. While this is not a complete decontamination, it will remove the vast majority of any contaminant and keep the hospital entrances safer.

Chemical detectors in the entry portals and treatment areas will alert on contaminant instruction and allow isolation of an area of the facility. The ventilation systems will ensure that all air is filtered appropriately. A combination of laminar flow and pressure gradients will keep cold zones safe.

6.2 A NUCLEAR EVENT ON CAPITOL HILL

While it is hoped that a nuclear event will not occur, preparedness for such a scenario is appropriate. Smaller nuclear devices that could be smuggled across borders are among the most ominous threats to public safety and national security.

Consider a one megaton nuclear detonated near Capitol Hill releasing its radiation, heat, and blast wave. Most facilities in a 2-mile surrounding radius will be destroyed or incapacitated. The *ER One* facility is designed to remain functional in this scenario. The initial radiation shielding is achieved with the heavy concrete walls facing the direction of Capitol Hill. There are no glass surfaces in this direction. The main and lower levels of *ER One* are protected with this material and remain unaffected by the radiation. Seismic detectors placed downtown activate blast shutters on glazed surfaces that are able to actuate before the blast wave arrives. The facility has been engineered to withstand the 20 psi blast wave predicted from detonation of this weapon of this size at the 2-mile distance. After the blast wave passes, the facility, still intact and protected from EMI, will continue to function and prepare for casualty and survivor arrival. Fallout shelters on lower levels are provided for survivors not working in *ER One*. The water supply is located in this area and remains usable. All portals are secured and relative positive pressure prevents entry of airborne radioactive contaminants. *ER One* personnel don appropriate protective gear and begin removing radioactive contaminants from arriving patients in the decontamination areas adjacent to the portals. Once decontaminated casualties are treated with iodine, their injuries are addressed in regular fashion. In the unusual event that individuals present with radioactive fragments imbedded, a radiation-shielded operating table is available to remove the fragments. The exterior itself will be able to wash off radioactive contaminant on its sloped roof and exterior surfaces with nozzles that are placed on the exterior structure. Despite this, eventual evacuation of the facility will be directed by authorities in the aftermath. In the interim, many lives will have been preserved and protected in this facility. Furthermore, it can be efficiently rehabilitated after the general area is deemed safe to return.

EROne

Section 7 *Conclusions*

SECTION 7

CONCLUSIONS

Project *ER One* undertook the task of developing design solutions to help address the emerging threats of disasters, epidemics, and terrorism. An extensive search was undertaken in Phase I to develop various concepts, features, and specifications that could make such a facility possible. The design compendium of Phase I provided the 'menu' for the design team of Phase II to develop a demonstration prototype on the Washington Hospital Center campus. The Phase I design compendium addressed both new and retrofit construction. Phase II focused on the design of a new demonstration prototype on an existing medical campus at Washington Hospital Center.

This study focused on threat mitigation, medical consequence management, and scalability, but many of the proposed features would also support the daily hospital requirements of infection control and patient flow. It has been demonstrated that a protective hospital design is compatible with maintaining a healing environment. The original premise that such features could be incorporated more effectively at the time of original design is affirmed by the study results. While it is most efficient to incorporate these features at the time of original design, many of these features can be considered in retrofit application, and some can be applied at very little cost.

The architectural design should be guided by a formal process that includes threat assessment and modeling. The mission and role of the facility in the community response also plays as key role in determining the extent of the development of these capabilities. There is a cost premium to design and develop an all-risks, scalable emergency department. In terms of space, this equates to approximately a 50 percent premium of the emergency department itself. However, a 50 percent space increment does not imply a 50 percent cost increase. The majority of the incremental space is extension of existing rooms to accommodate the scalability, which is less expensive than building additional rooms.

Many of the changes do not actually increase cost, but they do require a reconfiguration or rethinking of hospital design to allow for better function during contingency events. Nevertheless, there are additional costs to design and build facilities that have capabilities beyond routine medical care. The discussion of what is adequate and reasonable to provide the needed capacity and capability needs to continue. Both the cost/benefit of such design and construction and identification of appropriate funding sources are valid issues for discussion and policy development.

ER*One*

Section 8 *Recommendations*

SECTION 8

RECOMMENDATIONS FOR FUTURE STUDIES AND NEXT STEPS

The first task upon completion of the Phase II Design Study is to ensure dissemination of the material and lessons learned. Others are not expected to simply adopt or copy the design features forwarded in the Design Study; rather, it is hoped that these findings will initiate a similar thought process in other design efforts around the nation. Phase III will begin by disseminating the Phase II results at a conference to be held on April 30th in Washington D.C. (see Appendix G). In addition, CD-ROMS of Phase II findings will be available to appropriate entities upon request.

However, much development remains to be accomplished. While the Phase II design study incorporated the concepts and features into a workable design in a real setting of site constraints, detailed engineering specifications for the ventilation systems and structures need to be developed in order to fully understand the feasibility of such a facility.

This design study focused on the architectural elements of *ER One*. The areas of logistics, communications and data systems, vital to the function of such a facility, need additional focus. Phase I of Project *ER One* assembled a unique multi-disciplinary team of professionals from around the nation and developed a design compendium that reflected the current state of design knowledge. Since science and applied technology are developing more rapidly than ever, the design compendium will require continuous update and development. The efforts of Project *ER One* have established an infrastructure and platform from which an institute can be established to continue these activities for the national benefit. The *ER One* Institute will continue to pursue the knowledge needed to make hospital design better for the future (see Appendix F).

ER*One*

Appendix A *Work Plan, Phase II*

APPENDIX A

WORK PLAN PHASE II

Project *ER One*

Phase II Work Plan

Purpose:

In accordance with the Statement of Work a detailed work plan was to be submitted for prior to the initiation of Phase II work. The following document details the projected tasks, sequence and timeline for the development Phase II of Project *ER One*. It is understood that this represents the contractor's projected work plan. Certain tasks and the sequence of the tasks could be modified in order to ensure appropriate and timely completion of the deliverables required by the statement of work.

General:

Phase II of Project *ER One* will be the Design Study. Phase I was the preparatory program for Phase II – developing a compendium of design concepts, features and specifications sufficient to warrant a design study. The Phase II design study will apply the compendium findings to an actual site with existing functional requirements and constraints. The purpose is to determine the feasibility of employing such features in a real facility scenario. The process will include functional programming, contingency needs-assessment based on models of regional threats and a facility specific threat assessment and vulnerability analysis. Initial configurations of specific areas will be designed without constraints as potential ideal examples. The real-facility designs will include the site and operational constraints one would expect to encounter in the face of design and construction in the real world. A meta-commentary will be provided indicating why a specific solution was executed in a particular way. The goal will be to have a facility that is highly functional for every day emergency medicine yet can gracefully scale to meet the needs of the medical consequences of disasters, epidemics and terrorism.

Goals:

1. Determine the applicability of the many *ER One* design features to a real context including the constraints of site, codes etc.
2. To provide a rational process for arriving at design solutions when several choices exist

Deliverables:

A design study using the *ER One* concepts, features, and specifications with meta-commentary as to why a particular solution was chosen.

Process:

1. **Review of Phase I** compendium by design team - (see Phase One Technical Report)
2. **Functional Programming:** The projected operational (clinical) needs including the definition of the procedures and practices likely to be executed, the projected volume, the current technologies/equipment needed to achieve the mission, and the definition of an environment suitable to these operations will be identified in terms of square footage and number of rooms etc.
3. **Contingency Mission Assessment:** Requirements in terms of the WHC role in regional disaster response will be reviewed. Based on this role, the facility can identify the scope of level of service it may be required to provide in various scenarios. This will define the features that need to be incorporated and set the general scope of scalability required.
4. **Threat Assessment:** – A detailed threat assessment will be developed using the American Hospital Association (AHA) and the American Society of Healthcare Engineers (ASHE) threat analysis matrix. This will be accomplished by the Project Director and engineer(s) from ASHE. (See attached threat assessment Matrix) Only those features that address needs identified by the threat assessment will be considered in the design process.
5. **Vulnerability Analysis:** After assessing the threat a brief vulnerability analysis will be undertaken. Which parts of the ED are most vulnerable to the identified threats?
6. **Definition of Constraints:** The external and financial constraints will need to be defined. External constraints include the building site, zoning, codes, accrediting bodies and even local cultural acceptance. Realistic financial constraints will be applied. However, the purpose of the design study will be to develop the optimal solutions as opposed to the lowest budget.
7. **Critical Axis Determination:** Washington Hospital Center ED personnel along with consultants will determine which infrastructure, rooms, and equipment require the highest degree of protection to maintain functionality during contingencies. This will consist of a concise list of items that will have priority for protection.
8. **Multi-Objective Optimization:** In the final analysis trade-offs involving function, cost, esthetic, protection and other elements will need to be factored. This multi-

objective optimization process will be applied through out the Phase II process and will be reflected in the meta-commentary of the design study.

9. **Architectural Design Study:** Architectural renderings will be accomplished according to the work plan of the design team. (see below)

PHASE II DESIGN TEAM WORK PLAN

HKS	Pickard Chilton	
PHASE II (1) PROTOTYPE SPACE PROGRAM SUMMARY		
	X	Develop a list (with WHC) of departmental components and establish approximate capacity and through-put parameters for both normal and scaled-up operations
P	X	Determine component module sizes, such as exam/treatment spaces, offices, waiting capacity, etc. for basis of area calculations
P	X	Generate component areas, based upon the above, in terms of department net and department gross area.
J	J	Review of final area allowances for overall architectural development and design flexibility
PHASE II (2) PROTOTYPE DEVELOPMENT		
P	A	Compilation of individual concepts into an integrated pre-schematic plan/model indicating desirable component adjacencies.
P	A	Indicate patient intake steps (such as decontamination, triage, and registration), treatment, and admission or egress flows.
J	A	Indicate incremental clinical expansion / contraction avenues.
PHASE II (3) WHC SPECIFIC SPACE PROGRAM		
J	J	Meet with WHC task force to establish overall program goals, components, and objectives. Determine overall scope parameters for both normal, and scaled-up operations.
P	A	Develop room-by-room listing of spaces and assign net areas for each.
P	A	Develop notes and comments related to functional relationships and desired adjacencies between the components.
P	A	Establish department and building gross area.
J	J	Review draft version with WHC task force.
P	A	Edit, revise, and issue completed space program for WHC written approval to proceed into schematic design.

PHASE II (4) WHC SPECIFIC SCHEMATIC DESIGN CONCEPT

The objective of this task will be to develop conceptual schematic design drawings for ER ONE including appropriate site plan, floor plans, and elevations. These documents will be developed in concert with WHC input in a series of work sessions using preliminary drawings, sketches, and study models.

The conceptual schematic design documents consist of drawings and other documents illustrating the general scope, scale and relationship of project components. Designs will be conceptual in character and based on the Client approved project requirements developed during previous phases

These documents will be developed in concert with WHC input in a series of work sessions using preliminary drawings, sketches, and study models.

HKS	Pickard Chilton	
J	J	We anticipate up to three (3) work sessions, spaced 2–3 weeks apart, with WHC task force to jointly develop concepts.
PP	PA	Within the context of the latest WHC conceptual work executed by this architectural team earlier this year, and consistent with the general expansion principles per the WHC master plan, we will apply the prototypical planning concepts to the WHC specific space program and adapt to the WHC site.
P	A	Make recommendations regarding the need for additional technical consultants.
PP	PA	Based upon the approved program for the project and appropriate planning guidelines, prepare architectural conceptual schematic design proposals and documents for the Client's review and approval, including:
PP	PA	Develop detailed commentary, which explains the reasons why variations from the ideal prototype are necessary to fit the specifics of the WHC site.
PP	PA	Study and develop building form, massing, and configuration.
PP	PA	1/16" scaled floor plans.
PP	PA	Conceptual schematic exterior design, including material finishes.
PP	PA	Conceptual schematic building site plan—Conceptual schematic street level lobby character studies.
PP	PA	Conceptual schematic building elevations.
X	P	In-house study model.
A	P	Conceptual interior public spaces.
J	J	Conceptual schematic plaza and landscape plans and above-grade drop-off arrangements.

Timeline:

Initiation of Phase II – Upon acceptance of Phase I deliverables by OEP. Projected 10 July

Items 1-7 above will be initiated concurrently and will be accomplished in parallel. The expected completion date for these items is sixty days after the initiation of Phase II. (Projected- September 10, 2002)

Items 8-9 above (architectural rendering and multi-objective optimization) will be ongoing through out Phase II with a completion expected 6 months after initiation of the design team functions (For details of architectural timelines see attached Design Team Work Plan)

ER*One*

Appendix B *Architectural Materials*

APPENDIX B

ADDITIONAL ARCHITECTURAL MATERIAL

No.	Legacy from Website (not in Technical Report)	Abstract/Key words/Comments	Title, First Author	ER One Workgroup: Biological Detection & Surveillance	Biological Threats	Communications	Finance	Biological Diagnosis and Treatment	Chemical	Facility Threat Mitigation	Global Integration	Informatics & Technology	Intergovernmental Relations	Pediatrics	Institute	Logistics/Operational	Psychology & Mental Health	Radioactive & Nuclear	Security	Toxic & Hazardous Materials	Transport	Trauma & Mass Casualty	Design Phase: Program	Concepts	Master Planning	Schematic Design	Design Development	Relevant Discipline: Site	Architecture	M.E.P.	Structural	Telecom	Clinical	Equipment	Interiors	Other	Concept Sketch	Area of Impact: Threat Mitigation	Medical Consequence Management	Scalability	Informatics & Connectivity	Considered in Phase II
			Legend: 1. Primary relationship. 2. Secondary relationship.																																							
6	X		Minimizing Risk of Airborne Transmission of Bioterrorism Agents in a Hospital, Artenstein			2		1															2				2			1		2	1	2			X				X
8	X	Software recommendation	Bldg Ventilation: Dilution Ventilation - 15-25% Outside Air, Kowalski		1					1						2							1	1						1							X				
10		Staff support; Related to 23, 5004, 5297	Modular single-place decontamination units for Rapid Decontamination Scalability															1		1			1			1	1			1				1	1				X			
14		Daily clinical alerting/interactive, nationally, call to improve sensors to provide real time alerts; Similar to 5005, Same as 5309	Communication of Basic Surveillance Information, Pietrzak	1	1	2		1		1		2	1			1														2		1	1	1				X			X	X
23	X	Issues related to portables inside facility; Related to 10, 5004, 5297	Use of portable decontam units indoors, Pietrzak					2										2					1							1				1						X		
61	X		Where to park patient drop-off vehicles							1						1											2	1									X		X		X
5004	X	Self contained, self functioning mobile treatment units, existing status, cost, and potential modifications. Related to	Modular patient treatment units, Pietrzak										1								1	1								1			1	1				X	X		
5005			Automated Biological Diagnostic Assist/Decision Tools			1		1				1																		2		1	1					X		X	X
5006		Various socio/psychological considerations during and follow-up; Similar to 5166	Parent-Child Connection in Disaster Situations, Pietrzak					1		1			2	1		2	1					2	1				2			2			1					X	X		X
5007		3 alternatives to shielding are discussed.	Facility electromagnetic/particulate radiation shielding,							1								1									1	1	1		1						X				X
5142	X		Tele-education																														1								X	
5149	X	Balance security needs with ease of use and speed desired for clinical effectiveness	Network Security, Feied	1		2		1		1		1											1										1									
5151	X	Directly related to #5202	Hardening Against Interference, Feied			2						1	1		2									1			1						1	1								
5152		Comparison between small individual systems vs large multi-zoned systems; Similar to 5493	HVAC Compartmentalization vs Smart HVAC Systems, Pietrzak							1																1				1								X				X
5156	X	Need for a better way to track patients, charts, staff, supplies. Related to #5206.	Geospatial Tracking of Human & Material Resources, Roberts			1		1				2				1								1									1								
5157		Scalability concept; discusses ramp up methodologies	Flexible modular units, Pietrzak		1			1	1		1							1					1	1		1	1												X		X	X
5158	X	Argues against portables.	Decontamination capabilities, Ennis							1											1			1	1		1			1	1				1							X
5159	X	Maze entry design; MEP considerations; signage recommendations	Detection of radioactive contamination: automated radiation contamination containment features, McNamara							1						2		1								1	1			1	1				1	1						X
5160	X	General discussion	Protect the ED staff, McNamara							1				1			1						1			1	1	1	1	1		1	1									X
5161	X	Basic, general discussion of decontamination issues	Decontamination of fall-out victims within the ED, McNamara					1	1							1		1				1			1				1	1			1									X
5164	X	Scalability concept related to #5156	Web-Enabled Remote Monitoring of Patients, Roberts			1		1				2				1								1									1								
5165			Design Issues Regarding Re-unification of Parents and Children During Mass Casualty Incidents			1						1		1								1	1			1				1			1	1	1				X		X	X
5173		Prototype design: ED in Oak Ridge, TN	Designated radiation emergency area in the ED - Dr. Maltz, McNamara													1	1									1				1						X	X	X		X
5174	X	Retention ponds, holding tanks	Environmental contamination control, McNamara							1							1						1			1		1	1	1											X
5180	X	Clean water storage. Related to #5218 and #5240.	Exposure control-community from a potential meltdown of a nuclear power facility, McNamara							1			1		1			1					1																			X
5189	X	Need non-medical staff to oversee these pts.	Triage Supervision, Chamberlain										2	1	2	1																	1								
5193	X	Risk Assessment question. Related to 5221.	Operating room availability, Llewellyn																			1																			X
5199	X	Security concepts.	Facility operations, Ennis							1						1		1	1									1													
5200	X	Related to #5198	Facility protection from contamination, Ennis	1						1	1				2	1		1	1											1											
5201		Clarify bond with allocations	Network infrastructure capacity, Feied			2						1	1										1	1						1		1	1						X	X	

No.	Legacy from Website (not in Technical Report)	Abstract/Key words/Comments	Title, First Author	ER One Workgroup																		Design Phase					Relevant Discipline											Area of Impact				
				Biological Detection & Surveillance	Biological Threats	Communications	Finance	Biological Diagnosis and Treatment	Chemical	Facility Threat Mitigation	Global Integration	Informatics & Technology	Intergovernmental Relations	Pediatrics	Institute	Logistics/Operational	Psychology & Mental Health	Radioactive & Nuclear	Security	Toxic & Hazardous Materials	Transport	Trauma & Mass Casualty	Program	Concepts	Master Planning	Schematic Design	Design Development	Site	Architecture	M.E.P.	Structural	Telecom	Clinical	Equipment	Interiors	Other	Concept Sketch	Threat Mitigation	Medical Consequence Management	Scalability	Informatics & Connectivity	**Considereded in Phase II**
				Legend: 1. Primary relationship. 2. Secondary relationship.																																					
5202	X	Need for equipment that is RF hardened. Related to #5201	Choosing a Wireless Standard, Feied			2						1	1		2									1								1		1								
5203		Dual use space.	Dialysis and Pheresis Treatment Rooms for Contaminated Patients					1														1				1						1	1	1				X	X		X
5205		Single stall concept; Implies stall by stall approach with both overhead and handheld shower nozzels.	Hand-Held Showers and Water Pressure for Decontamination of Children, Henretig					1							1							1					1		1								X				X
5205	X		Surfaces to Facilitate Decontamination and Cleaning afterExposure to Radioactive Material		1				1	1								1		1						1								1				X				
5206	X	Related to #5156, bar coding	Wireless Location Tracking, Feied			1		1				2				1								1								1										
5207		Directions for future development and design; list of devices to develop	Mobile Computing, Feied			1		1				1			2									1			1						1	1	1				X	X	X	X
5208		Voice recognition	Mobile Voice Input & Output, Handler			2		1				1				1										1							1	1					X		X	X
5209	X	Related to article by Wang. Segregation similar to current practice - portal (triage) segregation	Prevention of Unnessary Exposure to the Severely Injured and the Grosteque, Norwood			2								1	2	1	1					1				1		1	1													X
5210		Pleasant "nature" scenes to mitigate stress. Related to windows article	Healing environments, Norwood					1								1	1					1				1	1		1							7			X			X
5211		Support of windows/views for improved clinical outcomes; importance of the "nature" view vs built/brick "hard" environment, and NOT viewing the patient intake process. See also Internal atrium comment by Melton.	Pyschological impact of windows, Norwood					1								1	1					1		1	1	1	1	1	1				1						X			X
5212	X	Scalability concept. Relates to chemical & biological	Design concept of radioactive decontamination, Maltz					1	1	1	1		1					1							1		1		1														X
5213		Materials Mgmt. Issues, storage; recommendations do not work w/ case cart system; Similar to 5281	Features for Protection of Supply/Storage Items from Contamination													1		1					1	1			1		1				1				X			X		X
5214	X	Most likely queues will start forming outside the facility (some assumptions unclear)	Planning orderly queues, Jolly					1			1					1					1	1						1							1							X
5215		Contingency staff parking capacity and associated planning	Providing accessible parking, Jolly								1					1					1	1						1							1				X			X
5217		Security considerations for materials mgmt; significant discussion regarding safe & secure material screening and disabling & decontam fixed and modular portals and relation to all other svcs. Focus on vehicles.	Entry Portal Logistics, Pietrzak							1						1								1	1	1	1		1	2		1			1		1	X			X	X	X
5218		Underground holding tanks; Related to 5405	Contaminated water containment and disposal, Maltz							1								1						1			1		1	1	1							X				X
5221		scalability is NOT an issue for O.R.'s	Spatial Orientation of Operating Rooms to ED to Facilitate Mass Casualty Management		1											1						1	1			1						1		1					X			X
5222		Related to #5160, relate this to the sacrifical façade idea	Prehospital buildings for patient, visitor, staff egress, Melton							1							1						1	1		1		1		1		1							X			X
5223	X	Recommends redundant communications systems; affects of traffic tie-ups, non hospital diversions, multiple communications methods	Lessons of Y2K-Communications, Melton			1				1		1			2								1								1										
5227	X	Relates to Informatics Paper	Communication needs, Ennis			1		1				1									1	1	1									1	1	1							
5231	X	Developing clear operations protocol & support for those assisting in "unsalvagables"	Triage Psychological Concerns, Chamberlain										1	1	2		1					1				1						1									X
5232		Basic discussion of decontamination process. Related to 5235, 5242, 5297, 5300, 5312, 5402, 5404, 5407, 5484.	Decontamination of Multiple Children/Patients Simultaneously: Parallel vs Serial Design, Henretig					1							1			1				1				1			1	1			1	2		Y		X	X		X
5233	X	Recommend this program be added to the commonly used adult triage protocol	JumpSTART Triage, Chamberlain					1				1		1	2		2					1		1							1	1									
5234	X	Decontam may occur outside but children need to be protected more than adults	Correct Water and Ambient Air Temperature for Decontamination of Children, Henretig					1							1		1							1				1					1	1								X
5235		Suggestions for finishes; floor grids and sloped floors to drains	Non-Slip Floor Surfaces for Decontamination Showers for Children, Henretig					1							1											2	1		1			1		1					X	X		X
5236	X	Suggested equipment for administering medications in infants	IntraOsseous (IO) Auto-Injector for Quick IO Access, Waddell					1							1		2																1	1							
5237	X	Segregate mass casualties from normal hospital population at Triage, related to #5252	Additional Isolation Space, Linton		1												2						2						2												X
5238		UVGI lamps in ductwork and/or AHU to protect against contam from outside air; Related to 5289	UVGI-Disinfection of Ventilation Air, Kowalski		2					1												1				1			1			1					X	X	X		X
5240	X	Scalability concept	Modular single-place decontamination units, Melton										2		2			1							1				1												X

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				Biological Detection & Surveillance	Biological Threats	Communications	Finance	Biological Diagnosis and Treatment	Chemical	Facility Threat Mitigation	Global Integration	Informatics & Technology	Intergovernmental Relations	Pediatrics	Institute	Logistics/Operational	Psychology & Mental Health	Radioactive & Nuclear	Security	Toxic & Hazardous Materials	Transport	Trauma & Mass Casualty	Program	Concepts	Master Planning	Schematic Design	Design Development	Site	Architecture	M.E.P.	Structural	Telecom	Clinical	Equipment	Interiors	Other	Concept Sketch	Threat Mitigation	Medical Consequence Management	Scalability	Informatics & Connectivity	Considereded in Phase II
				Legend: 1. Primary relationship. 2. Secondary relationship.																																						
5240	X	Display panel used in nuclear plants & submarines; Supports HVAC zone concept	Radioactive detection alert systems, McNamara							1								1					1			1				1												x
5242	X	List of recommendations	Decontamination Disrobing and Re-clothing Areas for Families and Teens, Henretig					1		2				1		1	1					1	2				1			2												x
5245		Concerns about atriums. Related to Security White Paper.	Atrium considerations for blast mitigation, Keenan															1							1				1		1							x				x
5246		Door hardware criteria; Related to 5217, 5279	Controlled access doors for personnel and visitors, Keenan							1								1									1		1			1						x				x
5247		Standard procedure no longer adequate. Related to 5298.	Emergency water purification systems (EWPS) for Secondary Water Supply, Keenan							1						1		1									1	1		1								x				
5248		Effort to synthesize multiple systems with zone concept.	Interior intrusion detection systems, Keenan							1	1	1						1									1			1		1		1				x				
5249	X	Good parking discussion; more in White Paper	Parking lot configurations as a security measure, Keenan													1										1	1											x		x		x
5250		Basic discussion of defensive site design.	Use of barriers in perimeter security, Keenan							1								1					1	1	1	1		1								Y	x				x
5251	X	Recommends storing medications & equipment near E.D.	Treatment of Botulism Intoxication, Artenstein		1			1		2													2		1								1	2		?		X			x
5251			Intrusion Detection Systems (IDS) for Perimeter Security			1				1		1						1					1		1			1			1	1					x			x	
5252	X	Related to #5237; Expeditious ID at triage and subsequent isolation of pts. Filtration in non-isolation room	Triage of Patients w/possible airborne contagion, Artenstein		1			1																1		2				1			2			?					x
5252		Call to integrate security requirements into design.	Lighting strategies as a security measure, Keenan							1		1						1							1		1	1		2		2					x			x	
5253		Similar to 5302, 6020.	Back-up and redundant utility sources, Keenan							1						1		1							1		1	1	1		1		1				x				
5255	X	Related to #5268 & #5252; questioning the efficacy and cost of UV devices	Ultraviolet Radiation to Prevent Transmission of Airborne Pathogens, Artenstein		1			1		1														1						2			1			Y					
5255	X	Relate to sacrificial façade	Standoff distance, Keenan							1								1						1																	
5256	X	Designated manned vehicle access points.	Vehicular access control, Keenan							1								1		1						1	1															x
5256	X	Related to article by Norwood - not yet written	Diagnostic consideration in trauma and mass casualty, Wang																			1																				
5257		Related to #5265 & Security White Paper	Wall hardening strategies for blast mitigation, Keenan															1								1	1	1		1		1					x				x
5258		See Security White Paper	Window security for blast mitigation, Keenan															1							1	1	1	1		1		1					x				x
5259	X	Zoned design ideas.	Safe havens, Keenan							1								1						1	1			1													x
5260			Use of Blister Switch Technology to Allow Ease of Facility Decontamination		1					1										1				1			1				1			1			x				x	
5262		Improve speed & quality of info from trauma sites	Crash Notification Data Monitoring, Pietrzak	1		2					1	1				2						1										1	1						X	X	
5263		Reduce nosocomial infection and mitigate biological threats. Similar to 5292	Use of Silver Ion Impregnated Metals to reduce Hospital-acquired Infection, Pietrzak		1			1		1						2											1			1				1			x				
5264		Related to 5260, 5281.	Use of Surface Coatings to improve infection control & decontam in existing structure, Pietrzak		1					1						2											1							1	1		x				
5265	X	Compare w/sloped roof article	Use of heavy concrete to mitigate radiation effects on the critical infrastructure of the facility, Pietrzak							1							1							1			1	1	1		1										
5266		Retrofit; Related to #5267, 5238	Sizing of Filtration Systems for Retrofit Application in Existing HVAC Systems.		1					1																	1			1							x				
5267	X	Questions use of HEPA filters - recommends use of filtration to clean inside air in retrofits.	Filtration -Recirculation Units, Kowalski		1											2																									
5269		Similar to 5366, 6020.	Facility Layout Considerations for Entry Point Accessibility							1														1	1	1		1								Y	x				x
5270			General Design Strategies for Protection from Chemical/Biological and	1	1					1							1	1	1				1			1			1				1				x				x
5271			Electrical Outlet Caps to Mitigate Facility Contamination		1															1							1								1	Y	x				
5272			Immune Room Concepts and Features		1				1		1								1				1		1				1	1					Y	x				x

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			Legend: 1. Primary relationship. 2. Secondary relationship.																																							
5310		Good list of S.D./D.D. considerations	Facility design for treating pediatric patients, Schor					1						1								1	1			1			1	1			1		1				X		X	
5311	X	Good basic list for materials mgmt. Planning and equipment storage	Essential equipment and supplies for pediatric emergencies, Schor					1						1		1							1				1		1													X
5312		Related to 5402, 5404, 5407	Decontamination Shower "Baby Baskets", Henretig					1						1		1						1	1	2			1			1	2		1	1	1		Y		X	X		X
5315			Transportation On Site-Parking																		1						1	1											X		X
5316			Transportation On Site - Access into Site																		1				1		1	1					1			1			X	X		X
5319			Bed Availability, Location and Reservation System Concept			1						1				1					1	1					1			1		1	1						X		X	
5320			Dashboard Concept for Display of User Information			1						1				1								1			1					1	1	1					X		X	
5324		Related to 5325	The Use of Fragrance as Healing Environment Strategy														1							1			1			1			1						X			
5325		Related to 5324	Psychological Impact of Noxious Odors														1							1			1			1			1						X			
5326			Utilizing Music for Stress Reduction			1						1				1	1										1		2	1			1		1				X			
5327			Potential Dual Use Operations/Conference/Briefing Room for Staff and Family/Group Therapy Room for Patients and Family			1						1				1	1		1				1			1			1			1	1						X	X		X
5328		Related to 5348.	Effective Use of Communication Systems as Stress Mediators			1					1	1				1	1						1				1			1		1							X			
5329		Related to 5295, 5473.	Telepsychiatry Concepts			1						1					1										1			2		1	1		1				X	X	X	
5331		Dual use space.	Incorporation of Chaplain Facilities								1						1					1	1			1			1			1		1					X	X		X
5332		Related to 5367, 5370, 5371.	Dealing With Other than Patient Populations									1					1		1				1			1	1	1	1			1							X			X
5333		Related to 0014, 5005.	Identification of Regular Patients for Rapid Throughput			1						1				1			1								1			2		1	1						X	X		
5334			Behavioral/Psychological Issues Associated with Detector Technologies	2				2	2			1					1		1				1				1						1							X	X		
5337			Med/Psych ER Beds vs. Med/Psych Beds at Other Sites												1	1	1				1		1				1		1												X			
5338			Color-Coding in Pediatric Emergency Care									1		1		1								1			1		1				1	1	2	1				X	X	X	
5339		Related to 5328.	Sharing Informaiton, Reducing Panic									1				1	1							1			1		2	1			1	1		1				X	X	X	
5341			Dual use Holding/Seclusion Room Beds for Disturbed, Violent, Suicidal, or Homicidal Psychiatric Patients														1		1		1			1			1		1		2		1		1					X	X		
5343			Features That Mitigate Workplace Violence									1				1	1		1			1	1		1		1	2	1				1							X	X		X
5345			Contaminated Pedestrians			1							1			1	1		1		1	1			1	1	1	1	1				1							X			X
5347		Dual use space?	Design Issues Surrounding Fatality Management																2	1	2	1	1			1		2	1				1					X	X	X		X
5348		Coordinate w/ 5328	Features for Background Noise Reduction			1					1	1				1	1								1	1		1	1			1	1		1					X			X
5349		Critical axis elements.	Critical Access and Elements Concept Applied to ED Design								1					1			1						1	1		1		2		1						X	X			X
5351		Automated Detectors	Hardwired Instruments for the Detection of Radioactive Materials and Ionizing Radiation	1	1			1		1								1		1				1			1		1	1		2	1	1	2			X				
5355			Issues Regarding for Storage of and Access to Response Equipment for Various Episodes													1					1		1				1		1				1		2					X	X		X
5356			Physical Space for Access to Emergency Room																1		1		1		1	1		1	1												X		X
5359			Separate Isolation Enterance to ER/Isolation Room to Prevent Propagation	1	1			1	2	1						2					1		1	1		1		2	1			2			2				X		X		X

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				Biological Detection & Surveillance	Biological Threats	Communications	Finance	Biological Diagnosis and Treatment	Chemical	Facility Threat Mitigation	Global Integration	Informatics & Technology	Intergovernmental Relations	Pediatrics	Institute	Logistics/Operational	Psychology & Mental Health	Radioactive & Nuclear	Security	Toxic & Hazardous Materials	Transport	Trauma & Mass Casualty	Program	Concepts	Master Planning	Schematic Design	Design Development	Site	Architecture	M.E.P.	Structural	Telecom	Clinical	Equipment	Interiors	Other	Concept Sketch	Threat Mitigation	Medical Consequence Management	Scalability	Informatics & Connectivity	Considereded in Phase II
				Legend: 1. Primary relationship. 2. Secondary relationship.																																				
5363		Alternate/ Dedicated Entrances. Related to 5351, 5406.	Segregated Warm-Zone Entrances to ED for Potentially Contaminated Prehospital Personnel and Equipment		2			2		1					1		1	2	1		1	1	1		1			2	1			2			2		X		X		X
5364		Rapid Scalability	Use of the Aeromedical Base Unit as Modular Patient Treatment Units for Rapid Scalability							1					1						1	1	1	1		1		2	1				1	1				X	X		X
5365		Related to 5217, 5246, 5279, 5280.	Secure Ingress/Egress Control Concepts and Features							1					1			1						1	1	1		1	1			1					X			X	X
5366		Related to 6020.	Controlled Vehicle Access			2				1		1			2			1		2				1	1	1		1	1	2	2	1		2			X		X		X
5367		Related to 5370, 5371.	Landscape Strategies for Enhanced Security							1	1				1			1						1	1	1		1	1							1	X		X		X
5368			Use of Landscape Features to Mitigate Natural Hazards							1	1				1			1						1	1	1		1	1							1	X		X		X
5369			Use of Landscape Features to Enhance Emergency Operations							1								1		1		1					1	1	1							1			X		X
5370		Related to 5371.	Landscape Features as Site Operational Controls							1	1				1			1						1	1	1		1	1							1	X		X		X
5371		Related to 5370.	Landscape Features to Enhance Way-Finding							1	1				1			1						1	1	1		1	1							1	X		X		X
5372			Separation of Decontamination Runoff from Traffic	1	1			1	1	1										1	1			1			1	1	1	1							X				
5373		Related to 5381.	Design of Ambulance Parking Configuration to Maximize Throughput and Safety															1		1				1		1		1	1										X		X
5374			Design Strategies for Channeling Traffic According to Emergency and Security Level															1		1				1		1		1	1										X		X
5376		Related to 5377.	Use of Dynamic vs. Static Signange Strategies			1												1		1				1			1	1	1	1						1			X		
5377		Related to 5376.	On-Site Traffic Control Center to Manage Emergency Traffic														1			1		1	1	1		1		1	1										X		X
5378			Use of Traffic Barriers for ER Area Security															1		1				1		1		1	1										X		X
5379			Separate Staff ED Access for Security and Accessibility During Emergencies							1		1			1			1		1			1		1	1		1	1								X				X
5380		Retrofit	Safety Issues Concerning Pedestrian Access and Conflicts With Vehicles							1										1				1		1		1	1								X		X		X
5381		Related to 5373.	Traffic Flow Strategies Through ER Receiving Zones														1			1		1		1		1		1	1										X		X
5382		Alternate Routes	Use of Alternate Stealth Routes For Contingency Operations (traffice movement-safety)													1	1			1		1		1		1		1	1								X		X		X
5383			Designation of Areas for Facility Support Vehicles													1	1					1		1		1		1	1										X		X
5384		Related to 5441.	Canopies for Unloading Areas														1					1		1		1		1	1		2							X		X
5385			Engineered All-Weather Performance features for Traffic Zones (safety)														1					1		1			1	1	1										X		X
5386			Designation of Snow Storage Areas														1					1		1	1		1	1	1										X		X
5387			Use of Curb Design to Facilitate Access														1			1		1		1			1	1											X		
5390			Designing Egress Capacity to Match Access Capacity																	1		1		1	1	1		1	1										X		X
5391			Designated Areas for Media Access, Parking and Staging													1	1			1		1		1	1		1	1	1							1				X		
5392			Physical Separation of Delivery Loading Docks														1			1		1		1	1	1		1	1								X		X		X
5398			Facility Communication System Design			1						1									1		1				1		1	1		1								X	
5399			Patient and Family Access to Needed Information			1						1											1				1		1	1		1								X	X
5402		Related to 5404, 5407.	Basic Design Features for Patient Decontamination Area	1	1			1	2	1					2		2	1	1		1	1			1	1		2	1	1	1		1	2				X			X
5404		Related to 5402, 5407.	Decontamination of Patients with Special Needs	1	1			1	2	1									1			1				1		2	1	1	1		1					X	X		

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				Legend: 1. Primary relationship. 2. Secondary relationship.																																							
5405		Related to 5218.	Features to Reducing Environmental Threats From Decontamination Processes		1			1	1	1						1				1				2		1	1	1	1									X		X		X
5406		Related to 5351, 6021	General Strategies for Agent Detection and Monitoring	1	1			1		1			1		2	1		1		1			2	1		1		2	1				1	1	2		X	X			X
5407		Related to 5402, 5404	Contaminant Removal	1	1			1	2	1							2		1				2				1		1	1			1	2				X			
5414			Issues of Transporting Lab Specimens in Disasters	1	1			1	2	1	1	1				2			1	1				1			1	1	1				1					X	X		
5418			Design Issues Surrounding Personal Protective Equipment	1	1			1	2							1			1				1			1	1		1					1	2			X	X		X
5420			Evacuation vs. Shelter in Place							1			1			1			1		1	1	1			1		1	1			1							X	X	X
5422		Robotics	Mobile Self Navigating Hospital Beds (future considerations)								1	1				1			1					1			1		2	1		1		1	2						X
5424		Automated Monitoring	Automated Monitoring and Reevaluation of Patients Waiting to Be Seen by Providers.			1					1	1				2							1				1		1	1		1		1					X	X	
5428		Dedicated loading docks	Emergency Department Docking Stations								1					1			1		1		1		1		1	1											X		X
5430			Use of Elevators for Ambulance Staging while Resupplying								1					1			1		1					1		1	1											X		X
5431			Multiple-Use Portable Data Terminals for Inputting Patient Data in Disasters			1					1	1				1			1				1				1		1	1		1		1					X	X	
5432		Related to 5424	Computer Based Patient-Tracking system During Disasters								1	1				2								1						1		1	1	1					X	X	X	
5434			Use of Retractable Ceilings to Expose Additional Expose Pre-gridded Life Support Systems							1	1	1				1					1		1			1	1		1	1	1	2		2	2					X		X
5435		Patient Transport	Large Capacity Elevators for Patient Transport							1	1					1					1		1			1	1		1	1	1								X		X
5436		Alternate Location	Remote Treatment Area							1						1			1			1	1	1	1	1		1	1	1	1	1	1	2	2		X	X	X		X
5441		Surge Capacity	Retractable Awning/Hospital Tents as Temporary Surge Capacity								1					1			1		1	1	1			1	1	1	1	1	1									X		X
5443			ED as Primary Urban/Suburban Biosurveillance Site	1	1	1		1		1	1	2				1							1				1		1	1		1		1						X	X
5444			The Use of Electronically Captured Syndromic Surveillance in the Emergency Department	1	1	1		1				1				1			1								1		1	1		1	1	1						X	
5445		Related to 5459	What ED Surveillance Information Best Serves the Public Health Department?	1	1	1		1				1															1			2		1		1						X	
5446			Use of Municipal and Emergency Department Data Geospatial Mapping to Aid in Biosurveillance and Patient Care	1	1	1		1				1				1			1								1		1	1		1	1	1				X			X
5447		Related to 5444	The Role of the ED in Decreasing Community Syndromic Surveillance System Background Noise	1	1	1		1				1				1			1								1		1	1		1		1							X
5448		Patient Confidentiality	Ethical and Legal Issues in the Use of Emergency Department Biosurveillance Data by Public Health	1	1	1		1				1				1			1								1		1	1		1		1							X
5450		Related to 0014, 5005, 5295, 5309, 5333, 5451, 5453	On-Line Biological Decision Analysis Tools	1	1	1		1				1															1			2		1	1	1						X	
5451		On-Line Physicians; Related to 0014, 5005, 5296, 5309, 5333, 5450, 5453	Use of Hot Screens in the ED	1	1	1		1				1															1			2		1	1	1						X	
5452		Related to 5453	Use Rapid Diagnostics to Aid in Disease Recognition (Biosurveillance Section)	1	1	1		1				1											1				1		1	1		1	1	1						X	
5453		Related to 5295, 5450	Rapid Live Evaluation & Video Transmission of Patient Images for Specialized ED Surveillance	1	1	1		1				1															1			2		1	1	1						X	
5454		Surveillance Data	Internal Hospital Use of ED Biosurveillance	1	1	1		1				1															1		1	1		1		1							X
5455		Data Collection	Data Collection in Individual Emergency Departments	1	1	1		1				1											1				1		1	1		1		1							X
5456		Related to 5455	Where Is Biosurveillance Data Analysis Best Performed?	1	1	1		1				1											1				1		1	1		1		1							X
5457		Related to 5455	Data Transfer in the Biosurveillance System	1	1	1		1				1											1				1		1	1		1		1							X
5458		Related to 5450	Central Data Analysis in the Biosurveillance System	1	1	1		1				1															1			2		1		1							X

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				Biological Detection & Surveillance	Biological Threats	Communications	Finance	Biological Diagnosis and Treatment	Chemical	Facility Threat Mitigation	Global Integration	Informatics & Technology	Intergovernmental Relations	Pediatrics	Institute	Logistics/Operational	Psychology & Mental Health	Radioactive & Nuclear	Security	Toxic & Hazardous Materials	Transport	Trauma & Mass Casualty		Program	Concepts	Master Planning	Schematic Design	Design Development		Site	Architecture	M.E.P.	Structural	Telecom	Clinical	Equipment	Interiors	Other	Concept Sketch		Threat Mitigation	Medical Consequence Management	Scalability	Informatics & Connectivity		Considereded in Phase II
				Legend: 1. Primary relationship. 2. Secondary relationship.																																								
5459		Related to 5450, 5451	Use of Hot Beeper by Public Health to Respond to ED Surveillance Issues/Questions	1	1	1		1				1																1			2		1		1								X		
5461		Retrofit.	Medical Gasses and Other Pipes/Plumbing		1				1	1						1		1		1						1	1	2	1	1	2								X				X
5462		HVAC Intakes; Related to 5301	Elevating HVAC Air Intakes to Mitigate Fallout Consequences						1	1						1		1		1						1	1	2	1	1	2								X				X
5463			L-Shaped and Z-Shaped Corridors						1	1						1		1		1				1		1	1		1						1	1			X		X		X
5465		Related to 5418	Issues Surrounding Personal Protective Equipment Dress Out Areas	1	1			1	2							1				1			1					1		1				1		2				X	X		
5470		Related to 6029	Floor Drains in Each Room for Ease of Facility Decontamination	1	1			1		1										1					1		1	1	1	1	1	2							X				X
5471		Related to 6029	Hydrogen Peroxide to Decontaminate Exam Rooms	1	1			1		1						1				1					1			1		1	1				1	2			X				
5473		Related to 5295, 5450, 5453	Telemedicine for Rapid Diagnosis and Therapy	1	1	1		1				1																1			2		1	1	1						X			X
5474			Autoclave Waste Decontamination	1	1			1		1						1								1				1		1					1				X				X
5475		Dual use space?	ED Point of Care: Complete ED Laboratories	1	1			1								1								1			1	1		1	2			1						X	X		X
5476			ED Microscope to Include Fluorescence Capability and Built-in Camera	1												1												1						1	1					X			
5480		Related to 5368, 5370, 5371, 5867	Use of Berms and Grade for Radiation Protection		1					1					2			1								1	1	1	1								2	X				X
5482		System Redundancy	Lessons of Y2K - communications			1						1							1					1				1			1		1		1				X				X
5484		Related to 5235, 5297, 5300, 5312, 5402, 5404, 5407	Hand-Held Showers and Water Pressure for Decontamination of Children					1						1					1					1				1	1	2		1								X	X		X
5486		Related to 5292, 5293	Filtration - High efficiency and HEPA In-Dust Systems	1	1			1	2	2						2								1				2	1									X				
5492			Communications Authentication Concept			1						1	1						1					1							1												X	
5493		Single Room HVAC; Related to 5152	Single Room Air Handling Systems for Maximal Protection							1						1									2		1	1	2	1	1	2							X				X
5497	X	I.T. Hardware	Mobil Voice Input & Output: Hardware Considerations			1						1							1					1				1		1	1		1		1								X	
5498		Addresses HIPAA issue.	Mobile Voice Input & Output: User Authentication			1						1				1			1					1				1		1	1		1										X	
5499			Monitoring Network Status			1						1							1					1				1		1			1										X	
5500			Documentation Technologies			1						1			1	1								1				1		1	1		2	1	2						X			X
5501			Choosing Screen Size and Resolution									1				1								1				1			1		1		1								X	
5502			Computer Mouse Standards									1				1								1				1					1										X	
5503			Computerized Physician Order Entry (CPOE)			1						1			1	1								1				1		1	1		1	1	1						X			X
5504		Bio-Metrics	Network Access: Identification and Authentication Technologies			1						1				1			1					1				1		1	1		1		1								X	
5505			Handheld Computing Devices: Updating the Central Data Repositories			1						1				1								1				1		1	1		1	1							X			X
5506			Monolithic vs. Multiple Niche Systems for the Electronic Medical Record (EMR)			1						1				1								1			1	1		1	1		1	1							X			X
5507			Noise, Dust, and PC's in the ED									1				1								1				1		1	1		1		1								X	
5508		Life-Cycle Costs	PC Maintenance Costs and Planning									1				1			2									1			1		1		1								X	
5509			PC Workstations: How Many Are Needed?									1				1			2					1				1		1	1		1	1	1							X			X
5510			Software Mechanisms for Data Access			1						1				1			1													1		1										X	
5511			Data Systems: Integrate vs. Interface			1						1				1								1			1					1												X	

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				Legend: 1. Primary relationship. 2. Secondary relationship.																																						
5512			The Need for Wireless Accessibility			1						1				1							1				1					1	1					X		X	
5513			Cordless Phones and ER1			1						1				1							1				1					1	1					X	X	X	
5514			BlueTooth and ER1			1						1				1							1				1					1								X	
5515		Related to 5514	Choosing PDA's for ER1			1						1				1							1				1					1								X	
5516			Space on Countertops								1	1				1			1				1				1	1													X	
5517		Related to 5516	Recharging Stations			1						1				1							1				1	1	1			1								X	
5518			Augmented Reality and ER1			1					1	1				1											1		1			1	1	1				X		X	
5519		Related 5523	Who and What Should Be Wirelessly Tracked			1						1				1							1				1	1	1			1	1	1						X	
5520			Preemptive Bed Requests			1						1			1	1							1				1	1	1			1								X	
5521		Paper wins.	Paper versus Paperless			1						1				1			1								1	2				1		1						X	
5522			Information Overhead			1						1																										X			X	
5523		Related to 5424, 5519	Wireless Tracking for Workflow Redesign								1	1				1			1								1	2				1		1	2						X	
6001			Design Features to Mitigate Flood Damage							1														1		1	1	1			1					X					X
6002			Design Features for the Mitigation of Wind Damage							1														1		1	1	1			1					X					X
6003			Multi-Hazard Approach to Resist Progressive Collapse							1														1		1	1	1			1					X					X
6004		Structural Ductility. Related to 6005	Effective Mitigation of Progressive Collapse in Steel Frame Buildings using Discrete Ductile High-Capacity Beam-to-column Moment Connctions Exhibiting Discrete Structural Continuity across a Failed Column							1														2				1	1				1					X					X
6005		Progressive collapse; Related to 6004	Seismic Rehabilitation of Steel Moment Frames							1																		1				1					X					
6006		Retrofit; Masonry; Related to 6009	Strengthening of Hollow Masonry Walls Using Internal Components							1																		1	1			1					X					
6007		Retrofit; Brick Masonry	Strengthening of Brick Masonry Walls Using Internal Steel Rods Encased in Cement Filled Cores							1																		1	1			1					X					
6008		Retrofit; Cores	Strengthening of Walls using Reinforced Cores							1																		1	1			1					X					
6009		Post-Tension; Related to 6006	Strengthening of Brick Masonry Walls Using Post-Tensioning Systems							1																		1	1			1					X					
6010		Retrofit; Shotcrete	Retrofitting Wal and Columns Using Shotcrete							1																		1	1			1					X					
6011		Retrofit; Fiber	Retrofitting Walls for Seismic, Wind and Blast Loads using a High Strength Fibers							1																		1	1			1					X					
6012		Retrofit; Surface Coating	Retrofitting Walls for Seismic and Wind Loads using Surface Coatings with Steel Mesh							1																		1	1			1					X					
6013		Retrofit; Interior Metal Studs	Retrofitting Walls for Seismic, Wind and Blast Loads using Interior Metal Studs							1																		1	1			1					X					
6014		Retrofit; Walls	Retrofitting Walls for Seismic, Wind and Blast Loads using a Steel-backed Gypsum Board							1																		1	1			1					X					
6015		Retrofit; Geotextile	Retrofitting Walls for Blast Loads Using a Geotexile Fabric and Other Catch Systems							1																		1	1			1					X					
6016		Retrofit; Steel Straps	Retrofitting Walls for Blast Loads Using Steel Posts, Composite Steel Straps and Other Attached Steel Components							1																		1	1			1					X					
6017		Shields and Catch Systems	Use of Roof Shields and Interior Catch Systems to Mitigate Explosive Effects							1										1								1	1			1					X					
6018		Retrofit; Concrete Shields	Using External Reinforced Concrete Shields for Retrofitting Walls for Blast Loads							1																		1	1			1					X					

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				Biological Detection & Surveillance	Biological Threats	Communications	Finance	Biological Diagnosis and Treatment	Chemical	Facility Threat Mitigation	Global Integration	Informatics & Techology	Intergovernmental Relations	Pediatrics	Institute	Logistics/Operational	Psychology & Mental Health	Radioactive & Nuclear	Security	Toxic & Hazardous Materials	Transport	Trauma & Mass Casualty	Program	Concepts	Master Planning	Schematic Design	Design Development	Site	Architecture	M.E.P.	Structural	Telecom	Clinical	Equipment	Interiors	Other	Concept Sketch	Threat Mitigation	Medical Consequence Management	Scalability	Informatics & Connectivity	
				Legend: 1. Primary relationship. 2. Secondary relationship.																																									
6019		Retrofit	Column Retrofit Methods for Seismic and Blast Protection							1																1		1		1							X				
6020			Site Work Considerations							1								1						1				1									X				
6021			Integrated Multimedia Protection Alarm and Active Control for Chemical/Biological Agents	1	1	1		1	1	1		1				1		1						1			1		1	2	1		2	2			X			X	
6022		Foundation/ Soils	Foundation Design Considerations							1																1	1	1		1											
6023		Seismic; Energy Dissipation	Seismic Strengthening Using Seismic Isolation and Energy Dissipation							1																1		1		1							X				
6025		Retrofit; Glazing	Multi-Hazard Window (Glazing) Retrofit Design							1	1								1							1	1		1								X				X
6026			Full Service Laboratory Integrated into ED to Reduce Cross Contamination	1	1			1		2						2							1	1		1			1	2		1	1			X	X	X		X
6027		Related to 5473; Video Monitoring	The Use of Video Monitoring Systems to Reduce Staff Exposure to Highly Infectious Patients	1	1	1		1				1				2		1					1				1			1		1	1	1				X		X	
6028		Related to 6029	Self-Cleaning Toilet Facilities for Patients in Every Room to Reduce Cross Contamination	1	1			1	1							2							1			1			1	1		1		1			X			X
6029		Self-Cleaning ED Room - Related to 6028	Built-In Aerosolizing Nozzls for Decontamination After Room Use		1			1	1	2						2							1			1	1				2				X				X
6216	X	General pedestrian crowd control & tools such as barriers, signage & security, personal protective equipment	Pedestrian access routes, Jolly								1					1					1	1					1								?			X		
5244	X	Potential Risk Assessment outline and Program List	Destination guidelines and system issues, Pasquale			1						1		1							1										1						X		
9, 19-29	X		Electrostatic Filtration for Air Decontamination																																	X				
	X	Establish clinical diagnosis benchmarks; call for testing measurements to differentiate natural from terrorist sources of infection;	Background Naturally Occurring Anthrax, Pietrzak	1	1			1				1			2						1										1	1	1				X		
	X	Related to #1, getting data from other parts of community; identification of protocols, benchmarks	Geospatial Biosurveillance System, Roberts	1	1	2		1				1	1																			1	1				X			X	
	X		Filtration - recirculation units, Kowalski																																	X				
	X		XML data exchange, Vange																														1							X	
	X	Related to #5268, #5252, #5152, #5238	Filtration - high efficiency and HEPA in-duct systems, Kowalski		1		1			1														1						1						X				
	X		Psycho-social considerations, Dolan											1			1																						X		
	X	White paper on scability - good programming info.	Resource utilization, Klein							1	1	1	1			1						1	1	1				1	1										X		X
	X	High numbers of patients with a particular specialized need; mgmt of and rapid treament with access to supplies & equipment; and transfer out to specialty facilities	Acute management of multiple burn patients																			1										1						X		
	X	Concepts of portable and dual use ramping up in hallways, etc.; for surgery	Modular mobile surgical capability																			1										1						X		
	X		Triage design features to improve scalability																			1														?				X	

EROne

Appendix C *Casualty Modeling*

APPENDIX C
CASUALTY MODELING

Michael P Pietrzak, MD
David Roberts, PhD

C.1 CASUALTY MODELING SCENARIOS

C.1.1 General

The Project *ER One* design study is to apply the principles, concepts and features developed in Phase I of the project to a design prototype located on the site of Washington Hospital Center in Washington DC. This facility was chosen due to its capability, size as well as its proximity to key government activities making it a likely receiving facility for major disasters in the national capital region.

In Phase I the Project developed design concepts and features for medical facilities in the multi-threat environment. The three primary areas focus for the design study included threat mitigation, medical consequence management and scalability. The features selected for threat mitigation are largely determined by the hazard assessment and vulnerability analysis provided in the section entitled "Project *ER One* Threat Assessment". Likewise, the medical consequence management features one chooses to place in the facility are largely determined by the potential medical entities one would be faced with. Scalability is of a different nature. It makes little sense to build something larger than could ever be needed. On the other hand it is essential that the medical system have a robust surge capacity to manage the volumes of patients that could be generated as a result of today's threats from terrorism, epidemics and disasters. Scalability, unlike the other elements, requires some quantitative understanding of the magnitude of casualties that could be expected from the potential scenarios as well as some general idea of the portion of the casualties for which a facility might be responsible.

C.1.2 Casualty Modeling Methodology

The Defense Threat Reduction Agency has developed a suite of specialized software, the Consequence Assessment Tool Set (CATS) to estimate the consequences of different types of natural and man-made threats, including deployment of nuclear, chemical, and biological weapons, in a specific location and under specific weather conditions. Project *ER One* applied the CATS software to five different scenarios in the Washington, DC, area to estimate potential casualty numbers, and to take a reasonable approach to scalability decisions. The estimates assume normal summer weather conditions, Washington, DC, residential population statistics in 1997. Tourists, shoppers, and major event users are not included yet could significantly alter the results. The five scenarios included a nuclear

detonation, a biological release, a chemical release, a HAZMAT accident, and a high yield explosive. Each scenario and its potential consequences will be discussed below.

C.1.2.1 Scenario 1: Sulfur Mustard Release

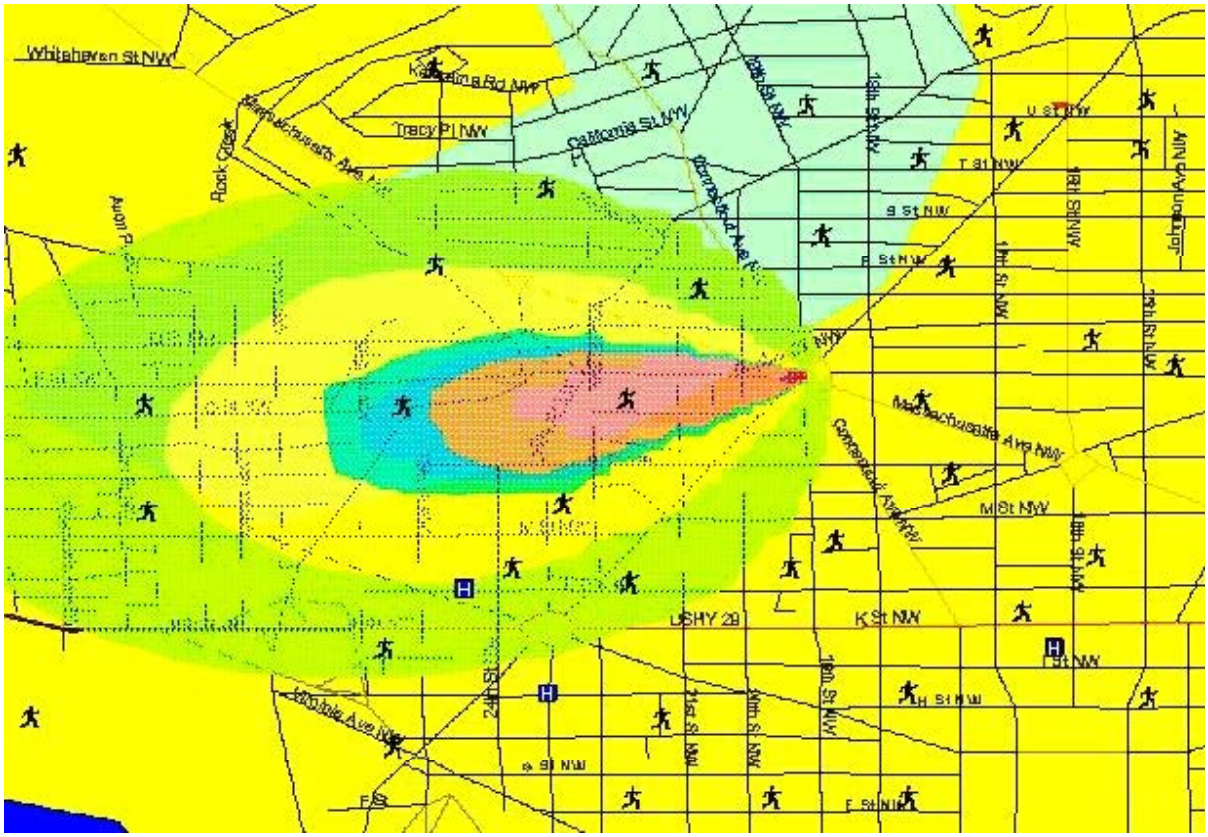

Figure C-1. Plume dispersion, sulfur mustard 200 kilogram rapid release at Dupont Circle NW with winds blowing east to west at 10 mph.

Many factors are involved with chemical agents. Each agent would have its' own characteristics and clinical effect. Sulfur mustard (HD) is available in certain nations that have been known to sponsor terrorism and has been used by those states in military actions. The effects of sulfur mustard consume large amounts of medical resources as it requires burn and ventilatory interventions. A 200 kilogram release of HD at Dupont Circle in Washington DC is predicted to significantly affect 1500 individuals. The initial care of the victims will involve decontamination, burns, wound care and ventilator support. The burn unit at Washington Hospital Center has only a few beds. Such a scenario would require rapid assessment and treatment with eventual distribution to other burn centers.

C.1.2.2 Scenario 2: Nuclear Detonation

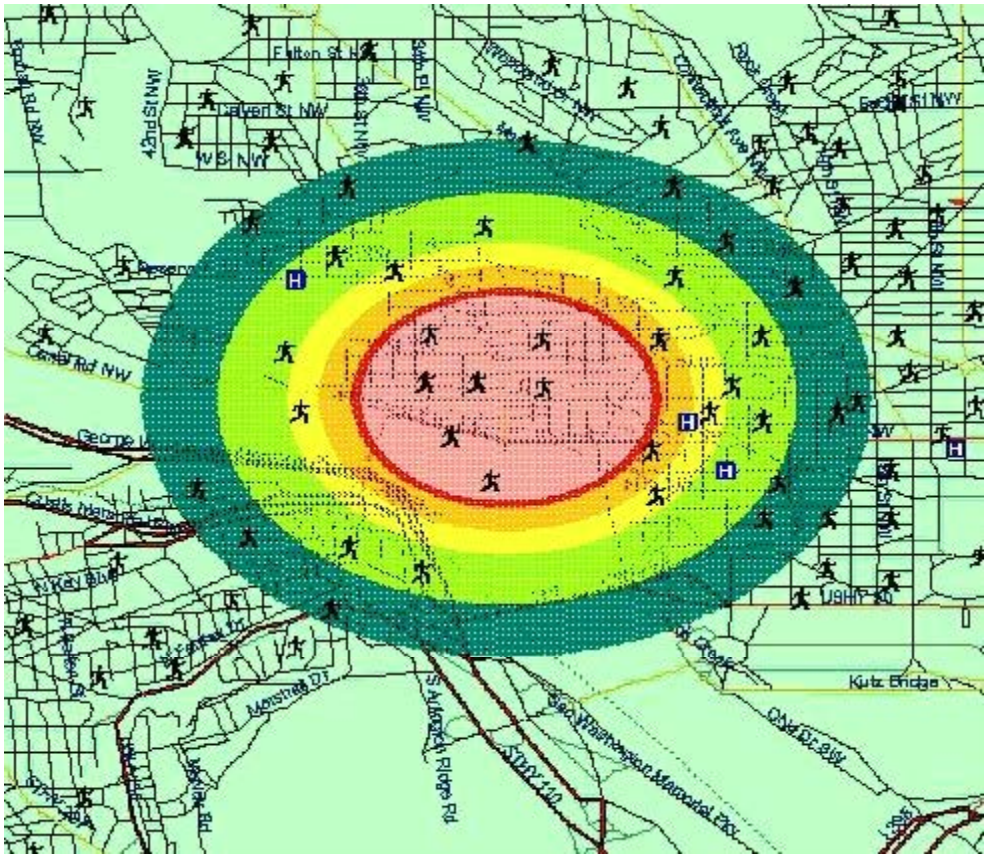

Figure C-2. Blast effect, one-kiloton nuclear detonation at Wisconsin Avenue and M Street NW

Many factors are involved with chemical agents. Each agent would have its' own characteristics and clinical effect. Sulfur mustard (HD) is available in certain nations that have been known to sponsor terrorism and has been used by those states in military actions. The effects of sulfur mustard consume large amounts of medical resources as it requires burn and ventilatory interventions. A 200 kilogram release of HD at Dupont Circle in Washington DC is predicted to significantly affect 1500 individuals. The initial care of the victims will involve decontamination, burns, wound care and ventilator support. The burn unit at Washington Hospital Center has only a few beds. Such a scenario would require rapid assessment and treatment with eventual distribution to other burn centers.

C.1.2.3 Scenario 3: High Yield Explosive

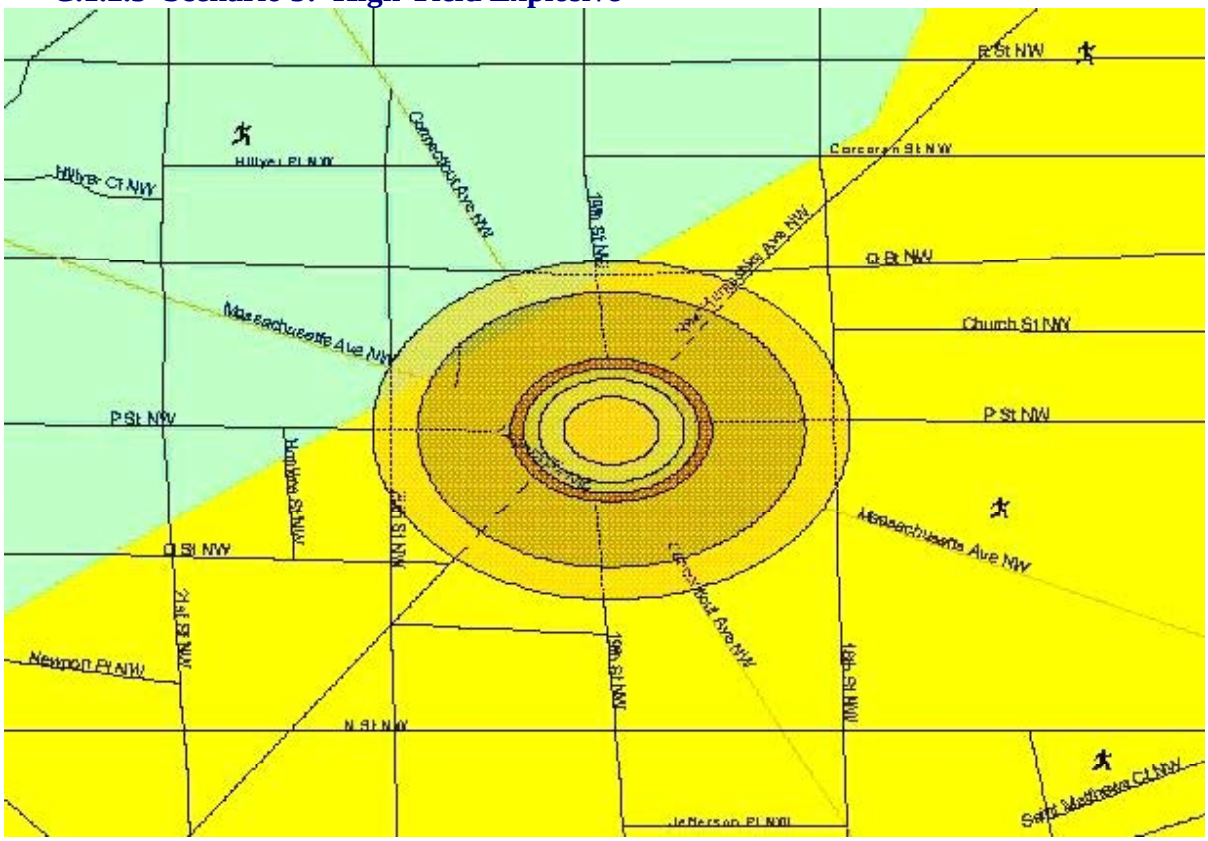

Figure C-3. Blast effect, twenty ton TNT explosion at Dupont circle

High yield explosives damage via blast effect as well as developing shrapnel and shards from objects nearby the explosion. Studies of blast effect indicate that most of the injuries to individuals are a result of shard and shrapnel. The blast effect itself tends to cause “baro” injuries especially to the lungs. This particular scenario model indicates approximately 715 deaths, 26 survivors with severe lung damage, and 315 individuals with significant traumatic injuries. The number of individuals with severe lung damage is mitigated by the fact that buildings are absorbing the blast wave. If such a blast were to occur in a stadium filled with people the number with severe lung injuries would be much higher.

C.1.2.4 Scenario 4: Hydrogen Cyanide Release

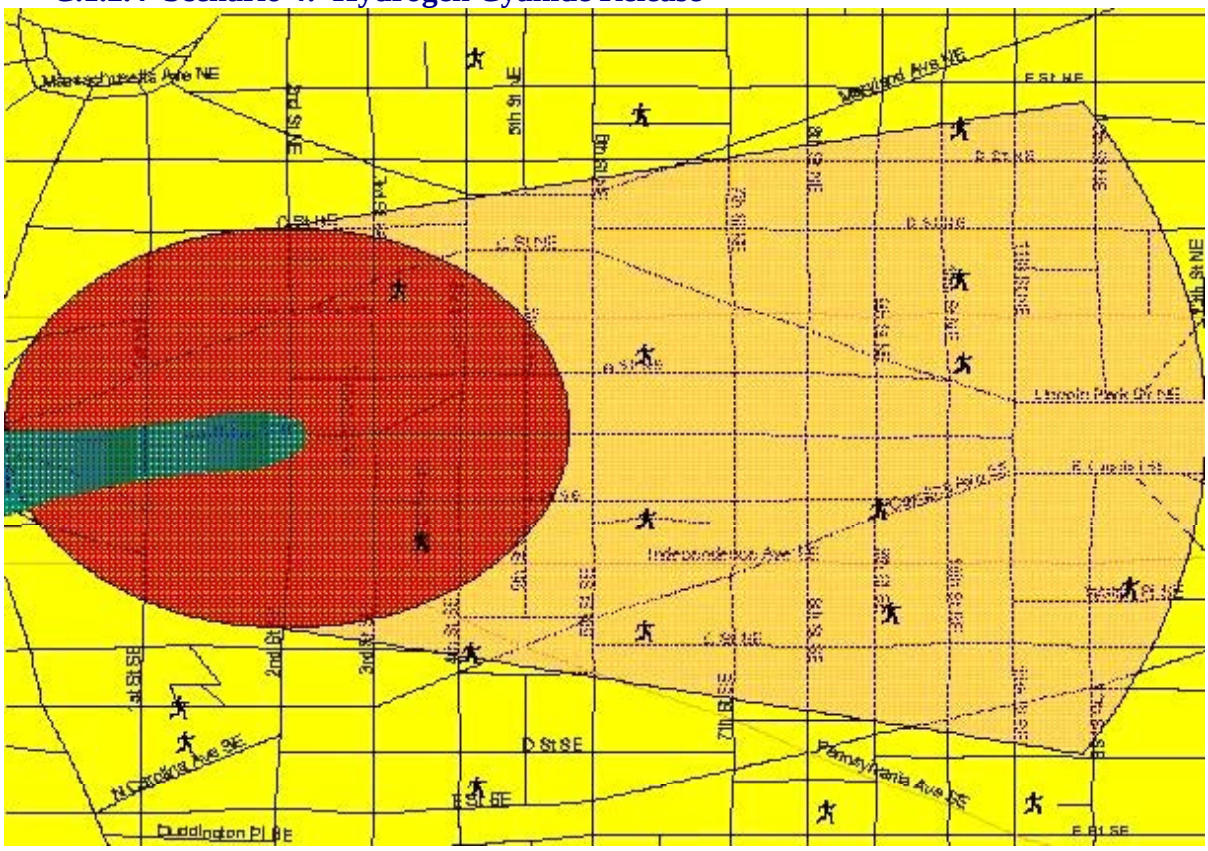

Figure C-4. ***Hydrogen cyanide plume after 200kg release at 2nd Street and E Capitol Street NE with winds blowing west to east***

The use of toxic industrial chemicals for terrorist purposes is often overlooked in discussions of terrorist threats. However, the relatively easy availability of such materials in quantity, and the potential harm they can cause, makes them an attractive alternative to terrorists. Hazardous spills pose a threat to the public even without deliberate hostile intent. Numerous chemicals such as chlorine are stored and transported through major cities.

The release of hydrogen cyanide, of a magnitude easily generated by mixing sodium cyanide and sulfuric acid on a 55-gal drum scale, an act easily accomplished in the back of a small van, was analyzed. The plume would affect approximately 10,000 residents (see attached data). Although not all would be seriously affected, most would seek immediate medical attention. These numbers would have the potential to overwhelm medical facilities.

C.1.2.5 Scenario 5: Biological Agent Release

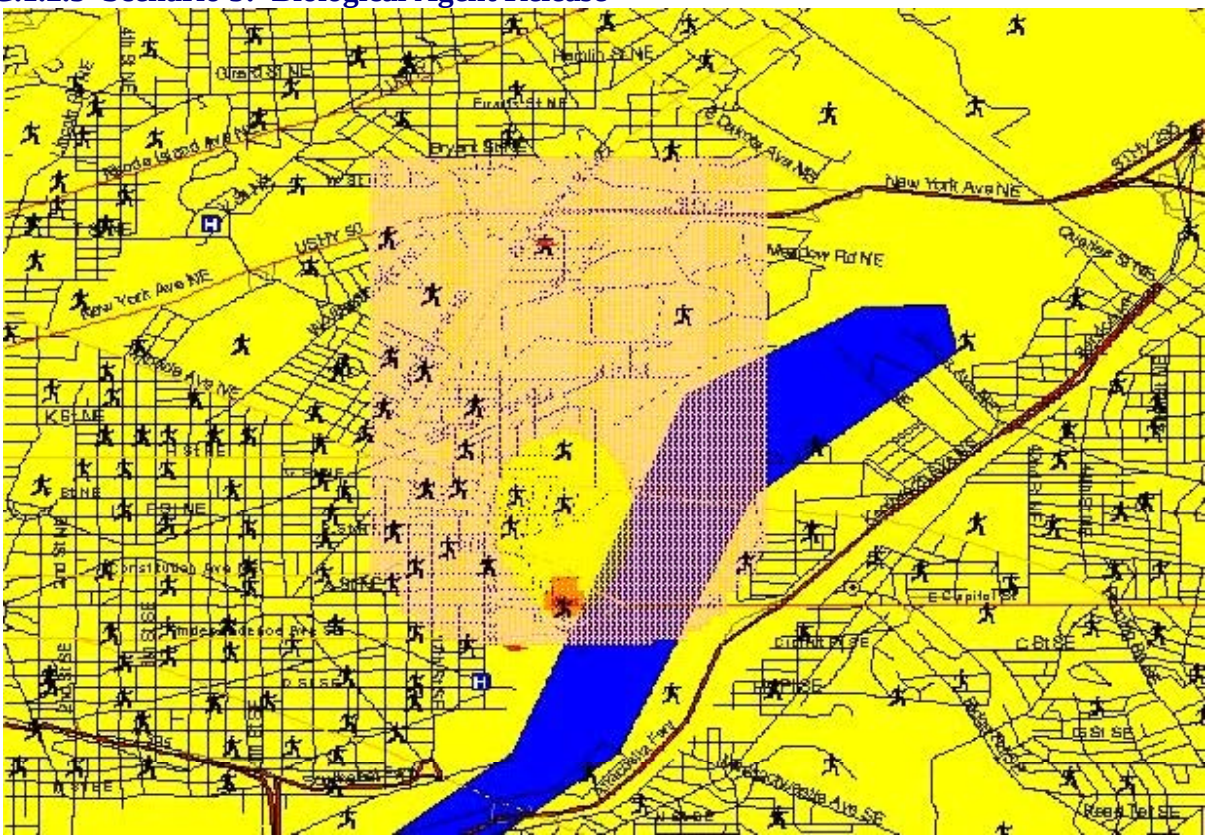

Figure C-5. Anthrax 2 Kilogram Grenade at RFK Stadium

Biological agents lead the list of tools of terrorism that citizens fear most. A four-gram anthrax (2kg of material - 0.2 percent spore purity) release by means of grenade explosion at RFK stadium is estimated to generate 148 deaths. While in itself not an overwhelming number, the entire stadium with its capacity of 50,000 individuals. Additionally, thousands of other residents of the metropolitan area that would be seeking medical attention as soon as it became evident that anthrax spores were released, demanding testing for exposure and antibiotic therapy. The ability to test and process this number of individuals would indeed be challenging.

C.2 DISCUSSION AND CONCLUSION

Clearly a range of casualty results could be generated by inputting other scenarios into various software programs.

Additionally, the consequences of biological weapon deployment really cannot be done reliably as there are effectively no data with which to validate the models. Dispersion models

should work well for biological agents, but once having dispersed an agent, there is little to go on as far as human health effects are concerned, and the decontamination efforts required would be hard to estimate. Most importantly these models do not account for human to human transmission that would increase the overall effect of the agent.

The consideration of large gatherings such as sports events and inaugurations would raise the estimates dramatically. However, after viewing the data from a nuclear detonation and nitrogen mustard exposure it became clear that a number of scenarios would not only overwhelm the current surge capacity of the NCR medical system but would also exceed the potential scalability that could be affordably generated. Further these scenarios do not account for the number of individuals that will present for evaluation because of fear of injury or exposure. It is doubtful the economy can support the development of facilities to rapidly evaluate and treat 20,000 casualties. Thus it becomes a decision not to build to the size of the potential number of injuries or casualties, but rather to design and build the amount of scalability that can be reasonably accomplished within the general size and manpower capability of a facility. There is little purpose in building capacity that cannot be manned.

ER*One*

Appendix D *Hazard Vulnerability Analysis*

APPENDIX D

HAZARD VULNERABILITY ANALYSIS

Dale Woodin, ASHE
Michael P Pietrzak, MD

D.1 HAZARD VULNERABILITY RESULTS

In support of *Project ER One*- Phase II, a Hazard Vulnerability Analysis (HVA) using the HVA tool and scoring system of the American Hospital Association and American Society of Health Care Engineers was accomplished. The Washington Hospital Center had previously accomplished a full HVA using a modified version of the Kaiser Permanente HVA tool and scoring system. These tools score the facility in three areas: the likely hood of the threat, the potential magnitude of the consequence and the perceived level of preparedness of the facility. Because the design study was addressing a new emergency facility scores of the current level of preparedness were not considered critical to the project. The on site observations and interviews were performed by Michael P. Pietrzak, MD, FACEP, (Project Director Phase I) and Dale Woodin (Chief Engineer ASHE) on July 22 and 23. The process included a review of the previous HVA, visual inspection of the facility and its environment and a formal survey of individuals in the following positions:

- VP of Physical Plant and Security
- Chairman of Emergency Department
- Risk Manager
- Facility Manager
- Security Manager
- Readiness Director

Each survey participant completed the survey (see attached HVA survey form) and their ratings were averaged to provide a rating based on input from multiple areas. This multi-discipline approach provides an analysis preventing one discipline from skewing the rating system.

D.1.1 Probability of Event Occurring

Each participant was asked to rate the probability of a major event occurring. This probability is not specific to the organization and is a product of geographic and community factors. The ratings of high, medium, low or none are based on factors including known risks, historical data and statistics.

The participants rating the following as the incidents with greatest probability to occur:

- Snow fall
- Mass Casualty Incident (trauma)
- Mass Casualty Incident (medical)
- Severe Thunderstorm
- Labor Action
- VIP Situation
- Electrical Failure
- Terrorism, Chemical
- Terrorism, Biological
- Temperature Extremes
- Infant Abduction
- Epidemic
- Communications Failure
- Blizzard

Risk (magnitude of consequence if event were to occur)

Each participant was then asked to rate the risk (or consequence) to the organization if the event took place. These included life threatening, threat to health and safety, or disruptive to services. Within these ratings the issues of damage or failures, loss of community trust, financial impact, and legal issues were considered.

The participants rating the following as the incidents with greatest risk (or magnitude of consequence) if they were to occur:

- Terrorism, Chemical
- Terrorism, Biological
- Epidemic
- Mass Casualty Incident (medical)
- Generator Failure
- Fire, Internal
- Mass Casualty incident (hazmat)
- Hostage Situation
- Structural Damage
- Hazmat Exposure, External
- Civil Disturbance
- Medical Gas Failure
- Mass Casualty Incident (trauma)
- Infant Abduction
- Bomb Threat

- Fire Alarm Failure
- Hazmat Exposure, Internal
- Tornado

D.1.2 Preparedness

The final area that participants were asked to rate was the organization's preparedness for any given disaster. Through system redundancy, backup, and contingency planning, the overall risk of negative outcomes in response to a disaster may be greatly reduced. Participants were asked to rate the organizational preparedness as good, fair, or poor taking into account issues such as status of current plans, availability of back-up systems, and community resources. These findings were not considered critical to the design study for the new facility.

D.2 HAZARD VULNERABILITY ANALYSIS RESULTS

The average rating for probability and risk are factored and weighted to identify potential threats that may require attention to reduce the overall risk faced by the organization. The events that rated the highest overall were:

- Terrorism, Chemical
- Terrorism, Biological
- Epidemic
- Mass Casualty Incident (medical)
- Mass Casualty Incident (trauma)
- Mass Casualty incident (hazmat)
- Hostage Situation
- Fire, Internal
- Hazmat Exposure, External
- Generator Failure
- Structural Damage

D.3 CONCLUSIONS OF THE HVA FOR PROJECT *ER ONE*

The results of this HVA are highly specific the Washington Hospital Center. It is not likely that most hospitals will ultimately rate terrorism as their greatest threat. These specific results reflect the proximity to the Nation's Capitol and other high profile targets as well as the temporal proximity to the 2001 attacks on the Pentagon and the Hart Senate Building (anthrax). The areas identified in the HVA results that were rated the highest overall were given special consideration in the design study. Finally, this tool was considered an as an initial assessment to aid prioritization. It did not create an absolute priority list for the design team to adhere to. However, it underlined the need for appropriate threat mitigation features to be incorporated into the *ER One* design. Specific potential events that needed to be addressed for mitigation included four general areas terrorism, accidental events, natural

events and crime (internal and external). In the terrorism category airborne biological release (internal and external), waterborne contamination, blast effect, radio-nuclear effect, chemical agents, and plume effect from more distant events were of concern. Accidental events identified hazardous materials (specifically chlorine) based on routine activity near the facility. Natural events that can occur in the National Capital Region include tornadoes, electrical storms, and heavy rain. Seismic activity is possible in the region. The criminal activity concerns are similar to most city hospitals. A new criminal threat to hospitals is emerging through cyber theft of information or financial resources.

ER*One*

Appendix E *Threat Mitigation in Medical Facility Design*

APPENDIX E

THREAT MITIGATION IN MEDICAL FACILITY DESIGN

Authors:
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Craig Beale, FAIA, FACHA, RIBA, CHE, CHC
David R. Vincent, AIA, ACHA

E.1 INTRODUCTION

Today's world environment poses many threats, natural, accidental or deliberate, including unfortunate overt acts of terrorism. The notion that hospitals are immune or protected from such events is no longer plausible. To date, modern hospital design has been driven largely by functional programs and operational models, strategic business plans, and the desire to create healing environments. In more recent years, operating efficiencies and expense reduction have been the primary driving force due to reductions in reimbursement and increasing labor costs.

In the conventional design process, functional programs and operational models describe the purpose of the facility, the projected demand or utilization, staffing patterns, departmental relationships, space requirements, and other basic information relating to fulfillment of the institution's objectives. The functional program typically includes a description of those services necessary for the facility's operation under normal or routine conditions. External constraints include building site, zoning, fire and building codes, requirements of accrediting bodies, and even local cultural acceptance. Financial constraints are also ever present.

The architecture of a healthcare institution reinforces the mission of the organization and assists in defining the character of the facility. Usually related to these goals is a desire to create an aesthetically pleasant atmosphere of a wellness or healing environment. Designers and clinicians alike feel that healing environments lower overall anxiety and stress levels. The patient-centered environment coupled with quality clinical care maximizes the healing process.

These issues will all continue to be major factors in hospital design and modernization. However, today we must ask ourselves – what if? What if there is a natural disaster? What if the nearby government facility was attacked? What if the hospital was targeted? In the future, the hospital must not only be able to function clinically and provide a healing environment, it should also provide reasonable protection from external threats.

Additionally, hospitals must be prepared and responsive to assist with management of the medical consequences of events which injure a large number of people. This has historically been accomplished with make-shift or parking lot solutions after the facility has already been built. To optimize a facility's ability to scale up for such events, functional and operational programs should describe that facility's model in normal routine as well as stressed contingency-demand conditions.

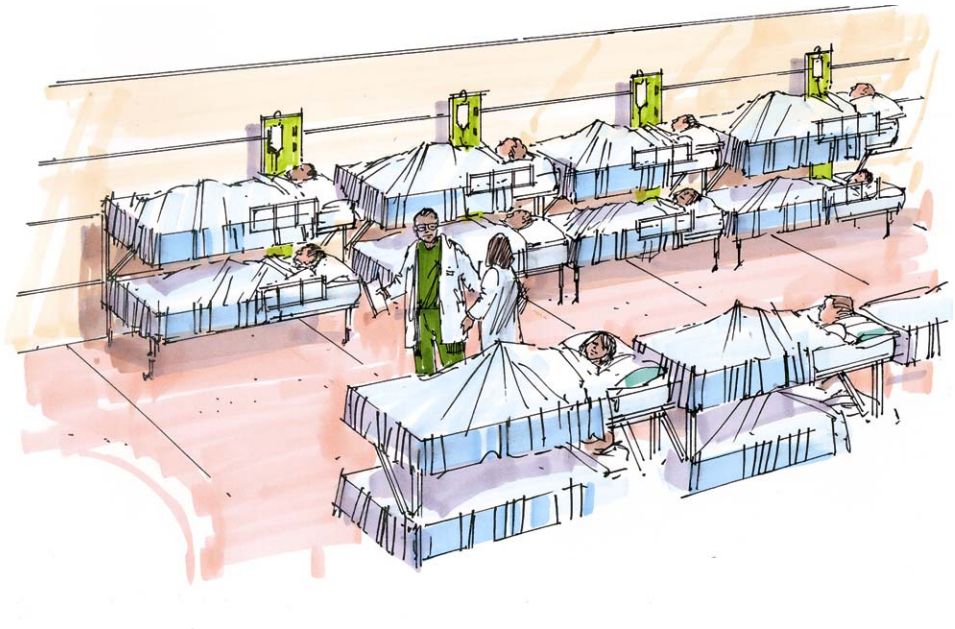
There is no claim that all threats can be eliminated, or that any hospital could be designed to handle overwhelming numbers of casualties. However, there is a fundamental premise that reasonable efforts should be made to mitigate the threats when possible. This, of course, must be achieved within existing external constraints and financial realities while preserving the foremost priority of providing optimal clinical care in a healing environment.

E.2 RECOMMENDED PRINCIPLES

In order to most effectively achieve threat mitigation in an operational setting, a number of general principles should be considered in the design process:

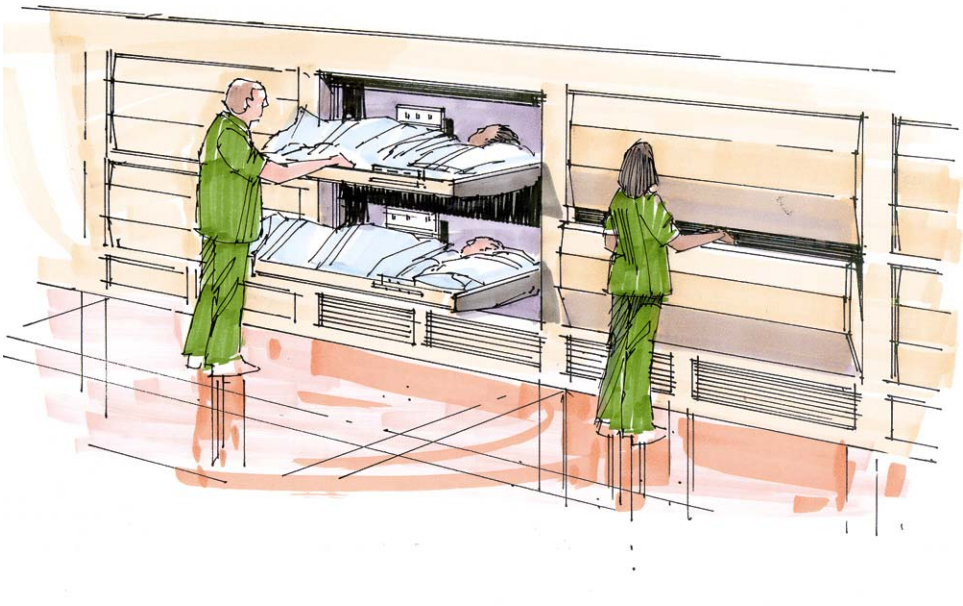
The **daily routine principle** promotes the concept that individuals perform best in critical situations if they are completing familiar tasks similar to their daily work.

The **dual-use principle** recognizes that rarely used, specialized, or contingency equipment and spaces consume financial and area resources. In addition to being costly, such contingency equipment and spaces are often neglected during regular facility maintenance. The design strategy for the dual use principle is that, whenever feasible, contingency spaces have daily uses that can be set-aside during the contingency. For example, a mass casualty triage area that is needed during contingency operations is a lobby during normal operations. Hospital corridors are pre-plumbed and wired (medical utility ready) to accommodate medical care in scaled-up contingency operations. In this specific example, additional patients in contingency operations are placed parallel along a corridor wall or in other public spaces and administered care**.**



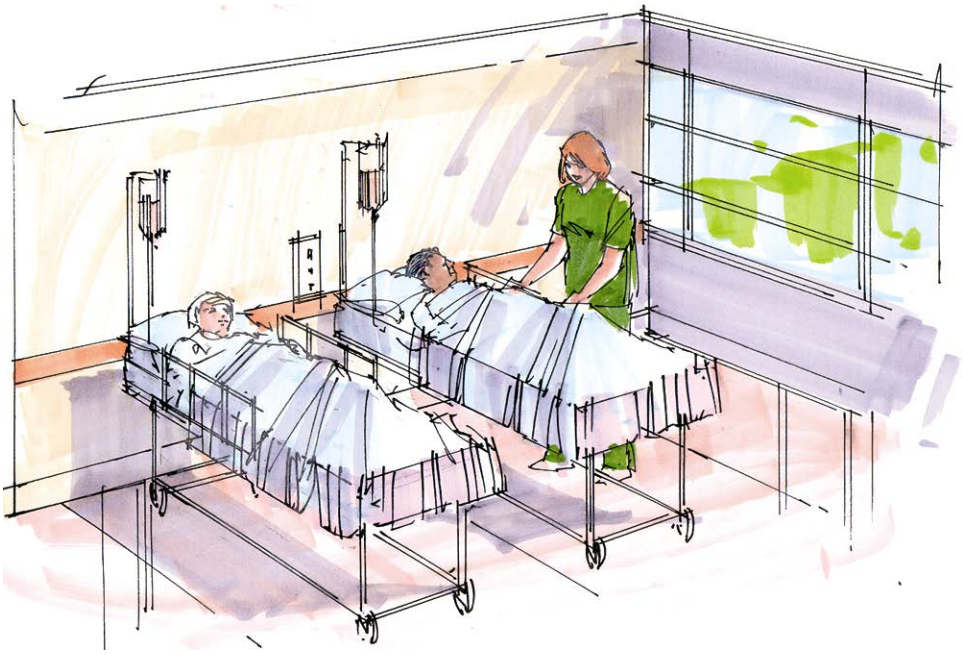
Contingency Treatment in Public Spaces

The **minimal over-design principle** allows for a reasonable inherent excess capacity beyond that which is required by the routine functional and operating structure. The amount or extent of minimal over-designed capacity is limited by both the initial and operating capital budgets. An example of this principle is to minimally increase corridor widths beyond code requirements. In conjunction with provisions for the corridors to be medical utility-ready, the result is significantly higher scaled-up capacity yields due to patients now being placed perpendicular in corridors. This model does not excessively burden functional efficiencies or resulting gross area.



Corridors Used for Treatment Space

The **contingency code relief principle** allows for less than optimal facility design provisions only in extraordinary emergency response events. This principle recognizes that the primary goal of emergency preparedness and response is to treat and save as many lives as possible. Similar to treating patients in the battle field, in the face of life or death, effective contingency provisions may not reflect modern day code requirements. In the setting of a mass casualty event, it may not be practical to provide all the design code requirements in the physical facility contingency environment. An example of an acceptable compromise may be a reduction in space between patient positions, or dedicated patient area based upon certain acuity levels. It is assumed that similar design code variances would be agreed to with the appropriate authorities having jurisdiction in the early planning stages.



Contingency Code Relief

The **knowledge management principle** is often never considered in hospital design. However, individuals cannot memorize and retain all the information and procedures needed to address any given situation. The facility design should ensure that appropriate responses occur when a given situation is presented. For example, smart intrusion detection systems automatically contain an area of a hospital by locking the appropriate doors, sealing the appropriate ventilation ducts, or providing proper ventilation pressurization for the threat.

Threat mitigation cannot be accomplished by facility design alone. It needs to be an integrated solution with procedures, personnel training, and technology applications.

E.3 DESIGN PROCESS FOR THREAT MITIGATION

An appropriate design process should be developed before approaching any discussion of threat mitigation in facilities. However, the elements of the threat mitigation design process do not encompass the entire design process of a medical facility. The elements listed must be integrated into the global design process. The basic elements of the author's process include:

- Operational (clinical) needs assessment
- Threat assessment

- Vulnerability analysis
- Establishment of threat mitigation features desired
- Definition of constraints
- Defining the critical axis of the hospital
- Selecting solutions via multi-objective optimization

The projected operational/clinical needs assessment includes the definition of the service procedures and practices likely to be executed, the projected volume, current technologies/equipment needed to achieve the mission, and the definition of an environment suitable to these operations.

A threat assessment is essential in the planning process. Tools such as the threat assessment matrix for healthcare facilities developed by the American Hospital Association and the American Society of Healthcare Engineers are useful.

After assessing the threat, a vulnerability analysis should be undertaken. Which threats make the hospital most vulnerable? Which threats may indeed exist, but the hospital does not deem itself vulnerable? For example, a hospital threat analysis may identify a high crime rate in the community, but the hospital itself does not feel vulnerable due to the number of police in the neighborhood. Which parts of the hospital are most vulnerable to the identified threats?

Most state licensing authorities only require clinical observation standards that generally increase with patient acuity levels. These provisions are primarily for the patients' safety and well being. From the perspective of outside threats and fundamental security, few standards apply holistically to the contemporary medical facility. Today, additional threat mitigation thought processes must be addressed and integrated into facility design and operations. Issues such as vehicular access and proximity to the structure, multiple building entrances for dedicated services, and unrestricted access to the mechanical system's fresh air intakes must be analyzed with respect to potential mitigation features.

Two current exceptions to the existing relaxed security climate in healthcare are newborn nurseries and the emergency department. Nurseries are usually required to have controlled access and egress. Emergency departments are required to provide a level of security at areas including reception, triage, and control station. Design codes require that these areas are located to permit staff observation and control of access to treatment area, pedestrian and ambulance entrances, and public waiting area. The triage area also requires special consideration. As the point of entry and assessment for patients with undiagnosed and untreated airborne infections, the triage area is designed and ventilated to reduce exposure of staff, patients, and families to airborne infectious diseases.

External constraints include the building site, zoning, codes, accrediting bodies, and local cultural acceptance. Some communities object to a highly secure facility in their vicinity.

Due to the financial constraints, it is often impossible to include all threat mitigation features throughout the entire facility.

It is useful for a medical facility to determine its critical axis to prioritize decisions on incorporating specific features. Large medical centers are complex and often sprawling facilities with numerous functions and capabilities. Within any hospital, critical areas and infrastructure exist to maintain the effectiveness of the hospital. These areas and infrastructure are expected to continue providing essential services during contingency planning. The elements of the critical axis of a hospital generally include:

- Emergency department
- Operating suites
- Critical care and acute care beds
- Imaging, lab, and pharmacy capabilities (essential elements only)
- Vital facility resources and supplies such as food service
- Utilities such as water, medical gases, power, ventilation systems, etc.
- Connectivity
- Communications, informatics
- Command and control center

These are elements that permit continued operations of the medical facility. Depending on the hospital's mission, operations, and values, the elements of the axis will differ. For instance a cardiac care facility may determine that a cardiac catheterization suite is critical due to the number of patients in the facility with cardiac conditions that might require intervention. Ultimately, only the facility's administration determines the hospital's critical operations.

Even within a given department, a critical axis for optimal component protection applies. The planning staff should carefully assess which elements of the department are most vulnerable and critical to protect. Administrative offices, education space, and outpatient functions are generally not considered critical infrastructure unless they are designated to have a specific higher-use role in contingency situations. Examples of higher-use roles are:

- Casualty receiving area
- Command center or safe room functions
- Additional inpatient bed housing

Once the critical axis is established, prioritized security recommendations are reviewed. A practical example is the decision to provide blast mitigation features. For example, a higher priority for the hospital might be the emergency department entrance as opposed to the administration offices. This would be affected by other factors such as the vulnerability of the particular area. In some cases, the critical infrastructure may already be relatively safe from threats. However, all other factors equal, the critical axis – as determined by the facility

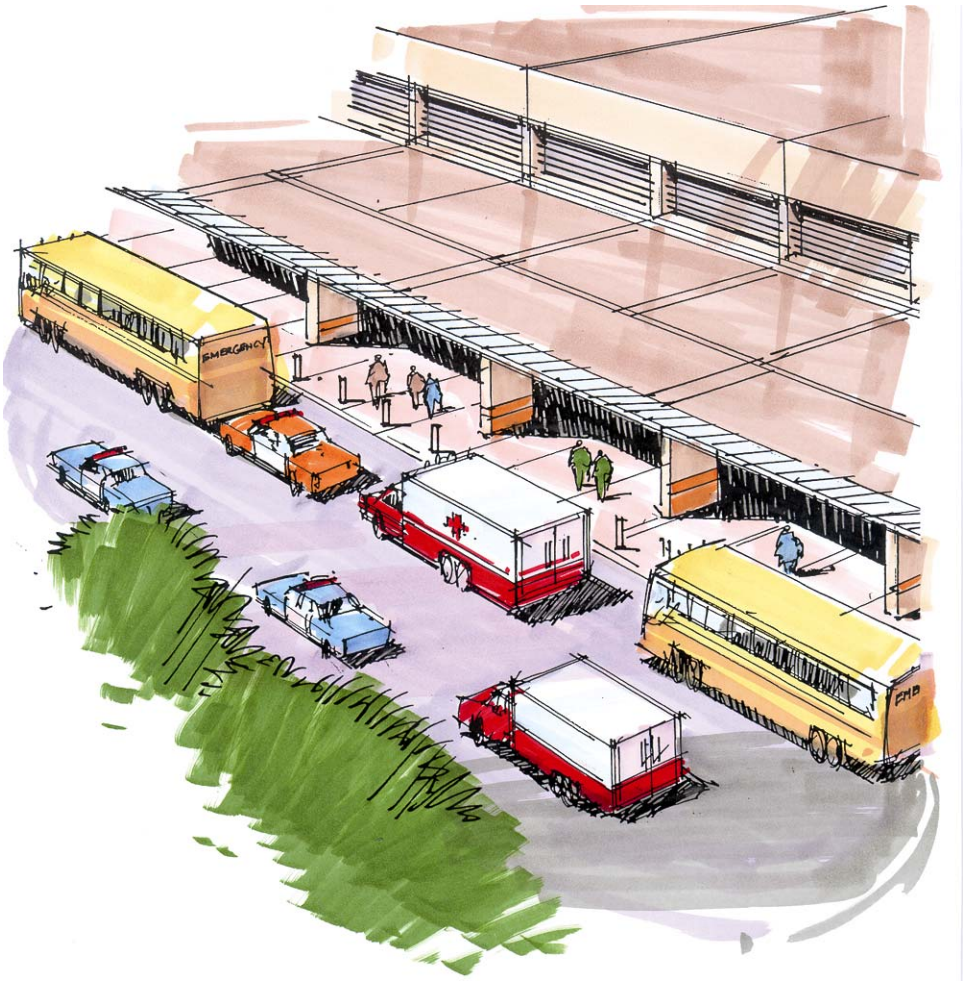
– is the priority when spending security improvements dollars. Some high-value resources, such as ultra-high cost medical equipment, may also require priority for protection – even though it is not part of the critical operating axis.

In the final analysis, a multi-objective optimization process needs to be employed. Even if threat is determined to exist and the mitigation solution is affordable and acceptable, it may compromise hospital operations. A deliberate decision needs to be made weighing the variables and advantages. This can be formally completed with a matrix and an assigned-value scoring system. Even with use of scoring systems, ultimately the process requires subjective decision-making.

E.4 DESIGN CONCEPTS FOR THREAT MITIGATION

E.4.1 Strategic Location/Configuration Decisions

Clinical directors are not given much choice in determining the location of their hospital. They may have input into the location of their department within a campus or facility. Standoff distance is one of the most useful mitigation strategies for blast, radiation, and chemical threats. Critical axis services should attempt to choose a location on-campus with sufficient standoff distance from uncontrolled public access – such as highways or a nearby government building. In the urban setting, hospitals must consider, for example, vehicular congestion when locating critical axis services.



Stand-Off Distance

Additionally, open space and buffer areas are ideal as security setbacks. Traditionally, the luxuries of incorporating such security options have been rare. In reality, planners usually have only the choice of orientation and configuration of the site. Even within those constraints, the same principles should apply to the extent possible.

Traffic Access Management

E.4.2 Traffic Access Management

Traffic management concepts should employ solutions proven in other venues to improve traffic management. Multi-lane uni-directional traffic patterns allow for easier access control and safer traffic movement. These have been well demonstrated at airport terminals. Access through multi-lane, drive-through checkpoints should exist. These checkpoints can be vehicle

portals designed to employ a variety of screening technologies as well as rapid external vehicle decontamination. Ambulances are given priority while private vehicles are directed to appropriate portals with automated traffic management signs. Landscape barriers prevent vehicle operators from attempting aberrant routes as well as excellent blast mitigation. Smart pop-up barriers with sufficient vehicle stopping can be strategically employed to control and divert traffic flow. Back-in docking of ambulances, typically used at most facilities, has several disadvantages.

A deliberate explosion or contamination at the ambulance loading dock can severely limit the functionality of that facility. Approaches to terminals at airports are configured to accept numerous vehicles simultaneously. Damage to any one area along the length could be by-passed for a more favorable arrival point. Landscaping and overhead signs along drives should be carefully assessed because both may block access of high-clearance emergency vehicles.

E.4.3 Immune Building: Surface Technology

Hospitals have long struggled with the challenge of treating infected patients while keeping the facility clean and safe for others. Some biological and toxic agents of terrorism seem to be able to resist repeated attempts to successfully decontaminate the environment in which they were released. Hospital rooms have surfaces, seams, equipment, and outlets that are difficult to decontaminate. For example, the typical lay-in acoustical tile ceiling is very porous and typically does not provide an airtight seal. Once a contaminant infiltrates into the fissures and above the ceiling cavity adhering to all of the building service equipment is impossible to decontaminate. The consequences of having a key community facility critical axis service closed for months due to anthrax contamination could create strain on other medical resources.

Anti-Microbial Blister Switch

Immune building enhancements include compartmentalized, non-central air handling systems with high efficiency specialized filters providing clean air in and out. These dedicated individual HVAC systems permit the closing of units, floors, or wings without having to lose entire sections of the healthcare facility – as compared to co-dependant zones.

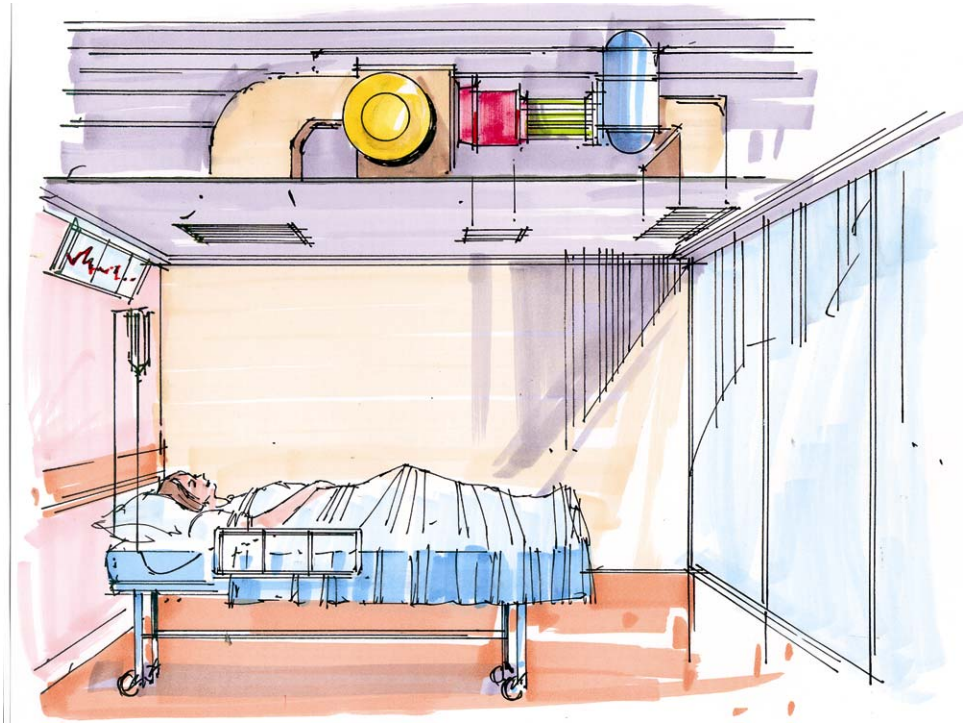
Systems could be designed to easily accommodate new developing technologies. Seamless surfaces of non-porous materials allowing ease of cleaning and preventing the sequestration of spores, bio-agents or chemicals in cracks are recommended throughout

critical axis departments. Corners can be coved for easier cleaning. These surfaces should be able to withstand degradation from repeated decontamination.

Self-decontaminating materials and surfaces can be selectively applied to critical areas. For example, drains are harbors for bacteria. When water is introduced in a high velocity fashion, this bacterium can be dispersed. Metal impregnated with ionic silver can reduce bacterial counts on sinks, drains, and other metal surfaces significantly. Blister switches and controls can replace standard toggles and controls for ease of decontamination. Smooth covers for electrical outlets prevent the entrance of contaminants into outlets. The immune facility will enhance the hospital's inherent infection resistance capability by further limiting hospital infections. These solutions can also be applied in public restrooms.

E.4.4 Immune Building: Advanced Ventilation Systems Technology

Despite a long-standing set of requirements for ventilation and filtration standards in the emergency department, the reality is that most hospitals continue to struggle with the challenges of proper air movement and filtration. Airborne pathogens, such as *Aspergillus* spp.b, *Mucorales* (*Rhizopus* spp.), *Mycobacterium tuberculosis*.b, Measles (rubeola) virus**,** Varicella-zoster virus, and Legionella, can be spread from person to person in waiting spaces and open care areas.



Compartmentalized and Highly Filtered Ventilated Systems

Most ventilation systems are able to remove all but the smallest particulates (1µm - 5 µm in diameter) through the standard ventilation system. Many facilities have installed high efficiency HEPA filters (HEPA filters are at least 99.97 percent efficient for removing particles >0.3 µm in diameter) providing an almost particulate free atmosphere. The new ventilation standards of the CDC and related design codes require airborne infection isolation and decontamination rooms to have negative air pressure with air exchange rates of 12 air changes per hour and all air exhausted to the outside.

When considering all the potential airborne threats (natural or deliberately introduced), more than high efficiency filters will be required to protect patients and healthcare workers. In addition to HEPA filters, other filters using photo-catalytic processes could be applied where appropriate. Photo-catalytic filters potentially eliminate the need for exchanging filters and reduce maintenance. The surfaces of the ducts may need to include self-decontaminating materials such as silver ion impregnated metals or coatings ensuring microbial agents will not survive in the ductwork.

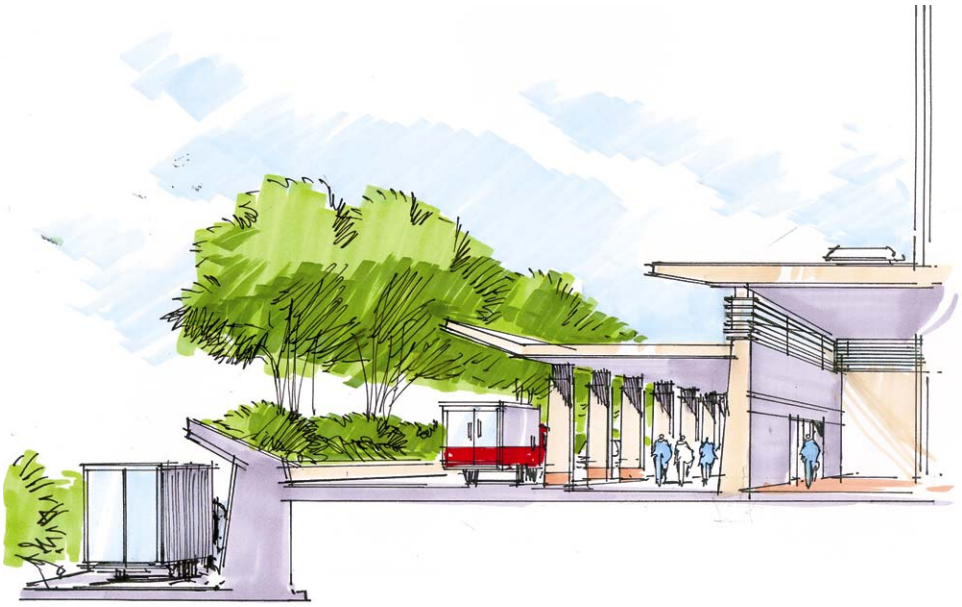
There are many different methodologies to consider in designing ventilation systems in hospitals. HVAC systems that are highly compartmentalized permit the isolation of particular departments or services from other parts of the hospital. Smart controls permit systems to be quickly converted from a re-circulating system to either a 100 percent exhaust system or become passive. Smart systems rely on the function of internally mounted duct detectors and automated actuation technology for closing dampers or shutting down system fans. For these systems to be effective, the sensitivity/specificity of the detectors and the reliability of the actuating systems need to provide a high level of assurance.

Given these concerns and the need for critical axis departments to stay operational, a separate individual room, isolated ventilation system may be needed. This has been adapted in the hotel industry without excessive cost. The ability of HVAC systems to automatically overpressure the interior space from the outside can provide hardening from external contamination. During this overpressure mode, some internal rooms will continue to need relative negative pressure for isolation purposes. Additional features can include automated smoke evacuation systems that not only provide protection from fire smoke but incremental protection from introduced chemical agents. Laminar flow strategies can be used in large entry portals and other areas where directional flow is desirable for protection or environmental considerations.

These systems not only provide enhanced capability to deal with chemical and biological weapons but will also provide significant improvement in the reduction of spread of airborne pathogens or toxic material during normal hospital operations.

E.4.5 Blast Mitigation

Hospitals could be deliberately targeted as part of a terrorist strategy. While all major facilities serving the public are potential targets or could suffer collateral damage as a result of high yield explosive detonation, hospitals hold great strategic value in helping to maintain calm and manage the medical consequences of an attack. The public expects that hospitals will be safe-havens for those who have suffered injury or illness. All critical axis areas are subject to this threat. The emergency department in particular, due to its inherent need to have open access, is one of the most vulnerable areas of a hospital.



Blast Mitigation Features

While the first line of defense is vigilant security and prevention measures, ultimately, even the best such measures can only reduce – not completely eliminate – the risk. Therefore, hospitals should consider incorporating features that mitigate the consequences of blast effects.

Because it must function effectively and appropriately on a day-to-day basis, hospitals cannot be built as blast-proof bunkers. The facilities must be inviting and composed of healing spaces. Fortunately, there are creative engineering solutions and present technological advances that can be incorporated into the construction to reconcile the need for protection while maintaining an appropriate healing environment.

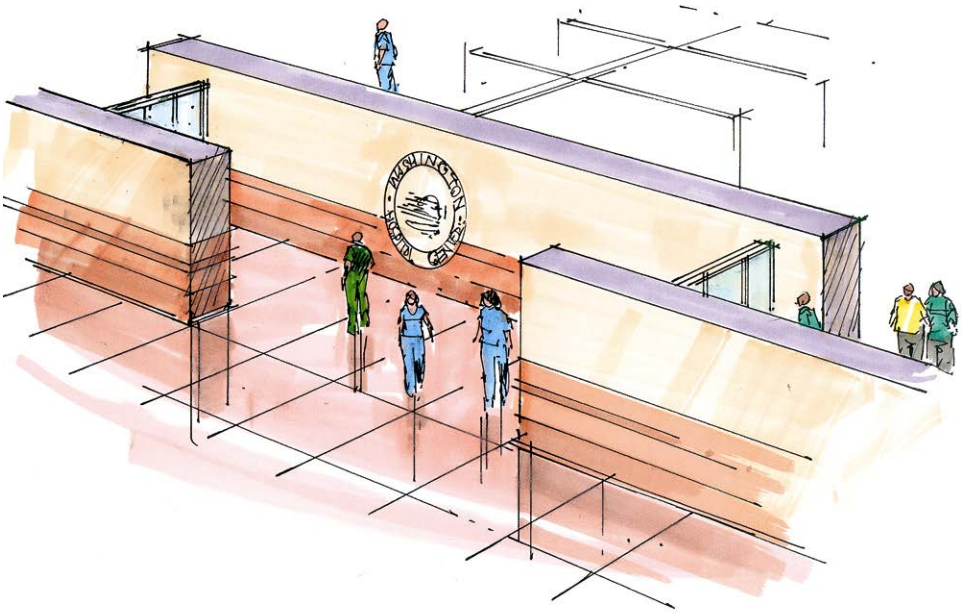
For example, landscape features can provide environmental beauty as well as a barrier-effect for traffic control and protection against blast propagation. External structure hardening and facade shields can be selectively incorporated – especially at vulnerable entrances near vehicle traffic. Specially treated glass and glazing materials can be used in public areas and atriums to mitigate shard damage.

Internal wall materials and coverings are chosen on the basis of strength and ability to reduce the effect of blast through principles of projectile energy reduction and baffling. Several internal wall coatings and coverings have been demonstrated to dramatically reduce fragment projectile effects. Overpressure escape technologies, such as blast panels and vents, provide additional protection from blast effects.

Additionally, lessons learned from progressive collapse of structures due to seismic effects can be applied to blast activity to some extent. Ultimately, the blast mitigation technologies and solutions incorporated in a hospital setting depend on the threat assessment and vulnerability analysis of the particular facility.

E.4.6 Radiation Mitigation

Nearly forgotten after the 1960s, efforts to protect public use facilities from radiation effect are being reconsidered. Protection from both particulate and electromagnetic radiation (EMR) will be considerations. The use of heavy concrete to shield from EMR has been employed in nuclear plants and hospitals to contain radiation. Heavy concrete, incorporating ferric particles or depleted uranium, has significant broad-spectrum radiation attenuation capability at a lower cost than metallic shields. The density of heavy concrete provides superb structural strength. Selective use of heavy concrete could protect critical areas of medical facilities. In addition to filtration, the placement, orientation, and height of intake ducts can mitigate radioactive particulate matter intake.

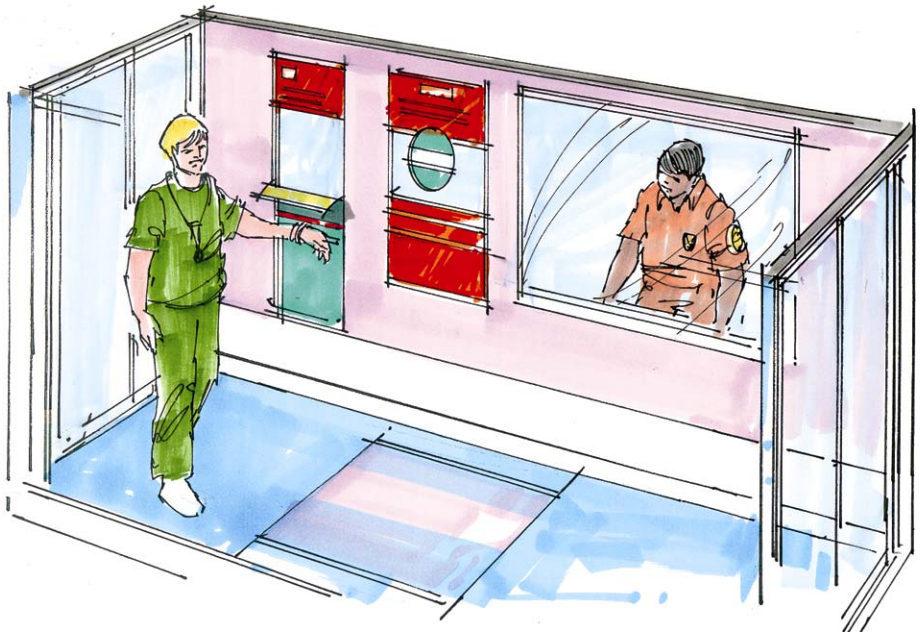


Radiation Mitigation

E.4.7 Advanced Security Technologies

Hospitals are vulnerable facilities due to their open nature. They must allow visitors, patients, staff, suppliers, contractors, and others to enter and leave the hospital repeatedly. During high security scenarios, ingress and egress limitations may impede hospital operations. Intrusive security measures would quickly make a facility undesirable from a customer standpoint. It is essential to employ non-intrusive technologies to enhance security and safety for all staff, clients, and stakeholders. In addition to being non-intrusive, the security measures should not cause significant delays.

Multiple entry/exit ports, designed to accommodate security technologies, are ideal. These ports can feature non-intrusive walk-through screening. It can also be architecturally integrated into the facility having the ability to employ various screening and detection technologies as well as accommodate new technologies. Detection sensors in the ports could check for explosives and toxic materials. Metal detection is also easily accomplished.



Advanced Security Technologies

Bio-metric identification, such as facial recognition or iris scans, is now being developed or already employed. These will uniquely identify the individual. They are relatively non-intrusive and require minimal cooperation from the individual as opposed to retinal scans. Iris scans are reported to have specificity similar to DNA testing. Even if an individual has presented false credentials, the scan will connect the individual with those credentials from that point on. An identification/access band can be attached to all entering the facility. The band will have the ability to track all movements of the individual. Similarly, equipment can be tracked. Smart security doors will allow instant lock-down of specific areas as needed.

These technologies and design solutions will dramatically improve hospital security during critical and normal operations. Additional benefits to biometric identification would be reduction in transfusion errors as well as other medical mishaps resulting from misidentification.

E.4.8 Portal Concepts

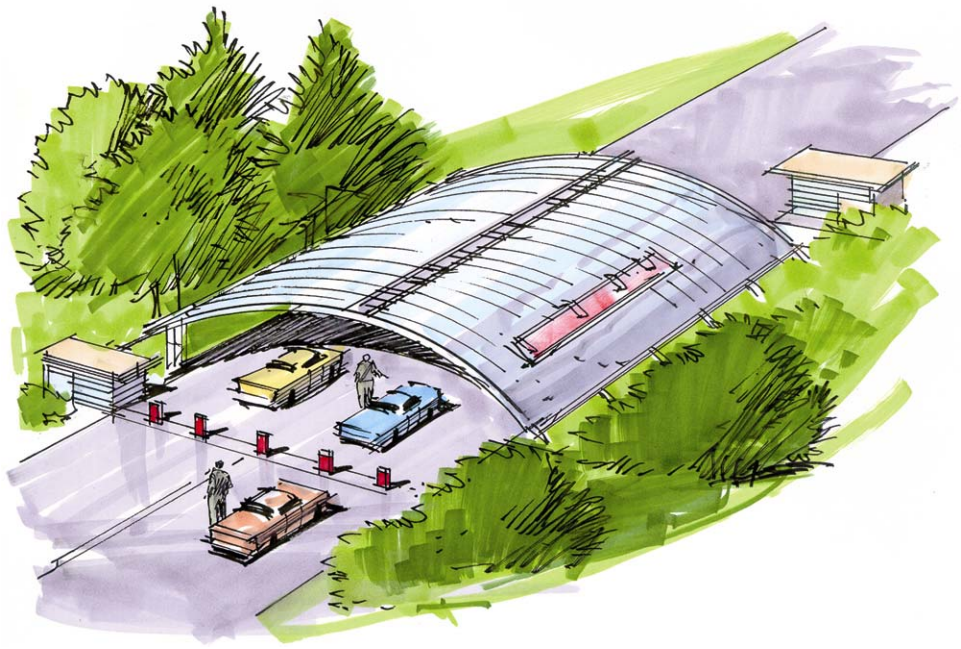
People, vehicles, packages, food, water, air, and information all enter and exit major medical centers in large volumes daily. Any of those modes may provide a vehicle for intrusion into the facility with undesired consequences. The portal design concept implies functionality beyond basic ingress and egress. It involves determining all the processing

desired at the time of entrance and egress and identifying and categorizing all who enter or leave the facility. Estimates of throughput requirements during normal and surge requirements will need to be defined.

Hospitals must also decide specifically what needs must be accomplished in each type of portal. For instance, irradiation used to mail/package handling portals should not be necessary in the personnel portals. Likewise, biometric identification is not necessary for a package. The portal should, to the greatest extent possible, provide all the identification, control, security, and mitigation interventions. The appropriate threat and vulnerability analysis determines specific measures to be accomplished while projected volumes outline the number of needed portals.

The specific design, appearance, configuration, number, and location of portals varies from facility to facility. However, several general principles apply. The first principle is standoff distance. Most threats other than informatics threats are significantly decreased with distance. This is true of blast, radiation, and chemical. Designers/planners should attempt to place traffic portals at sufficient distances from critical infrastructure such as the power supply or communications center. The definition of those critical areas varies from facility to facility. In most cases, the portals for emergency departments will, by necessity, be adjacent to the operational areas of the department. Stand-off distance for mailrooms, loading docks, and vehicle control may be achievable depending on site constraints.

Whatever the design configuration, the portal should have the flexibility to accommodate newer technologies that can be inserted or removed in a modular fashion. Ideally, the portal interiors for human use will appear pleasing, non-threatening, and non-intrusive. The portals themselves should have surfaces that are easily decontaminated. The technologies applied should be non-intrusive, automated, and with little labor requirements allowing rapid throughput with high reliability. In some cases, the desirable technology features may not have yet achieved acceptable efficacy or reliability. Relocate-able and portable approaches would be desired as well as fixed-site solutions. This would allow for scalability and adaptability in contingency situations. Fixed-site solutions could have significant blast mitigation features in the portal structure.



Portal Concepts

In order for the portals to be effective, they must be integrated with other features in the master plan. Secure portals are of little use if other access is easily used. Effective measures to prevent entry via any method other than the designated portal will be necessary. The monitoring and detection technologies in the portals need to be connected and integrated with an overall security/monitoring system. Appropriate data collected from proposed screening systems needs to be transmitted to a control site separated from the portal site for interpretation and archival. Finally, the portal concept addresses external threats but not internal threats such as patient-to-patient violence or workplace violence. Appropriate internal security measures are needed.

The portal concept should not be limited to visible physical structures. What information comes in? How? Where? How much? How does one control it and protect it from threats? Ultimately, the portal concept is more of an approach to design – considering all the factors of ingress and egress rather than prescribed physical structure. Appropriate application of this concept in the design process could improve operational effectiveness as well as security.

E.5 SUMMARY

In today's environment, hospitals should be considered critical community infrastructure. In order to appropriately protect this critical asset, the design process should incorporate a

systematic approach for threat mitigation and medical consequence management capabilities. An appropriate threat assessment and vulnerability analysis matched with the mission requirements of the facility can lead to optimized solutions.

ER*One*

Appendix F *ER One Institute Proposal*

APPENDIX F

ER One Institute

Purpose:

The objective of this document is to obtain support for the establishment of an ER One Institute that can continue to develop design concepts, features and specifications to improve emergency department and medical facility design for all emergency departments nationally as well as to share with our allies in the war on terrorism. The ER One Institute would enable hospitals and other medical centers to incorporate all risks-ready designs in their facilities with the benefit of the knowledge and experience gained by others in the ER One project and related pilot efforts around the country. By disseminating the latest knowledge and sharing common solutions from pilot efforts and studies, the Institute would contribute to more consistent and rapid implementation of emergency department upgrades thus improve the overall preparedness and response posture nationwide at more efficiently and rapidly than individual efforts alone could achieve.

Background:

Project ER One was established by a congressional earmark in 2000 to develop a design study for the "all risks" emergency department of the 21st century. Project ER One successfully completed Phase I with the submission of the Design Document Compendium on 30 June 2002. This compendium included the design features, concepts and specifications developed by the ER One team members and task forces from October 2001 through May 2002. During the development of this phase of the project numerous participants from various professional societies and disciplines learned of the project and joined in the effort. Over 250 valuable design concepts, features or specifications were developed. While this in itself is of value, of even greater value has been the assembly of the multidisciplinary teams capable of generating this material. Collaborative relations with the National Institute of Building Sciences, American Institute of Architects, the American Hospital Association, the American Society of Hospital Engineers, the Army Corps of Engineers, the American Society of Landscape Architects, the American Society of Civil Engineers, the Construction Industry Institute and The Infrastructure Security Partnership as well as key industry corporations has been firmly established. This coupled with the strong multidisciplinary clinical and academic foundation in Project ER One presents a unique opportunity to continue design concept development key to homeland security.

General Proposal:

The Washington Hospital Center Project ER One Team in conjunction with the National Institute of Building Sciences proposes to establish a national institute to continue development of design concepts features and specifications that will enhance the ability of medical facilities to protect from and respond to the consequences of terrorism, disasters and epidemics.

Why should there be an ER One Institute now?

Project ER One, initially funded September 2001- $2.2 million included the development of design concepts and features, a design study for Washington Hospital Center (WHC), and public dissemination of the findings through a symposium. There was no funding to continue development or maintain the ER One web-site beyond the term of the original contract of 18 months. Sustaining of this effort would continue to address the needs of Emergency Departments around the country and would allow the ER One concept to continue to evolve. During the development of Phase I, team members identified additional key subject areas. Among these were communications, landscape, transportation and radiological-nuclear issues. Unfortunately, while some of these areas were initiated, the funding levels and terms of the contract prevented in-depth development of these areas. Additionally, the ER One Website that is widely used as a resource by individuals across the nation should be continually updated with the latest developments. Project ER One is currently sufficiently funded to meet the deliverables outlined in the statement of work. At this time, there is no designated funding to continue to program beyond the initial deliverable submissions. As a result of a visit from Secretary Thompson, additional funding was provided to WHC to retrofit and upgrade the current facility with implementation of a number of ER One design features. The result will provide some threat mitigation features, medical consequence management capability and surge capacity. This effort is underway and will greatly benefit from the knowledge gained in Phase I of Project ER One. When completed the upgrade effort should significantly enhance the National Capital Region preparedness. However, these funds do not assist the Project ER One effort directly or indirectly.

Project ER One has accomplished many things. However, the greatest potential lies ahead. The assembly of the multidisciplinary teams in this area was unprecedented. Previous efforts had often attempted in “silos” of specialty areas with little sharing of concepts between the clinicians, researchers, engineers, architects, etc. As the Project gained momentum, new experts from various fields were continuing to join the effort at a rapid rate up to the closing days of Phase I. A critical mass of credible experts dedicated to the goals of the project had jelled and was able to work even more effectively than the beginning of the project. Further, numerous societies, institutions and professional organizations informally

or formally joined the effort. Among these were the Infrastructure Security Partnership (TISP), the American Society of Civil Engineers (ASCE), and the American Society of Health Care Engineers (ASCE) creating an unprecedented network or "virtual infrastructure" of expertise. The establishment of this "virtual infrastructure" provides significant advantage for continuous knowledge development. A key objective of the establishment of the ER One Institute would be to maintain and enhance this infrastructure. This informal consortium focused on emergency department design features has been gradually built over the initial eight months of the project. The management of project ER One and collaborating entities are interested in the continuation of design feature and best practice development. Ultimately this would be a continuing contribution to public health and national security.

The ER One Institute Concept

Vision

To be the premier center of excellence for the advancement of emergency medical facility design especially in the areas of preparedness for catastrophic events.

Mission

To rapidly and efficiently advance knowledge, processes, and technology pertinent to emergency facility design from science and theory to practice and provide these advances to the hospital community nationwide.

Concept of Operations

The ER One Institute is based on the premise that science in design and material technology pertinent to emergency medical facilities is rapidly expanding. The Institute will be the forum and force to bring together the sources of the science and knowledge through projects and through various information sharing and communication mechanisms. Collectively the Institute and its collaborators will analyze, interpret, improve understanding and disseminate the science and knowledge to those that must apply the science. As innovative designs are fielded, the Institute will be an experience repository, feeding operational experience into future efforts. Thus the Institute will have multiple functions and execute them through a variety of mechanisms.

Functions

1. Continue developing design concepts, features and specifications
2. Develop priorities for research and development in industry and government
3. Disseminate information to appropriate stakeholders
4. Provide technical support to projects around the country as requested
5. Test and evaluate R&D and commercial products
6. Others TBD

Mechanisms

1. Design concept workgroups (see below in section on first year work-plan)
2. Conferences
3. Development and maintenance of interactive website
4. Development staffed resource center and evaluation facility
5. Fellowship programs for motivated graduate students in architecture and emergency medicine

Collaborators and Participants

The Institute will seek participation from a broad and varied collection of organizations and entities including government, industry, academia, research, professional societies and medical institutions among others. Early response to the initiative has been very positive.

(The following is a preliminary list including only those organizations that have already been approached and indicated firm commitment or interest in participation. Many others are proposed for contact)

Operating Organizations- Washington Hospital Center/Medstar, National Institute of Building Sciences

Nonprofit Organizations – Mitretek Systems

Academic Centers- Texas A&M University, School of Architecture

Government Organizations – US Army Corps of Engineers (USACE), National Institute of Standards and Technology (NIST) –Department of Commerce, Office of Emergency Response (OER) –Department of Health and Human Services

Professional Societies – American Institute of Architects, American Society of Civil Engineers, American Hospital Association via American Society of Healthcare Engineers

Industry – HKS Inc. - Architecture, Thornton-Tomasetti Group, Inc.- Engineering

Member Medical Institutions – Washington Hospital Center, Georgetown University Hospital

Proposed Institute Work Plan Outline for First Year of Operations:

Project ER One will continue design concept development in at least for focused subject areas each year. Each focused subject area will assemble a multidisciplinary task force directed and facilitated by ER One Project management and chaired by an expert in the subject areas. These task forces will generally meet one time for two days, each quarter of the year.

An advisory council representing the interests of the medicine and built environment communities would help establish the work program agenda of the Institute. The proposed subject areas for the first fiscal year of ER One Institute operations include

1. Hospital Communications Design Concepts
2. Automated Logistics Design Concepts
3. Surface technologies
4. Scalability Features

It is projected that each design group will develop 20-30 design concepts or features in the two-day sessions. A structured submission format will provide rapid transfer of concepts to the ER One web site for public dissemination as appropriate.

The ER One web-site will continue to be maintained and updated. The section previously called design documents will be renamed the "ER One Forum" where authorized users belonging to the participating professional societies, academic institutions and other organizations will continue to be able comment and provide input. Thus the ER One Design Compendium will become a living document encouraging participation and innovation as well as providing an up to date resource for hospitals nation-wide.

The ER One "Institute Activity" through Washington Hospital Center and Project ER One has already initiated a sponsored graduate student architectural program with the University of Texas A&M School of Architecture and this will continue after the establishment of the chartered ER One Institute.

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The proposed subject areas for the first fiscal year of ER One Institute operations include

5. Hospital Communications Design Concepts
6. Automated Logistics Design Concepts
7. Surface technologies
8. Scalability Features

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The ER One "Institute Activity" through Washington Hospital Center and Project ER One has already initiated a sponsored graduate student architectural program with the University of Texas A&M School of Architecture and this will continue after the establishment of the chartered ER One Institute.

An annual academic conference will be held to disseminate the Institute products and encourage academic exchange with researchers and stakeholders.

For further information or budget issues contact Michael P. Pietrzak, MD, FACEP, Director.

EROne

Appendix G *Work Plan Phase III*

APPENDIX G

WORK PLAN PHASE III

(To be submitted to HHS Project Officer directly.)

ER*One*

Appendix H *Simulation Modeling*

APPENDIX H
SIMULATION MODELING

Pierce Story, ProModel

The development of a realistic and workable plan for any Emergency Services facility requires more than an architectural design. In fact, the architectural design of any given emergency department is only a part of that department's ability to function properly. While the position of rooms, beds, and spaces is important, more important still are the actual processes that occur that allow patients and staff to flow within a given space. Without effective processes, no emergency department can function well, regardless of the circumstances or the spatial environments.

The process requirements of the *ER One* facility demand that it function effectively both under normal circumstances and during an event scenario. Creating a space that functions under both conditions requires a deep understand of the processes and patient flows that go into that function. This demands the ability to somehow map and model the flow of processes as patients would move through the facility. Under normal circumstances, an Emergency Services facility must function effectively as a normal ED. However, under an event scenario, the *ER One* facility must quickly transform and be able to handle huge increases in patient arrivals, rapid and concentrated patient acuity changes, and increased overall demands on the facility's systems.

Static tools such as flow charts and spreadsheets are often used to analyze process flow. However, these static analytical tools fail to capture the dynamic and stochastic nature of a system such as an Emergency Department, particularly a department in an event scenario. Tools which can capture the rapidly and ever-changing conditions of a dynamic environment are required to fully and deeply understand the effects of changes on the system.

Therefore, a stochastically driven Discrete Event Simulation was chosen as the tool for understanding the processes that would be necessary to allow the *ER One* facility to function properly. This Process Simulation allows an accurate and realistic model of a dynamic environment such as the *ER One* facility and allows developers a detailed understanding of the specifics of process, staffing, flow, and overall system requirements.

H.1 WHAT IS PROCESS SIMULATION?

Process Simulation, simply put, allows one to accurately model or mimic a complex process environment for the purpose of analysis. Imagine tearing the roof off an emergency department and looking down to see all the patients, staff, and Physicians moving in real time. This is essentially what a simulation is. By accurately mimicking the actual processes

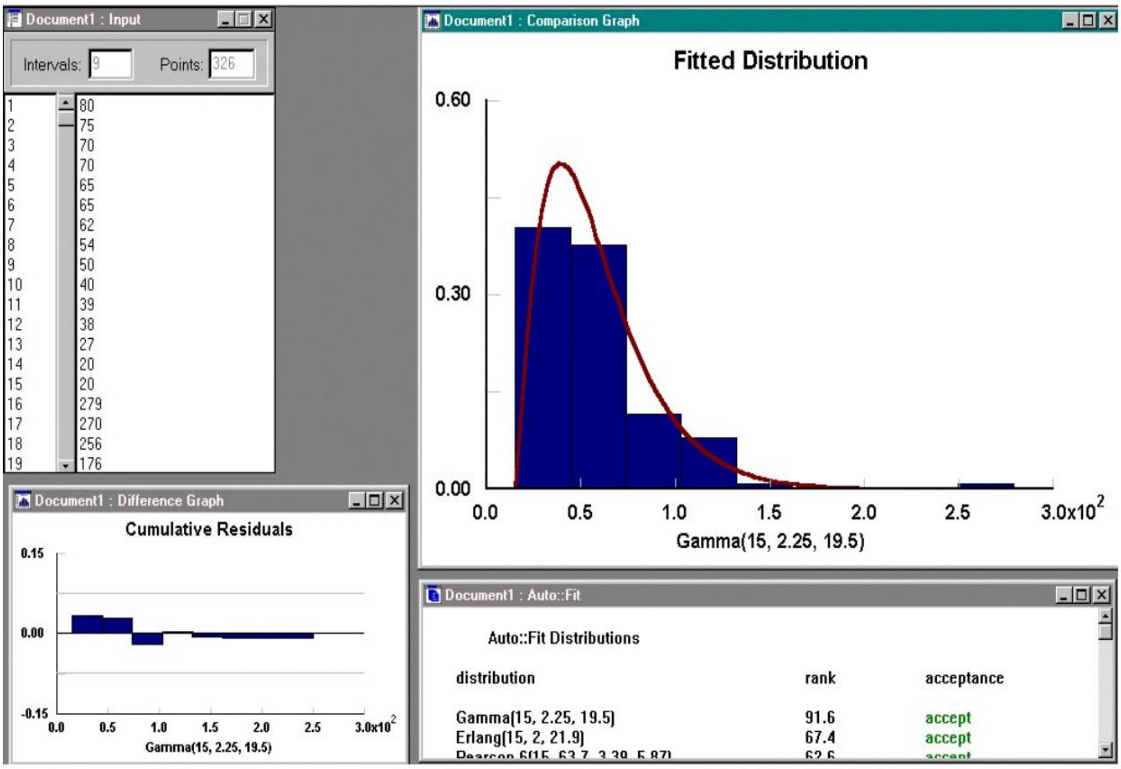
that take place, we can thereby accurately model the entire system and predict the effects of changes to the system by changing the parameters of our model. We can then quickly analyze the results of those changes in the risk-free environment of the model. Simulations are used in many environments where either the testing new processes is difficult or expensive, or where systems are not yet created, such as the *ER One* facility. By simulating the systems first, we can accurately predict how a system will function once it is in place.

Simulation has been used in American industry since the 1970's as a tool for understanding complex systems and analyzing change. In recent years, hospitals have increasingly selected this tool as a means for examining their even more complex environments. In fact, because of what simulation is capable of offering, and because of the relative extreme complexity of the clinical setting, simulation has some of its best applications in healthcare.

In general, the benefits of using process simulation as a predictive analysis tool in healthcare lies in its ability to deal effectively with five key concepts:

1) **Variability in and between processes**. All human activity is variable. That is, no two iterations of a process performed by humans are exactly the same…there is always some degree of variability in process time. Variability within a series of processes has the effect of compounding. That is, the variability of one process directly affects the next process, and the next, and the next. This variability can severely alter total system process times and flow. Worse, since each process can have its own variability, the effect of the variability on the entire system can be difficult if not impossible to understand without the proper tools. Thus, it is necessary to account for this variability in order to accurately examine processes and parameters such as patient flow, throughput, process times, wait times, staffing requirements, etc. Averages numbers commonly used in process analysis fail to account for process variability, resulting in what is called the "error of averages", which can lead to misleading results and, worse, bad decisions. And because spreadsheets and flowcharts that utilize averages do not account for this important variability, they too can yield misleading conclusions.

   In order to truly understand process, simulations take variability into account, thus allowing a much more realistic depiction of real-life processes, and more accurate predictions of throughput, process times, etc. Simulations use distributions or data curves that accurately represent the inherent variability in processes, thus mimicking reality. And because simulations account for this variability, they are inherently more accurate that other static analysis tools such as spreadsheets and flowcharts. By accounting for the variability of all of the key processes within a system, we can create a true depiction of the reality of the functional working environment.

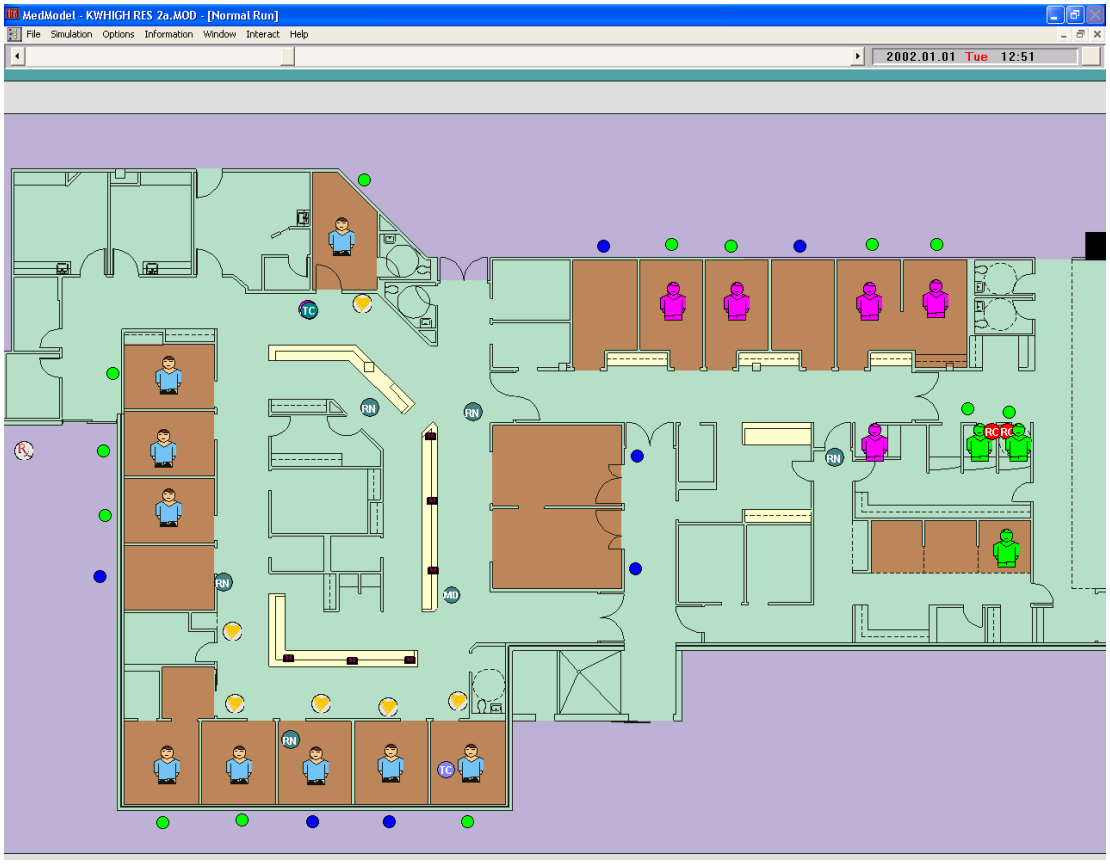


2) **Interdependencies**. Because hospital processes are interrelated, changing one affects the others in the system. For example, Radiology process times affect Physician disposition time, and lab turn-times effect triage wait times. Coupled with the inherent and often drastic variability within processes, these interdependencies make process analysis particularly complex. Simulation takes the interdependencies of processes into account, thus allowing the user to see how changes to one process can affect others both upstream and downstream. Without this capability, examination of systemwide processes and changes becomes extremely difficult, particularly in cases of complex systems such as Emergency Departments. This is particularly critical when stressing a system, such as in an event scenario. As an example, it is critical to understand the effects of increased flow and rapid patient arrivals on the entire system, and how changes to one area will affect the rest of the facility's overall functionality.

3) **Time**. Processes take place over time. Processes also change over time. Thus, in order to properly account for the effects of changes to processes, particularly subtle changes, one must be able to evaluate those changes over a span of time. Simulations

can run for hours, days, weeks, months, even years, in order to determine the true effects of changes to a system. This allows the user to see how changes, combinations of changes, and even subtle changes, will affect the overall system over the course of short or extended time periods. In the case of *ER One*, changes happened rapidly and severely, and the impacts of those changes are both immediate and long-lasting. Rapid increases in patient arrivals needs to be examined in the context of available resources, and simulation can accurately depict these time-dependent variables.

4) **Graphics**. Because simulations are not only statistical but also visual, one can actually *see* the effects of changes and problems take place as they happen in the model. For example, one will see the waiting room fill up with patients and work get backlogged when staff utilization goes down, just as it does in real life. One can see how far nurses and staff will have to travel in a new design, and understand issues around layouts and flow. This visual aspect is critical to a full understanding of changes, and allows for much better communication with staff, management, and physicians.



5) **What-Ifs**. One of the most important benefits of simulation lies in its ability to take a modeled environment and test out what-ifs. Because simulations account for variability, the interdependencies within a system, and the effects of time, **they are accurate representations of real-life systems** such as *ER One* (documented accuracy versus real-life as high as 99 percent). Because of this inherent accuracy and the structure of a simulation model, it allows the user to test the effects of proposed complex changes on the system very quickly and easily. By testing possible solutions to problems, the model becomes a risk-free environment for the evaluation of ideas and potential solutions. Combinations of complex solutions can be tried in minutes using a simulation that might take months to implement and analyze of the hospital floor. In the case of *ER One*, only a true event will test the system as accurately as the simulation model can. Thus, simulations serve as an easier, more effective predictive analysis tools for decision-making.

H.2 ACCURACY

By taking into account variability and interdependencies of processes, the complexity of multiple inter-related processes, and the effects of change over time, simulations are very accurate representations of actual complex systems. And since they are so accurate, they become not only easy but accurate predictive analysis tools.

This allows the *ER One* management staff to make some predictions about staffing needs, patient flow, and wait times, and the effects of changes to the processes, physical space, and staffing algorithms.

H.3 COMPLEXITY

And because of the robustness of the simulation software, it can account for literally hundreds of variables and processes simultaneously, enabling us to build the complexity of multiple scenarios into a useable format for decision making. Without this accounting for complexity, many decision-support tools and typical consultants far short of a full evaluation. Simulations are thus accurate, complex, and objective predictive analysis tools. And since they allow you to get to answers you might otherwise not attain, they are a valuable decision support tools for *ER One* staff. By analyzing everything from patient flow to wait times to staff utilization, simulations allow *ER One* staff a better overall view of systems and operations. And the simulation's objectivity allows for solid decision-making with objective criteria.

H.4 THE *ER ONE* SIMULATION

Due to its capabilities in predictive analysis, a simulation model was developed to study the effects of multiple possible event scenarios on the function and performance of a normal, working Emergency Department. The *ER One* Simulation allows the *ER One* staff to accurately predict the system and process alterations and requirements brought on by the

extreme and rapid changes to system conditions and demands. In doing so, the *ER One* staff can better understand what will actually happen within the facility as the events and their aftermaths unfold. This will aid in everything from staffing to contingency planning to resource and space allocation, and allow for a higher level of confidence in dealing with possible events by allowing accurate foresight into the effects of those events.

The event scenarios envisioned are inherently complex and chaotic. Patient acuities, patient types, arrival patterns, patient volumes, staffing, resources constraints, and available physical space will all change rapidly into conditions that had not yet been adequately studied. The *ER One* simulation was therefore designed to do what no commercial Emergency Services simulation had ever done before; capture the chaotic environment of various event scenarios and drop them onto the processes of a normal, working Emergency Services facility. This will allow for the kind of process testing and analysis that is required to understand the functional capability of the facility.

H.5 SIMULATION METHODOLOGIES AND INPUTS

Capturing this chaos and developing a realistic model requires a great number of inputs. The data for the *ER One* model is based on several event scenarios developed by the *ER One* staff. Each event can be modeled separately so as to allow better contingency planning based on the specifics of the scenario. In order to develop the parameters and data for each scenario, several key process drivers were required.

First, Patient types were developed based on particular event scenarios. Certain event scenarios will generate certain patient types. For example, an explosion will generate more burn victims than a biological attack. Thus each event will have its own unique patient characteristics, which can be altered within the model depending on the specific nature of the particular event.

Each patient type has a particular arrival pattern. We know from previous disaster experiences that ambulance patient do not begin to arrive immediately. Rather there is a delay in the initial arrivals. Once that arrival pattern begins however, it ramps significantly. The arrival patterns will be based on available resources, such as ambulances and helicopters, to the area of the event. Additionally, general proximity of the facility from the event site may also drive arrival delays or occurrences. So each event, depending on the cause, type, and proximity, will have its own arrival patterns.

Each patient type requires certain processing within the facility. Burn patients require different processing, staff attention, resources, and time than do laceration or orthopaedic patients. Orthopaedic patients require x-rays, others require blood work and lab tests. Some patient types such as contaminated patient with head trauma may require multiple tests of various types. Furthermore, the arrival of a critical patient into the facility will require the prioritization of tasks and the addition of specific resources. Thus, each patient type’s

processing must be accurately modeled, both in terms of the resource requirements and the prioritization of specific tasks and patient types, in order to capture the flow within the entire system.

Resources must be modeled according to their responsibilities. Physicians perform different tasks than Radiology Techs. These tasks, however, must match to patient care demands, else the model will fail to reflect the requirements on hospital resources. Thus each resource must be modeled according to a specific list of tasks and sub-tasks that the particular resource is allowed and/or supposed to perform. Furthermore, if multiple resources are allowed to perform a certain task, the priority of one resource over another may be important. For instance, a Phlebotomist might be a preferred (or primary) resource for drawing blood. But if one is not available, an RN may perform that duty in the absence of that primary resource. A third resource might be an ED technician. Therefore, it is important to specifically define the priority of resources so that the model can reflect the reality of the actual hospital environment.

As mentioned, the resources are matched with demand for care. In order to judge the number of a given resource required, the model can allow for an infinite number of possible resources, then count the number of resources being demanded at any given point in time. In doing so, the model can determine, based on the number of patients and the specific patient types in the system, the number of resources required to care for those patients.

This methodology can apply to any resources in the system, from Nurses to Beds to Respirators. Thus, based on a given patient volume and certain patient types, the model can determine the needs generated and the number of resources required to meet those needs.

In the case of the *ER One* model, certain resource types were created to fill specific tasks. Triage Runners, for example, are tasked with no other job than to transport patients from the triage area to the main ED and the patient care areas in order to free up the nursing staff from transporting tasks, allowing them to focus on nursing duties. Through the simulation what-ifs it is possible to test many possibilities for resource allocations, thus allowing experimentation with various resource mixes to determine the effects on staff utilization and patient flow.

Spatial considerations and movement is important, particularly in large area. The simulation accounts for this very precisely. Using the CAD layout of a facility as a background, the model accurately depicts the actual distance and time required to move from one place to another. The model can even determine how long it takes a nurse to move from one area to another with a loaded gurney.

All this creates the reality of the event scenario. From this new computerize reality, the *ER One* staff can then confidently test alternatives to process, staffing, and other parameters to check the results of changes made. The accuracy of the modeling process ensures a level of confidence available with no other analytical tool.

As part of any simulation, the outputs of the model are critical to understanding the important issues. As models run, data is constantly gathered on events as they happen. Imagine counters and timers attached to each patient, nurse, Physician, process, and procedure in the ED. These results of these counters and timers, if they could be captured in one place, could offer us insights into the workings of the overall system as well as specific elements of that system. Models do just that. A simulation can track hundreds, even thousands, of processes, people, and events real-time. The simulation then compiles all this information into various outputs for analysis. These outputs include graphs, charts, text, and other formats that can offer tremendous insights into the workings of a system. Everything from wait times to resource utilization to bed turns to throughput can be tracked and monitored for performance and gap analysis.

H.6 WHAT SIMULATION DOES FOR *ER ONE*

The *ER One* model focuses on the throughput and capacity of the system in order to determine critical breakdowns in process flow, process bottlenecks, staff requirements, and resource utilization. In doing so, the simulation can help the *ER One* staff determine specifically what certain event scenarios will mean to the patient flow and function of the system. The simulation will also:

- Help determine the effects of bottlenecks in the system, and the subsequent effects of correcting them.
- Help optimize spatial requirements, equipment and storage requirements, and other spatial considerations.
- Help determine proper staffing levels and the effects of various staff mixes on process and patient flow.
- Help determine the effects of various patient types, arrival patterns, acuities, and the impacts of their overall demands on the system.
- Assist in determining overall process changes necessary to implement event scenario management.

Through the use of simulation, the *ER One* staff will be better able to judge the impacts of the events on the system, the space, the staff, and most importantly the patients.