1. Danielle L. Henry hereby submit this original work as part of the requirements for the degree of Master of Architecture in Architecture (Master of).

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Supporting the System: Emergency Medical Shelters Serving in the Aftermath of a Disaster

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Supporting the System: Emergency Medical Shelters Serving in the Aftermath of a Disaster

A thesis submitted to the Graduate School of the University of Cincinnati in partial fulfillment of the requirements for the degree of

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Abstract

In the aftermath of a devastating disaster, access to even basic medical care may be limited or nonexistent. Many medical infrastructures are ill-prepared to handle the influx of cases and quickly become overtaxed. Hospitals can be damaged and rendered nonfunctional. The situation is exacerbated if the medical infrastructure was previously failing under normal circumstances. Hastily established refugee camps set up in the immediate hours and days following a natural disaster are typically unsanitary and unsafe. Under these conditions, simple abrasions can develop into more serious issues when proper facilities are not available. As a response, emergency medical shelters would be deployed into a disaster zone to provide more immediate, safer, and sanitary care to victims. They would be sent in as a modular unit system that could expand over time as additional modules are added to become a substantial field hospital. For effective pre-planning, units would be stored in various locations worldwide near areas prone to natural disasters. Final delivery to the site, following a disaster, would be via helicopter. Simple setup is required and would be accomplished within hours of delivery, typically by someone familiar with the unit and with the aid of the local community. Each unit would have the equipment and functioning systems, such as electricity and water, it needs built into it, allowing for self-sufficiency in at least the first few days. These emergency medical shelters would serve to temporarily alleviate the system and provide support until the health care system can stabilize to pre-disaster conditions.
Table of Contents

Abstract............................................................................................................................................................................................ i
Table of Contents............................................................................................................................................................................ ii
List of Illustrations........................................................................................................................................................................... iii
Illustration Credits.......................................................................................................................................................................... iv
List of Images............................................................................................................................................................................... viii
Images Credits.............................................................................................................................................................................. ix

Part 1: A Situation........................................................................................................................................................................... 1
  Setting the Scene
    Haiti: An Account of a Disaster’s Force
    Architecture’s Role
    Medical Conditions
  Perspectives on Disaster
    Disaster Relief
    Haiti: Beyond A Natural Disaster

Part 2: A Site................................................................................................................................................................................. 25
  Identifying Potential Locations
  Site Conditions
  Site Possibilities
    A Closer Look: Memphis, Tennessee, USA
  Identifying a Site

Part 3: A Solution.......................................................................................................................................................................... 45
  Precedents
    Modules
  Parameters
  Initial Design

Conclusion....................................................................................................................................................................................76

Endnotes.........................................................................................................................................................................................79
List of Illustrations

Figure 1.1: Phases of a Disaster
Figure 1.2: Actions in Phases of a Disaster
Figure 1.3: Relief Aid Relationships and Funding Channels
Figure 1.4: Non-Governmental Organizations

Figure 2.1: Documented Earthquakes, 2001-2011
Figure 2.2: Documented Earthquakes, 1951-2011
Figure 2.3: Populations at Risk
Figure 2.4: Political Risk Based on Civil War and Weak Political Structure
Figure 2.5: Population Without Access to Water
Figure 2.6: Number of Physicians Per 10,000 People
Figure 2.7: Adjusted Populations at Risk
Figure 2.8: Common Site Conditions
Figure 2.9: Common Medical Conditions
Figure 2.10: Common Secondary Medical Conditions

Figure 3.1: Combat Support Hospital
Figure 3.2: Saint Louis Hospital
Figure 3.3: USNS Comfort
Figure 3.4: MSF Mobile Clinic
Figure 3.5: Response to Haiti Timeline
Figure 3.6: Walkthrough
Figure 3.7: Activities
Figure 3.8: Spatial Areas by Importance in a Surgical Facility
Figure 3.9: Organizational Relationships
Figure 3.10: Organizational Relationships - Surgical Site
Figure 3.11: Delivery Constraints

Figure 3.12A Medical Equipment 1
Figure 3.12B Medical Equipment 2
Figure 3.12C Medical Equipment 3
Illustrations Credits

*All figures created by author as an interpretation of source given data, unless otherwise noted.

Figure 1.2

Figure 1.3

Figure 1.4


International Medical Corps, “International Medical Corps’ Mission: From Relief to Self-Reliance”, International Medical Corps,internationalmedicalcorps.org/section/about/mission (accessed November 15, 2011).


Figure 2.1

Figure 2.2
Documented Earthquakes, 1951-2011 National Geophysical Data Center / World Data Center (NGDC/WDC), Significant Earthquake Database

Figure 2.3
Populations At Risk Donald Hyndman and David Hyndman, Natural Hazards and Disasters, 2006 Update Includes New Chapter on Hurricane Katrina (Belmont, CA: Thomson Brooks/Cole, 2006), 72.

Figure 2.4

Figure 2.5

Figure 2.6

Figure 2.7
Frederick C. Cuny, Disasters and Development (New York: Oxford University Press, 1983)

Figure 2.8
David E. Hogan, “Tornadoes,” in Disaster Medicine
Figure 2.10
David E. Hogan, “Tornadoes,” in Disaster Medicine, 174-178.
David L. McCarty, “Tsunamis,” in Disaster Medicine, 231-233
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Ralph Ford and David E. Hogan, “Volcanic Eruptions,” in Disaster Medicine, 225-228.

Figure 3.1

Figure 3.2
Inside MSF’s Inflatable Hospital [Video]. (Jan. 29, 2010).

Figure 3.3

Figure 3.4

Figure 3.5
Paul Farmer, Haiti: After the Earthquake

Figure 3.11

Figure 3.12A-C
List of Images

Image 1.1: The National Palace in Port-au-Prince, Haiti
Image 1.2: The nursing school in Port-au-Prince, Haiti
Image 1.3: Tent clinic outside the General Hospital
Image 1.4: Injured boys in wheelbarrows at the General Hospital
Image 1.5: Dr. Dubique Kobel
Image 1.6: Signing of the revised Geneva Conventions
Image 1.7: Dr. Henry W. Bellows
Image 1.8: Clara Barton
Image 1.9: U.S. Sanitary Commission

Image 2.1: New Madrid seismic zone
Image 2.2: Main Hospitals in Memphis, TN
Image 2.3: Delta Medical Center
Image 2.4: Potential Site

Image 3.1: The Depot Field Hospital
Image 3.2: Partial view of into the 11th Portable Surgical Hospital
Image 3.3: Aerial of the 45th MASH unit
Image 3.4: Aerial of the 67th Combat Support Hospital
Image 3.5: An interior view of a Combat Support Hospital
Image 3.6: Aerial view of the USNS Comfort
Image 3.7: Saint Louis Hospital setup
Image 3.8: An MSF mobile clinic entering Camp Aviation
Images Credits

Image 1.1

Image 1.2
Ibid

Image 1.3
Ibid

Image 1.4
Ibid

Image 1.5
Ibid

Image 1.6

Image 1.7

Image 1.8
Ibid

Image 1.9
Ibid

Image 2.1

Image 2.2


Image 2.3

Image 2.4

Image 3.1

Image 3.2
"WW2 Military Hospitals Pacific Theater of Operations Minor

Image 3.3

Image 3.4

Image 3.5

Image 3.6

Image 3.7
MSF Haiti Inflatable Hospital Tent Setup [Video]. (Jan. 21, 2010).

Image 3.8

Part 1: A Situation
Setting the Scene

Haiti: An Account of a Disaster’s Force

On January 12, 2010 an earthquake devastated Port-au-Prince, Haiti. Measuring a 7.0 magnitude on the Richter scale, the natural event demolished the city. The earthquake lasted moments but the destruction it created is a disaster still being resolved today. Survivors, even months later, still refer to the earthquake as a life shattering experience. A 7.0 magnitude equates to enough force to destroy most masonry structures and has the capability to incite panic in people. The shaking typically lasts 20-30 seconds and can result in a visible ground offset and/or ground surface rupture. That understanding, however, does not fully encompass the intensity of the damage in Haiti. Port-au-Prince is one of the most densely populated areas in Haiti.

The city of three million is precariously built on steep, unstable hillsides, running from mountaintops into the harbor. Building construction is poorly regulated: the building code is less than a two-page document.
communities are even worse in establishing building standards. One estimate states that only five percent of the Haiti’s buildings were built by professionals while the rest are self-constructed. Shoddy construction and building practices combined with a crumbling infrastructure due to rapid urbanization and persistent poverty made it simple for the earthquake to create a death trap. A perilous situation previously, the earthquake created a catastrophe; in addition to an estimated 30,000 commercial buildings and 250,000 homes collapsing, very few municipal buildings survived. Counted among the wreckage were the Presidential Palace, the National Assembly, City Hall, and the main jail. Downed buildings and utility poles obstructed paths through the city. An estimated 300,000 died; countless others were injured. Left dealing with the deaths of loved ones and the devastation of communities, approximately a third of Haiti’s population was directly affected by the disaster. It only took days, though, for the indirect effect to grip the country.

Today, Port-au-Prince is an urban disaster. The destruction left millions of Haitians homeless. People were
crowded into a city, surrounded by rubble, without access to basic amenities such as water, sanitation and shelter.\textsuperscript{10} In the aftermath, survivors salvaged what they could and began creating new shelter. Spontaneous settlements appeared across the city. People filled the interstices and public spaces; parks became gathering grounds and makeshift homes to thousands. By mid-February, more than one million people were living in nearly a thousand camps. Some of the largest camps reached a population to rival a medium city.\textsuperscript{11} Survivors used any material on hand, creating shelter from blankets, sticks, cardboard, and any other item that could act as a roof or roof support. Attempts were made by the local authorities and the aid community for an organized response to the housing crisis, but very few achieved execution.

Dealing with shelter issues after a natural disaster has been a constant concern among disaster relief agencies and governmental organizations. Many relief personnel seek a structured approach, which would provide a comprehensible, organized method of dealing with a chaotic situation. In 1993, the United Nations High Commissioner for Refugees lectured on the lack of experienced agencies to deal with shelter problems, commenting on the necessity of a “comprehensive shelter strategy with appropriately developed standards, supply methods, specifications for units and industries to make the right products available in time.”\textsuperscript{12}
Figure 1.1: Phases of a Disaster

- Relief
- Recovery
- Reconstruction
Figure 1.2: Actions in Phases of a Disaster

RELIEF
- search and rescue
- first aid
- emergency medical assistance
- restoration of emergency communication and transportation networks

RECOVERY
- people’s returning to work
- permanent repair of infrastructure
- repair of damaged buildings

RECONSTRUCTION
- physical reordering of the community and environment
- people construct housing and other buildings
- repair roads and other community facilities
Architecture’s Role

Providing shelter is a calling to architecture. Architects can provide these needed buildings, with the belief that it will most likely be better than if the community was left to its own devices. Robert Kronenburg, an architect and senior lecturer at the University of Liverpool, notes that many relief workers “enter with the premise that those without housing in a critical post-disaster situation require outside help to replace their destroyed homes.” Ian Davis, an expert in disaster relief, comments on the standard myth that victims are helpless after a disaster and only sit in a daze simply waiting for outside help to arrive. In reality, many immediately begin to mobilize and take action to salvage and rebuild. In the last decade, a new theory has begun to take a stronger hold in which the needs of the community takes priority over the expectations of the relief agencies providing aid. This approach calls for seeking and providing for the actual needs of a victims rather than responding to the expected needs. Ultimately, the belief is this approach will result in more effective disaster response.

The architectural profession must question the appropriate roles for architects when responding to disasters. Obviously, a role exists, considering the types of destruction that victims are left with: collapsed buildings. While there are many misconceptions about what that role should be, there is still a great need for what it could be. Dissatisfactions and ongoing debates with current practices are prominent and it is undeniable that effective preparation is lacking in pre-disaster plans and post-disaster actions. While flexibility is key in dealing with any disaster scenario, disasters do follow a repetitive pattern. There is room for architecture in disaster relief but it must be analyzed as to the where and how. This process will take years, possibly decades, but there are opportunities for architecture to presently take to get involved in disaster relief.

One clear challenge is defining a role for architecture as a first responder. Dealing with developmental and reconstruction issues, a greater strength for architecture, typically falls into the category of second responder missing transition. Is it possible, however, to push for a place in architecture within the first few days? One method is to push
the standard ideas of architecture. Beyond housing, there are other important structures to tend to in the wake of a natural disaster: schools, hospitals, and municipal buildings, facilities that a community gathers around and comprise the backbone for the community have a high priority as well. Even if housing is exemplary and satisfies the collective group, without a local economy or community there is little reason for residents to remain. As Kate Stohr, a cofounder of Architecture for Humanity, asks, regarding the work being done in Haiti: “You’re just going to do housing in a place that needs everything?”

Architecture for Humanity has a multitude of ongoing projects in Haiti, specifically in Port-au-Prince, from community centers to schools to local businesses. The organization believes that by investing now in commercial corridors in the main Haitian city, there will be greater potential for economic stability, thereby preventing the government funded housing projects from turning into slums. As much as it may be desired, there is no catch-all solution to handling the destruction of infrastructure following a natural disaster. Rather than seeking perfect plans, it is more important to identify areas where architects can contribute. Housing, an obvious choice, is important, but not the only priority. Schools, commercial corridors, and medical facilities are also significant necessities if a society is expected to return in a stronger state than before disaster struck.
Medical Conditions

There is another part of the story in Haiti. In Haiti: After the Earthquake, Paul Farmer discusses the conditions in Haiti during the year following the earthquake. Farmer, a professor at Harvard’s medical college, is a cofounder of Partners In Health (PIH), a non-profit medical group that is working to provide health care to developing countries. Though Farmer touches on a variety of topics, his main concern, as a physician, is the medical conditions of Haiti after the natural disaster. Partners In Health has been stationed in Haiti for over twenty-five years. They, however, like so many other international medical organizations, were unprepared to deal with the devastation that the earthquake wrought.

The majority of Partners In Health’s work has been in the rural areas of the country but the organization has made connections in Port-au-Prince, including General Hospital, the main government hospital in the city.

The earthquake on January 12 managed to obliterate two-thirds of the hospital, incapacitating the surgical hospital, emergency room, and main operating suites as well...
as destroying the lab and its equipment and the pharmacy.\textsuperscript{20} Three days after the earthquake, the General Hospital campus was unrecognizable. The central courtyard was covered with tents and makeshift lean-tos built from sheets and pieces of plastic; this was the only protection provided to the injured. The campus was mostly dark with only a few small generators chugging power into a couple of the main wards.\textsuperscript{21} Evan Lyon, a volunteer doctor with PIH, describes conditions on the fourth day at the General Hospital:

“Approximately fifteen hundred sick and injured people were spread around the grounds of the hospital, seeking shade or creating shelter from salvaged materials. Many had nothing more than a cloth sheet for cover. A small, newer building at the top of the sprawling campus that had not been seriously damaged by the earthquake was quickly converted into basic operating rooms... Operating time was limited by daylight, though teams pushed into the night wearing headlamps. Conditions were clean but far from sterile.”\textsuperscript{22} Main hospital wards, however, were still either in the open air or set up in suffocating tents. Few survivors were willing to stay indoors for extended lengths of time; after the destruction of the initial earthquake, the aftershocks that continued for days were terrifying.\textsuperscript{23} The majority of injuries in the first few days following the earthquake were open fractures and crush injuries, procedures the initial teams at the General Hospital could not perform.\textsuperscript{24} There was where to send patients requiring advanced surgical care. For those at the General Hospital there was the possibility of being transferred to the Partners In Health-affiliated hospitals in central Haiti. Relief teams from the University of Miami had erected new MASH units near the airport; additional MASH units were made available via the Israeli Defense Forces. Follow-up care, however, was limited at these locations. Often there was no plan.\textsuperscript{25} Some victims could be stabilized for an extended period of time and then sent aboard the USNS \textit{Comfort}, a hospital ship, once it finally reached the harbor in Port-au-Prince. At the General
Hospital campus, the emergency department was setup near the hospital’s entrance in a series of tents, a difficult setting for medical work. In a *Globe* article written by Stephen Smith, the working conditions were starting to be put into words:

“The clinic treats babies, children, pregnant women, adults, the mentally troubled. A pharmacy dispenses drugs; a lab performs tests. But the staff work in a clutch of steamy tents...[said Dr. Anany Gretchkol Prosper] ‘We cannot continue to give health care under a tent. At midday, it’s [more than 100 degrees] inside, you understand?’”

These conditions such as those already described were not limited to the General Hospital. Farmer also offered stories from colleagues living and working in Haiti when the earthquake occurred. Louise Ivers, “an internist, an infectious disease and tropical medicine specialist, and a public practitioner” with PIH, was in Haiti when the earthquake struck dealt with her series of medical cases. Ivers, with a fellow colleagues, set up a makeshift first aid hospital on the driveway of the World Food Program building. Using red stickers, the two established a triage system and cared for a group of patients through the night. The work, however, was generally discouraging. “A driveway and a first aid kit are not meant to treat mass casualties,” admitted Ivers.

Dr. Dubique Kobel, a clinician with PIH, provides a narrative of living in the settlement camp established in Parc Jean-Marie Vincent. The conditions of the camp were deplorable. The air reeked from burning trash and excrements. Flies covered everything. When word spread that there were doctors in the camp and people began arriving at the Kobel’s tent. As Dr. Kobel explains, “we did the best we could in those unsustainable, unhygienic conditions.”

He and his wife each owned a stitching kit they had received upon graduating medical school in Cuba. These were the only supplies they used to begin operating on people. Eventually they were able to refer more difficult cases to a surgeon who was operating at Centre Ste Catherine and also able to travel to the pharmacy to buy medicine.
In these narratives, conditions could have been improved with a medical-specific shelter solution. Emergency operations, such as amputation, frequently happen in the open air or within poor quality makeshift shelters during a natural disaster. Even if tents are available, interior temperatures are usually sweltering, the air stale and foul, making the overall environment nearly unbearable. These situations are exponentially worse when the community lacks a sufficient health care system prior to the disaster. In the aftermath of a disaster, people may lack access to basic medical care. Refugee camps that are hastily set up in the immediate hours and days following a natural disaster are typically unsanitary and unsafe. Under these conditions, simple abrasions can develop into more serious issues when proper facilities are not available. The quality of care, however, cannot improve greatly without improving the crude conditions available for its distribution. As a response, emergency medical shelters could be deployed into a disaster zone to provide more immediate, safer, and sanitary care locations to victims.

The conditions for the victims in the Haitian earthquake are not region specific. Shortages of hospital facilities can occur in any location that suffers from a natural disaster. If a natural event renders a facility unusable, the medical system will be over-capacitated without regard to the quantity or quality of health care services prior to the event. Hospitals are built structures and therefore vulnerable to the tremors created by earthquakes. The Northridge earthquake in Los Angeles, CA, USA had a significant impact on the hospital system in the region. Eight hospitals in the city were damaged
enough to warrant the evacuation of at least one patient. Within the first twenty-four hours, four hospitals had to be completely evacuated. Assessments in the following two weeks led to the total evacuation of an additional two hospitals. Ultimately, four were forced to permanently close and face demolition.\textsuperscript{31}

It is important to note that even if all hospitals remain standing, stable, and usable they would not be able to meet the entire demand of a natural disaster. Natural disasters produce significant causalities; a disaster is medically indicated by the inability to handle the influx of cases. Hospitals are not sized for maximum capacity depending on the occurrence of a natural disaster. Therefore, the scenario frequently leaves victims with a shortage of hospital beds and lack of medical facilities.\textsuperscript{32} Considering shortages will occur even with all hospitals at complete operating capabilities, an unlikely occurrence to happen in a disaster, emergency medical shelters maintain a significant potential for use.
Perspectives on Disaster

Disaster Relief

With each disaster, hundreds of relief agencies descend upon the victims. The most common relief agencies are non-governmental organizations (NGOs). Although they are typically affiliated with a country, such as the American Red Cross is associated with the U.S., NGOs function under their own set of principles and restrictions, outside of a governing body. This separation was standardized with the sanction of the first modern NGO, the International Committee of the Red Cross.

Henri Dunant and the ICRC

Humanitarian aid stems from war. Sympathy generated from seeing wounded soldiers spawned what is now a multi-billion dollar movement. One of the first international aid workers was Henri Dunant. Dunant was a Genevan banker and businessman who, while travelling, witnessed the Battle of Solferino, a battle during the Franco-Sardinian Alliance. Local villagers helped to care for the wounded, filling in the gap left by a lack of army doctors. Volunteers, motivated by Dunant, helped all wounded men, including the enemy Austrian soldiers. During the days of tending to wounded, Dunant began to envision a group that would be trained to serve the war-wounded and accomplish what the villagers of Solferino were doing. When he returned home to Geneva, he began lobbying for the creation of such an institution.33

In 1863, Dunant, with four other Genevans, established Image 1.6 - Signing of the revised Geneva Conventions following the aftermath of World War II. In this version a provision was added to protect civilians during times of warfare.
the International Committee of the Red Cross (ICRC). The ICRC is the forerunner to all Western humanitarian aid organizations of today.\textsuperscript{34} The organization’s mission is to unconditionally ease human suffering, offering the promise of neutrality, impartiality, and independence. These ideals later became the outlines for the principles of the Geneva Conventions, first signed in 1864.\textsuperscript{35} The ICRC still functions under its original decree of helping wherever, whenever, and whomever it can and emphasizes its neutrality in any military conflict.

Significant changes came with the aftermath of World War II. Although the Geneva Conventions had already been previously expanded, after the devastation of the war, another change was made. This time civilians came under the protection of the Conventions. During the bombings and raids of the World War II, civilians had become military targets. Warfare, for the first time, claimed nearly the same number of civilians as it did soldiers.\textsuperscript{36} Majority of the International Red Cross’s work lies with helping refugees of wars. Although the ICRC maintains its only efforts in areas of military disaster, other similar groups were quicker to move beyond this scope into non-military situations. The American chapter of the Red Cross was one of them.

American Red Cross

The American Red Cross (ARC) was the brainchild of Clara Barton. Barton had volunteered during the American Civil War, dealing with the wounded first hand. Following the bloody war, she toured the country giving lectures about the conditions of the battle-wounded and the work she did. Early in her career, Barton provided aid to both sides of the war. A prescribed relaxation trip to Europe, following all of her talks, led her to become involved with the International Red Cross. She served as a volunteer at Strasbourg, France during the Franco-Prussian War of 1870-71. Upon her return to America, Barton began seeking the creation of a similar organization in her homeland.\textsuperscript{37}

The American Red Cross was not the first humanitarian organization in America. Dr. Henry W. Bellows initiated the American Association for the Relief of Misery, as an extension of the U.S. Sanitary Commission, an organization dedicated
to bringing sanitary conditions to the camps and hospitals in the Union Army, following the Civil War. None of these organizations, however, lasted longer than a decade. Clara Barton lobbied tirelessly for the United States Congress to sign the Geneva Conventions. Dr Bellows had made a previous attempt and failed, resulting in the disbanding of the American Association for the Relief of Misery from lack of funds and governmental support. Success for the ARC came in 1882, when Congress finally signed the Conventions; official government recognition of the American Red Cross arrived shortly after. 38

The American Red Cross also stood out by expanding its original work to providing aid to civilians in crises beyond war. Although the American Red Cross was officially commissioned in 1882, Barton had already formed the group in 1881 and begun working. Their first mission arrived that summer in the form of Michigan forest fires. The disaster killed 125 people and left thousands homeless. Famine reigned in the aftermath. The ARC sprang into action providing extensive assistance.39 The services provided by Barton and her troop set the tone for the expectations of the organization in the following decades.
Figure 1.3: Relief Aid Relationships and Funding Channels
The disaster relief arena is engorged with non-governmental organizations. The diagram below highlights a few that focus on medical relief and are compared based on their relative size, scope, and stance on neutral humanitarianism versus human-rights advocacy.
Non-Governmental Organizations

Since the 1980s, the number of humanitarian aid organizations has essentially exploded. Hundreds or more of non-governmental organizations and international non-governmental organizations (INGOs) descend upon each disaster event. In the 1980s, there were about 40 INGOs actively serving in camps set up for Cambodian refugees near the border of Thailand. In 1994, 250 organizations flocked to help during the war in former Yugoslavia. In 2004, nearly two thousand organizations arrived to help in Afghanistan. The United Nations Development Program estimates the total number of INGOs reaches nearly 37,000 today. As is evident, there are a lot of people and plans circling every major disaster. Rather than providing greater help, the massive influx of multiple groups can add to the chaos. Without an overall governing body for NGOs and INGOs, members are free to serve as they chose, often compounding problems through the redundancy of some issues and the negligence of others. In this environment it becomes even more critical to identify what victims need and as well as to learn to work with groups already on the ground, including locals and more experienced relief agencies.

In developing an emergency relief shelter, it would be beneficial to collaborate with a NGO already on the ground and established in the relief response system. The purpose of humanitarian aid is to serve the needs of victims but the practices of medical care have been fairly standardized in the last few decades. Though the atmosphere and layout of the medical space remains under the realm of architecture, the partnership with a medical relief agency could fill in the logistic gaps such as distribution and delivery as well as stocking supplies.

There is a range of tasks that each non-governmental organization plans to achieve when it enters into a disaster zone. Some focus on nutrition, some on shelter, and others on medical. For the development of this project, emergency relief shelters, it is important to focus on groups which enter a disaster region with the primary goal of providing medical assistance. Another dividing faction within NGOs is the stance between humanitarian aid and human rights. Where in between the two ends an organization falls impacts the methods it uses to provide relief aid as well as how the organization will interact with other NGOs.
The outspoken human rights versus impartial humanitarian aid controversy has become a greater area for debate within the disaster response community and impacts the politics of interactions among NGOs.

One well-known NGO is Medecins Sans Frontieres (MSF). MSF is an ideal partner based on four key points. The organization focuses on relief rather than development. Their primary function is aiding populations in acute medical crises. Medecins Sans Frontieres is ultimately a humanitarian organization rather than a human-rights organization. It does, however, reserve the right to speak out in extreme cases in which members believe impartial humanitarian aid is being abused. The group is the world’s largest independent medical humanitarian organization, meaning it does not require donations from government agencies. This in particular is a point a pride for the organization because being freedom from government funding allows MSF to maintain their political freedom and speak out when they believe corruption is occurring. Most importantly, for the purpose of this project, MSF seeks to address the medical needs of a community and provides it services where a medical infrastructure does not exist or where the existing structure is failing.41

Medecins Sans Frontieres

Medecins Sans Frontieres was born out of the Biafran War. In May of 1967, a region of eastern Nigeria declared itself the independent nation of Biafra. In the civil war that ensued, Nigerian troops cut off supply lines to civilians in Biafra; malnutrition set in and the International Red Cross was deployed. Though most of the world’s nations sided with Nigeria, Biafra did have one sympathizer in France. One volunteer with the French Red Cross was Bernard Kouchner. Realizing the starvation was a direct result of the blockade, Kouchner believed he was watching a genocide. When he returned to France, Kouchner broke the neutrality agreement each ICRC volunteer is required to sign and began to raise awareness of the crisis. In 1971, Kouchner and small group of French doctors and journalists created Medecins Sans Frontieres, or MSF.42

In comparison to other humanitarian groups,
Medecins Sans Frontieres takes a unique position on the spectrum. Although still considering itself a humanitarian aid organization, which espouses principles of neutrality and serving wherever needed, the organization has some human-rights tendencies. When MSF members witness any actions particularly disturbing it does not hesitate to speak out against such actions. The group has pulled out of refugee camps where it thought its relief services were overly advantageous to the rebel groups that caused the creation of the refugee camps. Typically these political scenarios play a greater role in man-made disaster situations rather than a result of a natural disaster. Regardless, this philosophy sets MSF apart from other humanitarian groups, such as the more prominent but resolutely mute International Red Cross.

Beginning as a small group in Paris, MSF has grown to touch multiple continents with its headquarters in Geneva, Switzerland and organization stemming from its main operational centers in Paris, Brussels, Amsterdam, Geneva, and Barcelona. Every national sector of MSF reports to one of the main regional five headquarters. MSF is an international organization that mainly concentrates on providing for the medical conditions of a disaster, natural or man-made. Members immediately began serving victims of natural disasters after the organization’s creation. Today, MSF is reknown for its speedy arrival, often before any other group.

In Sierra Leone, a clinic needed to be built from scratch and required completion in less than ten days. Medecins Sans Frontieres provided a fence, walls, buildings, wells, latrines, and a staff all within the time constraint. “When there’s an emergency, MSF can be on the ground with staff and equipment within days.” MSF relies on pre-packed medical kits that can be shipped anywhere within 48 hours. For an earthquake, there is a specific kit, weighing approximately 600 pounds, packed to treat one thousand slightly wounded people. Each crisis is unique but the organization realizes that natural disasters have many predictable elements.
Disaster Perspective

Beyond a Natural Disaster

Natural events can occur anywhere and frequently do. Natural disasters, however, do not occur everywhere. It takes the combination of vulnerable conditions with a natural event to create a natural disaster. In recent decades, defining disasters has become a complex process. Disasters are the results of multi-dimensional interactions and generate multi-dimensional outcomes that include elements in the socioeconomic, cultural, political, humanitarian and physical arenas. In 1994, the United Nations Center for Human Settlements attempted to provide a holistic definition. The UNCHS defines a natural disaster as:

“...the interaction between a natural hazard, generated in most cases from a sudden and unexpected natural event, and vulnerable conditions which cause severe losses to man and his environment (built and natural). These losses create suffering and chaos in the normal patterns of life, which lead to socioeconomic, cultural, and sometimes, political disruption. Such a situation requires outside intervention at international and national levels in addition to individual and communal responses.”

While the UNCHS definition takes each aspect into consideration, it is still difficult to understand the depth of natural disasters. An expansion in the perceptions of disasters is necessary. The understanding of the physical elements a disaster, such as an earthquake occurs from the movement of tectonic plates, serves its purpose but should be limited to the comprehension of natural events and natural hazards. Natural disasters, however, fall under the scope of environmental, social and developmental issues. Each of these has a different perspective on the occurrences and reasons for natural disasters.

According to the ecological perspective, human actions are increasing natural disasters through inadequate or inappropriate interaction with the environment. Often people and cultures make changes in the environment without realizing its long-term impact. When someone chooses to built on sand dune, the construction ultimately destroys
a natural barrier to the sea leaving the homeowner more susceptible to hurricanes and storm surge, thereby increasing the potential for a natural disaster. 49

The social perspective views a society’s values and institutions as factors of the society’s vulnerability. 50 People continue to live in disaster prone areas because their day-to-day routines have a greater significance than a potential event in the future. When a typhoon struck Chittagong, Bangladesh in 1992, people returned and rebuilt in the same vulnerable areas because the coastal region supports port and fishing activities, which, in turn, financially supports them. 51 There was an ingrained social heritage and way of living that took precedence over the potential of another disaster in determining resettlement.

Prior to the occurrence of a natural disaster, the developmental perspective discusses settlement growth and construction materials. Rapid urbanization is a common vulnerable condition that leads to a disaster. 52 Shoddy building practices as a result of poor construction regulation in Haiti should stand as a testament to the importance of appropriate construction methods and building materials in a hazard zone. The developmental perspective also encompasses human actions following a natural disaster. The impact of a natural disaster can be magnified by poor relief responses and inadequate emergency operations. Hurricane Katrina in 2005 and the devastation in New Orleans are exemplar models of the impact a poor response can have.

Natural events do not discriminate but often have a greater impact in certain parts of the world, such as developing countries regions. As mentioned above, natural disasters are the outcome of natural events interacting with vulnerable conditions created by human action. Each of the current perspectives on disaster discussed some of these vulnerable conditions. Common actions that develop vulnerable conditions include rapid urbanization, poor housing conditions, environmental degradation, inadequate resources, and political instability. 53 Haiti was the result of the vulnerable conditions and a natural event. Since its formation following the slave revolution in 1804, Haiti has been stricken with political violence and consistent upheaval. The
instability this fosters has repeatedly ruptured the development of infrastructure. Evan Lyon, a physician with Partners In Health, provides a summation of Haiti’s condition:

“A number of factors, from physical and environmental to political and social, left Haiti vulnerable and exposed to the devastation of the earthquake. This is a scenario that is often repeated in developing countries as well as some developed countries. People and societies continue to make poor decisions, which foster vulnerable conditions.

“Earthquake illness is a disease of social construction its severity determined more by the capability of buildings to withstand seismic activity than by the intensity of a tremor. The capability to respond as emergency and health care workers depends, as we’ve seen tragically in Haiti, almost entirely on how physical and human infrastructure fare on shaking ground.”

A number of factors, from physical and environmental to political and social, left Haiti vulnerable and exposed to the devastation of the earthquake. This is a scenario that is often repeated in developing countries as well as some developed countries. People and societies continue to make poor decisions, which foster vulnerable conditions.
Part 2: A Site
Identifying Potential Locations

Designing an emergency medical unit requires understanding its potential locations of use. At first pass it may be assumed that a unit could possibly be sent anywhere in the world. This expectation, however, is not entirely necessary. There is a wide range of disasters that afflict populations worldwide yet a shelter of this style would serve victims of acute natural disasters. Acute disasters include earthquakes, volcanoes, tsunamis, hurricanes, tornadoes, and floods. Although the majority of these events are predictable, their onset is rapid and can therefore still be overwhelming and overtaxing to a system. Each of these natural event types has occurred at least once in past few decades, though some more frequent than others. Natural events, however, do not occur everywhere. One area, for example, may suffer from frequent hurricanes but rarely see a tornado.

Decades of scientific study have lead to the production of risk maps. Risk maps are developed based on past activity of a particular natural event, such as an earthquake risk map would be the result of data from previous earthquake locations and their frequencies. A risk map indicates that potential of an area to suffer from the natural event identified for the risk map generation. Figures 2.1-2.3 show the progress in the development of the risk map; in this example, the natural event studied is the occurrence of earthquakes. Figure 2.1 “Documented Earthquakes, 2001-2011” displays the location of earthquakes recorded in 2001-2011 by the National Geophysical Data Center. It also illustrates the magnitude, or measured size, of the earthquake, as well as the intensity, or impact, of the earthquake. Though informative, this diagram alone, however, is inadequate in predicting future earthquake occurrences. Seismologists, therefore, research a greater range of past earthquake activity. Decades, versus only years, of recorded seismic activity provides a more accurate understanding of earthquake frequency and locations that can be utilized for earthquake prediction. Figure 2.2 “Documented Earthquakes, 1951-2011” shows this expansion of data from the previous data set shown in Figure 2.1. An analysis of this data translates into a risk map, as shown in Figure 2.3 “Populations
Risk.” Risk maps are used to identify which areas of the world are most likely to suffer from the physical occurrence of an earthquake.

While risk maps provide one level of elimination, further defining potential locations that may require a medical shelter following an acute natural disaster can continue to be narrowed. As discussed previously, the occurrence of a natural event does not inevitably equate to a natural disaster. It also does not inevitably equate to a need for a medical shelter. An emergency medical shelter would be sent when the existing infrastructure is swept away by the disaster. The intention for the shelter is to provide a temporary link between the current, unanticipated situation and the development of a permanent solution. Prior to the occurrence of a natural disaster, it would be beneficial to identify areas likely to suffer from the destruction of the medical service infrastructure.

There are a variety of factors that can be analyzed to identify areas with weakened infrastructures. Figures 2.4-2.6 present some of these factors. Political risk, identified in Figure 2.4 “Political Risk Based on Civil War and Weak Political Structure”, has an impact on the response system following a natural disaster. Without a definitive authoritative hierarchy, a society suffering from a natural disaster will lack guidance creating a greater potential for the exacerbation of the disaster. A rapid action plan can help minimize the secondary effects of a natural disaster. When the leadership role is defined there is someone or organization to step up and activate rehabilitation plans; areas dealing with political strife will most likely lack that capability.

A society will also have greater difficulty handling a natural disaster if there are inadequate resources. Natural disasters will overtax a system in any location but this is amplified in areas already suffering from insufficiencies. One necessary resource to performing medical care is water. Areas previously lacking access to water, indicated in Figure 2.5 “Population Without Access to Water”, face a more pronounced crisis when a natural disaster strikes.

Another prior condition impacting medical care is an already weakened system. If the medical infrastructure operates at, near, or over peak capacity prior to the disaster, it
will most likely collapse under the additional weight brought by the disaster. Figure 2.6 “Number of Physicians per 10,000 People” illustrates areas of the world already suffering from a poor medical structure by looking at the number of physicians per ten thousand people.

Once these adjustment factors are accounted for, an adjusted risk map can be developed. One example is shown in Figure 2.7 “Adjusted Populations in Risk.” In the adjusted risk map, each of the previously mentioned factors that can affect a natural disaster’s impact has been enveloped in determining a population’s potential need for an emergency medical shelter. Additional factors that can be included are indicators of an increased potential for a natural disaster to escalate to a social disaster. These factors include the number of hospitals per population, additional resource inadequacies, including sanitation and electricity, and population density. Higher population densities typically indicates a greater risk for injury. All of these factors, as well as others not outlined here, provide insight into who will most likely require this particular medical aid in the aftermath of a natural disaster.
Figure 2.1: Documented Earthquakes, 2001-2011

LEGEND
- Year
  - 2001-2011

Magnitude
- 4.0
- 6.5
- 9.0
*based on size of circle

Intensity
- 2
- 7
- 12
*based on opacity
Figure 2.2: Documented Earthquakes, 1951-2011

<table>
<thead>
<tr>
<th>Year</th>
<th>Magnitude</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001-2011</td>
<td>4.0</td>
<td>2</td>
</tr>
<tr>
<td>1991-2000</td>
<td>6.5</td>
<td>7</td>
</tr>
<tr>
<td>1981-1990</td>
<td>9.0</td>
<td>12</td>
</tr>
</tbody>
</table>

*Based on size of circle

*Based on opacity
Figure 2.3: Populations At Risk

LEGEND
- lowest hazard
- low
- medium
- high
- very high
- highest hazard
Figure 2.4: Political Risk Based On Civil War and Weak Political Structure
Figure 2.5 : Population Without Access to Water
Figure 2.6: Number of Physicians Per 10,000 People
Figure 2.7 : Adjusted Populations At Risk
Conditions

Site Conditions

Siting an emergency medical shelter can be a challenge considering its exact required location is very unlikely to be known prior to a natural disaster. This means a variety of site accommodations need to be developed within the model. There are, however, certain site conditions, shown in Figure 2.8 “Common Site Conditions”, which can be expected depending on the type of natural disaster. These are common outcomes of a natural disaster and can help plan accordingly prior to the occurrence of a natural disaster.

Medical Conditions

It is important to understand the medical conditions brought on by natural disasters. Grasping the types of the activities required to treat victims will translate into the spaces needed for medical care. Outlined in Figure 2.9 “Common Medical Conditions” are acute medical conditions that may arise out of natural disasters depending the type of disaster. Figure 2.10 “Common Secondary Medical Conditions” shows secondary medical conditions, such as communicable diseases, that begin to appear in a second wave of medical care.
### Figure 2.8: Common Site Conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Earthquake</th>
<th>Tsunami</th>
<th>Volcano</th>
<th>Hurricane</th>
<th>Tornado</th>
<th>Flood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Destroyed or damaged buildings</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sunken buildings</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underground structures collapse</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damage from debris</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inundates all structures in path</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buries buildings</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Disrupts waterways</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Broken utility lines</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Broken water and sewage lines</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Flooding</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Avalanches/landslides</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Fires</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Disruption of transportation</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Disruption of communication</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
KEY OF MEDICAL AILMENTS
A. fractures       E. severe head injury
B. lacerations     F. puncture wounds
C. blunt trauma    G. skin rashes
D. crush injury    H. respiratory ailments
I. hypothermia     J. near drowning
K. fluoride poisoning
L. nausea and vomiting
M. headache
Figure 2.10: Common Secondary Medical Conditions

- Crowded living conditions
- Broken energy sources
- Broken sewage lines
- Broken water pipes
- Floodwaters/storm surge
- Airborne illnesses
- Vectorborne illnesses
- Waterborne illnesses

Events:
- Earthquake
- Volcano
- Tsunami
- Hurricane
- Tornado
- Flood
Site Possibilities

A Closer Look: Memphis, TN, USA

Memphis, Tennessee lies within the New Madrid Fault Zone. While earthquakes are commonly known for occurring at tectonic plate boundaries, intraplate earthquakes are also a frequent occurrence. The New Madrid Fault Zone, comprised of several thrust faults, generates such intraplate tremors.2

New Madrid Fault Zone

Light to moderate earthquakes occur with regularity in the New Madrid Fault Zone. Approximately 150 earthquakes are recorded in the Central United States each year.3 Most are too small to be felt but some have been significant enough to cause damages and result in loss of life. Large earthquakes, however, have occurred in the past and the fault zone has potential to generate very large earthquakes in the future. Over the past 4,500 years, the New Madrid fault zone has produced sequences of major earthquakes with regularity.4

The three most powerful earthquakes in recorded United
States history struck the Mississippi Valley in the winter of 1811 and 1812. Historic reports from survivor accounts indicate the strength of the earthquakes even though their occurrence precedes the seismograph, today’s standard measurement of an earthquake’s magnitude. Accounts tell of visible cracks in the Earth’s surface, rolling grounds, and large areas of land to sink or rise, including the formation of the Reelfoot lake. There are even accounts of the Mississippi River flowing backward for a period. Current best estimates place the earthquakes power between 7.0 and 8.0 magnitude. Earthquakes recorded at 5.0 magnitude in the New Madrid Fault Zone are fairly common with historical seismic patterns indicating a threat for another large earthquake equal to or larger than the 1811 earthquakes.

The Current Threat

If an of equal magnitude to the 1811 earthquake were to occur in the region today the impact would cause greater devastation. Over three million people live in the region with areas of dense urban population, including Memphis. A recent simulation conducted by the Mid-America Earthquake Center estimates potential effects for the region should there be a New Madrid Earthquake repeat. The study estimated that nearly two million people would likely require short-term shelter by day three after the event. Numerous fires would likely occur, particularly near the epicenter and metropolitan areas. Approximately fifty percent of urban households would suffer from lack of water with restoration of services taking weeks to complete. An estimated 2.6 millions households would be without power. The number of buildings damaged could reach close to 715,000, hospitals included. In fact, hospitals would likely suffer significant damage with of nearly 150 becoming nonfunctional. The study released numerous other indications about the harsh realities of the potential devastation from the New Madrid Fault Zone. Most of the population, however, has not taken action to prepare these possibilities.

In the Line of Fire

Lack of preparation only identifies one piece of the potential to increase the impact of an earthquake occurring
in the New Madrid Fault Zone. Due to a variety of factors, Memphis does not need to experience an earthquake of large magnitude (7.5 or greater) to suffer from significant damage. Memphis sits on a one-kilometer thick layering of soils, sands and clays deposited in the Mississippi Valley. Geological compositions can significantly change the way an earthquake feels and how the ground shakes during the tremors. Softer soils, such as those Memphis is built on, have a lower attenuation meaning a larger increase in ground motion. Seismic waves traveling in such soils travel for greater distances and at slower time periods, creating greater potential for damage. 

Loess soil underlies much of downtown Memphis as well as along the Wolf and Lossahatchie Rivers. Loess soil is a type of silt, classified between clay and sand, and noted for the uniformity in size and shape of its particles. The particles also have rounded edges which allows for the particles to slide past one another once they become moist. High volumes of water, such as during heavy precipitation, can cause collapse. By nature, loess soil is geologically unstable, even without disturbance. Historic earthquakes have resulted in liquefaction and large areas of sand blows. The 1811 earthquake produced ground shaking strong enough to force sand eruptions at the surface and triggered landslides. Due to the area’s geology, Memphis has significant potential to suffer damage from liquefaction and prolonged ground shaking as well as widespread damage from larger areas being impacted.

One of the worst building types to handle earthquake tremors and the subsequent ground shaking is masonry constructed without steel reinforcement. This type of building, unfortunately, was very popular when the Memphis region was settled and such construction flourished until the 1970s. Many residences and some commercial buildings are constructed as unreinforced masonry creating a greater hazard and potential for collapse. Older buildings can be retrofitted to increase seismic resistance, but it is unlikely this has occurred on a widespread scale, particularly in residential buildings.
Identifying a Site

Although site possibilities can be nearly anywhere since earthquakes, and other natural disasters, strike in multiple places around the world, there is still a process in site selection that could become relatively standardized. In this scenario, Memphis, Tennessee is used to showcase the steps.

Upon learning about a devastating natural disaster and recognizing the need for the emergency medical unit system, first identify hospitals in the area. This can be done through quick, rough research, or, more ideally, by communicating with locals on the ground. In Image 2.2, the main hospitals in Memphis, TN have been indicated by red dots.\(^{18}\) Gathering basic information about each of the hospitals identified is also significant. The purpose is to determine the most appropriate hospital with which to associate. When people are traumatized it is most likely they will travel to what is familiar.

The next step is to actually pick a hospital. When under medical distress people are most likely to migrate to the nearest hospital, particularly if a hospital is known for its trauma care and/or emergency center. This hospital will quickly become
overtaxed and overwhelmed, even if it is unaffected structural by the earthquake tremors. Hospitals located in or near areas that are poorly constructed, rapidly deteriorating, and/or suffering from rapid urbanization will most likely experience a great caseload as these types of areas are impacted greater by an earthquake. In Image 2.3, the Delta Medical Center is indicated on the map. The Delta Medical Center is well known in Memphis for its trauma care, and therefore likely location that people will take their injured.19

Finally, locate a green space nearby for a site with the greatest potential. Majority of injured people will be travelling to the nearest hospital locating the emergency medical unit in the prime location to serve the injured. A green space is also likely to be free, or nearly free, from debris following an earthquake. Image 2.4 shows a potential site very near to the Delta Medical Center, on which the emergency medical units could set up. Following this method in each disaster scenario can lead to a quicker site potential assessment leading to a faster setup, as well as meeting the affected population where they already are.
Part 3: A Solution
Precedents

Currently, there are organizations already handling the development and use of field hospitals. They are, typically, groups who enter a disaster zone with specific attention to providing medical care. Over decades of experience, medical relief agencies have been honing their skills and response times to various disaster scenarios. One group, Medecins Sans Frontieres, has already been discussed. There are many additional organizations that utilize deployable hospitals. The group that has made some of the most significant contributions to the development and use of field hospitals is the United States military.

Image 3.1 - The Depot Field Hospital, the largest of seven field hospitals set up at City Point, VA during the American Civil War.

Modules

U.S. Military

Field Hospital

The United States military has been developing deployable hospitals for decades. The first were mainly used during the American Civil War, a common beginning ground for American humanitarian efforts. The first in a series of on-site hospitals was the field hospital. Its development derived from the necessity to fill a gap in the chain of evacuation for wounded men off the battlefield. A mobile unit that could temporarily treat soldiers on site until they can be removed, it traveled as a kit with tent-like structure to allow for easy setup. The Depot Field Hospital was the largest of the seven field hospitals that operated out of City Point, Virginia during the American Civil War. Covering nearly two hundred acres, it had the capacity for ten thousand patients and included twelve hundred tents and ninety log cabins. Due to the excellent care provided by the staff, it was also considered one of the finest hospitals of its kind.
Portable Surgical Hospital

In the 1940s, the military developed the portable surgical hospital. As the name suggests, it was designed to be portable but more specifically, it was designed to be carried by only the team operating it. This design marks a significant departure from past mobile units. Under this parameter, all equipment, supplies and rations were limited to what twenty-nine men could carry. Unfortunately, it was a limitation that severely hindered the hospital’s capability. Within less than a decade, the portable surgical hospital would be edged by the mobile army surgical hospital.

MASH

The mobile army surgical hospital, better known as MASH, was first established in August 1945 and then deployed during the Korean War. Originally identified as auxiliary surgery groups (ASGs), MASH units developed from research on the optimal delivery of surgical care in the battlefield. Traveling with the troops, these units were small and mobile, easy to setup and closer to the frontline than the larger field hospitals that supported it. Their implementation lead to fewer casualties and large improvements in combat medical care. MASH units were used in every major United States military conflict until the last one was retired on February 16, 2006 during Operation Iraqi Freedom.²
Combat Support Hospital

Combat Support Hospital (CSHs) are the most recent in a long line of field hospitals used by the United States military forces. From their introduction in the 1970s, they began phasing out the use of the MASH unit.3 CSHs are delivered in standard military owned Demountable Containers (MILVAN) Cargo containers.4 A distinct advantage is the flexibility of scale since tents can be chained together. Due to its modularity, the CSH can easily expand by linking tents together. The CSH takes an additional unique step compared to its predecessors through separation into two components, and Hospital Unit Base (HUB) and Hospital Unit Surgical (HUS). Each of these can be deployed ahead of the other as well as be added to later. Unlike some of its predecessors, the combat support hospital does not setup at the front line. Soldiers first medical contact, instead, occurs at Battalion Aid Stations. The units are capable of creating and maintaining a climate-controlled environment as well as providing sterile operating rooms and intensive care units.5 The current design is second generation following the less successful, Medical Unit Self Contained Transportable
Figure 3.1: Combat Support Hospital

A Combat Support Hospital includes a Hospital Unit Base and Hospital Unit Surgical.

Delivered via military owned Demountable Containers.

Set up of either Hospital Unit Base or Hospital Unit Surgical.

Chain together to expand as needed.
(MUST) Hospital, which required too much fuel to remain a sustainable solution. Combat support hospitals are set up in the Corps Support Area. Parts are assembled by the staff into a functioning tent hospital.

The bulk of the combat support hospital needs to be further understood. The United States military functions as a well-oiled machine. Actions may not translate well into civilian scenarios. Military operations rely on a distinct organizational structure with a clear leader. Even in situations less of a social disaster than Haiti, the organization is minimal. Though there is an option for a relief organization to step in with a pre-defined structuring, it is widely recommended and accepted to defer to the authority of the afflicted country.

Still, it remains that the CSH could present a option in handling the situations created by natural disasters considering its experience in man-made disasters. Issues it faces are similar to those of the Saint Louis Hospital set up by Medecins Sans Frontieres. Shipping containers would most likely arrive via aircraft, requiring a landing area in an area devastated by destruction. A large site is also required as well as a large labor force to set up the tent. Unlike military scenarios where the staff is already on the ground, a staff would have to be flown in as well or planned to cultivate and establish a unit on the ground.

Hospital Ships

The United States Navy has also developed its own specific mobile hospitals, U.S. Navy Hospitals Ships. Since the late 1980s, two have been created. One, the USNS Comfort, is an oil tanker outfitted as a mobile hospital that can be fully manned and out to sea within five days. It has twelve operating rooms and a 1,000-bed ward. It is intended to function as a full hospital on the water.
Responses to Haiti

Responses to the earthquake in Haiti exemplify some of the most recent uses of field hospitals and deployable medical shelters. The three precedents outlined below include the Saint Louis Hospital set up by Medecins Sans Frontieres, the USNS Comfort docking at the harbor in Port-au-Prince, and MSF mobile clinics that travelled from camp to camp to provide medical care to refugees. Each has its advantages but ultimately all could be improved upon.

MSF: St. Louis Hospital

When the earthquake struck Haiti, Medecins Sans Frontieres already had a team on the ground dealing with chronic medical conditions in Haiti. Similar to many organizations in Haiti, however, their facilities were part of the damage and therefore unusable. Patients that survived were relocated outside and treated under tents for days following the catastrophe. Within three days of the earthquake, the main MSF headquarters had loaded a plane with shelter materials and taken off to Haiti. However, a lack of a viable landing strip forced the supplies to deplane in the Dominican Republic. From there, the units were loaded onto trucks and delivered to the site. The final setup would include nine tents, each approximately 1,000 square feet, requiring a grand total of nearly 9,000 square feet to set up. A soccer field behind a high school became the designated location. Once the pallets were on site, it took 48 hours to erect all nine tents with the help from hundreds of locals. In its completion, each unit was set aside for a specific function, including one for surgery. Within a week of the disaster, MSF had a fully functioning hospital.8
Initially, the setup MSF provided is difficult to critique. In less than a week, the organization had an entire hospital unit setup, including an intensive care unit. The scale alone of a hospital at 9,000 square feet is impressive. Even when many of their own structures were destroyed and staff lost, MSF was able to mobilize efficiently and effectively. The hospital created a sanitary and controlled location to provide medical care to victims. It also provided potable water, sustained its own electricity and handled its own waste.\textsuperscript{9} A single tent could be set up in three hours.\textsuperscript{10}

The setup and delivery, however, could still use some perfecting. The material was sent via aircraft. Although three days is a quick turnaround for providing enough material and supplies, the delivery method created a significant time lapse. Aircraft landings were not possible in an area where the majority of the infrastructure had been ruined. Though this time of transport is glossed over, knowledge of other scenarios informs of a strong possibility of issues with customs and other governmental slowing points. Pallets still had to be loaded onto trucks and driven to the site. Once there, 48 hours of patience were still required before the setup would be complete and functional, and many helping hands were necessary through the whole ordeal. Overall, the system seems very labor intensive. Yet, the organization can still be commended for establishing Saint Louis Hospital within a week time frame.
Figure 3.2: Saint Louis Hospital

0
flooring is laid out and then air introduced into the tent skin

3 HRS
the tent gradually inflates over a few hours
the tent is pulled and set into place using ropes

Configuration - nine tents

Layout
operating area
observation area
recovery area

one of the nine is a surgical unit
USNS Comfort

The USNS Comfort was activated to serve Haiti, docking at Port-au-Prince eight days after the disaster. Patients were brought aboard by boat or helicopter, treated and then discharged back to hospitals on the ground. The ship held one thousands beds, with nearly hundred of them outfitted for intensive care. It also included twelve operating rooms, a large staff and diagnostic equipment.\textsuperscript{11} The greatest factor about the USNS Comfort is the fact that it is a high quality hospital, meaning it was clean and efficient and spacious, with mobile capabilities as well.\textsuperscript{12} Its capacity is significant considering the extent of its surgical capability. The amount of care the ship was able to provide to victims is nearly unqualifiable. USNS Comfort offered a feasible emergency unit at a critical time. Not only did it provide quality care, it provided a sanitary and spacious medical facility when there were few available on the ground.

There are still critiques, however, for consideration. It took five days for the USNS Comfort to be manned and prepared for departure. The travel time took an additional two-to-three days, pushing its arrival to day eight in the aftermath of the earthquake in Haiti. The additional medical facilities, particularly their superior quality of environment, and staff were a welcome addition to the relief effort. However, patients could only reach the facility by boat or helicopter. Helicopters are disadvantaged by their limited capacity; multiple trips must be scheduled to relocate patients from site to ship and back. The second arrival option, by boat, can have even greater limitations. Some patients would not be able to weather the choppy ride through waves to the boat forcing them to join the helicopter queue. A trip by boat also took up to twenty minutes, a significant amount of travel time for an emergency care situation.\textsuperscript{13} The ship’s overall arrival at eight days past the earthquake also begins to push it out of the emergency response category. At that point the USNS Comfort is mainly dealing with second response conditions.
Figure 3.3: USNS Comfort
MSF: Mobile Clinic

Medecin Sans Frontieres, MSF, frequently use mobile clinics as part of their missions. These mobile clinics take the forms of SUVs, with the Land Cruiser being a favorite, as well as boats and buses. The mobile clinic that MSF brought into the Aviation Camp in Haiti, one of the largest refugee camps following the Haiti earthquake, was a refitted school bus. It was one of four that MSF mobilized in the months of the disaster. The bus contained four consultation rooms. While on the move, these consultation rooms serve as storage. Once the clinic reached the camp, the team found a location to set up, setting out tables, chairs, and canopies to create makeshift waiting areas as well as additional consultation areas if enough privacy could be available. Two doctors, a nurse, a midwife, and a mental health officer man the clinic, which functions as an outpatient unit. At the Aviation Camp, the clinic saw approximately 160-170 patients a day ranging from general practitioner to emergency aid.

Though no hard data is provided, it is most likely the four mobile clinics were deployed mainly in the months after the earthquake rather than days. Considering the extent of the damage to the infrastructure would make the areas quite impassable for days. Additionally, the intent of the mobile clinics is to spread out and travel to where people have established refuge. This ideal sets it more firmly in the recovery stage rather than the response stage. It is a viable medical outreach option but during disaster crises it hits multiple limitations, particularly actual travel. It is common in natural disasters for the medical infrastructure to be significantly damaged and/or flooded. Both of these conditions limit the travel of most types of vehicles.

A distinct advantage of the mobile clinic is its site flexibility. The clinic requires only a small lot to set up; as long as the bus can park it can function. Ideally the lot would be more spacious than a single parking location. More space allows for greater expansion of the clinic, another advantage to this type of response setup. The clinic sent to the Aviation camp will consistently have four consultation rooms but the clearing surrounding the bus allowed for additional tables and chairs. Not only did it increase the number of patients
handled per day but it facilitated better organization, such as in providing waiting areas and queuing locations.

Image 3.8 - An MSF mobile clinic entering Camp Aviation
Figure 3.4: MSF Mobile Clinic

Layout
Figure 3.5: Response Timetable to Haiti

- **DAY 3**: Supplies loaded on a plane and sent to Haiti, however forced to land in Dominican Republic for Saint Louis Hospital.
- **DAY 5**: Saint Louis Hospital set up begins on Saint Louis Hospital.
- **DAY 7**: USNS Comfort sets sail from Baltimore port.
- **WEEK 3**: MSF Mobile Clinics sent out to camps.
Parameters

Activities

Figures 3.6-3.7 begin to explore the types of activities that will occur within a medical unit. Figure 3.6 “Walkthrough” establishes three walkthroughs from the viewpoint of a doctor, patient, and nurse. Each has their own function and activity but interaction between each type of person still occurs. Figure 3.7 “Activities” begins to define more specific activities that will need to occur in the medical unit based on the patient and the doctor or nurse.

A doctor’s tasks typically revolve around providing patient care, spending most of the day/shift examining patients and administering appropriate medical care as well as delegating tasks to the nursing staff on hand. The other main task for a doctor is determining the need for surgery and beginning the process.\(^\text{17}\)

The main focus of the nurses is patient care. A nurse’s main tasks include administering medication and treatment as per doctor’s instructions, monitoring the patient, preparing and updating patient records and assisting the doctor in various medical procedures.\(^\text{18}\)

Patients are generally at the mercy of the doctors and nurses. Consultations are used to determine the severity of a patient’s medical condition and then assessed to determine the appropriate treatment. When surgery is determined to be necessary, a patient is setup to be prepared for surgery. Patients will be sent to preoperative care, then to undergo surgery, followed by postoperative care and finally recovery, until they are stable and able to be discharged.\(^\text{19}\)

Figure 3.8 “Spatial Areas by Importance in a Surgical Facility” shows the beginning of exploration in the definition of spaces. It is organized to reflect the hierarchy of spaces with the most essential elements are in the center. Since the unit is sent in a short amount of time, it is important to understand what is necessary versus what is ideal. The most basic unit to be sent as an emergency medical shelter is the surgical unit. Working from this knowledge, it is important to understand what are the current expectations of a surgical suite as a standard of design. Although adjustments will have to be made
to accommodate the use of the facility as a deployable structure, or field hospital, the standard for a typical hospital provides a good baseline to begin to work from.

A typical surgical suite is divided into three areas. The unrestricted area includes a central control point to monitor the entrance of patients, personnel and material. The semirestricted area includes the support areas for the operating and procedure rooms, such as storage for supplies. The restricted area includes the operating and procedure rooms, the clean core, and the scrub sink areas. A surgical suite must be located and designed to prevent non-related traffic through the area. It must also be arranged to prevent crossover between sterile areas and contaminated areas. The number of operating rooms and recovery beds are sized based on the expected surgical workload.20

One of the main areas of the surgical suite, and the focus of the emergency shelter design, is the operating and procedure rooms. These areas will require the greatest amount of design and restrictions in size and creation of a sterile environment. Other main areas of a surgical suite are the pre-operative and post-operative holding areas. In these environments a patient’s surroundings will mainly be confined to his/her bed. These areas should be under the direct control of the nursing staff. There should also be privacy provided between the patients.21

Support areas for a surgical suite include: a control station, a documentation area (to keep medical records, etc.), a medication station, scrub facilities, a patient holding area, a clean room, a soiled or disposal room, an anesthesia workroom, storage for equipment and supplies, as well as a staff changing area.22 Figure 3.9 “Organizational Relationships” begins to look at a possible spatial arrangement of the main spaces. Figure 3.10 “Organizational Relationships - Surgical Suite” narrows in on the surgical suite and focuses on a possible arrangement of its main spaces.

Spatial arrangements will be impacted by the activities and connectivity needs of certain spaces. Direct connections are needed between the preoperative, postoperative and operation rooms. Separation of soiled versus clean areas is also significant. The layout of surgical area components will setup a system for the extension of the rest of the field hospital.
Figure 3.6: Walkthrough

Doctor
- assesses cases brought to him by nurses
- examines patients
  - administers appropriate medical care
    - delegates medical directions to nurse
      - determines patient needs surgery
        - prepares for surgery
          - performs surgery
            - checks in on recovering patient
            - repeats process starting with examining patient
  - delegates medical directions to nurse
    - determines patient needs surgery
      - prepares for surgery
        - performs surgery
          - checks in on recovering patient

Patient
- sustains injury
  - arrives at surgical facility
    - taken to consultation area by nurse
      - examined and determined to need surgery
      - given anesthesia (timeline gap)
        - wakes in recovery area; other patients on either side
        - stays in bed, occasionally dozing, waiting to be discharged
        - seen by doctor for follow-up
          - nurses continually check on him

Nurse
- handles patients as they arrive and directs them to the correct area
  - conducts initial assessment of patient
    - administers medical care
      - retrieves the doctor
        - follows doctors instructions
          - prepares patient for surgery
            - prepares self for surgery
              - assists doctor in surgery
                - takes patient to post-operative area
                  - takes patient to recovery area
                    - monitors patient
                      - repeats process and continues to see patients
                        - end of shift/day
Figure 3.7: Activities

Patients

preparation for surgery
undergoing surgery
waiting to be discharged
waiting to be seen by a doctor
private area to receive medical care
receiving intensive medical care
receiving routine medical care
processing paperwork
checking in to receive medical care
recovering from surgery
waiting between steps of medical care

Doctors and Nurses

preparation for surgery
performing surgery
performing emergency surgery
monitoring patients
private conversations concerning patients
stabilizing a patient to be relocated
providing intensive medical care
providing routine medical care
processing paperwork
checking in at the start of shift
storing supplies and equipment
disposing of biohazard waste
washing hands
cleaning up
managing waste
administering medicine
changing out of soiled scrubs
preparing to start the shift
Figure 3.8: Spatial Areas by Importance in a Surgical Facility
Figure 3.9: Organizational Relationships

- Biohazard waste disposal
- Surgical area
- Consultation and exam rooms
- Nurses station
- Storage for supplies
- Waiting area
- Recovery area
Figure 3.10: Organizational Relationships - Surgical Suite

- Pre-operative waiting area
- Operation room
- Post-operative area
- Prep area
Delivery

Bringing the medical unit to the site establishes its own sets of problems. A logical system will need to be set up and prepped for quick deployment following a natural disaster. Prior to a disaster occurring, units will be stored in nearby areas, such as Medecins Sans Frontieres stores its disaster kits to be pulled when necessary. The purpose is to establish a network that keeps a unit within a reasonable distance from a potential disaster site.

Delivery is constrained by shipping containers. A potential delivery method is the use of helicopters. Helicopters will be able to reach locations that are limited to trucks and other road vehicles, as well as reaching inland where hospital ships cannot. Figure 3.11 “Delivery Constraints” outlines some of these factors.

Shipping container sizes have been standardized globally. This standardization allows for easy and efficient stacking in a variety of transportation methods, including ships, trains, and trucks. A standard unit is measured at a 8’ width and 8’6” height with a length of twenty feet or forty feet. A pallet-wide shipping container is also available. While the height and length measures at the same footage of the standard, the width widens to 8’2”. The final shipping container option is a high-cube unit. At a height of 9’6”, this type is higher than a standard shipping container; there is also an option for a height of 10’6”. Each of these containers defines a separate advantage. For the initial series of design the focus would be of fitting the emergency medical unit to the dimension of the standard, 20’ depth, shipping container. These likely have greater availability as well as greater shipping availability.

The standard shipping container, at a twenty foot depth, has the internal dimensions of approximately 18’ 8” in length by 7’ 8” in width by 7’ 9” in height. Each shipping container has doors fitted at one end. The door aperture measures at 7’8” in width by 7’ 5” in height. Shipping containers are constructed with a corrugated weathering steel called Corten. This material is mold resistant, unlikely to rust or corrode and stronger than normal steel. It is also capable of withstanding typhoons, tornadoes, hurricanes,
and earthquakes. These factors created a possibility to use the shipping container unit itself to develop a medical unit. The weight and size of a shipping container, however, will require them to be placed by a crane or forklift, a machine unlikely to be available at each disaster site. Once initially brought to the site, the unit should be fairly mobile enough for a few people to move around if necessary, or at least be brought into place with minimal need for adjustments.

While trains, ships and trucks will be required to send the emergency medical units to the storage areas, a helicopter will be the primary method of delivery to the necessary site. This requires the design to be lightweight and capable of being lifted by a helicopter. There are few different types of helicopters capable of lifting an emergency medical unit, or shipping container. The lifting capacity of a helicopter will factor into the design, setting limitations on its weight.

The strongest helicopter currently in use is the Erikson Air-Crane. Developed by Igor Sikorsky, who envisioned a helicopter that carried all its loads externally, the Skycrane is built with a minimum airframe. There is just enough built to house the engines, rotors, fuel and crew. The helicopter can complete a variety tasks including setting up transmission towers, fighting fires, harvesting logs, delivering a bulldozer, and transporting a small building to a remote site. It is capable of lifting 25,000 pounds and can place its load within an inch or two of its intended location. A limitation, however, is the small number in operation. Only a handful are owned by operators in a few countries.

The medium lift helicopter is next in line for a potential aid helicopter. A standard version of a medium lift helicopter is the Kaman K-MAX. This helicopter is specifically designed to perform repetitive external lifting. Logging, power line construction, fire fighting, and ski-lift installation are just a few examples of the tasks it can perform. The medium lift helicopter can lift 6,000 pounds, impressive considering it does not even weigh that much itself. Unfortunately, it has some of the same limitations as the Skycrane in terms of availability. There are very few built and only a couple operators in a few Western countries.

Another possible helicopter is the light utility
A prime example of this smaller helicopter is the Kamov Ka-26. Commonly used as an agricultural, ambulance, survey and search-and-rescue helicopter, it is typically civilian owned and operated. The design configurations allow it to takeoff from land bases as well as small ships. As a flying crane, it is capable of lifting 2,425 pounds. As of 2011, nearly 1,200 have been built, making it comparatively much more available for use in disaster delivery situations.

Each of these factors, shipping requirements and delivery methods, needs to be taken into consideration when designing the emergency medical unit. If a helicopter is unable to lift the unit, it will be severely limited in reaching its intended, and needed, destination. By fitting into a shipping container, the unit would be able to enter the market easily. Staying within the standards eliminate the need for special instructions and delays. All actions need to serve towards getting the units there easier and faster.
Figure 3.11: Delivery Constraints

Shipping Containers

- **standard unit**: 8'6" x 8' x 20' or 40'
- **pallet wide unit**: 8'6" x 8'2" x 40'
- **high-cube unit**: 9'6" or 10'6" x 8' x 40'

Helicopter Carrying Capacity

- **light utility**: 2,425 lb
- **medium lift**: 6,000 lb
- **aerial crane**: 25,000 lb
Medical Equipment

The medical shelter would need to arrive with basic medical equipment to be functional. Figures 3.12A-C “Medical Equipment” outline some of the major pieces. This equipment would already be packaged into the delivered structure requiring only basic setup once the unit was deployed and opened. There are a variety of pieces that need to be included. The largest items are the operating table and the anesthesia machine. The operating table is necessary to elevate the patient, as well as serve as a location for the patient to lay, during the surgery. An anesthesia machine is used to sedate the patient and keep the patient sedated. It must monitored constantly throughout the procedure creating the necessity for an anesthesiologist to be present during procedures.

Additional items are also required to provide medical care, particularly in a surgical setting. An autoclave sterilizer, using superheated stream under pressure, is used to sterilize instruments and other similar items necessary for surgery. A patient monitor is constantly attached to each patient. It monitors vital medical data which is displayed continuously to allow for easy readings. The respiratory ventilator mechanically breathes for the patient by moving breathable air in and out of the lungs. It is commonly used to support a patient who is physically unable to breathe or breathing insufficiently, as can happen during surgery. An electrocautery is used to stop the bleeding in small vessels by using a heated metal probe. An endoscope is more commonly understood to be a camera, to reach places the naked eye of the doctor cannot. Suction pumps are used to remove fluid, tissue, or foreign bodies from the body through a vacuum connection.

Some medical equipment should be on hand for common general medical use. A defibrillator, or AED, is used to restore the rhythm of a heart that is fibrillating, having rapid irregular contractions, by sending an electric shock into it. The electrocardiograph, better known as ECG or EKG system, records changes in the heartbeat, specifically useful in diagnosing heart abnormalities. A pulse oximeter indirectly monitors oxygen saturation of a patient’s blood. Infusion pumps release a measured amount of medication for a specific
period of time.49

Specific equipment is also needed for basic treatment and recovery situations. These include a treatment cart, a crash cart, and a medication cart. Possibilities for more direct lighting is very useful. Directed can help a doctor or nurse focus into a specific problem and will definitely need to be included in the setup of an operating room. All equipment needs to be assessed for certain areas and noted to be included.
Figure 3.12A: Medical Equipment 1

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Size</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anesthesia machine</td>
<td>54&quot;H x 28.4&quot; W x 31.5&quot;D</td>
<td>165.4 lbs</td>
</tr>
<tr>
<td>Operating table</td>
<td>76&quot;L x 27&quot;W x 18&quot;-25&quot;H</td>
<td></td>
</tr>
<tr>
<td>Respiratory ventilator</td>
<td>10&quot;H x 13&quot;W x 11&quot;D</td>
<td>30 lbs</td>
</tr>
<tr>
<td>Defibrillator</td>
<td>24&quot;H x 7.1&quot;D x 8.9&quot;W</td>
<td>3.5 lbs</td>
</tr>
<tr>
<td>Autoclave sterilizer</td>
<td>21.5&quot;D x 20&quot;W x 14.4&quot;H</td>
<td>95 lbs</td>
</tr>
<tr>
<td>Patient monitor</td>
<td>21.85&quot;H x 13.2&quot;W x 9.25&quot;D</td>
<td>11 lbs</td>
</tr>
<tr>
<td>Portable suction device</td>
<td>13.25&quot;L x 8&quot;W x 9.75&quot;H</td>
<td>12.6 lbs</td>
</tr>
<tr>
<td>Infusion pumps</td>
<td>10.15&quot;H x 6.5&quot;W x 5&quot;D</td>
<td>7 lbs</td>
</tr>
</tbody>
</table>
**Figure 3.12B : Medical Equipment 2**

<table>
<thead>
<tr>
<th>Medical Equipment</th>
<th>Size</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECG/EKG system</td>
<td>16.5&quot;W x 13&quot;D x 4.75&quot;H</td>
<td></td>
</tr>
<tr>
<td>pulse oximeter</td>
<td>6.25&quot;H x 3&quot;W x 1.4&quot;D</td>
<td>13 oz</td>
</tr>
<tr>
<td>electrocautery</td>
<td>10.25&quot;W x 6&quot;H x 12&quot;D</td>
<td>14 lbs</td>
</tr>
<tr>
<td>endoscopy</td>
<td>9.8&quot;W x 4&quot;H x 15&quot;D</td>
<td>13 lbs</td>
</tr>
<tr>
<td>cast saw/cutter</td>
<td></td>
<td>4.3 lbs</td>
</tr>
<tr>
<td>scrub sink</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV pole</td>
<td></td>
<td></td>
</tr>
<tr>
<td>instrument table</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 3.12C: Medical Equipment 3

- **Treatment Cart**
  - Size: 16.5"W x 13"D x 4.75"H
  - Weight: 13 oz

- **Crash Cart**
  - Size: 6.25"H x 3"W x 1.4"D
  - Weight: 14 lbs

- **Medication Cart**
  - Size: 10.25"W x 6"H x 12"D
  - Weight: 13 lbs

- **Treatment Bed**
  - Size: 9.8"W x 4"H x 15"D
  - Weight: 13 lbs

- **Feeding Pump**
  - Size: 4.3 lbs

- **Surgical Lights**
  - Size: 
  - Weight: 

- **Oxygen Tank**
  - Size: 
  - Weight: 

- **Trauma Board**
  - Size: 
  - Weight: 
Due to the nature of the project there are many factors to consider and handle. The design must be handled on a modular and cluster level. Each module needs to be perfected to provide for its intended space, such as an operating room versus a recovery ward, as well as store its necessary material. These units, however, must be standardized so they may fit together. Clusters should be developed to provide areas for various functions such as the surgical suite versus privacy areas for the staff.

Each module also needs to be self-sufficient, or work as a team to make the entire unit self-sufficient. The unit should be as prepared as possible for any type of site. This requirement means it will need to provide for its own water, waste management, electricity, heating and cooling, if there is not something available. There should also be, however, the option to plug into the local grid if amenities such as water are available and usable, as this will most likely be more sustaining.

The hospital setup will also require capabilities to handle various types of terrain. Adjustable elements will be ideal to allow the emergency medical unit to adjust at various points and level on uneven ground. These lifts could be used to elevate the entire shelter if light flooding were to occur. Since the focused use of this design is deployment after earthquakes, it will need to handle aftershocks, some which can be nearly as large as the original earthquake. The unit also needs to withstand high winds. Many earthquakes occur in tropical areas where hurricanes are a yearly occurrence. The medical shelters should be able to withstand these varying conditions.

A driving force in the design is to get the units there faster, within 72 hours. This requires for there to be a previous network, an easy way to ship and deliver the units, and minimal setup. Each module should be lightweight enough that it can be handled by a few people rather than requiring a piece of machinery that is unlikely to be available. There is also a restriction on necessary tools. A few simple tools such as a screwdriver or hammer are acceptable, and can even be included in the unit delivered, but it is ideal to avoid the use of power tools and/or heavy machinery.

Finally, setup should be simple and easy to understand. Though there may be multiple steps involved there should be
a logical progression with minimal explanation necessary. A short field guide could be a possibility, as well as short training sessions within the organization that distributes the units. In the training scenario, only one person would need to be sent to help with set up. This possibility could also eliminate the language barriers the field guide would have to accommodate.

The purpose of these emergency medical units is to support the medical infrastructure that already exists. It is not intended to take over and become a permanent fixture within the community. Periods of use will vary from location to location depending on the medical situation prior to the disaster, as well as the impacts of the disaster. It is pertinent, however, to remember that ultimately the intention is temporary. These units will be sterilized, repackaged, and sent onto the next disaster once the previous location has stabilized enough to support itself again.
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