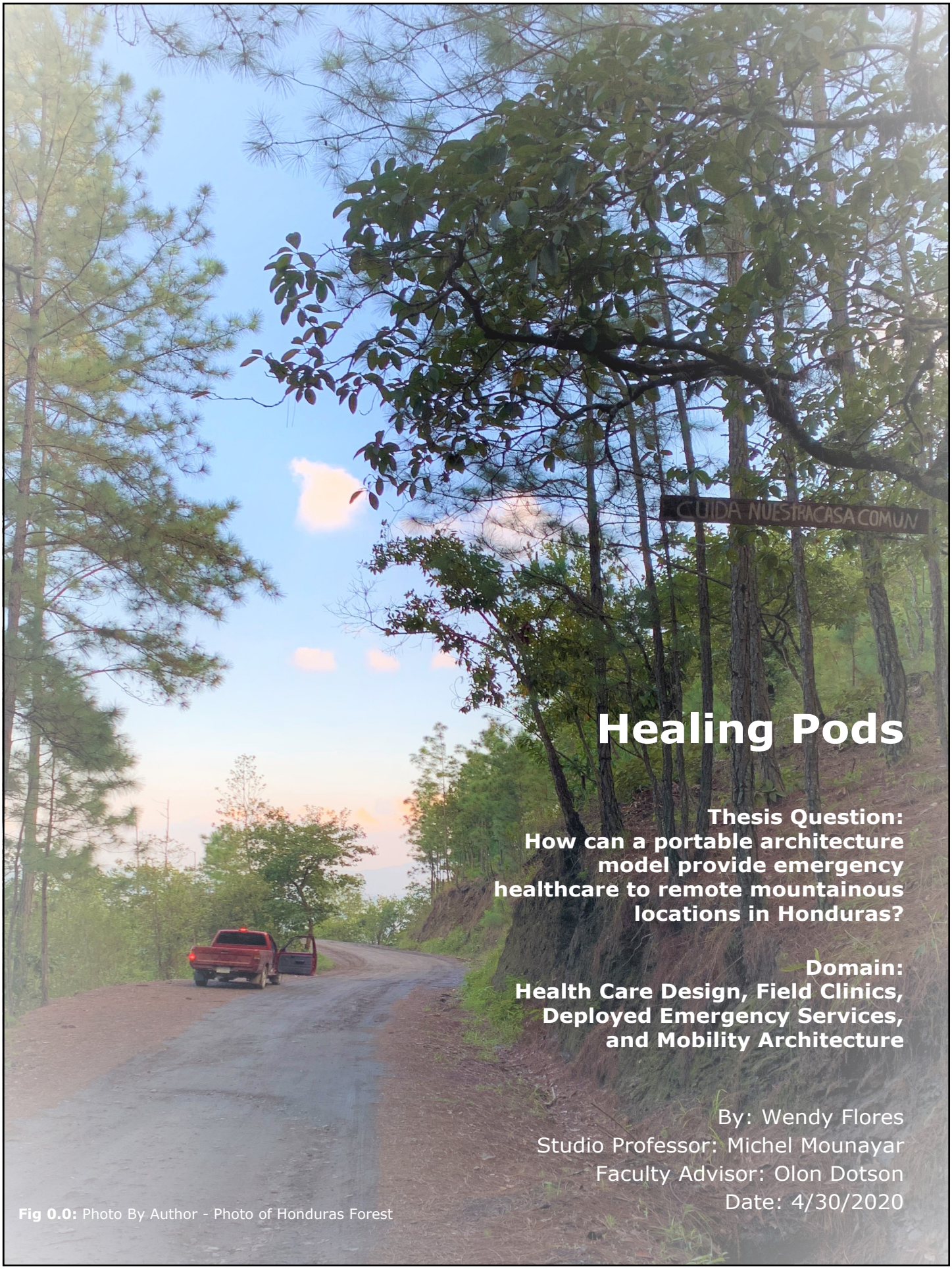

Healing Pods

Thesis Question:
How can a portable architecture model provide emergency healthcare to remote mountainous locations in Honduras?

Domain:
Health Care Design, Field Clinics, Deployed Emergency Services, and Mobility Architecture

By: Wendy Flores
Studio Professor: Michel Mounayar
Faculty Advisor: Olon Dotson
Date: 4/30/2020

Fig 0.0: Photo By Author - Photo of Honduras Forest

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Model Expansion Animation Flip Here

Transport Animation Flip Here

Fig 0.2: Photo By Author - My Nephew December 2019

Preface

Abstract

Through this thesis we explore the possibilities of an all-terrain clinical model. It will be based in Honduras due to its need of care and unique land limitations. Through extensive research of past mobile medical practices and the countries conditions we can make knowledgeable decisions in the model's design process. Consideration into the models practicing programming will be applied. Hopefully this concept can be a precedent towards a solution for global health care.

Introduction

Honduras has many remote communities and very mountainous terrain. It has been plagued by gang violence and political corruption for many years. This results in the injury and homicide of many innocent citizens of the country. Proper care can be very difficult to acquire in much of the country's mountainous remote areas. In order to resolve this issue, I propose an all-terrain clinic vehicular model that carries prefabricated, modular "pods." This concept could help to save lives of those suffering from a lack of access to professional care in this country. These pods are intended to be mobile in order to constantly serve where they are most needed. They would be able to attach and detach from the car in order to create stationary clinics anywhere they deem necessary. This model could set a precedent for similar remote areas that suffer from the same issue.

These pods could have a prefabricated shell and interchangeable interiors that could be custom or built to standard to serve different functions. Stationary pods could be adapted to become self-sustainable clinics. There will be a designated vessel for servicing power and water to accommodate for expansion. Another purpose they may serve would be as medical research stations. In order to expand research, they need to communicate with each other. They could help establish a global network resource for experimenting new practices. This model could set a precedent for similar remote areas, like other Latin American countries or desserts in the middle east that suffer from comparable issues.

These pods could be a collaborative project serving the needs of organizations such as the Peace Corp, Doctors without Borders, or Red Cross.

Ideally, they would only be available to medical professionals, loaned or sold to regions that request them. Medical Professionals could also purchase them and sponsor or loan them to a community of their choice Alternatively, they could be sponsored by their nearest hospital and the citizens of the country could nominate someone to be trained as a specialist or emergency care nurse. This would give the opportunity to create local jobs and to hire people that are familiar with the area.

There are many things to take into consideration for the construction fabrication of the pod models. How will its source power and what equipment will be necessary? It will need equipment for self-sustainability and to serve its function. Materials will need to allow for movement and prefabrication. Certain design specifications will also need to be identified for the program, like connecting units to each other in a functional matter. In order to perform different medical procedures, they may need different designs or modifications. When considering how to adapt to the land there is more to question. Adjustments would have to accommodate function in different elements with different terrains. These are all things to keep in mind while designing the model.

Fig 0.3: Photo By Author - Grandparents January 2020

Chapter 1: History

Hondoras Relevant History

Early findings in British Honduras defined the robust terrain as, "folded Upper Carboniferous marine beds, with granitic intrusions, surrounded by unfolded limestone."[1] The land was described to have Large faults into water of 2,000 ft. The terrain of Honduras is hilly or Mountainous over seventy-five percent of the country. Flat land is very valuable in the country due to its scarcity and lowlands can only be found along the coasts or river valleys. Its bordering waters are the Caribbean Sea and the North Pacific Ocean. Its neighboring countries are El Salvador to the South West, Nicaragua to the South East, and Guatemala to the West. The climate is tropical and typically hot and humid variating from elevations. It is mostly covered in forests and farmlands that have been created through deforestation that result in heavy erosion. "Honduras, like its neighbors in the region, is a developing nation whose citizens are presented with innumerable economic and social challenges, a situation that is complicated by rough topography and the occasional violence of tropical weather patterns."[2]

In 1998 Honduras took the hardest hit from the category five, Hurricane Mitch. It resulted in 11,000 casualties. Twenty percent of the population, over 1.5 million Honduran civilians where left homeless. One third of the country was left wrecked from the hurricane and its aftermath. They received 6 feet of heavy rainfall which drowned crops and created high debris.[3] They lost around seventy percent of their crops in a country that has over half the population working in agriculture. Since much of Honduras agriculture can be found on sloped inclines that were cleared by burning forests, there was an excessive amount of overflow that created massive amounts of flooding. Extremely high flood levels and heavy debris contaminated much of the countries water supply which resulted in epidemics of infectious disease. There where reported cases of cholera, malaria, leptospirosis, dengue fever and hemorrhagic dengue fever.[4] Many people suffered from pneumonia, diarrhea, and acute respiratory illness especially young children. With the excessive amount of flooding it became even more difficult to navigate the land and treat those in need, there also was so many affected by the hurricanes conditions that they could not keep up with the medical aid demands. Due to shortages in medical aid and difficulty in access to care some of these easy to treat ailments where neglected and brought more complications. This hurricane had a long-lasting impact on this nation, and it may have never fully recovered.

Honduras began its economic downfall in 2009 after President Manuel Zelaya was exiled from his position, which brought a lot of controversy and left the country divided. He was illegally exiled by a military coup, based on supreme court orders and was not allowed to complete his term. The rest of the world seemed to demand for the return of Zelaya but when the de facto government failed to do so the country suffered from many severed relationships internationally. "Honduran society generally has been under strict control since Zelaya's removal. Following the ouster, a curfew was put in place, security forces have patrolled the streets, and several local and international television and radio stations have been shut down or intimidated…the Honduran National Congress approved a decree suspending a number of constitutional rights. The decree allows security forces to enter private homes without a warrant, allows the detention of persons for 24 hours without charges, and suspends the rights of free association and free movement during curfew hours."[5] Due to the nature of Zelaya's exile the United States and many other countries pulled much of its aid for the country but continued to provide aid for military and police force. They disregarded the countries violence and governmental history of human rights violations.

Fig: 1.1 Hurricane AfterMath
https://science.howstuffworks.com/nature/natural-disasters/10-worst-hurricanes9.htm

Honduras has been plagued by an extreme amount of violence. San Pedro Sula has been named the murder capital of the world for a number of years. There has been a constant issue of gang violence between MS 13 and Barrio 18. "Actual gang members and other well-funded criminals bribe prosecutors and judges to drop cases against them. The government has yet to bring a major organized-crime case against the leadership of either Mara Salvatrucha or 18th Street... The police aren't just committing a lot of the crimes but have almost no capacity to solve the crimes they aren't committing. The impunity rate in Honduras crimes that go unprosecuted is more than 90 percent."[6] Now even Mexicohas outsourced its cartel operations outside of Honduras where they can conduct illegal activity relatively unnoticed. Being the most Central country amongst the Americas, it suffers from the conflicts of neighboring countries and cross trafficking of humans and narcotics. Much of this results in the terrorization of the countries citizens and many casualties. Hopefully with more accessible care they can provide a positive intervention that helps lower death rates.

1 Leslie H. Ower "Geology of British Honduras."
2 Wayne M. Clergern, J. Roberto Moncada R, and Ralph Lee Woodward. "Honduras."
3 Sungduk Kim. Hojin Lee, and Kye-Won Jun. "The Impacts of Debris Torrents in Caribbean Coast of Honduras, Central America."
4 "Environmental Impacts of Hurricane Mitch." Environmental Health Perspectives.
5 "Honduran Political Situation." 2009. International.
6 James Verini. "DISPATCH: Prisoners Rule: Welcome to the Deadliest City in the Deadliest Country in the World."

Country Health

There are many health issues and concerns within Honduras and much of Central America. "It is documented that Honduras lacks adequate access to health services: 83% of Honduras is without health insurance and 30% is without health care as of 2007. Infant mortality, a standard measure of population health, is 25 per 1,000, 10 more than the regional average. The reasons for healthcare limitations in Honduras are multiple, including inadequate numbers of physicians (0.8 per 1,000 persons), variable medication supplies, gaps in infrastructure, financial constraints, and sociopolitical factors."[1] There is a serious trend of malnutrition and protein deficiency due to extreme poverty. Viral outbreaks are very common through the spread of mosquitos, lack of sanitation, and water contamination. Overcrowding of facilities is a huge issue. People do not bother to take the time to get medical attention because even after all the efforts they must make to travel to their nearest destination they do not have the guarantee that they will be seen. They cannot sacrifice multiple days without working or caring for their children in order to possibly attain the medical attention they may need. Mobile care units would be beneficial for this country to have more local health care in rural communities of the land. Then in severe cases of emergency they could be transported to the nearest hospital to receive immediate attention, rather than being forced to travel without the guarantee of treatment.

Viral diseases can be spread through mosquitos. Recently the Zika virus called for a national warning alerting mothers against having children for the following 3 years in Honduras many cases of complications with birth and malformation in newborns due to viral spread through mosquitos. There is also a serious concern of STI transmission, especially AIDS and HIV. There is often a scarcity of supplies that do not allow for proper wound treatment in order to prevent infection, Lack of sanitation is a huge contributor to infections spreading. Hundreds of thousands of mothers die worldwide during child labor due to birth complications. "Nearly all studies that have sought to explain the persistence of high maternal mortality levels have focused on the supply of and demand for particular health services,… inquiry on health services is useful but insufficient."[2] There are many concerns with mothers having children outside of specialized facilities. This can endanger the child and the mother due to improper practices, cleansing regime, and lack of professional care if complications where to occur. These units could accommodate mothers in labor to provide proper care during their child delivery without having to travel to their nearest hospital which may not be reachable before birth. Overall much of the country's largest concerns derive from lack of access and a poor standard of living.

In rural areas the closest medical facilities can be hours away by car and not everyone has access to mobile vehicles. There are few main highways and in order to arrive to certain destinations you must walk on foot or take a motorbike that can maneuver the terrain and narrow roads. "Leon reported healthcare users in Honduras feeling they are "passive recipients of services." They must "walk long distances to catch a bus or get a ride" only to find the clinics are full: "we are told to come back another day." Rural Honduran populations consider themselves disenfranchised, and "are preoccupied almost exclusively with obtaining a basic modicum of health care and medication in their communities."[3] Duration of travel to the nearest healthcare facilities heavily vary based on proximity and methods of travel, ranging from thirty minutes to eight hours. "A 25-item questionnaire was approved by the Institutional Review Board of Virginia Commonwealth University and was administered at HOMBRE mobile clinic sites in Coyoles, Lomitas, and La Hicaca in June 2011."[4] they found that, "The majority (59%) of respondents in Coyoles accessed their health provider in less than thirty minutes. The majority (80%) of respondents in La Hicaca accessed their health provider in 1–3 hours, while the majority in Lomitas (58%) reported greater than 3 hours travel to access medical care. The mode of transportation used to access medical services varied between the sites. The majority of respondents in Lomitas accessed healthcare by foot (70%), while travel by automobiles was most common in La Hicaca (60%) and use of public bus was most reported in Coyoles (51%)."[5] Scarcity in medical attention heightens when it comes to seeing a specialist, receiving require blood testing, or undergoing radiography. There is a very clear distinction in class where the most obvious line can be drawn at impoverished individuals not getting immediate care or any treatment by medical professionals.

With the implementation of the proposed mobile care units we can possibly combat many of these issues and provide this country with, much needed accessible health care. It will take into consideration all these issues and try to find solutions for all these concerns within its design. While Providing care for its community it can also serve to educate them on any health concerns they may have or how to prevent common issues. They will care for those that need it most and hopefully better their lives for years to come.

1 Catherine A. Pearson, Michael P. Stevens, Kakotan Sanogo, and Gonzalo M. L. Bearman. "Access and Barriers to Healthcare Vary among Three Neighboring Communities in Northern Honduras."

2 Jeremy Shiffman, and Ana Lucía Garcés Del Valle. "Political History and Disparities in Safe Motherhood between Guatemala and Honduras."

fig. 1.2 Hombre Medical Clinic
http://www.hombremedicine.org/

3 Catherine A. Pearson, Michael P. Stevens, Kakotan Sanogo, and Gonzalo M. L. Bearman. "Access and Barriers to Healthcare Vary among Three Neighboring Communities in Northern Honduras."

4 Catherine Pearson p. 2

5 Catherine Pearson p. 3

History of Emergency Response

Napoleon's surgeon general is known as the founder of modern military surgery, Dominique Jean Larrey (1766–1842) was, "a proponent of resuscitation at the site of injury and improvised a system of so-called flying ambulances placed near the line of battle, which, with immediate amputation where necessary, had a major effect on the prevention of tetanus and gangrene."[1] His works had a lasting impact and "laid the foundation for medical evacuation as we know it today with his "ambulance volante." He was also one of the first military physicians to conceptualize forward surgical hospitals by bringing medical support to the frontline. These concepts translated later to the mobile units of World War II and the Korean War."[2] Those units are known as, (MASH) mobile army surgical hospitals. These units are responsible for saving countless lives amongst battlefields of war, benefiting both military and civilian immediate health. "These hospitals were comprised of three or four smaller units, with a combined 400-bed capacity. These medical units were generally situated near airfields, to facilitate transport of injured patients out of the combat zone."[3] During the Korean war the MASH units underwent various modifications and adaptation through practice discoveries. They implemented the use of medevac flights and battalion aide stations that identified the next move for the patient based on the severity of their condition.

The Vietnam war required different needs for medical facilities due to their guerilla tactics and non-evident battlefronts. This introduced the use of (MUST) Medical Unit Self-Contained Transportable. These mobile units were expandable shelters with inflatable wards. The biggest difference between these units is that MASH is very mobile and broken up into various units on the battle fronts, while MUST is semi permanent and houses more function in one unit. The MUST units were eventually adapted to become mobile and work as redeveloped MASH units.

During the Gulf war mobility became even more crucial and (CSH) Combat Support Hospitals units had to become smaller and more flexible for better transportation. These units would get shipped out along with MASH units to keep up with the constant mobilization of force and supplies. They where utilized as forward surgical teams (FST) or forward surgical elements (FSE) to MASH units. They carried less materials and supporting equipment than the Mash units and were hauled by smaller vehicles to make them more mobile. They were mostly made of quick assembly tents that where covered with heavy duty tarps that varied in assembly type based on the size of the unit. Afterwards MASH units were broken up into more units to make it even more mobile.

After the Gulf war many questioned the use of MASH units though they have had much advancements they were still not mobile enough for the everchanging conditions of war. They

fig. 1.3 Medical personnel respond to a mass casualty event during Operation Desert Storm. https://www.airforcemedicine.af.mil/News/Article/645788/afms-operations-during-the-gulf-war-operations-desert-shield-desert-storm/

1 Margaret Hudson. 2001. "The Enduring Legacy of Napolean's Surgeon-General."
2 Booker King. "The Mobile Army Surgical Hospital (MASH): a Military and Surgical Legacy."
3 Booker King. Pg. 1-2.

fig. 1.4 23rd Tactical Hospital out of England AFB, Louisiana during Operation Desert Storm. https://www.airforcemedicine.af.mil/News/Article/645788/afms-operations-during-the-gulf-war-operations-desert-shield-desert-storm/

were deployed into Iraq and did not prove to be as successful in this war setting. MASH units became obsolete and were replaced with more FST units which were essential for the more recent wars against terrorism in Afghanistan and Iraq. During the operation Iraqi Freedom, the 212th MASH unit became the last to be used in 2006. This unit was essential in the early days of this operation working 24/7 for the span of nineteen days. "As a completely mobile, 36-intensive care unit bed hospital configured for rapid relocation and set-up, the MASH was uniquely qualified to assume the role as the most forward-deployed level III hospital to receive casualties during the initial weeks of combat operations in Iraq.[4] Under the Army's Medical Reengineering Initiative, this unit was phased out and reflagged as the much larger 12th CSH in October 2004. The MASH configuration and capability continue to exist as a 44-bed portion of the 96-bed CSH."[5]
They had to learn how to adapt to different climates and terrain especially the sandy desserts of Iraq. The sand would put many of their operating systems out of commission. Learning how to prepare for different war tactics will be a constant issue for army hospitals. They learned mostly how to organize and categorize different levels of severity for medical treatment. This allowed them to make efficient use of their facilities and better means of fast-tracking services for the increased demand. There were many mistakes made and lessons learned during this unit's operation that the Army Medical Field will continue to heed as an example.

Field Hospitals have been a more permanent means of emergency care. They started with the army but became impractical due to lack of mobility. More lives were lost to the lack of immediate treatment and viral infection than to injuries suffered from combat.[6] Field Hospital became more prevalent to care for the victims of natural disasters. They are amongst the greatest practice for crisis response. Often they can be deployed by the military or the emergence of Missions trips groups. These groups largely contribute to the amount of aid that is provided after a crisis. In Honduras missions' trips can be continuous health efforts contributed to the country from the goodwill of others.

4 Booker T. King, Ismail Jatoi, Alfonso S. Alarcon, Todd M. Morton, John M. Cho, and Jeffrey M. Hermann. "Operation Iraqi Freedom: Surgical Experience of the 212th Mobile Army Surgical Hospital." Military Medicine170, no. 4 (2005): 268–72.
5 Booker King, "Operation Iraqi Freedom" pg. 272.
6 Henry Veale. "A Lecture on The Organization Of Field-Hospitals

Conclusion

Fig 1.4: Photo By Author - Mountain view August 2017

Honduras has a unique terrain that makes it difficult to have widespread access to many services. They have large cities that are surrounded by mountainous rural areas. Finding flat land in Honduras is very rare and valuable being that much of the country is hilly or sloped. From my experience travelling there I had to take multiple means of transportation. I took buses or taxis on the main roads but to reach my relatives ranch I had to walk by foot or take a motor bike taxi. Motorcycles and motorbikes are a popular means of travel because they can easily maneuver the narrow and hilly terrains. Many roads are unpaved and narrow. Some roads follow the edge of a mountain with little or no barriers to prevent you from rolling off the cliff. The country is very tropical and has periods of rainfall and drought in sequences. The land flourishes with fruits and plants that take a lot of water. The country often has Its climate and terrain create many obstacles for adequate resources in much of the rural areas.

Honduran citizens have suffered a lot from the turmoil of natural disasters, inequality, and excessive violence. These economic and social challenges drive many natives to flee the country in hopes of a better life. There are many concerns they need to overcome but for it to become a more suitable place to live it requires a better means of caring for its citizens. This country needs a better solution for its health care needs. Many simple ailments go untreated or neglected that bring more complications in the long run. If they are treated well they can learn to care for themselves better to prevent these issues for themselves and others.

There has been a constant need for adaptations in the medical field, especially for emergency response which changes per circumstance. Field hospitals are dependent of the nature of field that they are attending to. Most emergency care started and evolved from times of war when they had vast amounts of people to care for in a short time frame. They learned to categorize different areas of injury by severity and divided them into different areas of response and care. In the military they needed to accommodate war injuries and for natural disasters they must care for a large variety of issues that they become aware of as the disaster settles. The main thing to keep in mind is that in any case emergency response requires quick and deliberate actions.

These transportable medical pods could work towards gaining a global health care solution. With the incorporation of design, hopefully a unit can function as an all-terrain service that can reach even the most remote locations. Our amazing planet boasts a huge variety of terrains that pose different design complications that must be considered for optimum performance. Though there are existing solutions to this problem we must continue to strive for improvements, especially with everchanging technological advances.

Honduras is not the only country that suffers from medical health disparities and challenges. Many countries find themselves in the same predicament for various reasons. The design of mobile care pods for this region can potentially function as a precedent care example for other countries with similar concerns. Basic healthcare should not be first world exclusive or a battle to acquire in any stretch of the planet.

Fig 2.0: Photo By Author - My Nieces December 2020

Chapter 2: Precedent Studies

Precedent Study:
Mount Sinai Kyabirwa Surgical Facility

Fig 4.1: Project Rendering
https://kliment-halsband.com/work/mount-sinai-kyabirwa-village-surgical-facility/

Location: Kyabirwa, Uganda

Square Footage: 8,000 sf

Architect: Kilment-Halsband Architects (KHA)

Awards: AIA Healthcare Design Award

"This prototype for an independent, self-sustaining ambulatory surgical facility will provide life-saving treatments in underserved parts of the world.[1]"

This surgical facility provides health services that were not available in this community before. It will also provide quality training for nurses and surgeons. The staff will be supported by New York's Mount Sinai Hospital and will receive real-time video operation assistance. The firms hope is that this facility can serve as an example for facilitating global health care. They believe that everyone deserves quality care, and this is their solution. "Roughly 5 billion people--two-thirds of the world--do not have access to safe and affordable surgery, causing 19 million deaths per year. " Chairman of Mount Sinai Hospital, Dr. Michael Marin, is dedicating his services to provide surgical care in underserved communities, with the help of donors and KHA. The firm had no previous experience in health care design and learned from a guided tour of Mount Sinai. Together they were able to come up with a stripped-down design giving the essentials and most common necessities for a surgical facility.

1 "Mount Sinai Kyabirwa Surgical Facility." Kliment Halsband Architects | Mount Sinai Kyabirwa Surgical Facility. https://kliment-halsband.com/work/mount-sinai-kyabirwa-village-surgical-facility/.

The design consists of three separate volumes surrounding a reception courtyard. It includes an office volume, a pre-op and recovery volume that cares for patients before and after a surgery, and a sterile volume that has two operating rooms and immediate support. The operating rooms are equipped with high speed internet and videoconferencing technology to have immediate support. This facility needed to incorporate self-sustainable design to have enough resources for its purpose. The solar panel tree provides solar energy and enough shading for its occupants. Its design was inspired by the native banana tree. It has its own water collection and purification system.

The building is a steel and masonry structure filled with natural local materials. The project largely employs its community, building with local labor and operating under local Ugandan surgeons and nurses. In the future they plan to incorporate a cloth factory that uses the banana plant fibers to provide income for its operations.

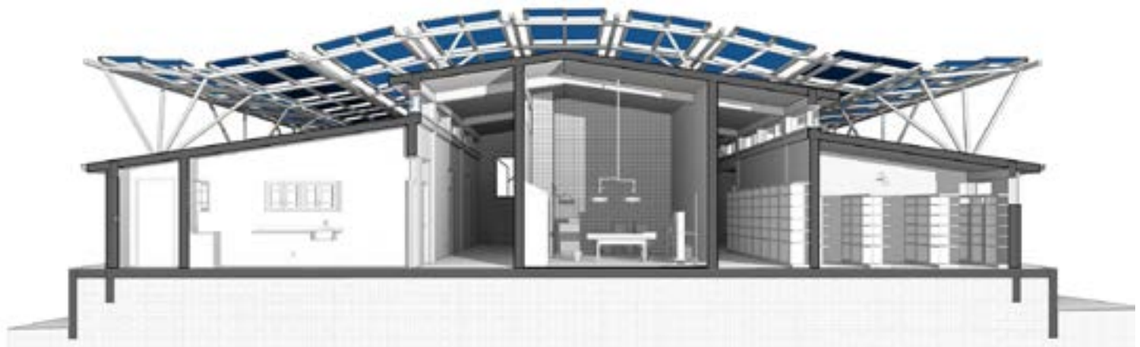


Fig 2.2: Project Section through Operation Volume
https://kliment-halsband.com/work/mount-sinai-kyabirwa-village-surgical-facility/

This project embodies the same spirit that will be incorporated into the mobile health clinic pods in Honduras. It provides health services for the community and engages them through employment and service. It proves the willingness people have, to care for others globally and the contributions they are willing to provide to help others receive quality care. The Mount Sinai surgery department wants to debunk the stigma that, "the practice of surgery and organization of providing surgical services are too expensive and complicated to undertake.[1]" They believe in the mission that everyone should have the opportunity for quality healthcare no matter where they are and hope to lead by example with this project.

The incorporation of the community is very admirable. With the programming of training others, they create opportunities for locals and expansion in their health services in the future. They did not want a mobile hospital unit because they wanted it to be specific to the community and to have "unique features." There are a lot of benefits to making a stationary facility. It is more long term and has room for larger programming. This project can become an icon for its location and can also serve its neighboring areas especially in rural communities.

Though this project is different than the proposed solution in Honduras it is also very similar. It incorporates its community and runs on the good nature of others. It provides the most common and basic surgeries as the pods will in health care.

1 O'Brien, Bridget. "THE MOUNT SINAI DEPARTMENT OF SURGERY YEAR IN REVIEW—2018." Breaking Barriers Creating a New Model of Care, 2018. https://www.mountsinai.org/files/MSHealth/Assets/HS/Care/Surgery/About/Dept-Surgery-Year-Review.pdf.

Fig 2.3: Project Site Plan
https://kliment-halsband.com/work/mount-sinai-kyabirwa-village-surgical-facility/

The takeaway from this precedent is in the facilities organization and volumes of function.This unit incorporates the bare necessities for a surgical unit, which is much more in depth than a clinic. The largest considerations are the pre-operation and recovery volume. It gives a simple scale of operation for surgery purposes that can help develop the clinics design. This project helps to put into perspective what will need to be accounted for in the mobile clinic. It also draws questions for the future development of the pods and how they can be expanded upon. This project serves its purpose in an elegant and noble manner that will influence the design of the health pods.

Fig 2.4: Concept Sketch Banana Trees to Solar Panels
https://kliment-halsband.com/work/mount-sinai-kyabirwa-village-surgical-facility/

Precedent Study: Ten Fold Designs

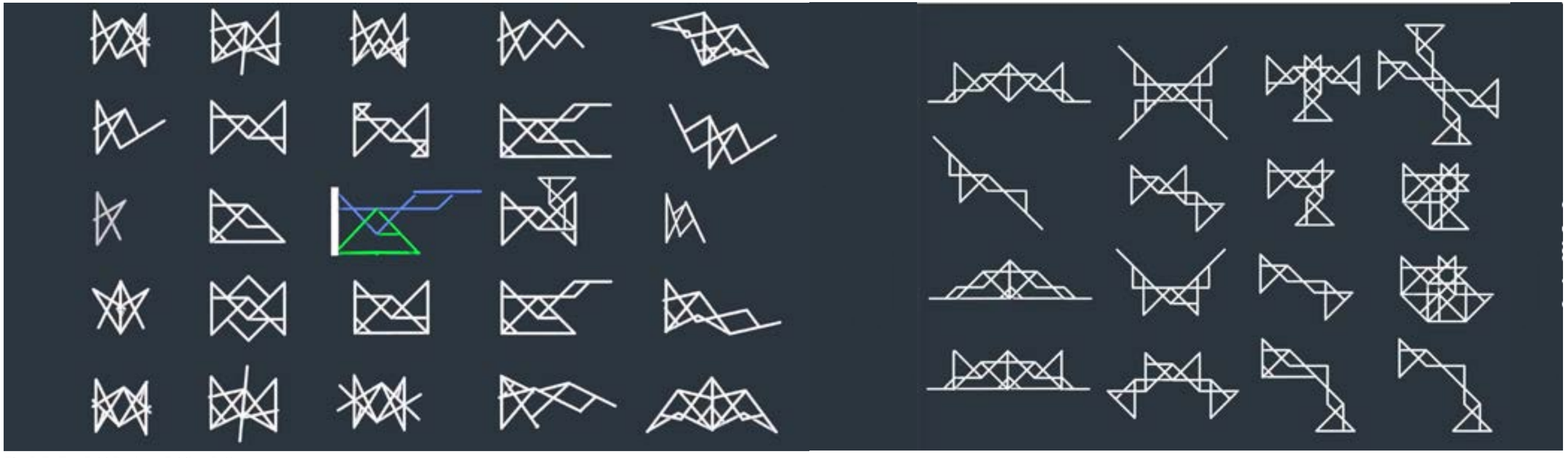


Fig 2.5: Ten Fold Designs Folding Patterns
https://www.tenfoldengineering.com/?utm_medium=website&utm_source=archdaily.com#section-what-we-do

Company: Ten Fold Designs

Project Type: Folding Structures

Base: United Kingdom

"Eight minutes. That is the length of time UK-based company Ten Fold Engineering's self-deploying structures can transform itself from a portable rectangular container into a fully habitable space that can be used for either the residential or service sector. Transported by truck, the company offers a shelter that is energy efficient, eliminates labor costs, and is highly customizable in an effort to revolutionize the possibilities of prefabrication and construction."[1]

1 Ten Fold Designs, Arch Daily

Ten-Fold Design has created fast tracked self-deployed structures. They are easy to transport and extremely Compact. They have developed a multitude of different folding designs to accommodate a large variety of shapes and forms. They also License their technology to other designers. "Ten Fold's family of counterbalanced folding linkages are designed to bring mobility, speed, ease and reliability to your products and services." The design only requires a stable ground and its standard model can expand to 729 SF and collapses to 112 SF when closed.

They have been exploring various methods of expansion and delivery to meet different needs of production for its consumers. They have the ability to provide motor driven and manual expansion options so that they can function in any environment. This technology is designed to be very adaptable and can be constructed in different sizes with various material finishes to fit any conditions and geography. It can add other modules to its ends to grow other functional spaces if need be.

The lever functions by equally dividing its weight and balancing its lever configurations on both sides. It expands with the use of counterbalancing components which allows it to be used without motors if desired. Their levers are designed to carry objects in straight or curved trajectories allowing for multiple methods of expansion.

Fig 2.6: Ten Fold Designs Folding Patterns
https://www.tenfoldengineering.com/?utm_medium=website&utm_source=archdaily.com#section-what-we-do

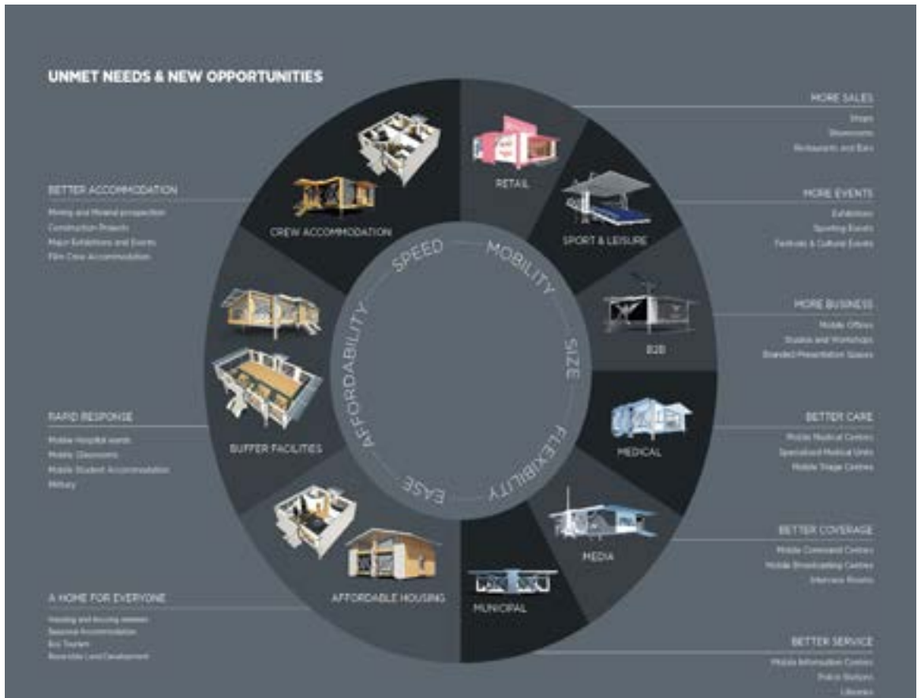


Fig 2.7: Ten Fold Designs Opportunities
https://www.tenfoldengineering.com/#

From this project I can take away from the compact ability and methods of expansion they have explored. These forms can expand to be over twice their size. through the use of balanced levers. It is a relatively new technology that expands on lever design. They are triangulated and pin jointed to make them stronger and flexible. What I find most appealing is their promise to move in different directions simultaneously from one driving force.

This technology appears to be experimental still and does not have many real built examples to prove its claims and ease of adaptation. It shows a multitude of application or incorporation methods in design that have not been tested for practicality. It claims to be a cheaper application without evidence of it on their website or a breakdown of materials to know the structural integrity of their designs.

From this technology I can take away ideas for a foldable clinic and methods in which to expand it. I learned that I could incorporate levers and use counterbalancing components to do it without a motor.

Precedent Study: Relocatable Healthcare Facilities for Southeast Asia

Fig 2.8: Relocatable Healthcare Facilities for Southeast Asia
http://buildingtrustinternational.org/MOVEDTOCARE1.pdf

Location: South East Asia

Square Footage: 1615 SF

Architect: Student Winner

Awards: Move to Care Winner

"In a region with an average of less than 1 physician per 4,000 individuals, the need for quality and broad ranging care is immense. By integrating clinical space into community space, the barrier to access can be removed and healthcare can be delivered safely, effectively, and can generate dramatic improvements on health outcomes for the rural South East Asian population. The prefabricated core opens up to reveal circulation space and bold colors which are used to differentiate areas. Local building skills are then encouraged to create shading and rain protection elements for waiting areas."[1]

This precedent is an example of student work. The project offers an alternative response to providing transportable medical care in a different area of the world. It uses recycled materials in its design to minimalize its carbon footprint and to incorporate the community. It calls attention to the need for privacy while still utilizing natural light. This unit travels in a truck bed and expands at its destination. With this project they have given careful thought into all the functions of the space and have decided to include a community center space to bring people together. Here the users can learn from each other as well as the professionals of the space. The gathering and learning spaces would be facilitated outside without bordering structures. They have also decided to push the circulation and waiting areas to the outdoors with a canopy cover in order to maximize on space and to reduce the spread of communicable diseases.

They have decided to incorporate bright colors into their design in order to create a happier environment for its clients. This distracts visitors from often discerning news they may experience. It also makes it very visible so that it can be easily identified no matter what its surrounding environment may be, making it an ideal location for the community to congregate. The designer has taken special considerations into local materials for the shading awnings that are necessary for South East Asia's climate. They have projected that each unit with a staff of four can provide care for 30 thousand people per year. Where sixty percent

1 Arch Daily, "Move to Care" Winners Envision Relocatable Healthcare Facilities for Southeast Asia

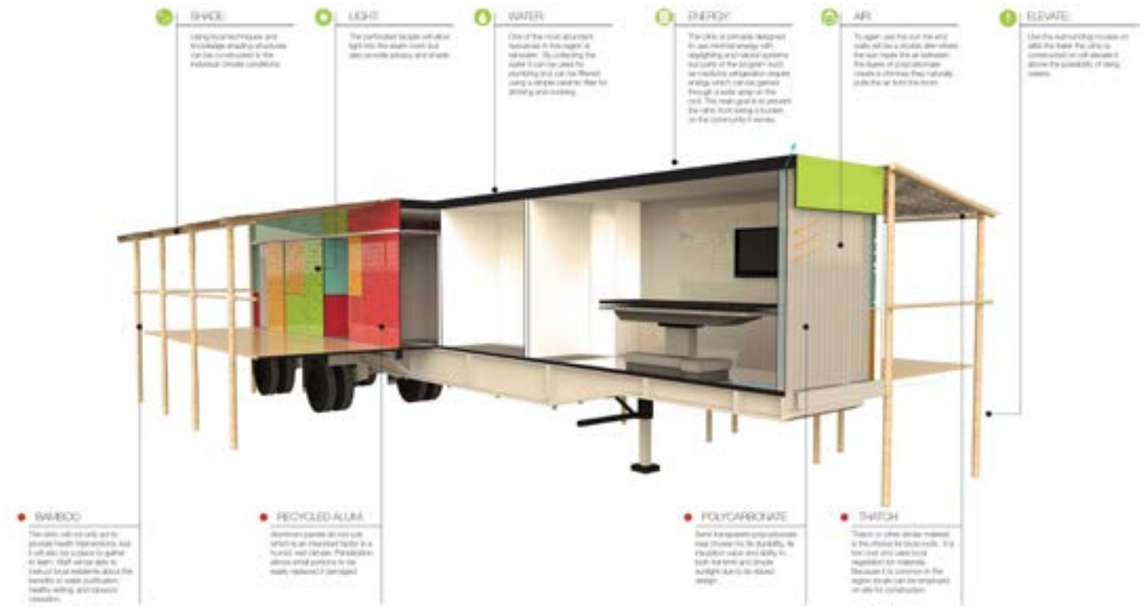


Fig 2.9: Relocatable Healthcare Facilities for Southeast Asia
http://buildingtrustinternational.org/MOVEDTOCARE1.pdf

of the country's population, equaling to 280 million people living in rural communities.

From this project I can see an example of processes that work, and it brings things to consider into my design. It works with its community and engages them further than just their health. It also works with its climate by working with its abundant natural resources. The unit collects water and runs it through a simple ceramic filter for drinking and cooking. It diffuses light into the interior spaces and uses a solar array on the roof to power the few necessary electrical equipment components. An aspect that I found very intriguing in the design was the incorporation of a double skin wall ventilation system that uses the sun to heat the air between the layers of polycarbonate that creates a chimney effect that naturally pulls air from the room out and circulates new air in. This creates a constant circulation of fresh air into the space. Much of the areas rural housing is built on stilts to avoid rising

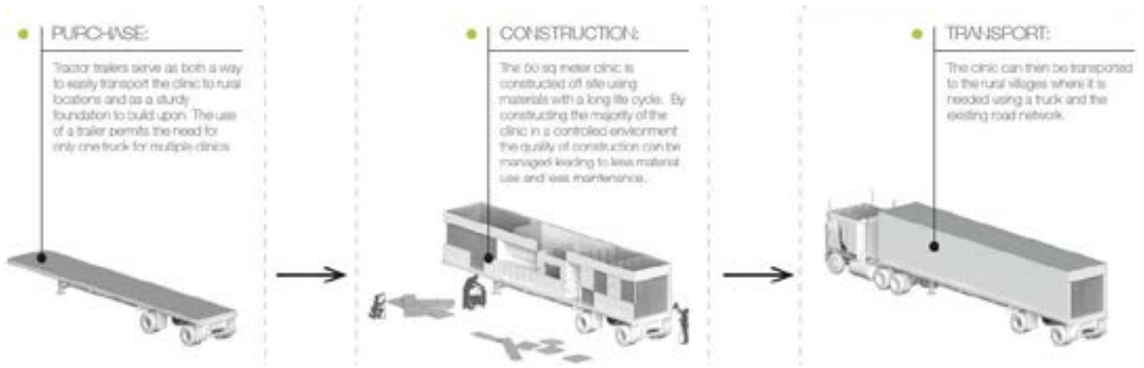
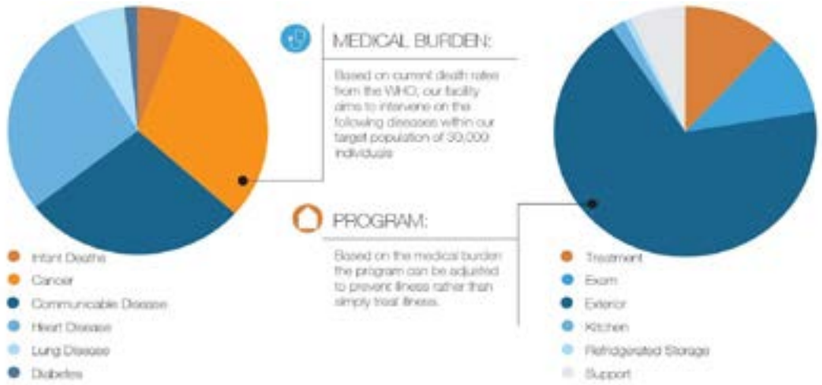


Fig 2.10: Relocatable Healthcare Facilities for Southeast Asia
http://buildingtrustinternational.org/MOVEDTOCARE1.pdf



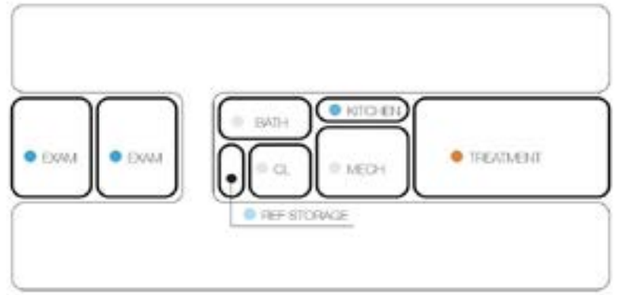


Fig 2.11: Relocatable Healthcare Facilities for Southeast Asia - Plan Layout
http://buildingtrustinternational.org/MOVEDTOCARE1.pdf

flood plains. This unit has height given to it due to its trailer bed that prevents it from suffering water damage.

From the floor plans I can take away the simple necessary spaces in a portable clinic. I find the incorporation of a kitchen interesting because it is not something that you would commonly find in a small clinic, but it makes sense for a community center. They have also designated a refrigerator storage space to maintain medicine temperatures. A downside is that I do not see many efforts of security for the design to protect it from theft or intrusion.

This design seems like a probable solution for flat terrains or large open spaces. It is pulled by a tractor trailer which can be difficult to maneuver in narrow or steep roads, like the ones in Honduras. I do like that much of the units' functions are programed into the exterior of the building which opens more space for the interior to maintain necessary services. They also have incorporated telemedicine to communicate with a large range of medical professionals when necessary. The treatment room provides a sterile facility meant to attend to injuries, minor surgeries, treatable birth complications or lifesaving interventions. This treatment room can provide an exceptional improvement towards the health of its occupants.

Precedent Study: Pediatric Clinic

Fig 2.12: Twenty Modules grouped around 5 courtyards
http://4ofseven.com/84/?utm_medium=website&utm_source=archdaily.com

Location: East Africa

Square Footage: 290 SF (each)

Architect: 4 of 7 Architects

"Responsive solutions in building industry are normally associated with high budgets. In contrast, this is a low-cost application of adaptable architecture. Proposed design is not site specific; it is configured to suite different surroundings and varied demands. For practical reasons, it is based on the use of a single component designed for infinite growth within a recursive geometric pattern."[1]

1 Pediatric Clinic East Africa, 4 of 7 Architects

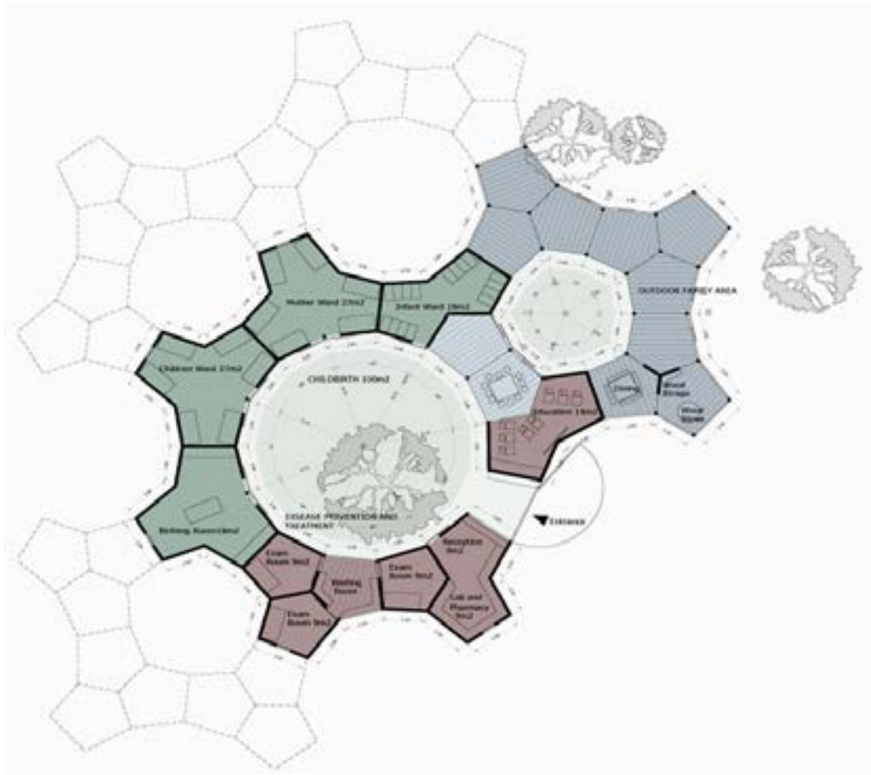


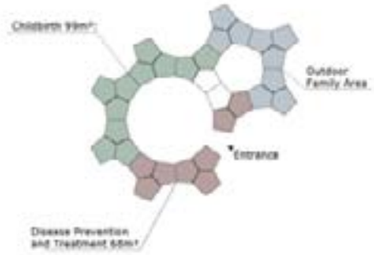
Fig 2.13: Courtyard Rendering
http://4ofseven.com/84/?utm_medium=website&utm_source=archdaily.com

"The proposal was an entry for the "Design for the Children" competition which asks designers from around the world to develop a sustainable, culturally responsive, pediatric clinic model for Rwanda. This modular configuration is a "spatial solution" that will connect a major network of health care."[2] This design really takes into consideration the connectivity of the modules. It is intended to be versatile in varied surroundings and demands.

Its structure is built out of I-beams positioned on the base perimeter of two concentric circles. There are three evenly spaced interior columns and an outer column array of 6 with connecting beams that form three even pentagons. The three interior beams come to a single central node and the outer beams connect the outer columns to the interior beams and columns. The exterior columns are all sheathed with a corrugated steel shell. This form allows for infinite repetition of the geometric pattern.

`The module was designed for fast and simple construction. It would be built on site and its components can be shipped in containers that can be easily deployed on land, air, or sea. Its composition would be made up of a low-cost material frame and then you can gradually introduce other building components like insulation, floors, windows, doors, and finishing details. The construction would then use basic labor skills that could employ the community to create jobs.

2 Pediatric Clinic / 4of7 Architecture
https://www.archdaily.com/48188/pediatric-clinic-4of7-architecture?ad_source=search&ad_medium=search_result_all



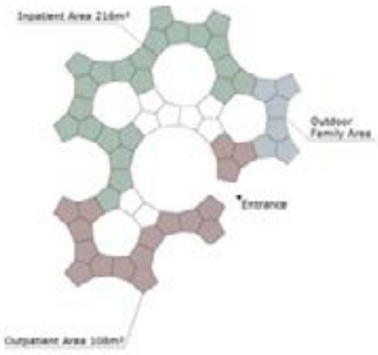


Fig 2.14: Organization Exampls
http://4ofseven.com/84/?utm_medium=website&utm_source=archdaily.com

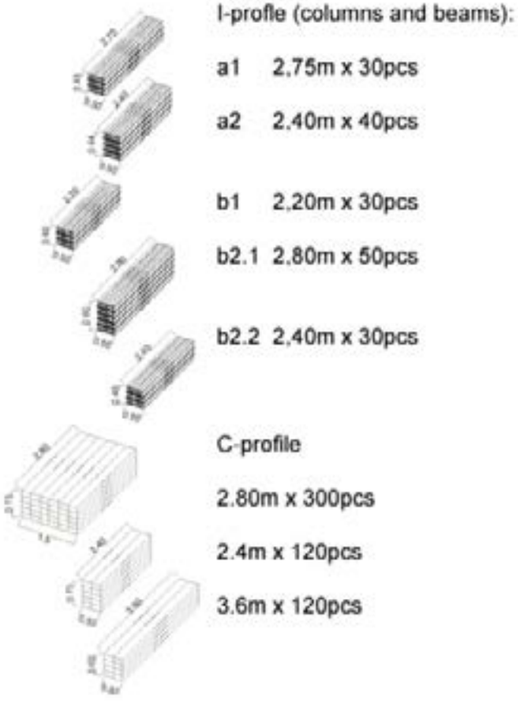


Fig 2.15: Structural Components
http://4ofseven.com/84/?utm_medium=website&utm_source=archdaily.com

The geometric pattern promotes social interaction by creating a network of centralized outdoor connecting courtyards. Facilities would open up into the courtyards which allows for the opportunity to have a main entrance point to ensure a security point. The courtyards also allow for the integration of between spaces that allow gathering for education, recreation, and living purposes.

The programming that this project introduces makes a basic footprint for a medical facility that can expand to serve multiple functions. It creates a basic footprint from which you can build upon and customize to meet the needs of the community. I believe this infrastructure could function for more than a clinic like a school or community center. I appreciate its adaptability to be constructed anywhere that they can transport the materials to. The basic setup is a 7-step process for the standard build. Though it has few steps to create, once you incorporate the finishing components it would become a set-in place facility. It does not seem practical to use this construction method for a continuously transportable clinic. It has endless potential for a set location creating a build your own hospital design.

The pattern and modularity of the units inspire methods of connectivity to my thesis proposal. What geometric shapes could create the best interior and exterior functional spaces in an endless pattern? I also can learn from the projects programming to know necessary functions of a medical facility at a larger scale. They have incorporated an infant ward, mothers ward, children's ward, birthing room, exam rooms, labs, dining space, family space, educational space, and waiting rooms. I enjoy the idea of courtyards that are enclosed by the units. Within its infrastructure you can create a circulation network by creating openings in the units format. That would create shaded interior passageways from which you can maneuver the facility without compromising growth. This proposal is a great solution for low income communities in need of ready to build facilities.

Precedent Study: Blob vB3

Fig 2.16: Blob VB3
https://www.dmva-architecten.be/en/projects/blob-vb3

Location: Verbeke Foundation, Belgium

Square Footage: 215 SF

Architect: DMVA Architects

"This space-egg houses all necessary items one could possibly need; bathroom, kitchen, lighting, a bed and several niches to store your stuff. The nose can be opened automatically and functions as a kind of porch. You could easily use this mobile unit as an office, a guestroom, a reception, a garden-house, or whatever you want to"[1]

The blob incorporates a design with an ample amount of space that is incorporated all around the interior space. Its egg like shell is made of a timber frame that is covered by a stretchy material and is plastered with polyester. It was then vigorously sanded to get a smooth seamless finish. It has an outer and inner shell that are filled with insulation to maintain comfort. Storage niches align the interior shell and they are lined with led lighting that gives the interior space a subtle indirect light source. It also has a pop-up ventilation cap in the center of its roof to circulate a fresh air flow. It is a unique project that explores mobile small units.

1Blob VB3, Arch Daily

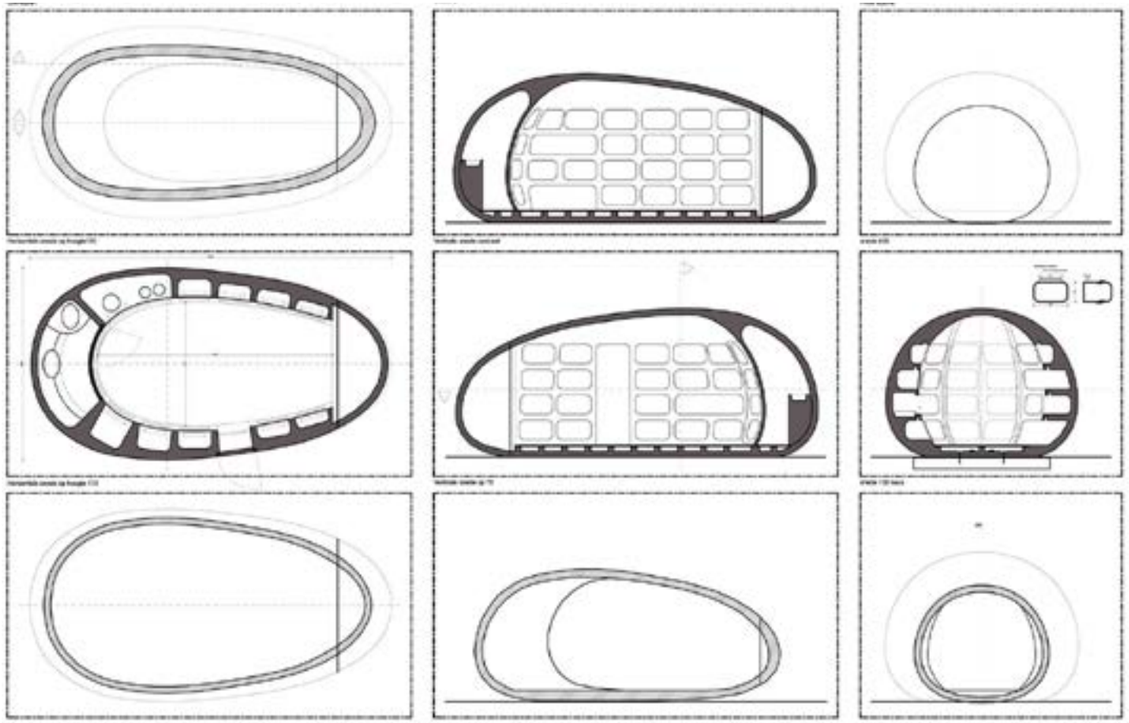


Fig 2.17: Blob VB3 Diagrams
https://www.dmva-architecten.be/en/projects/blob-vb3

Fig 2.18: Blob VB3 Interior Space
https://www.dmva-architecten.be/en/projects/blob-vb3

Fig 2.19: Blob VB3 Perpective
https://www.dmva-architecten.be/en/projects/blob-vb3

This unit was created to serve as an extension to the owner's house. Unfortunately, this project was repeatedly rejected by its local building regulations. Luckily they were able to blur the restrictions and pass it as a mobile unit and art installation.

This project design inspires me to consider different storage methods and object forms. The mobile clinic could possibly impede its components into its wall cavities to maximize on its interior space. I also appreciate its method of indirect lighting that evenly radiates an intense glow enhanced by its reflective white surfaces. The unit incorporates a dual shell infrastructure that creates functional spaces and storage out of its negative cavities. This maximizes on the functionality of the interior space regardless of its abstract shape.

The unit lacks any renewable energy efforts that would be beneficial for a mobile unit. For it to properly work it would require service hookups for water and power. This is also a custom build project that would result in a costly manufacturing venture. These are some things to consider if the idea where to be readapted.

Precedent Study: Clinic in a Can

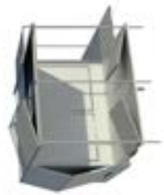


Fig 2.20: Clinic in a Can
http://www.clinicinacan.org/#media-resources

Partners: GE Healthcare, Midmark, Hill-Rom, Welch Allyn

Square Footage: 119 SF

Manufacture: Clinic in a Can

"We believe that every human being should have access to quality healthcare. Our hearts are bent toward meeting the needs of the underserved populations of the world. These relocatable clinics are designed and built to serve patients in remote or isolated environments, or in areas where a more traditional hospital is impractical."[1]

These containers finished interior space is 20ft x 17ft x 7ft. These clinics are easily transported and self-sustainable. It incorporates an open floor plan to maximize on space. Medical equipment and storage cabinets are mounted onto the structural walls to free floor space. It also keeps objects stable during times of transport. They are built with a life expectancy of a minimum of 30 years, making them a long lasting and durable solution. The doorway and windows are accessed behind the cargo doors which can be closed for extra security and allows it to be shipped as standard cargo containers. The design is customizable but has standard preferences for optimal performance. Certain altercations limit the mobility of the interior space and its shipping abilities. They have taken careful consideration into the material build of the container, including high quality materials for increased longevity and performance. There are optional solar and diesel-powered components and it has been engineered to operate on less than 500 watts of energy. It only incorporates low energy, green technology. There is a power hybrid options that uses both a diesel generator and a solar array that also charges lithium batteries for backup power in case of rain or heavy overcast.

1 Clinic in a Can http://www.clinicinacan.org/#about

Fig 2.21: Clinic in a Can Exterior
http://www.clinicinacan.org/#media-resources

Fig 2.22: Clinic in a Can Exterior
http://www.clinicinacan.org/#media-resources

Fig 2.23: Clinic in a Can Composition
http://www.clinicinacan.org/#media-resources

There are multiple prefabricated options to choose from to serve different functions. Some examples are emergency medicine, primary care, and infectious disease. These alternating functions holds different equipment to better serve its purpose. They share a breakdown of installed equipment options that teaches me what mechanical systems and technologies would be necessary for this service. They have partnered with leading healthcare specialists to ensure that they provide care to the best of their ability.

These units can serve as a natural disaster response model which has expansion capability through connections to serve a larger population. It meets E.U and U.S health and energy standards. The units are built out of recycled shipping containers reducing its carbon footprint.

This model is an excellent example of a portable medical clinic. It fits all the required needs and functions for its service. The units may have a relatively large fixed footprint that could be hard to maneuver without being air deployed to certain sites. It is not a very creative solution, but it performs at an ideal standard. This company is working to lower its cost but may be pricey for underdeveloped communities. I can learn what practical systems and methods function for my thesis through this example. This is a simple solution that performs well but doesn't meet its full potential.

Fig 3.0: Photo by Author - My Niece January 2020

Chapter 3:Preliminary Design

Issues and Obligations

Global Healthcare is a continuous issue in many underdeveloped communities. There has been extensive research and practices conducted in order to resolve this issue. There are many different solutions to fit specific site and functional needs for this issue. I believe that the largest concern with achieving global health care is that there are not enough practitioners that can readily work wherever need be. They either cannot commit their time and resources to the cause or must focus their efforts wherever they have available space. It is very costly to set up stationary clinics that meet all the needs of the communities and not all practitioners can justify these ventures. If they can it is often a few and they must carefully select where they want to commit their resources to.

There are many individuals that choose to fulfill their medical practicums by collaborating and working to help this cause. They are students that cannot afford to start their own practices. They often work through missions' trips, internships, or residencies. They have the time to contribute but not the funds or resources to fully collaborate or commit towards these clinics. I believe with today's technology a very transportable mobile clinic could be a viable solution towards giving practitioners the ability to freely practice globally without restraints.

These portable clinics could run with a programmatic plan that connects learning practitioners to trade experts to best serve its users. It could also serve as hospital extensions that communicate through real time telemedicine communications. It could establish partnerships with existing health brigades to strengthen their infrastructure and create a global medical remote network. There are so many possibilities when you give medical technicians the freedom to practice anywhere.

I have chosen to base my study in Honduras because it has a difficult terrain to navigate in much of the country. It poses different design considerations to withstand the conditions and elements. It is also in need of this service to better the lives of its inhabitants. There is a clear distinction of class where the underprivileged could possibly never receive the medical attention they need to live long healthy lives.

Experiential Criteria

Through my research I have gained an understanding of remote medical processes that work or have the potential to. There are existing solutions that work but lack full mobility. I reviewed design concepts that offer unique solutions to storage and modularity. I was able to find common circulation methods that maximize the interior space. This research has given me an awareness of the spatial limitations and its minimum allowance. I learned of the most minimal necessary equipment for standard clinical functions. These findings will guide me through my design process to develop educated decisions in my deliverables.

In order to explore this thesis, I will create 3D models and run an energy analysis to ensure optimal performance. Through my schematic design process, I will explore design options through a vignette. The model will be run through an animated terrain analysis to explore its mobility range. An energy analysis simulation can be run through sefiera. I may also run it through a virtual reality simulation to check the designs tightness and efficiency. Physical models of details may be included especially for expansion elements.

Fig 3.1: Photo by Author - Group Family Photo January 2020

Experiential Requirements

The unit's main purpose will be to serve as a medical clinic. With one unit it would serve its communities most basic clinical needs. With the adaption of more units per community it can expand on its medical functions and purposes. It would also be able to serve more patients at a faster rate. Each unit would be able to support two practitioners and one patient at a time. These units would be able to connect to expand on its space and create larger scale plans. Units will have live video communication so if they need guidance or input from another medical professional they can communicate with them in real time. This should put patients at ease that even though they may be serving a broad spectrum of concerns they can receive the guidance they need to serve them.

Defining the extent of the unit's mobility is essential to its design. What are the methods in which it can have the best terrain accessibility, to what extent is it all terrain? In order to accommodate a multitude of terrains it will need to be self-stabilizing. To do this it will have adjustable posts that can maintain it leveled no matter where it is located. I plan for the unit to be as compact as possible and then to open into a larger space. Fig 1.1 gives an example as to how it could expand and a footing it could use to self-stabilize. With this design I will consider its carriers design and what kind of wheel bet supports this model. I also plan on exploring different methods of deployment and see how many I can fit into its programming. I hope to make it easily air deployed.

These pods will be compact, but I hope that it can be designed to feel more spacious than it is. Pods can either stand alone or function together to serve a larger demand of patients. The use of the unit's outdoor perimeter will be incorporated into its programming. These mobile units when brought together should have a plan to contribute to its area and through that outdoor space. In that outdoor space I could program for family planning or educational services for the community. Hopefully it can create a welcoming environment where its users can feel comfortable and trust that they are being properly cared for.

Site Criteria

Fig 3.2: Map sourced from Ball States GIS Library
Honduras Map

Climate

The climate is tropical and generally hot with a mean annual temperature of 58 °F. It does fluctuate a lot based on elevation. The country has high humidity rates, especially in the tropical coastal lowlands, that begin to variate towards the countries interior elevations. There are occasional summer hurricanes that are accompanied by heavy rain falls. The countries rainy season begins in May continuing until mid-November. From December to April there is little to no rainfall.

The terrain of Honduras is hilly or Mountainous over seventy-five percent of the country. Flat land is very valuable in the country due to its scarcity and lowlands can only be found along the coasts or river valleys. Its bordering waters are the Caribbean Sea and the North Pacific Ocean. Its neighboring countries are El Salvador to the South West, Nicaragua to the South East, and Guatemala to the West. It is mostly covered in forests and farmlands that have been created through deforestation that result in heavy erosion. "More than three-fourths of the land area of Honduras is mountainous, lowlands being found only along the coasts and in the several river valleys that penetrate toward the interior. The interior takes the form of a dissected upland with numerous small peaks. "

The following maps (fig 1.2-3) is an interactive map that can be accessed through the link and it shows different populations and their proximity to their nearest hospital. It also displays the major roads and the countries contour lines to demonstrate its terrain.

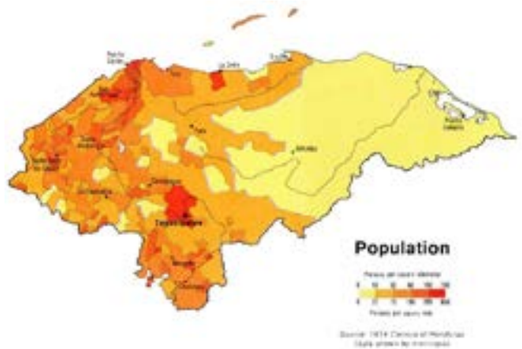


Fig 3.3: Map sourced from Ball States GIS Library
Country Population

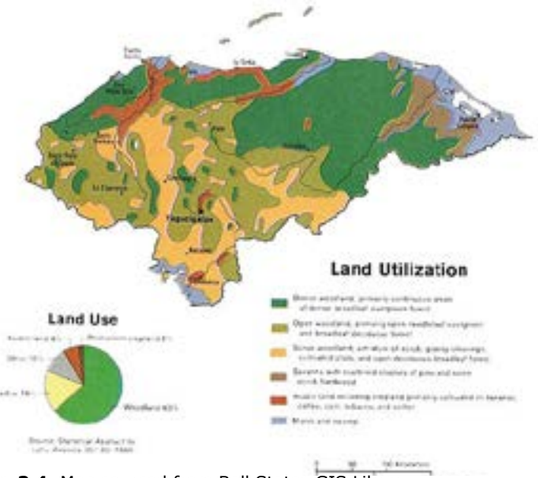


Fig 3.4: Map sourced from Ball States GIS Library
Country Land Utilization

Fig 3.5: Map sourced from Ball States GIS Library
Country Economic Activity

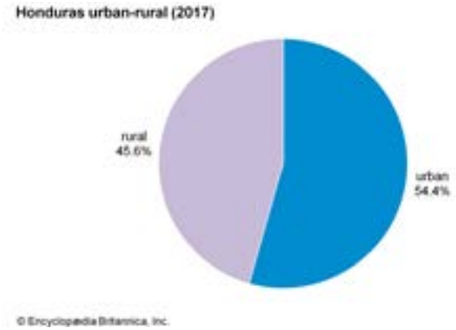


Fig 3.6: Wayne M. Clergern, J. Roberto Moncada R, and Ralph Lee Woodward. "Honduras." - Statistics https://www.britannica.com/place/Honduras.

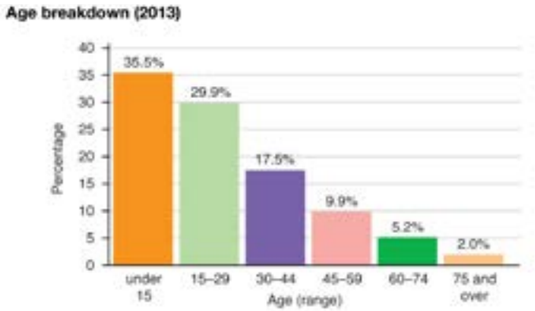
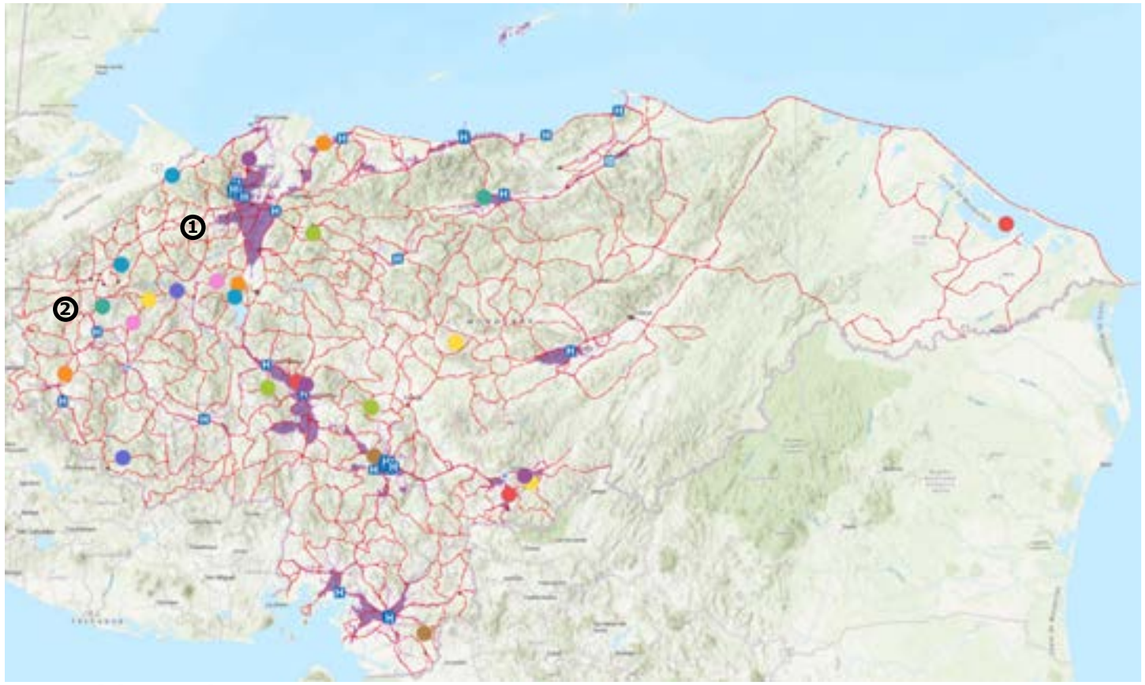


Fig 3.7: Wayne M. Clergern, J. Roberto Moncada R, and Ralph Lee Woodward. "Honduras." - Statistics https://www.britannica.com/place/Honduras.

Honduras Hospitals Compared to Population



Map with Roads

Map with Terrain

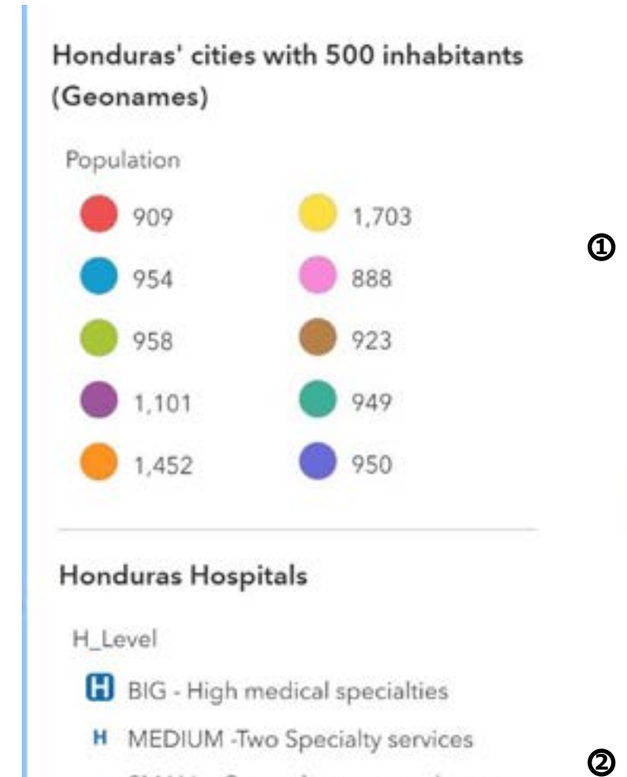


Fig 3.8: Map by Author - Honduras Hospitals Compared to Population

① Site 1

② Site 2

Fig 3.9: Photo by Author - Rural Middle Class

Fig 3.10: Photo By Author - Urban Inner City

Fig 3.11: Photo By Author - Rural Lower Class

Demographics

The country is close to evenly divided by its rural and urban context. A majority of its rural population are below the poverty line. The country is mostly populated on its North West and South West regions. A lot of territory on the East is predominantly inhabitable and protected land. Over half of the country's population is younger than 30 and less than 10 percent of the country is above the age of 60."Honduras, like its neighbors in the region, is a developing nation whose citizens are presented with innumerable economic and social challenges, a situation that is complicated by rough topography and the occasional violence of tropical weather patterns." Fig 1.4-6 demonstrates a range of different lifestyles per class in the country. Many of its structures are built out of concrete block in both urban and rural context.

Honduras has been plagued by an extreme amount of violence. Being the most Central country amongst the Americas, it suffers from the conflicts of neighboring countries and cross trafficking of humans and narcotics. Much of this results in the terrorization of the countries citizens and many casualties. Hopefully with more accessible care they can provide a positive intervention that helps lower death rates.

Land Types

There are four typical different land types. It has dense tropical evergreens that boast broad leaf trees and dense forest belts that border the north and fill much of the north west. On the west there are rainy sandy plains with a pine savanna in the lowlands. There are coastal and lagoon swamps that have mangroves and palm forests. Finally, there is a large amount of deciduous tropical forests. They have temperate grasslands and open dry deciduous woodlands. You can find it in the country's interior highlands, basins, and valleys.

Soil Types

There are three different soil types in Honduras. The northern coastal side has alluvial plains and coastal sierras with clayey and sandy loam soils. It makes up one-eighth of the land area and produces bananas, rice, cassava (manioc, or yuca), oil palm, corn (maize), citrus fruits, and beans. The central highlands have fertile soils derived from lava and volcanic ash. It covers two-thirds of the national territory and a vast majority of the population. It offers numerous flat-floored valley between 2,000 and 4,000 feet in elevation. The pacific lowlands also offer very fertile soils that are composed of alluvium or volcanic detritus. It is a small portion of the land area with a smaller population. This soil produces sesame seed, cotton, some corn, coffee and sorghum.

Environmental Requirements

Fig 3.12: Lifestraw Community Filter
https://www.lifestraw.com/products/lifestraw-community

This unit will need to be self-sustainable to function in various environments that may not have access to active systems. Health facilities typically consume large amounts of energy due to its equipment and standards. it will have renewable energy sources implemented. The country has a very constant sun exposure through most of the year, but it has a couple of heavy rain months that could inhibit the photovoltaic systems. It also has a large amount of foliage overcast that may block direct sunlight from reaching the panels. It will include Lithium batteries to store energy and backup generators. Possibly other renewable energy strategies could be adapted into the design to support the system when the photovoltaics do not have optimal conditions.

It requires a clean sterile environment with plenty of readily available clean water. It will need its own water filtration system to be able to provide constant clean water. A built-in water filtration system for the unit will be necessary for its plumbing. A separate water filter unit could be incorporated for the communities use so people could bring and filter water to support a healthy lifestyle. A large amount of the country's ailments is due to a lack of clean water. Fig 2.3 is a viable option for water sanitation for the community. With an open water filter, they can have more reasons to visit the unit and have regular checkups. This would also make it a more commonly recognized unit known for being a resource to the community which would make it more inviting.

With a multiple unit clinic, It could incorporate an architectural pneumatic structure. A pneumatic structure is a stabilized membrane through the pressurization of compressed air. It would have to be air-inflated rather than air-supported so it can be built up and down. It would have a building element that are shaped to support loads or provide a shelter. This could be a simple or a complex system that would become an indoor-outdoor space for the clinic and it would work to further connect the units. Fig.2.4-5 demonstrates an example of pneumatic architecture and its buildup. It does rely heavily on its foundation and may require a lot of energy to be supported. This is an idea that I am exploring but may or may not include in the final design.

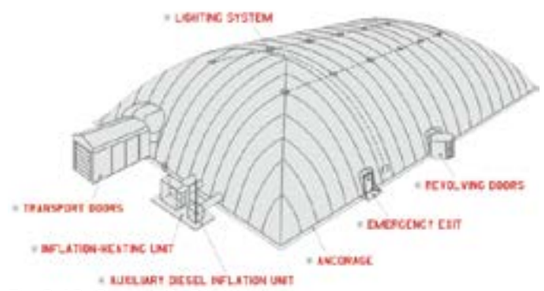


Fig 3.13: Pneumatic Diagram
https://sites.google.com/site/pneumaticstructures1/home/components-of-pneumatic-structures

Fig 3.14: Pneumatic Construction by Koch Membranen
https://www.architonic.com/en/product/koch-membranen-pneumatic-construction/1435839

Behavioral Requirements

There are many health issues and concerns within Honduras and much of Central America. "It is documented that Honduras lacks adequate access to health services: 83% of Honduras is without health insurance and 30% is without health care as of 2007. Infant mortality, a standard measure of population health, is 25 per 1,000, 10 more than the regional average. The reasons for healthcare limitations in Honduras are multiple, including inadequate numbers of physicians (0.8 per 1,000 persons), variable medication supplies, gaps in infrastructure, financial constraints, and sociopolitical factors."[1] Mobile care units would be beneficial for this country to have more local health care in rural communities of the land. Then in severe cases of emergency they could be transported to the nearest hospital to receive immediate attention, rather than being forced to travel without the guarantee of treatment.

For these pods it will be very important to establish an operational plan. They should have open communication with other units and its partnered or closest hospital. This will make it so they have access to other medical professionals for guidance or input. They would maintain contact through a telemedicine communication system. It could be an established team specifically for the units or they could partner with their nearest hospital or a global organization. They could also have a set home base designed for extending its programmatic facilities. That facility could be designed to coordinate pods,host more procedures and provide trainng. Possible collaborations could include the American red cross or doctors without borders. They could eventually start a residency training fellowship for medical school graduates. This could work to connect learning practitioners to trade expert. It could also practice with existing medical practices in Honduras, like Honduras Outreach Medical Brigade Relief Effort (HOMBRES). They are "committed to not only providing the best medical care for the people of Honduras and the Dominican Republic but to also provide education in global health medicine to the future doctors of the United States."[2]

If a community felt they needed access to closer medical care they could crowdfund online or partner with a hospital to train graduates and receive care from the pods. They wouldn't be contracted by the government of a country so they wouldn't be under their legislation for practice. This gives medical practitioners the ability to travel to wherever they feel that they are needed in cases of natural disasters or outbreak epidemics.

1 Catherine A. Pearson, Michael P. Stevens, Kakotan Sanogo, and Gonzalo M. L. Bearman. "Access and Barriers to Healthcare Vary among Three Neighboring Communities in Northern Honduras."

2 Catherine A. Pearson, Michael P. Stevens, Kakotan Sanogo, and Gonzalo M. L. Bearman. "Access and Barriers to Healthcare Vary among Three Neighboring Communities in Northern Honduras."

Spaces Lists

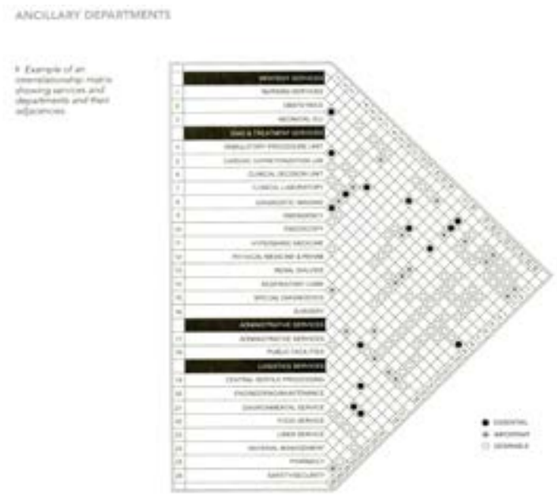


Fig 3.15: Richard L. Kobus, Building Type Basics for Healthcare Facilities, pg 24

Standards

The standard unit would be designed to be a ready to use exam room. It will have an open plan that incorporates outdoor circulation. It will need to be able to accomodate two practioners a patient and a guest. The interior space should incorporate sufficient lighting. It will have its standard unit light and a procedure light. The procedure light is required for many medical assessments. There are numerous options like fiber optics, halogen lights, mobile units and portable headlights. The walls should be well insulated for optimal conditions. Medical grade materials would need to be included to provide infection control.

It will need to minimize its system wattage and incorporate equipment that consumes a lower voltage. It would be supported by a sustainable solar panel array. An inverted heat-pump and air-conditioner may be the best solution for a climate-controlled space. It would also need ample storage to carry equipment and materials. Certain equipment will be required per unit. It would require fixed equipment and interchangeable pieces to service various functions and procedures.

The pods would be durable, modular and expandable to service various needs. Single units will be able to connect to other units to expand on the space and programming of a plan. These single units could possibly function as an OBGYN, ophthalmology, dental, maternal/infant, trauma/ER, infectious disease, family medicine, primary care, intensive care unit, orthopedics, and inpatient hospital service rooms. A typical standard primary care clinic would have an examination, treatment, and diagnostic unit. This will allow for a quicker turnover through a phase progression.

First you would get a general examination and if the patient requires further treatment they would proceed to the treatment unit. Sometimes extended examination will be required then they would proceed to the diagnostic unit followed by the treatment unit. These three pods would require a support unit. This unit would facilitate the phase progression. have a bathroom and a pharmacy. It would store any specialty equipment and a community water filter. These units will be customizable and become building blocks for a custom clinic.

Room Data Sheet

An emergency room has certain required equipment that cannot be avoided. The most important piece is an adjustable exam table. One that can lower to eighteen inches and holds underneath storage would best serve this unit's purpose. It typically has a length of 57.5" and extends to 71" with a width of 26.5". The leg extension length is 15" with a 20.5" by 11" by 8.6" step. It required a clear floor space of 30" by 48" minimum adjacent to the exam table. The adjoining accessible route makes it possible to do a side transfer into the exam table. The unit door entry requires 32-inch minimum clearance with 90 degree opening.

A patient monitor is necessary to keep track of key clinical measurements. The GE healthcare B105 OR B125 patient monitor is a viable option for this model. An integrated diagnostic system provides all the necessary tools for a basic examination. It is wall mounted and includes an ophthalmoscope, otoscope, sphygmomanometer, and an electronic thermometer. This retains the equipment charge while keeping everything in arms reach. A spot vitals instrument captures blood pressure, pulse rate, and temperature. An Automated External Defibrillator (AED) is a must for any medical location to be ready at a moment's notice. A respiratory module keeps track of the patient's respiratory patterns.

Some equipment that can be shared between units is a scale and pediatric scale. A medical refrigerator is necessary to maintain and store certain supplies. An electrocardiogram (ECG) Device records electrical activity of the heartbeat and may be needed for treatment but not constantly. A spirometer allows you to assess pulmonary issues such as obstructive restrictive disorders. An anoscope is not required but it helps to determine an accurate diagnosis by ruling out many concerns and eliminating the need for further testing.

Some miscellaneous equipment is necessary for ideal examination performance. A computer stand or cart allows for easy access to an electronic health record (EHR). It will require a sterilizer chamber for proper tool maintenance. An IV pole, base instrument (mayo) stand, glove dispensers, sharps containers, trash cans, and biohazardous medical waste disposal.

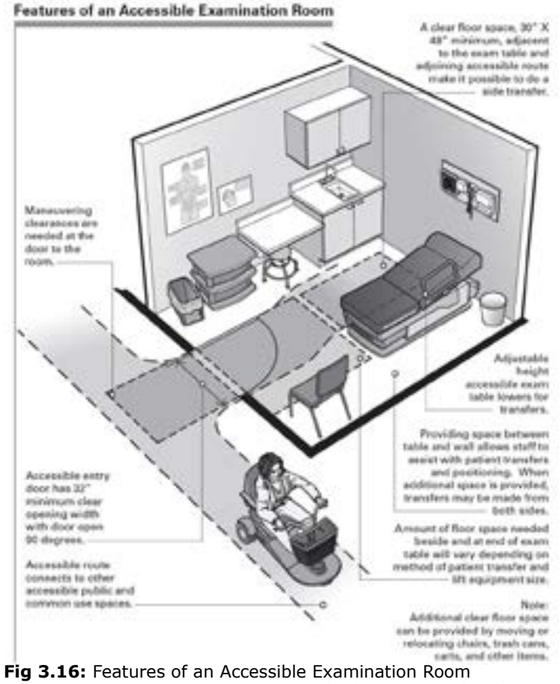


Fig 3.16: Features of an Accessible Examination Room https://www.ada.gov/medcare_mobility_ta/medcare_ta.htm

Automated external defibrillator

Spirometer

Sterilizer

Anoscope

Medical Scale

Procedure Light

IV Pole

Respiratory Module

Spot Vitals

Base Instrument Stand

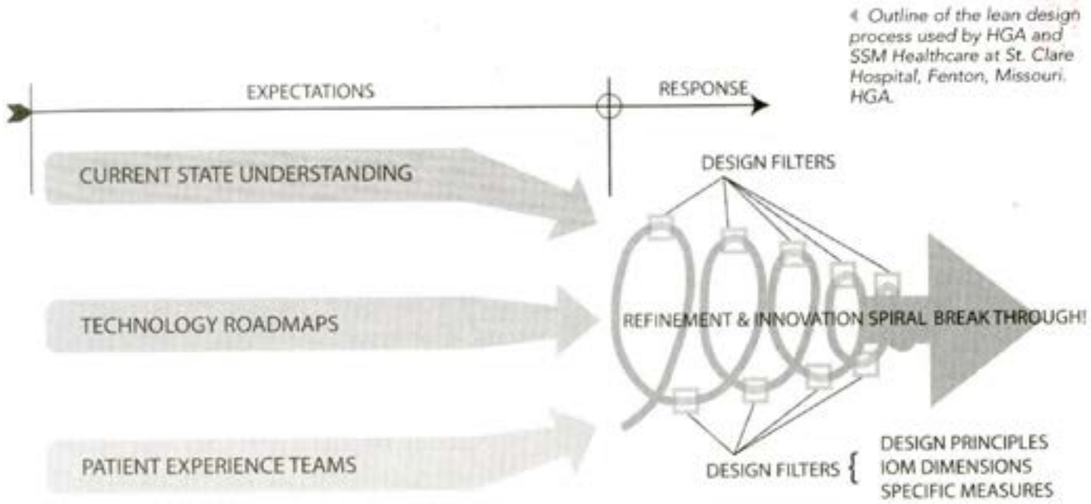
Exam Stool

Fig 3.17: Created by author - Examples of Medical Equipment

Summary

A standard exam room includes a large amount of necessary equipment. Careful consideration in the products power consumtion and size will need to be made.With the incorporation of multiple units they could carry more equipment to further its medical abilities. The minimum necessary equipment is listed below (shown in fig 3.3.)Some of these tools can be limited to one per shared units.

- Exam Table
- Desk Charger
- Integrated Diagnostic System
- Spot Vitals
- Exam Light
- ECG Devices
- Spirometer
- AED
- Anoscope
- Computer Stand or Cart
- Exam Stool`
- Guest Seating
- Storage Cabinetry
- Sink and Counter
- Scale
- EHR readiness



Outline of the lean design process used by HGA and SSM Healthcare at St. Clare Hospital, Fenton, Missouri. HGA.

Fig 3.18: Richard L. Kobus, Building Type Basics for Healthcare Facilities, pg 13

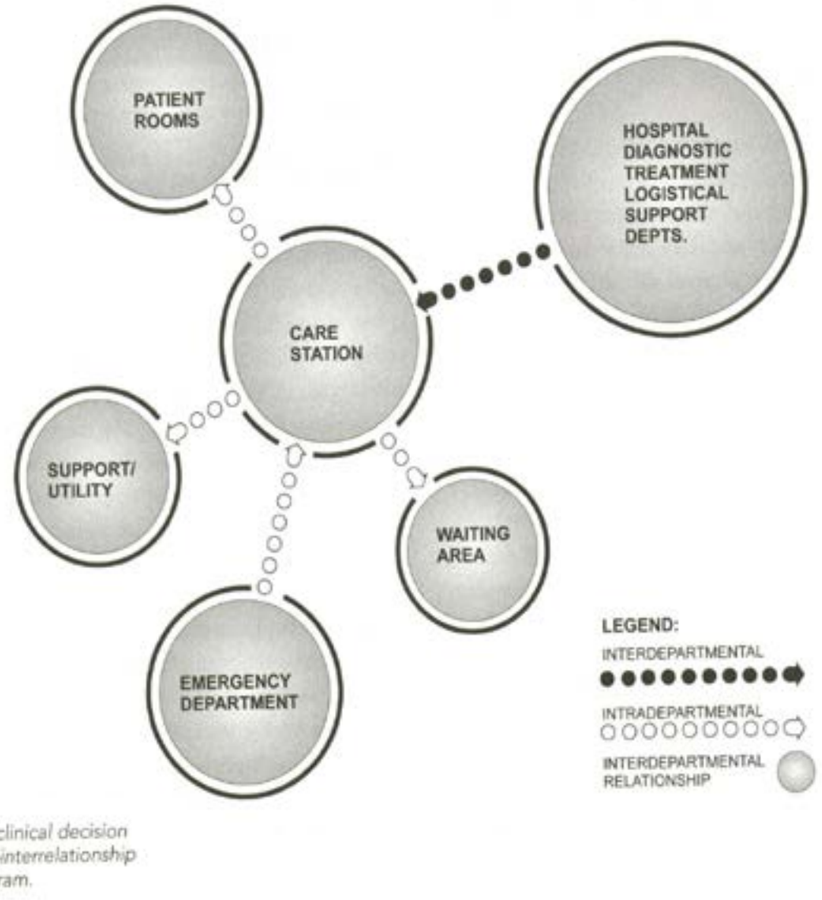
Organization

In the pod design I explored what is necessary for its functions I came up with three basic units that could make up a successful clinic for general practice. This design will primarily focus on the Diagnostics, Treatments, and Examination of a patient. Each one of these phases will receive a unit for a general care model. afterwards more units can be established to further its medical practices. I decided to keep the volume as a rectangle because it meets its service best and allows for simpler expansion.

In the design it has to understand the expectations of the current state, the required technologies, and the patient experience. Some alternative functions the units could be adapted for is as an infectious disease ward, an infant and mothers ward, a children's ward, a surgery unit, or research lab.

Currently the plan is 12 feet by 8 feet before its expansion making it 96 square feet. After expansion the unit should be close to 200 square feet. I am evaluating how to connect units through the expanded elements with air sealed joints. The following Diagrams and sketches demonstrate some conceptual ideas for the further development of the pod units.

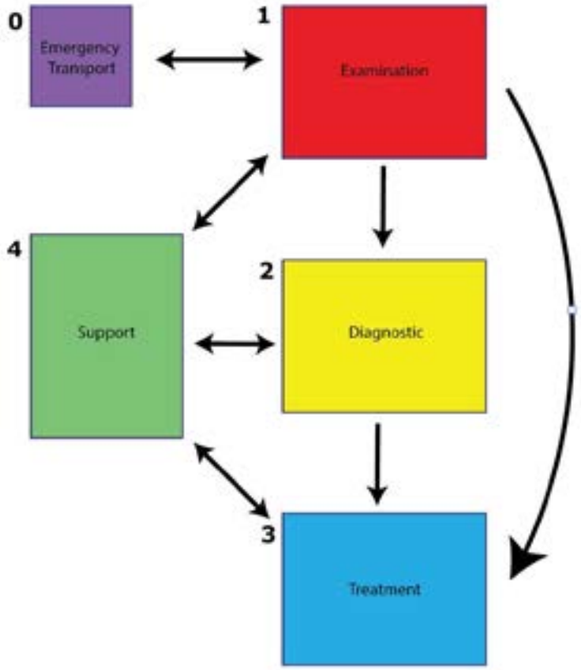
Common illnesses and concerns that the unit will need to be prepared to treat are malnutrition, infections and parasites, gastroenteritis, tuberculosis, influenza, malaria, typhoid, pneumonia, AIDS/HIV, cholera, diabetes, and cerebrovascular disease. More research for how these illnesses are treated will need to be done to determine strategies for treatment.



A clinical decision unit–interrelationship diagram.

Fig 3.19: Richard L. Kobus, Building Type Basics for Healthcare Facilities, pg 26

Unit Program Diagram



1. Examination
Main pod cares for common and minor ailmentd. Decides how to proceed.

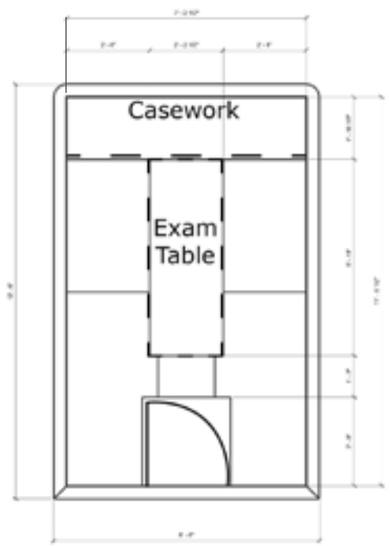
2. Diagnostic
Runs studies and tests on patient. Has interchangeabble equipment from support.

3. Treatment
Sterile unit that provides extended care after examination or diagnostics.

4. Support
Holds supporting equipment and materials. Would mainly support Diagnostic and treatment programs. It may support circulation and a pharmacy.

0. Emergency Transport
An emergency ambulatory unit that would transport an at risk patient to the nearest hospital.

Unit Plan Layout



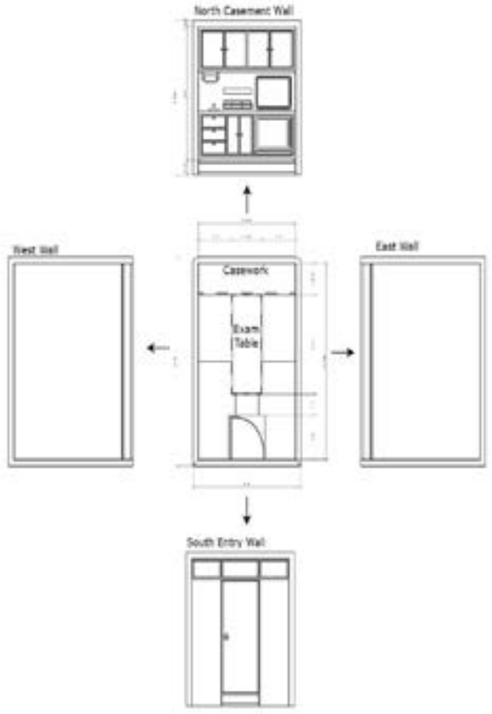
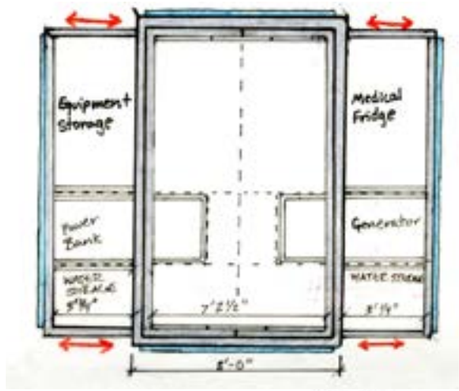


Fig 3.20: Sketch by author - Preliminary sketches of Unit Program and Layout

Conceptual Unit Diagram



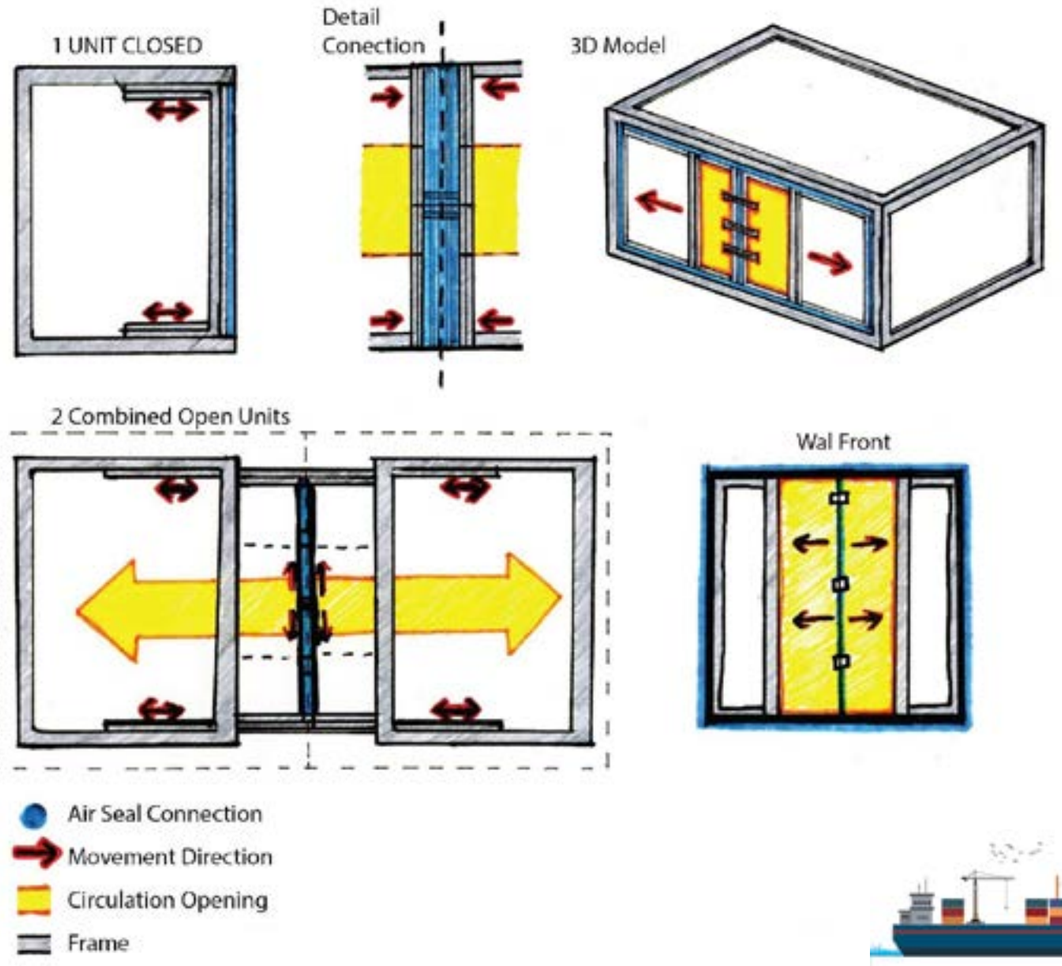


Fig 3.21: Sketch by author - Preliminary sketches of Unit Expansion/ Connection and Support Layout

Code Ordinances & Regulations

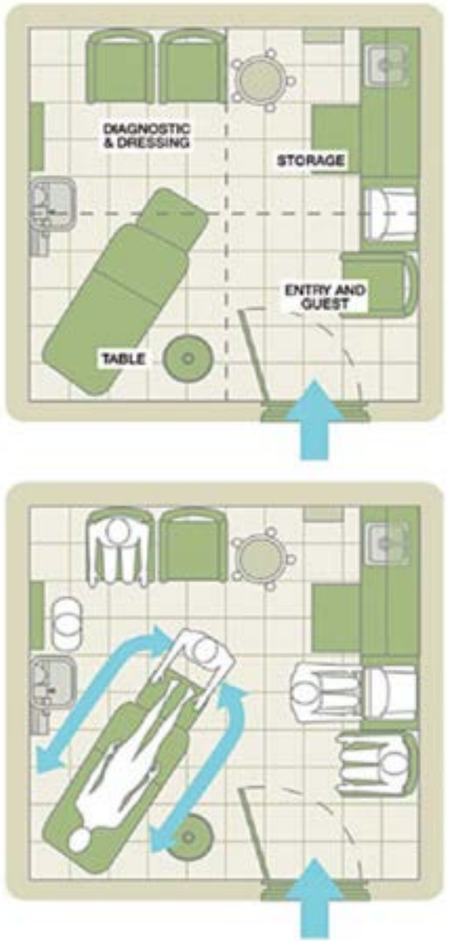


Fig 3.22: Features of an Accessible Examination Room
https://www.aafp.org/fpm/2007/0500/p46.html

Code Ordinances

11B-805.4.1 Beds, Exam Tables, Procedure Tables, Gurneys and Lounge Chairs. A 36 inch (914 mm) minimum wide clear space shall be provided along the full length of each side of beds, exam tables, procedure tables, gurneys and lounge chairs.
EXCEPTION: General exam rooms in non-emergency settings may provide clear space on only one side of beds, gurneys and exam tables.

Also, new amendments to the 2013 CBC which are to be effective as of July 1, 2015 include additional text in the 'OSHPD' code sections of 1224 that will affect us in application of access requirements, see below:

1224.4.4.1.1 Examination room. Unless specified elsewhere, if an examination room is provided, it shall have a minimum clear floor area of 80 square feet, the least dimension of which shall be 8 feet. The room shall contain a handwashing fixture and accommodations for written or electronic documentation shall be provided.

1224.4.4.1.2 Treatment room. Unless specified elsewhere, if an examination room is provided, it shall have a minimum clear floor area of 120 square feet, the least dimension of which shall be 10 feet. A minimum of 3 feet is required between the sides and foot of the bed/gurney/table and any fixed wall or obstruction. The room shall contain an examination light, work counter for medical equipment, a handwashing fixture, cabinets, medication storage, and counter space for writing or electronic documentation. Multi-bed treatment rooms shall have separate patient cubicles with a minimum clear floor area of 80 square feet. Each cubicle shall contain an examination light, counter and storage facilities. In multi-bed treatment rooms, a hand washing fixture shall be provided in the room for each three or fewer cubicles.[1]

Regulations

Exam rooms need to have certain regulations to ensure a safe working environment. The staff face many bodily hazards in this workspace. The staff must use personal protective equipment when they risk exposure to bodily fluids, sharp objects and hazardous chemicals. This equipment includes latex gloves, masks, eye protection, and aprons. After each use it must be removed before leaving the exam room and placed in a container for disposal or washing. Bloodborne pathogens from needles is one of the largest hazards staff will face in an exam room. If they were to be stuck by a needle they must report this incident followed by a post-exposure prophylaxis to prevent HIV or Hepatitis infection. Contaminated sharp objects including needles, IV connectors and disposable razors must be disposed of in an appropriate container labeled as biohazardous.[2] Waste receptacles should have a seamless foot operated lid. Staff must be properly trained on cleaning procedures with disinfectant chemicals and they must be clearly labeled. Finally, each room must have exit routes for a safe escape in case of emergencies.

It is the facilities responsibility to promote effective management of concentrated injectable medicines. They also need assurance of accurate care transitions and correct procedure on the proper body location. According to the world health organization (WHO) exam rooms are expected to have hand washing positions in a convenient location. This will promote improved hand hygiene for the prevention of healthcare associated infections. Computers should be positioned so the physician can chart information while facing the patient. The room layout should allow for ready access to frequently used equipment and provide staff and patient zones for privacy. A dressing room may be required in this small space it could be accommodated using cloth curtains and partitions on wheels.

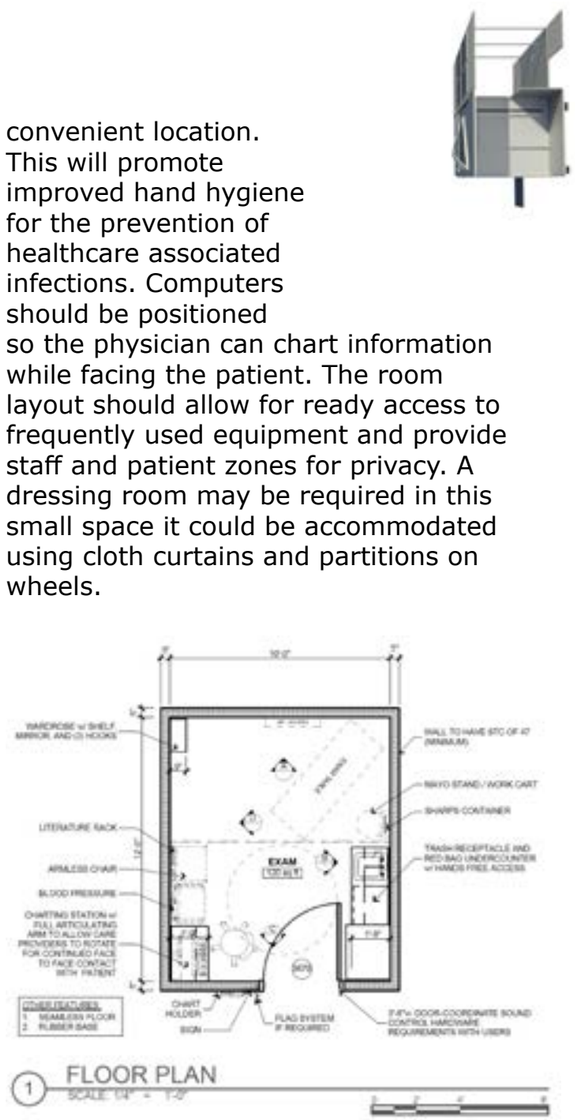


Fig 3.23: Diagrammed Exam Floor Plan
http://portals.clevelandclinic.org/Portals/57/Standard%20Room%20Layouts.pdf

1 https://casinstitute.org/content/exam-diagnostic-and-treatment-rooms
2 https://work.chron.com/osha-guidelines-exam-room-20671.html

Architecture & Engineering Criteria

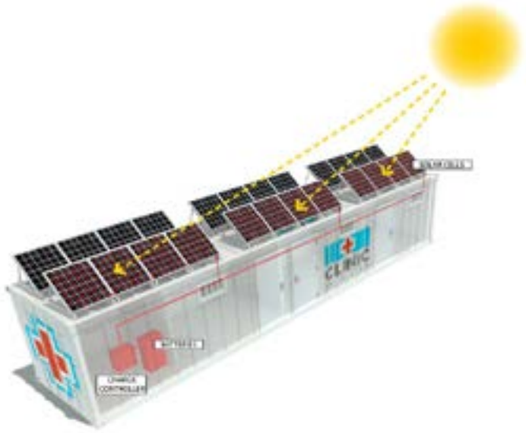


Fig 3.24: Clinic in a Can
http://www.clinicinacan.org/solar-powered-clinics

Systems

The mechanical, electrical, and plumbing (MEP) systems need to work together to create a comfortable and environmental safe space. The mechanical systems will need to control noise, vibrations, humidity, and temperature with comfort control. It will need to mitigate air-change rates, smoke control, air quality and filtration. The plumbing system must have a developed plan for waste discharge. This system should be flexible for accommodate upgrades and maintenance.

This unit requires clean water through sourcing, collection, and filtration. There are various methods to do this, but which is the best suited and most light weight? How large is the water demand? The system will need to provide enough clean water for its regular function and community demand. This could be done with a singular or dual system. One servicing all of it or a system that provides for plumbing and another for drinking. Since the water is a medical facility any water used for the procedure should be sterilized. LifeStraw is a company that sells community water filters. They can support a high capacity and are long lasting, able to produce a lifetime of 26,000 gallons of water. This is an example of one vendor that produces a technology that could be used in this design.

Sustainable Systems

It will need to have sufficient renewable energy storage and resources. It could carry lithium battery packs and a backup generator and fitted solar PV panels for its main source. A complete 3.4 KWh 1920-watt solar system with batteries, inverter and charge controller cost less than a quality diesel generator.[1] The only solar system maintenance is washing the solar panels as needed. A single lithium battery will run two 6 mt solar arrays. That would power a clinic for a more than a standard work week. These pods goal is to fully function with a power consumption of less than 500 watts. The backup battery would power the clinic for around 18 hours with regular use. Consideration for the solar arrays build and format will be important. Which will be most suitable for this environment? Would it be possible to incorporate wind energy, and would it be beneficial? The unit needs to be a quality-controlled space that ensures a healthy sterile space with air circulation and purification.

Structure Systems

The pods structure will be very important for its expansion methods. It will need to be lightweight steel or aluminum frame. The structure could possibly be prefabricated either as a custom build or through a vendor. For it to transform into a larger space it will need levers of expansion. The tenfold design levers or something similar could be incorporated into the structure. "Ten Fold's family of counterbalanced folding linkages are designed to bring mobility, speed, ease and reliability to your products and services." The design only requires a stable ground and its standard model can expand to 729 SF and collapses to 112 SF when closed.

This system uses lever functions by equally dividing its weight and balancing its lever configurations on both sides. It expands with the use of counterbalancing components which allows it to be used without motors if desired. Their levers are designed to carry objects in straight or curved trajectories allowing for multiple methods of expansion. This model would need a simple deployment and expansion strategy. The largest concern with the structure is that it will become to bulky in the interior due to expansion components.

Connecting Systems

A goal for the pods is that they can attach and detach from a mobile unit. That would allow mobile units to become stationary units. These units should also be able to connect to each other. They would need to have air sealed joints at the linking point. To design this, I will look into the design of air sealed doors and windows. For example, an aircraft door functions like a drain plug. It is fixed in place by interior pressure the doors open inward and some retract upward into the ceiling. This is something I will consider in the connection's openings. They could have different geometries but through my research, I have found that a rectangle is the most practical shape for the function. These connecting geometry should be able to have up to endless expansion options.

Material Systems

The wall build of these units will require a high performing building envelope. With the usage of connecting systems the joints need to have special attention to avoid thermal leakage. The walls should have a high R value to minimize its energy consumption. The exterior of the units could be cladded in lightweight aluminum or made up of a seamless polyester. Hopefully it could use recycled metals for the exterior walls. On the interior it is very important that they are medical grade materials. This is necessary so that it is not porous or absorbent of toxic biohazards and can withstand the constant chemical cleanings. The materials should incorporate a light color palette to make it feel more spacious on the inside. On the outside it should look uniform and come together to form a consistent pattern.

1 http://www.clinicinacan.org/solar-powered-clinics

Cost Evaluation

Item	Calculator	$ sub-total	$ total
Unit Cost	(150 gsf x UC x CI x 1.1)	3585.4	
10 units cost	(1,500 gsf x UC x CI x 1.1)	537,809.25	537,809,25
Fixed Equipment	8% of building cost	43,024.74	
Total Construction Cost	(additive of total above)	580,834.00	580,834.00
Moveable Equipment	9% of building cost	48,402.83	
Professional Fees			
Architecture	5% of construction cost	40,658.38	
Contingencies	10% of construction cost	58,083.40	
Total Budget	(additive total above)	1,268,154.22	1,268,154.22

UC = 365
CI = .893
CM = 87,100
Size Factor = .017 (use 1.1)

Fig 4.0: Photo by Author - Little Cousins December 2019

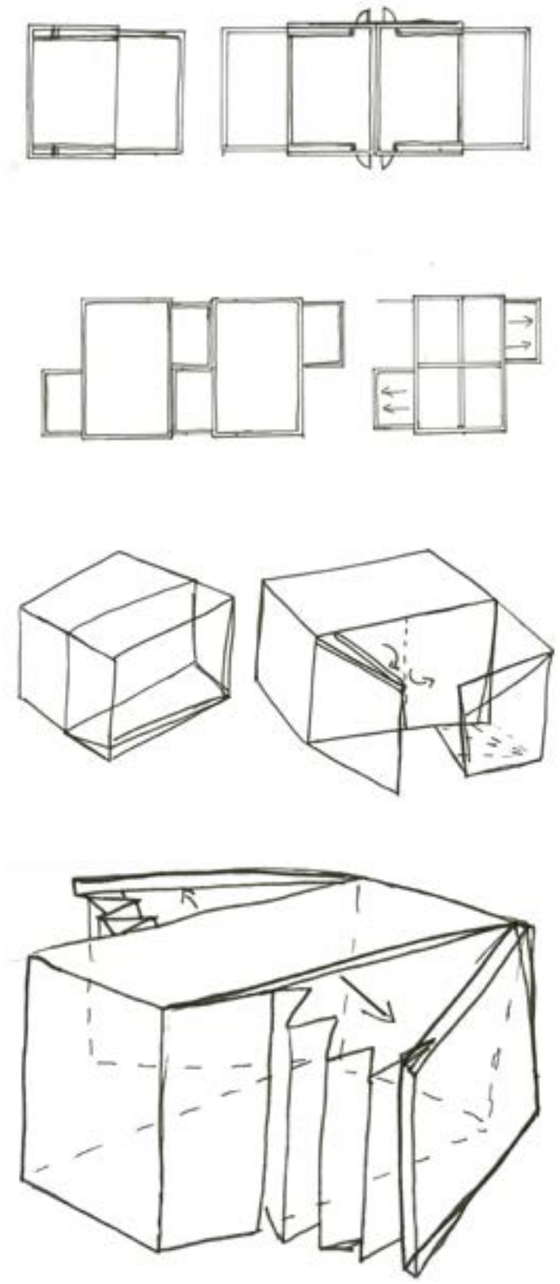
Chapter 4: Design

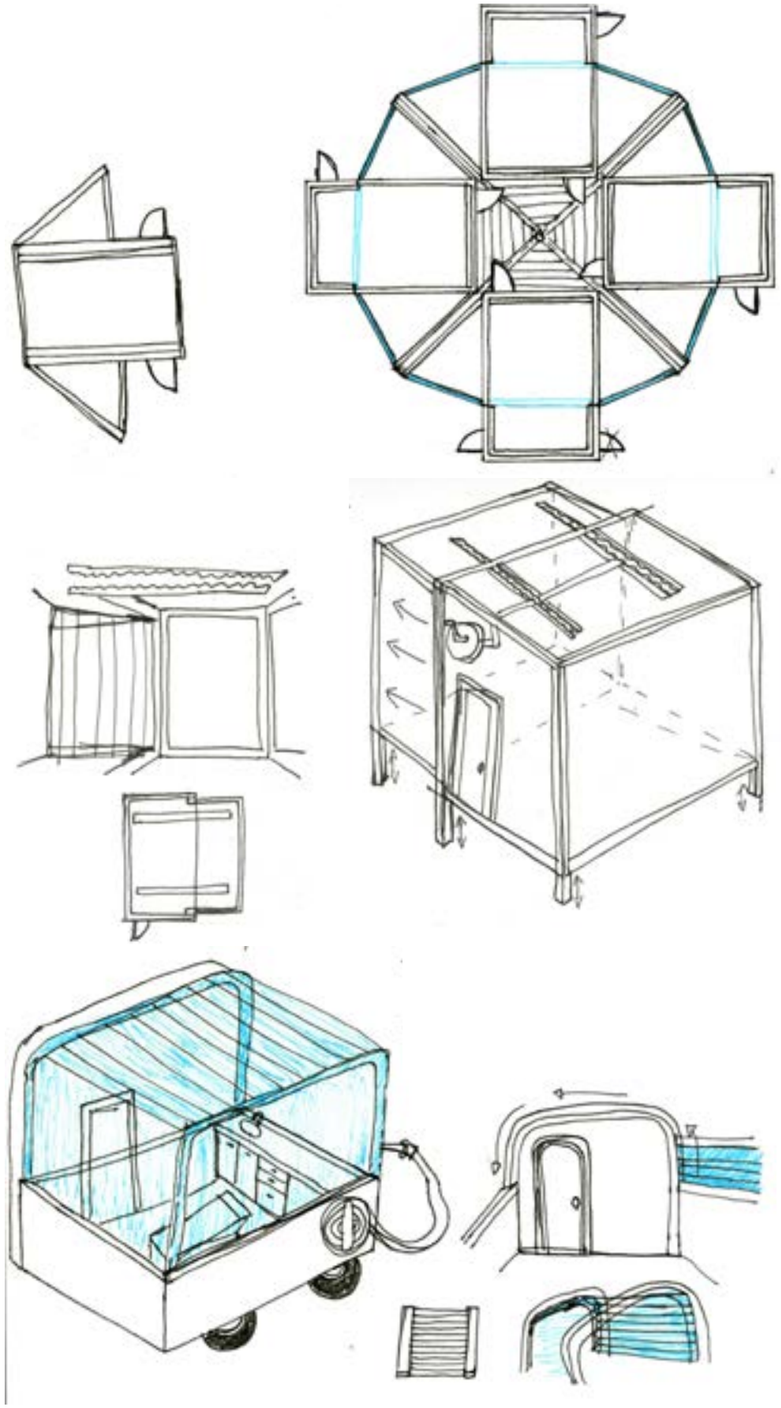
Process

In the beginning stages of my design I figured out how I wanted the clinic program to run together and what standard equipment it required. The program has three main stages that allow for consistent use. The Support unit will be the only different unit and will hold a washroom. Then I focused on its expansion and tried to find the best way to maximize its footprint.

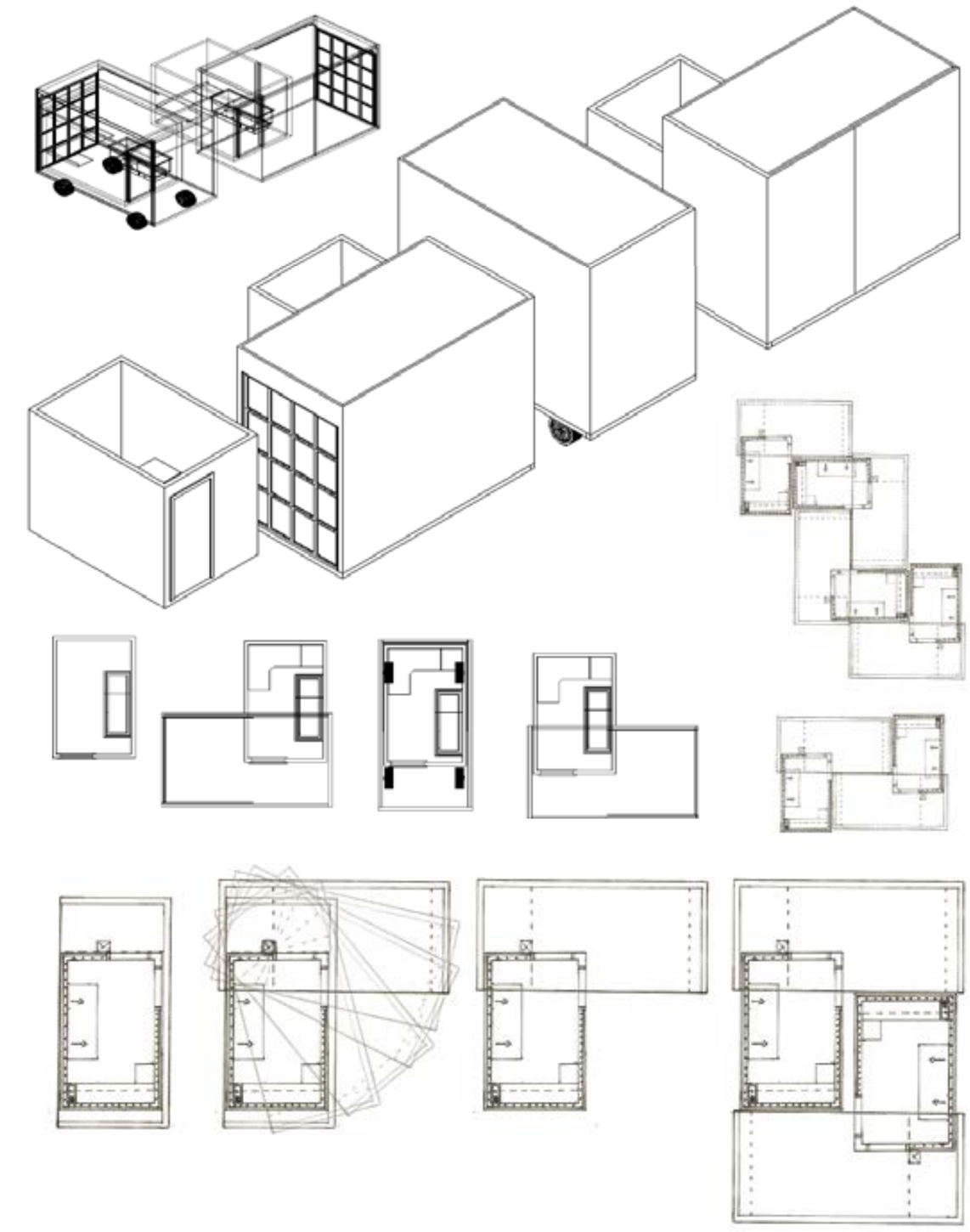
Fig 6.1: Clinic in a Can
http://www.clinicinacan.org/solar-powered-clinics

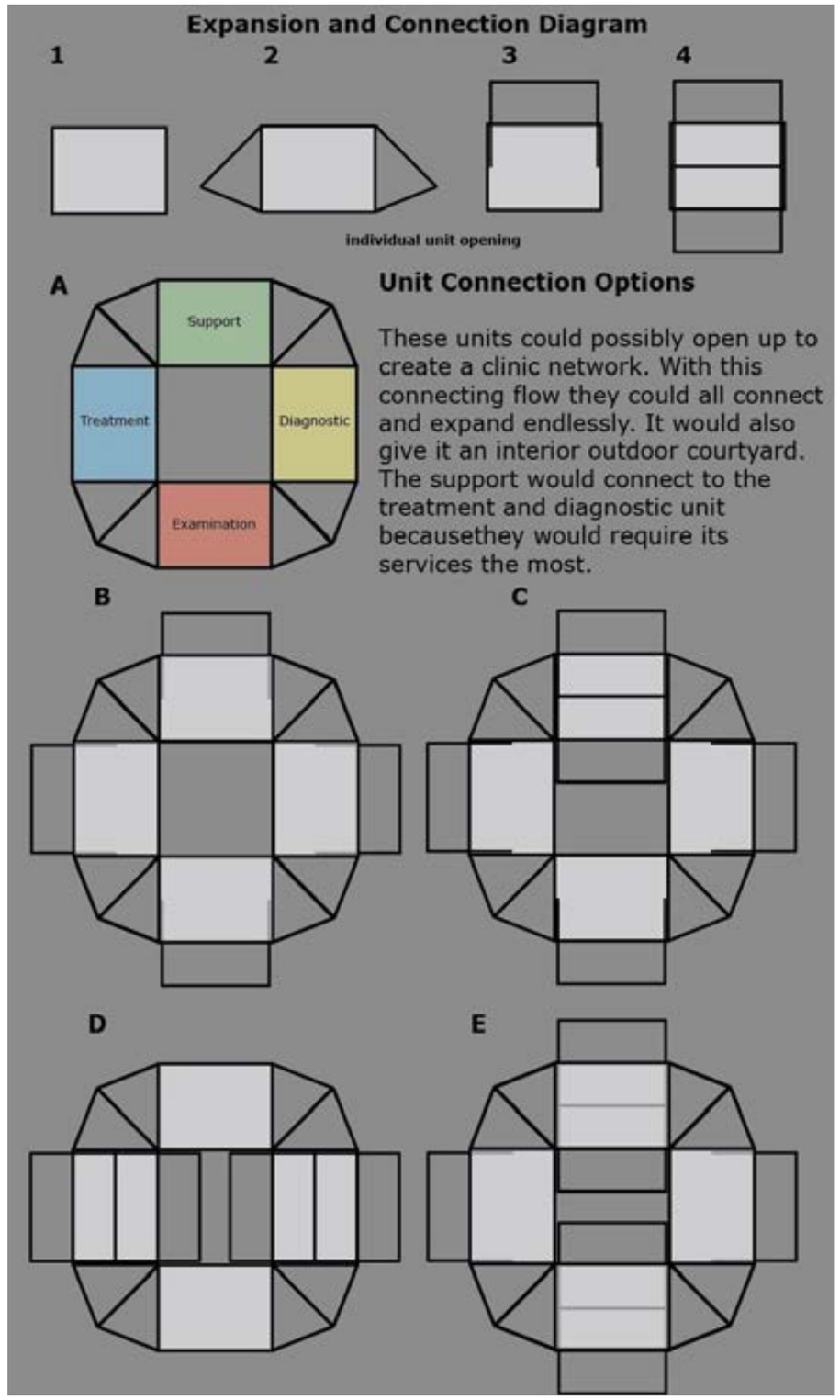
Model Expansion Charrette



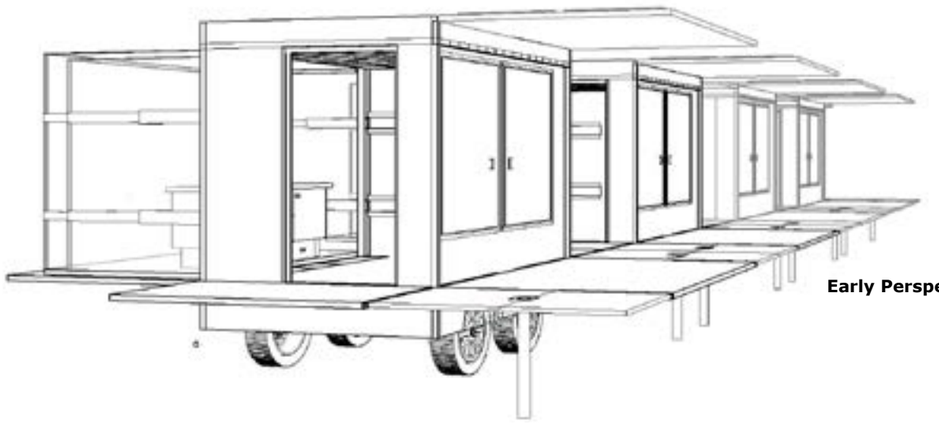


Swivel Unit Design

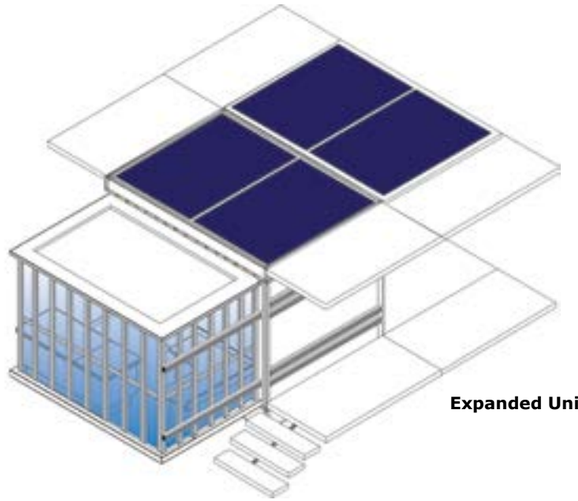




Form

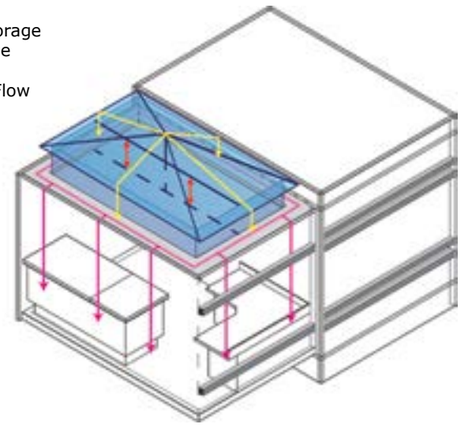


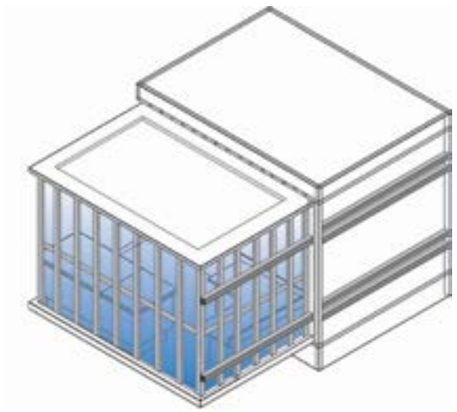
Early Perspective

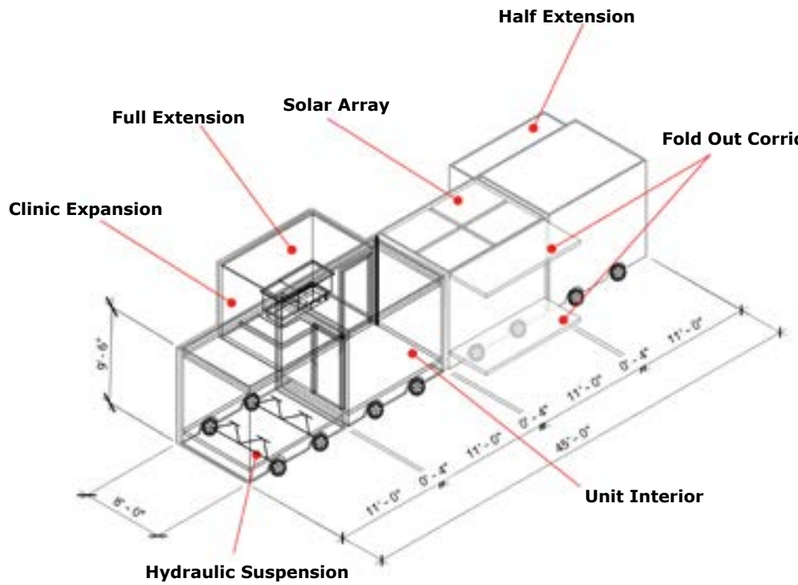


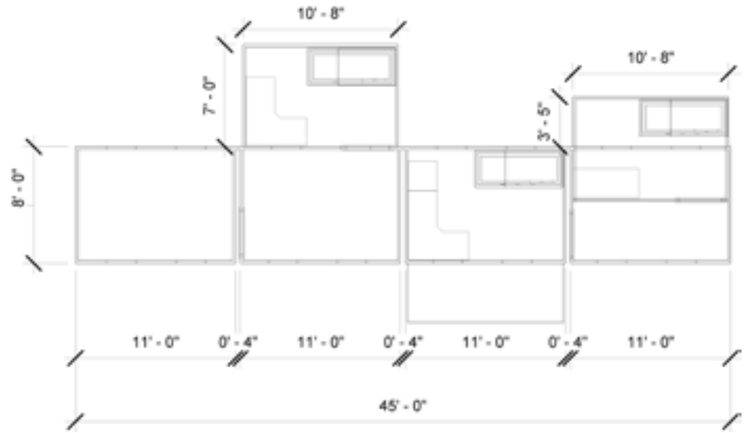
Expanded Unit

- Clean Water Storage
- Water still Frame
- Still Movement
- Purified Water Flow





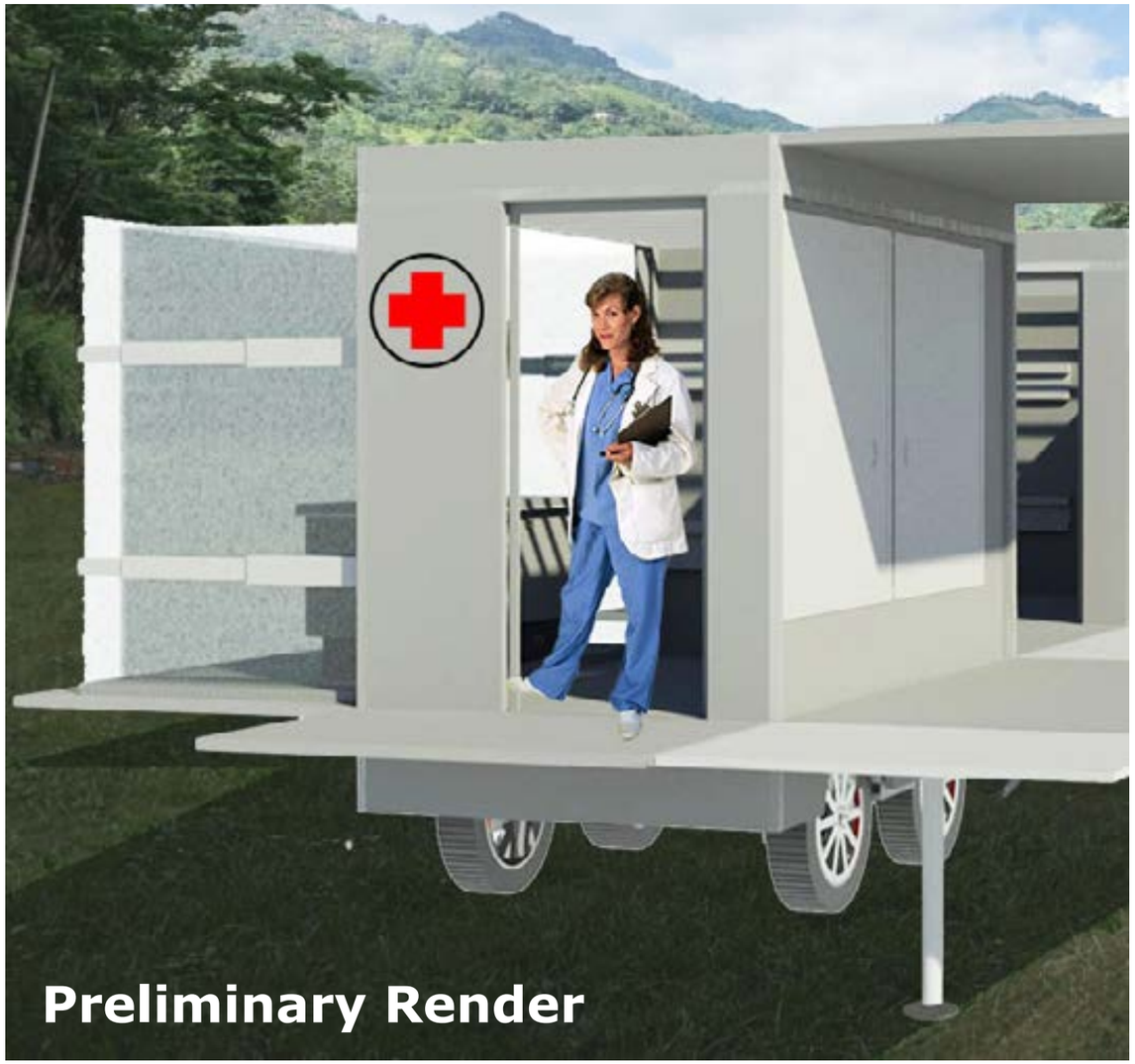


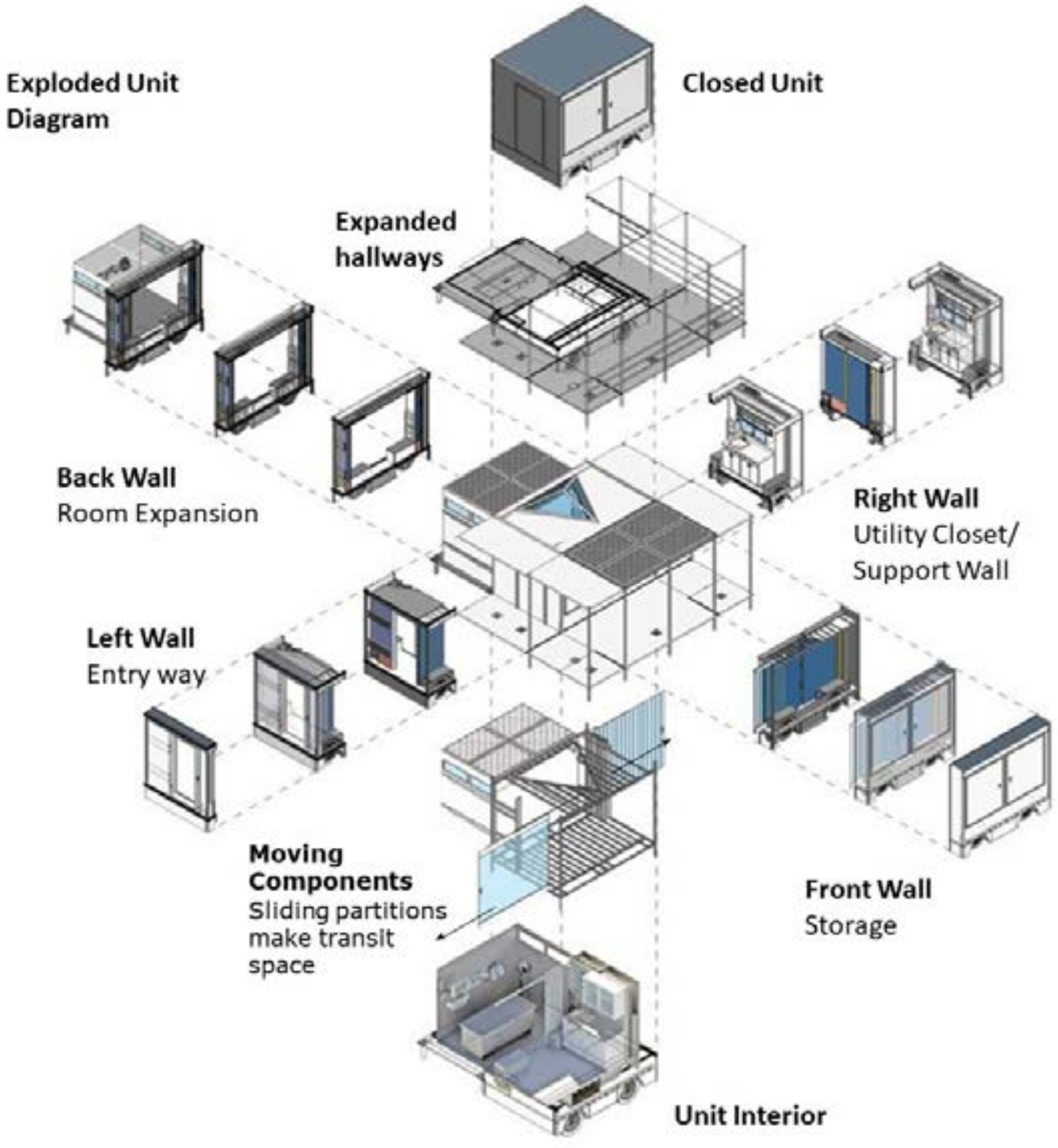


Combined Units

Study Model

I used this model to explore how this unit would expand to scale. It is at a 1” equals 1’ scale. This model helped put the project scale in perspective and allowed me to identify design strategies and concerns.


Preliminary Render



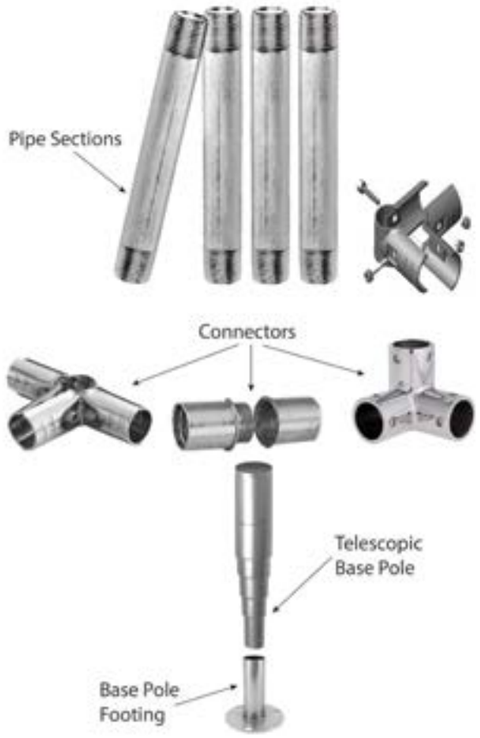
Final Design

The pod design is intended to withstand various terrain conditions to serve wherever it is most needed. The units will be dimensioned to the size of a shipping container so that they can be transported as a regular container and upon arrival it can be divided apart for easier transport to site. This unit expand to almost twice the size of the original stature and utilizes exterior corridors for circulation.

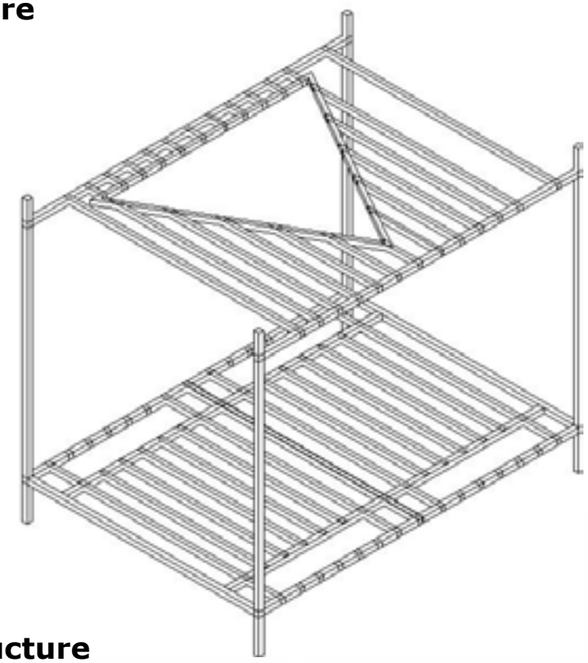
Structure

All structure is made from hollow steel members. The modular structure beams will be stored underneath the unit and will screw together. They will be bolted to the ground with plates

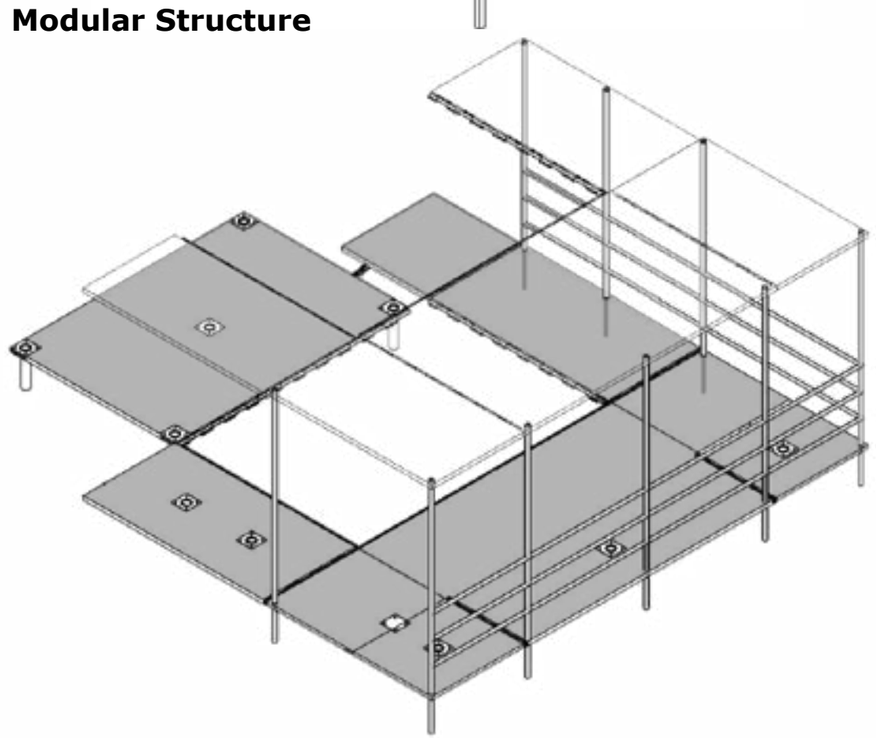
Structural Elements Diagram

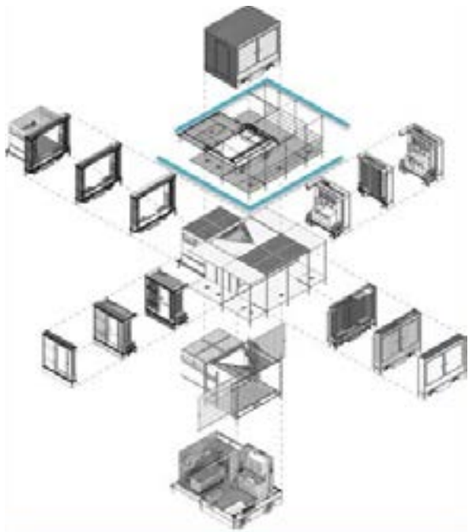


Main Structure

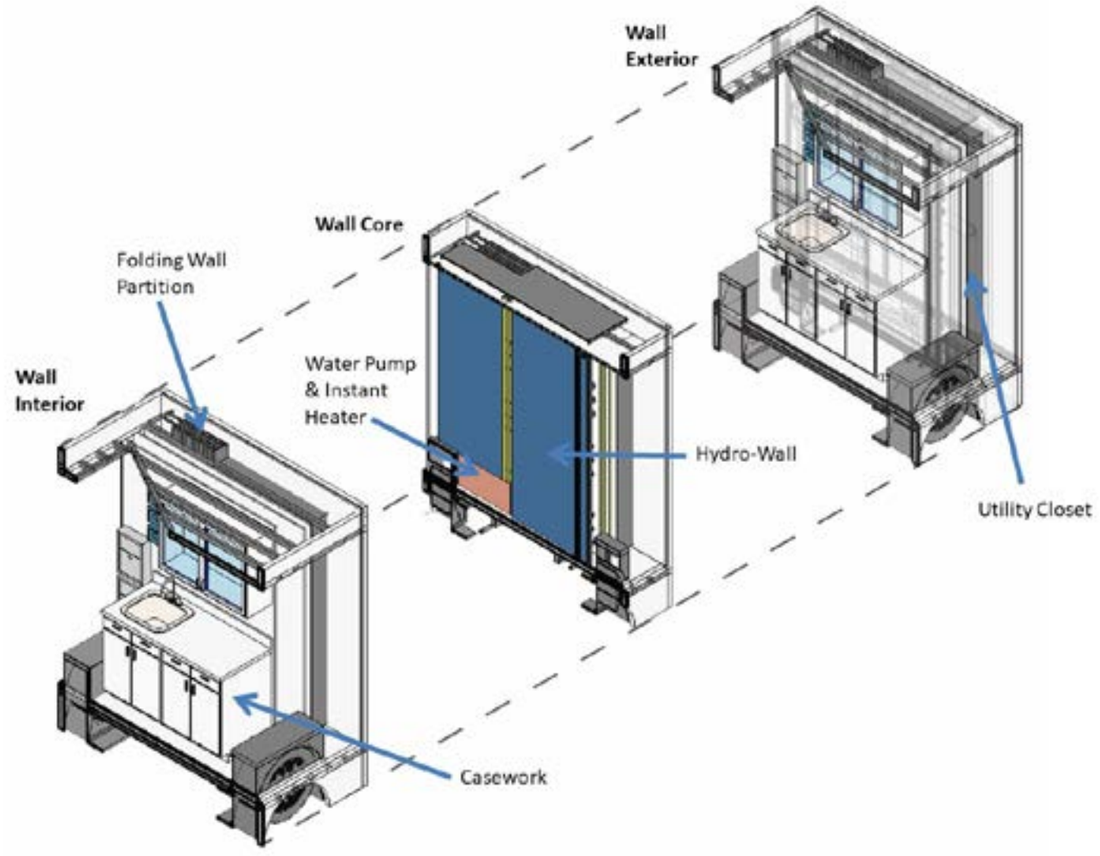


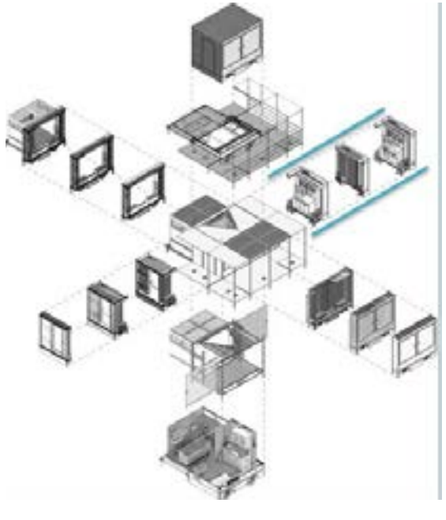
Modular Structure





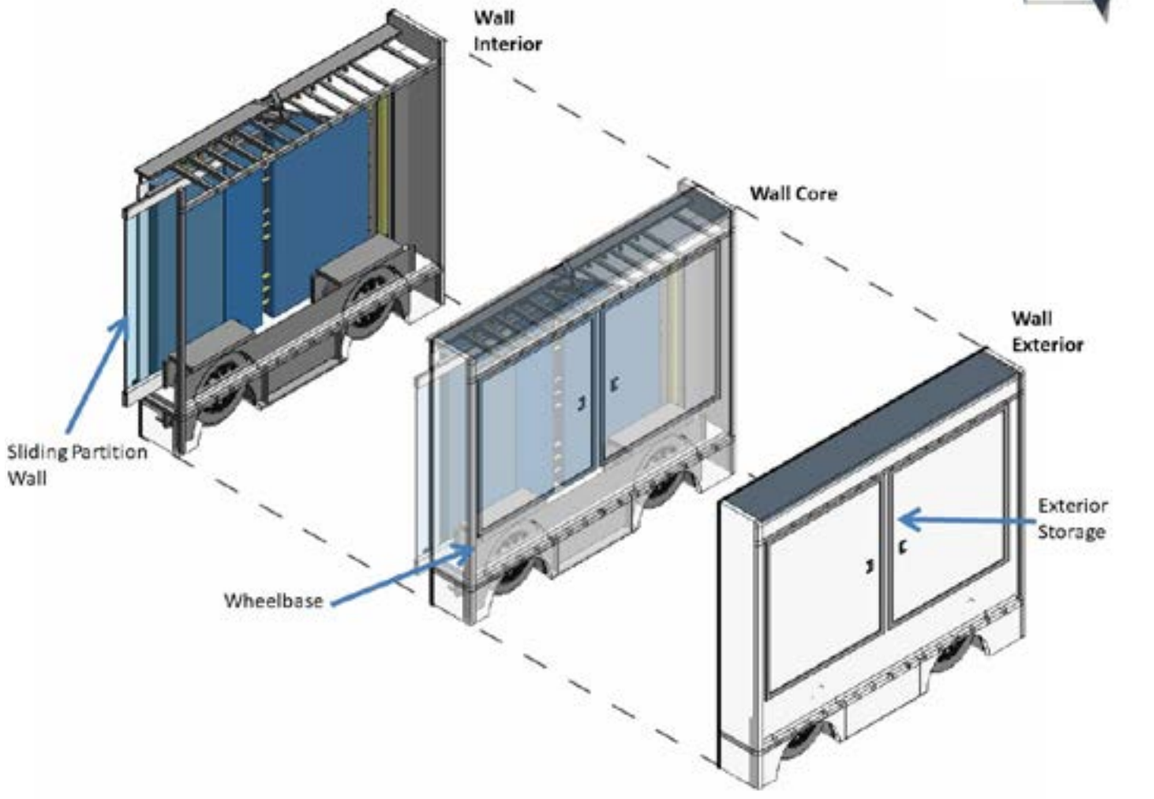
Right Wall

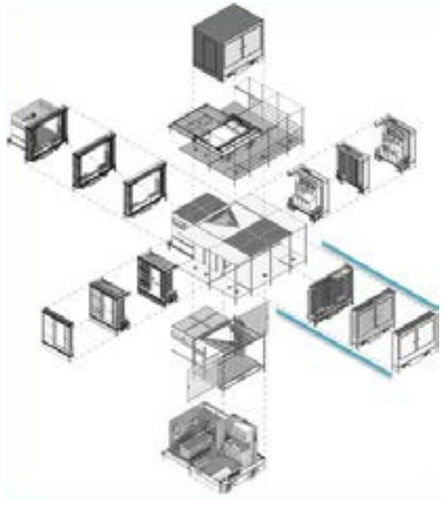




The right wall holds utility support for the system. It hosts the unit's casework which includes a sink and cabinetry. This portion of the hydro-wall system has the water pump and instant water heater. On the backside of the wall is the utility closet and folding wall partition.

Front Wall



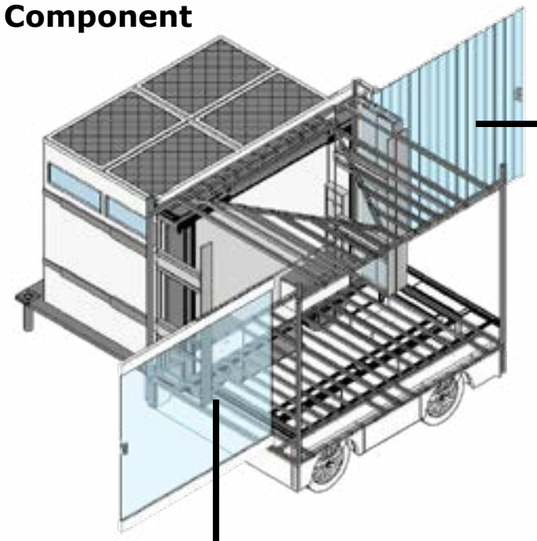


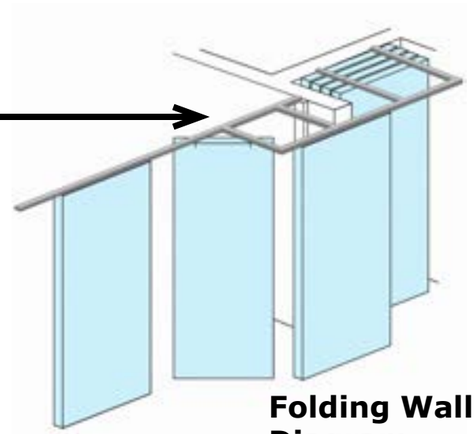
The Front wall has built in storage that is accessible through the exterior. The walls thickness is due to it taking up the width of the wheelbase. The wheelbase has an axle less suspension and hydraulics to lower and raise it into the cavity.

Moving Components

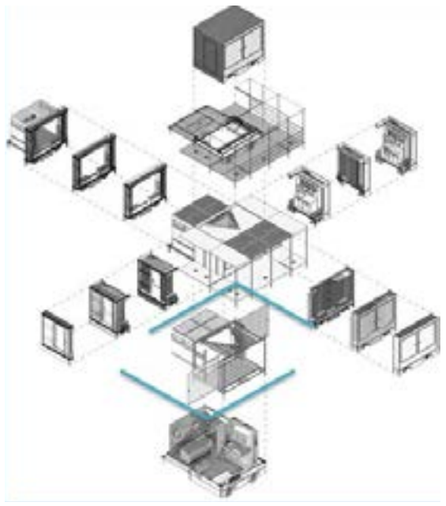
These moving components create a dynamic expansion that opens the space to have a larger footprint. The partitioning walls open into the corridor to create transept spaces that regulate the unit's interior.

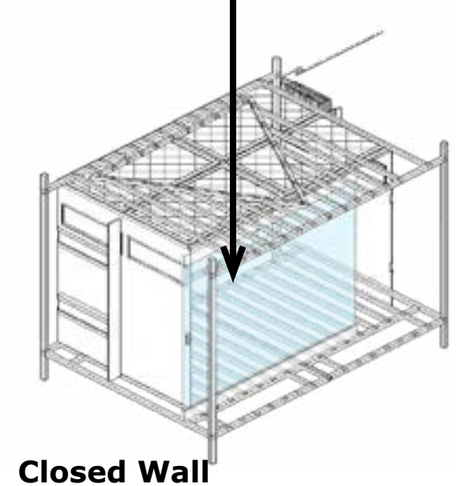
Unit Moving Component





Folding Wall Diagram



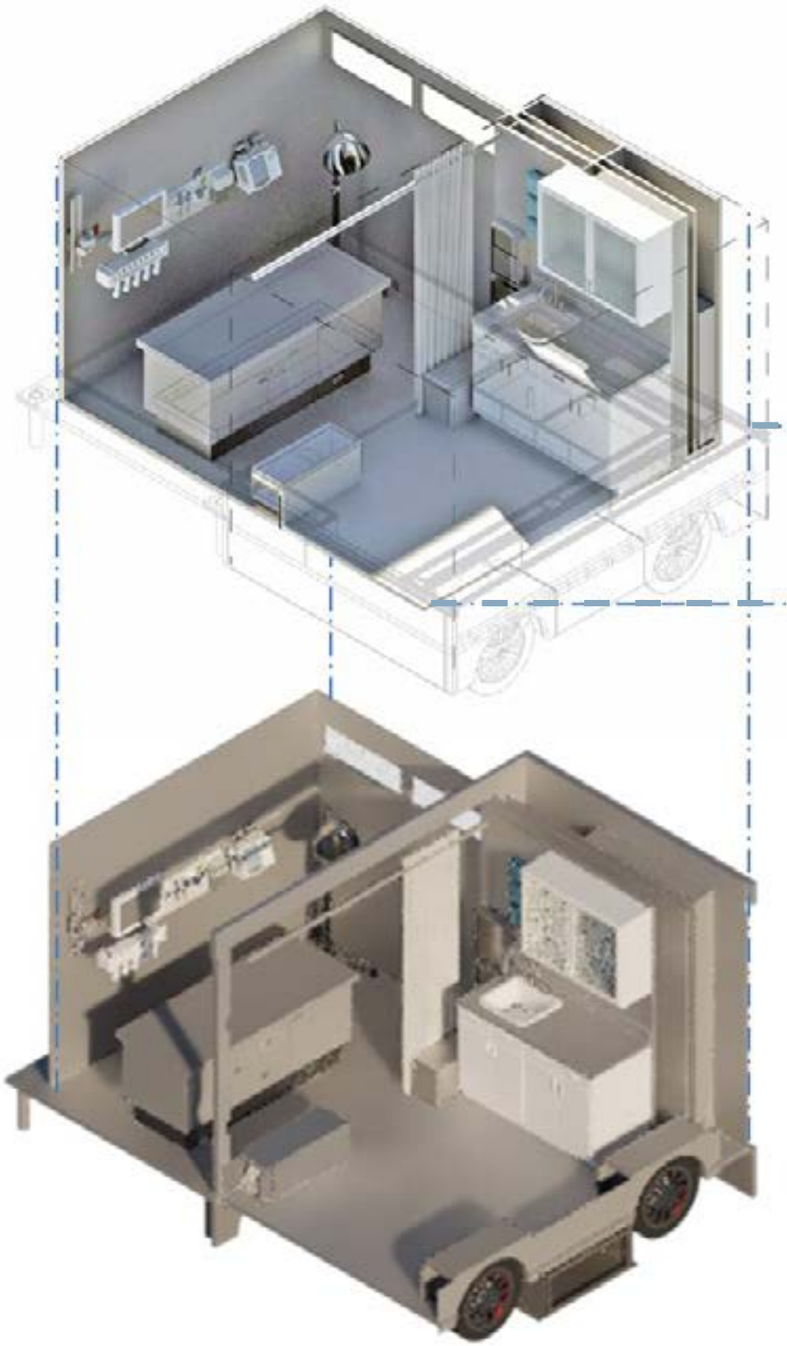


Closed Wall Partition

Opened Room Extension

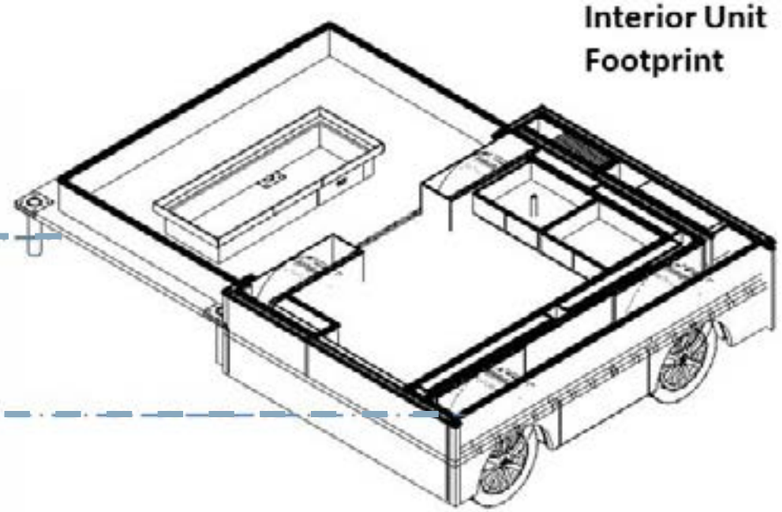
Closed Room Extension

Unit Interior

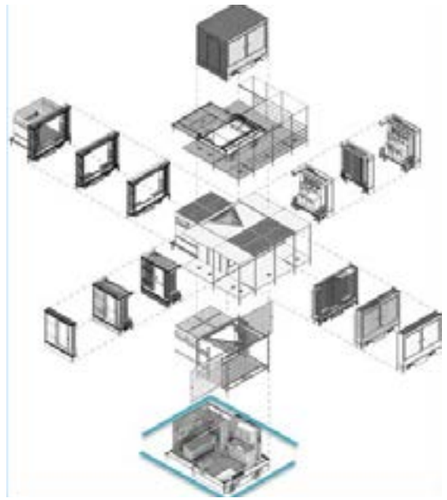


Interior Usable Space

Unit Interior Extents

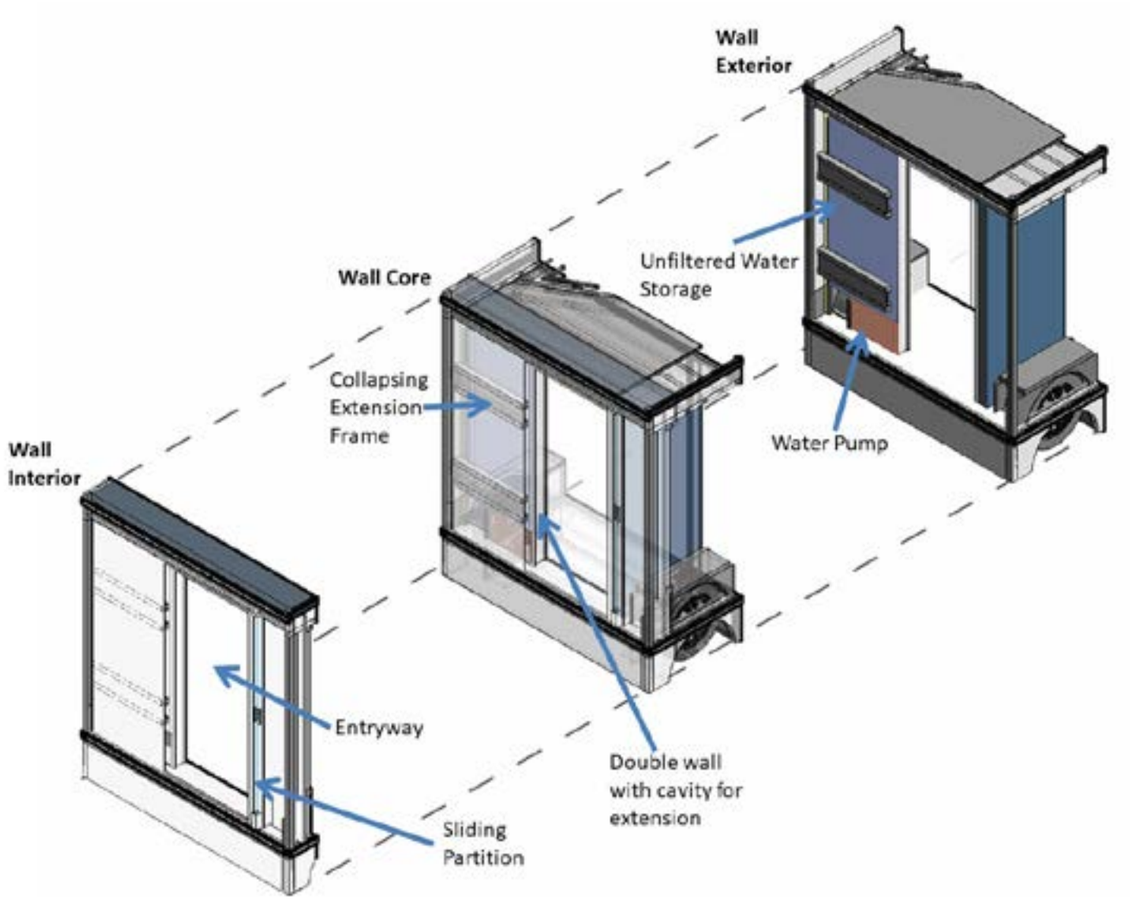


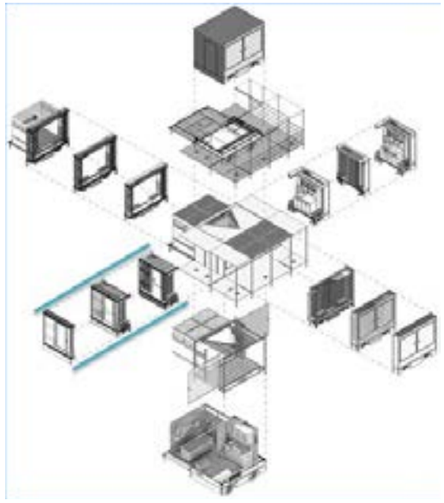
Interior Unit Footprint



The interior opens up to create a fully accessible footprint. The equipment moves to fit into the space when the unit is closed. There is a curtain that separates the room for privacy.

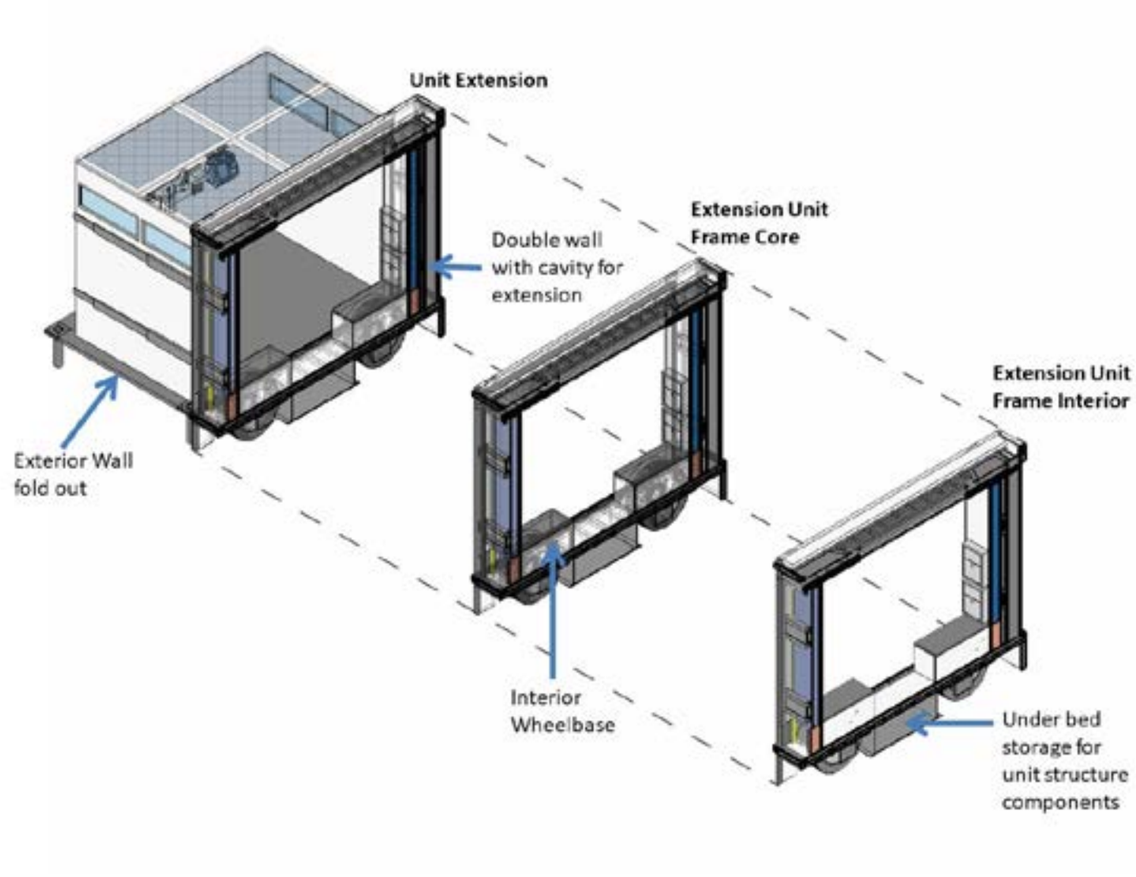
Left Wall

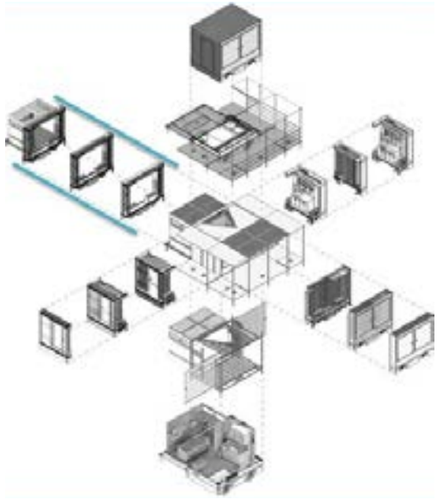




The left wall has the entryway into the unit. It also holds the unfiltered water storage which is then pumped into the water still to be purified. This wall holds the collapsing drawer frame tracks that extend the unit. The sliding partitions extend to enclose a transept space to regulate the entryway.

Back Wall

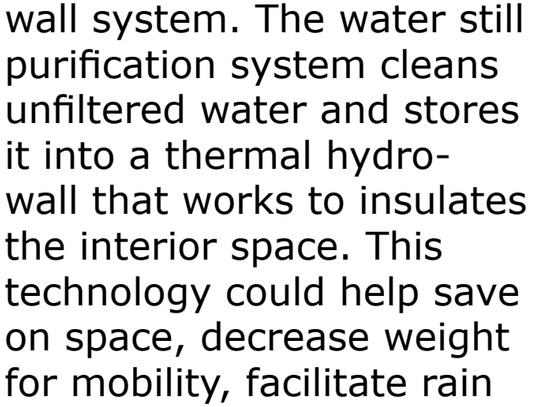




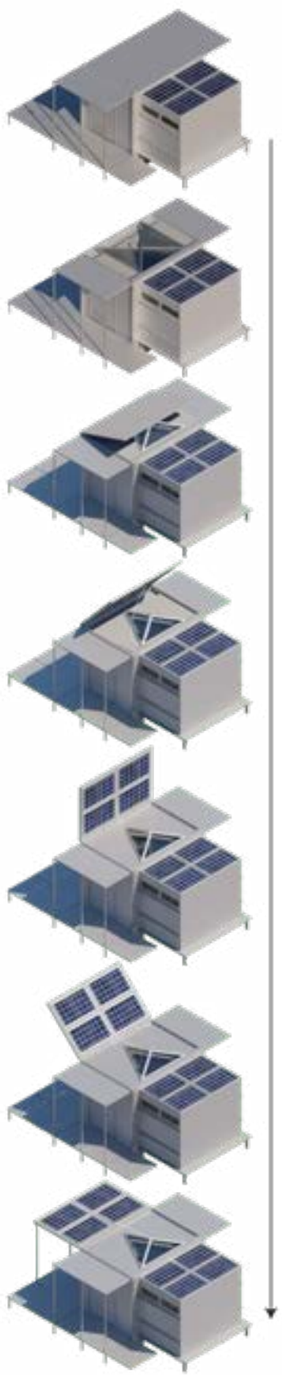
The back wall extends outwards and is controlled with a vacuumed air seal. The exterior wall folds down and the extension is pulled out over it. The wheelbase is set in the frame and accommodates interior seating in the unit.

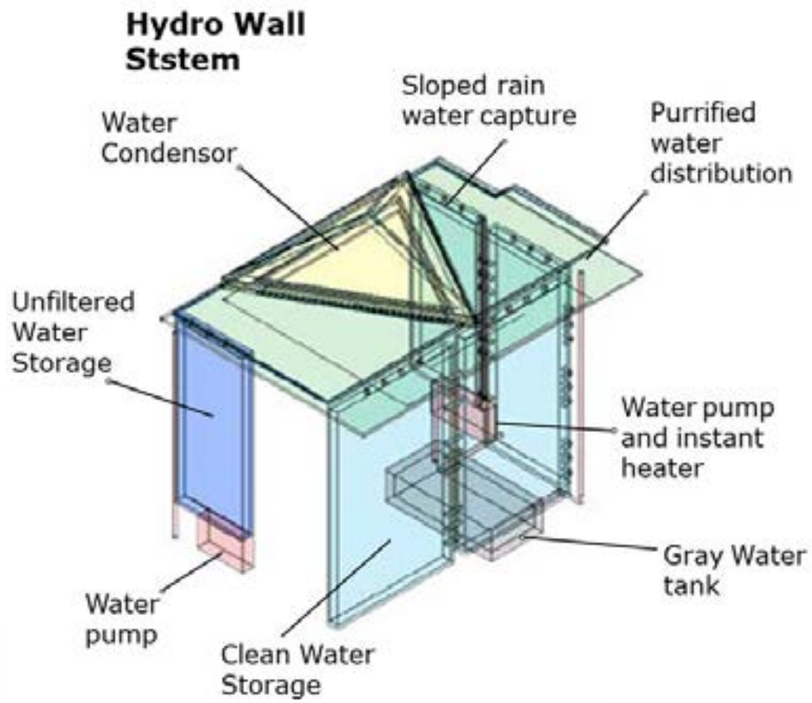
Water Still & Hydro-Wall

The biggest idea that was developed with this project is the water still and hydro-wall system. The water still purification system cleans unfiltered water and stores it into a thermal hydro-wall that works to insulates the interior space. This technology could help save on space, decrease weight for mobility, facilitate rain capture and purify water all in one combined system.

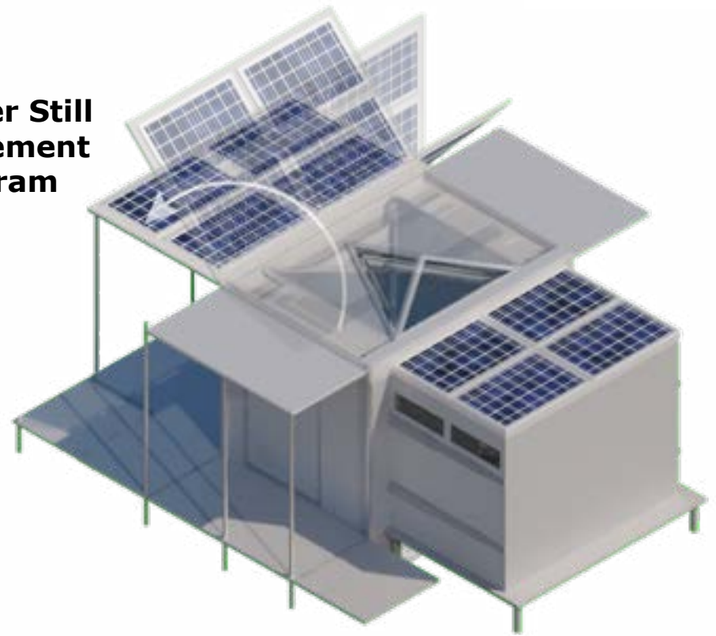


Preliminary Sketch



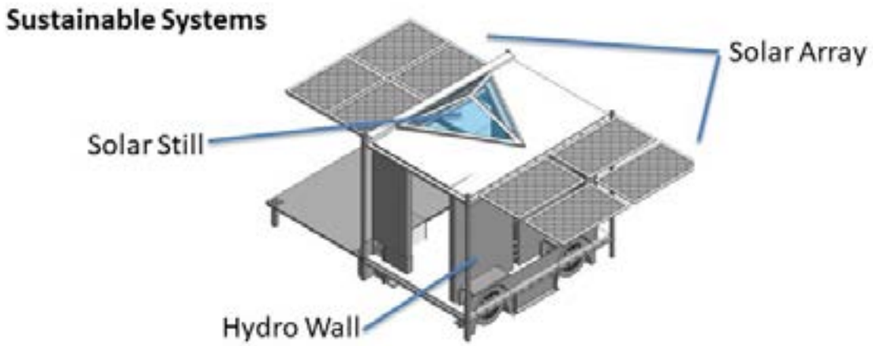


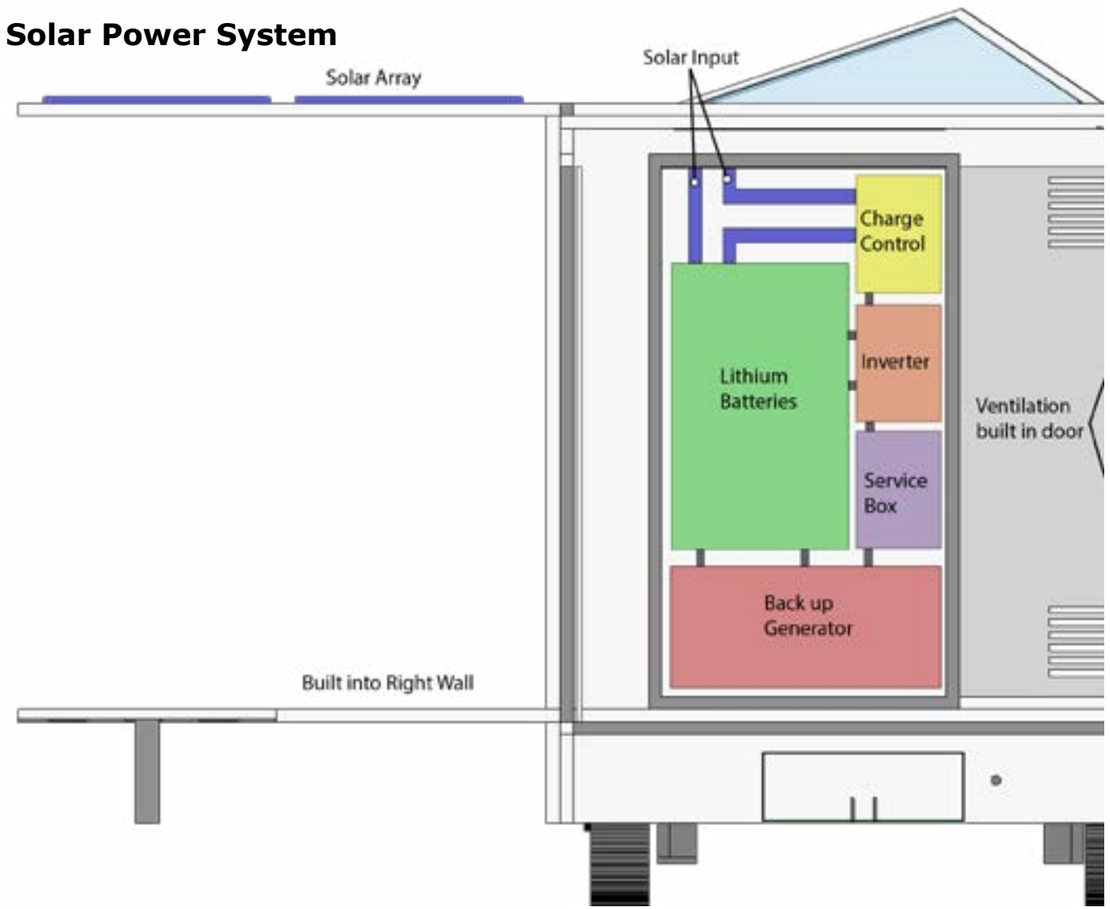
Water Still Movement Diagram

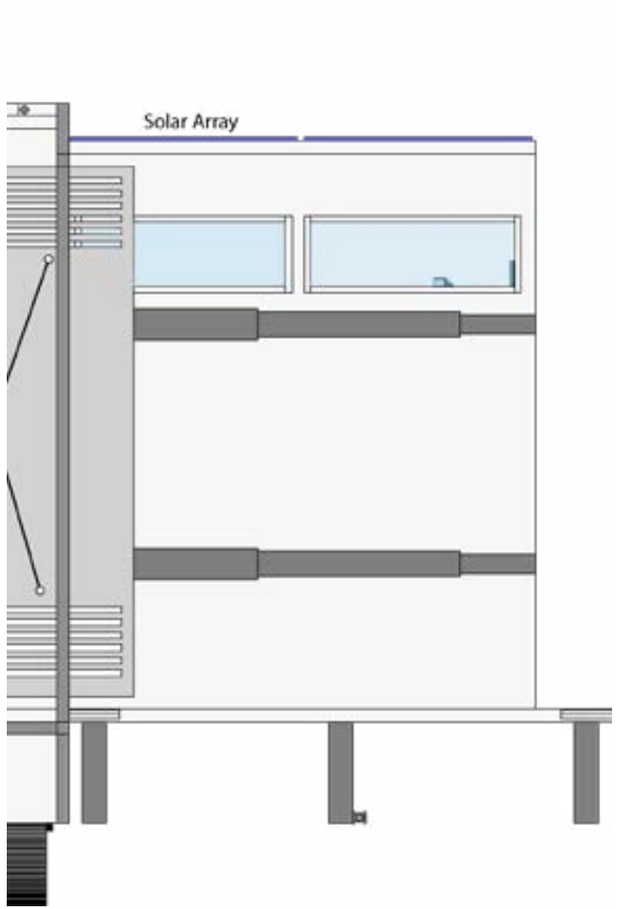


Water Still & Hydro-Wall

The Solar array will be supported from the built-in energy closet that will hold Lithium batteries, converter, and a backup generator. Lithium batteries have a larger upfront cost but offer better performance. There are two fixed solar arrays on the unit, but you can easily add more solar on top of the other fold out roofs.



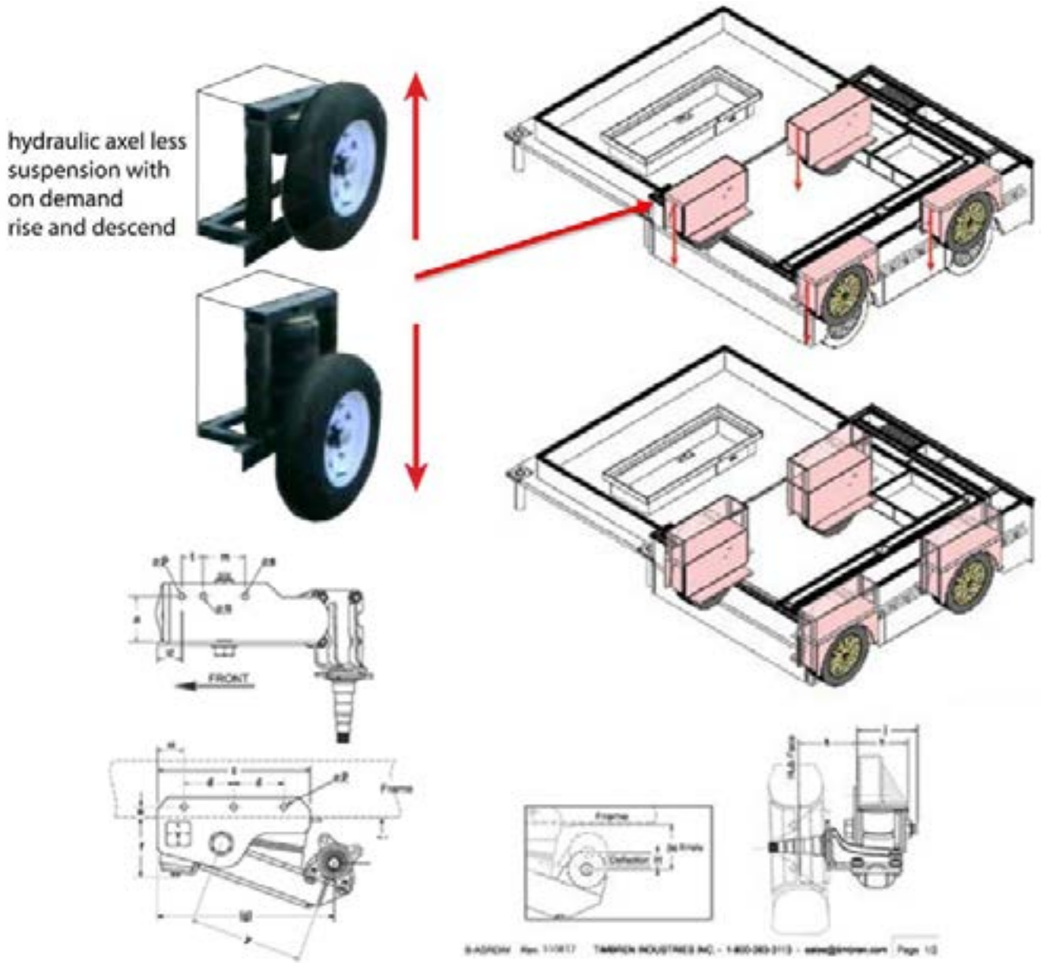




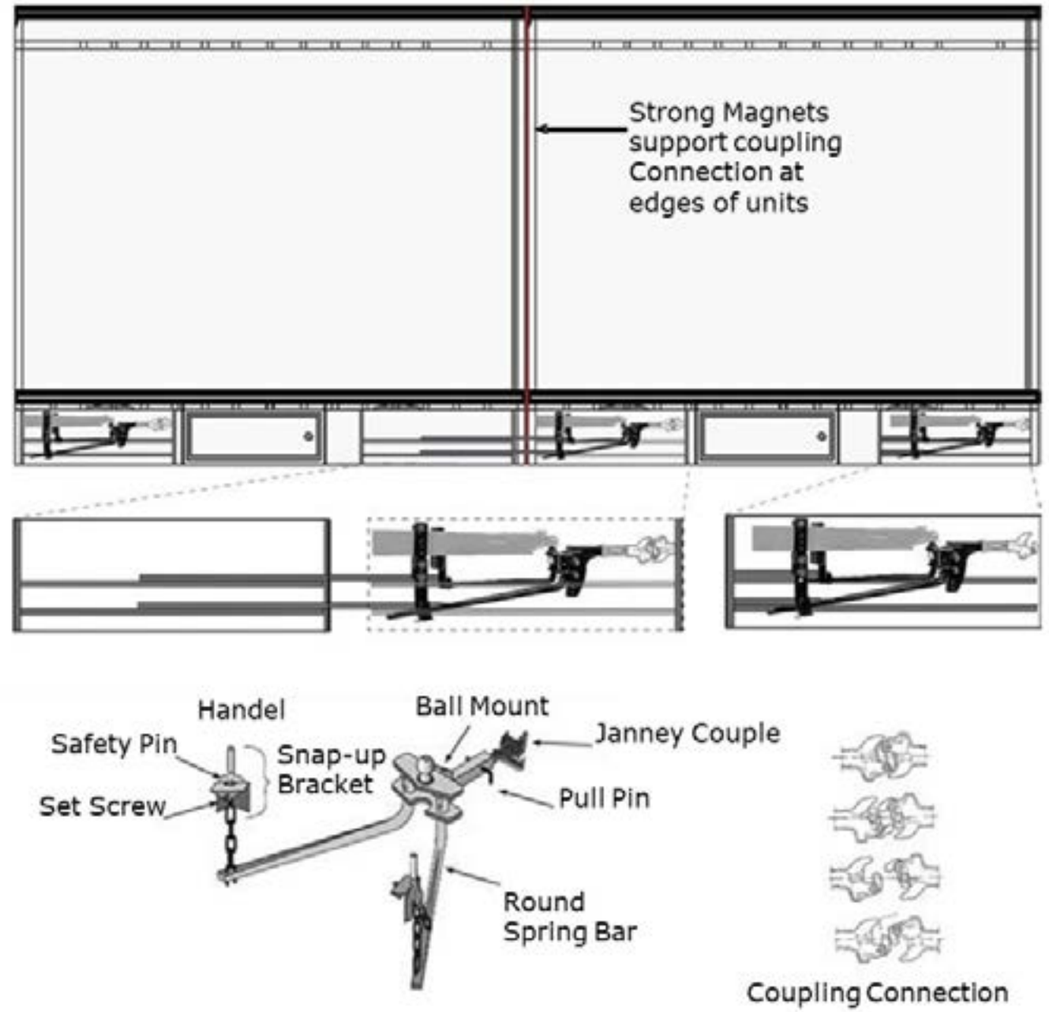
Unit Stats

- Each individual unit has a max weight capacity of 2,000 Ibs.
-
- One cubic inch of steel equals 0.283 pounds
-
- One cubic inch of aluminum equals .0979 pounds

Unit Base

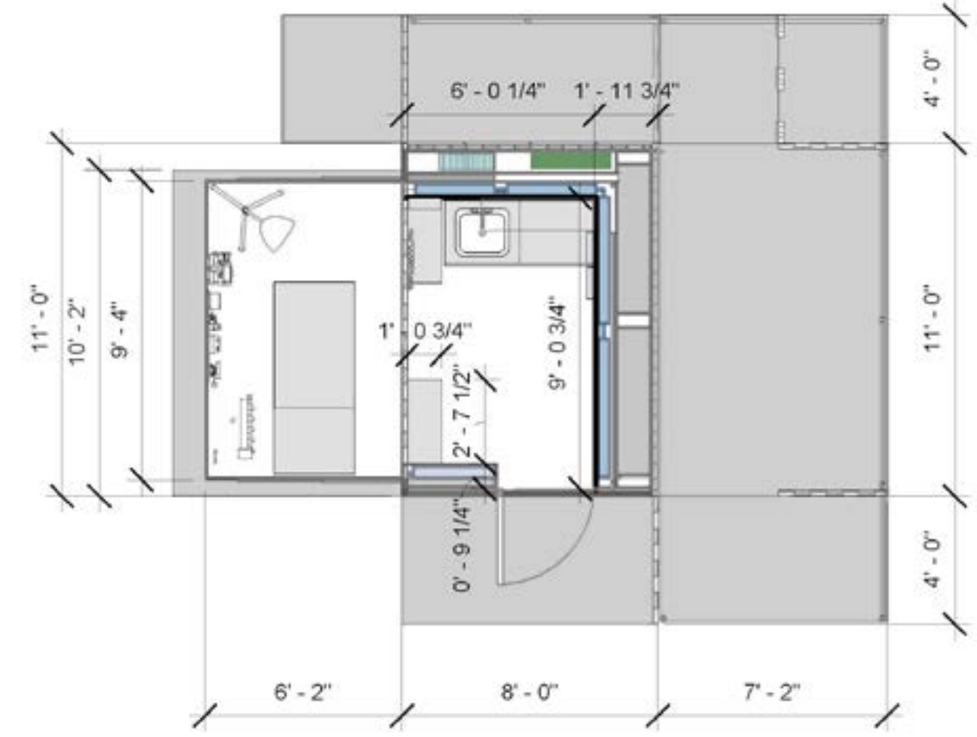


Axel less Wheel Suspension



Unit Hitch and Coupling Connection

Standard Unit

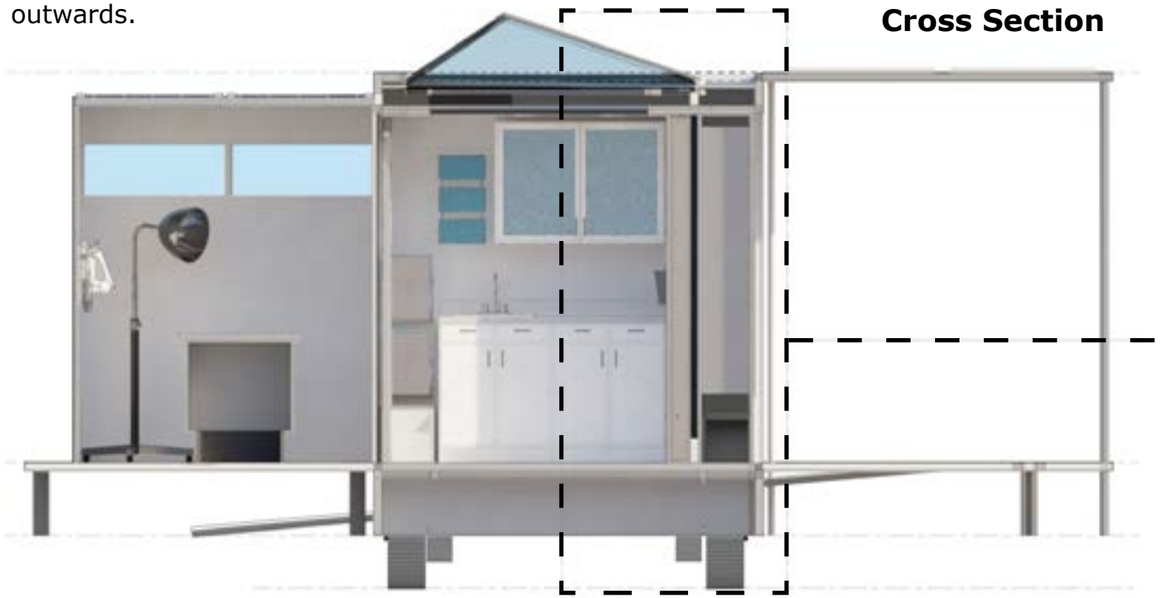


Support Unit

Sections

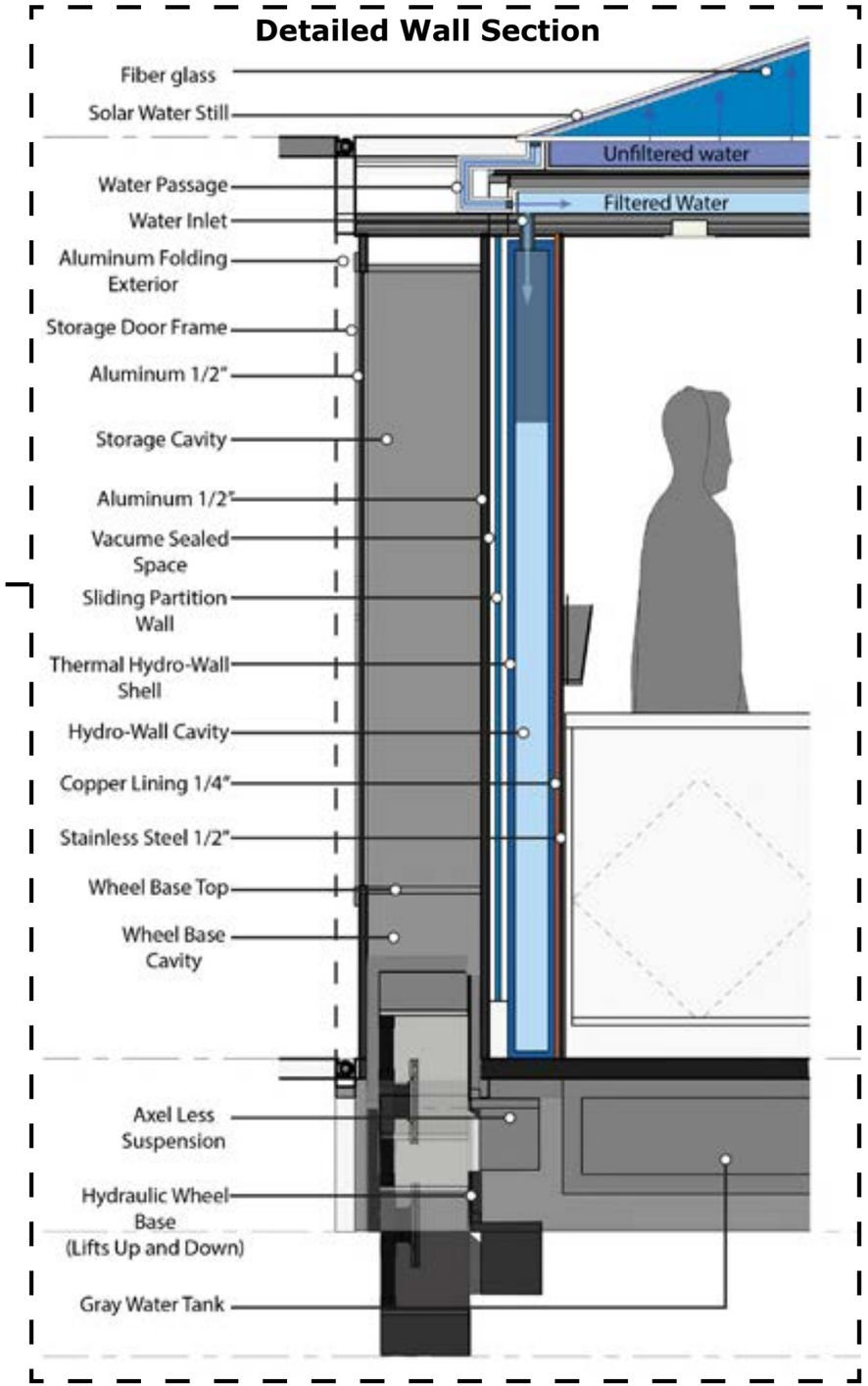
All walls will be primarily made from light-weight aluminum. The hydro-walls and sliding partitions will be made of durable fiberglass. I took inspiration from thermal water bottle design to create a controlled interior space. The copper lining radiates cool temperatures in the interior and reflects hot air outwards.

Cross Section

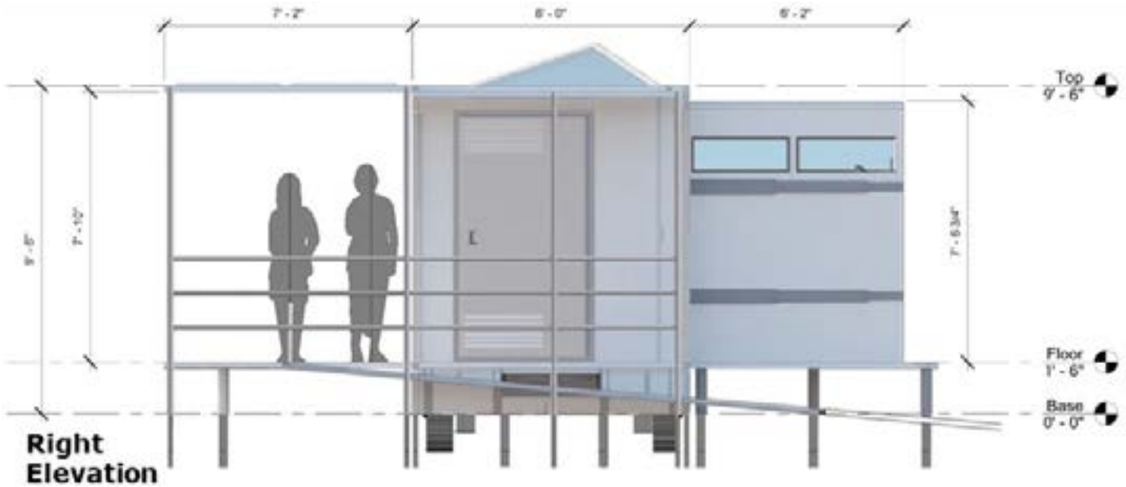


Long Section

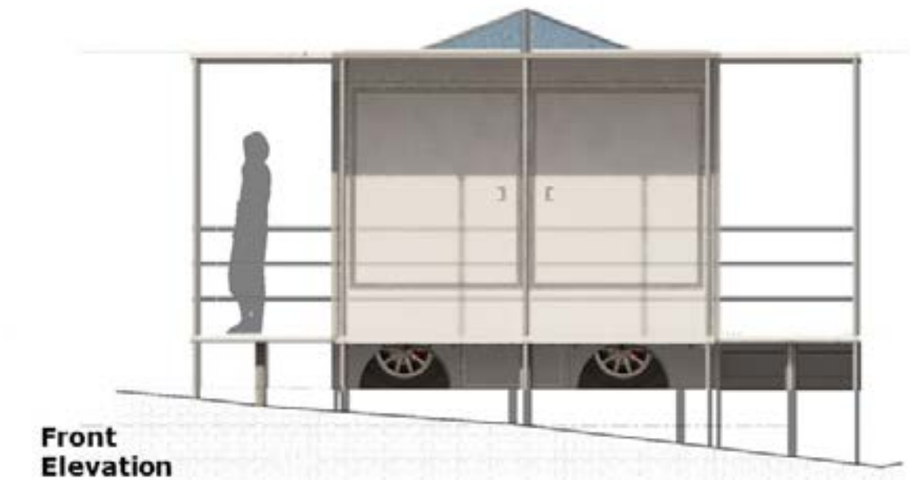
Detailed Wall Section



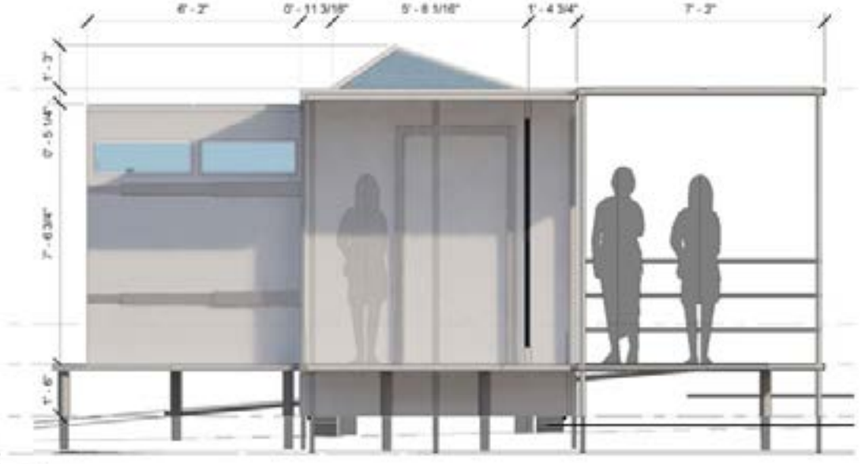
Elevations



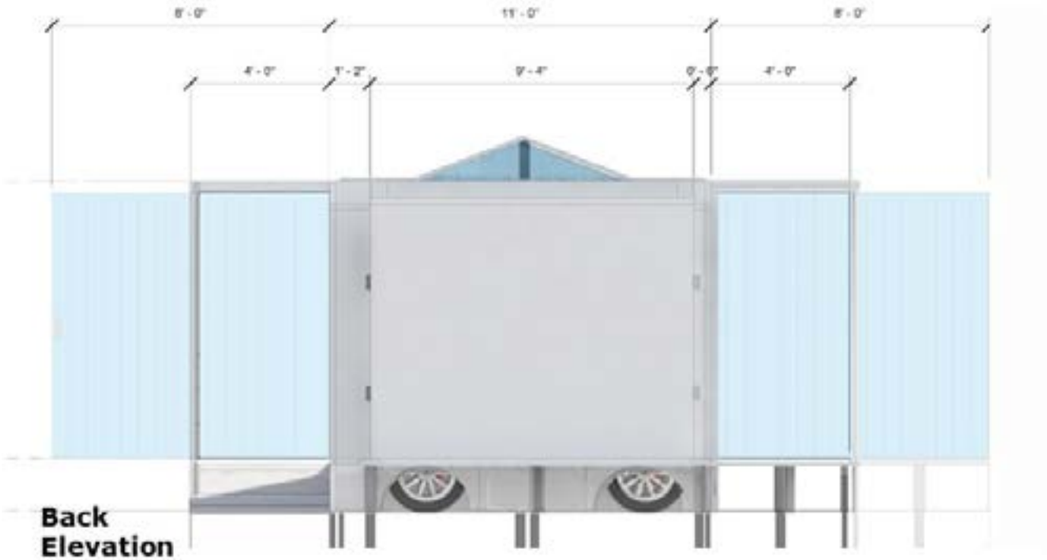
Right Elevation



Front Elevation



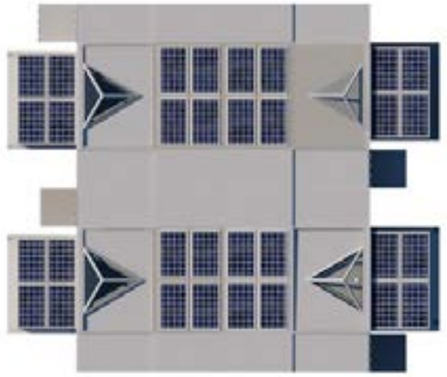
Left Elevation



Back Elevation

Unit Grouping

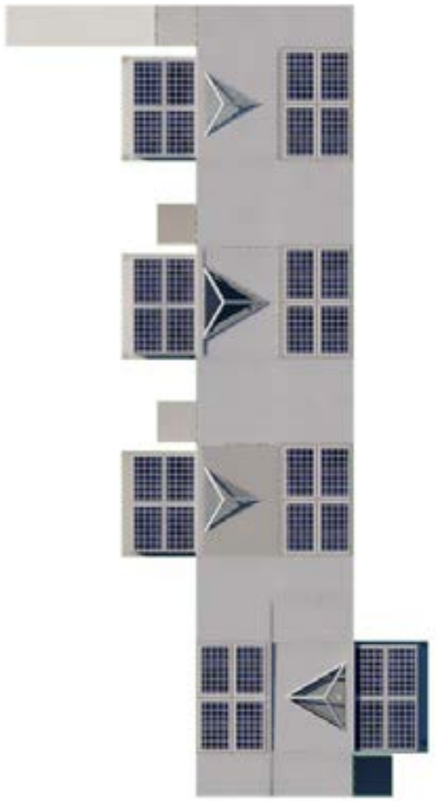
Clustered Units

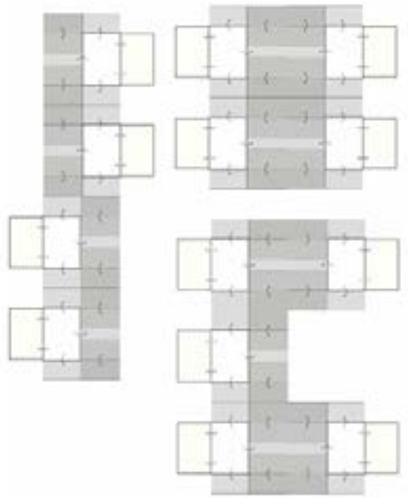


Linear units are Ideal for set up in uneven terrain. This set up creates a long liner passageway on the outside. This layout allows for individual units to meet at different land grades.

Clustered units are Ideal for set up on more level plains. This grouping creates a very large interior space that could be adapted for social use or as a waiting lobby.

Linear Units





General Unit Groupings

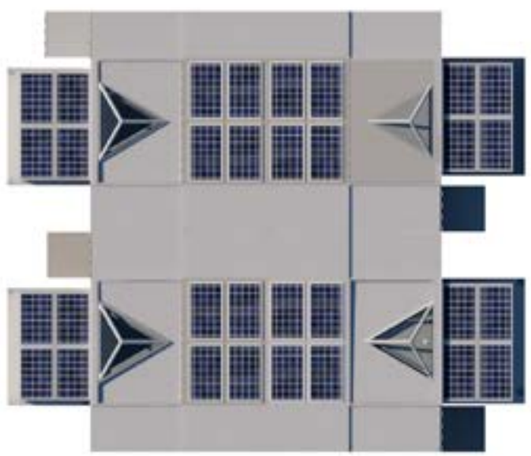
Site 1

Perimeter

855 ft

Area

3,833.33 m²



Site 2

Perimeter

686 ft

Area

2,887.8 m²

Conclusion

This project could potentially be manufactured in Detroit. I believe that this project has good intentions for its outcome and should similarly have them with its production. Detroit has plenty of space and existing facilities that could host its build. It also relates to the cities automobile industry. There is a surplus of available workers. Welding would be one of the largest tasks in the build of this project. I would want most of the build to be handmade which could allow for a build program that teaches welding as a transferable skill. There are plenty of incentives as to why Detroit could be an ideal location for this project's build program.

Detroit has existing railways and much of the available industrial zoned properties can be found near the riverfront. This would be ideal for this project because, the design is intended for those means of transport. The four connecting units are dimensioned to the size of a shipping container which would easily be transported to its desired locations from here. Detroit offers new financial incentives like Opportunity Zones. This project would likely start at a smaller scale and could potentially take off to be larger. "The Detroit Planning and Development Department has been pioneering an approach it calls "tactical preservation" to reutilize a portion of a large building while preserving the remainder of the building for future development. This approach recognizes that demand may not exist to reuse an entire building today, but that partial reuse may be necessary to stabilize and preserve the building as a whole. This approach could have applicability for adaptive reuse within vacant industrial areas." (Detroit, 2018) Implementing tactile preservation allows this facility to grow alongside its demand with less of an upfront cost for the necessary space.

Fig 5.0: Photo By Author - Father fixing Fence January 2020

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