North Dakota State University
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Title

Adaptive Re-Use of the American School Bus

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MASTER OF ARCHITECTURE

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ADAPTIVE RE-USE OF THE AMERICAN SCHOOL BUS

DESIGING AN AFFORDABLE LIVE, WORK AND PLAY ENVIRONMENT FOR NOMADIC LIVING

A Master's Thesis Paper
Submitted to the Graduate Faculty
of the
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ABSTRACT

This project explores the alternative needs of modern nomadic living. Rather than living life with the focus of the collection of things, 21st century nomadism places a focus on experiences and stories. This project will focus on adapting the cultural phenomenon of the American school bus by designing an affordable, sustainable, and flexible conversion into a home fit living work and play.

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1. Introduction

1.1. Problem Statement

Housing or shelter is one of the basic needs that need to be accommodated for and thus will more than likely always be a social issue. The problem that is often presented with housing is the concept of affordability. Affordability is most certainly something that we must tackle, but this project is going to focus on is the concept of livability within the realm of what is affordable. Livability being defined as by Webster's dictionary as the suitability for human living. Livability is thus more of a scale or percentage rather than having a definitive answer. If as a society, the issue affordability is solved then the next step will undoubtedly be about livability. Many government programs already consider standard of living such as the Washington D.C. Height Act which allows buildings to have a higher height limit if there are dedicated units for affordable housing that do not differentiate from the mean (Heights & Views (ncpc.gov)). However, that still does not determine if the mean of housing could be considered suitable.

As Americans, often the errand mistake of qualitatively defining livability by square footage or cost per square foot is made. Unfortunately, affordability is about money and the bottom line, but there are alternative lifestyles such as nomadism that relinquish certain comfortabilities for other advantages. One group of people in which this lifestyle could be attractive to is young professionals who cannot afford to purchase a home and are still in pursuit of finding a location that is right for them. In what ways can nomadic architecture and design be made financially accessible for young professionals looking to further their career?

Figure 1.1.1 Chris McCandless
https://californiahistoricalsociety.blogspot.com/2011/08/back-to-school

The members of our society who are not burdened by the limits of their wallets and can assume that they live in the most livable environments are almost always found with a view of nature. The most expensive apartments in New York are the ones overlooking Central Park, and in San Francisco the Bay or in Seattle the Pudget Sound. In fact, it is the view that often determines the worth of a property rather than the actual quality of the built environment. Thus, the argument is that the pursuit of livability is actually the pursuit of nature. Christopher McCandless knew this, but unlike him, the goal of this project is not to abandon society and venture Into the Wild as he did, but rather see if there is a way to bring society with (Krakauer, J 2018).

As a self-proclaimed adventurer, I have always been fascinated with the natural world and travelling. Which is very ironic considering I am pursuing a profession that is tasked with the development and construction of the built world. I am not alone and in fact many famous architects such as Antoni Gaudi, Alvaro Alto, Frank Lloyd Wright just to name a few who also draw inspiration from nature. The more I have studied architecture and the built environment, the more I understand how sacred nature is.

This thesis explores this odd, but not unique wanderlust that many architects seem to have. Given the rise of working from home due to adjusting workplace standards and new technology that allows internet connection from the most remote places, nomadic living is a real option for many that seek an alternative. The research of this project focused on studying and collecting information on nomadic living and how flexible design and new technology can turn limited space into a 21st century nomadic live, work and play environment. The apparatus in which this exploration takes place is a school bus as they are the perfect opportunity for adaptive re-use.

1.1.1. Research Question

In my research and design I am seeking a better understanding of several questions that deal with nomadic lifestyle and the challenges and differences that it presents compared to a traditional within urban and suburban America. All of which is a question of livability in the terms of square footage. 1). How can a design replicate the needed spaces of a work from home lifestyle with limited square footage? 2). How can comfortability and a connection with society be maintained in remote locations? 3). How can nomadic architecture be affordable and sustainable?

1.1.2. Proposed Outcomes

The scope of this thesis is the redesign of a Thomas 35-foot-long school bus that was purchased from the Breckenridge Minnesota school district for $2,250 dollars. The project deliverables shall include a floor, ceiling, roof, electrical, plumbing, and HVAC plan. Along with interior and exterior elevations, sections latitudinal and longitudinal sections showcasing the structure and systems inside the school bus. Most importantly, supplemental details of the design will be provided that will showcase why and how the project will be constructed. The construction will be extracurricular.

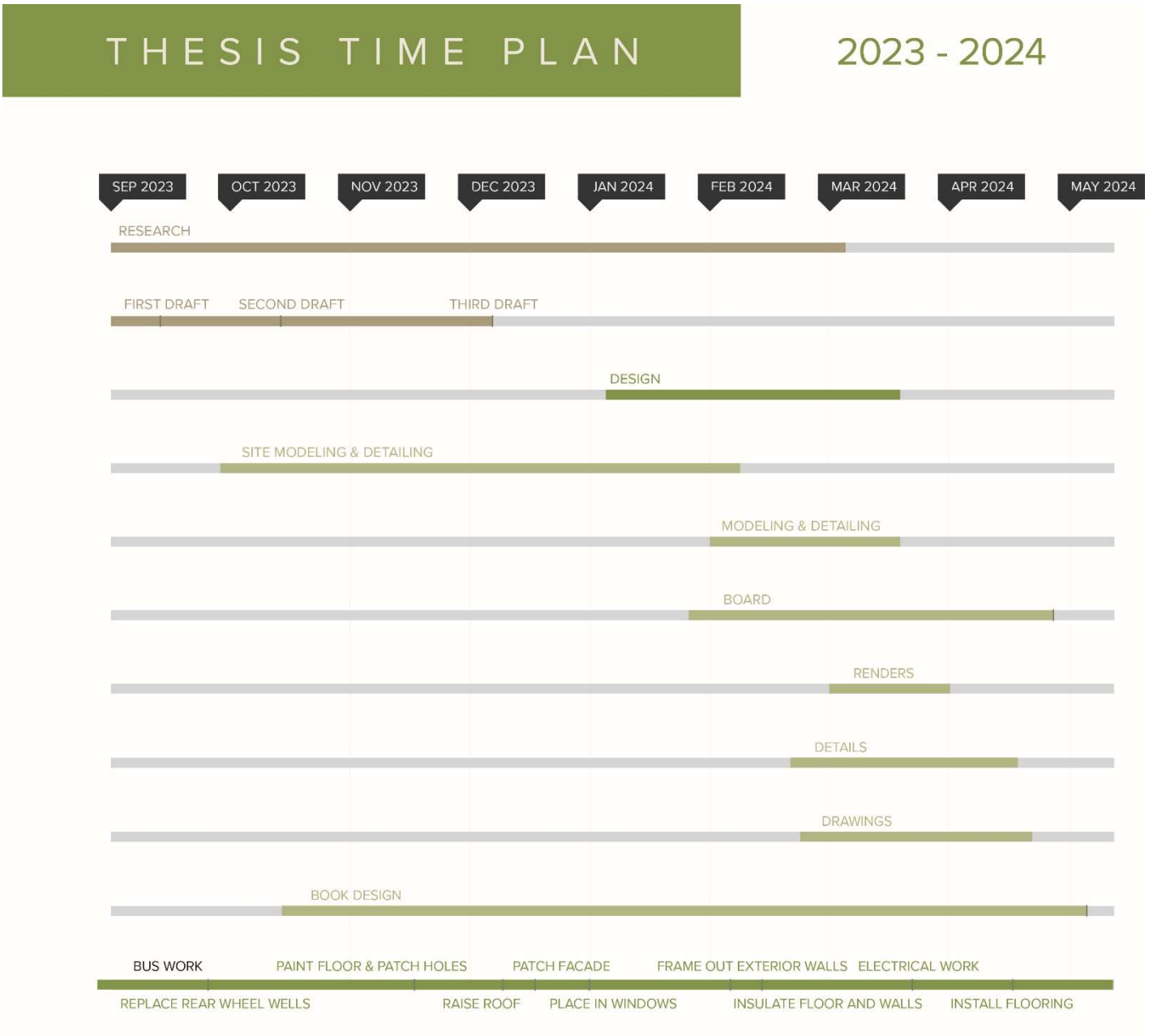


Figure 1.1.2.1 Thesis Time Frame

1.1.3. Objective

The objective of this thesis project is to redesign and adaptively re-use an American school bus into a nomadic life, work and play environment that redefines what is a livable lifestyle. The project design will focus on flexible spaces, modern technology and sustainable and affordable materials to maintain a comfortable living in uncomfortable places.

Figure 1.1.3.1 Historic School Buses.
https://californiahistoricalsociety.blogspot.com/2011/08/back-to-school

Figure 1.1.3.2 Historic School Buses.
https://californiahistoricalsociety.blogspot.com/2011/08/back-to-school

2. Background

The focus of research was to gain a better of understanding of the American school bus as it is the initial form and mass of the adaptive re-use design. The other information that was sought, focused on what defines nomadism and the history of nomadism, efficient and adaptive space utilization, modern technology to bridge between remote locations and connection with society. The viability, affordability and sustainability of various power generation, heating and cooling mechanisms as well as different glazing options were also topics of research throughout the project.

2.1. Project Type

The project type is of adaptive re-use. The shell of an American school bus has been converted and recycled into a nomadic environment fit for work, play and living. It is considered to be an abode on wheels suitable for the lifestyle of traveling from place to place and is not permanent. The growing popularity of hybrid and remote work environments has led to a trend in the alternative nomadic lifestyle that is in stark contrast with average American work life.

This project is highlighted by a series of ironic instances. The irony of a uniquely American object being adapted to avoid American materialism. The irony of adapting an object into an abode, to avoid the purchasing of a standard home. The design is intended for an architect who designs homes, who avoids living in one. The pursuit of wilderness and exploration side of nomadic living, just to bring civilization with.

There have been similar adaptive re-use projects of vehicles for nomadic living done by architects, contractors, or casual designers. Projects include everything from the conversion of school buses, military vehicles or updating decaying airstream trailers or older GMC RVs.

Figure 2.2.1 1970's GMC Motorhome Interior
https://www.macsmotorcitygarage.com/1973-1978-gmc-motorhome-general-motors-grand-rv-experiment/

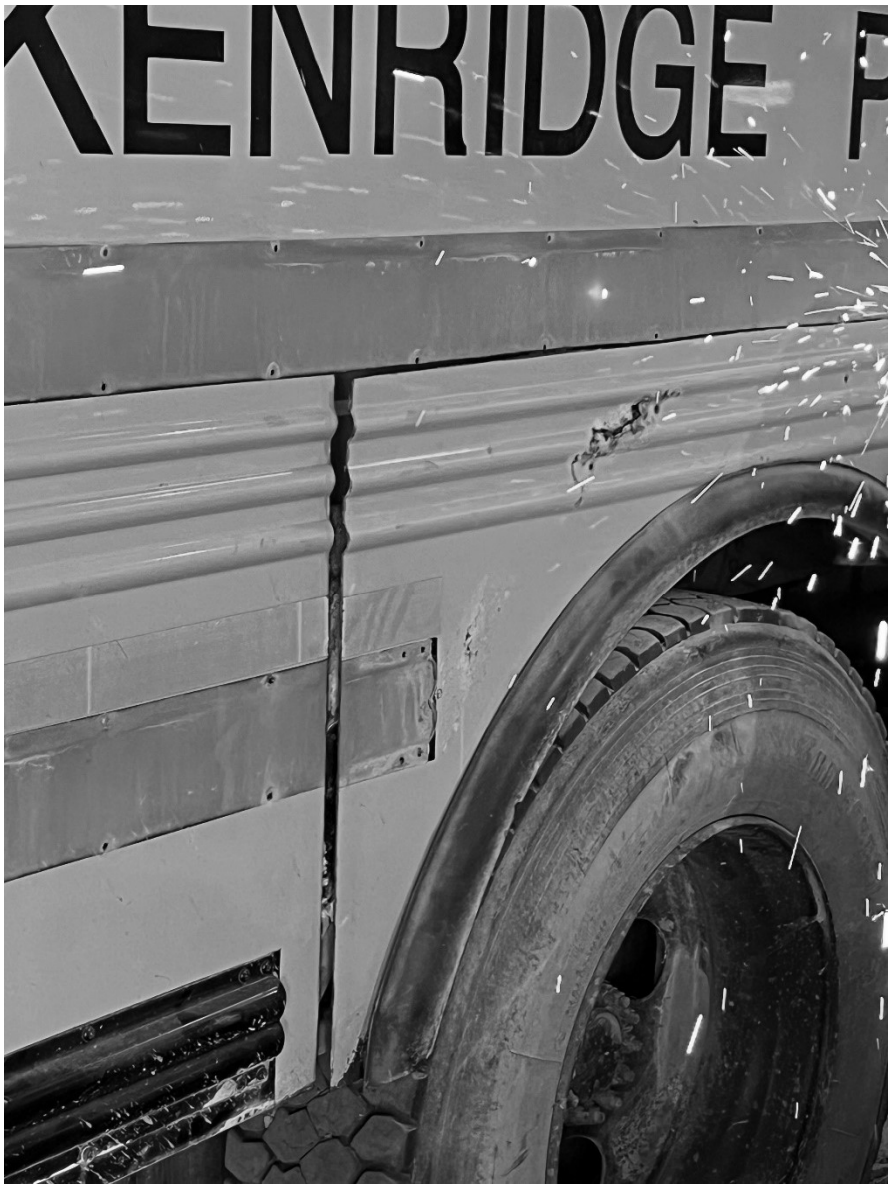


Figure 2.3.1 Rust Hole in Exterior of School Bus

2.2. Project Issues

This project attempts to provide an alternative solution to the global housing crisis, specifically for young professionals who have the ability to work remotely. The goal being to provide a design for a living situation that allows for a decrease in spending on material items allowing for an increase in life satisfaction and savings for the future while maintaining traveling and the overall pursuit of adventure. The major project issues are a limiting budget, limited space and a limiting form of the school bus.

3. Methodology

As with any design project, a guiding principle or parti is necessary for the design process. The guiding principle used was a tiered system of affordability, sustainability and then flexibility. Inspiration comes from a cultural and historical analysis of the American school bus and other American nomadic icons such as the Airstream and GMC RVs of the early 1970's.

3.1. Approach

The guiding principles of affordability, sustainability and flexibility determined design choices and solutions for the project. Affordability being the most essential as a budget is what defines all projects and determines what is most essential when it comes to the design. Especially since the building of the design will be extracurricular, making sticking to the budget being of upmost importance.

The next guiding principle focused on sustainability, mainly in the form of adaptive reuse. This included sourcing materials that were recycled from other buildings or vehicles as well as the re-use of materials from the school bus itself. A major goal of the project is having all materials be recycled other than structural steel, plumbing and electrical components, and appliances.

The third guiding principle dealt with flexibility. This principle derived from research about nomadic lifestyle and the varying needs depending on the environment or season. Space is viewed as a representation of time spent, reducing one-use spaces such as bathrooms to increase the overall usability of each square foot. Space is viewed as an essential resource and not as something to be wasted.

3.1.1. Budget

The size of the budget is the most defining part of the project. It needed to represent what a young adult would be able to afford without severely compromising the ability to design. The budget of 20,000 was chosen as that is roughly what can be earned through the donation of plasma over the course of four years. Plasma donations provide an additional income source especially for college students (France R, 2020). Allowing for students to save the additional funds for the project rather than increasing financial burden of traditional income sources.

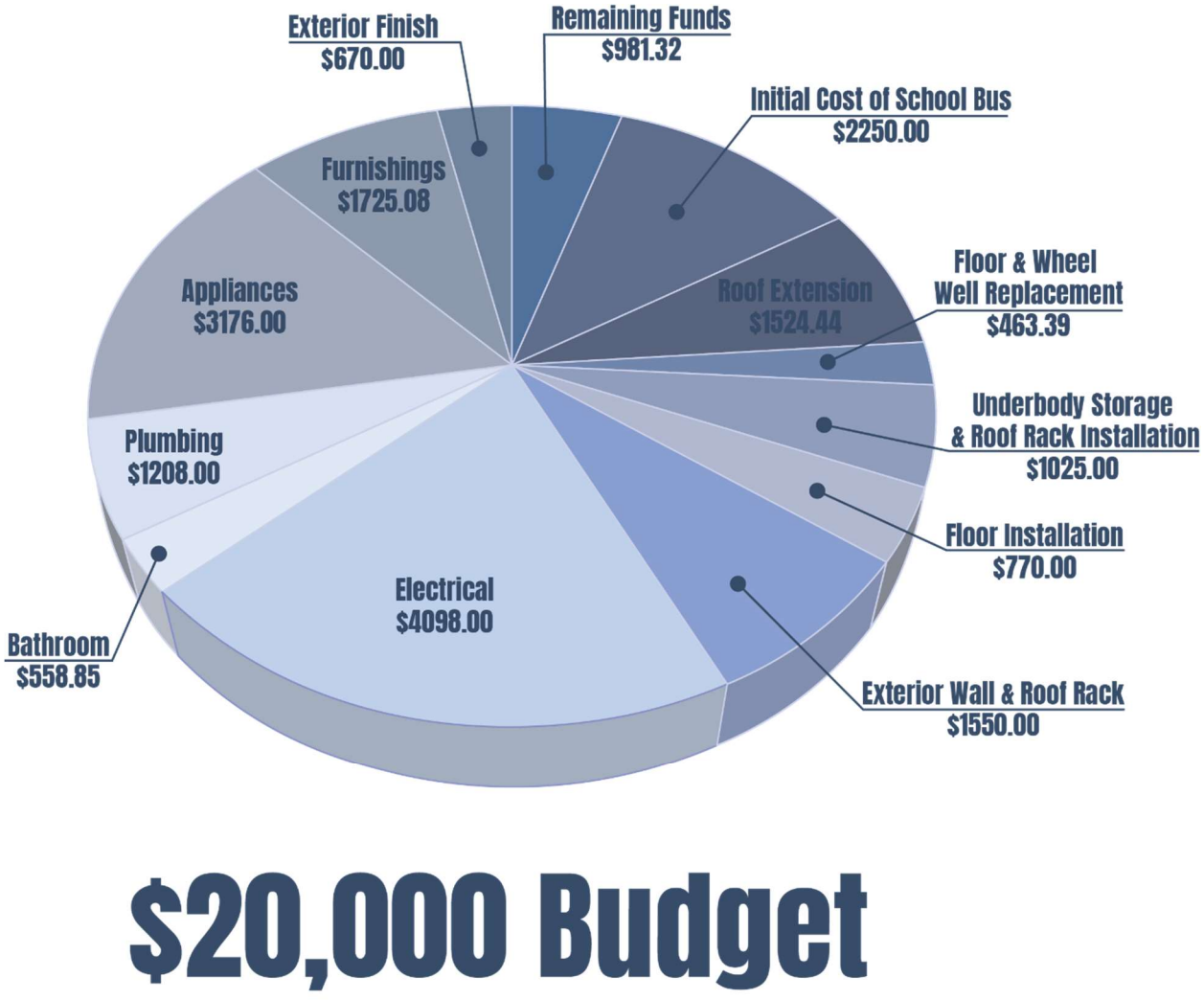


Figure 3.1.1 Budget

3.2. Site

Given that the project is based on nomadic architecture, it will not have a typical site. Instead, the site will be the school bus itself. The specific bus that is used for the shell of the project is a 35’ Thomas Freightliner with an Alison cummings transmission. The bus has over 200,000 miles on it, but diesel engines are known to last over half a million miles. There are zero mechanical issues with the school bus, but the body does present some design challenges that needed to be accounted for.

The first of which is the height of the bus. At the very center, the hat channels that run across the roof sit at only 6’-2’ which not only limits the head height, but also any potential for increase in insulation factor. A roof extension was needed to solve this issue and increase comfortability.

Federal regulations exist for safety standards that often establish deadlines when a school bus no longer becomes useable to transport students commercially. Often these deadlines deal with mechanical problems but can include the condition of the body. In the case of this bus, severe rust was present near both wheel wells creating a hole in the façade which deadlined the bus, forcing the school district to sell the bus despite the continued reliability of the engine. The wheel wells thus had to be replaced.

Figure 3.2.1 School Bus Elevation

The third design challenge that is presented by the bus is the limited space being around 187’ square feet. Conventional floor planning design needed to be adapted to decrease the amount of wasted space and increase the flexibility for multi-use functionality. This included the three distinct modes the school bus is used in. The first is simply traveling, getting from one place to another often with making nightly stops for sleep in parking lots or other less than ideal locations. This does not include hookups for electrical or plumbing so comfortability will rely on excess battery charge from driving, water storage, and non-electrical heating and air conditioning. Boondocking is similar to travelling in which no hookups are available but extended setup would be available unlike during traveling phase. The third mode is when external plumbing and electrical hookups are available. This allows for amenities of a higher comfortability level to be used such as split unit air conditioning or electrical heating such as in-floor heating.

Along with the requirement for flexible floor planning, exterior conditions must be altered to accommodate storage requirements for contrasting environments that nomadic living requires. Thus, alterations to the roof and lower body will be required to increase storage capacity.

Figure 3.2.2 School Bus Exterior

3.2.1. Destinations

With the goal of the school bus to provide a comfortable living situation in the most remote areas, power, heating and cooling as well as a proper internet connection are a must. The destinations are defined by one of three; national park, state park, or national forest all of which are Bureau of Land Management Land and often overlap. The destinations are all rural locations, often mountainous, making flexibility in all weather conditions a necessity just as it was for the earliest nomads.

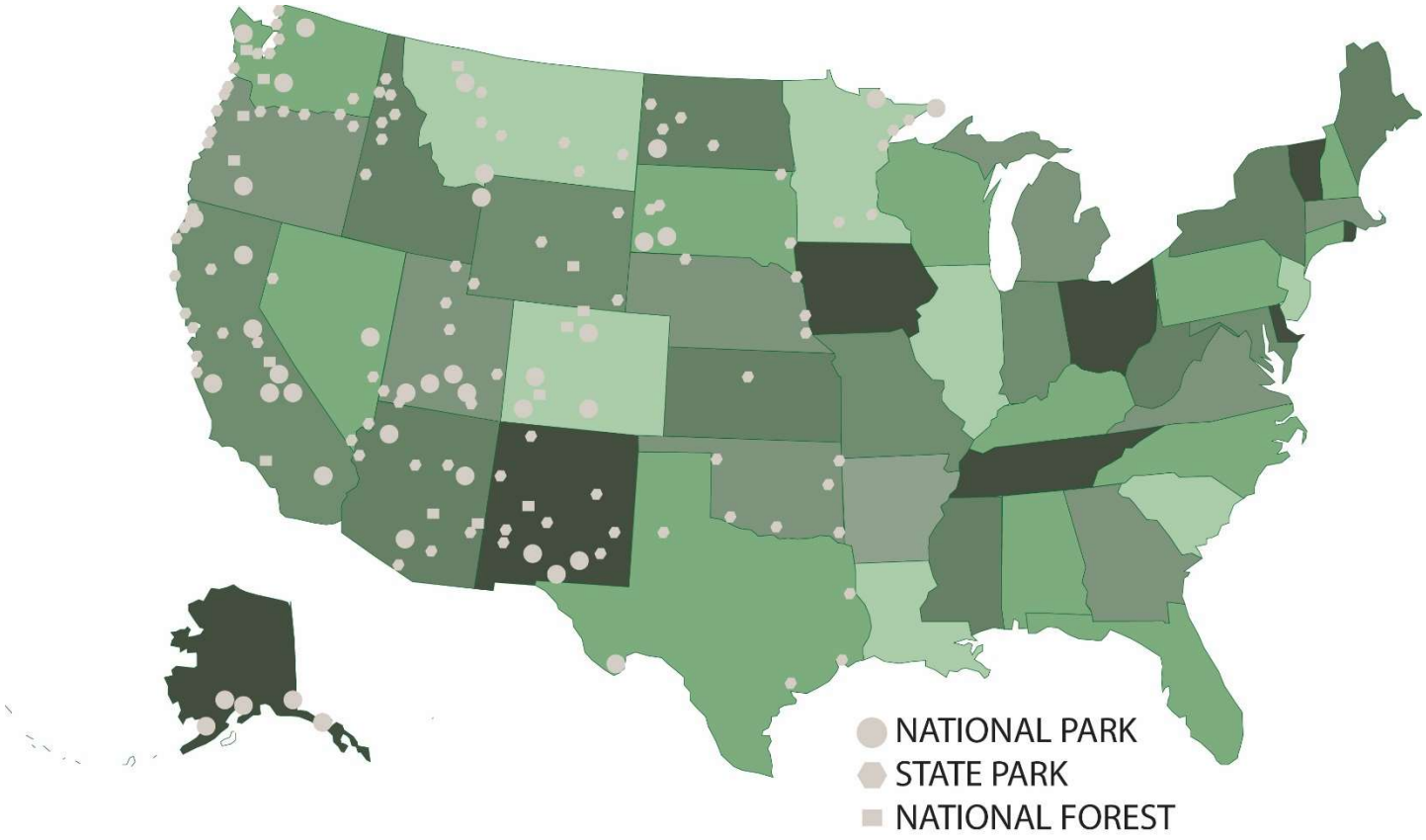


Figure 3.3.1.1 Destinations Map

3.3. Additional Research

3.3.1. The American School Bus

Bright yellow with black striping, curved roof, sliding windows and flashing stop sign, undeniably American. The school bus is one of the most recognizable to symbols of American culture and it will not only be a chassis that is re-designed into a flexible living environment, but also served as inspiration for the project. The American yellow school bus is a cultural icon, and its history represents the American attitude and way life. In order to have a better understanding of the American classic, it was of upmost importance to learn how the original school bus came to be and how the design developed into where it is today.

Figure 3.3.1 School Bus Purchased from Breckenridge Minnesota

3.3.2. History of the School Bus and Safety Standards

School buses are directly correlated with education, a value that is embedded and engrained into American culture, in fact, the first compulsory education law was sanctioned over a hundred years before the conception of the Constitution (Katz, M 1976). It was enacted in the predominately Puritan Massachusetts Bay Colony which is a major reason why Massachusetts was the first state to pass a compulsory education law in 1852(Lenz L, 2022). As it is sort of an American tradition to refuse to listen to governing bodies, mandatory education had little enforcement until states provided transportation to school and thus the need for a school bus was born. School buses were originally referred to as kid hacks and there were often modified farm wagons designed to transport as many kids as possible (Baron, 2013). With the modernization of America came the internal combustion engine and thus the first vehicle that could be considered a school bus in 1914 by a company called Wayne Works (Lenz L, 2022).

In 1918, all states in the union had passed compulsory educational laws, but it was not till 1930 did most of the states successfully enforce it (Katz, M 1976). Safety became a major concern considering the scale of kids attending schools and a majority of school buses during this time were generally a wooden carriage that was bolted to a steel automobile chassis (Lenz L, 2022). Many of these carriages would become loose due to the constant jostling of the uneven rural roads that most school buses drove on including the one I recently purchased. It was because of this reason, Albert Luce Jr, the founder of well-known school bus production company, Blue Bird, started producing all steel school buses which is the standard of design today (Lenz L, 2022). In 1939, a professor from Columbia, Frank Cyr held a conference in establishing safety guidelines and the coloring of school busses. It was at this meeting that the national school bus chrome yellow was selected to be the exclusive paint coloring for school busses in the United States (New York Times). This was chosen because in studies conducted by Frank Cyr, yellow and green were the easiest colors visibly seen by the human eye (Lenz L, 2022). Besides all steel chassis and color, there are a number of other safety designs built into the school bus that hasn't been changed since the 1970's (Baron, 2013). The three major safety design choices that were highlighted in

the U.S. Federal Motor Vehicle Safety Standards for School Buses are flashing lights for stopping, crash testing for structural weaknesses and compartmentalization.

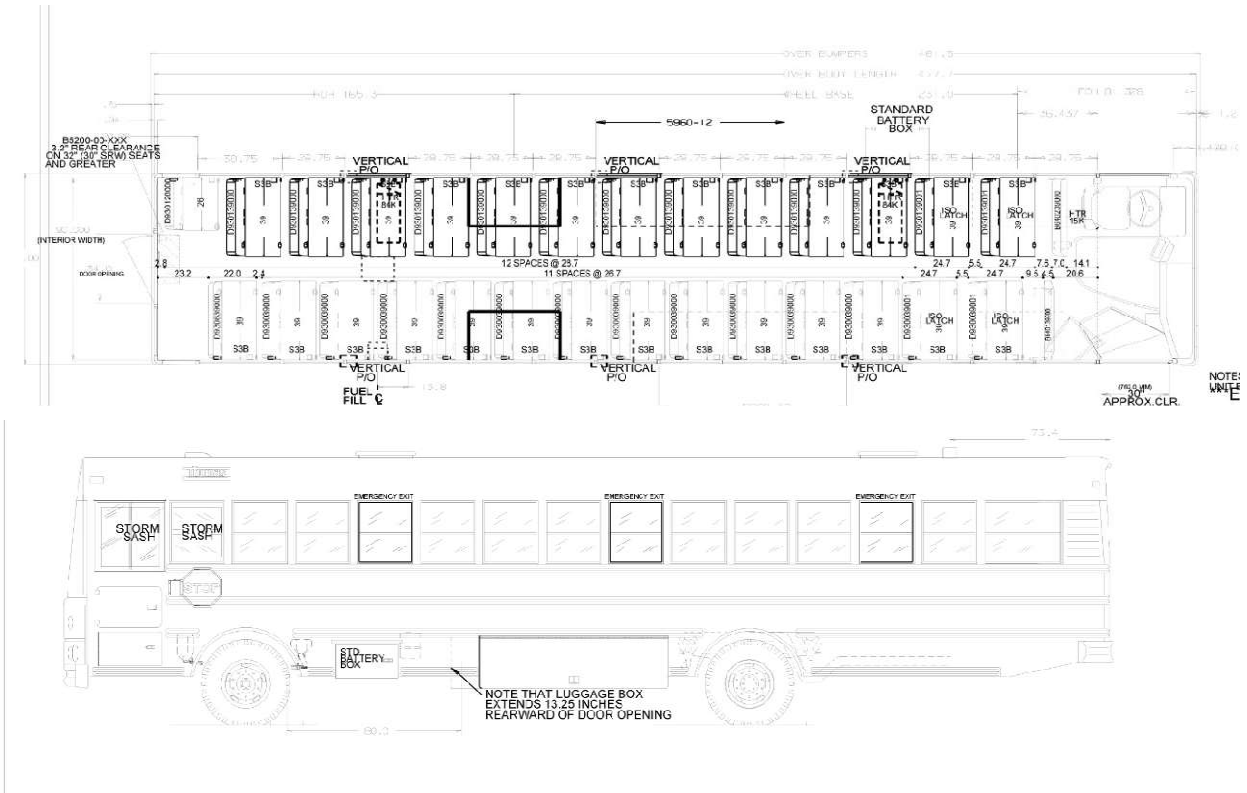


Figure 3.3.2.1School Bus Elevation and Floor Plan
https://thomasbuiltbuses.com/school-buses

3.3.2.1. Compartmentalization

If you have ever wondered why school buses don't require seat belts but nearly every other vehicle does, it is because of the design for compartmentalization (Smithsonian). In school buses, the floor is situated higher than most cars so any accident that takes place, the impact zone is typically below the floor (Baron, 2013). The seats are also designed to be closer together and have higher backs to create a barrier that prevents ejection. Windows are also specified to be placed higher up and designed to not shatter or allow ejection which has made school bus crashes 1/7th as deadly as a typical car crash. (Baron, 2013). As a result, school buses are overdesigned structurally to provide safety to its precious cargo. Designs continue to develop each year to make school buses safer, more efficient and more affordable.

Figure 3.3.2.1 Interior of School Bus

3.3.3. How School Buses are Built

School buses consist of two main parts, the frame in which houses much of the mechanical functions of the bus such as the wheels and engine and the body which is the part that houses the passengers. The frame is constructed first using two large beams that run the length of the bus. The axles, wheels, and engine are attached to the frame and the fiberglass cab is placed on the front of the frame along with the engine housing. When the body and frame are ready to be attached, the body is placed on the steel beams with rubber spacers in between for shock absorption and then a steel connection is bolted.

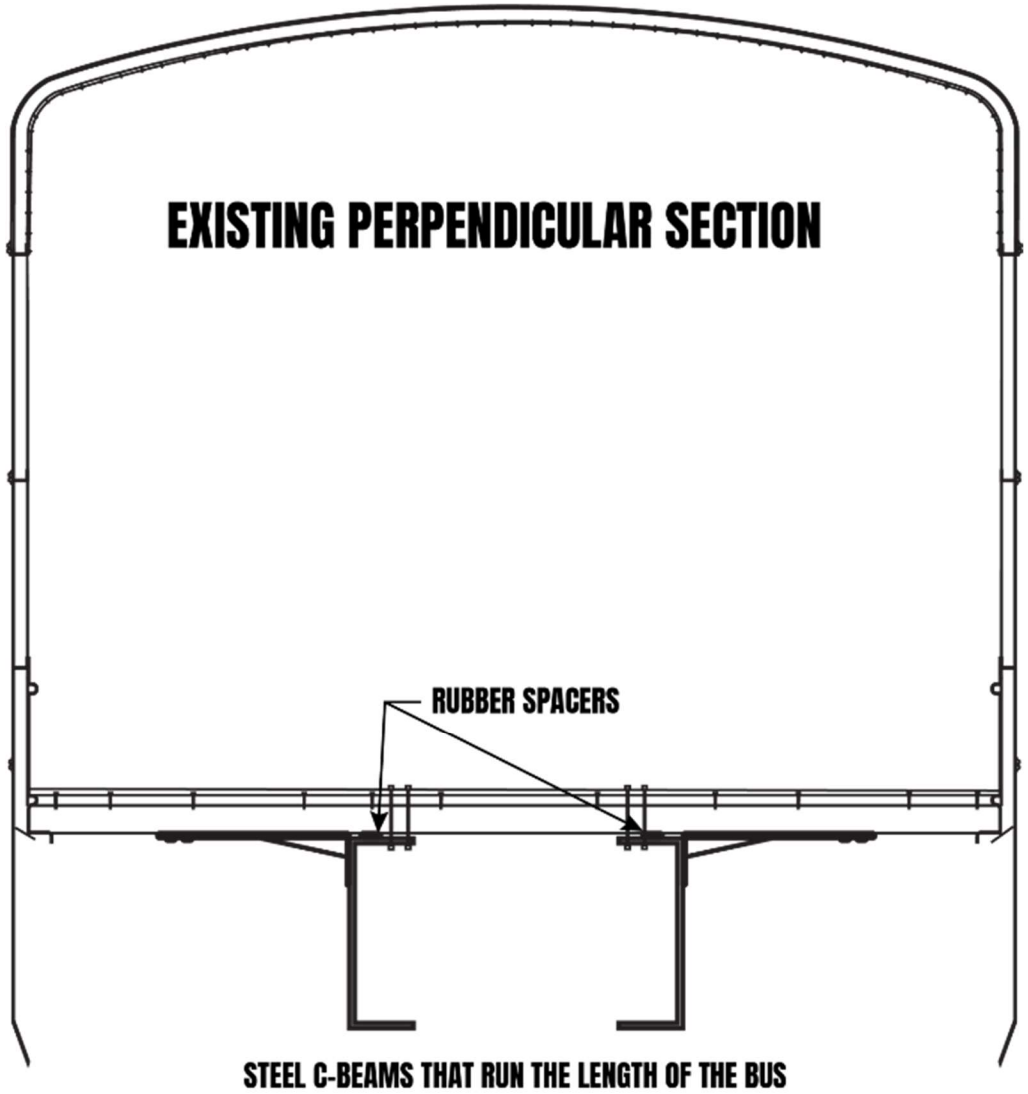


Figure 3.3.3.1 Body to Frame Connection Section

The body of the bus is fabricated using steel C-channels that are welded together to make the floor. Then steel hat channels are bent to create the frame of body and this is where the classic roof shape comes from. This design makes the walls not perfectly perpendicular to the floor but more of a bowed effect. A piece of sheet metal called the chair rail is bent to create rigidity and then welded to the C-channel floor. Then the hat channels are attached to the chair rail and L-angles are then used to connect the hat channels together to create ribs along the body which encompasses most of the structure of the body.

Figure 3.3.3.2 Framing of School Bus

The exterior sheet metal is then attached to the hat channels and windows are placed in. Insulation is stuffed in the wall cavity and roof cavities and then perforated steel panels are placed on the interior of the hat channels. Then 3/4” plywood is placed on top of the C-channel floor and nailed to it. Once the plywood is down, rubber is glued to it. Finally, the seats are bolted to the floor and chair rail and then the body is bolted to the steel connections of the frame that connect the two beams that run the length of the body. This is the typical design of most school buses, but the details change between different companies and their various models.

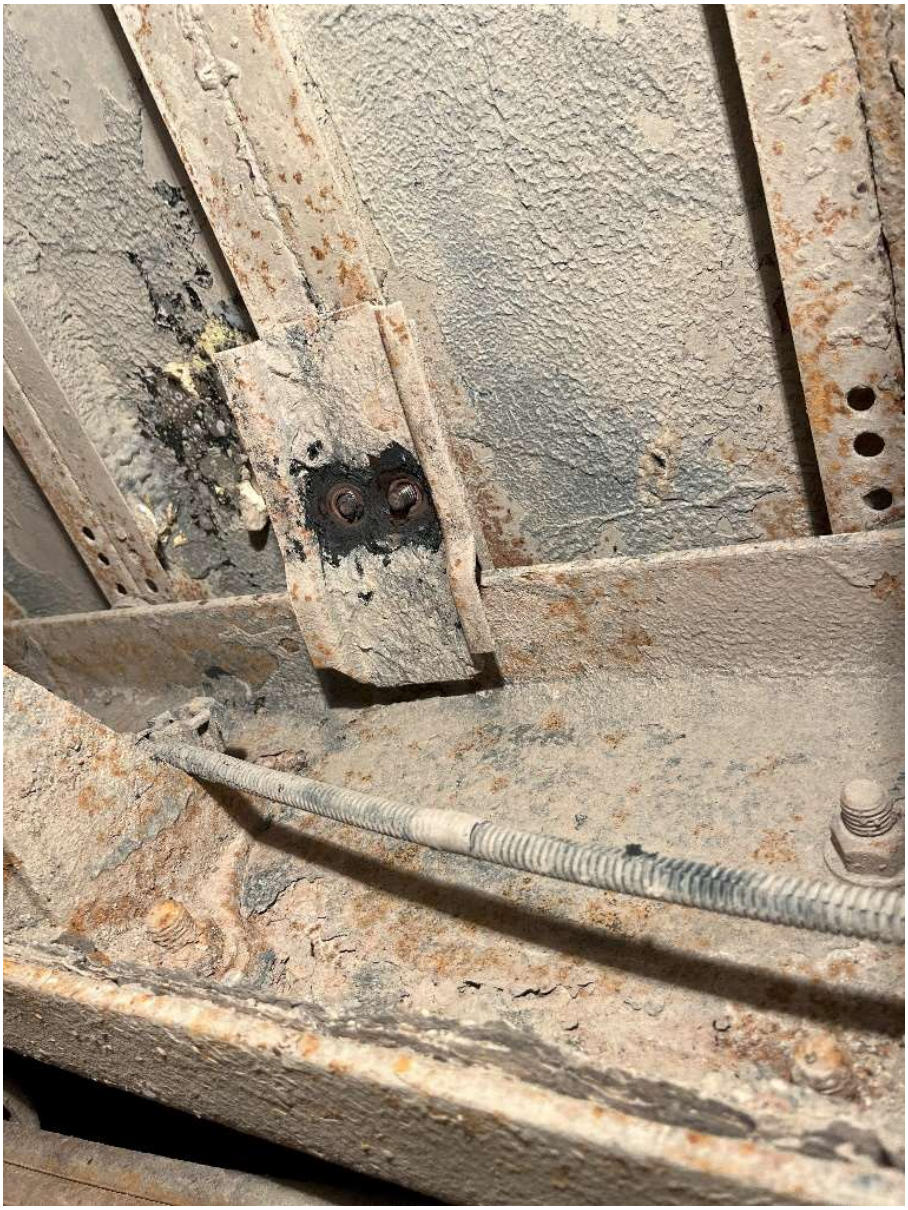


Figure 3.3.3.3 Body to Frame Connection

3.3.4. Defining Space in Terms of Time Spent

With limited space means that the design of the interior of the school bus needs to be efficient and one way to do this is compartmentalize these spaces by how much time is spent in each one. In all countries, roughly 18 to 20 hours are spent indoors each day for the average population (Khajehzadeh 2016). Time indoors actually increases on the weekend, especially for students and white collar professionals (Dey 2020). Finding further information that breaks down how much time is spent in certain spaces over a day has proven to be difficult but the design is focused on optimizing space based upon time spent. For example, a bed is only used when someone is sleeping on it, thus designing to allow for the bed to be on variable geometry will be essential.

Figure 3.3.4.1 Yurt
(Khasanov 2021)

3.3.5. Technology defines Nomadism

Humans have been nomadic since our species first was conceived. Explorers, traveling to new lands till eventually permanent residence was established in every continent except for Antarctica. The ability for our ancestors to travel to new places was always reliant on the ability to bring along tools, preserved food, and shelter. This technology evolved along with the needs and culture of the peoples who designed it. For example, on the east Asian Steppe, yurts constructed with bulky frames and heavy furs as they had domesticated horses (Khasanov 2021). On the other hand, nomadic Native American Tribes developed the tipi which was constructed by long and slender poles to reduce weight. They needed this as before European colonists, the best pack animal was domesticated dogs (Kronenburg 2018). European immigrants pioneered the Oregon trail with the covered wagon that featured wooden wheels that were notoriously known for the horrific sound of the wheels rubbing on the axle. With the invention of the internal combustion engine and the Model-T, the American Airstream trailer was invented in the 1920's and became the modern predecessor to the RV (Airstream 2018). Throughout history, the abilities of nomadic people were dependent upon the technology and mode of transportation available to them. However, this mode of transportation is no longer about physically getting from one place to the next but rather through a data connection. The ability to work from home is a game changer for nomadism giving many the ability to work from anywhere their laptop has a connection. According to a study conducted by the U.S. Bureau of Labor Statistics, over 67.5% of people with a bachelor's degree have the ability to work from home (Dey 2020). This number has gone up significantly in the amount of people actually conducting work from home which was only about 10% of people worked from home more than eight hours per week (Garrote 2020).

3.4. Case Studies

3.4.1. Some Drifters Skoolie Conversion

Figure 3.4.1.1 Some Drifters School Bus Conversion
https://aberdeenstudio.co/some-drifters

This adaptive re-use project often referred to as a skoolie conversion was designed and built by Jeff and Britt Osborne along with the help of Aberdeen Studios, a furniture design company. The skoolie features an assortment of design features that maximizes the use of space which include a roof raise, exterior storage, murphy bed out as well as multiple fold up and down shelves for more counter and table space. The design even has French doors in the living room that open up to a pullout patio space. The interior space is filled with earthly tones and custom wood cabinetry that is undoubtedly inspired by the American Southwest.

Above the bus, a custom rail system that houses the solar panel array can fold out and be angled to receive increased amounts of solar energy. The interior aesthetic blends and think fits well with the purpose of nomadic living. The interior and exterior of this skoolie work incredibly well with the multitude of environments in which it resides in, allowing for seamless indoor/outdoor living.

3.4.2. Mavis Airstream Renovation

The next re-use project features a 1975 Airstream Overlander. The build was done by Sheena and Jason Armstrong and it took around 10 months. The airstream was purchased for 7,200 dollars and the material cost was roughly 20,000 dollars not including some gifted materials. The trailer did not have a large amount of rust due the aluminum finish which is one of the major benefits of Airstreams. The existing clear finish on the aluminum sheet metal was removed and a new coating was re-applied. Similarly, the window frames on the airstream were the frames were stripped and repainted and the bug screens were re-attached or replaced if large gaps were present.

Rather than removing the entire interior finishes, Sheena and Jason removed the existing layer of paint from the vinyl finish and added on a new, low VOC paint to avoid potential off gassing issues. They went with a contemporary light gray and white base interior. There are wood accents, particularly the bedroom door that I see as a farmhouse aesthetic and do not think it fits the Airstream. Some of the design choices on the interior were questionable, but the level of documentation when it came to the build was un-parallel and gave great insight into the process.

Figure 4.4.2.1Mavis Airstream Renovation
https://mavistheairstream.com/mavis1-vintage-airstream-renovation

4. Results and Conclusion

4.1. Final Project Description

Through research of understandings the physical and cultural contexts of not only the American School bus design but nomadic culture as well, the final project outcome is one that focuses on simplicity. The three main design challenges were presented as affordability, sustainability and flexibility.

The project took an existing functional school bus and adapted to a living, work, and play environment that is incredibly affordable. The design takes inspiration from various forms of nomadic architecture and focuses on simplicity. The body of the school bus consisting of only 187 square feet, not much larger than a typical bedroom, serves as a viable living environment for those looking to pursue the alternative lifestyle of nomadic living without forfeiting essential comforts.

4.2. Project Objectives

The goal of tis project was to provide a design that allows the user to experience the multiple environments throughout the western half of the United States through nomadic living. The project objectives were to maintain affordability by sticking to the 20,000-dollar budget. Focus on sustainability through the recycling of materials through various uses. Design adaptably to increase space utilization.

4.2.1. Sustainable

The project met these objectives through a number of different design choices. Sustainability was met as the only materials of the existing bus that were thrown away was the existing rotted plywood floor that had rubber glued to it. Otherwise, everything was recycled, including the school bus seats which the steel tubing from them was used for structural support and framing. The plywood from the seats was cut into strips and used to create the countertops and exterior wooden panel. The foam from the seats was used as insulation for the wall cavities and the leather was sold.

The interior finishes of the school bus, which included perforated steel panels were recycled along with any remaining rusted metal. The interior lights and speakers are being re-used while the former electric heaters were incorporated into vehicles outside the scope of this project. Finally, the extra windows that were not re-used in the design were sold on auction with the only windows not being recycled were the RV, two pane large windows at the front of the bus to allow for a better sightlines while traveling and working. The windows that were recycled were fire-escape windows to provide a safe exit in case of emergency.

There were also materials that were adapted and re-used within this project which includes materials and appliances harvested from RVs no longer in use, such as steel paneling, plywood, and RV ceiling fans. Other appliances such as the fridge and washing machine were sourced from contractors who specialized in renovations. Wood from decks were re-planed and routed to for the shiplap siding and plywood was cut into 2” strips to provide for a more sustainable and affordable solution for the interior framing of the walls and ceiling.

4.2.2. Flexibility

When it comes to flexibility a number of design solutions needed to be addressed when it comes to the shell of the school bus. These include raising the school bus height, replacing the wheel wells, treating the floor, adding on a roof rack and underbody storage. The roof rack and underbody storage in particular were added to increase the flexibility of the design as a whole. They both provide essential storage needed for heating and cooling mechanisms such as diesel heaters, propane, as well as external storage for the occupant for changing environmental conditions.

The focus of the flexible design was acknowledging the different situations of nomadic lifestyle and increasing comfortabilities for all three, traveling, boondocking, and wet camping. Traveling is simply being in the process of going to one destination from another, quickly setting up and quickly tearing down without external hookups. The next, boondocking is stay situated in one spot for several days without external hookups for power or water. The third being wet camping which is staying in place with hookups to allow for greater power and water usage.

A variety of appliances and solar array were sized to fit the various capacities of these different situations. The solar array and battery setup was scaled specifically to fit the essential needs of keeping the fridge powered at all times, running the 12-volt electrical appliances needed for working remote which include lights, phones, laptops, and Wi-Fi connection as well as the highly efficient ceiling fans. The solar will not support appliances such as the mini split air conditioning unit or dryer as shore power will be needed to operate such appliances. The heating of the interior will mostly come from diesel heaters that are hooked to the fuel line of the bus to provide flexibility in all environments. A wire chase was designed to go down the middle of the bus and a plumbing chase was positioned near the rear wheel wells that also acts as a

step to make getting into the bed much easier as well as additional insulation for coming out of the shower for more comfortability.

The interior of the school bus was designed to increase space utilization as much as possible. This was done in a number of ways such as decreasing the size of limited use spaces such as the bathroom and increasing the multiple functions of spaces. The bed is placed using hardware allowing it to be retracted when no longer in use, turning the bedroom into an office. In front of the bus, the couch is placed above the normal limit to allow for additional storage and a kennel for pets without placing overhead storage to make the space feel more open and larger than it appears. The table in the middle of the dinette also can be lowered to create a spare bedroom for any guests. The end result is a kitchen, bathroom, two bedrooms, a living room, and two offices all fitting within the limiting square footage of 187 feet, only 33 percent large than the standard American bedroom size.

4.3. Project Design and Documentation

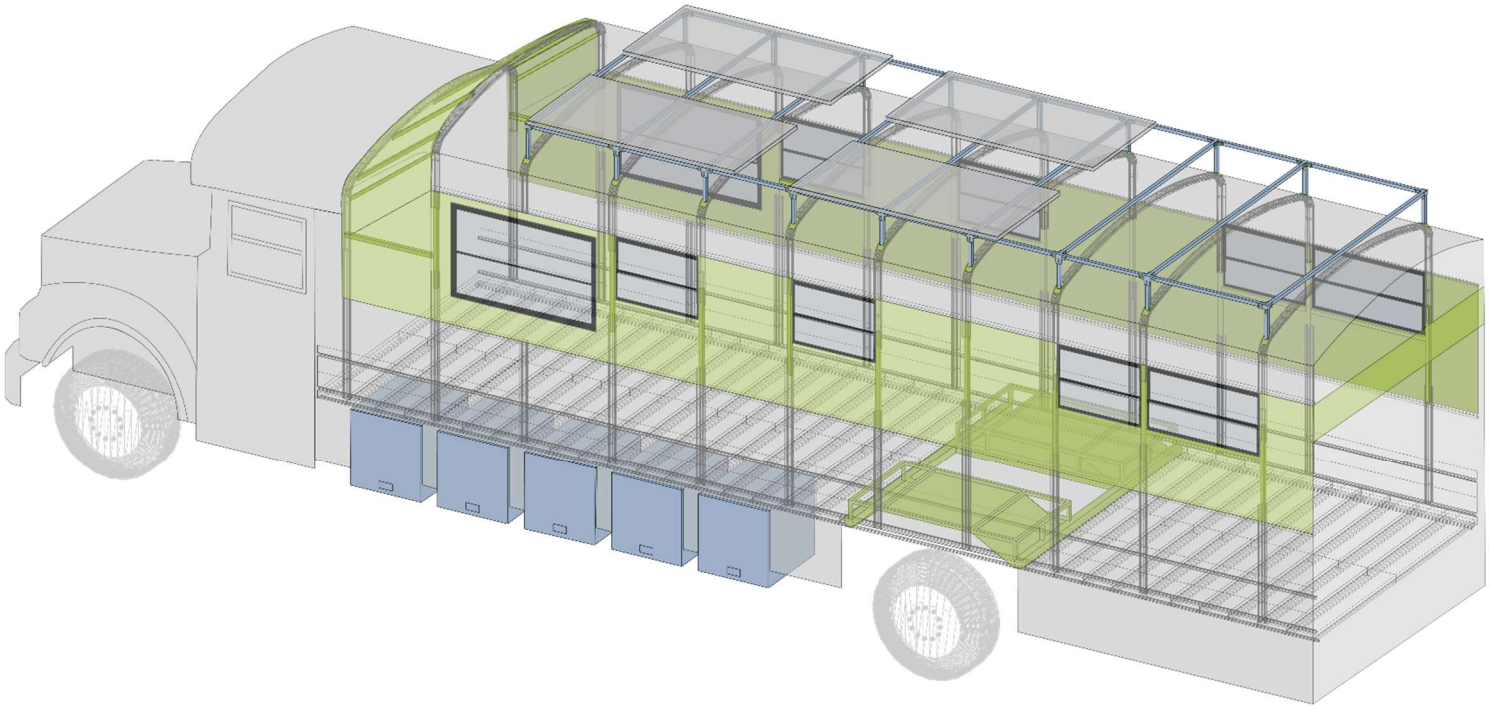
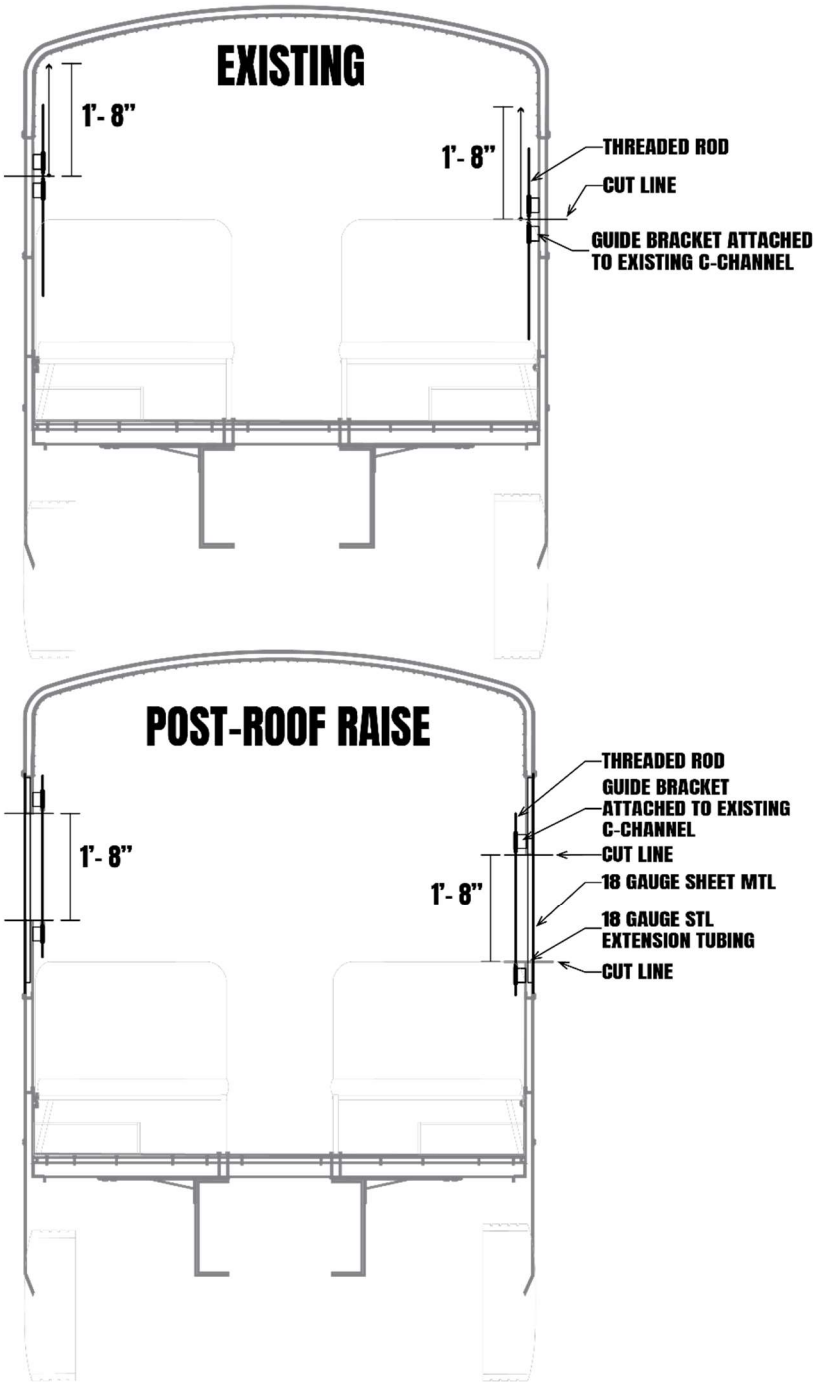


Figure 4.3.1 Structural Changes Diagram

4.3.1. Roof Raise

The roof of the school bus was raised by 20” as the existing height from bottom of hat-channel framing to top of C-Channel floor was around 6’-3”. The roof raise was done by placing four guides that functioned as a jack in each of the corners of the bus and was slowly raised by hand. The guides were needed because the walls were not perpendicular to floor in order to keep everything aligned. Steel tubing was welded to the exiting frame and then exterior sheet metal panel was attached to the tubing. The transition between the new roof level, and the fiberglass cab was framed out by steel tubing and then sheet metal was cut to form and screwed down similar to sheet metal on the side.

Figure 4.3.1.1 Roof Raise Detail



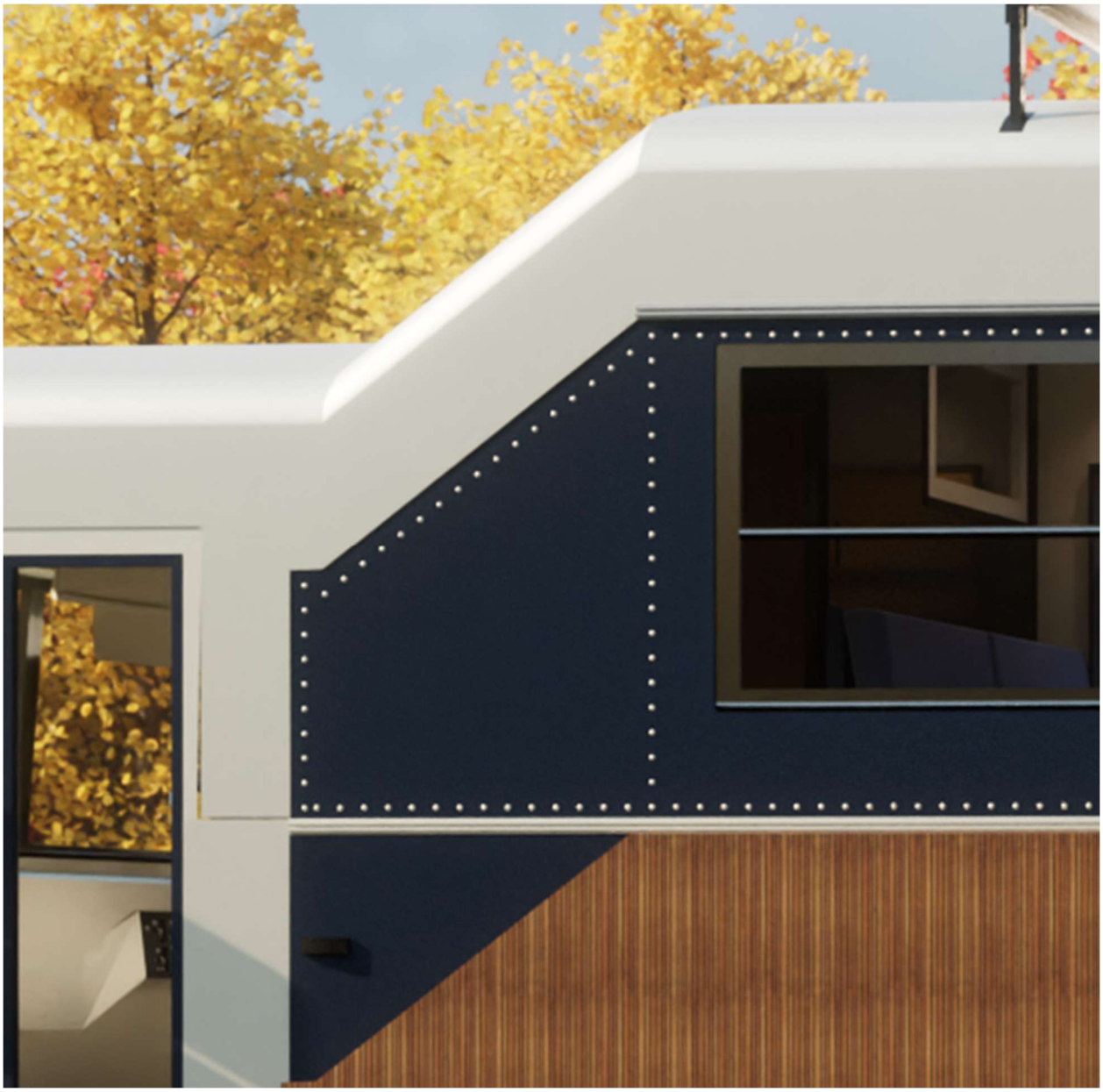


Figure 4.3.1.2 Roof Raise Transition

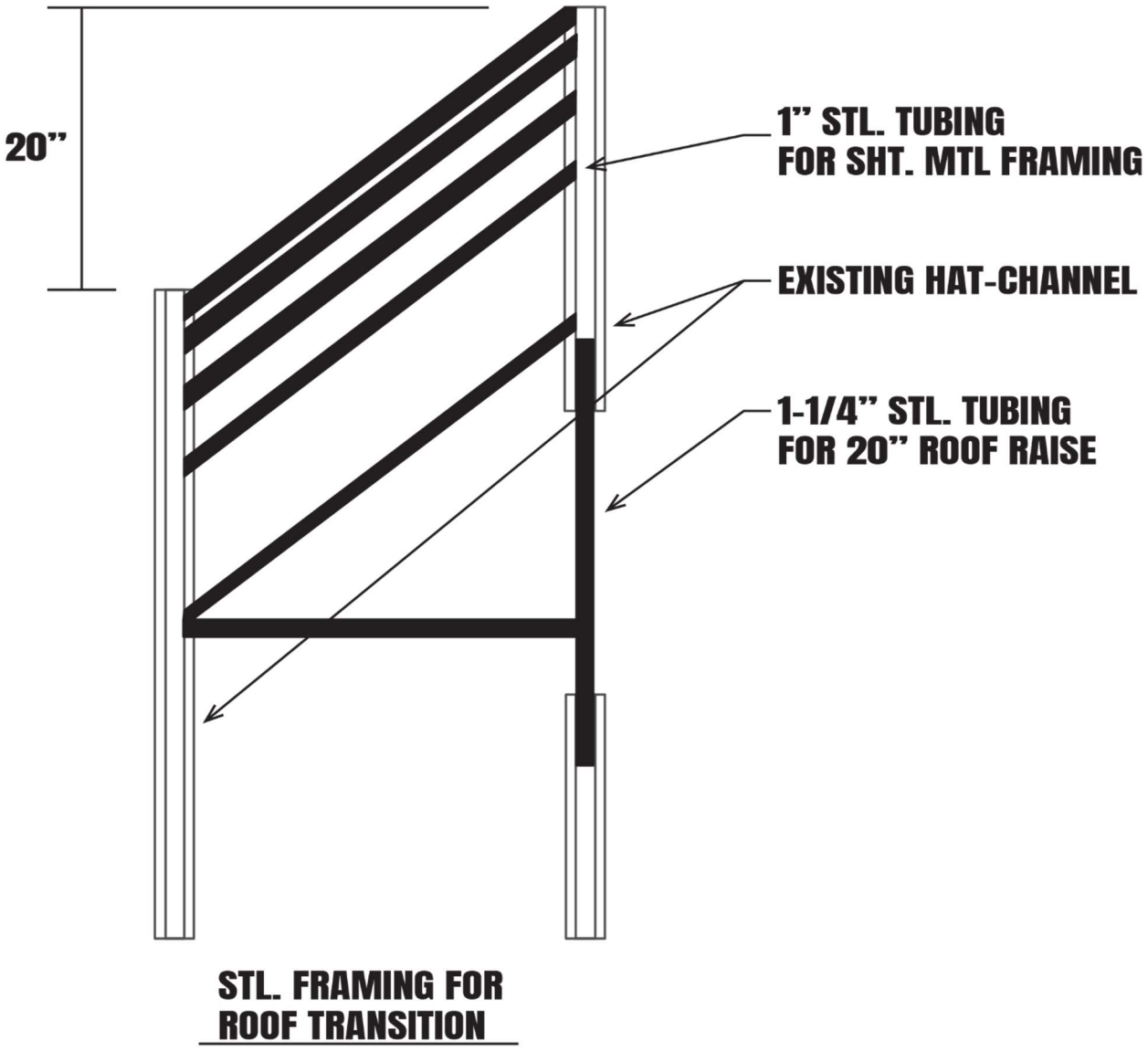


Figure 4.3.1.3 Roof Raise Transition

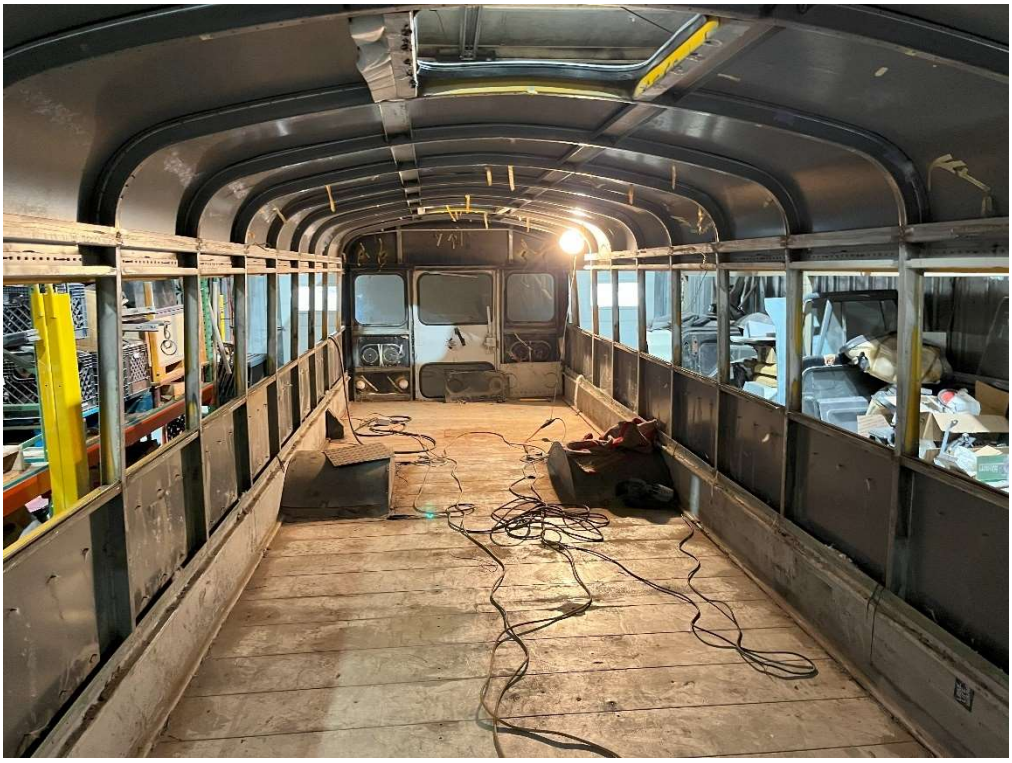


Figure 4.3.1.5 Interior Before Raise

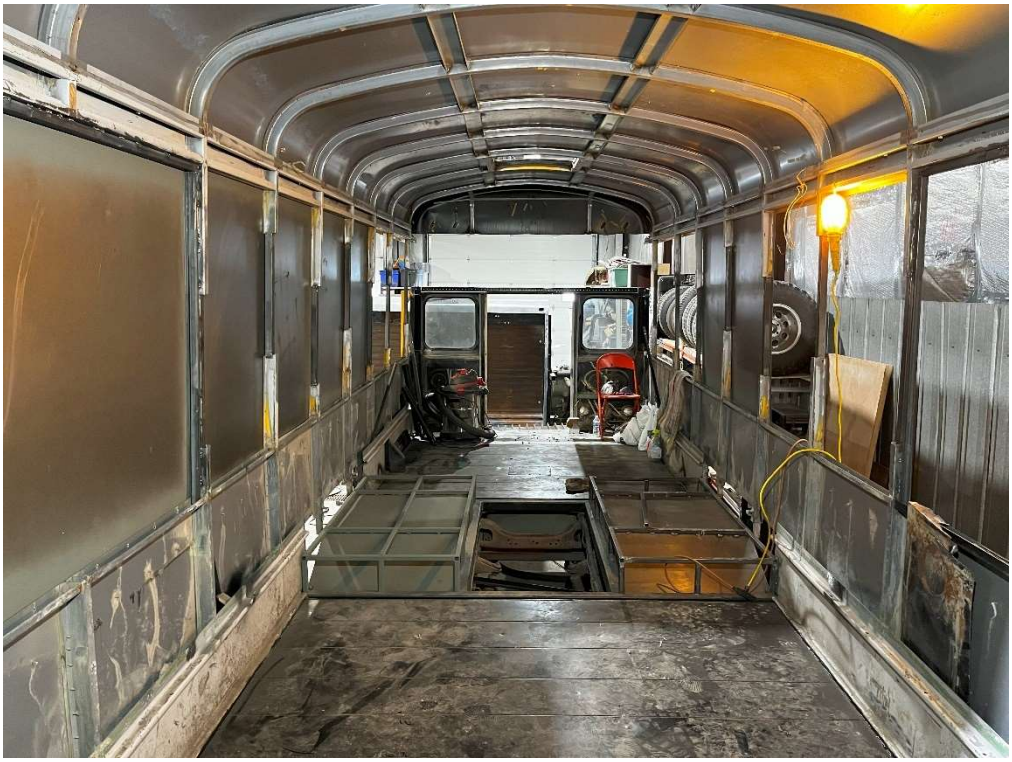


Figure 4.3.1.5 Interior After Raise

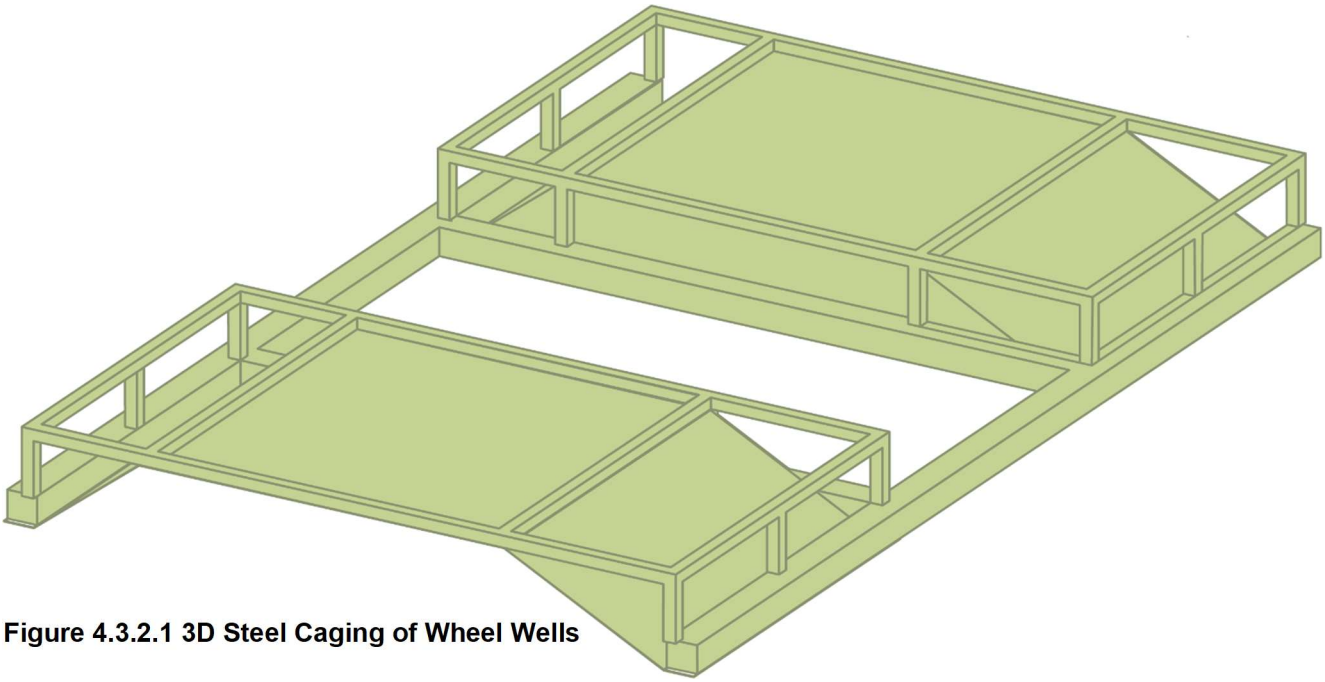


Figure 4.3.2.1 3D Steel Caging of Wheel Wells

4.3.2. Wheel Well Replacement

The floor around the rear wheel wells as well as the wells themselves were entirely rusted out and provided little to zero structural integrity. The wells and surrounding floor were replaced with using 2.5” steel tubing to replace the structural integrity and sit on the existing beams that run the length of the bus. A cage using 1” steel tubing was constructed around where the original wells were and then sheet metal was attached to provide the form with small holes in the corners to allow water to be wicked out of the well. Everything was then insulated, and plywood applied to the steel tubing cages. Recycled angle iron from the school bus seats were used with recycled steel shelving then replaced the missing floor and EPDM roofing and plywood placed above.

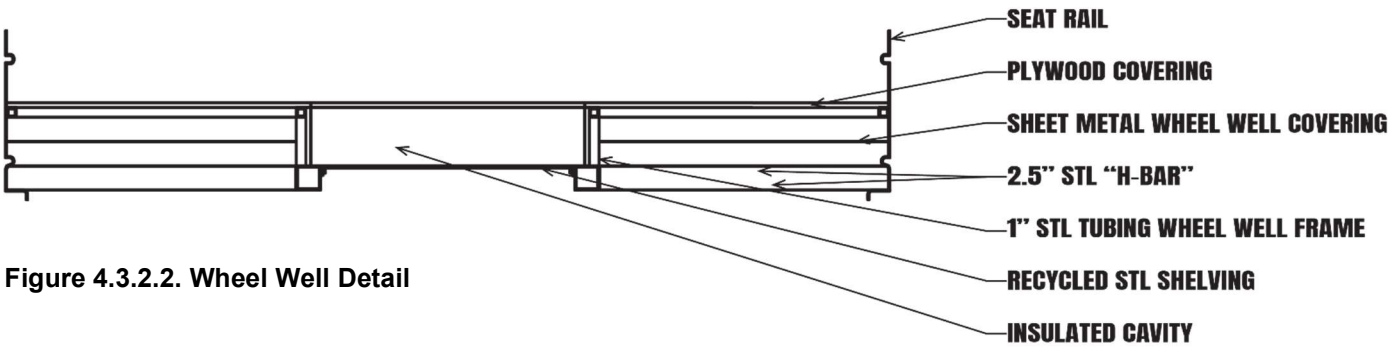


Figure 4.3.2.2. Wheel Well Detail

4.3.2.1. Wheel Well Replacement Process

Figure 4.3.2.3 Wheel Well Existing

Figure 4.3.2.4 Wheel Wells Removed

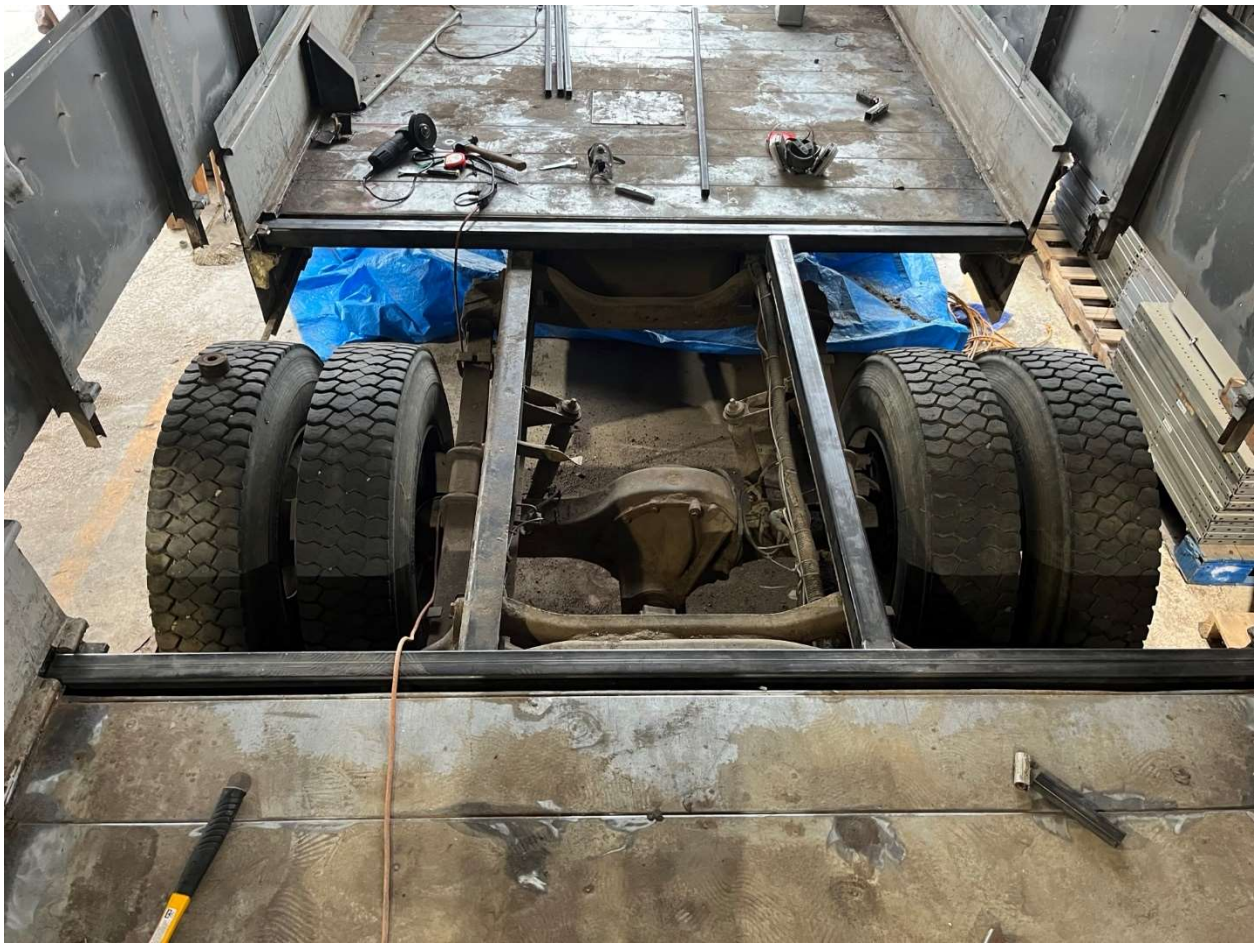


Figure 4.3.2.5 2.5” Steel Tubing

Figure 4.3.2.6 2.5” Steel Tubing in Seat Rail Pocket

Figure 4.3.2.7 Steel tubing in Wall

Figure 4.3.2.8 Steel Framing of Wheel Well

Figure 4.3.2.9 Sheet Metal Attached to Framing

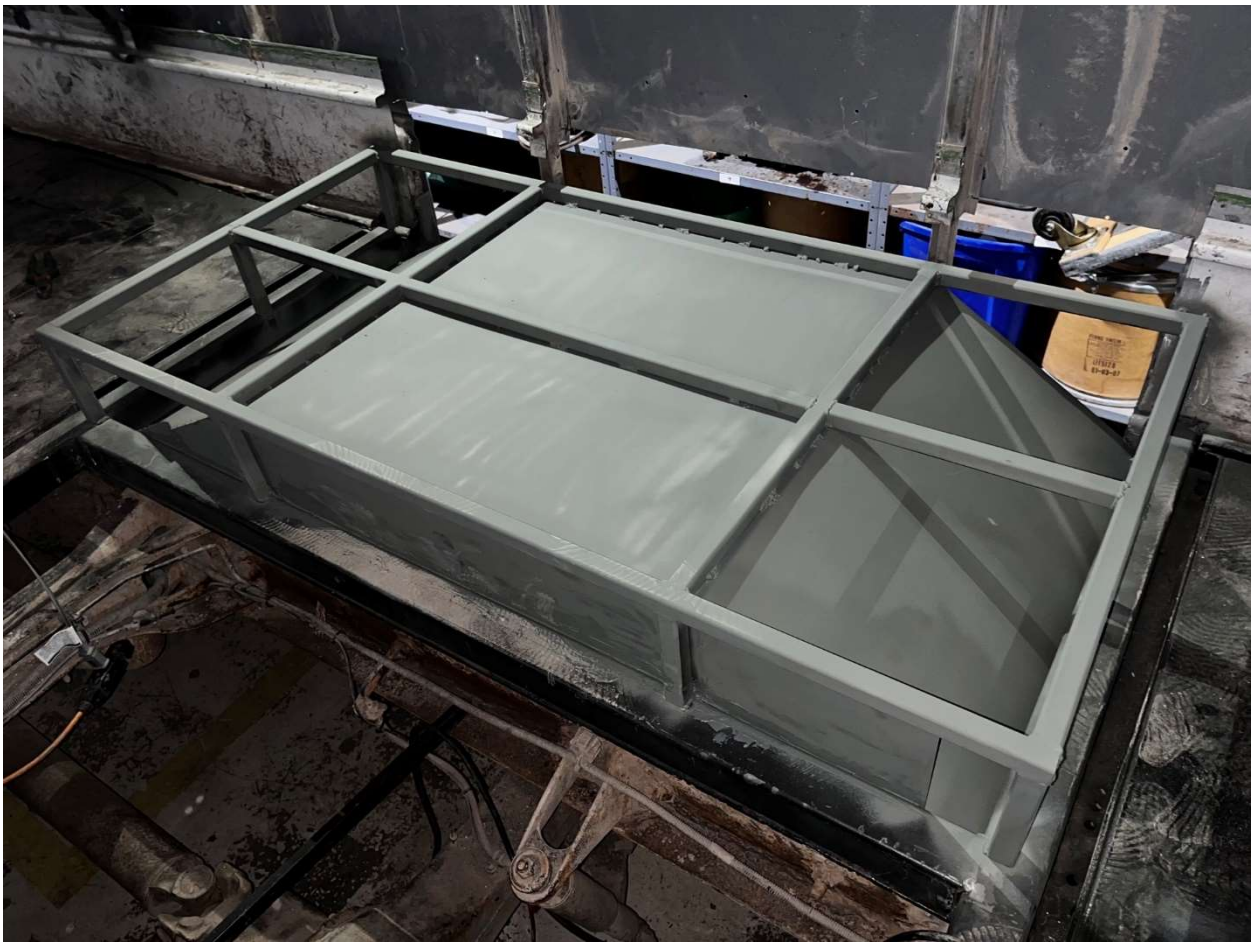


Figure 4.3.2.10 Framing before Insulation and Plywood

Figure 4.3.2.11 Wheel Well from Exterior

4.3.3. Floor Treatment

The existing floor of the school bus was steel c-channel floor trusses with plywood nailed to the steel floor. With the removal of the original rotting plywood, the holes were patched. A floating floor of EPDM roofing textile was placed directly above the steel and then plywood to attach the finish to. This was done to decrease the amount of future rust on the floor as the original design had wet plywood causing much of the rust.

4.3.4. Roof Rack

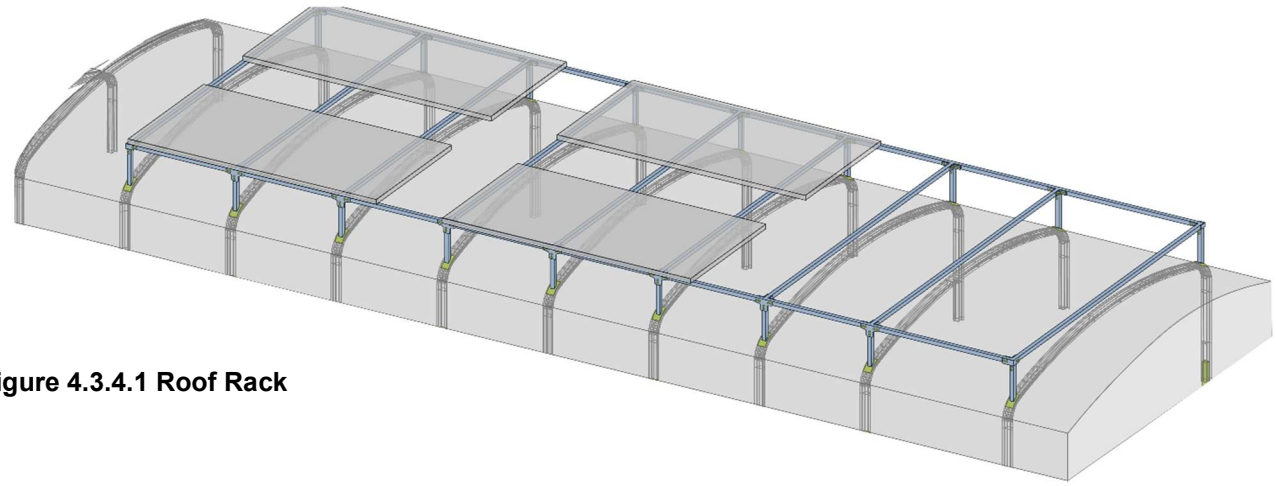


Figure 4.3.4.1 Roof Rack

4.3.5. Underbody Storage

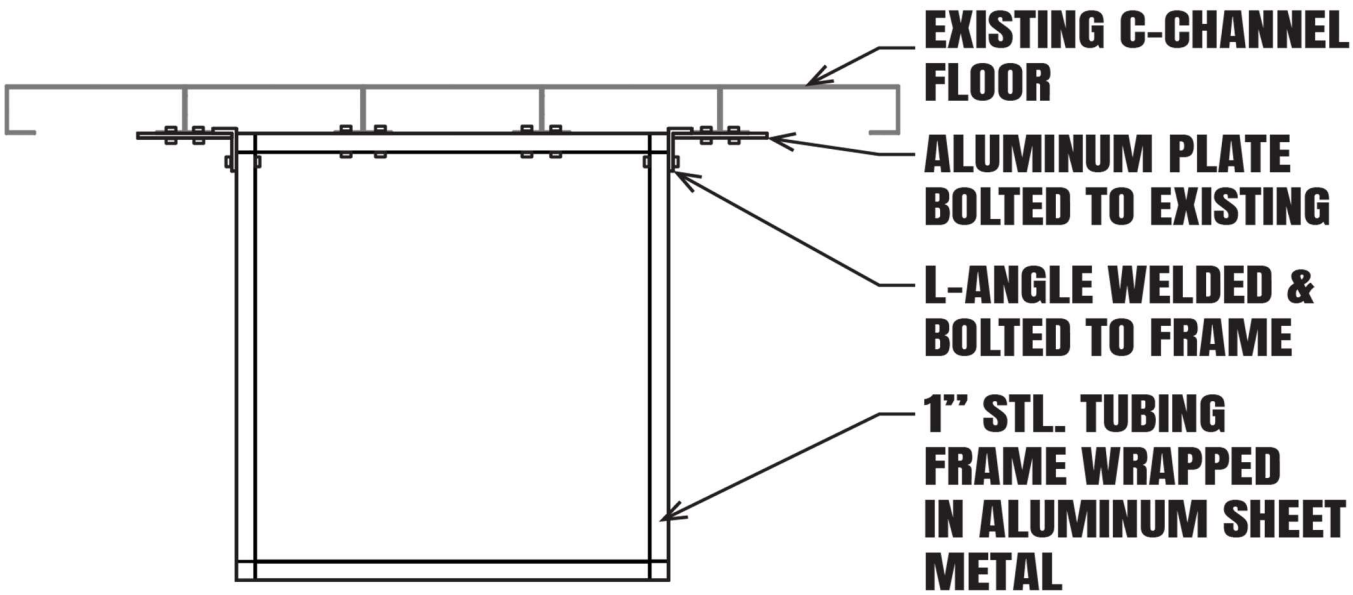


Figure 4.3.5.1 Underbody Storage Detail

4.3.6. Framing

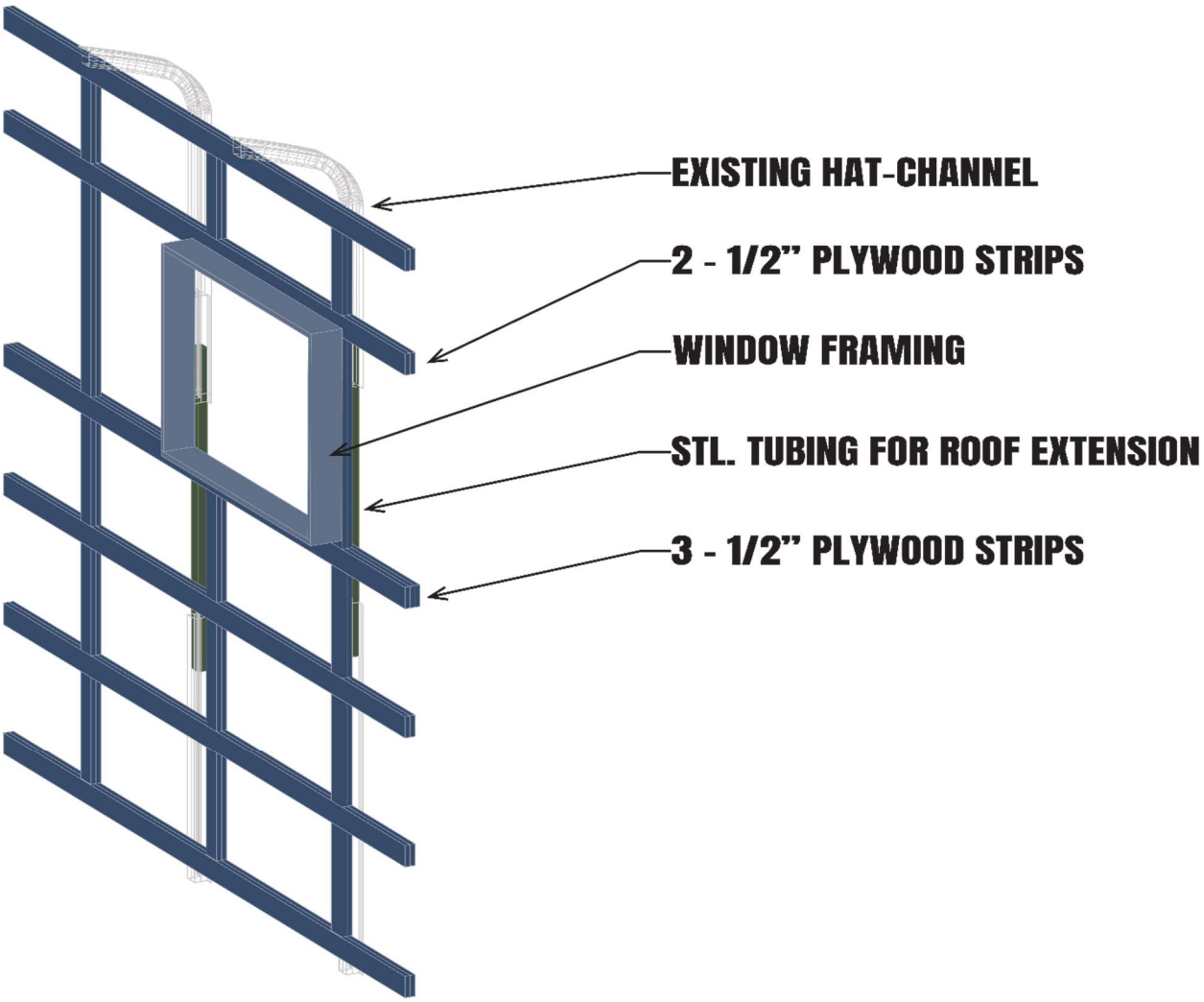


Figure 4.3.6.1 Interior Framing Detail

4.4. Final Design

4.4.1. Exterior

Figure 4.4.1.1 Exterior 1

Figure 4.4.1.2 Exterior 2

4.4.2. Interior

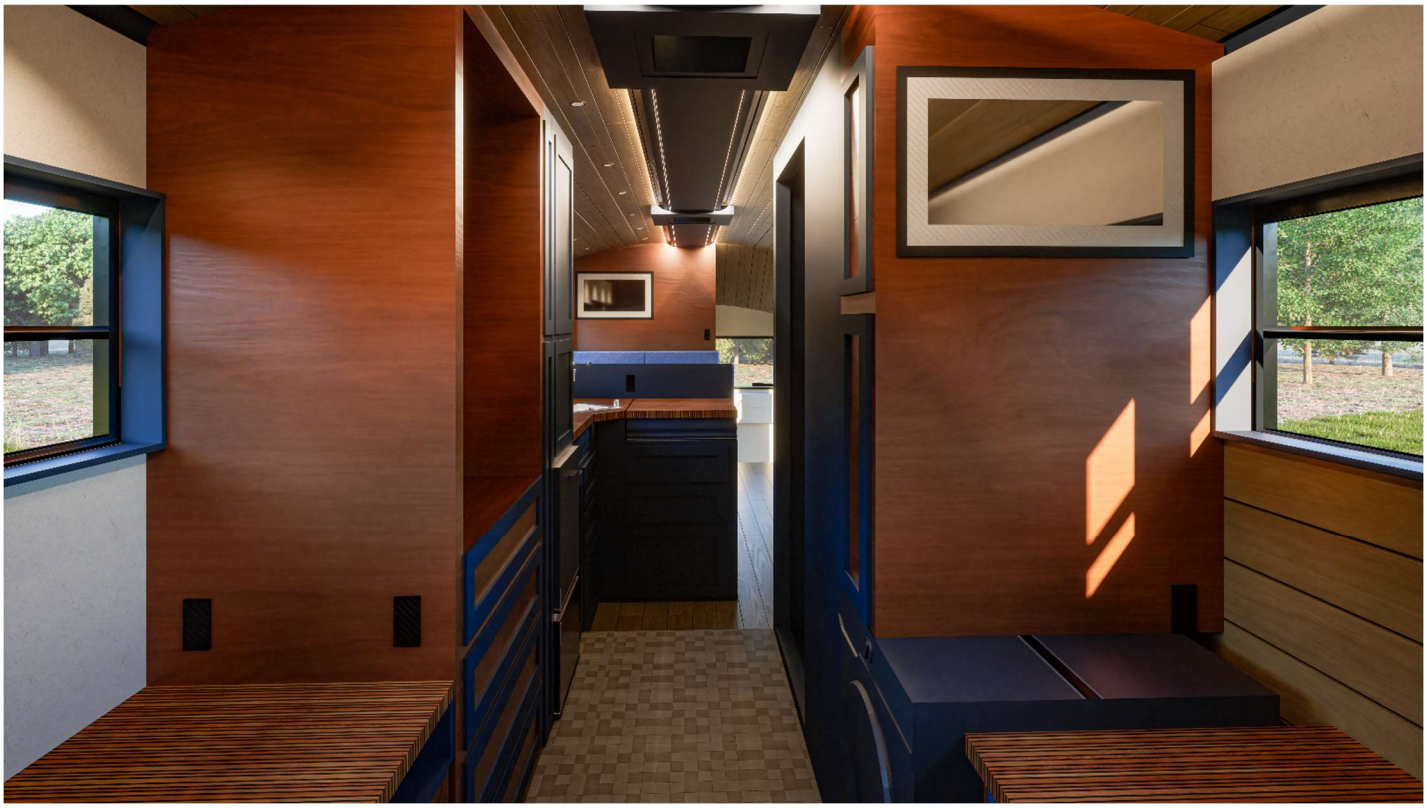


Figure 4.4.2.1 Interior Render

Figure 4.4.2.2 Interior Render 2

4.4.2.1. Variable Geometry

Figure 4.4.2.3 Bedroom and Office Render

Figure 4.4.2.4 Living Room and Spare Bedroom

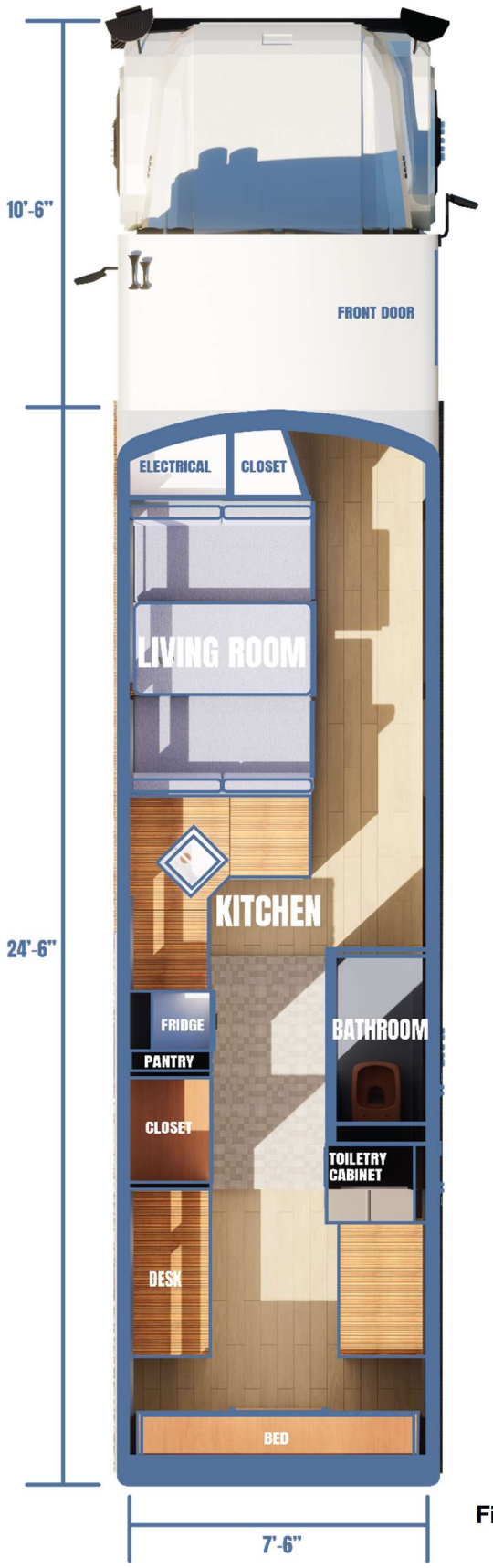


Figure 4.4.2.5 Floor Plan

4.4.2.2. Floor Plan

4.4.2.3. Sections

Figure 4.4.2.6 Driver's Side Section

Figure 4.4.2.7 Passenger's Side Section

4.4.2.4. Section Detail

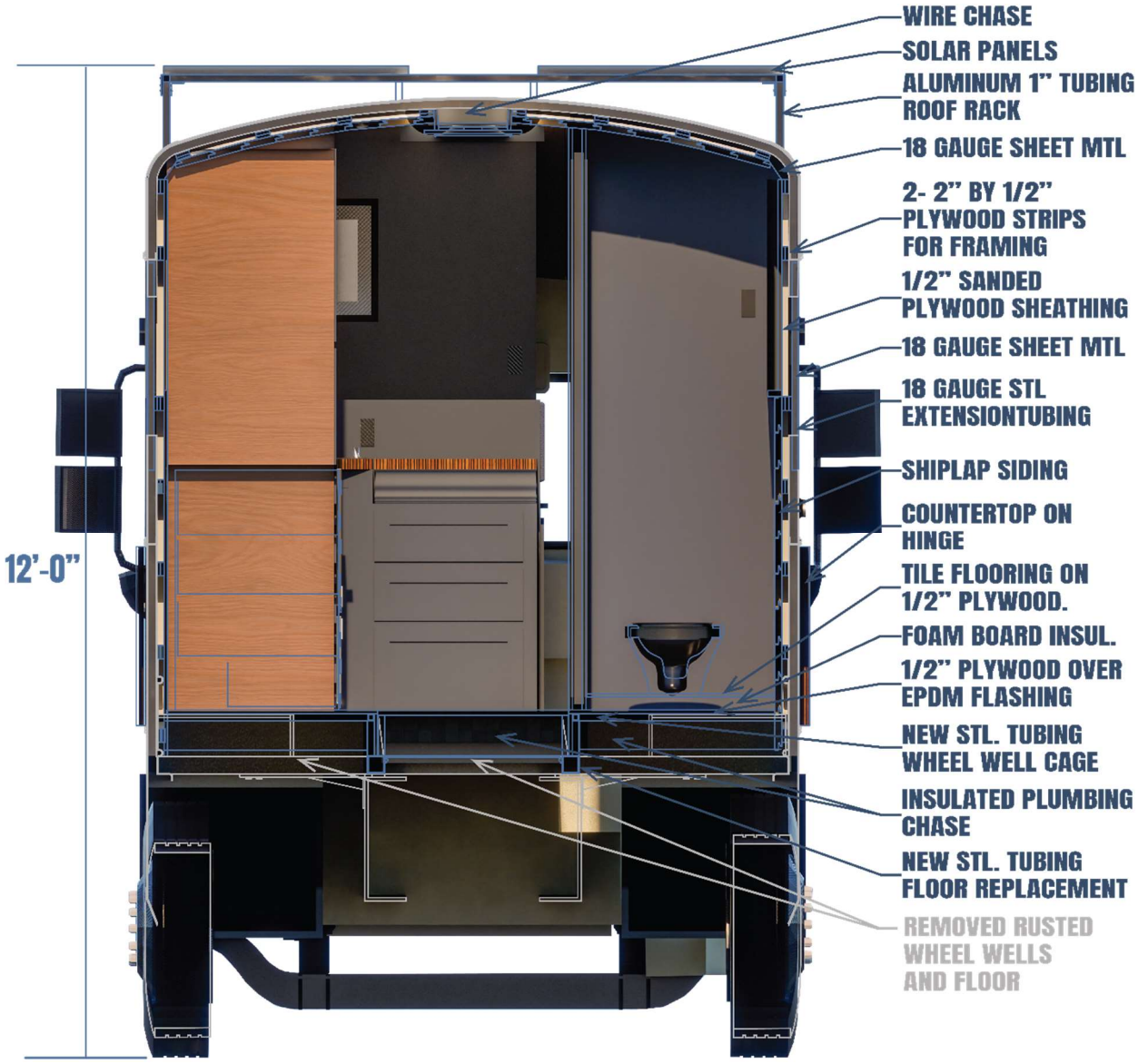


Figure 4.4.2.8 Section Detail

4.4.2.5. HVAC Plan

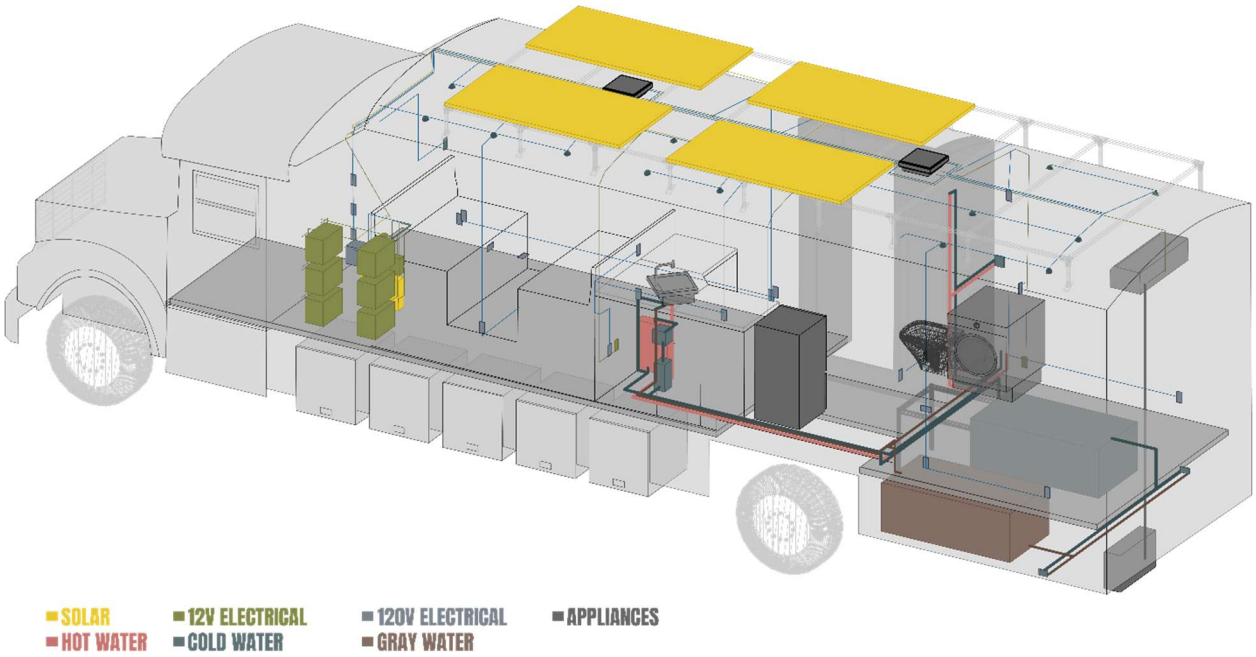


Figure 4.4.2.9 HVAC Plan

5. Conclusion

The two biggest design challenges present in this project was the budget of only 20,000 dollars and the limited confines of a standard American school bus being only 187 square feet. Overall, the design issues were mostly solved but there was a significant left to be desired. Due to the budget, roof top deck, and a deck on the back of the bus were cut which would have greatly improved the flexibility of system as a whole and further increase the connection between the design of the bus and the environments it would be in.

One challenge in particular that was not included within the budget of the school bus was that of a variance in grade. Typical RVs include a system of jacks for leveling the interior and are often complicated and very expensive. Manual jacks could easily be used when it in boondocking or wet camping for a period of time but were not included in the project as it would have pushed the project past the budget but could easily be acquired by an occupant.

Another design challenge that was not addressed was that of security. Beyond locks of the front door and to the storage, there are no security measures such as exterior lights or cameras due to budget concerns. However, this was planned for with the wire chase in the ceiling making any modifications that include electrical extremely easily and accessible. Overall, the project achieved what it was intended to, an affordable school bus conversion that is not only sustainable but flexible in its design.

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