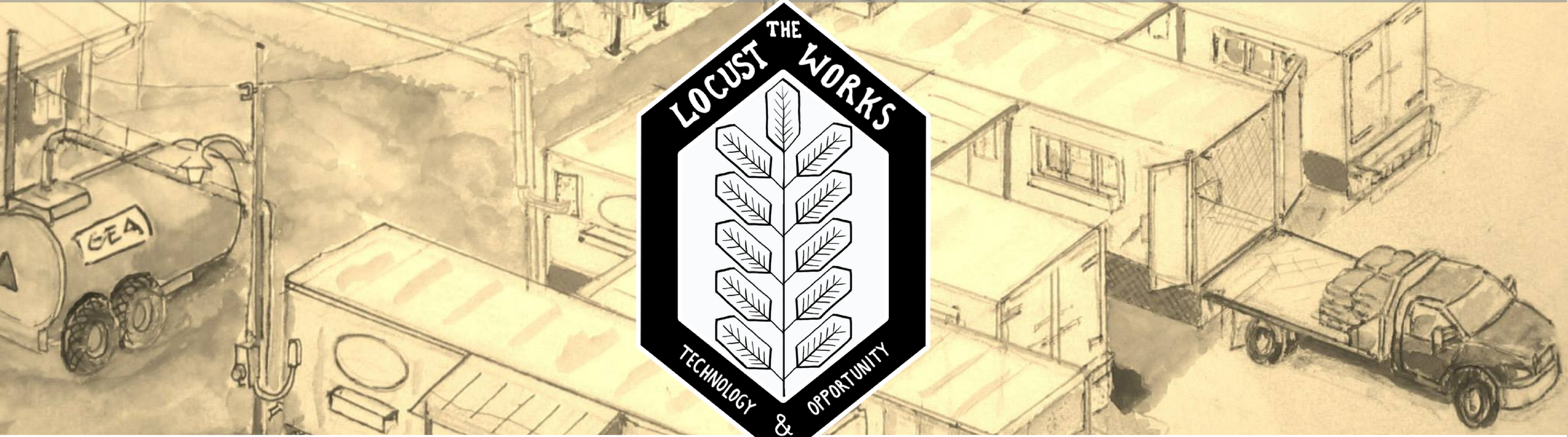
Modular Meat Plant Development Report

An Introduction to Opportunity Engineering and the Modular Agricultural Processing System

Brian Leach, 12/28/2022



THE LOCUST WORKS
TECHNOLOGY & OPPORTUNITY

Funding Partners:

NORTHEAST SARE
Sustainable Agriculture Research & Education

VERMONT
WORKING LANDS ENTERPRISE INITIATIVE
www.vermontworkinglands.com

Vermont Land Trust

Acknowlegements

This material is based upon work supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, through the Northeast Sustainable Agriculture Research and Education program under subaward number FNE19-937. A special note of thanks to Allen Matthews, friend, mentor and technical advisor on this project.

Haystack Farmstead, has received grant funding through the Vermont Working Lands Enterprise Initiative to assist with the purchase of building materials and contractor labor to complete the proposed on-farm processing facility. Special thanks to Seth Butler and Mara Hearst, fellow farmers and collaborators in the project. VT WLEI and the Agency of Ag in general have been very supportive of the small producer and none of my work would be possible without their help.

The Vermont Land Trust has supported this project by connecting Haystack Farmstead to private donor sources concerned with agricultural viability in Southern Vermont and beyond. The ongoing work of VLT is deeply felt and appreciated across generations of my family. I hope in time organizations in the areas of farm infrastructure and marketing can become as impactful and steadfast as VLT has been in the areas of conservation and land access.

Preface to the Report:

Thanks for taking the time to review this report related to the development of a Modular Meat Processing facility at Haystack Farmstead in Pawlet, VT.

I'm a husband, father, 7th generation farmer and engineer. In 2013, I started a grazing enterprise on the farm that I now own with my wife Breya and boys Orrin and Rylan. My journal and correspondences from that time are loaded with references to my desire to process my end-product on farm. For nearly 10 years I struggled to make a dedicated grazing enterprise work and I couldn't do it. I never had the tools I needed, every sales arrangement was delicate and fleeting. Cost of processing, cost of bale wrap, cost of tractor parts. I could never afford help, I had to build everything from scratch, fix everything myself. My wife lovingly teases that I have the eyes of a 80 year old man in a 34 year-old's body and that's probably why.

When our longest-standing wholesale buyer demanded a 30% price reduction in the thick of the post-pandemic inflation crisis, when all of our costs were skyrocketing, we decided to pull the plug. We opted to sell the entire herd rather than struggle to keep 60+ animals fed through another Vermont winter while we spun our wheels looking for a market.

As painful as elements of my farming experience have been, there are glimmers of hope and plenty of cause to keep working on it. Imagine meat proteins being produced 100% carbon-neutral with zero food-miles to salable form. With creative logistics and promotion of at-home butchering, plastic use in the food-chain can even be reduced. Every career secured with a small on-farm value-adding operation is one less commuter on the road.

I think it's unethical to accept, much less plan systems that rely on roles that you yourself would not do. This notion of engineering technology for the smallholding is as much about work ethics as anything. As for me, I would not want to work in a slaughterhouse every day. I would be glad to slaughter my animals on farm once or twice per month and stagger the skilled butchering of those carcasses over the course of the month. There's a fundamental difference and the central theme is dignity and well-being.

I am confident that with good design, networked on-farm processing systems can provide nourishment to the public at reasonable expense to the end consumer. Enter the Opportunity Engineer - A specialist in the development of state of the art distributed systems that make sure people in all communities have opportunities to earn a living. My area of focus is just one within a massive potential field of work.

It will take creativity to figure out how to mobilize and pay Opportunity Engineers and it will take research and policy to determine how to protect our investments in their work. However, I hope my work with the MMP offers a glimpse into what's possible when technology is applied with community-level outcomes in mind.

It will be time consuming and clunky to finish the MMP. It will take time to iron out the kinks, work out a HACCP plan and pursue USDA Inspection. At that point we'll switch the lights back on and resume operating the farm, this time as a livestock enterprise incubator. Interns will move the cattle through the managed paddocks and build their butchering craft in the MMP. If this process works, we'll have laid the groundwork for building more facilities for young farmers that want to make a career of it.

Brian Leach, Owner-Operator, Haystack Farmstead and The Locust Works 12/28/22

Report Contents

SECTION

Section 1: Key Terms and Definitions

Modular Agricultural Processing System (ModAPS): First conceptualized in 2012, ModAPS is a build system that uses standardized components and interconnections to enable the cost-effective and rapid implementation of value adding capacity on farms. Using modular, semi-portable techniques, value adding capacity becomes more flexible, more fluid. Over time, the construction details and blueprints could be held as state or federal standards, allowing a network of shop facilities like the Locust Works to tap manufacturing opportunities and build systems for farmers.

ModAPS Unit: A individual section of a modular building that is constructed in a shop, delivered and set by crane. In the case of the prototype stage ModAPS system, these units are 8'6" (2.59m) wide and 9'6" (2.90m) tall.

Modular Meat Plant (MMP): The MMP is the first on-farm value adding system to be constructed using ModAPS. It is a USDA inspected slaughter and cut & wrap facility to be operated at Haystack Farmstead as a small cooperative with other local producers. The facility is presented in detail in this report.

DFMA-Local: Design for Manufacturing and Assembly using locally available materials and locally available manufacturing technology. DFMA is a concept long-used in Engineering and Manufacturing to describe the methodology of designing systems that can be built easily. Often times, simple changes to a component's design can offer huge manufacturing time savings with little comprise to product performance. DFMA-Local extends that concept to include the socio-economic impact of engineering choices that provide economic opportunities locally. In the case of ModAPS, it's driven the decision to include local rough-sawn lumber and sheet-metal components that can be bent with inexpensive brakes etc.

USDA Inspection: A meat processing facility that operates under USDA Inspection produces a finished salable product that is certified in compliance with the Federal Meat Inspection Act and the Poultry Products Inspection Act if applicable. Part of a facility's compliance is the development and adherence to a Hazard and Critical Control Point (HACCP) Plan that identifies and controls all potential food safety hazards within the facility. Having a well-conceived, sanitary and safe facility is a perquisite for achieving USDA Inspection. This is one of the primary objectives of ModAPS and the MMP.

Kill Floor: The area of the meat processing plant into which animals are brought for slaughter.

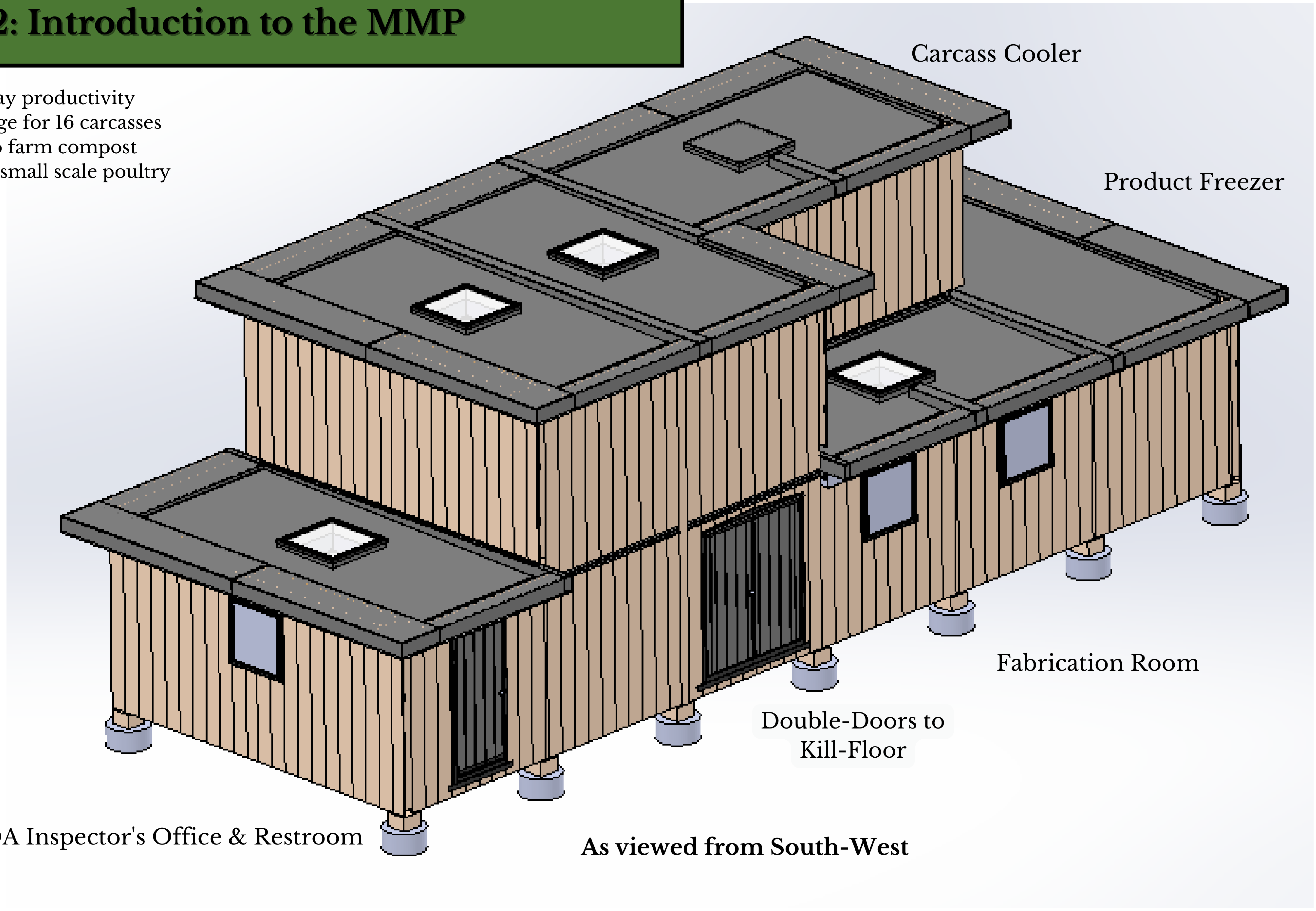
Stun Box: A specially designed rectangular space into which an animal is moved prior to stunning. These are often equipped with some form of head restraint to ensure accurate aiming of the stunner. After stunning, either a swinging or vertically sliding door releases the animal onto the kill floor for bleeding and dressing.

Fabrication: In the meat processing industry, fabrication refers to the skilled break-down of large primal cuts into finished, individually packaged items of salable product.

Carcass Cooler: After slaughter, each animal is closely inspected for abnormalities or contamination. If the animal passes inspection and no unacceptable procedures were observed by plant workers, the carcass is moved into a cooler, typically by rail and trolley where it later receives a USDA stamp, marking it approved for further processing.

Section 2: Introduction to the MMP

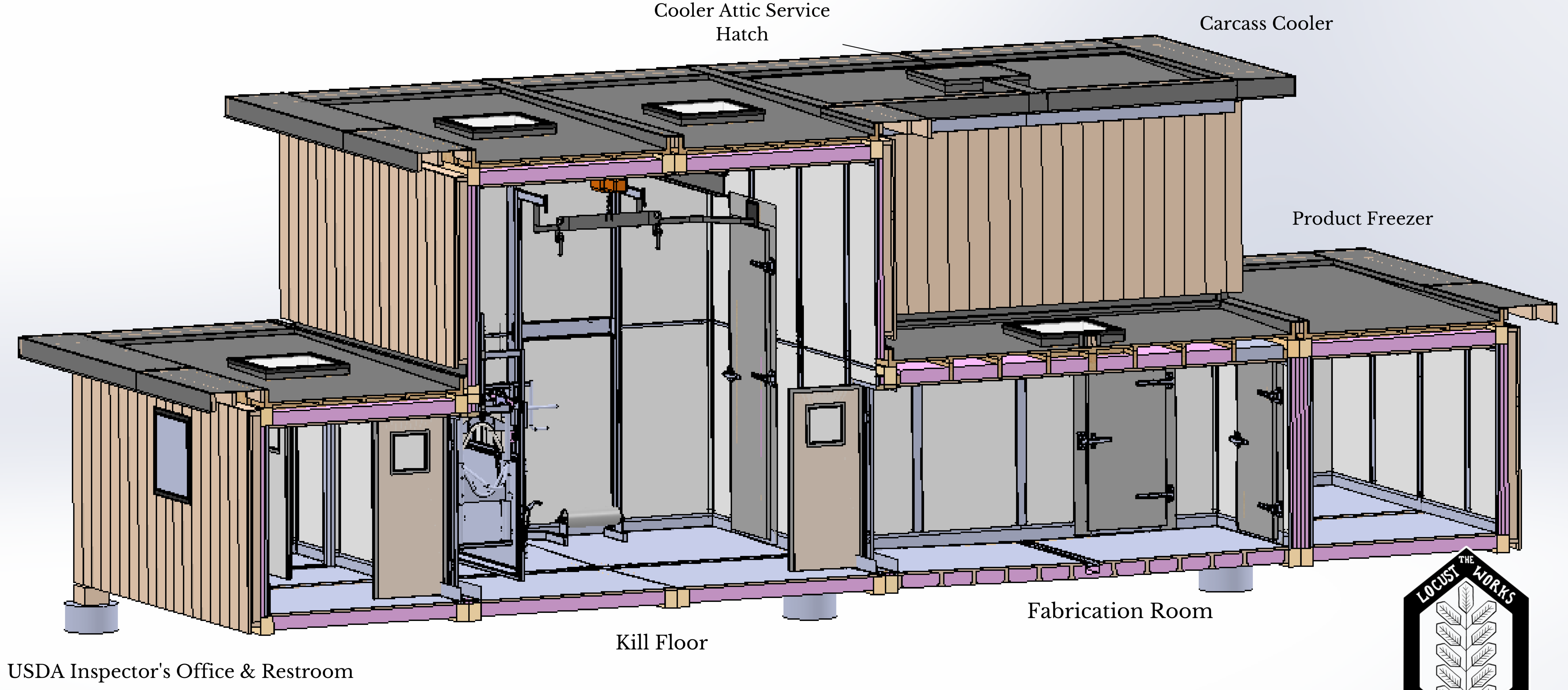
- 4-8 beef per day productivity
- Hanging storage for 16 carcasses
- All residuals to farm compost
- Capability for small scale poultry



As viewed from South-West

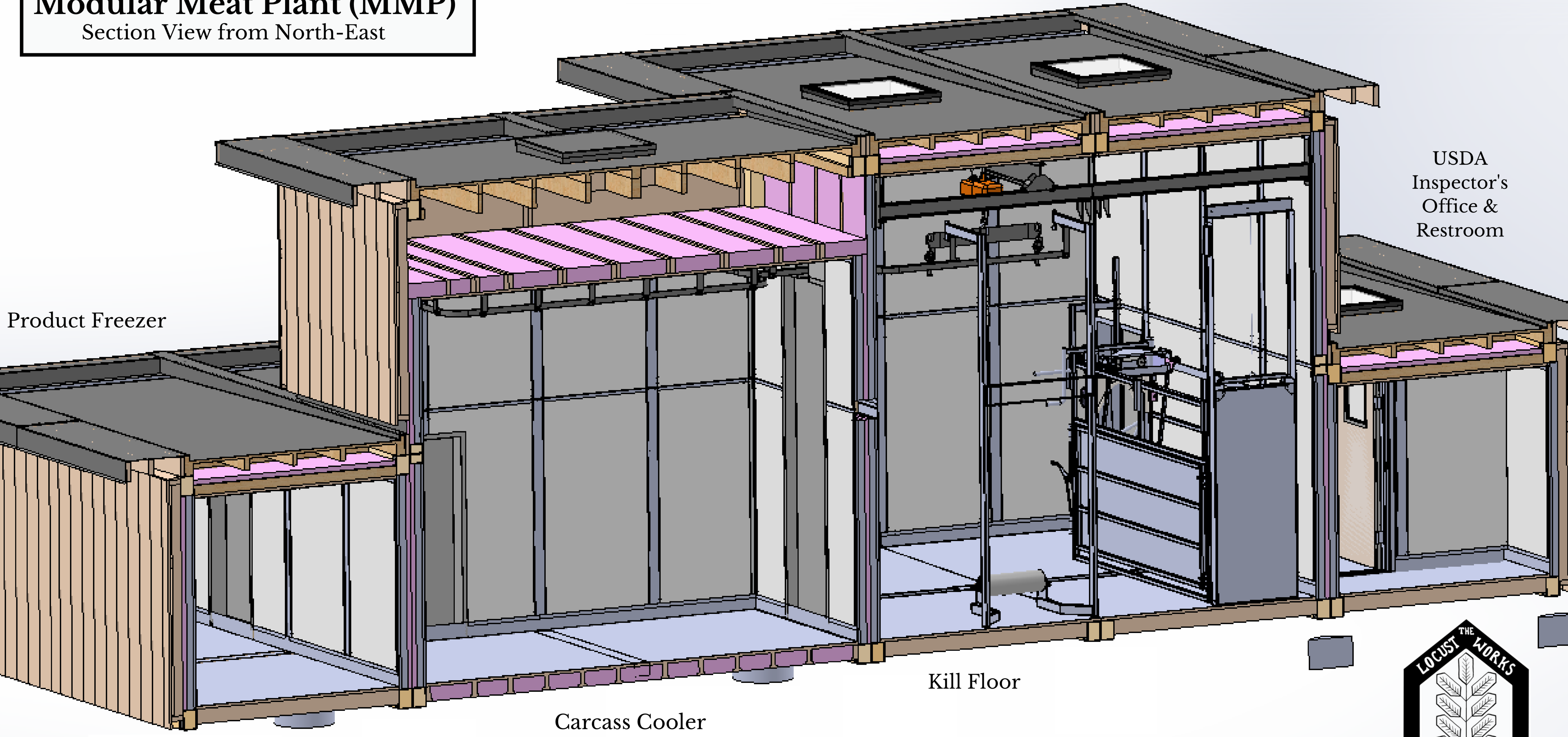
Modular Meat Plant (MMP)

Section View from South-West



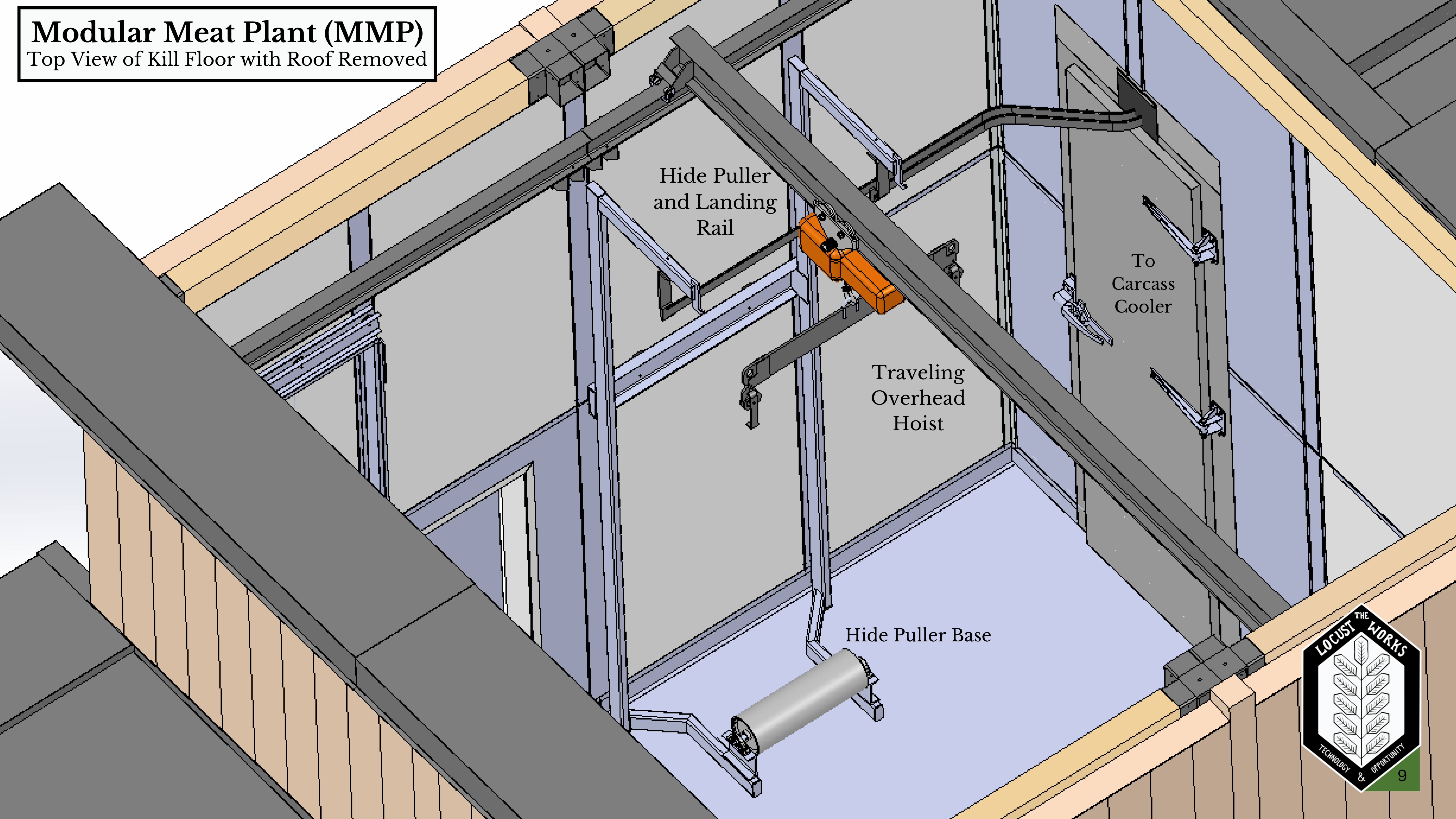
Modular Meat Plant (MMP)

Section View from North-East



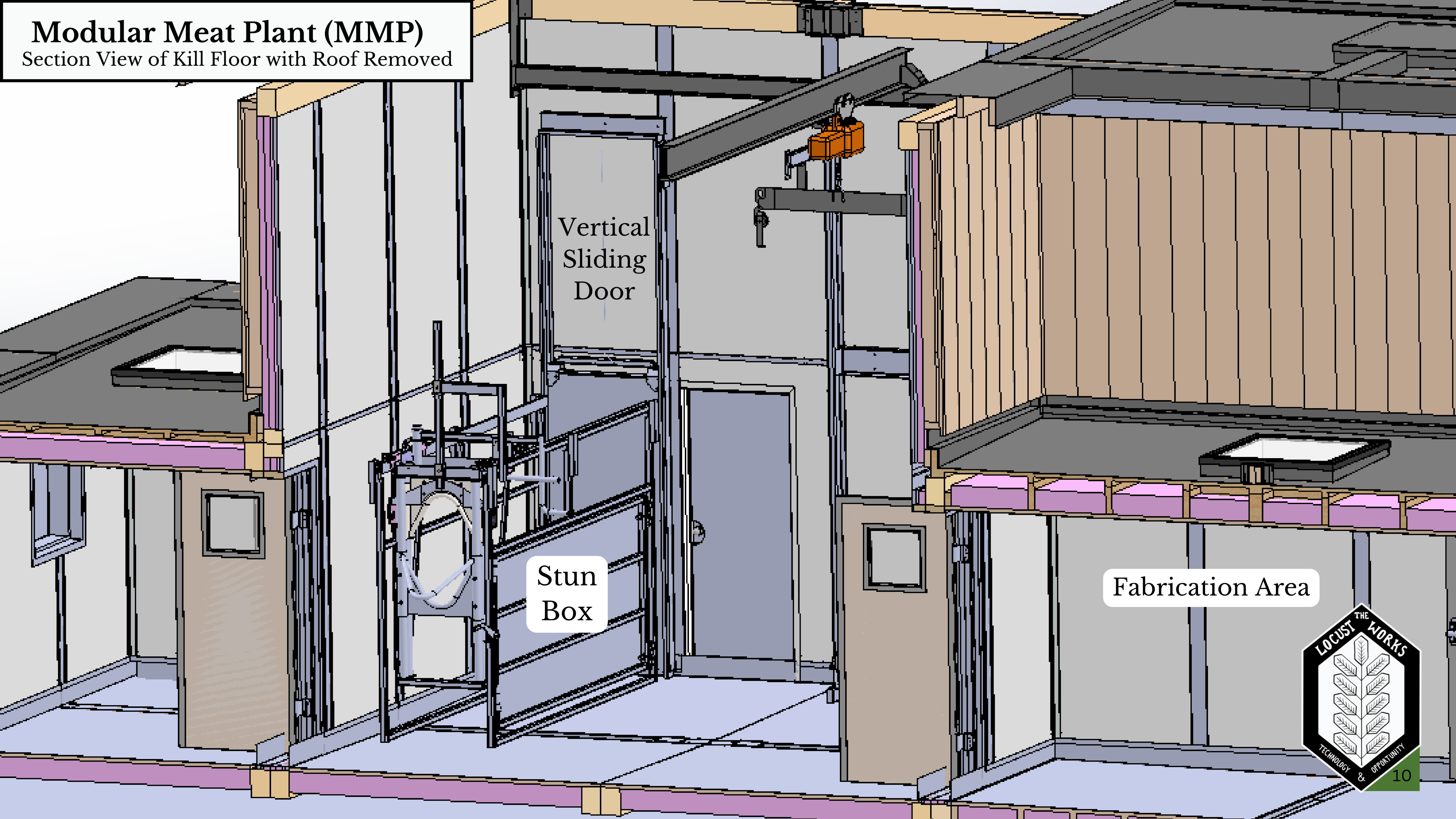
Modular Meat Plant (MMP)

Top View of Kill Floor with Roof Removed



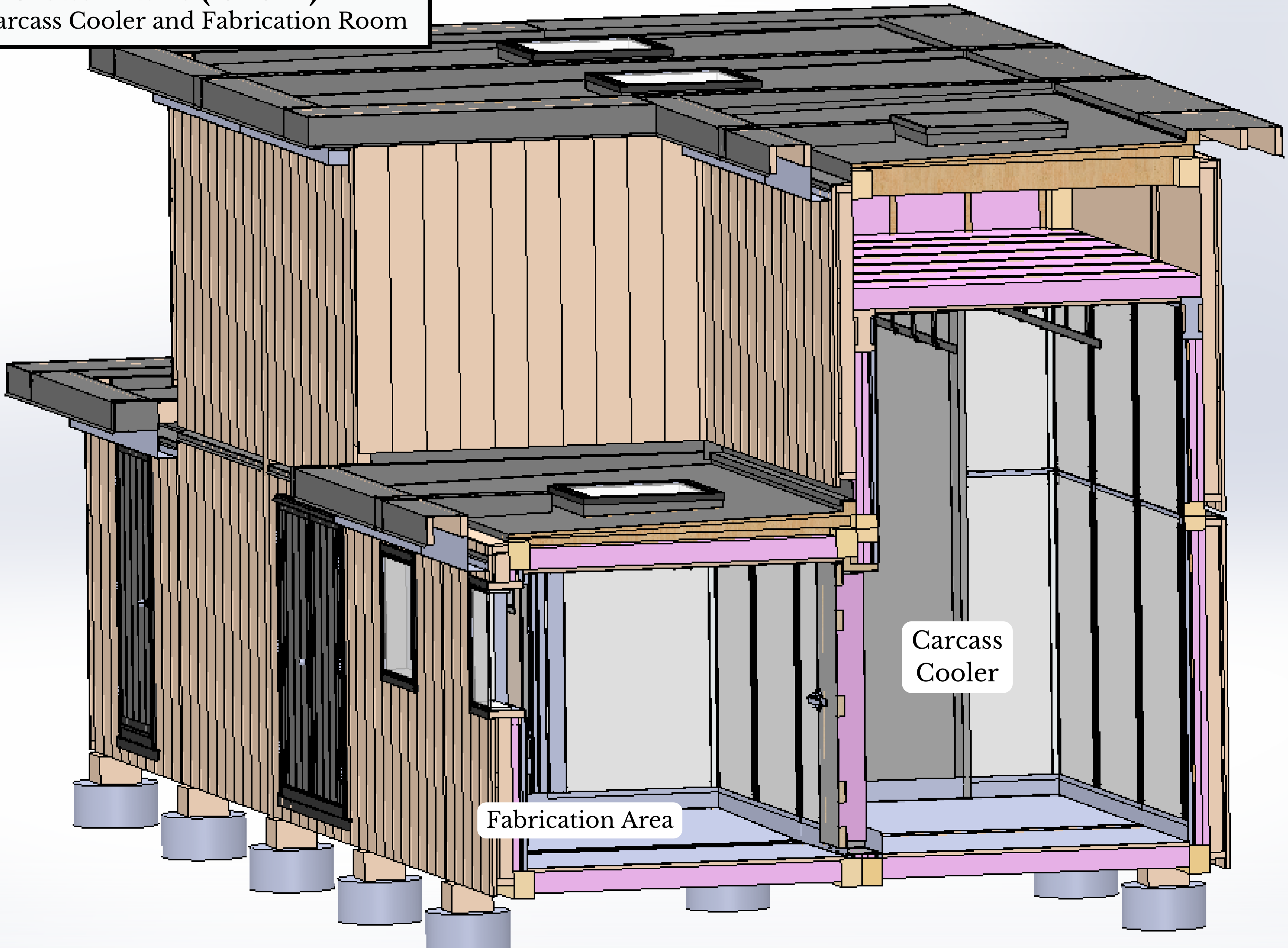
Modular Meat Plant (MMP)

Section View of Kill Floor with Roof Removed



Modular Meat Plant (MMP)

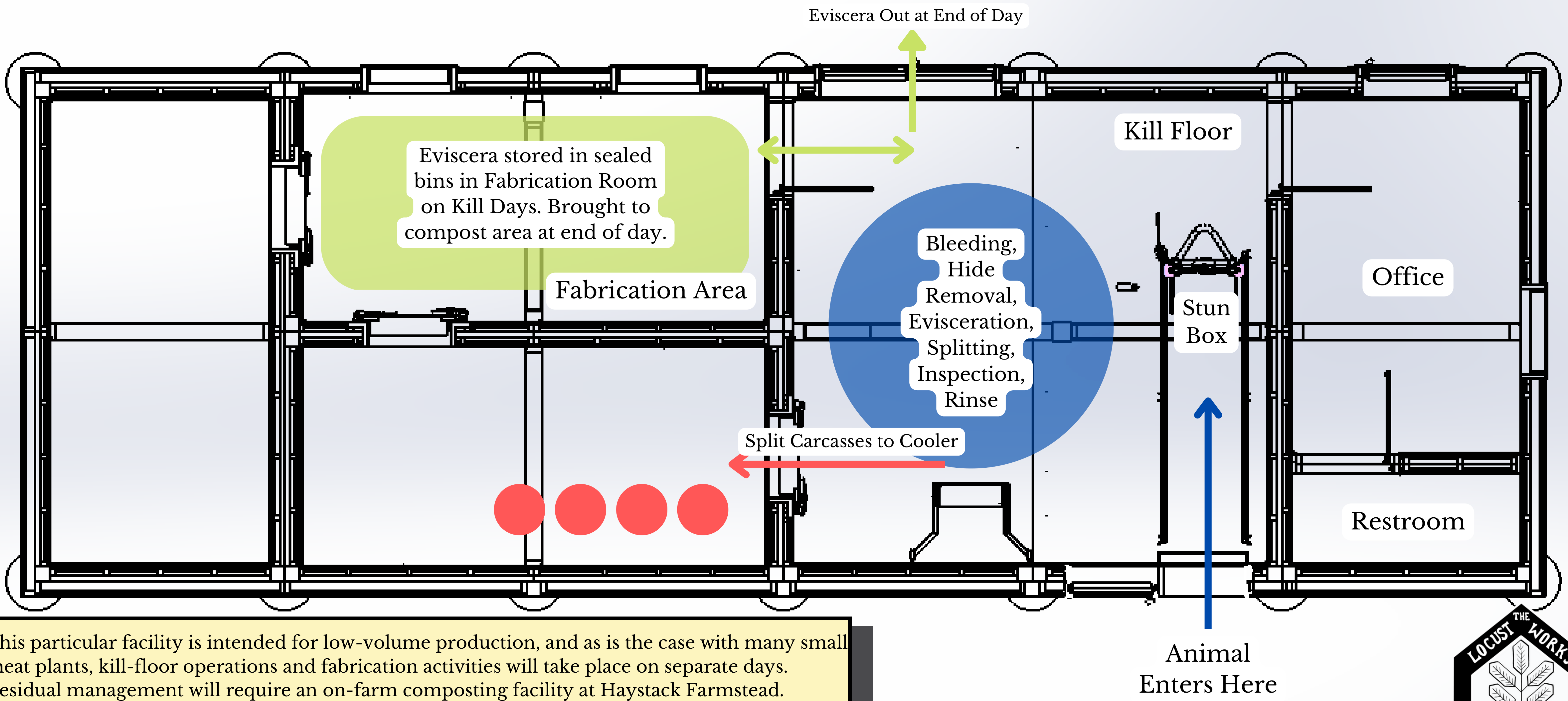
Section View of Carcass Cooler and Fabrication Room



Modular Meat Plant (MMP)

Top Section with Process Flows

Process Flows on Kill Days

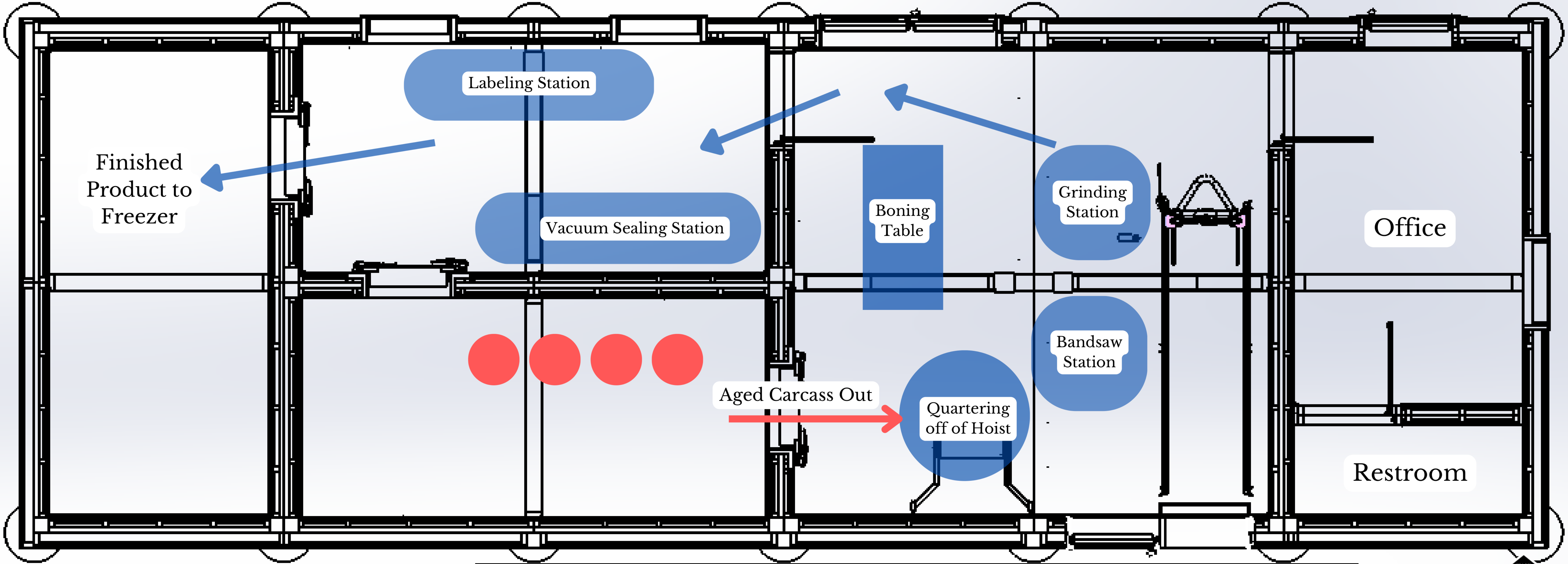


This particular facility is intended for low-volume production, and as is the case with many small meat plants, kill-floor operations and fabrication activities will take place on separate days. Residual management will require an on-farm composting facility at Haystack Farmstead. Returning animal nutrients back to the farm is one of several advantages on-farm processing offers. The 16' (4.88m) square Kill Floor offers ample space for a 1-2 person cutting team to perform operations. Required throughput for this operating model is likely not to exceed 4 beef per day and will be driven primarily by the skill level of the plant operator(s).

Modular Meat Plant (MMP)

Top Section with Process Flows

Process Flows on Fabrication Days



On fabrication days, the Kill Floor is utilized for fabrication activities. The Main Hoist is used to lower carcasses from the rail during quartering. From there, cuts and grind meat are broken down and delivered to the Vacuum Sealing and Labeling Stations in the dedicated Fabrication Room. It is worth noting that this is a low-volume facility configuration. More fabrication area could be added to transition the facility to continuous operation with simultaneous slaughter and fabrication operations.

Section 3: Examining the Modular Agricultural Processing System (ModAPS)

ModAPS Design Objectives

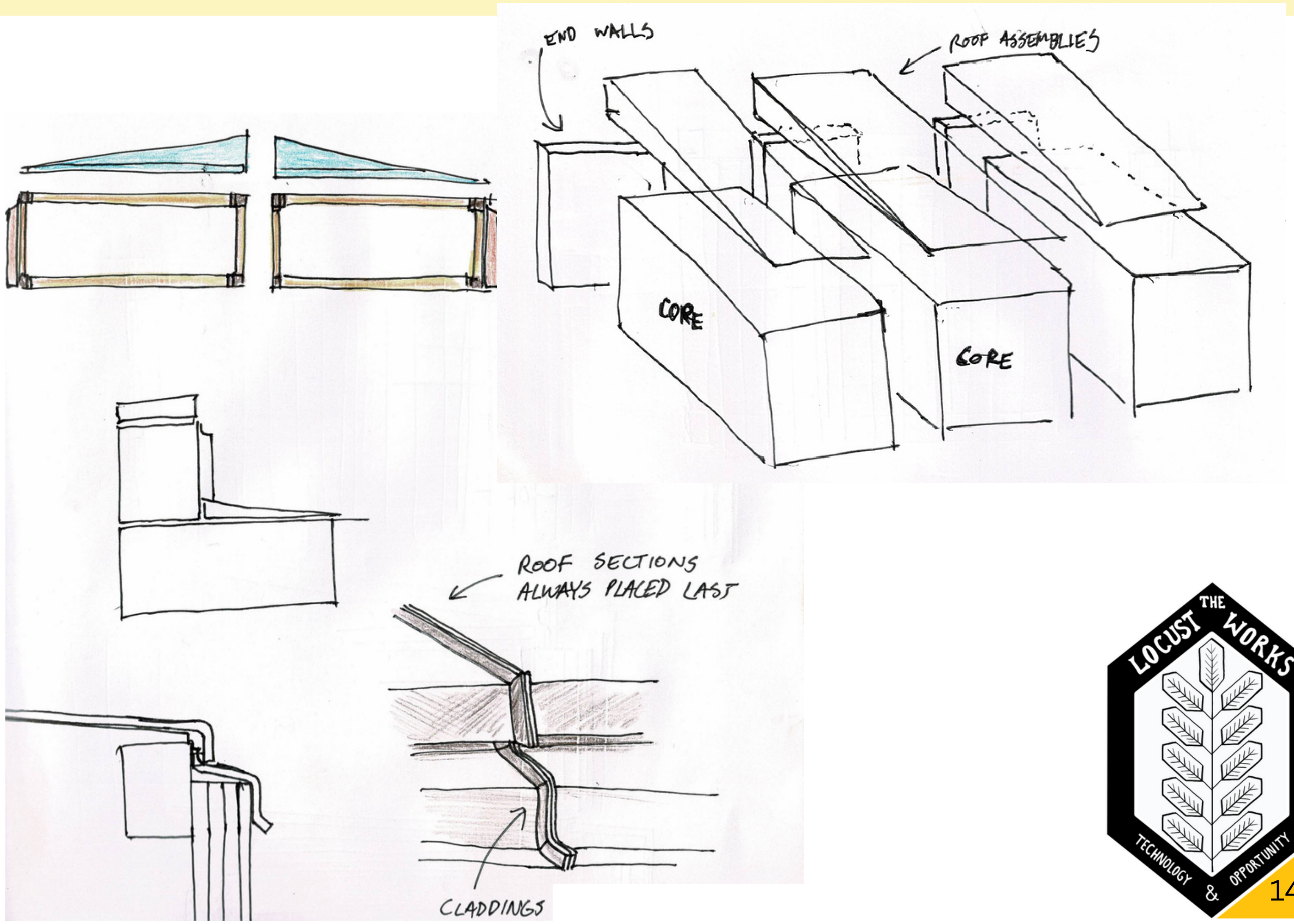
- Use modular construction methods that enable most construction activity to take place in a dedicated shop environment prior to shipping. Targeted facility installation time on-site is ~ 1 week.
- The system is designed with "DFMA-Local" methodology: Deliberately incorporate the use of locally sourced and processed forestry products.
- Each ModAPS Unit is built to 8'6" (2.59 m) transport width meaning they can ship individually on standard farm trailers, or as pairs on "step-deck" commercial truck trailers without special permitting and escorting.

"Core and Cladding" Concept

To make the most efficient use of build materials and wall sections, it was decided that the walls and roofs of the ModAPS should be considered discreet components from the framing core, as shown in the early sketches on this page.

Following this approach enables the ModAPS as a whole to become a more versatile building system. This was helpful in designing the Modular Meat Plant: The high ceiling requirements in the Kill-Floor and the Carcass Cooler required double-height units with transitions to lower units.

The approach is essentially what's employed with modern timber-frame home construction where the frame is commonly externally clad with Structural Insulated Panels (SIPs).

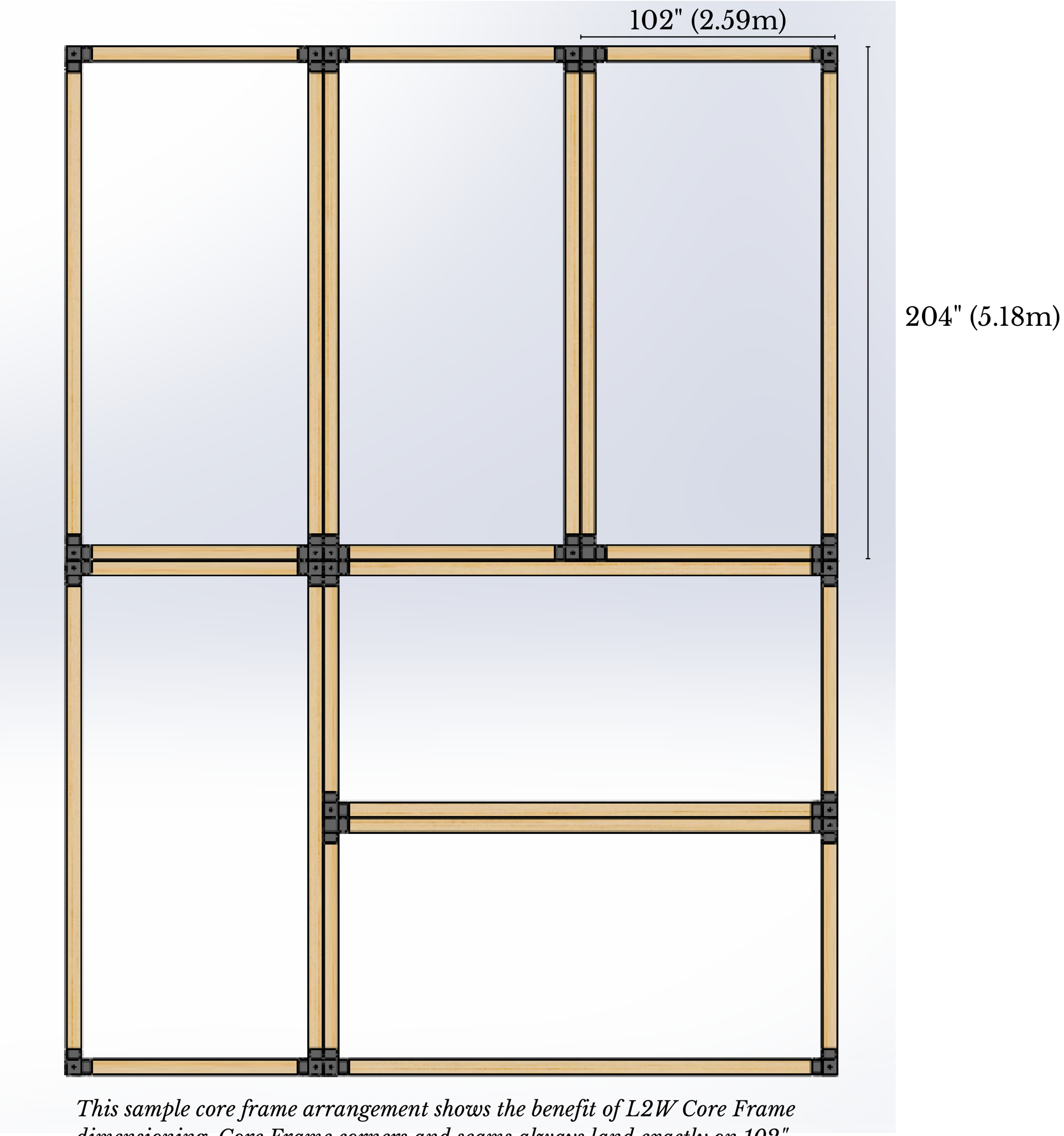


"L2W" Concept

My original modular building experience was with shipping containers. I moved away from that approach because I found the requirements of facilities such as the MMP required larger spaces with often complicated geometry. The more modifications that were required of the shipping containers, the less viable the approach became. Once I was allowed to set the dimensions of the ModAPS units, I realized the significant advantage of setting the length dimension of the core frame to exactly twice that of the core frame's width. This is not possible with shipping containers, as the width and lengths of the containers are not even multiples.

I refer to the concept of Length = 2 x Width as "L2W". It's not a complicated theory, but it's powerful in its effect on facility layout versatility. Units can be turned 90 degrees within the facility envelope without changing the location of seams and interfaces for interior and exterior panels (see figure at right).

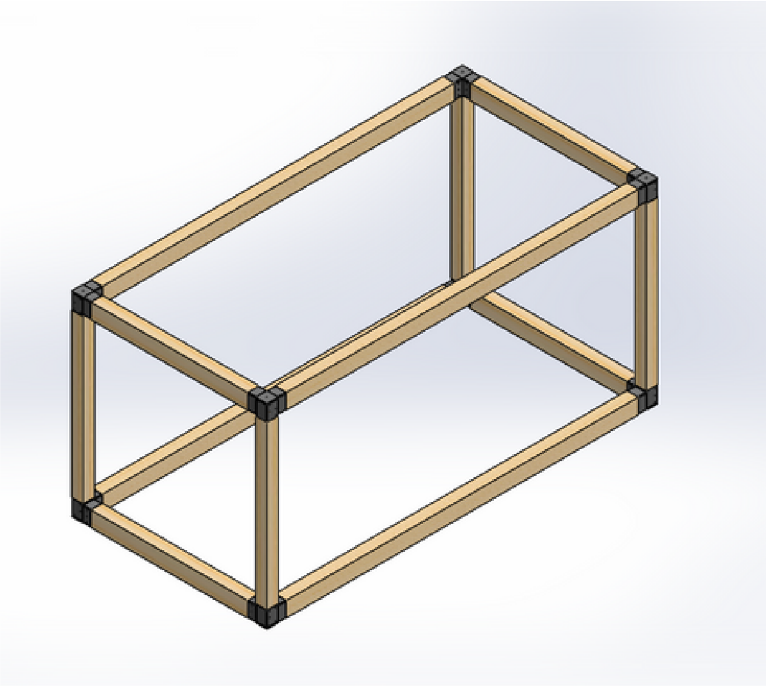
At this time, without the ability to "finger-joint" laminated boards in composite beams, I'm limited to timber lengths dictated by log length, which in my case is 16'. In the future, if a typical ModAPS production facility is able to produce timbers of longer length, ModAPS of units of L3W or L4W would also be possible.



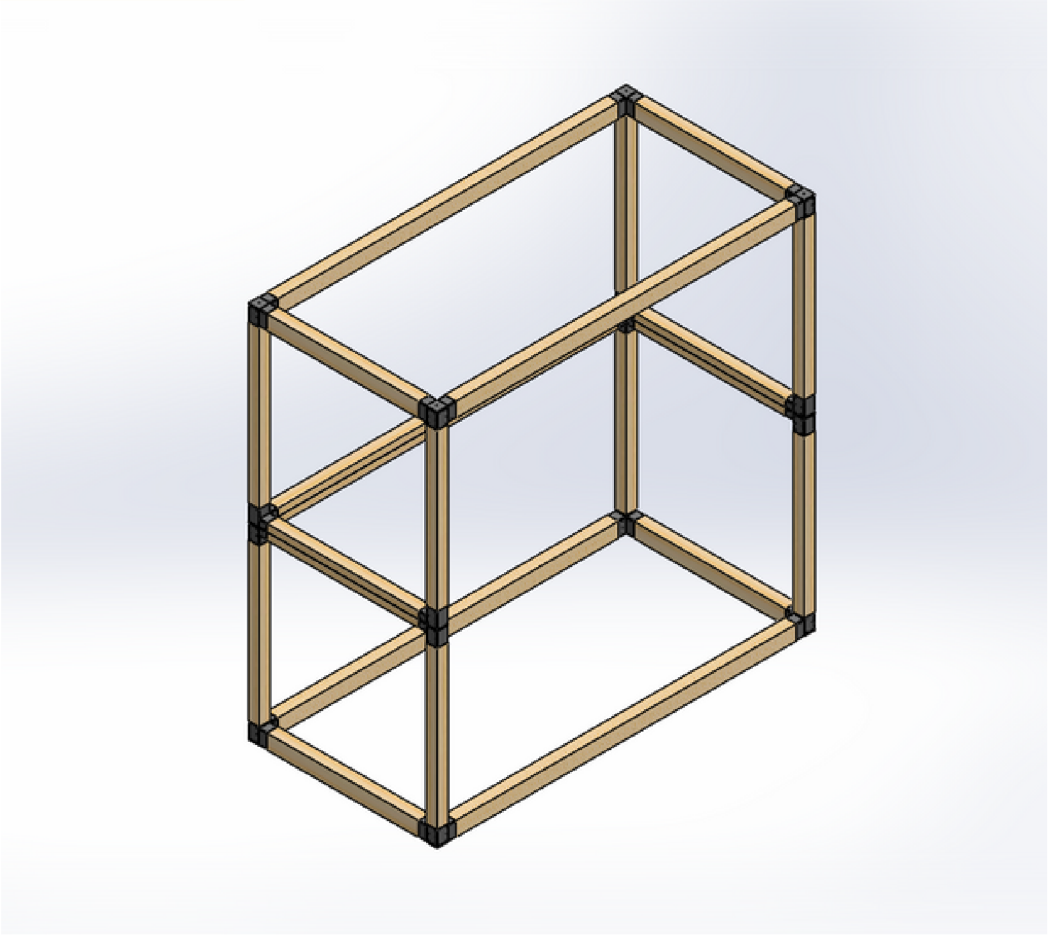
This sample core frame arrangement shows the benefit of L2W Core Frame dimensioning. Core Frame corners and seams always land exactly on 102" (2.59m) increments, allowing for inherently flexible layouts for small agricultural workspaces.

Core Frame Configurations

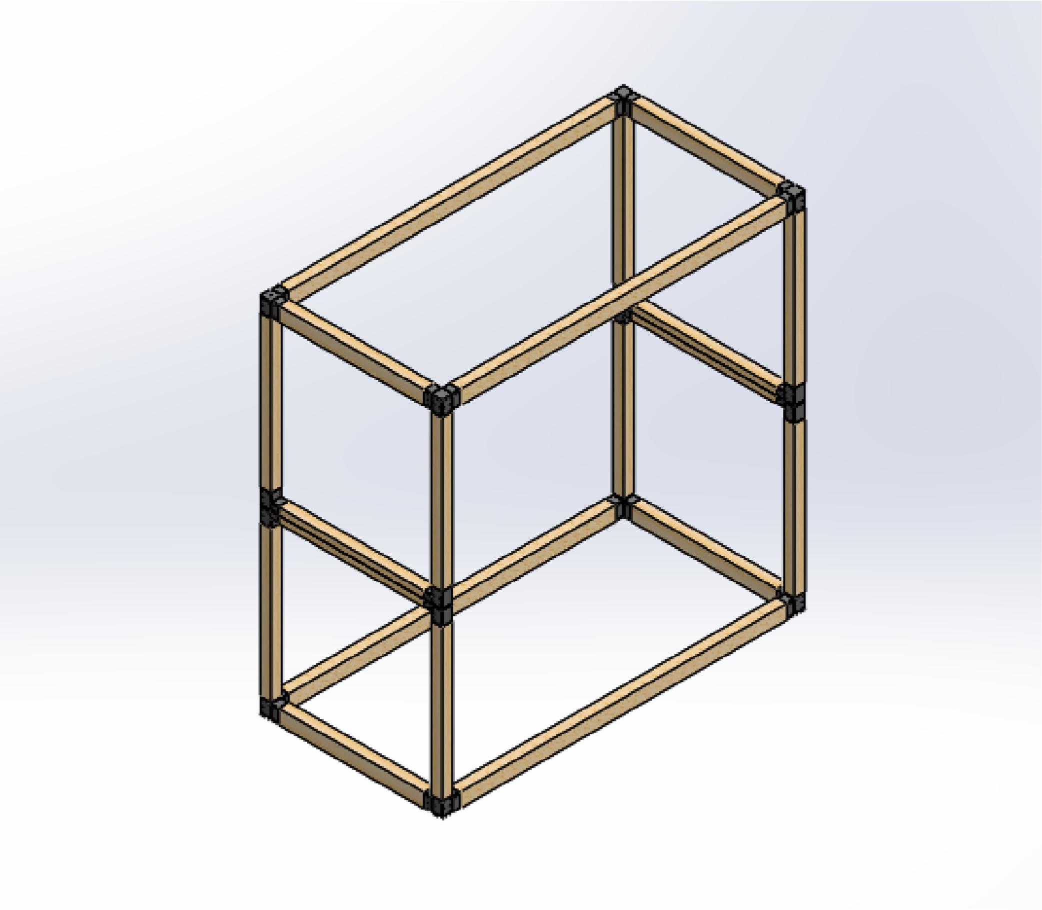
As with all subcomponents of ModAPS, the core frame can take the shape of several application-specific configurations. This is a powerful design tool enabled by modern digital drafting software. Should I need to make a fundamental change to the core frame, that change automatically extends to all different configurations of the root part.



Standard Configuration: *Used for single-story or 1st floor applications where a ceiling is installed underneath the roof of the unit.*



Double-Height, End-R Configuration: *Two individual units are combined to create a workspace of nearly 16' of ceiling height. Applicable to cattle processing, repair shop, flour milling, biofuel etc.*



Double-Height, Ends-Clear Configuration: *Features two individual units without end walls. This enables the double height workspace to extend "n-units" that is to say; "as long as you want". Stiffness and moment transfer concerns with this arrangement are handled by "Peripheral Columns" that are installed outside the walls after the units are set on-site. Temporary braces between walls are installed for transport and can be removed once the Peripheral Columns are installed.*

Laminated Timbers and Brackets

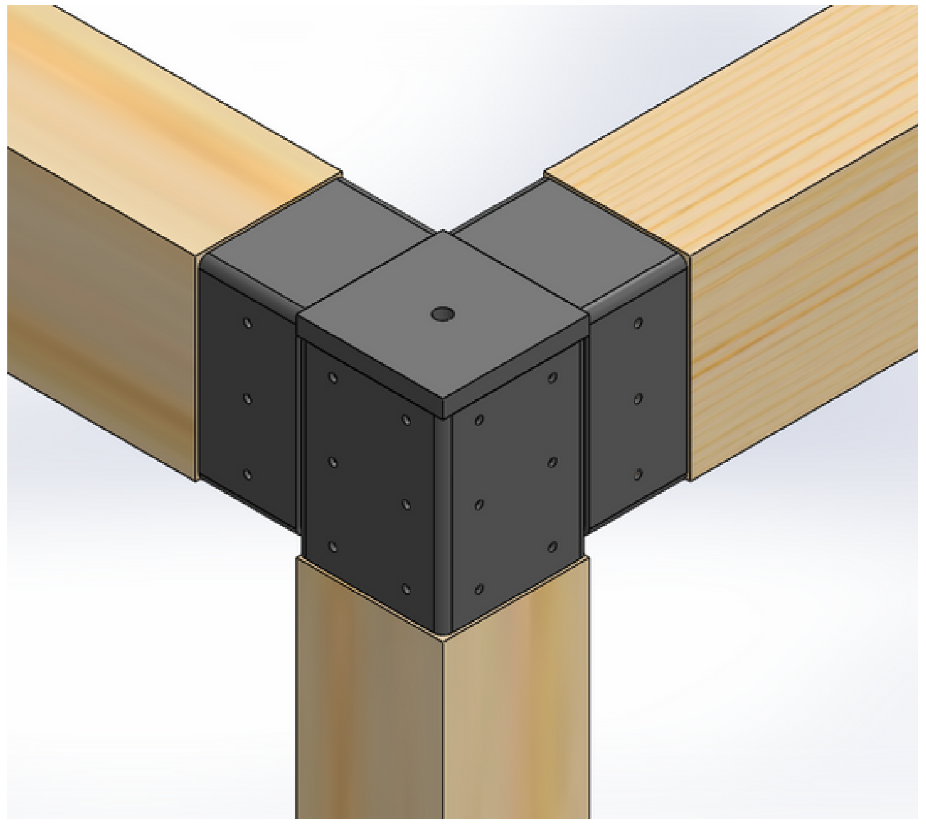
Factory-produced laminated timbers (LTs) have existed for decades now, but are steadily finding their way into more commercial multi-floor construction. One of the macro benefits of LTs is resource utilization: Using combinations of joint machining and high-pressure adhesion, large, strong, highly valuable timbers can be made from many individual boards coming from logs that previously were unsuitable for timber-framing.

For this prototype, following the methodology of DFMA-Local (See "Key Terms and Definitions"), led me to pursue an approach inspired by Mass Timber construction to build the primary frame timbers from hand-made laminated timbers. For ease of construction, structurally-rated wood screws are used to join the dimensional-planed boards together.

I opted for a bracket design that fully captures the connected timbers inside a steel pocket. The strength of the joint exceeds the strength of the timber and ensures the ends of the timber are held together and evenly transmit their load into the joint.

At a glance, the timber and bracket combination appears excessive. However, the bracket design enables more rudimentary beam construction methods, and the bending moment capacity of the joint reduces the wall sheathing shear rating requirements. This enables the safe replacement of plywood with locally-sourced sheathing alternatives. Design specifics such as this would greatly benefit from future inter-disciplinary development consortiums.

The before-mentioned benefits of wood utilization are clearly felt using this approach. I strongly believe that Laminated Timber construction appropriate to small sawmill operations should be the focus of more study and development. Quota production of standardized timber assemblies could be very meaningful revenue stream for small sawmill operators, loggers and land-owners alike.



Detail View of typical junction of Laminated Timbers and Corner Bracket. Note the threaded 3/4-10 hole for lifting eyes.

The top portions of a typical ModAPS Core Frame being constructed at The Locust Works. Note the standardized lifting points and dedicated spreader system.

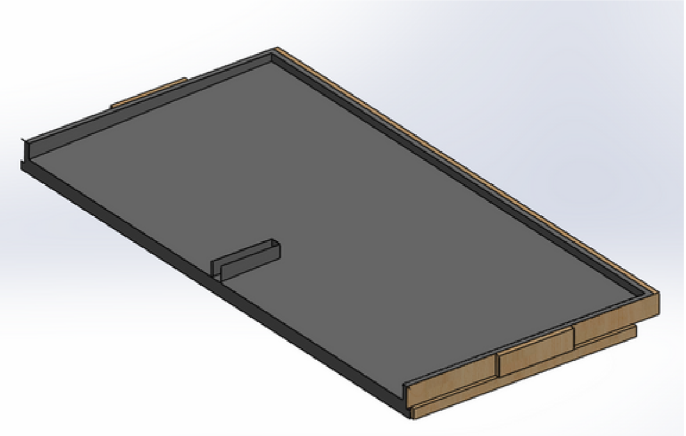
The Corner Brackets are weldments that can be fixtured and welded to close tolerances. If the timbers are carefully cut to length and pulled in tight to the brackets as shown, the ModAPS units come together very square.

Roof Assemblies

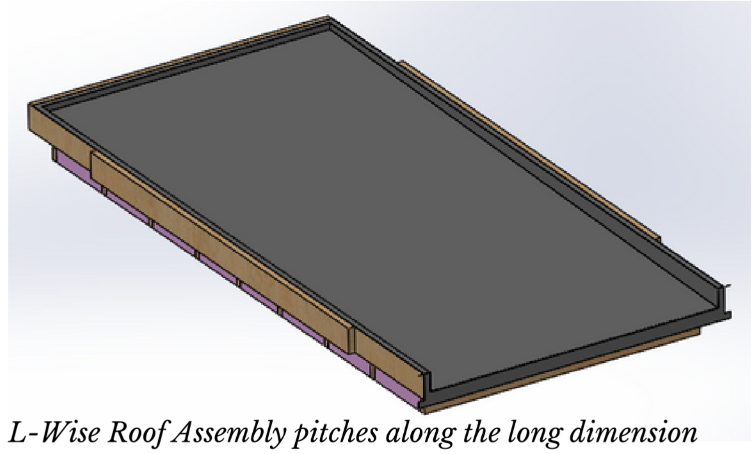
In developing the Roof Assemblies for the ModAPS, I was faced with the question of how much flexibility to build into their configurations. Should the roofs be forward-compatible with potential facility expansions and if so, to what extent? I opted to break the roof assembly into a lengthwise and width-wise pitched roof assemblies with Eave-Assemblies that could be installed during the shop construction phase or after unit installation on site depending on their location on the ModAPS Unit. See adjacent figures and notes for clarification.

Emulating roof construction on shipping containers, I decided to use welded 16 ga. steel. This was driven by the need to have a robust, trouble-free unit to unit roof-transitions that was best accomplished with raised flanges and curbs with pre-fabricated sealing caps. I also was committed to incorporating skylights into the design for the light and spacious feel they contribute. Due to the inherent limited-pitch roof design of this system, I was very concerned about leak issues in the areas of skylight curbs.

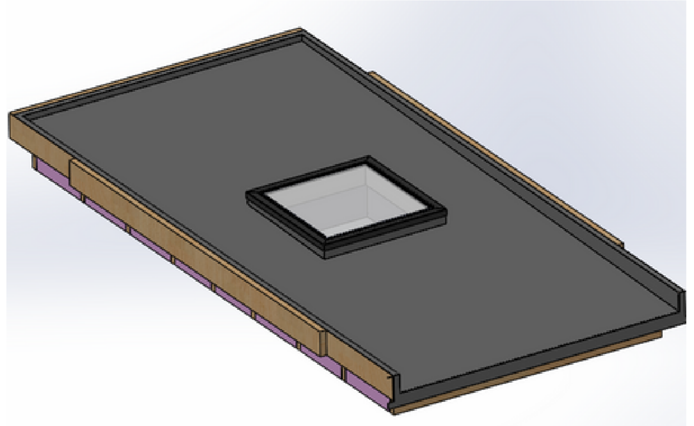
Further cost and performance analysis will be needed in this area, but part of the justification of the approach is the context of where the roof is being built. In a controlled shop environment, with appropriate set-ups, fixtures and proficiency, intuition suggests very robust and economic outcomes are possible.



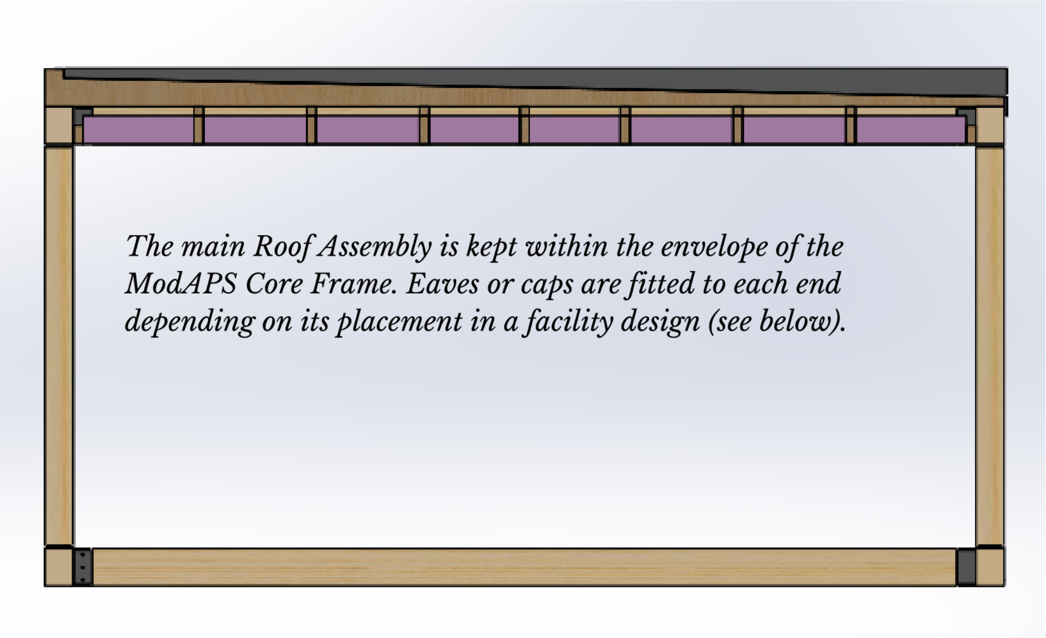
W-Wise Roof Assembly pitches along the short dimension



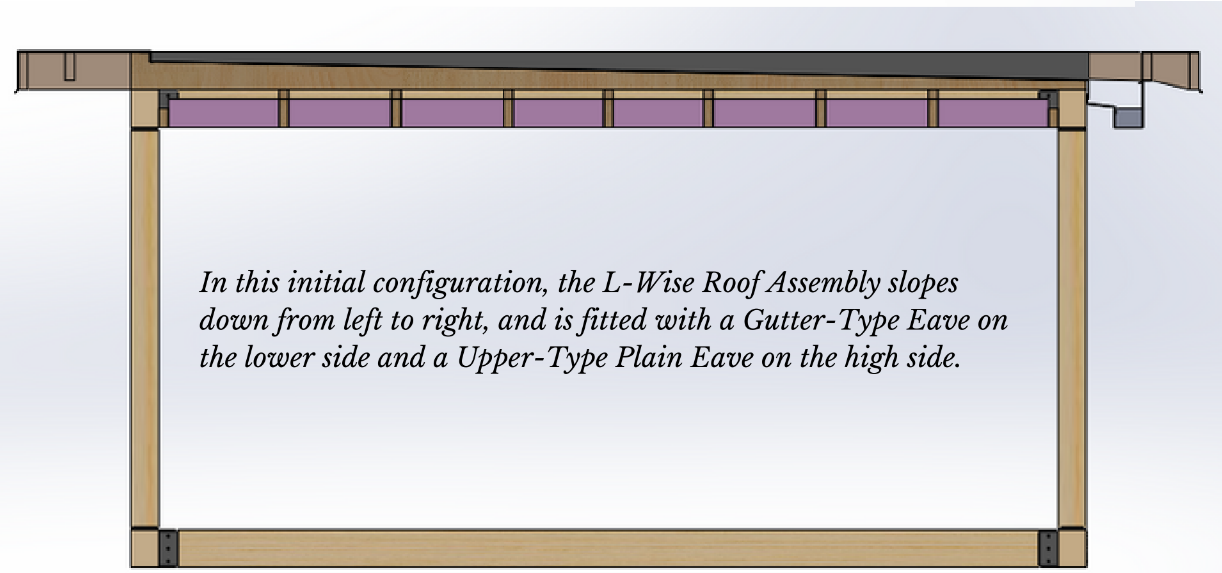
L-Wise Roof Assembly pitches along the long dimension



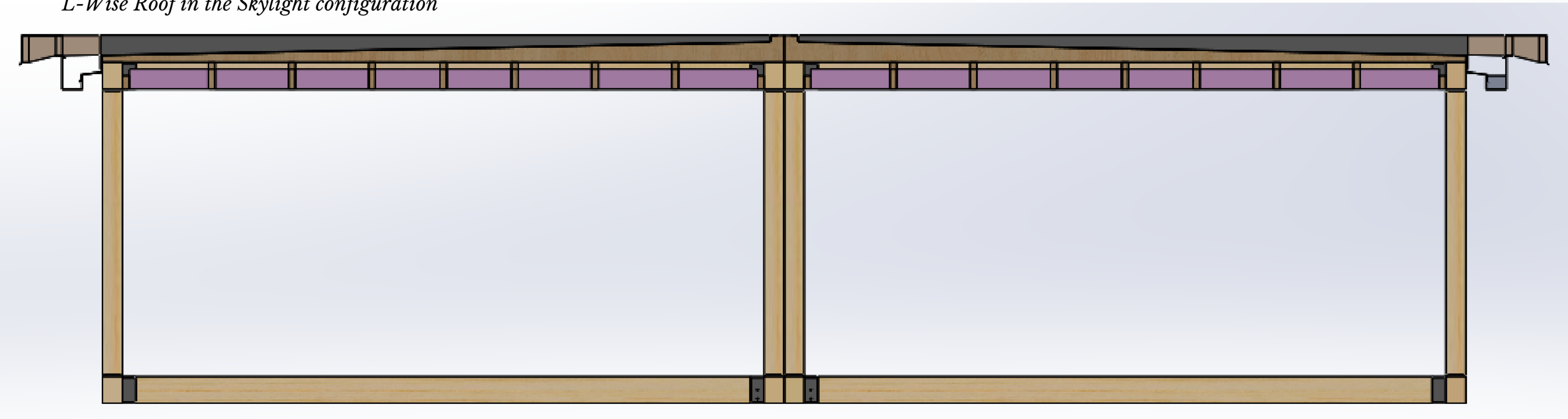
L-Wise Roof in the Skylight configuration



The main Roof Assembly is kept within the envelope of the ModAPS Core Frame. Eaves or caps are fitted to each end depending on its placement in a facility design (see below).



In this initial configuration, the L-Wise Roof Assembly slopes down from left to right, and is fitted with a Gutter-Type Eave on the lower side and a Upper-Type Plain Eave on the high side.

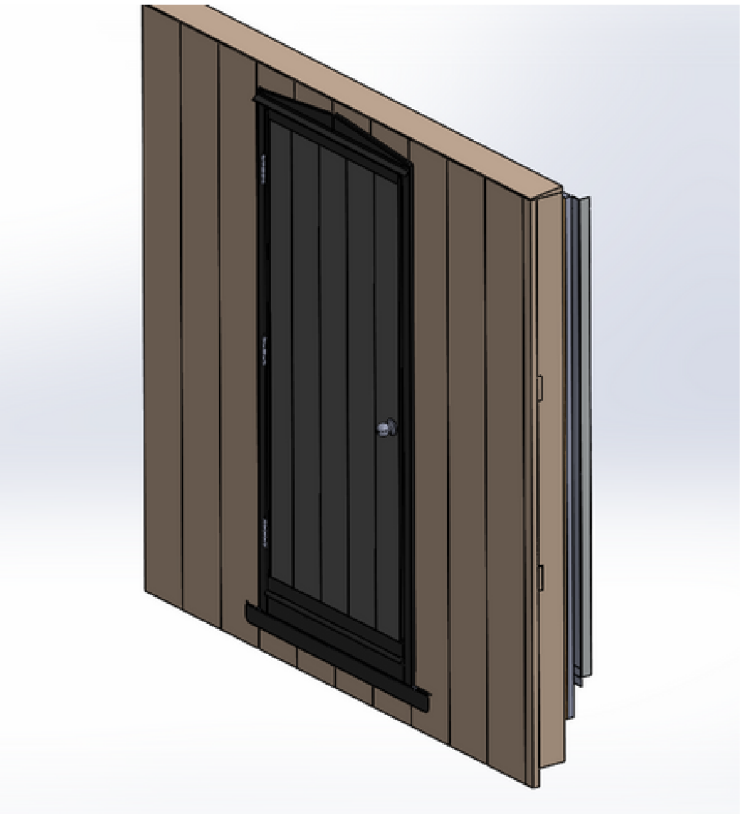


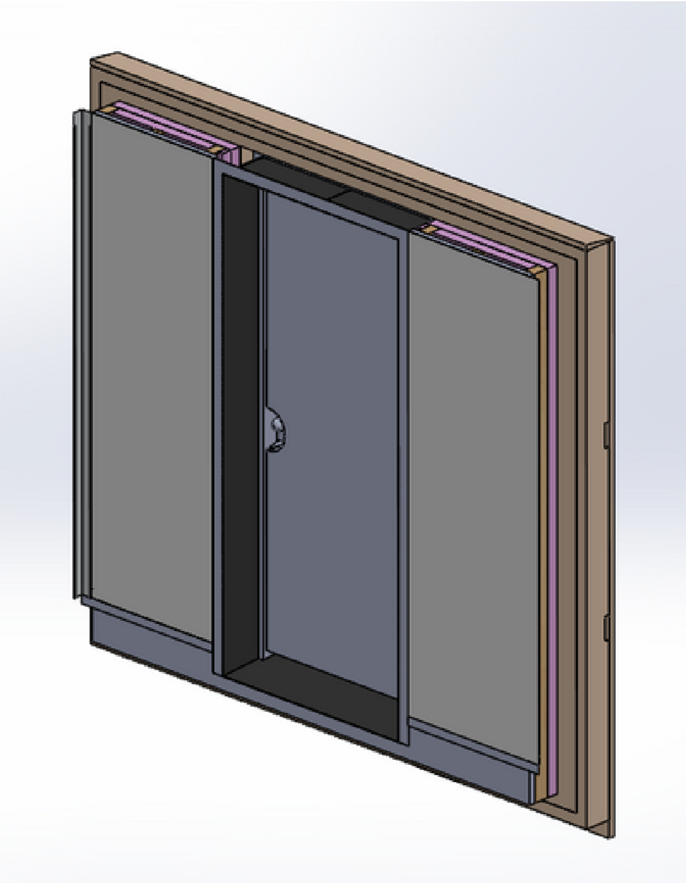
In this configuration, there are are 2 ModAPS Units with L-Wise Roof Assemblies: One pitching to the right, one pitching to the left. Notice how the main portion of the roof is unchanged in the two scenarios. All that's changed is that the Eave Assembly on the high-side has been removed to allow placement of the 2nd ModAPS Unit

Claddings and Interior Panels

Configurable interior panels and exterior claddings require substantial up-front work in design software, but once in place, make quick work of wall design. This is an especially useful tool for specifying order quantities of purchased materials such as the recycled plastic liner panels and aluminum sheet for trim.

Claddings are built using locally-sourced "5/4" rough-sawn that is kiln-dried and planed and shaped to profile. Like with the incorporation of locally-constructed timber, the use of rough-sawn planking provides a potentially meaningful market for the small sawmill operation.





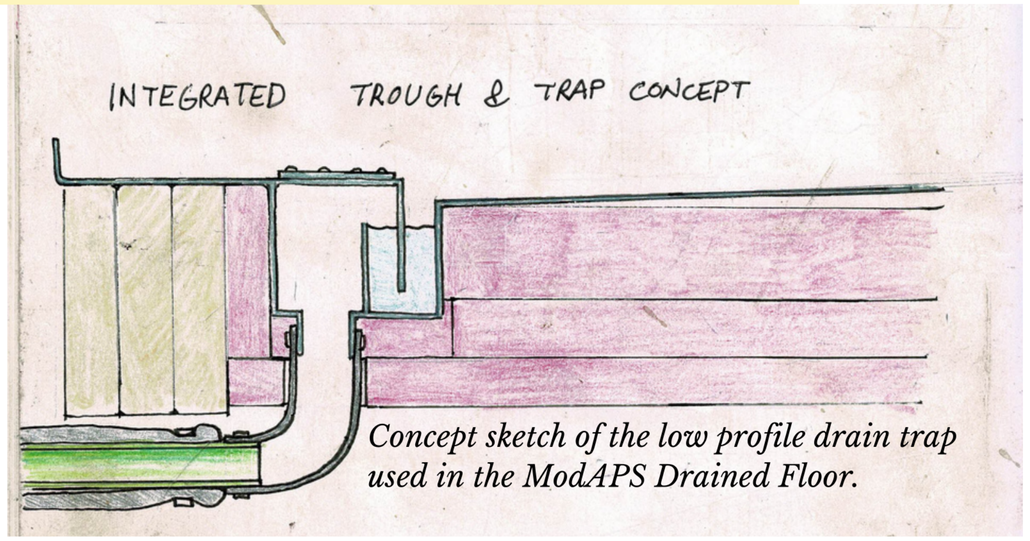
"Panelized Features" in software enable claddings and interior panels to be modified to accept doors, windows and other special features. This essential process enables the generation of accurate blueprints and bills of materials. Eventually, all claddings for a particular build can be built in one batch, with careful labeling of the parts to match the blueprints. This sort of batch production is needed to control labor costs.

Exterior Wall Claddings being batch manufactured at The Locust Works. The role of the cladding is primarily weatherization and supplemental insulation. As previously mentioned, wall shear is provided by the heavy corner brackets comprising the Core Frame.

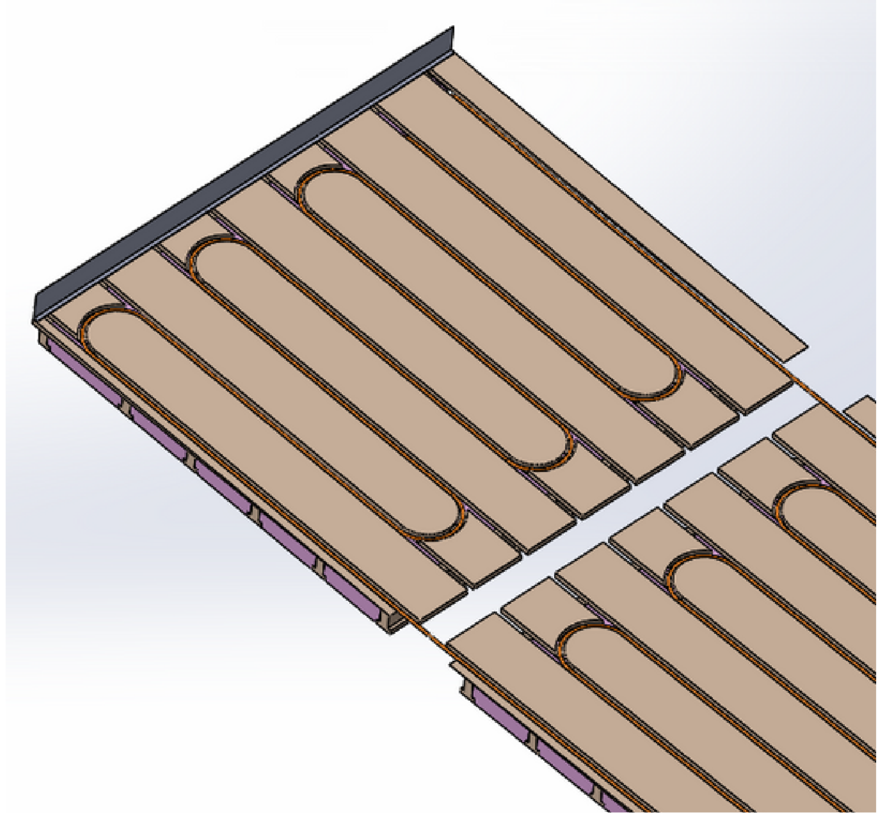
Floor Assemblies

Aluminum welded pan construction was chosen for the challenging application of washdown duty over wood structure. The material cost of 3003 Aluminum was nearly 2x that of Steel, but the longevity and avoidance of painting made it the clear choice.

Although the MMP under construction will require very little interior heat (processing areas should be as cold as possible), radiant heat has been included in the floor design. The radiant heat tubes are placed in slats that will vent to the wall cavities, up through furring cavities in the wall and back to the facility interior. While every effort is being made to avoid moisture intrusion to the floor base, active drying of the floor is an attempt to protect the longevity of the structure.



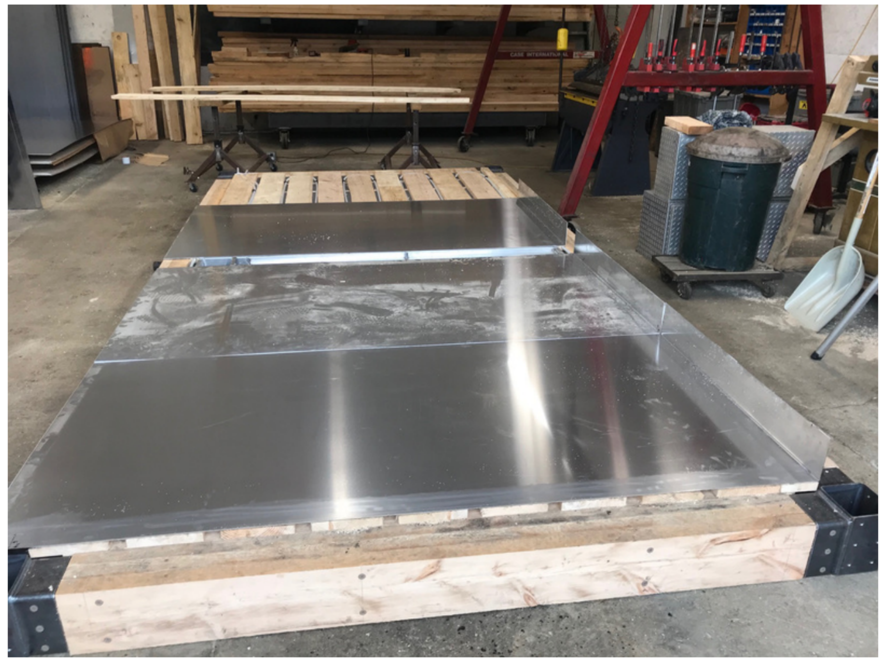
Concept sketch of the low profile drain trap used in the ModAPS Drained Floor.



Digital model of the floor showing the radiant heat tube routing.

Floor Assembly under construction. Note the XPS insulation in the floor joist cavities. The foam segments sit on nailers added to the joist bases, enabling the foam to provide additional stiffness to the subfloor.

Exact placement of the joist hangers on the inner faces of the floor girders establishes the floor pitch to the central trough drain.



Floor Pan under construction.

Section 4: Sample Facility Configuration using ModAPS

Hypothetical Goat Dairy Creamery Build: Baseline Capacity

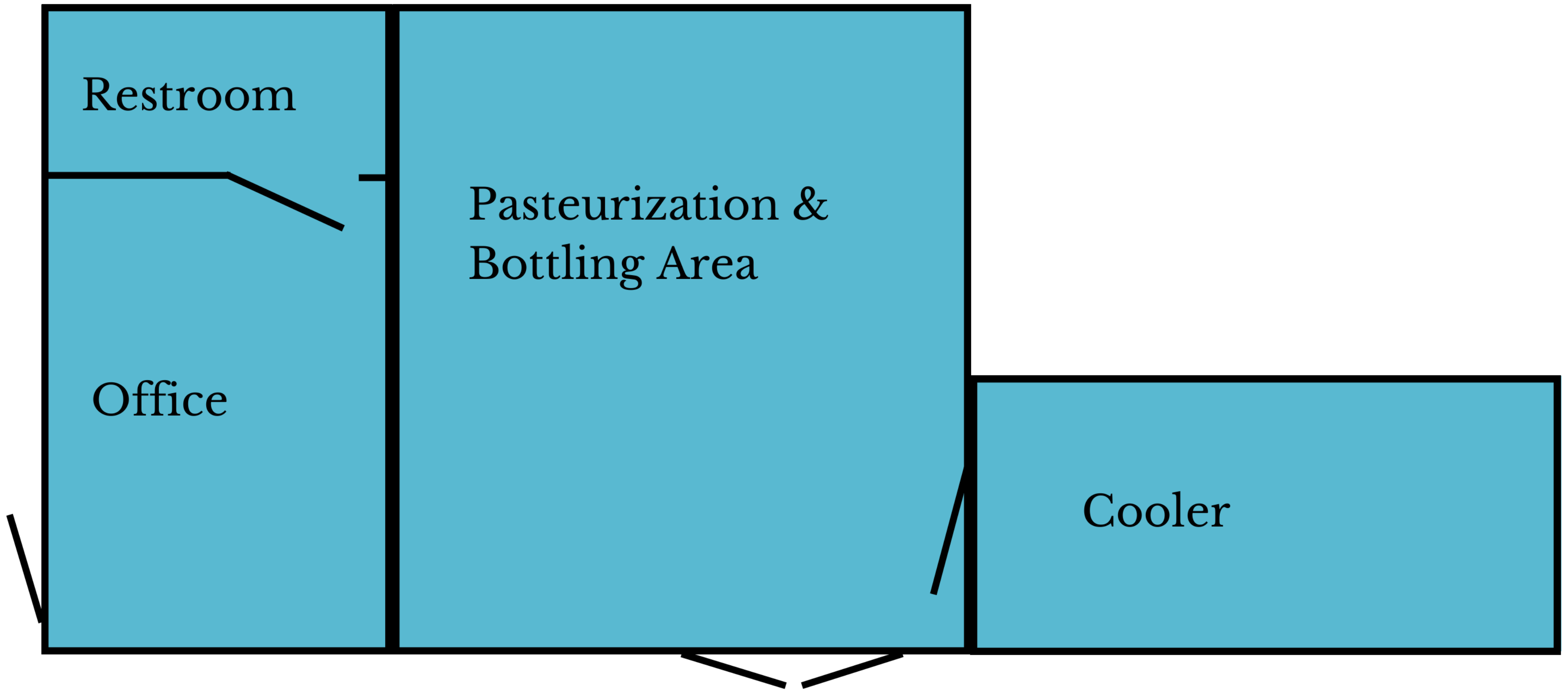
I'd like to demonstrate that the design details of the MMP shared in the last section are the output of a build system, not just a digital rendering. Let's use ModAPS to design a space altogether different from the MMP...

Imagine a regional goat's milk dairy cooperative is managing a growing market demand, and has the option of adding capacity by presenting one of its eligible farmers-in-training with a herd ownership opportunity.

The cooperative phases new producers in with baseline production capacity. For the sake of simplicity let's say it translates to 2 pallets of bottled milk that gets picked up every 2 days.

Assume the simplified layout at right reflects the actual needs of the small creamery.

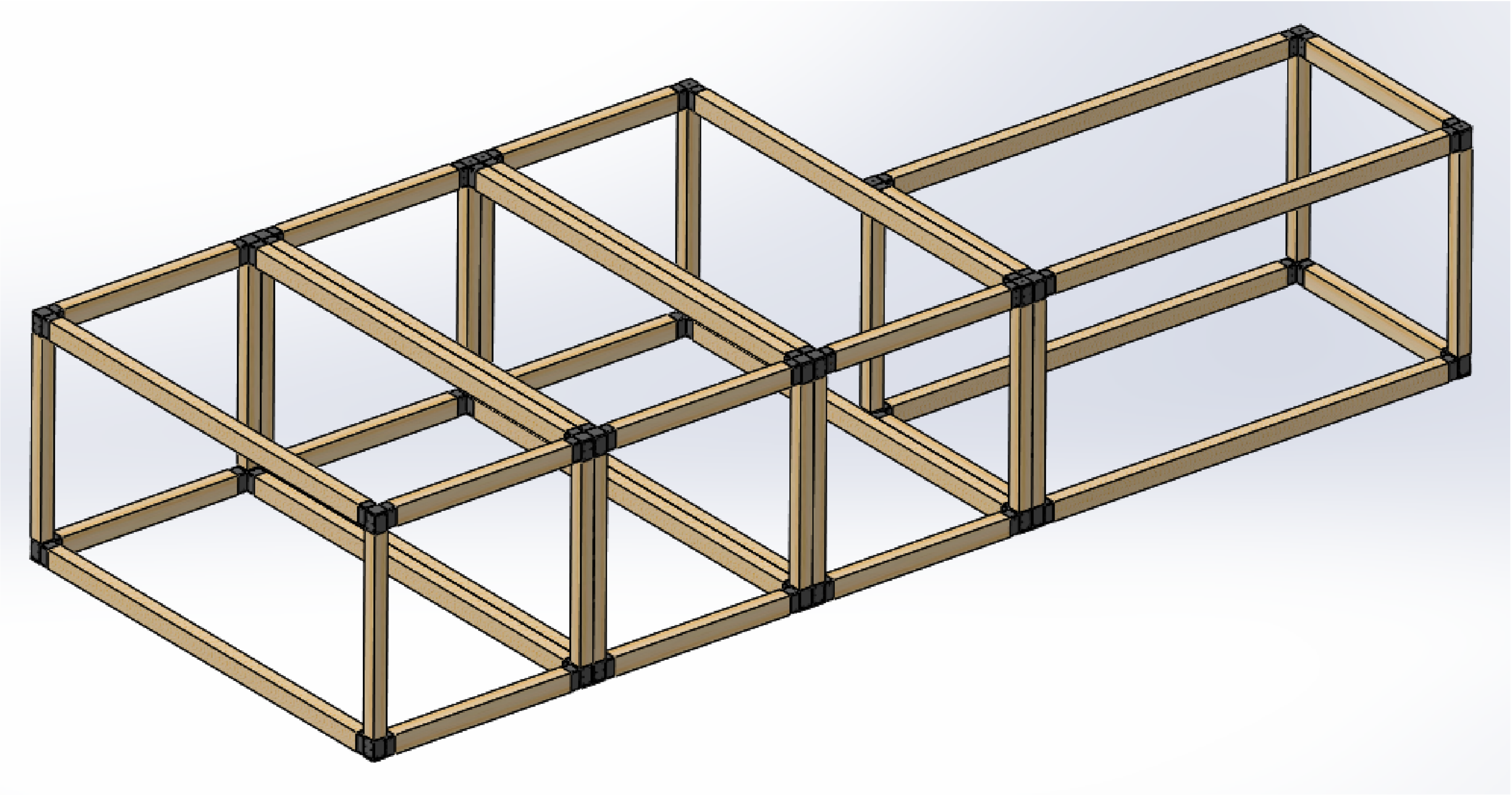
Step 1: Conceptualize Layout



Simplified Layout for the Hypothetical Use-Case

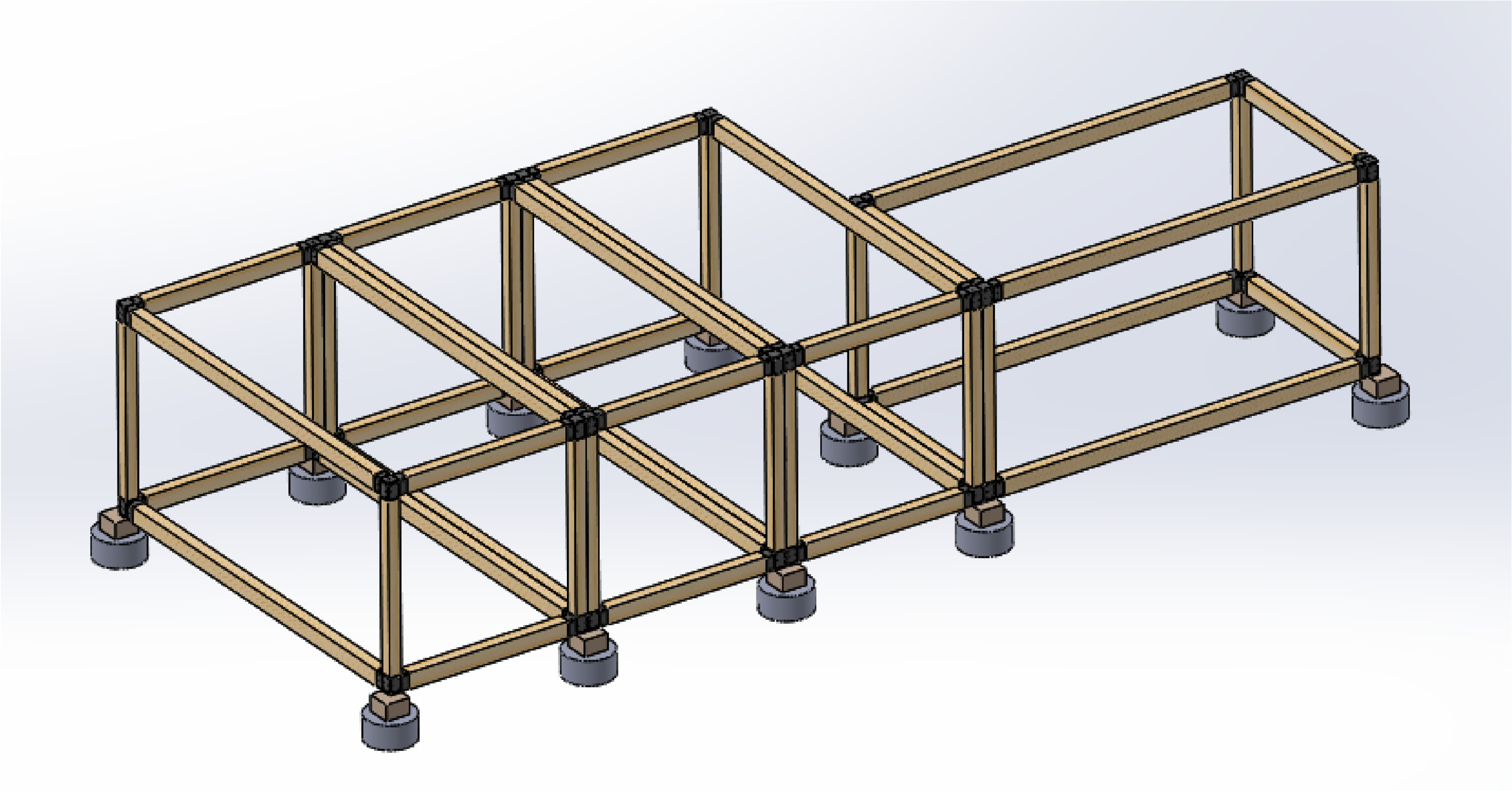
Step 2: Place the Appropriate Core Frames

Time to Completion: 5 min



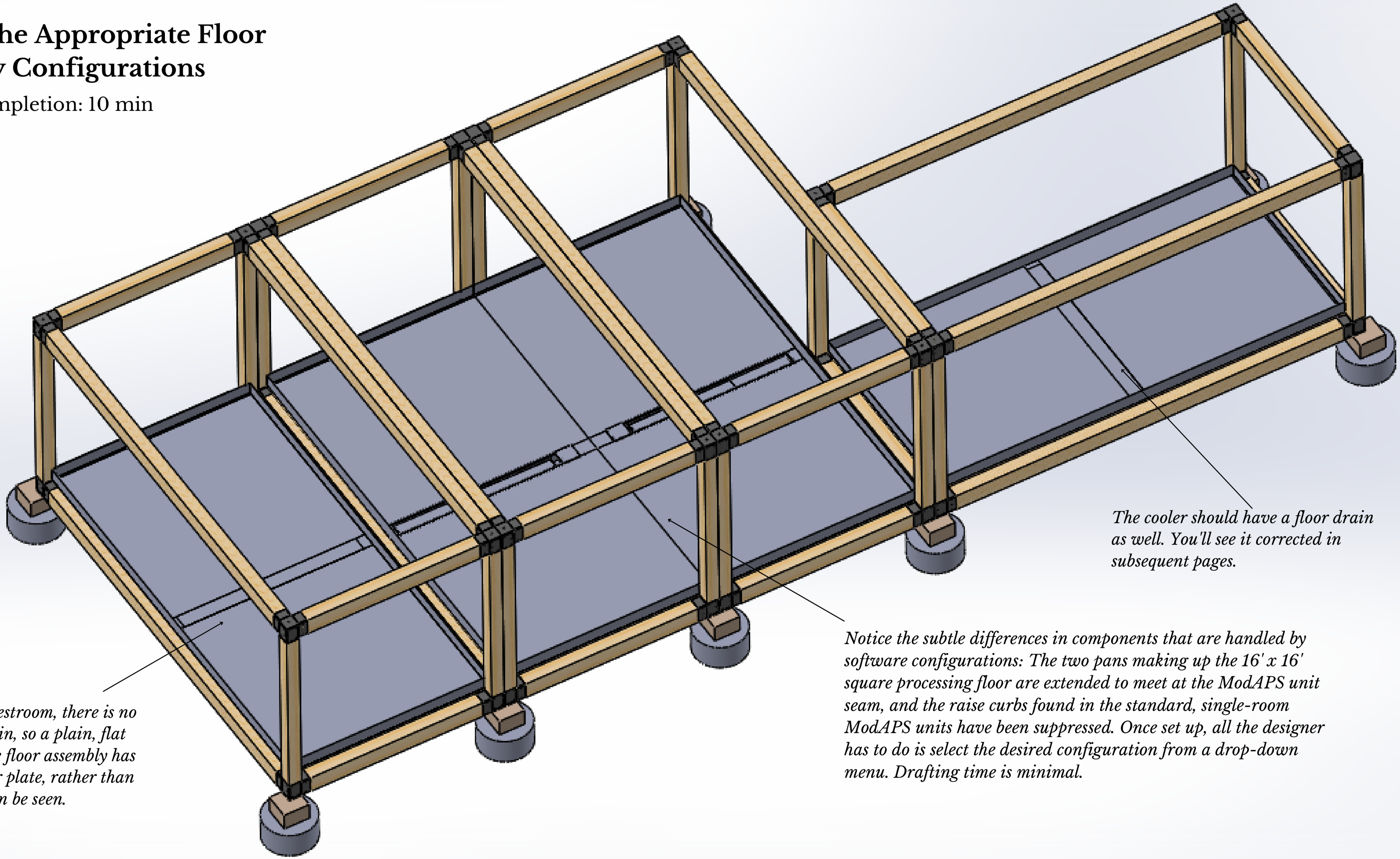
Step 3: Establish Support Block Locations

Time to Completion: 5 min



Step 4: Place the Appropriate Floor Assembly Configurations

Time to Completion: 10 min



For the office and restroom, there is no need for a floor drain, so a plain, flat configuration of the floor assembly has been chosen. A filler plate, rather than the trough drain can be seen.

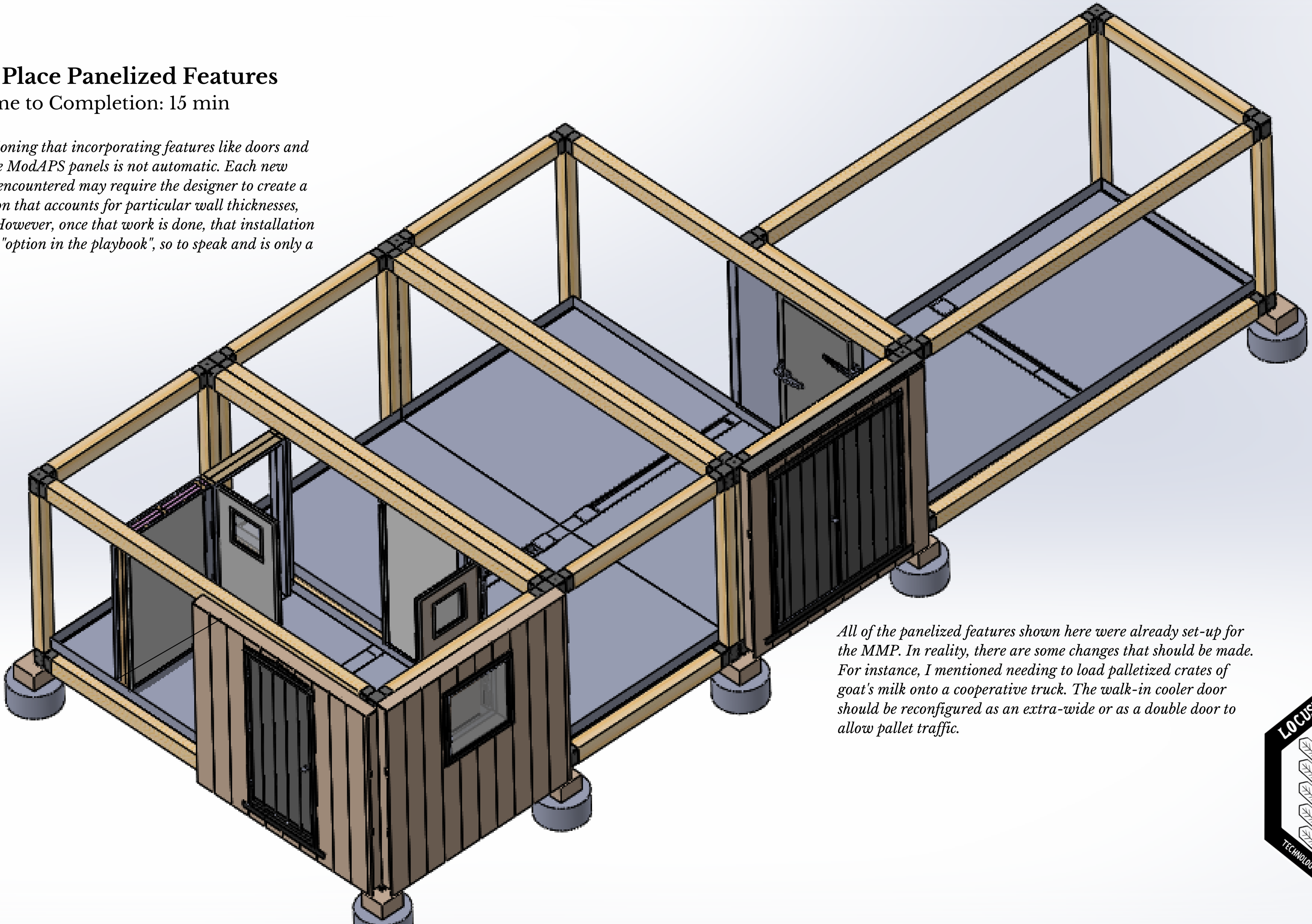
Notice the subtle differences in components that are handled by software configurations: The two pans making up the 16' x 16' square processing floor are extended to meet at the ModAPS unit seam, and the raise curbs found in the standard, single-room ModAPS units have been suppressed. Once set up, all the designer has to do is select the desired configuration from a drop-down menu. Drafting time is minimal.

The cooler should have a floor drain as well. You'll see it corrected in subsequent pages.

Step 5: Place Panelized Features

Time to Completion: 15 min

It is worth mentioning that incorporating features like doors and windows into the ModAPS panels is not automatic. Each new situation that is encountered may require the designer to create a new configuration that accounts for particular wall thicknesses, post offsets, etc. However, once that work is done, that installation becomes another "option in the playbook", so to speak and is only a few clicks away.



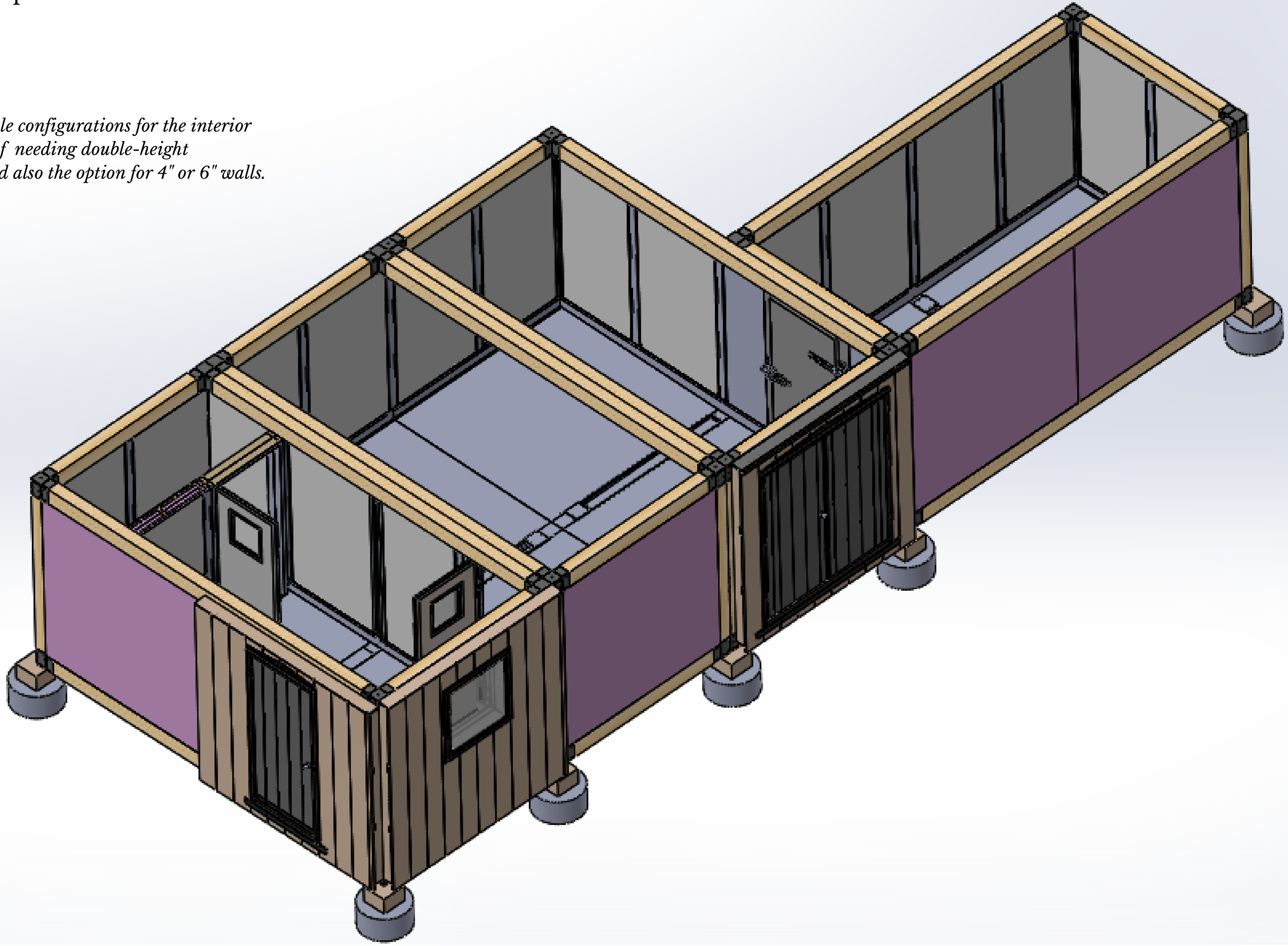
All of the panelized features shown here were already set-up for the MMP. In reality, there are some changes that should be made. For instance, I mentioned needing to load palletized crates of goat's milk onto a cooperative truck. The walk-in cooler door should be reconfigured as an extra-wide or as a double door to allow pallet traffic.

THE LOCUST WORKS
TECHNOLOGY & OPPORTUNITY

Step 6: Place Remaining Interior Wall Panels

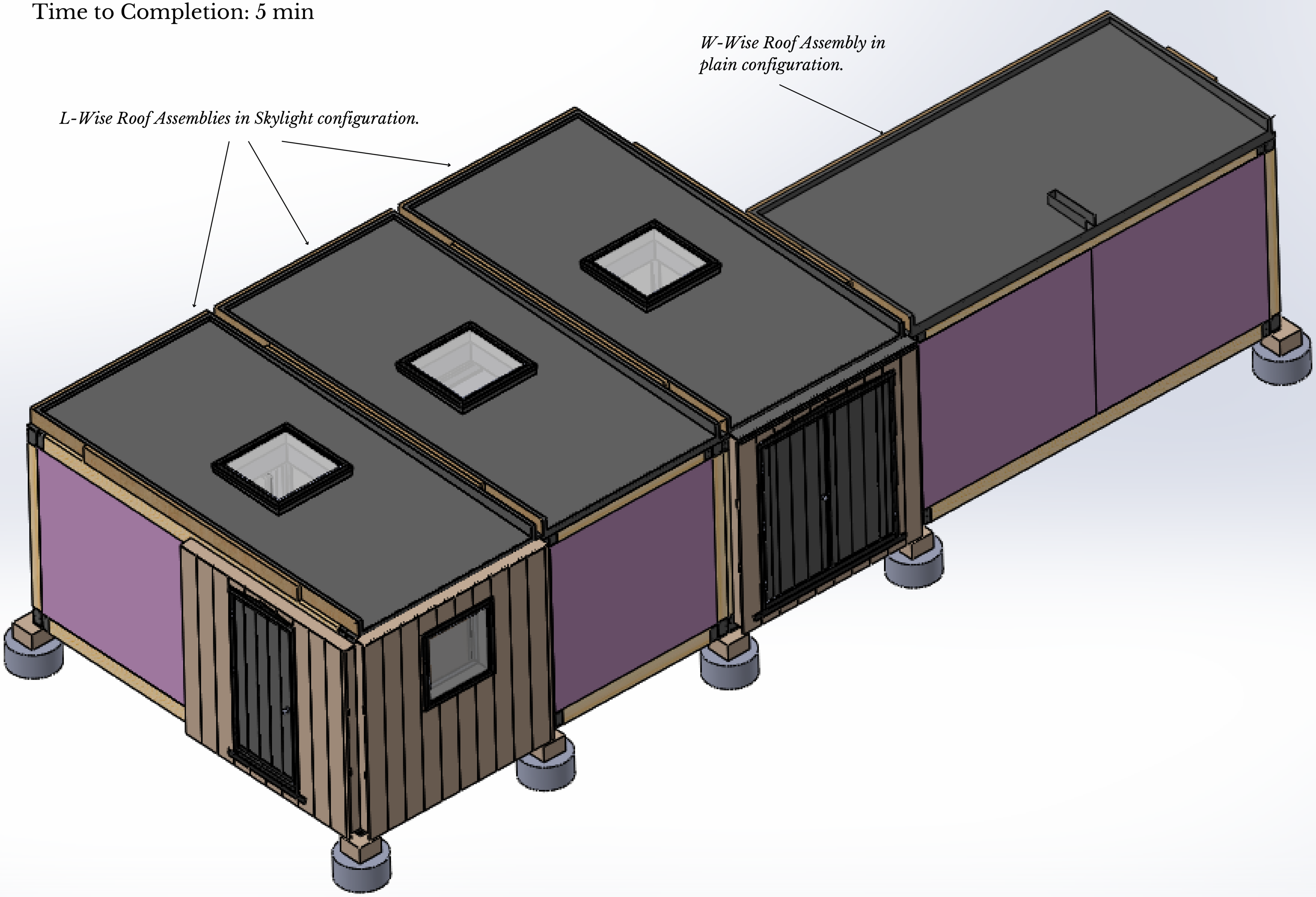
Time to Completion: 30 min

At this time, there are 82 possible configurations for the interior wall assembly! This is a result of needing double-height configurations for the MMP and also the option for 4" or 6" walls.



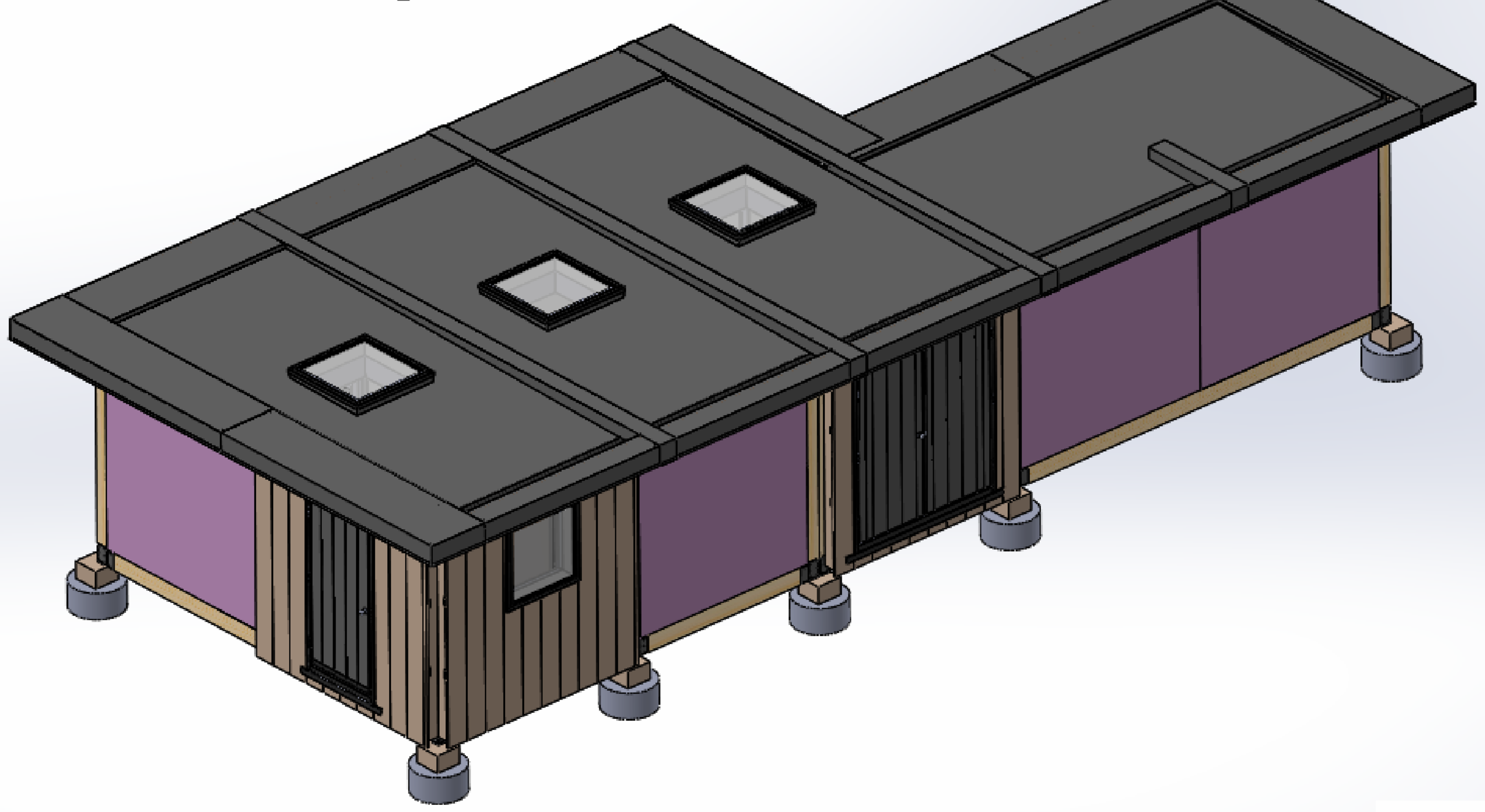
Step 7: Place Roof Assemblies

Time to Completion: 5 min



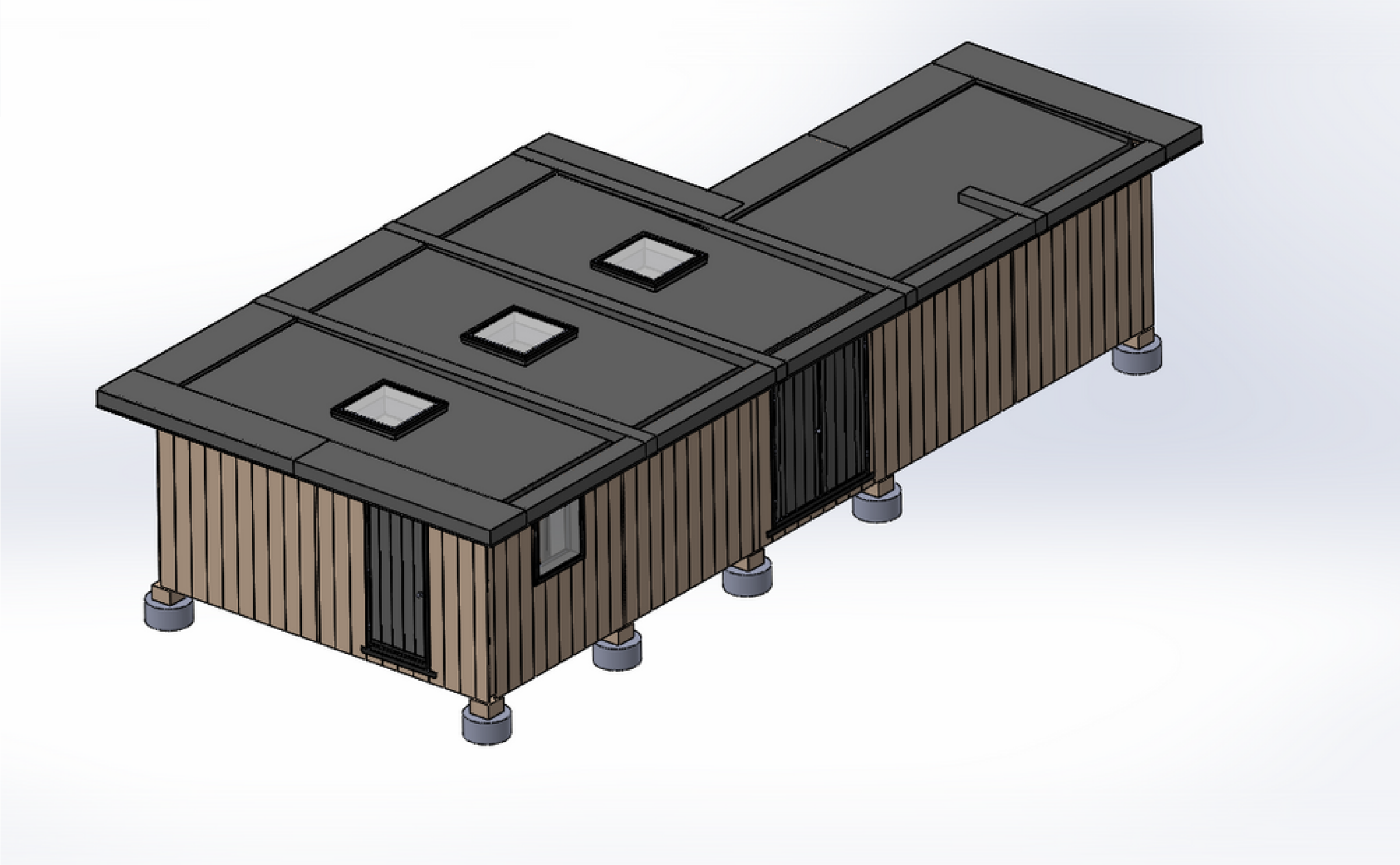
Step 8: Place Eave and Curb Cap Assemblies

Time to Completion: 15 min



Step 9: Place Remaining External Claddings

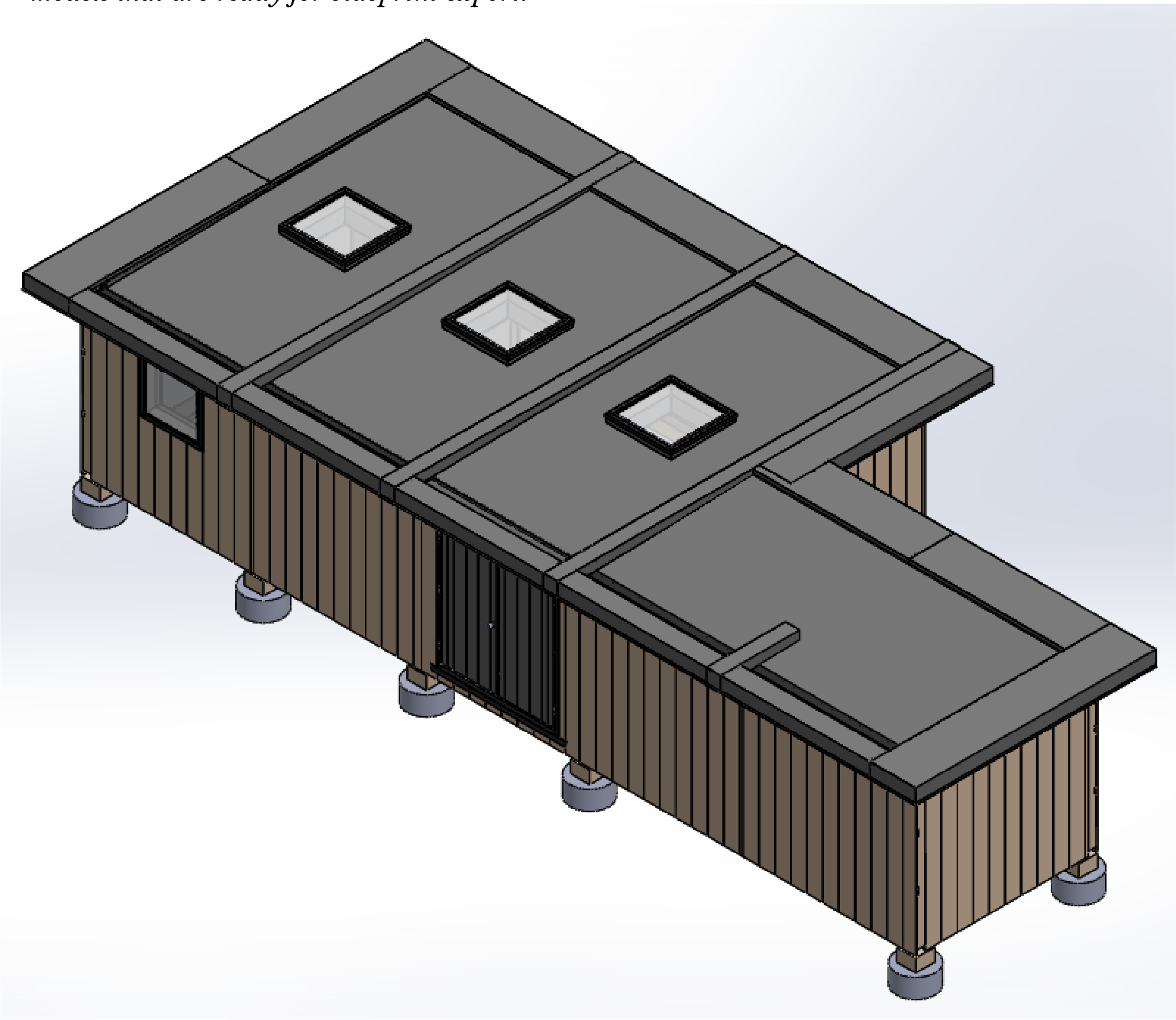
Time to Completion: 10 min

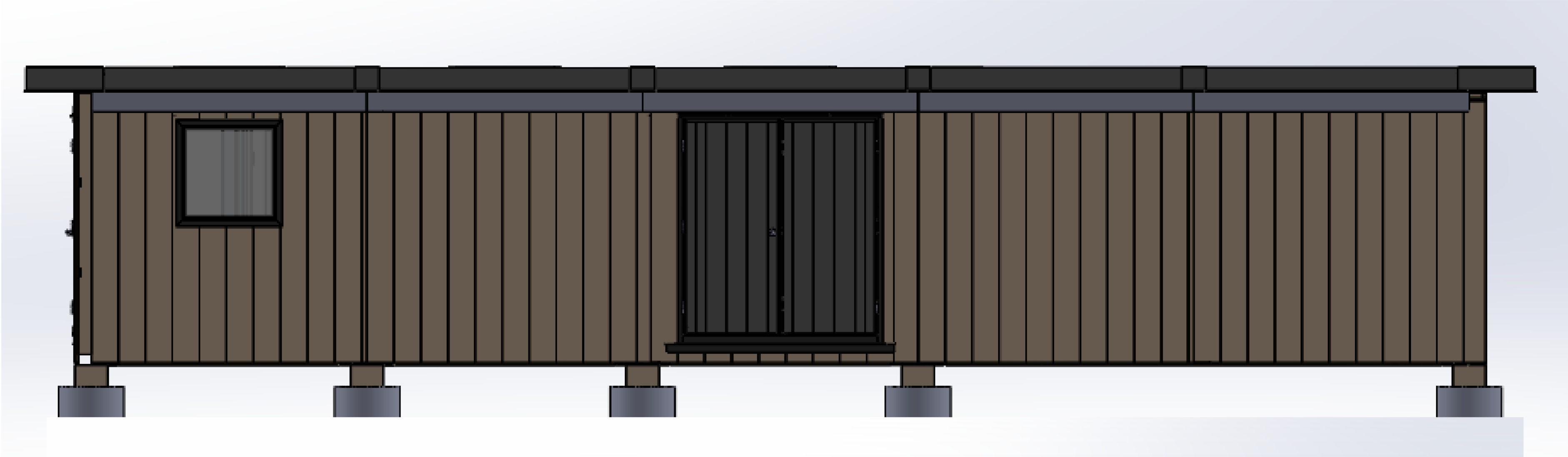


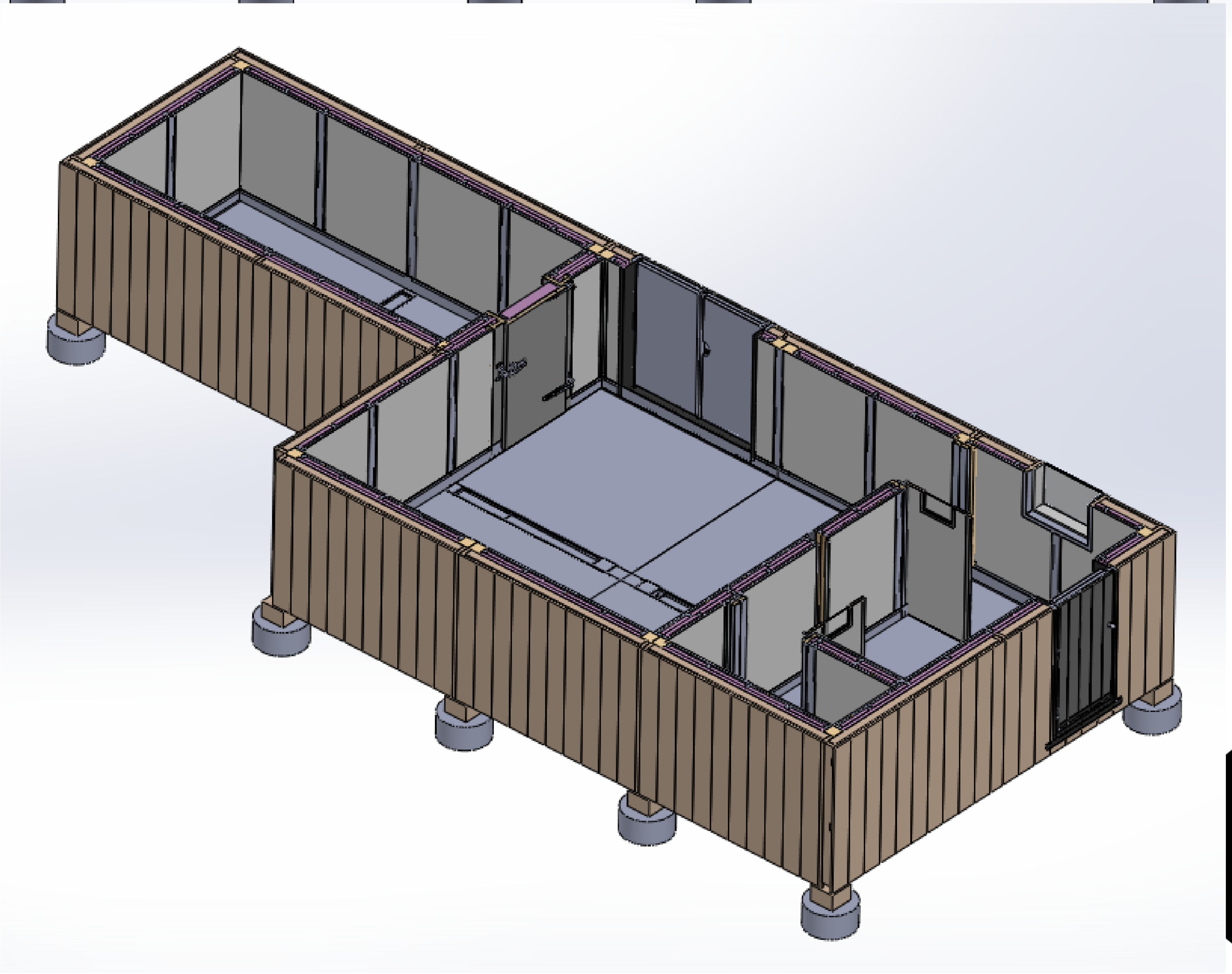
Envelope Complete

Total Time to Completion: 95 min

Time tracking through this exercise is not intended to trivialize the thorough work that must go into properly designing a facility. The aim is simply to highlight how efficient elements of the design process can be and how both design and manufacturing phases can benefit from component carry-over. Again, these are not just renderings, they are detailed models that are ready for blueprint export.







Conclusions & Work-Forward

As demonstrated, significant progress has been made with the sub-components of ModAPS and the detailed design of the MMP specifically. This report caps-off the design phase of the MMP project and in January of 2023, work will resume constructing the facility through the remainder of the Vermont Working Lands Enterprise Initiative Grant window which concludes in the fall of 2023.

Project Sequence:

- Complete facility build
- Begin performing limited slaughter operations under VT State "On Farm" Exemption
- Develop HACCP model and achieve USDA Inspection
- Seek collaboration for local cooperative marketing model
- Set-Up Haystack Farmstead as a livestock farmer incubator and training facility.
- Evaluate opportunities for MMP_02 Design Consortium and Build
- Evaluate potential for The Locust Works to formalize and grow as an organization
- Evaluate potential for State, Federal or International Standardization of ModAPS-type facilities