Conceptual Design, Engineering & Pricing of a CLT Addition to UMaine's Composites Center to House the GEM Factory of the Future

Prepared for:
United States Endowment for Forestry & Communities/U.S. Forest Service
University Mass Timber Grant Program
Subrecipient Agreement #E19-56

University of Maine's Advanced Structures and Composites Center
Report Number: 21-23-1784

November 13, 2020

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APPENDICES

1.0 Background and Vision

In October 2019, the Advanced Structures & Composites Center (ASCC) at the University of Maine (UMaine) was awarded one of ten University Mass Timber Grants, meant to support demonstration projects showcasing mass timber technologies on university campuses. Two of the ten awards were given to Maine colleges and universities, the one described herein focused on a CLT addition to the ASCC to (1) demonstrate to regional stakeholders the viability of CLT as a structural building material, (2) demonstrate cost-effective use of CLT in large, warehouse-style buildings, (3) show Maine's support for mass timber technologies to further encourage investment in CLT production in the state, (4) house a significantly expanded research program at UMaine in large scale, cellulose-filled, bio-based additive manufacturing (a.k.a. 3D printing) in support of Maine's evolving and innovative forest products industry.

This 78,000 ft^2, \$47.8 (52.8 including equipment) million CLT addition fits perfectly within ASCC's current strategic plan, titled Green Energy & Materials (GEM), which seeks to build on the Center's reputation as a national and international leader in commercially-scaled, next-generation R&D on composite materials and structures. The addition fits so well, in fact, into both ASCC's and UMaine's strategic plans that the addition will bear the name "GEM". Concurrently, the GEM addition will allow UMaine's students (Maine's future workforce) to be trained in a facility that will give them advanced skills allowing them to take the reins of, and become leaders in the new technologies developed within the GEM laboratories. The new industries that this research seeks to spur are envisioned to be key to Maine's innovation-led economic recovery. The GEM CLT addition proposed herein will be a centerpiece of realizing this strategic vision.

Research within the GEM laboratories will be focused on additive manufacturing of cellulose-filled biopolymers using novel materials such as nano-cellulose. Cellulose at this scale is mostly species agnostic, allowing for use of low grade material, underutilized species, commercial thinnings and mill residuals. The GEM addition will house and allow for expansion of the world's largest polymer 3D printer already operational at UMaine, as well as "The Factory of the Future" where the CLT building itself will be the frame for a dozen end effectors (printing, machining, tape layup) all working in tandem, controlled by artificial intelligence and high performance computing. This work will be conducted as part of an ongoing partnership with the Department of Energy's Oak Ridge National Laboratory (ORNL), which sees UMaine as an expert partner in large scale, bio-based 3D printing as part of their hub and spoke model (the hub being ORNL, the spokes a variety of research centers nationwide with expertise in specific areas of 3D printing – UMaine's being wood filled biopolymers). Other partners supporting this research include the U.S. Army, U.S. Dept. of Transportation, U.S. Department of Agriculture. and a myriad of private companies, with current funding levels in excess of \$30 million over the next five years.

The ASCC is itself a showcase of mass timber technologies, built 20 years ago to perform R&D on engineered wood technologies in order to make Maine-made products more competitive and to support its strong-but-evolving forest products industry. Originally named the Advanced Engineered Wood Composites (AEWC) Center, the building is itself a demonstration of what can be done with mass timber, built entirely of wood composites, including glulam, Parallam, LVL, I-joists, plywood and OSB. Two 20 ton cranes, for example, are supported by glulam crane rails, a unique demonstration of the ability to use mass timber in demanding structural applications when engineered properly.

UMaine has been supportive of mass timber products and technologies for decades, including its Alfond arena, Nutting Hall, Recreation Center and the ASCC, all of which are built with glulam. The GEM CLT addition, then, will be an extension of the university's ongoing support for mass timber products as well as the newest (and perhaps most promising for Maine) product - CLT - which Maine is perfectly suited to produce. CLT is manufactured using "two-by" dimension lumber, 500 million board feet of which was produced in Maine in 2019 (in the spruce-pine-fir-south, or SPF-S, lumber grouping). A typical CLT plant consumes approximately 50 million board feet annually, meaning a plant in Maine would demand/consume 10% of current production levels, which foresters and mills say would be easily achieved in a sustainable manner[1].

This GEM CLT addition leverages many other on-going activities seeking to transform Maine's forest products industry. Among these is the Maine Mass Timber Commercialization Center, a 3-year Economic Development Agency (EDA) funded program whose goal is to make the case for Maine as the ideal location for the region's first CLT manufacturing facility. Maine, being the most forested state in the nation (by % of forested land area), sits atop one of the world's most populated areas, and is therefore perfectly positioned to feed the growing urban demand for mass timber products.

The ASCC hosts thousands of visitors each year, who within the GEM addition will be able to see a demonstration of CLT as a viable building material of the future, especially in the Northeast. Additionally, ASCC seeks to make the GEM addition a R&D Gateway to UMaine, showcasing many of its visionary R&D programs (and the CLT building itself) to prospective students and investors alike.

2.0 Objectives

The primary objective of this project was to demonstrate CLT as a viable structural building material, educate stakeholders, attract CLT manufacturing to the state, and spur demand for CLT in the region. A secondary objective is to house a significantly expanded research program at UMaine in large scale, cellulose-filled, bio-based additive manufacturing (a.k.a. 3D printing) in support of Maine's evolving and innovative forest products industry.

3.0 Building Overview

The GEM CLT addition will be located south of, and directly adjacent to the existing ASCC building, in an open space between its offshore wind laboratory (OWL) and the Collins Center for the Arts parking lot (Figure 1). Note Murray Hall in the front right of the image – If a discussed demolition (and replacement elsewhere on campus) of that building occurs prior to construction of the GEM addition, the main entrance/lobby/parking for the addition will likely be shifted to that area.

[1] See "The Case for CLT Manufacturing in Maine" for more details: https://composites.umaine.edu/wp-content/uploads/sites/20/2020/01/MMTCC-Attraction-Package-ver-01_07_2020-complete.pdf

Figure 1 – Location of the GEM Addition

The GEM addition consists of four main parts (Figure 2), each described below. A breakdown of square footage by area is presented in Table 1.

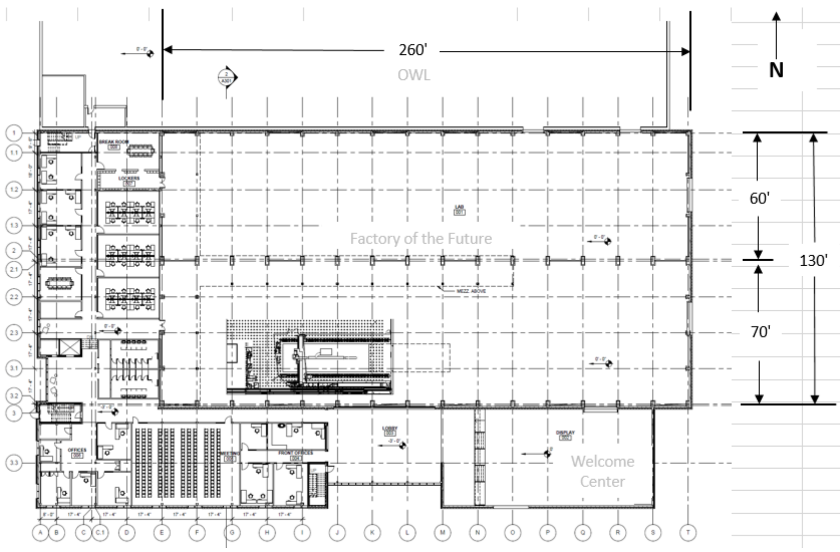

Figure 2a – GEM Addition Plan View

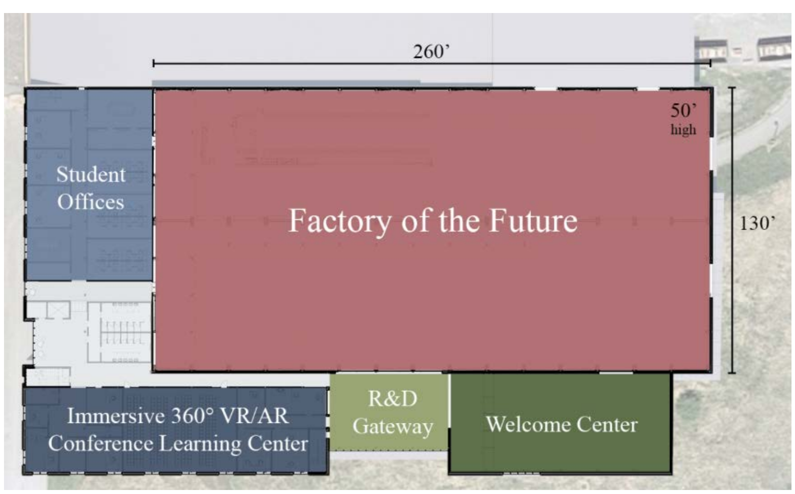

Figure 2b – GEM Addition Plan View

Table 1 - GEM Addition Square Footage Breakdown

Functional area	ft^2
Laboratories	34,804
Mezzanine	5,238
Welcome Center	4,837
Conference Center	2,127
Lobby	2,000
Individual offices (17)	3,406
Shared (double or triple) staff offices- (13)	4,472
Open (5+ people) student offices - (9)	5,556
Conference rooms (not including Conference Center)	1,803
Locker room	287
Break rooms	1,074
Bathrooms	1,674
Hallways/elevators/stairways/etc.	6,951
Wall thicknesses	4,238
Gross Total	**78,466**
Laboratories (including mezzanine)	40,042
Welcome Center/Conference Center/Lobby	8,964
Offices	13,433
Conference rooms	1,803
Lockeroom/Break rooms/Bathrooms	3,035
Net Total	**67,277**
Other (hallways/elevators/stairways/wall thickness)	11,189
Gross Total	**78,466**
Grossing factor	14.3%
Gross Building Footprint	57,995

3.1 Welcome Center

As the research gateway to the University, the GEM CLT addition will showcase the scale and vision of UMaine's R&D efforts. The Welcome Center (Figure 2, bottom right) will house displays of various ASCC and UMaine R&D projects, including interactive touch screens allowing for deep dives on specific technologies. Conceivably this area could be "uncontrolled", meaning walk-in visitors would be allowed and welcomed. As a secure facility conducting controlled work for government clients (e.g. DOD), the majority of the building needs to be fully secure, visitors vetted in advance, etc.. Having a non-controlled area will solve an existing obstacle for the many visitors that show up unannounced, giving them the opportunity to still learn about the varied research that is conducted at ASCC and UMaine.

3.2 Conference Learning Center

A 300 person, 360º Immersive Virtual/Augmented Reality Conference Learning Center (Figure 8b) will allow for large gatherings, something lacking within the existing ASCC. For example, large groups of prospective students and their parents/guardians can be introduced to UMaine, using circular floor-to-ceiling screens wrapping around the entire room presenting videos of UMaine's outstanding facilities and opportunities. The message: UMaine is a great choice to pursue a world-class education. The space can be divided into three separate, smaller, conference rooms as well.

3.3 Factory of the Future

This modern R&D factory will allow for innovative research primarily on large scale, bio-based additive manufacturing, cementing ASCC/UMaine's role as a world leader in this growing field. It will also include a business incubation space, where entrepreneurs-in-residence can cooperatively develop innovative products alongside UMaine researchers. Two large laboratories will be added (Figures 3,4,8) herein labeled North and South, each roughly 65' wide x 50' tall x 260' long, for a total of 34,000 ft^2. Importantly this will allow for expansion of the existing Ingersoll 3D printer from 65' to 100', with another 160' of outfeed and post-processing space.

3.4 Offices and Student Spaces

The GEM addition will add 39 much-needed offices for researchers and students, precisely double the existing 39. On a square footage basis, it will increase office space by a factor of 3.1, bringing the total to 24,000 ft^2. The number of desks will increase by 124, importantly including 72 for undergraduate and graduate students, many of whom will call the ASCC home during their time at UMaine. A summary is presented as Table 2.

Table 2 - GEM Addition Office Calculations

OFFICES	Current (Oct. 2020)				In CLT Addition			After CLT Addition			
	# Desks	# offices	Ave. size (ft^2)	Total (ft^2)	# Desks	# offices	Total (ft^2)	# Desks	# offices	Total (ft^2)	ft^2 Factor Increase over 2020
Individual offices	10	17	190	1,900	18	17	3,406	32	45	5,756	3.0
Shared staff offices (2-4/office)	55	12	70	3,850	34	13	4,472	103	25	9,247	2.4
Shared staff/student offices (5+/office)	55	10	35	1,925	72	9	5,556	139	22	8,856	4.6
Total	**120**	**39**		**7,675**	**124**	**39**	**13,434**	**274**	**92**	**23,859**	**3.1**

4.0 Project Partners

This project was a collaborative effort among five partners:

- ASCC/UMaine
- Scott Simons Architects (Conceptual design and renderings)
- Paul Becker Structural Engineers & Thornton Tomasetti (Engineering & life cycle analysis)
- Consigli Construction (Constructability & price estimating)
- SmartLam (CLT specification & pricing)

The output from each partner company is described in detail below. Note that the LCA and professional renderings were not funded from the University Mass Timber Grant, but as this grant leveraged other monies with direct benefit to this project, they are included in this report.

5.0 Architectural Design

5.1 Conceptual Design

The conceptual design and drawings were fully executed by Scott Simons Architects (SSA), Portland, ME, included as Appendix A. Ryan Kanteres, one of the principals at SSA, was the lead, heavily supported by Adam Wiles-Rosell. Their role included building design, code review and interaction with the rendering company. They handled scope creep gracefully as the building grew from the originally planned 21,000 to 78,000 ft^2. While not seen clearly in some of the drawings, there is a large solar array covering the entire roof of the South laboratory, fitting well within the Green Energy & Materials theme. Wood fiber insulation, manufactured by GOLab at a new factory in Madison, ME, has been specified.

5.2 Code Analysis

A code analysis was conducted, and a decision made to go with a Type III building. A summary of the fire ratings are shown in Figure 3 and detailed information included in Appendix A.

PRELIMINARY CODE SUMMARY

Table 4.1.1 Fire Resistance Ratings for Type I through Type V Construction (hr)

	Type I		Type II			Type III		Type IV	Type V	
	442	332	222	111	000	211	200	2HH	111	000
Exterior Bearing Walls [a]										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0[b]	2	2	2	1	0[b]
Supporting one floor only	4	3	2	1	0[b]	2	2	2	1	0[b]
Supporting a roof only	4	3	1	1	0[b]	2	2	2	1	0[b]
Interior Bearing Walls										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	2	1	0
Supporting one floor only	3	2	2	1	0	1	0	1	1	0
Supporting roofs only	3	2	1	1	0	1	0	1	1	0
Columns										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	H	1	0
Supporting one floor only	3	2	2	1	0	1	0	H	1	0
Supporting roofs only	3	2	1	1	0	1	0	H	1	0
Beams, Girders, Trusses, and Arches										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	H	1	0
Supporting one floor only	2	2	2	1	0	1	0	H	1	0
Supporting roofs only	2	2	1	1	0	1	0	H	1	0
Floor-Ceiling Assemblies	2	2	2	1	0	1	0	H	1	0
Roof-Ceiling Assemblies	2	1½	1	1	0	1	0	H	1	0
Interior Nonbearing Walls	0	0	0	0	0	0	0	0	0	0
Exterior Nonbearing Walls [c]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]

H: heavy timber members *(see text for requirements).*
[a]See *NFPA 5000*, 7.3.2.1.
[b]See *NFPA 5000*, Section 7.3.
[c]See 4.3.2.12, 4.4.2.3, and 4.5.6.8.
[**5000:** Table 7.2.1.1]

Figure 3 – Building Code Fire Resistance Ratings for Type III

6.0 Engineering

Engineering of the structural system (glulam and CLT) was carried out by Paul Becker Structural Engineers as well as Thornton Tomasetti (TT), both of Portland, ME. Paul Becker led the team, with significant contributions from Annavitte Rand. TT interacted directly with SmartLam on the specification and choice of the various CLT products. Noteworthy is the choice of hybrid trusses supporting the roofs of the laboratories. The glulam beams, with steel tension chords were chosen for both utility (allowing for greater crane heights and clearances) as well as an educational component, allowing engineering students to ponder why certain materials were chosen in particular applications. While timber is the focus of this grant, we all agree that the right material should be chosen for the right application, balancing cost vs. performance. In this case, a hybrid wood-steel system made sense. Becker and TT's work is included as Appendix B.

7.0 Price Estimating

7.1 Price Estimating of the Building

Price estimating was conducted by Consigli Construction, Portland, ME. Consigli is very familiar with UMaine projects, as they are currently constructing the new Engineering Education & Design Center building on UMaine's Orono campus. Consigli has also recently conducted a very similar estimate as that presented herein on a new College of Natural Sciences, Forestry & Agriculture (NSFA) Life Sciences Building (LSB) on the Orono campus. That project chose to compare a

CLT vs. a steel system. Finally, Consigli is a partner on the other University Mass Timber Grant program project in Maine at Bowdoin College. The team was led by Matt Tonello, with estimating work performed by Jeff Picoraro and Amanda Keane. A summary of their $28 million dollar estimate ($362/SF) is presented as Figure 4. Their complete estimate is included as Appendix C.

CONSIGLI
Est. 1905

University of Maine ASCC
Mass Timber Concept Estimate

9/14/20

Estimate Totals

Description	Amount	Totals	Rate	Cost per Unit
Subtotal	**21,289,988**	**21,289,988**		**271.210 /SF**
Design Contingency	2,128,999		10.000 %	27.121 /SF
Escalation				
Subcontractor Bonds/Insurance	327,866		1.400 %	4.177 /SF
Subtotal	**2,456,865**	**23,746,853**		**302.508 /SF**
Contractor's Contingency	712,406		3.000 %	9.075 /SF
General Conditions	1,662,280		7.000 %	21.176 /SF
General Requirements	831,140		3.500 %	10.588 /SF
Subtotal	**3,205,826**	**26,952,679**		**343.346 /SF**
Builder's Risk Insurance	73,854		0.260 %	0.941 /SF
General Liability Insurance	397,676		1.400 %	5.066 /SF
Building Permit(by UMaine)				
GC Performance & Payment Bond	153,868			1.960 /SF
Subtotal	**625,398**	**27,578,077**		**351.313 /SF**
Fee	827,342		3.000 %	10.539 /SF
Total		**28,405,419**		**361.852 /SF**

Figure 4 – Building Cost Estimate

7.2 CLT Price Estimate

CLT estimates were provided by SmartLam of Columbia Falls, MT (Figure 5), whose full quote is also included in Appendix C. Note the high cost of shipping, further justification for a CLT plant in Maine to supply regional projects. SmartLam and ASCC/UMaine have been collaborating on research for several years, including recent manufacturing and qualification testing which will lead to two new grades of "E" rated CLT made from Maine SPF-S lumber, which will have among the highest design values published in PRG-320, the ANSI standard governing CLT production and design.

	CLT SPECIFICATIONS	QTY	SQUARE FT	CUBIC FT.	WEIGHT		SUBTOTAL
CLT Roof System:	5 ALT SL-V4	111	57,825	33,043	1,274,779		$839,859.56
	5 SL-V5M2	33					
CLT Floor System:	5 ALT SL-V4	55	19,800	11,314	436,392		$288,223.57
CLT Walls:	5 ALT SL-V4	135	33,403	18,905	729,170		$486,816.77
CLT Stair & Elev Shaft:	5 ALT SL-V4	24	8,400	4,800	185,268		$170,959.45
CLT Hardware/Fasteners:	Spline Material, CLT to CLT and CLT to Bearing Material Fasteners Only						$55,600.00
Shipping Estimate:							$589,050.00
	TOTALS:	358	119,428	68,062	2,625,609	**$**	**2,430,509.35**

Figure 5 – CLT Cost Estimate

7.3 Total Project Cost Estimate

Estimating of total project costs (including all items above and beyond those included by Consigli, such as soft costs, wetland permitting, contingency and escalation) was provided by UMaine's

Facilities Management (FM), conducted by Walter Shannon and Josh Burke. Their detailed quote is included as Appendix C

.

Table 3 presents the total building cost of $52.8 million dollars, including Consigli, FM and estimated equipment costs. Note that excluding equipment the $/ft^2 cost is $609.

Table 3 – Total Project Cost Estimate

	Cost	$/ft^2
Construction Contract (Consigli estimate)	$ 28,405,419	$ 362
Facilities Management Estimate of other costs (includes 10% contingency)	$ 19,414,581	$ 247
Equipment costs	$ 5,000,000	$ 64
Total	**$ 52,820,000**	**$ 673**

8.0 Life Cycle Analysis and Carbon Assessment

The life cycle assessment (LCA) and carbon assessment of the GEM CLT addition was conducted by Thornton Tomasetti. The objective of the report was to determine the embodied carbon impact and anticipated operational energy use of the GEM CLT addition. The work was funded by the EDA Maine Mass Timber Commercialization Center, positively leveraging each grant/project. It is recognized that environmentally friendly building materials are increasingly valued, especially by the younger generations, which may lead to increased demand for mass timber buildings in the future, making assessments like these an additional tool during project promotion. Alexandra Davis was the lead, assisted by Duncan Cox and Vamshi Gooje. Ben Herzog of ASCC directed the effort from UMaine. The LCA is included as Appendix D. Using the results from the LCA, low carbon benchmarks will be developed for major structural components, to inform future mass timber projects on the University campus and Northeast region at large.

9.0 Site Planning

9.1 ASCC Site Selection

The University's Facilities Management (FM) Department has been involved in this project from its inception, including the following significant contributions to-date:

a) A 2017 study where FM conducted an analysis of four site options around the existing ASCC for a large building addition. These are presented in Appendix E.
b) Meetings with the University's wetlands consultant (Woodard & Curran) to discuss potential impacts and mitigation strategies.
c) Synchronization of this project within the 2010 University Master Plan.
d) Providing a total project cost estimate, including those items deemed to be missing from the Consigli pricing (e.g. wetlands, soft costs, contingency and escalation costs).

9.2 Coordination with University Master Plan

Stewart Harvey of UMaine Facilities Management requested that when siting the facility, parking and roadways entering the new addition, that it be kept in line with the University's Master Plan, conducted in 2008-09 by Sasaki Associates. The GEM addition will fit within the area called "Core Campus Infill" (Figure 6). The "Green Corridor" is intended to be left undeveloped. Other snapshots of the Master Plan that include the area around the ASCC are presented in Appendix F.

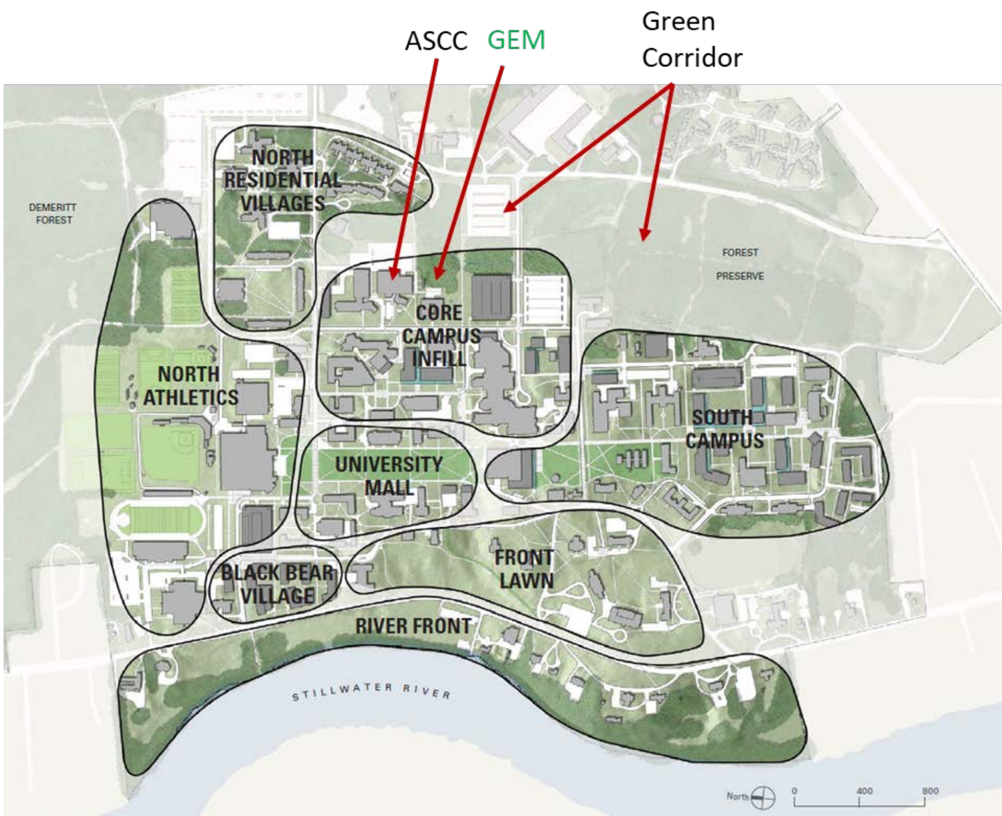

Figure 6 – Alignment with UMaine Master Plan

10.0 Preliminary Design Files

Early (pre-2019) conceptual drawings of this addition project conducted at ASCC are presented in Appendix G. ASCC staff that worked on these early-stage designs included James Anderson, Alex Cole and Peter Jalbert.

11.0 Conclusions and Next Steps

This project has produced the conceptual design, engineering and costing that will allow the GEM CLT addition to move to the University's decision makers, who will now have a comprehensive plan and vision to assess. A very similar project has been concurrently conducted on a new Life Sciences Building at UMaine, meaning there are two fully developed, conceptual packages showcasing CLT buildings on a university campus, one a large, warehouse-style laboratory, the other a more typical academic/classroom building. Having one or both of these CLT buildings constructed as a demonstration building will be critical to the promotion and expansion of CLT construction in the State and the region.

APPENDIX A

University of Maine
Advanced Structures and Composites Center

Mass Timber Addition Study
October 2020

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PROJECT SUMMARY

The University of Maine Advanced Structures and Composite Center continues to grow its equipment capacities, research funding, and range of projects exploring cutting edge technologies. This study was conceived as way to couple an in-depth review of the ASCC's ever growing spatial needs with a grant funded opportunity to develop the conceptual architectural and engineering design and preliminary cost estimation for a large-scale academic mass timber building.

The Advanced Structures and Composite Center's recent acquisition of the world's largest 3D printer, and the current inability to utilize it to its full capacity, exemplify the pressing needs to expand the facility. The mass timber building design developed for this study is the product of months of previously completed study of programmatic space needs, and a series of meetings, internal reviews and iterative presentations conducted between February 2019 and September 2020.

While the fundamental focus of this study was to develop a conceptual design for a mass timber facility the design process served to highlight and further clarify a number of key issues. Among these key issues is an immediate and near term need for additional space to meet the facilities' research needs, a significant and immediate need for additional office and meeting space for staff and students, a requirement for a welcoming yet secure lobby, and the need for a proper display space for large scale demonstration projects which can serve as safe place to engage with tour groups. In addition to organizing and providing for these programmatic needs within a modern mass timber facility, the study aimed to create a public presence that represented the character to the institutions exciting research to the campus, and the state.

SPACE PROGRAM

Tabular space plan as implemented in the final conceptual floor plans.

Individual Spaces	ft^2
Lab 1 (3D printer, South)	18,761
Lab 2 (TBD, North)	16,043
Lab Mezzanine	5,238
Welcome Center	4,837
Conference Center	2,127
Lobby	2,000
First floor Front offices (4) - one 1 person, one 2 person, one 3 person, one work room,	1,497
First floor Executive offices (6) - five one person, one two person	1,804
First floor student/open offices (3) - 8 person	1,847
First floor staff/shared offices (3) - 3 person	1,104
First floor (small) conference room	325
First floor Elevator Support	75
First floor Breakroom	549
First floor Locker room	287
Second floor student/open offices (6) - 8 person	3,709
Second floor staff/shared offices (6) - 3 person	2,168
Second floor individual offices (12)	1,304
Second floor Large Conference/Observation Room	926
Second floor Small (corner) Conference Room	552
Second floor Elevator Support	75
Second floor Storage Closet	101
Second floor Breakroom	525
Bathrooms	1,620
Circulation	6,951
Total	**74,425**
By functional area	**ft^2**
Laboratories	34,804
Mezzanine	5,238
Welcome Center	4,837
Conference Center	2,127
Lobby	2,000
Individual offices	3,406
Shared (double or triple) staff offices	4,472
Open (4+ people) student offices	5,556
Conference rooms (not including Conference Center)	1,803
Locker room	287
Break rooms	1,074
Elevator Waiting Areas	0
Bathrooms	1,674
Circulation	6,951
Total	**74,228**
Gross Footprint	57,995
Gross second floor footprint (including mezzanine)	20,471
Gross Total (14% grossisng factor)	**78,466**

PRECEDENT ANALYSIS

As part of the early development of the project the design team and building committee reviewed numerous precedent projects. Significant inspiration was found when reviewing examples of day lit historic industrial spaces such as Albert Kahn's chrysler tank plant, and the elegant repetitive kit of parts approach taken in the Vitsoe Headquarters project. In addition to these building which are represented below an assortment of projects exemplifying contemporary wood construction technologies in similar building typologies such as

the Princeton University Embodied Computation Lab

University of Maine
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scott simons architects
designed for human potential

Precedent Analysis

SITE ANALYSIS AND DESIGN

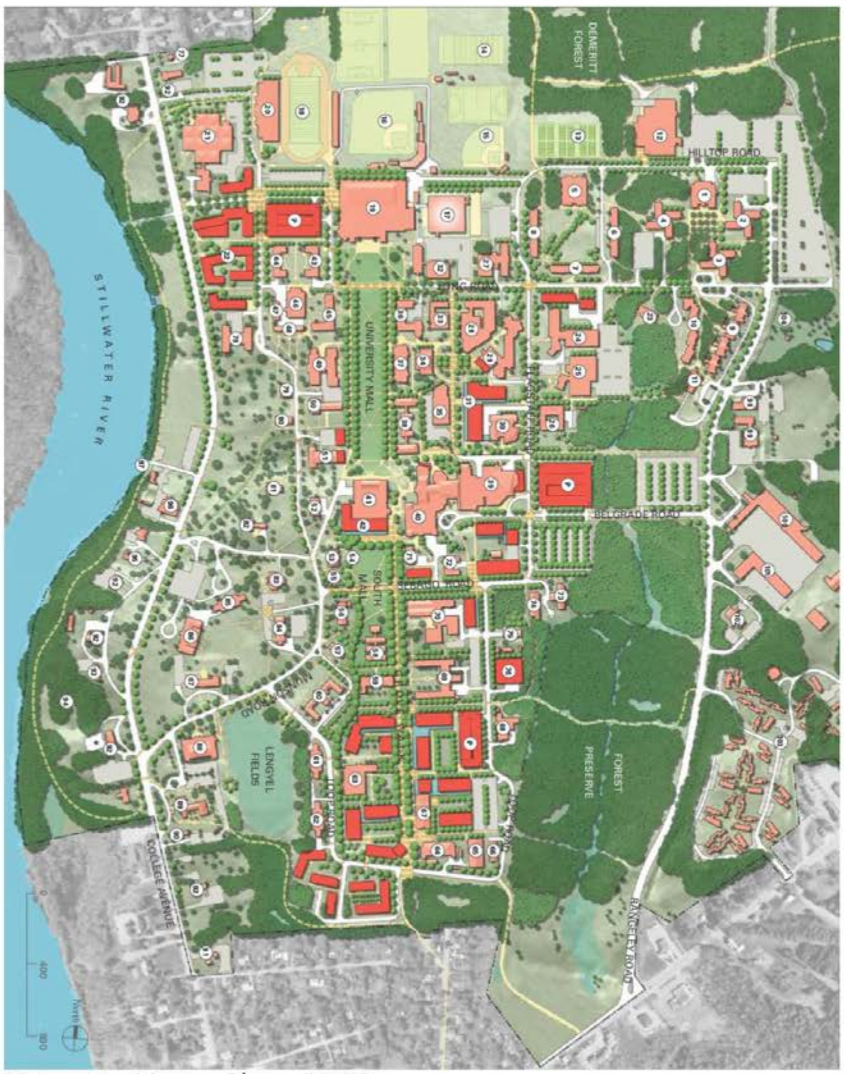
The location for an addition of this scale was largely dictated by site constraints. A previous feasibility study evaluated three locations adjacent to the current ASCC facility and concluded the location between the south edge of the lab and the CCA lot was the most viable. Developing the addition in this location will require mitigation of the impacted wetland, as well as utility work (including but not limited to the relocation of an electrical service and transformer currently servicing the lab). This siting provides a number of inherent benefits for the project and will accommodate needed adjacencies with existing occupancies, grouping office function with existing office functions and providing for a beneficial connect between the new and existing lab spaces. In addition to these benefits the site location allows for the establishment for a prominent entry location which can be a functional gateway to the labs and an exceptional opportunity to publicly WW.

It is important to note that detailed analysis of storm water drainage and investigation of existing conditions were beyond the scope of this study.

SITE ANALYSIS AND DESIGN

University Maine - Campus context

SITE ANALYSIS AND DESIGN

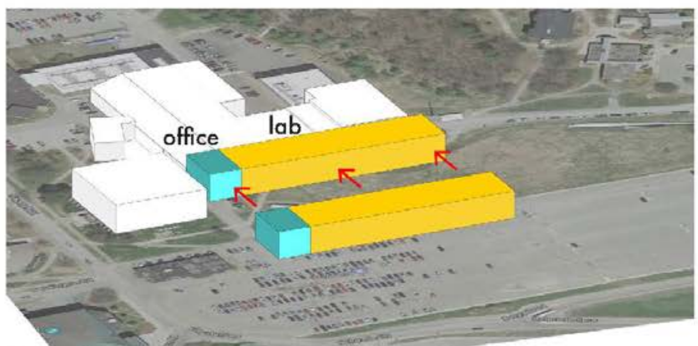


University Master Plan - 2009
Illustrating goals of revegetation and improving the watershed at east of campus

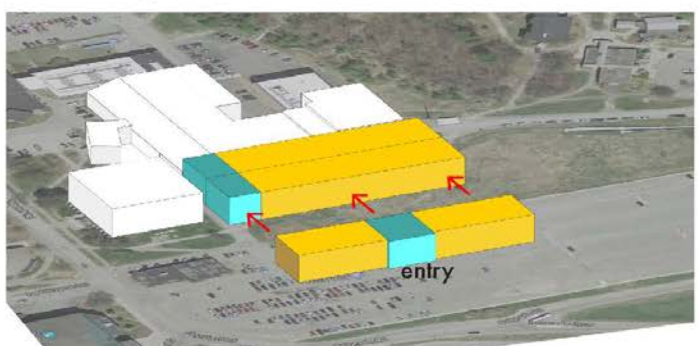
SITE ANALYSIS AND DESIGN

The addition allows for favorable adjacency between new and existing programmatic elements and also allows for a prominent entry at the south. This area will require modification of electric lines and transformers, but will not impact the steam line running along the edge of the parking lot

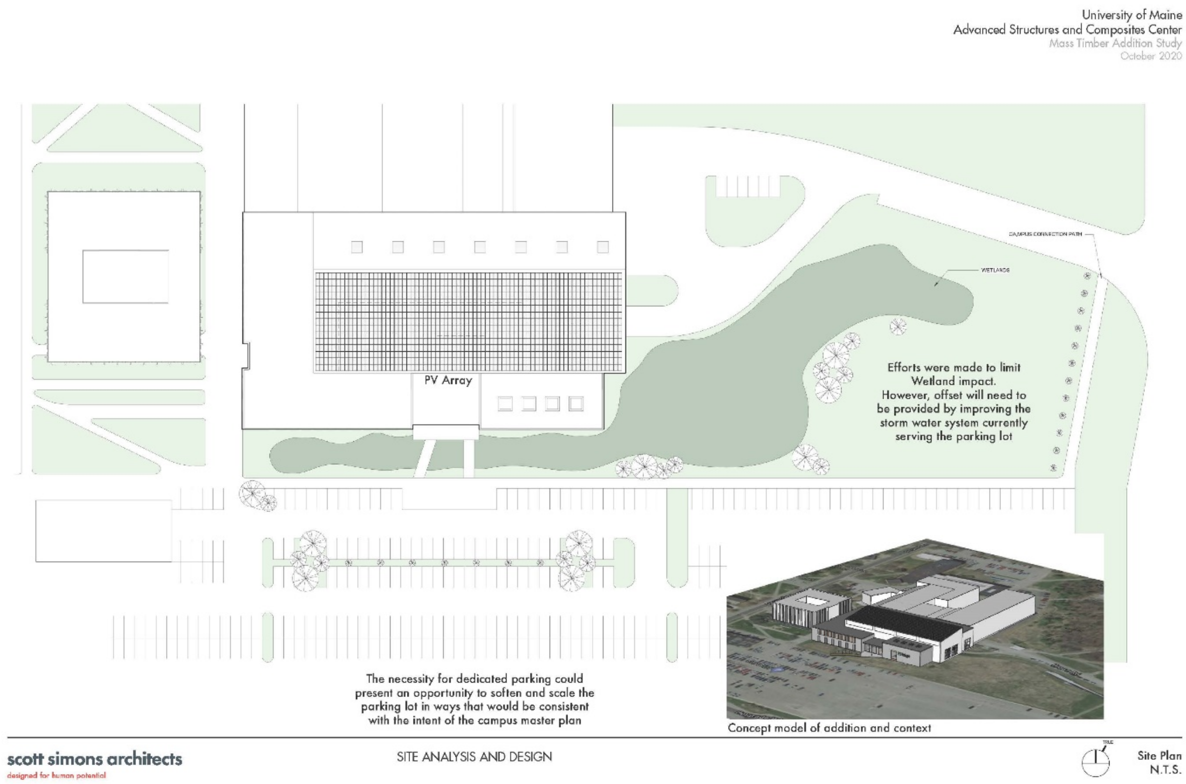
Existing condition



Favorable adjacencies



South Entry opportunity


University of Maine
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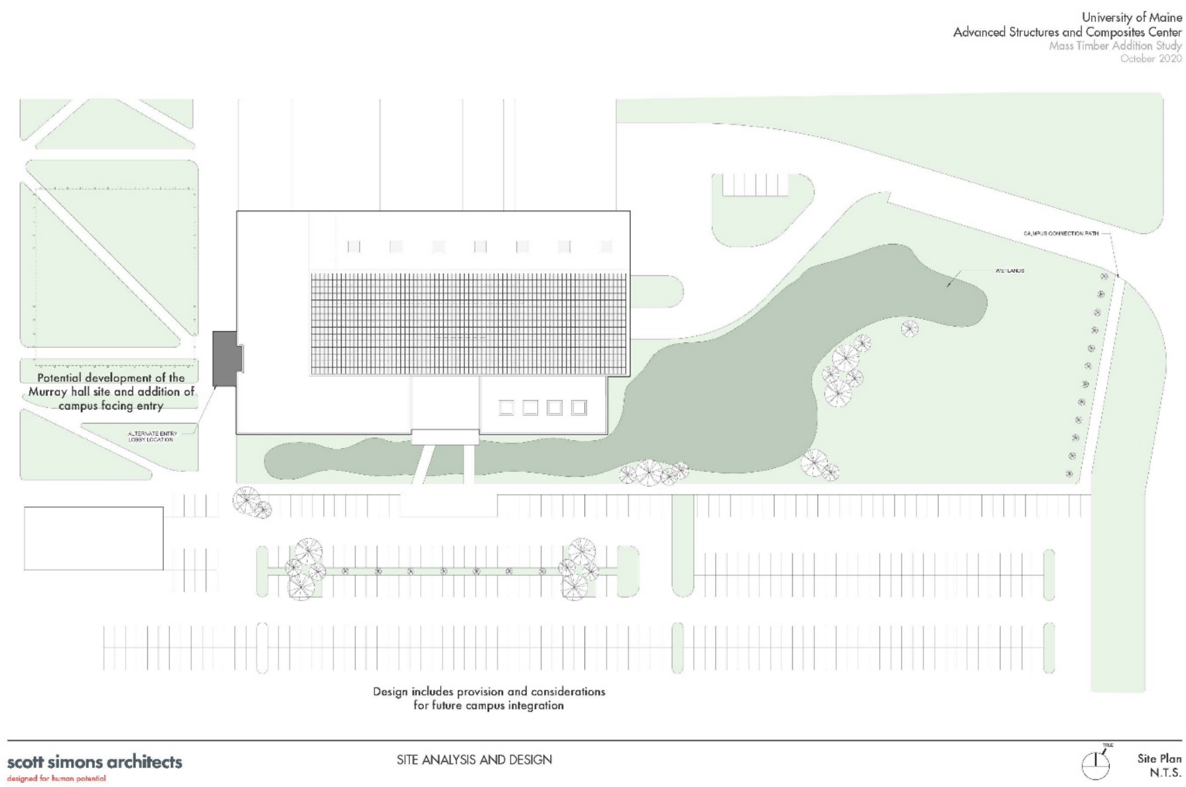
Mass Timber Addition Study
October 2020
PV Array
Efforts were made to limit Wetland impact. However, offset will need to be provided by improving the storm water system currently serving the parking lot
The necessity for dedicated parking could present an opportunity to soften and scale the parking lot in ways that would be consistent with the intent of the campus master plan
Concept model of addition and context
scott simons architects
designed for human potential
SITE ANALYSIS AND DESIGN
Site Plan
N.T.S.


University of Maine
Advanced Structures and Composites Center
Mass Timber Addition Study
October 2020
Potential development of the Murray hall site and addition of campus facing entry
Design includes provision and considerations for future campus integration
scott simons architects
designed for human potential
SITE ANALYSIS AND DESIGN
Site Plan
N.T.S.

ARCHITECTURAL DESIGN

Employing the simplicity and repetitive forms of traditional industrial architecture, the design of this addition aims to efficiently explore the implementation of mass timber construction techniques while providing an unique approach to daylighting the large span industrial research and development bays. The location of the addition and the configuration of the major programmatic elements of this project are largely dictate by the site and existing buildings. These factors in turn inform the mass and form of the proposed addition. Composed of a few innovatively configured simple large-scale forms the building is organized to provide an orderly continuation of the research and office functions. The addition also incorporates a new public lobby, display, and presentation spaces. This new entrance lobby and welcome center will highlight the capacity and identity of the university's research programs.

The design entails a welcoming yet secure entry lobby, a welcome center display space, an immersive conference presentation space, a two-story office wing composed of a mix of meeting rooms and private and shared offices, and two large high bay research spaces. The entry lobby on the south of the complex is located between the welcome center and conference space, and will serve as a public space and entry for the entire ASCC complex. The conference space is incorporated into the two-story office wing. The mix of offices and meeting spaces in the new office wing also provides a 40 person meeting room on the second floor overlooking and directly connecting to a mezzanine in the south research bay. The circulation for the office wing ties the new lobby to the corridor of the existing offices and includes a doubled-sided elevator. The elevator lobbies are located such that they could be developed as a secondary entry or accommodate an addition in the event of a future redevelopment of the Murray hall site. On the other side of the entrance lobby the welcome center will connect the public entry to the lab space with a high bay display area where research projects could be prominently displayed and tour groups could convene. A different approach is taken to structuring each of the two high bay research areas. The north bay adjacent to the existing structure is framed with deep glulam beams and columns and spanned with CLT panels. The south high bay is framed with glulam columns and a sloped hybrid glulam and steel truss which is also spanned with CLT panels. The sloped roof over the south bay is configured to extend partially over the other bay to create a large north facing clearstory monitor, which will effectively bring daylight to both spaces. This innovative approach leverages the benefits of the hybrid truss to create an efficient and striking structure. The south bay will also have translucent panels along the south wall further contributing to the overall daylighting.

The building exterior is intentionally simple utilizing two types of metal panels and a curtain wall system connect the distinct masses of the office wing and welcome center. In addition to the metal panel cladding the south wall facing the CCA lot will include translucent wall panels. The south facing sloped roof above is ideally located for on site solar energy generation and has been configured to incorporate a large-scale PV array. The intent of the architectural design of this project is to develop a contemporary mass timber building which successfully bridges the scale of industrial and campus buildings, while creating a welcoming presence that represent the ASCC capacity and identity.

PRELIMINARY CODE SUMMARY

APPLICABLE CODES
Maine Uniform Building and Energy Code "MUBEC"
Consists of the following applicable codes:

2015 International Building Code (IBC)
2015 International Existing Building Code (IEBC)
2009 International Energy Conservation Code (IECC)
2007 ASHRAE 62.1, 2 (Ventilation for Acceptable Indoor Air Quality)
2007 ASHRAE 90.1 - (Energy Standard for Buildings except Low-Rise Residential Buildings)
E-1465-2006, Standard Practice for Radon Control Options for the Design and Construction of New Low-Rise Residential Buildings.
Maine State Internal Plumbing Code based on the 2009 Uniform Pluming Code
State of Maine Subsurface Wastewater Disposal Rules Version dated: Jan 18, 2011
2011 National Electrical Code (NEC)

Fire / Life Safety

NFPA Life Safety Code as adopted by the State of Maine Including but not limited to:

2018 NFPA 101: Life Safety Code
2016 NFPA 13: Installation of Sprinkler Systems,

Accessibility

2010 ADA Standards for Accessible Design

NOTE: All Codes shall include changes/amendments by the State of Maine

OCCUPANCY CLASSIFICATION (IBC Sec 302, 303, 304, 508.3.1) (NFPA 6.1.14.3.2)
Mixed Use – Separated Occupancies
Business B (Higher Education office and support, Academic research and testing)
Assembly A-3 (Exhibition / Lecture hall) applied to lecture hall only
1 Hour separation between occupancies (dedicated egress should be considered)

AUTOMATIC SUPPRESSION SYSTEM (NFPA 13)
Automatic sprinkler system provided per NFPA 13 throughout

PRELIMINARY CODE SUMMARY

GENERAL BUILDING INFORMATION
Building Height (highest point of the roof) – 58', 2 Stories
Building Footprint 57,995
Total Area 78,466
Perimeter 658'

TYPES OF CONSTRUCTION (IBC Table 601, Sec 602, NFPA 220)
Type IIIB (Type 3 (2,0,0)

OCCUPANCY LOAD
(IBC Table 1004.1.1)
(NFPA)

Business B	100 Gross Sqft per Occupant
Assembly A-3	15 net Sqft per Occupant
Accessory Storage	300 Gross Sqft per Occupant
Mechanical	300 Gross Sqft per Occupant

ALLOWABLE BUILDING HEIGHTS AND AREA (IBC Chapter 5, Table 503) (NFPA)

ALLOWABLE BUILDING HEIGHT
75' Maximum
4 Stories Maximum

ALLOWABLE BUILDING AREA

OCCUPANCY	B	(PER IBC CHAPTER 3)
CONSTRUCTION TYPE	IIIB	(PER IBC CHAPTER 6)

(separated from existing building by continuous Fire Wall)
(intumescent coatings not needed)

ALLOWABLE AREA	57,000	(IBC TABLE 503)
ADJUSTED ALLOWABLE AREA	64,600	
ACTUAL AREA	57,909	

Area adjustment
[F/P -0.25]W/30
(0.65-0.25)30/30 = 0.40

Allowable = Tabular + (Tabular Non-sprinklered x Increase Factor)
64,600 = 57,000 + [19,000 x 0.40]

PRELIMINARY CODE SUMMARY

STRUCTURAL FIRE RESISTANCE (IBC chapter 6, NFPA 220)

(Note- the use of CLT for exterior wall construction would provide an inherent fire resistive propertied which would exceed the zero hour requirement, however CLT is not classified as Non-combustible construction. The use of CLT for the exterior walls on similarly classified construction has been allowed where AHJ provided local interpretations. Engagement with local AHJ has not been undertaken as part of this study. This is an area of recommended further study. This issue does not affect the code provisions for frame, floor, or roof construction. As an alternative to CLT panelized light gauge metal framing should be consider as an exterior wall construction, or reduction to the building height and area, and the provision of intumescent coatings should be studied to meet the provision of Type V construction.)

-Perimeter columns and beams to meet exterior wall rating requirement
-Greater than 30' separation requires 0 hour rating on exterior walls

PRELIMINARY CODE SUMMARY

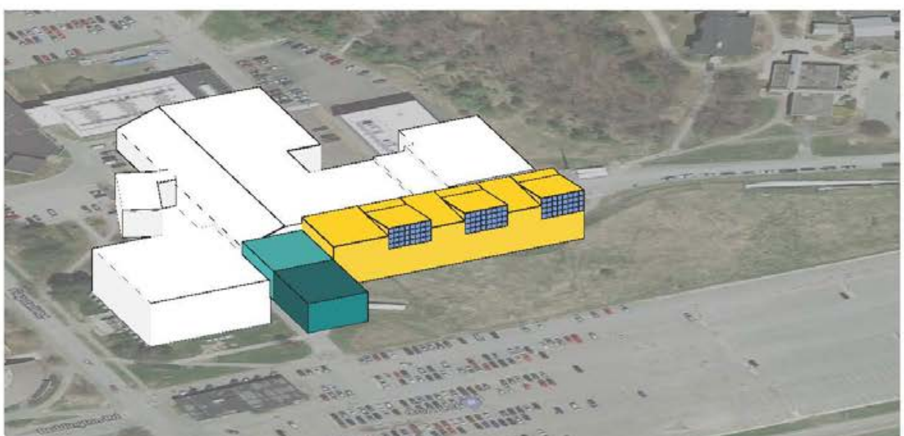
Table 4.1.1 Fire Resistance Ratings for Type I through Type V Construction (hr)

	Type I		Type II			Type III		Type IV	Type V	
	442	332	222	111	000	211	200	2HH	111	000
Exterior Bearing Walls [a]										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0^b	2	2	2	1	0^b
Supporting one floor only	4	3	2	1	0^b	2	2	2	1	0^b
Supporting a roof only	4	3	1	1	0^b	2	2	2	1	0^b
Interior Bearing Walls										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	2	1	0
Supporting one floor only	3	2	2	1	0	1	0	1	1	0
Supporting roofs only	3	2	1	1	0	1	0	1	1	0
Columns										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	H	1	0
Supporting one floor only	3	2	2	1	0	1	0	H	1	0
Supporting roofs only	3	2	1	1	0	1	0	H	1	0
Beams, Girders, Trusses, and Arches										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	H	1	0
Supporting one floor only	2	2	2	1	0	1	0	H	1	0
Supporting roofs only	2	2	1	1	0	1	0	H	1	0
Floor-Ceiling Assemblies	2	2	2	1	0	1	0	H	1	0
Roof-Ceiling Assemblies	2	1½	1	1	0	1	0	H	1	0
Interior Nonbearing Walls	0	0	0	0	0	0	0	0	0	0
Exterior Nonbearing Walls [c]	0^b	0^b	0^b	0^b	0^b	0^b	0^b	0^b	0^b	0^b

H: heavy timber members *(see text for requirements)*.
[a]See *NFPA 5000*, 7.3.2.1.
[b]See *NFPA 5000*, Section 7.3.
[c]See 4.3.2.12, 4.4.2.3, and 4.5.6.8.
[**5000:** Table 7.2.1.1]

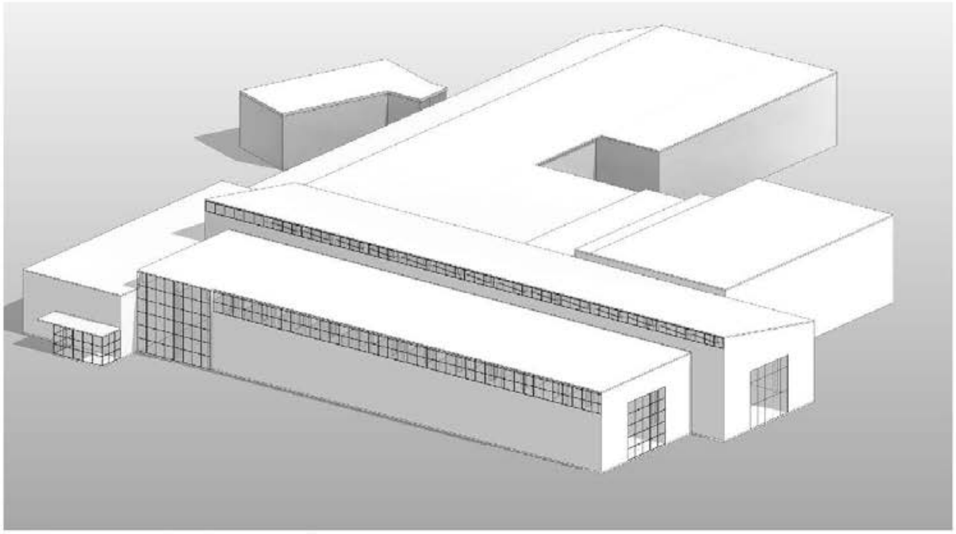
PRELIMINARY CONCEPT STUDIES

Concept from original grant package

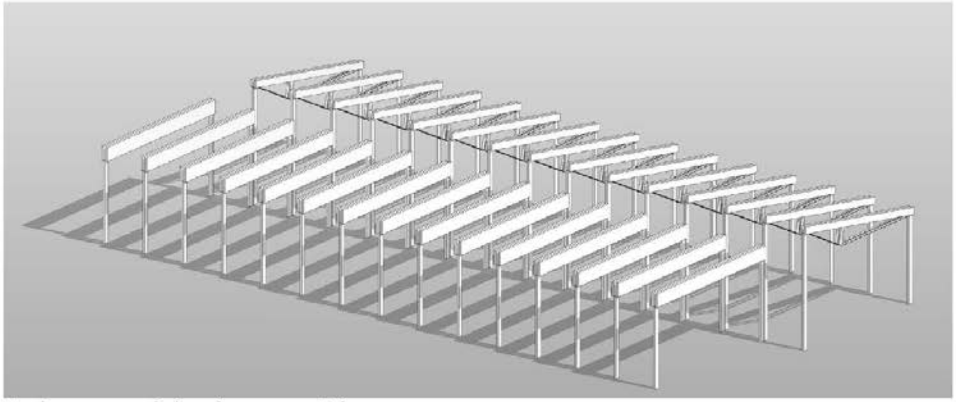


Early concept development

PRELIMINARY CONCEPT STUDIES



Early concept development - 2 bays



Early structural development - 2 bays

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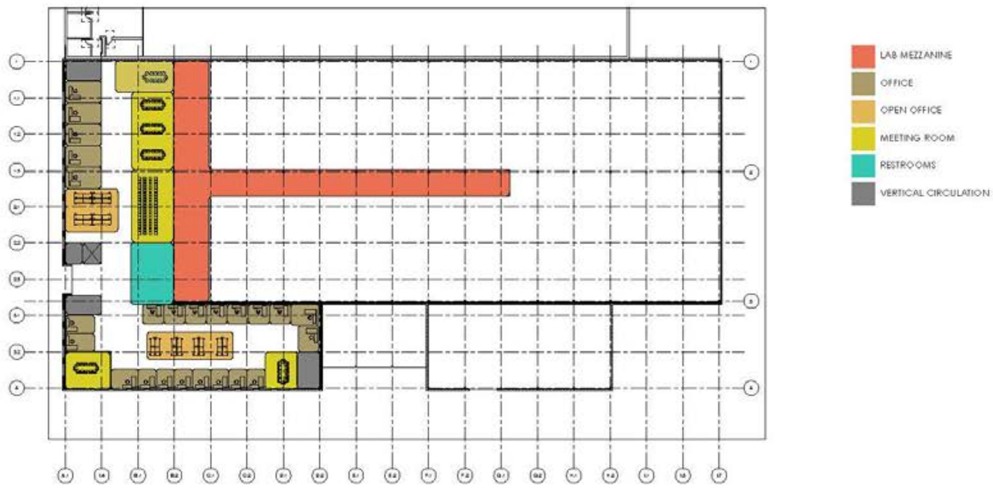
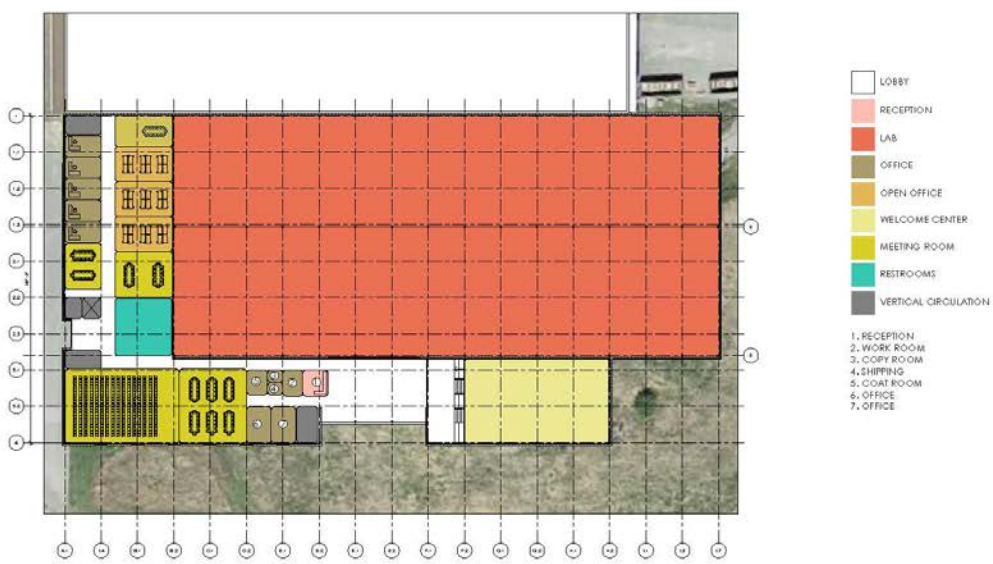
PRELIMINARY CONCEPT STUDIES



Early diagram plan - final concept - second floor



Early diagram plan - final concept - first floor

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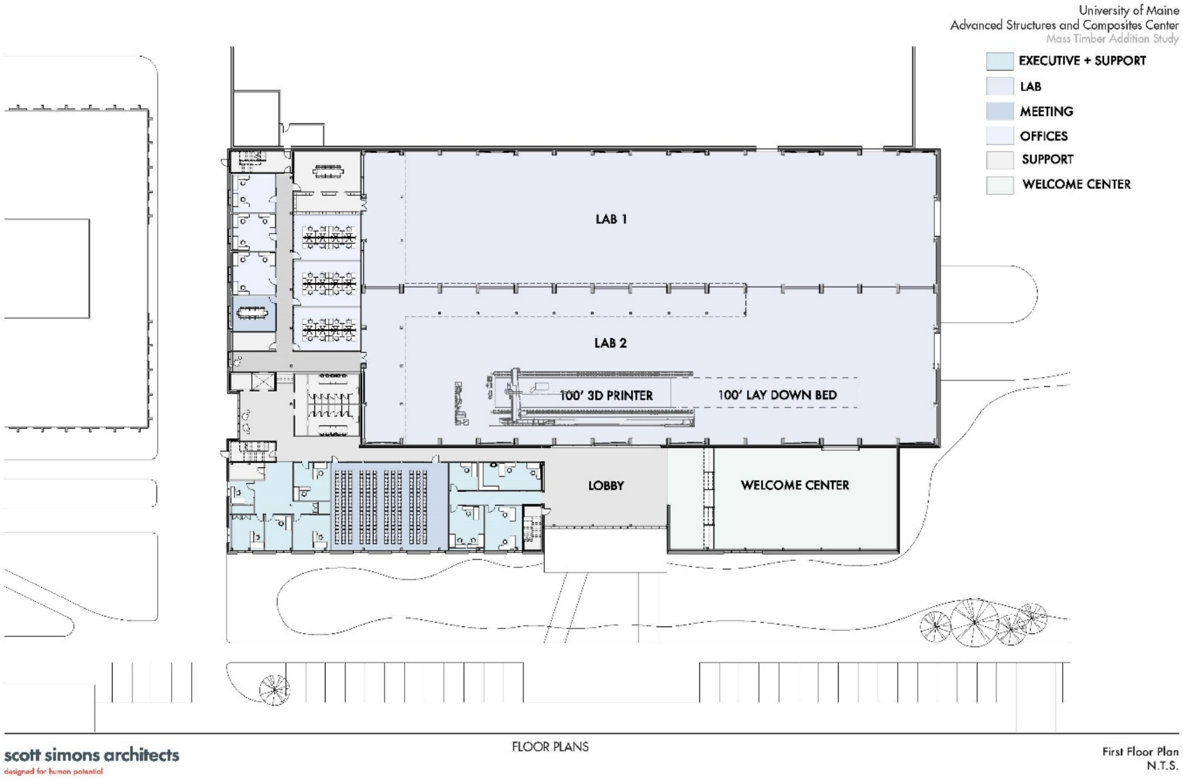
PRELIMINARY CONCEPT STUDIES

Concept development - section

Concept development


University of Maine
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Mass Timber Addition Study
EXECUTIVE + SUPPORT
LAB
MEETING
OFFICES
SUPPORT
WELCOME CENTER
LAB 1
LAB 2
100' 3D PRINTER
100' LAY DOWN BED
LOBBY
WELCOME CENTER
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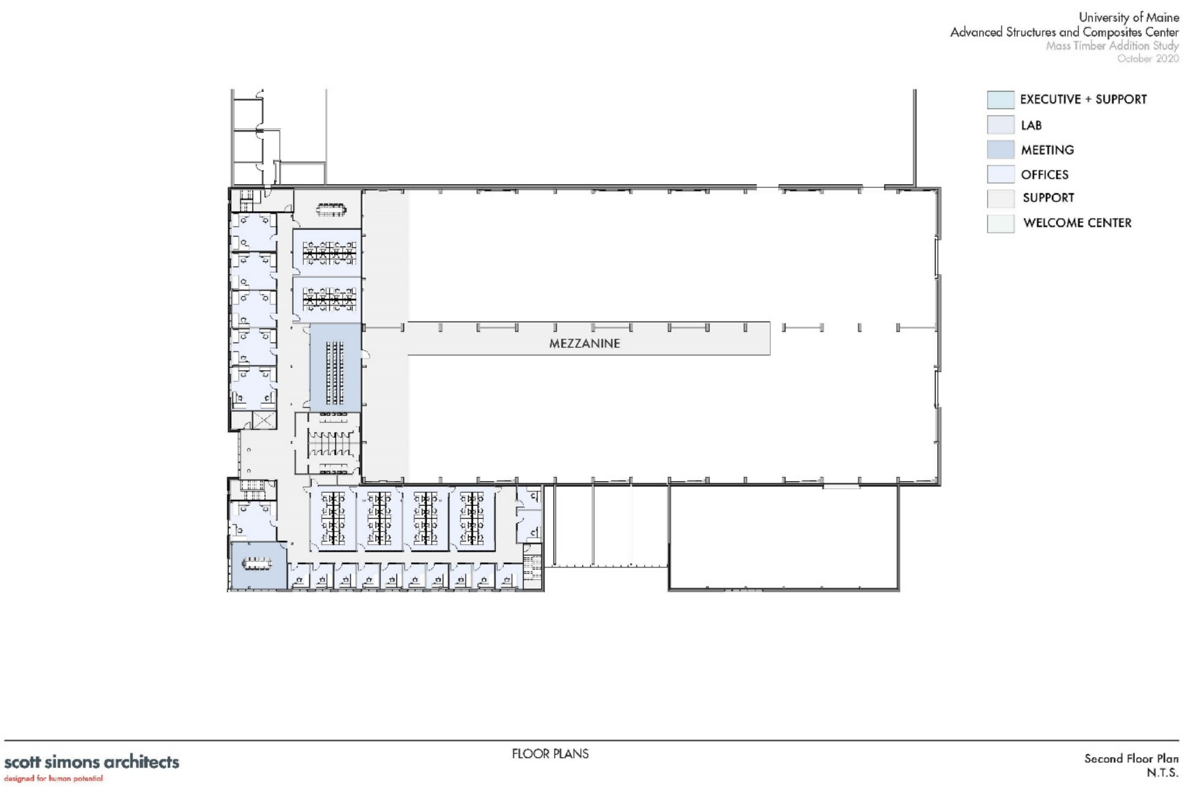
FLOOR PLANS
First Floor Plan
N.T.S.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Mass Timber Addition Study
October 2020
EXECUTIVE + SUPPORT
LAB
MEETING
OFFICES
SUPPORT
WELCOME CENTER
MEZZANINE
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FLOOR PLANS
Second Floor Plan
N.T.S.

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MODEL VIEWS AND BUILDING SECTION

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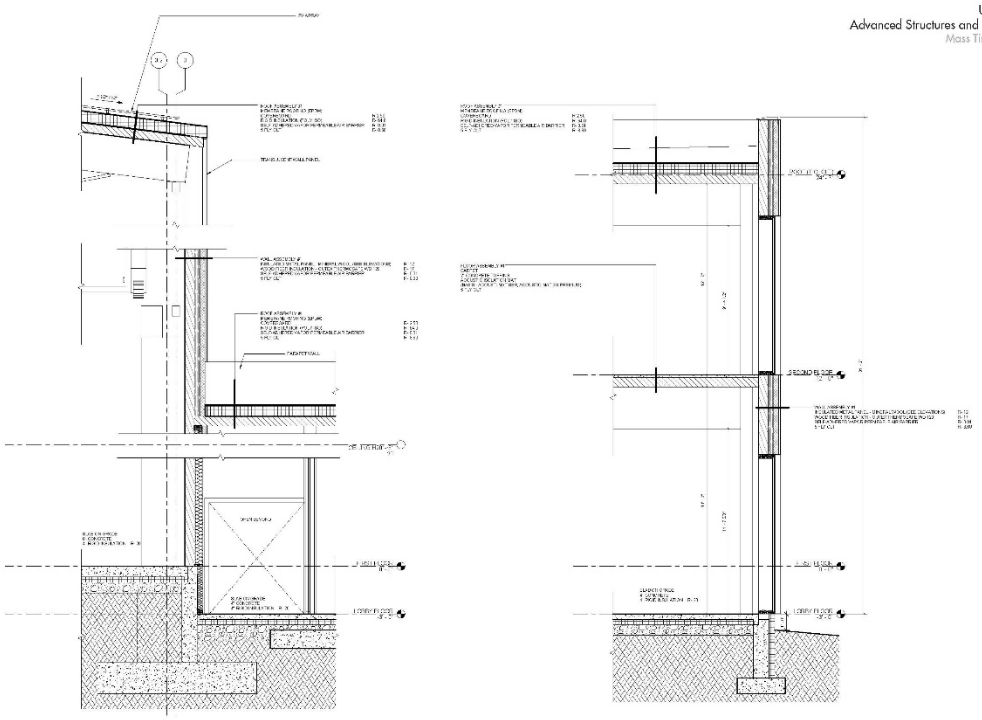

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WALL SECTIONS + ASSEMBLIES

MASS TIMBER STRUCTURAL SYSTEM

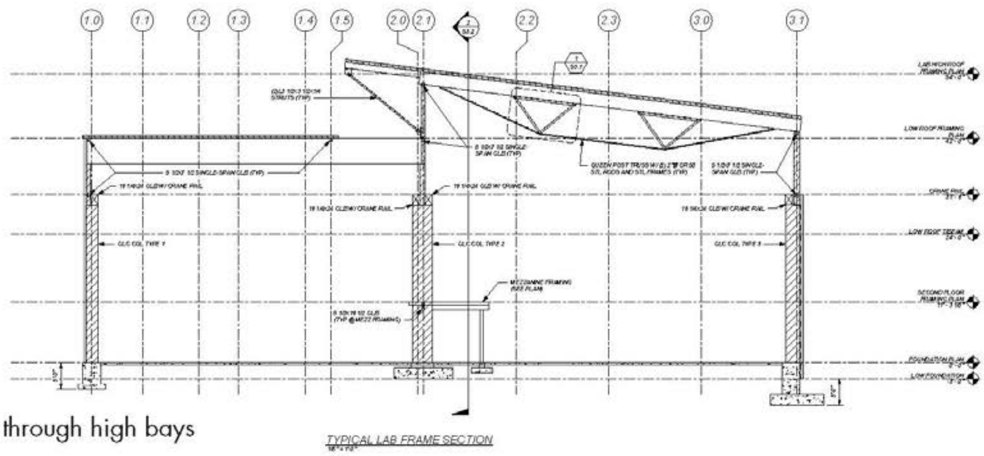
The mass timber structural system addresses numerous unique challenges, and incorporates a hybrid approach to most efficiently meet the demands of the long clear span structure and the lateral force resistive systems. The building design is organized around several major programmatic elements including; two large high bay industrial research spaces (approximately 260' x 60'), A large high bay display space, a secure public lobby, assembly space for approximately 250 people, and two stories of office and meeting spaces. The office wing is framed with glue laminated beams and columns with CLT cross laminated panels and 2" concrete topping at the floors and CLT panels at the roof. The display space and lobby roofs are framed similarly to the office wing. Each of the two industrial research and development high bays spaces takes an different approach to the clear span and has been designed to accommodate several heavy duty industrial gantry cranes. The south bay is designed to use a hybrid glulam and steel truss on its main space, while the north bay makes use of deep glulam beams for the clear span.

Please see the attached Conceptual Pricing Package drawings dated 7/8/20 for more detail information on the mass timber structural system

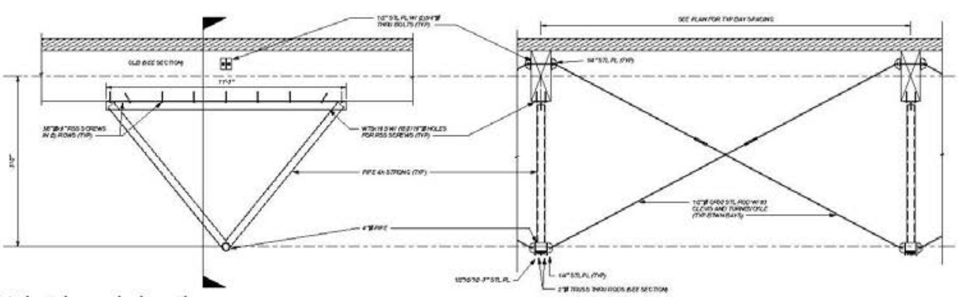
Cut away view highlighting various mass timber structural systems

University of Maine
Advanced Structures and Composites Center
Mass Timber Addition Study
October 2020

Cut away view highlighting various mass timber structural systems



Sections through high bays



Hybrid steel details

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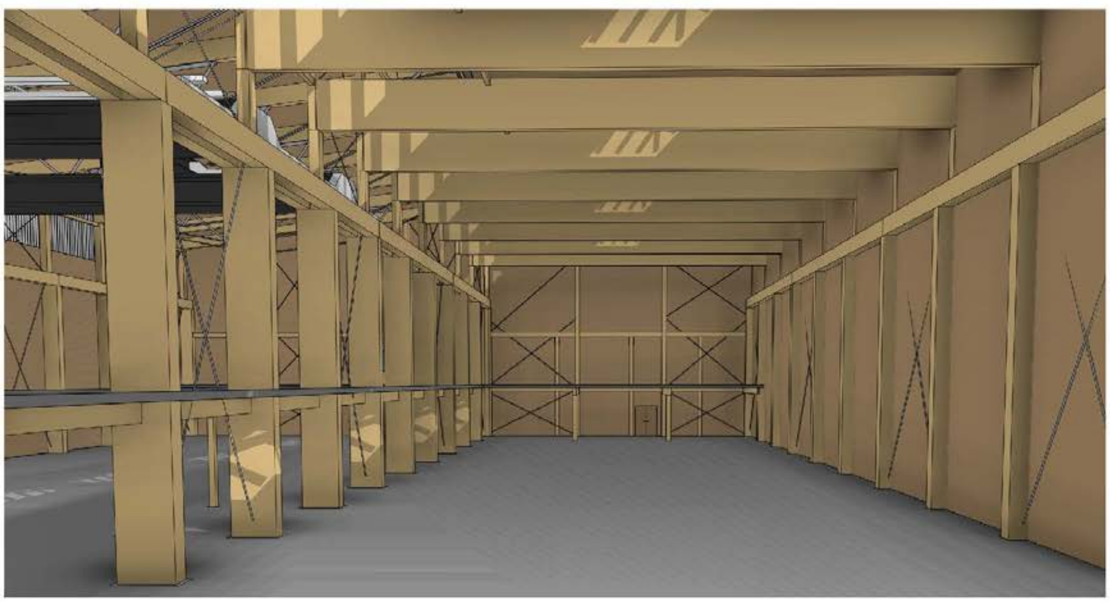
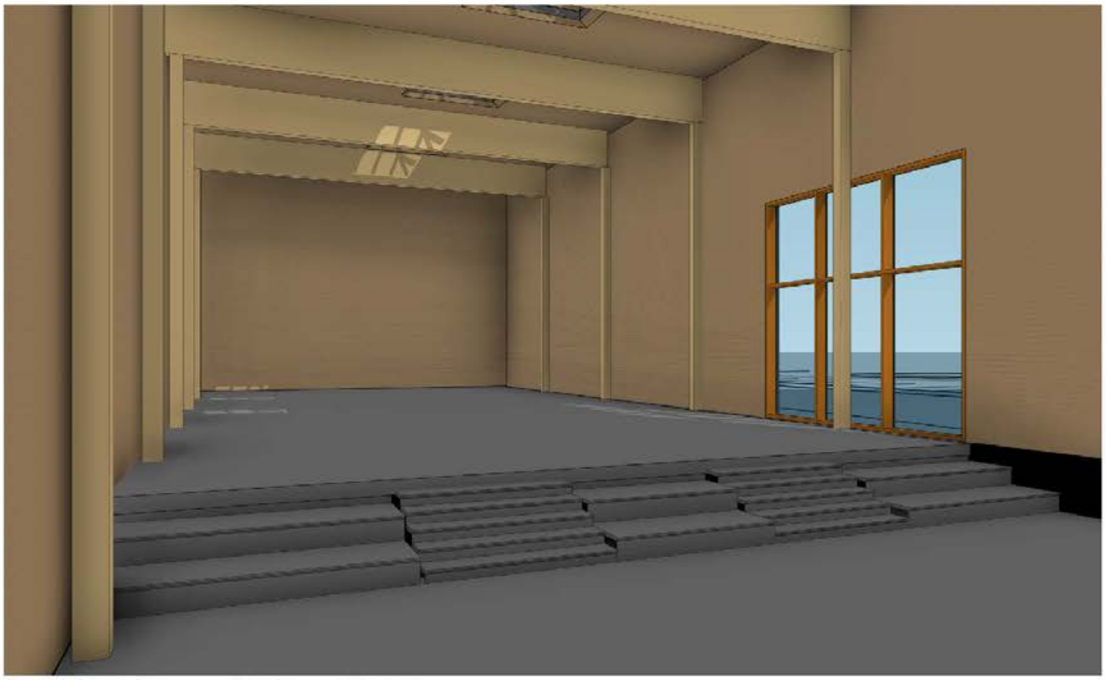
Mass Timber Structural System

View of South bay



View of North bay



View of Display area (Welcome Center)

View of Lobby

PRELIMINARY PROJECT BUDGET

The summary below is from the Consigli Construction Co. Inc, September 17th Conceptual Estimate. Additional information can be found in the full conceptual estimate included as an addendum to this document.

UNIVERSITY OF MAINE ASCC
MASS TIMBER CONCEPT ESTIMATE
SEPTEMEBR 17, 2020

Consigli Construction Co., Inc. is pleased to provide this opinion of probably cost to The University of Maine. We recommend that for addition of 78,500 Square Foot Advanced Structures and Composites Center, that you budget $28,400,000. The attached cost estimate dated 9/14/2020 is the basis of this opinion. Pricing is based on documents from Scott Simons Architects including 100% Conceptual Pricing Set dated 7/8/20 and Site Plans & MEP Narrative received 8/7/20. Cost Estimating

Methodology:
The cost estimating methodology is important to review in order to evaluate the potential sources of error in the cost assumptions. The cost estimate is broken down divisionally and our approach to pricing varies on a division by division basis. Three primary strategies for pricing the trade level costs include:
· Quantity Takeoff / Unit Price: Measured scope of work presented in design and use of historical unit prices. This method is used where the scope or quantity of design information is able to be defined and where the scope of work is well known in the local market due to our experience with procuring similar scopes of work.
· Quantity Takeoff with Subcontractor / Supplier product guidance: For specialty work such as the mass timber, we received supply pricing based on the documents provided. We utilized internal self perform erection numbers for the erection of the mass timber and received budgetary costs for the supply of the CLT floor, roof and wall systems only from SmartLam. We have received two budgets from Glulam vendors for the Glue laminated Timbers elements, and have checked those numbers against historical costs.
· Comparable Project Costs: Where a design did not exist for the scope of work, we utilized gross square footage comparable costs from projects that we have recently procured or set Guaranteed Maximum Prices on. For these scopes of work, we have used educated guesses at modifying the gross square foot cost to modulate the pricing to a predicted use based on the program presented.

PRELIMINARY PROJECT BUDGET

Assumptions & Areas for Clarification:
Items below have been refined in the estimate since our issued draft dated August 19, 2020
· Div 6 – We received pricing on the glulam beams and columns from two vendors and have updated the value carried for that work.
· Div 7 – We have continued to carry an allowance for intumescent paint is included as it is assumed required at some locations of exposed steel hardware.
· Div 7 – Fire separation between the new and existing building has been clarified by SSA. We have carried a fire rated assembly wall and have included a painted drywall surface at the interior side of the new addition and have included the assumption that the exterior wall of the existing building will be removed in order to construct the assembly specified by SSA in order to connect the fire separation wall with break away aluminum connections.
· Div 23 – Dedicated exhaust and fume hoods are excluded as it is assumed none are required. No material science lab spaces are shown.
· Div 26 – PV Array is shown at the sloped roof on the elevations and sections. A $10/SF allowance is included. Limitations / Use of Cost Data:
· The pricing presented is developed with the primary goal of evaluating the design's total construction cost. We see a number of cost savings opportunities but also understand at this early stage, features may not yet be included in the drawings and have carried contingencies for design progression in the overall budget.
· Soft Costs are not included, the University Facilities Department are expected to be consulted to add to this construction cost items such as Design Fees, Furniture, Fixtures and Equipment, along with legal, fundraising and non-construction related costs in order to target a "Total Project Cost".
· The costs are presented are based on March 1, 2020 pricing. We have not included escalated costs of lumber that has recently significantly risen, but that we feel will settle back to historical rates in the coming months.

COVID-19 impacts:
We are in a tumultuous time in the economy we have not yet seen the longterm impact that the COVID-19 virus will have on the design and construction market.

We have not applied a cost penalty due to the impacts from COVID-19 on the construction operations.

We have not applied a cost factor for any future changes that may result from changes required in design codes, standards or any macro-economic affects driven by the pandemic. It is possible that economic impact to the construction markets could drive subcontractor and supplier prices down or up in the future.

PRELIMINARY PROJECT BUDGET

Alternative Procurement:
We have included in the pricing, the assumption that a mass timber vendor will be engaged at the early stages of design in order to complete the required early coordination efforts inherent in a prefabricated timber floor plate and shear wall system. This early procurement is required in order to achieve the schedule advantage and will likely include early stage Alternative Procurement prior to the completion of construction documents. Alternative Procurement is defined as selecting a trade contractor on either a

Design Assist Basis or a Design/Build basis prior to the design team completing Construction Documents. The reason this alternative procurement method is required in order to achieve the savings predicted in cost and schedule on the mass timber option are as follows:

1. Early procurement of Mass Timber is required due to the lack of a sufficient local market (as of Q2 2020) in the Northeast, for the supply of Cross Laminated Timber and Glued Laminated Timber, selection of a supplier is required earlier in the design phase than for a structural steel and concrete structure in order to achieve the schedule and cost savings predicted in this study.

2. The early mass timber procurement (at 50% DD) could provide more savings / advantages. (the source of the predicted cost savings is two-fold – a 4 to 8 week shorter overall construction duration along with the reduction in winter conditions costs – due to the ability to erect the superstructure without having to enclose and heat for the placement of the structural concrete slabs in the structural steel option).

a. This additionally provides a hedge against long distance procurement risk, cross border delivery delay risk, and the potential for Non-US based structural products that will need to be re-specified if European products are chosen.
b. Procuring and advancing the fabricator's design details for the mass timber elements allows for more efficient design and allows for an earlier start in the structural coordination with MEP trades.
c. Earlier procurement of the mass timber will allow more flexibility in choosing the species of mass timber product for the project, which can have an effect on sizing, aesthetics, and production lead time. (Choices between Southern Yellow Pine, Spruce (SPF South), Black Spruce and European Spruce can have an affect on how the timber vendor is selected and the ultimate size and detailing of project)

3. Early procurement of MEP trades allows for the precise dimensional coordination requirements of mechanical, electrical, plumbing penetrations in the mass timber beams, floor plates and shear walls. Timing of MEP procurement should be targeted at the Design Development completion stage in order to provide for an organized coordination effort for the timber material.

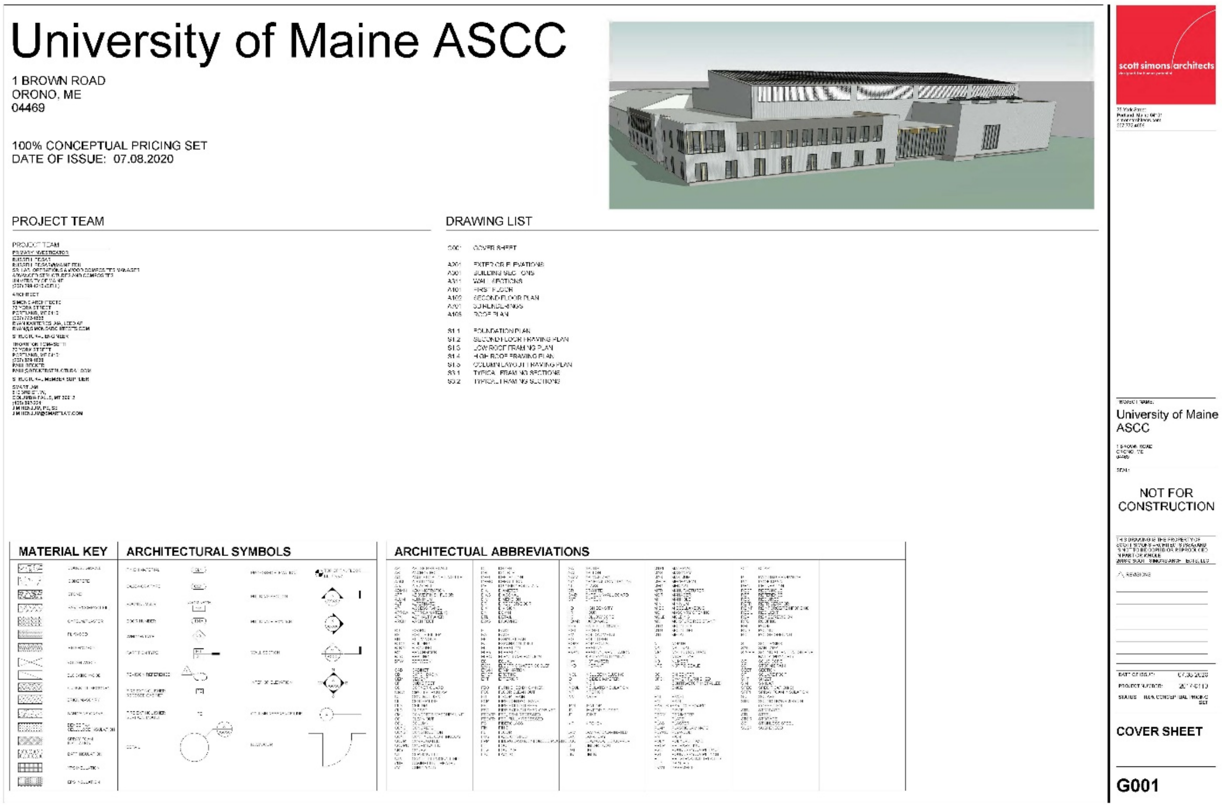
APPENDIX

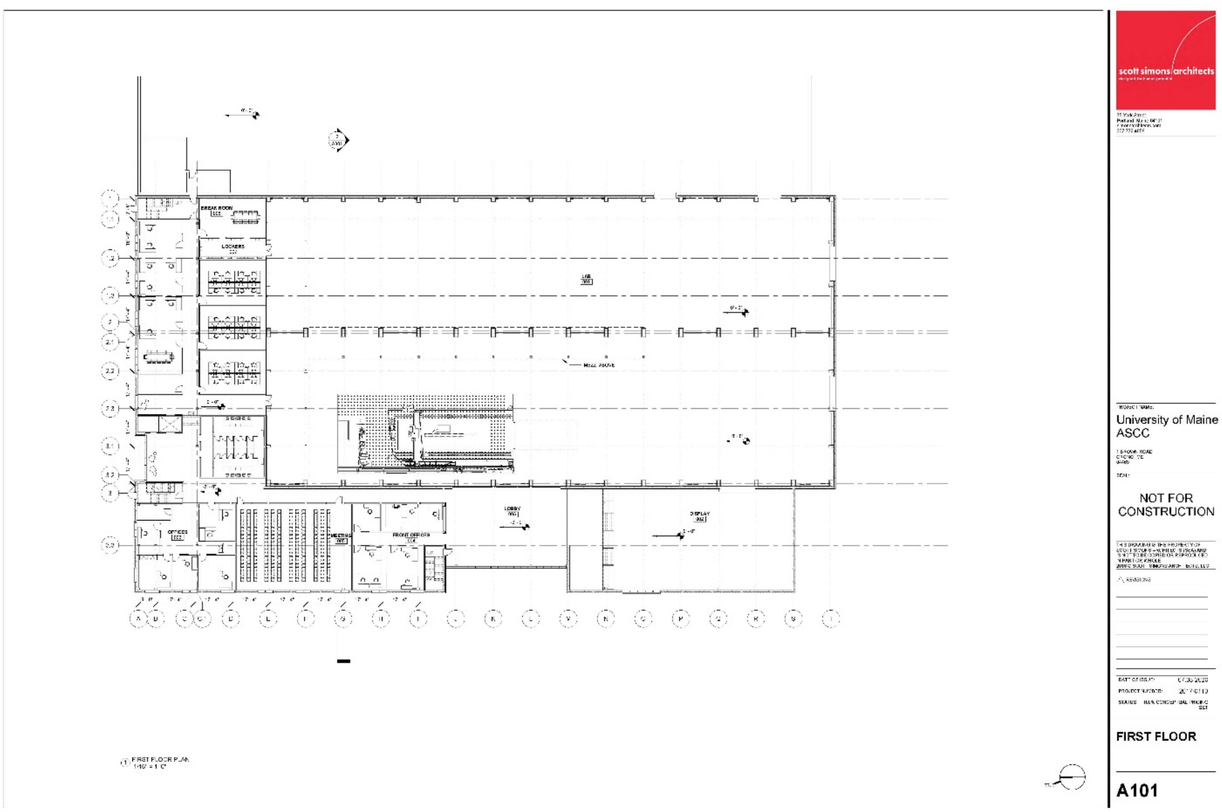
List of Meetings

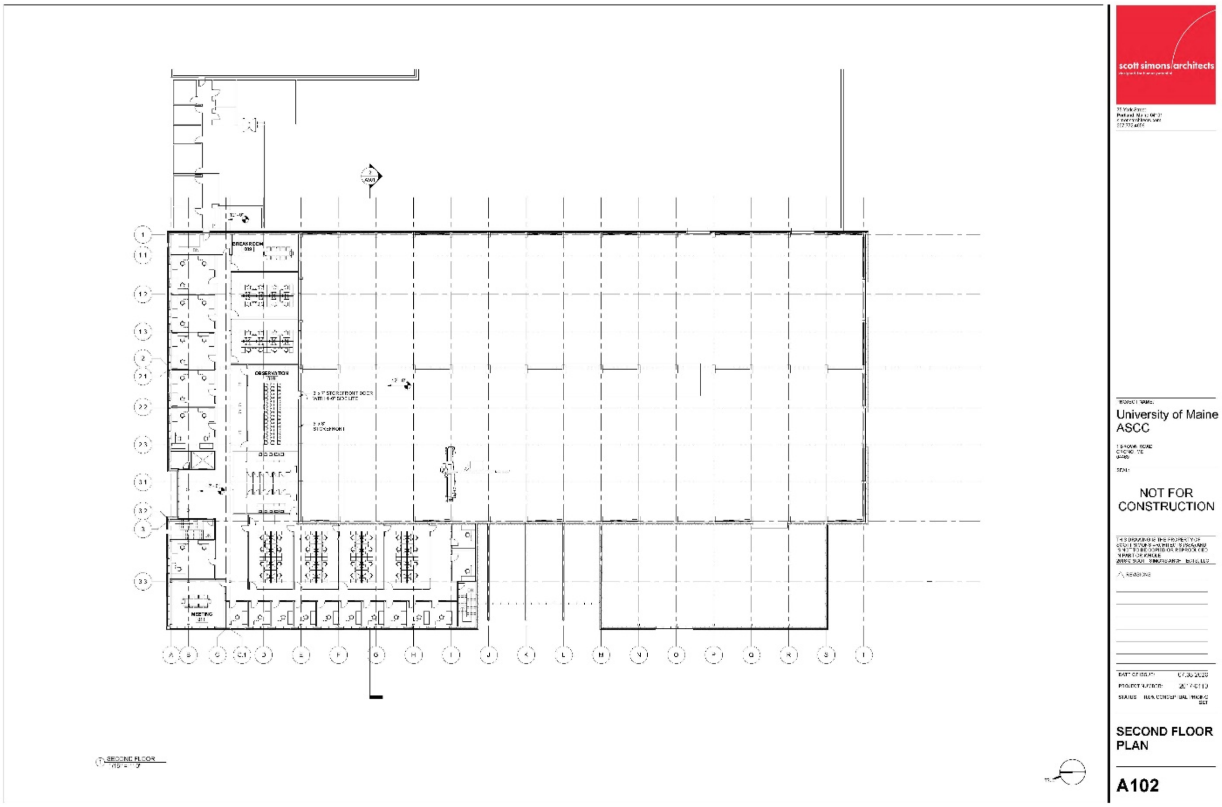
September 20, 2019	Kick off Meeting
October 18, 2019	Meeting #2
November 15, 2019	Meeting #3
December 17, 2019	Remote progress Review
January 20, 2020	Meeting #4
February 25, 2020	Campus Wetland Review
July 29, 2020	Pricing Package Deliverable Review

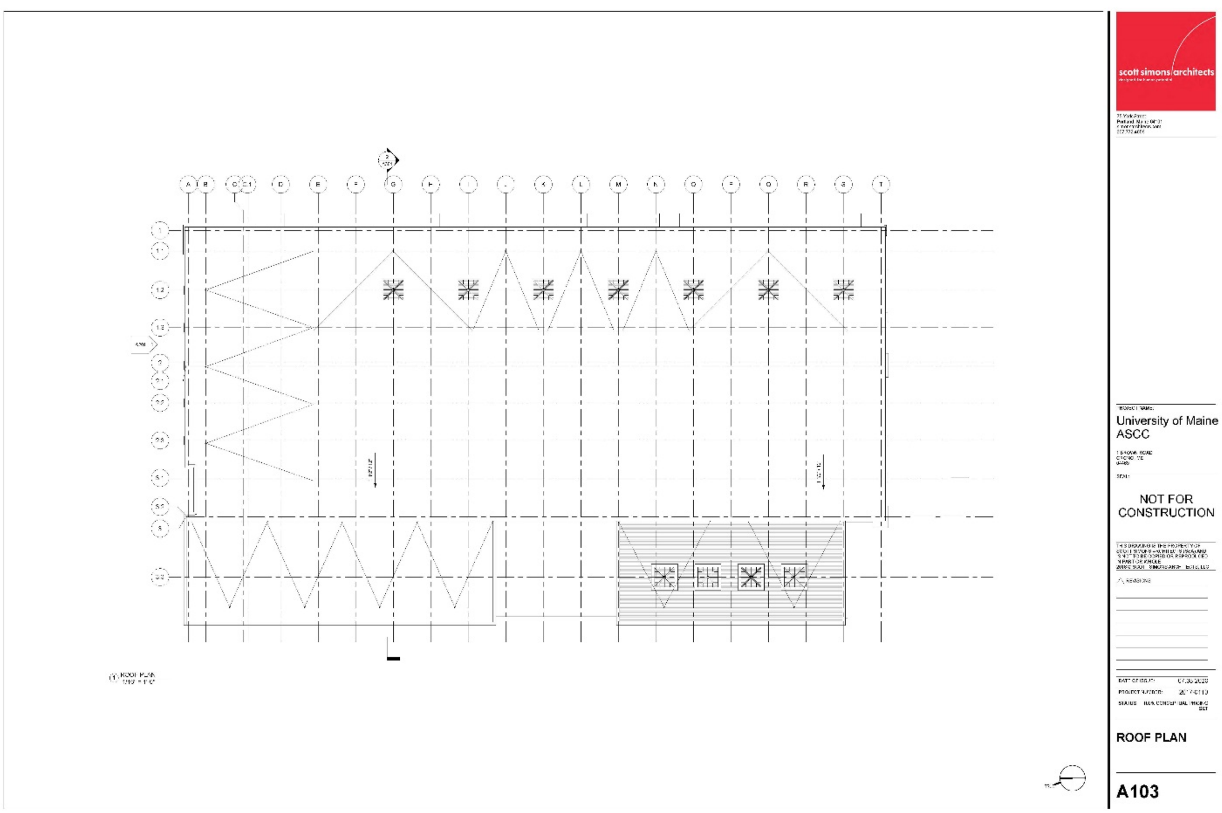
APPENDIX

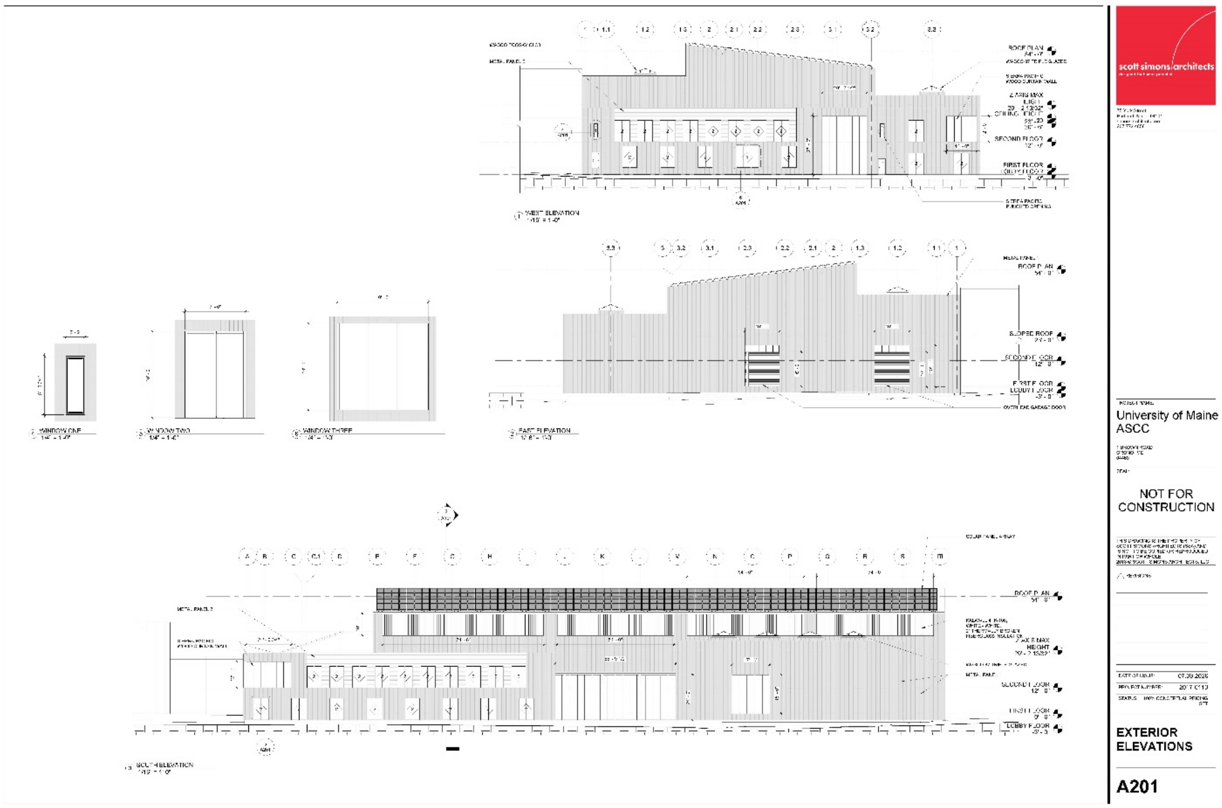
Conceptual Pricing Package dated 7/8/20


University of Maine ASCC
1 BROWN ROAD
ORONO, ME
04469
100% CONCEPTUAL PRICING SET
DATE OF ISSUE: 07.08.2020
PROJECT TEAM
DRAWING LIST
MATERIAL KEY
ARCHITECTURAL SYMBOLS
ARCHITECTUAL ABBREVIATIONS
scott simons architects
University of Maine ASCC
NOT FOR CONSTRUCTION
COVER SHEET
G001


scott simons architects
University of Maine ASCC
NOT FOR CONSTRUCTION
FIRST FLOOR
A101


scott simons architects
University of Maine
ASCC
NOT FOR
CONSTRUCTION
SECOND FLOOR
PLAN
A102


scott simons architects
University of Maine
ASCC
NOT FOR
CONSTRUCTION
ROOF PLAN
A103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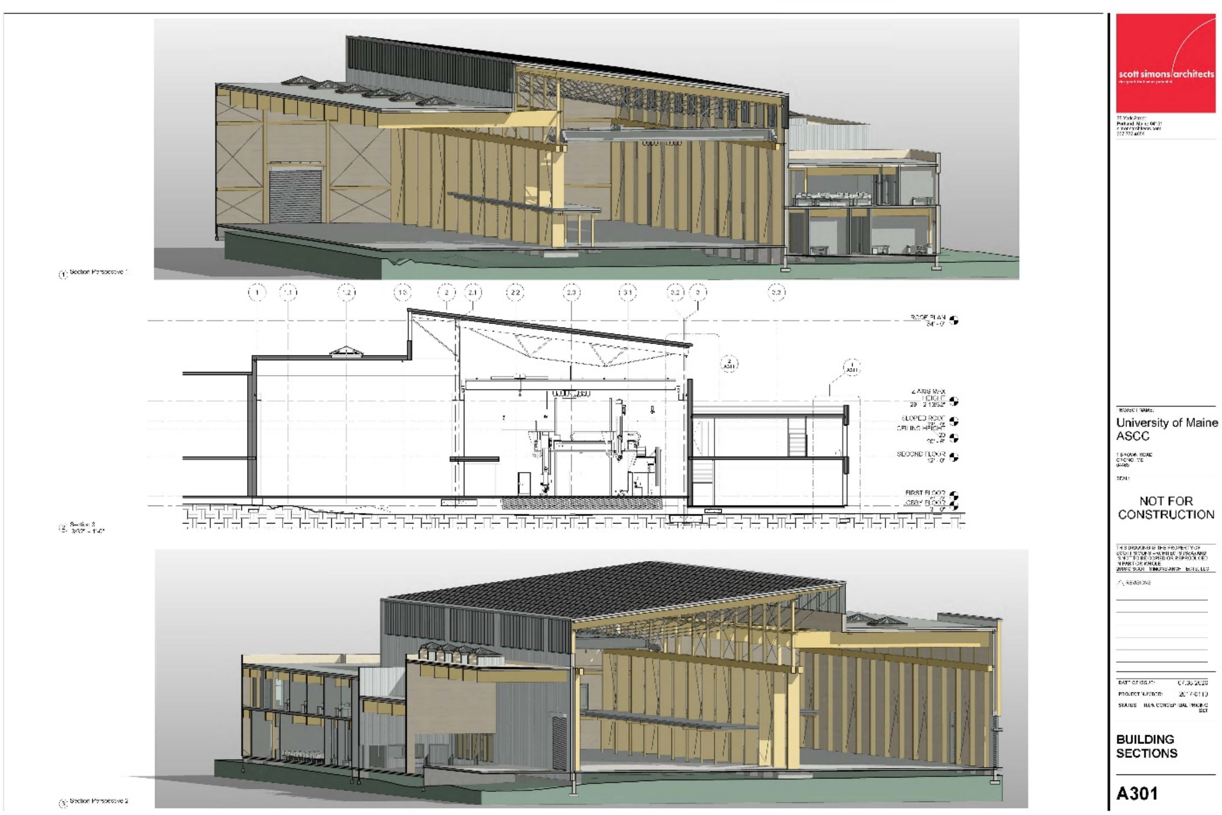
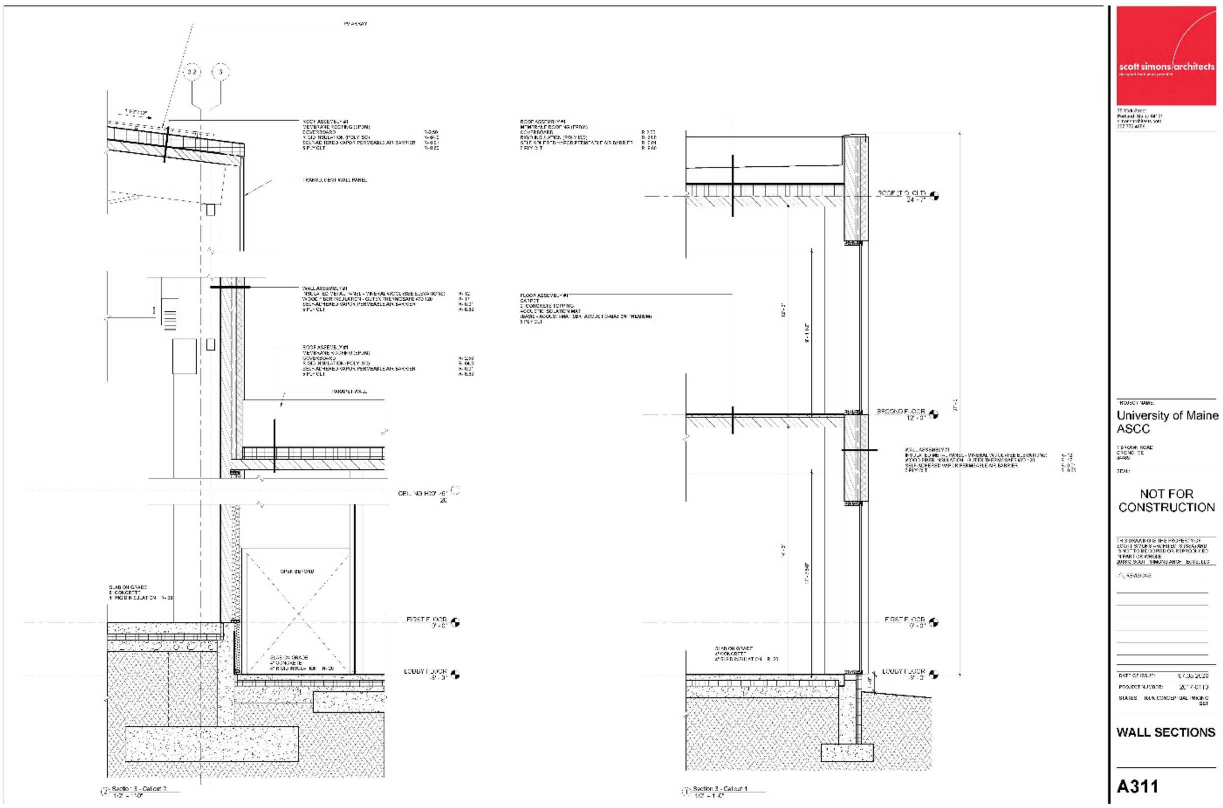
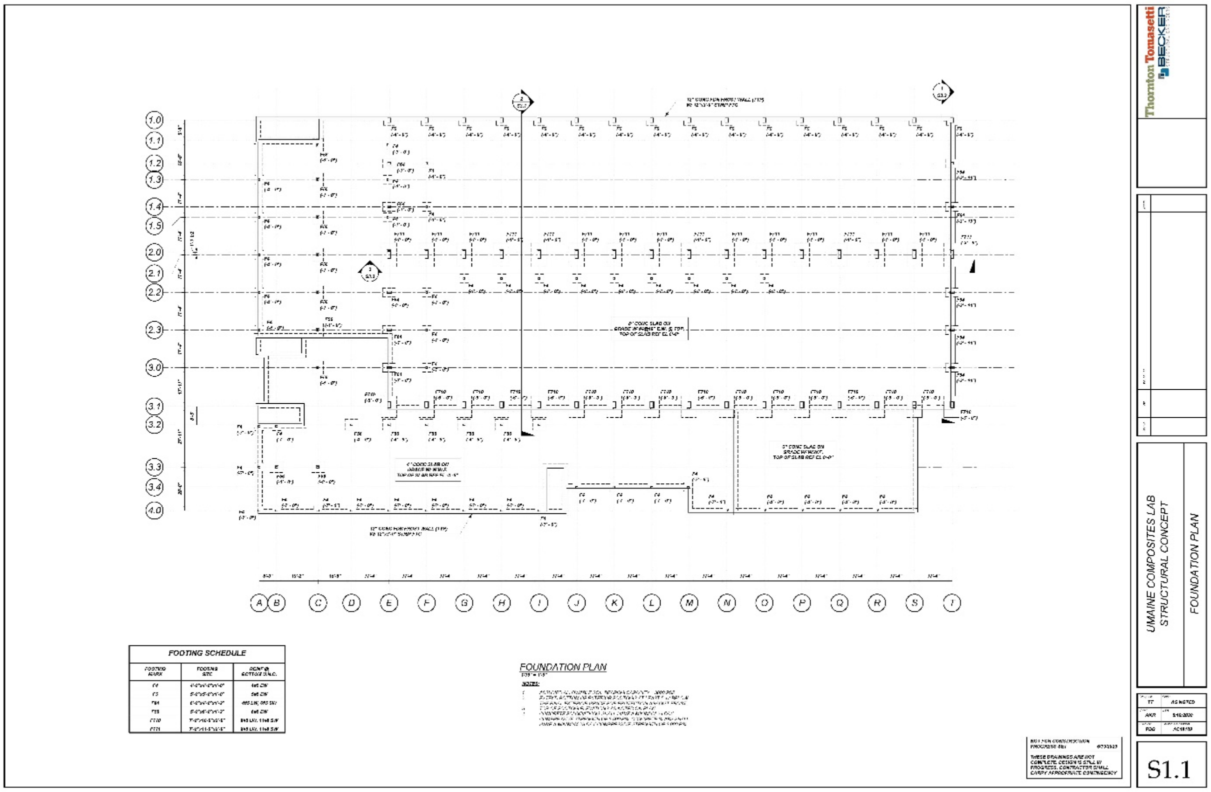
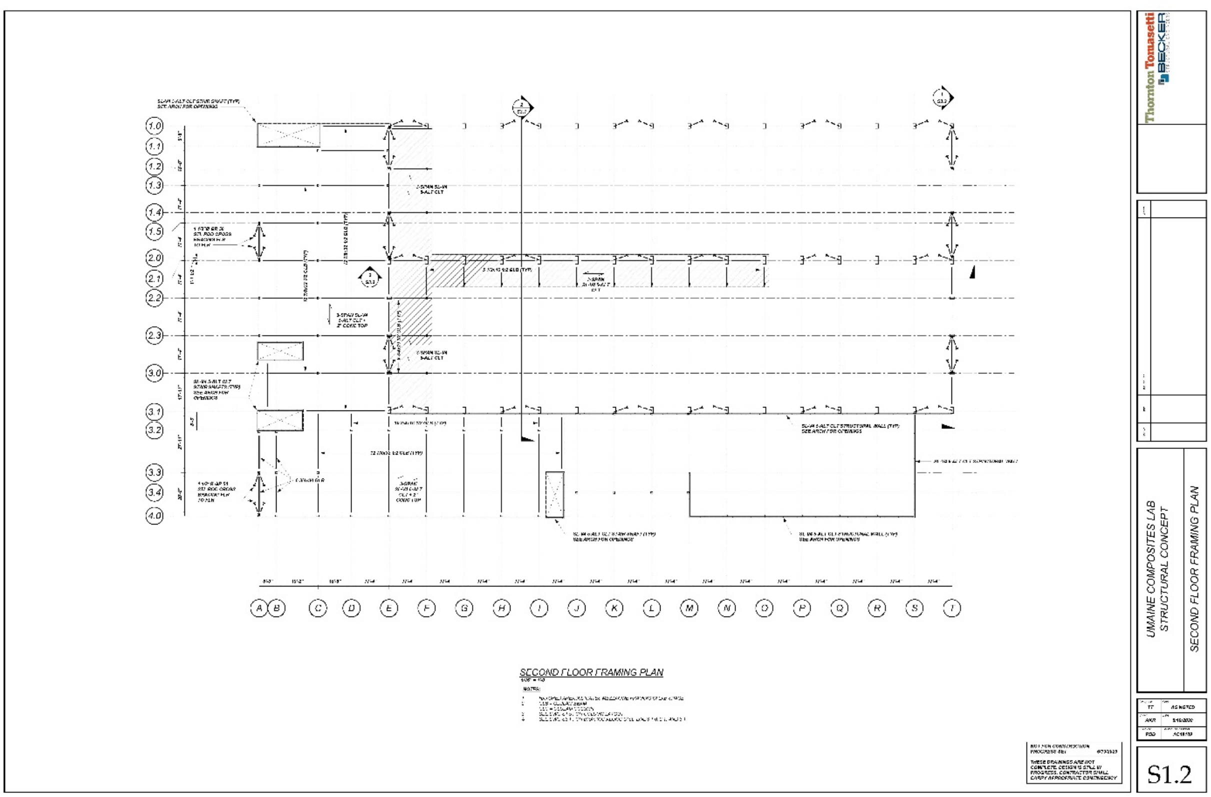
ASCC
NOT FOR
CONSTRUCTION
EXTERIOR
ELEVATIONS
A201

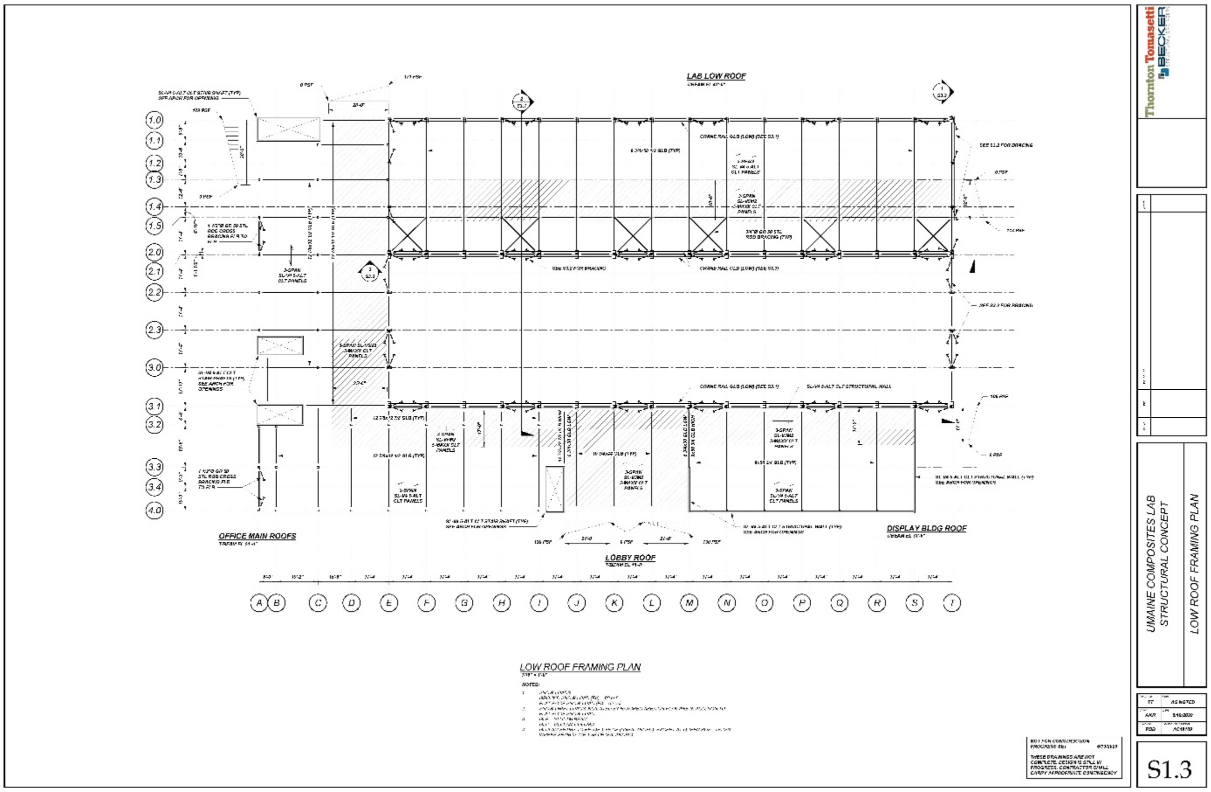

scott simons architects
University of Maine
ASCC
NOT FOR
CONSTRUCTION
BUILDING
SECTIONS
A301

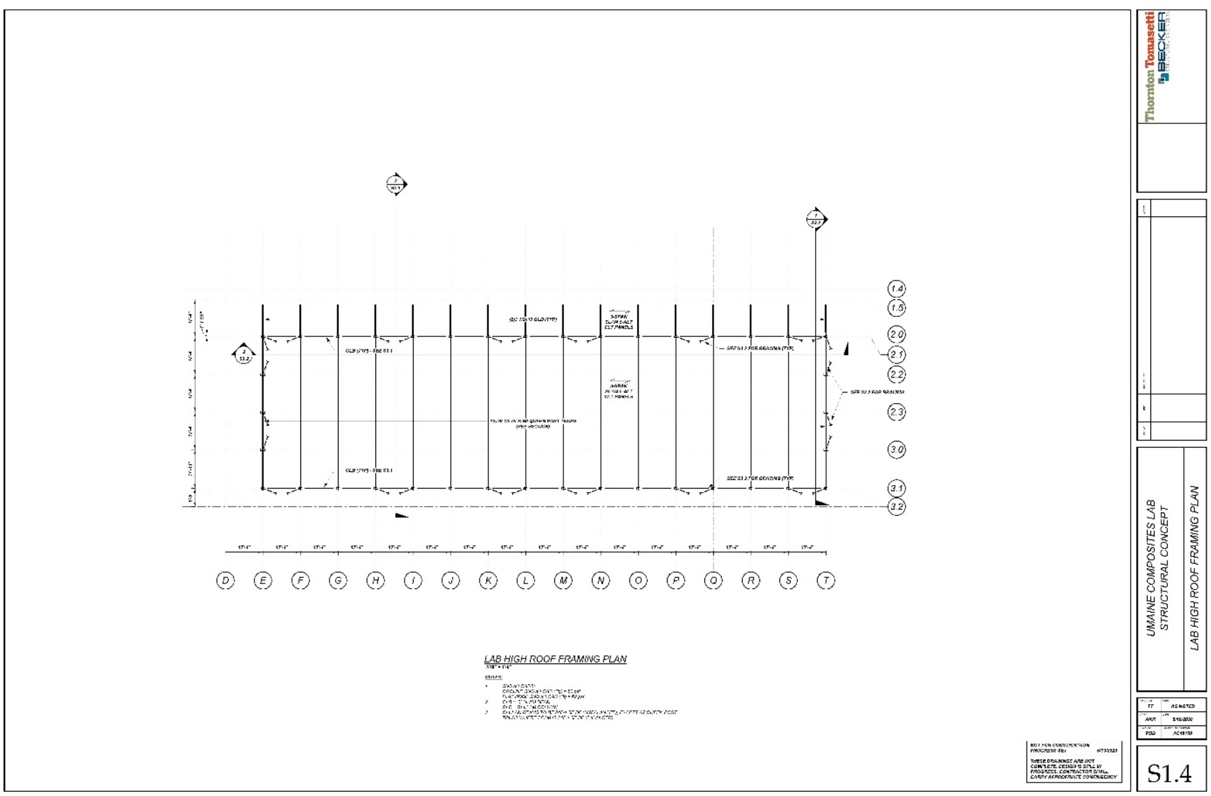

scott simons architects
University of Maine
ASCC
NOT FOR
CONSTRUCTION
WALL SECTIONS
A311

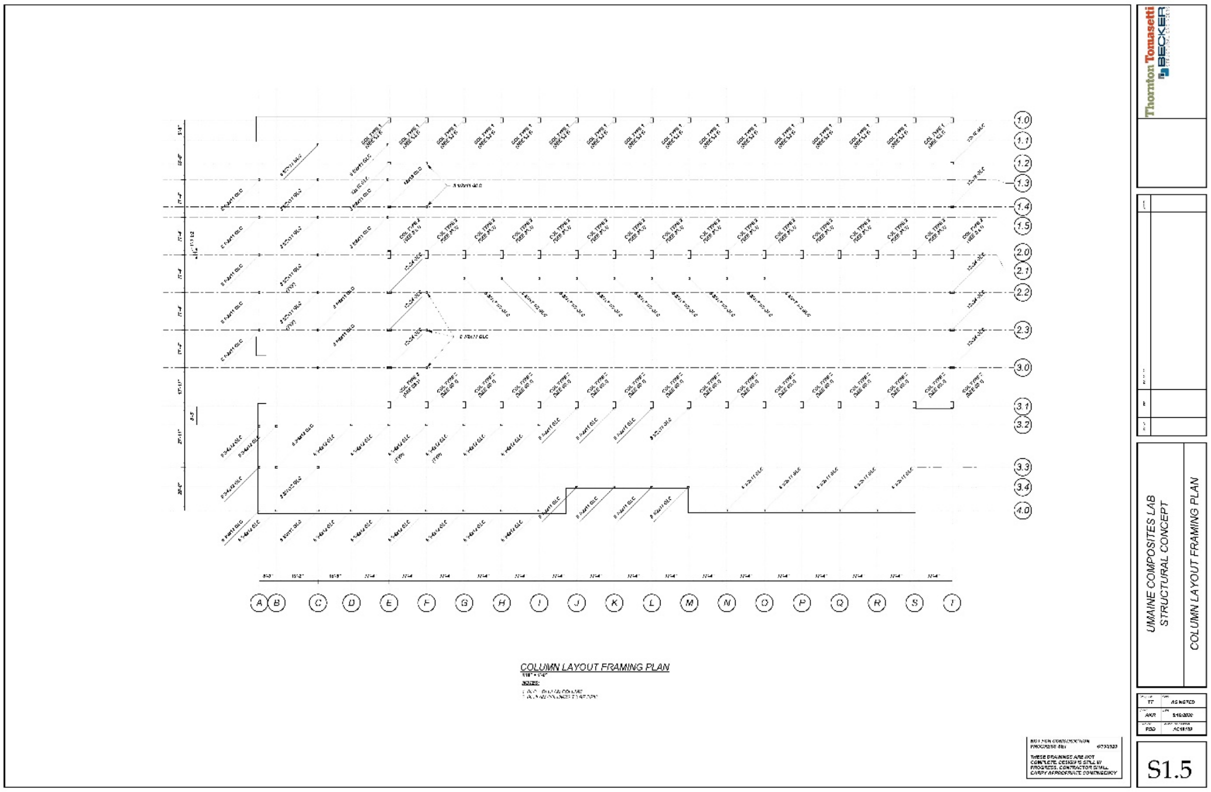

scott simons architects
University of Maine
ASCC
NOT FOR
CONSTRUCTION
3D RENDERINGS
A701

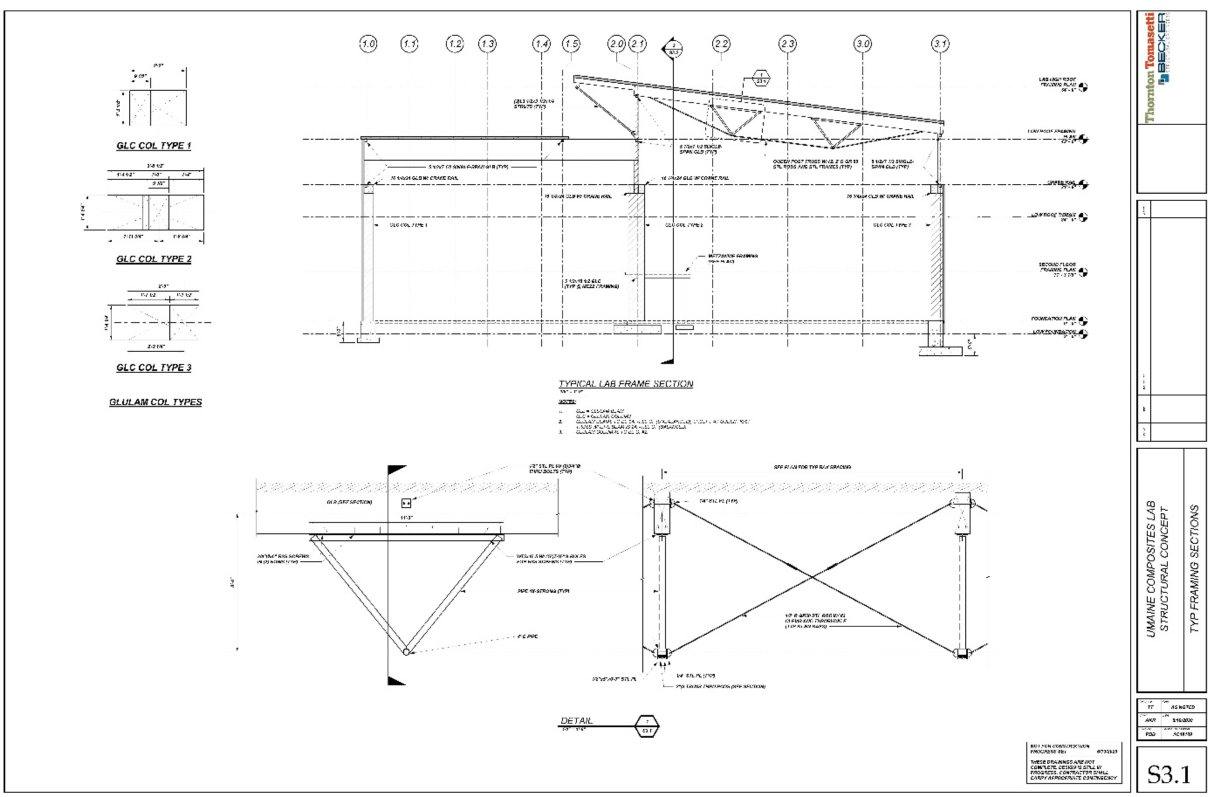

Thornton Tomasetti
BECKER
UMAINE COMPOSITES LAB
STRUCTURAL CONCEPT
FOUNDATION PLAN
FOOTING SCHEDULE
FOUNDATION PLAN
S1.1

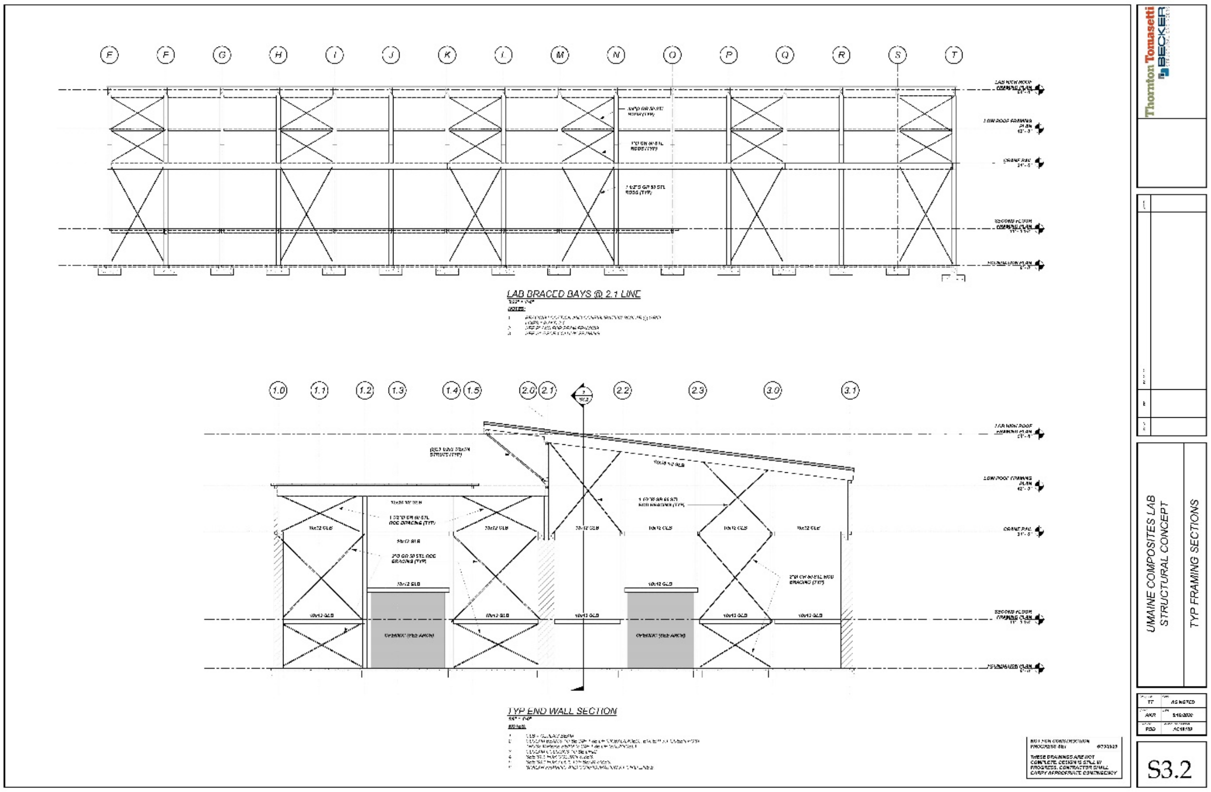

Thornton Tomasetti
BECKER
UMAINE COMPOSITES LAB
STRUCTURAL CONCEPT
SECOND FLOOR FRAMING PLAN
SECOND FLOOR FRAMING PLAN
S1.2


LAB LOW ROOF
OFFICE MAIN ROOFS
LOBBY ROOF
DISPLAY BLDG ROOF
LOW ROOF FRAMING PLAN
Thornton Tomasetti
BECKER
UMAINE COMPOSITES LAB
STRUCTURAL CONCEPT
LOW ROOF FRAMING PLAN
S1.3


LAB HIGH ROOF FRAMING PLAN
Thornton Tomasetti
BECKER
UMAINE COMPOSITES LAB
STRUCTURAL CONCEPT
LAB HIGH ROOF FRAMING PLAN
S1.4


Thornton Tomasetti
UMAINE COMPOSITES LAB
STRUCTURAL CONCEPT
COLUMN LAYOUT FRAMING PLAN
COLUMN LAYOUT FRAMING PLAN
S1.5


Thornton Tomasetti
GLC COL TYPE 1
GLC COL TYPE 2
GLC COL TYPE 3
GLULAM COL TYPES
TYPICAL LAB FRAME SECTION
DETAIL
UMAINE COMPOSITES LAB
STRUCTURAL CONCEPT
TYP FRAMING SECTIONS
S3.1


LAB BRACED BAYS @ 2.1 LINE
TYP END WALL SECTION
Thornton Tomasetti
BECKER
UMAINE COMPOSITES LAB
STRUCTURAL CONCEPT
TYP FRAMING SECTIONS
S3.2

APPENDIX

Supplemental Mechanical Narrative

Heating/Cooling & Ventilation Options

MEP systems are expected to be standalone and separate from existing lab.
HVAC can tie into existing campus steam for heating (which will still be considered as an alternate option).
Investment in point source ventilation for 3D printer will be of a significant long term benefit eliminating odors and pollutants directly while minimizing energy wastage from not exhausting from larger conditioned volume.
Main Lab – Space will be tempered and not conditioned for tight comfort setpoints (to maintain temperature and humidity)

Option 1: Chiller/Heater

Plant: A chiller heater can produce hot water and chilled water and take advantage of simultaneous heating and cooling loads by simply transferring energy from one side to the other side. The offices are equally spread between perimeter and core of the footprint which results in simultaneous heating and cooling. This plant could tie into the campus steam or have a stand-alone boiler (electric or natural gas). It provides flexibility to make the building all-electric, if desired. A cooling tower may be necessary depending on MEP's load calculations.

Air Distribution: A displacement ventilation system, where the air is delivered within occupied zone (6-8 ft from the finished floor) is very efficient for large volume spaces. It conditions just the volume where occupants are. The cold air stays where occupants are (cooling mode). The diffusers (supply and return) can be located appropriately to help with destratification. Where height restrictions allow (other side of the 3D bay), a large fan (Big Ass Fans) can gently move the air during heating mode. Offices can be served with fan coil units (four -pipe on the perimeter and two- pipe in the core zones). A 100% outside air system with high-efficiency heat recovery can provide needed ventilation. A Demand Control Ventilation strategy will help to dial down the ventilation as occupant density varies and minimize wastage of energy for cooling, heating and dehumidification.

Option 2: Chiller/Heater

Plant: Campus steam produces hot water while a magnetic bearing air cooled chiller produces chilled water.

Air Distribution: Same system as in Option 1

Option 3: Hybrid VRF
Scot Simons mentioned some reservations with a VRF system due to refrigeration needs and maintenance issues. However, there's an innovative technology that centralizes the refrigeration cycle and produces hot and chilled water. It is called Hybrid VRF. This is a new technology (at least in the USA) from Mitsubishi so depending on UMaine's comfort level to adopt a new technology it could be considered or eliminated. More info provided here: (http://library.mitsubishielectric.co.uk/pdf/directory/air_conditioning/sales_literature/product_brochures)

Plant: Heat recovery Variable Refrigerant Flow system (VRF)

Air Distribution: Similar to Option 1

Special Considerations:

Lab Area

Option 1: Heat pipe recovery system for ventilation to prevent cross contamination (operates at ~50% efficiency)

Option 2: Cascading ventilation system (operates at ~70-80% recovery effectiveness). 3D printer will borrow heated air from adjacent spaces or from the return air.

Overhead doors: Provide air curtains to minimize exfiltration.

Main Lab consists of all slab-on-grade

There may be potential to consider radiant hydronic heating of slabs in the perimeter of the Lab space or in Office/Display spaces. There is concern for potential damage to the hydronic systems from machinery. However, perimeter areas where such concerns do not exist could be considered.

Hydraulic testing is being conducted to assess extra strength opportunities due to size and weight of objects to be 3D printed

Big Ass Fans could be considered for air circulation where feasible. Areas with large roof cranes and booms may not be suitable to accommodate these fans.

 COVID Considerations:

Emphasis on demand control ventilation, increased mechanical ventilation and strategic location of air delivery and return grilles for improved air circulation for rooms with 8 persons or more.
This is less of an issue with the large Lab space.

Power Source—Fossil Fuel vs Electric Potential

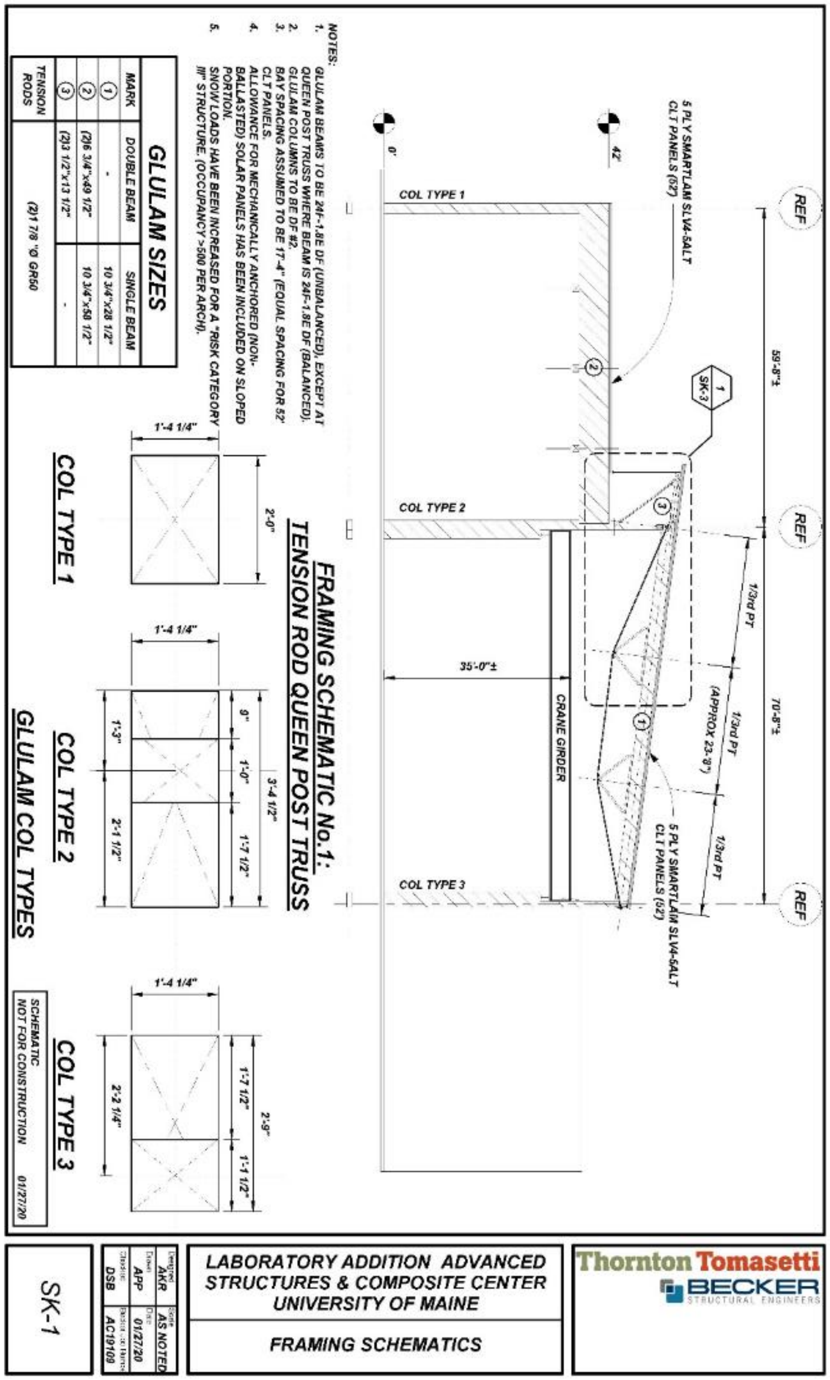
Net Zero Potential – the project has significantly robust low carbon goals designing an all-electric or partially electric building (just for the office wing)
Maine's progress/ potential for grid decarbonization requires further exploration to evaluate the carbon advantages/ disadvantages with an electric vs district steam heated system, TT to explore this.
The circular economy narrative for C1-C4 End-of-Life and D Reuse, Recovery
& Recycling LCA stages should take into account the service life and replacement horizon for MEP systems to determine carbon advantages/drawbacks of specific systems.
Building is adjacent to a district steam and gas line so interest may be in utilizing existing lines (Consultation with UMaine Facilities Dept may be needed)
District heating steam system runs at ~40-60% efficiency, this overall inefficiency will have a considerable negative carbon impact
A standalone system will provide greater control for future maintenance
Environmental and life cycle cost considerations with fossil fuel vs all-electric system:
Safety and availability of refrigerants impacts the longevity of the system – district heating or all electric

The typical service life for a building is 60 years before significant maintenance is required, consider the useful lifespan of the building and impact of maintaining or updating a central (district heat) vs standalone (electric) system

Operating Schedules

Meeting space - Anticipated to be used 2x per week, this is not an everyday classroom.
Main Lab: Normal building hours anticipated, at full capacity year -round to support summer grant research in addition to typical school year studies.
Lighting
LED high bay lighting to be used in lab with potential for automatic lighting control sensors to adapt to daylight from window and skylights.
Wall Assemblies
Thermal insulation value should be identical throughout.
Wall assemblies are comprised of insulated metal panels (mineral wool – R12)and wood fiber insulation (R 17 at 4.5 in) with 5 ply CLT panels;
Roof assemblies consist of EPDM membrane and polyiso rigid insulation (R64 at 8 in) with 5 ply CLT
Insulation choices greatly affect the carbon footprint of the building in terms of embodied carbon and operational carbon emissions. Limit the use of spray foams wherever possible as this is a carbon intensive material and is a significant contributor to a building's carbon footprint
Wall between existing and new lab addition is concrete masonry with 1 in gypsum panels and a 3-hour rating.
Slabs anticipated to be fully insulated slab with a preference of EPS over XPS XPS has considerable off gassing and thermal insulation potential / R value drops over time, EPS is a better long-term environmental option and maintains R value
PV array on roof – further inquiry into whether panels are anticipated to be polycrystalline or monocrystalline as the two have opposing carbon impacts
Tesla PV tiles are known to have some of the best performance in the industry; TT to provide additional information for consideration

APPENDIX B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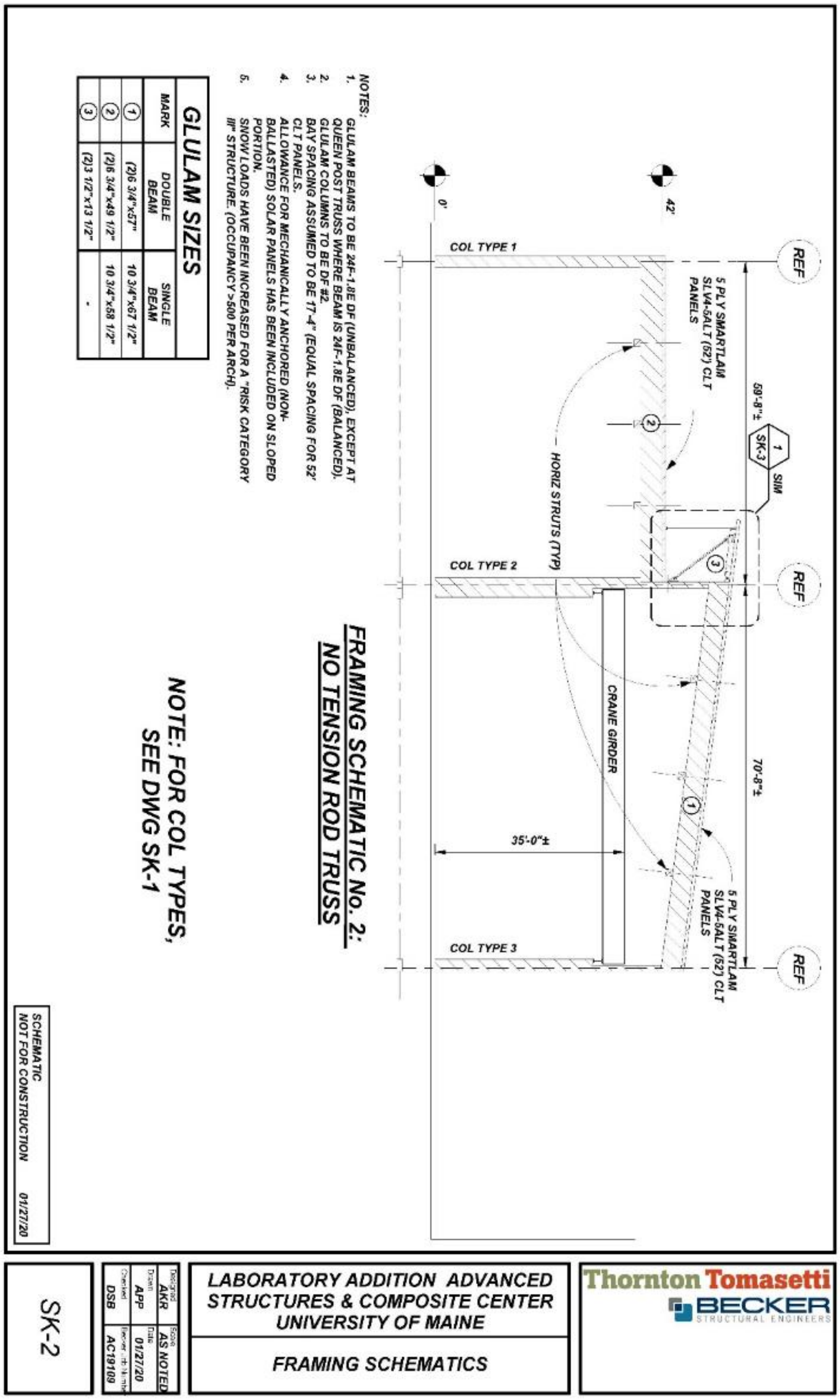
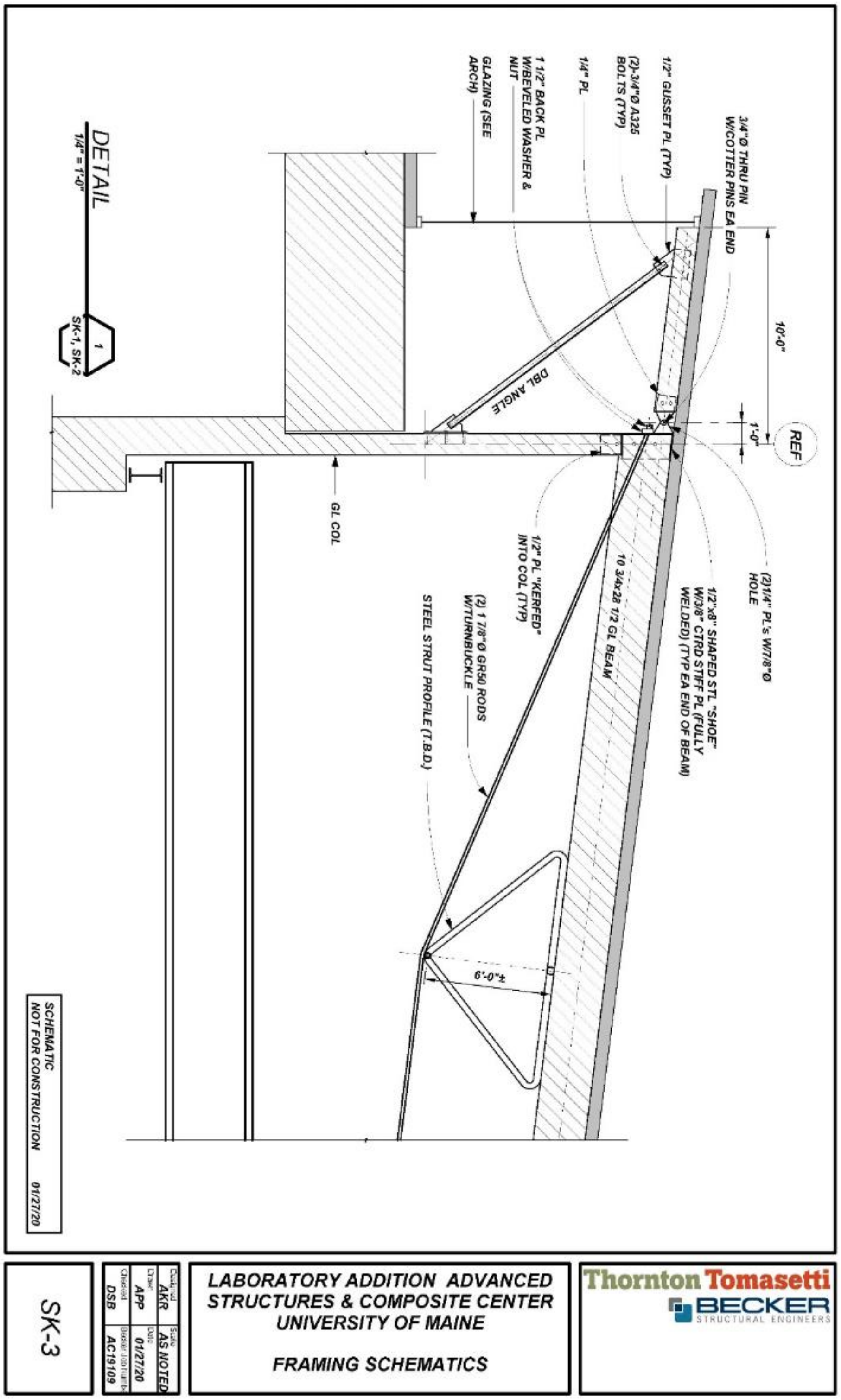
1. GLULAM BEAMS TO BE 24F-1.8E DF (UNBALANCED), EXCEPT AT QUEEN POST TRUSS WHERE BEAM IS 24F-1.8E DF (BALANCED).
2. GLULAM COLUMNS TO BE DF #2.
3. BAY SPACING ASSUMED TO BE 17'-4" (EQUAL SPACING FOR 52' CLT PANELS.
4. ALLOWANCE FOR MECHANICALLY ANCHORED (NON-BALLASTED) SOLAR PANELS HAS BEEN INCLUDED ON SLOPED PORTION.
5. SNOW LOADS HAVE BEEN INCREASED FOR A "RISK CATEGORY III" STRUCTURE. (OCCUPANCY >500 PER ARCH).
GLULAM SIZES
MARK | DOUBLE BEAM | SINGLE BEAM
1 | - | 10 3/4"x28 1/2"
2 | (2)6 3/4"x49 1/2" | 10 3/4"x58 1/2"
3 | (2)3 1/2"x13 1/2" | -
TENSION RODS | (2)1 7/8 "Ø GR50
5 PLY SMARTLAM SLV4-5ALT CLT PANELS (52')
REF
59'-8"±
70'-8"±
1/3rd PT
1/3rd PT (APPROX 23'-8")
COL TYPE 1
COL TYPE 2
COL TYPE 3
35'-0"±
CRANE GIRDER
0'
42'
SK-3
FRAMING SCHEMATIC No.1:
TENSION ROD QUEEN POST TRUSS
1'-4 1/4"
2'-0"
9"
1'-0"
1'-3"
2'-1 1/2"
1'-7 1/2"
3'-4 1/2"
2'-9"
2'-2 1/4"
1'-1 1/2"
COL TYPE 1
COL TYPE 2
COL TYPE 3
GLULAM COL TYPES
SCHEMATIC
NOT FOR CONSTRUCTION
01/27/20
Thornton Tomasetti
BECKER STRUCTURAL ENGINEERS
LABORATORY ADDITION ADVANCED STRUCTURES & COMPOSITE CENTER
UNIVERSITY OF MAINE
FRAMING SCHEMATICS
AKR
AS NOTED
APP
01/27/20
DSB
AC19109
SK-1


FRAMING SCHEMATIC No. 2:
NO TENSION ROD TRUSS
NOTE: FOR COL TYPES,
SEE DWG SK-1
NOTES:
1. GLULAM BEAMS TO BE 24F-1.8E DF (UNBALANCED), EXCEPT AT QUEEN POST TRUSS WHERE BEAM IS 24F-1.8E DF (BALANCED).
2. GLULAM COLUMNS TO BE DF #2.
3. BAY SPACING ASSUMED TO BE 17'-4" (EQUAL SPACING FOR 52' CLT PANELS.
4. ALLOWANCE FOR MECHANICALLY ANCHORED (NON-BALLASTED) SOLAR PANELS HAS BEEN INCLUDED ON SLOPED PORTION.
5. SNOW LOADS HAVE BEEN INCREASED FOR A "RISK CATEGORY III" STRUCTURE. (OCCUPANCY >500 PER ARCH).
GLULAM SIZES
MARK
DOUBLE BEAM
SINGLE BEAM
1
(2)6 3/4"x57"
10 3/4"x67 1/2"
2
(2)6 3/4"x49 1/2"
10 3/4"x58 1/2"
3
(2)3 1/2"x13 1/2"
-
REF
REF
REF
5 PLY SMARTLAM SLV4-5ALT (52) CLT PANELS
5 PLY SMARTLAM SLV4-5ALT (52) CLT PANELS
59'-8"±
70'-8"±
1
SK-3
SIM
HORIZ STRUTS (TYP)
CRANE GIRDER
35'-0"±
COL TYPE 1
COL TYPE 2
COL TYPE 3
42'
0'
SCHEMATIC
NOT FOR CONSTRUCTION
01/27/20
Thornton Tomasetti
BECKER
STRUCTURAL ENGINEERS
LABORATORY ADDITION ADVANCED STRUCTURES & COMPOSITE CENTER
UNIVERSITY OF MAINE
FRAMING SCHEMATICS
Designed AKR
Drawn APP
Checked DSB
Scale AS NOTED
Date 01/27/20
AC19109
SK-2


3/4"Ø THRU PIN W/COTTER PINS EA END
1/2" GUSSET PL (TYP)
(2)-3/4"Ø A325 BOLTS (TYP)
1/4" PL
1 1/2" BACK PL W/BEVELED WASHER & NUT
GLAZING (SEE ARCH)
10'-0"
1'-0"
REF
DBL ANGLE
GL COL
(2)1/4" PL's W/7/8"Ø HOLE
1/2"x8" SHAPED STL "SHOE" W/3/8" CTRD STIFF PL (FULLY WELDED) (TYP EA END OF BEAM)
10 3/4x28 1/2 GL BEAM
1/2" PL "KERFED" INTO COL (TYP)
(2) 1 7/8"Ø GR50 RODS W/TURNBUCKLE
STEEL STRUT PROFILE (T.B.D.)
6'-0"±
DETAIL
1/4" = 1'-0"
1
SK-1, SK-2
SCHEMATIC NOT FOR CONSTRUCTION
01/27/20
Thornton Tomasetti
BECKER
STRUCTURAL ENGINEERS
LABORATORY ADDITION ADVANCED STRUCTURES & COMPOSITE CENTER
UNIVERSITY OF MAINE
FRAMING SCHEMATICS
AKR
APP
DSB
AS NOTED
01/27/20
AC19109
SK-3

APPENDIX C


CONSIGLI
Est. 1905
UNIVERSITY OF MAINE
ASCC MASS TIMBER
Concept Estimate
SUBMITTED BY:
Consigli Construction Co., Inc.
15 Franklin Street
Portland, ME 04101
September 17, 2020

UNIVERSITY OF MAINE ASCC

MASS TIMBER CONCEPT ESTIMATE

SEPTEMEBR 17, 2020

CONSIGLI
Est. 1905

Consigli Construction Co., Inc. is pleased to provide this opinion of probably cost to The University of Maine. We recommend that for addition of 78,500 Square Foot Advanced Structures and Composites Center, that you budget **$28,400,000. The attached cost estimate dated 9/14/2020 is the basis of this opinion.** Pricing is based on documents from Scott Simons Architects including 100% Conceptual Pricing Set dated 7/8/20 and Site Plans & MEP Narrative received 8/7/20.

Cost Estimating Methodology:

The cost estimating methodology is important to review in order to evaluate the potential sources of error in the cost assumptions. The cost estimate is broken down divisionally and our approach to pricing varies on a division by division basis. Three primary strategies for pricing the trade level costs include:

- Quantity Takeoff / Unit Price: Measured scope of work presented in design and use of historical unit prices. This method is used where the scope or quantity of design information is able to be defined and where the scope of work is well known in the local market due to our experience with procuring similar scopes of work.
- Quantity Takeoff with Subcontractor / Supplier product guidance: For specialty work such as the mass timber, we received supply pricing based on the documents provided. We utilized internal self perform erection numbers for the erection of the mass timber and received budgetary costs for the supply of the CLT floor, roof and wall systems only from SmartLam. We have received two budgets from Glulam vendors for the Glue laminated Timbers elements, and have checked those numbers against historical costs.
- Comparable Project Costs: Where a design did not exist for the scope of work, we utilized gross square footage comparable costs from projects that we have recently procured or set Guaranteed Maximum Prices on. For these scopes of work, we have used educated guesses at modifying the gross square foot cost to modulate the pricing to a predicted use based on the program presented.

Assumptions & Areas for Clarification:

Items below have been refined in the estimate since our issued draft dated August 19, 2020

- Div 6 – We received pricing on the glulam beams and columns from two vendors and have updated the value carried for that work.
- Div 7 – We have continued to carry an allowance for intumescent paint is included as it is assumed required at some locations of exposed steel hardware.
- Div 7 – Fire separation between the new and existing building has been clarified by SSA. We have carried a fire rated assembly wall and have included a painted drywall surface at the interior side of the new addition and have included the assumption that the exterior wall of the existing building will be removed in order to construct the assembly specified by SSA in order to connect the fire separation wall with break away aluminum connections.
- Div 23 – Dedicated exhaust and fume hoods are excluded as it is assumed none are required. No material science lab spaces are shown.
- Div 26 – PV Array is shown at the sloped roof on the elevations and sections. A $10/SF allowance is included.

Limitations / Use of Cost Data:

- The pricing presented is developed with the primary goal of evaluating the design's total construction cost. We see a number of cost savings opportunities but also understand at this early stage, features may not yet be included in the drawings and have carried contingencies for design progression in the overall budget.
- Soft Costs are **not included**, the University Facilities Department are expected to be consulted to

Page 1 of 2

add to this construction cost items such as Design Fees, Furniture, Fixtures and Equipment, along with legal, fundraising and non-construction related costs in order to target a "Total Project Cost".

- The costs are presented are based on March 1, 2020 pricing. We have not included escalated costs of lumber that has recently significantly risen, but that we feel will settle back to historical rates in the coming months.
- COVID-19 impacts: We are in a tumultuous time in the economy we have not yet seen the long-term impact that the COVID-19 virus will have on the design and construction market.
  - We have not applied a cost penalty due to the impacts from COVID-19 on the construction operations.
  - We have not applied a cost factor for any future changes that may result from changes required in design codes, standards or any macro-economic affects driven by the pandemic. It is possible that economic impact to the construction markets could drive subcontractor and supplier prices down or up in the future.

Alternative Procurement:

We have included in the pricing, the assumption that a mass timber vendor will be engaged at the early stages of design in order to complete the required early coordination efforts inherent in a prefabricated timber floor plate and shear wall system. This early procurement is required in order to achieve the schedule advantage and will likely include early stage **Alternative Procurement** prior to the completion of construction documents. Alternative Procurement is defined as selecting a trade contractor on either a Design Assist Basis or a Design/Build basis prior to the design team completing Construction Documents. The reason this alternative procurement method is required in order to achieve the savings predicted in cost and schedule on the mass timber option are as follows:

1. Early procurement of Mass Timber is required due to the lack of a sufficient local market (as of Q2 2020) in the Northeast, for the supply of Cross Laminated Timber and Glued Laminated Timber, selection of a supplier is required earlier in the design phase than for a structural steel and concrete structure in order to achieve the schedule and cost savings predicted in this study.
2. The early mass timber procurement (at 50% DD) could provide more savings / advantages. (the source of the predicted cost savings is two-fold – a 4 to 8 week shorter overall construction duration along with the reduction in winter conditions costs – due to the ability to erect the superstructure without having to enclose and heat for the placement of the structural concrete slabs in the structural steel option).
   a. This additionally provides a hedge against long distance procurement risk, cross border delivery delay risk, and the potential for Non-US based structural products that will need to be re-specified if European products are chosen.
   b. Procuring and advancing the fabricator's design details for the mass timber elements allows for more efficient design and allows for an earlier start in the structural coordination with MEP trades.
   c. Earlier procurement of the mass timber will allow more flexibility in choosing the species of mass timber product for the project, which can have an effect on sizing, aesthetics, and production lead time. (Choices between Southern Yellow Pine, Spruce (SPF South), Black Spruce and European Spruce can have an affect on how the timber vendor is selected and the ultimate size and detailing of project)
3. Early procurement of MEP trades allows for the precise dimensional coordination requirements of mechanical, electrical, plumbing penetrations in the mass timber beams, floor plates and shear walls. Timing of MEP procurement should be targeted at the Design Development completion stage in order to provide for an organized coordination effort for the timber material.

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University of Maine ASCC

Mass Timber Concept Estimate

9/14/20

Description	Takeoff Quantity	Total Cost/Unit	Total Amount
02-20 SELECTIVE DEMOLITION	78,500.00 SF	0.64 /SF	50,000
03-30 CONCRETE	78,500.00 SF	12.89 /SF	1,011,634
05-50 MISCELLANEOUS METALS	78,500.00 SF	6.58 /SF	516,500
06-13 HEAVY TIMBER FRAMING	78,500.00 SF	56.50 /SF	4,435,214
06-25 FINISH CARPENTRY	78,500.00 SF	5.25 /SF	412,000
07-10 WATERPROOFING & JOINT SEALANTS	78,500.00 SF	2.41 /SF	189,364
07-42 METAL PANELS	78,500.00 SF	13.58 /SF	1,065,902
07-50 MEMBRANE ROOFING	78,500.00 SF	15.25 /SF	1,196,875
07-81 FIREPROOFING	78,500.00 SF	0.26 /SF	20,000
07-84 FIRESTOPPING	78,500.00 SF	1.00 /SF	78,500
07-95 EXPANSION JOINT ASSEMBLIES	78,500.00 SF	1.17 /SF	91,670
08-10 DOORS, FRAMES & HARDWARE	78,500.00 SF	3.01 /SF	236,000
08-41 GLASS & GLAZING	78,500.00 SF	12.46 /SF	978,090
08-52 WOOD WINDOWS	78,500.00 SF	1.88 /SF	147,450
09-21 DRYWALL	78,500.00 SF	11.77 /SF	924,100
09-51 CEILINGS	78,500.00 SF	0.90 /SF	70,650
09-61 FLOORING	78,500.00 SF	9.11 /SF	715,400
09-90 PAINTING	78,500.00 SF	2.61 /SF	205,208
10-01 TYPICAL SPECIALTIES	78,500.00 SF	2.10 /SF	164,800
11-53 EQUIPMENT	78,500.00 SF	11.21 /SF	879,580
14-20 ELEVATORS	78,500.00 SF	1.15 /SF	90,000
21-01 FIRE PROTECTION	78,500.00 SF	5.50 /SF	431,750
22-01 PLUMBING	78,500.00 SF	5.25 /SF	412,000
23-01 HVAC	78,500.00 SF	42.31 /SF	3,321,000
26-01 ELECTRICAL	78,500.00 SF	30.21 /SF	2,371,300
31-23 SITEWORK	78,500.00 SF	15.61 /SF	1,225,000
32-10 LANDSCAPING	78,500.00 SF	0.64 /SF	50,000

Estimate Totals

Description	Amount	Totals	Rate	Cost per Unit
Subtotal	**21,289,988**	**21,289,988**		**271.210 /SF**
Design Contingency	2,128,999		10.000 %	27.121 /SF
Escalation				
Subcontractor Bonds/Insurance	327,866		1.400 %	4.177 /SF
Subtotal	**2,456,865**	**23,746,853**		**302.508 /SF**
Contractor's Contingency	712,406		3.000 %	9.075 /SF
General Conditions	1,662,280		7.000 %	21.176 /SF
General Requirements	831,140		3.500 %	10.588 /SF
Subtotal	**3,205,826**	**26,952,679**		**343.346 /SF**
Builder's Risk Insurance	73,854		0.260 %	0.941 /SF
General Liability Insurance	397,676		1.400 %	5.066 /SF
Building Permit(by UMaine)				
GC Performance & Payment Bond	153,868			1.960 /SF
Subtotal	**625,398**	**27,578,077**		**351.313 /SF**
Fee	827,342		3.000 %	10.539 /SF
Total		**28,405,419**		**361.852 /SF**

CONSIGLI
Est. 1905

University of Maine ASCC

Mass Timber Concept Estimate

9/14/20

Description	Takeoff Quantity	Total Cost/Unit	Total Amount
02-20 SELECTIVE DEMOLITION			
Demo & existing exterior prep at connection to new building	1.00 ls	50,000.00 /ls	50,000
02-20 SELECTIVE DEMOLITION	**78,500.00 SF**	**0.64 /SF**	**50,000**
03-30 CONCRETE			
Misc tools & equipment	1,713.00 cy	10.00 /cy	17,130
Concrete pumping	2.00 day	1,800.00 /day	3,600
Spread footing F4 4x4x1' (25 CY)	43.00 ea	400.00 /ea	17,200
Spread footing F5 5x5x1' (15 CY)	16.00 ea	500.00 /ea	8,000
Spread footing F56 5x6x1'2" (19 CY)	15.00 ea	600.00 /ea	9,000
Spread footing F64 6x4x1'2" (10 CY)	10.00 ea	600.00 /ea	6,000
Spread footing F710 7x10x2' (83 CY)	16.00 ea	1,200.00 /ea	19,200
Spread footing F711 7x11x2' (91 CY)	16.00 ea	1,500.00 /ea	24,000
Continuous footing 3x1 (133 CY)	1,201.00 lf	50.00 /lf	60,050
Foundation walls 12" - 3'8" tall (141 CY)	1,040.00 lf	100.00 /lf	104,000
Slab on grade 4" (134 CY)	10,854.00 sf	7.00 /sf	75,978
Slab on grade 6" (72 CY)	3,888.00 sf	8.00 /sf	31,104
Slab on grade 8" (990 CY)	40,095.00 sf	9.00 /sf	360,855
Concrete at pan stairs (treads and landings)	3.00 ea	3,500.00 /ea	10,500
Topping slab 2"	19,800.00 sf	4.50 /sf	89,100
Underslab vapor barrier	54,837.00 sf	0.80 /sf	43,870
Underslab insulation	54,837.00 sf	1.40 /sf	76,772
Form interior column boxouts	68.00 ea	200.00 /ea	13,600
Set anchor bolts / grout base plate	168.00 ea	180.00 /ea	30,240
Rigid insulation - foundation walls	3,812.00 sf	3.00 /sf	11,436
03-30 CONCRETE	**78,500.00 SF**	**12.89 /SF**	**1,011,634**
05-50 MISCELLANEOUS METALS			
Metal fabrications - misc	78,500.00 gsf	3.00 /gsf	235,500
Metal pan stairs (3 stairs @ 2 stories each)	6.00 flts	20,000.00 /flts	120,000
Railing at Mezz	460.00 lf	350.00 /lf	161,000
05-50 MISCELLANEOUS METALS	**78,500.00 SF**	**6.58 /SF**	**516,500**
06-13 HEAVY TIMBER FRAMING			
Bracing rods	2,966.00 lf	15.00 /lf	44,490
Timber / glue-lam columns	9,554.00 cf	36.22 /cf	346,046
Timber / glue-lam beams	14,429.00 cf	36.22 /cf	522,618
Truss assembly (16 EA)	2,600.00 cf	36.22 /cf	94,172
CLT 5ALT SL-V4 floor (19,800 SF)	11,314.00 cf	27.06 /cf	306,157
CLT 5SL-V5M2 & 5ALT SL-V4 roof (57,825 SF)	33,043.00 cf	27.06 /cf	894,144
CLT 5ALT SL-V4 shaft walls (8,400 SF)	4,800.00 cf	27.06 /cf	129,888

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Mass Timber Concept Estimate

9/14/20

Description	Takeoff Quantity	Total Cost/Unit	Total Amount
06-13 HEAVY TIMBER FRAMING			
CLT 5ALT SL-V4 exterior walls (33,403 SF)	18,905.00 cf	27.06 /cf	511,569
Mass Timber Install	1.00 ls	740,000.00 /ls	740,000
Temporary timber protection	1.00 ls	100,000.00 /ls	100,000
Glulam Shipping	1.00 ls	157,080.00 /ls	157,080
CLT Shipping	1.00 ls	589,050.00 /ls	589,050
06-13 HEAVY TIMBER FRAMING	**78,500.00 SF**	**56.50 /SF**	**4,435,214**
06-25 FINISH CARPENTRY			
Architectural millwork - SF excluding Open Lab	41,200.00 sf	10.00 /sf	412,000
06-25 FINISH CARPENTRY	**78,500.00 SF**	**5.25 /SF**	**412,000**
07-10 WATERPROOFING & JOINT SEALANTS			
Foundation wall waterproofing	3,812.00 sf	8.00 /sf	30,496
Drainage board at foundation waterproofing	3,812.00 sf	3.00 /sf	11,436
Elevator pit waterproofing - cementitious	1.00 ea	5,000.00 /ea	5,000
Self adhered vapor permeable air barrier	24,061.00 sf	2.00 /sf	48,122
Caulking & sealants - interior	78,500.00 gsf	0.70 /gsf	54,950
Caulking & sealants - exterior	32,800.00 gsf	1.20 /gsf	39,360
07-10 WATERPROOFING & JOINT SEALANTS	**78,500.00 SF**	**2.41 /SF**	**189,364**
07-42 METAL PANELS			
Wood fiber insulation - exterior wall	24,061.00 sf	4.30 /sf	103,462
Insulated metal wall panels - Type 1	22,365.00 sf	40.00 /sf	894,600
Insulated metal wall panels - Type 2	1,696.00 sf	40.00 /sf	67,840
07-42 METAL PANELS	**78,500.00 SF**	**13.58 /SF**	**1,065,902**
07-50 MEMBRANE ROOFING			
Membrane roofing - EPDM	57,650.00 sf	18.00 /sf	1,037,700
Parapet roofing/coping	585.00 lf	75.00 /lf	43,875
Miscellaneous flashing	57,650.00 sf	2.00 /sf	115,300
07-50 MEMBRANE ROOFING	**78,500.00 SF**	**15.25 /SF**	**1,196,875**
07-81 FIREPROOFING			
Intumescent fireproofing - allowance	1.00 ls	20,000.00 /ls	20,000
07-81 FIREPROOFING	**78,500.00 SF**	**0.26 /SF**	**20,000**
07-84 FIRESTOPPING			
Miscellaneous firestopping	78,500.00 sf	1.00 /sf	78,500

Description	Takeoff Quantity	Total Cost/Unit	Total Amount
07-84 FIRESTOPPING	**78,500.00 SF**	**1.00 /SF**	**78,500**
07-95 EXPANSION JOINT ASSEMBLIES			
Expansion joint assemblies - roof	311.00 lf	70.00 /lf	21,770
Expansion joint assemblies - exterior wall	70.00 lf	60.00 /lf	4,200
Expansion joint assemblies - ceiling	622.00 lf	50.00 /lf	31,100
Expansion joint assemblies - interior wall	70.00 lf	50.00 /lf	3,500
Expansion joint assemblies - interior floor	622.00 lf	50.00 /lf	31,100
07-95 EXPANSION JOINT ASSEMBLIES	**78,500.00 SF**	**1.17 /SF**	**91,670**
08-10 DOORS, FRAMES & HARDWARE			
Doors/frames/hardware	72.00 ea	3,000.00 /ea	216,000
Overhead door - exterior, steel, manual (16' x 16")	2.00 ea	10,000.00 /ea	20,000
08-10 DOORS, FRAMES & HARDWARE	**78,500.00 SF**	**3.01 /SF**	**236,000**
08-41 GLASS & GLAZING			
Translucent facade wall - Kalwall 4" K-100	2,373.00 sf	90.00 /sf	213,570
Aluminum storefront exterior doors	2.00 lvs	4,500.00 /lvs	9,000
Curtain walls - Sierra Pacific wood	2,454.00 sf	180.00 /sf	441,720
Metal-framed skylights (approx 70sf ea at 11ea total).	770.00 sf	140.00 /sf	107,800
Premium for fire-rated glass - excluded	***sf***	***/sf***	
Misc interior glazing and borrowed lites - SF excluding Open Lab	41,200.00 gsf	5.00 /gsf	206,000
08-41 GLASS & GLAZING	**78,500.00 SF**	**12.46 /SF**	**978,090**
08-52 WOOD WINDOWS			
Furnish wood windows - Sierra Pacific punched opening	2,409.00 sf	50.00 /sf	120,450
Install wood windows	36.00 ea	600.00 /ea	21,600
Trim and flashing	36.00 ea	150.00 /ea	5,400
08-52 WOOD WINDOWS	**78,500.00 SF**	**1.88 /SF**	**147,450**
09-21 DRYWALL			
Rough Carpentry - blocking - SF excluding Open Lab	41,200.00 gsf	2.00 /gsf	82,400
Gypsum fire wall system at the existing building wall in new space	10,000.00 sf	35.00 /sf	350,000
GWB partition - standard 12'	23,870.00 sf	11.00 /sf	262,570
GWB partition - furred @ 15% of CLT walls	6,270.00 sf	9.00 /sf	56,430
Gypsum board ceilings - assume 10% GSF	7,850.00 sf	12.00 /sf	94,200
Misc drywall framing & patching	78,500.00 gsf	1.00 /gsf	78,500
09-21 DRYWALL	**78,500.00 SF**	**11.77 /SF**	**924,100**
09-51 CEILINGS			
Acoustical ceiling tile - assume 15% GSF	11,775.00 sf	6.00 /sf	70,650

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9/14/20

Description	Takeoff Quantity	Total Cost/Unit	Total Amount
09-51 CEILINGS	**78,500.00 SF**	**0.90 /SF**	**70,650**
09-61 FLOORING			
Acoustic mat 3/4" Acousti Mat	19,800.00 sf	7.00 /sf	138,600
Moisture mitigation & floor prep - SF excluding Open Lab	41,200.00 gsf	2.00 /gsf	82,400
Flooring subcontractor - SF excluding Open Lab	41,200.00 gsf	12.00 /gsf	494,400
09-61 FLOORING	**78,500.00 SF**	**9.11 /SF**	**715,400**
09-90 PAINTING			
Paint drywall partitions	45,348.00 sf	0.85 /sf	38,546
Paint drywall partitions - gysum fire wall	10,000.00 sf	0.85 /sf	8,500
Paint drywall ceilings	7,850.00 sf	1.00 /sf	7,850
Paint stairs	6.00 flt	1,750.00 /flt	10,500
Paint exposed MEP - assume 75% GSF exposed CLT ceilings	58,875.00 sf	1.50 /sf	88,313
Interior painting - doors/frames, misc	41,200.00 gsf	1.25 /gsf	51,500
09-90 PAINTING	**78,500.00 SF**	**2.61 /SF**	**205,208**
10-01 TYPICAL SPECIALTIES			
Specialties	41,200.00 gsf	4.00 /gsf	164,800
10-01 TYPICAL SPECIALTIES	**78,500.00 SF**	**2.10 /SF**	**164,800**
11-53 EQUIPMENT			
Crane (Somatex) 15 ton double girder cranes - 2 per each bay	4.00 ea	187,250.00 /ea	749,000
Crane (Somatex) 260ft runway rail and conductor bar per each bay	2.00 ls	25,925.00 /ls	51,850
Crane (Somatex) install per each bay	2.00 ls	39,365.00 /ls	78,730
11-53 EQUIPMENT	**78,500.00 SF**	**11.21 /SF**	**879,580**
14-20 ELEVATORS			
Passenger elevator - standard finishes 3500lb	2.00 stop	45,000.00 /stop	90,000
14-20 ELEVATORS	**78,500.00 SF**	**1.15 /SF**	**90,000**
21-01 FIRE PROTECTION			
Fire protection allowance	78,500.00 gsf	5.50 /gsf	431,750
21-01 FIRE PROTECTION	**78,500.00 SF**	**5.50 /SF**	**431,750**
22-01 PLUMBING			
Plumbing allowance - standard	41,200.00 gsf	10.00 /gsf	412,000
22-01 PLUMBING	**78,500.00 SF**	**5.25 /SF**	**412,000**

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Mass Timber Concept Estimate

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Description	Takeoff Quantity	Total Cost/Unit	Total Amount
23-01 HVAC			
HVAC allowance - open lab	34,800.00 gsf	30.00 /gsf	1,044,000
HVAC allowance - offices & circulation	41,200.00 gsf	35.00 /gsf	1,442,000
HVAC allowance - controls	78,500.00 gsf	10.00 /gsf	785,000
HVAC adjustments from solar wall deletion at existing building	1.00 ls	50,000.00 /ls	50,000
23-01 HVAC	**78,500.00 SF**	**42.31 /SF**	**3,321,000**
26-01 ELECTRICAL			
Electrical allowance - open lab	34,800.00 gsf	20.00 /gsf	696,000
Electrical allowance - offices & circulation	41,200.00 gsf	35.00 /gsf	1,442,000
PV array - allowance (cost to be defined)	23,330.00 sf	10.00 /sf	233,300
26-01 ELECTRICAL	**78,500.00 SF**	**30.21 /SF**	**2,371,300**
31-23 SITEWORK			
Clearing & grading	1.00 ls	85,000.00 /ls	85,000
Excavation & fill - foundations	1.00 ls	400,000.00 /ls	400,000
Rock removal - excluded	***1.00 ls***	***/ls***	
Dewatering - excluded	***1.00 ls***	***/ls***	
Shoring - excluded	***1.00 ls***	***/ls***	
Erosion & sedimentation control	1.00 ls	40,000.00 /ls	40,000
Base courses	1.00 ls	40,000.00 /ls	40,000
Paving (flexible & rigid), sidewalks & curbs	1.00 ls	75,000.00 /ls	75,000
Water utilities	1.00 ls	15,000.00 /ls	15,000
Sanitary sewerage utilities	1.00 ls	50,000.00 /ls	50,000
Storm drainage utilities	1.00 ls	150,000.00 /ls	150,000
Subdrainage	1.00 ls	40,000.00 /ls	40,000
Fuel distribution utilities	1.00 ls	30,000.00 /ls	30,000
Steam utilities	1.00 ls	100,000.00 /ls	100,000
Electric utilities	1.00 ls	200,000.00 /ls	200,000
31-23 SITEWORK	**78,500.00 SF**	**15.61 /SF**	**1,225,000**
32-10 LANDSCAPING			
Planting & grasses	1.00 ls	50,000.00 /ls	50,000
32-10 LANDSCAPING	**78,500.00 SF**	**0.64 /SF**	**50,000**

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Mass Timber Concept Estimate

9/14/20

Estimate Totals

Description	Amount	Totals	Rate	Cost per Unit
Subtotal	**21,289,988**	**21,289,988**		**271.210 /SF**
Design Contingency	2,128,999		10.000 %	27.121 /SF
Escalation				
Subcontractor Bonds/Insurance	327,866		1.400 %	4.177 /SF
Subtotal	**2,456,865**	**23,746,853**		**302.508 /SF**
Contractor's Contingency	712,406		3.000 %	9.075 /SF
General Conditions	1,662,280		7.000 %	21.176 /SF
General Requirements	831,140		3.500 %	10.588 /SF
Subtotal	**3,205,826**	**26,952,679**		**343.346 /SF**
Builder's Risk Insurance	73,854		0.260 %	0.941 /SF
General Liability Insurance	397,676		1.400 %	5.066 /SF
Building Permit(by UMaine)				
GC Performance & Payment Bond	153,868			1.960 /SF
Subtotal	**625,398**	**27,578,077**		**351.313 /SF**
Fee	827,342		3.000 %	10.539 /SF
Total		**28,405,419**		**361.852 /SF**

SMARTLAM NORTH AMERICA
PO BOX 2070, Columbia Falls, MT. 59912
Phone: 406.892.2241
sales@smartlam.com
www.SmartLam.com

BID SUMMARY **UMAINE ASCC**

FOR BUDGETARY PURPOSES ONLY ***Manufacture Location: Columbia Falls, MT***

Customer: Consigli
Primary Contact: Russell Edgar
Phone: 207.299.4215
Email: russell.edgar@maine.edu
Project Street Address: 1 Brown Road
Project City, State & ZIP: Orono, ME 04469

Project ID: 20.075
Quote Number: 200731JR
Plan Description: 100% Conceptual Pricing Set
Plan Set Date: 07.08.2020 **Addendum:** N/A
Quote Date: 8/5/2020 **Valid Until:** 8/26/2020
Completed By: Josh Robinson

Cross Laminated Timber Scope

	CLT SPECIFICATIONS	QTY	SQUARE FT	CUBIC FT.	WEIGHT		SUBTOTAL
CLT Roof System:	5 ALT SL-V4	111	57,825	33,043	1,274,779		$839,859.56
	5 SL-V5M2	33					
CLT Floor System:	5 ALT SL-V4	55	19,800	11,314	436,392		$288,223.57
CLT Walls:	5 ALT SL-V4	135	33,403	18,905	729,170		$486,816.77
CLT Stair & Elev Shaft:	5 ALT SL-V4	24	8,400	4,800	185,268		$170,959.45
CLT Hardware/Fasteners:	Spline Material, CLT to CLT and CLT to Bearing Material Fasteners Only						$55,600.00
Shipping Estimate:							$589,050.00
	TOTALS:	358	119,428	68,062	2,625,609	**$**	**2,430,509.35**

CROSS LAMINATED TIMBER NARRATIVE

Includes CLT package consisting of SL-V5M2 CLT panels manufactured using Select Structural Hem Fir & optional Douglas Fir face layer 2x6 & 2x8 timber members laminated together using PURBOND Polyurethane adhesive. CNC fabrication included.

Includes CLT package consisting of SL-V4 CLT panels manufactured using Spruce, Pine & Fir - South 2x6 or 2x8 timber members laminated together using PURBOND Polyurethane adhesive. CNC fabrication included.

Each panel will have an Architectural Finish and will be sanded on 1 side only.

Stair & elevator shaft panels will have an Industrial Finish.

Shop Sealer will be applied to all faces of each panel.

Shop drawings and design support included.

Quote assumes SmartLam NA recieves an executable .IFC file.

Excluded from this quote are the items: Taxes, Customs, Brokerage & Duty.

Tax Exemption Certificate must be submitted with purchase order.

Installation services to be provided by others, not included within this quote.

FSC Certification, Chain of Custody/LEED Documentation is **NOT** included with this quote. Additional fee for this service.

SHIPPING TERMS & CONDITIONS ***(INCLUDED IN TOTAL ABOVE)***

FOB Factory. SmartLam makes every effort to provide accurate shipping estimates. However all shipping dates & amounts supplied in this quote are estimates only. The customer is responsible for additional shipping fees above the estimated amount.

Total Trucks: 56	**Shipment Type:** Legal Load	**Shipping Estimate:** $589,050.00

SMARTLAM PAYMENT TERMS

All orders require a 50% deposit upon execution of purchase order to secure of raw materials.

**** Quotes are good for 21 days and may vary due to the fluctuating price of our raw materials. ****

☐ **I AGREE TO THE WARRANTY, TERMS AND CONDITIONS OUTLINED ON BACK OF SHEET.**

PURCHASER

PRINTED NAME: ____________________

AUTHORIZED SIGNATURE: ____________________

DATE: ____________

PO Number: ____________

Billing Address: ____________________

____

SMARTLAM NORTH AMERICA

PRINTED NAME: ____________________

AUTHORIZED SIGNATURE: ____________________

DATE: ____________

UMaine Facilities Management Total Project Cost Estimate

			Account #	0	
			Date:	9/23/20	
	ASCC CLT Addition				
FUNDS	**PROJECT BUDGET**			**ORIGINAL BUDGET**	
A. Project Funding					**47,820,000**
B. Project Contingency (editable)		67004(810)	10.00 % of Line A)	4,782,000	**4,782,000**
C. Planning Level (Line A minus Line B = Line J)				43,038,000	
EXPENDITURES					
D. General & Site Clearance					
67000 (805)	. University Admin. (use as needed)		0.00 % of Line A)	956,400	
67005 (811)	1. Architect Fees			3,720,000	
67005 (811)	LEED & Certification Plaque			50,000	
	SFMO Permit			60,000	
67005 (811)	b.			0	
67006 (812)	2. Architectural Inspection			0	
67007 (813)	3.Engineering Fees			0	
	geotech			25,000	
	testing/ inspections			70,000	
	in-lieu fee (wetland)			150,000	
	Survey (topo/ wetland)			25,000	
	DEP Permitting (design/ fees)			25,000	
	Commissioning			350,000	
	Plumbing			25,000	
	Other (generator, etc)			20,000	
67008 (814)	4. Engineering Inspections			0	
67010 (816)	5. Site Clearance and Building Demo [building areas]			0	
67011 (817)	7. University Overhead- Advertising, Telephone, etc.			10,000	
67019-01(819)	8. Miscellaneous- Use for Architect Reimbusables			0	
67005 (811)	9. Other-			0	
	TOTAL GENERAL				**5,486,400**
E. Construction					
67100 (821)	1. Project Construction Contract- Main Construction Contract			28,400,000	
	Escalation (2 years 1.03 rounded)			1,800,000	
	Precon services (CM)			400,000	
	AV Allowance			1,250,000	
	Signage allowance			40,000	
	Allowance for Undefined Sitework, Hardscape and Parking			800,000	
	Generator Allowance			500,000	
67100 (821)	a. Changer Order			0	
67100 (821)	b. Changer Order			0	
67100 (821)	c. Changer Order			0	
67100 (821)	d. Change Order			0	
	2. Supplemental Contracts/Work				
	a. Utility Lines				
67209 (833)	1. Heating			0	
67210 (834)	2. Water			0	
67208 (835)	3. Sewer			0	
67203 (831)	4. Electric			0	
67201 (832)	5. Telecom Infrastr- Voice, Data, Fiber, Comm Hubs, Etc.			1,000,000	
67207 (837)	b. Parking			0	
67207 (837)	c. Roadways & Walks			0	
67205 (838)	d. Landscaping			200,000	
	e. Facility Management - Trades			0	
67200 - 01 (841)	1. Carpentry, Roofing			10,000	
67200 - 02 (842)	2. Plumbing			10,000	
67200 - 03 (843)	3. Electrical			2,000,000	
67200 - 04 (844)	4. Painting			10,000	
67200 - 05 (845)	5. Steamfitting			10,000	
67200 - 06 (846)	6. Custodial			10,000	
67200 - 07 (847)	7. Grounds (does not include moving offices or equipment)			130,000	
67200 - 09 (840)	9. Lockshop			150,000	
67206 (830)	f. Site Clearance- Non Building Demo			0	
	3. Other Construction not contracted (list)				
67301 (848)	a. Asbestos Administration-			0	
67300 (849)	b. Asbestos Removal-			6,600	
	Other-			0	
	Other-			0	
	Other-			0	
	TOTAL CONSTRUCTION				**36,726,600**
F. Moveable Equipment- Not in Construction Contract					
67400 (851)	a. Office, Furnishings & Moveable Equip [Unit Price <$5K]			750,000	
67401 (855)	b. Office, Furnishings and Moveable Equip [Unit Price >=$5K]				
	Other-			0	
		TOTAL EQUIPMENT			**750,000**
G. Land / Building Acquisition	67602/67601				**0**
H. Moving Expense	67500(861)				**25,000**
I. Other Project Expense (list)					
67002/(802)	1. 1 Percent for Art Artwork			42,500	
67003 (803)	2. 1 Percent for Art Administration			5,000	
67003(803)	3 Maine Arts Commission Fee			2,500	
	Other-			0	
	Other-			0	
	Other-			0	
		TOTAL OTHER			**50,000**
J. Expenditure Budget					
		(TOTAL D,E,F,G,H, & I)			**43,038,000**
Total Project Budget (Expenditure Budget + Contingency)					**47,820,000**
	NOTE: Expenditure Budget cannot exceed Planning Level Funding (Line C) variation=			0	

APPENDIX D

Thornton Tomasetti

University of Maine

Advanced Structures and Composites Center CLT Lab Addition

Building Life-Cycle Carbon and Operational Energy Report

Prepared For:
Russell Edgar & Benjamin Herzog

University of Maine
35 Flagstaff Road
Orono, ME 04469

Ryan Kanteres

Scott Simons Architects
75 York St #4670
Portland, ME 04101

Prepared By:
Duncan Cox
Senior Associate

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Portland, ME 04101
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October 2020

TABLE OF CONTENTS

INTRODUCTION

The premise of this report is to surmise the embodied carbon impact and anticipated operational energy use of the 57,995 sf cross-laminated timber (CLT) and glulam addition to the Advanced Structures and Composites Center (ASCC) on the University of Maine campus. The project will contain open lab space for the world's largest prototype polymer 3D printer, offices, and a presentation venue.

A life-cycle assessment is a methodology for quantifying environmental impacts at all stages of a building's life cycle. This is a cradle-to-grave assessment of the building, beginning from raw material extraction and sourcing, to manufacturing, transportation, construction, energy use, maintenance and building end-of-life recycling/disposal. Figure 1 notes the individual stages which comprise the whole building life cycle.

The intent of the life-cycle assessment (LCA) is to evaluate the embodied carbon impact of the timber design and identify opportunities for impact reductions. The primary goal of the engineering analysis is to understand and determine the feasibility of the project operational energy use to achieve Zero Net Energy (ZNE) for the new lab addition. Using the results from the LCA, low carbon benchmarks will be developed for major structural components, to inform future timber developments on the University campus and in the Northeast region at large.

This report has been broken down by the following life-cycle stages:

- A1-A3: Product Stage
- A4: Transportation
- A5: Waste
- B1-B5: Maintenance/ Material Replacement
- B6: Operational Energy Use
- C1-C4/D: End-of-Life/ Reuse, Recycling, Disposal

Operational Energy Definitions:

Zero Net Energy : A zero net energy (ZNE) building is an energy-efficient building that produces as much energy as it consumes over the course of a year, usually by incorporating renewable energy generation on-site (Credit-NBI).

Energy Use Intensity : An Energy Use Intensity (EUI) is the total building annual energy use divided by the gross floor area. EUI enables comparison of similar building types.

Funding for this report was provided by the Maine Mass Timber Commercialization Center, a U.S. Economic Development Administration (EDA) funded effort to promote mass timber production in the Northeast.

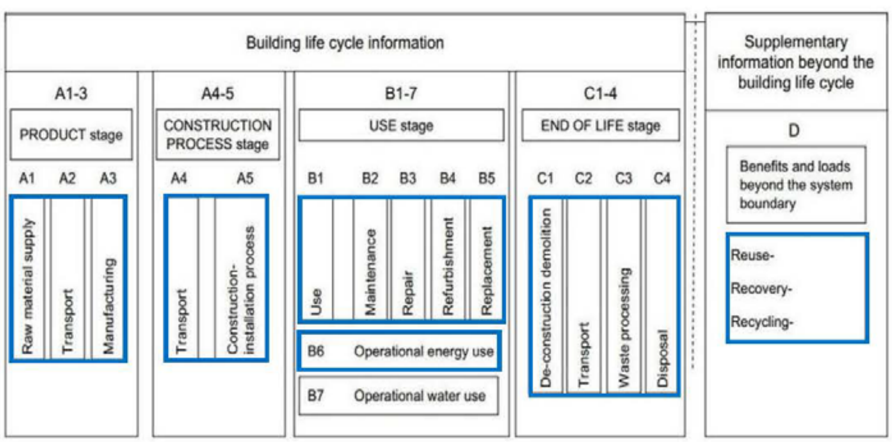


Figure 1: Stages of the whole building life cycle. Blue outline indicates stages incorporated into this assessment.

EXECUTIVE SUMMARY

A building's overall carbon emissions result from a combination of the carbon embedded in materials (embodied carbon) and the energy associated with maintaining building operations (operational carbon). As buildings have become more energy efficient over the last twenty years, research shows that the relative contribution of embodied carbon over the building lifecycle has become more significant (Architecture 2030). It is with this in mind that the University looks to build toward a sustainable future, taking advantage of the low carbon benefits offered by mass timber construction.

Life Cycle Assessment (LCA) Synopsis

To capture the full carbon picture of the Advanced Structures and Composites Center CLT Lab Addition, a preliminary cradle-to-grave whole building life cycle assessment was performed to examine the material carbon impact from major structural and architectural elements in the timber design.

The results demonstrate that the biggest stage contributor to the overall building embodied carbon footprint is the Product Stage carbon (1,397 tons CO2e). It accounts for approximately 82% of embodied carbon in the building. The Construction and Waste (181 tons CO2e), Maintenance and Replacement (60 tons CO2e) and End of Life (63 tons CO2e) stages have a minimal impact by comparison (Figure 2).

Operational energy is calculated separately but when factored in over the service life of the building, this energy use accounts for 86% of total carbon emissions. This includes all energy for lighting, HVAC and equipment plug loads in addition to a rooftop solar array.

Although wood is a renewable product that sequesters carbon during a tree's growth cycle, this carbon advantage is measured apart from the material life cycle stages. Following harvesting, a timber product's storage of carbon is highly dependent of the adaptive reuse or recycling strategies implemented at the end of the building's service life. Timber products should be repurposed whenever possible to keep the carbon they sequester within existing supply chains and prolonging the point at which they are landfilled or incinerated. Thus biogenic carbon is reported on in detail later in this report.

Overall, the life cycle stage that poses the greatest opportunity for embodied carbon reductions is the Product/material stage, which includes the selection, sourcing, and manufacturing of materials.

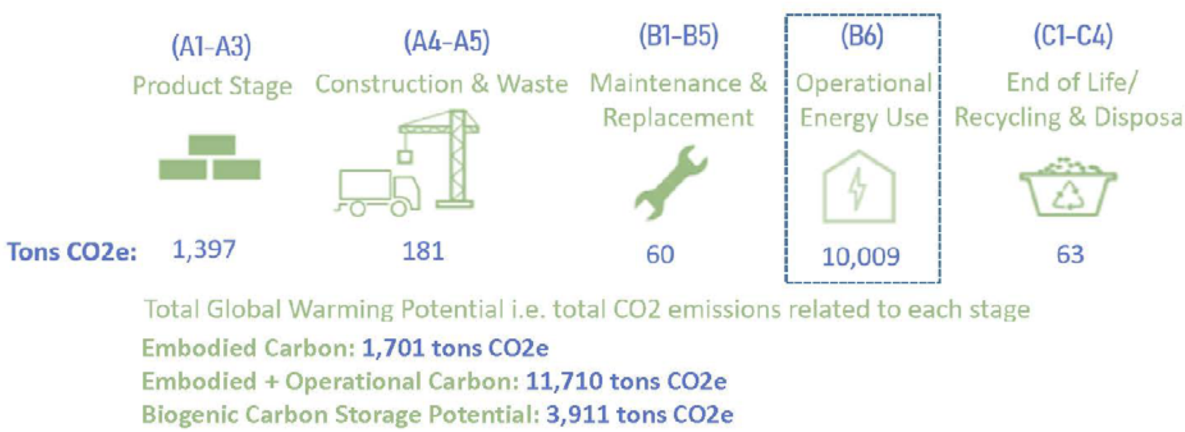


Figure 2: Total embodied and operational carbon emissions for the ASCC CLT Lab Addition.

EXECUTIVE SUMMARY

Operational Energy Analysis

Thornton Tomasetti (TT) facilitated discussions with the project architect and the owner to understand the nuances of the project design and operational schedules. Based on the information gathered, TT performed a preliminary energy analysis and estimated potential electric energy generation from Photovoltaic (PV) System.

TT's preliminary energy analysis indicates the project has an Energy Use Intensity (EUI) of 73 Kbtu/sf-yr. This metric normalizes the energy use of a building and allows comparison with typical building typologies in the same climate zone.

This provides a benchmark for the project to measure its performance against similar buildings. For the purposes of benchmarking, TT used CBECS database which indicates the design project performs roughly 47% better than a similar building in the same climate zone.

This project type demands high power draw due to the lab equipment and its consistent use pattern. TT's preliminary energy analysis shows that the project cannot meet the Zero Net Energy (ZNE) status with solely an on-site PV system. To achieve ZNE status an EUI of 28 Kbtu/sf-yr must be achieved. The estimated equipment plug load alone has an EUI of 25.

TT recommends that the design team review the information in this report and provide feedback on any variations to operational use or proposed systems to reduce the EUI. However, to attain ZNE status the project must achieve 28 EUI or lower. This is assuming a PV system only on the roof. Different from a typical office building, this project type demands high power draw due to the lab equipment and its consistent use pattern. The equipment plug load alone uses 25 EUI while HVAC/Lighting/Hot Water use the remainder of the EUI (47).

PRODUCT STAGE (A1-A3)

The first stage of the life-cycle assessment considers solely the Product Stage embodied carbon. This is the carbon emitted through the raw material supply chain, the transportation of these materials to the factory, and the manufacture of these materials.

The information used to conduct this analysis was drawn from architectural and structural drawings, Revit models and obtained through discussions with Scott Simons Architects, the University and the structural engineer, Thornton Tomasetti. The OneClick LCA tool was used to perform the LCA.

When comparing the global warming potential of materials, the biggest element type contributors to the building's overall embodied carbon are the facade and foundations, accounting for 69% of the building's total embodied carbon emissions (Figure 3). The main carbon drivers of the façade include the metal panel siding and glulam curtain wall system, while the concrete comprising the slab on grade and footings represents the bulk of the carbon found in foundations.

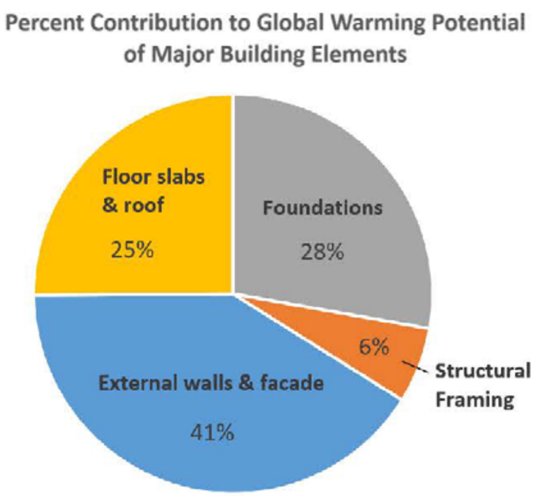


Figure 3: Percent contribution to embodied carbon by building element

To understand the impact of the major construction elements, which are the biggest contributors to the timber design, we have normalized the foundations, floors, and framing by floor area (57,995 sf), and the façade by vertical wall area (~83,176 sf), respectively.

When normalized by vertical wall area there is a significant carbon contribution from the façade (8.4 lbs CO2e/sf) which is due not to the intensity of the materials (glulam curtain wall and metal panel siding) but rather to the volume of material used to clad the structure. Foundations, however are materially heavy (8.1 lbs CO2e/sf) because of the carbon intensity of concrete. Floors (7.4 lbs CO2e/sf) and structural framing (1.8 lbs CO2e/sf) are comparatively smaller based on the volume of material (Figure 4).

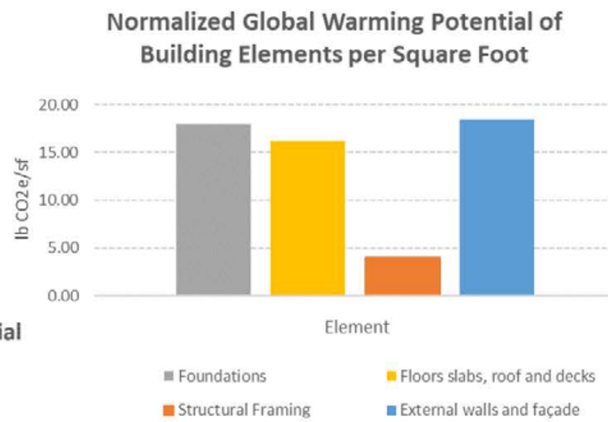


Figure 4: Embodied carbon normalized by square foot

This normalization further highlights opportunities for flexibility in making additional carbon reductions. The element currently exhibiting the highest efficiency is the structural framing.

A concrete mix with high cementitious material replacement value would positively impact the contribution of the foundations and floor slabs. Additionally, as the architectural walls do not require the added strength of 3 or 5 ply CLT, consideration should be given to selecting an alternative wood-based façade cladding material such as laminated veneer lumber or another panelized wood construction. This would reduce the quantity and cost of the material, thereby improving the carbon savings of the element category as a whole.

PRODUCT STAGE (A1-A3)

To further understand the carbon implications of specific materials, the life-cycle assessment data was parsed by individual materials. This again highlights the distinction between material quantity and carbon intensity, the two main factors that determine overall impact of a product on the building's embodied carbon emissions.

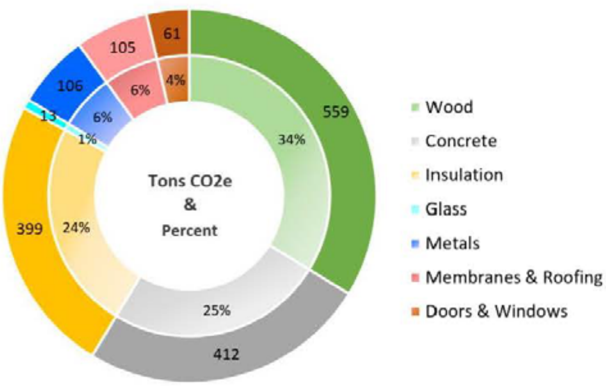


Figure 5: Embodied carbon and percent contribution of individual materials

The results demonstrate that the shear quantity of timber and insulation, including wood fiber, EPS, rock wool and sandwich panels, comprise 34% and 24% respectively, of the building's total embodied carbon.

Due to the energy intensive production process of cement, the concrete used in foundations and slab on grade, constitutes 25% of the overall material impact. The remaining 17% of carbon is associated with the glass, doors, windows, metal and membranes/roofing materials (Figure 5).

Although timber accounts for 34% of the building's total embodied carbon, when compared to traditional steel or concrete, wood is a highly efficient material choice.

When comparing the global warming potential of materials, Environmental Product Declarations (EPDs) provide product specific or industry average data on what a product is made of and how it impacts the environment across its life cycle.

To understand where the most effective material reductions can be made, the energy intensity of the production and manufacturing processes per material is important.

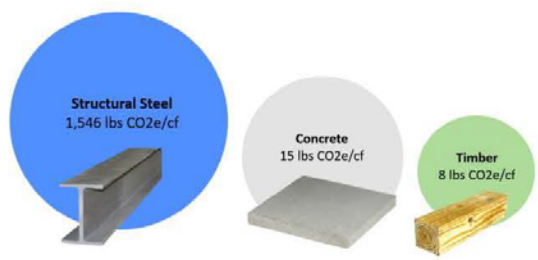


Figure 6: Industry average embodied carbon comparison of concrete, steel and timber per cubic foot of material

The manufacturing process of steel is roughly 100 times more carbon intensive than concrete, however in building construction a greater volume of concrete is used, which results in higher carbon emissions from concrete (Figure 6). For example, where 1,000 cubic feet of steel might be used, 150,000 cubic feet of concrete may be needed, resulting in a difference in emissions of more than 600,000 lbs CO2e. This highlights the material areas with the greatest potential for meaningful impact reductions.

With respect to timber, while the carbon emitted during the felling and processing of timber in the product stage is low relative to other materials, harvesting from sustainably managed forests and incorporating adaptive reuse of materials at end of life will ensure the project can take full advantage of the timber's low carbon properties. Refer to section on Timber Sourcing on page 9 and Adaptive Reuse on page 18 for more.

BIOGENIC CARBON

Timber sequesters carbon during a tree's growing life and this is known as biogenic carbon. While age and tree species determine exactly how much carbon is stored by a particular specimen, research indicates that a single timber product stores on average 1 ton of CO2 per 1.3 cubic yards of wood.

This carbon storage is not accounted for in the product stage of the life cycle (A1-A3), if it were timber would have a far lower product stage embodied carbon emissions. Instead biogenic carbon is reported separately.

To fully utilize the advantages of carbon sequestration potential, timber will be procured from suppliers that adhere to sustainable forestry practices which ensure that harvesting does not outpace the rate of tree regrowth. In addition, the building design will consider the value, both in reduced material costs and carbon emission, of maintaining products within a circular economy.

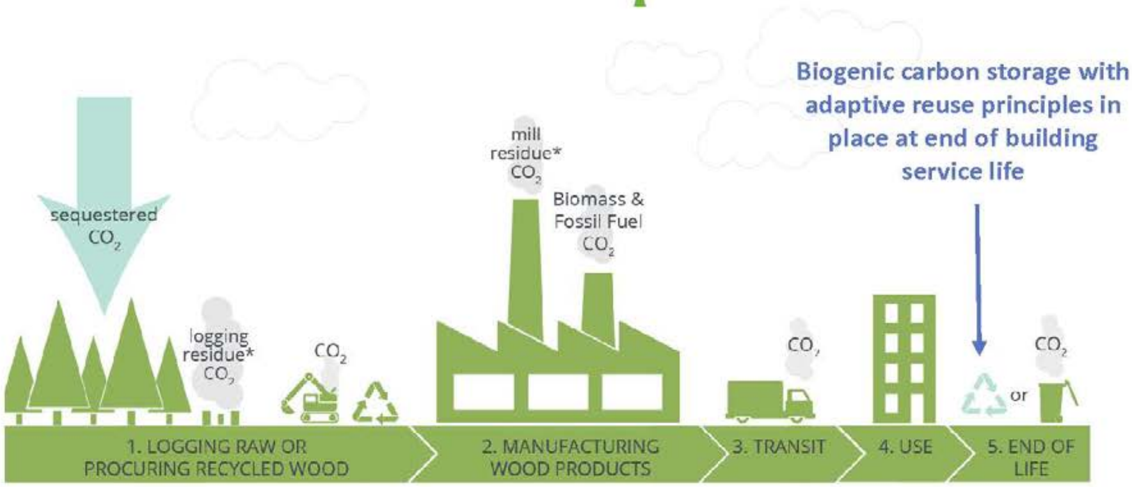
This adaptive reuse of materials can be achieved through good administration of documentation including drawings and models, which may be used to determine the structural integrity of materials for future reuse. Refer to section on Adaptive Reuse page 16 for more.

The LCA for the CLT Lab Addition revealed a biogenic carbon storage potential of 3,911 tons CO2e (Figure 7). This project will integrate a strong end-of-life narrative to ensure the carbon storage potential in TT's calculations is realized.

Timber cannot be assumed to be a carbon positive until proper end-of-life stage principles like adaptive reuse are executed upon. Therefore, the benefit of this carbon storage is kept separate from the overall assessment of the building's fossil related embodied carbon emissions.

Total Embodied + Operational Carbon:
11,710 tons CO2e

Biogenic carbon storage potential:
3,911 tons CO2e



*logging and mill residue: including branches, stumps and bark left behind in processing logs into lumber, releasing CO2

Figure 7: Life-cycle of timber, including carbon sequestration during growth, carbon emissions of manufacturing and end of life landfilled or incineration emissions, and biogenic carbon storage with adoption of circular economy strategies for materials used in built design. Credit – Architecture 2030.

MATERIAL SELECTION AND OPTIMIZATION

Assumptions

The LCA results represent the total life cycle impact of the building over a 60 year service life. The facades modeled in the LCA are assumed to have a service life matching the building.

Product specific Environmental Product Declarations (EPDs) were used whenever possible to accurately capture the carbon impact of specific material quantities. Where product specific EPDs were not available, industry averages have been used.

Wood

In the case of the cross laminated timber (CLT) panels, which have been priced by SmartLam, precise quantities have been used to reflect the amount of timber to be utilized on the project. A comparable EPD for North American CLT was used to ascertain the carbon impact of the material. Similarly, an industry average North American EPD was selected to capture the carbon impact of glue laminated timber (GLT) on the project.

Concrete

Based on TT's design expertise with mass timber in the Northeast and in consultation with the structural engineer, the LCA assumes a 20% cementitious material replacement for all concrete. Concrete mix designs which utilize between 20% and 40% cementitious material replacement are widely achievable. On occasion, the availability of a specific cement replacement material such as slag, fly ash or pozzolan, may vary regionally, but all are capable of achieving similar carbon reductions. Winter conditions and the heat hydration necessary to obtain proper curing and strength will impact the exact percentages. Coordination with local suppliers is necessary to achieve the maximum carbon savings from concrete. TT has assumed a medium level cement replacement of 20% for all concrete in this analysis and a transport distance of 130 miles, based on regional typical values from manufacturing to construction site.

Transport impacts are accounted for in A4 of the life cycle. Dependent on the right conditions, proper equipment and the compressive strength desired, increased carbon savings can be attained with a higher degree of cement replacement in concrete Figures 8 & 9 serve as blueprints for future projects of what is currently achievable.

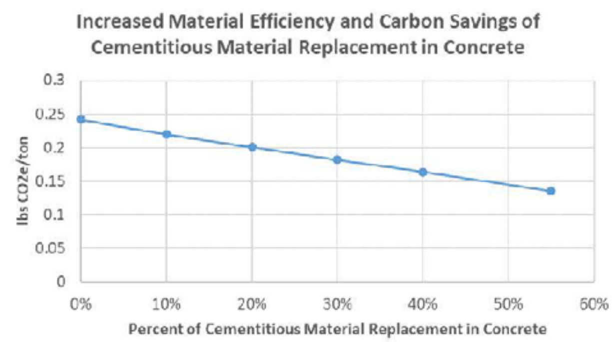


Figure 8

Steel

A high degree of recycled content is common for all structural steel (80-100%) and reinforcement steel (90-100%). For structural steel profiles this LCA assumes a recycled content 90% and 97% for reinforcement steel (rebar). The exact percentages achievable are dependent on individual manufacturers and locations; these thresholds were selected due to their wide acceptance and availability across industry.

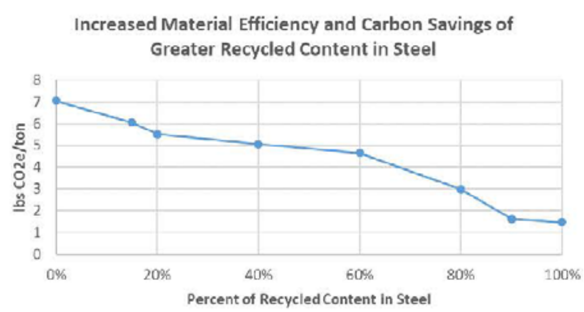


Figure 9

TIMBER SOURCING

The second stage of the life-cycle evaluates the transportation of the building materials to the site, and any waste associated with the installation of those materials. This covers impacts of product transport from factory to the construction site.

Timber Sourcing

In order to maintain a balanced ecosystem, where the use of mass timber for construction does not outpace the growth of new trees, it is imperative that projects specify and source timber from sustainably managed forests. Forest regrowth in Maine takes between 40 and 60 years depending on the location and tree species.

A sustainably managed forest ensures that only select trees are cut, allowing a subset to grow uninhibited and replenish those that have been harvested. This maintains a carbon balance by not harvesting more than can be regrown. Sustainable forestry is key to ensure projects are not doing more harm than good by contributing to deforestation or supporting illegal logging.

Forest management schemes curb illegal forestry practices and Chain-of-Custody (COC) certification tracks wood products from certified forests to the point of sale to ensure that certified material is kept separate from non-certified material throughout the supply chain.

Certification schemes which should be sought out are Forest Stewardship Council (FSC), Programme for the Endorsement of Forest Certification (PEFC) and Sustainable Forestry Initiative (SFI) (Figure 10). It is important to note that not all schemes are created equal, though taking a conservation based approach to managing forests is crucial.

FSC
www.fsc.org
FSC® C012959
The mark of responsible forestry

SUSTAINABLE FORESTRY INITIATIVE
SFI-01737

Figure 10: Sustainable forestry labels denote environmentally responsible forest practices and prevent over-harvesting.

Adhesives

When sourcing timber attention should be paid to the particular glues or adhesives used to bond wood laminations, many contain formaldehyde which is a known volatile organic compound (VOC) and off-gasses into the atmosphere and indoor environment. The current industry standard for CLT is to use a formaldehyde-free polyurethane (PUR) adhesive, though some manufacturers use Melamine- Urea Formaldehyde. PUR is the only adhesive that is classified as Red List Free by the International Living Future Institute (ILFI) and the Living Building Challenge (LBC) – the most stringent green building rating system available at present. Red List Free materials are absent from the worst in class chemicals that negatively impact human and environmental health (Figure 11).

Emissions from engineered wood products, like CLT are widely recognized as being much lower than emissions from traditional particleboards, primarily because the adhesive in CLT comprises only a small percent of the overall volume. Glulam production, however, may involve formaldehyde based adhesives such as Phenol Formaldehyde (PF) and Phenol Resorcinol Formaldehyde (PRF). Careful consideration should be given to the end of life for wood products which include formaldehyde based adhesives, as they will need to be properly treated ahead of being repurposed or biodegraded, such that chemicals with not leach into the environment or hinder the natural carbon cycle.

Figure 11: Typical glue lamination process for wood and the Red List Free label which designates a product as being free from chemicals with the greatest adverse effects on human and environmental health.

TRANSPORTATION (A4)

Material sourcing is a key driver of embodied carbon in the life-cycle assessment due to the carbon intensity of placing timber on a truck or train and bringing it to Orono, Maine. TT evaluated the carbon intensity of steel, CLT and glulam transportation from domestic, local and international suppliers to illustrate the carbon impact of regional sourcing.

The tons of CO2e emitted in delivering 1,000 cubic feet of material to the project site is five times greater for steel from Pennsylvania than from Canada, a difference of 5.8 tons CO2e. Both mills manufacture steel via electric-arc furnaces (EAF), which involve a greater power consumption but overall use less raw material than a blast oxygen furnace, relying instead on recycled steel scrap. In EAF steelmaking the primary source of emissions is indirect from electricity usage (approx. 50%), natural gas combustion (40%) and actual steel production accounts for roughly 10% (Credit- EPA).

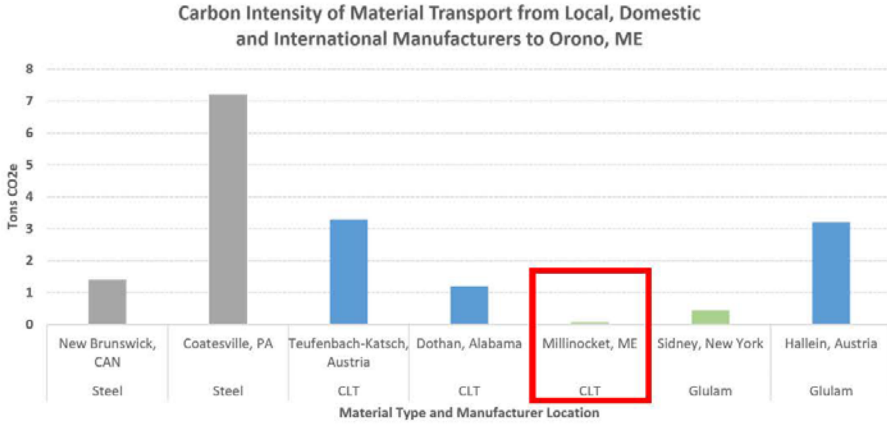
For CLT, the choice to source from SmartLam in Alabama as opposed to the international market results in a carbon savings of just 2.1 tons CO2e. Whereas trucking emits approximately sixty times more carbon than an ocean liner, a larger quantity of material can be accommodated on a container vessel than on a flatbed truck, thus reducing the number of overall trips necessary and the carbon emitted. If CLT was sourced from a future plant in Maine, the impact of transportation emissions would be almost negligible at 0.1 tons CO2e.* Sourcing CLT within the state of Maine results in a 1.1 tons CO2e reduction from domestic sourcing and a 3.2 tons CO2 reduction from the international market.

In the case of glulam, the proximity of New York to the site makes the international market a less effective carbon choice, with a savings of 2.8 tons of CO2 for selecting the domestic sourcing option (Figure 12).

The results demonstrate the competitiveness of a local sourcing option not only from a carbon emissions perspective but also in terms of shipping costs. For materials with energy intensive production processes, like steel, source location can significantly impede the carbon efficiency of a project (Table 1). Overall the project team's choice to source material locally wherever possible has resulted in the relatively low 181 tons of CO2 for life-cycle stage A4-A5, while also having the dual benefit of supporting the local economy.

Table 1: Tons of CO2 Emitted by Material based on Location

Material	Manufacturer/ Location	Mileage to Orono, ME	Transport Ton CO2e
Steel	Ocean Steel / New Brunswick, CAN	116 mi	1.4
Steel	ArcelorMittal/ Coatesville, PA	578 mi	7.2
CLT	KLH/ Teufenbach-Katsch, Austria	3,790 mi	3.3
CLT	SmartLam/ Dothan, Alabama	1,525 mi	1.2
CLT	Future Manufacturer/ Millinocket, ME	67 mi	0.1
Glulam	Unalam/ Sidney, NY	506 mi	0.4
Glulam	Binderholz/ Hallein, Austria	3,720 mi	3.2



*Note:

For the purpose of this study a CLT plant was assumed in Millinocket as it is central to spruce, pine and fir forest resources and is close to a main highway for ease of goods transportation.

Figure 12: Carbon Impact of Material Transport based on Manufacturer Location

WASTE (A5)

To account for the waste of materials associated with their installation on the project, TT has incorporated predicted waste rates into the life cycle assessment for the CLT Lab Addition. These waste rates are industry average assumptions for major building materials, and exact rates will depend on the materials, products and installation approach taken therein.

For all materials, including insulation, membranes, roofing and others not listed in Table 2, every attempt should be made to recycle products or component parts via manufacturer recycling programs or repurpose materials on other projects or via alternative applications.

These waste rates were combined with the transportation to site and construction for a total of carbon emissions from the A4-A5 Construction and Waste stage.

Transportation to Site: 135.0 tons CO2e

Waste Contribution: 46.0 tons CO2e

Total stage emissions: 181 tons CO2e

Table 2: Estimated Waste Rates for Major Building Materials

Material	Waste Rate (WR)	Global Warming Potential (GWP Ton CO2e)	Total Waste Contribution (Ton CO2e)
Concrete	5%	412.1	20.6
Steel reinforcement	5%	63.6	3.2
Steel frames (beams, columns, braces)	1%	42.3	0.423
Timber frames (beams, columns, braces, walls)	1%	109.9	1.1
Timber floors	10%	49.5	5.0
Timber roof	10%	144.6	14.5
Aluminum frames	1%	60.9	0.609
Glass	5%	13.2	0.660
TOTAL	-	-	**46.0**

MAINTENANCE/ MATERIAL REPLACEMENT (B1-B5)

This life-cycle stage includes environmental impacts from replacing building products after they reach the end of their service life. The emissions cover impacts from raw material supply, transportation, and production of the replacement material, as well as impacts from manufacturing the new material and handling waste generated during that production process.

For the purposes of the life-cycle assessment, a typical 60 year building service life has been assumed. The building service life defined as the period of time which the building is in use, prior to the need for significant renovation or refurbishment.

Materials modeled in the LCA are anticipated to have a service life on par with that of the building. However, product service life can vary depending on material selection, product maintenance needs or potential replacement. Material replacement cycles that are less than the service life of the building will inject additional carbon into the overall footprint of the building.

Table 3 identifies the service life to assigned materials included in the life cycle assessment. Overall embodied carbon associated with this stage will fluctuate based on anticipated product replacement needs.

Table 3: Service Life Assumptions for Building Elements

Building Element Type	Service Life
Substructure	
Foundations	Permanent
Lowest Floor Slab	Permanent
Superstructure	
Frame	As building, 60 years
Upper Floors	As building, 60 years
Roof	As building, 60 years
Membrane roofing	30 years
Internal Finishes	
Internal Curtain Walls	As building, 60 years
Insulation	As building, 60 years
External Envelope/ Facade	
External walls/ cladding	As building, 60 years
Curtain walls	As building, 60 years
Windows	As building, 60 years
External Doors	30 years
Glazing	30 years
Photovoltaic System	30 years

OPERATIONAL ENERGY (B6)

Design Narratives

Architectural

The building's program includes a 3D printer lab, office spaces and other ancillary spaces (Figure 13). The design team has chosen a mass timber construction with the goal of creating a low embodied carbon structure.

The proposed building is connected to an existing building on the east wall.

The envelope will be insulated metal panels and wood fiber insulation with an effective assembly U-factor of U-0.049 and a roof assembly of U-0.014. The windows will be high-efficiency thermally broken window frames with a center of glass U-0.26 and argon filled double pane glazing. Slab on grade will be fully insulated with R-10 EPS insulation.

Lighting

Daylighting is achieved through a combination of optimal window sizes, skylights and Kalwall (in the main lab). The spaces with daylight will be provided with daylighting controls to minimize usage of artificial lighting. Emergency lighting will not be controlled by daylighting sensors.

LED fixtures are considered in the basis of design for all lighting needs which provide lighting efficiently while significantly reducing the heat load from the fixtures.

A 40% reduction from ASHRAE 90.1-2016 lighting power is assumed in the analysis as a place holder until lighting design is fully developed. This estimate is based on TT's experience with other projects.

HVAC

Three options have been discussed with the design team. In future updates, TT will evaluate these systems based on the feedback from the design team and the owner. The option that could enable the project to go carbon neutral in phases, is used for this analysis as described in the following sections.

Plant:

A chiller heater can produce hot water and chilled water and take advantage of simultaneous heating and cooling loads by simply transferring energy from one side to the other side. The offices are equally spread between perimeter and core of the footprint which results in simultaneous heating and cooling. This plant could tie into the campus steam or have a stand-alone boiler (electric or natural gas). It provides flexibility to make the building all-electric, if desired. A cooling tower may be necessary depending on the MEP's load calculations.

Air Distribution:

A displacement ventilation system, where the air is delivered within occupied zones (6-8 ft. from the finished floor) is very efficient for large volume spaces. It conditions just the volume where occupants are. The cold air stays where occupants are (cooling mode). The diffusers (supply and return) can be located appropriately to help with destratification. Where height restrictions allow (opposite side of the 3D printer bay), a large fan (Big Ass Fans) can gently move the air during heating mode. Offices can be served with fan coil units (four-pipes on the perimeter and two-pipes in the core zones). A 100% outside air system with high-efficiency heat recovery can provide needed ventilation. A Demand Control Ventilation strategy will help to dial down the ventilation as occupant density varies and minimize waste of energy for cooling, heating and dehumidification.

Figure 13: A rendering of the CLT lab addition to the Advanced Composites Center, courtesy of Scott Simons Architects

OPERATIONAL ENERGY (B6)

Energy Analysis

TT performed a schematic whole building energy analysis to understand the operational use and potential for achieving Zero Net Energy (ZNE). As designed, the project is estimated to use 73 Kbtu/sf-yr. This is a reduction of nearly 50% from a typical building of similar use type.

Current estimate for equipment plug loads, defined as energy used by equipment that is plugged into an outlet in the project's labs (28%) and offices (5%), is alone approximately 25 Kbtu/sf-yr based on the information provided by the University. The rest of the energy use is from lighting and HVAC (Figure 14). As such, equipment plug loads present the greatest opportunity for efficiency improvements.

If the building were to pursue ZNE status, the project Site EUI could not exceed 28 Kbtu/sf-yr. TT recommends that the design team carefully review the equipment plug loads and use schedules to discuss opportunities to conserve plug load energy. Further opportunities for energy conservation in HVAC system can be explored as the design develops.

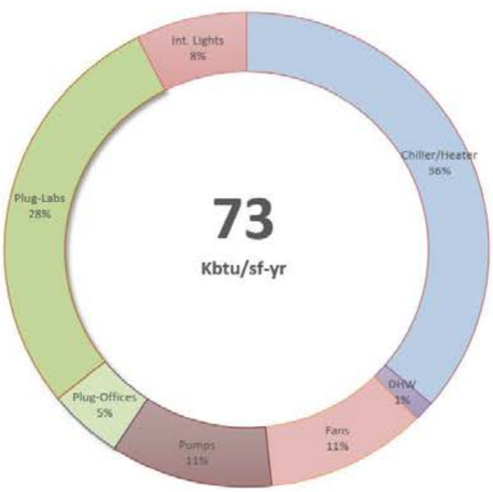


Figure 14: Breakdown of estimated energy end uses and EUIs

Building EUI: 73 **Equipment Plug Load EUI**: 25

Energy conservation strategies for reducing equipment plug loads will also reduce the HVAC energy associated with heat generated by all lab equipment. However, achieving ZNE will pose a challenge for this building due to the heavy energy consumption of the lab and large plug loads for industrial equipment.

This said, the project has several load sharing opportunities due to simultaneous heating and cooling load as a result of high internal loads and core versus perimeter zones. Strategies that help to further enable load sharing could reduce the HVAC energy by 15-20% (Figure 15).

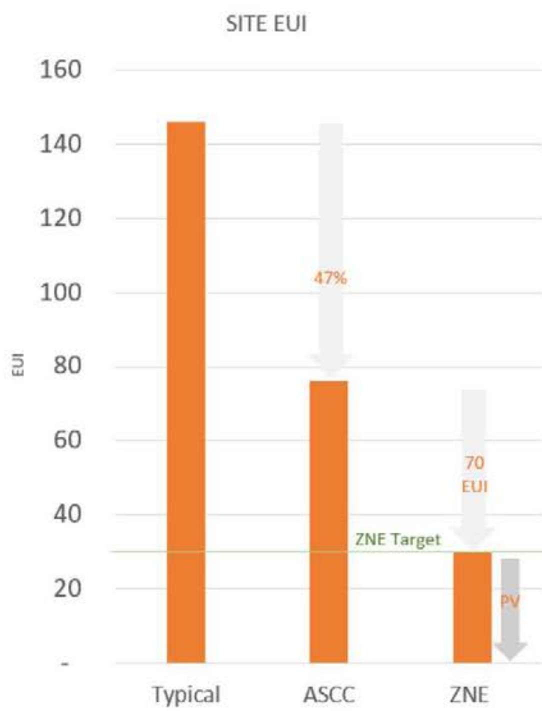


Figure 15: Comparison of site EUI reduction for a typical building vs the ASCC lab addition as a standard and zero net energy building

OPERATIONAL ENERGY (B6)

CHP Biomass System

A Combined Heat and Power (CHP) system is an integrated energy technology that when designed well provides the best fuel efficiency to generate electricity and utilizes the waste heat generated in the process (Figure 16). A biomass source such as wood residues from forests and mills, which are plentiful in Maine, can be a reliable and renewable resource for minimizing the carbon footprint of a building.

CHP can reduce greenhouse gas emissions by burning less fuel to produce each unit of energy output and by avoiding transmission and distribution losses of electricity.

For CHP to run at a higher efficiency, a continuous heat load is necessary throughout the year or the system should be operated only when there is a consistent heat load. A CHP system at the campus level could run more efficiently by aggregating campus wide diverse loads and running at its peak efficiency.

Typically, the combined source energy efficiency (electricity and heating) compared to the current system at the campus plant can be improved up to 40-50%. Additionally, if biomass is used as the fuel source there may be reasonable cost benefit.

The information provided here is for conceptual understanding of the impact of a Biomass CHP system on carbon emissions and has not been quantified through analysis.

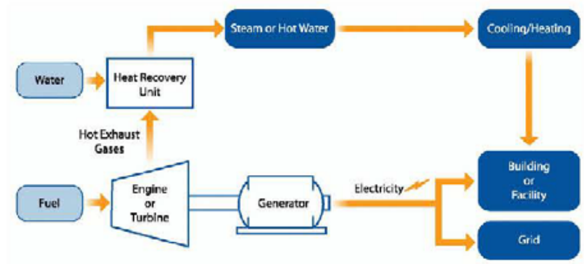


Figure 16: Schematic layout of CHP

(Image credit: https://www.epa.gov/chp/what-chp)

Wood sequesters carbon during a tree's growing period (refer to Biogenic Carbon section page 7 for more) however, combustion of wood scraps to produce energy releases the CO2 stored in these materials.

While a CHP biomass system does use up available and renewable forest byproducts, the project must also consider the carbon emissions released with the burning of wood biomass. This amount of carbon emitted will be based on the size of the biomass system, rate of energy consumption and type of tree species incinerated.

OPERATIONAL ENERGY (B6)

Photovoltaic (PV) System Analysis

Operational Energy

Based on the roof area, TT estimates that an approximately 500 KW PV system is feasible to install after accounting for equipment on the roof. No other areas have been explored for a PV system.

TT recommends that the project strive to bring the EUI to the lowest possible number before exploring PV opportunities. This exercise is meant to show potential for PV generation and as a result determine the feasibility of Zero Net energy (ZNE) for the project.

There are several high efficiency panels, Tesla being one of them. Assuming Tesla's efficiency, we estimate an approximate 500 KW DC PV peak production which translates into an EUI of 28 for the project. A monthly breakdown for the electricity generation for the 500KW system is shown in Table 4.

Table 4: Operational Carbon Contribution of PV System

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	2.87	38,338
February	3.88	46,212
March	4.82	62,088
April	5.40	64,936
May	5.72	70,616
June	5.89	68,738
July	6.18	73,477
August	5.91	70,176
September	5.03	59,198
October	3.39	42,466
November	2.57	31,985
December	2.16	28,636
Annual	4.49	656,866

Embodied Carbon

Assuming a high efficiency yield from monocrystalline panels, TT evaluated the embodied carbon payback contribution of the PV system (Table 4). Based on an anticipated system generation of 500 KW DC PV, a carbon factor of 429 lbs/MWH was assumed for Maine generated energy and using an average carbon coefficient for monocrystalline panels, the PV system is predicted to save 281,424 lbs CO2/yr.

The embodied carbon associated with the installation of the PV is 1,158,345 lbs CO2. This equates to an upfront payback of 4.1 years, however we anticipate the array will need to be replaced following a 30 year service life and this will re-inject carbon into the building's overall carbon budget, see Figure 17.

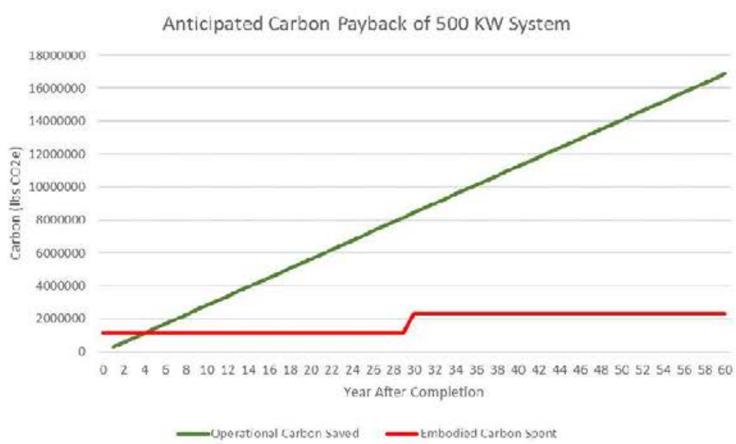


Figure 17 : Carbon Payback of PV System

OPERATIONAL ENERGY (B6)

Operational Carbon Contribution

The total life cycle carbon of the building includes both embodied and operational energy, used during building occupancy. The estimated energy use of 73 EUI for the lab addition is comprised of HVAC, which includes heating, cooling, fans and pumps, plug loads and the remainder of the energy use intensity is for hot water and lighting. This does not include the PV system, which alone can generate 28 EUI, equating to an overall EUI of 45 (Table 5).

The carbon contribution of these systems to the building's overall carbon budget weighs heavily on equipment efficiency and the source of energy generation. Maine has a cleaner energy grid compared to other states due to Hydro-Québec, which supplies energy to the cities of Bangor and Orono. Much of the other electricity generation comes from non-hydroelectric renewables, such as wind power and biomass from wood waste, a small amount is from natural-gas fired power plants (EIA, See Appendix A).

The low emissions generated by the hydroelectric dam result in a lower than US average, annual CO2 emissions for the Maine grid (429 lbs CO2/MWH). Assuming PV is incorporated on the project, an EUI of 45 emits 166,810 kg CO2/yr. Given this, the lab addition will contribute 10,008,593 tons of CO2e over its 60 year building service life.

Energy Use Conclusion

The proposed project has a high performance envelope and HVAC systems. TT's estimated energy use of 73 EUI performs approximately 47% better than a typical building type in the same climate zone. This is a significant improvement in performance compared to a similar building type.

However, to attain ZNE status the project must achieve 28 EUI or lower. This is assuming a PV system only on the roof. Different from a typical office building, this project type demands high power draw due to the lab equipment and its consistent use pattern. The equipment plug loads use 25 EUI while HVAC/Lighting/Hot Water use the remainder of the EUI (48).

TT recommends the following:

- Explore further opportunities to optimize equipment plug loads use such as occupancy sensor based receptacles and/or smart power strips in non-lab spaces, power management software for lab areas that do not disrupt the research activities
- Explore load sharing opportunities (passive or active) during simultaneous heating and cooling loads
- Consider, only after all conservation measures have been explored, on-site PV (non-roof), off-site PVs or Renewable Energy Credits (RECs) to achieve zero operational energy use

Table 5: Energy Use Intensity Breakdown and Carbon Emissions By System Type (Kbtu/sf/yr)

System	EUI (Kbtu/sf/yr)	KBTUs	MWH	CO2 (lbs)	CO2 (US tons)
HVAC	41	2,665,000	781	335,078	168
Plugs	25.55	1,660,750	487	208,811	104
DHW + Light	6.45	419,250	123	52,713	26
TOTAL	**73**	**4,745,000**	**1,391**	**596,602**	**298**

END-OF-LIFE/REUSE, RECYCLING & DISPOSAL (C1-C4 / D)

The end-of-life cycle stage includes impacts for processing recyclable construction waste flows for recycling (C3) through to the end-of-waste stage, where the impacts of processing and landfilling materials which cannot be recycled (C4) are captured. The impacts associated with building deconstruction are also included in this stage as emissions from waste energy recovery.

Life cycle stage D, Reuse, Recovery and Recycling accounts for the benefits of keeping existing materials within the production-supply chain. This has significant economic, social and environmental benefits, all dependent upon keeping climate change and carbon emissions from buildings and industry, in check to maintain ecological system balance (Figure 18).

This circular economy approach eliminates new waste generation by continually re-using resources. Steel, for example, can be recycled continuously without any impact to its tensile strength and steel which contains higher recycled content has a lower embodied carbon impact. Reusing materials reduces the need to inject new carbon into a building's carbon budget, allowing projects to take full advantage of the carbon savings of material reuse.

Deconstruction & Recycling

Consideration for where materials end up after leaving the project site or serving their use to the building is tantamount to balancing both building and ecosystem carbon. Designing for eventual deconstruction and dismantling is a critical component of sustainable design and especially relevant to timber due to its carbon sequestration properties.

Though wood is a carbon sink, at the end of the typical building's 60 year service life, the majority of timber products are discarded, select members may be recycled but more often are landfilled or incinerated. It is at this point in the end-of-life cycle stage that the biogenic CO2 stored in timber is released through combustion or decomposition. (Refer to Product Stage section page 5 for early stage emissions.)

The end-of-life for timber used in the lab addition should be taken into account in the early design stage, to preserve the carbon savings achieved with wood construction and promote sustainable use of this natural resource.

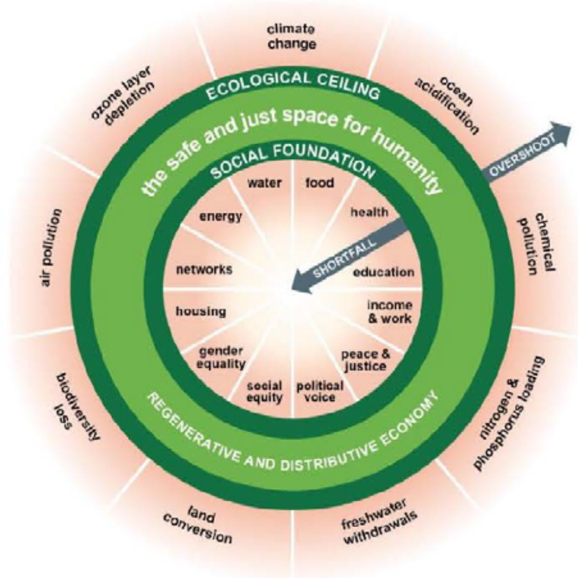


Figure 18 : The doughnut of social and planetary boundaries (Credit Kate Raworth)

Adaptive Reuse

Opportunities for elongating the building's service life should be discussed early on. A choice between bolted or welded connections will impact the dismantling and recycling potential of the structure. Whenever possible, bolted connections, which can be removed at the end of the building's service life, should be specified.

The CLT lab addition to the Advanced Structures and Composites Center is anticipated to serve students, staff, and faculty for 60+ years, however its service to the community will grow and change based on student learning needs and those of the University at large.

As such, these predicted use changes should be accounted for. The design team should utilize the intelligence capacity of their BIM environments so that data, such as the structural capacity of structural elements, façade material breakdowns, etc., are well documented. This will allow future design teams to be able to quickly assess material re-use and repurpose potential building elements.

LOW CARBON BENCHMARKS

In recognition that climate change is affecting every country on every continent, Goal 13 of the *United Nations Sustainable Development Goals* challenges countries, institutions and individuals to "take urgent action to combat climate change and its impacts." The UN has set forth an ambitious target of cutting global emissions by 45% by the year 2030. With 11% of global greenhouse gas emissions attributable to the building and construction industry alone, it is critical to understand how new construction aligns with the design targets of future sustainable construction.

Using industry accepted breakdowns for a typical comparable building, and TT's own internal studies, we have developed carbon benchmarks for each of the major carbon driving elements of the CLT lab addition which include foundations, floors, framing, and façade.

The carbon contribution of each of these building elements were compared to carbon targets for similar facilities, in order to benchmark the lab's overall progress in aligning with the goals for 25% reduction in CO2 by 2025, 45% reduction by 2030, 68% reduction by 2040 and zero carbon emissions by 2050.

The results demonstrate that the CLT lab addition is performing above the industry carbon benchmarks and is on target to meet the carbon reduction goals outlined for next 10 years (Figure 19).

This said, several elements will need to be considered for greater efficiency to remain aligned with these targets. The foundation embodied carbon will only meet target until 2028, at which point slab design efficiencies will need to be considered.

Facades currently meet the targets through 2025, but in 2027 they will fall short and similarly floors will fall away from the embodied carbon target beginning in 2042. Framing will meet the carbon target by 2042 and thereafter exceed it until 2050, when emissions from all buildings must be zero (See Appendix B).

The degree of performance for each element category is dependent on various factors including material type, quantity used, and carbon intensity inherent in manufacturing. These carbon benchmarks are meant to be a model for future buildings.

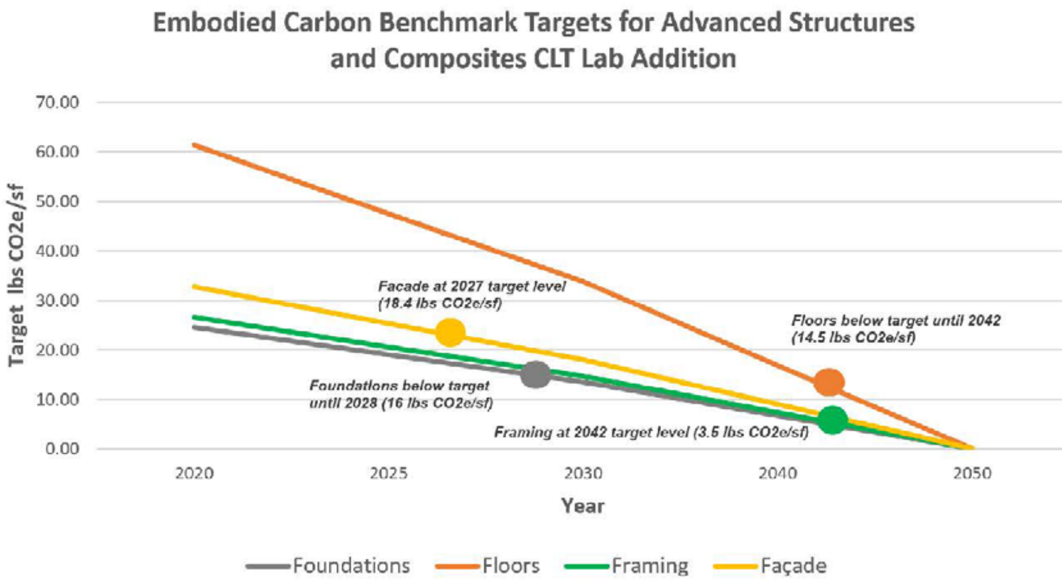


Figure 19: Embodied carbon emissions associated with major building elements in relation to UN climate reduction targets.

CARBON REDUCTION OPPORTUNITIES

Recommendations

In order to continue making progress towards these low embodied carbon benchmarks, strategies for optimizing building and material efficiency will need to evolve. The reduction targets currently set for 2040 and 2050 may indeed change based on global advancement and achievement in carbon reductions over the next 10 to 15 years. To ensure that the carbon emissions from new construction are properly curtailed, in order to maintain ecosystem balance and remain within our planetary resource boundaries, it is necessary to think broadly about a strategic approach to reducing carbon beyond just major building materials.

This can be done in a number of ways including development of a campus wide carbon strategy. This may take the shape of a low carbon procurement policy or a list of manufacturers whose products have been pre-approved as being low embodied carbon alternatives to typical building materials. Using the influence of the institution can drive change in the industry by putting pressure on manufacturers and the wider supply chain, ensuring continued advancement in low carbon design material options.

A low carbon strategy should also focus on transitioning the University's operational energy to more efficient, renewable fuel sources. The state of Maine grid mix is transitioning away from fossil fuels and towards renewables, like PV and hydropower. To further drive down building EUI an energy mix that takes advantage of this renewable energy should be evaluated, along with the potential to build up off and on-site renewables like solar or wind power.

In addition to the efficiency measures and reduction strategies outlined in the body of this report, TT recommends the project incorporate the following:

- Request Environmental Product Declarations (EPDs) for all building materials, not only to accurately capture the impact of product use but also as a means of driving the industry towards transparency around the carbon impact of their products
- Request supplier information to understand where materials and their component parts are being sourced. Consider local suppliers for the main carbon driving elements on the project:

Concrete: A local concrete supplier on previous Maine projects has been Dragon Concrete in Thomaston, ME. If sourcing is within a closer radius to the site carbon emissions from the A4 transport stage can be reduced.

Steel: Previous University project's have sourced steel from Ocean Steel in Canada, proximity to the project makes the international market a better option compared with domestic sourcing out of Pennsylvania.

CLT + Glulam: While SmartLam's CLT production facility in Alabama is expected to come online in time for the construction of this project, a future CLT manufacturing plant in Maine would provide significant transportation cost and carbon savings while making use of the state's plentiful varieties of sustainable forested timber and supporting the local economy

Where these large quantity and carbon driving materials are procured will impact the embodied carbon results outlined in this study.

Impact

The CLT lab addition life-cycle assessment and carbon benchmarking study demonstrates that the building is well designed and on target to meet the carbon reduction goals outlined for 2030 and beyond. Despite being a high energy powder draw space due to much heavy lab equipment, the building is able to demonstrate an EUI of 73, 47% less than an typical building of similar use type. This is substantial and further reductions are still possible through equipment plug load efficiencies or PV generation on or off-site.

The project attributes a high degree of consideration towards the sourcing location of key carbon driving materials. Although transportation is only a small percentage of carbon emissions, product stage material carbon accounts for the majority of life cycle stage emissions. It is at this early point of timber sourcing where the availability of a Maine-based CLT manufacturer would make transportation emissions nearly negligible (0.1 tons CO2e), while supporting continued sustainable management of Maine forests and the economic benefit of lower material costs, as well as overall benefit to the local economy.

This project seeks to bring awareness to mass timber constructability and serve as a case study for timber design. The life-cycle assessment results and low carbon benchmarks provided in this study are intended to be utilized by design teams to influence future designs.

APPENDIX A – ENERGY INPUT ASSUMPTIONS

GENERAL	
Steam rate	$20/MMBTU
Electricity rate (if known)	$0.14/KWH
Natural Gas rate (if known)	$0.9/Therm
Ventilation	30% greater than ASHRAE 62.1 ventilation rates.
Setpoints Summer (Occ / Unocc)	Offices : 72/75 Lab: 75/80 F
Setpoints Winter (Occ / Unocc)	Offices : 70/68 Lab: 60/55 F

OCCUPANCY	
Occupancy schedule	Offices: Typical office schedule (8-6P- Weekdays; Closed on Weekends & Holidays) Lab: School year (8A-8P); Summer- 50% of typical school year)
Total Occupancy	Offices: 150 SF/Person; Lab: 500 SF/Person

BUILDING ENVELOPE (CONSTRUCTION ASSEMBLIES)	
Roofs	U-0.014
Walls - Above Grade	U-0.049
Slab on Grade	2" EPS below entire slab
Vertical Glazing Description (storefront)	Aluminum Clad wood window Sierra Pacific - Aspen window - Basis of Design
Vertical Glazing U-factor, SHGC, VT	U-Value 0.24, SHGC 0.27, VT .64
Vertical Glazing Description (window units)	Timber Curtain wall Sierra Pacific - Architectural wall system - Basis of Design
Vertical Glazing U-factor, SHGC, VT	U-Factor 0.25, SHGC 0.19, VT .43
Shading Devices	Assume at storefront only SC-.30
Skylight Description Unitary (Lab space)	Wasco Ecosky CLC3
Skylight U-factor, SHGC, VT	U-Factor 0.33, SHGC 0.31, VT .40
Skylight Description Framed Pyramidal	Wasco (87 triple glazed)
Skylight U-factor, SHGC, VT	U-Factor 0.19, SHGC 0.14, VT .17
Translucent Panel Description	Kalwall - 4" K100, white - white, 2" thermally broken, fiberglass insulation - Basis of Design
Translucent Panel U-Factor	U-Value 0.08, SHGC 0.04, VT - .04
LIGHTING	
Lighting Power Density (W/sf)	Assuming LED - 0.55 w/sf (offices) ; Lab- 0.75 w/sf
Daylight Dimming Controls	Perimeter office spaces with continuous dimming controls; Lab-stepped switches

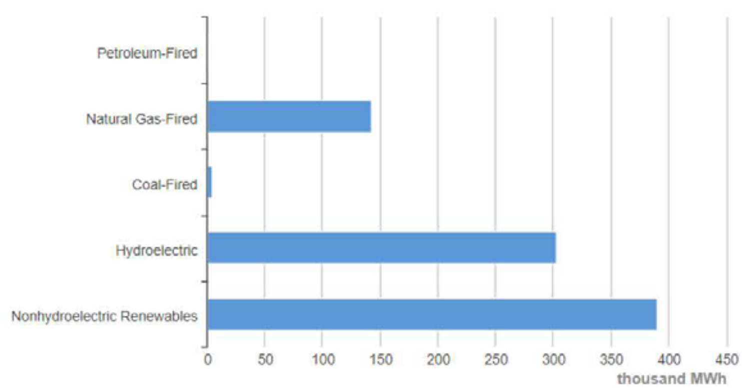
APPENDIX A – ENERGY INPUT ASSUMPTIONS

HVAC SYSTEM	
	Chiller/Heater
Plant	A chiller heater produces hot water and chilled water and takes advantage of simultaneous heating and cooling loads by simply transferring energy from one side to the other side. The offices are equally spread between perimeter and core of the footprint which results in simultaneous heating and cooling. This plant has been modeled with a stand-alone boiler (electric). A cooling tower is modeled for rejection of excess heat in the system.
Air Distribution	Displacement ventilation system: Air is delivered within occupied zone (6-8 ft from the finished floor) for large volume spaces. It conditions just the volume where occupants are. Offices served by fan coil units (four-pipe on the perimeter and 2 pipe in the core zones). A 100% outside air system with high-efficiency heat recovery system provides ventilation. A Demand Control Ventilation strategy will help to dial down the ventilation as occupant density varies and minimizes wastage of energy for cooling, heating and dehumidification.

SERVICE HOT WATER	
Water Heater type	Electric heat pump serving the bathrooms.
System efficiency	2 COP
Low Flow Fixtures	Low flow lavatories

Maine electricity generation breakdown by source fuel

Maine Net Electricity Generation by Source, May. 2020



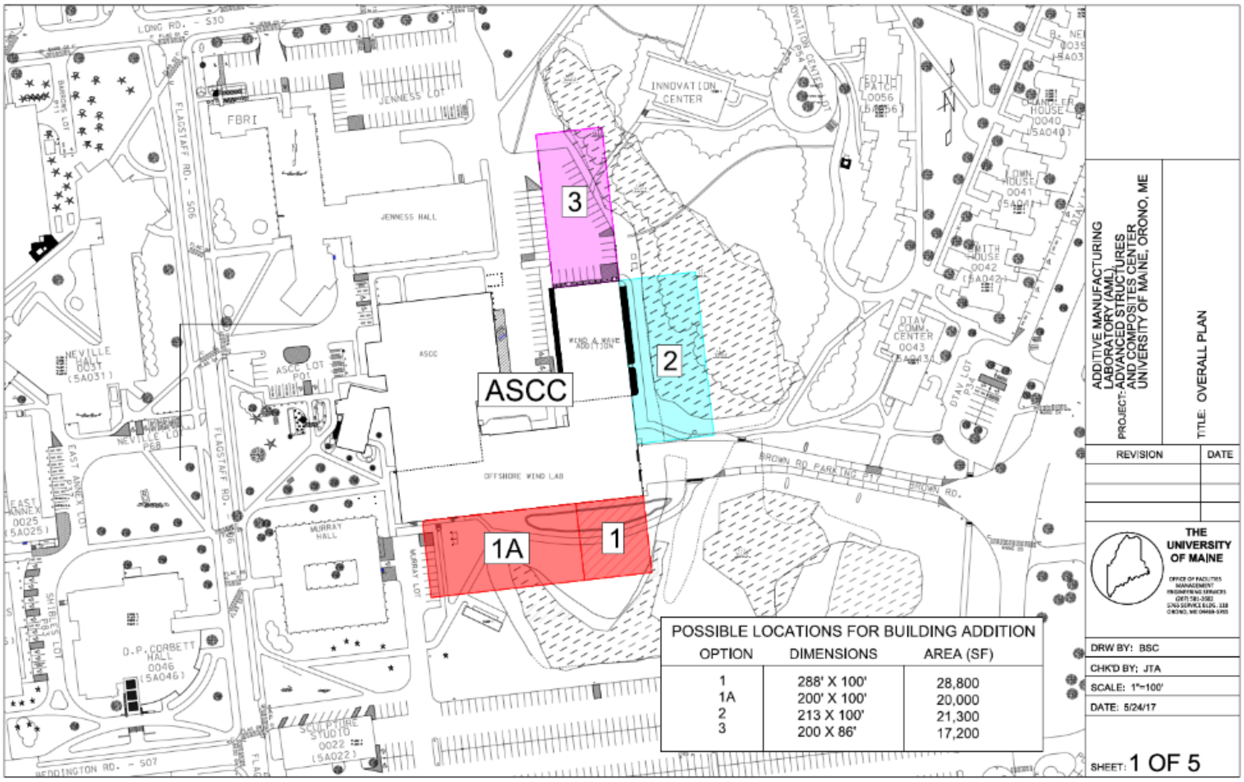
Source: Energy Information Administration, Electric Power Monthly

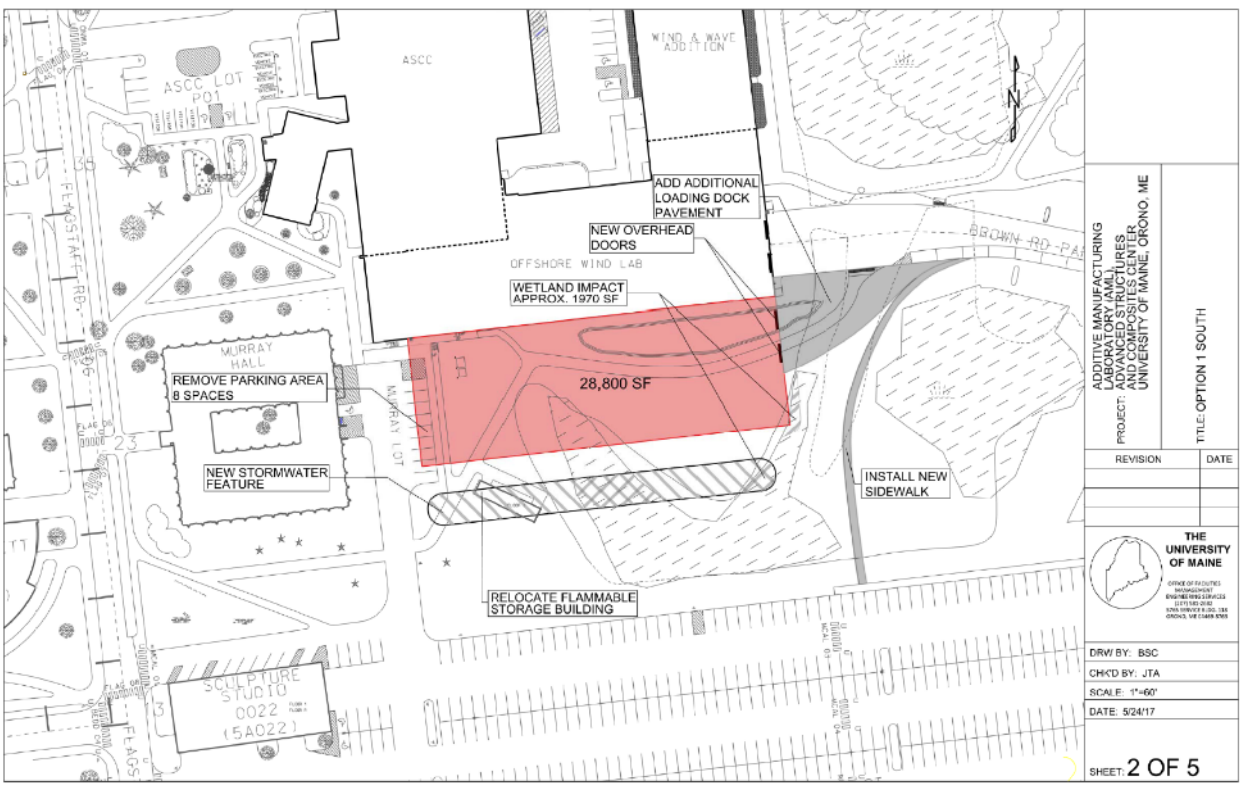
APPENDIX B – LOW CARBON BENCHMARKS

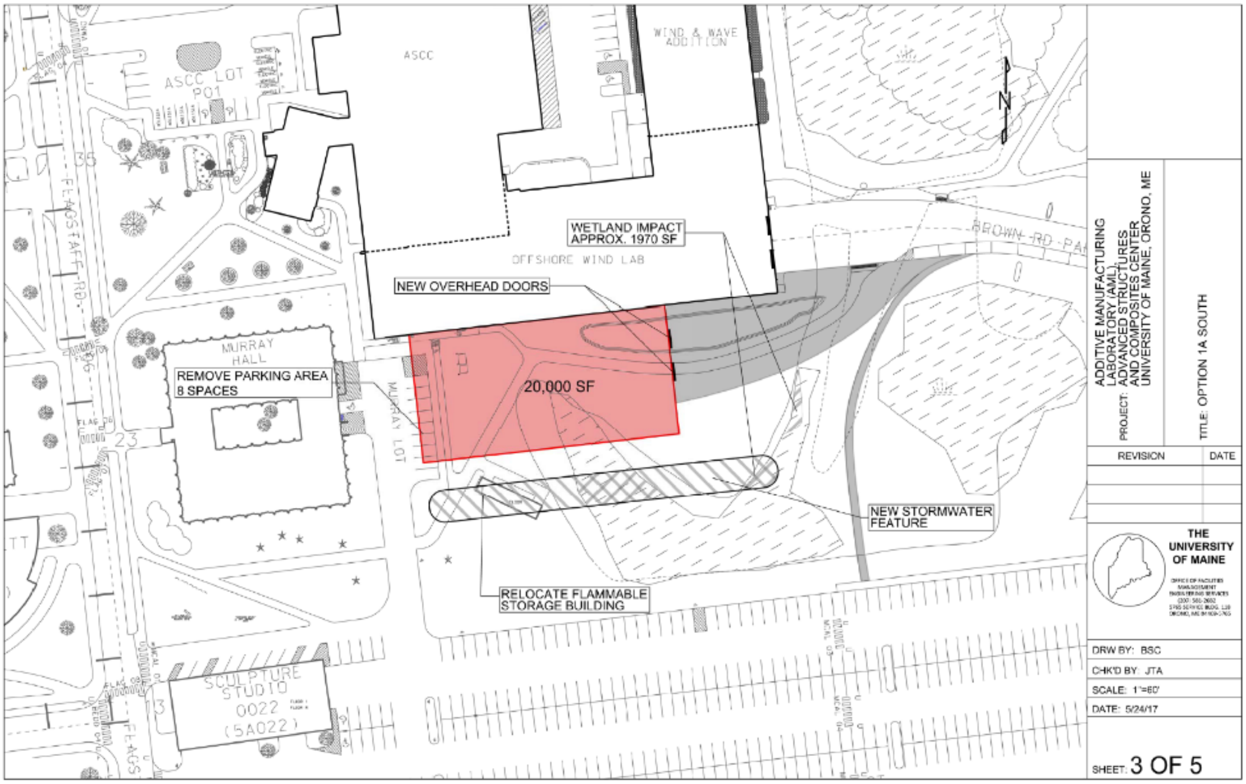
Building Element Type	Industry Target – 2020 lbCO2e/sf	Industry Target – 2025 lbCO2e/sf	Industry Target – 2030 lbCO2e/sf	Industry Target – 2040 lbCO2e/sf	Industry Target – 2050 lbCO2e/sf	Lab Addition As Design – 2020 lbCO2e/sf
Substructure						
Foundations / Lowest Floor Slab	24.53	19.01	13.49	6.75	0	16.06
Superstructure						
Frame	26.58	20.6	14.61	7.3	0	3.52
Upper Floors	61.31	47.52	33.73	16.85	0	14.52
External Envelope/ Facade						
External walls/ cladding	32.7	25.34	18.0	9.0	0	18.48

Note: *The above building elements were included in the scope of the life-cycle assessment for the lab addition. External site works, fittings, furnishings are excluded. Operational carbon from building services, including MEP, has been assessed separately in the Operational Energy B6 stage of this report.*

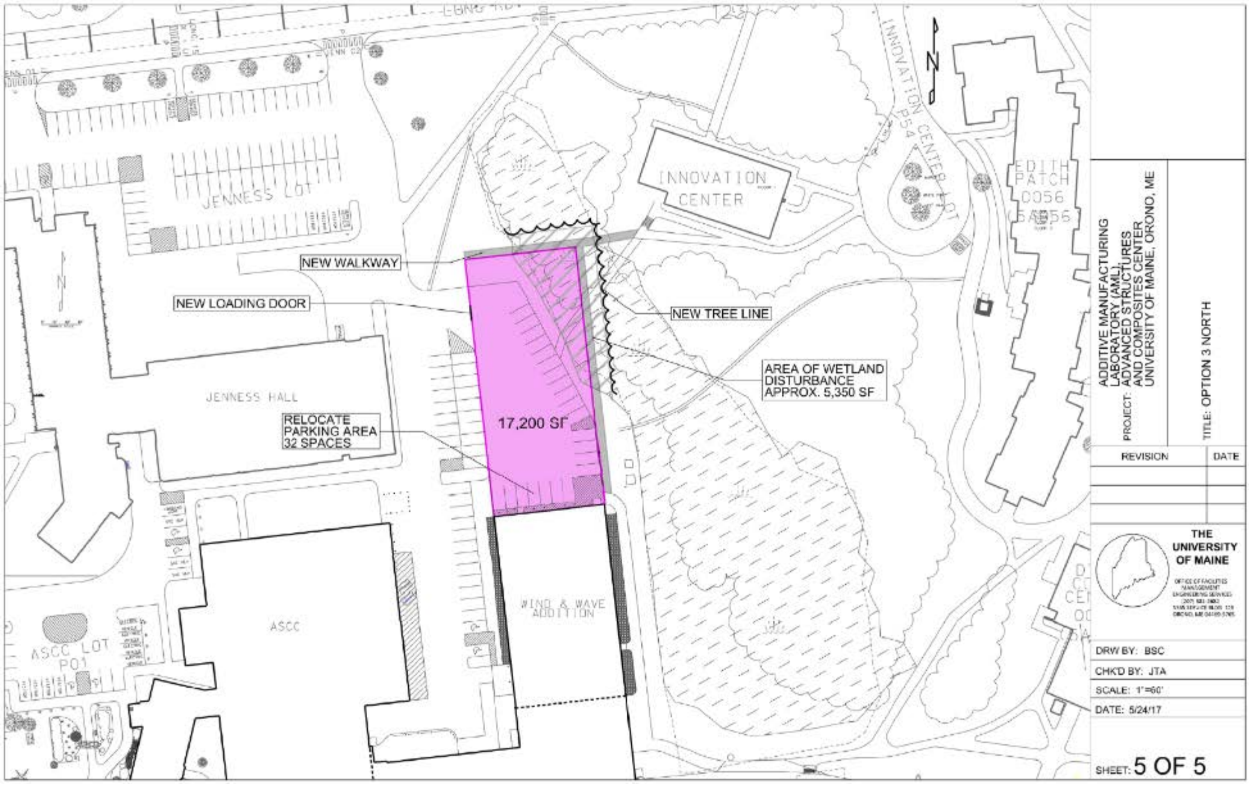
APPENDIX E


POSSIBLE LOCATIONS FOR BUILDING ADDITION
OPTION DIMENSIONS AREA (SF)
1 288' X 100' 28,800
1A 200' X 100' 20,000
2 213 X 100' 21,300
3 200 X 86' 17,200
ASCC
1A
1
2
3
PROJECT: ADDITIVE MANUFACTURING LABORATORY (AML) ADVANCED STRUCTURES AND COMPOSITES CENTER UNIVERSITY OF MAINE, ORONO, ME
TITLE: OVERALL PLAN
REVISION
DATE
THE UNIVERSITY OF MAINE
DRW BY: BSC
CHK'D BY: JTA
SCALE: 1"=100'
DATE: 5/24/17
SHEET: 1 OF 5


ADD ADDITIONAL LOADING DOCK PAVEMENT
NEW OVERHEAD DOORS
WETLAND IMPACT APPROX. 1970 SF
28,800 SF
REMOVE PARKING AREA 8 SPACES
NEW STORMWATER FEATURE
INSTALL NEW SIDEWALK
RELOCATE FLAMMABLE STORAGE BUILDING
PROJECT: ADDITIVE MANUFACTURING LABORATORY (AML) ADVANCED STRUCTURES AND COMPOSITES CENTER UNIVERSITY OF MAINE, ORONO, ME
TITLE: OPTION 1 SOUTH
REVISION
DATE
THE UNIVERSITY OF MAINE
DRW BY: BSC
CHK'D BY: JTA
SCALE: 1"=60'
DATE: 5/24/17
SHEET: 2 OF 5


ASCC
WIND & WAVE ADDITION
ASCC LOT P01
FLAGSTAFF RD
MURRAY HALL
REMOVE PARKING AREA 8 SPACES
WETLAND IMPACT APPROX. 1970 SF
OFFSHORE WIND LAB
NEW OVERHEAD DOORS
20,000 SF
MURRAY LOT
BROWN RD
NEW STORMWATER FEATURE
RELOCATE FLAMMABLE STORAGE BUILDING
SCULPTURE STUDIO 0022 (5A022)
PROJECT: ADDITIVE MANUFACTURING LABORATORY (AML) ADVANCED STRUCTURES AND COMPOSITES CENTER UNIVERSITY OF MAINE, ORONO, ME
TITLE: OPTION 1A SOUTH
REVISION
DATE
THE UNIVERSITY OF MAINE
DRW BY: BSC
CHK'D BY: JTA
SCALE: 1"=60'
DATE: 5/24/17
SHEET: 3 OF 5


JENNESS HALL
ASCC
WIND & WAVE ADDITION
NEW TREELINE
AREA OF WETLAND DISTURBANCE APPROX. 13,870 SF
21,300 SF
CONNECT TO LOADING AREA
OFFSHORE WIND LAB
NEW OVERHEAD DOORS
NEW WALKWAY
BROWN RD
DTAV COMM. CENTER 0043
0042 (5A042)
DTAV LOT
130
PROJECT: ADDITIVE MANUFACTURING LABORATORY (AML) ADVANCED STRUCTURES AND COMPOSITES CENTER UNIVERSITY OF MAINE, ORONO, ME
TITLE: OPTION 2 EAST
REVISION
DATE
THE UNIVERSITY OF MAINE
DRW BY: BSC
CHK'D BY: JTA
SCALE: 1"=60'
DATE: 5/24/17
SHEET: 4 OF 5


NEW WALKWAY
NEW LOADING DOOR
NEW TREE LINE
AREA OF WETLAND DISTURBANCE APPROX. 5,350 SF
RELOCATE PARKING AREA 32 SPACES
17,200 SF
JENNESS LOT
JENNESS HALL
INNOVATION CENTER
ASCC
ASCC LOT P01
WIND & WAVE ADDITION
EDITH PATCH
PROJECT: ADDITIVE MANUFACTURING LABORATORY (AML), ADVANCED STRUCTURES AND COMPOSITES CENTER UNIVERSITY OF MAINE, ORONO, ME
TITLE: OPTION 3 NORTH
REVISION
DATE
THE UNIVERSITY OF MAINE
DRW BY: BSC
CHK'D BY: JTA
SCALE: 1"=60'
DATE: 5/24/17
SHEET: 5 OF 5

	CRITERIA	OPTION			
		1	1A	2	3
	1) SIZE OF BUILDING	10	7	7	6
	2) SHAPE OF BUILDING	9	9	9	7
BUILDING RELATED	3) FFE	8	8	6	4
	4) ADJACENCY	8	8	7	4
	5) IMPACT TO EXISTING ASCC AND BUILDING UTILITY SERVICES	7	7	5	5
	6) WETLAND IMPACTS	8	8	1	5
	7) TRUCK ACCESS	8	8	7	4
SITE RELATED	8) STORMWATER MANAGEMENT	7	7	3	4
	9) PARKING IMPACTS	7	7	10	4
	10) SITE RELOCATION IMPACTS	6	6	9	8
	11) AESTHETICS	7	7	7	5
OTHER	12) PERMITTING DIFFICULTY	6	6	2	4
	13) CAMPUS-WIDE IMPACTS	6	6	9	4
	14) COST				
	SUMMATION	97	94	82	64

NOTES:
1) BY SQUARE FOOTAGE; PROPORTIONED TO LARGEST
2) WIDER IS PREFERRED; NO USE CONSIDERED
3) FFE
4) ADJACENCY; NEED USES
5) UTILITY
6) SQUARE FOOTAGE OF WETLAND IMPACT; PROPORTIONED TO LARGEST
7) LOADING/TRUCKS
8) SW, EXISTING AND NEW
9) PARKING, # OF SPACES AFFECTED
10) RELOCATION OF EXISTING FEATURES
11) AESTHETICS; BUILDING
11) AESTHETICS; SITE
12) NRPA/SW
13) FUTURE POTENTIAL FOR SOMETHING ELSE
14) WALTER; COSTS

AML Feasibility Study – Jeff Aceto, FM, May 2017 (DRAFT only)

Existing Conditions

The ASCC is a 77,340 square foot building located in the center of the University of Maine campus in Orono, Maine. It is located in a high traffic area surrounded by Long Road, Rangeley Road and Flagstaff Road. The building has 3 main areas of use: the ASCC, an Offshore Wind Lab (OWL), and the Wind and Wave Addition. As the ASCC is centrally located on the University's campus, it is surrounded by a variety of features including academic and residential buildings, wetlands, forested areas, roads, and parking lots. To the north of the ASCC is Jenness Hall with an associated Blue-tag parking lot. A dormitory, Cumberland Hall, is north of Long Road. Additionally, there is a small section of freshwater wetland. To the northeast is the Innovation Center. To the east is another large swath of freshwater wetland and the DTAV dorms. The building connects to Brown Road in the southeast. Brown Road leads to a loading zone area and large overhead door accommodating windmill blades as well as other pieces of large machinery. Brown road has parallel parking on the south side. To the south is a large storm water feature. Additionally to the south there is a small structure known as the Flammable Storage Building. Wetlands are also found to the south of the OWL and the north of the CCA lot. South east from the OWL is Murray Hall and a 9-space parking lot. To the West is the main ASCC entrance and parking lot with electric vehicle power stations.

The proposed project is a substantial addition to the existing ASCC facility. The addition must be contiguous with the current structure. Multiple options have been evaluated, and four possible locations and dimensions are detailed below. Each option was assessed based on square footage, dimensions, land impact, parking impact and permitting.

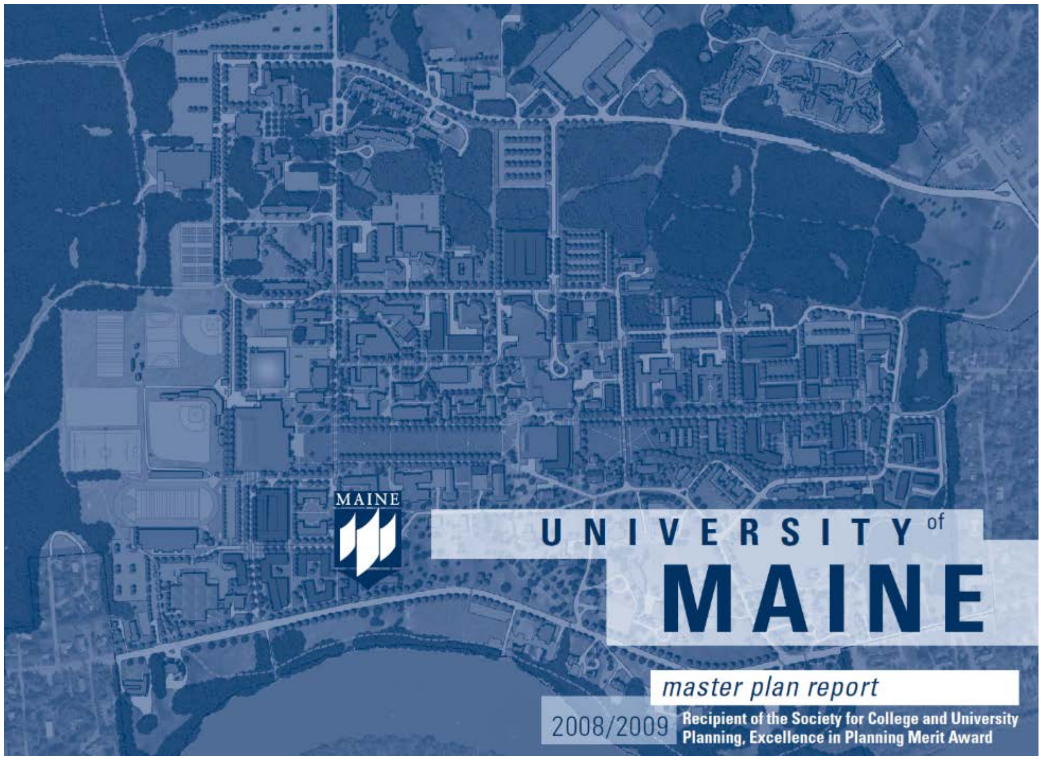
Option 1 is a 28,800 square foot addition adjacent to the south wall of the OWL. The dimensions are 288 feet by 100 feet. The new addition will have overhead doors on the east side, next to the existing OWL truck entrance. The existing storm water feature to the south of the OWL will be relocated closer to the CCA lot. The new addition necessitates relocating the Flammable Storage Building. Approximately 1970 square feet will be affected by this option. Option A includes an addition to the existing eastern loading dock pavement. A new sidewalk will come off Brown road and connect to the CCA parking lot. Option A will also impact 8 parking spaces in the Murray Hall lot, to the west of the proposed addition.

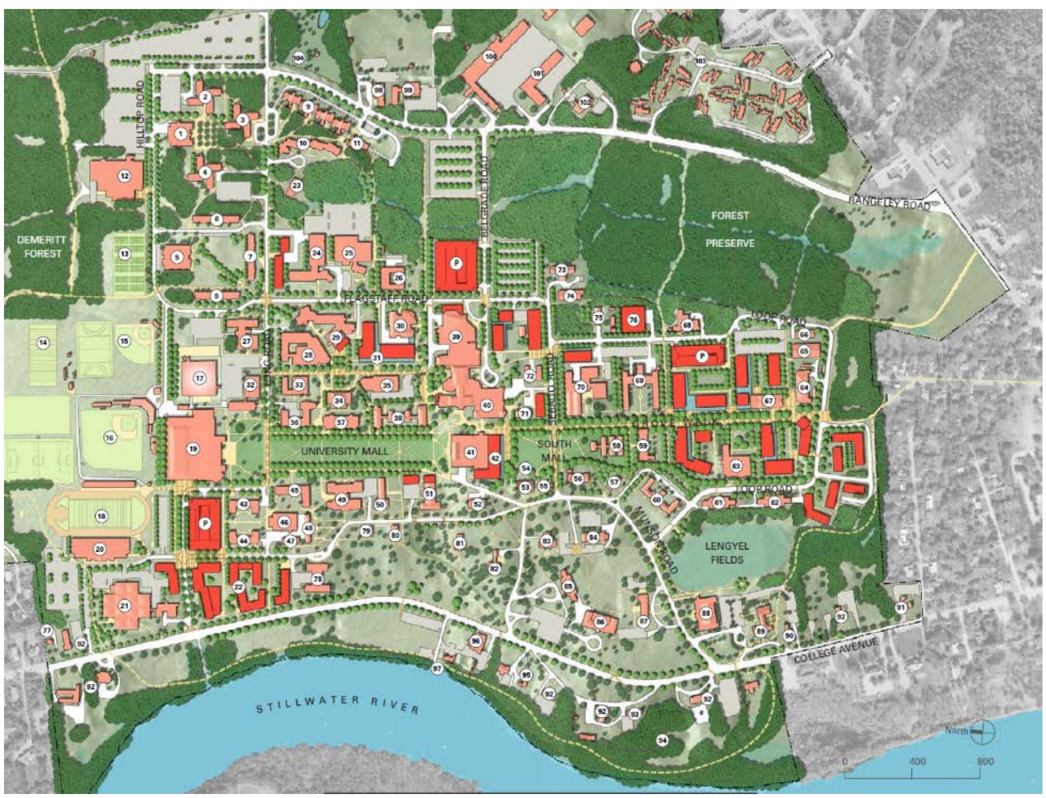
Option 1A is similar to Option 1 in that it will occupy the same area as Option 1, however it will be 20,000 square feet, with the dimensions being 100 feet by 200 feet. Similarly to Option 1, the existing storm water feature must be relocated as well as the Flammable Storage Building. There is the same wetland impact of 1970 square feet. The Murray Hall parking lot will also lose 8 parking spaces. A new loading dock and pavement area as well as the sidewalk from Brown Road to the CAA lot will be constructed.

Option 2 is a 21,300 square foot addition adjacent to the easterly walls of the Wind and Wave Addition and OWL. This addition will necessitate cutting the existing woodland tree line in an easterly direction for the addition. Additionally, there will be 13,870 square feet of wetland affected by this option. A new 6 foot wide walkway traces the north and east walls of the proposed addition connecting the Jenness Parking Lot with Brown Road. The addition will connect to the existing OWL loading dock area to the south. A small patch of pavement will connect Option 2 to Brown Road. No parking, storm water features or buildings will be directly affected by Option 2.

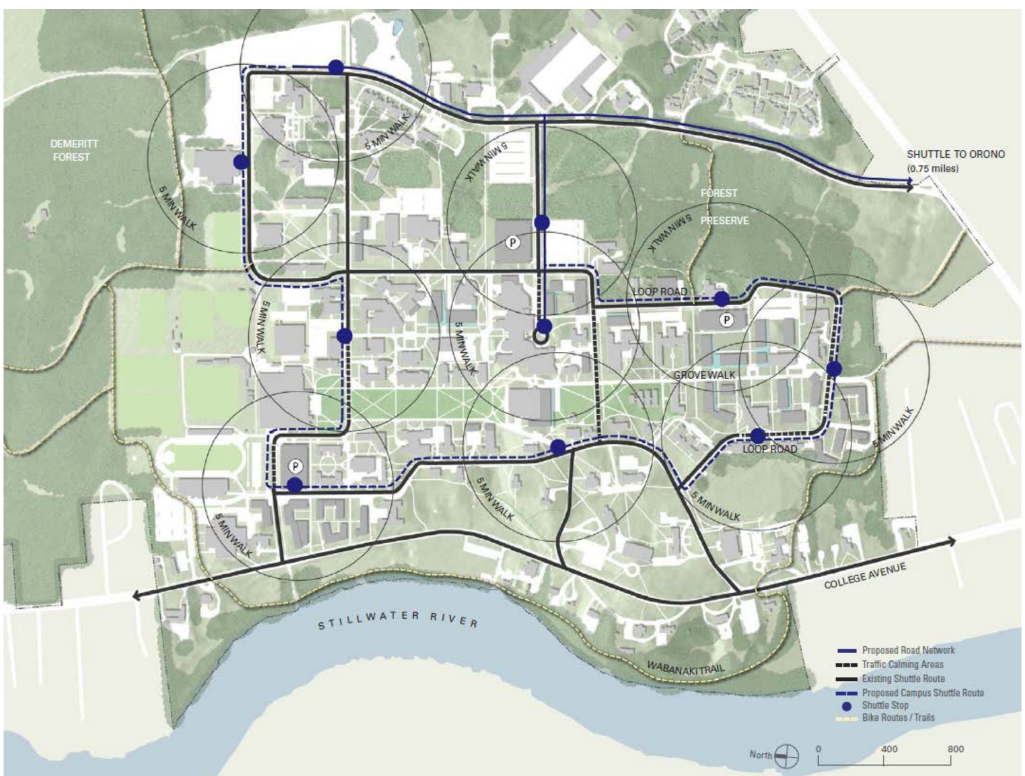
Option 3 is a 17,200 square foot addition connected to the north wall of the Wind and Wave Addition. The dimensions are 86 feet by 200 feet. The dimensions are based upon the existing width of the Wind and Wave Addition, which is 86 feet. Option 3 will disturb approximately 5,350 square feet of wetland and alter the existing tree line. A 6 foot wide walkway will be installed along the north and east edges of the addition as well as a spur connecting to the Innovation Center walkway to the north east. A new loading door will be on the west side of the addition, close to Jenness Hall. Option 3 will also commandeer 32 parking spaces from the Wind and Wave Addition parking lot.

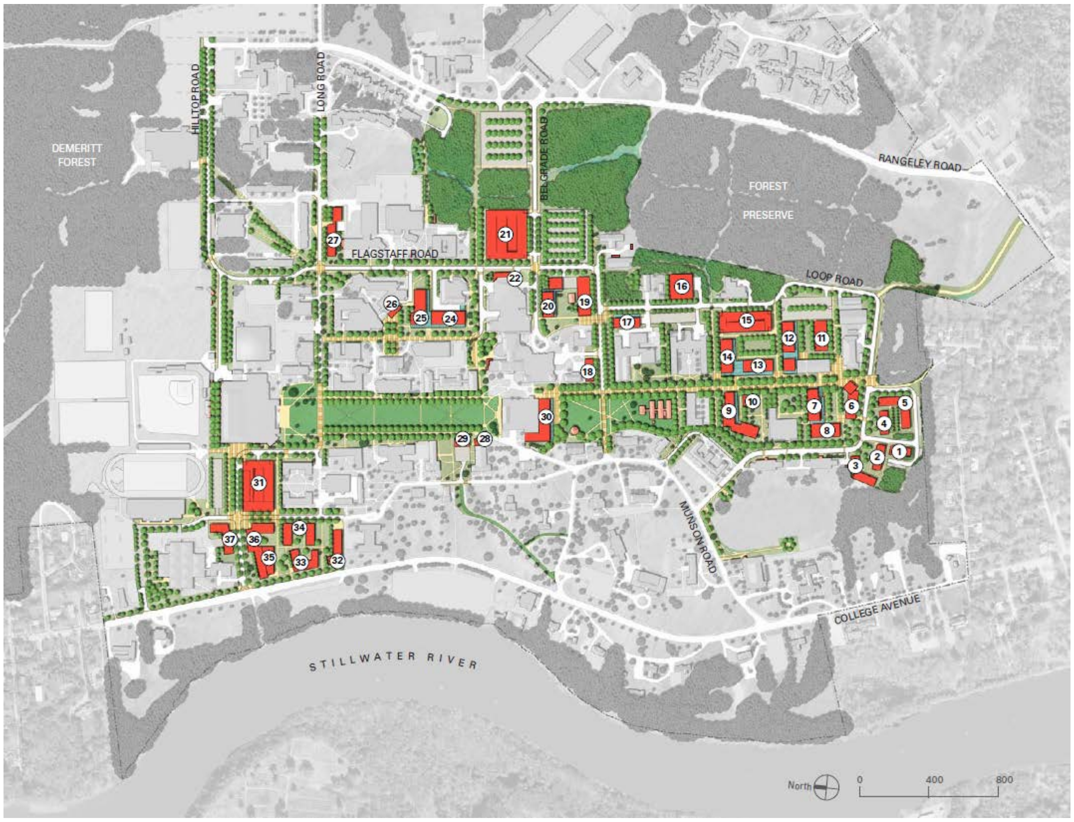
APPENDIX F

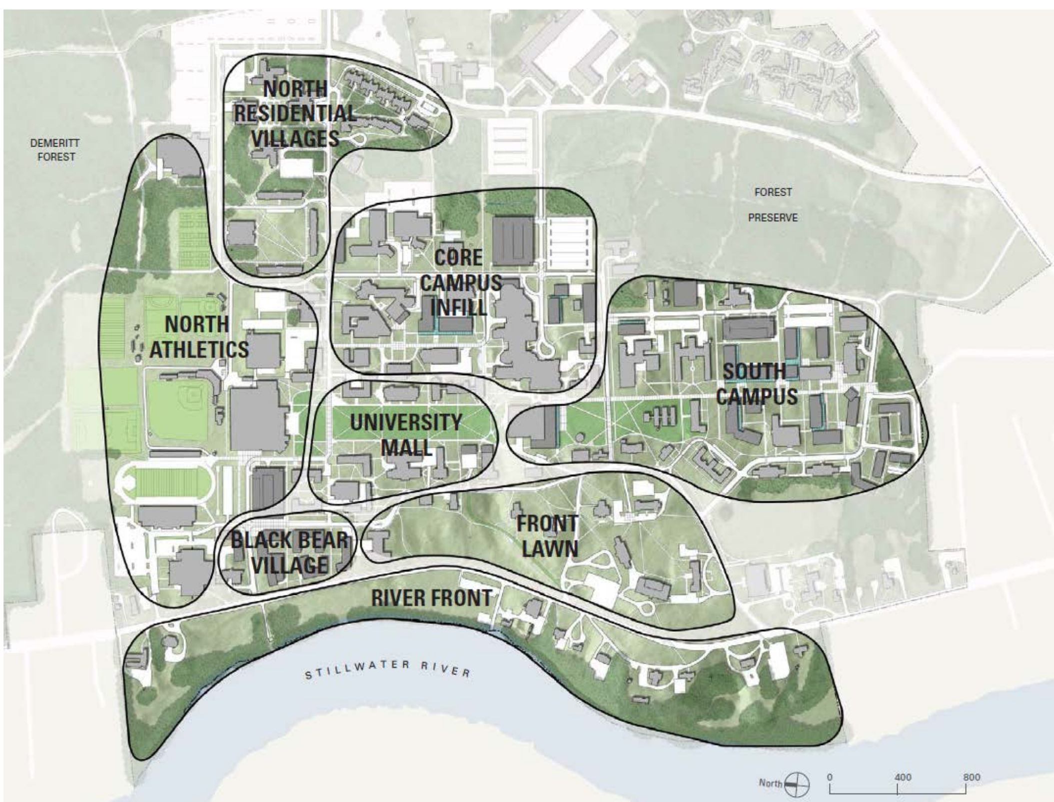

MAINE
UNIVERSITY of
MAINE
master plan report
2008/2009
Recipient of the Society for College and University Planning, Excellence in Planning Merit Award

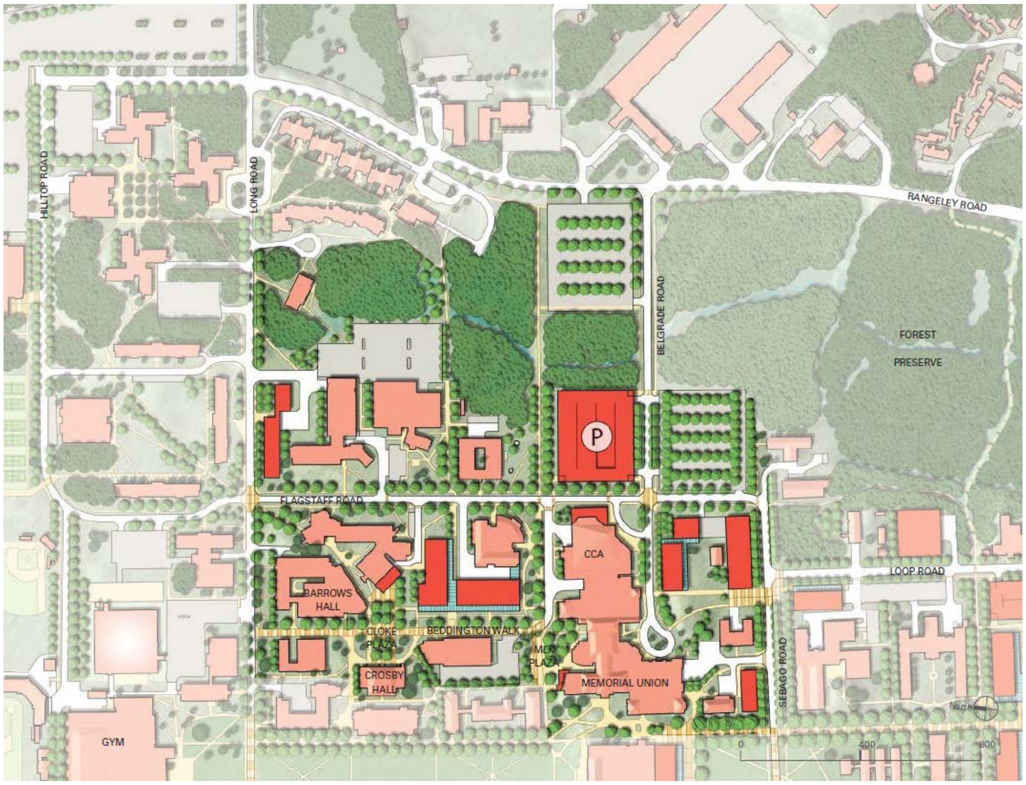

HILLTOP ROAD
DEMERITT FOREST
BELGRADE ROAD
RANGELEY ROAD
FOREST
PRESERVE
FLAGSTAFF ROAD
UNIVERSITY MALL
SOUTH MALL
LENGYEL FIELDS
COLLEGE AVENUE
STILLWATER RIVER
North
0
400
800


DEMERITT FOREST
HILLTOP ROAD
FLAGSTAFF ROAD
LONG ROAD
BELGRADE ROAD
FOREST PRESERVE
RANGELEY ROAD
LOOP ROAD
MUNSON ROAD
COLLEGE AVENUE
STILLWATER RIVER
1. Wetland Restoration
2. Reforestation
3. Stillwater River Flood Plain
4. Front Lawn
5. University Mall
6 South Mall
7. South Academic Quadrangle
8. Beddington Walk
9. Grove Walk
10. Windbreaks/Connectors
11. MLK Plaza
12. Cloke Plaza
13. Athletic Fields
14. Lengyel Fields
15. Bike Paths
16. Wabanaki Trail
17. Fay Hyland Botanical Garden
18. Littlefield Ornamental Garden
North
0
400
800

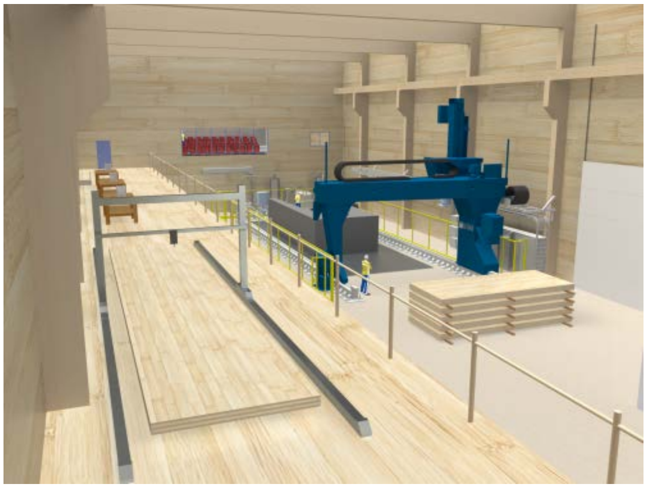

DEMERITT FOREST
FOREST PRESERVE
SHUTTLE TO ORONO
(0.75 miles)
5 MIN WALK
LOOP ROAD
GROVE WALK
COLLEGE AVENUE
STILLWATER RIVER
WABANAKI TRAIL
Proposed Road Network
Traffic Calming Areas
Existing Shuttle Route
Proposed Campus Shuttle Route
Shuttle Stop
Bike Routes / Trails
North
0
400
800

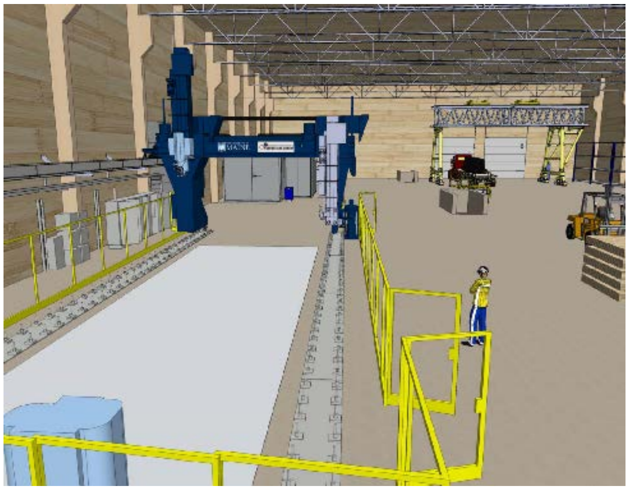

DEMERITT FOREST
HILLTOP ROAD
LONG ROAD
BELGRADE ROAD
RANGELEY ROAD
FOREST PRESERVE
FLAGSTAFF ROAD
LOOP ROAD
MUNSON ROAD
COLLEGE AVENUE
STILLWATER RIVER
North
0
400
800

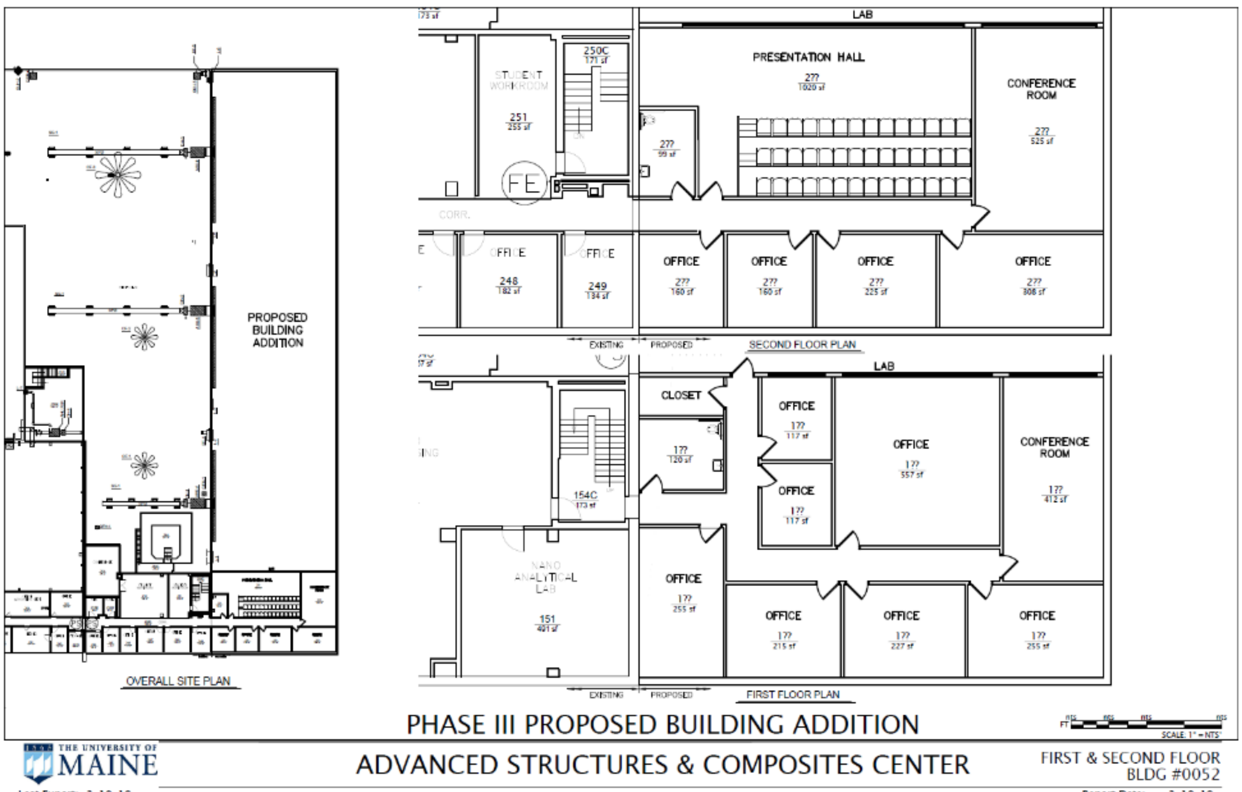

DEMERITT FOREST
NORTH RESIDENTIAL VILLAGES
FOREST PRESERVE
CORE CAMPUS INFILL
NORTH ATHLETICS
SOUTH CAMPUS
UNIVERSITY MALL
FRONT LAWN
BLACK BEAR VILLAGE
RIVER FRONT
STILLWATER RIVER
North
0
400
800

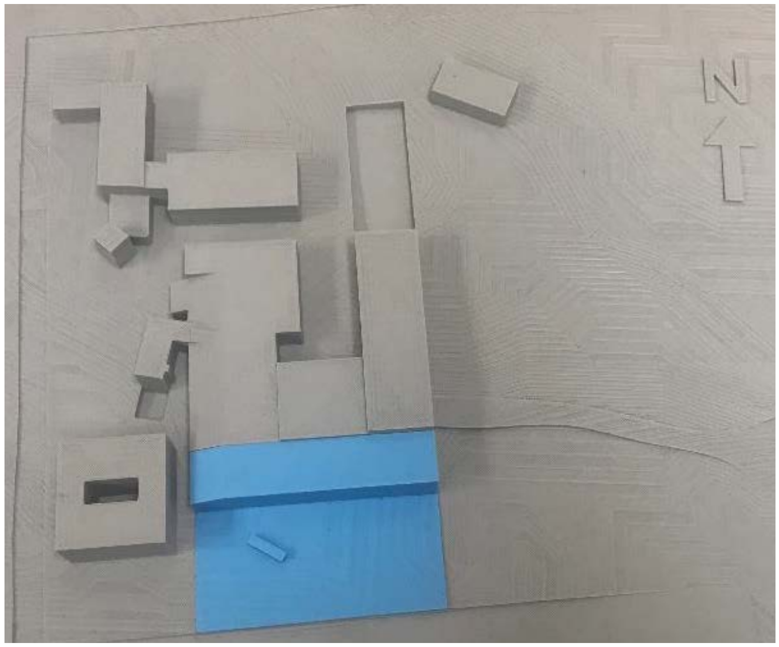

HILLTOP ROAD
LONG ROAD
RANGELEY ROAD
BELGRADE ROAD
FOREST
PRESERVE
P
FLAGSTAFF ROAD
CCA
LOOP ROAD
BARROWS
HALL
CLOKE
PLAZA
BEDDINGTON WALK
MLK
PLAZA
CROSBY
HALL
MEMORIAL UNION
SEBAGO ROAD
GYM
0
400
800

APPENDIX G






PROPOSED BUILDING ADDITION
OVERALL SITE PLAN
LAB
PRESENTATION HALL
CONFERENCE ROOM
STUDENT WORKROOM
251
250C
OFFICE
248
249
SECOND FLOOR PLAN
EXISTING
PROPOSED
CLOSET
154C
NANO ANALYTICAL LAB
151
FIRST FLOOR PLAN
PHASE III PROPOSED BUILDING ADDITION
THE UNIVERSITY OF MAINE
ADVANCED STRUCTURES & COMPOSITES CENTER
FIRST & SECOND FLOOR
BLDG #0052
Last Export: 3-10-19
Report Date: 3-10-19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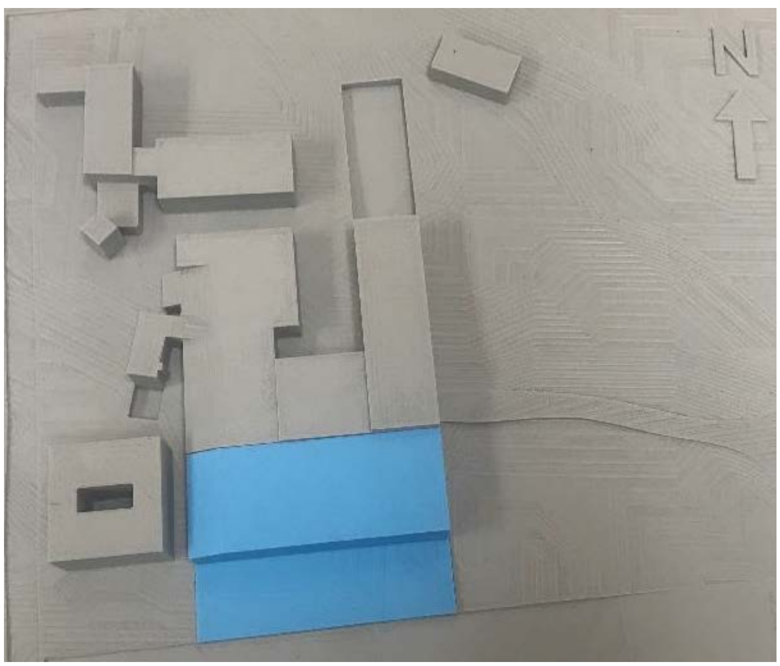
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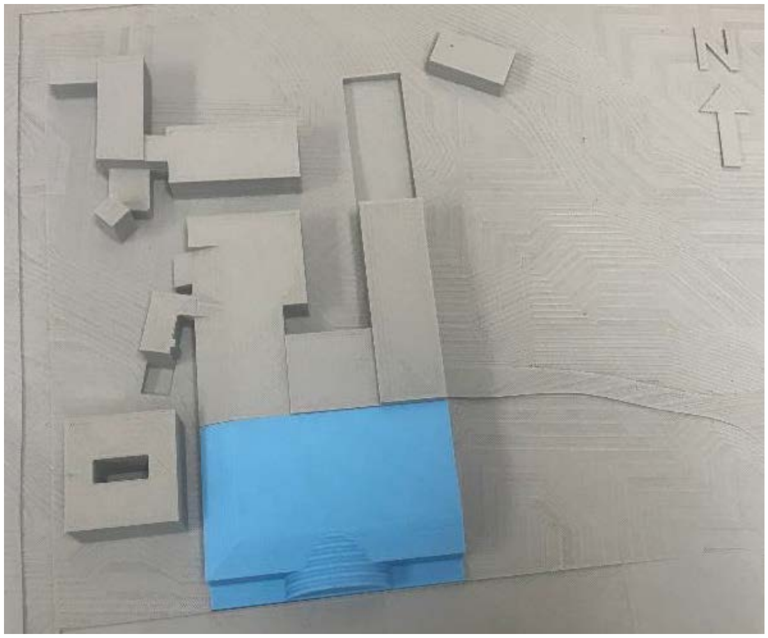
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