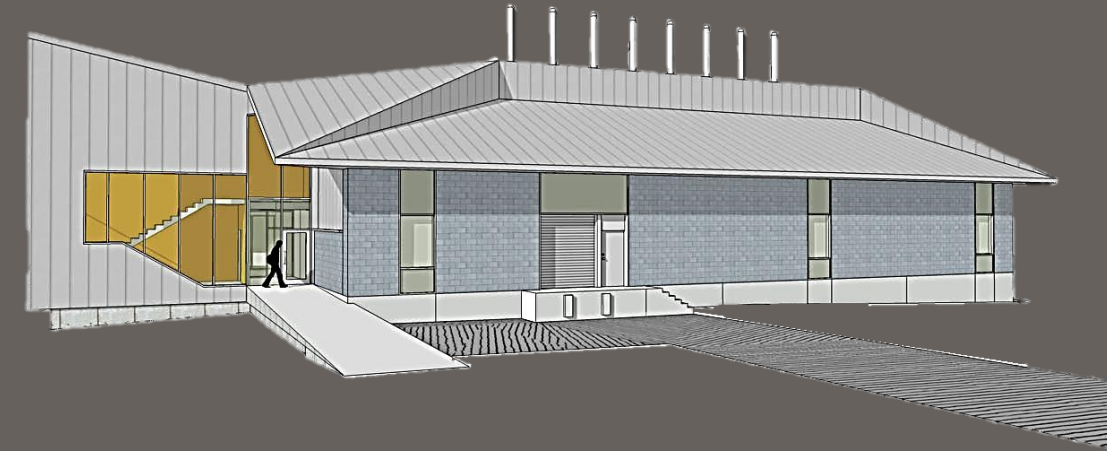


# BIOLOGICAL RESEARCH LABORATORY

THE PENNSYLVANIA STATE UNIVERSITY  
University Park, PA



PENN STATE AE SENIOR CAPSTONE PROJECT  
MICHAEL CARBONARA | CONSTRUCTION OPTION  
ADVISOR: DR. ROBERT LEICHT

# BIOLOGICAL RESEARCH LABORATORY



## Presentation Outline:

Project Background

Modularization of the Laboratory Spaces

BIM Implementation with Virtual Mockups

Sustainability

Labor Resources Schedule Acceleration

## PROJECT LOCATION

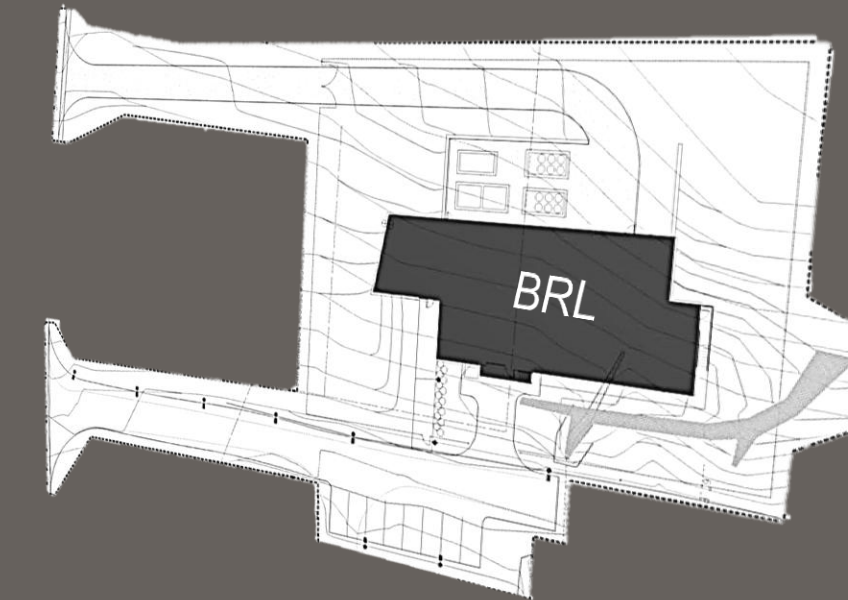
- WILEY LN, UNIVERSITY PARK, PA
- THE PENNSYLVANIA STATE UNIVERSITY

## BUILDING SIZE

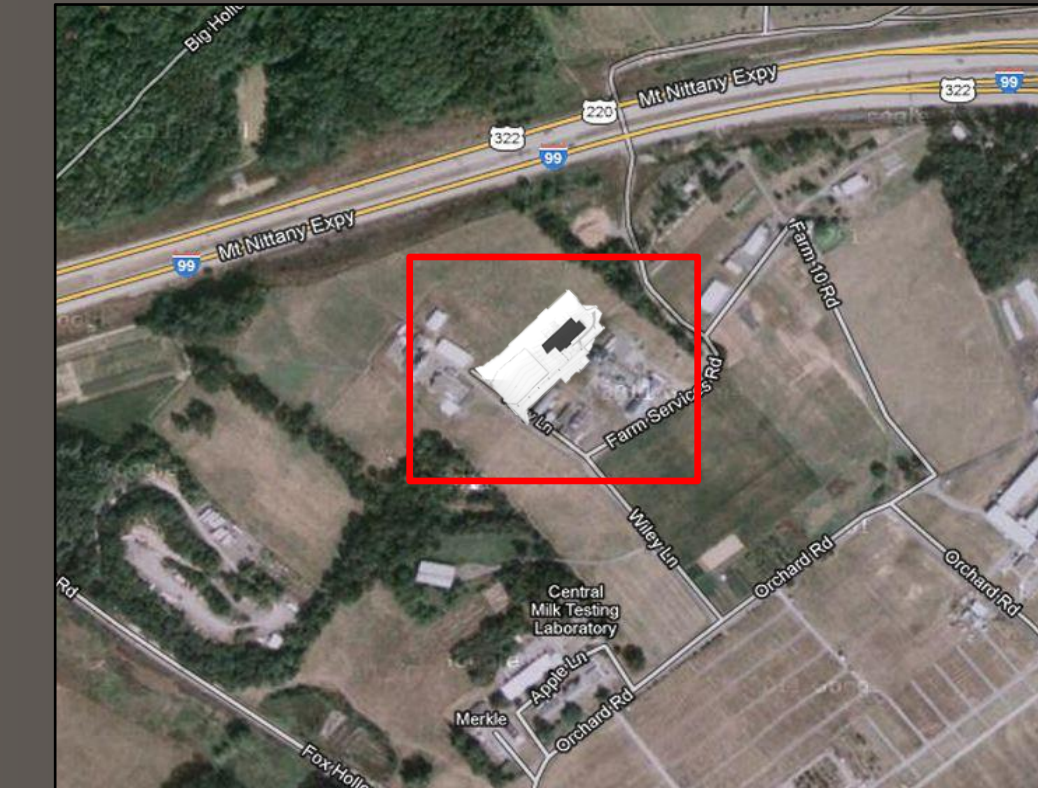
- AREA : 20,000 SF
- 3 STORIES

## PROJECT PARAMETERS:

- COST: \$23 MILLION GMP
- AUGUST 2011 – JANUARY 2013

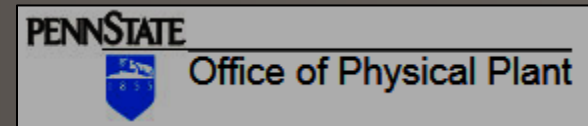


## GEOGRAPHICAL LOCATION





# BIOLOGICAL RESEARCH LABORATORY

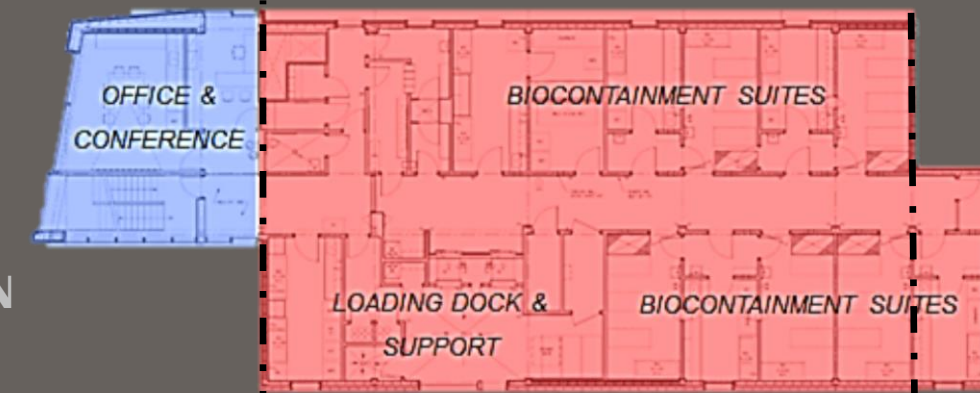


## PROJECT PARTICIPANTS

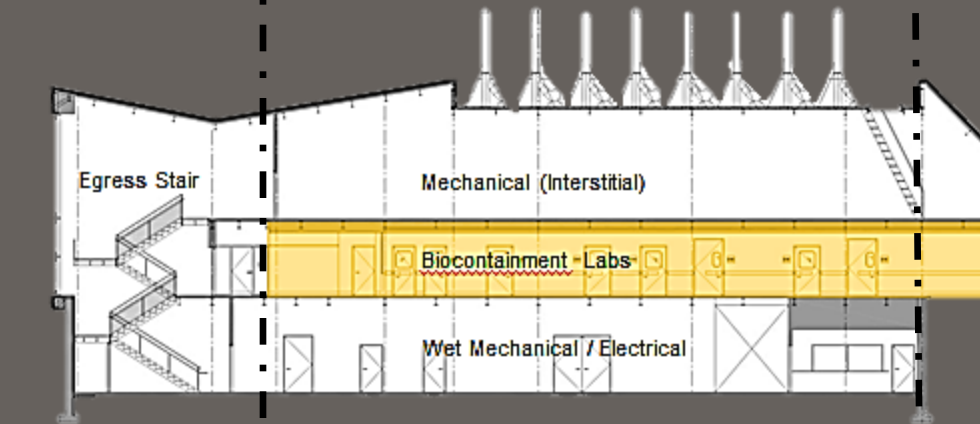
- OWNER: THE PENNSYLVANIA STATE UNIVERSITY
- CONSTRUCTION MANAGER: TORCON
- ARCHITECT: PAYETTE ASSOCIATES
- OWNER'S REPRESENTATIVE: OPP

## BUILDING DESIGN

- MECHANICAL (Mezzanine and Penthouse)
- Bio-containment Labs
- Wet Mechanical / Electrical



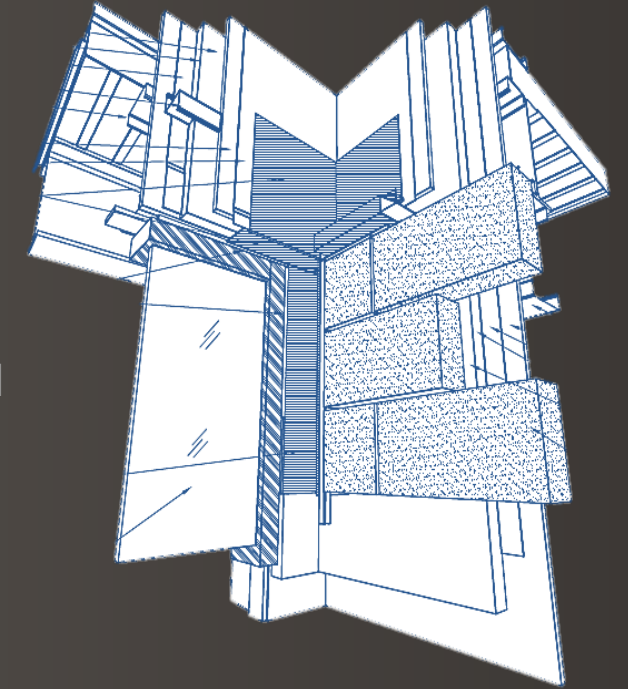
PLAN VIEW – PAYETTE ASSOCIATES



ELEVATION VIEW – PAYETTE ASSOCIATES

## BUILDING SYSTEMS

- STRUCTURAL SYSTEM
  - STEEL AND METAL DECKING
- MECHANICAL SYSTEM
  - ELEVEN AIR-HANDLING UNITS, VAV SYSTEM
  - HYDRONIC SYSTEM
- ELECTRICAL SYSTEM
  - MULTIPLE LINES FOR REDUNDANCY
- FAÇADE
  - DECORATIVE VENEER BLOCK
  - ALUMINUM CLADDING



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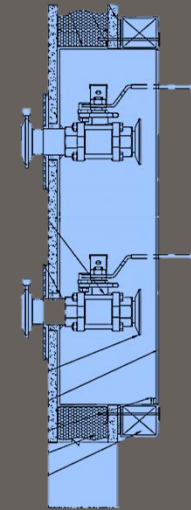
Sustainability

Labor Resources Schedule Acceleration



### PROBLEM

- QUALITY OF WORK IS A CONCERN OF THE BIOLOGICAL RESEARCH LABORATORY
  - WALL PENETRATIONS
  - MATERIAL FINISHES
  - GLOVE TEXT



### GOAL

- INCREASE FINISHED QUALITY OF WORK
- REDUCTION IN THE SCHEDULE
- REDUCTION IN COST



Wall Imperfection, Courtesy of NIAID



Such a small imperfection (left) can tear a glove (right) compromising the experiment and safety of the researcher.



Torn Glove, Courtesy of NIAID



### TRANSPORTATION:

- RULE FOR THE WIDTH OF A VEHICLE: 12 FEET
- RULE FOR THE HEIGHT OF A VEHICLE: 13.5 FEET
- RULE FOR THE LENGTH OF A VEHICLE: 12 FEET
- WEIGHT OF EACH POD IS APPROXIMATELY: 6 TONS

Combination of Vehicles	Maximum Gross Weight In Pounds
Two-axle truck tractor & single-axle semitrailer	58,400
Two-axle truck tractor & two-axle semitrailer	73,280
Three-axle truck tractor & single-axle semitrailer	73,280
Two-axle truck & two-axle trailer	73,280

### OFFSITE PRODUCTION:

- LOCATION: 2952 BENNER PIKE 4.5 MILES AWAY
- 38,000 SF WITH A PRICE OF \$7/SF







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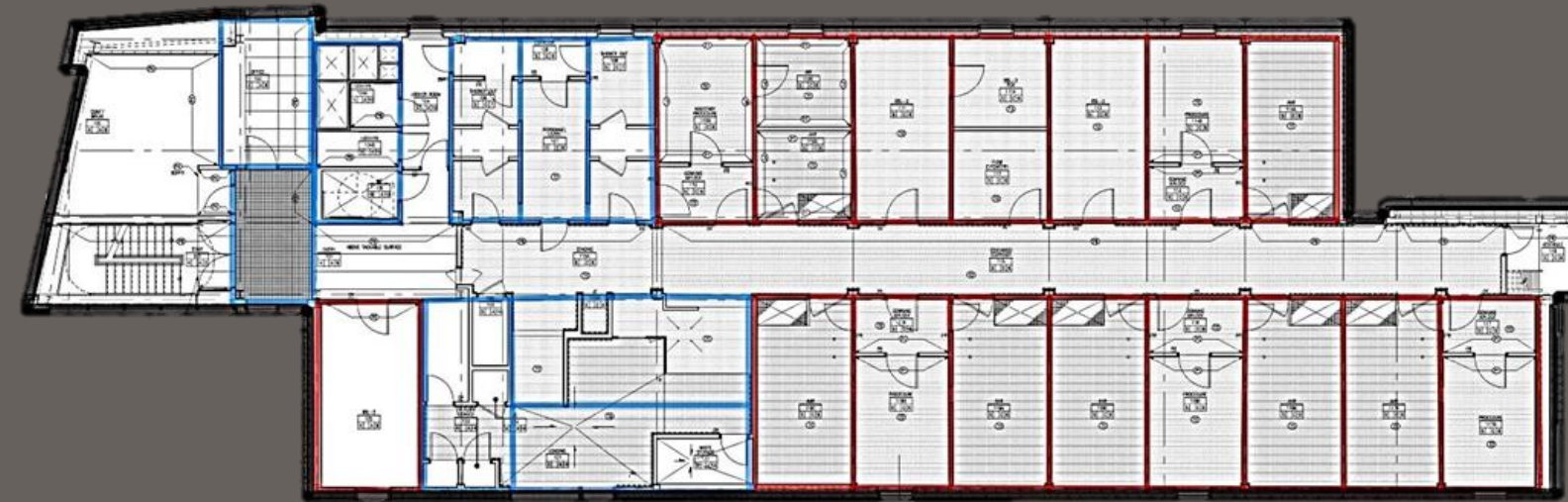
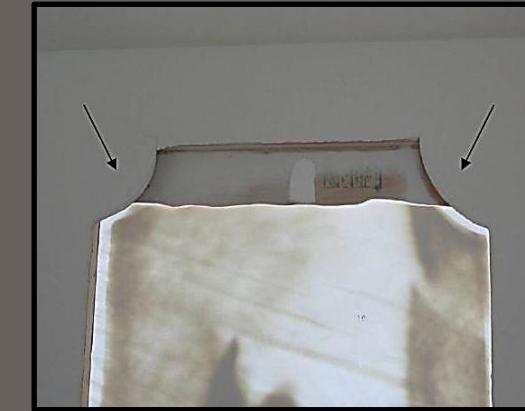
Sustainability

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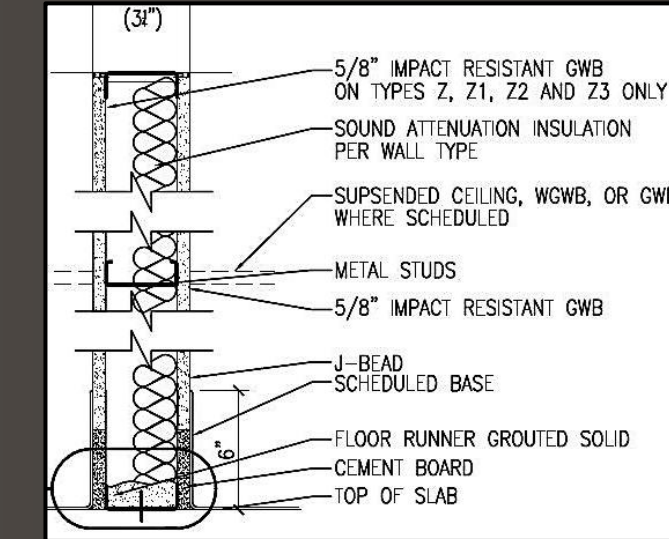
### SPACIAL BREAKDOWN

- LABORATORY SPACES BROKEN DOWN (11' X 21')
- SPACES OUTLINED IN **BLUE** ARE OFFICES, BATHROOM AND STORAGE SPACES
- SPACES OUTLINED IN **RED** ARE BSL-2 AND BSL-3 ROOMS



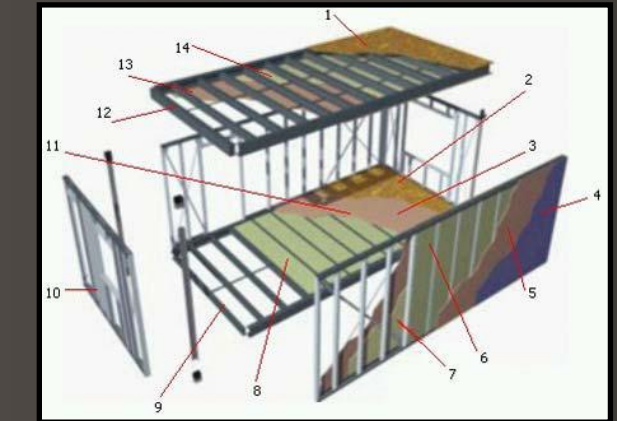
### DESIGN

- 2X4 METAL STUD CONSTRUCTION
- 5/8" GYPSUM WALL BOARD
  - IMPACT RESISTANT
- BAT INSULATION
- EPOXY WALL FINISH
- 2X3 CONSTRUCTION FLOOR WITH A STEEL PLATE

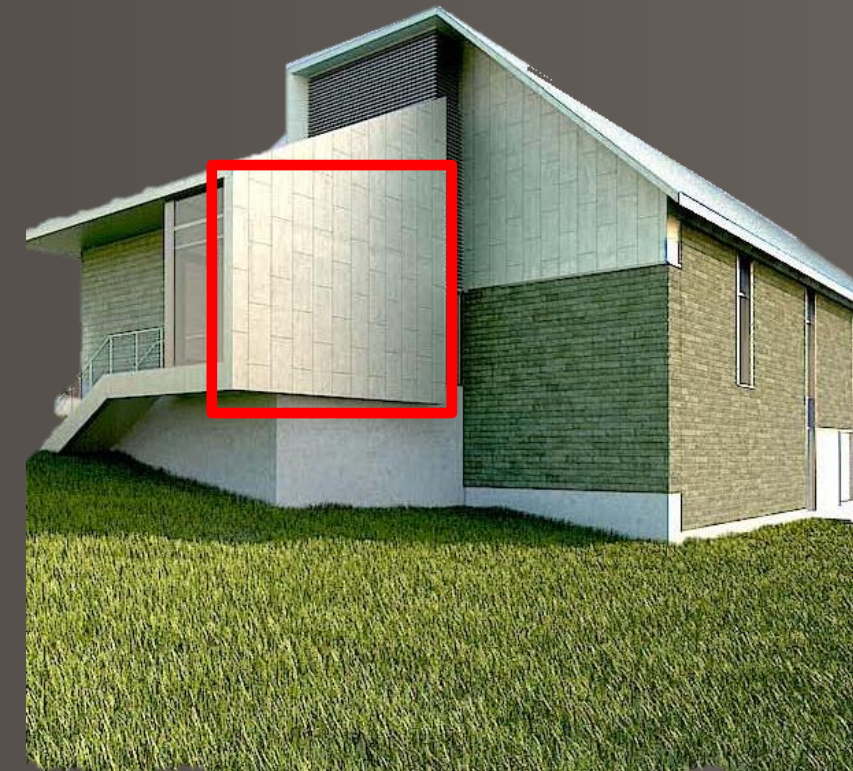


### DESIGN FOR TRANSPORTATION

- DOORS WILL BE INSTALLED ON SITE
- EXCESS DRYWALL AROUND DOORS
  - PREVENTS CRACKING
- ADDITION BRACING ON CEILING AT LIFT POINTS







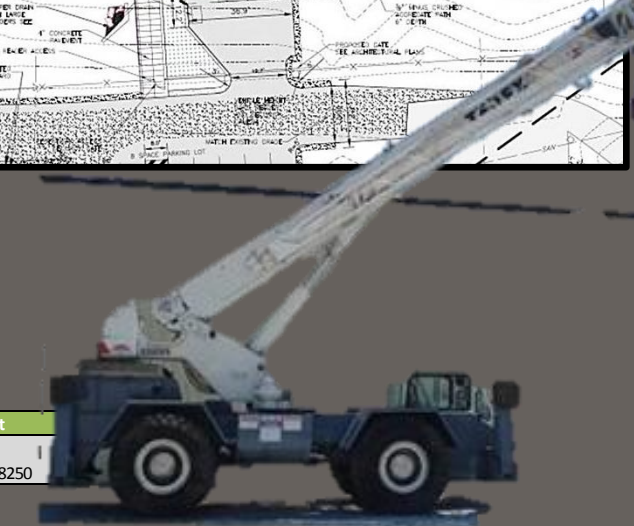
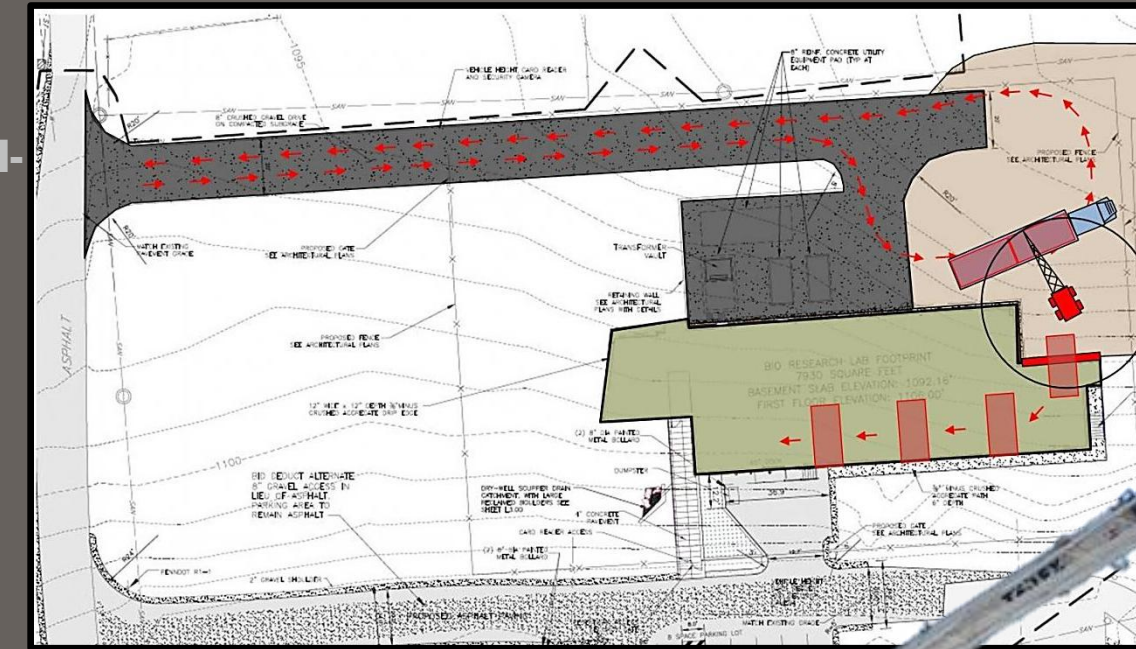
BRL | NORTH-EAST CORNER

## MODULAR STAGING

- PROPOSED AREA FOR INSTALLATION IS IN NORTH-EAST CORNER
- ALUMINUM CLADDING PANELING
  - PREVENTS THE DISRUPTION OF THE MASONRY TRADE
- INSTALL MODULAR UNITS FROM LEFT TO RIGHT

## CRANE SELECTION

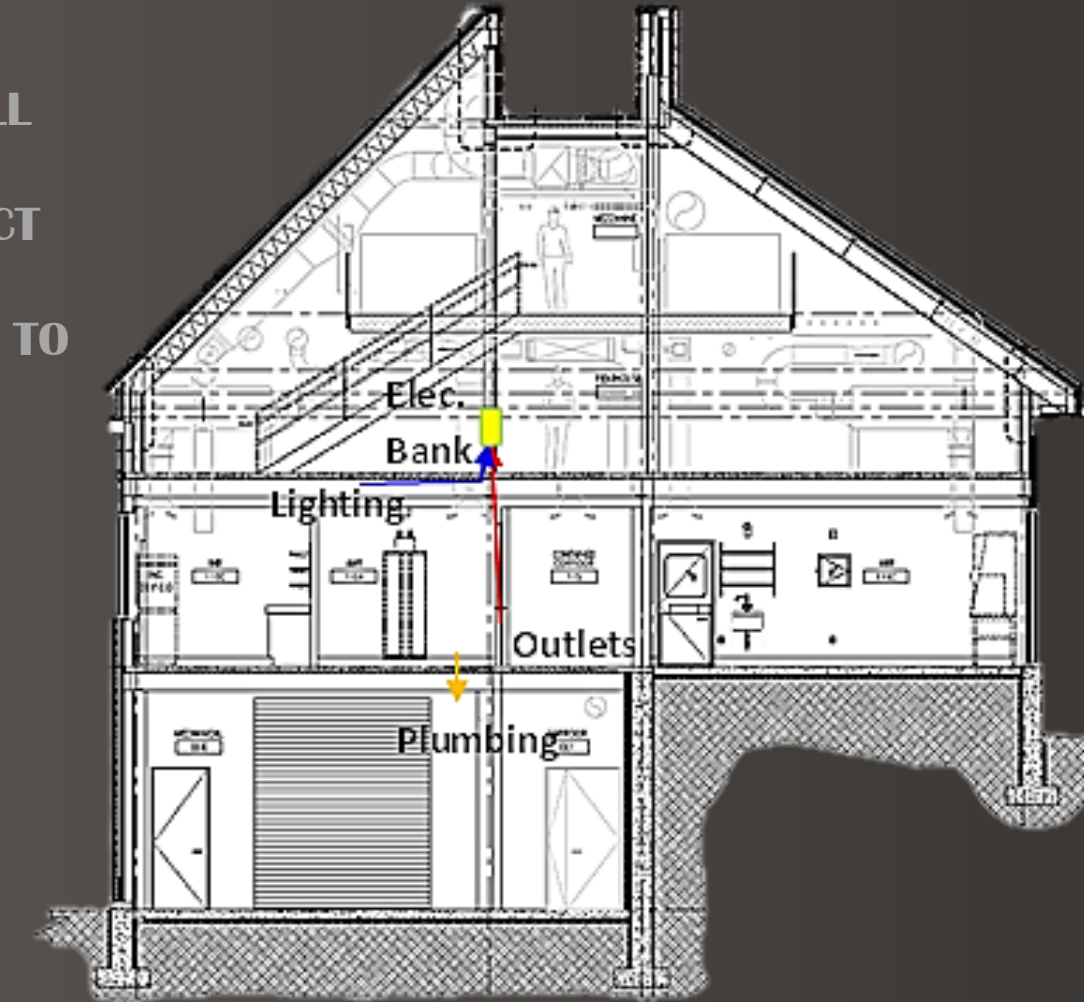
- TRUCK MOUNTED BOOM CRANE WAS CHOSEN
  - 25 TONS AT A 10 FT RADIUS



Crane	Crew	Daily Output	Labor Hours	Unit	Days	Labor	Equipment	Total	Total Incl O&P	Cost
truck mounted lattice boom crane 25 tons/10 foot radius	A-31	1	8	Day	5	355	1025	1380	1650	8250

## UTILITIES

- FIELD FABRICATED DRYWALL CEILING
  - DROP CEILING CONFLICT
- RE-ROUTE ELECTRICAL DUE TO NEC 2008
- PLUMBING TO MECHANICAL BASEMENT



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# ANALYSIS I

# BIOLOGICAL RESEARCH LABORATORY

MICHAEL CARBONARA | CONSTRUCTION OPTION | April 13, 2012

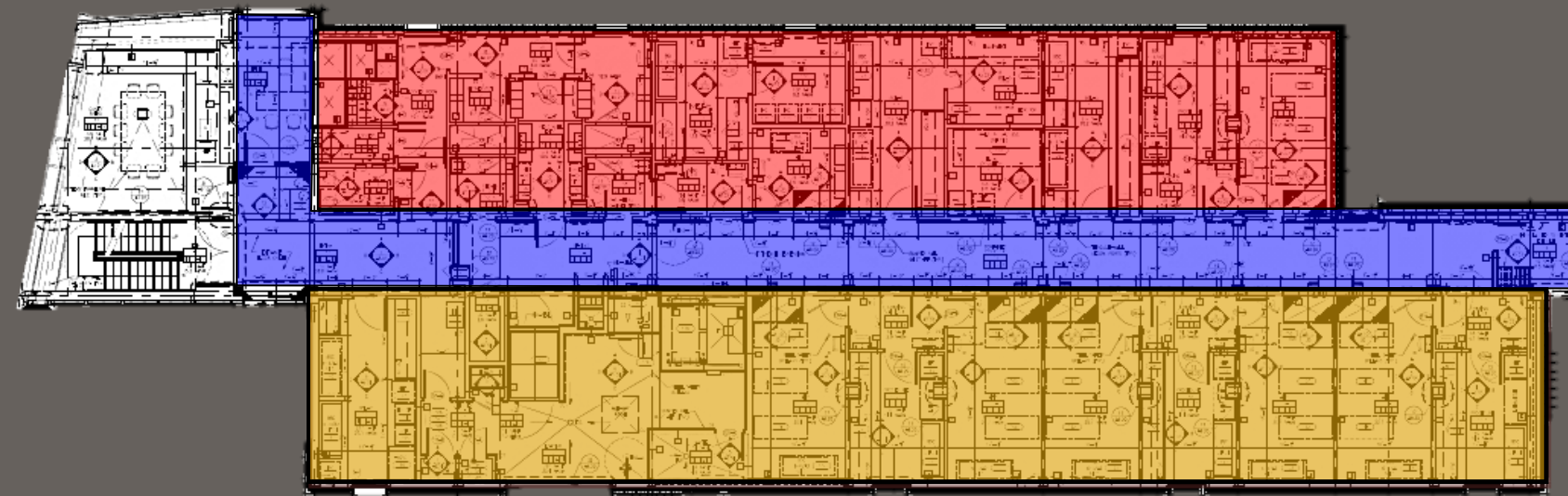
## SCHEDULE

- ABILITY TO COMPRESS A 10 MONTH SCHEDULE TO 6 MONTHS

Laboratory Compartments	Duration	Start	Finish
Partition Layout & Top Track	68 days	Fri 2/24/12	Tue 5/29/12
Partition Framing	47 days	Fri 4/6/12	Mon 6/11/12
HM Door Frames	15 days	Fri 4/6/12	Thu 4/26/12
Partition Grouting	5 days	Fri 5/4/12	Thu 5/10/12
HM Door Frames	5 days	Tue 6/5/12	Mon 6/11/12
Partition GWB	15 days	Tue 6/12/12	Mon 7/2/12
Ceiling Framing	5 days	Tue 6/19/12	Mon 6/25/12
Roll-up Doors	5 days	Tue 6/19/12	Mon 6/25/12
Ceiling GWB	17 days	Tue 6/26/12	Wed 7/18/12
Ceiling Framing	10 days	Tue 6/19/12	Mon 7/2/12
Tape & Finish	40 days	Tue 7/3/12	Mon 8/27/12
Tel/Com Wiring and Devices [FF]	15 days	Thu 7/19/12	Wed 8/8/12
Fire Alarm Wiring and Devices [FF]	15 days	Thu 7/19/12	Wed 8/8/12
Lighting Wiring and Devices [FF]	20 days	Thu 7/19/12	Wed 8/15/12
Power Wiring and Devices [FF]	20 days	Thu 7/19/12	Wed 8/15/12
OCTV/AC Wiring and Devices [FF]	20 days	Thu 7/19/12	Wed 8/15/12
Prime Paint & First Coat [FF]	5 days	Thu 8/16/12	Wed 8/22/12
Ceramic Tile [FF]	5 days	Thu 8/23/12	Wed 8/29/12
Polished Floors [FF]	5 days	Thu 8/23/12	Wed 8/29/12
Entrance Mat [FF]	5 days	Wed 9/26/12	Tue 10/2/12
Touch-up and Finish Paint [FF]	8 days	Wed 10/3/12	Fri 10/12/12
Resinous Flooring [FF]	16 days	Wed 10/3/12	Wed 10/24/12
Fiberglass Grating [FF]	5 days	Thu 10/25/12	Wed 10/31/12
Lab Casework [FF]	12 days	Thu 10/25/12	Fri 11/9/12
Doors & Hardware [FF]	12 days	Thu 10/25/12	Fri 11/9/12
Wall Coatings Topcoat [FF]	17 days	Tue 11/13/12	Wed 12/5/12
Hepa Filters [FF]	5 days	Thu 12/6/12	Wed 12/12/12
Wall Protection [FF]	5 days	Thu 12/6/12	Wed 12/12/12
Joint Sealants [FF]	5 days	Thu 12/13/12	Wed 12/19/12
<b>Total</b>	<b>417 days</b>		

## CONCRETE SEQUENCING

- THE AREA IN **RED** IS THE FIRST SLAB TO BE PLACED
- THE AREA IN **ORANGE** IS THE SECOND SLAB TO BE PLACED
- THE HALLWAY IN **BLUE** IS THE FINAL POUR
  - SLAB IS 2.5" GREATER IN DEPTH THEN THE RED AND ORANGE SECTION
  - ALLOWS FOR A LEVEL FINISH BETWEEN MODULES AND HALLWAYS



## COST BREAKDOWN

- ONLY THE LAB SPACES WERE QUANTIFIED, WITH A TOTAL SAVING OF **\$83,500.00**

Room	Reduced Material Cost	Material Cost	Reduced Labor Cost	Labor Cost
Animal Holding Room 1	\$ 10,852.29	\$ 11,423.46	\$ 12,732.46	\$ 16,976.61
Animal Holding Room 2	\$ 10,852.29	\$ 11,423.46	\$ 12,732.46	\$ 16,976.61
Procedure Room	\$ 16,669.77	\$ 17,547.13	\$ 8,927.78	\$ 11,903.70
Gowning Room	\$ 19,485.73	\$ 20,511.29	\$ 3,471.24	\$ 4,628.32
<b>Total</b>	<b>\$ 57,860.07</b>	<b>\$ 60,905.34</b>	<b>\$ 37,863.93</b>	<b>\$ 50,485.24</b>
<b>Total Saving</b>	<b>\$ 3,045.27</b>	<b>+</b>	<b>\$ 12,621.31</b>	<b>\$ 15,666.58</b>

Room	Reduced Material Cost	Material Cost	Reduced Labor Cost	Labor Cost
Animal Holding Room 1	\$ 10,852.29	\$ 11,423.46	\$ 12,732.46	\$ 16,976.61
Procedure Room	\$ 16,669.77	\$ 17,547.13	\$ 8,927.78	\$ 11,903.70
Gowning Room	\$ 19,485.73	\$ 20,511.29	\$ 3,471.24	\$ 4,628.32
<b>Total</b>	<b>\$ 47,007.79</b>	<b>\$ 49,481.88</b>	<b>\$ 25,131.47</b>	<b>\$ 33,508.63</b>
<b>Total Saving</b>	<b>\$ 2,474.09</b>	<b>+</b>	<b>\$ 8,377.16</b>	<b>\$ 10,851.25</b>

Room	Reduced Material Cost	Material Cost	Reduced Labor Cost	Labor Cost
Procedure Room	\$ 16,669.77	\$ 17,547.13	\$ 8,927.78	\$ 11,903.70
Gowning Room	\$ 19,485.73	\$ 20,511.29	\$ 3,471.24	\$ 4,628.32
BSL 2/3 Rooms	\$ 8,348.89	\$ 8,788.31	\$ 12,578.00	\$ 16,770.66
BSL 2/3 Rooms	\$ 8,348.89	\$ 8,788.31	\$ 12,578.00	\$ 16,770.66
<b>Total</b>	<b>\$ 52,855.29</b>	<b>\$ 55,635.04</b>	<b>\$ 37,555.01</b>	<b>\$ 50,073.34</b>
<b>Total Saving</b>	<b>\$ 2,781.75</b>	<b>+</b>	<b>\$ 12,518.34</b>	<b>\$ 15,300.09</b>

Room	Reduced Material Cost	Material Cost	Reduced Labor Cost	Labor Cost
BSL 2/3 Rooms	\$ 8,348.89	\$ 8,788.31	\$ 12,578.00	\$ 16,770.66
BSL 2/3 Rooms	\$ 8,348.89	\$ 8,788.31	\$ 12,578.00	\$ 16,770.66
<b>Total</b>	<b>\$ 499.42</b>	<b>+</b>	<b>\$ 4,192.67</b>	<b>\$ 4,632.08</b>

Room	Reduced Material Cost	Material Cost	Reduced Labor Cost	Labor Cost
AHR and IHR	\$ 10,852.29	\$ 11,423.46	\$ 12,732.46	\$ 16,976.61
Procedure Room	\$ 16,669.77	\$ 17,547.13	\$ 8,927.78	\$ 11,903.70
Gowning Room	\$ 19,485.73	\$ 20,511.29	\$ 3,471.24	\$ 4,628.32
<b>Total</b>	<b>\$ 47,007.79</b>	<b>\$ 49,481.88</b>	<b>\$ 25,131.47</b>	<b>\$ 33,508.63</b>
<b>Total Saving</b>	<b>\$ 2,474.09</b>	<b>+</b>	<b>\$ 8,377.16</b>	<b>\$ 10,851.25</b>



### Presentation Outline:

Project Background

Modularization of the Laboratory Spaces

BIM Implementation with Virtual Mockups

Sustainability

Labor Resources Schedule Acceleration



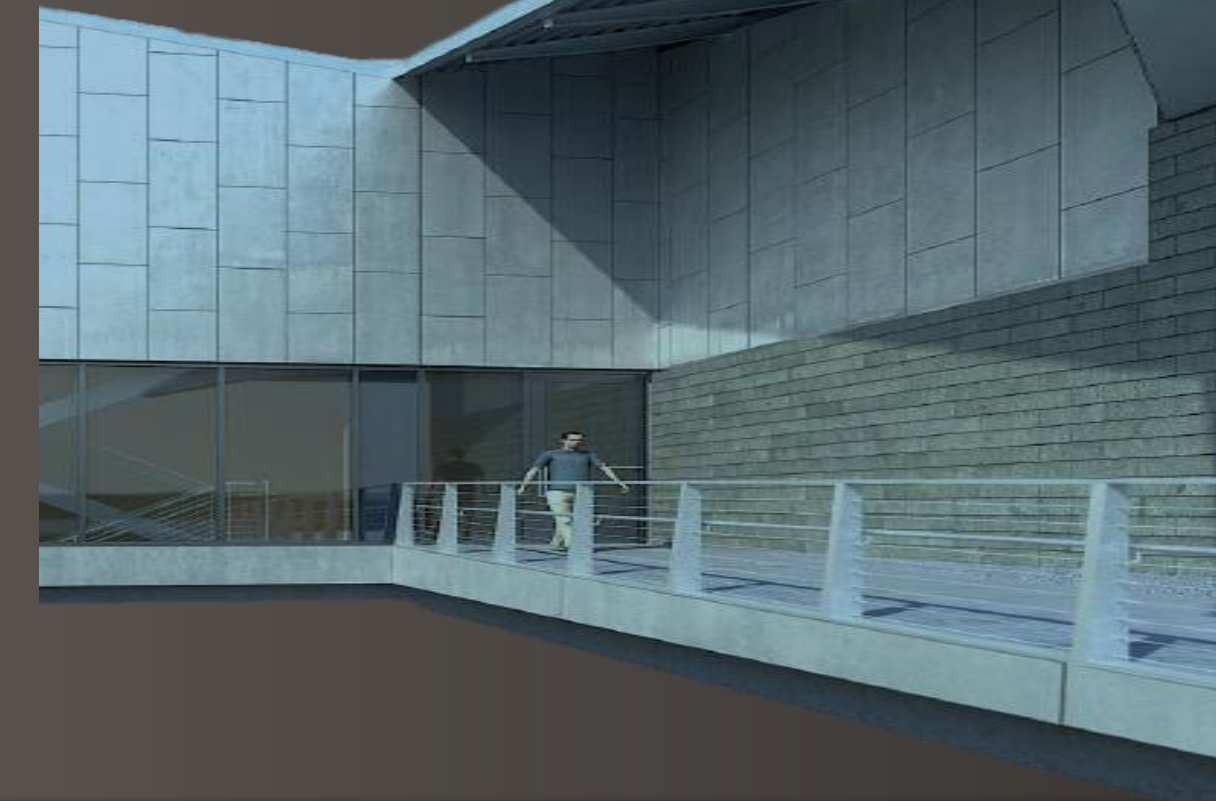


## CONCLUSION

- IMPLEMENTING MODULARIZATION SAVES \$ 83,500.00
- REDUCTION IN LABOR BY 25%
- REDUCTION IN MATERIAL BY 5%
- SCHEDULE REDUCED BY APPROXIMATELY 4 MONTHS



## BRL | ENTRY



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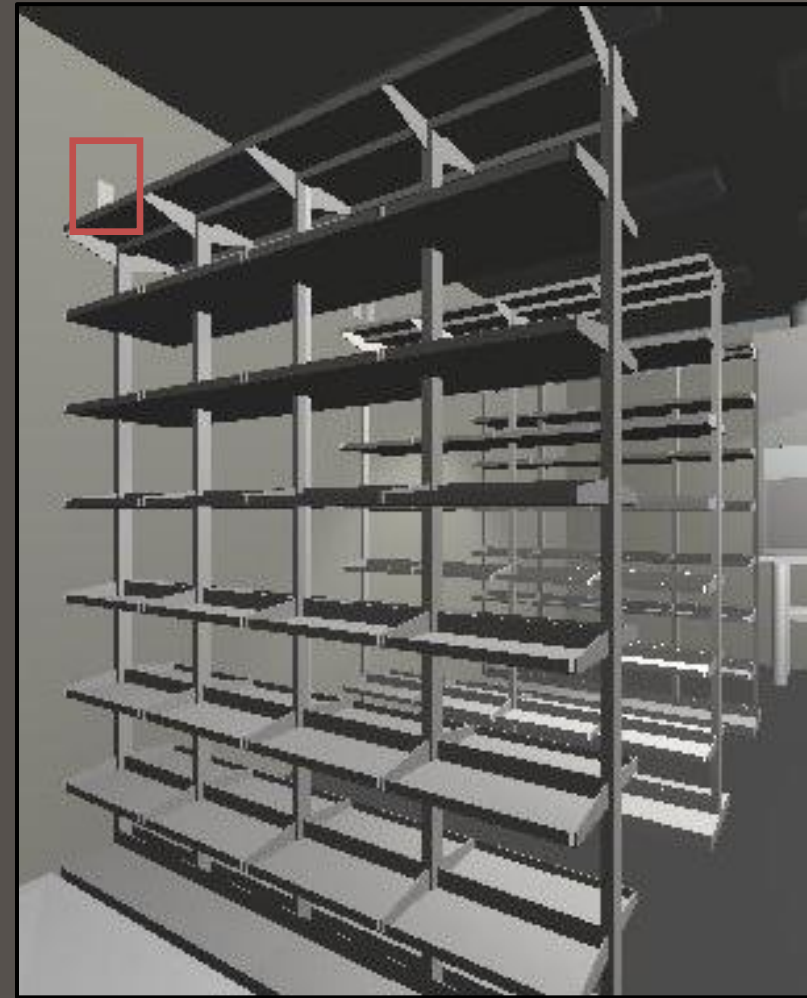
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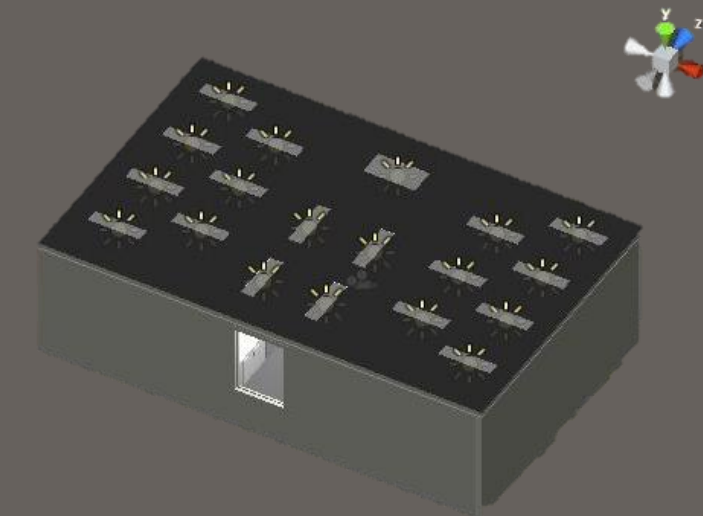


### PROBLEM

- RESEARCH SPACE IS EXTREMELY VALUABLE
  - OVER \$1000.00 PER SQUARE FOOT

### GOAL

- DEVELOP A VIRTUAL MODEL FOR REVIEW BY THE PROJECT TEAM AND USERS
- POTENTIALLY FIND HIDDEN PROBLEMS
- EXAMINE CABINTRY AND EQUIPMENT



### THE PRIMARY USER

- DR. GIRISH KIRIMANJESWARA
  - ASSISTANT PROFESSOR OF VETERINARY AND BIOMEDICAL SCIENCE
  - GOAL – “DEVELOPING PROPHYLACTICS AND THERAPEUTICS AGAINST INFECTIOUS DISEASES”
- LEADING RESEARCH ONCE THE BIOLOGICAL RESEARCH LABORATORY IS COMPLETE
  - PATHOGENESIS OF BORDETELLA







### Presentation Outline:

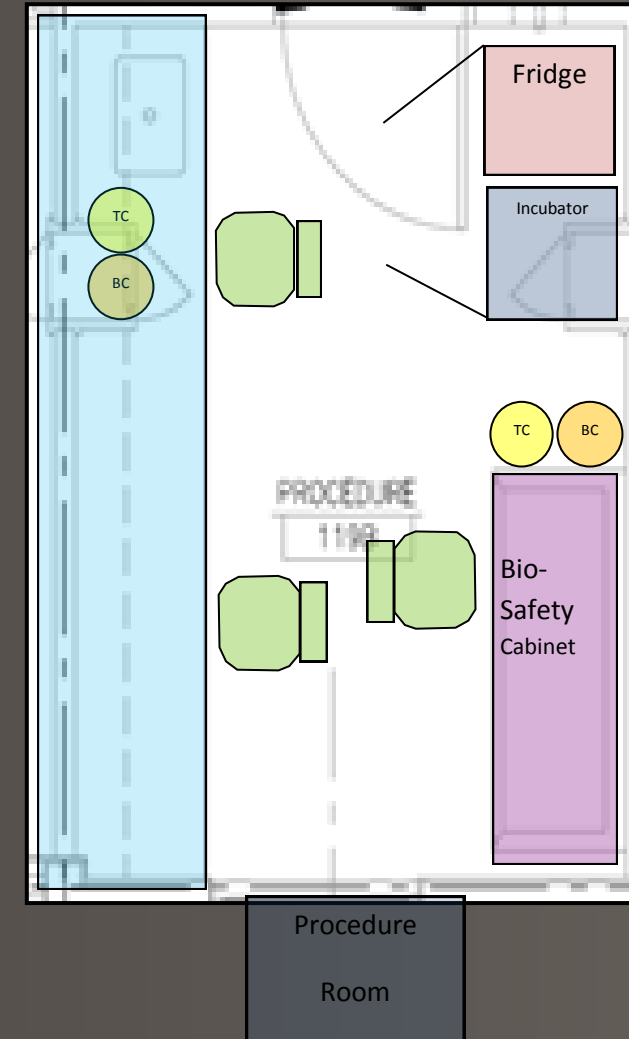
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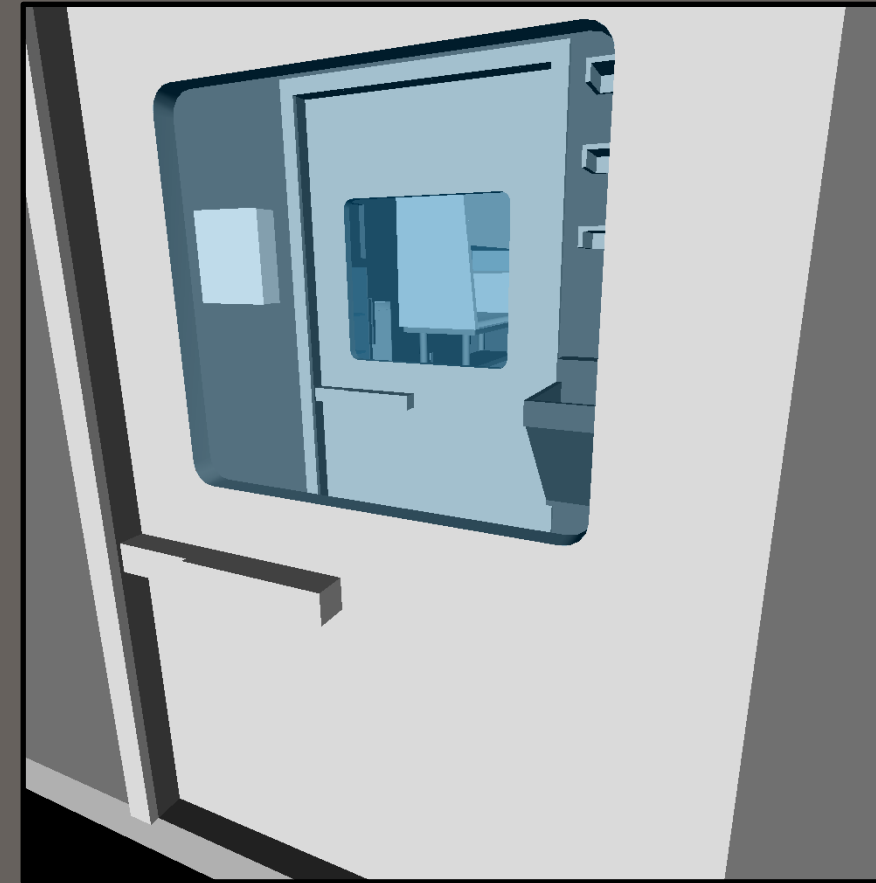
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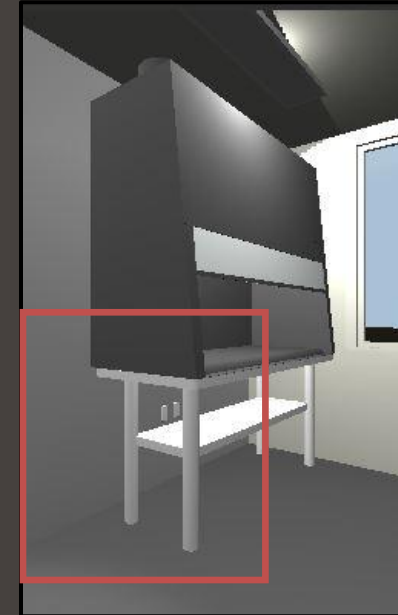
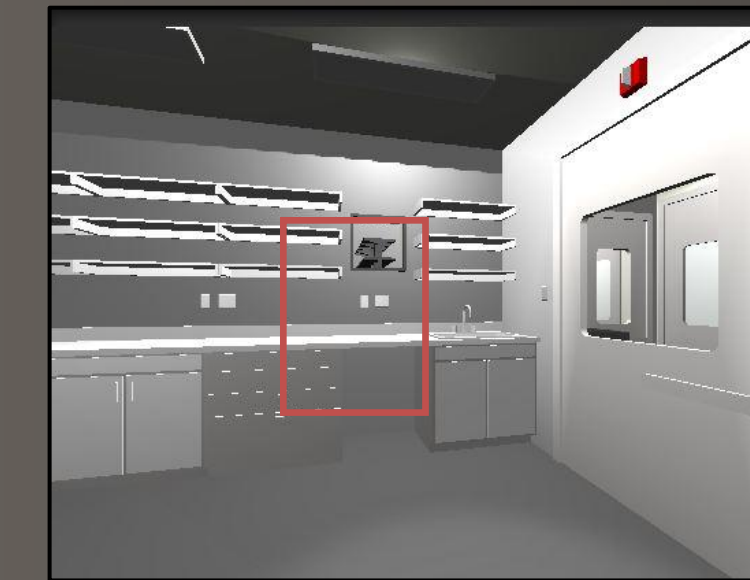
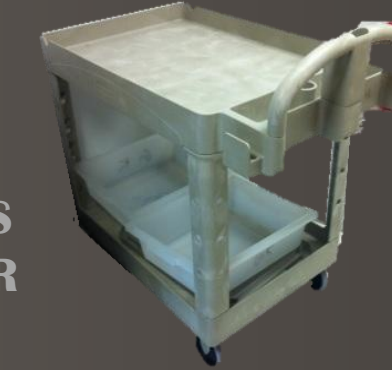


### MODEL EXPLORATION



### MISSING ITEMS

- LABORATORY CHAIRS
- BIO-HAZARDOUS TRASHCANS
- LABORATORY REFRIGERATOR
- INCUBATOR
- CARTS







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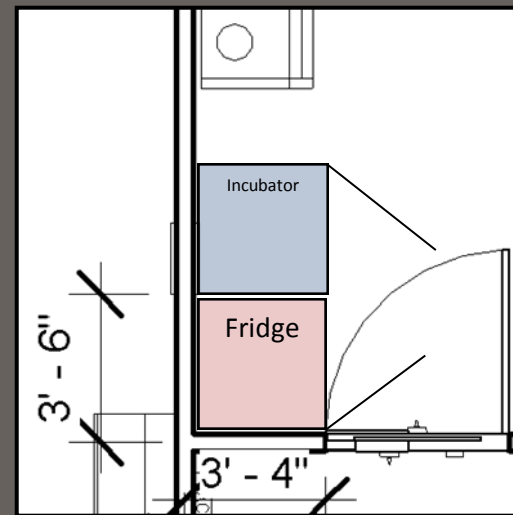
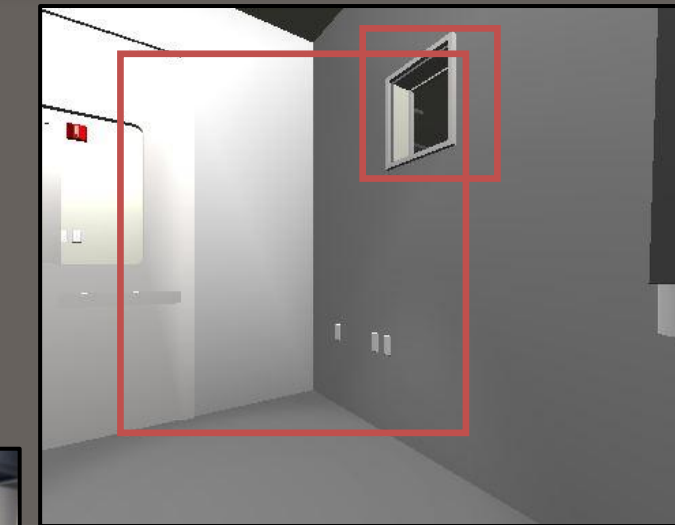
Sustainability

Labor Resources Schedule Acceleration



RED FLAGS

- REFRIGERATOR CONFLICTING WITH THE AIRLOCK DOOR
- INCUBATORS CONFLICTING WITH THE PASS THROUGH CABINETS



POTENTIAL COST SAVINGS

- INCORPORATE LABOR AND MATERIALS
- EQUIPMENT WAS EXCLUDED
- MODELING TIME WAS NOT ESTIMATED
- TOTAL SAVINGS AMOUNTED TO **\$111,390.00**

Room	Material Cost	Labor Cost
Animal Holding Room 1	\$ 11,423.46	\$ 16,976.61
Animal Holding Room 2	\$ 11,423.46	\$ 16,976.61
Procedure Room	\$ 17,547.13	\$ 11,903.70
Gowning Room	\$ 20,511.29	\$ 4,628.32
Total	\$ 60,905.34	\$ 50,485.24
Total Saving		<b>\$ 111,390.58</b>





Presentation Outline:

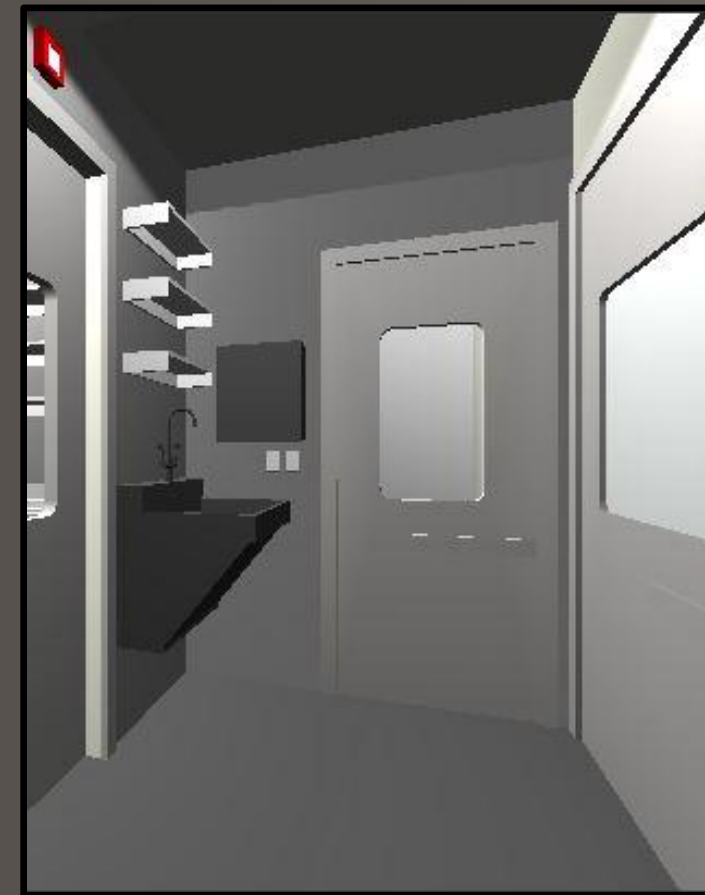
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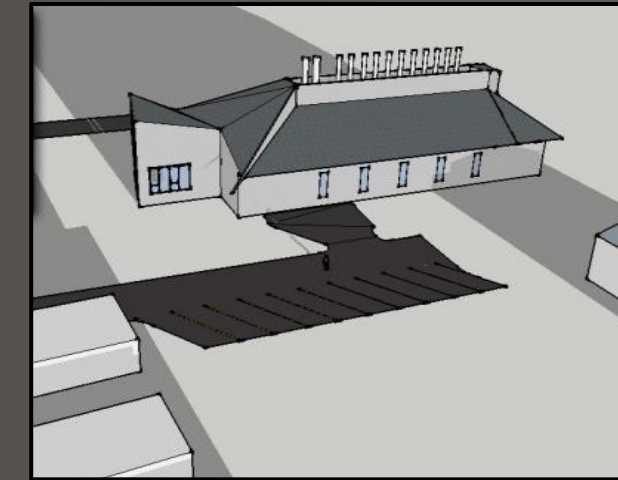


CONCLUSION

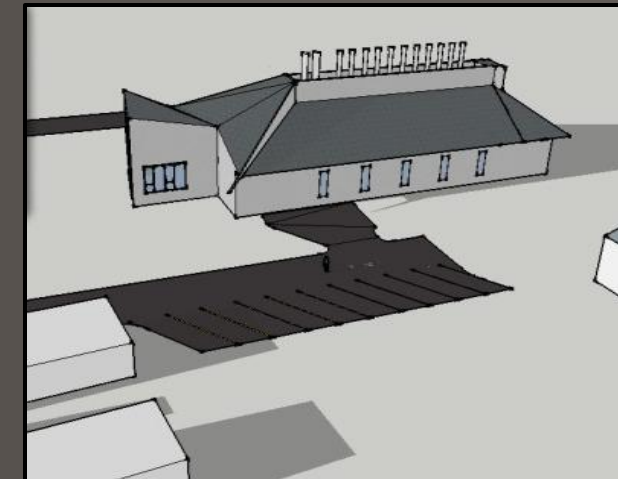
- THE VIRTUAL MOCKUP HELPED CREATE A BETTER LABORATORY ENVIRONMENT
- THE MODEL ALSO CAUGHT TWO POTENTIAL PROBLEMS IN THE PROCEDURE ROOM
  - THE REFRIGERATOR AND THE INCUBATOR
- HAS THE POTENTIAL TO SAVE \$ 111,000.00 IF A FIELD MOCKUP IS NOT CREATED







Shadowing during the Winter Solstice at 8:00 A.M.



Shadowing during the Winter Solstice at 4:00 P.M.

## PROBLEM

- THE BIOLOGICAL RESEARCH LABORATORY USES AN EXTREME AMOUNT OF ENERGY TO EFFECTIVELY OPERATE DAILY

## GOAL

- IMPLEMENT A RENEWABLE ENERGY SYSTEM
- IMPROVE THE LEED RATING FROM SILVER TO GOLD
  - INCORPORATE CAR CANOPIES

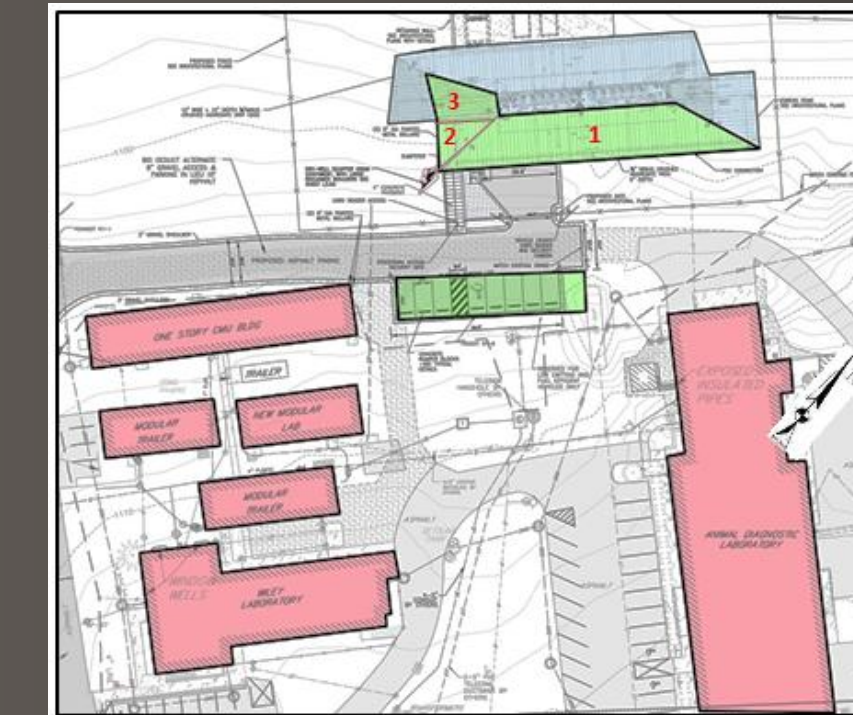
Google Earth Location	State College, PA	ADL and Wiley Complex
Site Characteristics	Degrees, Mins, Secs	Degree
Latitude	40°49'23" N	40.823°
Longitude	77°51'29" W	77.858°
Elevation	1107 ft	1107 ft

Location	Slope of roof	Total Area
BRL Roof 1	32°	3486 sf
BRL Roof 2	35°	429 sf
BRL Roof 3	35°	529 sf
Parking Canopy	10°	2588 sf
<b>Total Square Feet</b>		<b>6852 sf</b>



## SITE ISSUES

- **GREEN** - USABLE ROOF AREA
- **RED** - SURROUNDING BUILDINGS
- **BLUE** - UNUSABLE ROOF AREA



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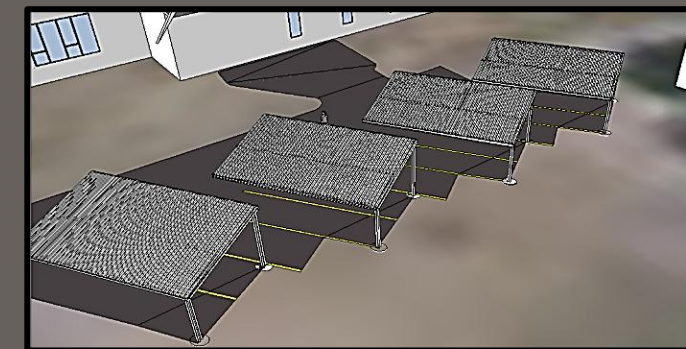
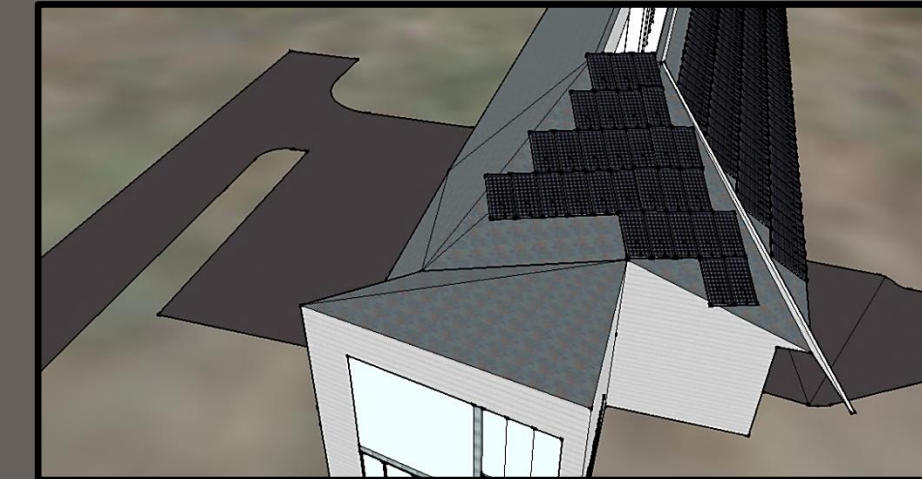
Labor Resources Schedule Acceleration

City (lat°)	Opt. Tilt; kWh/m <sup>2</sup> /day	% Off/ Opt.			% 25% Off/ Opt.			% 50% Off/ Opt.		
		Hor./ 45° Opt.	90° Off/ Opt.	96%	25% Off/ Opt.	25% Off/ Opt.	50% Off/ Opt.	50% Off/ Opt.	50% Off/ Opt.	
Rivas (11.4°N)	14°;5.11	97.5%	98.9%	96%	98.9%	96.9%	97.4%			
Miami (25.8°N)	24.5°;5.26	93.0%	96.9%	89%	97.1%	90.1%	92.2%			
Cairo (30.1°N)	24.5°;5.68	92.6%	96.4%	87.7%	96.7%	89.8%	91.5%			
Tuscon (32.1°N)	27.5°;6.59	87.7%	95%	82%	95.1%	84.5%	86.4%			
Atlanta (33.6°N)	30°;5.19	89.8%	95.4%	84%	95.8%	86.5%	88.3%			
Boulder (40°N)	38°;5.56	83.1%	93.3%	76.5%	93.3%	79.2%	81.4%			
<b>Madrid (40.5°N)</b>	<b>33°;5.08</b>	<b>87.2%</b>	<b>94%</b>	<b>79.4%</b>	<b>94.4%</b>	<b>82.7%</b>	<b>85.2%</b>			
Boston (42.2°N)	37°;4.63	84.7%	93.4%	77.6%	93.5%	80.7%	82.7%			
Seattle (47.4°N)	34°;3.83	87.2%	94.6%	80.5%	94.8%	83.4%	85.7%			
London (51.2°N)	34.5°;3.17	87.4%	93.8%	79%	94.3%	82.3%	84.9%			
Fairbanks (64.8°N)	51°;3.43	74.6%	91.5%	70.7%	91%	72.4%	73.5%			

The cities countries are named and the table abbreviations are explained here: [2](#).

## DESIGN

- ROOF 1: CONSISTS OF 120 PANELS
- ROOF 2: CONSISTS OF 30 PANLES
- CANOPIES 96 PANELS
- TOTAL SYSTEM: 246 PANELS



## ENERGY LOADS

- EMORY UNIVERSITY'S SYSTEM PARAMETERS
  - SIMILAR CALCULATIONS WERE PREFORMED ON THE BRL SYSTEMS
- 79.85 kWh/GROSS FT<sup>2</sup>/YR (BELOW) TO 80.33 kWh/GROSS FT<sup>2</sup>/YR CALCULATED

System	Key Design Parameters	Annual Energy Estimate (based on design data)
Ventilation (sum of wattage of all the supply fans and all the exhaust fans)	Supply = 1.0 W/cfm Exhaust = 1.25 W/cfm Total = 1.13W/cfm (1.0 cfm/gross ft <sup>2</sup> ; 1.5 cfm/net ft <sup>2</sup> and 2.1 cfm/gross ft <sup>2</sup> of labs)	19.8 kWh/gross ft <sup>2</sup>
Cooling Plant	2300 tons, 1.0kW/ton	20.4 kWh/gross ft <sup>2</sup>
Lighting	1.6Wft <sup>2</sup>	7.25 kWh/gross ft <sup>2</sup>
Process/Plug heating Plant	11 W/net ft <sup>2</sup> Not available	32.4 kWh/gross ft <sup>2</sup> Not available
<b>Total</b>		<b>79.85 kWh/gross ft<sup>2</sup>/yr (estimate based on design data for electricity only)</b>





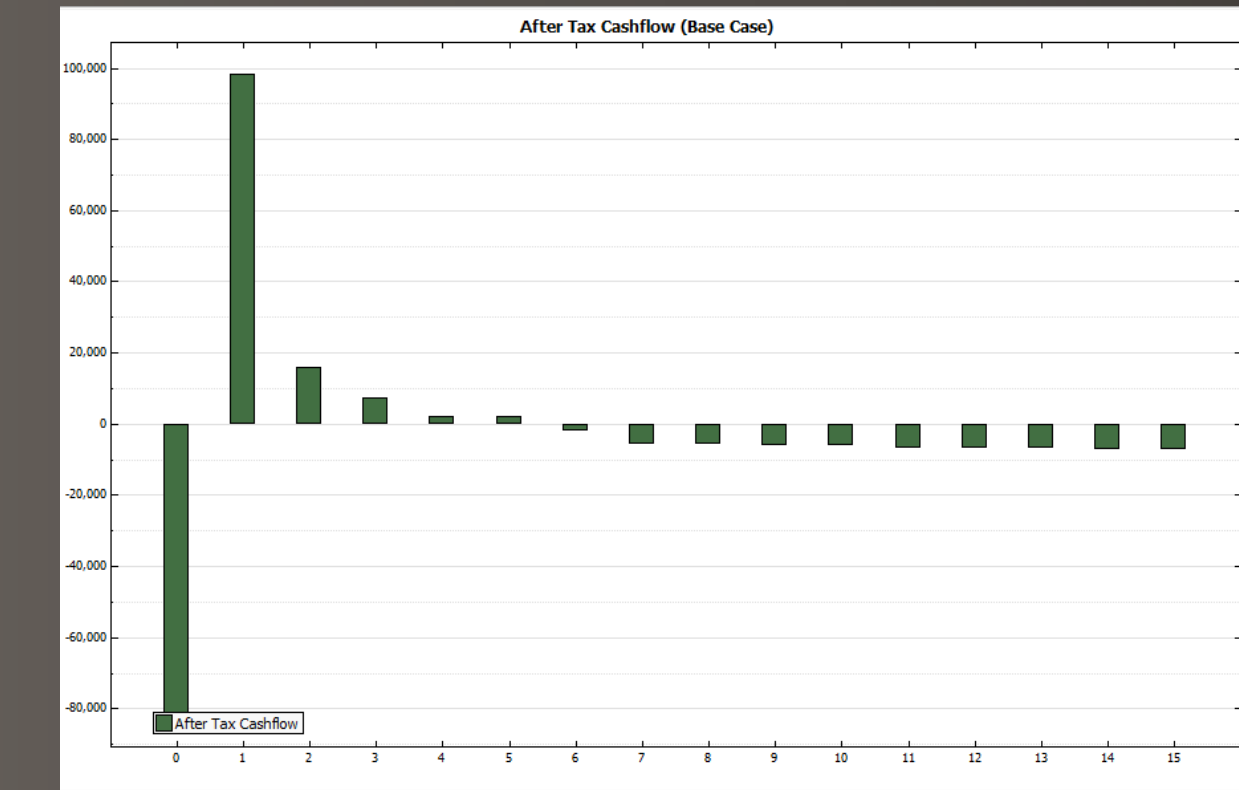
## ENERGY IMPACT

- USING PVWATTS A TOTAL OF 77,700 kWh CAN BE GENERATED
  - \$ 4662.60 IN SAVINGS PER YEAR

Summary Station Identification		Summary Results			
City:	Williamsport	Month	Solar Radiation (kWh/m <sup>2</sup> /day)	AC Energy (kWh)	Energy Value (\$)
State:	Pennsylvania				
Latitude:	41.27° N	1	2.55	4388	263.28
Longitude:	77.05° W	2	3.21	5071	304.26
Elevation:	243 m	3	4.22	7213	432.78
<b>PV System Specifications</b>		4	4.63	7499	449.94
DC Rating:	29.5 kW + 8.9 kW + 35.4 kW = 73.7 kW	5	5.43	8901	534.06
DC to AC Derate Factor:	0.77	6	5.68	8814	528.84
AC Rating:	27.3 kW	7	5.70	8926	535.56
Array Type:	Fixed Tilt	8	5.22	8103	486.18
Array Tilt:	10.0°, 32.0° 35.0°	9	4.38	6762	405.72
Array Azimuth:	135.0°, 180°	10	3.36	5335	320.1
<b>Energy Specifications</b>		11	2.23	3455	207.3
Cost of Electricity:	6.0 c/kWh	12	1.99	3243	194.58
		<b>Year</b>	<b>4.05</b>	<b>77710</b>	<b>4662.6</b>

## FEASIBILITY ANALYSIS (SAM)

- IMPLEMENT A POWER PURCHASE AGREEMENT
  - LCOE OF 5.88 CENTS/kWh
  - NET PRESENT VALUE OF \$5,771.71



### Presentation Outline:

Project Background

Modularization of the Laboratory Spaces

BIM Implementation with Virtual Mockups

Sustainability

Labor Resources Schedule Acceleration





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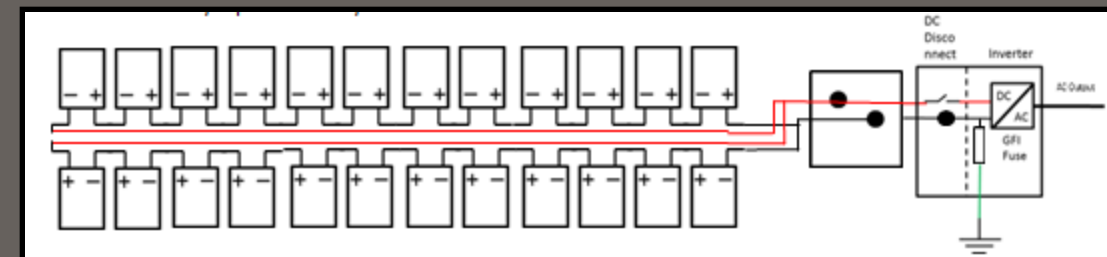
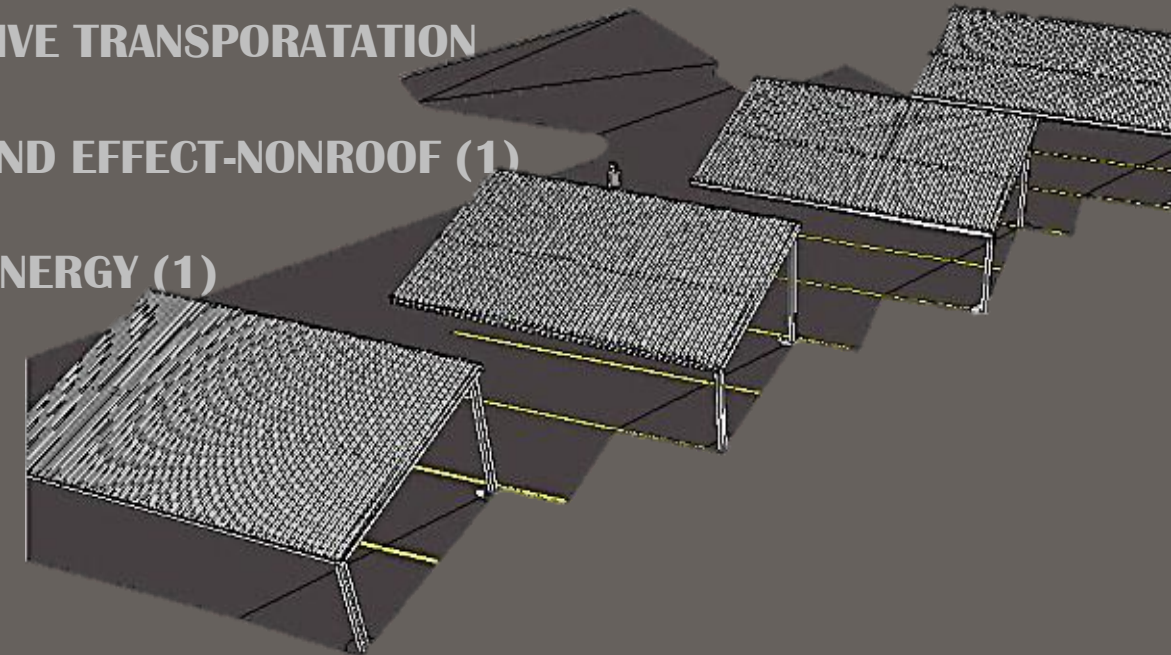
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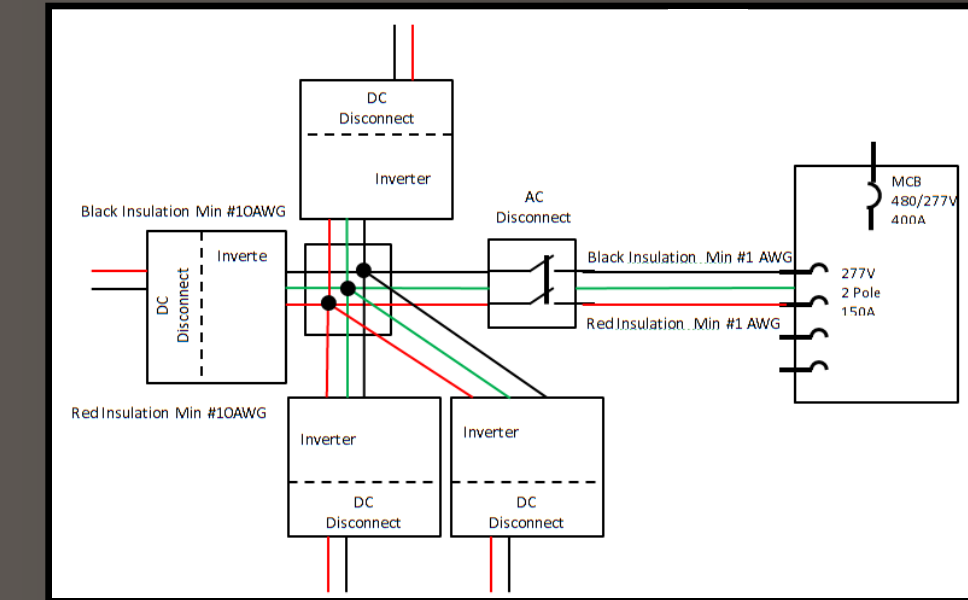


### LEED EVALUATION V2.2

- SUSTAINABLE SITES
  - CREDIT 4.3 ALTERNATIVE TRANSPORTATION (1)
  - CREDIT 7.1 HEAT ISLAND EFFECT-NONROOF (1)
- ENERGY AND ATMOSPHERE
  - ON SITE RENEWABLE ENERGY (1)



### ELECTRICAL BREADTH



ROOF	NUMBER OF PANELS	NUMBER OF STRINGS	WIRE SIZE BETWEEN MODULES	WIRE SIZE FROM D/C DISCONNECT TO INVERTER	WIRE SIZE FROM INVERTER TO A/C DISCONNECT	WIRE SIZE FROM A/C DISCONNECT TO SPLICE BOX	WIRE SIZE FROM TO SPLICE BOX TO PANEL BOARD
PARKING CANOPIES	24	2	12 AWG	8 AWG	10 AWG	10 AWG	1 AWG
SMALL ROOF	30	3	12 AWG	6 AWG	8 AWG	8 AWG	8 AWG
LARGE ROOF	120	12	12 AWG	6 AWG	8 AWG	8 AWG	2/0 AWG





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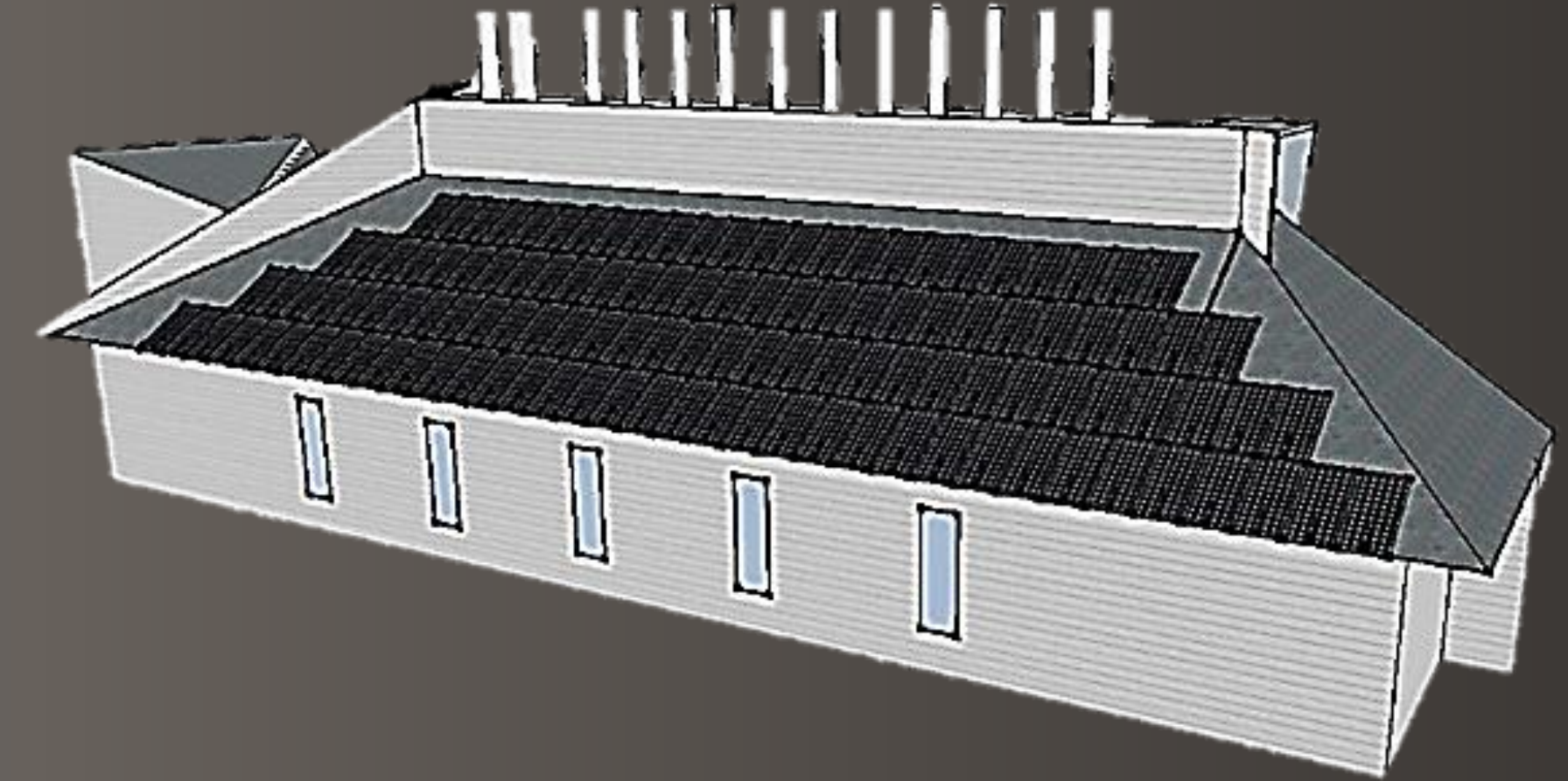
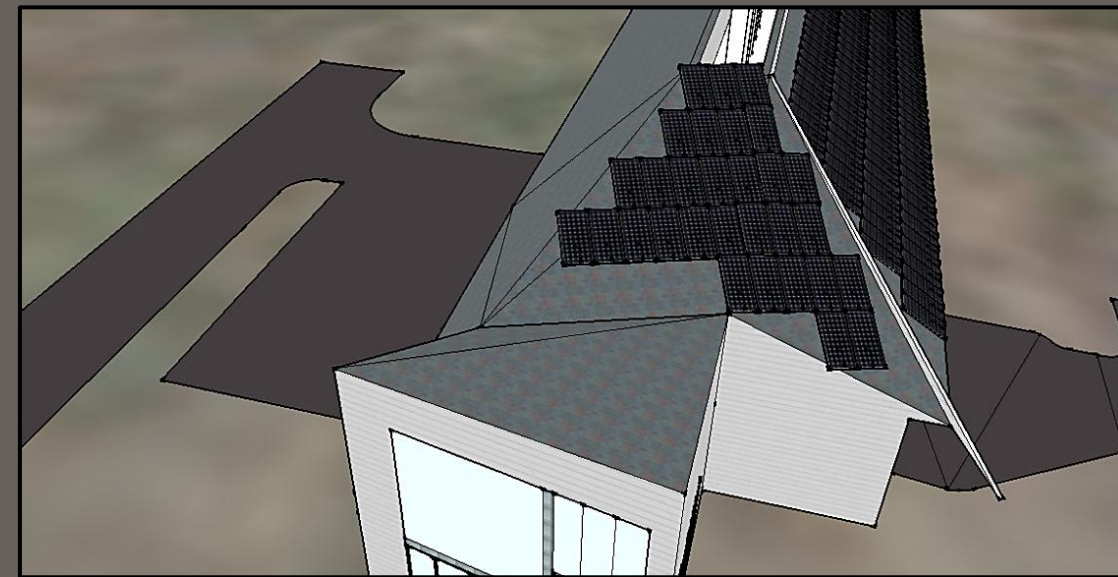
Sustainability

Labor Resources Schedule Acceleration



CONCLUSION

- PHOTOVOLTAIC SYSTEM
  - CREATES 3% OF RENEWABLE ENERGY
  - INCREASES LEED RATING TO GOLD
    - 38 POINTS TO 41 POINTS
- PPA FINANCIALLY VIABLE







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## PROBLEM

- **PROJECT IS BEHIND SCHEDULE BY 5 WEEKS**
  - **DUE TO PERMITTING**
  - **UNFORESEEN WEATHER CONDITIONS**



## RESEARCH GOAL

- **DEVELOP A SCHEDULE ACCELERATION SCENARIO**
  - **TO MAKE UP LOST TIME WITH OVERTIME HOURS EACH WEEK**
  - **FOCUS ON CRITICAL PATH TRADES**





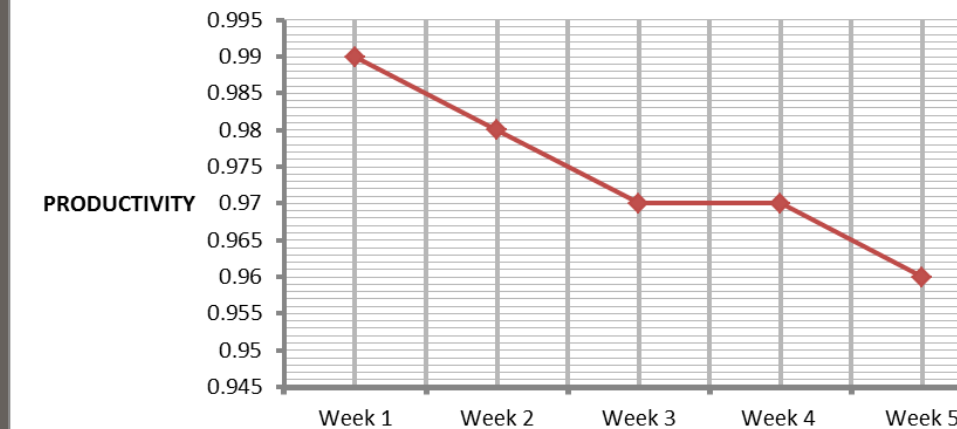


BRL | ENTRY - FROM EAST

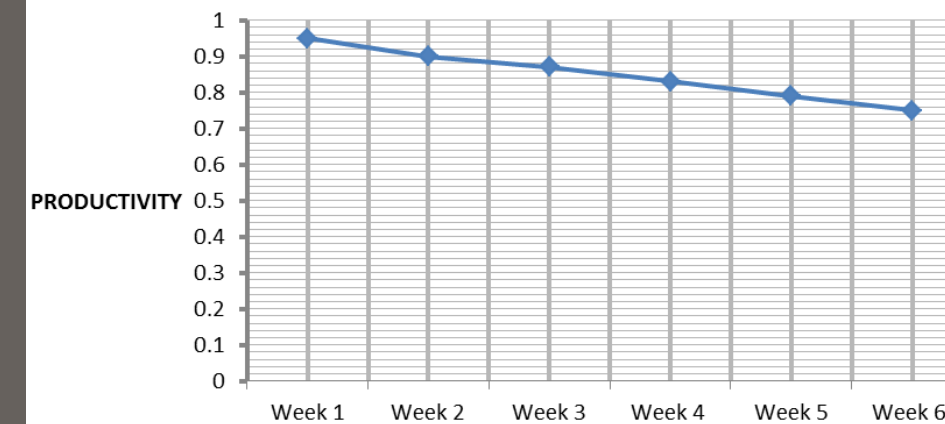
## WORK SCHEDULES

- ROLLING 4 DAY-10 HOUR
- 6 DAY-10 HOUR
- 5 DAY-8 HOUR

### 40 HOUR WORK WEEK



### 60 HOUR WORK WEEK



## STEEL CREW

- EFFECTIVE HOURS - 194.8
- 5 DAY-8 HOUR - 5 WEEKS
- 6 DAY-10 HOUR - 3 WEEKS, 5 DAYS
- ROLLING 4 DAY-10 HOUR - 2 WEEKS, 4 DAYS

6-10's	Productivity	Hours	Effective	Rolling 4-10	Productivity	Hours	Effective
Week 1	0.95	60	57	Week 1	1.18	60	70.8
Week 2	0.9	60	54	Week 2	1.33	60	79.8
Week 3	0.87	60	52.2	Week 3	1.5	60	90
Week 4	0.83	60	49.8	Week 4	1.55	60	93
Week 5	0.79	60	47.4	Week 5	1.6	60	96
Week 6	0.75	60	45	Week 6	1.65	60	99
<b>Total</b>	<b>0.848333333</b>	<b>360</b>	<b>305.4</b>	<b>Total</b>	<b>1.468333333</b>	<b>360</b>	<b>528.6</b>

5-8's	Productivity	Hours	Effective
Week 1	0.99	40	39.6
Week 2	0.98	40	39.2
Week 3	0.97	40	38.8
Week 4	0.97	40	38.8
Week 5	0.96	40	38.4
<b>Total</b>	<b>0.541111111</b>	<b>200</b>	<b>194.8</b>

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## CREW WEEKLY MAKE-UP

### NOMINAL ROLLING 4 DAY 10 HOUR SCHEDULE

WEEK	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	Crew 1 Crew 2	Crew 1 Crew 2	Crew 1 Crew 3	Crew 1 Crew 3	Crew 2 Crew 3	Crew 2 Crew 3	
2	Crew 1 Crew 2	Crew 1 Crew 2	Crew 1 Crew 3	Crew 1 Crew 3	Crew 2 Crew 3	Crew 2 Crew 3	NO WORK
3	Crew 1 Crew 2	Crew 1 Crew 2	Crew 1 Crew 3	Crew 1 Crew 3	Crew 2 Crew 3	Crew 2 Crew 3	
4	Crew 1 Crew 2	Crew 1 Crew 2	Crew 1 Crew 3	Crew 1 Crew 3	Crew 2 Crew 3	Crew 2 Crew 3	
5	Crew 1 Crew 2	Crew 1 Crew 2	Crew 1 Crew 3	Crew 1 Crew 3	Crew 2 Crew 3	Crew 2 Crew 3	
6	Crew 1 Crew 2	Crew 1 Crew 2	Crew 1 Crew 3	Crew 1 Crew 3	Crew 2 Crew 3	Crew 2 Crew 3	

WEEK	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	Crew 1 Crew 2	Crew 1 Crew 2	Crew 1 Crew 3	Crew 1 Crew 3	Crew 2 Crew 3	Crew 2 Crew 3	
2	Crew 2 Crew 3	Crew 2 Crew 3	Crew 1 Crew 2	Crew 1 Crew 3	Crew 1 Crew 3	Crew 1 Crew 3	NO WORK
3	Crew 2 Crew 3	Crew 2 Crew 3	Crew 1 Crew 2	Crew 1 Crew 3	Crew 1 Crew 3	Crew 1 Crew 3	
4	Crew 1 Crew 3	Crew 2 Crew 3	Crew 2 Crew 3	Crew 1 Crew 2	Crew 1 Crew 2	Crew 1 Crew 3	
5	Crew 1 Crew 3	Crew 1 Crew 3	Crew 2 Crew 3	Crew 2 Crew 3	Crew 1 Crew 2	Crew 1 Crew 2	
6	Crew 1 Crew 2	Crew 1 Crew 3	Crew 1 Crew 3	Crew 2 Crew 3	Crew 2 Crew 3	Crew 1 Crew 2	

### STAGGERING ROLLING 4 DAY 10 HOUR SCHEDULE

## COST BREAKDOWN

5 Day 8 Hour Work Schedule			4 Day 10 Hour Rolling Work Schedule		
Steel Erecting Crew	Hr.	Daily	Steel Erecting Crew	Hr.	40 hrs./ Week
1 Structural Steel Foreman	\$ 85.95	\$ 687.60	2 Structural Steel Foreman	\$ 85.95	\$ 6,876.00
4 Structural Steel Workers	\$ 82.45	\$ 2,638.40	6 Structural Steel Workers	\$ 82.45	\$ 19,788.00
1 Crane Operator	\$ 66.45	\$ 531.60	2 Crane Operator	\$ 66.45	\$ 3,987.00
1 Equipment Operator	\$ 57.35	\$ 458.80	1 Equipment Operator	\$ 57.35	\$ 3,441.00
1 lattice Boom Crane		\$ 1,767.70	Weekly Totals		\$ 34,092.00
56 L.H. Daily Totals		\$ 6,084.10	1 lattice Boom Crane		\$ 8,838.50
Week		\$ 30,420.50	Week		\$ 42,930.50
<b>5 Weeks</b>		<b>\$ 152,102.50</b>	<b>2 Weeks 4 days</b>		<b>\$ 117,427.50</b>

6 Day 10 Hour Work Schedule				
Steel Erecting Crew	Hr.	40 hrs./ Week	Overtime 20 hrs.	
1 Structural Steel Foreman	\$ 85.95	\$ 3,438.00	\$ 128.93	\$ 2,578.50
4 Structural Steel Workers	\$ 82.45	\$ 13,192.00	\$ 123.68	\$ 9,894.00
1 Crane Operator	\$ 66.45	\$ 2,658.00	\$ 99.68	\$ 1,993.50
1 Equipment Operator	\$ 57.35	\$ 2,294.00	\$ 86.03	\$ 1,720.50
Weekly Totals		\$ 21,582.00		\$ 16,186.50
1 lattice Boom Crane		\$ 8,838.50		
Week		\$ 30,420.50		\$ 46,607.00
<b>3 Weeks 5 days</b>				<b>\$ 178,334.75</b>

### Presentation Outline:

Project Background

Modularization of the Laboratory Spaces

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BRL | ENTRY - FROM EAST

**ADDITIONAL TRADES**

- CONCRETE SLABS 3 WEEKS
  - ROLLING SCHEDULE (1 WEEK 4 DAYS)
  - SAVINGS OF 1 WEEK
- MASONRY TRADE 5 WEEKS
  - ROLLING SCHEDULE (2 WEEKS 3 DAYS)
  - SAVINGS OF 2 WEEK

6-10's	Productivity	Hours	Effective	Rolling 4-10	Productivity	Hours	Effective
Week 1	0.95	60	57	Week 1	1.18	60	70.8
Week 2	0.9	60	54	Week 2	1.33	60	79.8
Week 3	0.87	60	52.2	Week 3	1.5	60	90
Week 4	0.83	60	49.8	Week 4	1.55	60	93
Week 5	0.79	60	47.4	Week 5	1.6	60	96
Week 6	0.75	60	45	Week 6	1.65	60	99
Total	0.848333333	360	305.4	Total	1.468333333	360	528.6

5-8's	Productivity	Hours	Effective
Week 1	0.99	40	39.6
Week 2	0.98	40	39.2
Week 3	0.97	40	38.8
Week 4	0.97	40	38.8
Week 5	0.96	40	38.4
Total	0.541111111	200	194.8

**CONCLUSION**

- IMPLEMENTING A ROLLING 4 DAY 10 HOUR SCHEDULE
  - SAVES 5 WEEKS ON THE SCHEDULE
  - SAVES \$ 35,000.00 IN JUST THE STEEL TRADE

**Presentation Outline:**

Project Background

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### Presentation Outline:

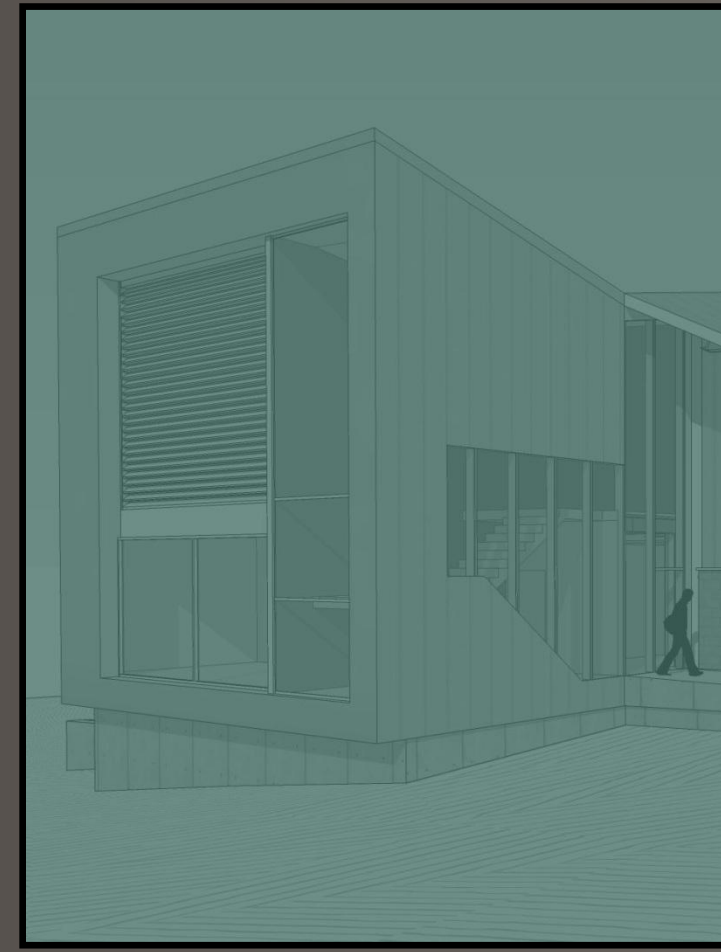
Project Background

Modularization of the Lab

**FINAL RECOMMENDATIONS**

Sustainability

Labor Resources Schedule Acceleration



### ANALYSIS: I MODULARIZATION

- I RECOMMEND IMPLEMENTING MODULAR UNITS BASED ON THE:
  - COST SAVINGS OF \$ 83,500.00
  - SCHEDULE REDUCTION OF 4 MONTHS
  - THE ABILITY TO DELIVER A HIGHER QUALITY OF WORK



### ANALYSIS: II BIM IMPLEMENTATION (VIRTUAL MOCKUPS)

- VIRTUAL MOCKUPS SHOULD BE USED ON THE BRL FACILITY BECAUSE
  - POTENTIAL TO CATCH DESIGN ERRORS
  - CAN ELIMINATE FIELD MOCKUPS
  - COST SAVING IN LABOR AND MATERIALS – \$110,000.00







### Presentation Outline:

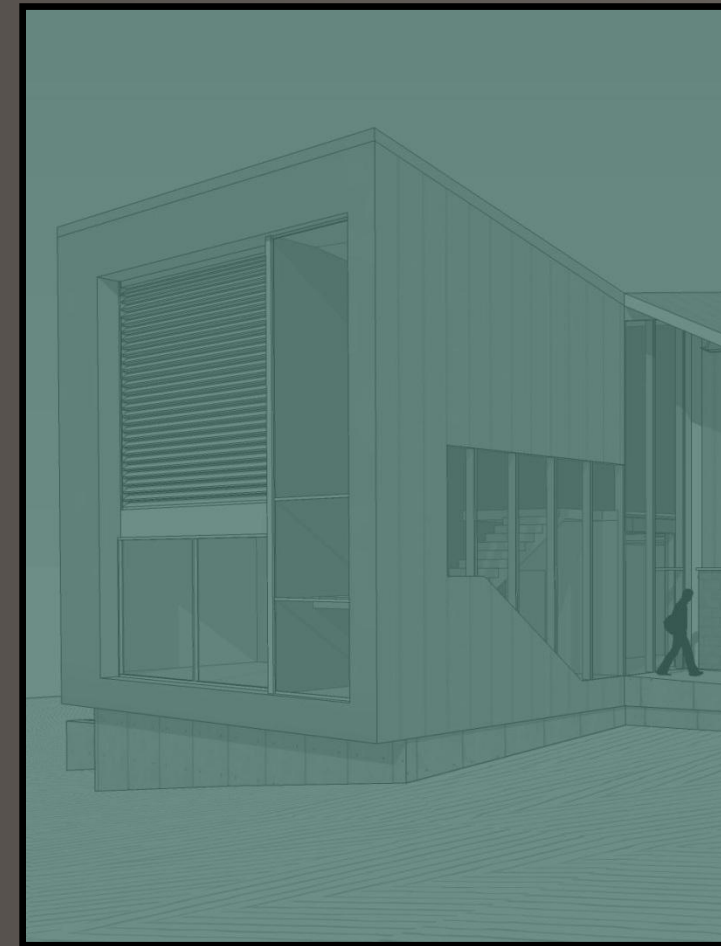
Project Background

Modularization of the Lab

**FINAL RECOMMENDATIONS**

Sustainability

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### ANALYSIS: III SUSTAINABILITY

- THE 246 PHOTOVOLTAIC PANEL SYSTEM SHOULD ONLY BE INSTALLED IF :
  - THE UNIVERSITY AGREES TO A PPA AGREEMENT
  - THE THIRD PARTY HAS THE ABILITY TO STILL APPLY FOR GOVERNMENT INCENTIVES



### ANALYSIS: IV SCHEDULE ACCELERATION

- A ROLLING 4 DAY 10 HOUR SCHEDULE SHOULD BE INCORPORATED BECAUSE:
  - THE SCHEDULE HAS THE POTENTIAL TO MAKE UP THE 5 WEEKS OF LOST WORK
  - CONSIDERABLE COST SAVINGS CAN BE QUANTIFIED

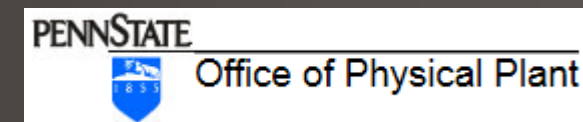
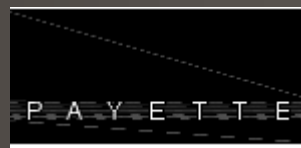




# BIOLOGICAL RESEARCH LABORATORY



## PROJECT ACKNOWLEDGEMENTS



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**QUESTIONS?**



# BIOLOGICAL RESEARCH LABORATORY



## Energy Load Analysis for Biological Research Facility

$$\frac{W}{cfm} \text{ for supply air} = 76.667 \text{ hp} * \left[ \frac{746 \left( \frac{W}{hp} \right)}{24228 \text{ cfm}} \right] = 2.28 \frac{W}{cfm}$$

$$\frac{W}{cfm} \text{ for return air} = 90.1 \text{ hp} * \left[ \frac{746 \left( \frac{W}{hp} \right)}{21726 \text{ cfm}} \right] = 3.09 \frac{W}{cfm}$$

$$\frac{2.28 + 3.09}{2} = 2.685 \frac{W}{cfm} \frac{21726 \text{ cfm (total cfm based on exhaust)}}{20000 \text{ sf}} = 1.08 \frac{cfm}{\text{gross sf}}$$

$$\text{Ventilation} - 2.685 \frac{W}{cfm} * 1.08 \frac{cfm}{\text{gross sf}} * \left( \frac{8760 \text{ hours}}{1000} \right) = 25.40 \frac{kWh}{\text{gross sf}}$$

$$\text{Cooling} - \frac{1kW}{\text{ton}} * 280 \text{ tons} * \frac{963 \text{ hours}}{20000 \text{ gross sf}} = 13.48 \frac{kWh}{\text{gross sf}}$$

$$\text{Lighting} - 1.0 \frac{W}{\text{gross}} \text{ ft}^2 * \left( \frac{4534 \text{ hours}}{1000} \right) = 4.534 \frac{kWh}{\text{gross sf}} **$$

\*\*Assumes lights are on for 87.2 hours a week

$$\text{Process/Plug} - 5.735 \left( \frac{W}{\text{gross sf}} \right) * 0.80 * \frac{5256 \text{ hours}}{1000} = 24.11 \frac{kWh}{\text{gross sf}} ***$$

\*\*\*Assumes that 80% of all equipment is operating 60% of the hours in a year

$$\text{Heating} - 44.3 \text{ kW} * \frac{5782 \text{ hours}}{20000 \text{ sf}} = 12.81 \frac{kWh}{\text{gross sf}}$$

$$\text{Total} = (25.40 + 13.48 + 4.53 + 24.11 + 12.81) = 80.33 \frac{kWh}{\text{gross sf}}$$

$$107.31 \frac{kWh}{\text{gross sf}} * 20000 \text{ sf} = 2,146,200 \text{ kWh/yr}$$

$$\frac{2,146,200 \text{ kWh}}{\text{yr}} * \frac{1 \text{ yr}}{12 \text{ months}} = \frac{178,850 \text{ kWh}}{\text{month}} * \frac{1 \text{ month}}{30 \text{ days}} = \frac{5,961 \text{ kWh}}{\text{day}}$$

## Parking Canopies (7.5-1)

### Electrical Calculations DC Side

Isc= 9.16 A

25% Safety Factor and another 25% for wire and fuses

Add 2 strings in parallel the amps multiply by 2

Max Wire Amp for 2 strings= Isc\*1.25\*1.25\*2= 9.16\*1.25\*1.25\*2=28.62

Max wire amp for 1 string= Isc\*1.25\*1.25=9.16\*1.25\*1.25=14.31 A

The minimum current carrying capacity of the wires between the combiner box and the inverter is 28.62 Amp

Conduit 1" above the roof add 22°C

Max Temp= 38°C

Ambient Temp= 38+22= 60°C

Correction factor for 60°C= .71 outside on roof

#12 AWG @ 90°C= 30A \* .71= 21.3A > 14.31 A ok to use for connecting string to combiner box

#8 AWG @ 90°C= 50A \* .71= 35.5 A > 28.62 (Max wire Amp), so wire is OK to use between the combiner box and inverter

### Electrical Calculations AC Side

Inverter Max AC Output 27.1A to connect to panelboard

Use 1.25 times inverter max output then round to the nearest breaker size for

27.1\*1.25=33.875 Amp

#10 AWG @ 90°C= 40A > 33.875 (Max wire Amp), so wire is OK to use between A/C disconnect and underground splice box

33.875\*4=135.5 Amps wire sizing from parking canopy to electrical box inside building

135.5 A < 150 A so #1 AWG in a 2" rigid PVC pipe

Next breaker size 150Amp

Assumed THWN 90°C from table 310.16

#1 Wire 135.5 Amps = 150 A Breaker size so OK to use

When connecting to an electrical panel a 150 A breaker is to be used to sufficiently take the load.

Structural Breakdown Cost	Crew	Daily Output	Labor Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P	Cost
<b>Material</b>										
2" dee psteel decking Ga. 19	E-4	3400	0.009 S.F.		1.53	0.44	0.04	2.01	2.41	\$ 1,484.96
3" dee psteel decking Ga. 19	E-4	2925	0.011 S.F.		1.65	0.52	0.05	2.22	2.66	\$ 1,638.56
										\$ (154.00)
<b>Structural Steel</b>										
8X10	E-2	600	0.093 L.F.		12.1	4.26	2.68	19.04	23.5	\$ (188.00)
14X30	E-2	900	0.062 L.F.		36.5	2.84	1.79	41.13	47	\$ (940.00)
16X45	E-2	800	0.07 L.F.		54.5	3.19	2.01	59.7	71.64	\$ (1,576.08)
12X19	E-2	880	0.064 L.F.		32.6	2.9	1.83	37.33	44.796	\$ 1,791.84
8X13	E-2	600	0.093 L.F.		15.21	4.26	2.68	22.15	26.58	\$ 425.38
14X22	E-2	990	0.057 L.F.		31.5	2.58	1.62	35.7	42.84	\$ 942.48
Concrete 6" slab	C-8	288	0.022 S.F.		1.96	0.76	0.29	3.04	3.67	\$ 1,541.40
										\$ 1,027.60
<b>Fireproofing</b>										
1 inch thick	G-2	2400	0.01 S.F.		0.53	0.35	0.05	0.94	1.16	\$ (510.40)
<b>Total Savings</b>										\$ 818.72
										Per Typical Bay