

Research Facility Core and Shell (RFCS)



Presented by Tim Maffett on April 8th, 2013

Introduction | Presentation Overview

- | Introduction
- | Prefabricated Exterior Wall Panels
- | Detailed Sequencing
- | Sizing of Rigging Beam
- | Solar Panel Installation at Roof Level
- | Mobile Technology Integration- Tablet Computers
- | Recommendations
- | Concluding Remarks

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Name | Research Facility Core and Shell (RFCS)

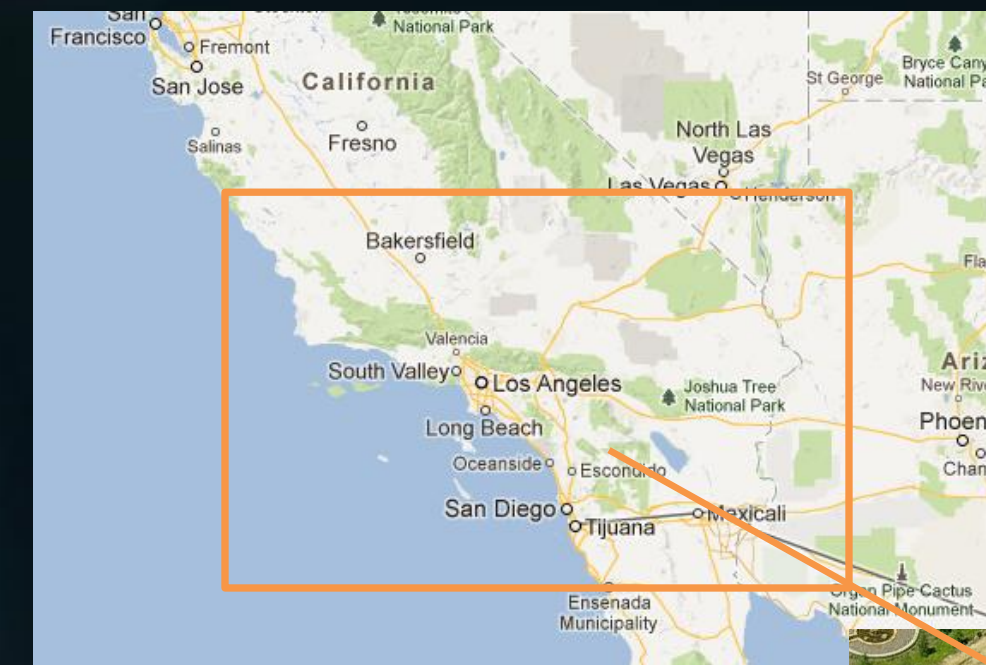
Location | Southern California

Building Use | Research Facility with Office Space

Owner | Faction

Architect | Dowler-Gruman Architects

General Contractor | DPR Construction



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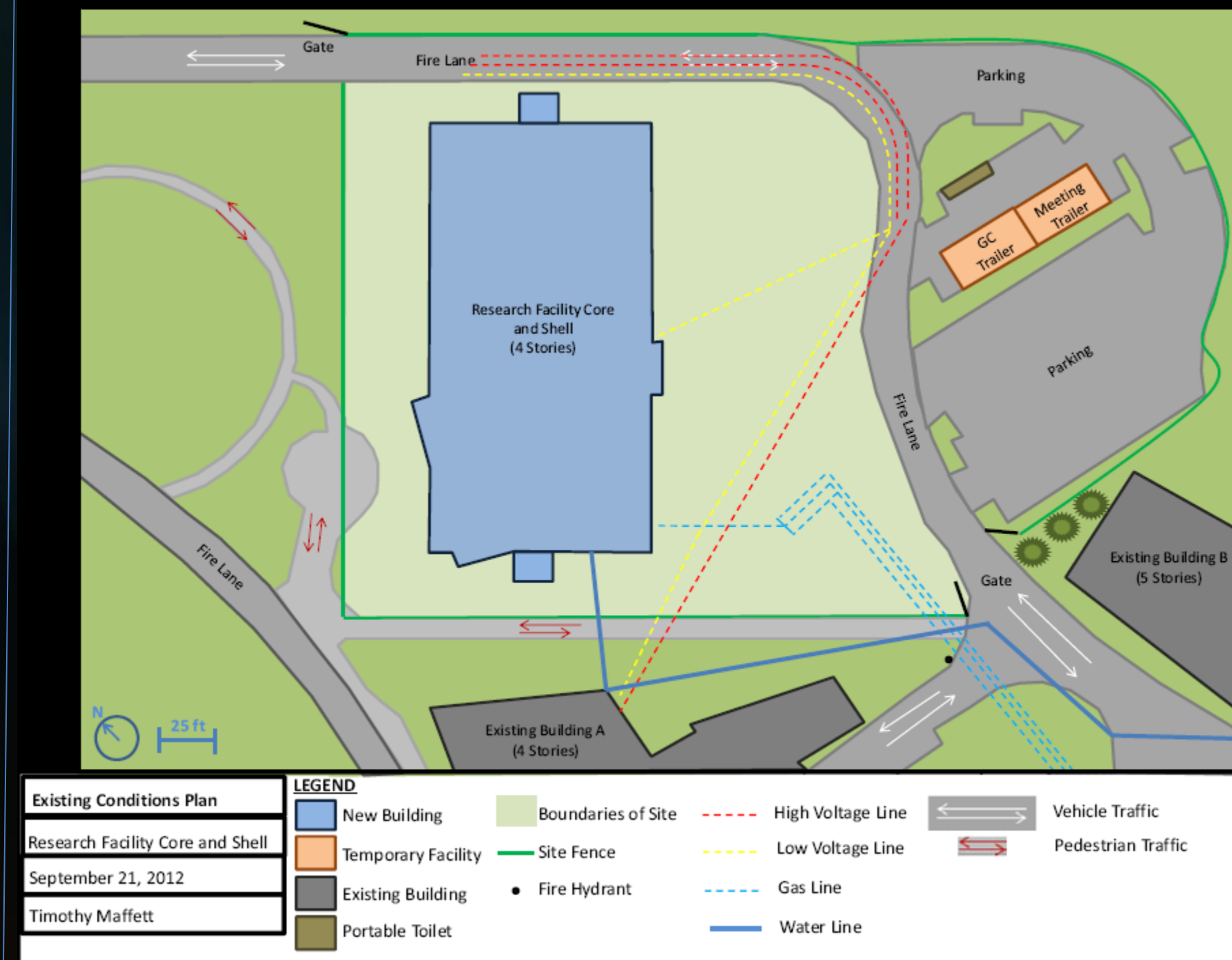
Project Delivery Method | Design-Bid-Build

Contract Type | GMP

Size | 130,000 SF

Cost | \$20,000,000

Schedule | 18 Months



Introduction | Design Goal

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Design Goal

Increase value through innovative and efficient construction.

Prefabricated Exterior Panels | Overview

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Prefabricated Exterior Wall Panels

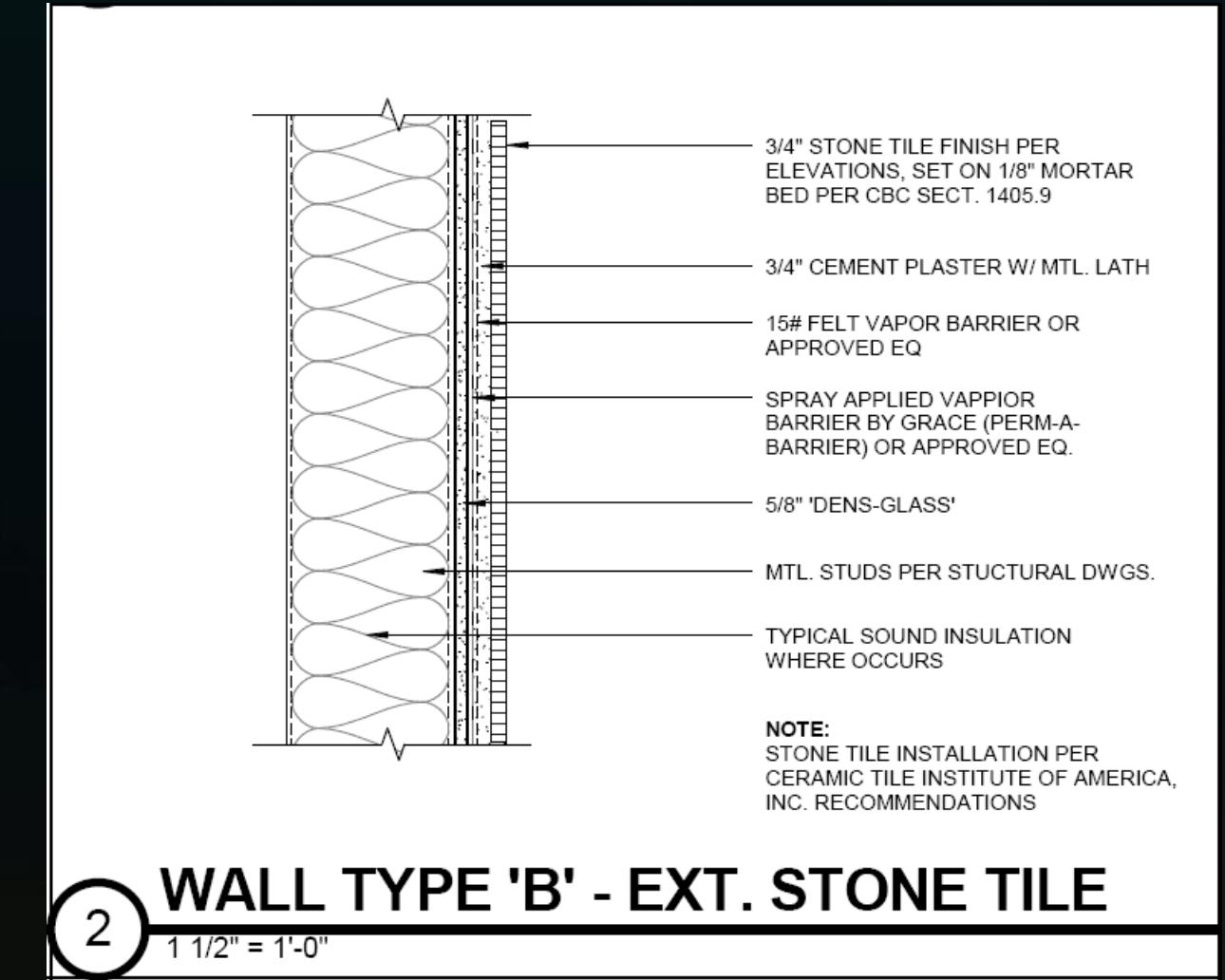
Prefabricated Exterior Panels | Problem Identification

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Existing System

- Stick-built metal stud wall with sheathing and masonry veneer
- Critical Path item for 24 weeks (1/3 of total schedule)
- Created congestion on site
- \$1,507,959 to complete



Typical Wall Section

Prefabricated Exterior Panels | Solution

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Proposed Solution?

Prefabricate exterior wall as panel modules.

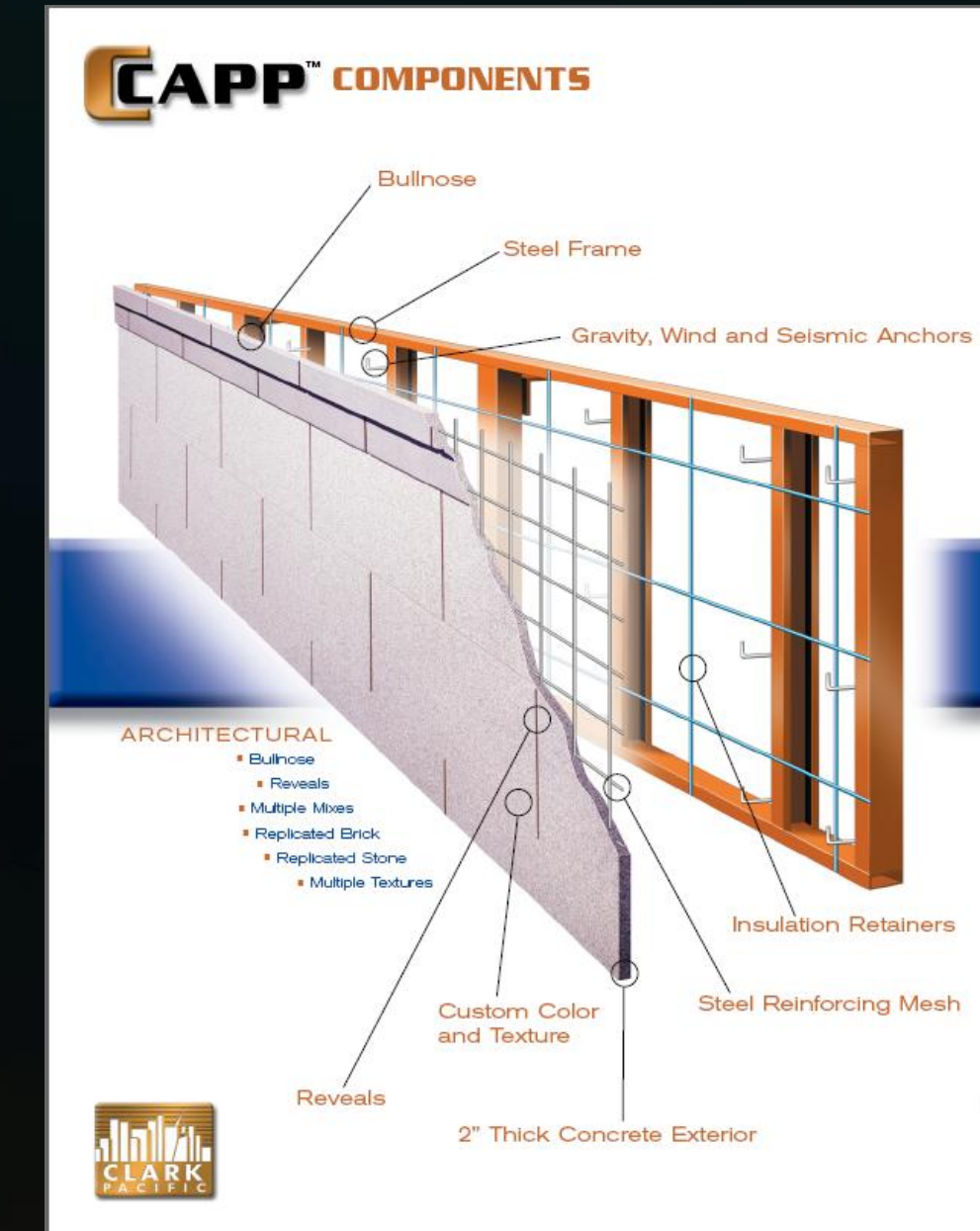
Prefabricated Exterior Panels | Alternative #1

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C-CAPP Prefabricated Panel System

- Architectural, lightweight, precast concrete panel system
- 2" thick concrete skin attached to a steel frame
- Durable, lightweight, closest match to existing facade
- Produced by Clark Pacific



Section of C-CAPP System

Prefabricated Exterior Panels | Alternative #1

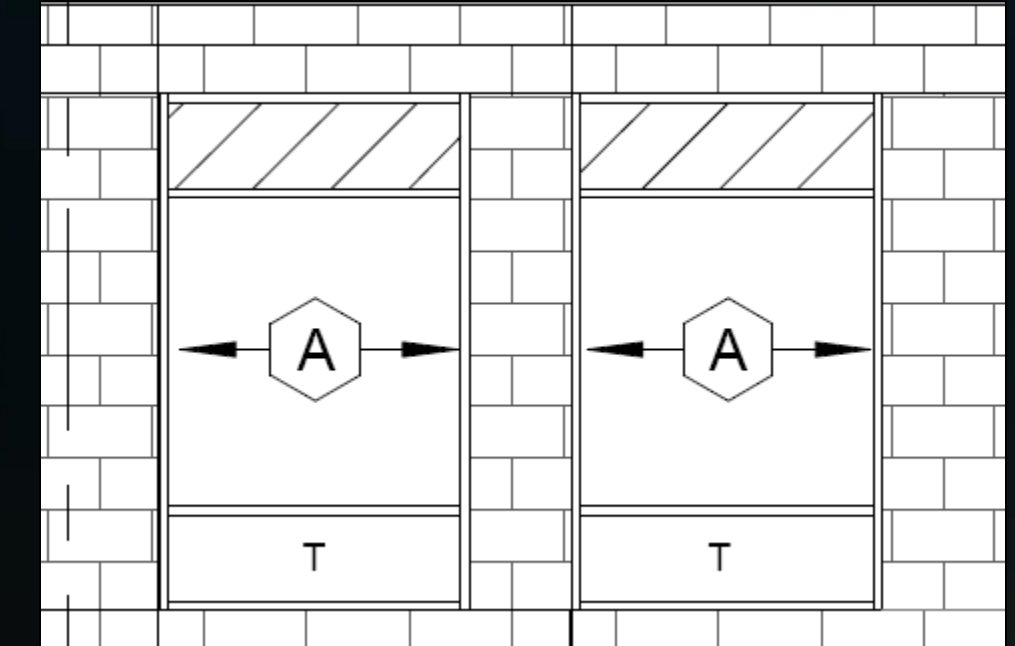
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Results

- Total Cost of C-CAPP System | \$1,115,000
- Critical Path Duration | 7 Weeks

| Quote on C-CAPP Prefabricated Panel System | | | |
|--------------------------------------------|--------------------|-------------------------------|----------------|
| Cost Breakdown (\$) | | Schedule (Duration) | |
| Base Budget | \$907,500 | Preliminary | Variable |
| Staining Panels | \$99,500 | | |
| Preweld Connections to Steel Structure | \$75,000 | Layout and Preweld | 3 weeks |
| Caulking | \$33,000 | Hanging Panels | 1 week |
| ----- | ----- | Final Aligning and Welding | 3 weeks |
| - | | | |
| Total Cost of System | \$1,115,000 | Total Duration on site | 7 weeks |



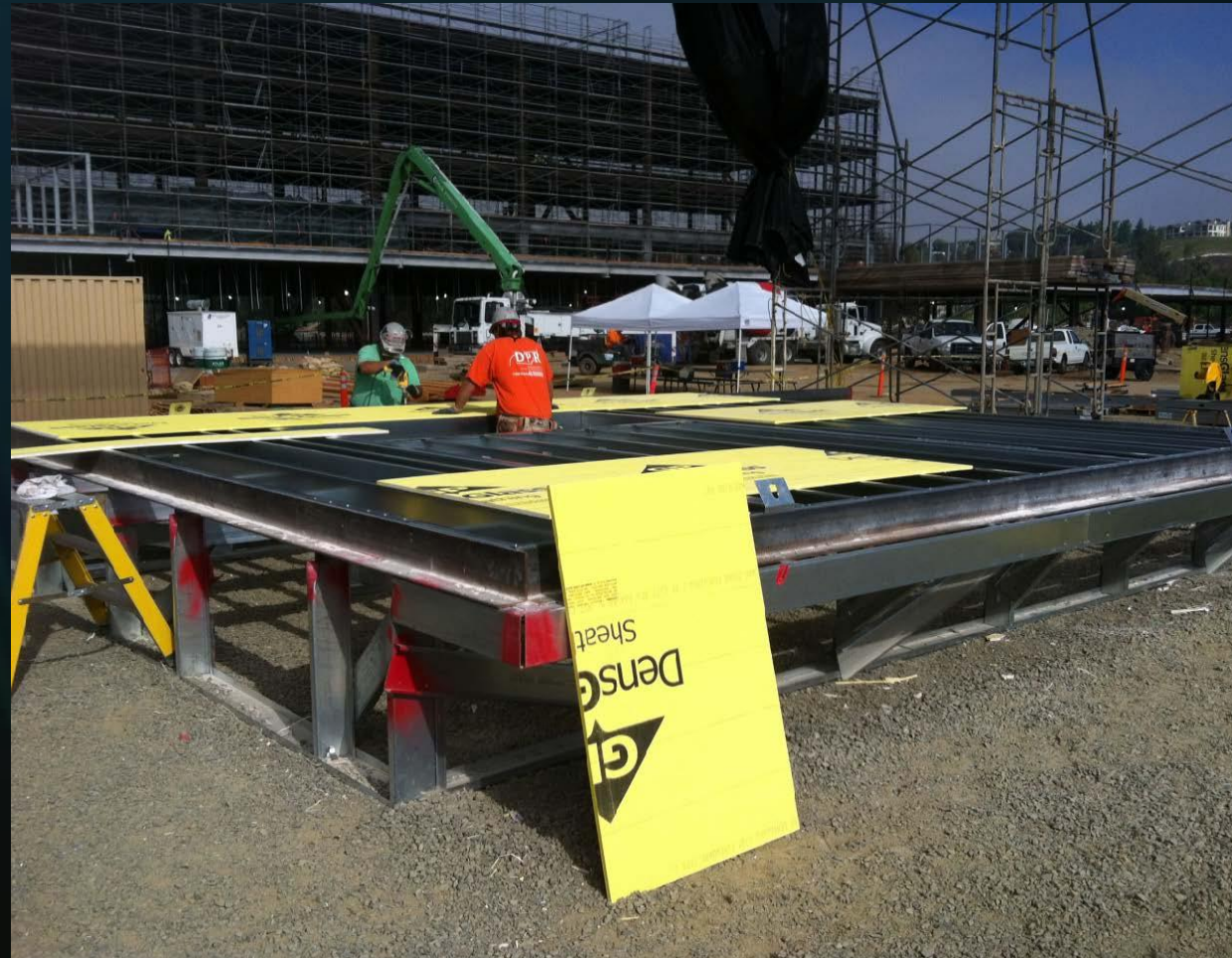
12' x 22' Typical Module for C-CAPP System

Prefabricated Exterior Panels | Alternative #2

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On-Site Partial Panel Prefabrication



Panel Prefabrication at Hospital in Temecula, CA

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Results

- Total Cost of Partially Prefabricated System | \$1,502,007
- Critical Path Duration | 21 Weeks



Prefabricated Exterior Panels | Chosen Alternative

- | Introduction
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Chosen Alternative On-Site Partial Panel Prefabrication

- **Architectural Properties** | Aesthetic Match
- **Planning** | Later in Process
- **Owner Hesitance** | Less Anxiety
- **Cost** | Decrease
- **Schedule** | Decrease
- **Safety** | Increase



Prefabricated Exterior Panels | System Comparison

- | Introduction
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On-Site Partial Panel Prefabrication vs. Stick-built Wall Construction

- **Cost Savings | \$5,953**
- **Schedule Reduction | 3 Weeks**

| Partially Prefabricated Panel Alternative vs. Original Stick Built Design | | |
|---------------------------------------------------------------------------|----------------------------------|-----------------------------|
| Description | Partially Prefabricated Panels | Original Stick-Built Design |
| Overall Cost | \$1,502,007 | \$1,507,960 |
| Difference +/- | \$5,953 Savings | |
| Overall Schedule | 21 Weeks | 24 Weeks |
| Difference +/- | 3 Week Schedule Reduction | |

Prefabricated Exterior Panels | Recommendation

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Recommendation

Implement Partially Prefabricated Wall Panel Strategy as opposed to original stick-built construction

Detailed Sequencing | Overview

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- | **Detailed Sequencing**
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Detailed Sequencing of Exterior Wall Panels

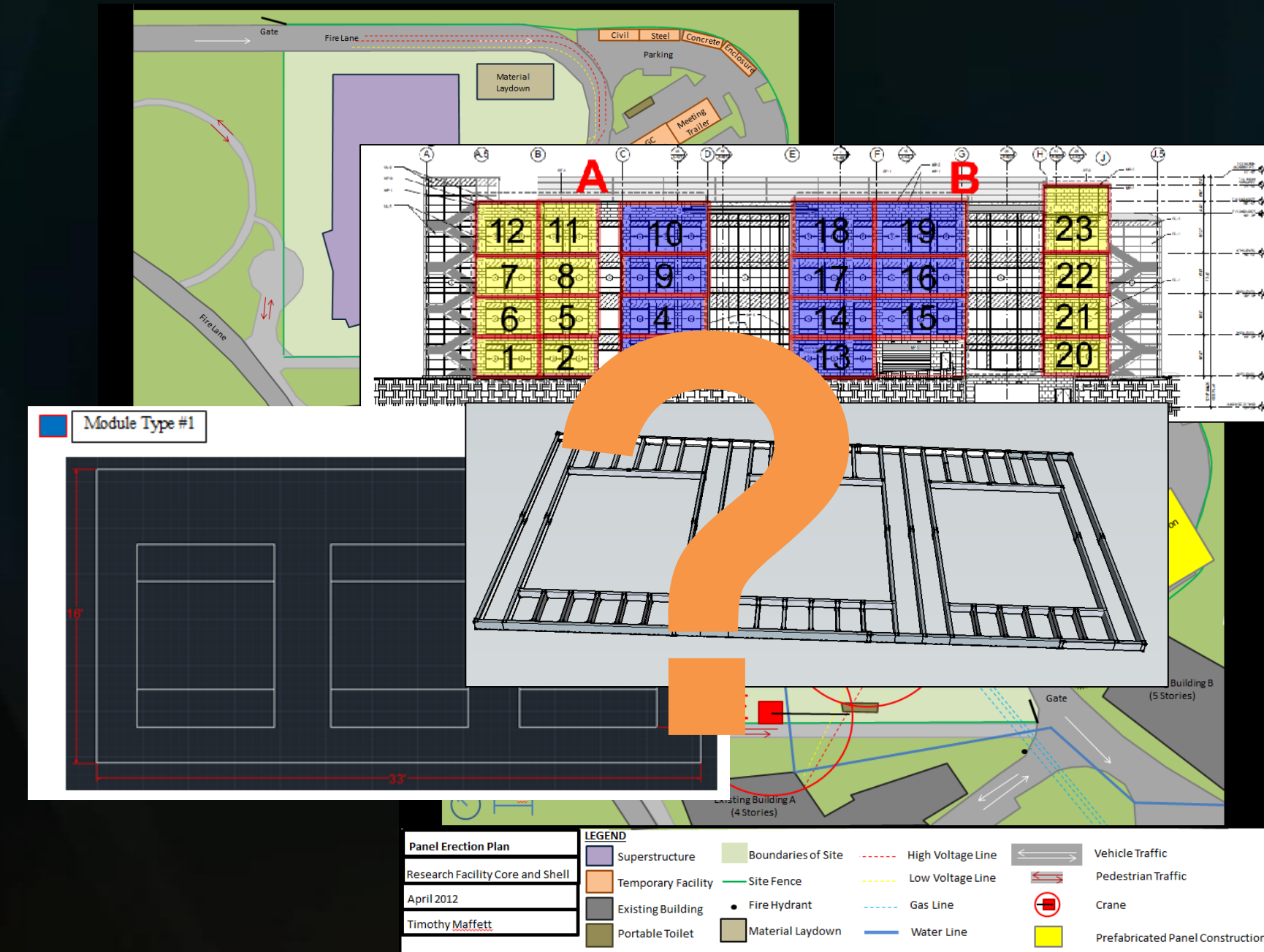
Detailed Sequencing | Constructability Concerns

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Constructability Concerns

- Where on site will we build panels?
- How do we modularize most efficiently?
- How do we plan necessary supplies?
- How do we schedule this activity?
- In what order will the panels be erected?
- How do we educate and create a safe environment?



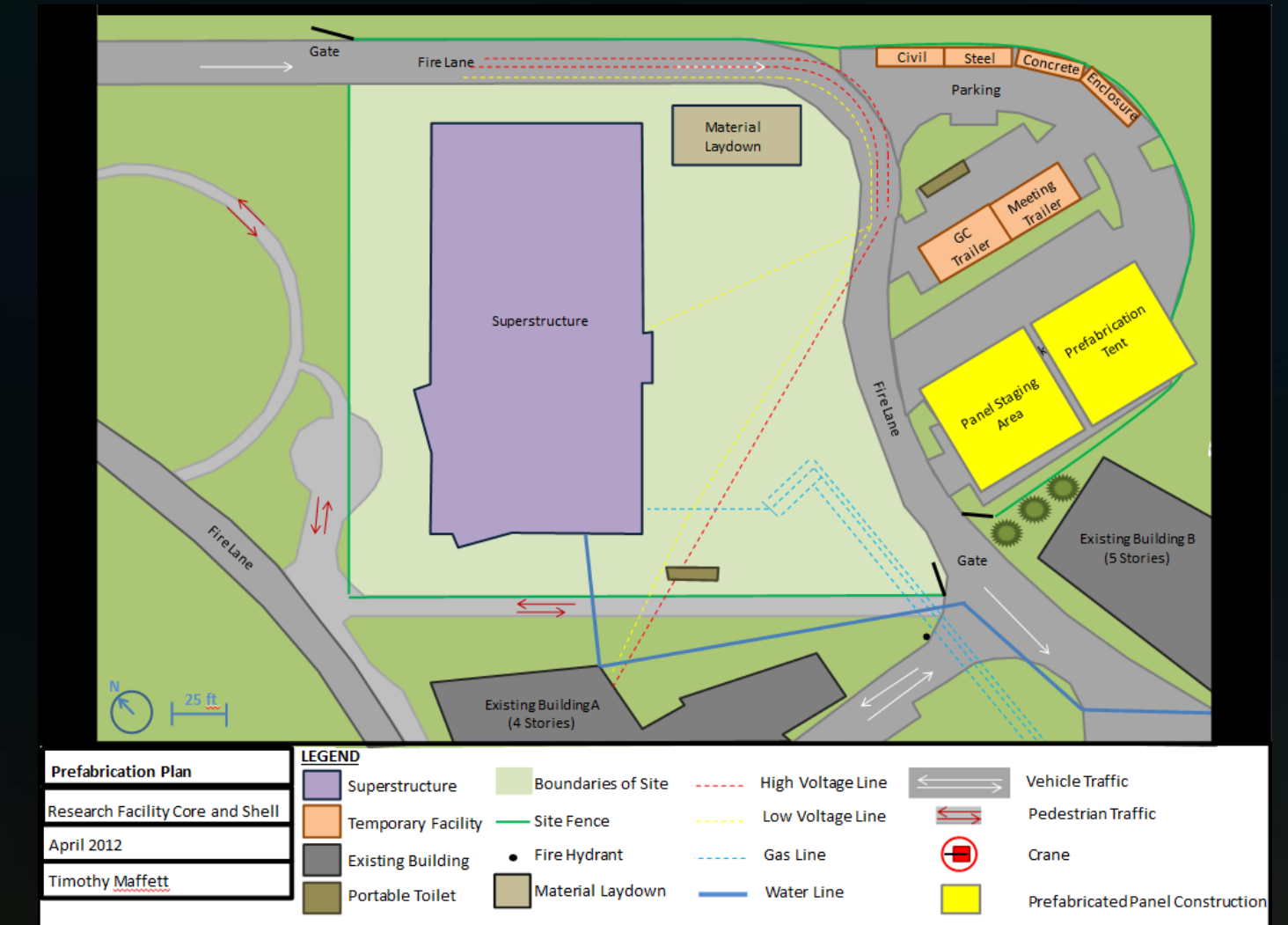
Detailed Sequencing | Prefabrication Tent & Staging

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Prefabrication Tent and Staging

- **Location** | On-site and near building
- **Description** | Metal framed tent to provide cover during construction
- **Staging** | Tarp to cover and protect completed panels

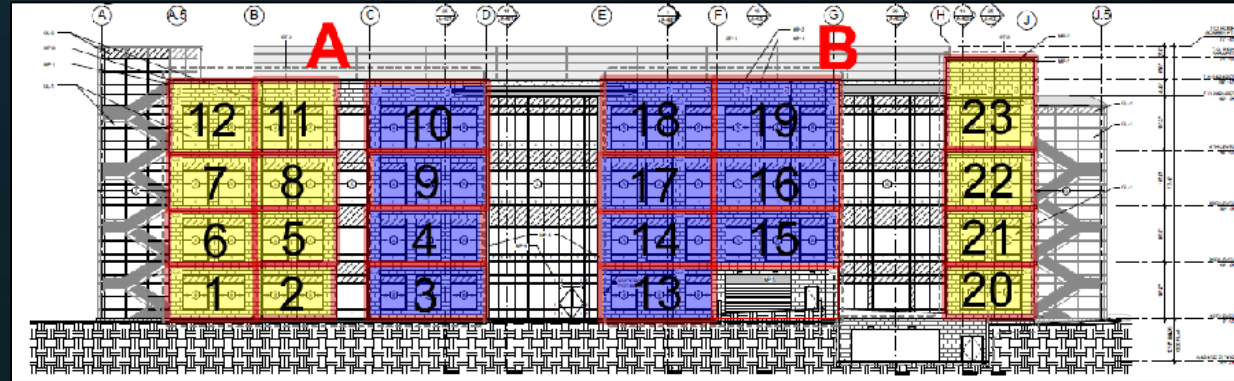


Detailed Sequencing | Module Breakdown

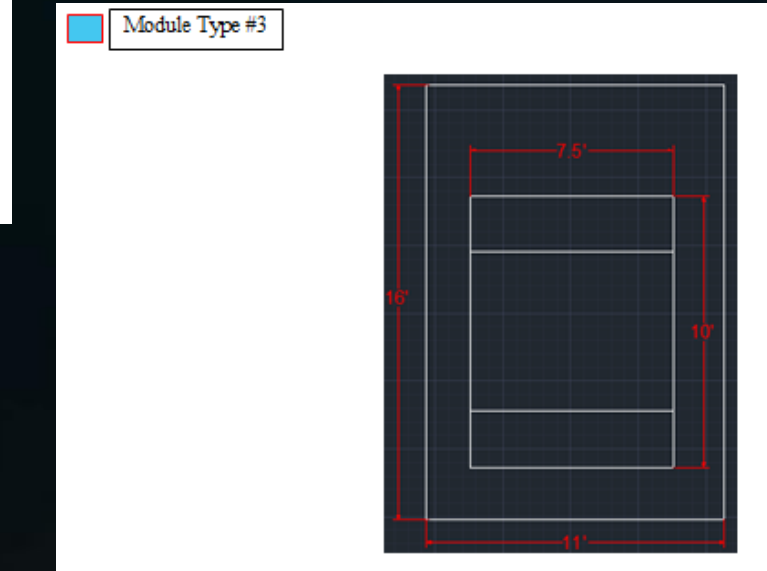
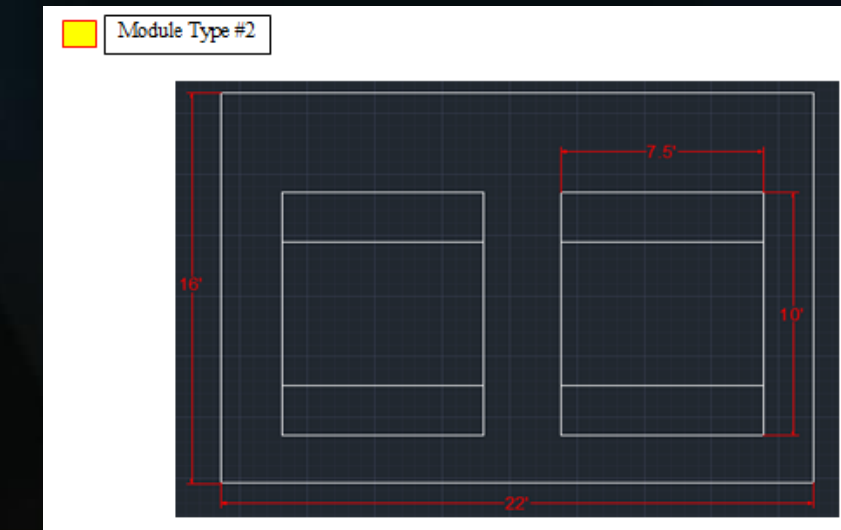
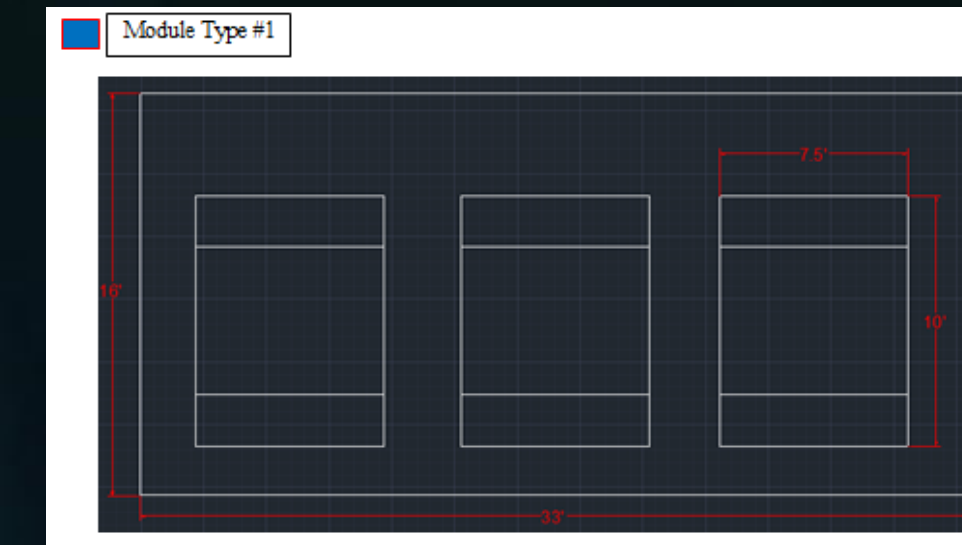
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Module Breakdown



| Panel Module Take-Off | |
|-----------------------|------------------|
| Description | Amount |
| Module Type #1 | 28 |
| Module Type #2 | 21 |
| Module Type #3 | 3 |
| Total | 52 Panels |



Module Types

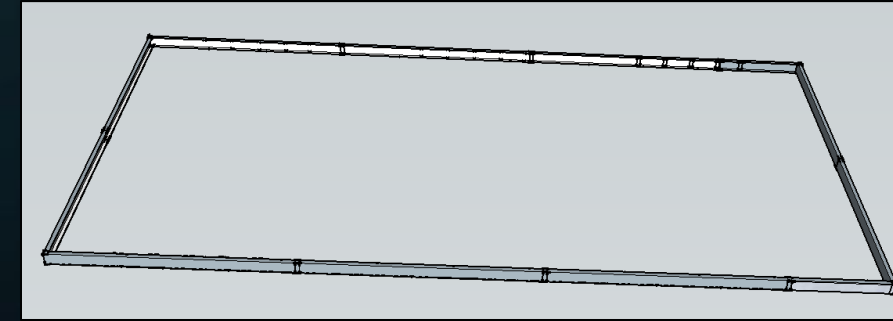
Detailed Sequencing | Building the Panel

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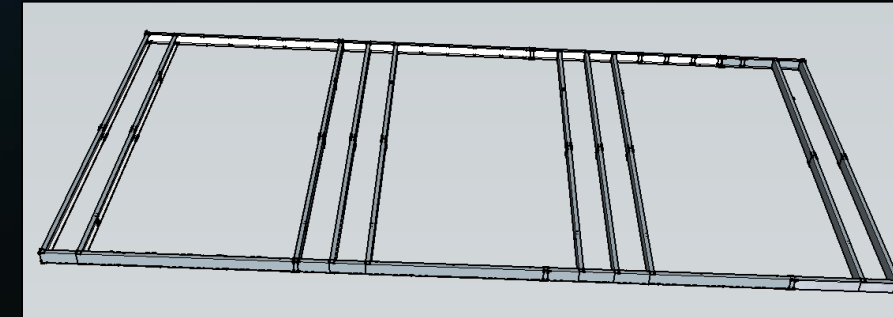


Building the Panel

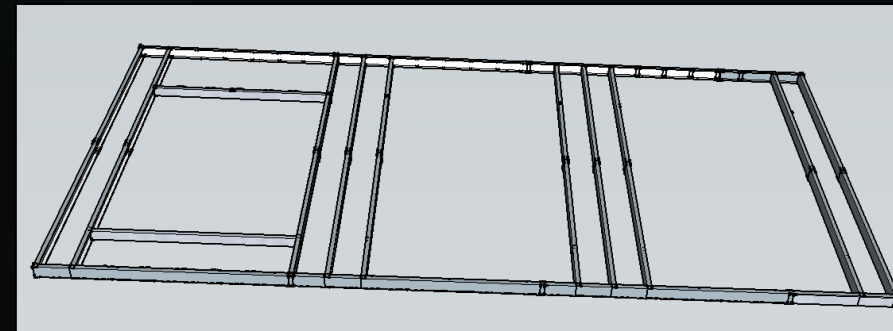
Step 1: Build Outer Framing



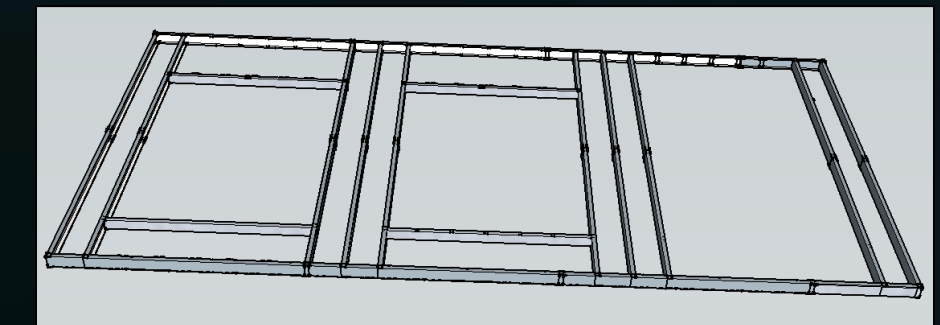
Step 2: Frame Full Length Studs



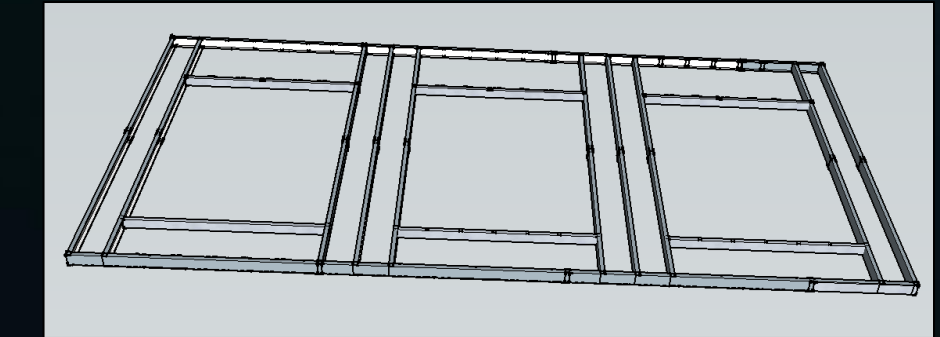
Step 3: Frame Window Opening 1



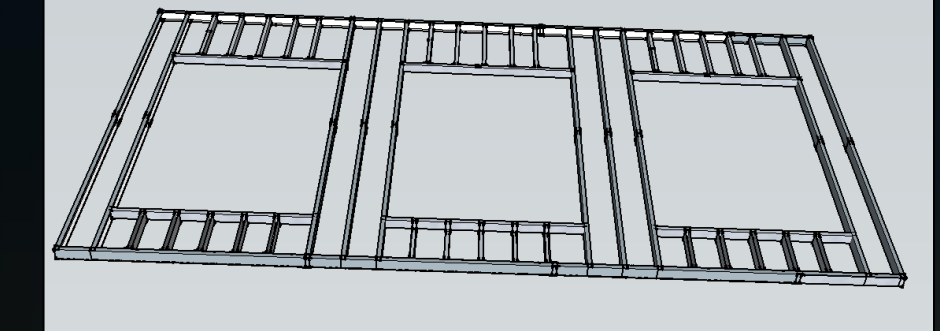
Step 4: Frame Window Opening 2



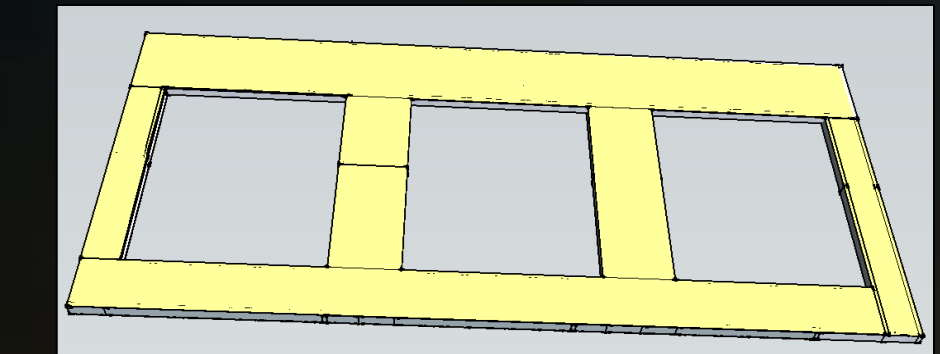
Step 5: Frame Window Opening 3



Step 6: Install Window Supports



Step 7: Sheath Panel

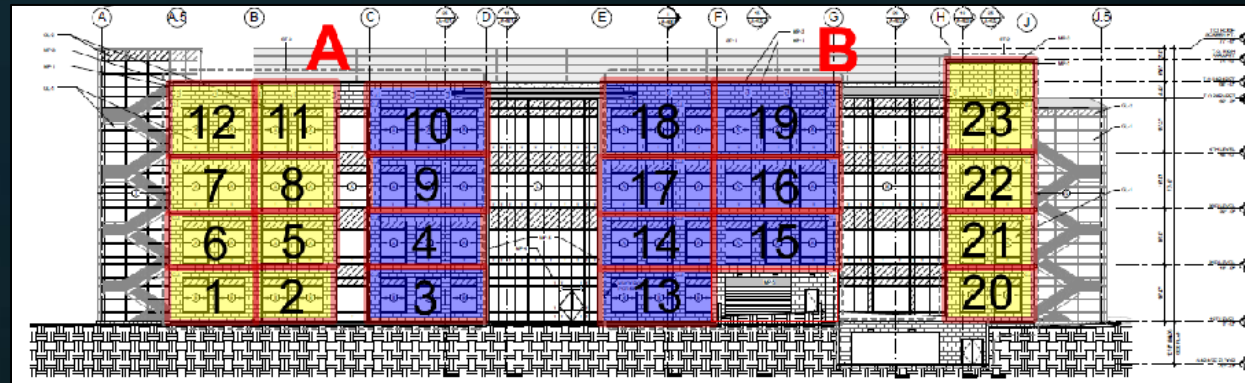


Detailed Sequencing | Erection Sequence

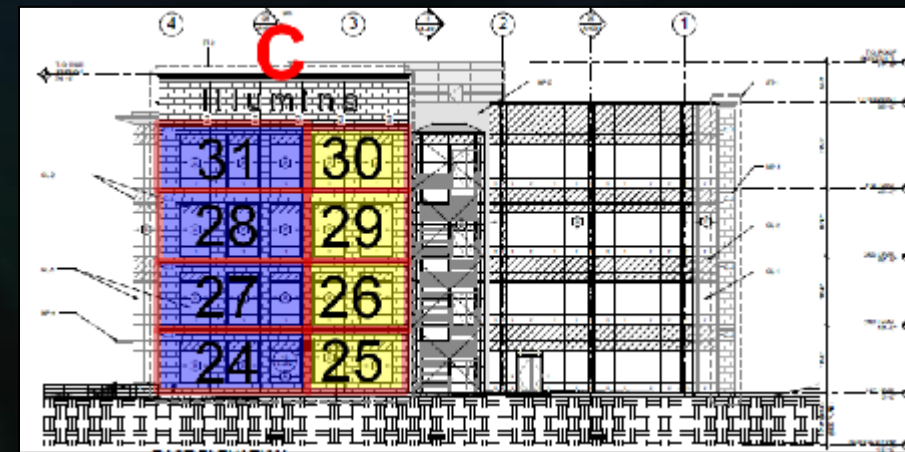
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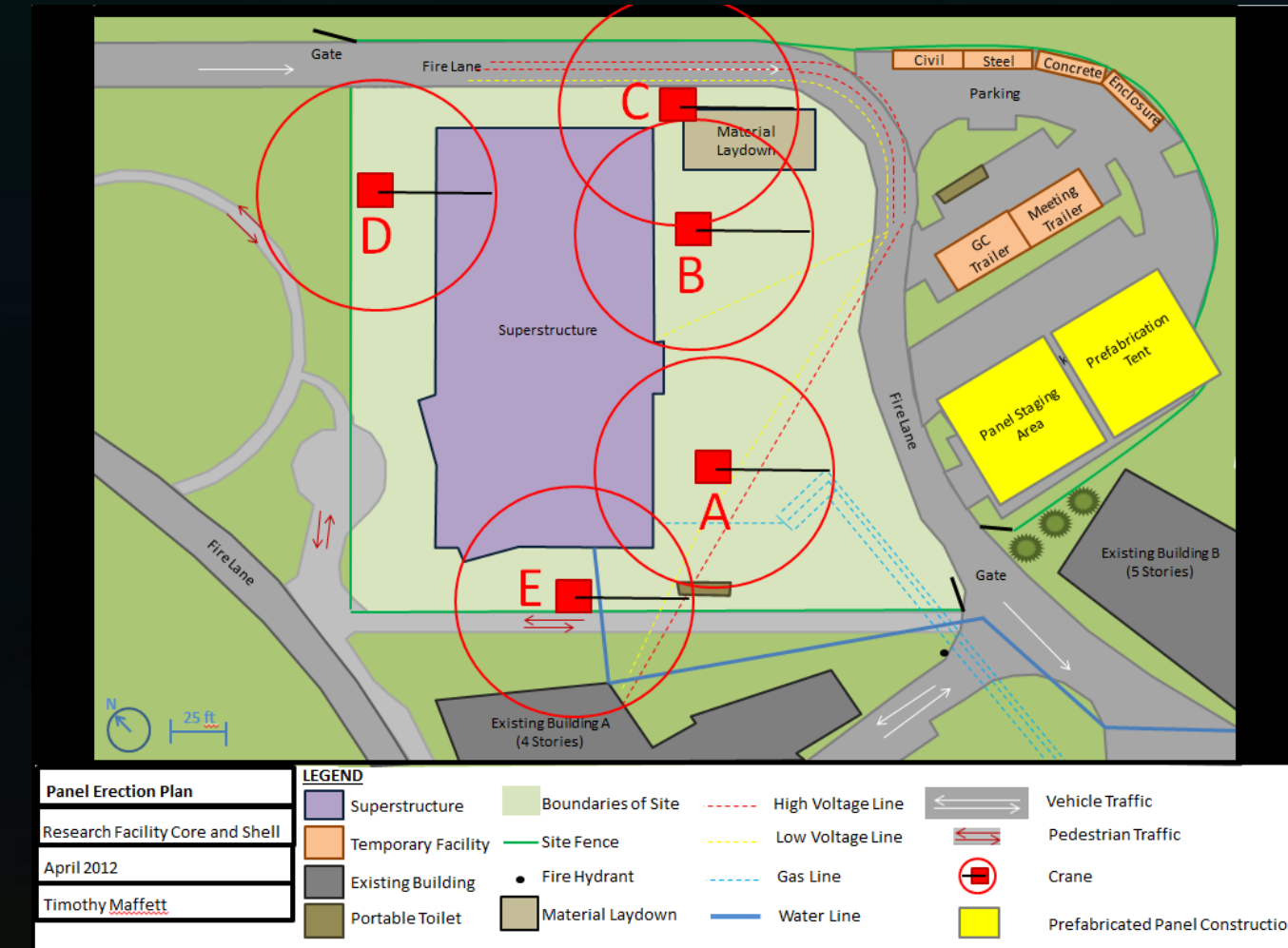
Erection Sequence



South Façade Phase A and B



East Façade Phase C



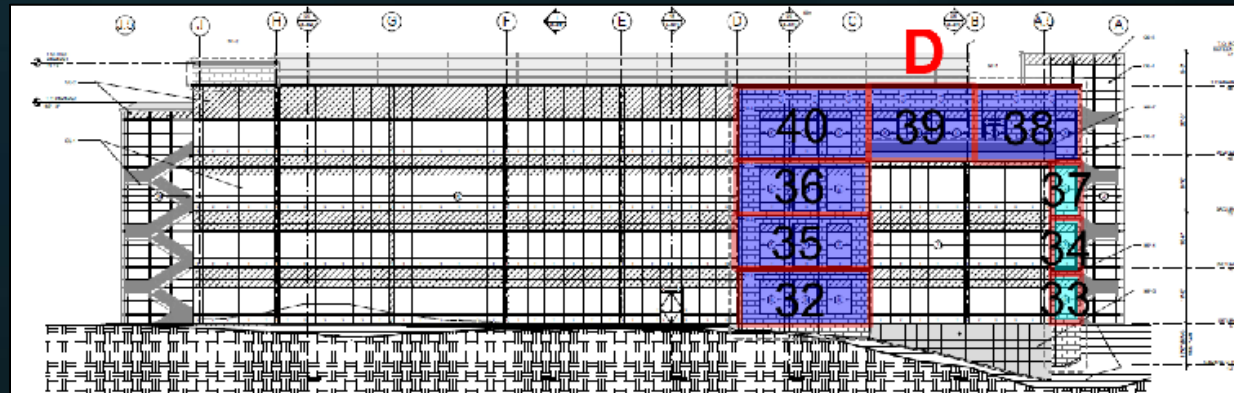
Sequencing

Detailed Sequencing | Erection Sequence

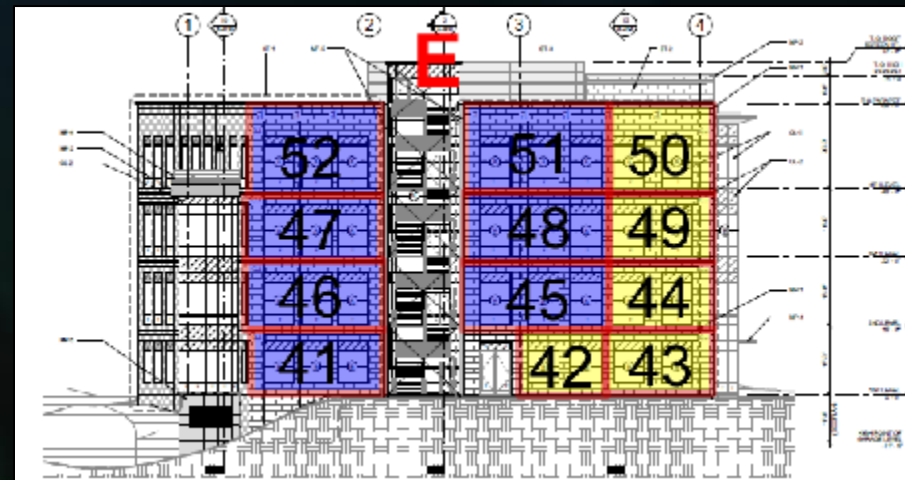
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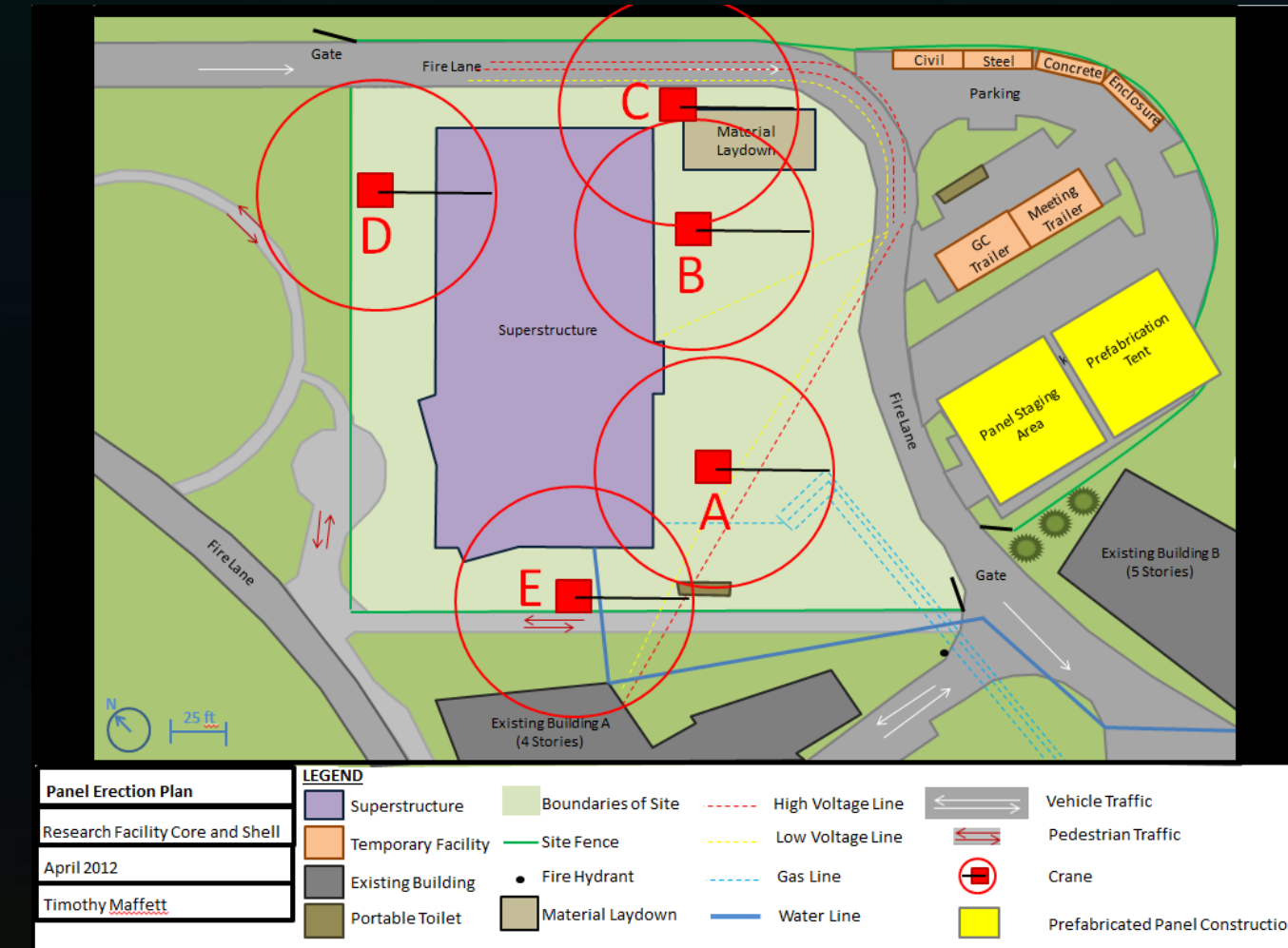
Erection Sequence



North Façade Phase D



West Façade Phase E



Sequencing

Detailed Sequencing | Benefits and Outcomes

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- | **Detailed Sequencing**
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Benefits and Outcomes

- Thorough planning
- Accurate material, schedule, and cost estimate
- Provides training and management tool
- Increased efficiency
- Increased safety
- Protection against crane sitting on site stagnantly

Sizing of Rigging Beam | Overview

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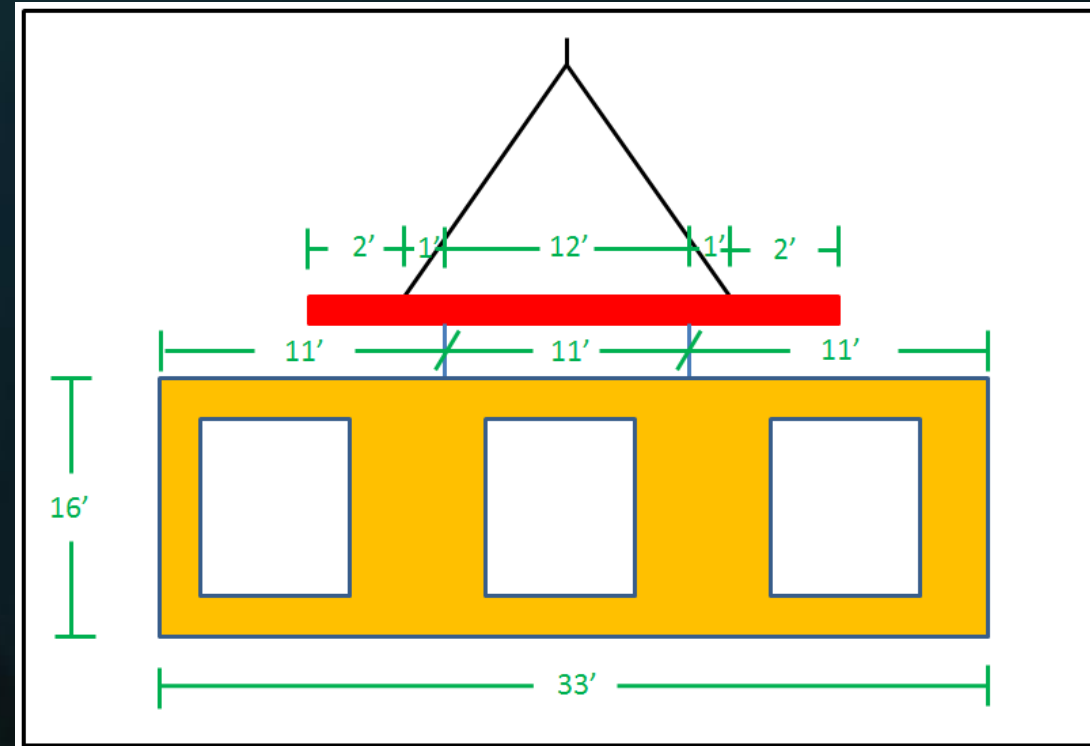
Sizing of Rigging Beam

Sizing of Rigging Beam | Outcome

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Outcome of Structural Breadth



| Results of Structural Calculations on Steel Beam in Rigging | |
|-------------------------------------------------------------|--------------|
| Description | Value |
| Dead Weight of Panel | 1580 lb. |
| Maximum Shear | .790 kip |
| Maximum Moment | .790 kip-ft. |
| Rigging Beam Necessary for RFCS | W 8x10 |



Rigging Beam at Hospital in Temecula, CA

Solar Panel Installation | Overview

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Solar Panel Installation at Roof Level

Solar Panel Installation | Problem Identification

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Requests of the Owner

- Achieve LEED Gold Certification
- Develop solution without simply point chasing
- Improve sustainability
- Take advantage of Southern California location

Solar Panel Installation | Problem Identification

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Proposed Solution?

Investigate implementation of solar panels on roof.

Solar Panel Installation | Background Information

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Background Information

- Roof made of EPDM membrane, rigid insulation, concrete on metal deck
- 30,250 SF total roof space (125' x 242')
- 9,900 SF centrally located mechanical space (50' x 198')
- Mechanical space surrounded by 13 ½' screen wall
- Parapet walls 4'

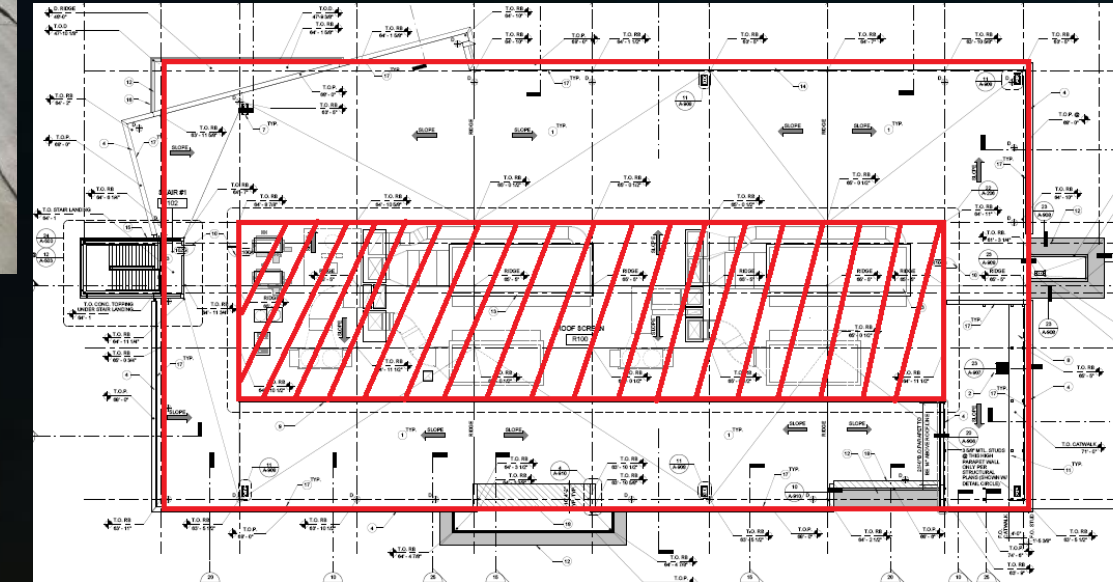


Photo of Rooftop and Plan View of Rooftop

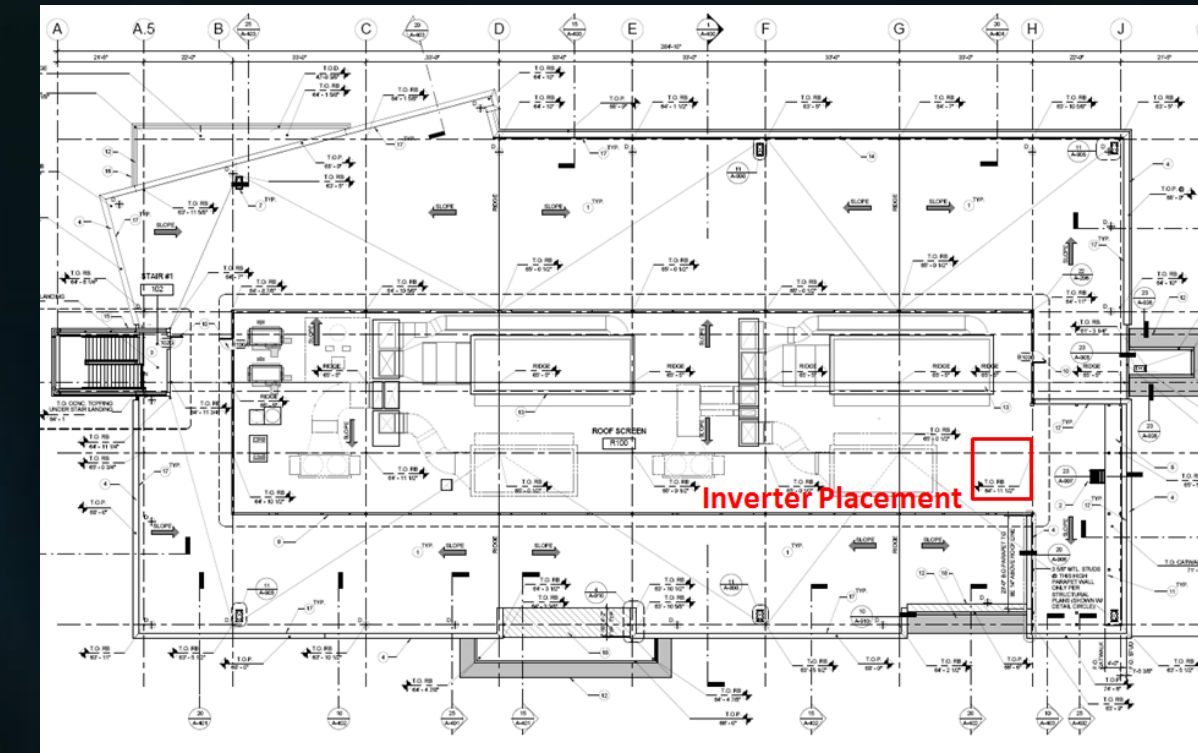
Solar Panel Installation | Design Decisions

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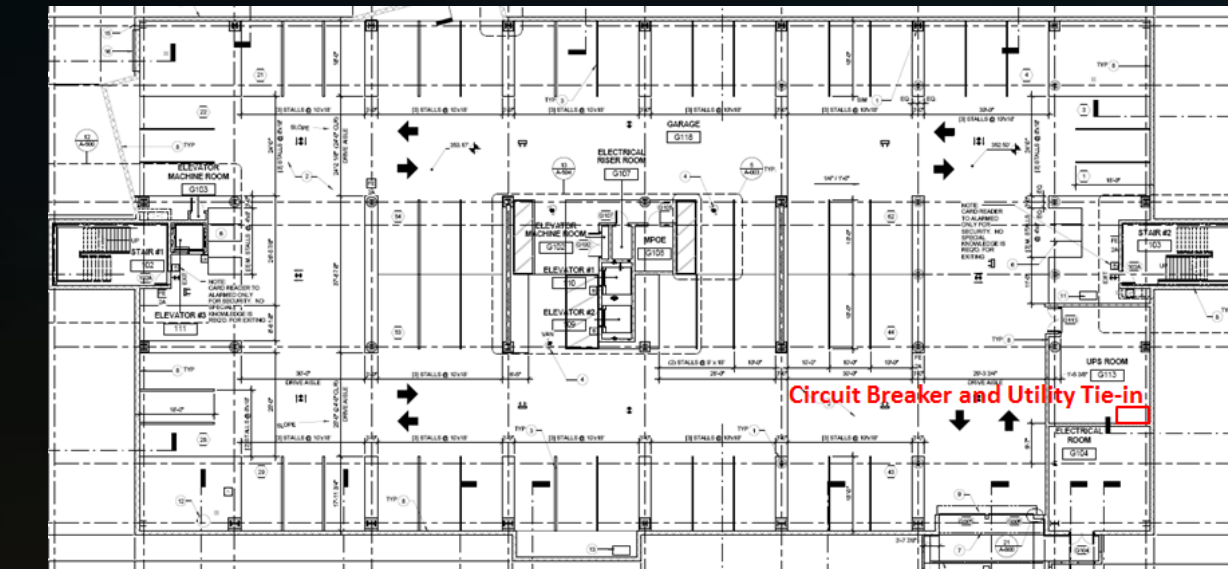
Design Decisions

- Grid Direct System (DC to AC Power) connected to utility
- Inverter placed at east side of the rooftop mechanical zone
- Circuit breakers and utility tie-in placed in basement main electrical room



Rooftop

Basement



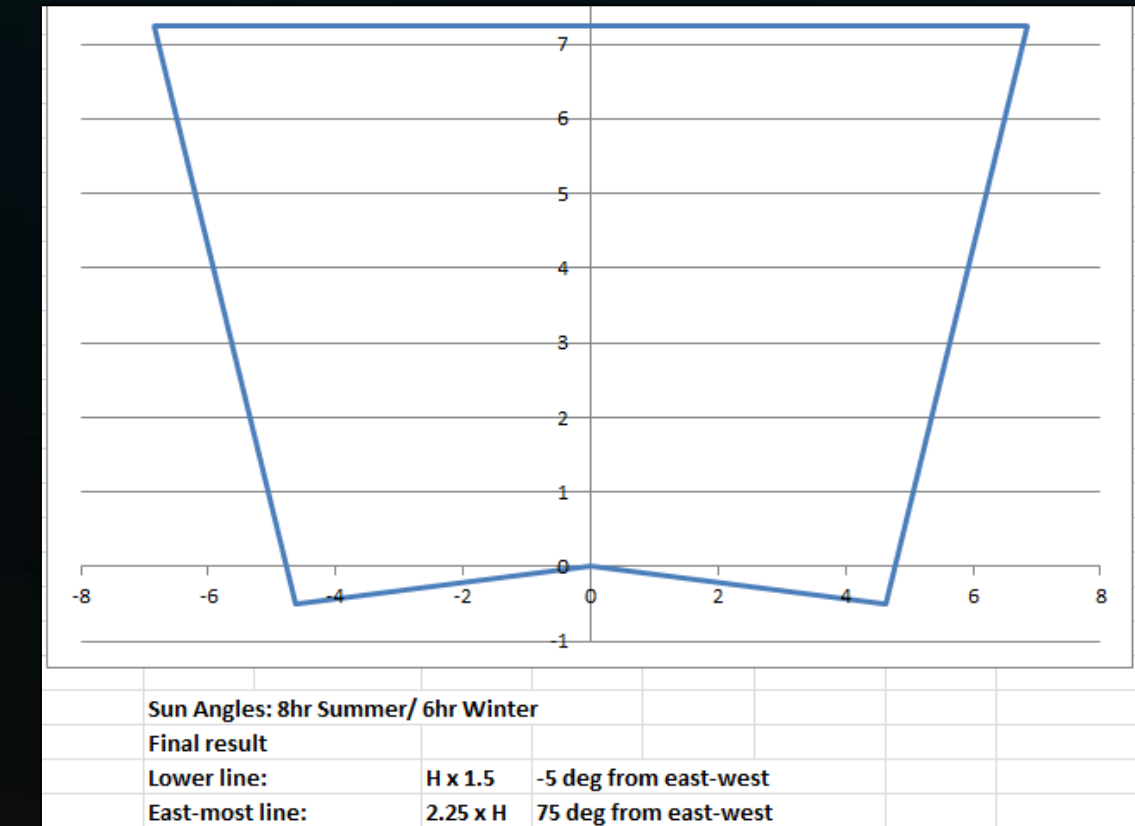
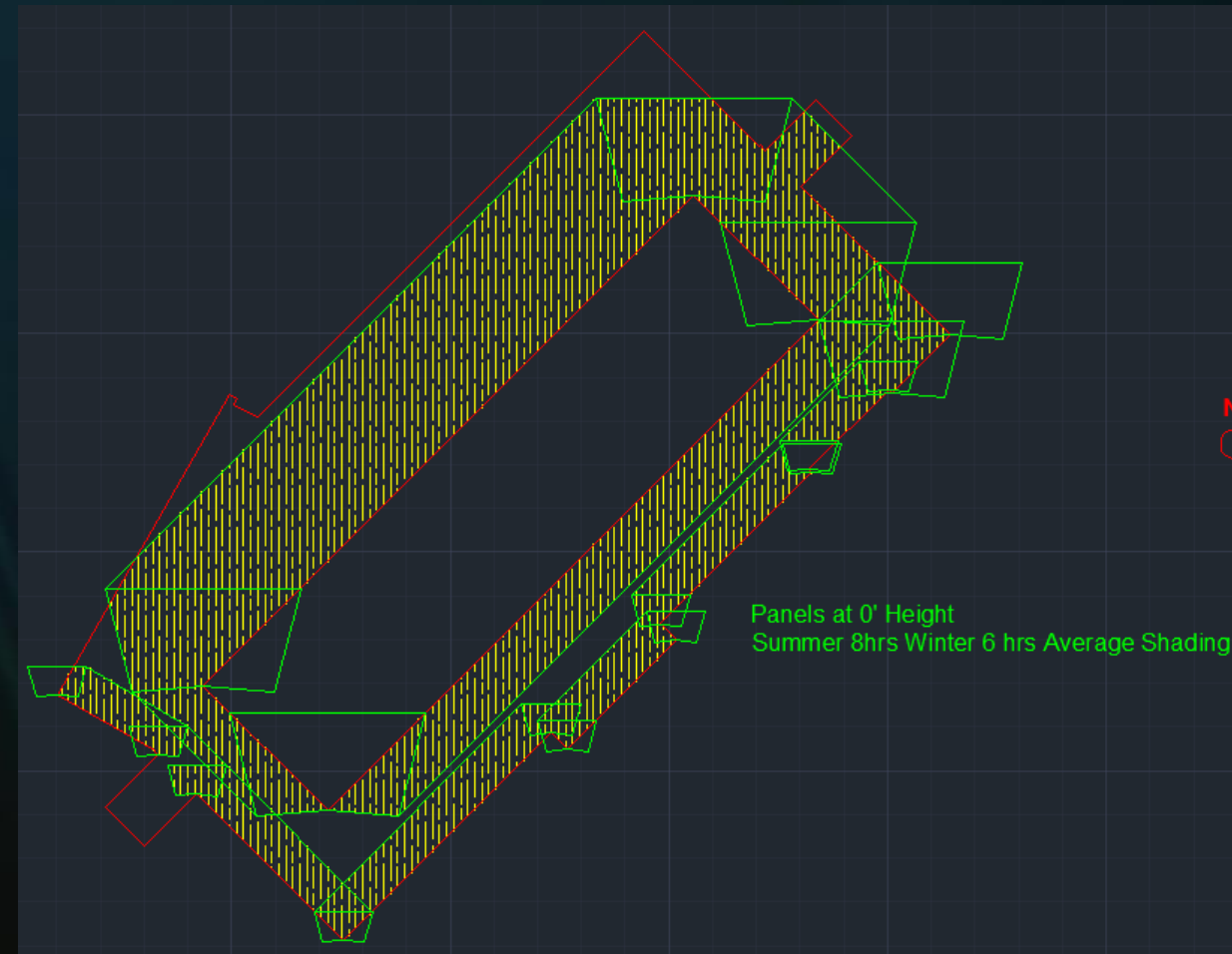
Circuit Breaker and Utility Tie-in

Solar Panel Installation | Shading Analysis

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Shading Analysis

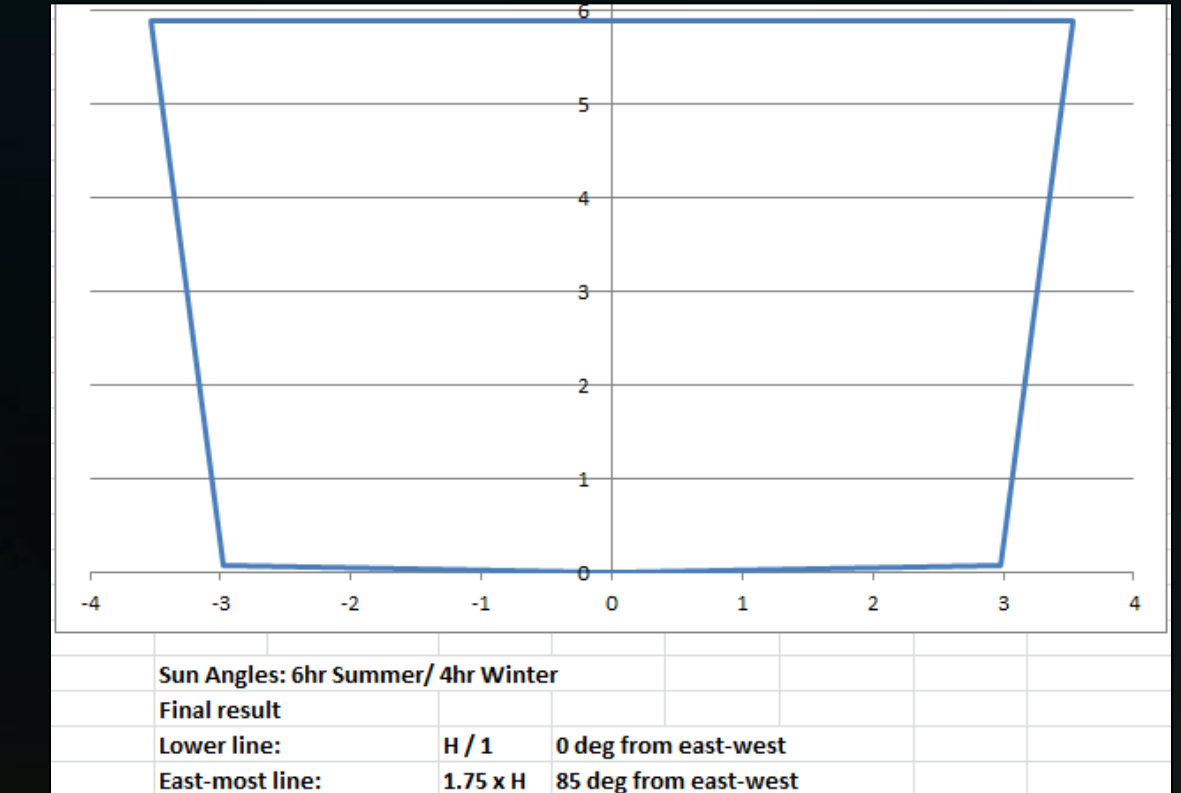
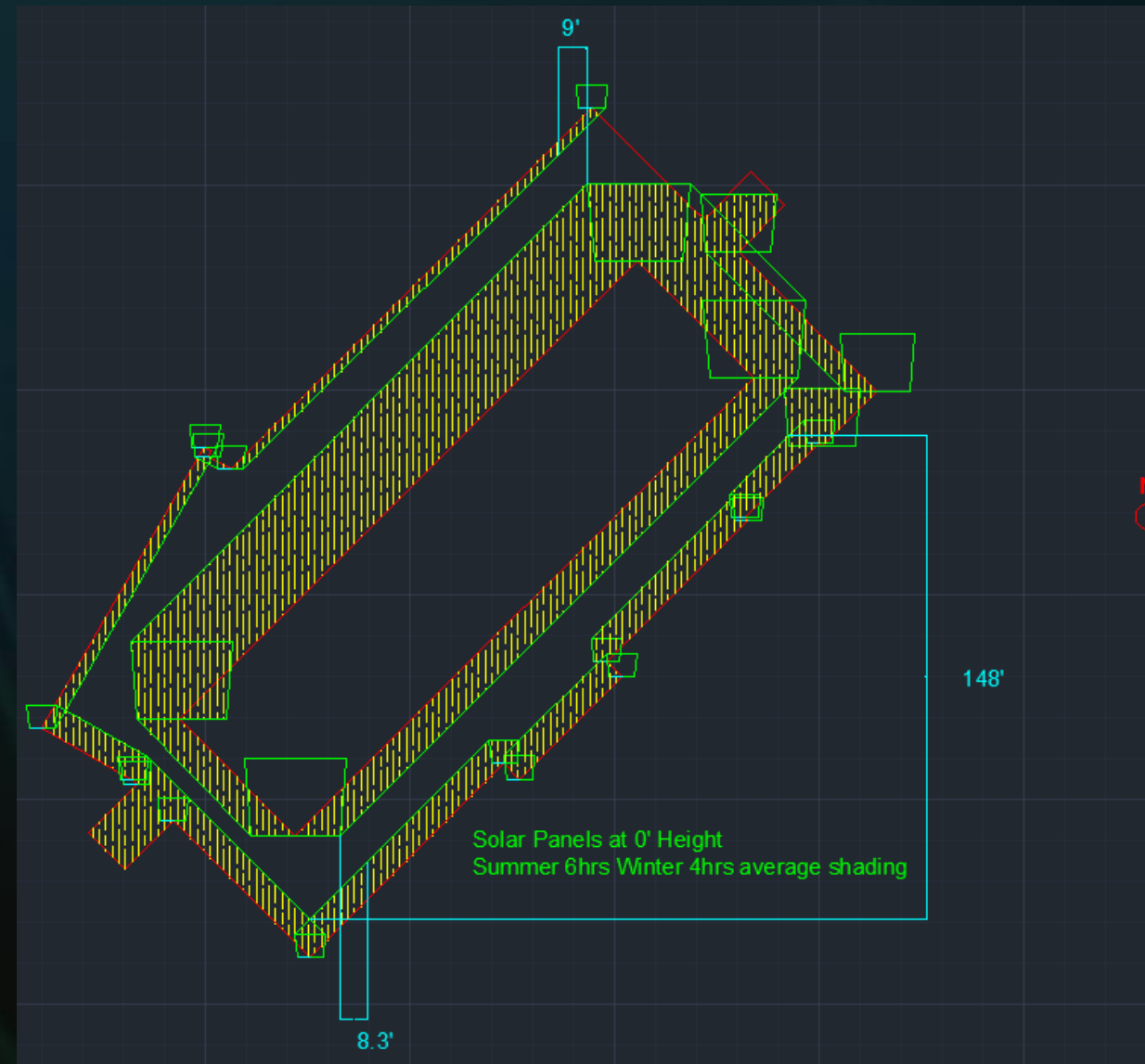


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Shading Analysis



Solar Panel Installation | System Design

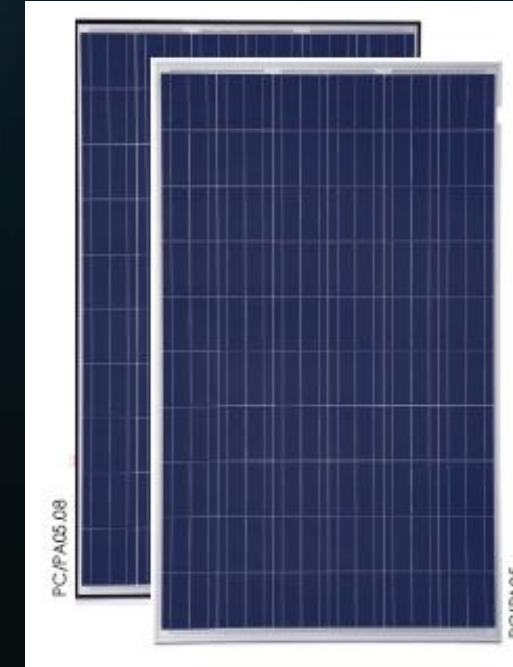
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Module, Inverter, and Racking

Module: Trinamount TSM-250PA05

- **Criteria** | Best efficiency for cost
- **Efficiency** | 15.3%
- **Maximum Power** | 250 W
- **Size** | 3 ¼' x 5 ½'



Inverter: Sunny Tower by SMA

- **Criteria** | Large, single inverter
- **Efficiency** | 96%
- **Maximum Load** | 42 kWdc power



Racking: Trinamount III

- **Type** | Ballasted racking system
- **Tilt** | 11 degrees



Solar Panel Installation | System Design

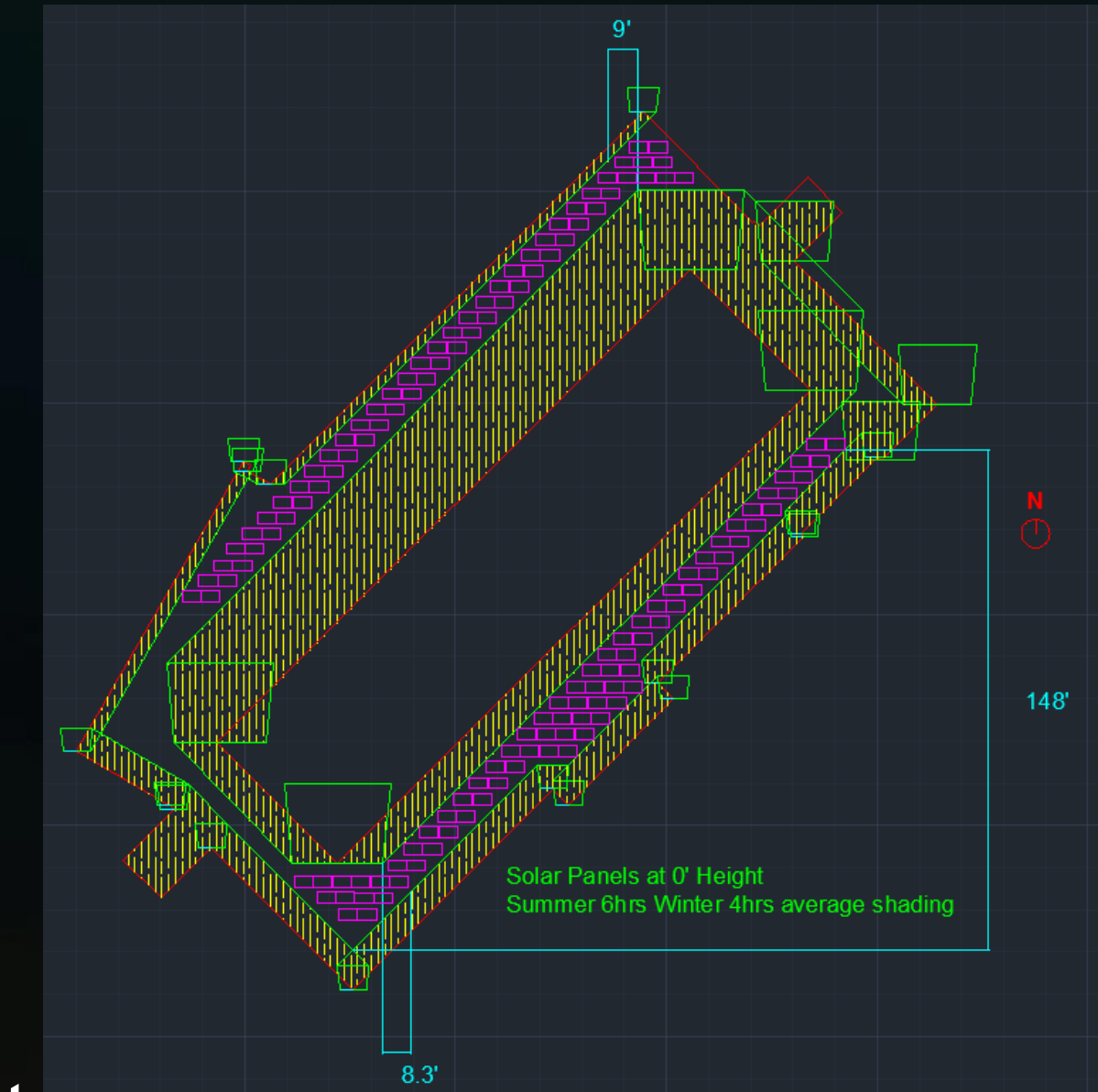
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Array Placement

- **Module Amount** | 143 modules
- **System Max Output** | 36 kWdc

Array Layout



Solar Panel Installation | System Design

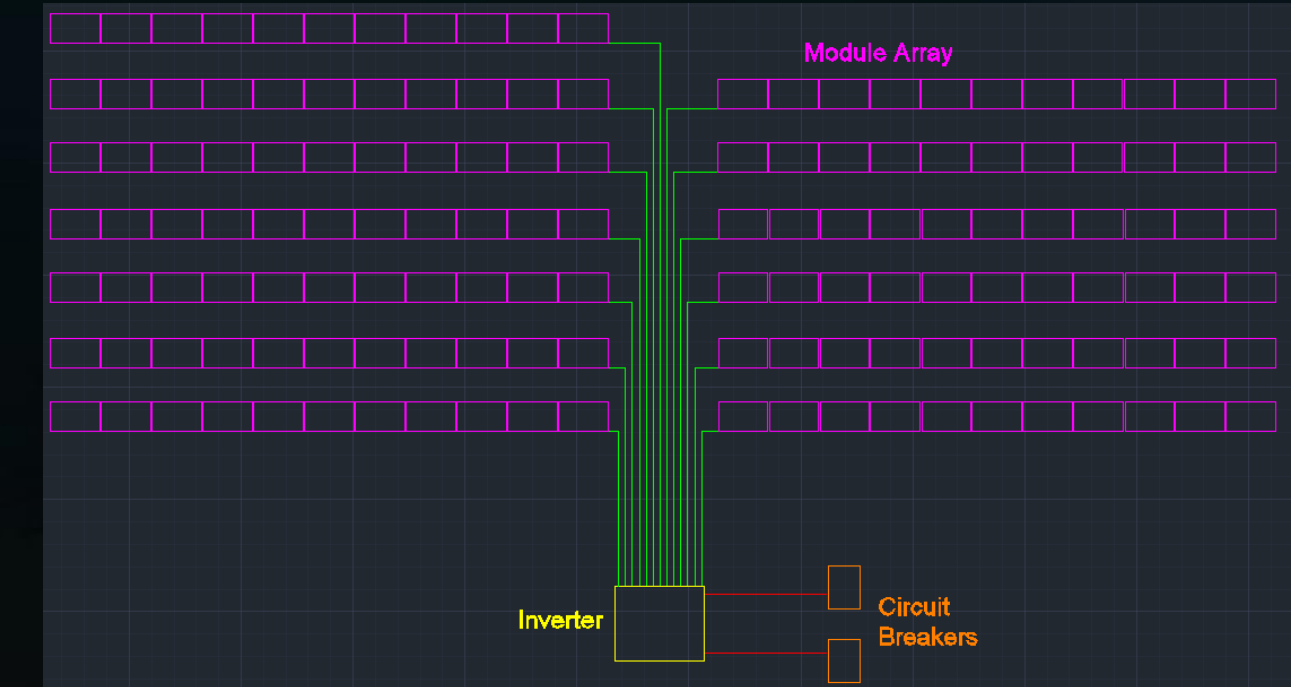
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Electrical Sizing and Design

- 13 Strings, 11 Modules per string

| Conductor Sizing Summary | | |
|-----------------------------------------------|--------------------------------------------|--------------------------------------|
| Connection | Description | Legend |
| Panels String to Inverter (DC Side) | | |
| Conductor Sizing (One Way) | (5) #12 AWG's per PV Output Circuit String | — |
| Maximum Run Length | 187 ft. one way for 2% Voltage Drop | |
| Inverter to Circuit Breakers (AC Side) | | |
| Conductor Sizing (One Way) | (3) #4 AWG conductors per 80-amp breaker | — |
| Maximum Run Length | 85 ft. one way for 1.5% Voltage Drop | |
| Circuit Breaker Sizing | (2) 80-amp circuit breakers | |



Riser Diagram of PV System

Solar Panel Installation | Construction Analysis

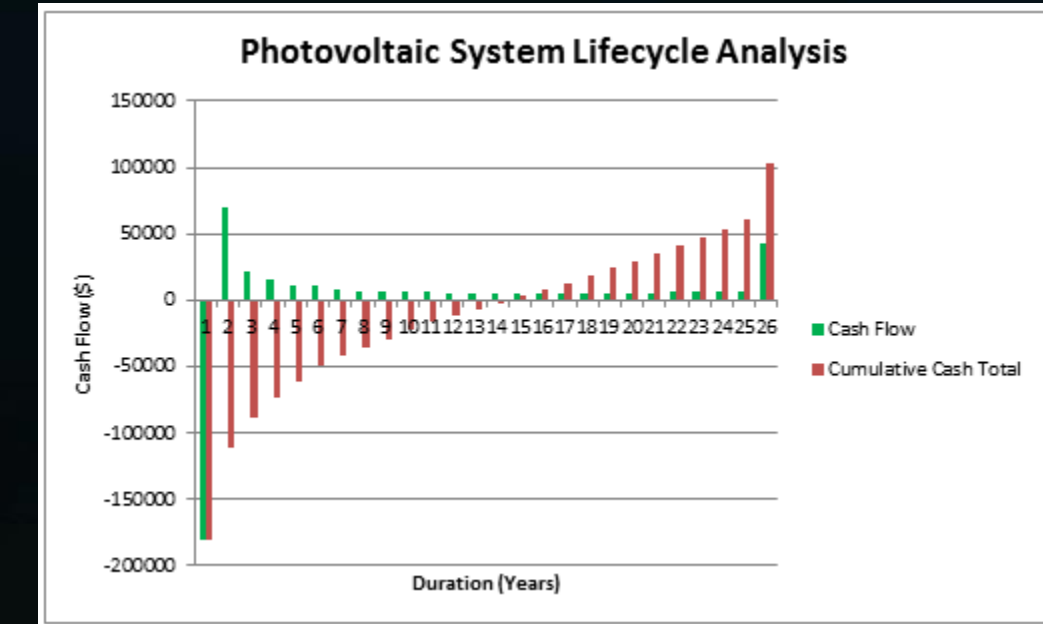
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Cost Analysis

- **System Direct Cost** | \$180,534
- **System Production** | 47,000 kWh / year
- **System Production (\$)** | \$6,110 / year
- **Incentives** | 30% Fed. Tax Credit, \$.05 / kWh State Credit

14 year Payback Period



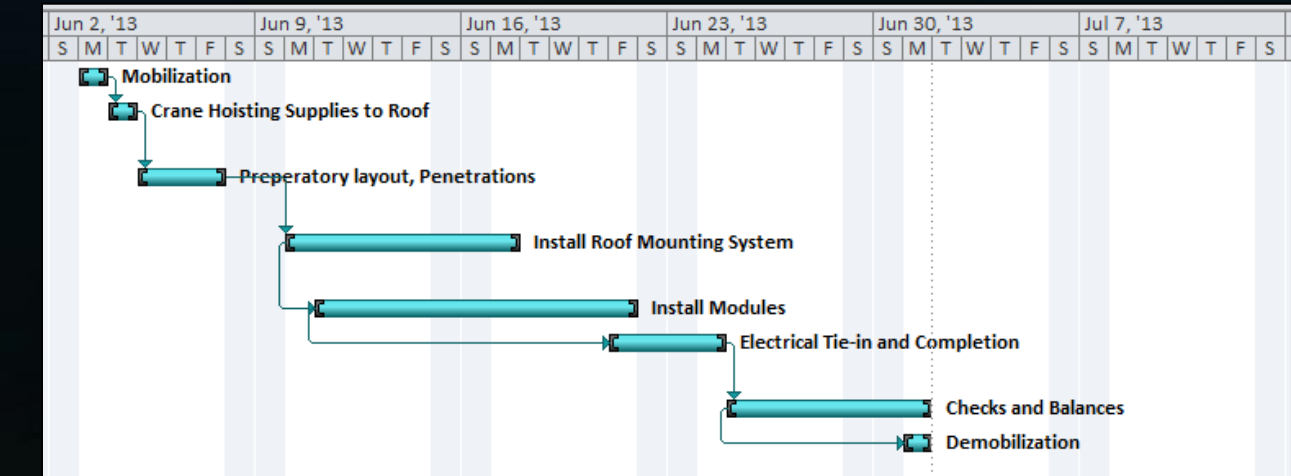
Solar Panel Installation | Construction Analysis

- | Introduction
- | Prefabricated Exterior Wall Panels
- | Detailed Sequencing
- | Sizing of Rigging Beam
- | **Solar Panel Installation at Roof Level**
- | Mobile Technology Integration- Tablet Computers
- | Recommendations
- | Concluding Remarks



Schedule Analysis

- **Duration** | 4 weeks
- **Construction Concerns** | Roof membrane, organization, system balance



Schedule for Photovoltaic System Installation

Solar Panel Installation | Recommendation

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Do not install solar panels at roof level.

Mobile Technology Integration | Overview

- | Introduction
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- | **Mobile Technology Integration- Tablet Computers**
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Mobile Technology Integration -Tablet Computers-

Mobile Technology Integration | Problem Identification

- | Introduction
- | Prefabricated Exterior Wall Panels
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Problem

- Engineers and site management following inefficient processes
- Data entry, field coordination, communication, organization- inefficient
- Available technology underutilized
- General Conditions competitive in this market

Mobile Technology Integration | Case Study #1

- | Introduction
- | Prefabricated Exterior Wall Panels
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ASCE Journal: Making the Case for Mobile IT in Construction

- Industry slow to change and adopt new information technologies
- Barriers include: low profit margin for GC, hesitation towards benefits, lack of awareness, lack of success stories
- Analyzed 11 construction projects

Results

- Reports generate faster and easier
- Increased customer service
- Ability to identify trends
- Reduced task turn around time
- Increased quality and efficiency

Mobile Technology Integration | Case Study #2

- | Introduction
- | Prefabricated Exterior Wall Panels
- | Detailed Sequencing
- | Sizing of Rigging Beam
- | Solar Panel Installation at Roof Level
- | **Mobile Technology Integration- Tablet Computers**
- | Recommendations
- | Concluding Remarks



DFW Airport- Terminal Renovation and Improvement Project

- **Cost** | \$900M
- **Duration** | 7 years
- **Size** | 2,000,000 SF



Results

| | |
|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Main Implementation | <ul style="list-style-type: none">• Updated Electronic Drawings• Coordination in the Field• Project Closeout and Archiving |
| Results | <ul style="list-style-type: none">• Improved Efficiency• Engineers Save 1 hr/day from Tablet Integration• Reprographics Cost Decrease of 71% or \$5.1M |
| Lessons Learned | <ul style="list-style-type: none">• Technology Must Have an Implementation Plan• Must Have Sole "Gatekeeper" of E-Documents• Architect Must be On-board |

Mobile Technology Integration | Case Study #3

- | Introduction
- | Prefabricated Exterior Wall Panels
- | Detailed Sequencing
- | Sizing of Rigging Beam
- | Solar Panel Installation at Roof Level
- | **Mobile Technology Integration- Tablet Computers**
- | Recommendations
- | Concluding Remarks



Pharmaceutical Processing Plant (Los Angeles, CA)

- **Cost** | \$150M
- **Duration** | 2 ½ years
- **Size** | 90,000 SF



Results

| | |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Main Implementation | <ul style="list-style-type: none">• Updated Electronic Drawings• Coordination in the Field and RFI's• Safety Evaluations |
| Results | <ul style="list-style-type: none">• Engineers Save 1.1 hr/day from Tablet Use• Superintendents Save 1.5 hr/day from Tablet Use• Reprographics Cost Decrease \$4000/Addendum |
| Lessons Learned | <ul style="list-style-type: none">• Tablet Becomes Integral. Must Keep With You• Must Have Sole "Gatekeeper" of E-Documents• Roadblocks with Technology (3D Model, Opening File Types) |

Mobile Technology Integration | Means and Methods

- | Introduction
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Original Practices

- **On Site Management** | 4 people
- **Technology** | Laptop Computers in Jobsite Office
- **Drawings** | Electronic and Paper (Mainly Paper)
- **Storage** | Cloud Server

Mobile Technology Integration | Application to RFCS

- | Introduction
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Proposed Tablet Integration Plan

- **On Site Management** | 4 people
- **Technology** | Table Computers & Laptop Computers in Jobsite Office
- **Drawings** | Electronic and Paper (Mainly Electronic)
- **Storage** | Cloud Server

| | | |
|---------------------------------|---------------------------|----------------------------|
| Accessing Drawings in the Field | Coordination in the Field | Documenting Field Issues |
| Email and Correspondence | Safety Evaluations | Daily Forms and Checklists |

Proposed Uses for Tablet Computers at RFCS

Mobile Technology Integration | Analysis

- | Introduction
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Costs of Tablet Computer Implementation

- **Direct Costs** | -(\$5,264)
- **Weekly Human Resource Savings** | \$1,688/ week
- **Overall Project Savings** | \$116,272
- **Benefits** | Efficiency, Quality, Customer Service

| Direct Costs of Tablet Computer Implementation | | | |
|------------------------------------------------|----------|------------|-------------|
| Description | Quantity | Cost/Unit | Cost |
| Tablet Computers | 4 | \$500/iPad | -(\$2,000) |
| Contingency for Software & Add-ons | 4 | \$300/iPad | -(\$1,200) |
| Training Project Manager | 6 hours | - | -(\$624) |
| Training Superintendent | 6 hours | - | -(\$624) |
| Training Project Engineer #1 | 6 hours | - | -(\$408) |
| Training Project Engineer #2 | 6 hours | - | -(\$408) |
| Total | - | - | -(\$5,264) |

| Human Resource Costs of Tablet Integration (Weekly) | | | |
|-----------------------------------------------------|----------|-----------|-------------|
| Description | Quantity | Cost/Unit | Cost |
| Costs | | | |
| IT Champion Time | 2 hours | \$68/hour | -(\$136) |
| Savings | | | |
| Project Manager Time | 4 | - | \$416 |
| Superintendent Time | 7 | - | \$728 |
| Project Engineer #1 Time | 5 | - | \$340 |
| Project Engineer #2 Time | 5 | - | \$340 |
| Total | - | - | \$1688/week |

Costs of Tablet Computer Integration

Mobile Technology Integration | Recommendations

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Implement tablet computers at RFCS.

Recommendations | Overview

- | Introduction
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- | Mobile Technology Integration- Tablet Computers
- | **Recommendations**
- | Concluding Remarks



Final Recommendations

Recommendations | Overall Thoughts

- | Introduction
- | Prefabricated Exterior Wall Panels
- | Detailed Sequencing
- | Sizing of Rigging Beam
- | Solar Panel Installation at Roof Level
- | Mobile Technology Integration- Tablet Computers
- | **Recommendations**
- | Concluding Remarks



Final Recommendations

1. Implement Partially Prefabricated Wall Panel Strategy as opposed to original stick-built construction.
2. Do not install solar panels at roof level.
3. Implement tablet computers at RFCS.

Concluding Remarks | Overview

- | Introduction
- | Prefabricated Exterior Wall Panels
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- | Recommendations
- | **Concluding Remarks**



Concluding Remarks

Concluding Remarks | Reflection

- | Introduction
- | Prefabricated Exterior Wall Panels
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- | **Concluding Remarks**



Reflection

Design Goal

Increase value through innovative and efficient construction.

Outcome

Schedule savings through innovative panel prefabrication.

Alternative energy system analyzed

Comprehensive and beneficial study of mobile technology integration

Successful Study

Concluding Remarks | Acknowledgements

- | Introduction
- | Prefabricated Exterior Wall Panels
- | Detailed Sequencing
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- | Mobile Technology Integration- Tablet Computers
- | Recommendations
- | **Concluding Remarks**



Thank you!

DPR Construction

AE Faculty

PSU Department of Sustainability

Audience

Concluding Remarks | Appendix

- | Introduction
- | Prefabricated Exterior Wall Panels
- | Detailed Sequencing
- | Sizing of Rigging Beam
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C-CAPP Estimate

| Quote on C-CAPP Prefabricated Panel System | | | |
|--------------------------------------------|--------------------|-------------------------------|----------------|
| Cost Breakdown (\$) | | Schedule (Duration) | |
| Base Budget | \$907,500 | Preliminary | Variable |
| Staining Panels | \$99,500 | | |
| Preweld Connections to Steel Structure | \$75,000 | Layout and Preweld | 3 weeks |
| Caulking | \$33,000 | Hanging Panels | 1 week |
| ----- | ----- | Final Aligning and Welding | 3 weeks |
| Total Cost of System | \$1,115,000 | Total Duration on site | 7 weeks |

Partial Panel Prefabrication Estimate

| Framing and Sheathing | | | | | |
|-----------------------------------------------------|-------|-------|----|-------------|-------------------|
| Engineering | 1 | LS | \$ | 19,000.00 | \$ 19,000.00 |
| Exterior Framing Mock-up | 1 | LS | \$ | 15,000.00 | \$ 15,000.00 |
| Crane Rental | 1 | LS | \$ | 35,000.00 | \$ 35,000.00 |
| Onsite Panel Shop | 1 | LS | \$ | 5,000.00 | \$ 5,000.00 |
| Build Panels | 26943 | SF | \$ | 6.95 | \$ 187,253.85 |
| Install Panels | 26943 | SF | \$ | 1.35 | \$ 36,373.05 |
| Complete screwoff of panels | 26943 | SF | \$ | 2.15 | \$ 57,927.45 |
| Patch in Densglass sheathing form pick points | 26943 | SF | \$ | 0.40 | \$ 10,777.20 |
| Sheath backside of parapets | 1300 | SF | \$ | 2.15 | \$ 2,795.00 |
| Deduct of scaffold time usage (-3 weeks rent) | 1 | LS | \$ | (7,000.00) | \$ (7,000.00) |
| Schedule savings general conditions cost (-3 weeks) | 3 | weeks | \$ | (10,700.00) | \$ (32,100.00) |
| Subtotal | | | | | \$ 330,027 |

Concluding Remarks | Appendix

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Solar Panel System Estimate

| Direct Costs for Solar Panel Installation | | | | |
|--------------------------------------------------|--------------|----------|------------------|--------------------------|
| Description | Cost/Unit | Quantity | Total Cost | Reference |
| Modules | \$190/Module | 144 | \$27,360 | Sunwize Quote |
| Ballast Racking System | \$0.30/Watt | 35730 | \$10,720 | Rocky Mountain Institute |
| Inverter | \$19553/Unit | 1 | \$19,553 | Affordable Solar Quote |
| DC Wiring #12 AWG | \$0.74/LF | 12400 | \$9,176 | RSMEANS |
| DC Conduit 3/4" | \$10.50/LF | 2480 | \$26,040 | RSMEANS |
| AC Wiring #4 AWG | \$2.29/LF | 250 | \$573 | RSMEANS |
| AC Conduit 1" | \$12.45/LF | 250 | \$3,113 | RSMEANS |
| Circuit Breakers 80 AMP | \$1025/Ea | 2 | \$2,050 | RSMEANS |
| Crane Rental (Truck Crane 4,000 lb. Capacity) | \$4200/day | 2 | \$8,400 | RSMEANS |
| Shipping | \$190/Pallet | 11 | \$2,090 | Sunwize Quote |
| Labor | \$3/Watt | 35730 | \$107,190 | Sunwize Rec. |
| Total | - | - | \$180,534 | |

RFCS Costs and Building Use

| Major Costs for Research Facility Core and Shell | | |
|--------------------------------------------------|---------------------|-----------------|
| | Construction Cost | Cost/SF |
| Actual Building Construction | \$16,031,402 | \$125.86 |
| Total Project | \$20,035,000 | \$157.29 |
| Mechanical System | \$1,574,261 | \$12.36 |
| Electrical System | \$1,014,666 | \$7.97 |
| Plumbing System | \$662,250 | \$5.20 |
| Fire Protection | \$298,462 | \$2.34 |
| Structural System | \$5,238,945 | \$41.13 |
| Exterior Skin | \$4,089,261 | \$32.10 |

| Building Use Description | | |
|----------------------------|-----------|---------------------------------------------------|
| Level | Size | Use |
| Underground Parking Garage | 31,197 SF | Parking; UPS, Electrical & Elevator Machine Rooms |
| First Floor | 31,850 SF | Lobby, Laboratory Space |
| Second Floor | 31,850 SF | Offices, Laboratory Rooms |
| Third Floor | 31,850 SF | Offices, Laboratory Rooms |
| Fourth Floor | 31,850 SF | Offices |
| Roof | 31,850 SF | Large Mechanical Equipment |

