



**Nico Pugilese**  
LIGHTING/ELECTRICAL



**Jeremy Heilman**  
CONSTRUCTION



**Penn State Ice Hockey Arena**  
The Pennsylvania State University



**Joshua Progar**  
STRUCTURAL



**James Rodgers**  
MECHANICAL



Final Thesis Presentation  
April 11<sup>th</sup>, 2012





PROJECT





Overview      Location      Team      Design

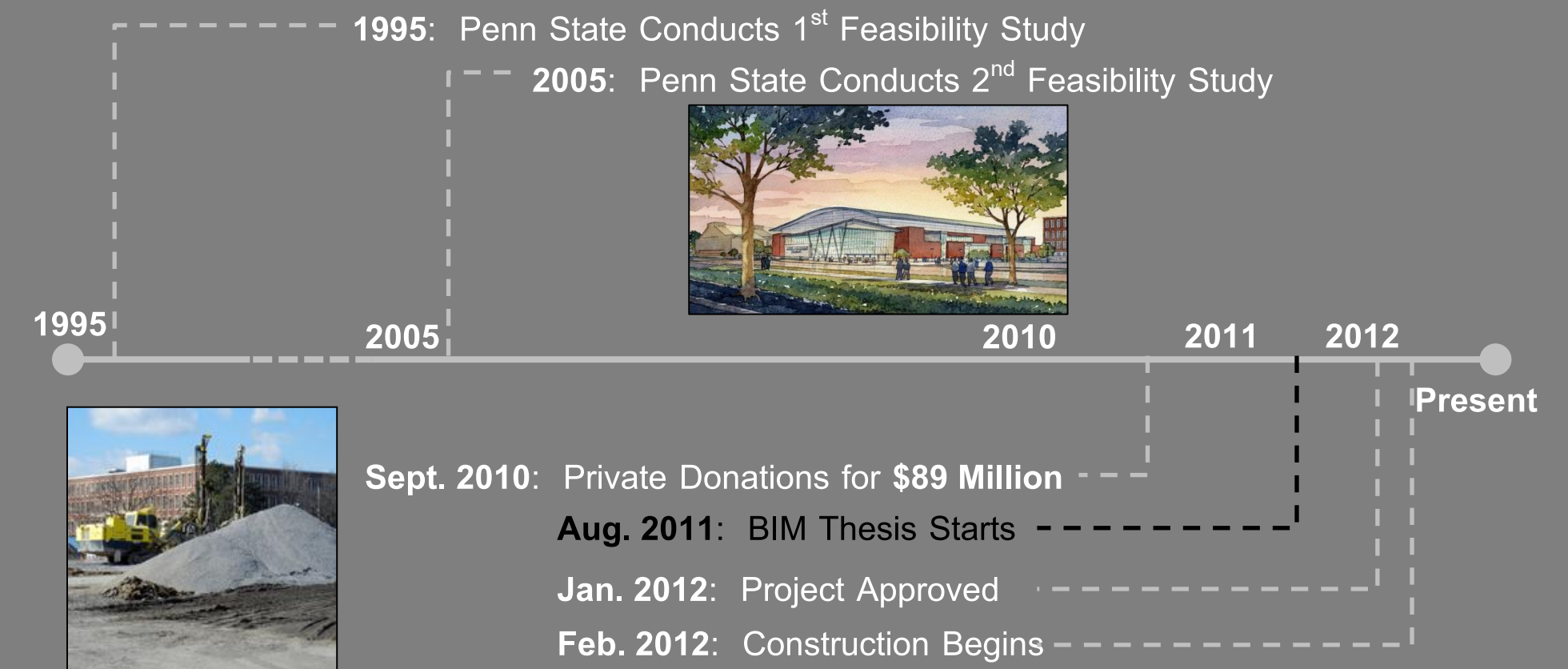


ACHA Division 1 Club Team  
 7-Time ACHA National Champions  
 30 ACHA National Tournament Appearances  
 All Time Record: 946-299-52 (.729%)

# Penn State Icers

Penn State Men's Ice Hockey Program

## Project Development History



**Owner:** The Pennsylvania State University

**Estimated Cost:** \$73,000,000.00

**Building Size:** 220,000 ft<sup>2</sup>

**Delivery Type:** Design-Bid-Build with CM at Risk



Highly Experienced Owner  
 Technologically Progressive Institution

- Demands:**
- Move to Division 1A Hockey
  - State-of-the-Art Hockey Arena (Men's and Women's Programs)





Overview

Location

Team

Design

Academic

Residential

Athletic





PROJECT

PROCESS

SAVINGS

PROMINENCE

FUNCTION

REFLECTION



Overview

Location

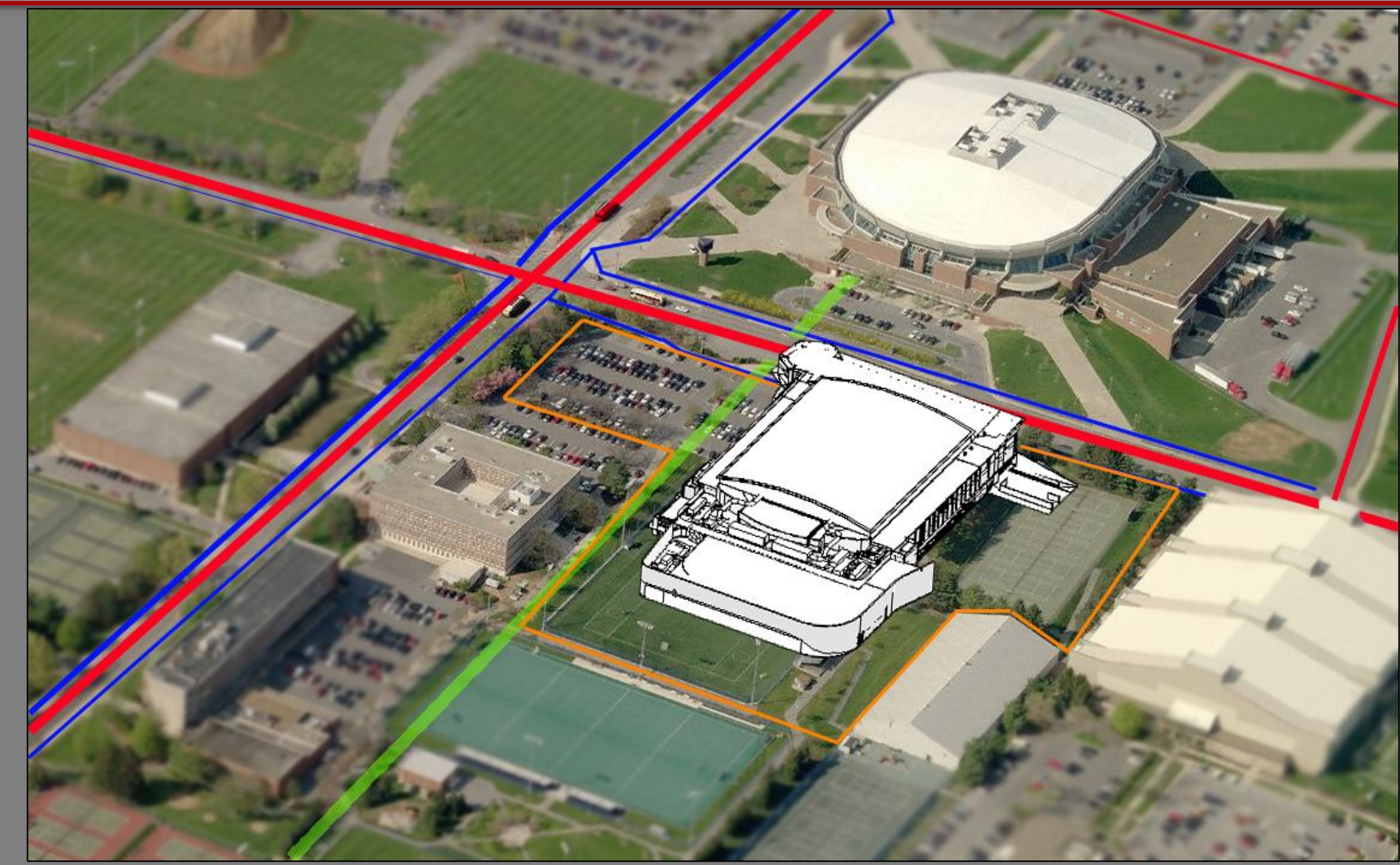
Team

Design

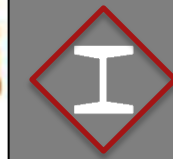
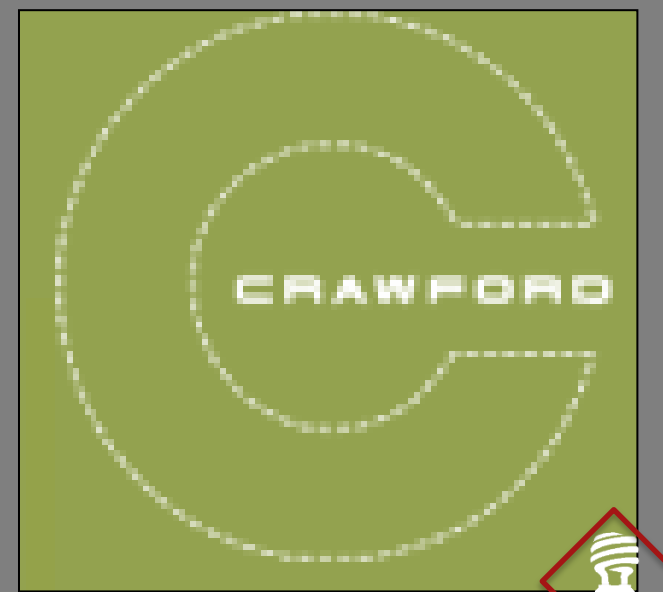
Academic

Residential

Athletic



Utilities Vehicular Pedestrian Site











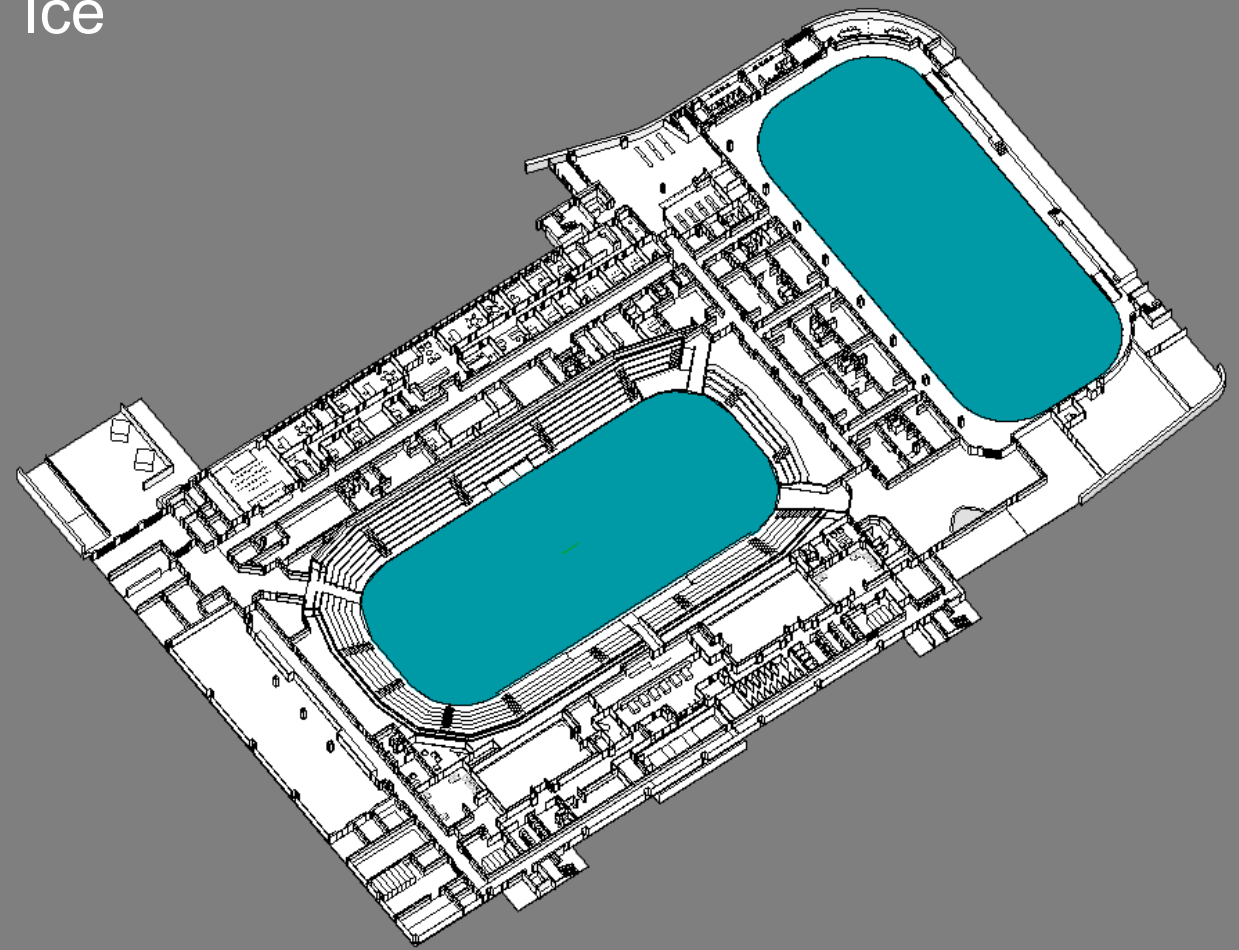
Location

Team

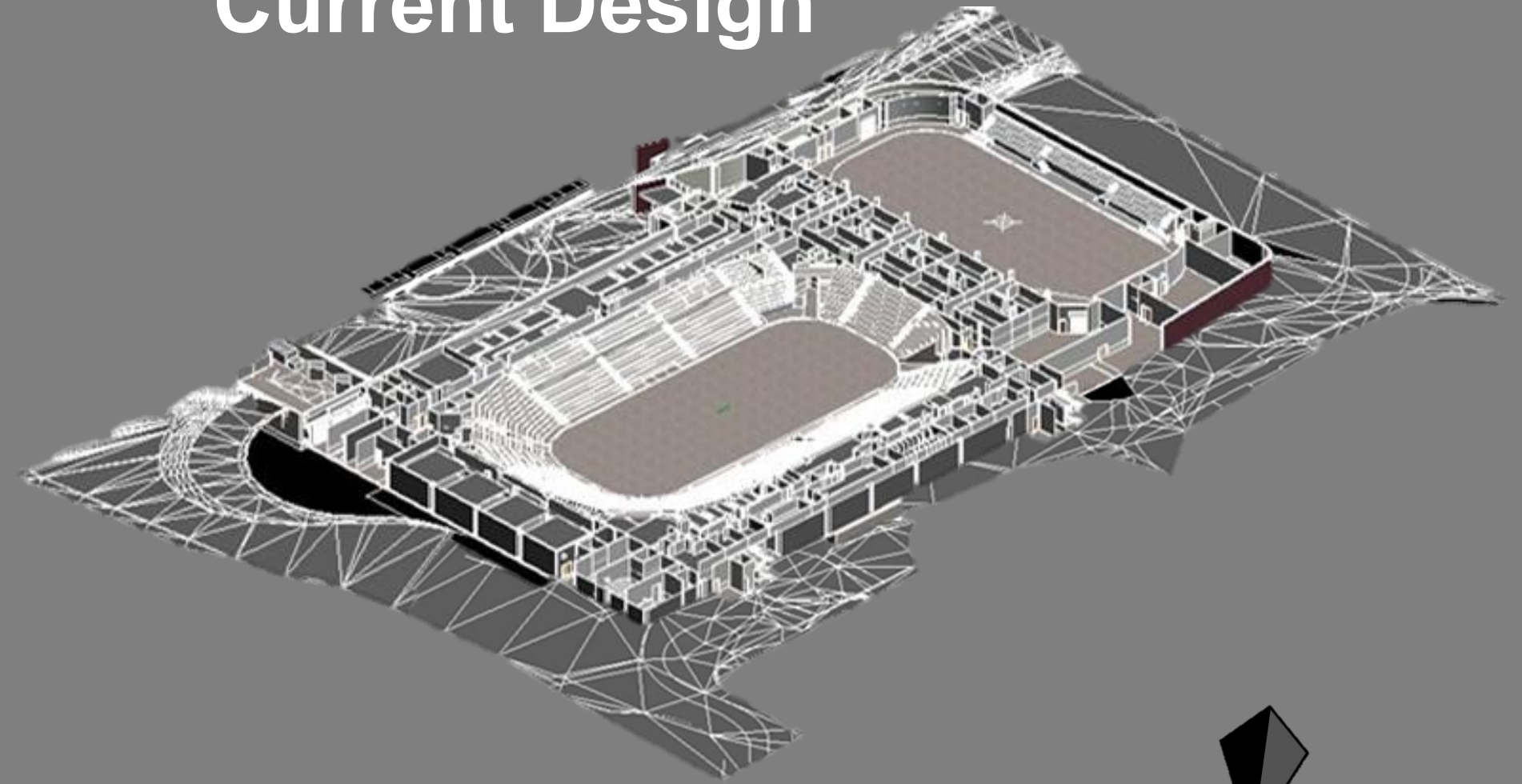
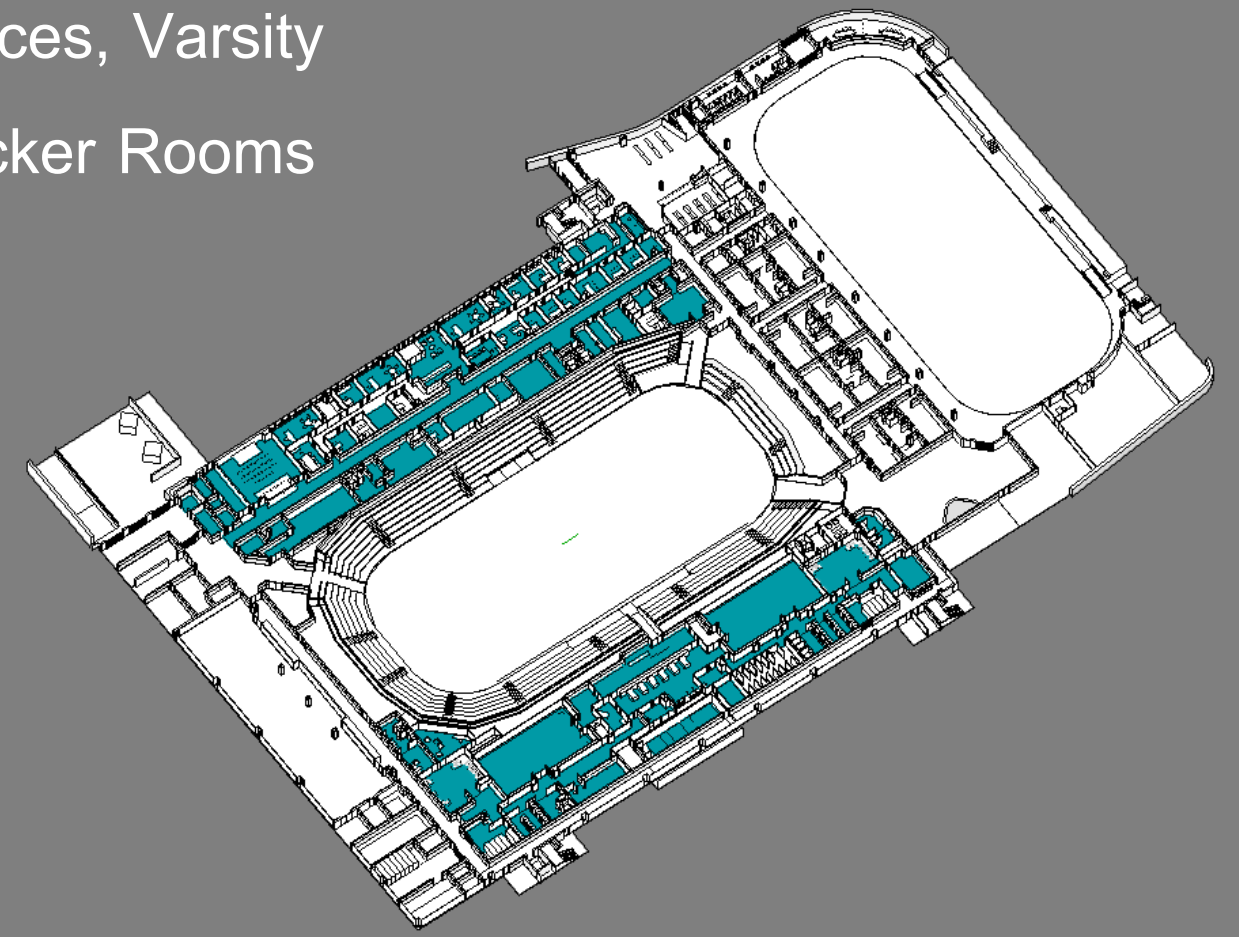
Design

# Current Design

Ice



Offices, Varsity  
Locker Rooms



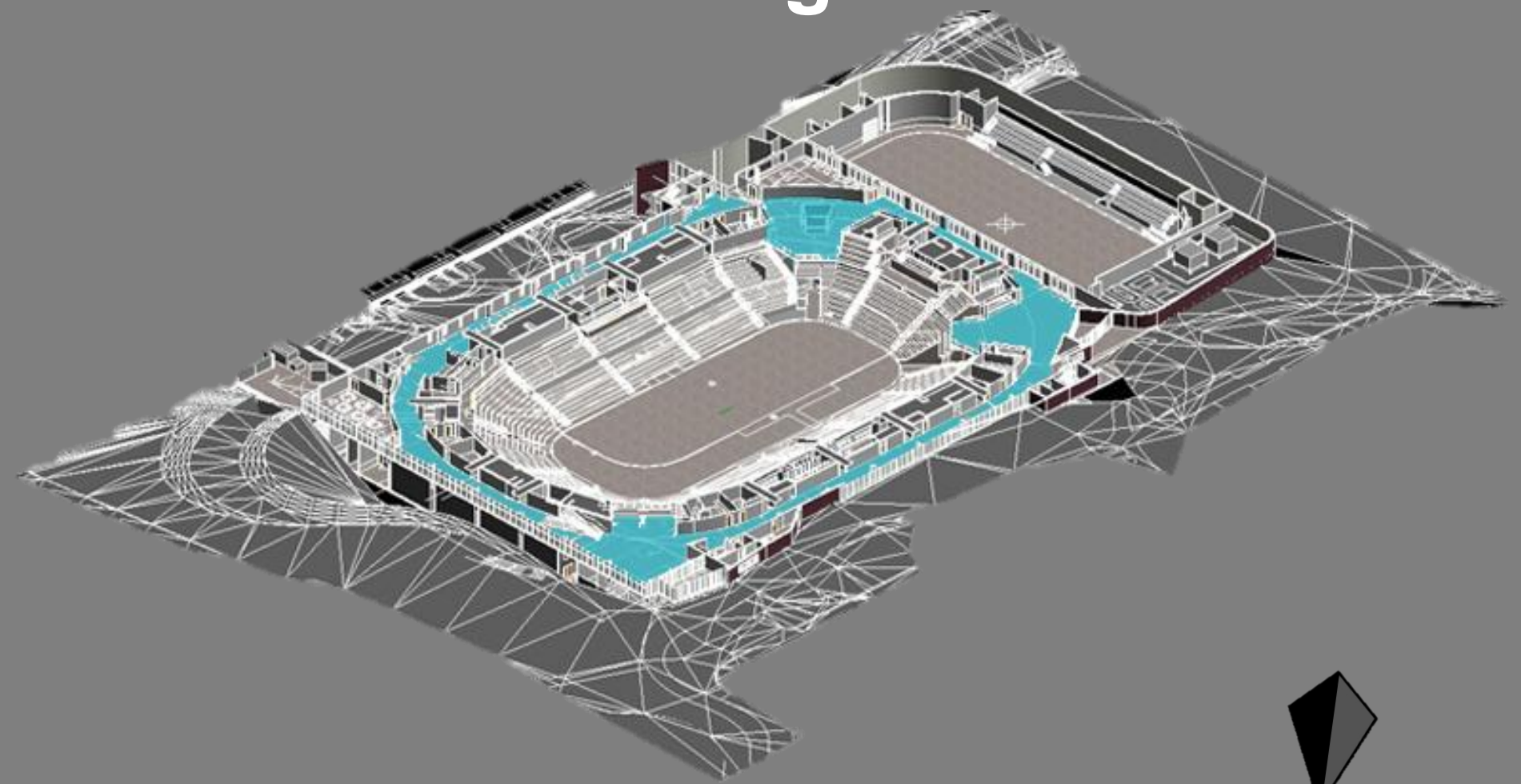


Location

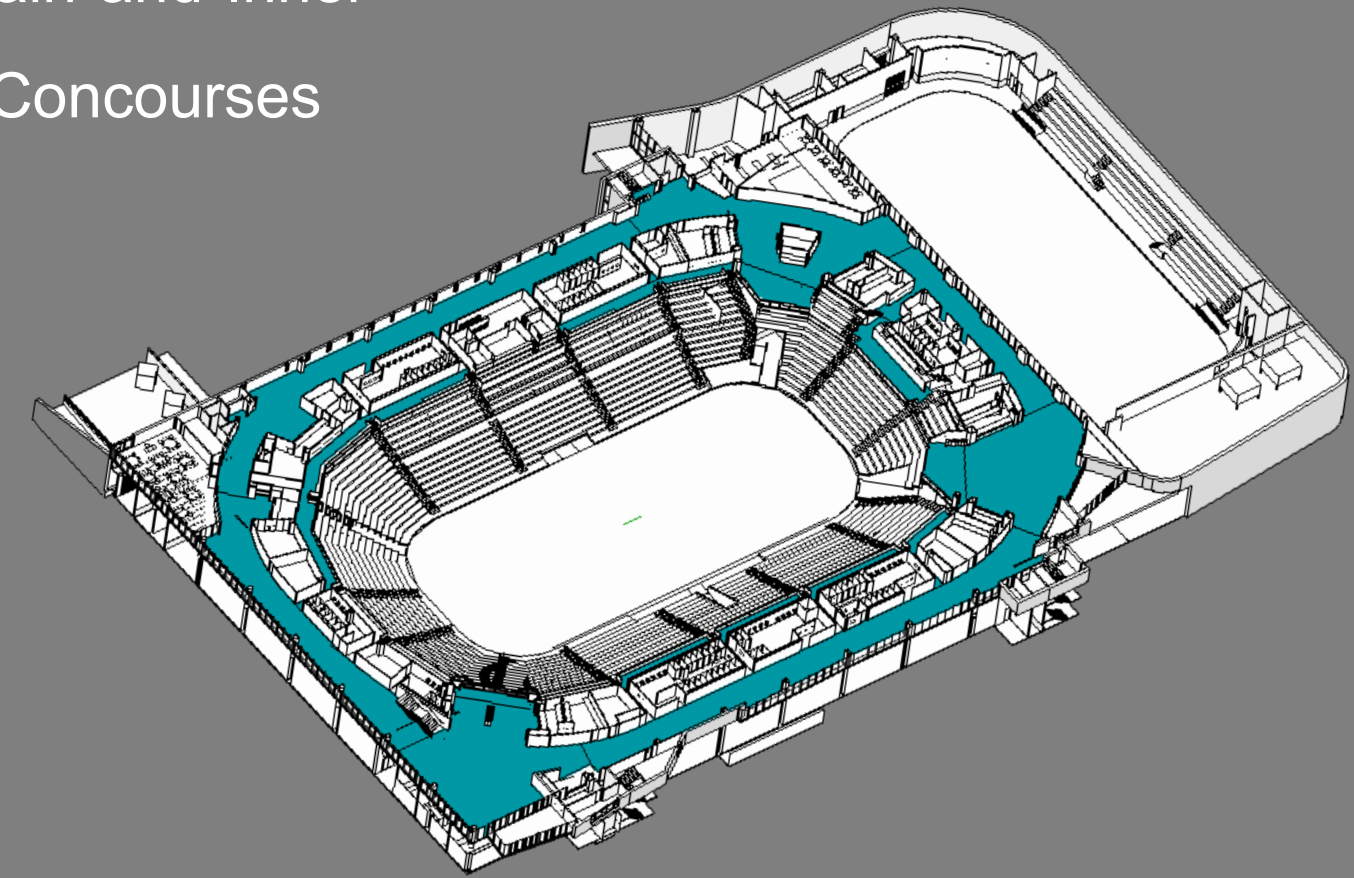
Team

Design

# Current Design



Main and Inner  
Concourses







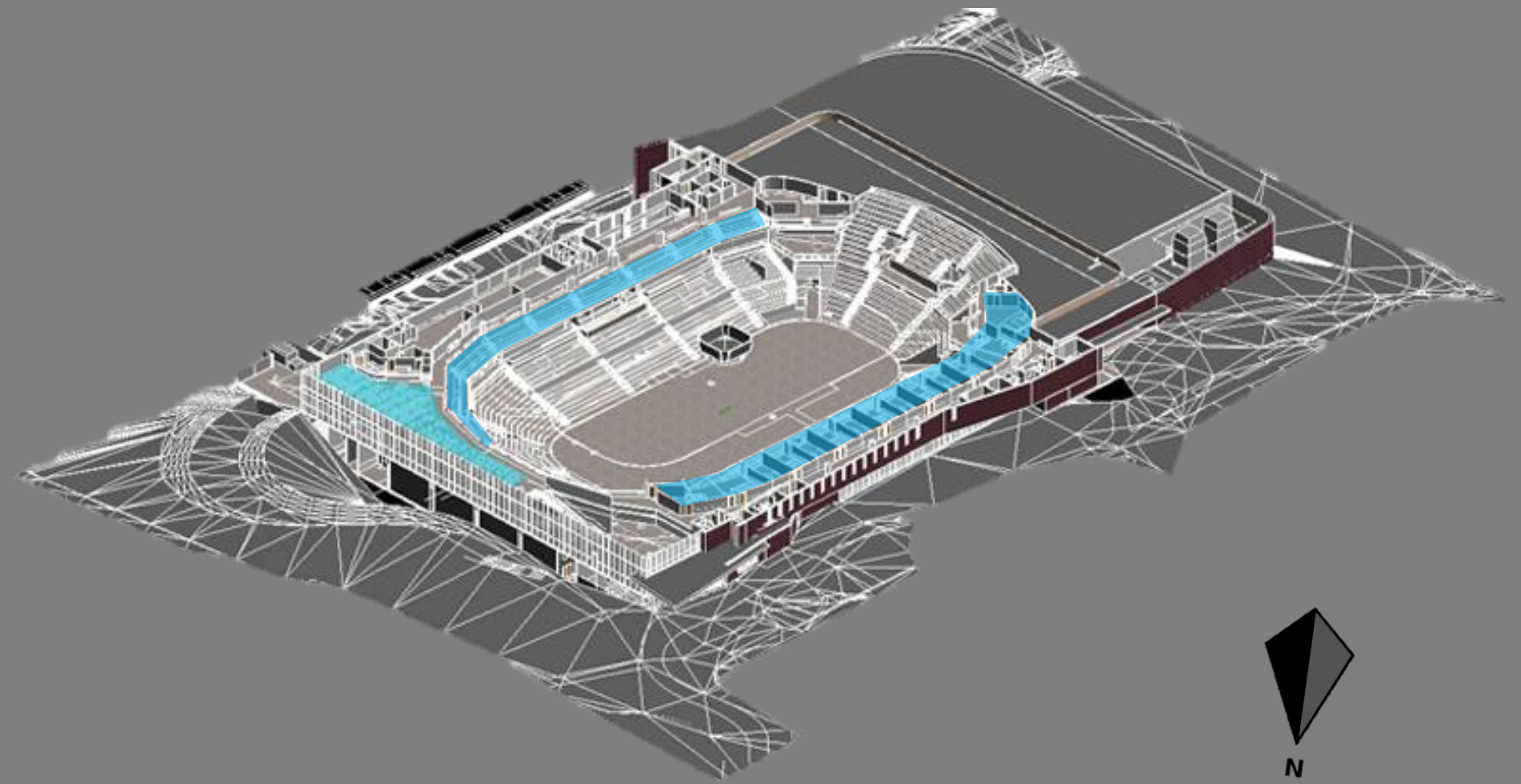
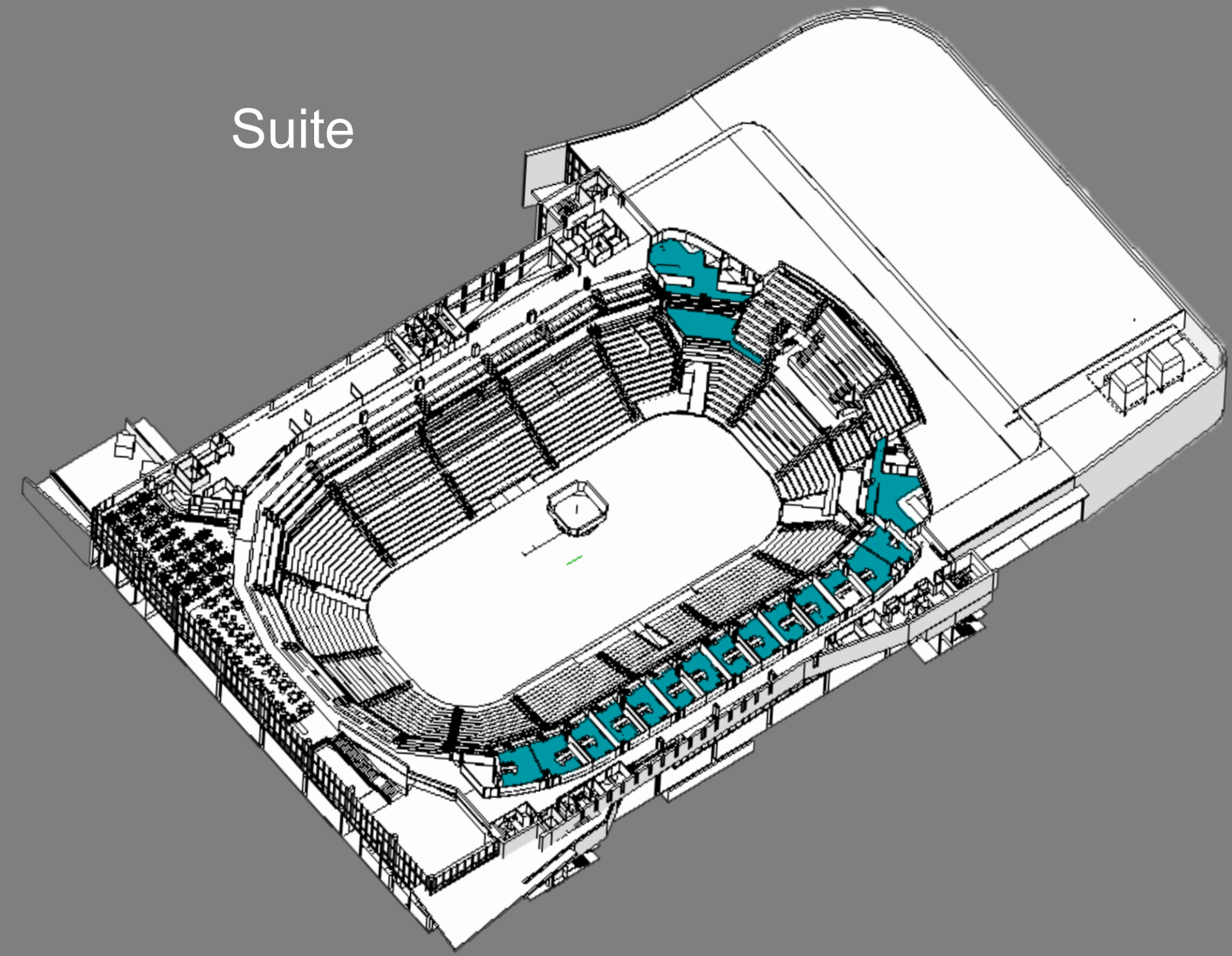
Location

Team

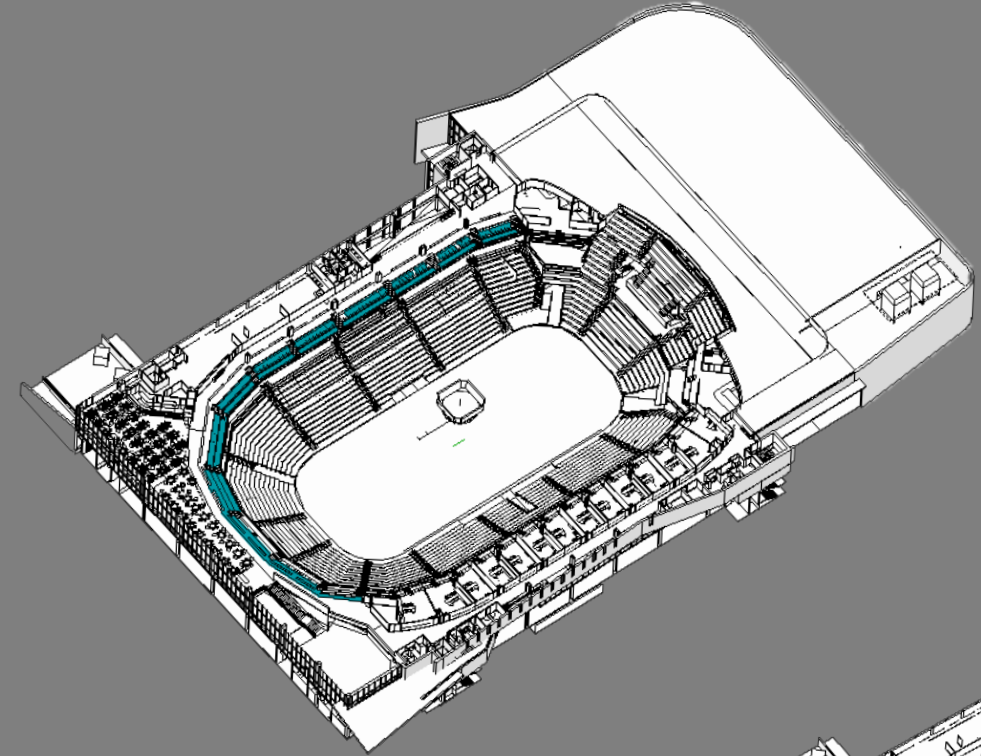
Design

# Current Design

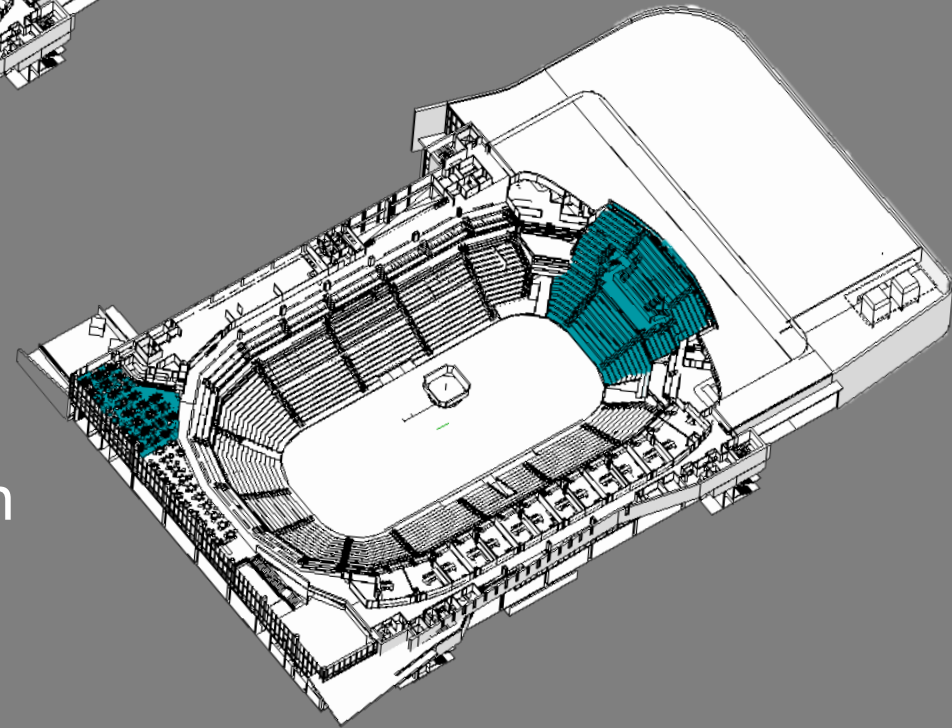
Suite



Club Seating



Steep Student Section  
and the Club dining  
Room







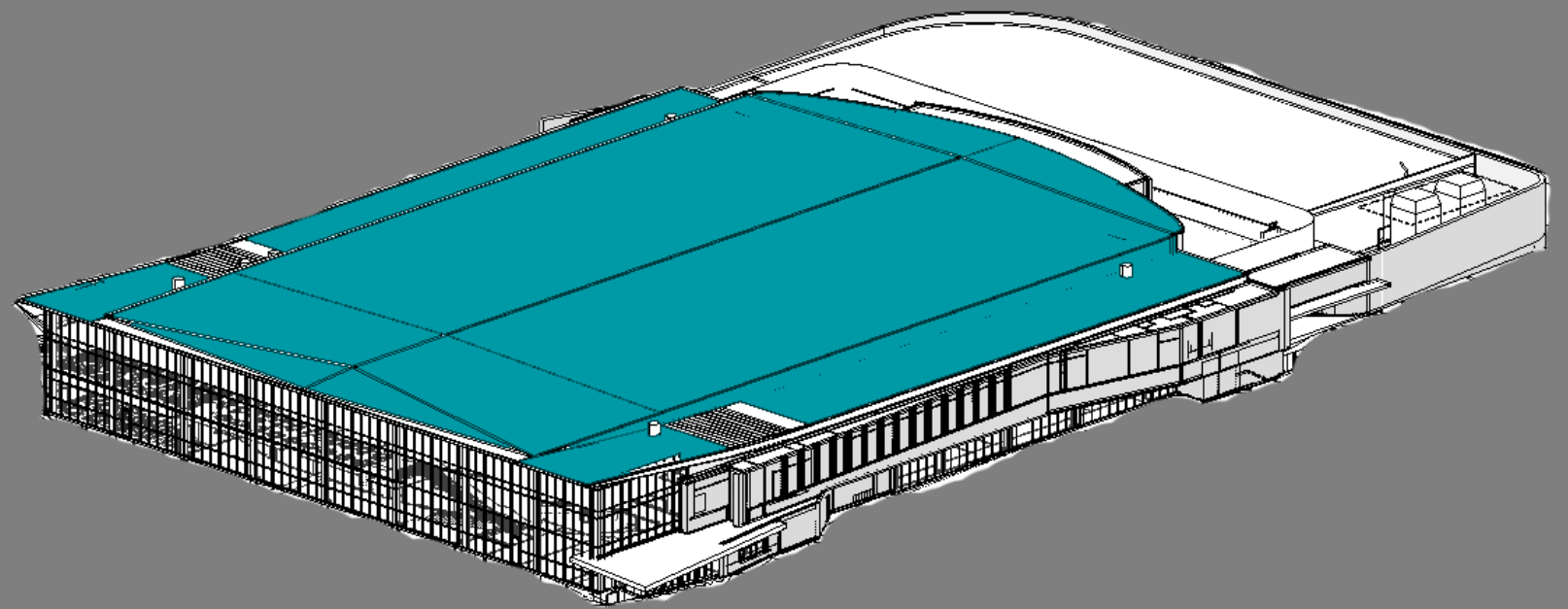
Location

Team

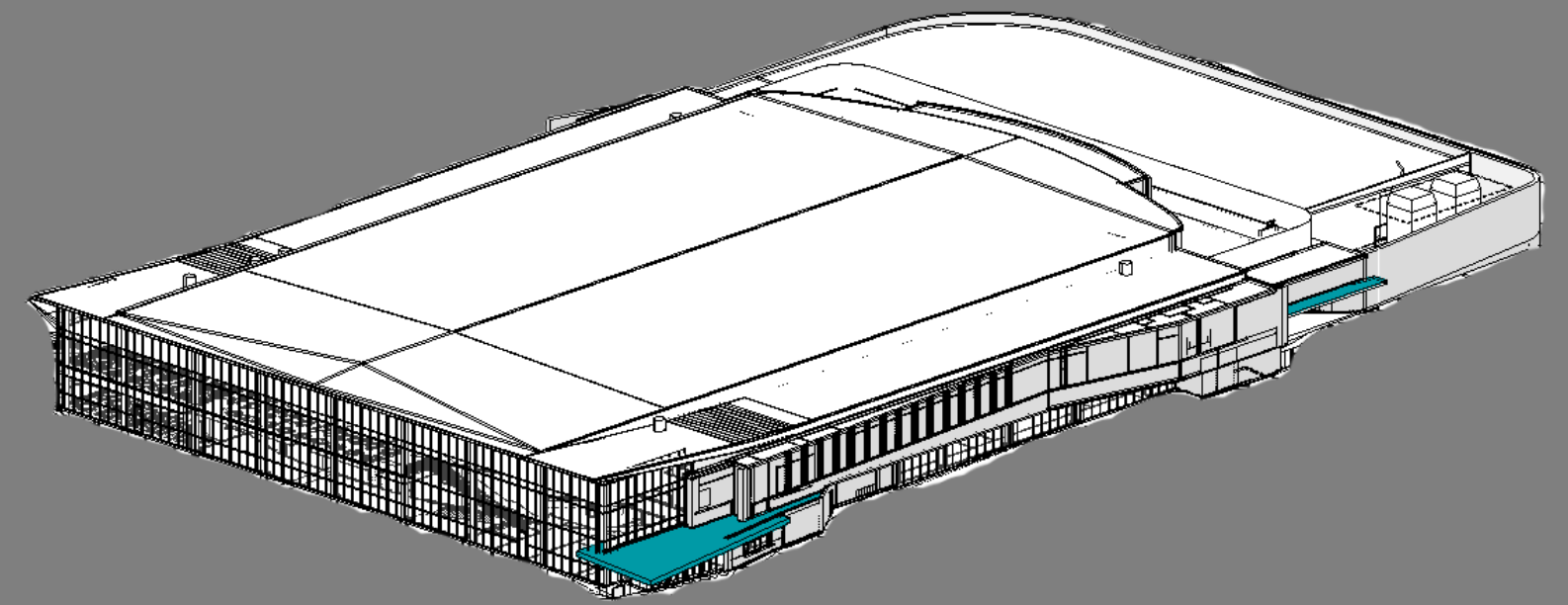
Design

# Current Design

Roof



Entrances







# PROCESS



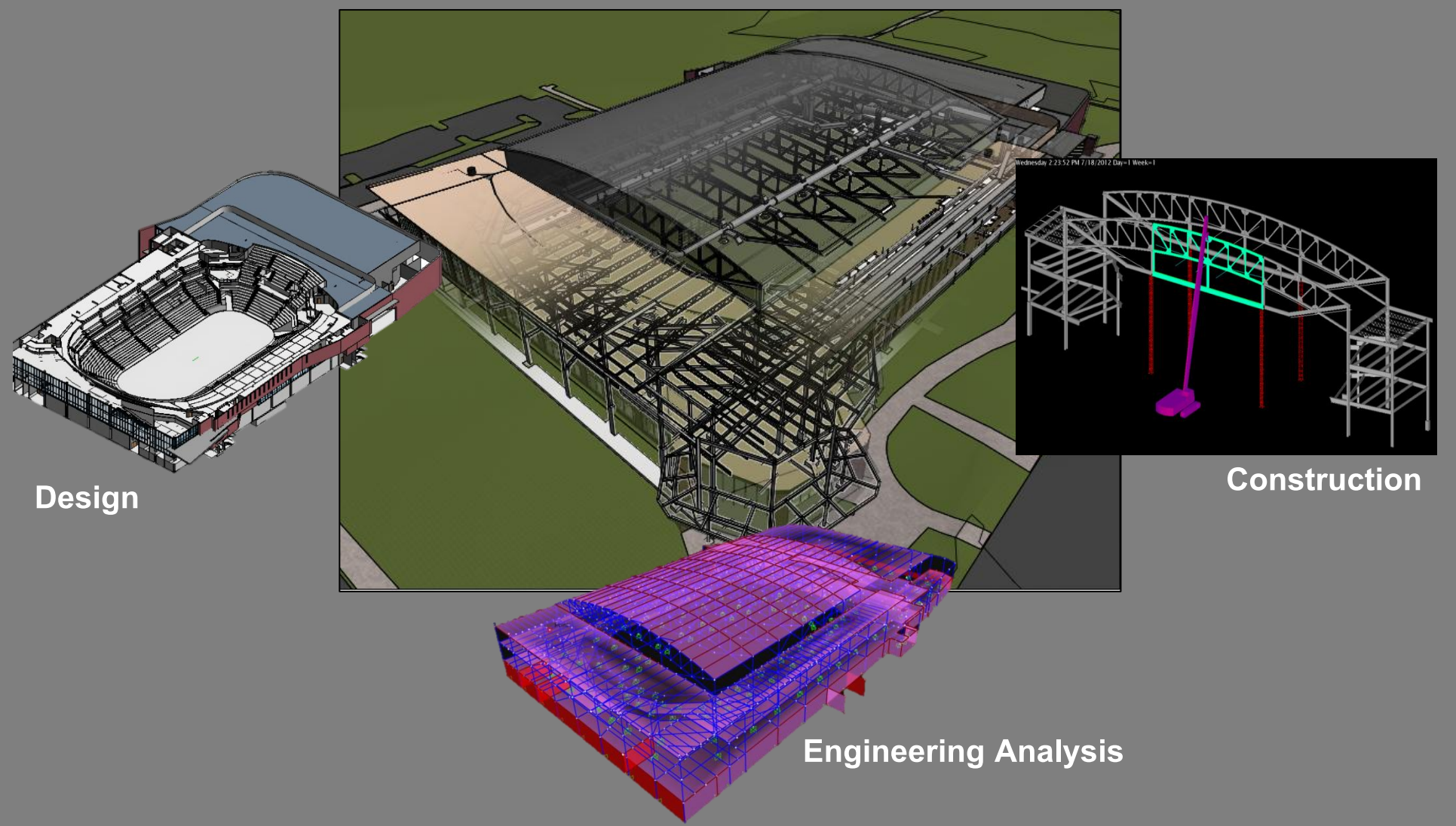


BIM

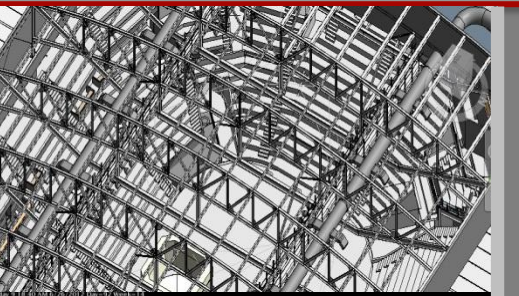
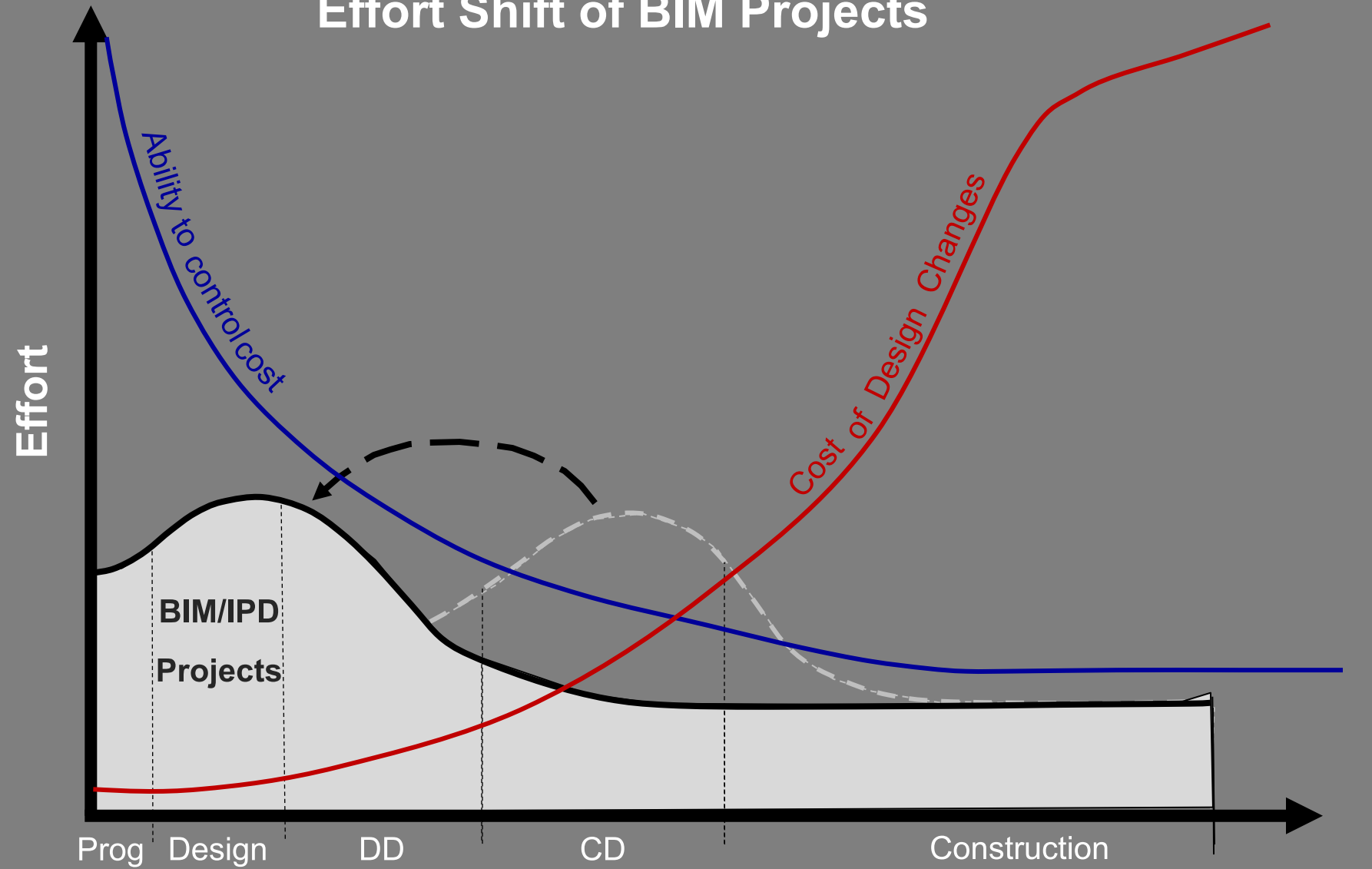
Execution Plan

Approach

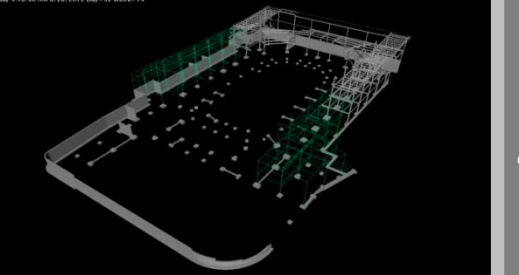
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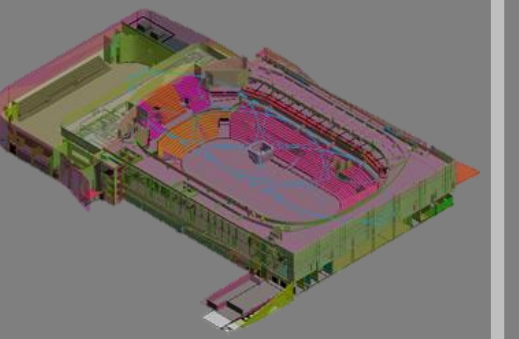
### Effort Shift of BIM Projects



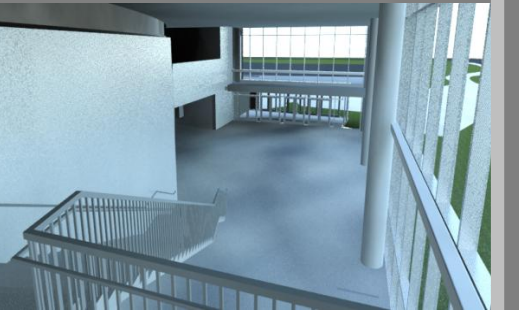
3D Coordination



4D Scheduling/Sequencing



Cost Estimation



Design Reviews



USES & GOALS



TECHNOLOGY



COMMUNICATION



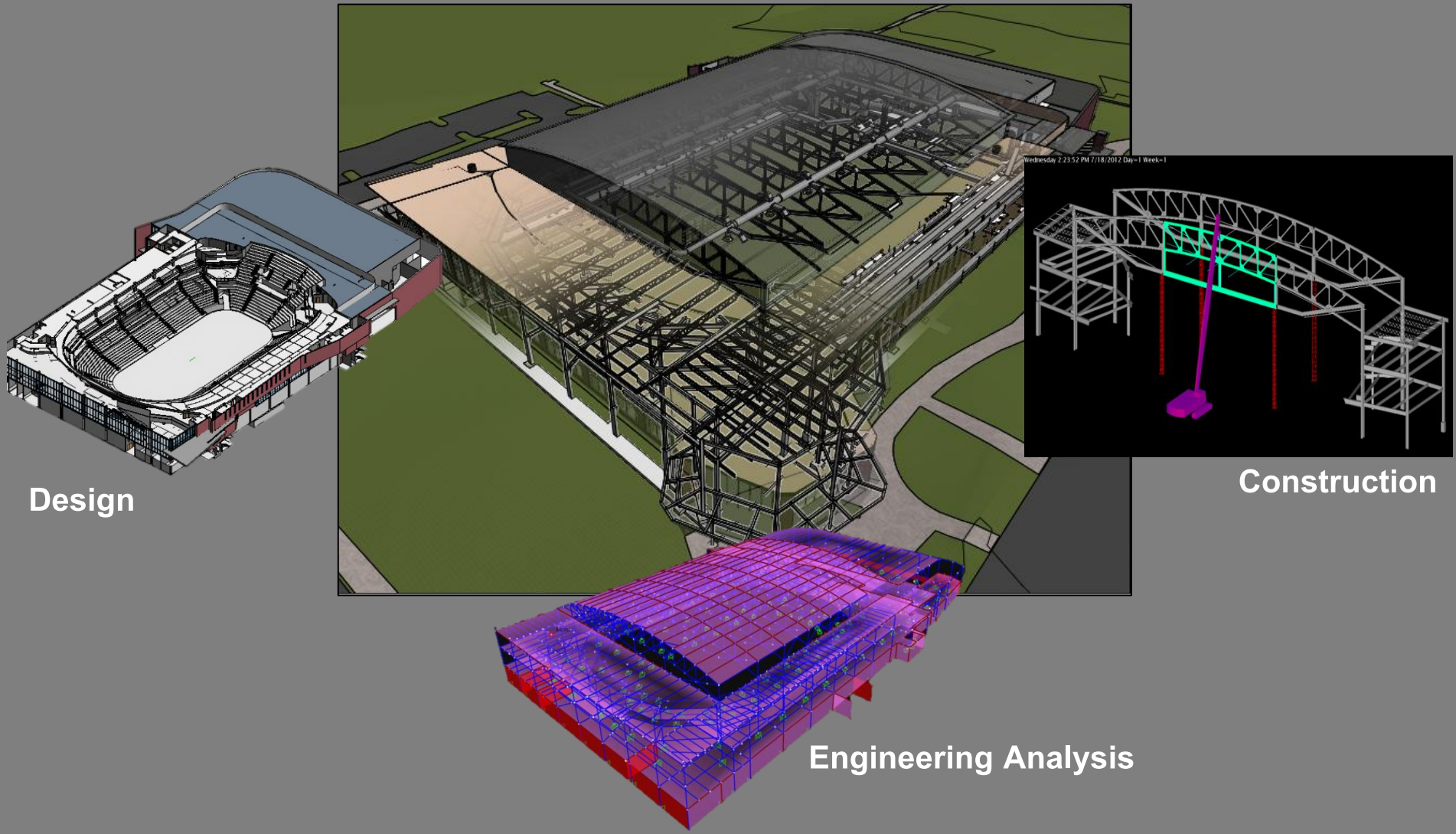


BIM

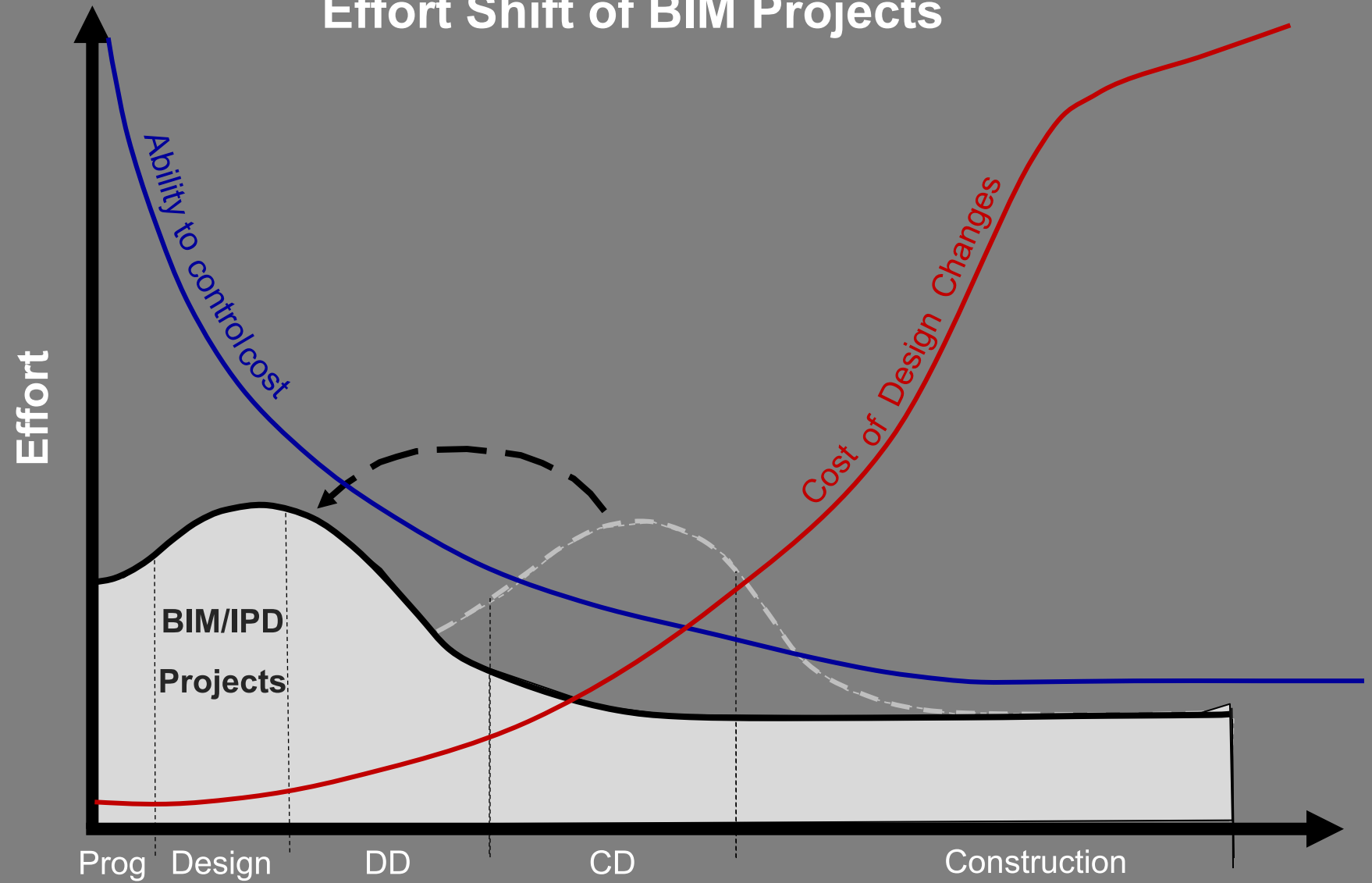
Execution Plan

Approach

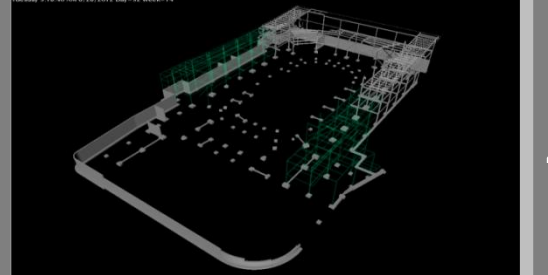
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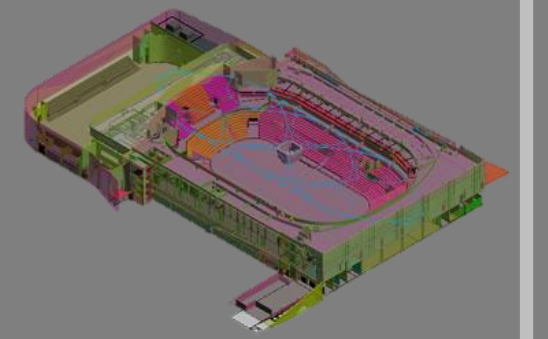
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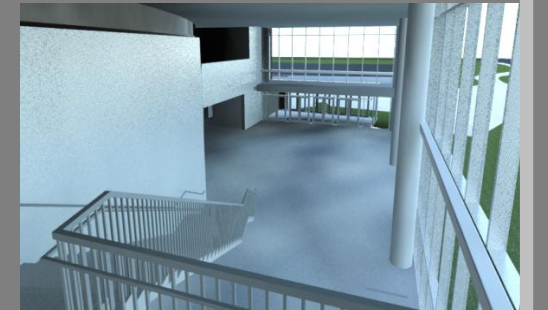
3D Coordination



4D Scheduling/Sequencing



Cost Estimation



Design Reviews



USES & GOALS



TECHNOLOGY



COMMUNICATION



# Primary BIM Uses



USES & GOALS

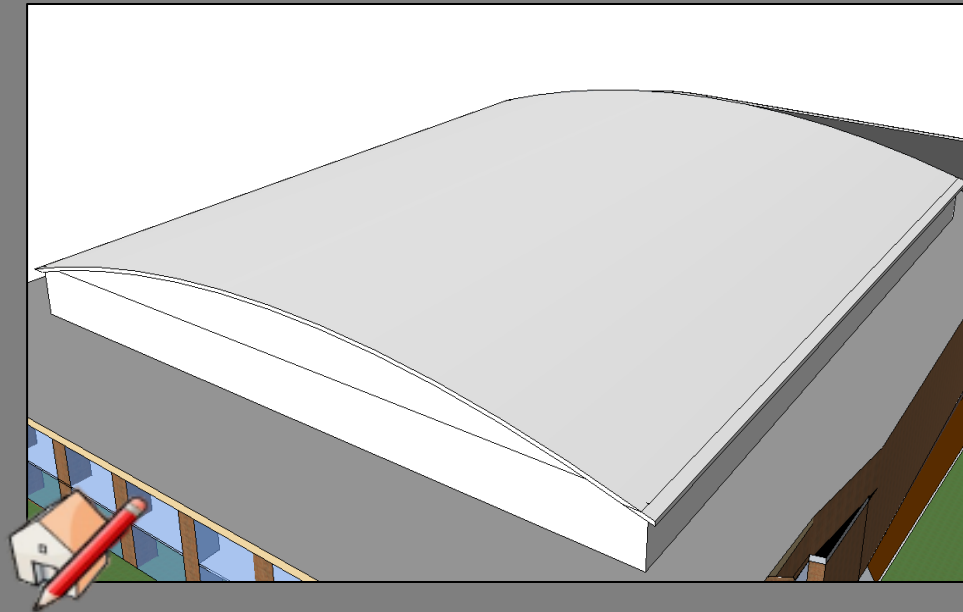


TECHNOLOGY



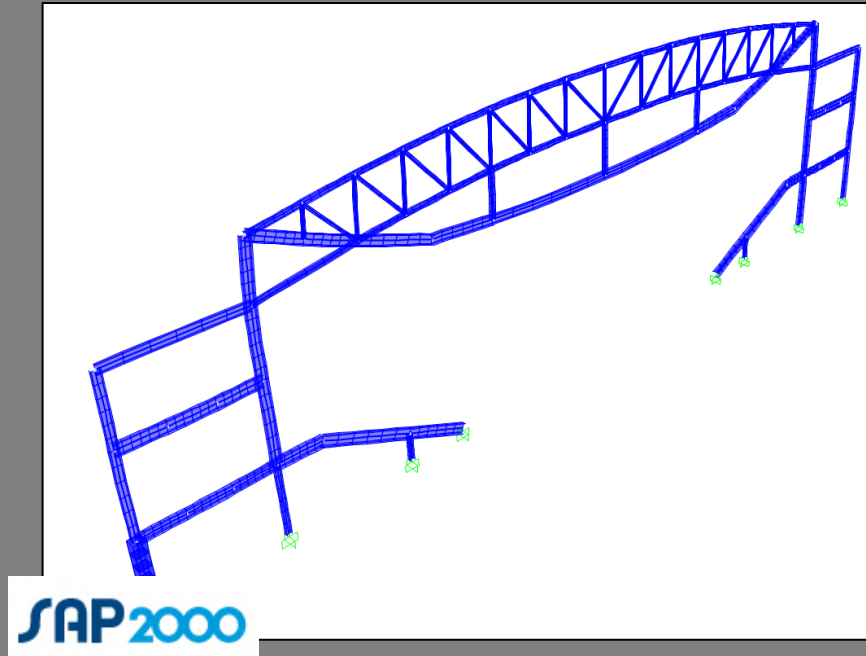
COMMUNICATION

Schematic



Inspiration

2D



Engineering Analysis

3D



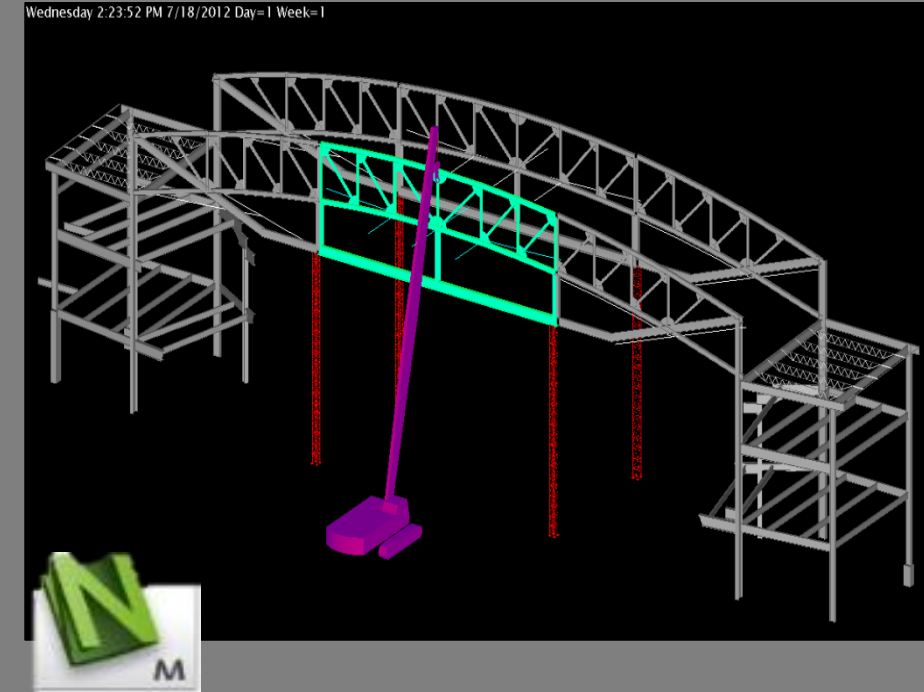
Coordination

Takeoff

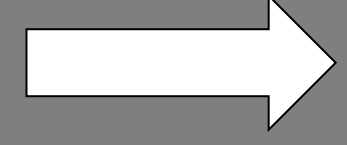
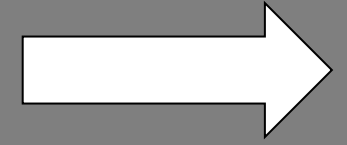
Task Name	Duration	Start	Finish
FOUNDATION PILES	14 days	Wed 3/28/12	Mon 4/16/12
FOUNDATION FOOTERS	35 days	Wed 3/28/12	Tue 5/15/12
FOUNDATION WALLS/SHEAR WALLS	59 days	Tue 4/3/12	Mon 6/25/12
STRUCTURAL STEEL EAST 1	7 days	Mon 5/21/12	Wed 5/30/12
STRUCTURAL STEEL EAST 2	7 days	Wed 5/23/12	Fri 6/1/12
STRUCTURAL STEEL SOUTH 1	12 days	Wed 5/23/12	Fri 6/8/12
STRUCTURAL STEEL NORTH 1	12 days	Tue 5/29/12	Wed 6/13/12
STRUCTURAL STEEL SOUTH 2	13 days	Tue 6/5/12	Thu 6/21/12
STRUCTURAL STEEL NORTH 2	12 days	Mon 6/11/12	Tue 6/26/12
SOUTH 3	12 days	Thu 6/14/12	Fri 6/29/12
NORTH 3	12 days	Wed 6/20/12	Fri 7/6/12
SOUTH 4	8 days	Mon 6/25/12	Thu 7/5/12
NORTH 4	8 days	Fri 6/29/12	Wed 7/11/12
PICK 1	1 day	Thu 7/12/12	Thu 7/12/12

Cost Estimating / Scheduling

4D



Phasing







BIM

Execution Plan

Approach

# WORKFLOW OVERVIEW



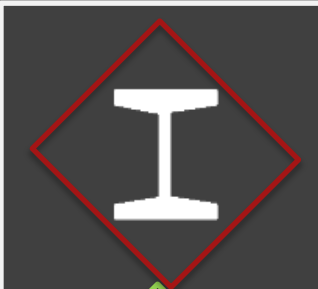
USES & GOALS



TECHNOLOGY



COMMUNICATION



Milestone #1



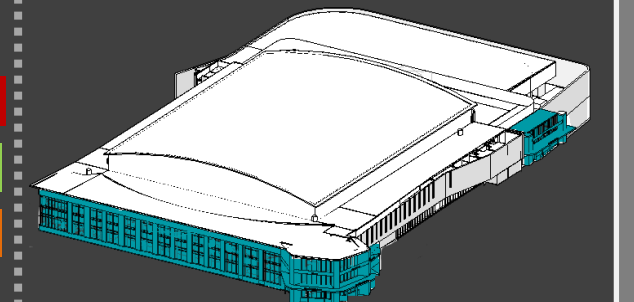
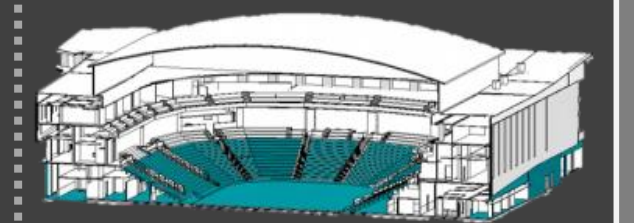
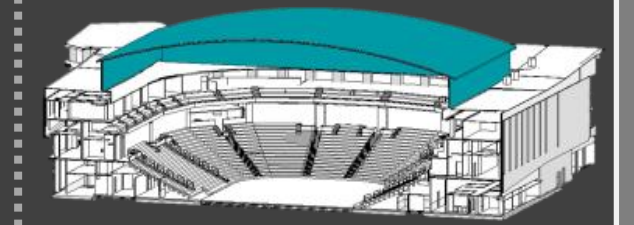
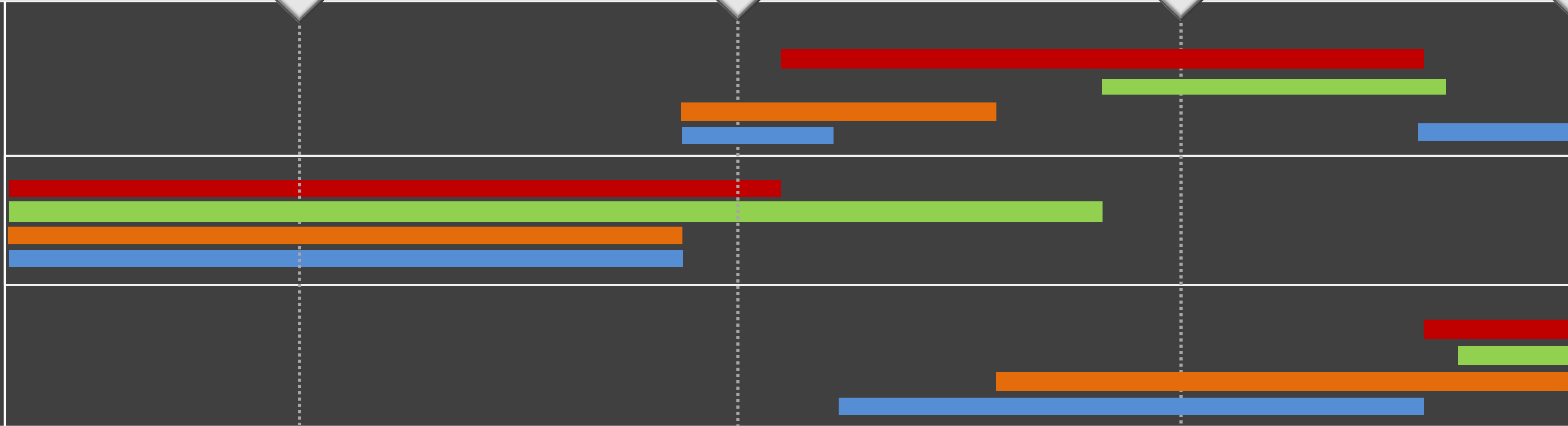
Milestone #2



Milestone #3



Milestone #4



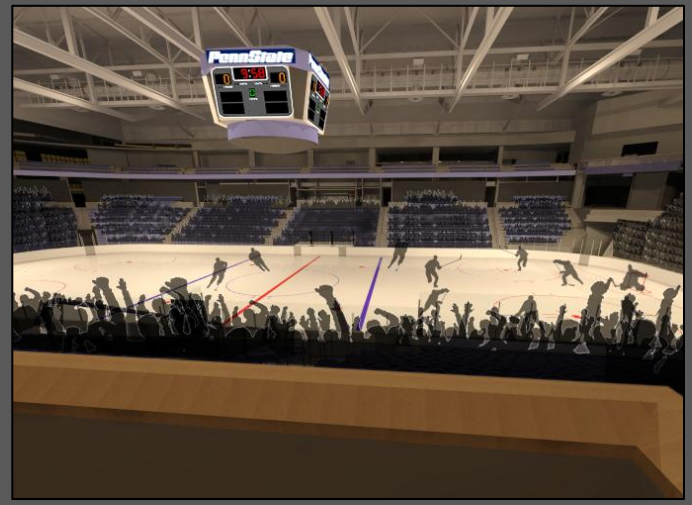
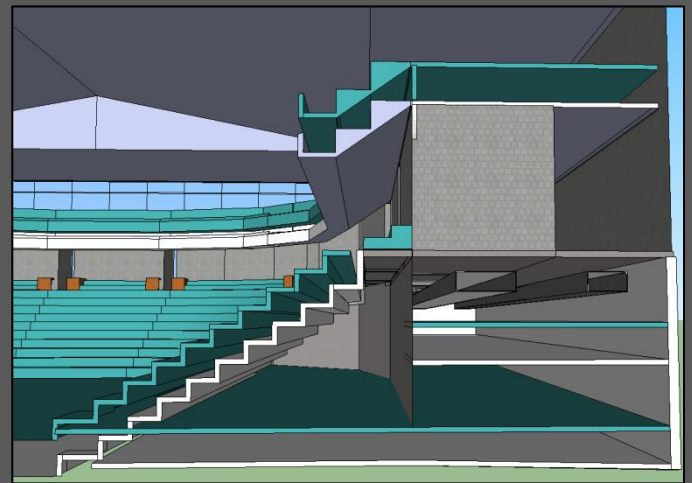




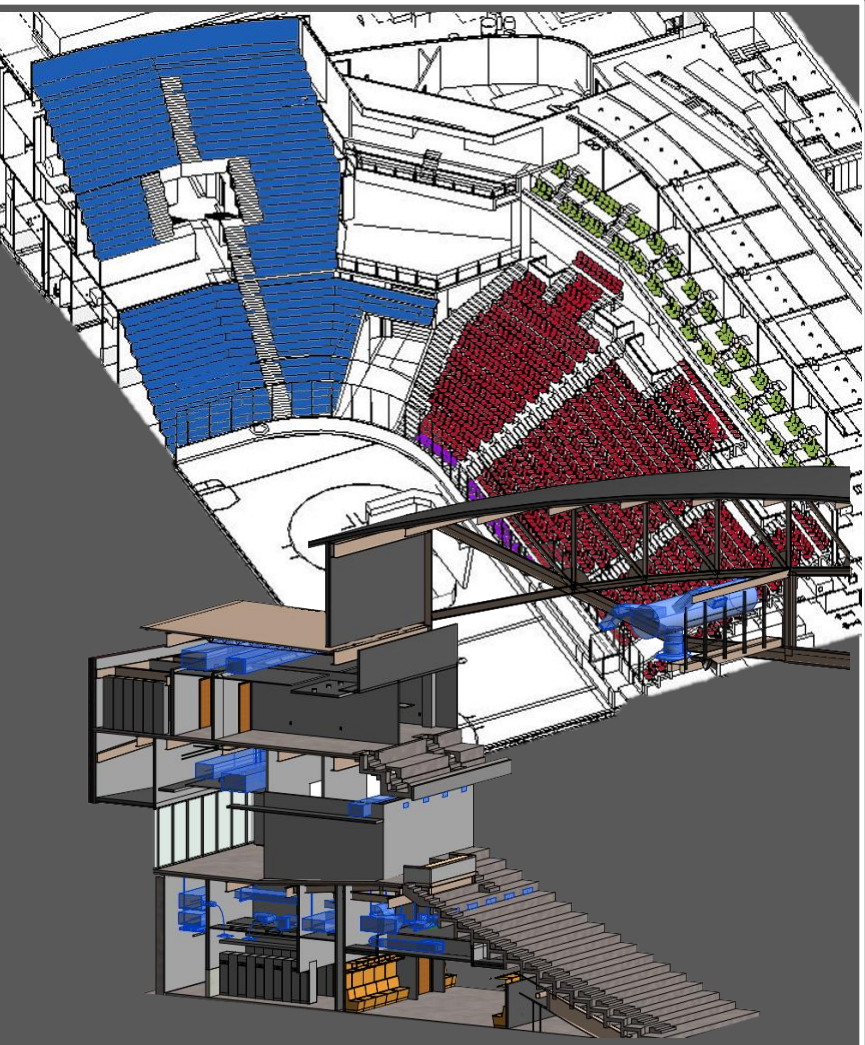
BIM

Execution Plan

Approach



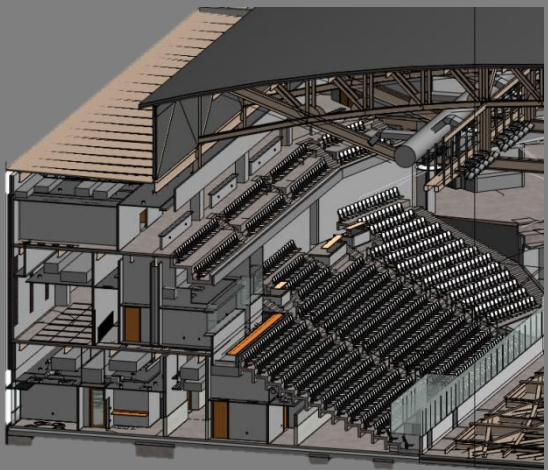
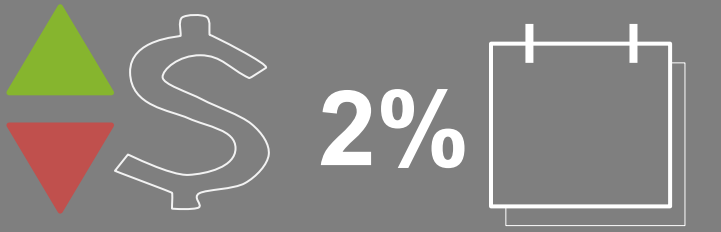
SAVINGS OPPORTUNITY



# Value Engineering

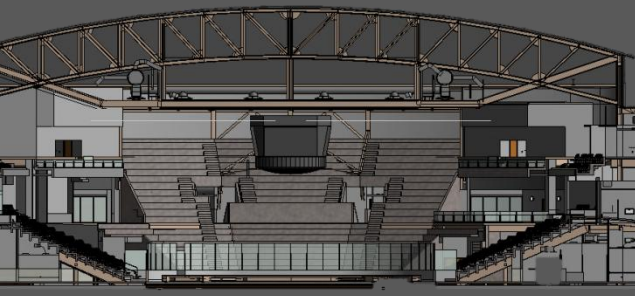
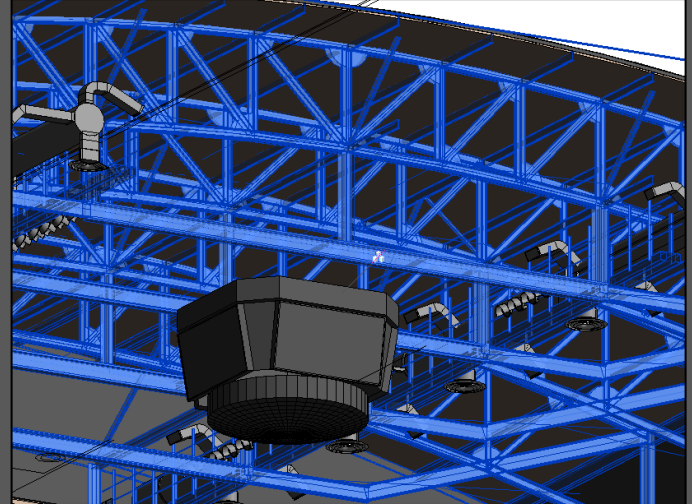
Systematic method to add value, by improving the function and/or reducing costs to a project through examination of a product and using best design practices.

Measures of Success:



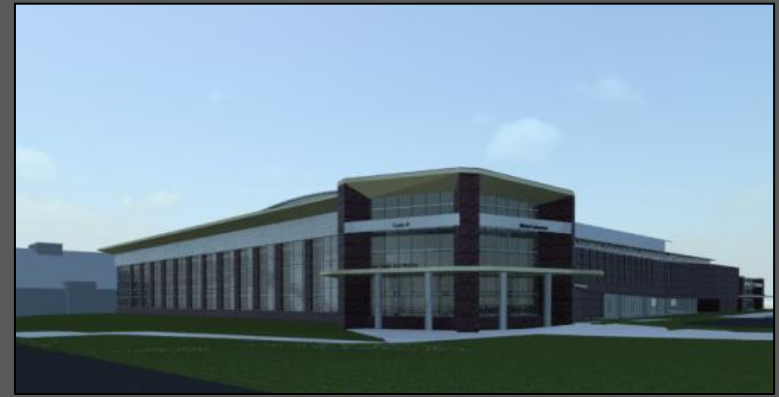
Savings  
↓  
Enhancements

PROMINENCE



ENHANCEMENT

FUNCTION



ENHANCEMENT





# SAVINGS



PROJECT	PROCESS	SAVINGS		PROMINENCE	FUNCTION	REFLECTION
	Opportunity	Goal	Strategy	Process	Results	

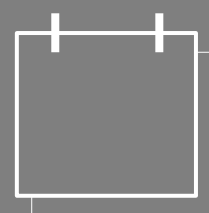




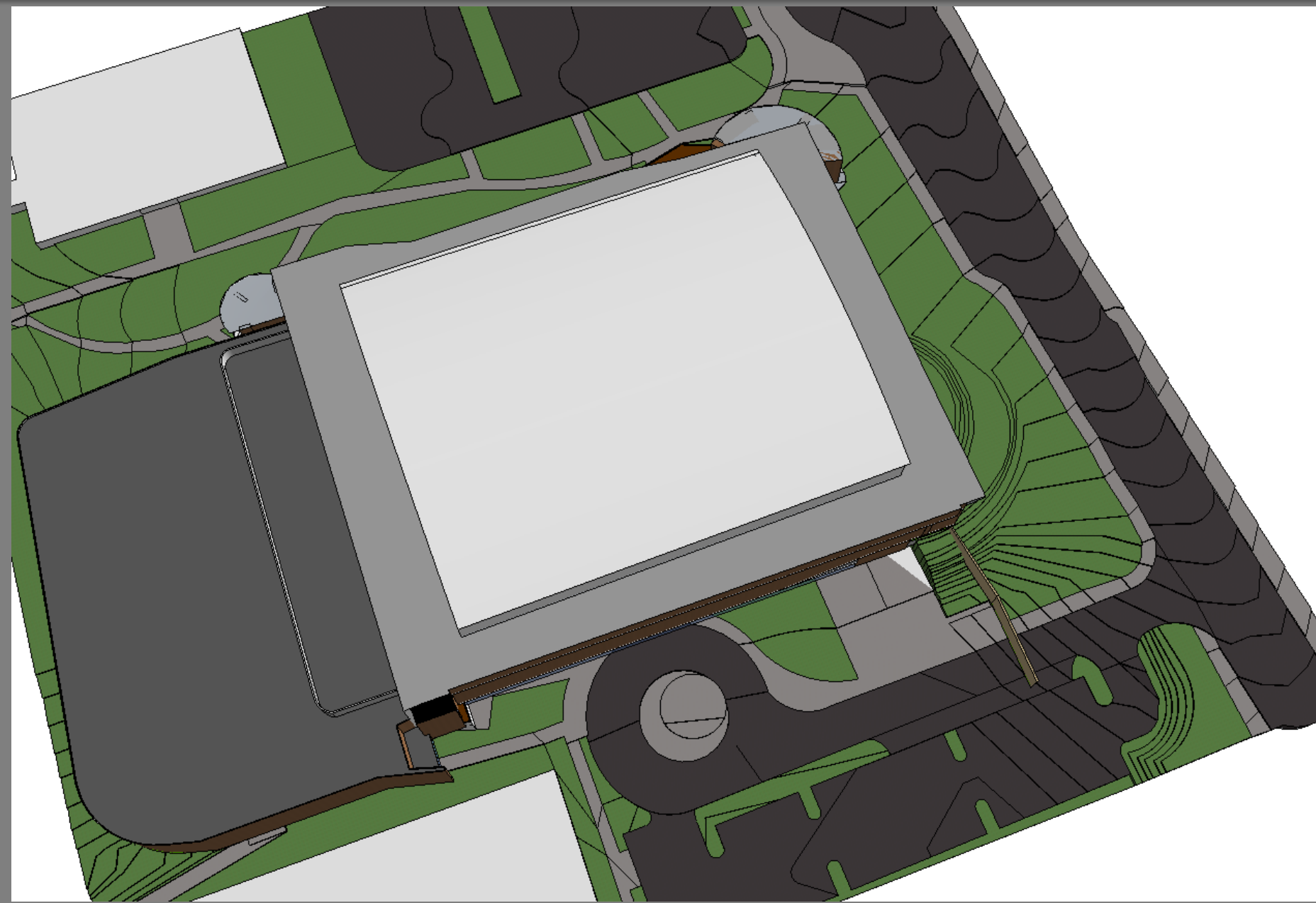
## Excavation Bid Package:



**\$2,500,000.00 (3.4%)**



- Overall Site - 35 Working Days
- Footprint- 25 Working Days
- Double Shifts



## Bid Packages:

- Earthwork: \$3,329,631
- *Excavation - \$2.5 million*
- Concrete & Carpentry: \$4,760,380
- Structural Steel & Stairs: \$6,886,900
- Masonry: \$1,428,680
- Metal Framing & Drywall: \$4,318,802



Opportunity

Goal

Strategy

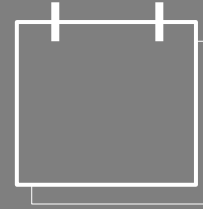
Process

Results

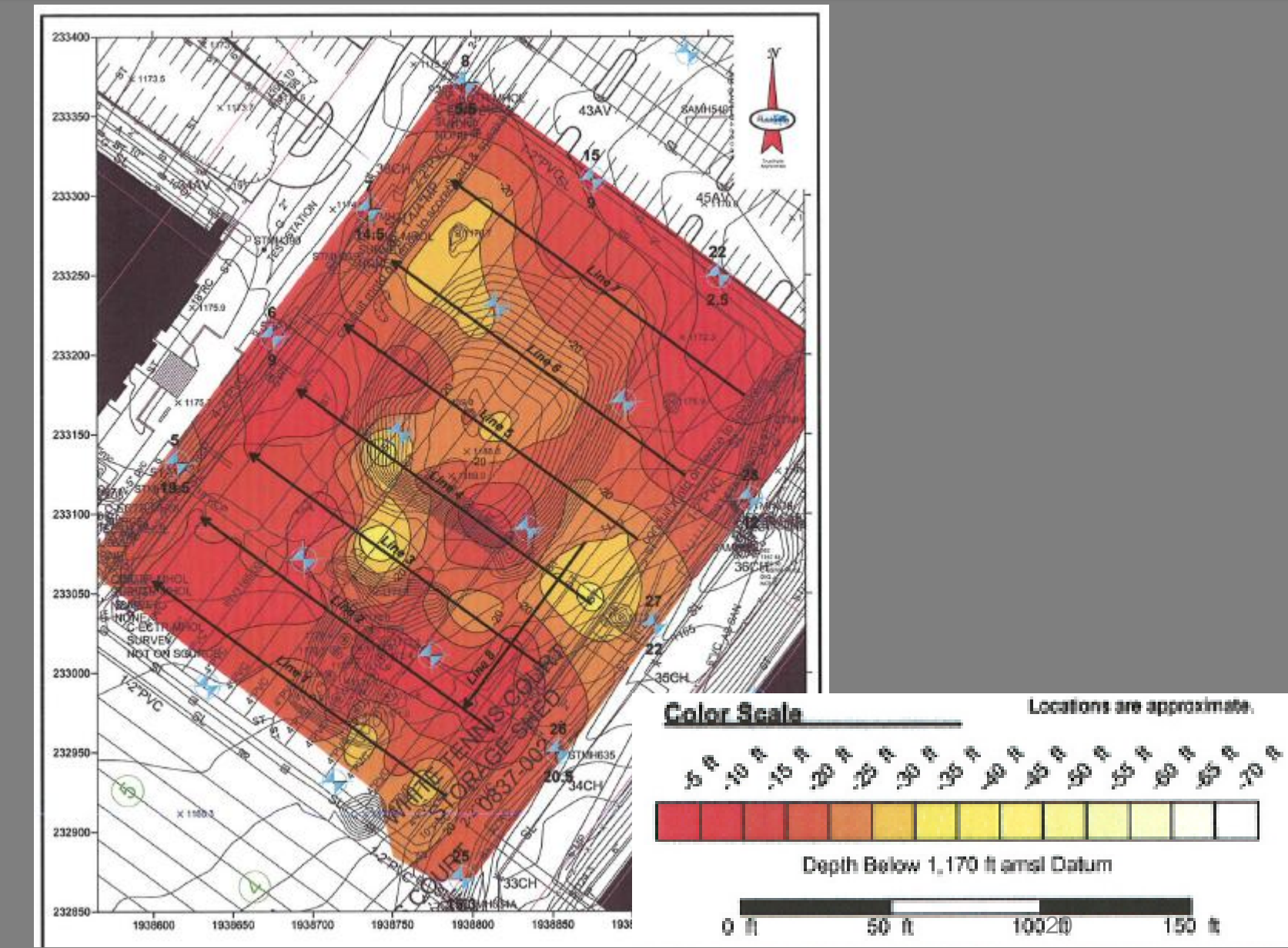
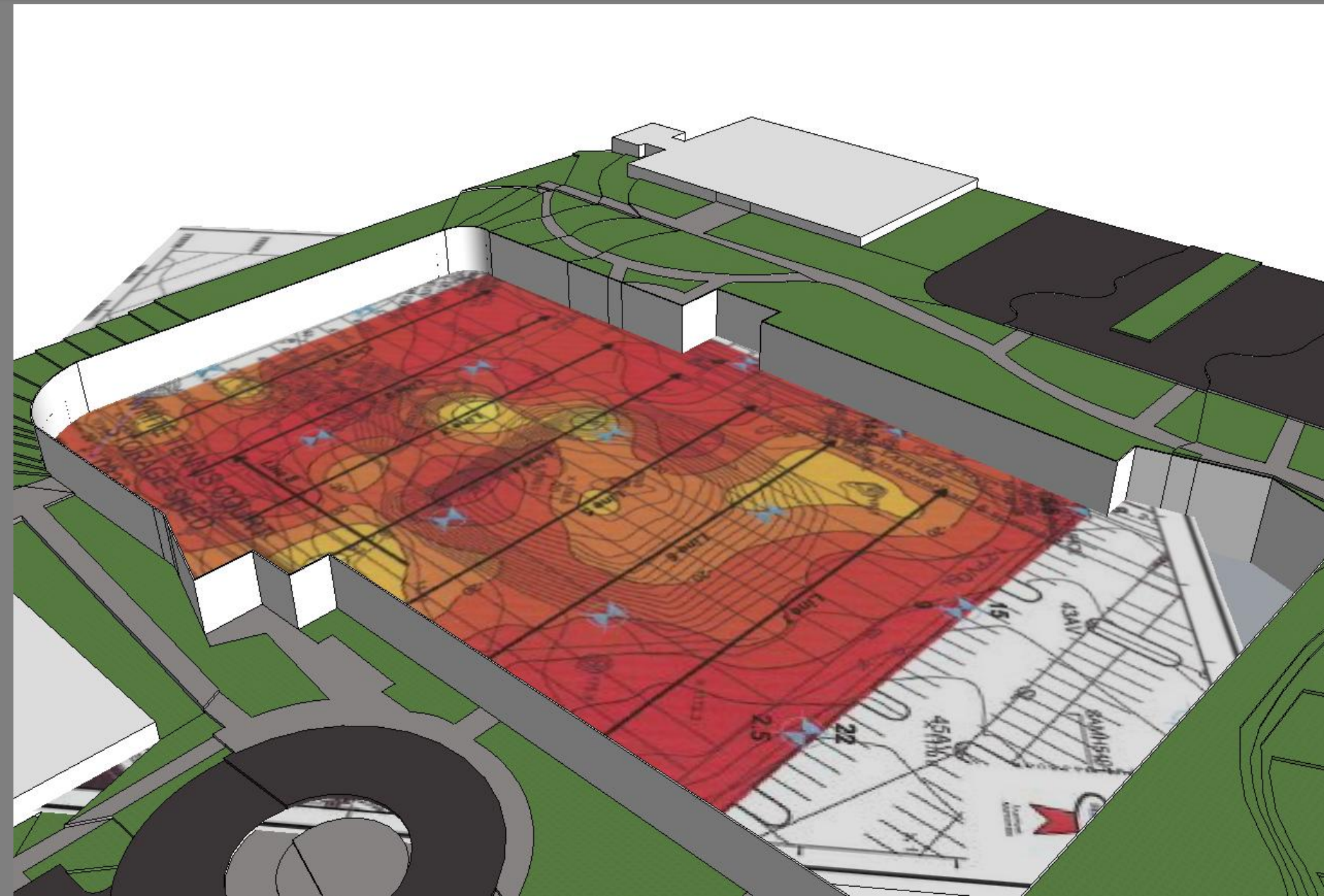
# Excavation Bid Package:



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Opportunity

Goal

Strategy

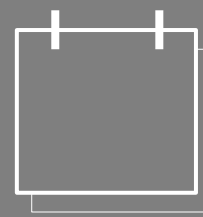
Process

Results

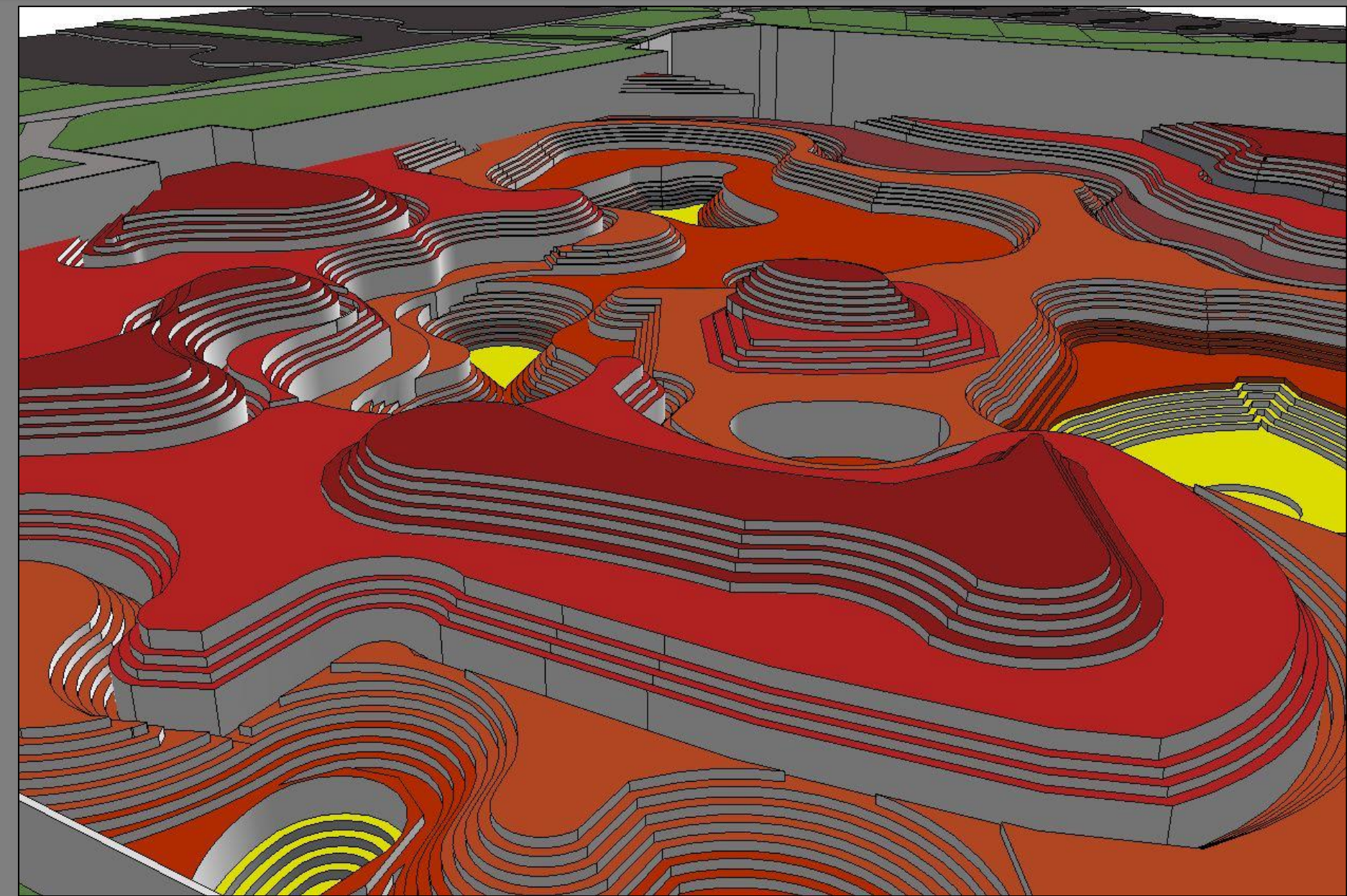
# Excavation Bid Package:



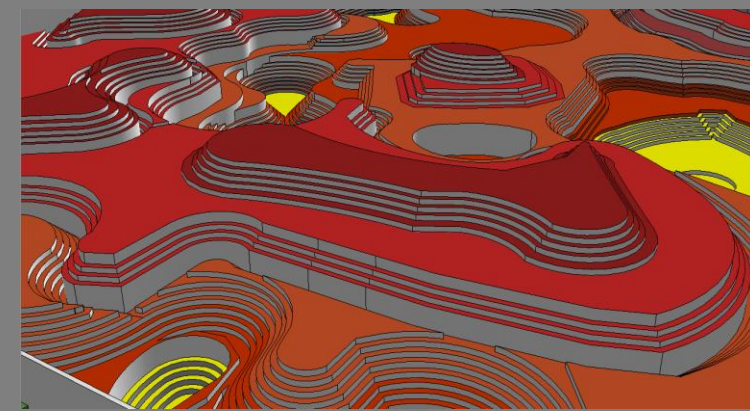
**\$2,500,000.00 (3.4%)**



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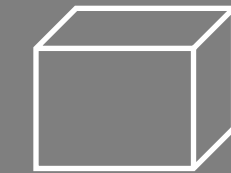


# Footprint Excavation:



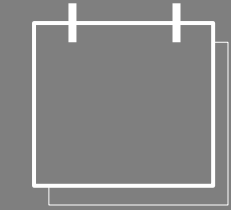
\$582,041

\$532,757



73,207 CY

25,401 CY

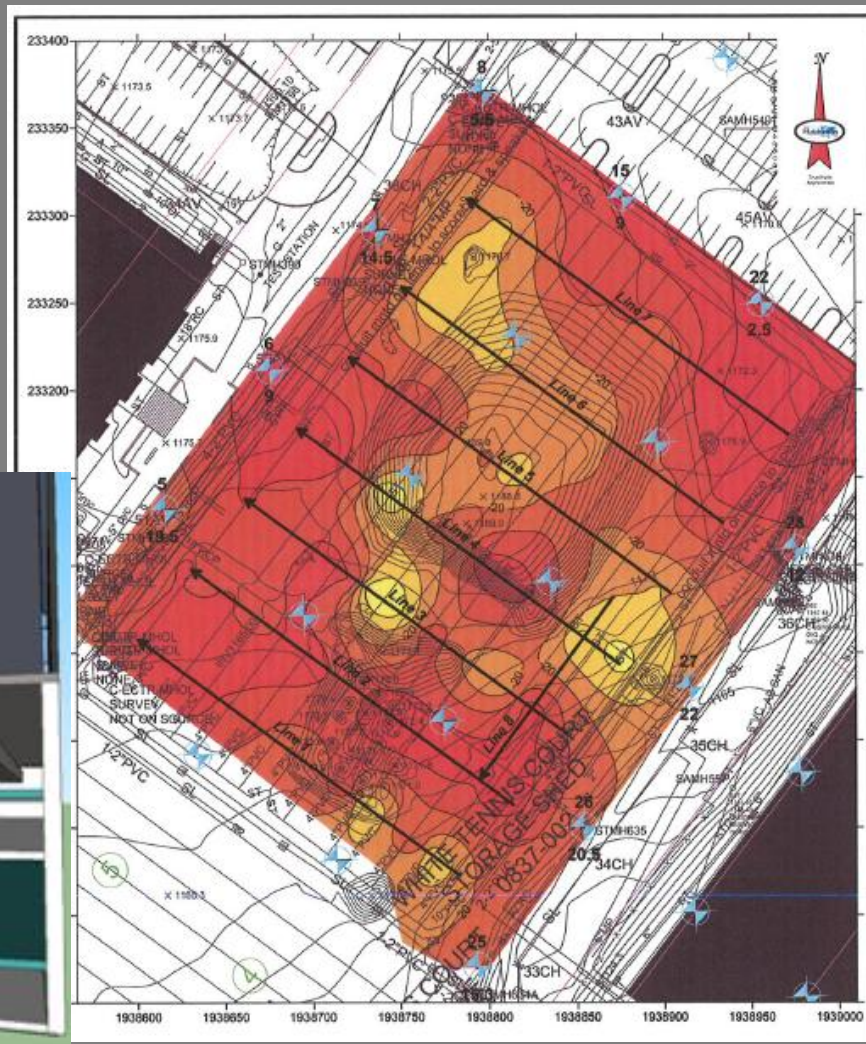
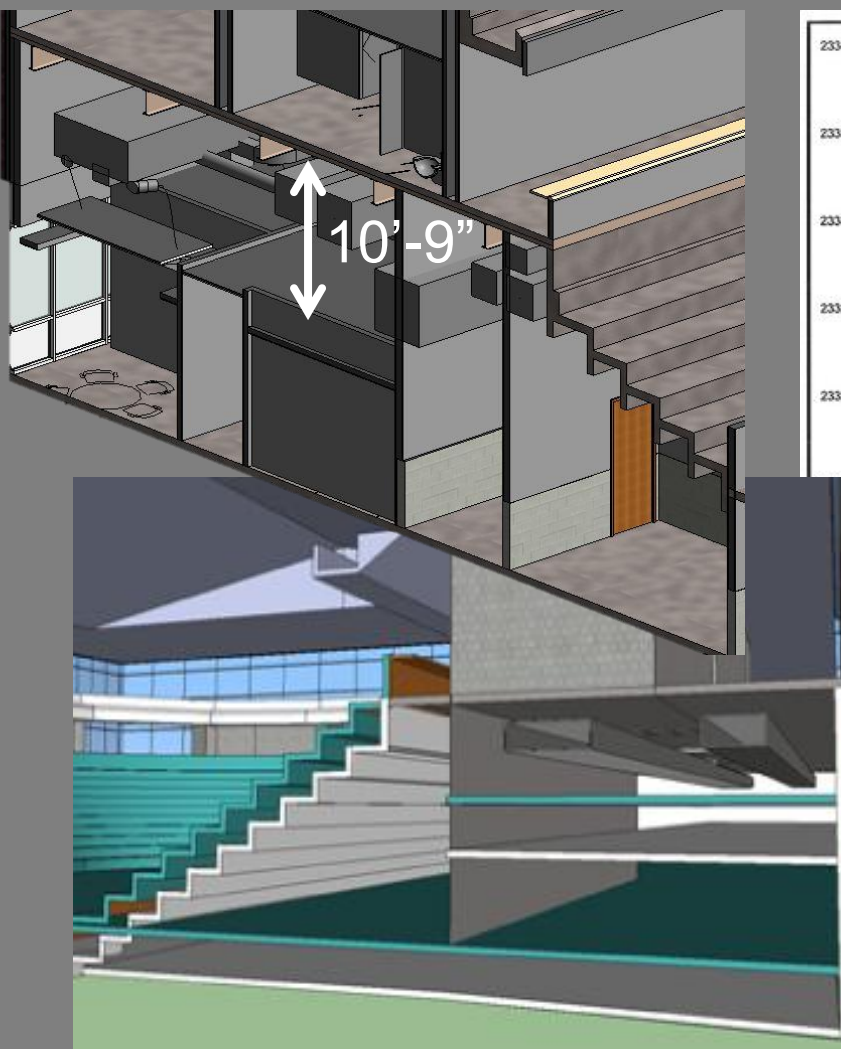


13.5 days

11.5 days



### Primary Goal: Cost Savings



### Primary Goal: Code Compliance



#### 2009 International Building Code (IBC)

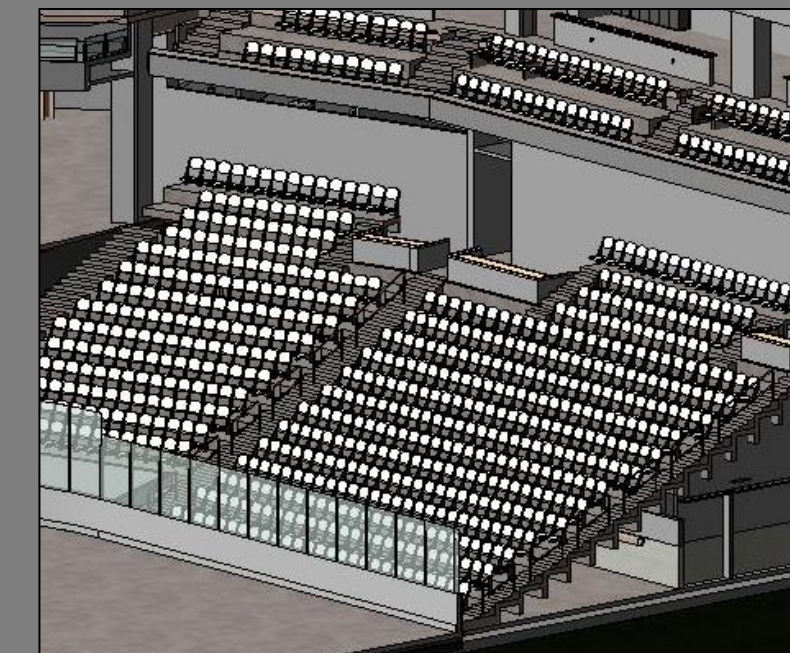
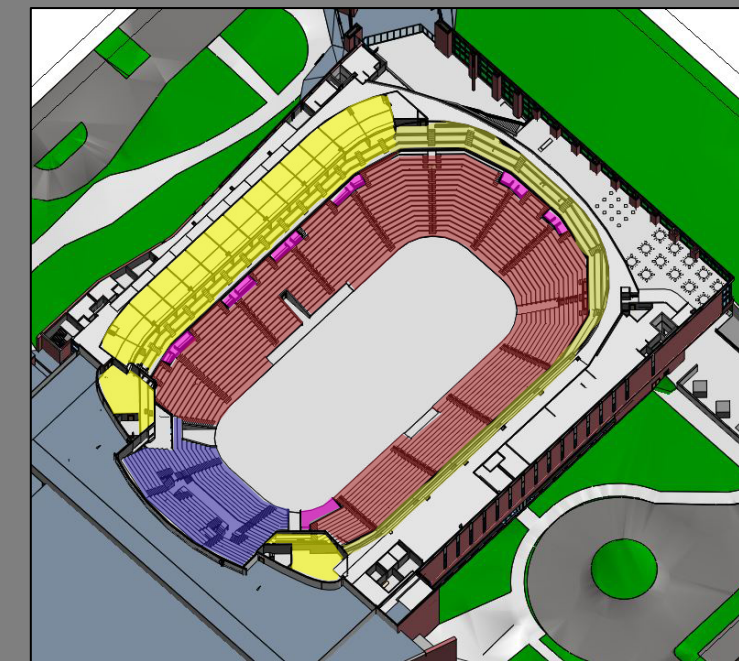
- Egress
- Head Clearances
- ADA Accessible Spaces



#### 2010 ADA Standards for Accessible Design

- Ramp Slope
- Minimum Turn Space
- Side & Front Reaches
- Sight Lines

### Secondary Goal: Business Model



PROPOSED PRICE POINTS:			
<span style="color: red;">■</span> General Admission	<b>+/- 5%</b>	3977	seats
<span style="color: blue;">■</span> General Admission - Students		1046	seats
<span style="color: orange;">■</span> Club Level		695	seats
<span style="color: green;">■</span> Suite		279	seats





Opportunity

Goal

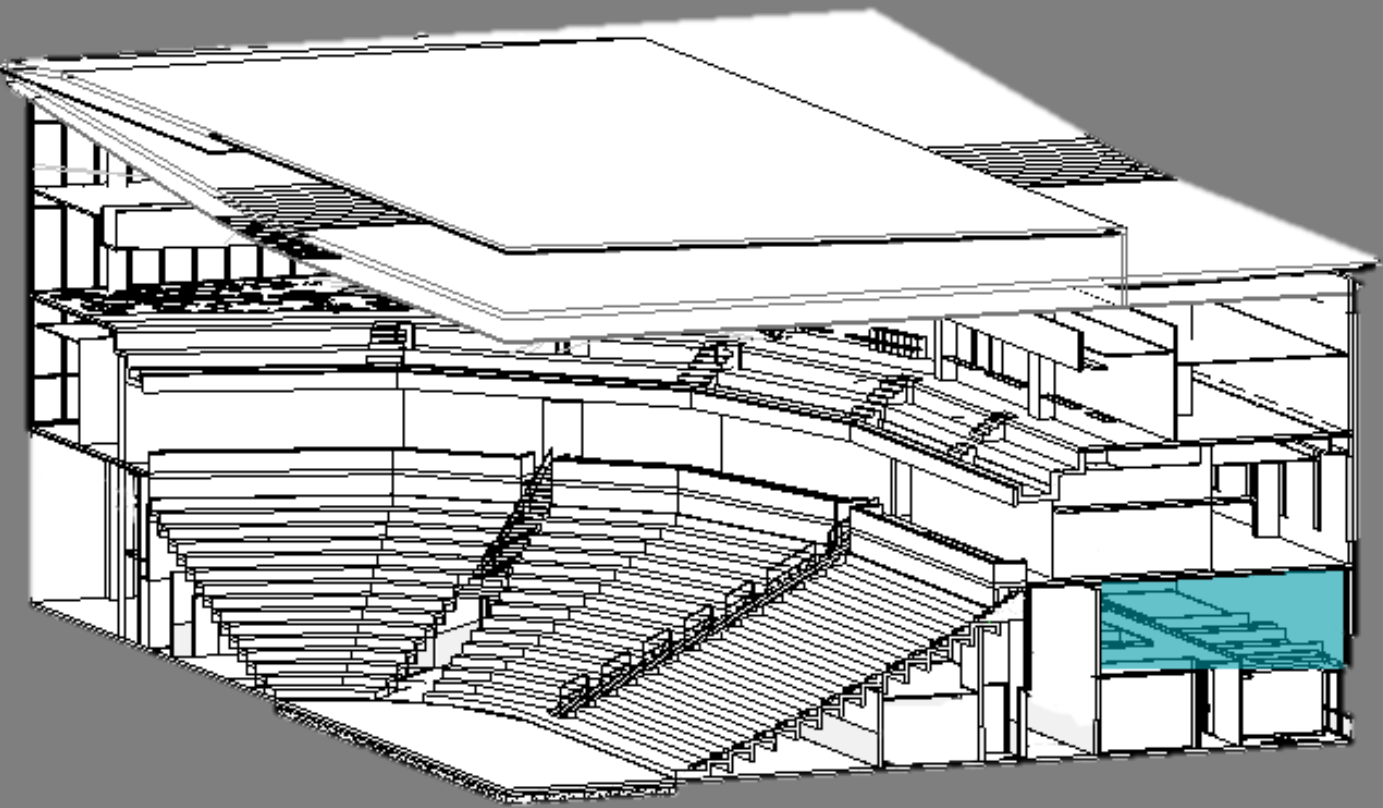
Strategy

Process

Results

# Driving Factor

**OK**







Opportunity

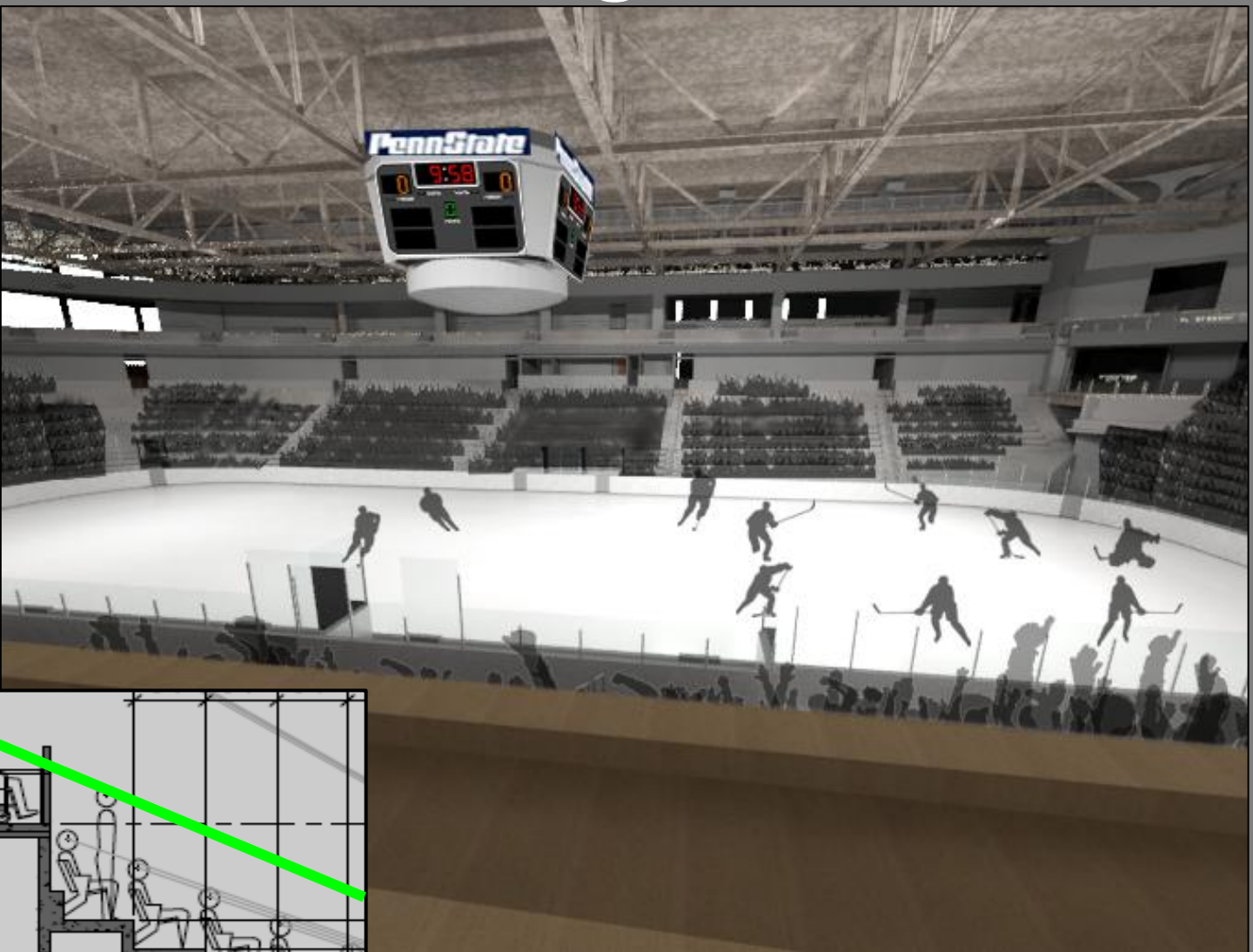
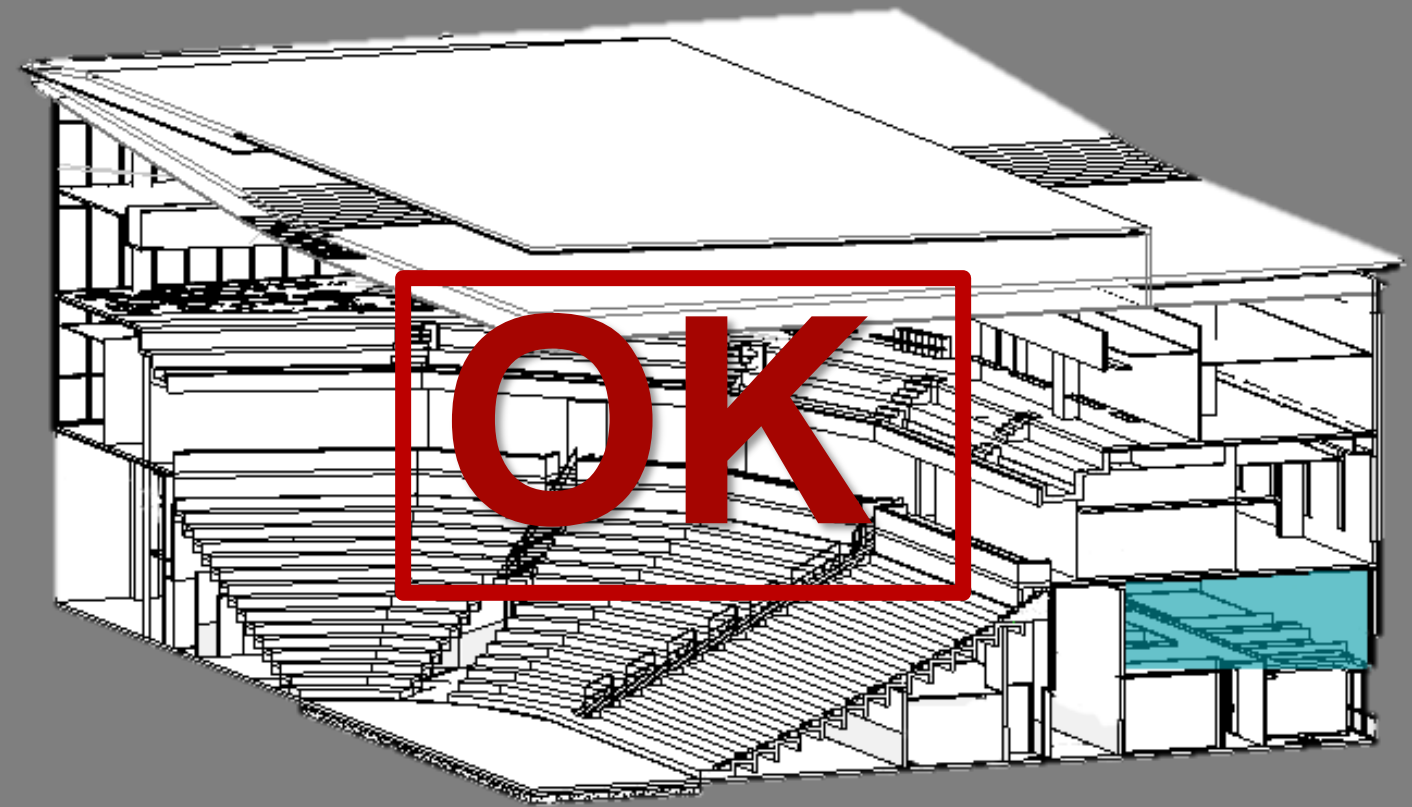
Goal

Strategy

Process

Results

# Driving Factor







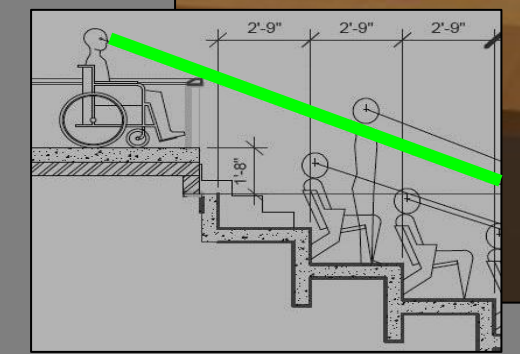
Opportunity

Goal

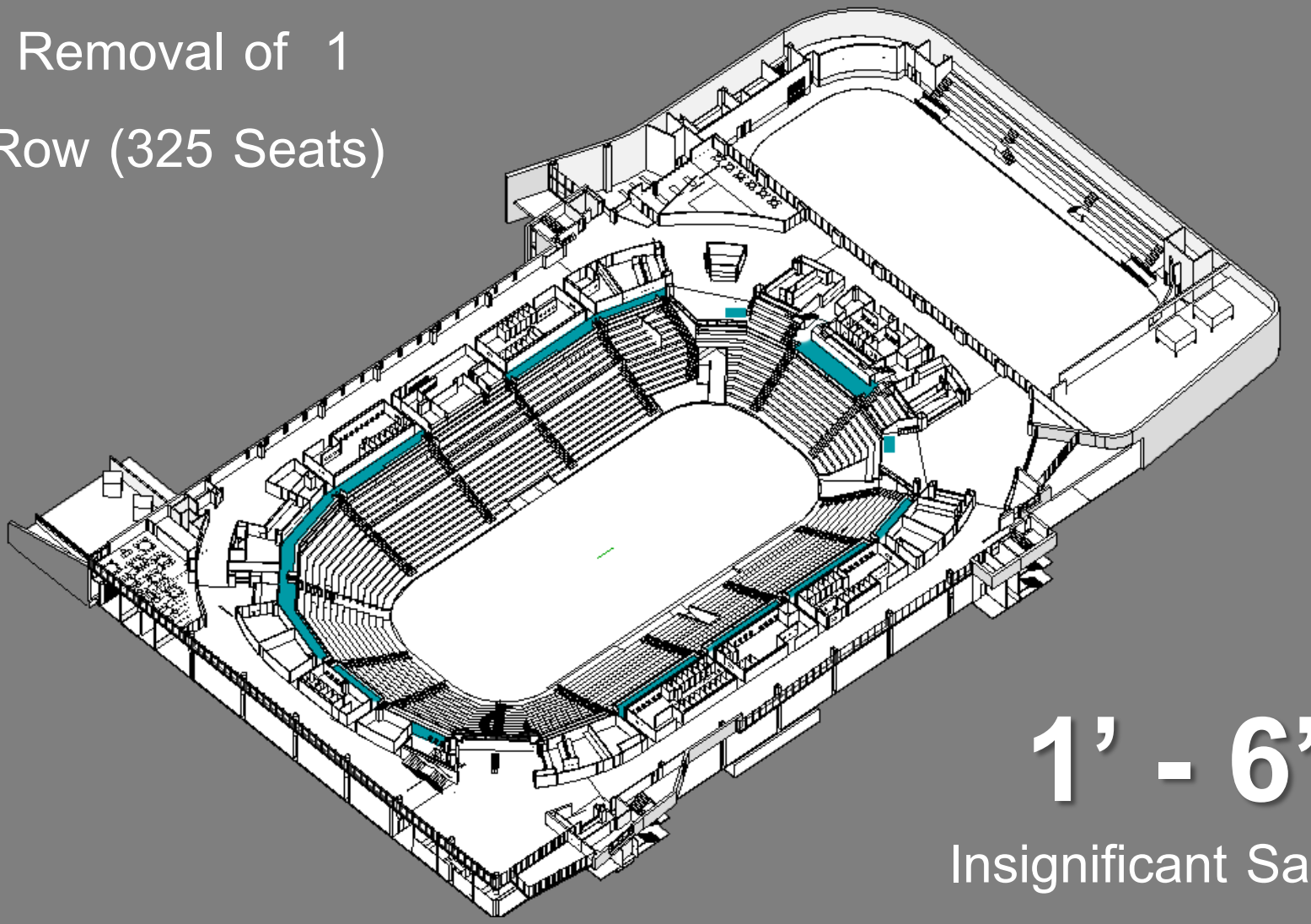
Strategy

Process

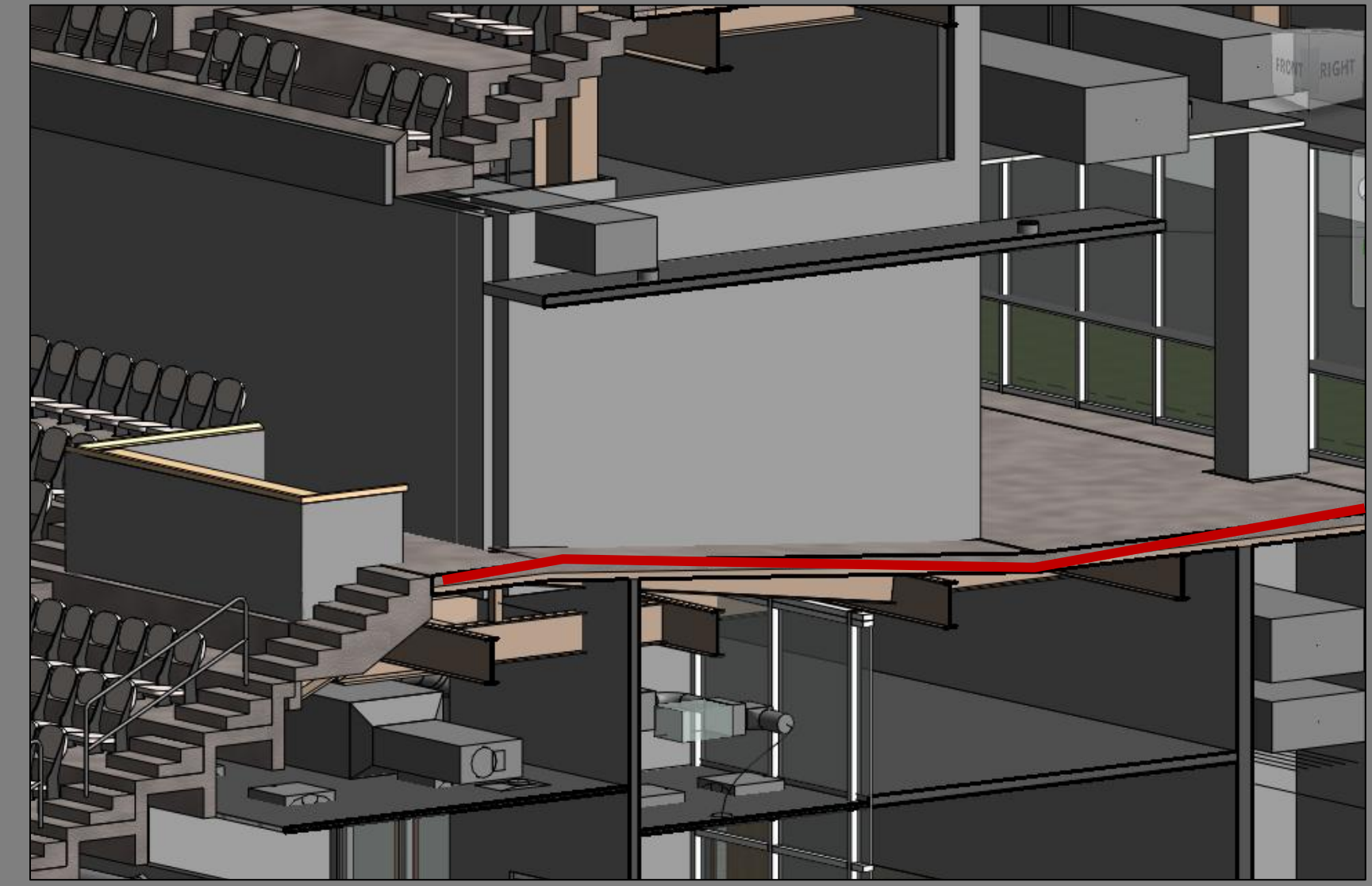
Results



Removal of 1 Row (325 Seats)



1' - 6" Insignificant Savings







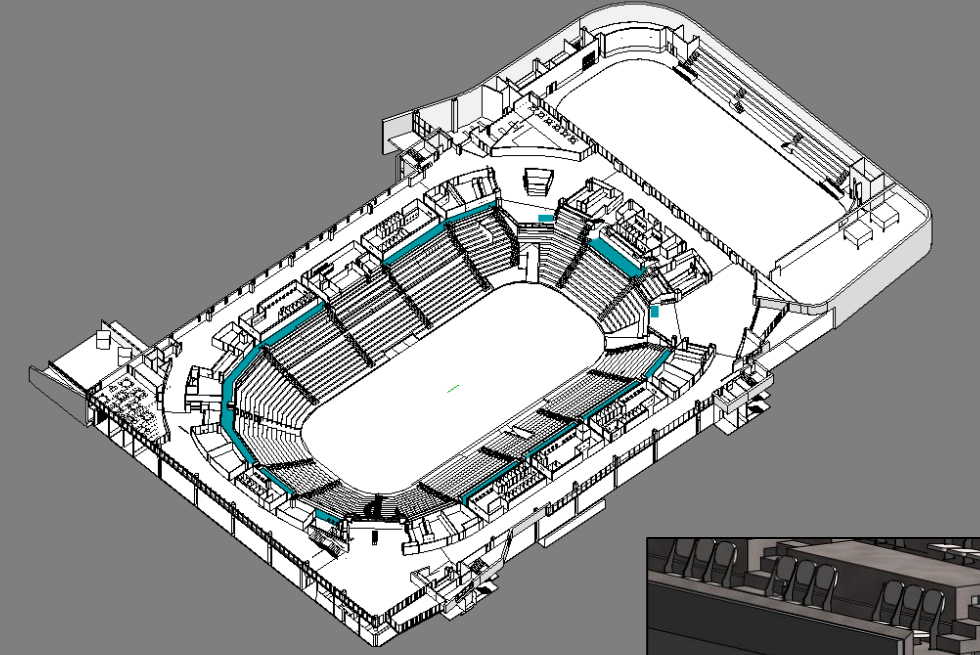
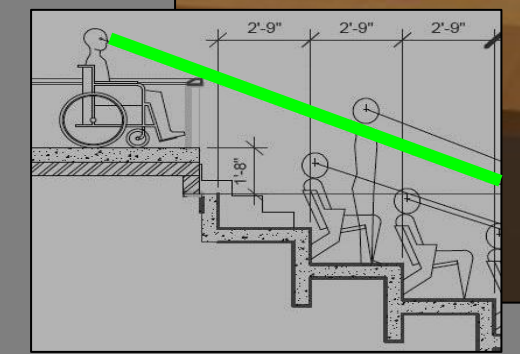
Opportunity

Goal

Strategy

Process

Results



# 3'-2"

- Excavation/ Back Fill **\$312.9K**
- Foundation Walls **\$162.4K**
- Event level Interior Wall **\$122.7K**
- Concrete Columns **\$29.3K**

## \$627,314



PROJECT

PROCESS

SAVINGS

PROMINENCE

FUNCTION

REFLECTION



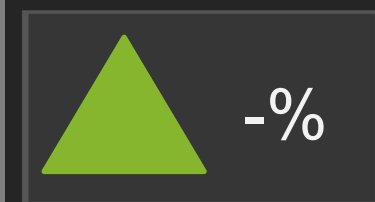
Opportunity

Goal

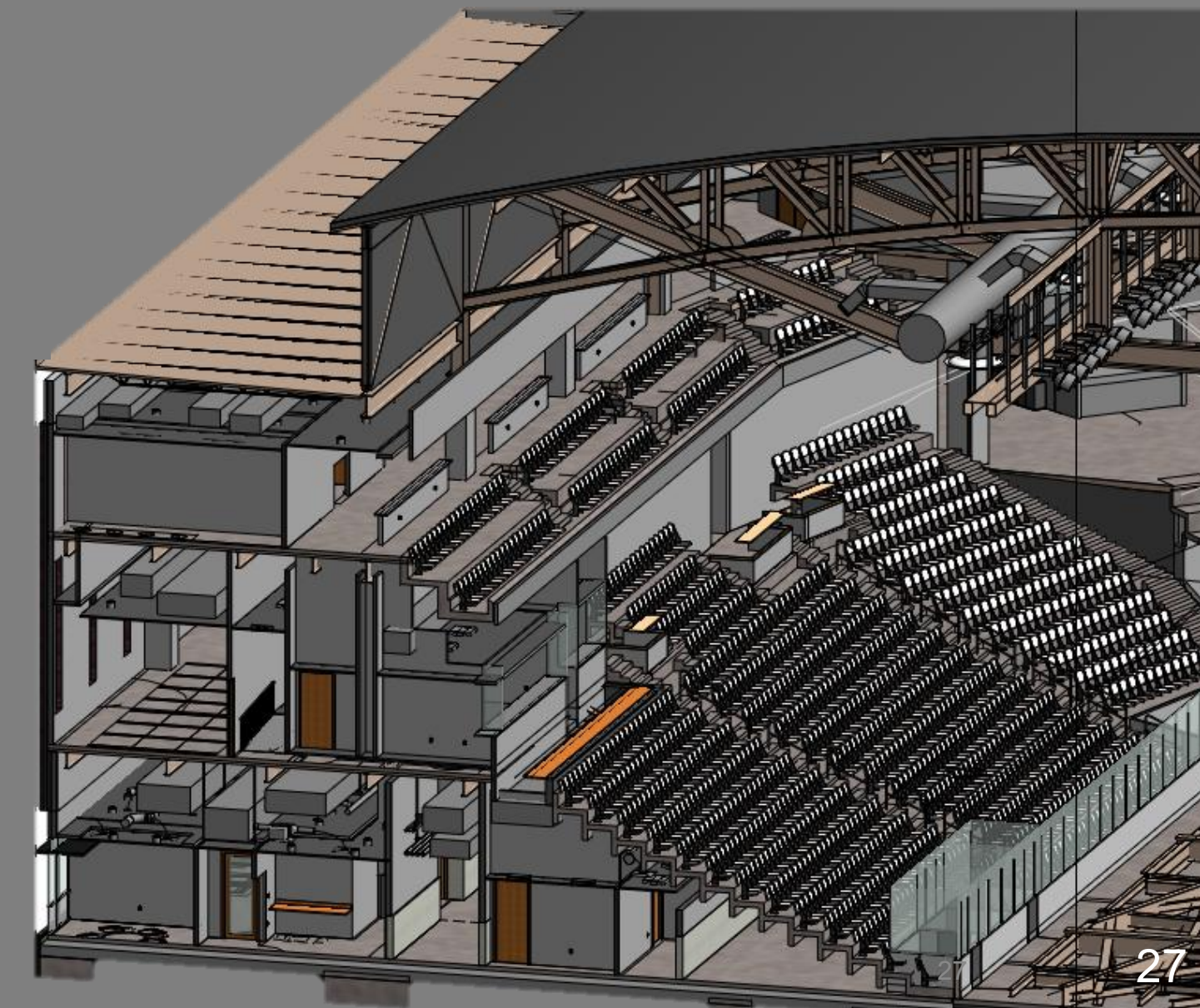
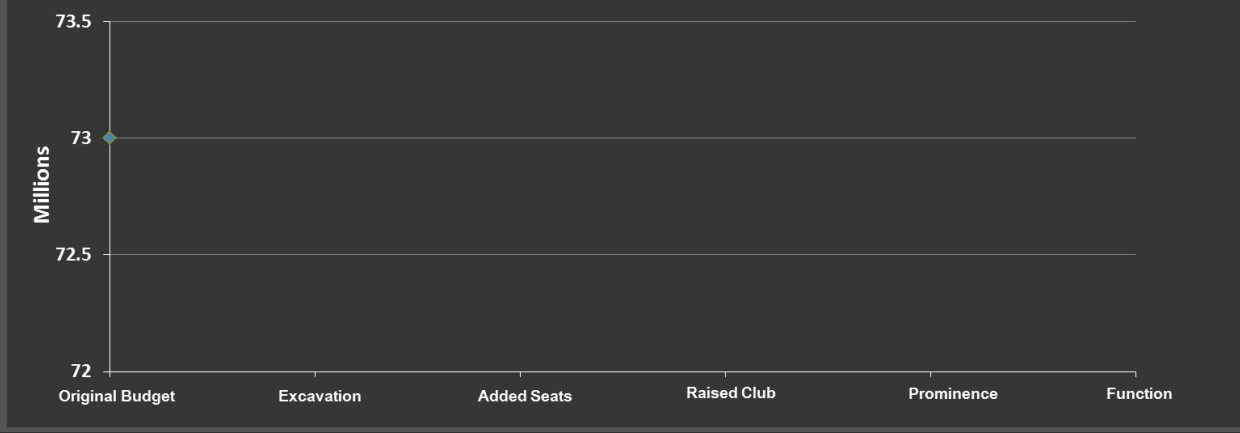
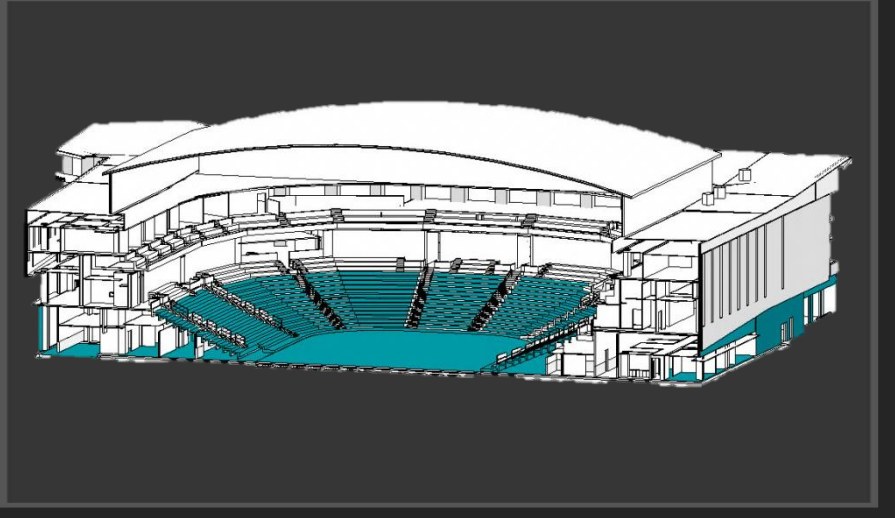
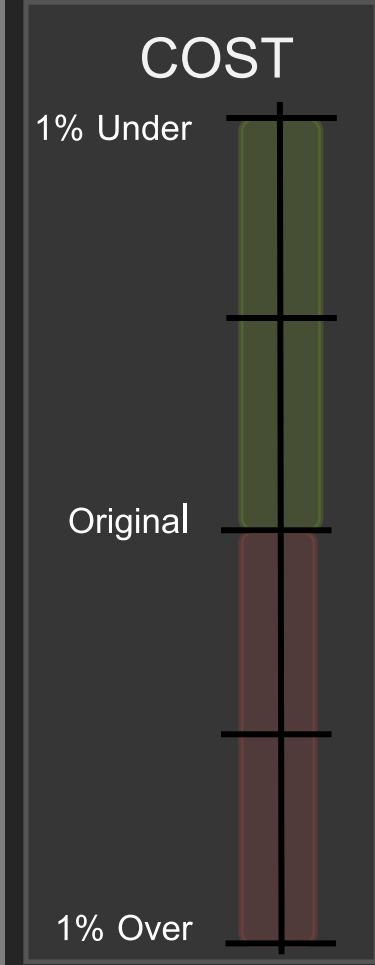
Strategy

Process

Results



HPR dash board







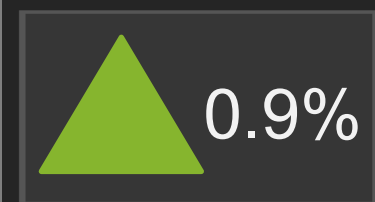
Opportunity

Goal

Strategy

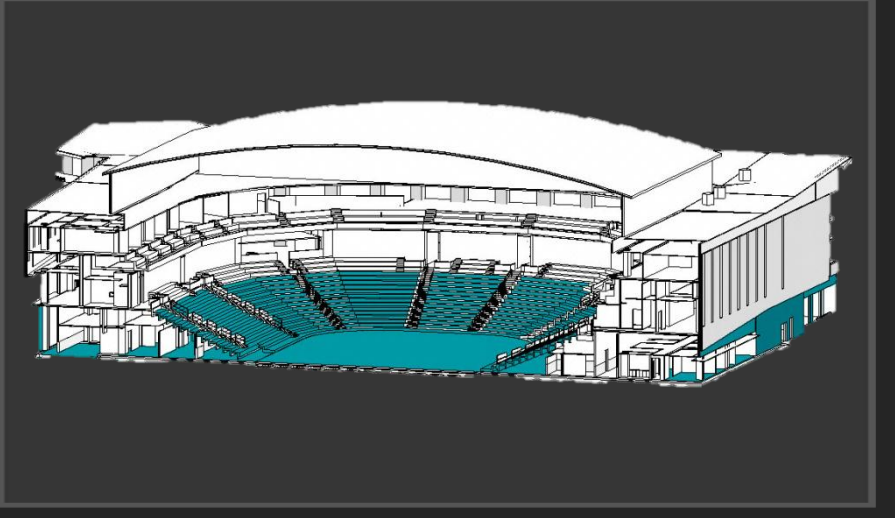
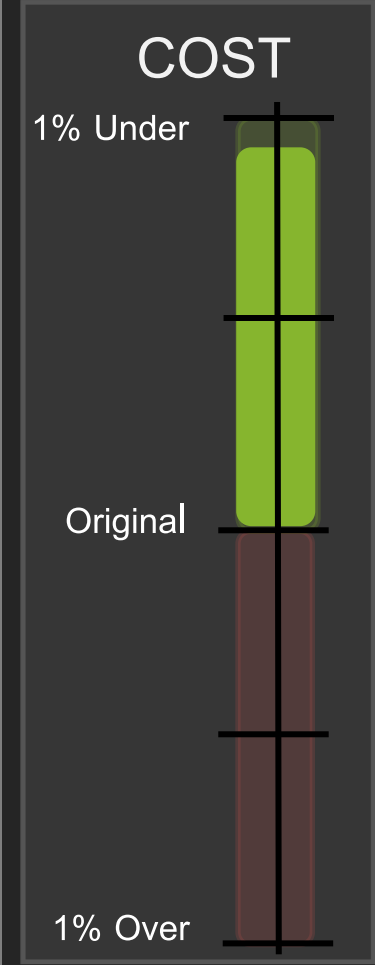
Process

Results



**HPR dash board**

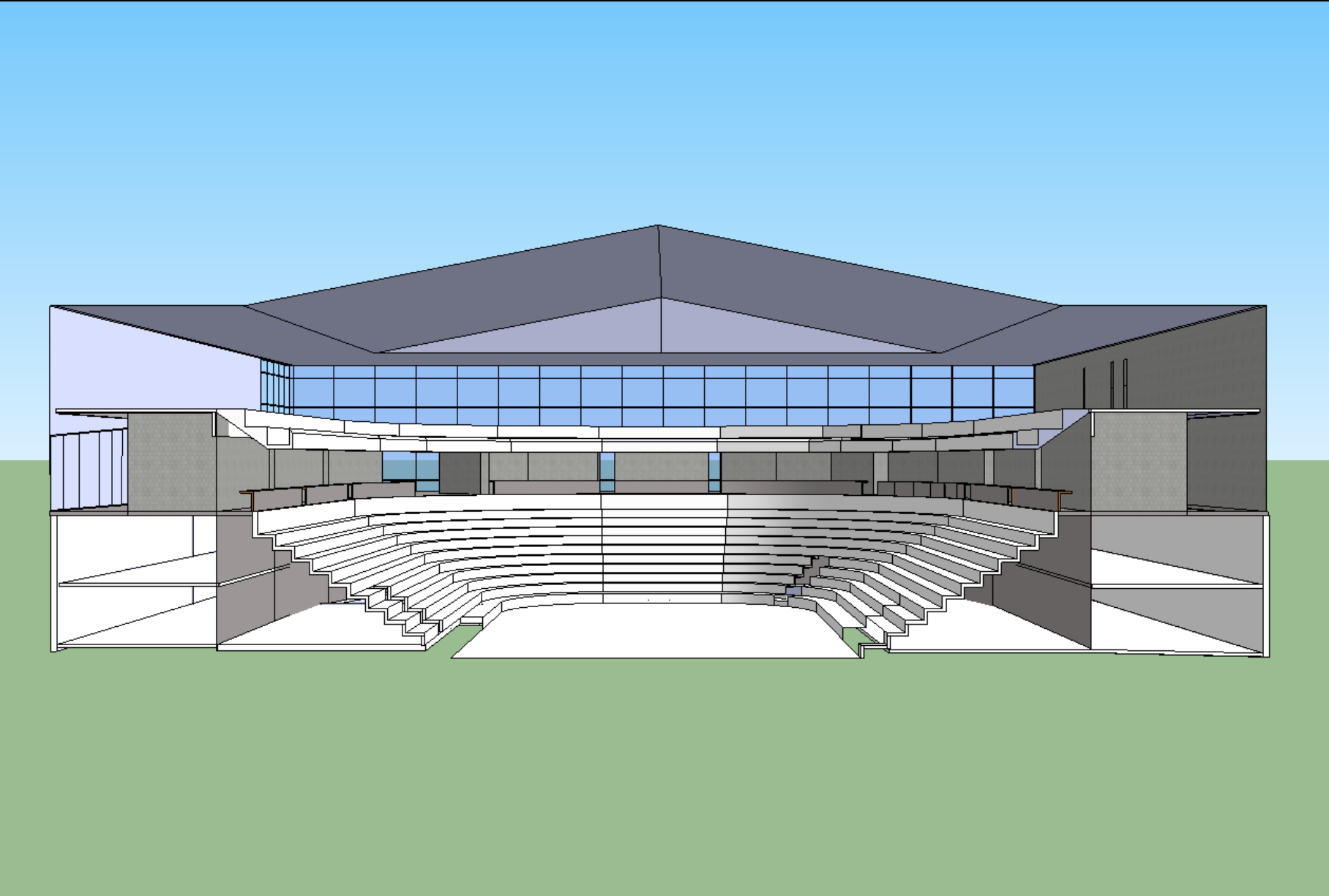
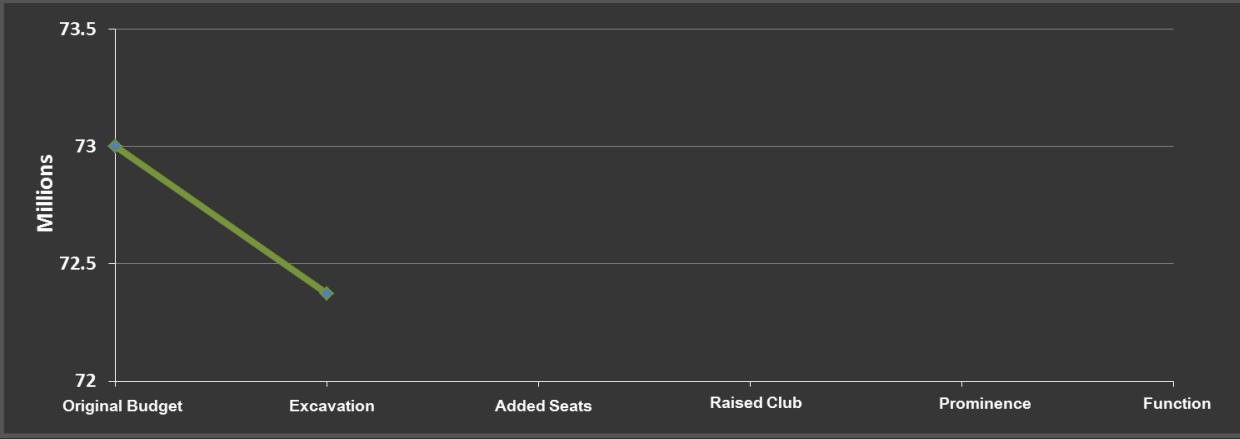
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**SEATS**

Proposed  
**6,031**

BOD  
**6,031**



- Excavation/ Back Fill **\$312.9K**
  - Foundation Walls **\$162.4K**
  - Event level Interior Wall **\$122.7K**
  - Concrete Columns **\$29.3K**
- \$627,314**





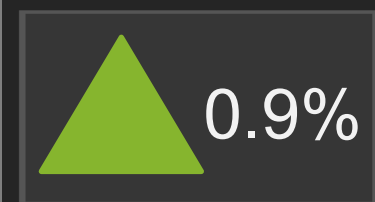
Opportunity

Goal

Strategy

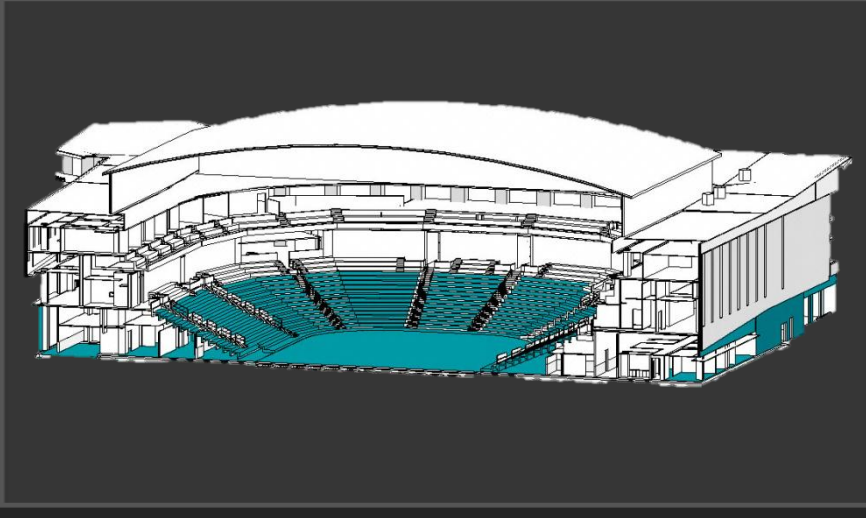
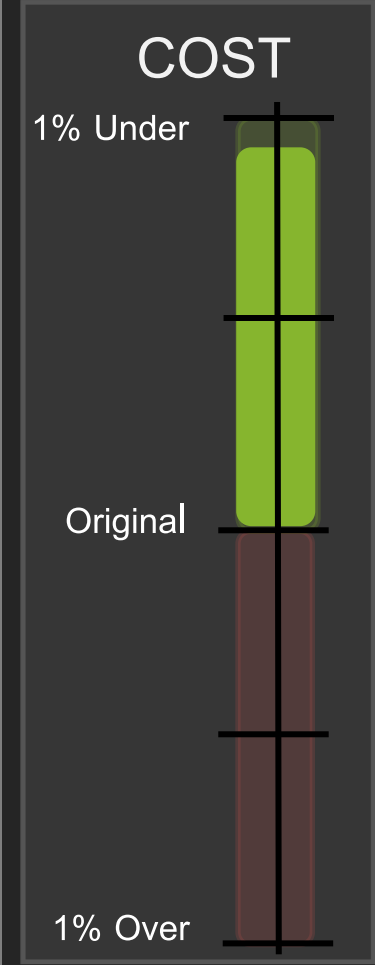
Process

Results



**HPR dash board**

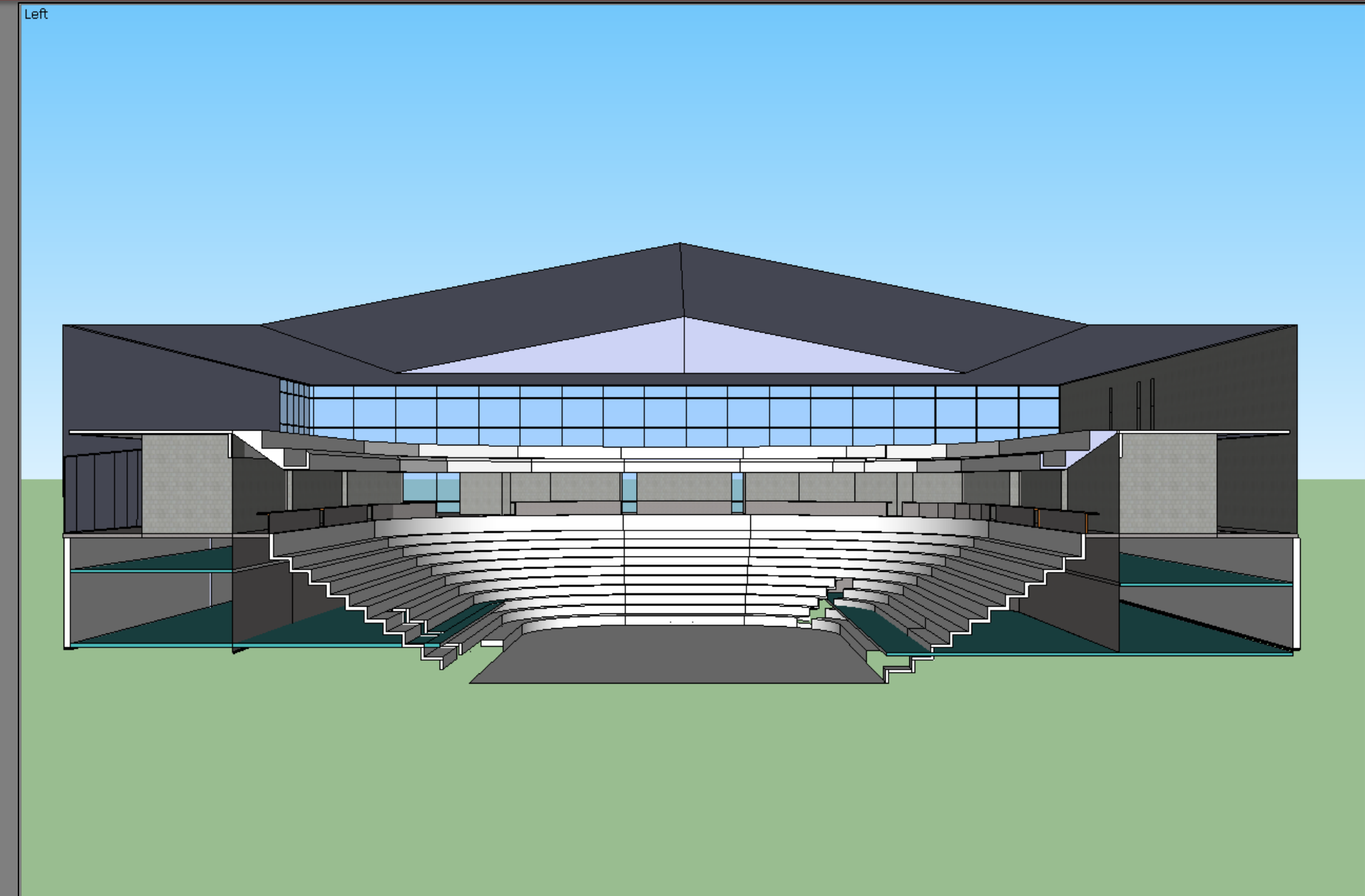
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**SEATS**

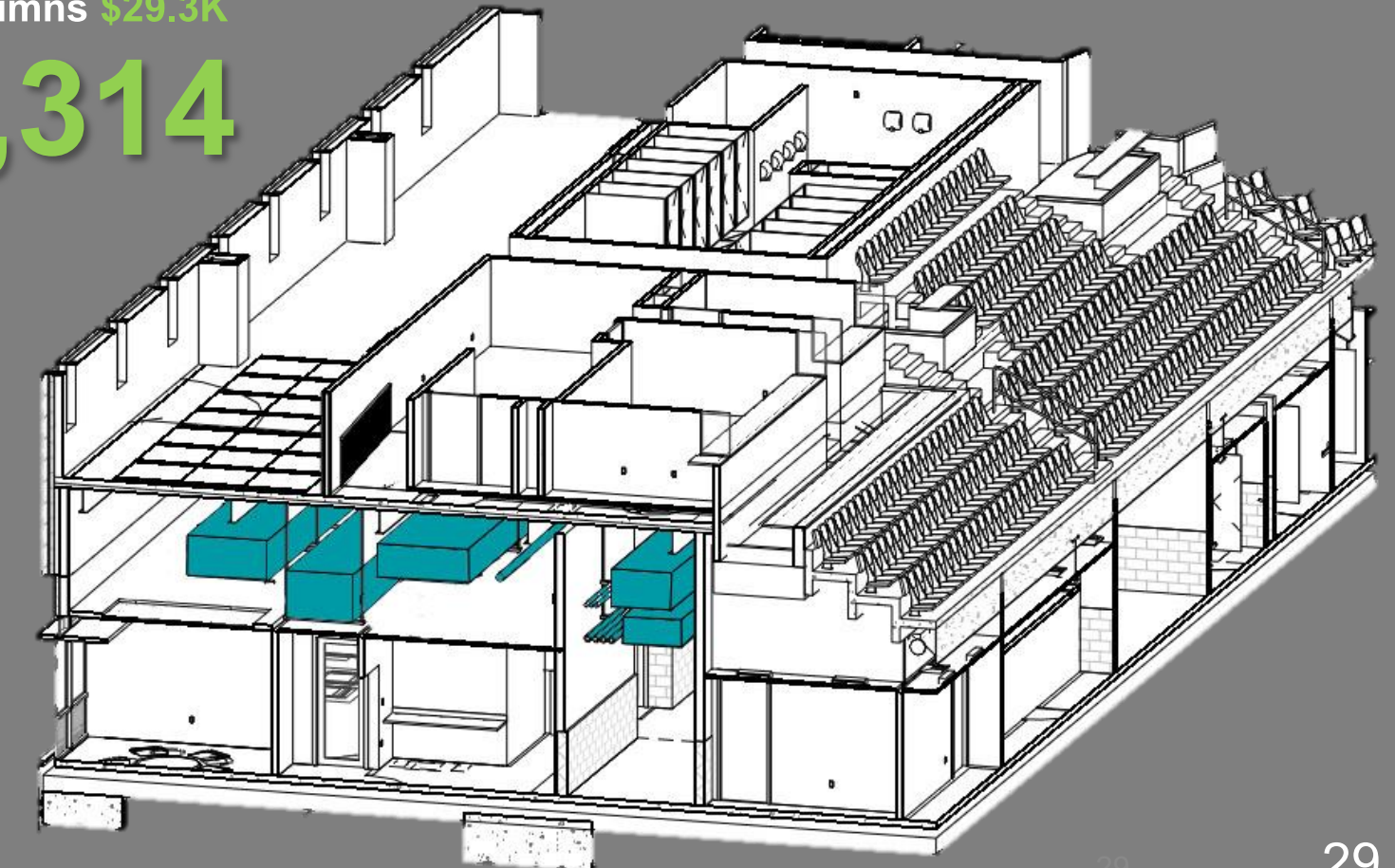
Proposed  
**6,031**

BOD  
**6,031**



- Excavation/ Back Fill **\$312.9K**
- Foundation Walls **\$162.4K**
- Event level Interior Wall **\$122.7K**
- Concrete Columns **\$29.3K**

**\$627,314**







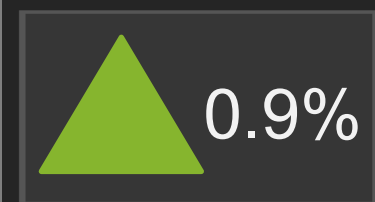
Opportunity

Goal

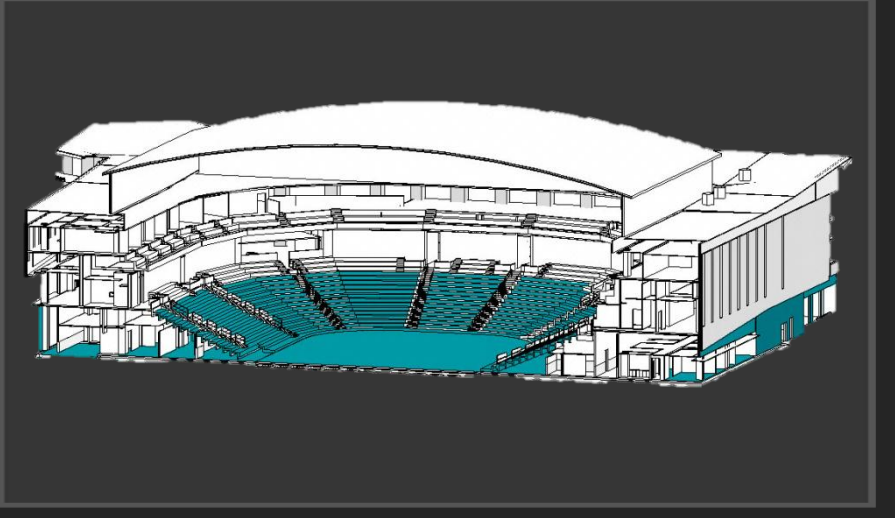
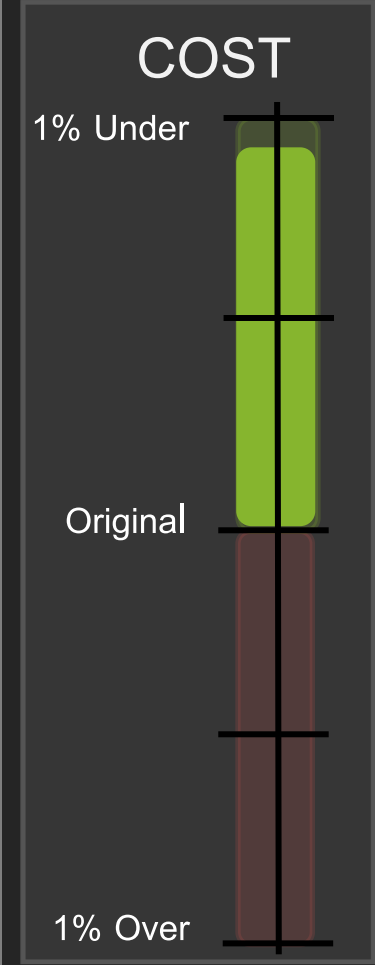
Strategy

Process

Results



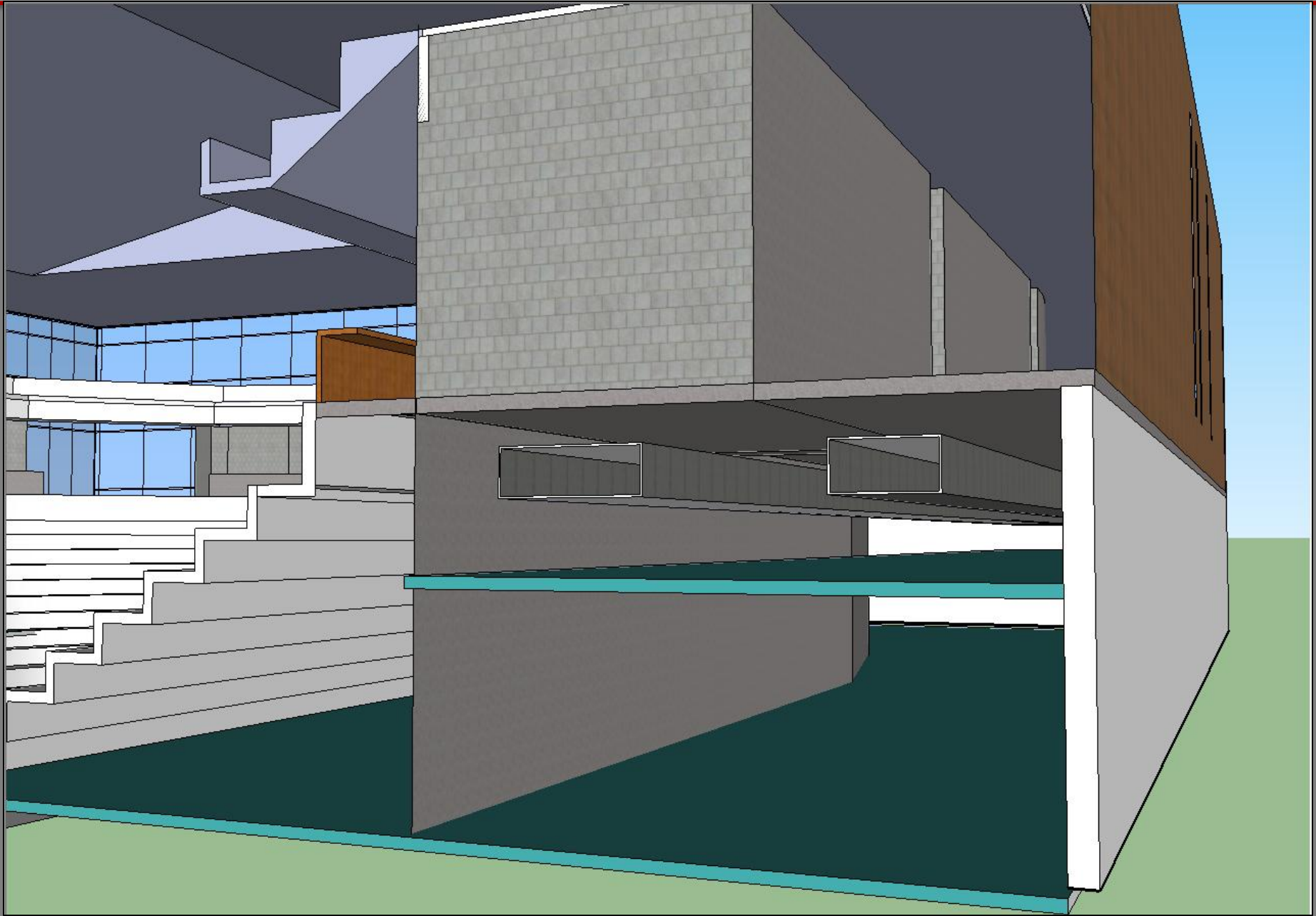
HPR dash board



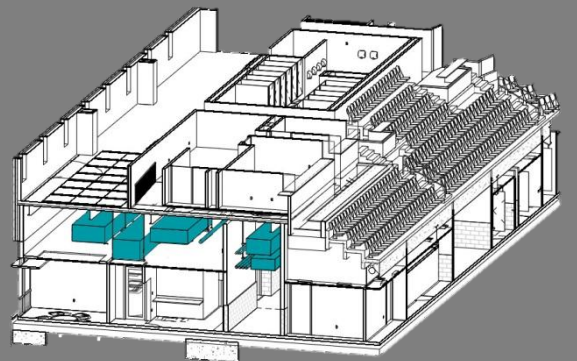
SEATS

Proposed  
**5,706**

BOD  
6,031



- Excavation/ Back Fill \$312.9K
  - Foundation Walls \$162.4K
  - Event level Interior Wall \$122.7K
  - Concrete Columns \$29.3K
- \$627,314**







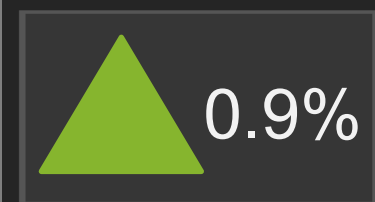
Opportunity

Goal

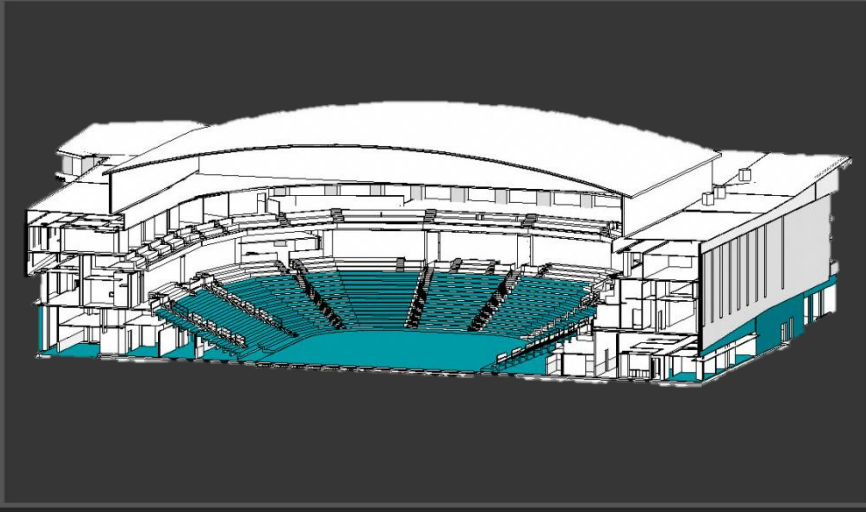
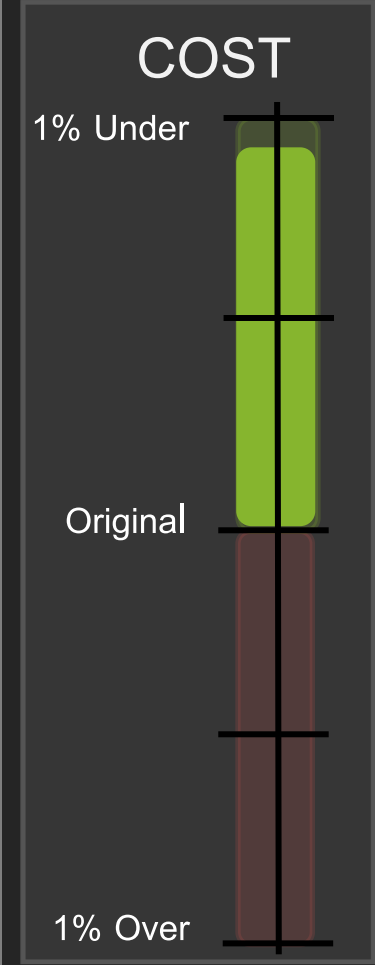
Strategy

Process

Results



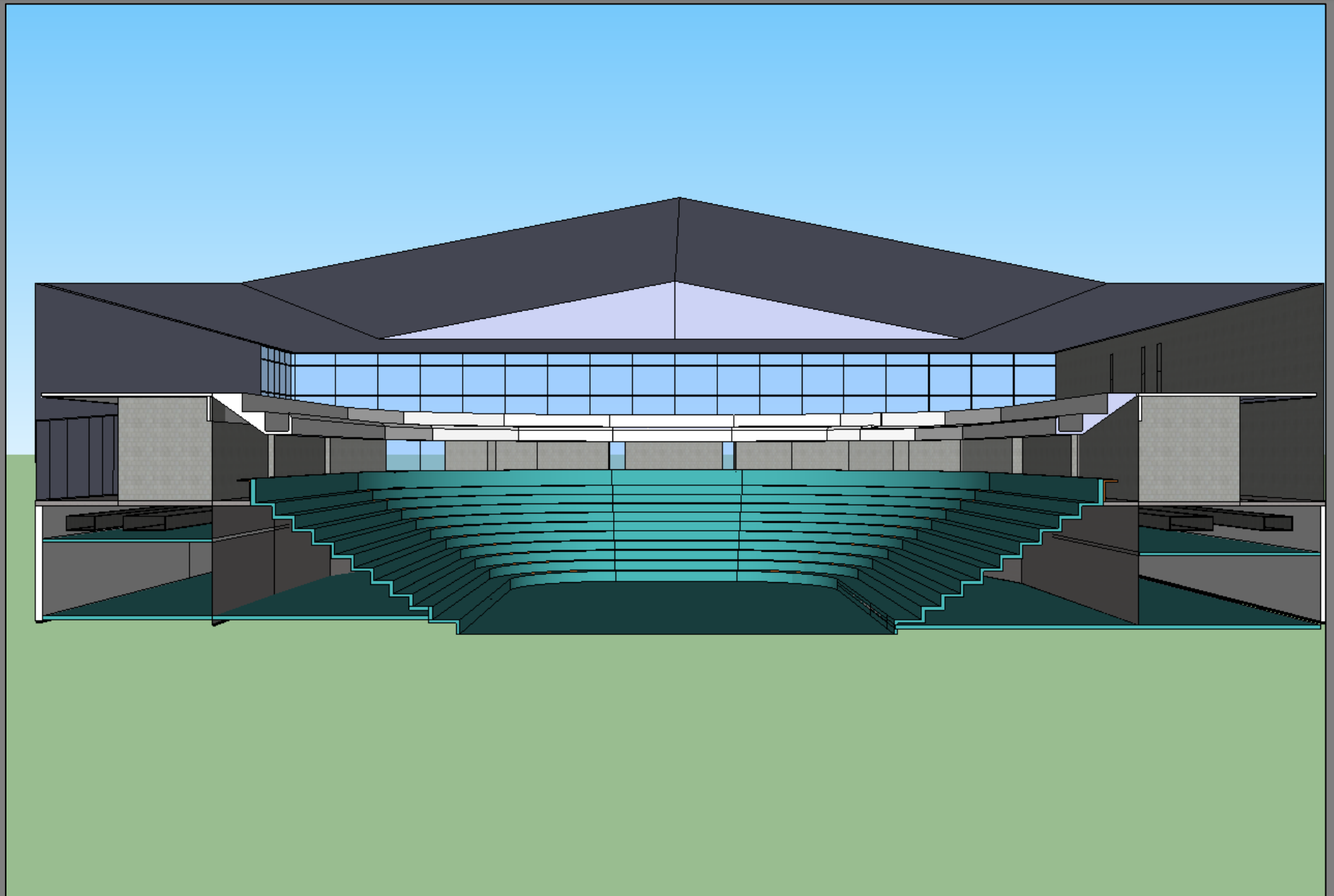
**HPR dash board**



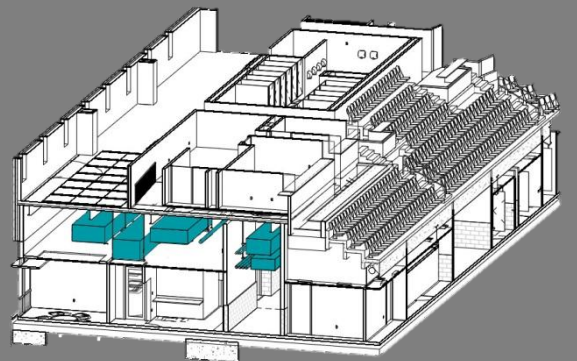
**SEATS**

Proposed  
**5,706**

BOD  
**6,031**



- Excavation/ Back Fill **\$312.9K**
  - Foundation Walls **\$162.4K**
  - Event level Interior Wall **\$122.7K**
  - Concrete Columns **\$29.3K**
- \$627,314**







Opportunity

Goal

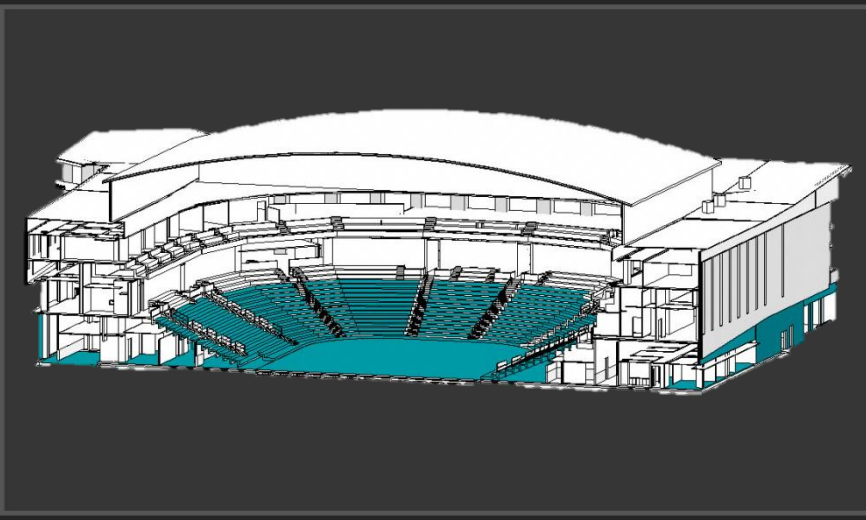
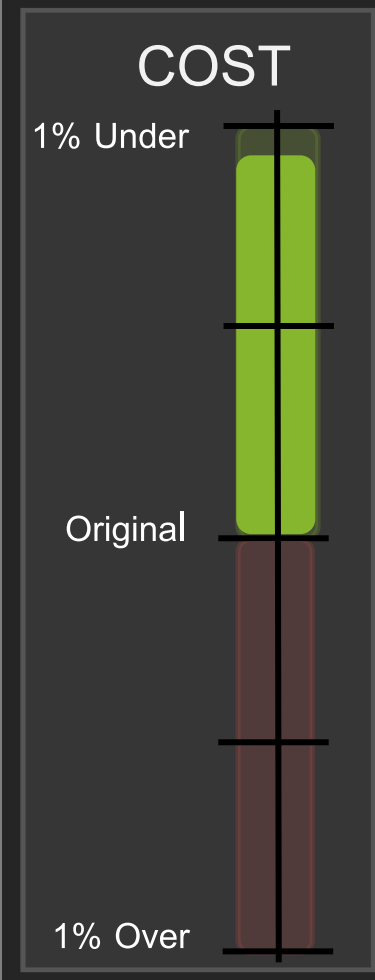
Strategy

Process

Results



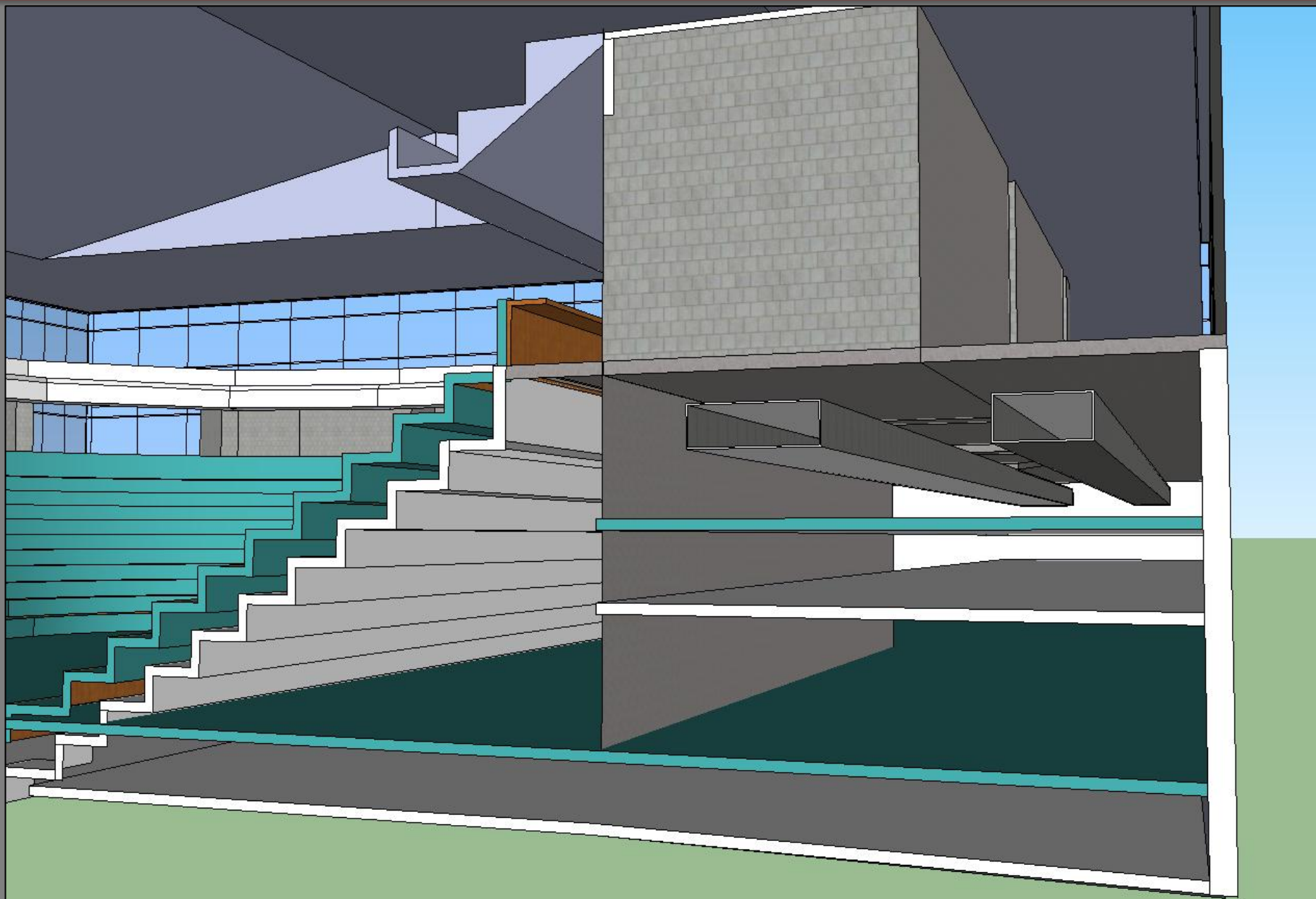
HPR dash board



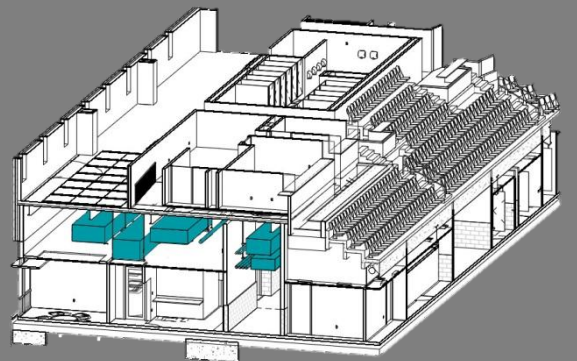
SEATS

Proposed  
**5,706**

BOD  
6,031



- Excavation/ Back Fill \$312.9K
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  - Event level Interior Wall \$122.7K
  - Concrete Columns \$29.3K
- \$627,314**







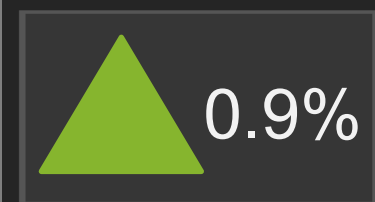
Opportunity

Goal

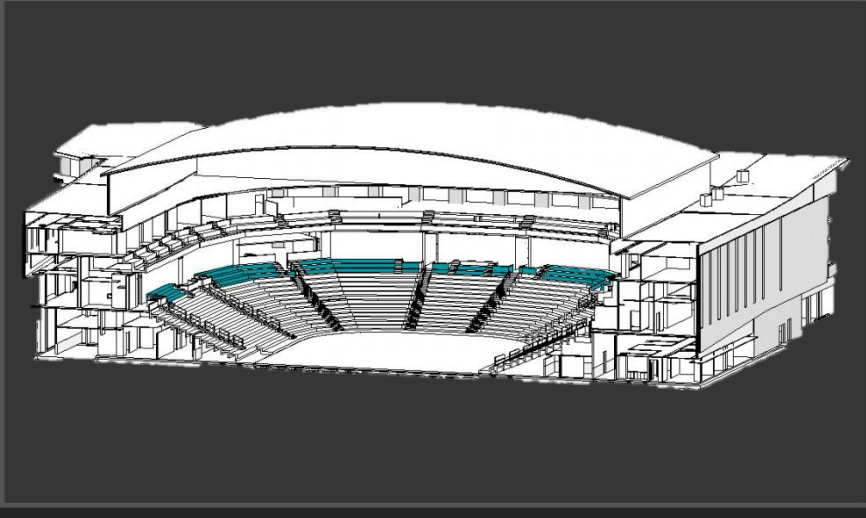
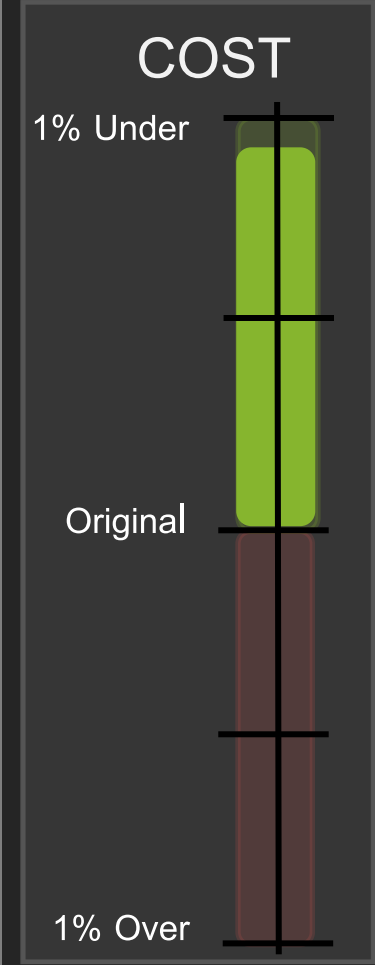
Strategy

Process

Results



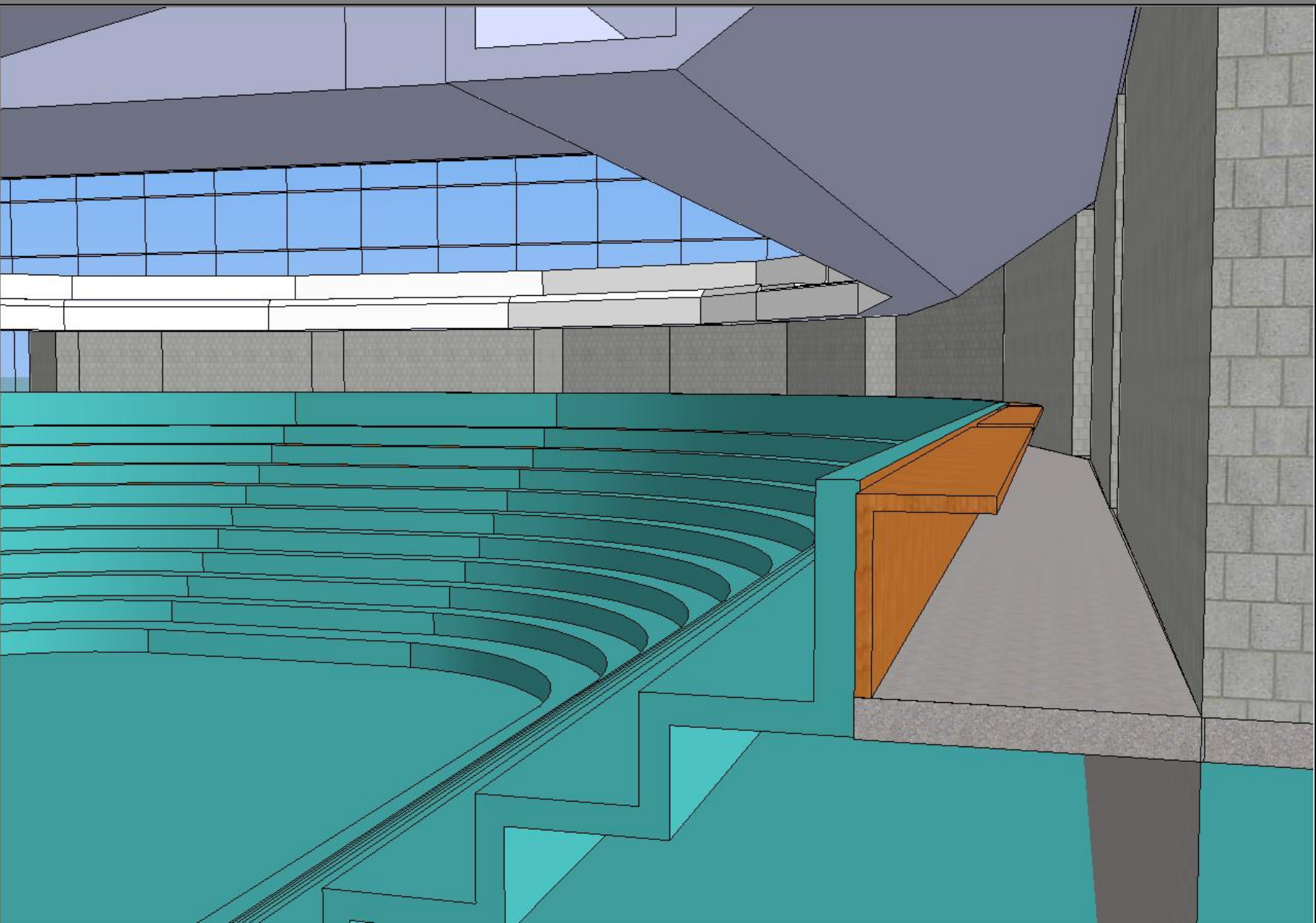
**HPR dash board**



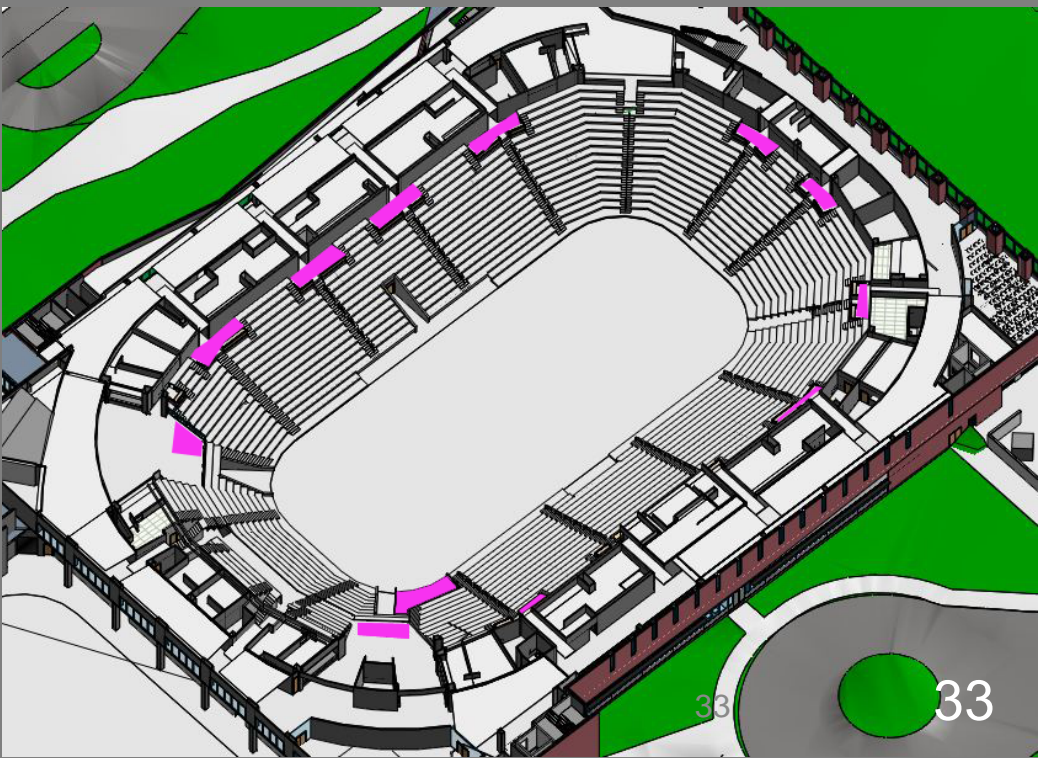
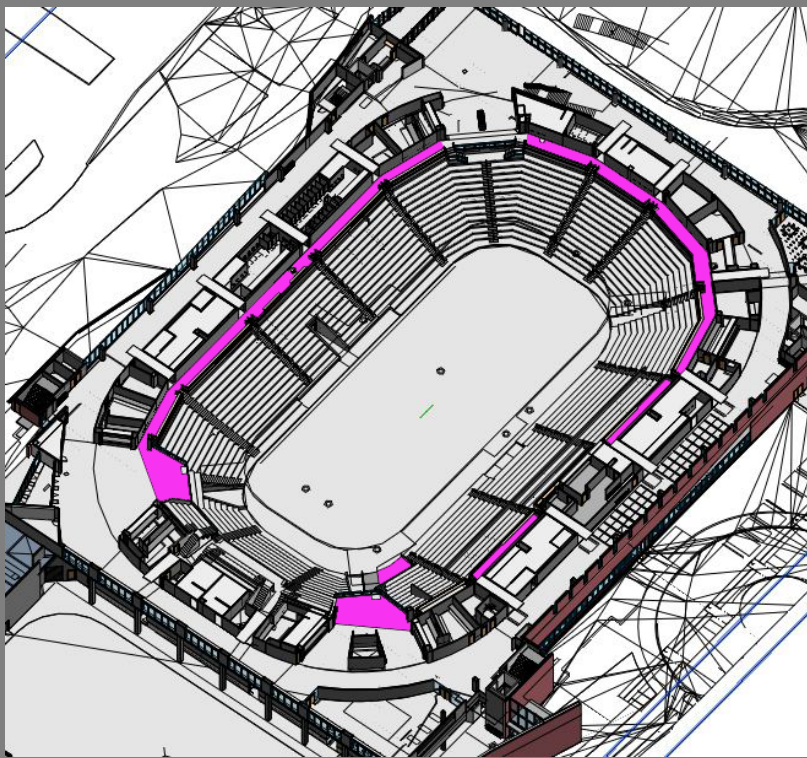
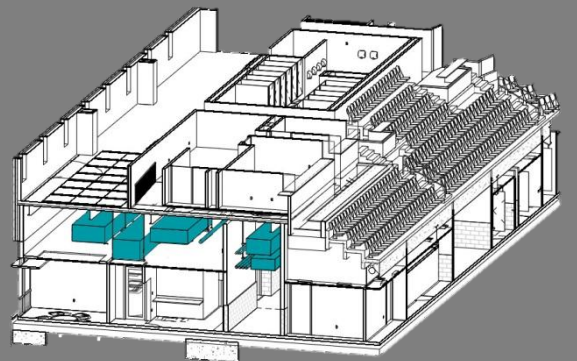
**SEATS**

Proposed  
**5,672**

BOD  
6,031



- Excavation/ Back Fill **\$312.9K**
  - Foundation Walls **\$162.4K**
  - Event level Interior Wall **\$122.7K**
  - Concrete Columns **\$29.3K**
- \$627,314**







Opportunity

Goal

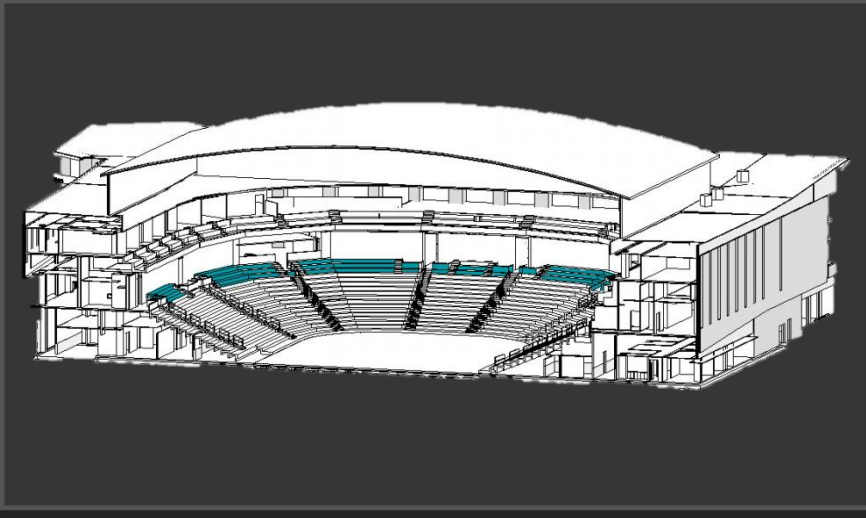
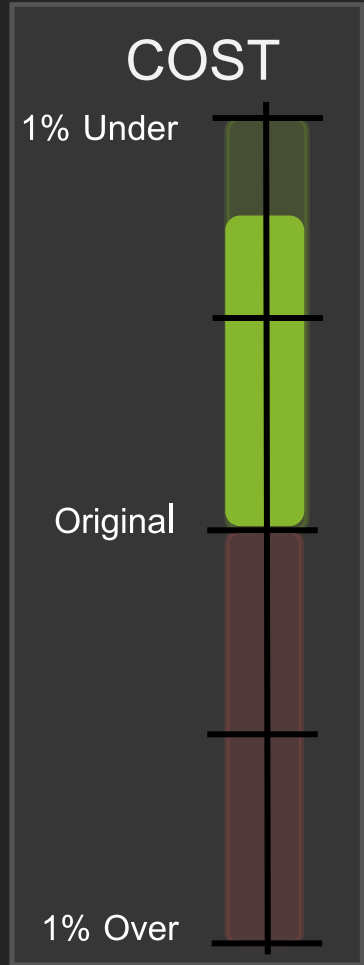
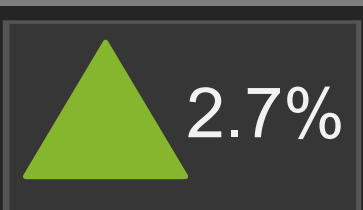
Strategy

Process

Results



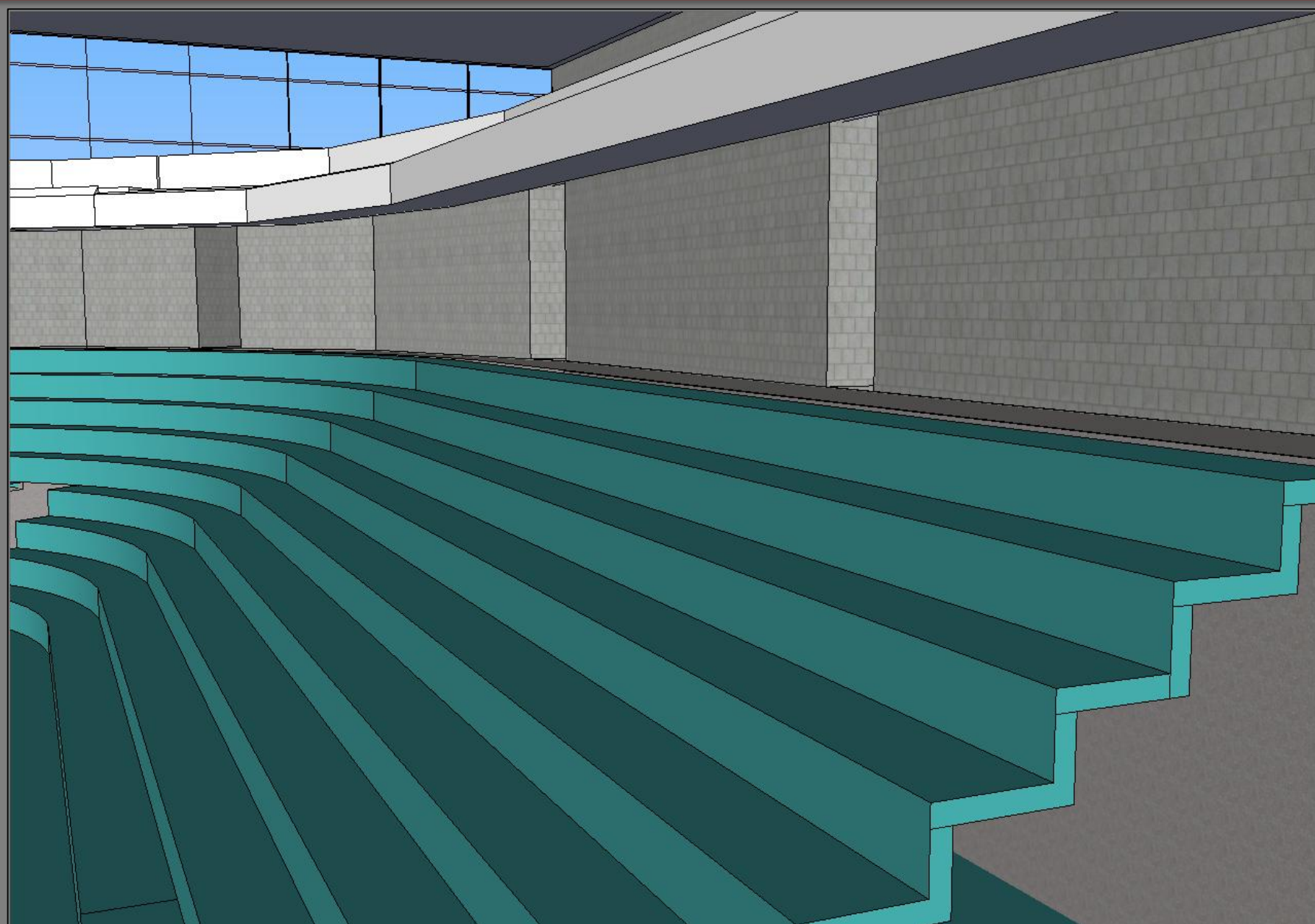
HPR dash board



SEATS

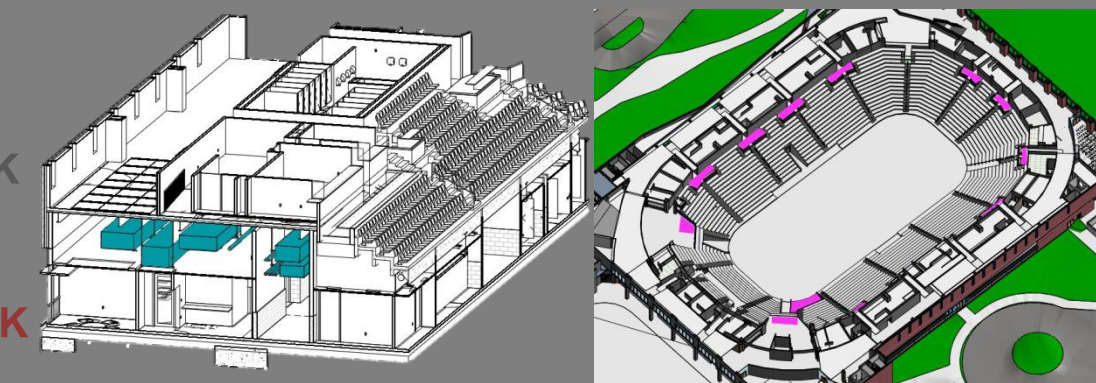
Proposed  
**6,185**

BOD  
**6,031**



- Excavation/ Back Fill \$312.9K
- Foundation Walls \$162.4K
- Event level Interior Wall \$122.7K
- Concrete Columns \$29.3K
- Main Arena Added Stadia **\$25.3K**
- Main Arena Added Seats **\$16.6K**
- Main Arena Steps **\$5.5K**
- Steel Beams & Conc. Footings **\$29.8K**

**\$561,126**







Opportunity

Goal

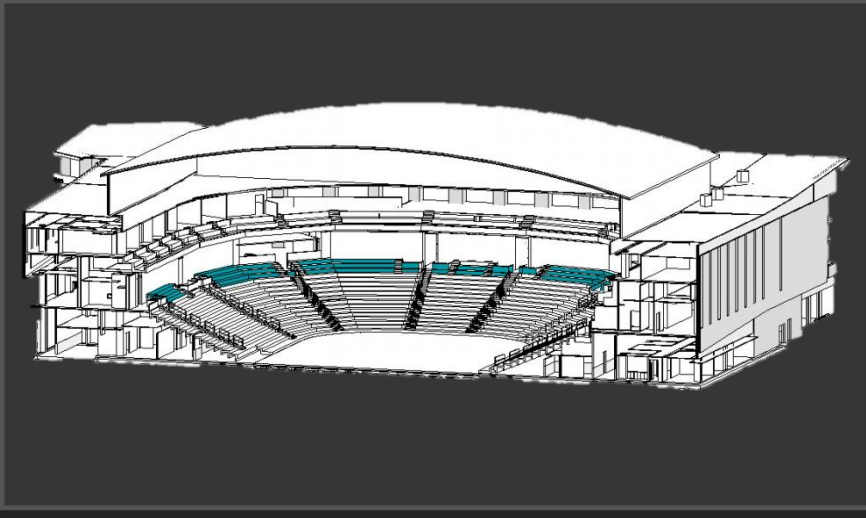
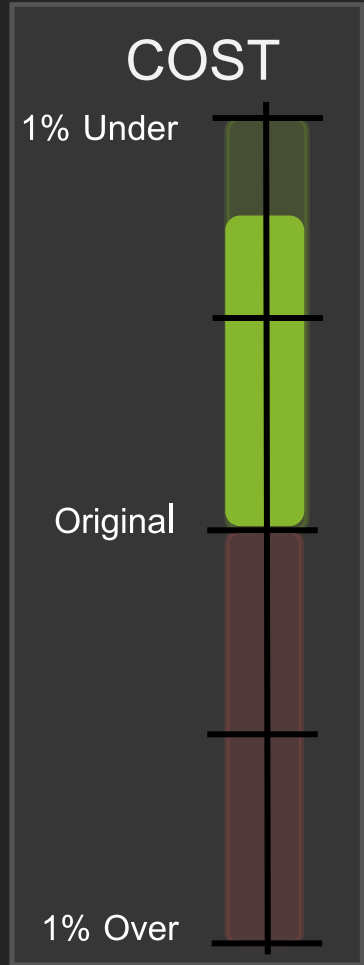
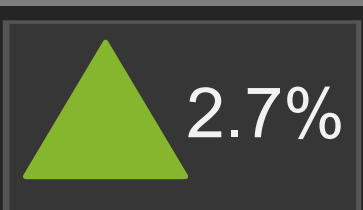
Strategy

Process

Results



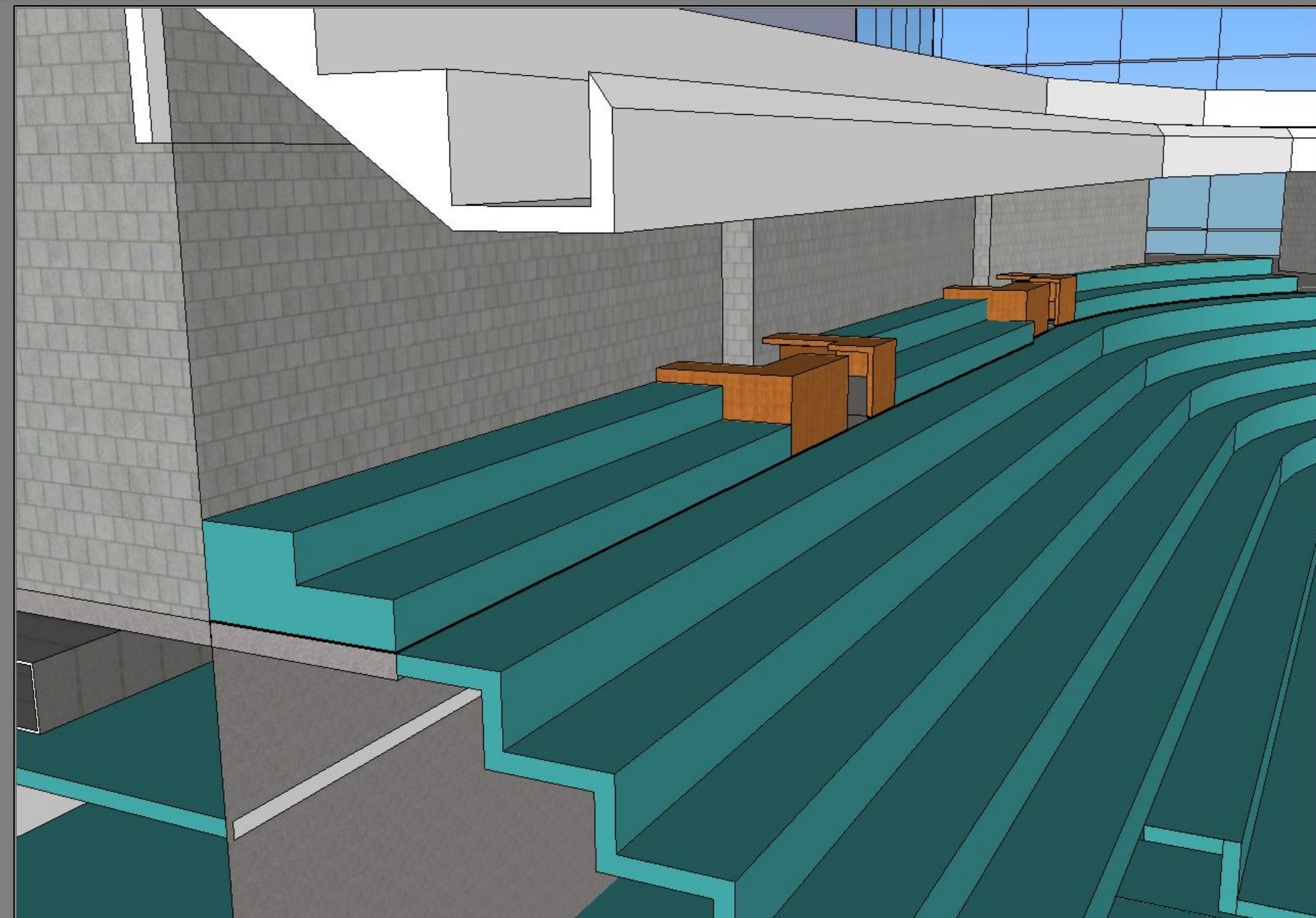
HPR dash board



SEATS

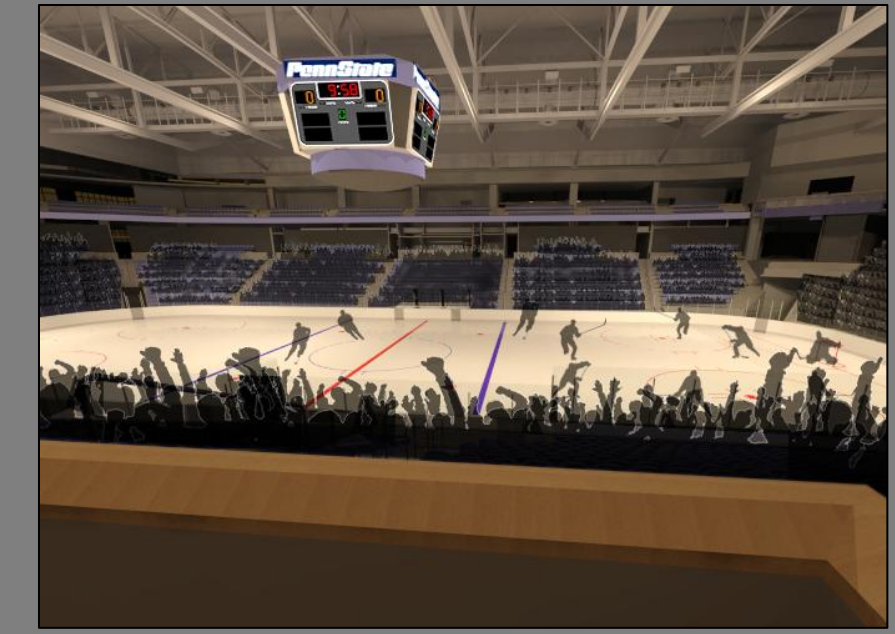
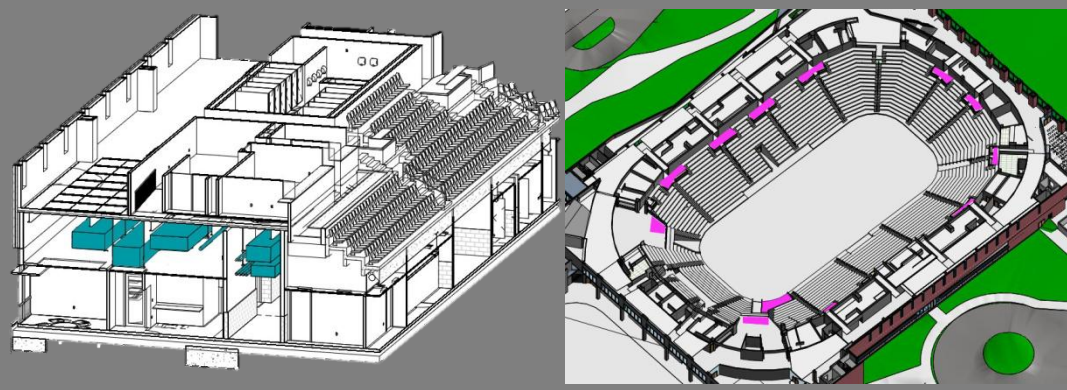
Proposed  
**6,185**

BOD  
6,031



- Excavation/ Back Fill \$312.9K
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- Main Arena Added Seats **\$16.6K**
- Main Arena Steps **\$5.5K**
- Steel Beams & Conc. Footings **\$29.8K**

**\$561,126**







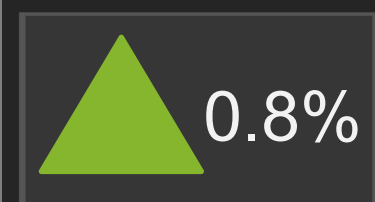
Opportunity

Goal

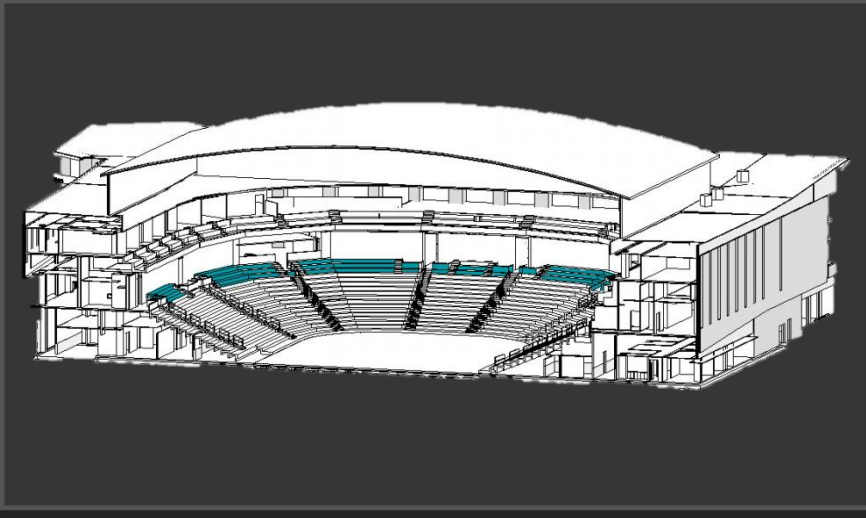
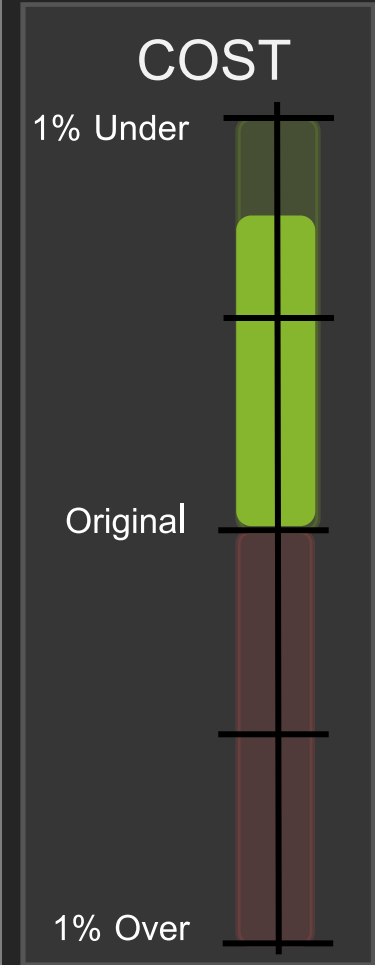
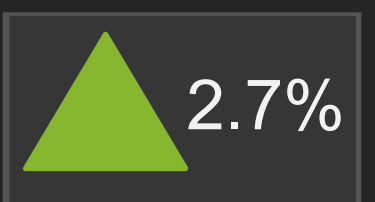
Strategy

Process

Results



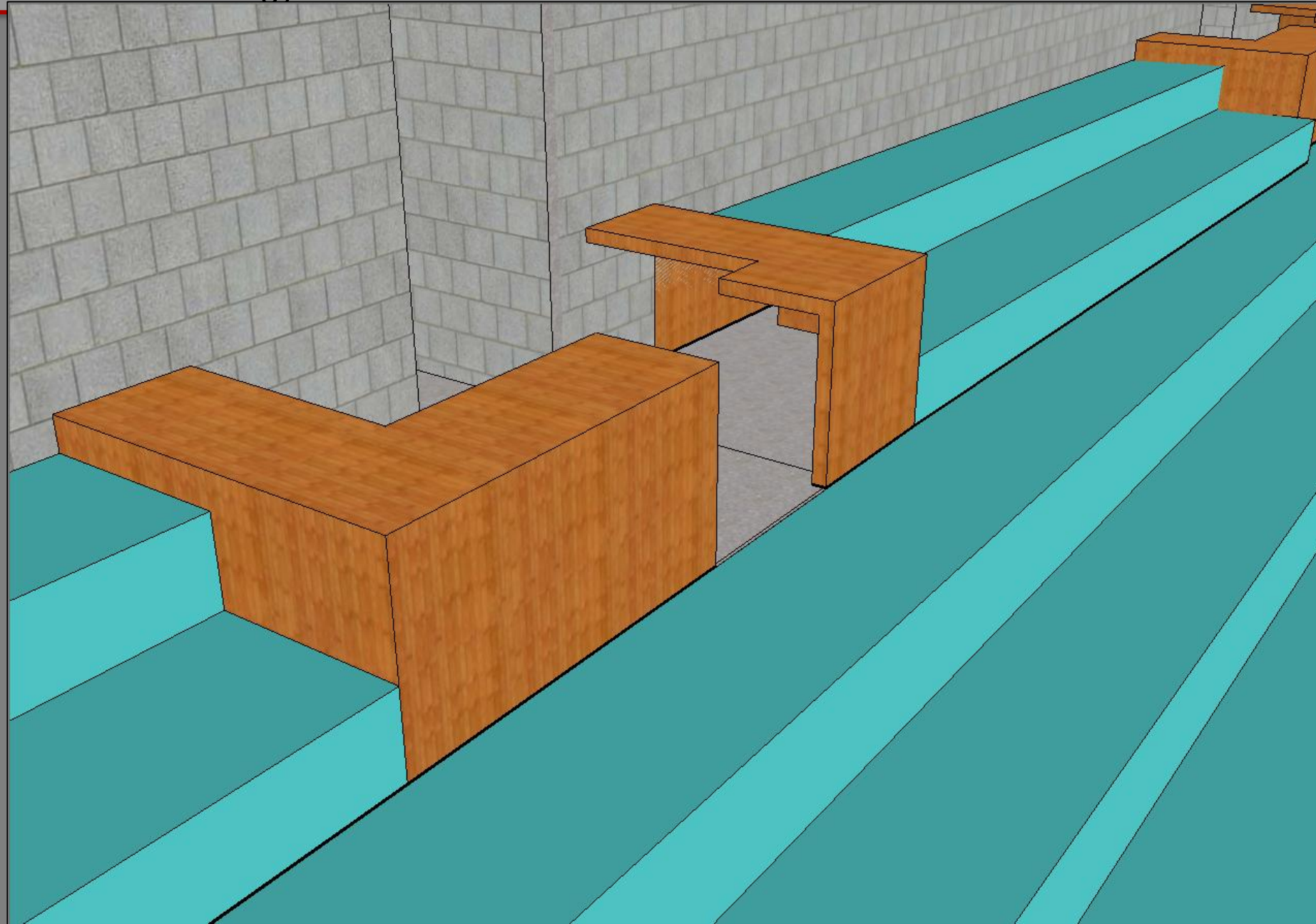
**HPR dash board**



**SEATS**

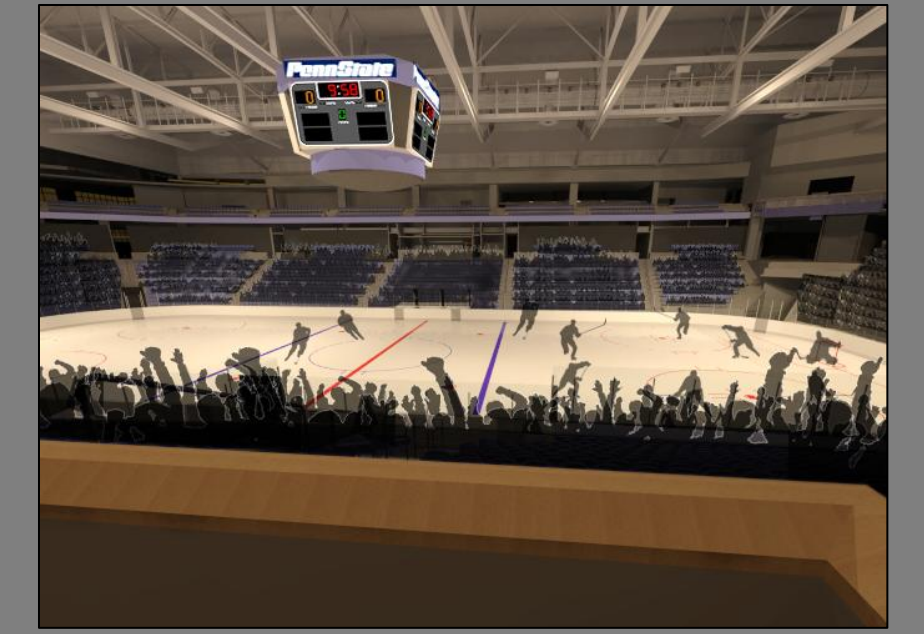
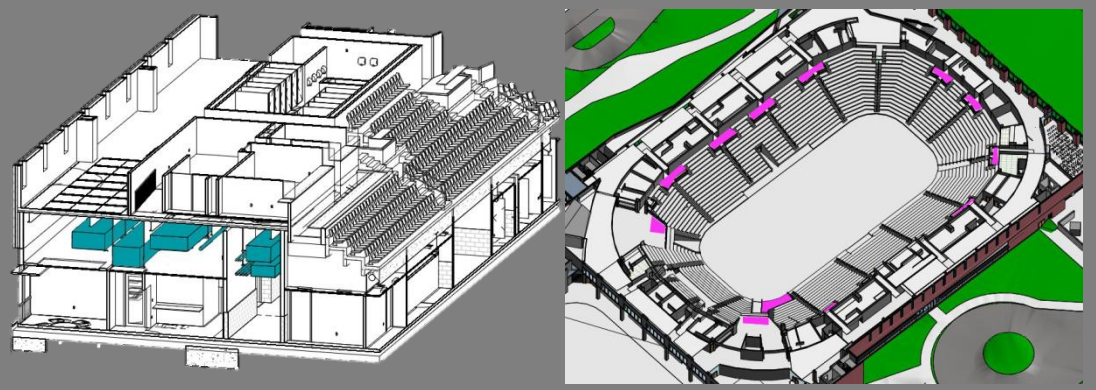
Proposed  
**6,185**

BOD  
**6,031**



- Excavation/ Back Fill \$312.9K
- Foundation Walls \$162.4K
- Event level Interior Wall \$122.7K
- Concrete Columns \$29.3K
- Main Arena Added Stadia **\$25.3K**
- Main Arena Added Seats **\$16.6K**
- Main Arena Steps **\$5.5K**
- Steel Beams & Conc. Footings **\$29.8K**

**\$561,126**





PROJECT

PROCESS

SAVINGS

PROMINENCE

FUNCTION

REFLECTION



Opportunity

Goal

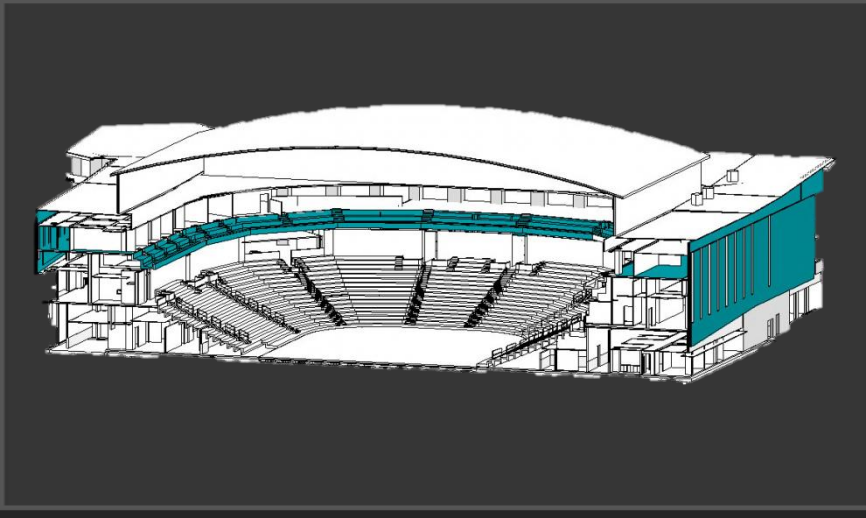
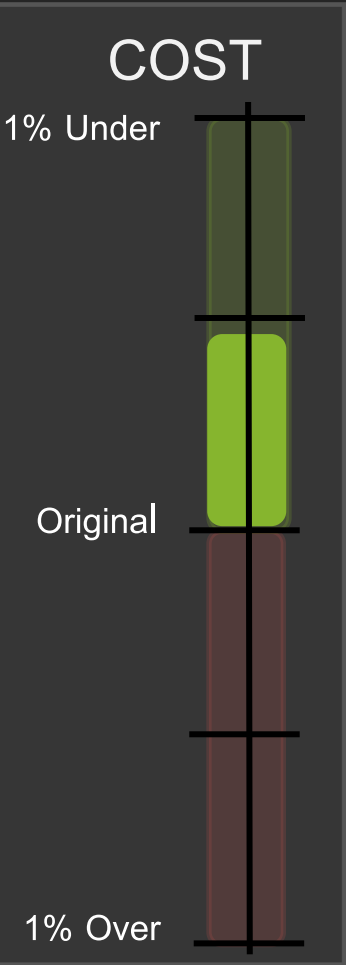
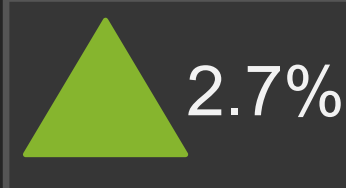
Strategy

Process

Results



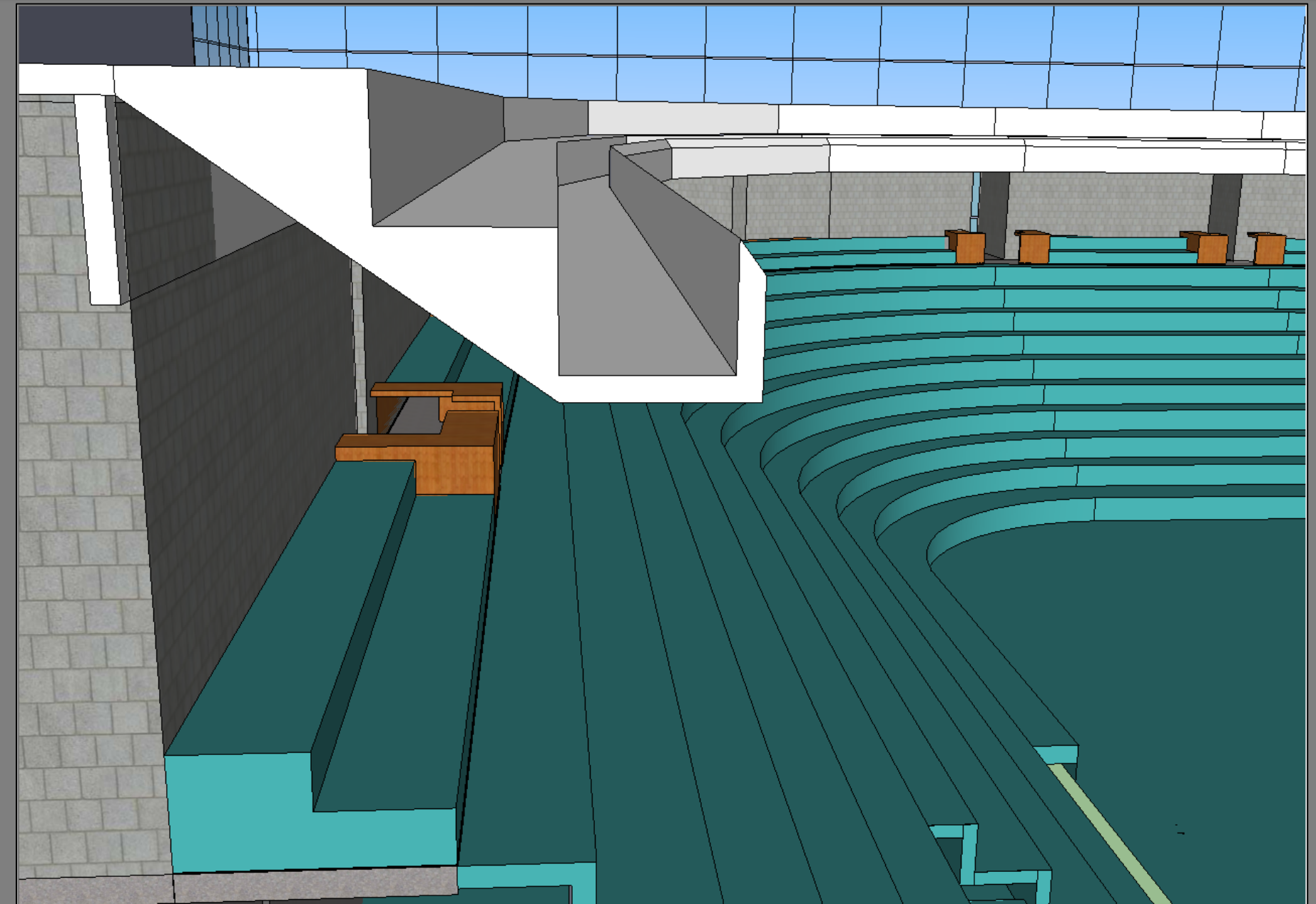
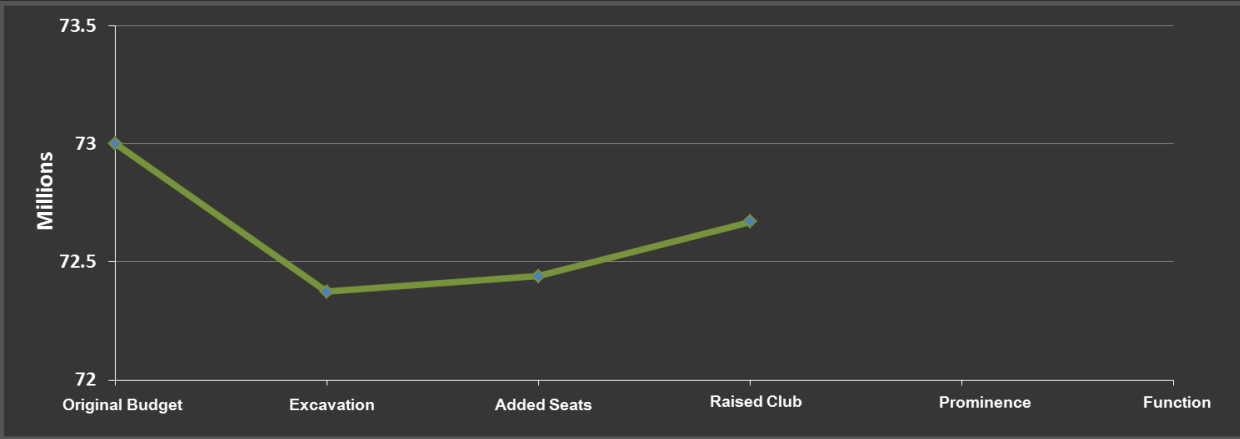
HPR dash board



SEATS

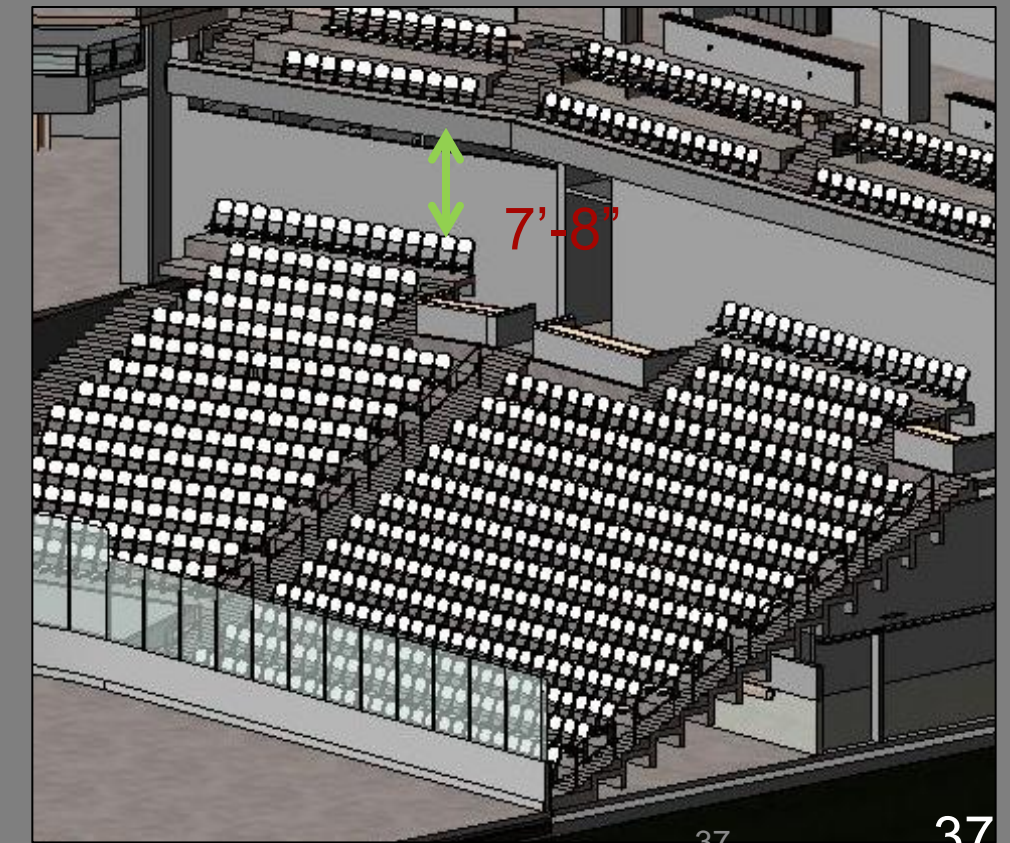
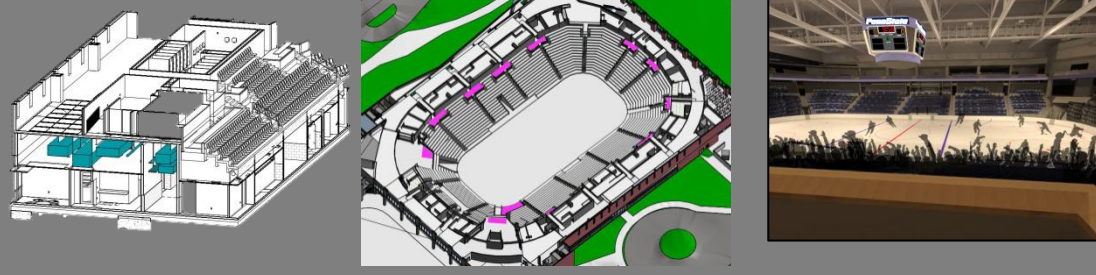
Proposed  
**6,185**

BOD  
**6,031**



- Excavation/ Back Fill \$312.9K
- Foundation Walls \$162.4K
- Event level Interior Wall \$122.7K
- Concrete Columns \$29.3K
- Main Arena Added Stadia \$25.3K
- Main Arena Added Seats \$16.6
- Main Arena Steps \$5.5K
- Steel Beams & Conc. Footings \$29.8
- Club Level Int Walls **\$19.8K**
- Main Concourse Int Walls **\$79.8K**
- Exterior Walls **\$137.9K**
- Exterior Glazing **\$22.8K**
- Steel Columns **\$28.2K**
- Miscellaneous **\$57.8K**

**\$330,406**





PROJECT

PROCESS

SAVINGS

PROMINENCE

FUNCTION

REFLECTION



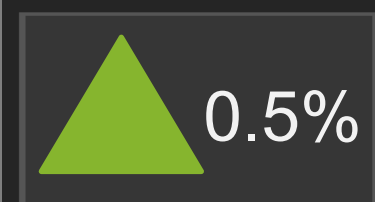
Opportunity

Goal

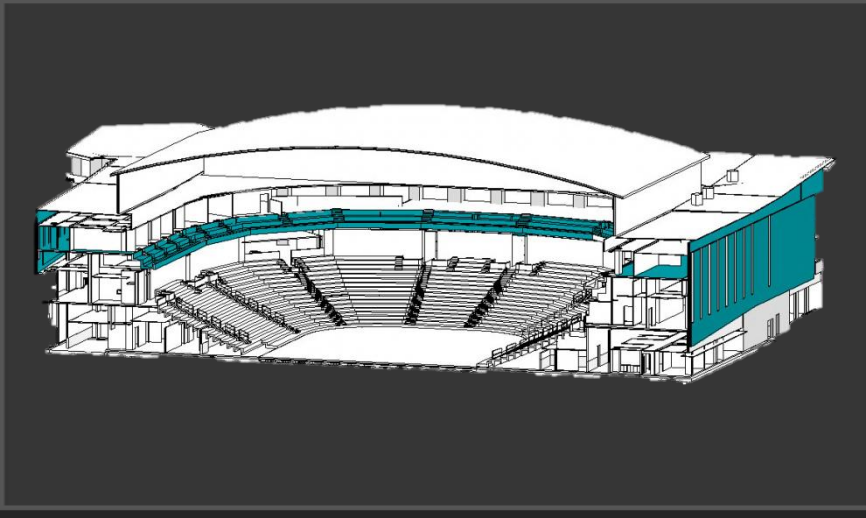
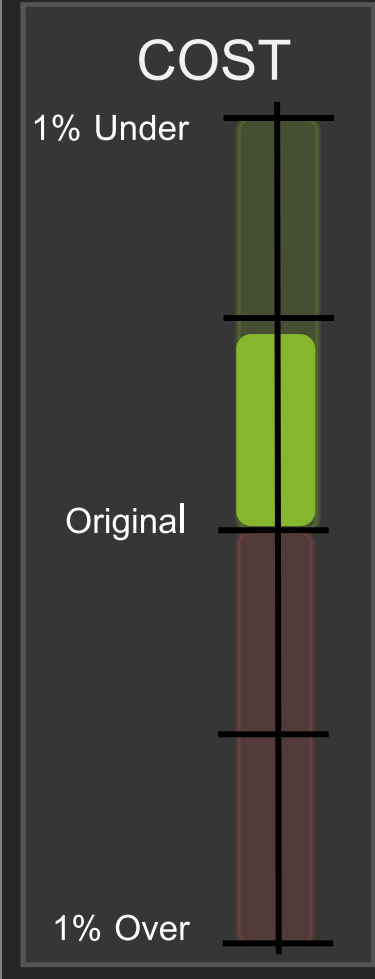
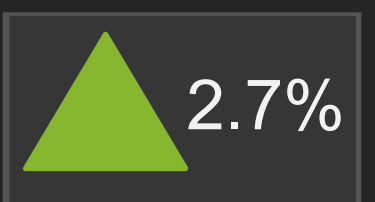
Strategy

Process

Results



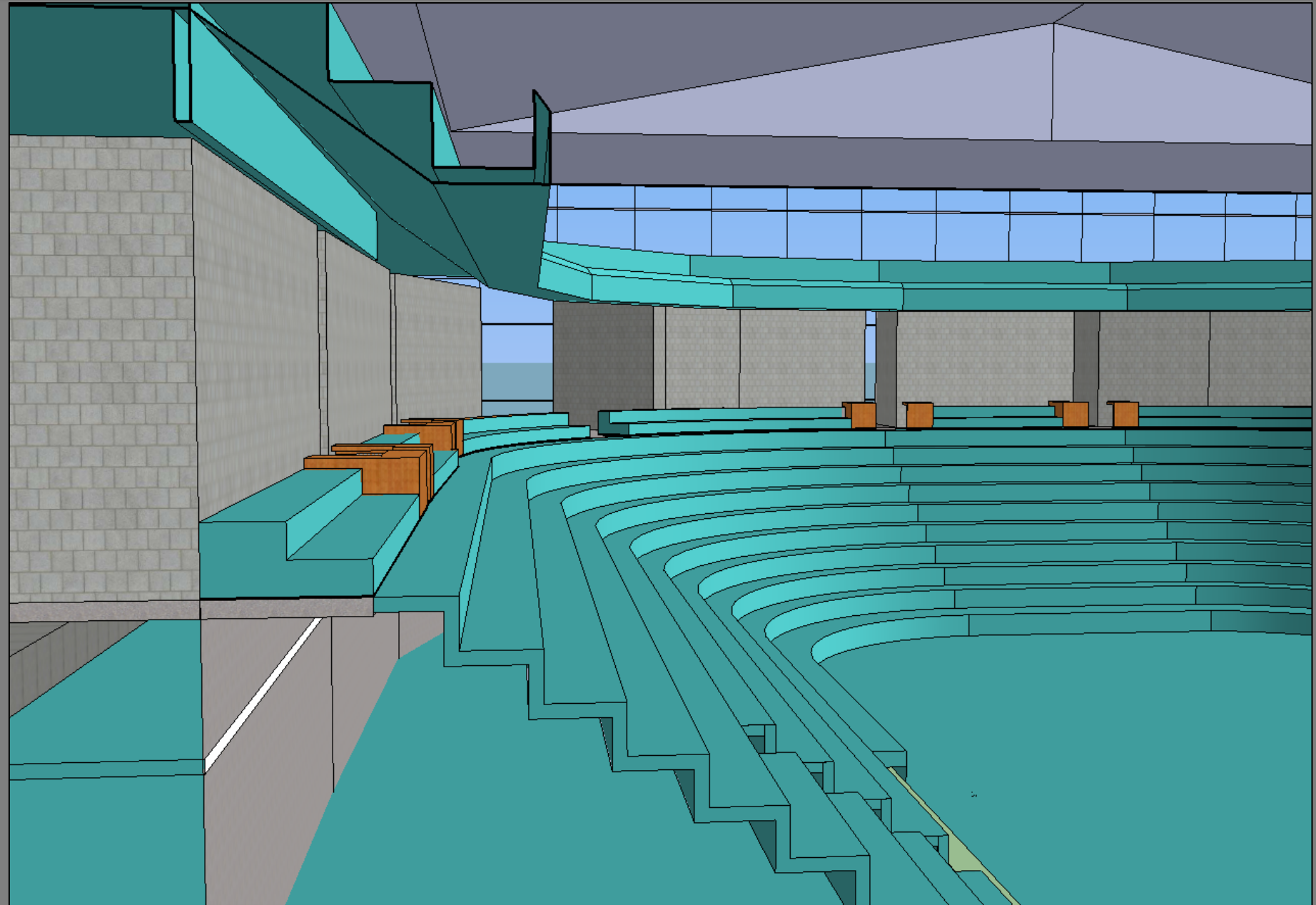
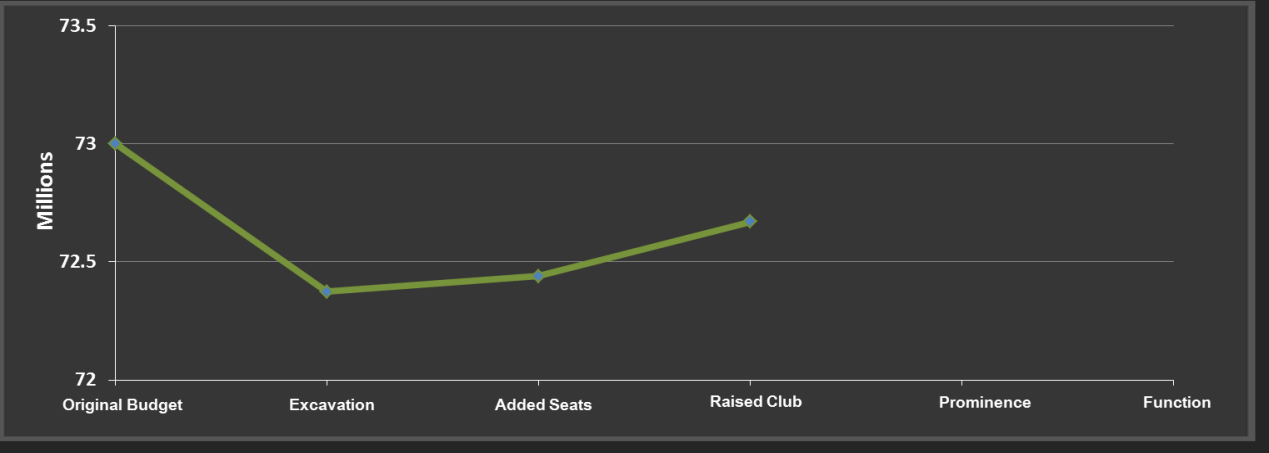
**HPR dash board**



**SEATS**

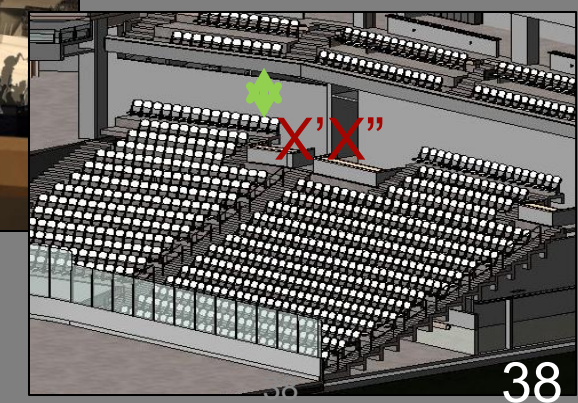
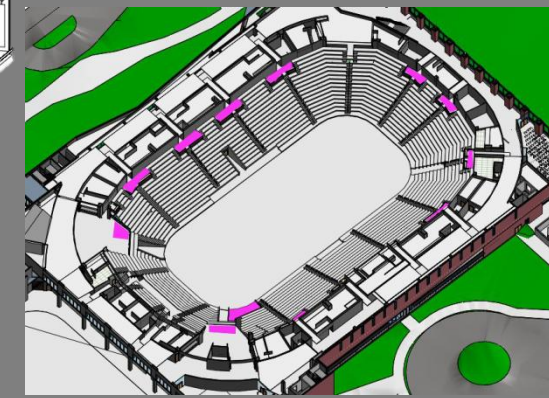
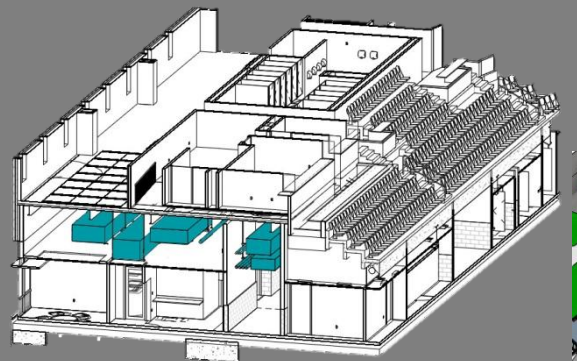
Proposed  
**6,185**

BOD  
**6,031**



- Excavation/ Back Fill \$312.9K
- Foundation Walls \$162.4K
- Event level Interior Wall \$122.7K
- Concrete Columns \$29.3K
- Main Arena Added Stadia \$25.3K
- Main Arena Added Seats \$16.6
- Main Arena Steps \$5.5K
- Steel Beams & Conc. Footings \$29.8
- Club Level Int Walls **\$19.8K**
- Main Concourse Int Walls **\$79.8K**
- Exterior Walls **\$137.9K**
- Exterior Glazing **\$22.8K**
- Steel Columns **\$28.2K**
- Miscellaneous **\$57.8K**

**\$330,406**

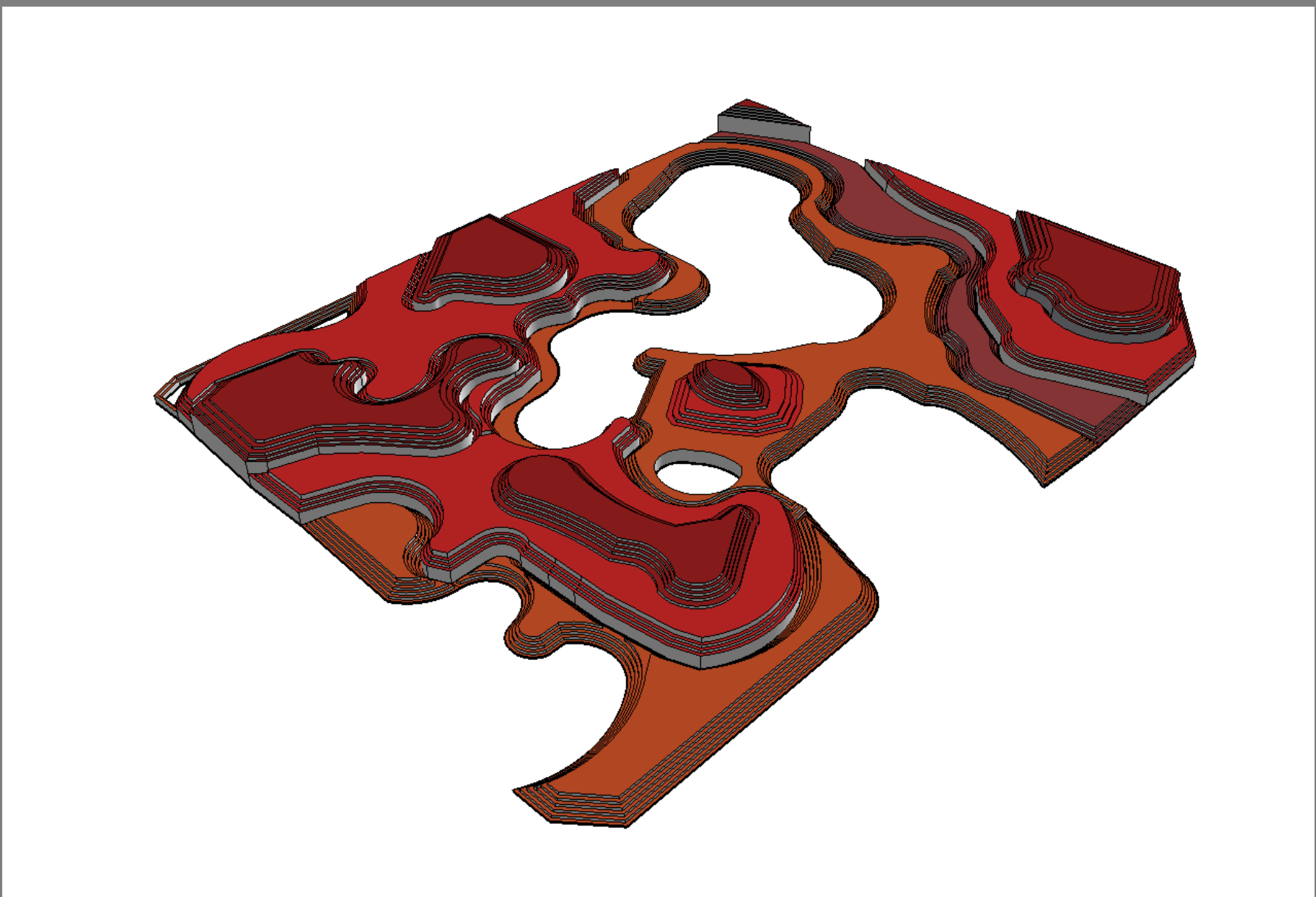
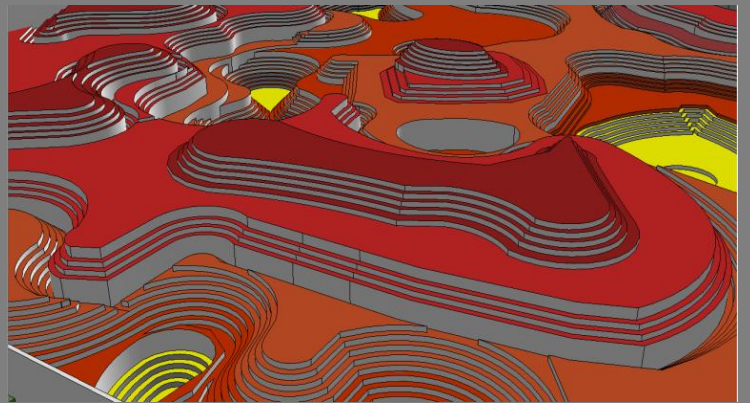




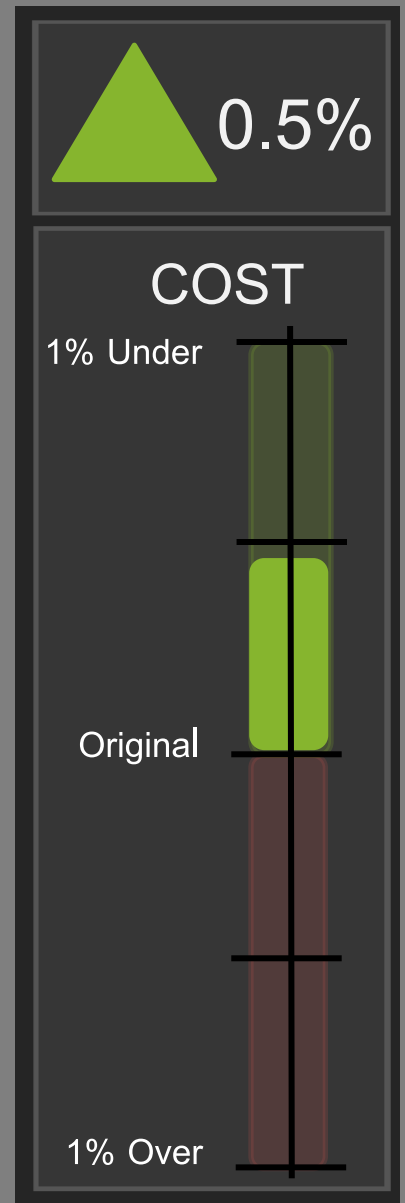


# Primary Goal – Cost Savings

Proposed Excavation Scope:



	\$533,569	8.3%	\$268,300	49.6%
	67,061 CY	8.4%	13,275 CY	47.7%
	12 days	11.1%	6 days	47.8%



**3'-2" (38")**

**\$330,406**

**7 days**



Opportunity

Goal

Strategy

Process

Results

# Primary Goal – Code Compliance

## Governing Codes:

2009 International Building Code (IBC)

2010 ADA Standard

Accessible ADA Wheelchair Spaces: IBC 2009 Section 1108.2.2.1

Minimum Required Egress Width: IBC 2009 Section 1005.1

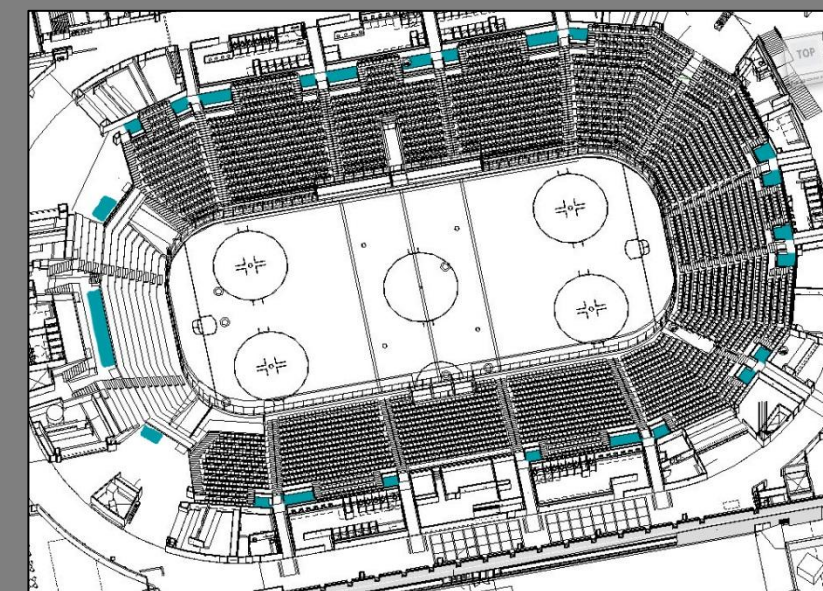
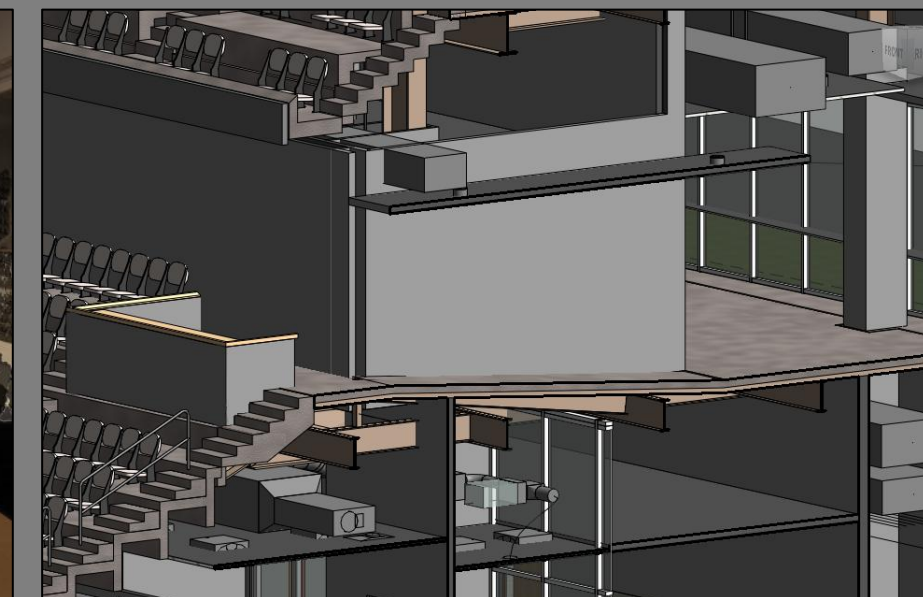
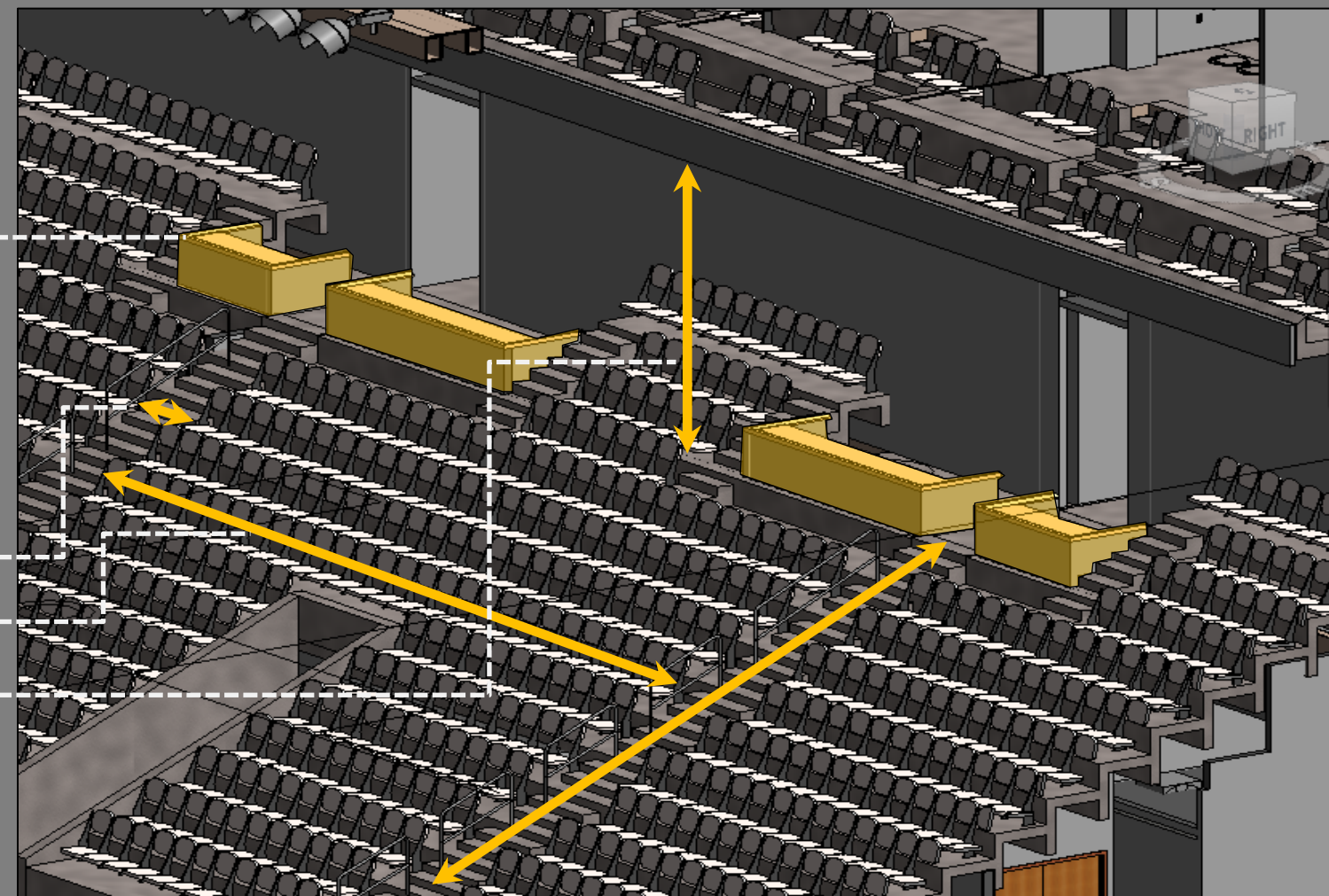
Egress Occupancy Load: IBC 2009 Section 1004.1

Minimum Ceiling Height (Clearance): IBC 2009 Section 1003.2

ADA Clear Turning Space: ADA 2010 Section 304.2

Companion Seat Criteria: ICC A117.1

ADA Compliant Ramps: IBC 2009 Section 1010.2







# Secondary Goal – Business Model

## Seating Capacity By Price Point:

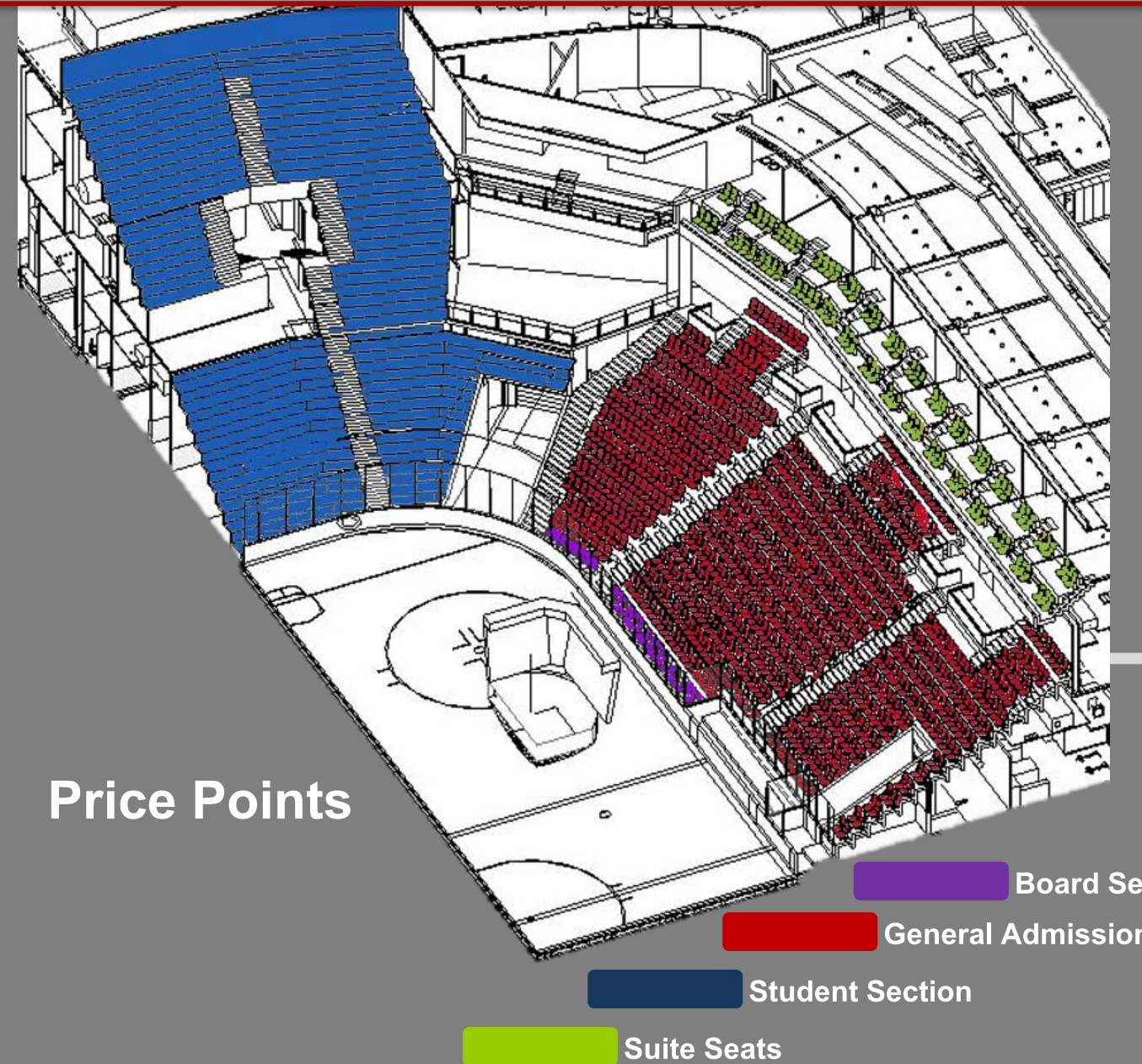
General Admission	4,154 seats	▲ 3.57%
Student Section	1,023 seats	▼ 4.11%
Club Level	695 seats	— 0.00%
Suites	279 seats	— 0.00%
<b>TOTAL</b>	<b>6,185 seats</b>	<b>▲ 2.70%</b>

▲ 2.7%

**SEATS**

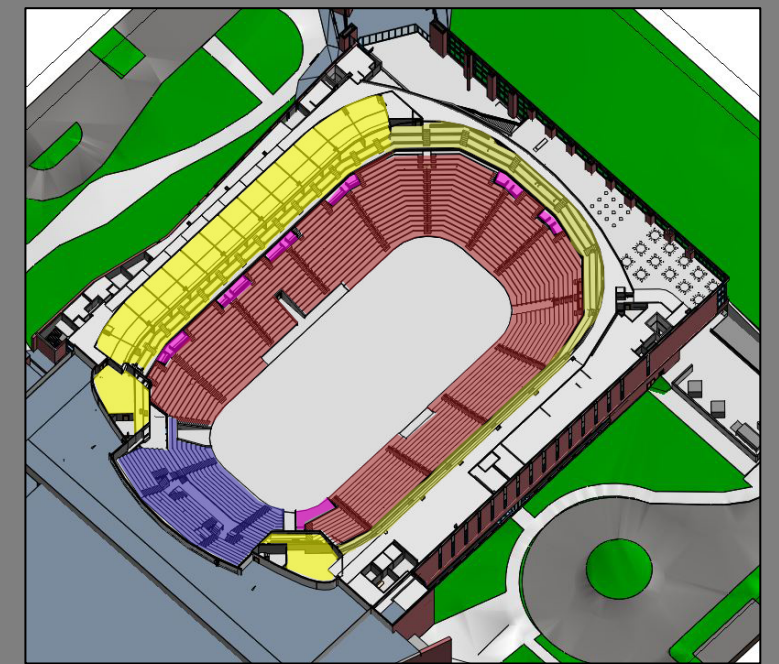
Proposed  
**6,185**

BOD  
**6,031**

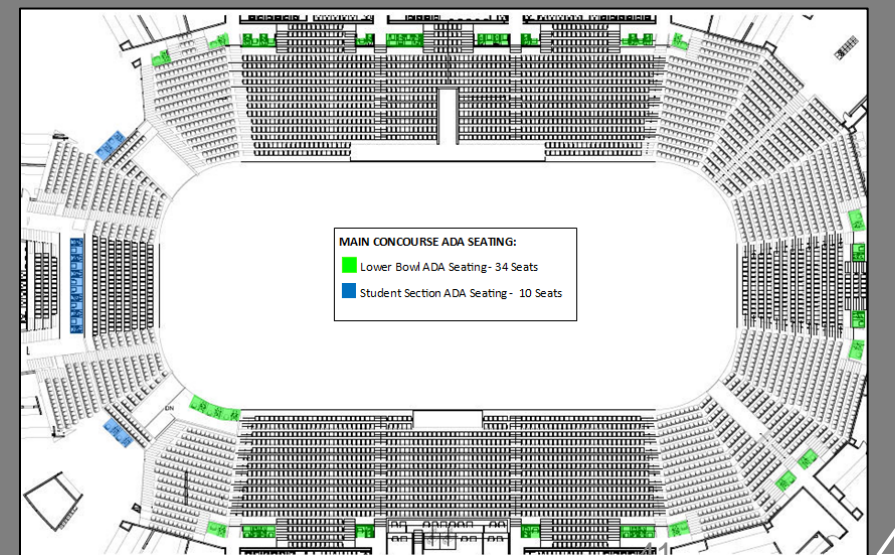


## Profitability Study:

General Admission	\$ 45,146
Student Section	\$ 5,115
Club Level	\$ 13,900
Suites	\$ 11,160
<b>TOTAL</b>	<b>\$ 75,321</b>



▲ 2.37%

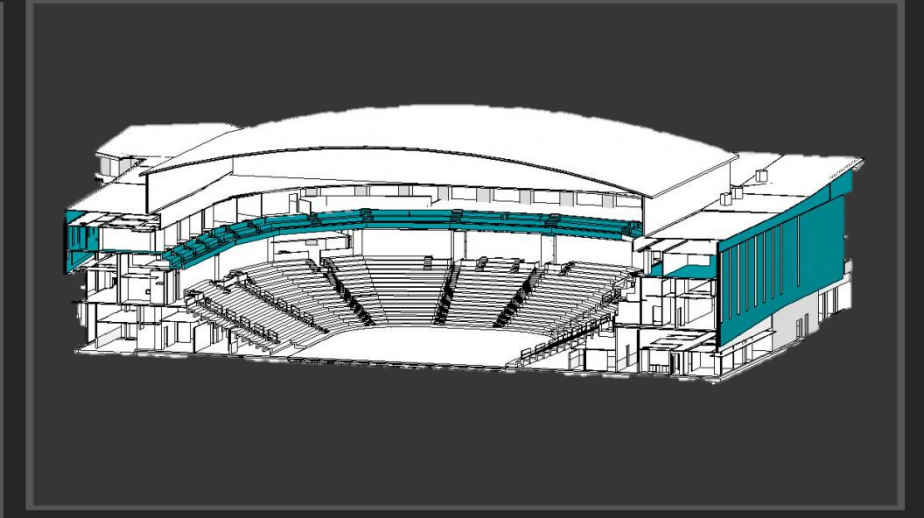
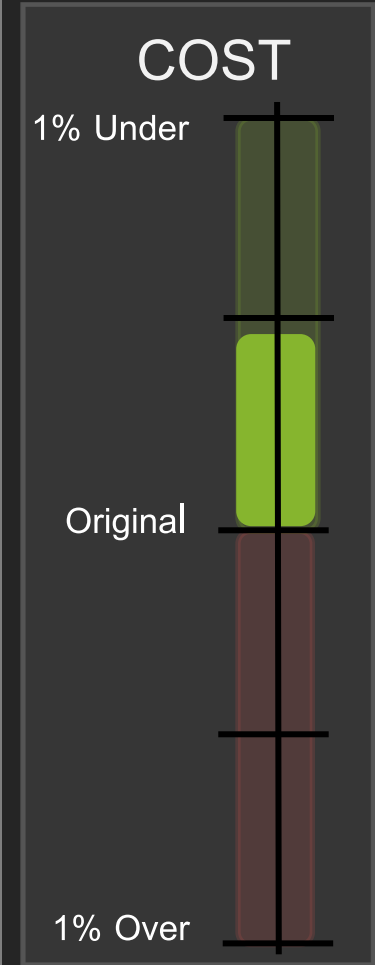




**0.5%**

**HPR dash board**

**2.7%**



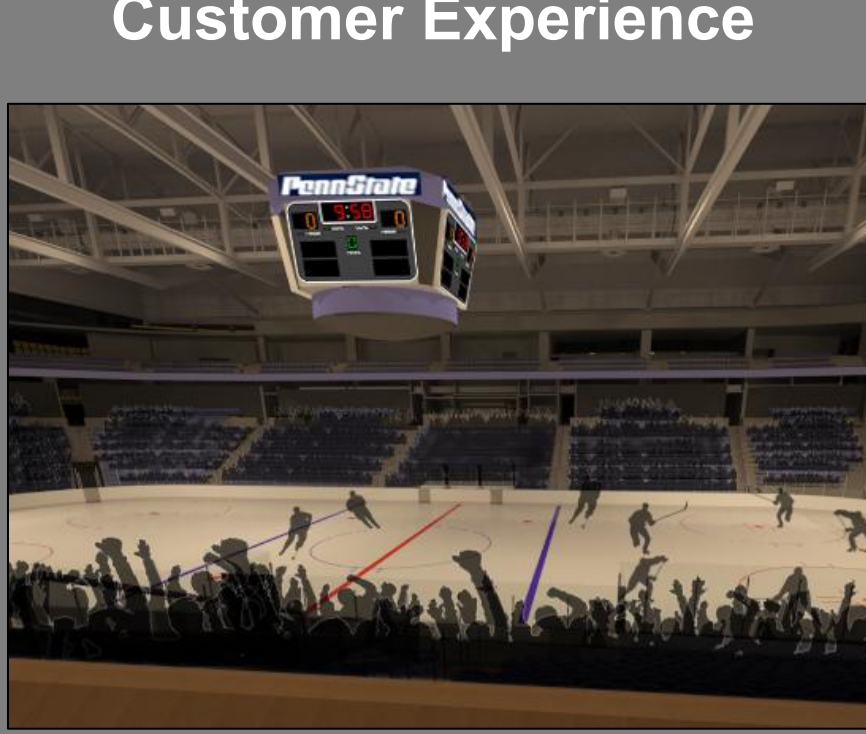
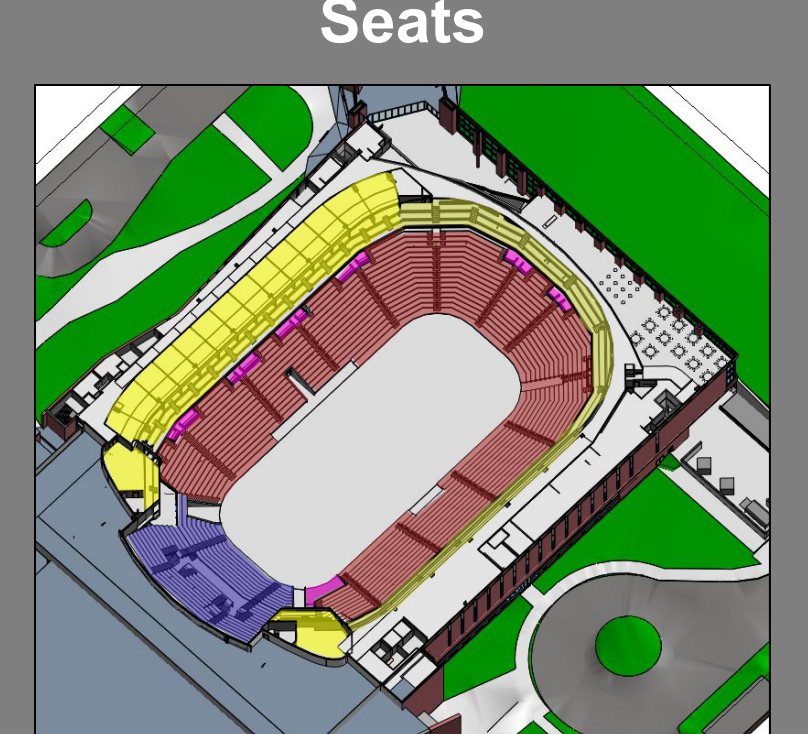
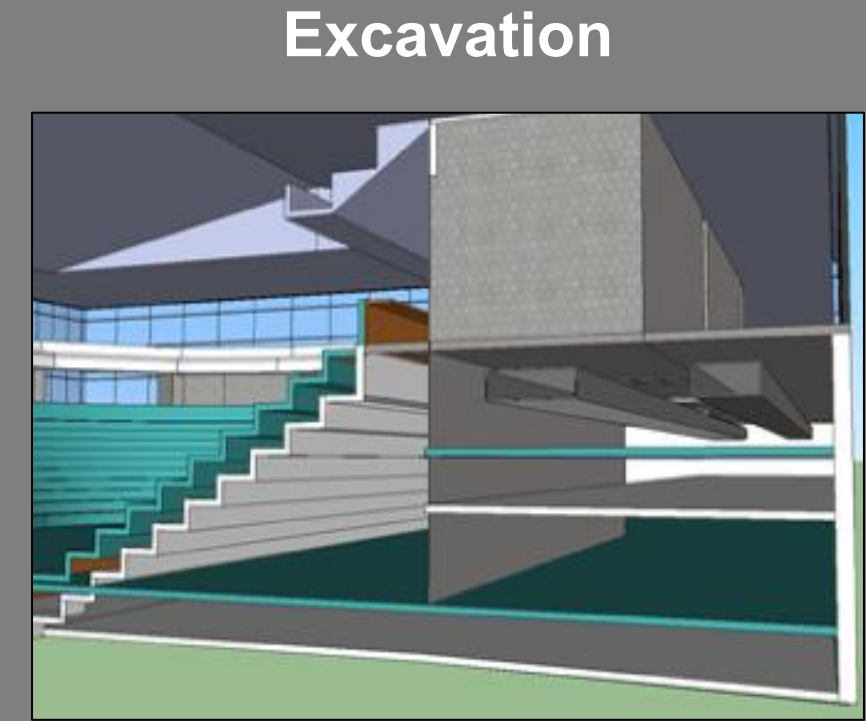
**SEATS**

Proposed  
**6,185**

BOD  
**6,031**



# Savings Package Summary



**\$330,406**

**15 days**





# PROMINENCE





Opportunity

Goal

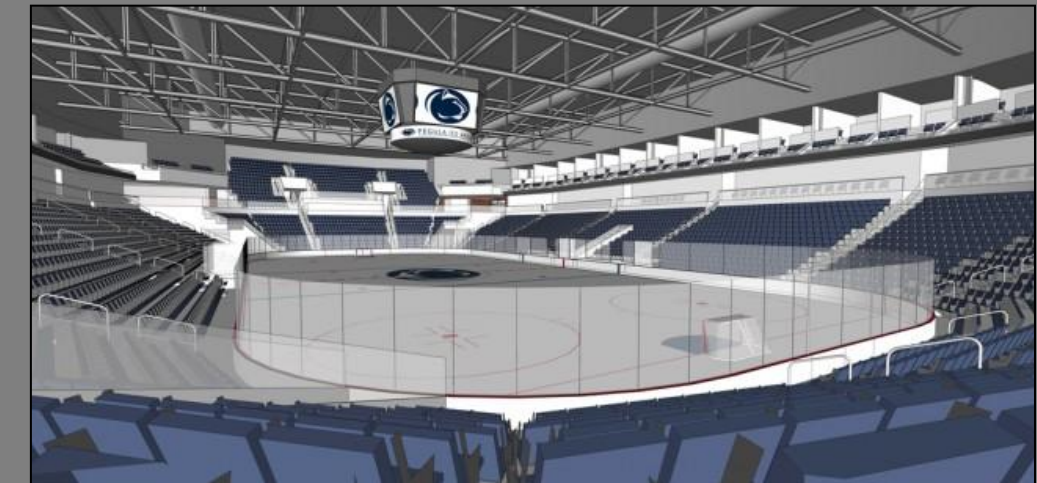
Strategy

Results

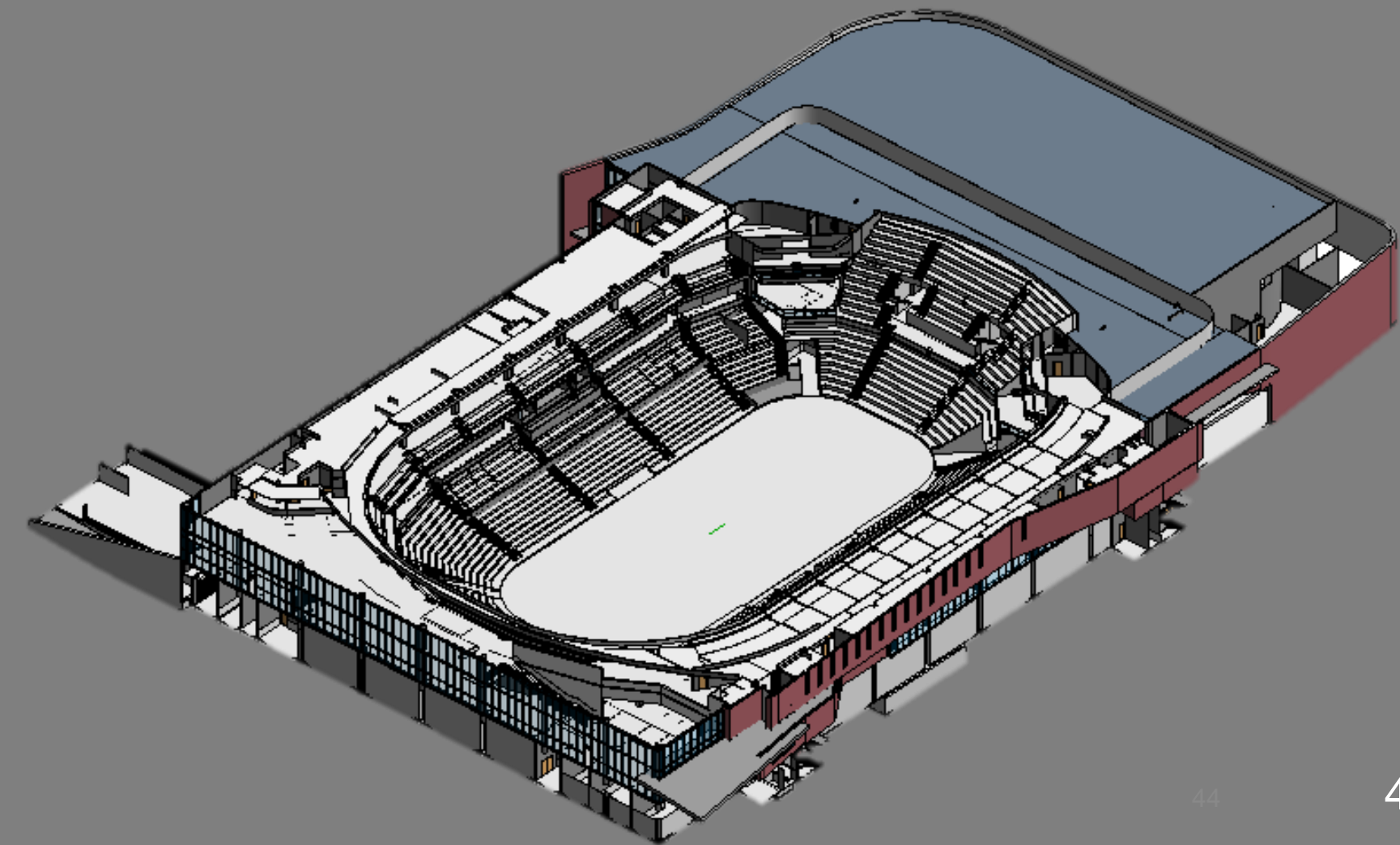
### PSU Facilities



### Existing Design



### Assignment Brief





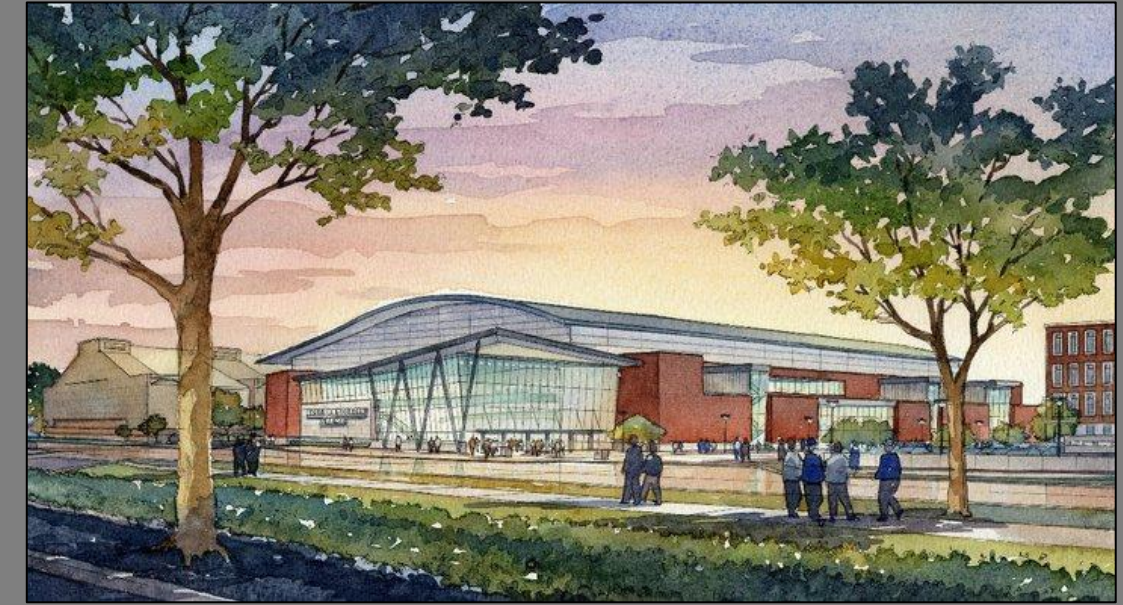


Opportunity

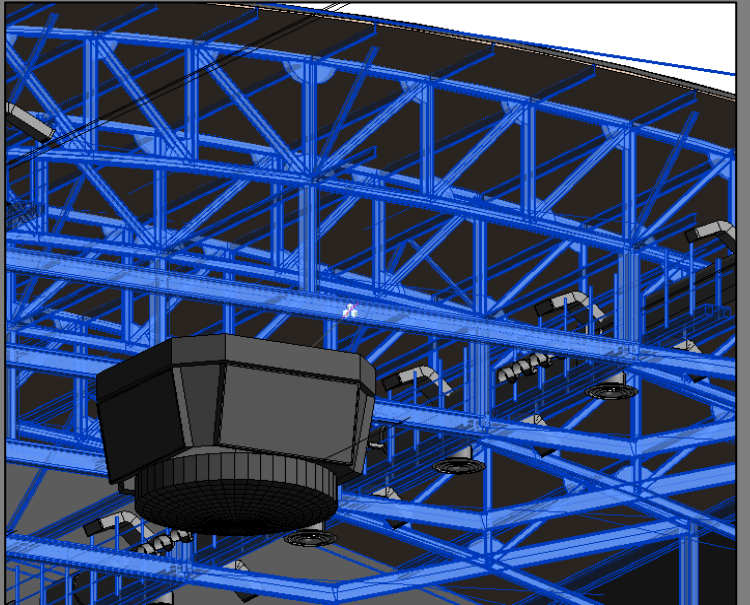
Goal

Strategy

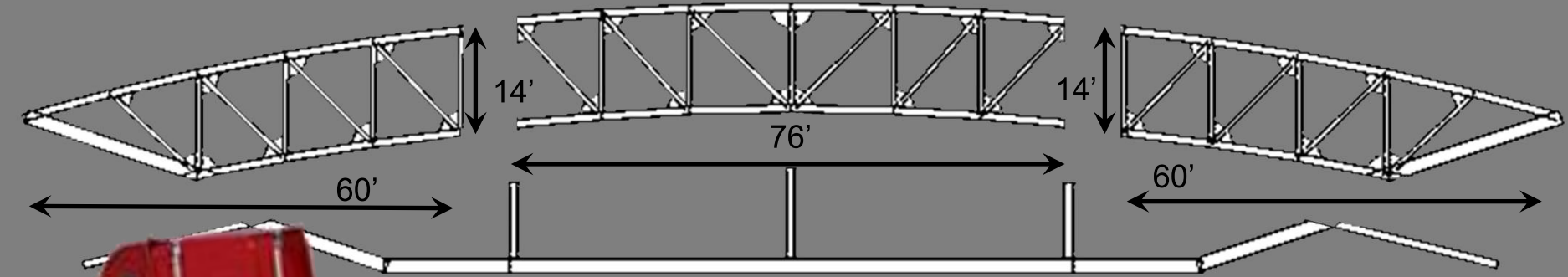
Results



### Feasibility Studies



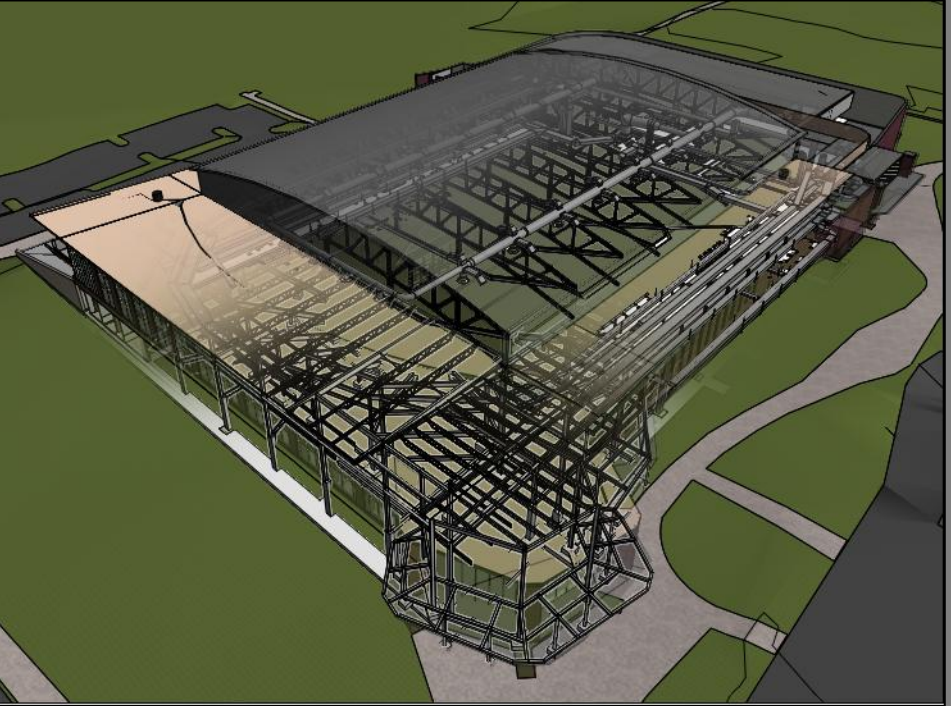
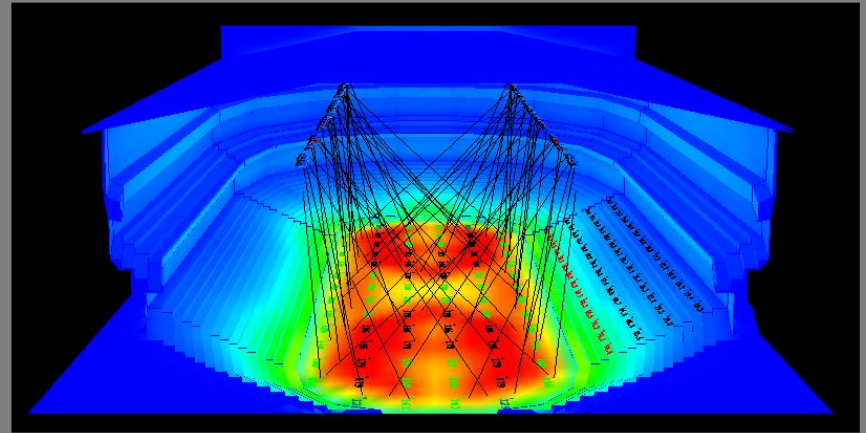
### Clean Roof Design



### Constructability & Cost



### Coordinated MEP Systems



### Optimum Lighting Design



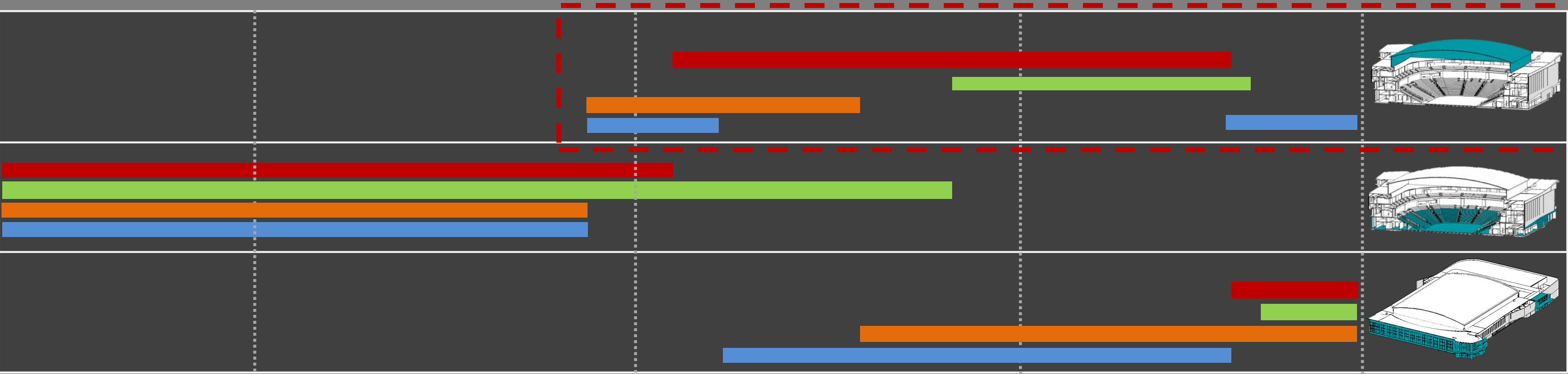
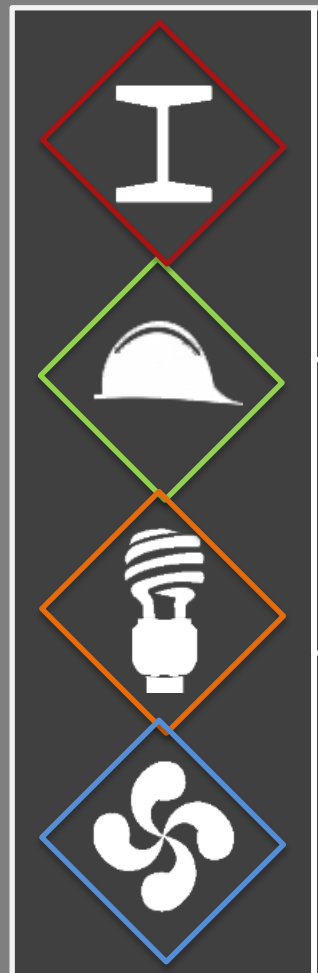


Opportunity

Goal

Strategy

Results





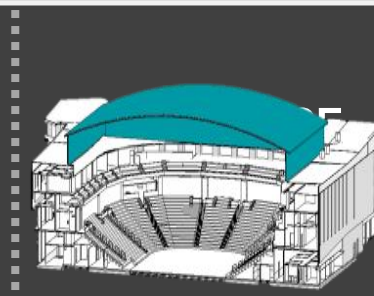
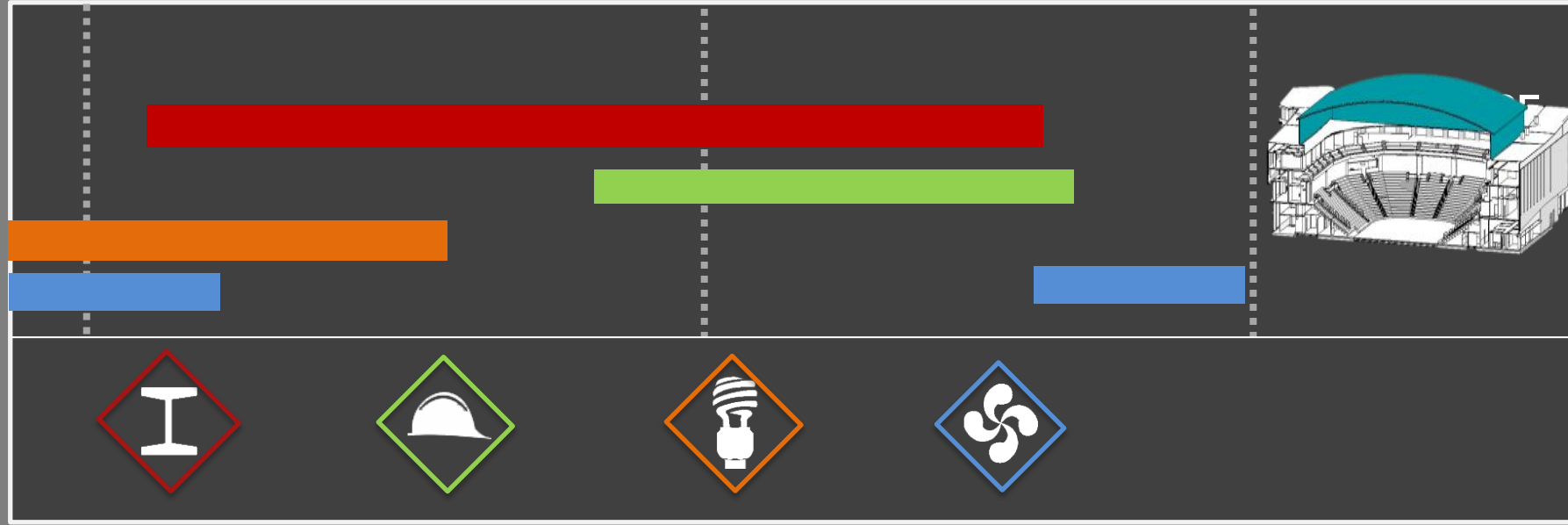


Opportunity

Goal

Strategy

Results



### Compton Family Arena

University of Notre Dame  
 5,000 Seating Capacity  
 156' Span



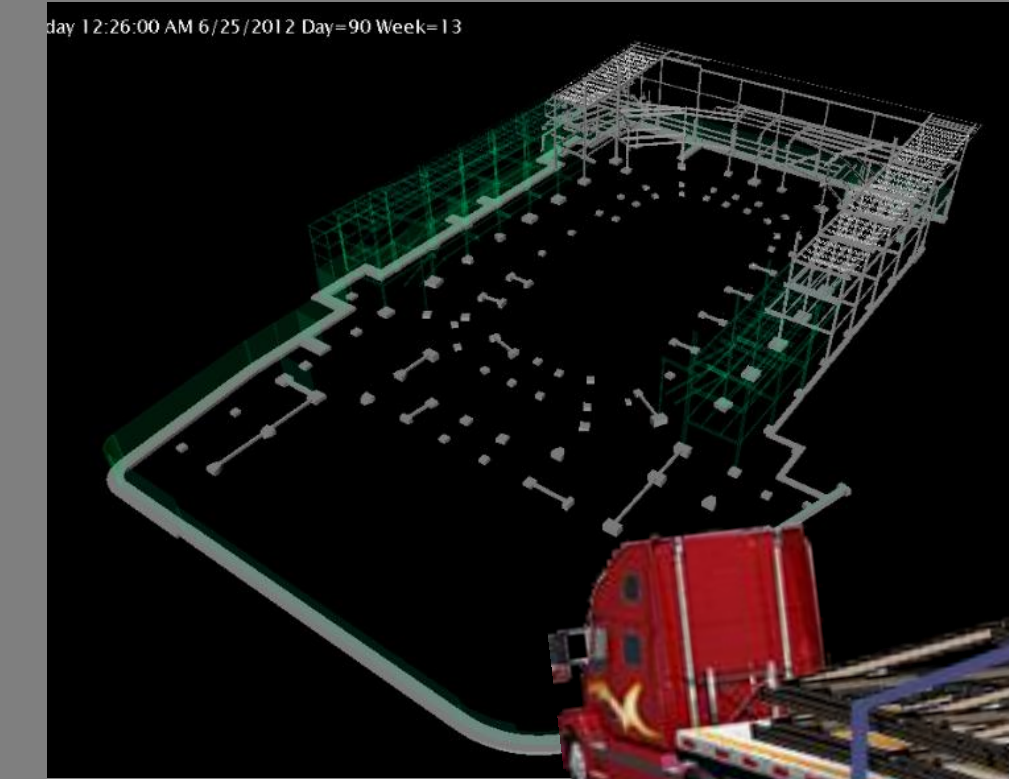
### Agganis Arena

Boston University  
 7,200 Seat Capacity  
 205' Span



### Penn State Ice Arena

Pennsylvania State University  
 6,000 Seat Capacity  
 196' Span

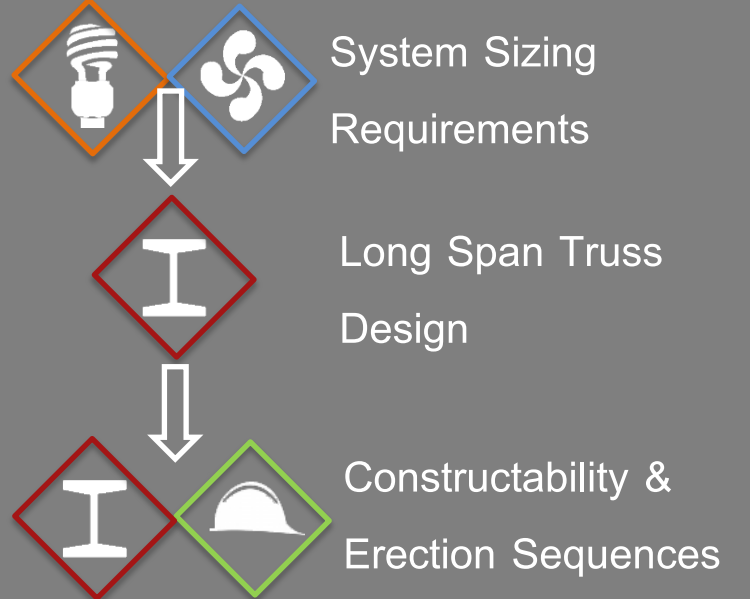


Sequencing

Constructability

### Case Study Investigation Included:

- Types of High Framing Systems
- Economy of Trusses
- Roof Profiles





**PROJECT**

**PROCESS**

**SAVINGS**

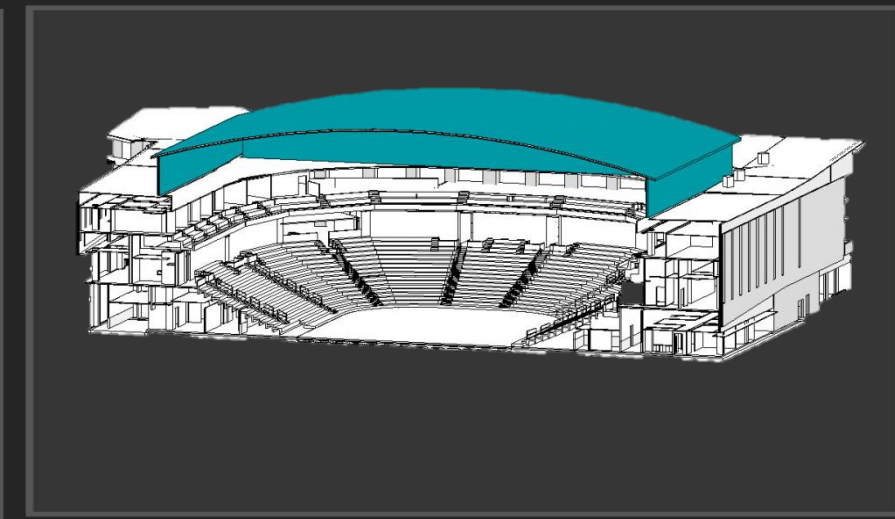
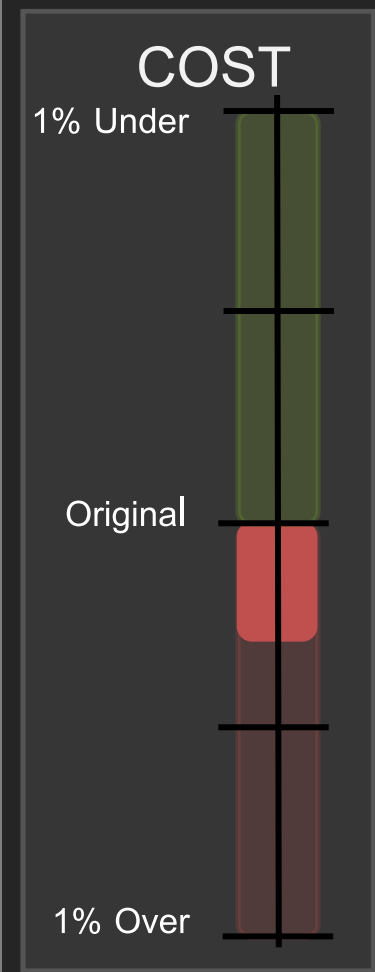
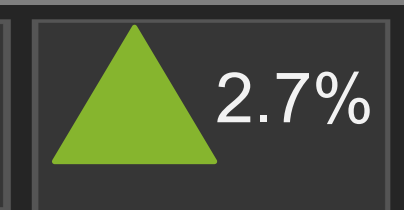
**PROMINENCE**

**FUNCTION**

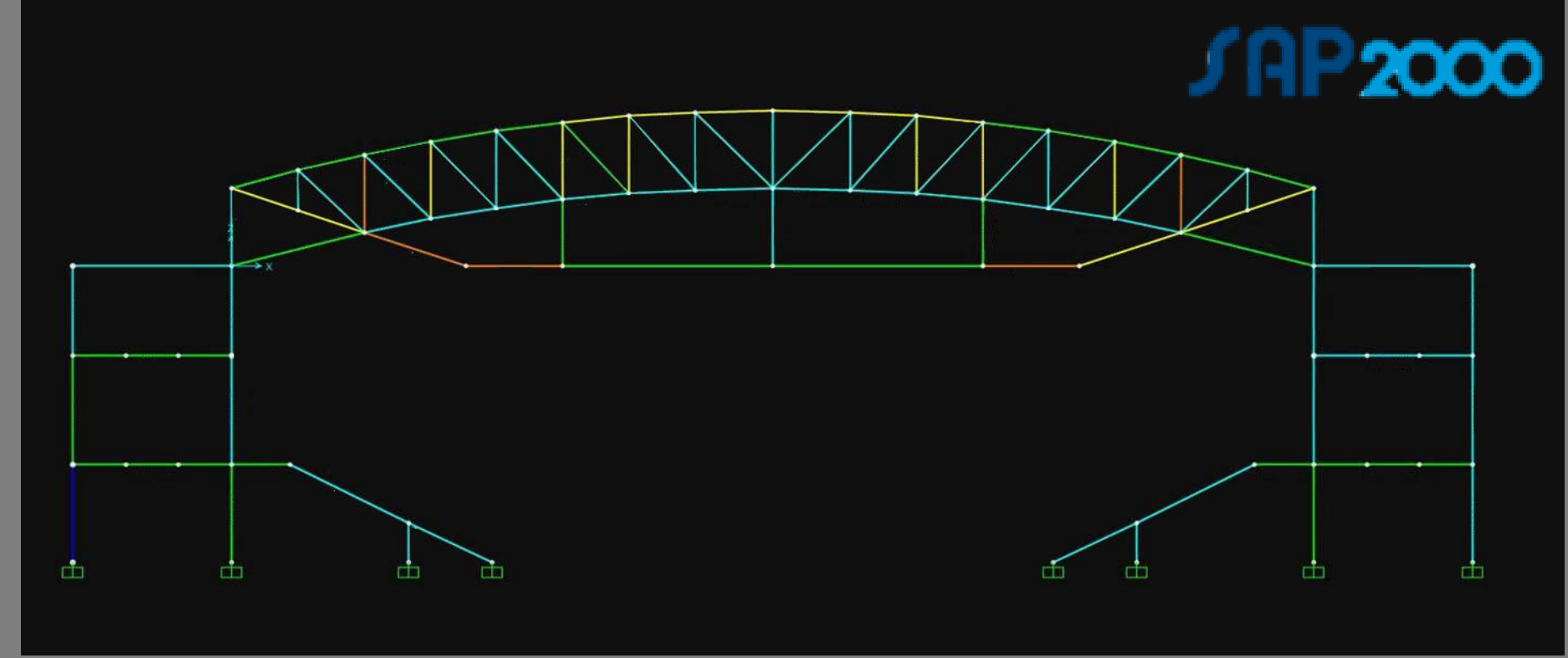
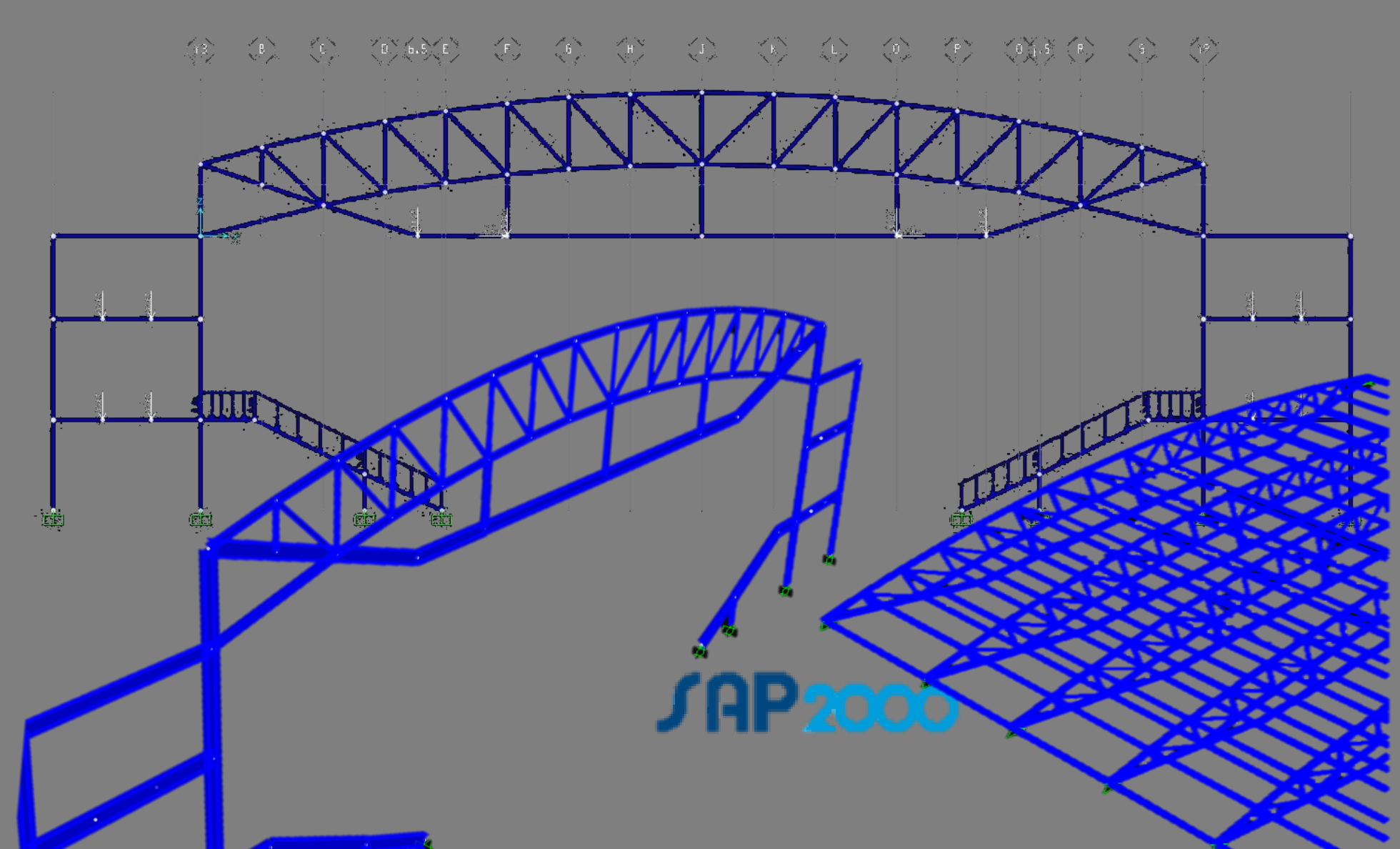
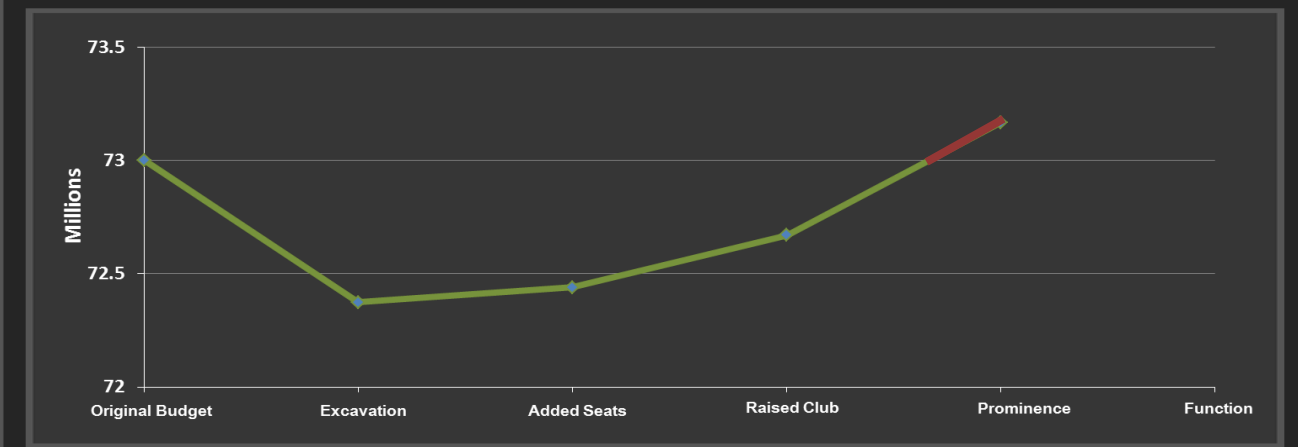
**REFLECTION**



**HPR dash board**



**SEATS**  
Proposed  
**6,185**  
BOD  
**6,023**



Member	Member Location	SECTION PROPERTIES					LOADING			COMPRESSION					TENSION		BENDING	
		Member Size	K Value	Length (ft)	I <sub>x</sub> (in <sup>4</sup> )	E (ksi)	Controlling LC	Load (k)	Tension/Compression?	P <sub>u</sub> (k)	KL	r <sub>y</sub>	KL/r <sub>y</sub>	ΦP <sub>n</sub> (k)	P <sub>u</sub> (k)	ΦP <sub>t</sub> (k)	M <sub>u</sub> (ft-k)	Neglected?
1	Top Chord	W14x43	1.00	12.438	428	29000	1.2D+1.6S+0.5W	463.03	Compression	463.03	12.438	2.46	5.0561	562	0	567	42.24	Yes
2	Top Chord	W14x43	1.00	12.328	428	29000	1.2D+1.6S+0.5W	468.03	Compression	468.03	12.328	2.46	5.01138	562	0	567	29.14	Yes
3	Top Chord	W14x43	1.00	12.234	428	29000	1.2D+1.6S+0.5W	509.06	Compression	509.06	12.234	2.46	4.97317	562	0	567	16.91	Yes
4	Top Chord	W14x43	1.00	12.156	428	29000	1.2D+1.6S+0.5W	542.08	Compression	542.08	12.156	2.46	4.94146	562	0	567	10.3	Yes
5	Top Chord	W14x43	1.00	12.094	428	29000	1.2D+1.6S+0.5W	550.84	Compression	550.84	12.094	2.46	4.91626	562	0	567	4.77	Yes
6	Top Chord	W14x53	1.00	12.052	541	29000	1.2D+1.6S+0.5W	600.33	Compression	600.33	12.052	2.46	4.89919	663	0	702	19.52	Yes
7	Top Chord	W14x53	1.00	12.021	541	29000	1.2D+1.6S+0.5W	643.83	Compression	643.83	12.021	2.46	4.88659	663	0	702	13.91	Yes
8	Top Chord	W14x53	1.00	14.000	541	29000	1.2D+1.6S+0.5W	664.58	Compression	664.58	14.000	2.46	5.69106	663	0	702	10.35	Yes
9	Top Chord	W14x53	1.00	14.000	541	29000	1.2D+1.6S+0.5W	664.58	Compression	664.58	14.000	2.46	5.69106	663	0	702	10.35	Yes
10	Top Chord	W14x53	1.00	12.021	541	29000	1.2D+1.6S+0.5W	643.18	Compression	643.18	12.021	2.46	4.88659	663	0	702		Yes
11	Top Chord	W14x53	1.00	12.052	541	29000	1.2D+1.6S+0.5W	599.06	Compression	599.06	12.052	2.46	4.89919	663	0	702		Yes





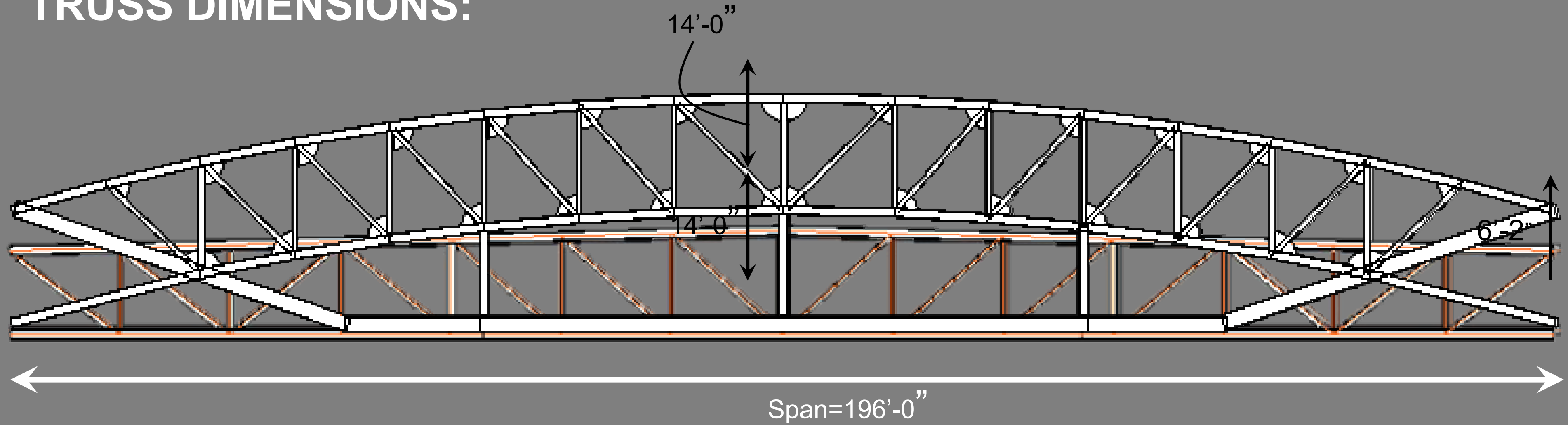
Opportunity

Goal

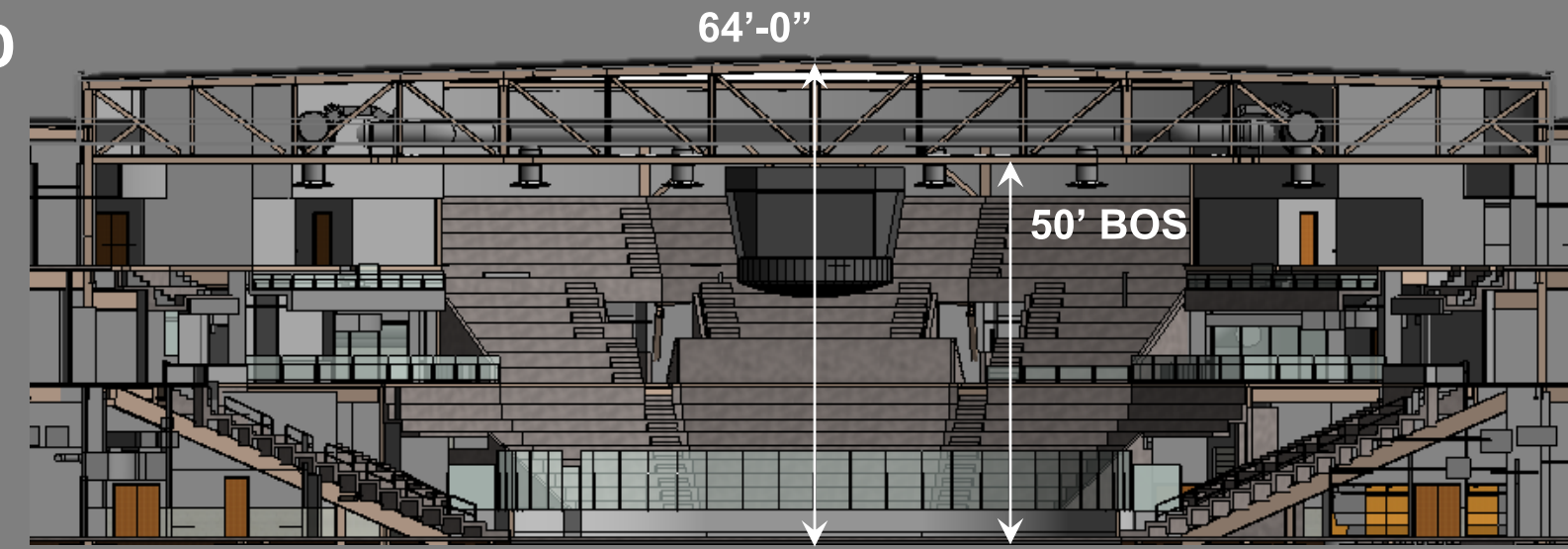
Strategy

Results

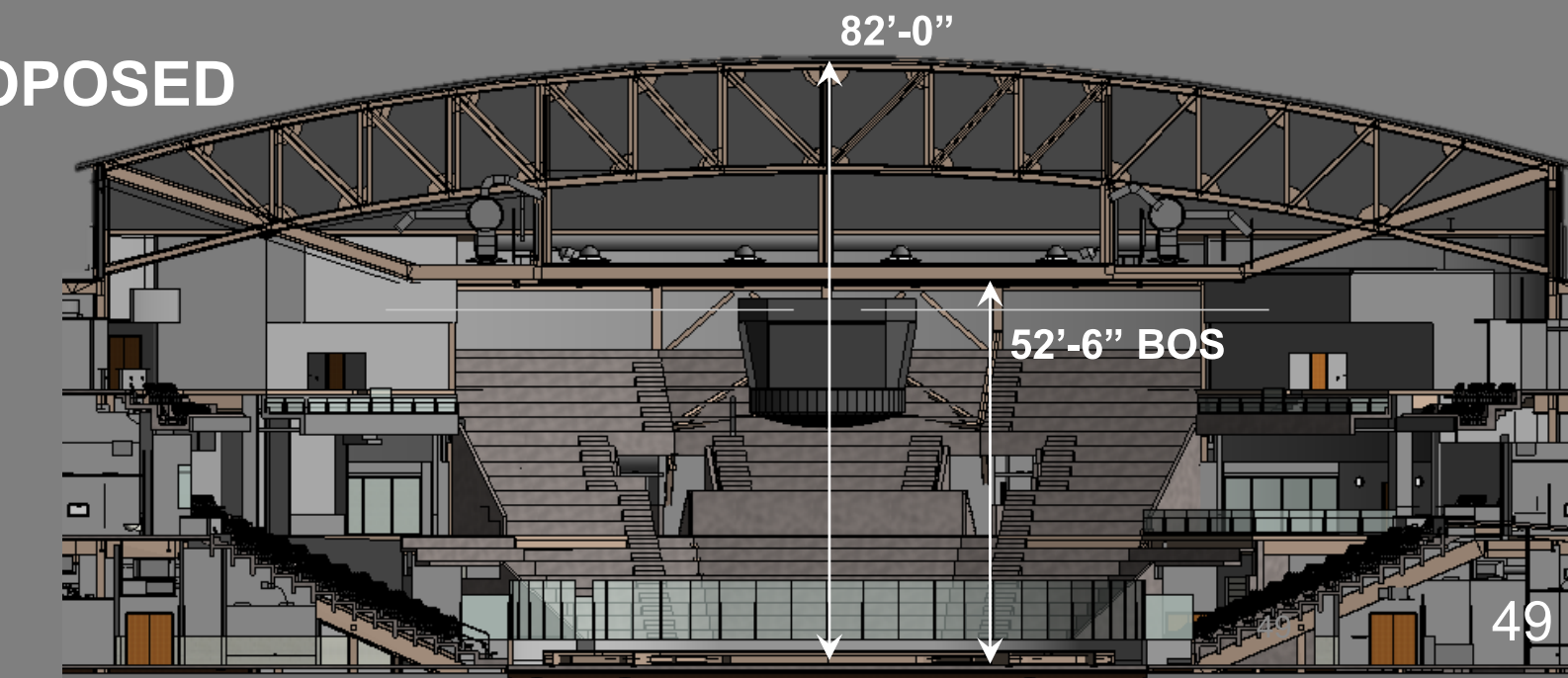
# TRUSS DIMENSIONS:



OLD



PROPOSED





Opportunity

Goal

Strategy

Results

## MEMBER SIZES:

TOP CHORDS: W14x43

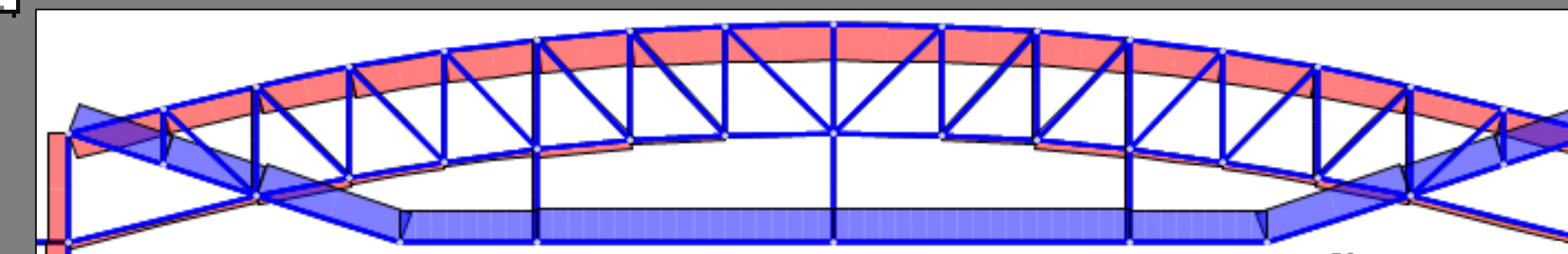
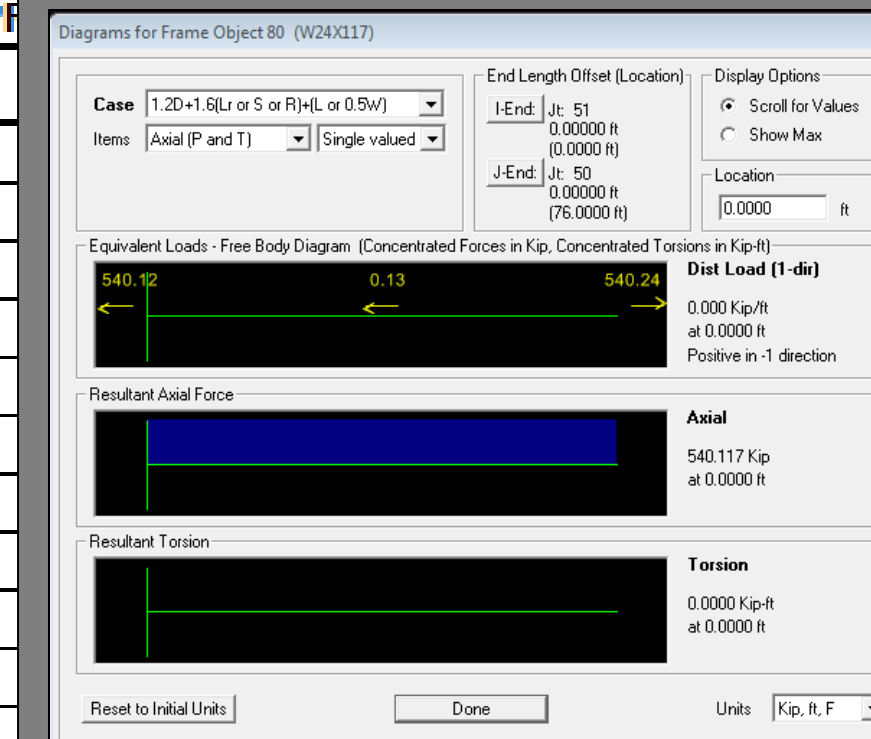
WEB MEMBERS: W8x18

VERTICALS: W14x68

DIAGONAL TIES: W27x146

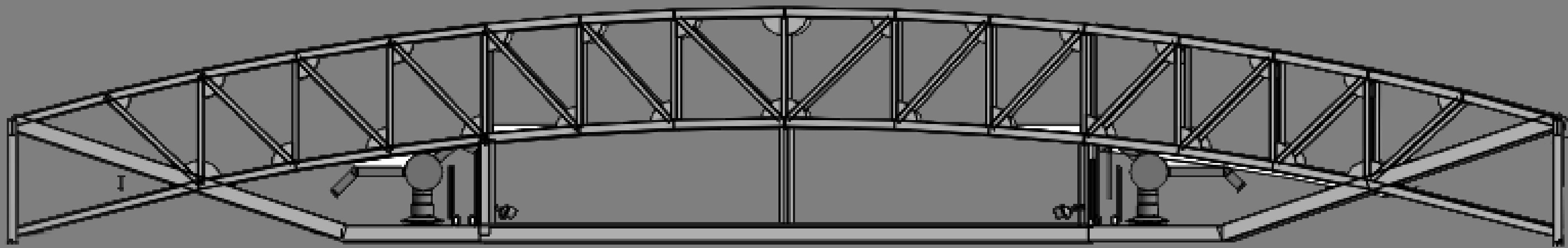
HORIZONTAL TIE: W24x117

SECTION PROFILE		
Member	Member Location	Member Size
1	Top Chord	W14x43
2	Top Chord	W14x43
3	Top Chord	W14x43
4	Top Chord	W14x43
5	Top Chord	W14x43
6	Top Chord	W14x53
7	Top Chord	W14x53
8	Top Chord	W14x53
9	Top Chord	W14x53
10	Top Chord	W14x53
11	Top Chord	W14x53





# MEP SYSTEMS:



# Lighting System Details:



- Luminaire Specs:
- 60 Indoor Sports Luminaire
  - 1000 W Metal Halide HID
  - Blackout Shutter
  - Glare Controlling Optics





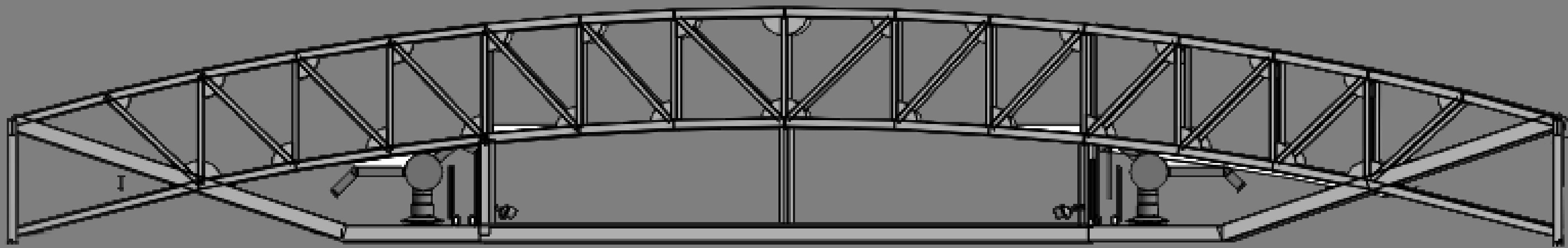
Opportunity

Goal

Strategy

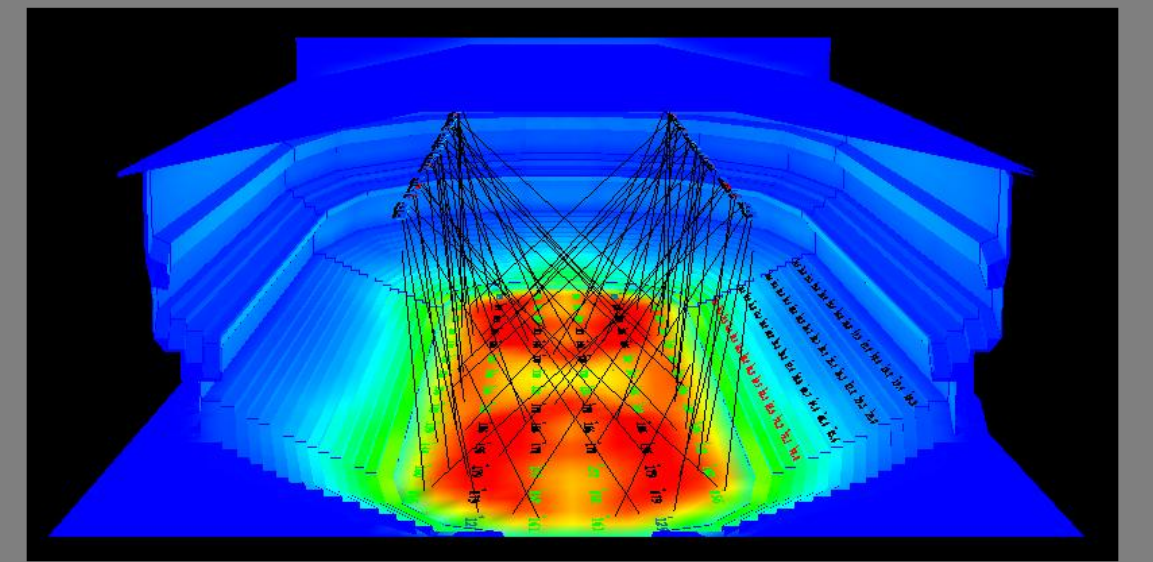
Results

# MEP SYSTEMS:



### Design Metrics

- 1714 lx Eavg,h @ Ice
- 1089 lx Eavg,v @ 3' - 5'AFF
- CV = 0.10
- E<sub>max</sub>:E<sub>min</sub> = 1.39







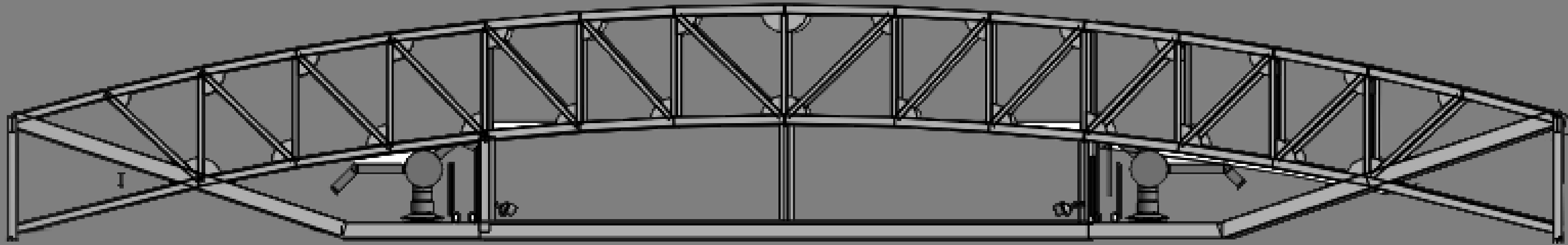
Opportunity

Goal

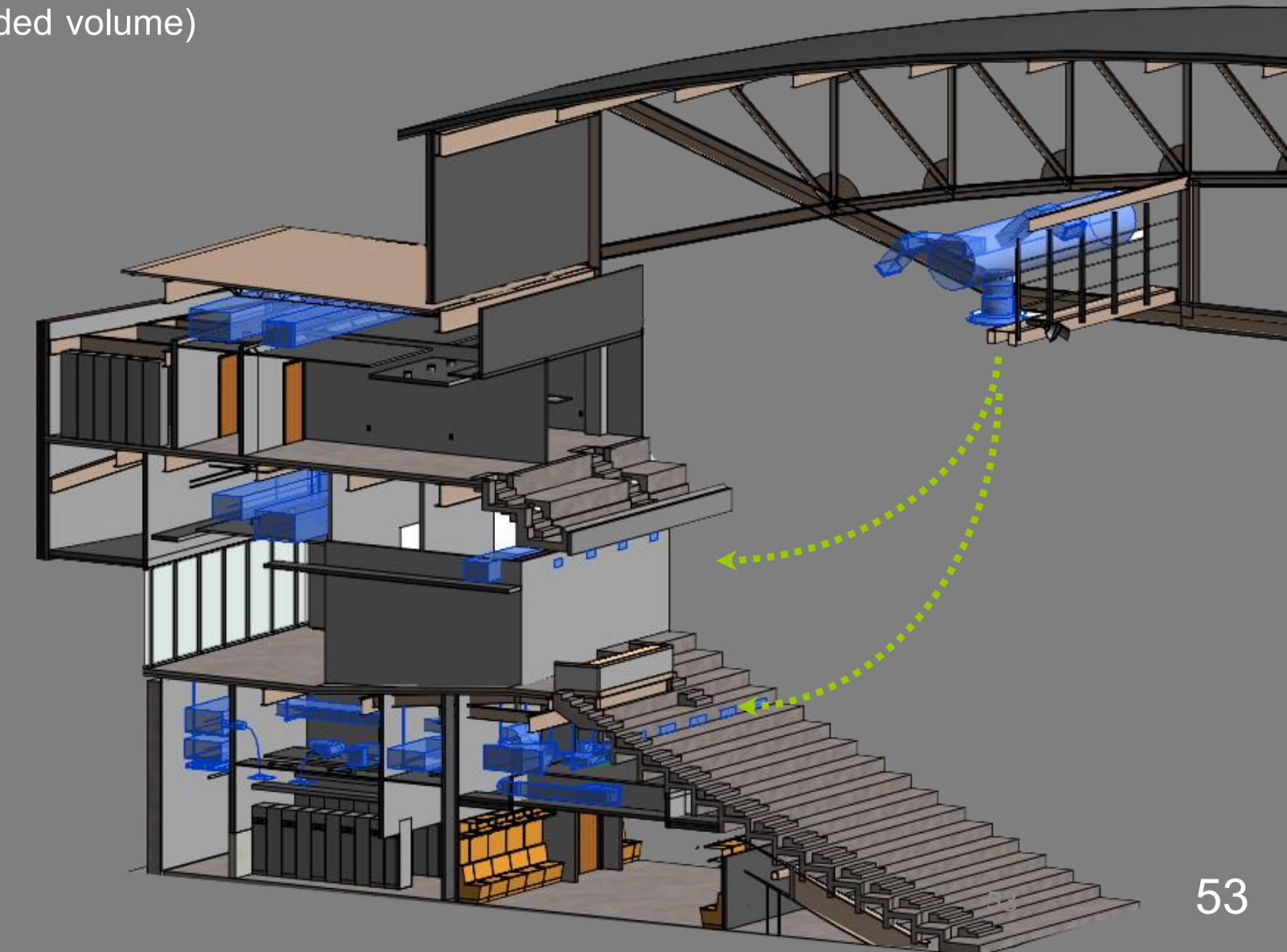
Strategy

Results

# MEP SYSTEMS:



- Two 45,000 cfm AHU's Energy Recovery/Dehumidification
- 90,000 cfm (for added volume)
- 64" round Duct
- Supply High
- Return Low





PROJECT	PROCESS	SAVINGS	PROMINENCE		FUNCTION	REFLECTION
		Opportunity	Goal	Strategy		
						
						
 <b>Size</b>	204'-0" x 322'-6" (65,700 SF)	156'-0" x 236'-5" (36,882 SF)	196'-0" x 240'-4" (47,105 SF)	196'-0" x 240'-4" (47,105 SF)		
 <b>Cost/SF</b>	<b>\$27.85/SF</b>	<b>\$24.57/SF</b>	<b>\$21.98/SF</b>	<b>\$26.41/SF</b>		







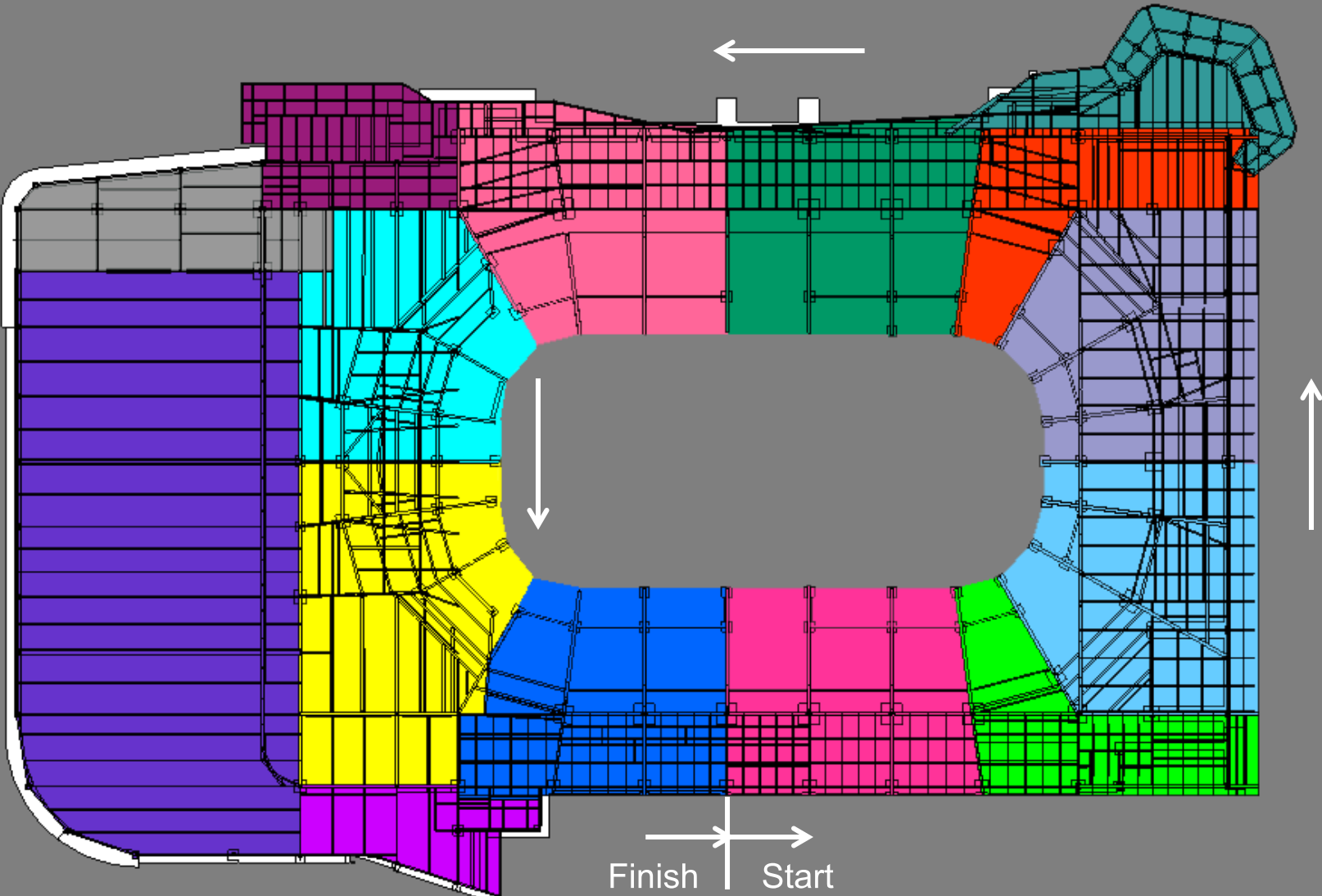
Opportunity

Goal

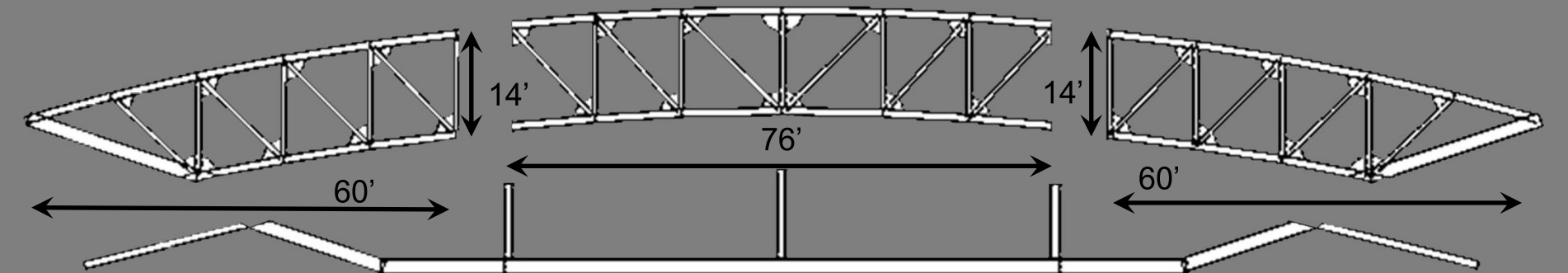
Strategy

Results

# Original Erection Sequence



## Delivery

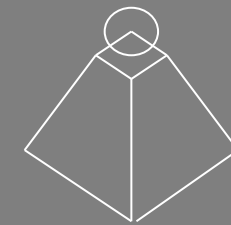


Constructability:

29 Nov 2012

Baseline Cranes: 200 Ton & 300 Ton Hydraulic

No Shoring



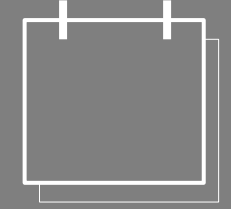
**538 Tons**

▲ **34.5%**



**\$623,055**

▲ **19.3%**



**18 days**





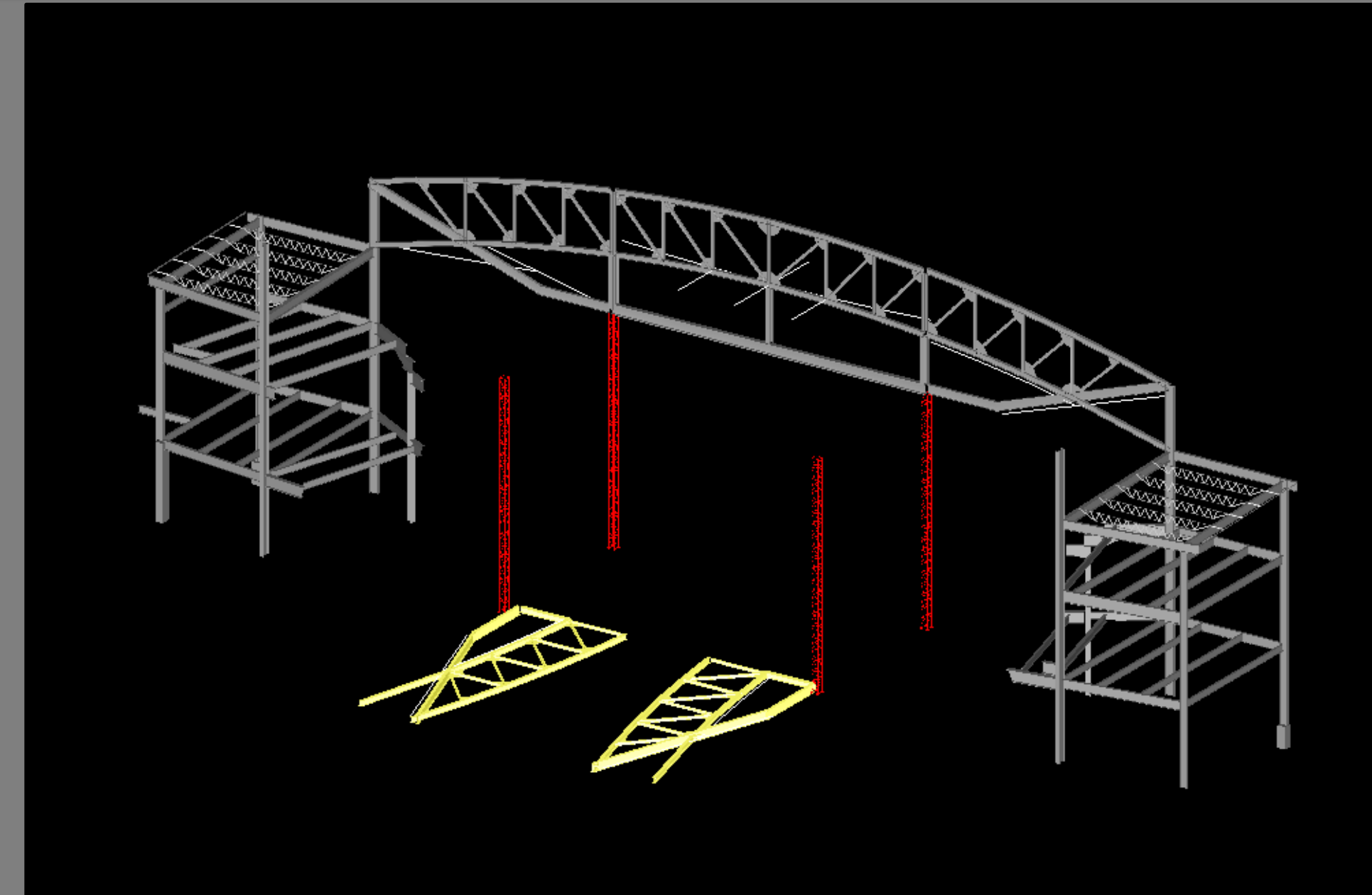
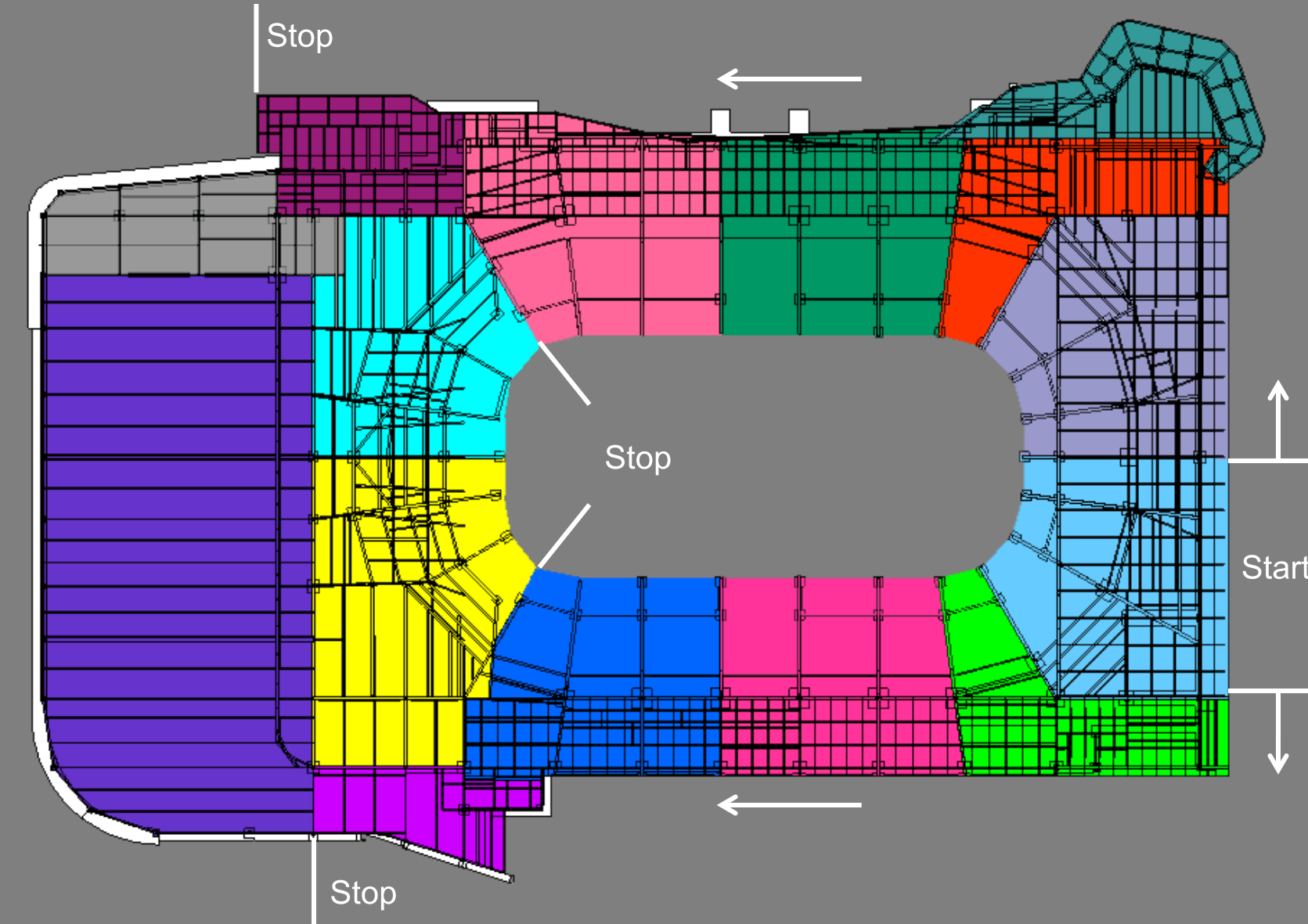


Opportunity

Goal

Strategy

Results



Deliveries on University Drive





Opportunity

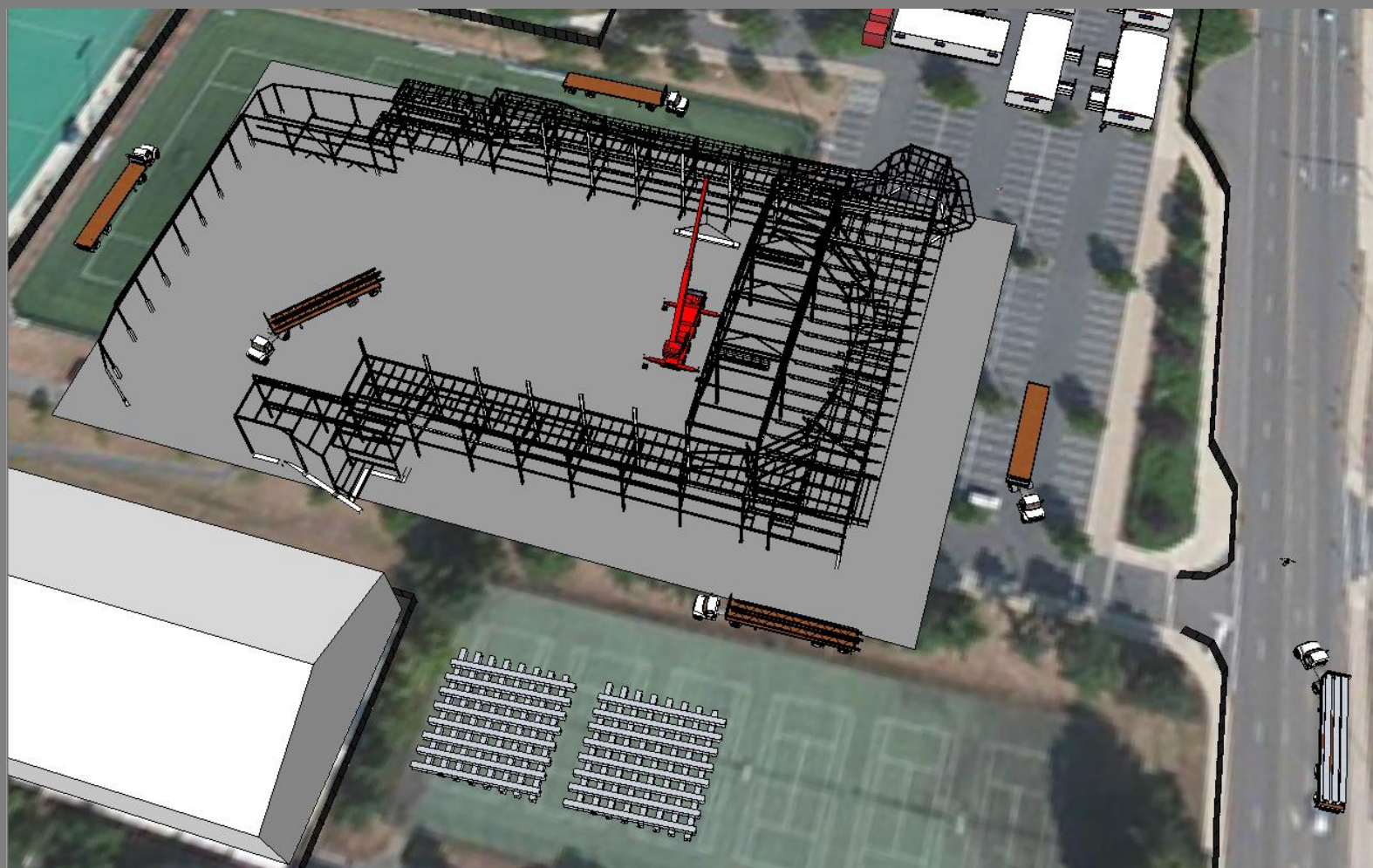
Goal

Strategy

Results

# Site Logistics

Tuesday 9:00:00 AM 3/27/2012 Day=1 Week=1



## Constructability:

24 Oct 2012

HPR Proposed: 150 Ton Hydraulic & Shoring

**\$623,055** ▲ **19.3%** Vs. **\$497,468** ▲ **15.4%**

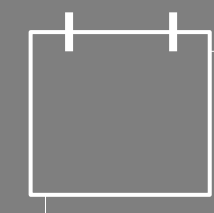
Original Erection Sequence

HPR Erection Sequence

**\$125,587** ▲ **26.2%**



**\$497,468**



**26 days**







Opportunity

Goal

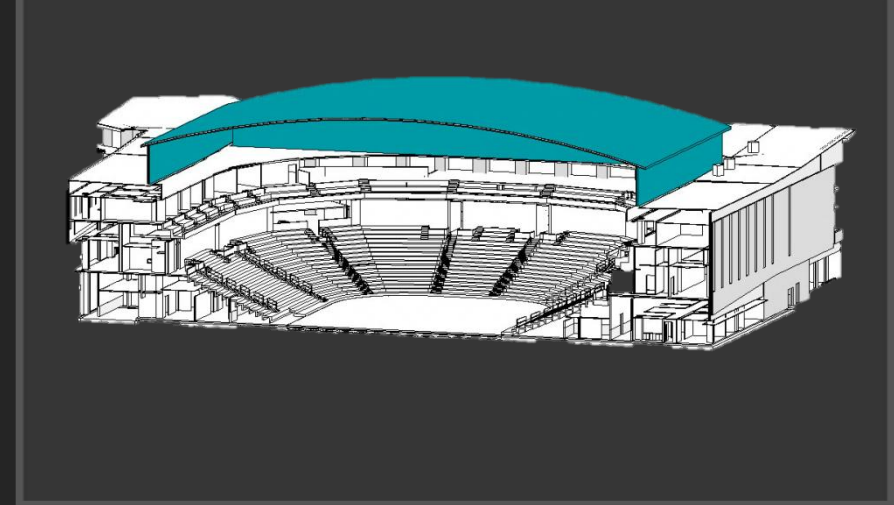
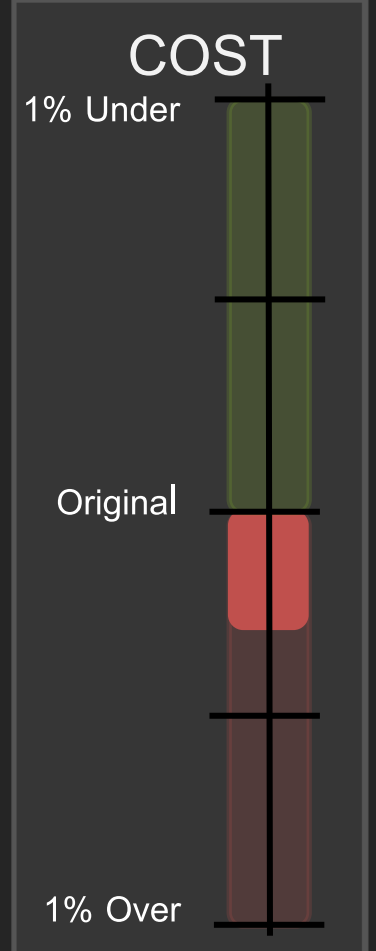
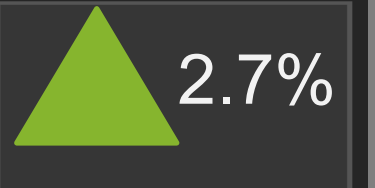
Strategy

Process

Results



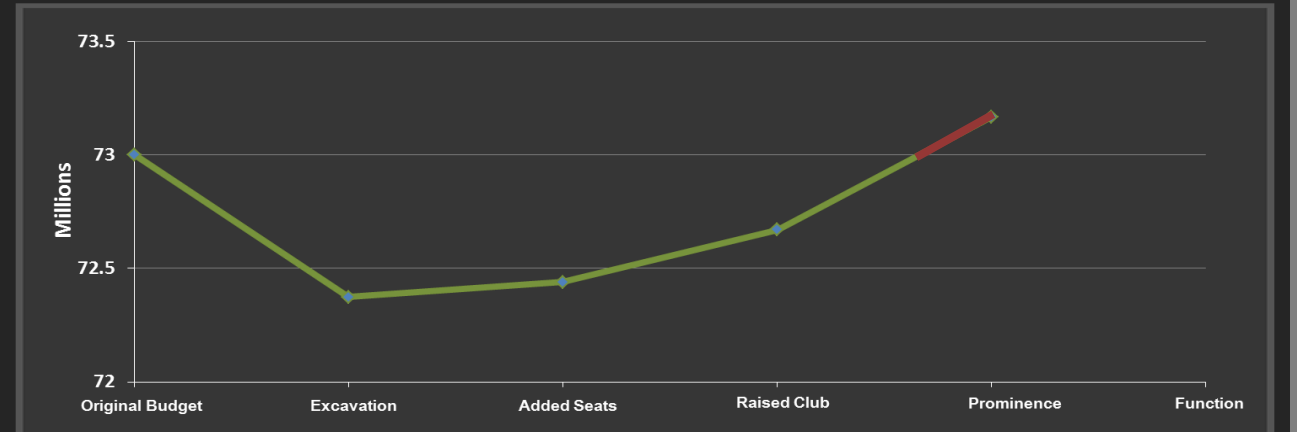
**HPR** dash-board



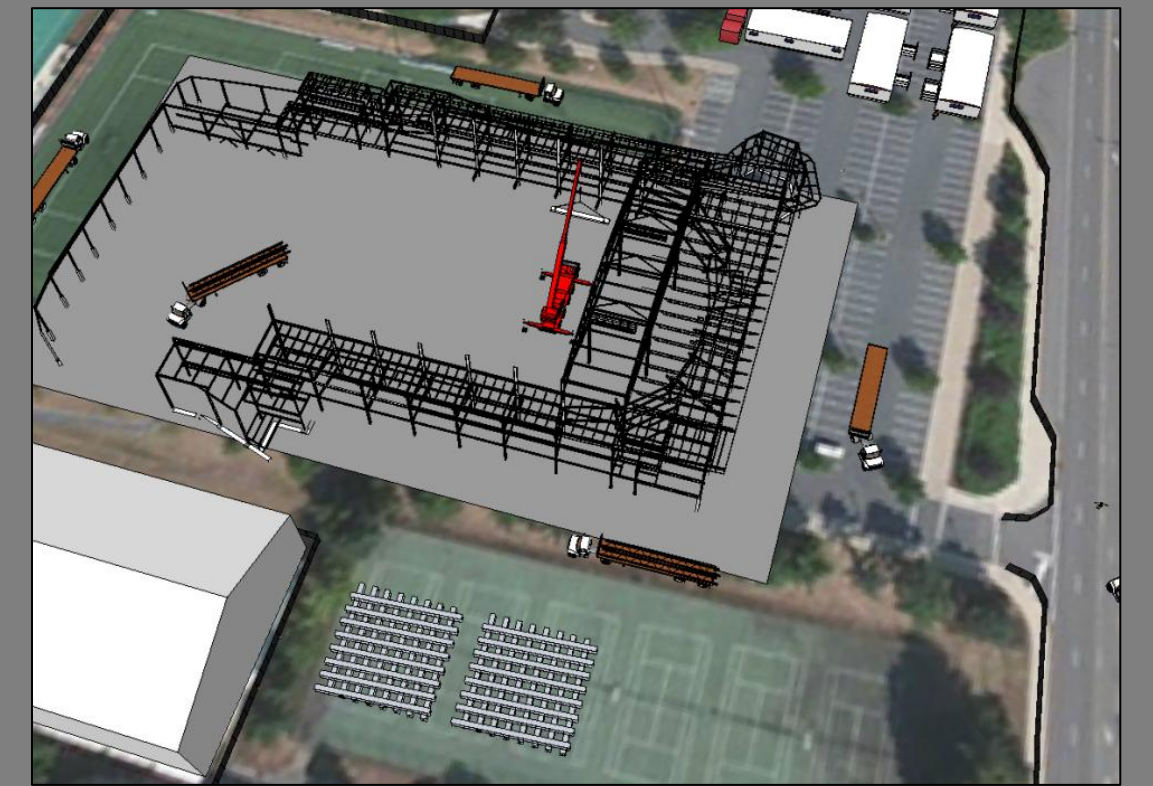
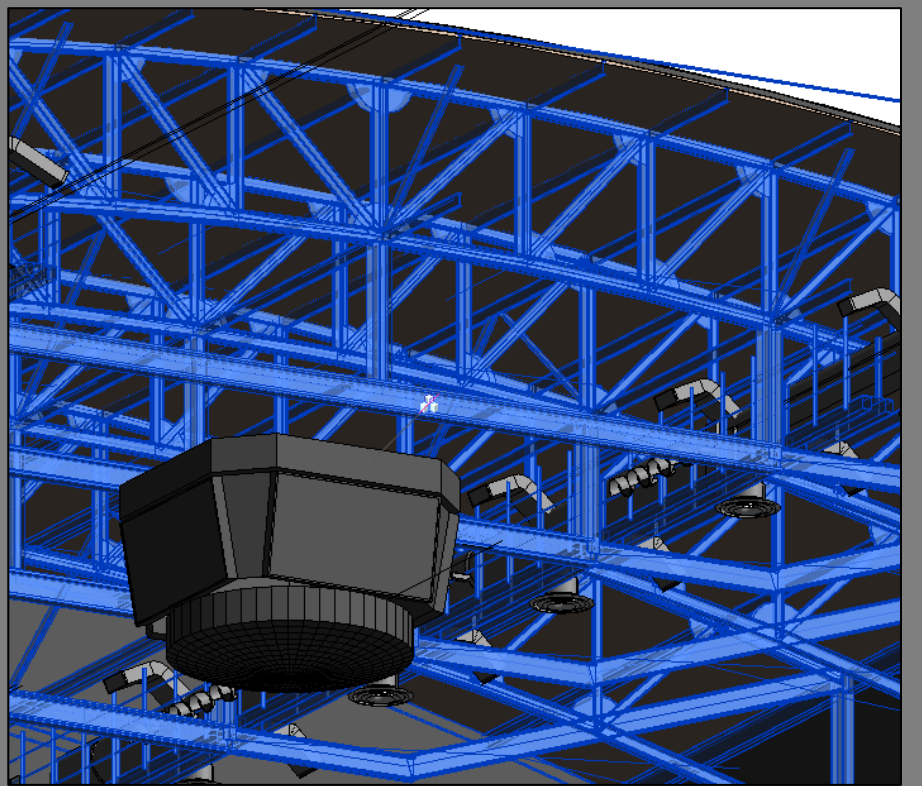
**SEATS**

Proposed  
**6,185**

BOD  
**6,031**



# Prominence Package Summary



**\$** **\$497,468**

**26 days**





# FUNCTION





Opportunity

Goal

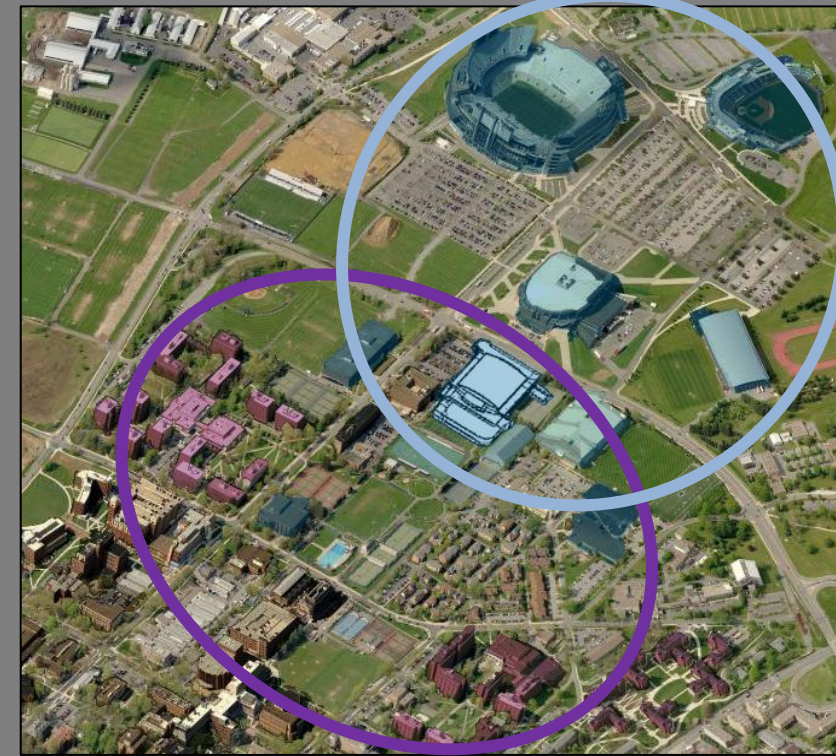
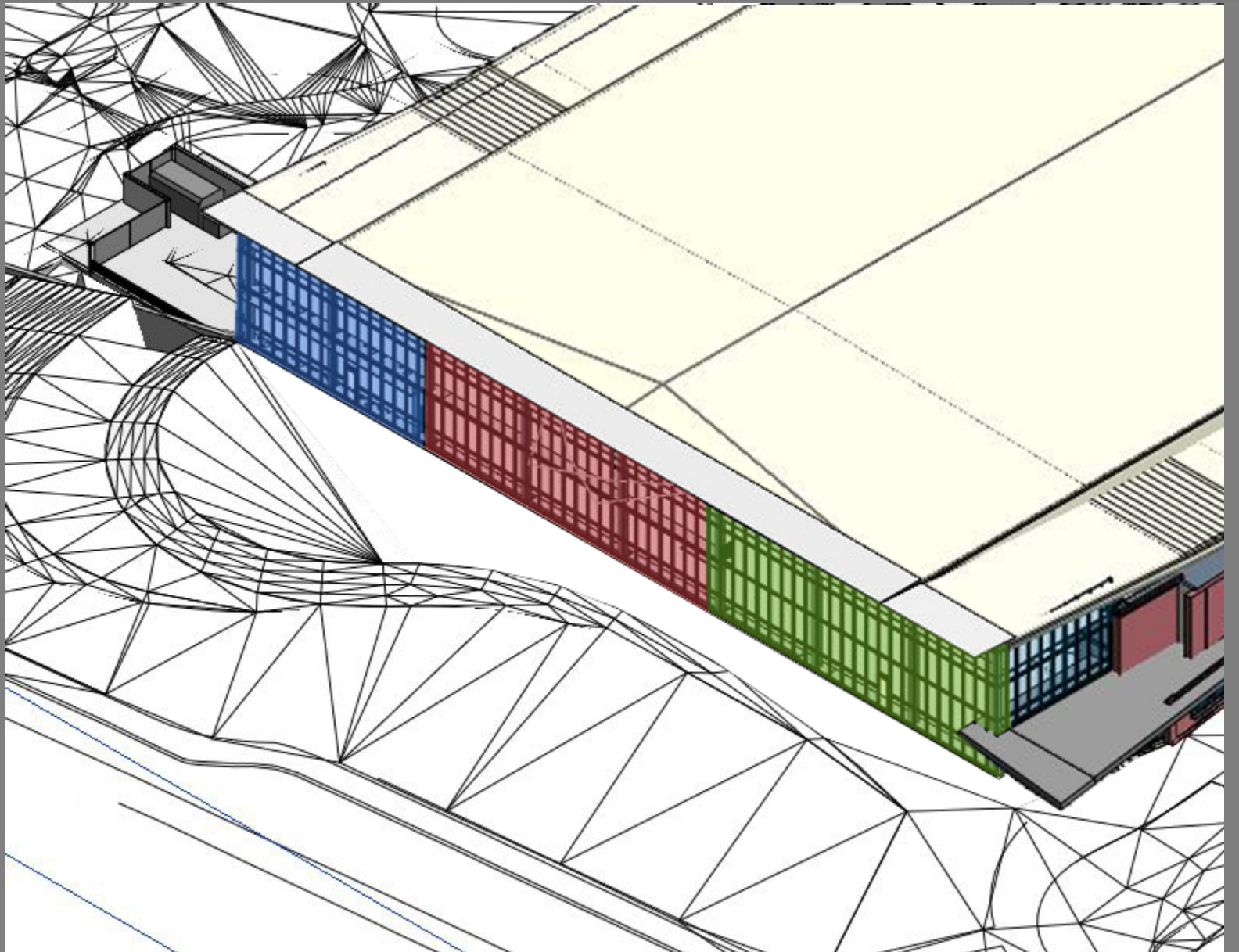
Strategy

Results



### Two entrances

Main Entrance and Student entrance



Energy and Atmosphere  
Optimize Energy Performance

5 of 19 Points





Opportunity

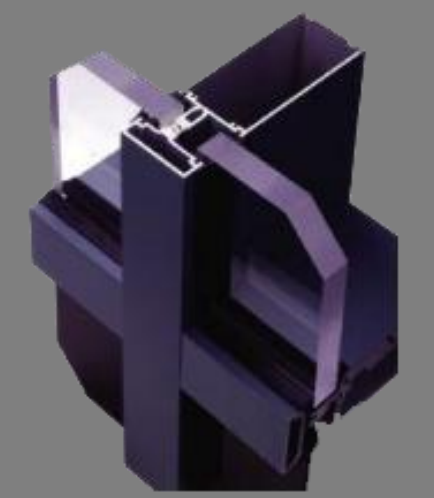
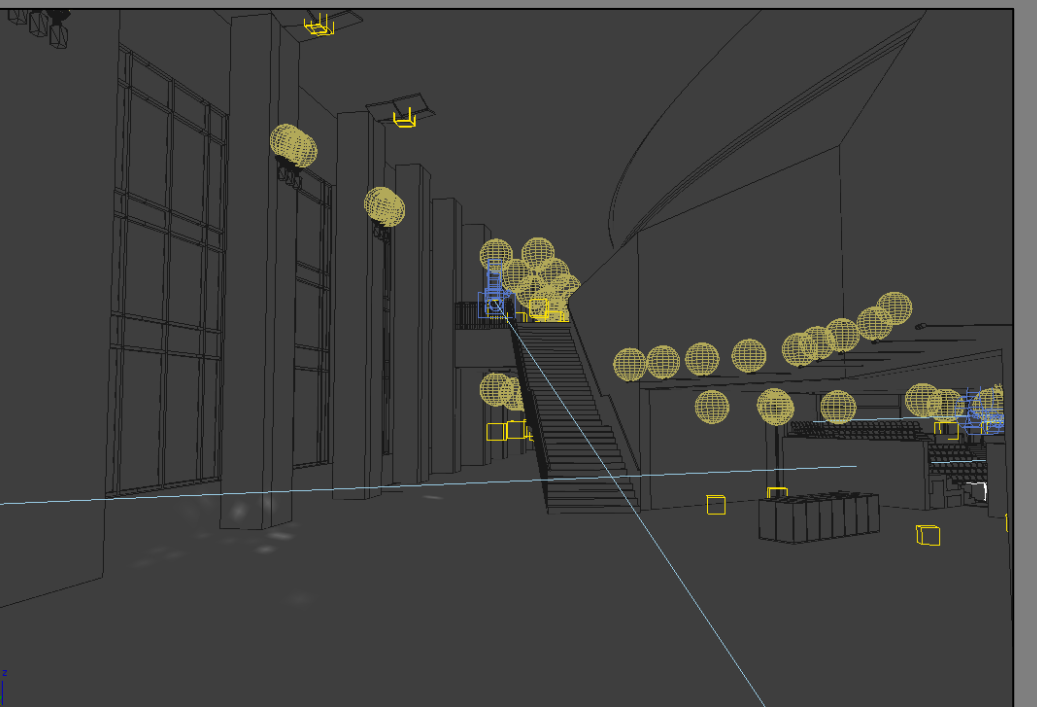
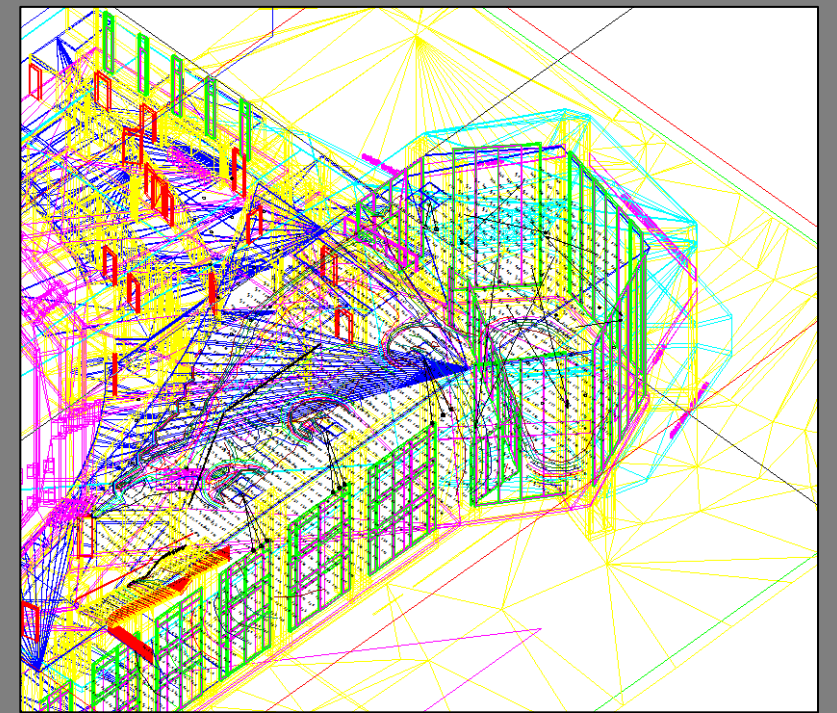
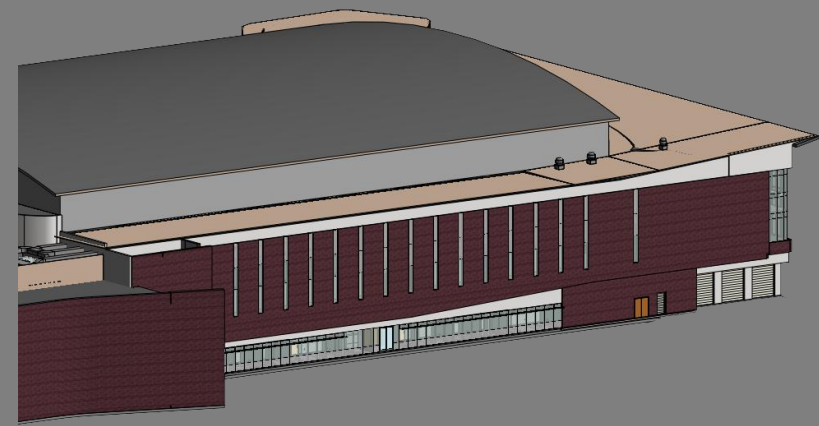
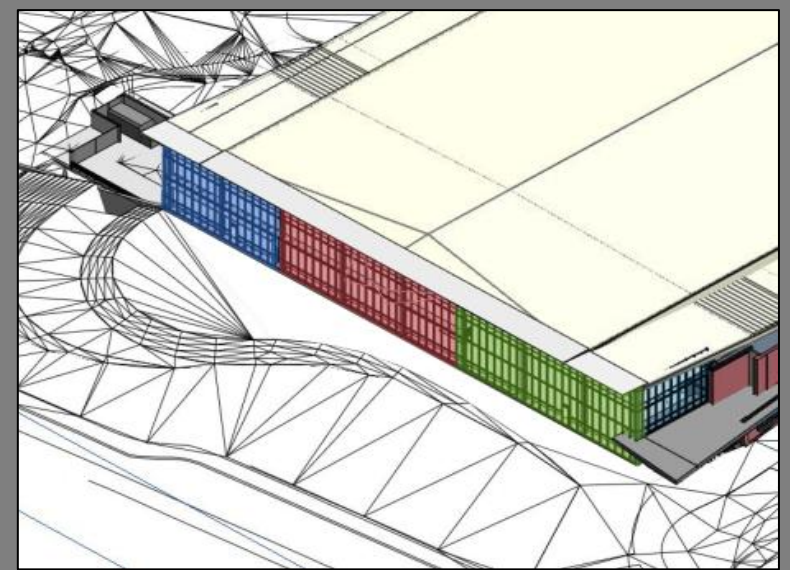
Goal

Strategy

Results



Reser Stadium



### % Glass Study

wall U-Value = .029  
Glass U-Value = .4

### Wall Type Comparison

Average U-Value = .055  
Good U-Value = .029

### Curtain Wall Comparison



Kawneer 1601  
Kawneer 1603

Kawneer 1602  
Kawneer 1603 UT





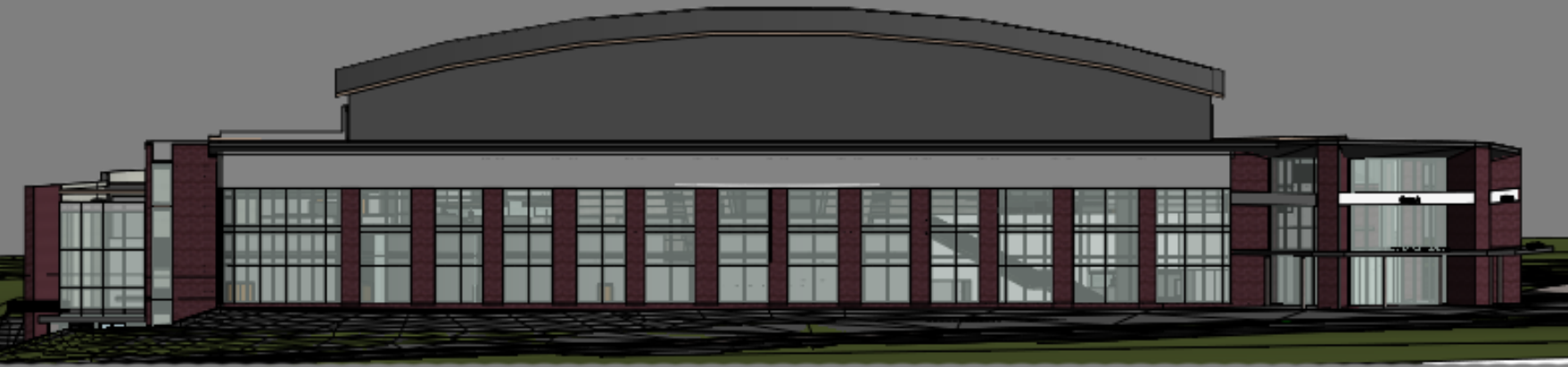
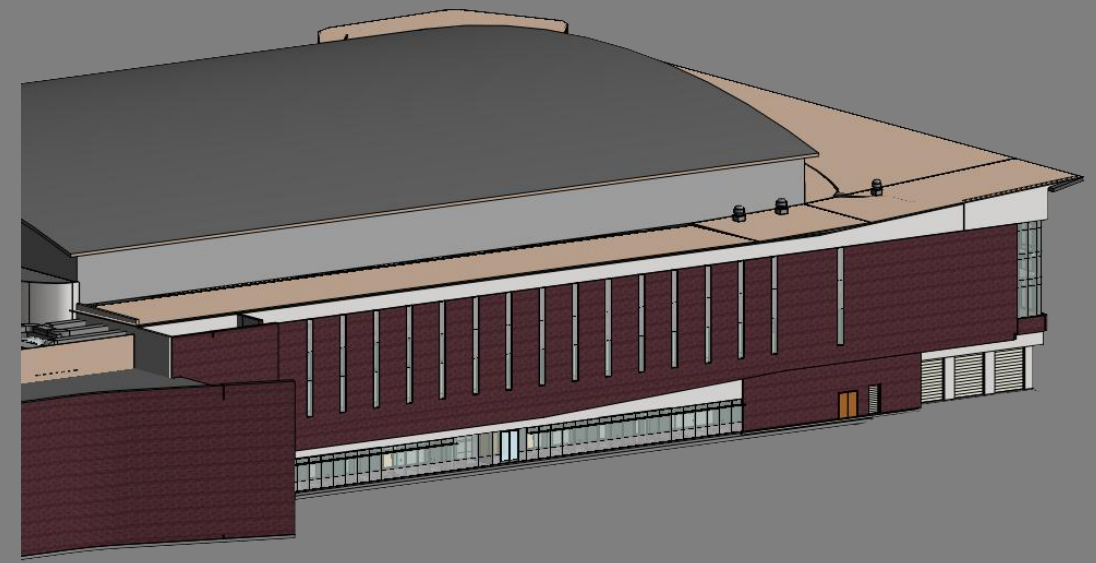
Opportunity

Goal

Strategy

Results

# Glass Study



% 100	\$ \$ 0	0 %	--
% 70	\$ \$ 2,078	0.37 %	▲
% 50	\$ \$ 3,998	0.7 %	▲
% 30	\$ \$ 5,923	1.04 %	▲
% 10	\$ \$ 8,150	1.43 %	▲

Wall U-Value = .029

U-Value : 0.4 & SHGC: 0.16 > ASHRAE min for Climate Zone 5A





# Glass Study

% 100	\$ \$ 0	0 %	--
% 70	\$ \$ 2,078	0.37 %	▲
% 50	\$ \$ 3,998	0.7 %	▲
% 30	\$ \$ 5,923	1.04 %	▲
% 10	\$ \$ 8,150	1.43 %	▲

Wall U-Value = .029  
 U-Value : 0.4 & SHGC: 0.16 > ASHRAE min for Climate Zone 5A

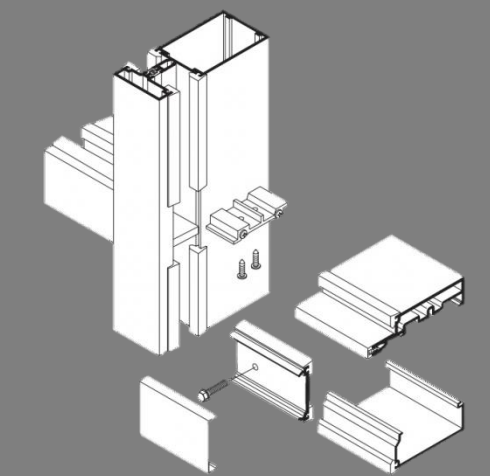
# Curtain Wall System

1601 Wall System	\$ \$ 1,120	0.2%	▲
1602 Wall System	\$ \$ 1,920	-0.3 %	▼
1603 Wall System	\$ \$ 1,925	0.4%	▲
1601 UT Wall System	\$ \$ 1,751	0.3 %	▲

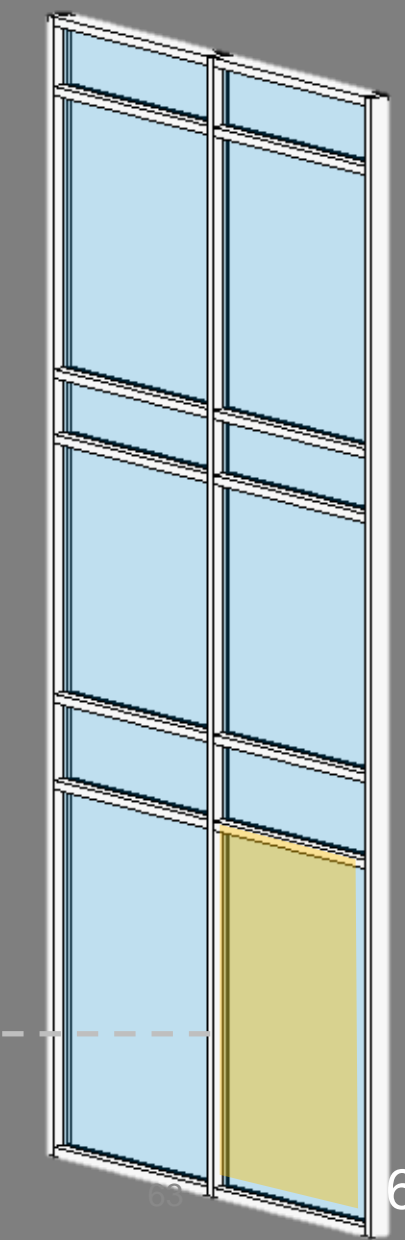
- Kawneer's "Ultra Thermal" Product
- Features a double thermal break
  - Real benefit realized at super low U-Values
  - 30% higher cost

# Kawneer 1600 Wall System ® 3

Thermal Transmittance <sup>1</sup> (BTU/h • ft <sup>2</sup> • °F)	
Glass U-Factor <sup>3</sup>	Overall U-Factor <sup>4</sup>
0.48	0.56
0.46	0.55
0.44	0.53
0.42	0.51
0.40	0.49
0.38	0.48
0.36	0.46
0.34	0.44
0.32	0.43
0.30	0.41
0.28	0.39
0.26	0.37
0.24	0.36
0.22	0.34
0.20	0.32



- Structural Mullion & Glazing Design
- Wind Strength Design (ASTM E1300)
  - Small Missile Impact (ASTM E2025)







Opportunity

Goal

Strategy

Results

Main Entrance

Student Entrance



### Energy and Atmosphere

Optimize Energy Performance 5 of 19 Points

New Buildings	Existing Building Renovations	Points
20%	16%	5
22%	18%	6
24%	20%	7
26%	22%	8
28%	24%	9
30%	26%	10
32%	28%	11
34%	30%	12
36%	32%	13
38%	34%	14
40%	36%	15
42%	38%	16
44%	40%	17
46%	42%	18
48%	44%	19

Original DD Design: \$585,299

**-3.9%**

5 pts = DD design  
20% less that ASHRAE  
appendix G

- +Curtain Wall
- +Wall Construction
- +Resizing AHU-7&8
- +Reducing % Glass
- Added Volume

23% less that ASHRAE  
appendix G  
6 pts = HPR's Redesign



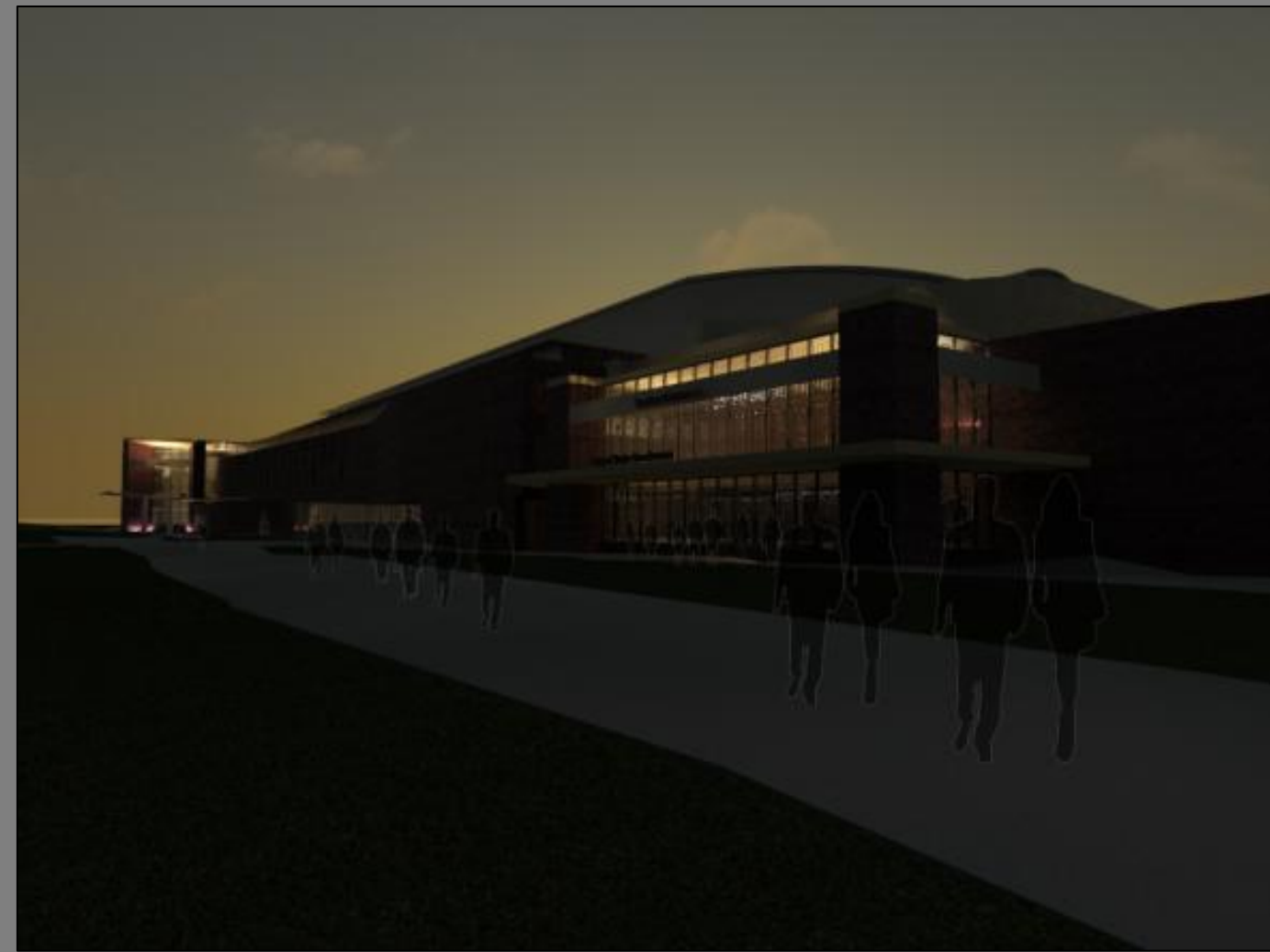


Opportunity

Goal

Strategy

Results



Illuminance Data:

153 lx Avg. horizontal

126 lx vertical

Luminaire Specs: 150 W Metal Halide HID

Mirror Specs: Matte, 30 degree spread



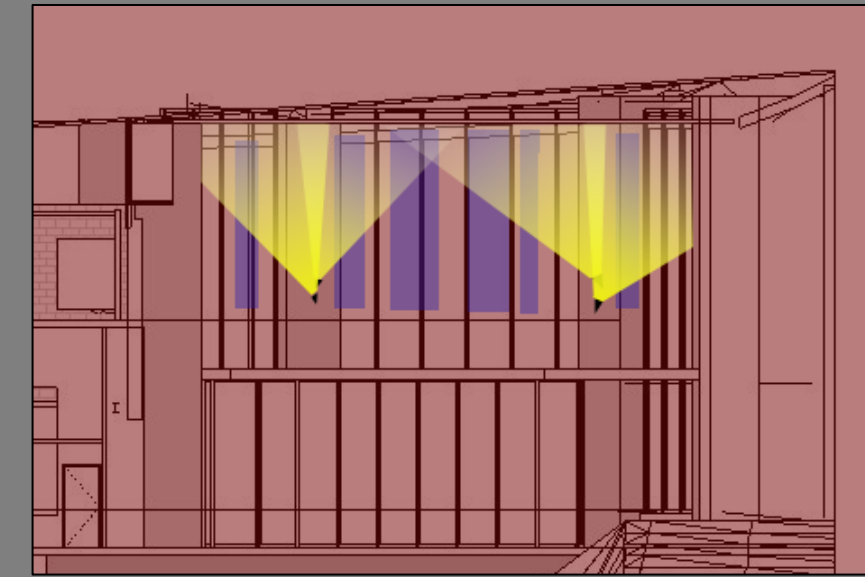
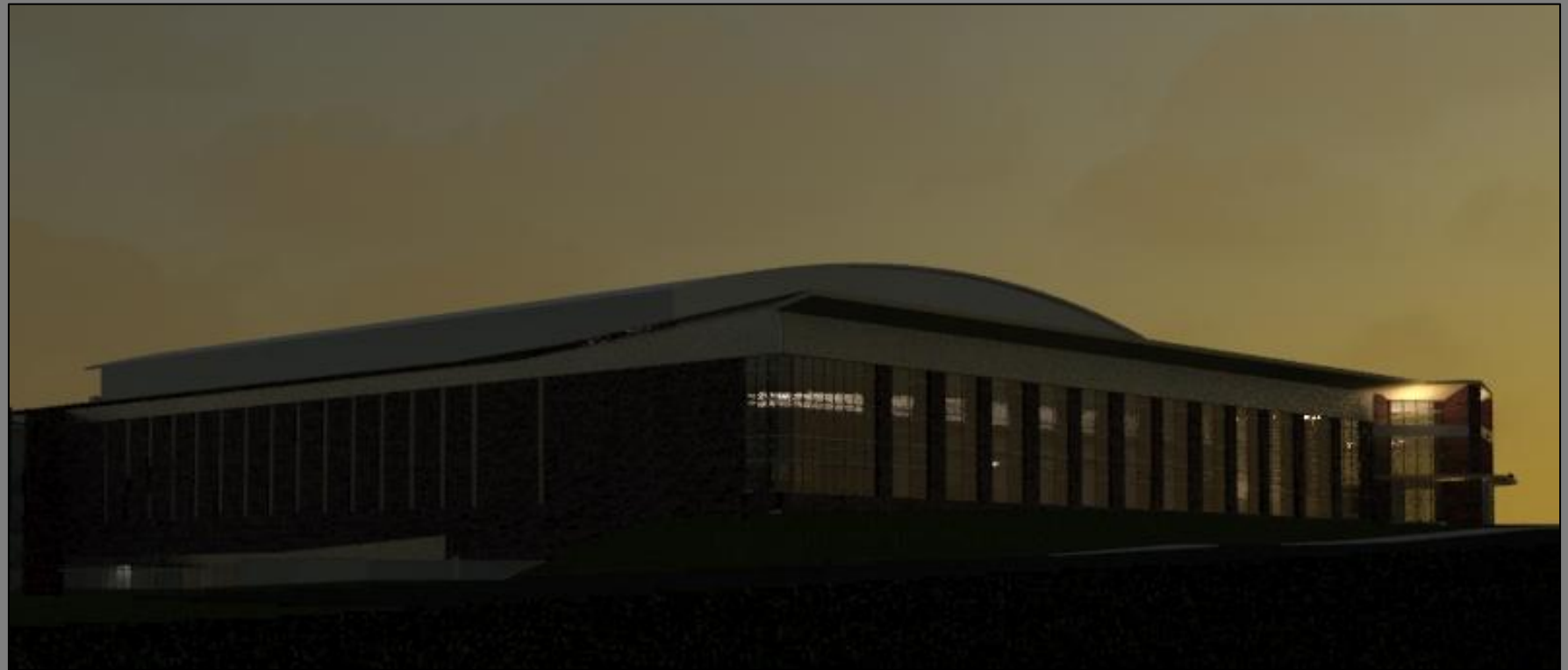


Opportunity

Goal

Strategy

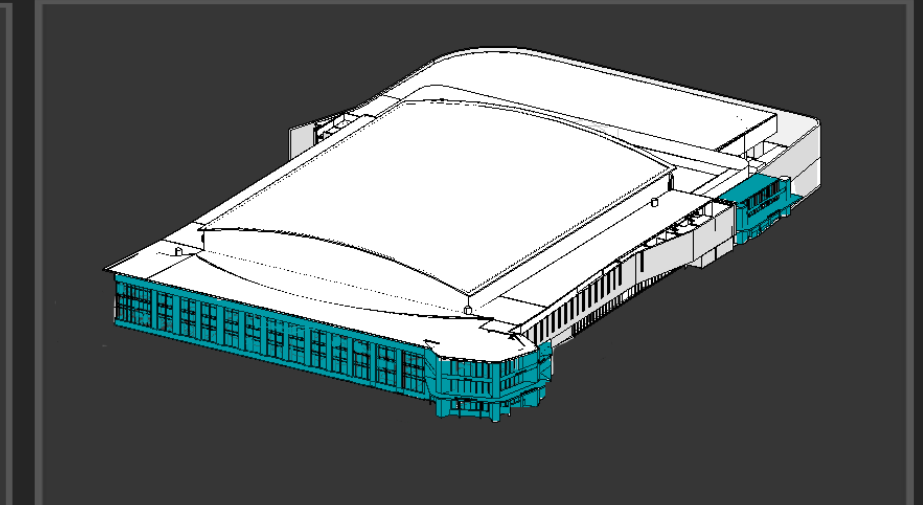
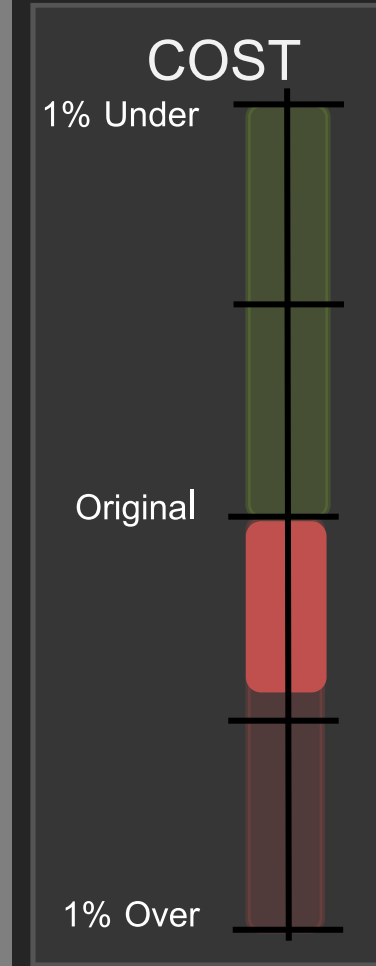
Results







0.5%
 HPR dash board
 2.7%

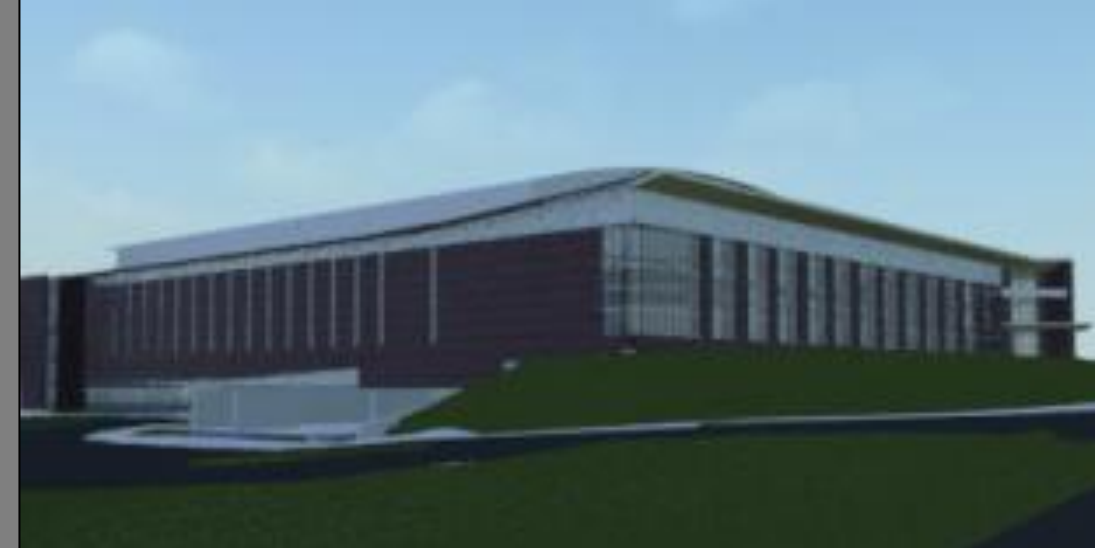


**SEATS**

Proposed  
**6,185**

BOD  
**6,023**

# Function Package Summary



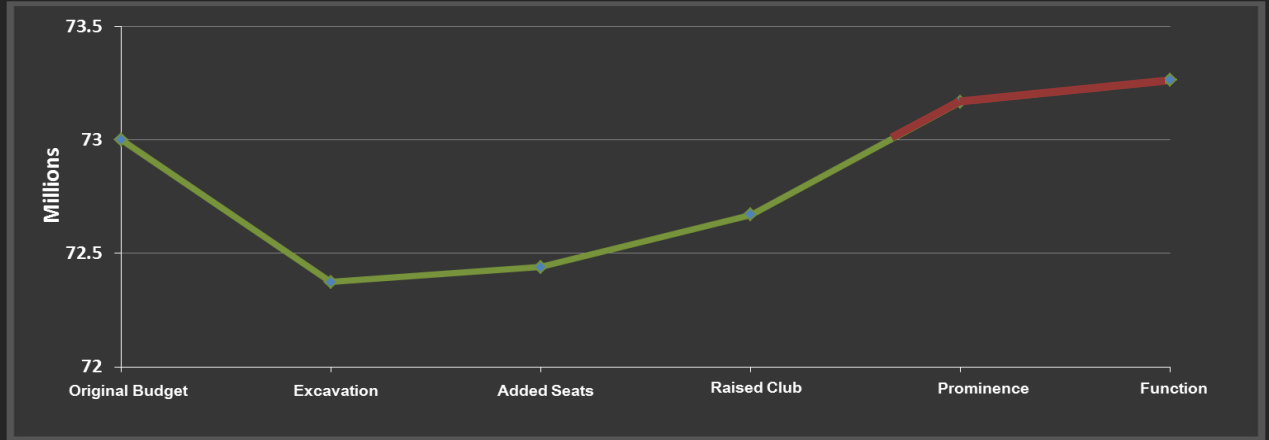
## Energy Impact



Save 3.9% in cost savings  
1 added LEED pts.

\$ **\$95,542**

**8 days**





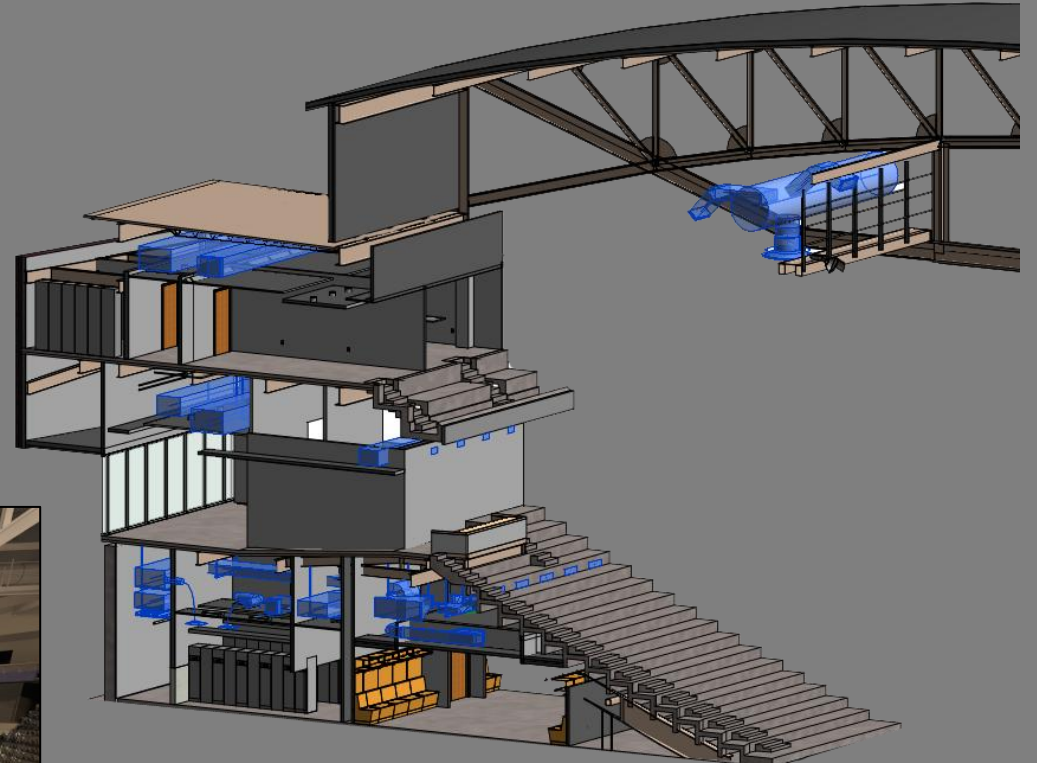
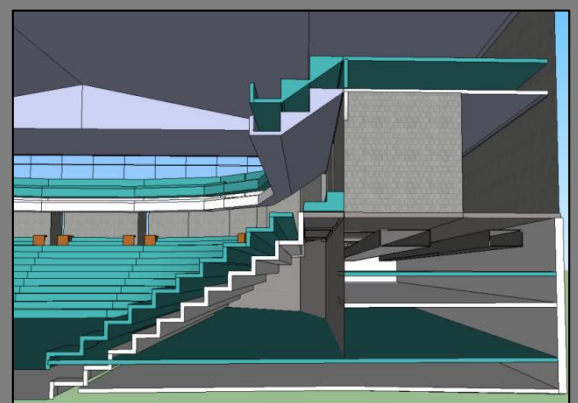


# REFLECTION





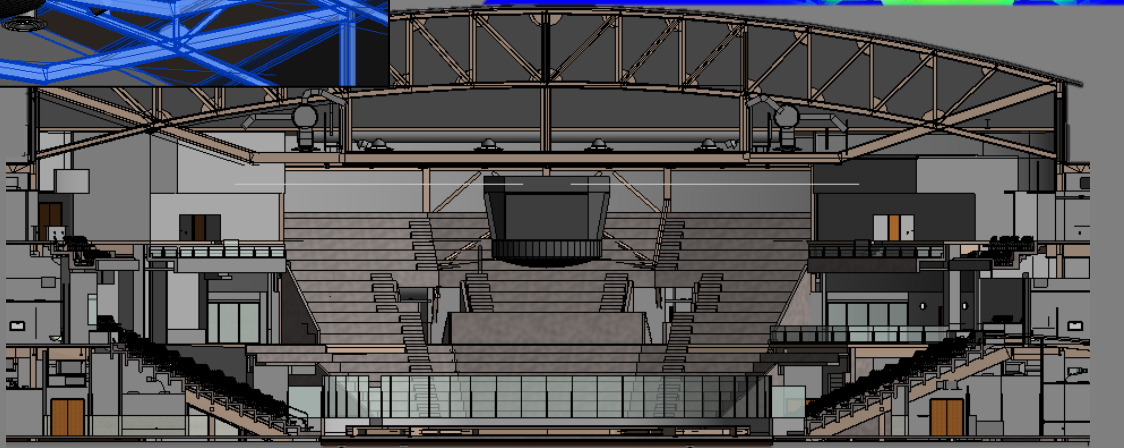
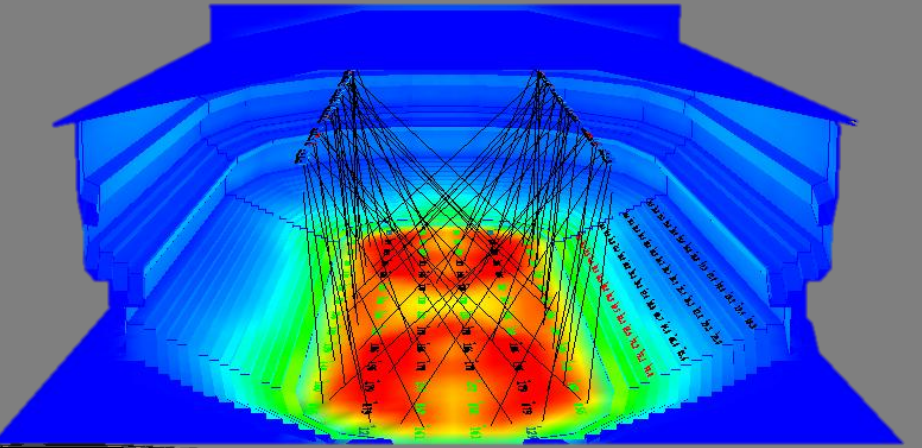
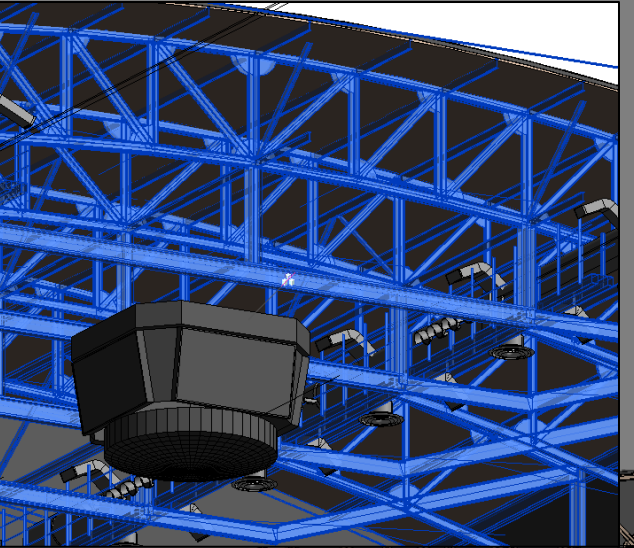
**Savings Package**



\$ **\$330,406**

☐ **15 days**

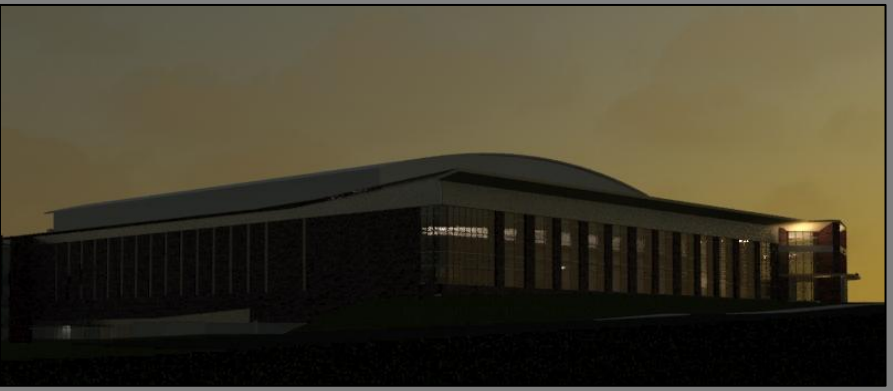
**Enhancement Package: Prominence**



\$ **\$497,468**

☐ **26 days**

**Enhancement Package: Function**



\$ **\$95,542**

☐ **8 days**







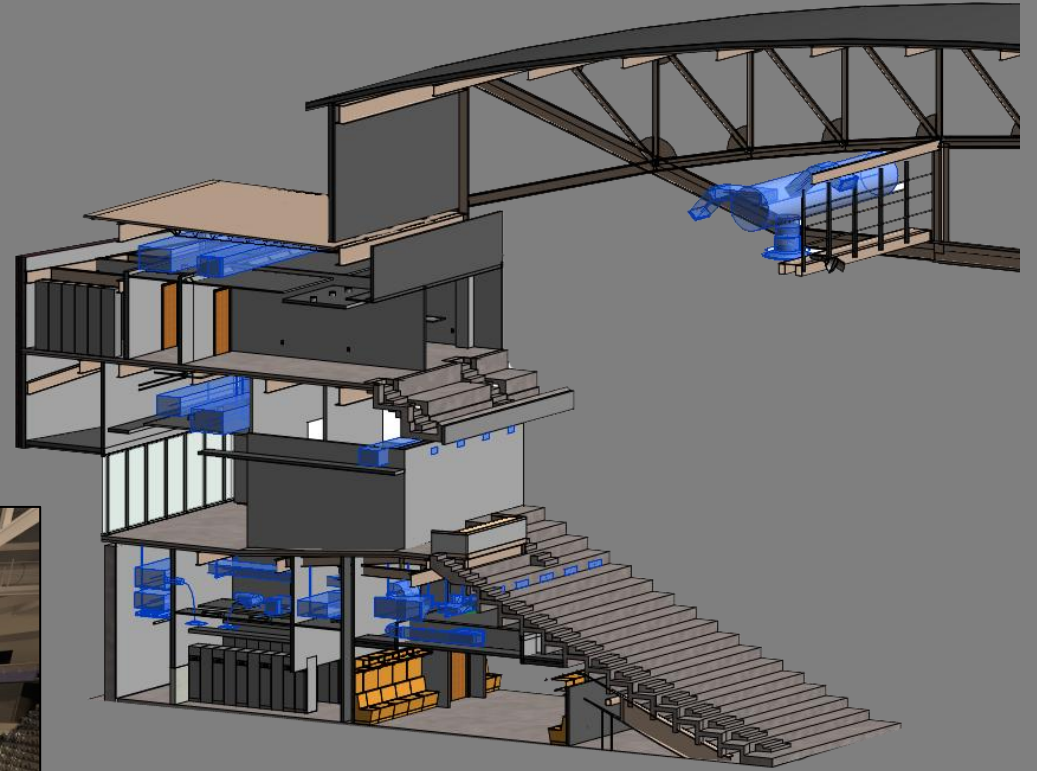
Packages

Benefits

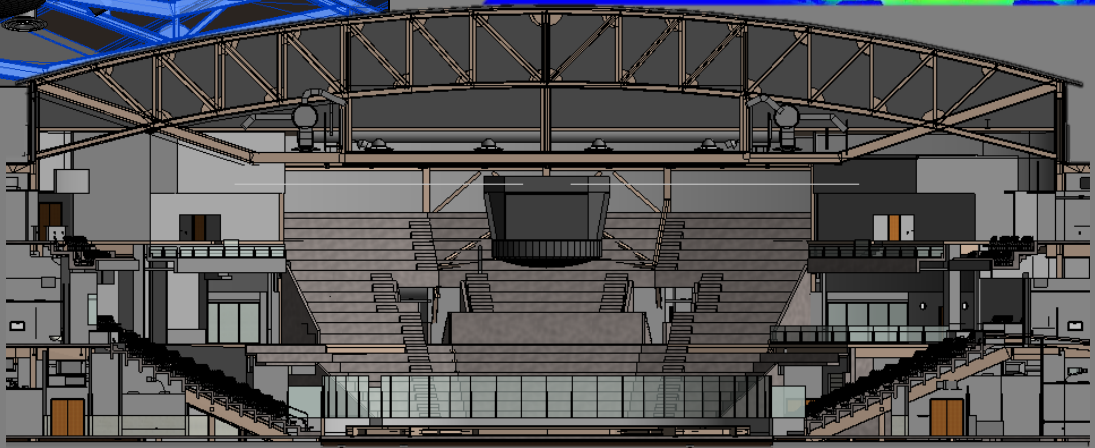
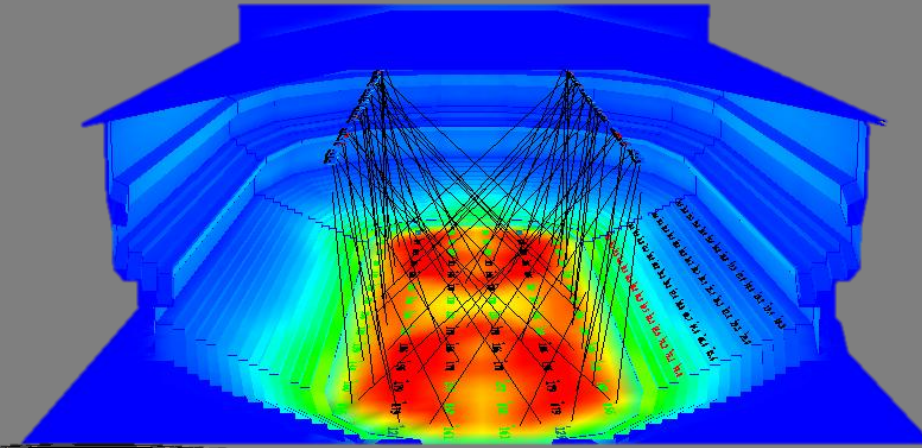
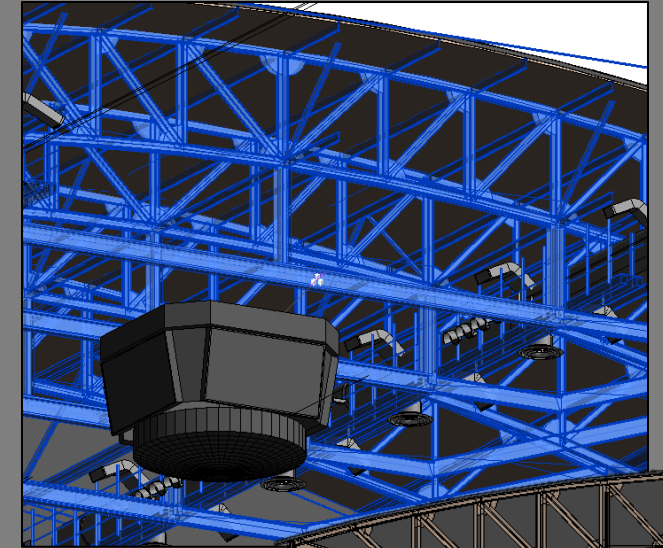
Struggles

Acknowledgments

### Savings Package



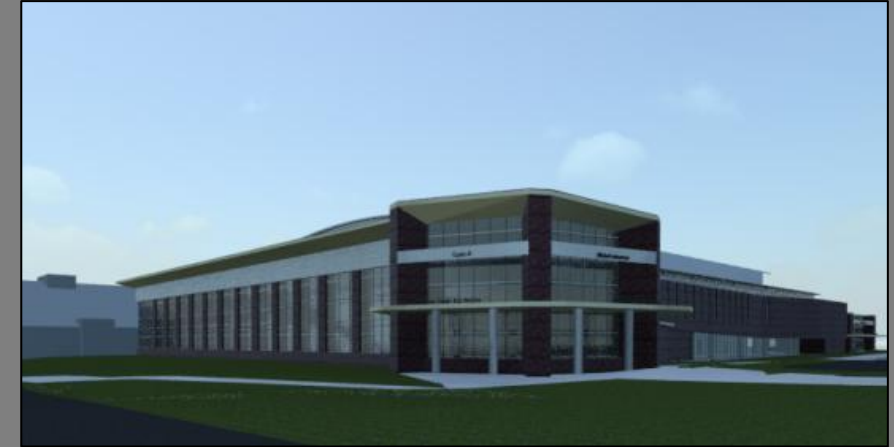
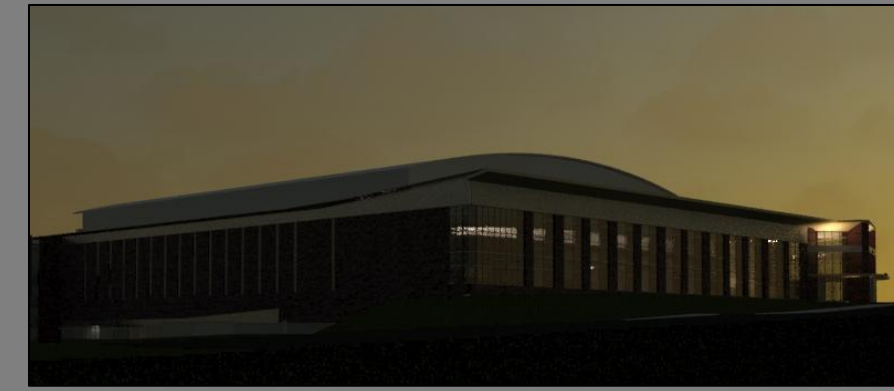
### Add Enhancement Package: Prominence



\$ \$263,003

17 days

### Add Enhancement Package: Function





PROJECT

PROCESS

SAVINGS

PROMINENCE

FUNCTION

REFLECTION



Packages

Benefits

Struggles

Acknowledgments

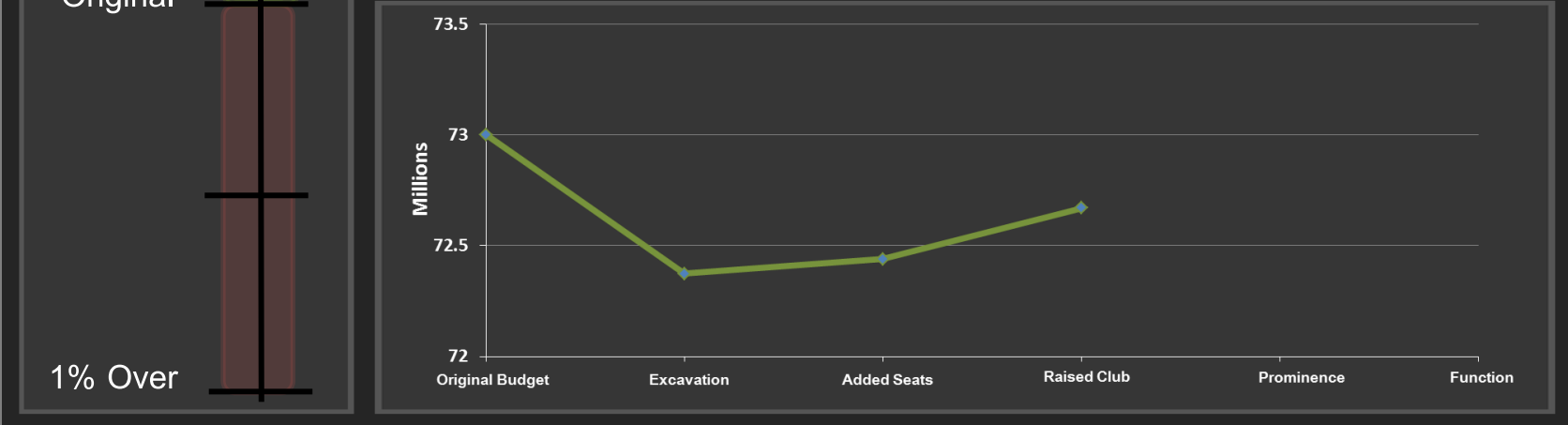
0.5%

HPR dash board

2.7%

**COST**  
1% Under

**SEATS**  
Proposed **6,185**  
BOD **6,031**



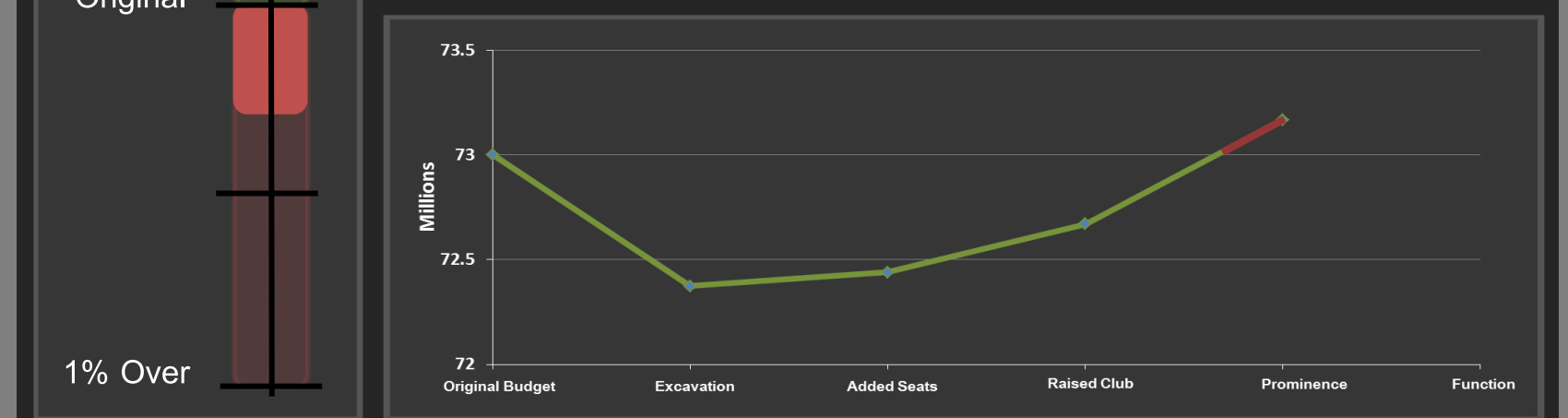
0.2%

HPR dash board

2.7%

**COST**  
1% Under

**SEATS**  
Proposed **6,185**  
BOD **6,031**



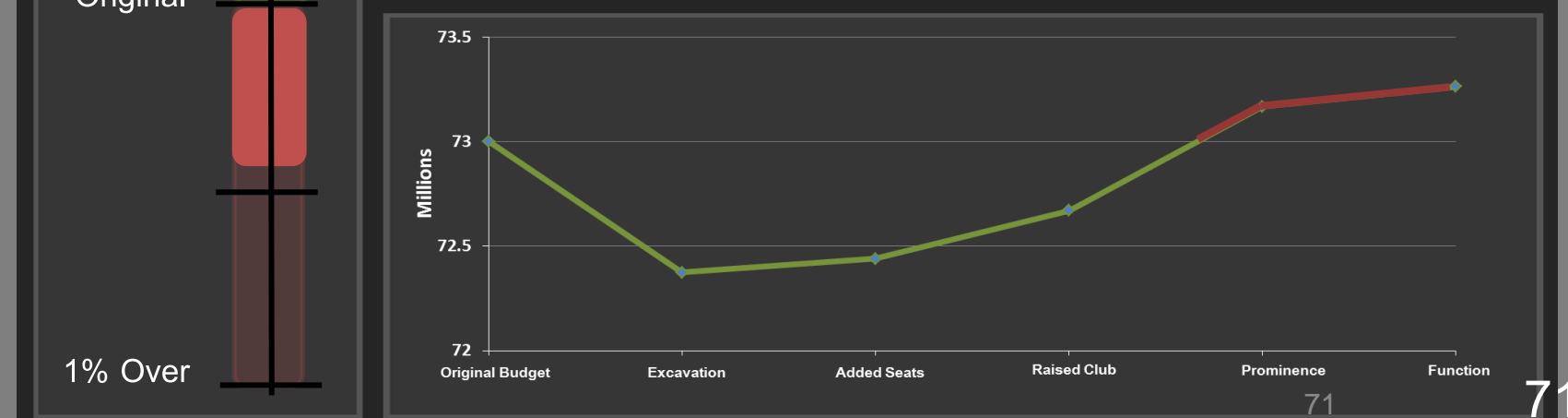
0.5%

HPR dash board

2.7%

**COST**  
1% Under

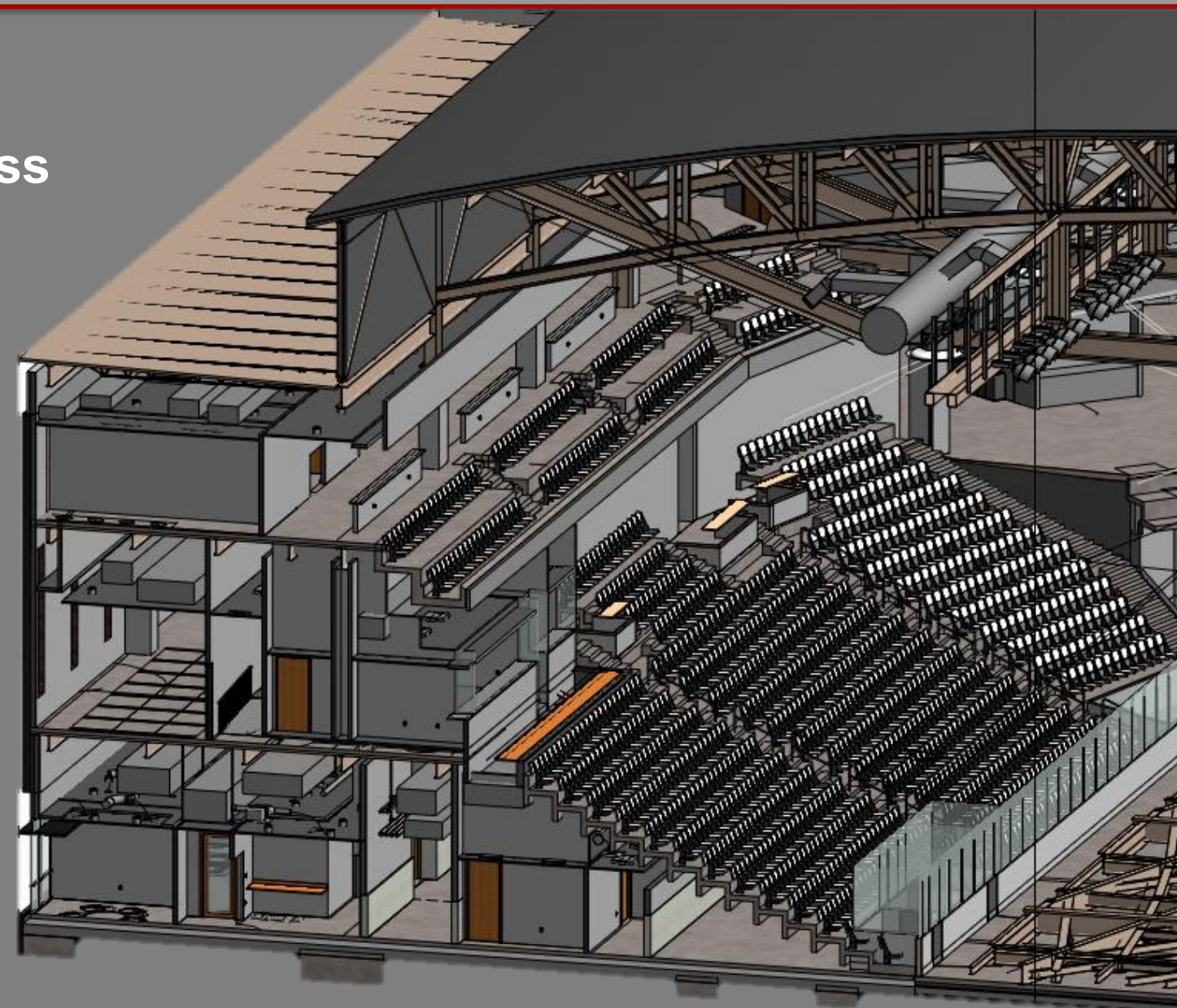
**SEATS**  
Proposed **6,185**  
BOD **6,031**







# Benefits of BIM/IPD Process



## BIM Process



Modeling Implications for Event Level Raising  
3D Coordination



Quick Quantity Takeoff Ability  
3D Coordination & Clash Detection



Export Revit Model to 3DS for Lighting Analysis  
Revit MEP software for system visualization



System Visualization for MEP System Integration



System Visualization for Structural System Integration

## IPD Process

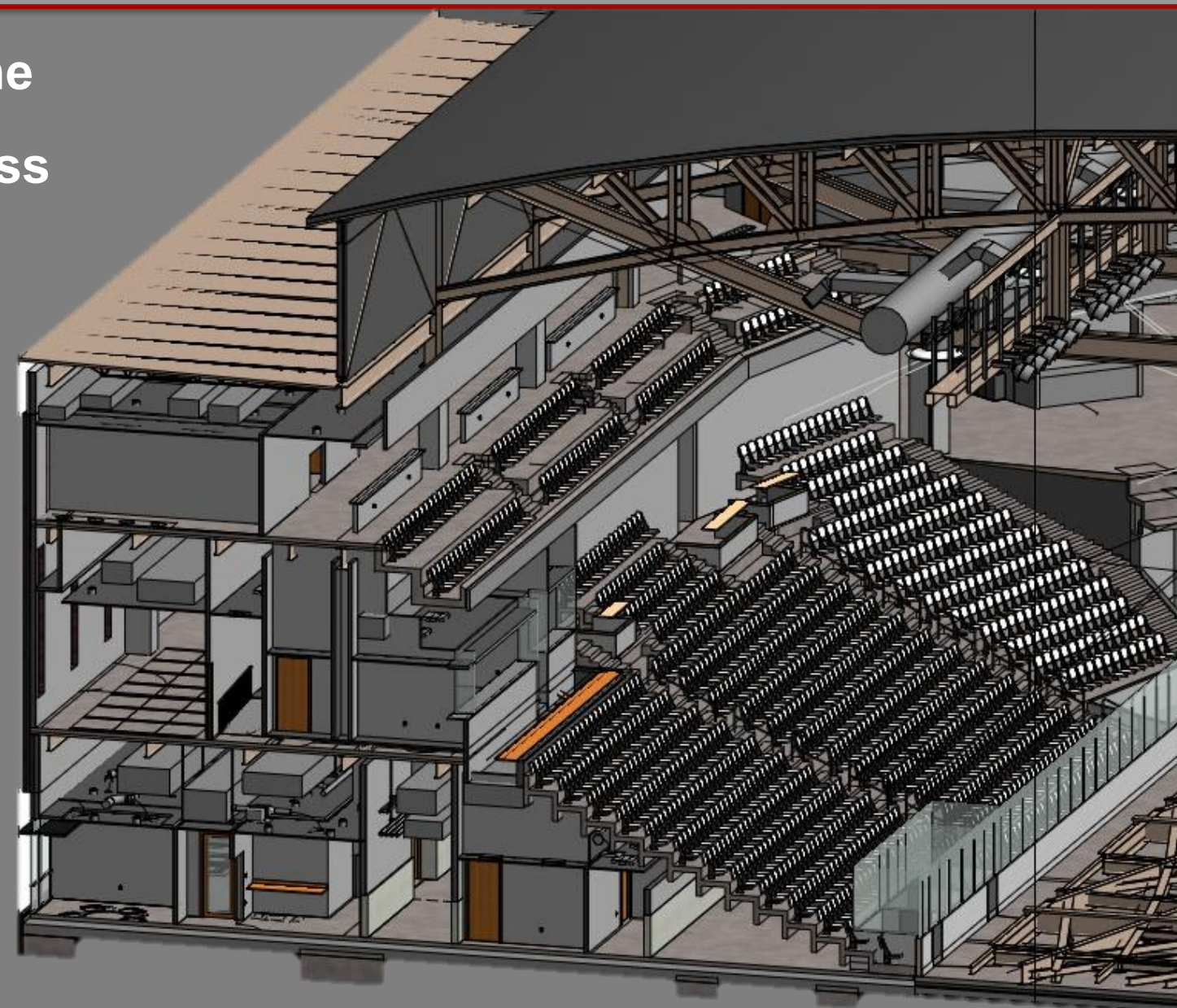


Collaborative Input Into Design Decisions  
Expedited Tracking of Cost and Schedule  
Enhanced Understanding of Building Systems  
Mitigates Rework for both Design & Modeling





# Struggles of the BIM/IPD Process



## BIM Process



Storage of Models  
Data Extraction Between Software Platforms



Scheduling Software Implementation into Navisworks



AGI wouldn't work with large file exports from Revit



Exporting gbxml files led to rework



Software Link Between Modeling and Analysis Program

## IPD Process



Progress is slowed due to collaborative nature  
Presentation generation slowed  
Meeting schedules were difficult  
Design ideas created conflict resolution issues





# SPECIAL THANKS TO...

- Family
- Friends
- iBuild
- Lights Out Design

## Academic Advisors:

- Kevin Parfitt, P.E.
- Robert Holland
- Andres Lepage, Ph.D., P.E., S.E.
- Moses Ling, P.E., R.A.
- John Messner, Ph.D.
- Richard Mistrick, Ph.D., P.E.

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- Mortenson Construction
  - Gene Hodge
- Crawford Architects
  - Stephen Colin
- Cannon Design
  - Rachael Chicchi
- LeMessurier Consultants, Structural Engineers
  - William Lovallo
- Thornton Tomasetti
  - Art Hortua
- Kawneer North America
  - Andy Zobel
- Greg Myford

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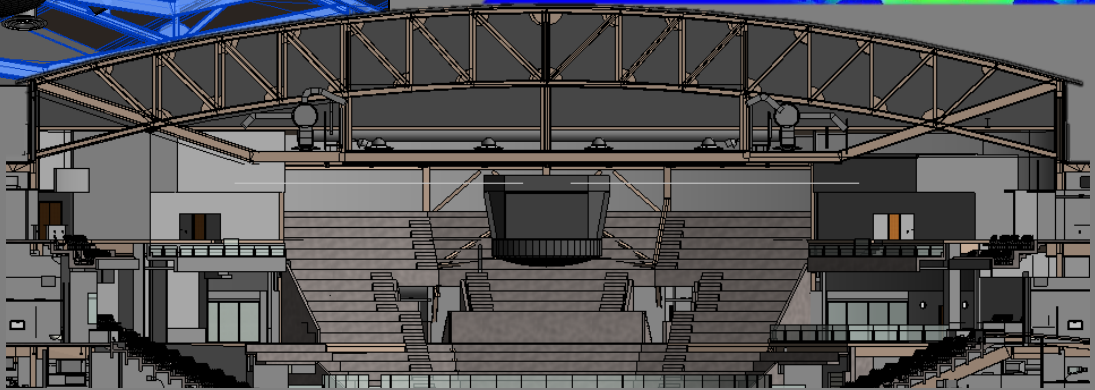
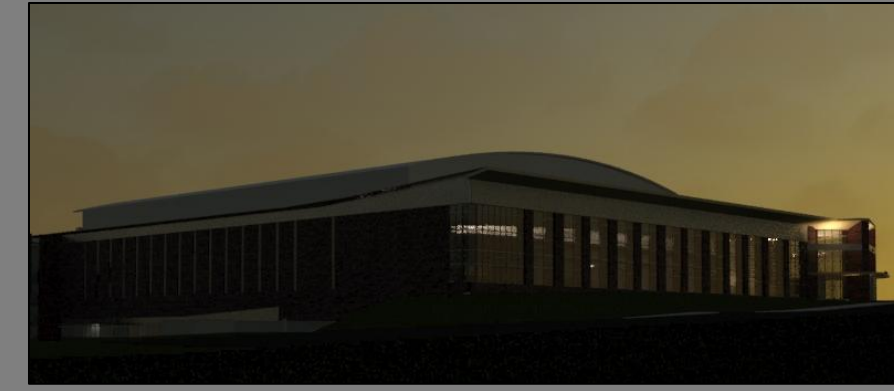
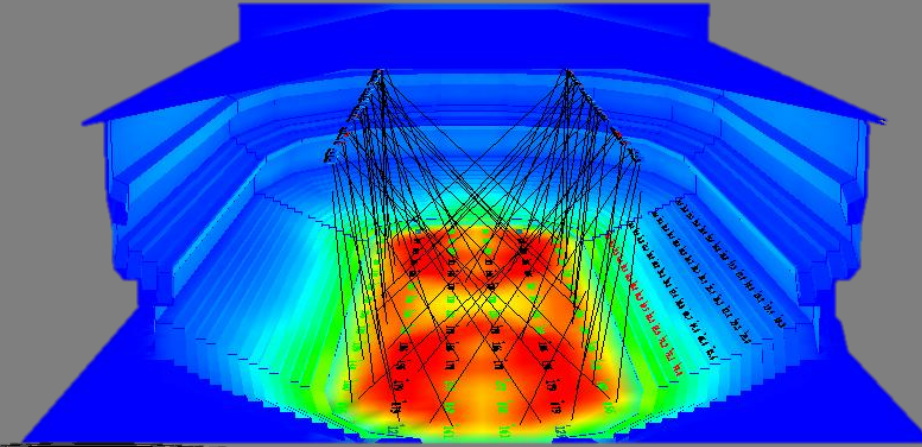
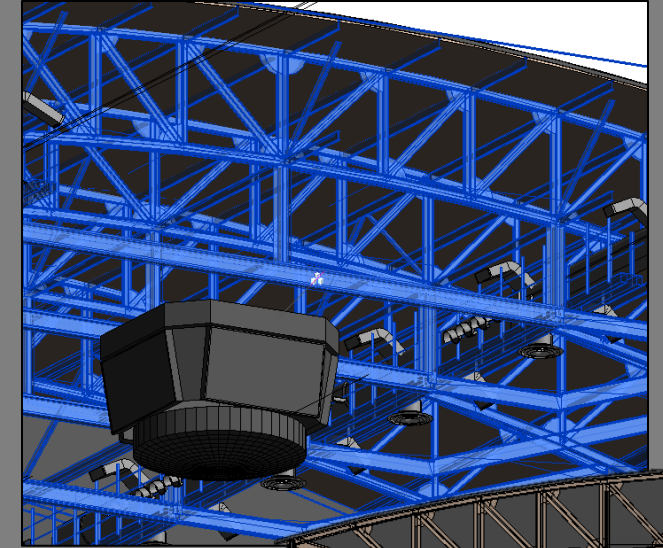
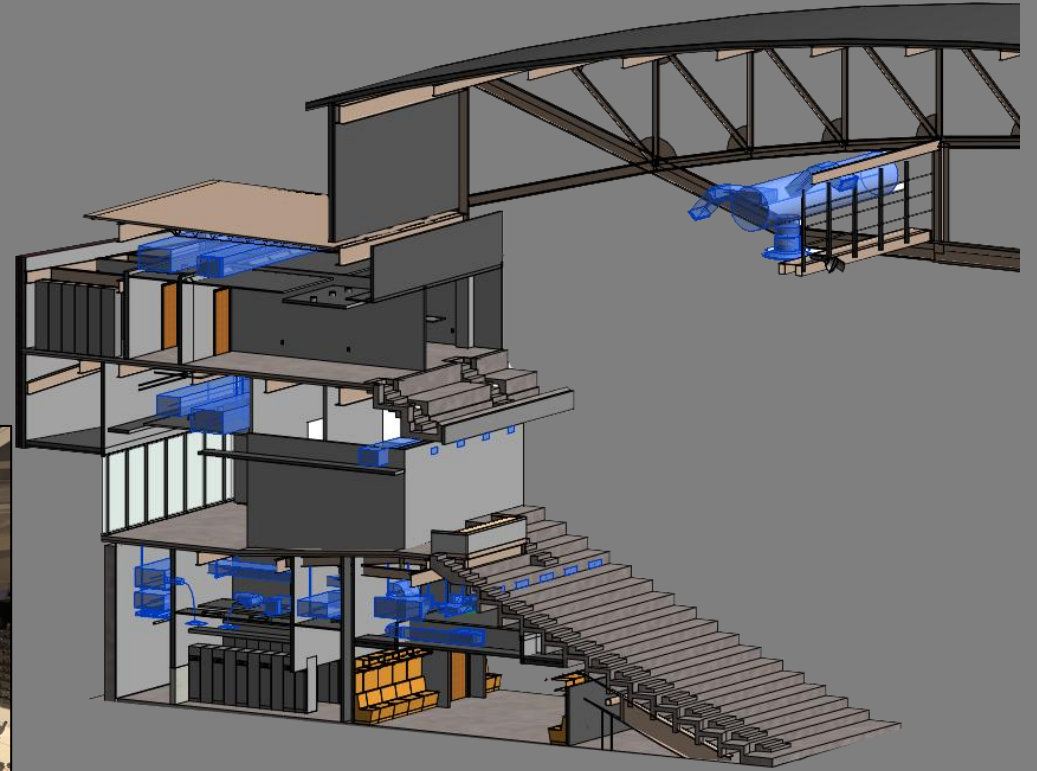
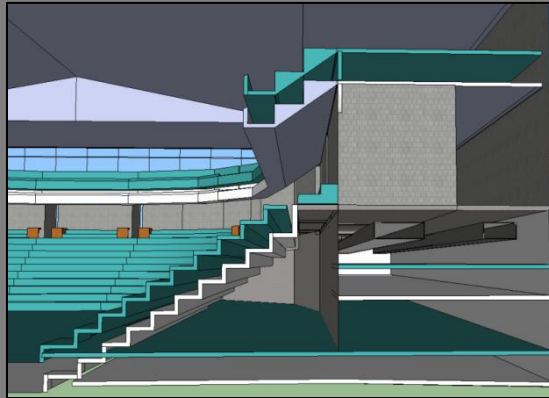


Packages

Benefits

Struggles

Acknowledgments



Nico Pugilese  
LIGHTING/ELECTRICAL



Jeremy Heilman  
CONSTRUCTION



Questions



Joshua Progar  
STRUCTURAL



James Rodgers  
MECHANICAL



	Baseline					Redesign					Difference (+/-)							
Item - Cost	Material Cost	Labor/Equip	O&P	Total Cost		Material Cost	Labor/Equip	O&P	Total Cost		Material (%)		Labor/Equip (%)		O&P (%)		Total (%)	
Excavation/Backfill	\$105,668.16	\$787,599.26	\$221,530.32	\$1,114,797.74		\$55,224.00	\$587,299.27	\$159,345.77	\$801,869.04		\$50,444.16	47.74%	\$200,299.99	25.43%	\$62,184.55	28.07%	\$312,928.70	28.07%
Foundation Walls	\$256,157.73	\$631,332.51	\$220,097.58	\$1,107,587.82		\$218,614.13	\$538,784.60	\$187,834.89	\$945,233.62		\$37,543.60	14.66%	\$92,547.91	14.66%	\$32,262.69	14.66%	\$162,354.20	14.66%
Evt Level Int Walls	\$258,577.16	\$354,392.30	\$152,016.43	\$764,985.89		\$219,989.17	\$294,671.71	\$127,635.90	\$642,296.78		\$38,587.99	14.92%	\$59,720.59	16.85%	\$24,380.53	16.04%	\$122,689.11	16.04%
Concrete Columns	\$26,390.66	\$100,879.10	\$31,562.90	\$158,832.66		\$22,227.34	\$81,531.06	\$25,732.08	\$129,490.48		\$4,163.32	15.78%	\$19,348.04	19.18%	\$5,830.82	18.47%	\$29,342.18	18.47%
Main Arena Bowl Stadia	\$72,175.16	\$18,764.16	\$22,552.95	\$113,492.27		\$83,470.28	\$27,755.32	\$27,583.95	\$138,809.55		-\$11,295.12	-15.65%	-\$8,991.16	-47.92%	-\$5,031.00	-22.31%	-\$25,317.28	-22.31%
Main Arena Bowl Seating	\$16,757.71	\$1,910.19	\$4,629.64	\$23,297.54		\$27,785.87	\$4,182.70	\$7,928.21	\$39,896.78		-\$11,028.16	-65.81%	-\$2,272.51	-118.97%	-\$3,298.57	-71.25%	-\$16,599.24	-71.25%
Main Arena Bowl Steps	\$6,843.69	\$6,143.63	\$3,220.86	\$16,208.18		\$4,524.55	\$4,061.72	\$2,129.39	\$10,715.66		\$2,319.14	33.89%	\$2,081.91	33.89%	\$1,091.46	33.89%	\$5,492.51	33.89%
Main Concourse Int Walls	\$127,270.20	\$134,588.62	\$64,940.99	\$326,799.81		\$164,774.13	\$161,008.68	\$80,794.14	\$406,576.95		-\$37,503.93	-29.47%	-\$26,420.06	-19.63%	-\$15,853.15	-24.41%	-\$79,777.14	-24.41%
Club Level Int Walls	\$35,304.61	\$71,614.31	\$26,515.89	\$133,434.81		\$39,790.35	\$82,974.77	\$30,445.75	\$153,210.87		-\$4,485.74	-12.71%	-\$11,360.46	-15.86%	-\$3,929.86	-14.82%	-\$19,776.06	-14.82%
Exterior Glazing w/ Mullions (not including East Façade)	\$65,769.31	\$10,276.56	\$18,859.38	\$94,905.25		\$81,582.24	\$12,743.59	\$23,392.81	\$117,718.64		-\$15,812.93	-24.04%	-\$2,467.03	-24.01%	-\$4,533.43	-24.04%	-\$22,813.39	-24.04%
Shaft & Column Walls	\$31,082.55	\$40,558.12	\$17,766.89	\$89,407.56		\$29,754.19	\$37,335.66	\$16,638.28	\$83,728.13		\$1,328.36	4.27%	\$3,222.46	7.95%	\$1,128.60	6.35%	\$5,679.42	6.35%
Exterior Walls (not Including East Façade)	\$475,102.63	\$531,049.55	\$249,525.74	\$1,255,677.92		\$530,146.89	\$586,559.93	\$276,943.29	\$1,393,650.11		-\$55,044.26	-11.59%	-\$55,510.38	-10.45%	-\$27,417.55	-10.99%	-\$137,972.19	-10.99%
Steel Columns	\$365,211.00	\$131,900.20	\$123,283.58	\$620,394.78		\$388,387.44	\$131,311.27	\$128,885.28	\$648,583.99		-\$23,176.44	-6.35%	\$588.93	0.45%	-\$5,601.70	-4.54%	-\$28,189.21	-4.54%
Shaft & Lobby Stairs	\$103,363.68	\$13,516.19	\$28,986.21	\$145,866.08		\$98,988.33	\$12,891.59	\$27,746.22	\$139,626.14		\$4,375.35	4.23%	\$624.60	4.62%	\$1,239.99	4.28%	\$6,239.94	4.28%
Steel Beams & Concrete Footings	\$591,835.66	\$213,722.56	\$199,778.44	\$1,005,336.66		\$619,143.70	\$210,264.09	\$205,693.13	\$1,035,100.92		-\$27,308.04	-4.61%	\$3,458.47	1.62%	-\$5,914.69	-2.96%	-\$29,764.26	-2.96%
Unchanged Steel	\$1,713,342.96	\$574,665.90	\$567,426.20	\$2,855,435.06		\$1,713,342.96	\$537,895.65	\$558,307.18	\$2,809,545.79		\$0.00	0.00%	\$36,770.25	6.40%	\$9,119.02	1.61%	\$45,889.27	1.61%
<b>Total</b>	<b>\$4,250,852.87</b>	<b>\$3,622,913.16</b>	<b>\$1,952,693.98</b>	<b>\$9,826,460.01</b>		<b>\$4,297,745.57</b>	<b>\$3,311,271.61</b>	<b>\$1,887,036.26</b>	<b>\$9,496,053.44</b>		<b>-\$46,892.70</b>	<b>-1.10%</b>	<b>\$311,641.55</b>	<b>8.60%</b>	<b>\$65,657.71</b>	<b>3.36%</b>	<b>\$330,406.56</b>	<b>3.36%</b>





# Appendix

## Design Loads:

### Dead Loads:

7 1/2" NWC Composite Slab	75 PSF
3N18 Roof Assembly	20 PSF
Superimposed Dead Load	15 PSF

### Live Loads (per 2009 IBC Table 1670.1):

Main Concourses/Lobbies	100 PSF
Fixed Arena Seating/Aisles & Stairs	100 PSF
Concessions & Restrooms	100 PSF
General Storage	125 PSF
All Other Areas	100 PSF

## Snow Loads:

Ground Snow Load:	$p_g = 40$ PSF	
Exposure Factor ( $C_e$ )	$C_e = 1.0$ (Fully Exposed)	ASCE7-10 Table 7-2
Temperature Factor ( $C_t$ )	$C_t = 1.1$ (Kept Just Above Freezing)	ASCE7-10 Table 7-3
Importance Factor ( $I$ )	$I = 1.1$ (Building Category III)	ASCE7-10 Table 7-4
Flat Roof Snow Load:	$p_f = 34$ PSF + Drifts	

**\*Flat Roof Snow Load of 36 PSF used per 4/13/11 FM Global Plan Review**

### Drifting Considerations:

#### Windward:

Height of Drift = 1'-6"	
Width of Drift = 6'-0"	<b>29 PSF</b>

#### Leeward:

Height of Drift = 5'-0"	
Width of Drift = 20'-0"	<b>96 PSF</b>

## Façade Loads:

Typical Brick Wall Assembly	56 PSF
Curtain Wall & Metal Panels	24 PSF

## Wind Loads:

ASCE7-10 High Rise Analysis (>60 ft) Chapters 26-27 – Method 2

Exposure Category C (ASCE7-10, 26.7.3)  
 Importance Factor  $I_w = 1.15$  (ASCE7-10, Table 1.5-2)  
 Basic Wind Speed  $V = 120$  mph (ASCE7-10, 26.5.1)

Velocity Pressure  $q_z = 37.99$  PSF @ 81'  
 Enclosed Building –  $G_{cpi} = +/- 0.18$

Windward Wall Pressure = Range from 26.5 PSF 15' to 34.88 PSF at Roof  
 Leeward Wall Pressure = -24.36 PSF  
 Roof Suction Pressures = -24.71 PSF





# Appendix

## Seismic:

Seismic Criteria per ASCE7-10, Chapters 11 & 12

Occupancy III (Table 1-1)

Spectral Response Accelerations:

$S_s = 0.147s$  (USGS)

$S_1 = 0.049s$  (USGS)

Site Coefficients:  $F_a = 1.2$  (Table 11.4-1)

$F_v = 1.7$  (Table 11.4-2)

### Seismic Design Category A

Fundamental Period  $T=1.09s$  (Sec. 12.8.2)

Long Period Transition Period  $TL= 6s$  (Fig. 22-15)

Building Weight = 11,539k

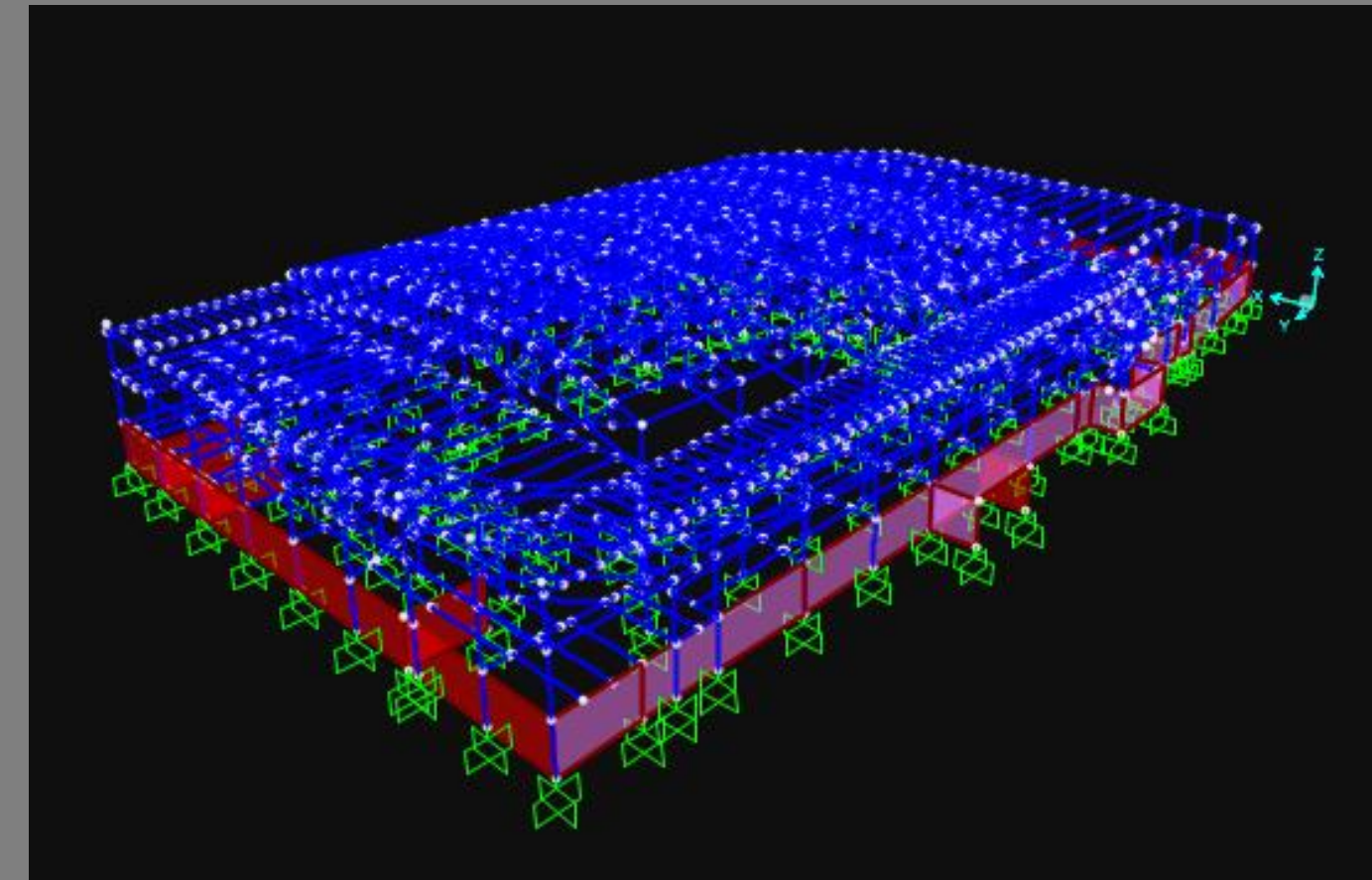
Base Shear = 245.29 K

X-Direction & Y-Direction Loading:

High Roof Level = 123 Kips

Low Roof Level = 44 Kips

Club Level = 78 Kips



## Interstory Drifts:

Allowable Story Drift – ASCE7-10, Table 12.12-1

Risk Category III, All Other Structures  $\Delta d = 0.015h_x$  (1.5% Interstory Drift – Allowable)

X-Direction:

High Roof	0.20%	<	1.5%	Meets Code Requirements
Low Roof	1.03%	<	1.5%	Meets Code Requirements
Club Level	1.04%	<	1.5%	Meets Code Requirements

Y-Direction:

High Roof	0.03%	<	1.5%	Meets Code Requirements
Low Roof	1.02%	<	1.5%	Meets Code Requirements
Club Level	0.46%	<	1.5%	Meets Code Requirements





# Appendix

## Two Way Flat Plate Design:

Design Criteria (per ACI 318-08):

Equivalent Frame Method

$f'_c = 5,000$  psi (NWC)

Spans Range from 32'-0" x 28'-0" to 37'-2" x 28'-0"

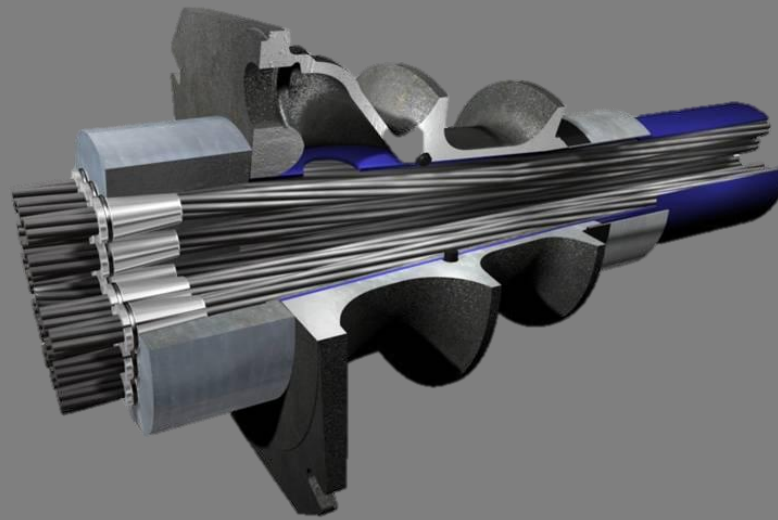
$f_{pu} = 270$  ksi

$f_{pe} = 159$  ksi

Tendon Specifications:

(7) 1/2" Diameter Tendons

$f_{pu} = 270$  ksi



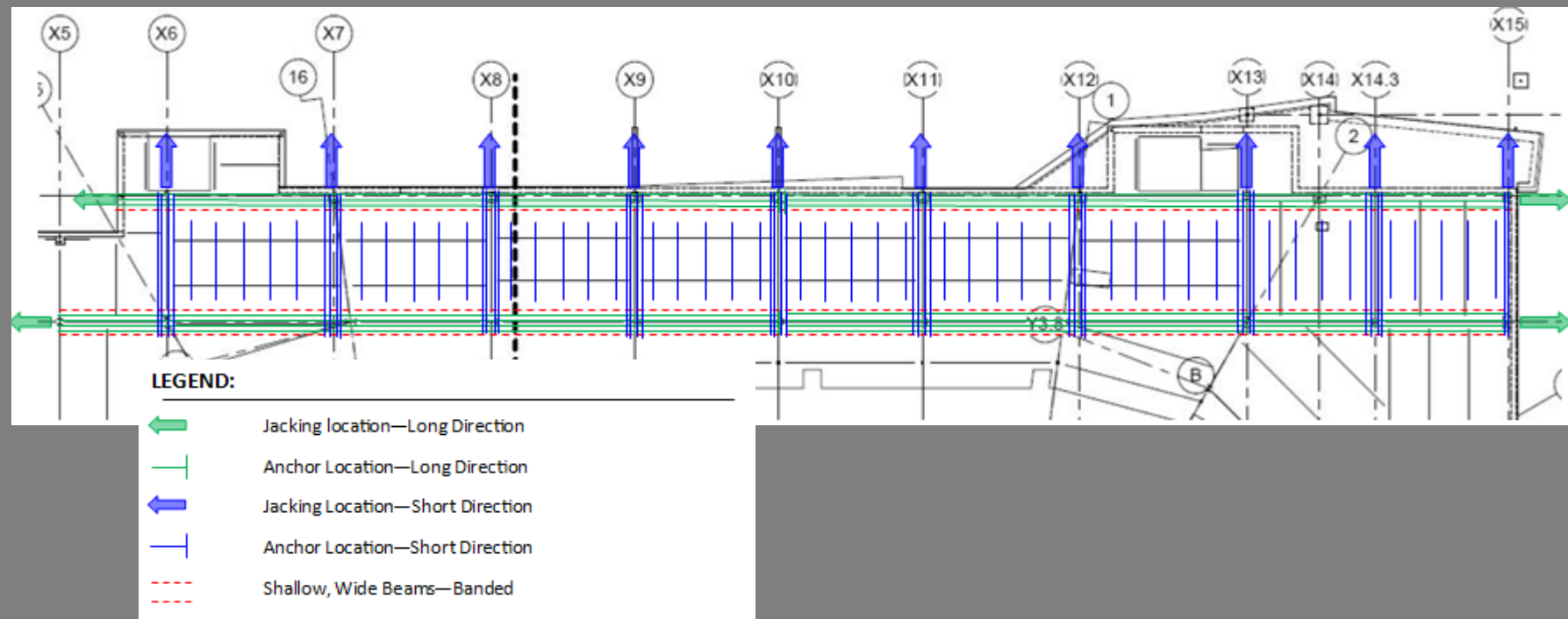
## Slab Thickness and Design:

10" Thick, 5,000 psi concrete slab ( $l/h = 45$  for trial slab thickness)

Uses 26 tendons to balance 100% of the Target Balanced Dead Load

Banded Tendon Layout in Long Direction

Distributed Tendon Layout in Short Direction



## System Conclusion: Not Efficient for Project

- Not Cost Effective
- System Not Effective for One-Span Application
- Constructability Issues with Steel and Concrete trades on site at same time
- Reduction in system thickness not required
- Curved Tendons may have been needed – lateral arches



# I Appendix

## Event Level Structural Considerations:

### Micropiles Foundations Capacity Checks:

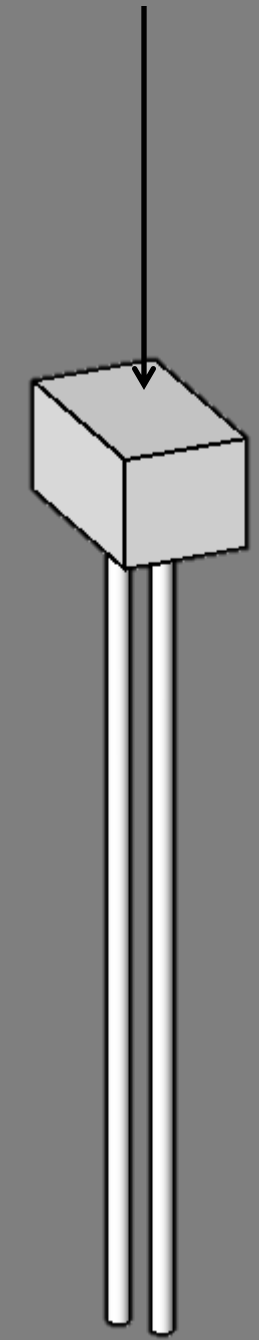
Reference: Das, B. "Principles of Foundation Engineering", 7<sup>th</sup> Edition

Piles: 10" Diameter Piles filled with >5,000 psi Grout  
300 kip recommended capacity

From Geotechnical Report:

- Boring Log No. B-22:
  - 2.5' of Soil
  - 15' of Bedrock -> Weathered Dolomite (Limestone)

$Q_{p,all} = 116.2 \text{ k/pile} > 79 \text{ k/pile}$



### Masonry Wall Design:

Reference: Building Code Requirements and Specifications for Masonry Structures  
ACI 530-08, ASCE5-08, ASCE6-08

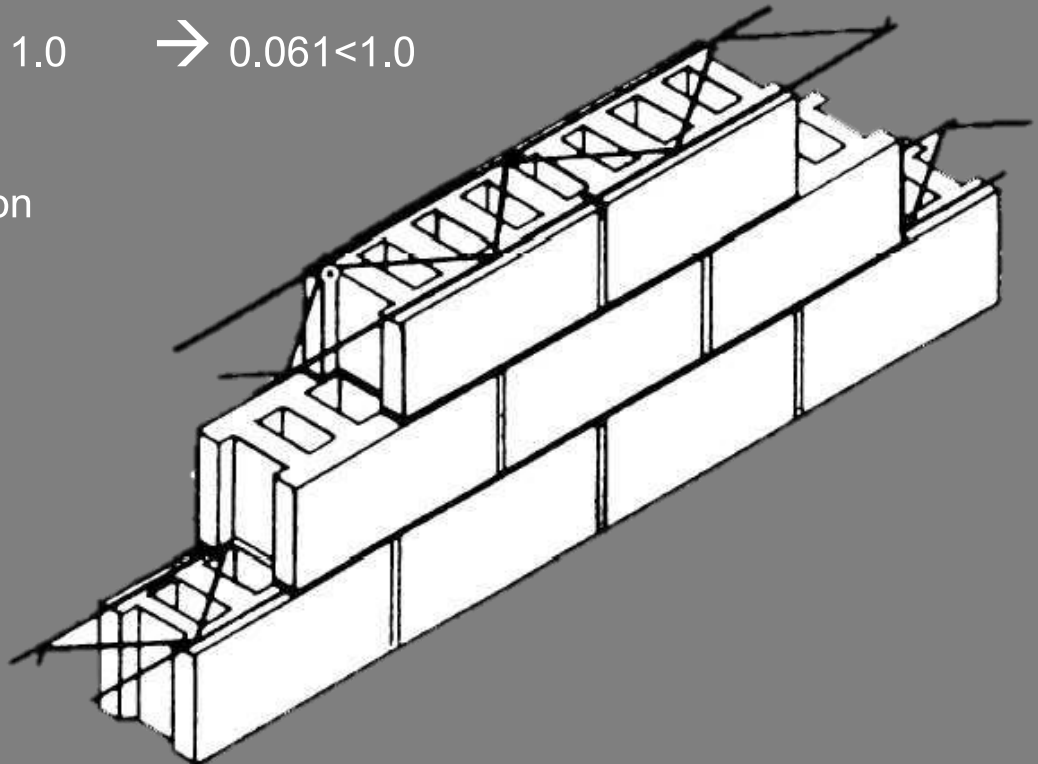
### 32" Knee Wall for Precast Stadia and Misc. Steel Support (ASD Design)

Use 8" CMU Hollow Units, Face Shell Embedded  
Type S PCL Mortar Cement Mortar

Unity Equation =  $f_a/F_a + f_b/F_b < 1.0 \rightarrow 0.061 < 1.0$

No Tensile Stress <  $F_t = 25 \text{ psi}$

Ok for shear and stability equation



### Column Capacity Checks:

Reference: AISC Steel Manual, 13<sup>th</sup> Edition

Example: Interior Column X13-Y3

Member Size: W24x176

Controlling Load Combination: 1.2D+1.6S+0.5W

Column Check:

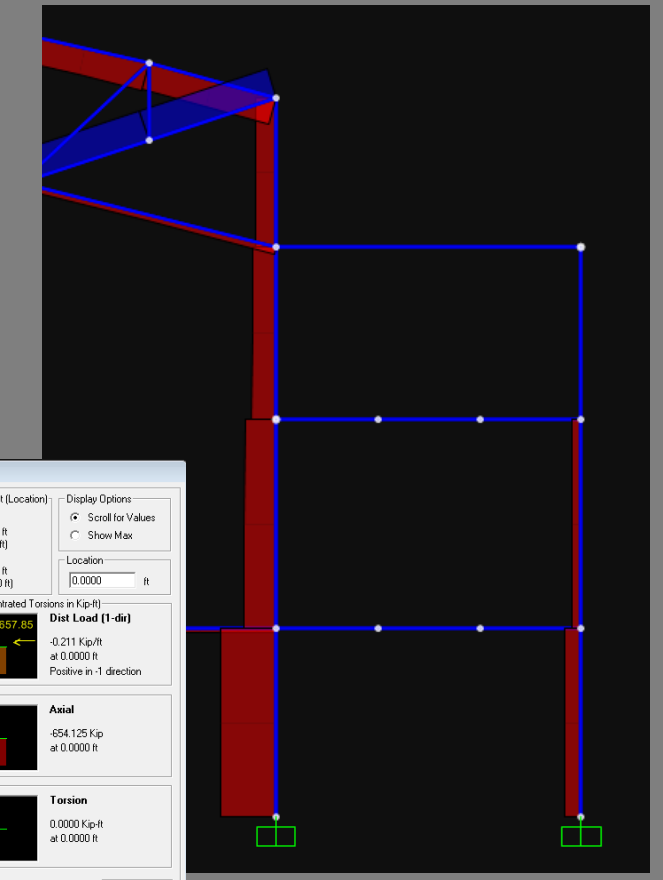
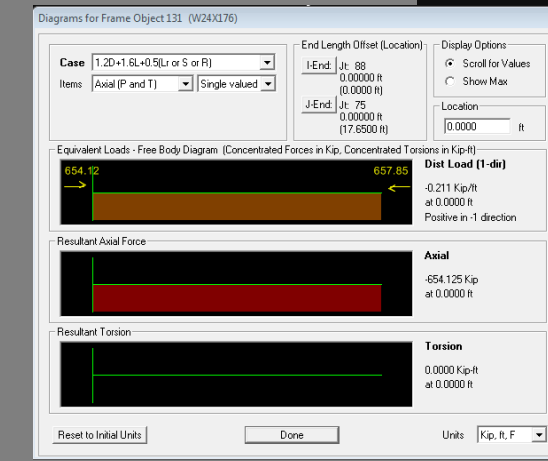
Axial Compression = 725 kips

Shear = 45 kips

Moment = 400 ft-k

$P_r/P_c < 0.2 \rightarrow 0.5 * P_r * (9/8) * (b_x * M_{rx} + b_y * M_{ry}) < 1.0$

**0.46 < 1.0 → Column Capacity is Good!**







# Appendix

## Detailed Cost Estimates for Trusses:

RMS Means Cost Works Cost Estimation Platform  
 High Framing Roof System Members Only  
 Overhead and Profit Included

LONG SPAN TRUSS ECONOMICS COMPARISON & DESIGN										
Existing Long Span Trusses										
Structural Member	Quantity	Weight/ft. (PLF)	Length (ft)	Total Weight (lb)	Total Weight (tons)	Cost/ft.	Cost	TRUSSES		
								Total Costs		
W14x74	4	74	40.25	11914	5.957	\$106.12	\$17,085.32			
W14x74	4	74	31.33	9273.68	4.63684	\$106.12	\$13,298.96			
W14x74	6	74	32	14208	7.104	\$106.12	\$20,375.04			
W14x38	12	38	41	18696	9.348	\$57.74	\$28,408.08			
W14x43	6	43	41	10578	5.289	\$64.13	\$15,775.98			
W14x30	8	40	41	13120	6.56	\$46.42	\$15,225.76			
W14x38	12	38	31.25	14250	7.125	\$57.74	\$21,652.50			
W14x43	6	43	31.25	8062.5	4.03125	\$64.13	\$12,024.38			
W14x30	8	30	31.25	7500	3.75	\$46.42	\$11,605.00			
W14x38	18	38	32	21888	10.944	\$57.74	\$33,258.24			
W14x43	9	43	32	12384	6.192	\$64.13	\$18,469.44			
W14x30	12	30	32	11520	5.76	\$46.42	\$17,825.28	<b>TOTAL</b>	<b>\$225,003.97</b>	
T-1	W14x132	2	132	60	15840	7.92	\$181.94	\$21,832.80		
T-1	W14x132	2	132	37.5	9900	4.95	\$181.94	\$13,645.50		
T-1	W14x99	2	99	59	11682	5.841	\$137.87	\$16,268.66		
T-1	W14x99	1	99	76	7524	3.762	\$137.87	\$10,478.12	<b>PER TRUSS</b>	<b>\$102,072.98</b>
T-1	W14x61	13	61	11.33	8984.69	4.492345	\$88.53	\$13,039.58	<b>QUANTITY</b>	<b>6</b>
T-1	2L8x8x1/2	14	52.8	17.6	13009.92	6.50496	\$108.80	\$26,808.32	<b>TOTAL</b>	<b>\$612,437.90</b>
T-2	W14x132	2	132	60	15840	7.92	\$181.94	\$21,832.80		
T-2	W14x132	2	132	38	10032	5.016	\$181.94	\$13,827.44		
T-2	W14x109	2	109	59.5	12971	6.4855	\$153.25	\$18,236.75		
T-2	W14x132	1	132	76	10032	5.016	\$181.94	\$13,827.44		
T-2	W14x61	3	61	11.33	2073.39	1.036695	\$88.53	\$3,009.13	<b>PER TRUSS</b>	<b>\$98,125.32</b>
T-2	2L6x6x1/2	4	39.2	11.33	1776.544	0.888272	\$81.60	\$3,698.11	<b>QUANTITY</b>	<b>1</b>
T-2	2L5x5x3/8	9	24.6	11.33	2508.462	1.254231	\$68.00	\$6,933.96	<b>TOTAL</b>	<b>\$98,125.32</b>
T-2	2L8x6x1/2	14	46	16	10304	5.152	\$74.82	\$16,759.68		
T-3	W14x132	2	132	59	15576	7.788	\$181.94	\$21,468.92		
T-3	W14x132	2	132	37.5	9900	4.95	\$181.94	\$13,645.50		
T-3	W14x99	2	99	59	11682	5.841	\$137.87	\$16,268.66		
T-3	W14x99	1	99	76	7524	3.762	\$137.87	\$10,478.12	<b>PER TRUSS</b>	<b>\$99,653.79</b>
T-3	W14x61	13	61	11	8723	4.3615	\$88.53	\$12,659.79	<b>QUANTITY</b>	<b>1</b>
T-3	W14x61	13	61	11	8723	4.3615	\$88.53	\$12,659.79	<b>TOTAL</b>	<b>\$99,653.79</b>
		14	52.8	16.5	12196.8	6.0984	\$108.80	\$25,132.80	<b>GRAND TOTAL</b>	<b>\$1,035,220.98</b>
								<b>S/SF</b>	<b>\$21.98</b>	

**Existing**

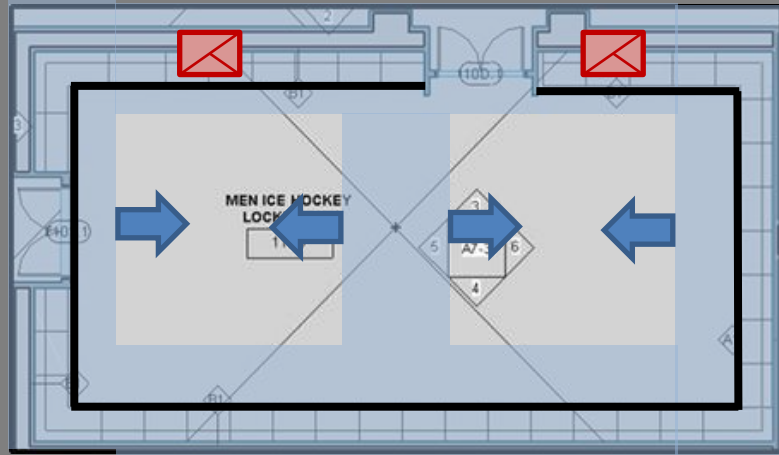
LONG SPAN TRUSS ECONOMICS COMPARISON & DESIGN										
Existing Long Span Trusses										
Structural Member	Quantity	Weight/ft. (PLF)	Length (ft)	Total Weight (lb)	Total Weight (tons)	Cost/ft.	Cost	TRUSSES		
								Total Costs		
W14x53	36	53	41	78228	39.114	\$88.53	\$130,670.28			
W14x26	36	26	35	32760	16.38	\$46.42	\$58,489.20			
W14x26	54	26	32	44928	22.464	\$46.42	\$80,213.76			
W24x104	4	104	41	17056	8.528	\$145.43	\$23,850.52			
W24x104	4	104	35	14560	7.28	\$145.43	\$20,360.20			
W24x104	6	104	32	19968	9.984	\$145.43	\$27,922.56			
2L5x3-1/2x3/8x3/8LLB	24		21.5	0	0	\$71.04	\$36,656.64	<b>TOTAL</b>	<b>\$378,163.16</b>	
Top	W14x43	2	43	12.4375	1069.625	0.5348125	\$64.13	\$1,595.23		
Top	W14x43	2	43	12.333	1060.638	0.530319	\$64.13	\$1,581.83		
Top	W14x43	2	43	12.229	1051.694	0.525847	\$64.13	\$1,568.49		
Top	W14x43	2	43	12.167	1046.362	0.523181	\$64.13	\$1,560.54		
Top	W14x43	2	43	12.094	1040.084	0.520042	\$64.13	\$1,551.18		
Top	W14x53	2	53	12.052	1277.512	0.638756	\$88.53	\$2,133.93		
Top	W14x53	2	53	12.021	1274.226	0.637113	\$88.53	\$2,128.44		
Top	W14x53	2	53	14	1484	0.742	\$88.53	\$2,478.84		
Bottom	W14x43	2	43	12.229	1051.694	0.525847	\$64.13	\$1,568.49		
Bottom	W14x43	2	43	12.167	1046.362	0.523181	\$64.13	\$1,560.54		
Bottom	W14x43	2	43	12.094	1040.084	0.520042	\$64.13	\$1,551.18		
Bottom	W14x43	2	43	12.052	1036.472	0.518236	\$64.13	\$1,545.79		
Bottom	W14x43	2	43	12.021	1033.806	0.516903	\$64.13	\$1,541.81		
Bottom	W14x43	2	43	14	1204	0.602	\$64.13	\$1,795.64		
Tie	W27x146	2	146	124.35	36310.2	18.1551	\$200.78	\$49,933.99		
Tie	W24x117	1	117	76	8892	4.446	\$163.43	\$12,420.68		
Verticals	W14x68	2	90	11.9375	2148.75	1.074375	\$98.00	\$2,339.75		
Verticals	W14x68	4	90	14	5040	2.52	\$98.00	\$5,488.00		
Verticals	W8x18	10	18	14	2520	1.26	\$33.60	\$4,704.00		
Diagonal	W8x18	14	18	18.439	4646.628	2.323314	\$33.60	\$8,673.71		
Verticals	W8x18	2	18	7.229	260.244	0.130122	\$33.60	\$485.79		
								<b>PER TRUSS</b>	<b>\$108,207.84</b>	
								<b>QUANTITY</b>	<b>8</b>	
								<b>TOTAL</b>	<b>\$865,662.70</b>	
								<b>GRAND TOTAL</b>	<b>\$1,243,825.86</b>	
								<b>S/SF</b>	<b>\$26.41</b>	

**New**





# Appendix



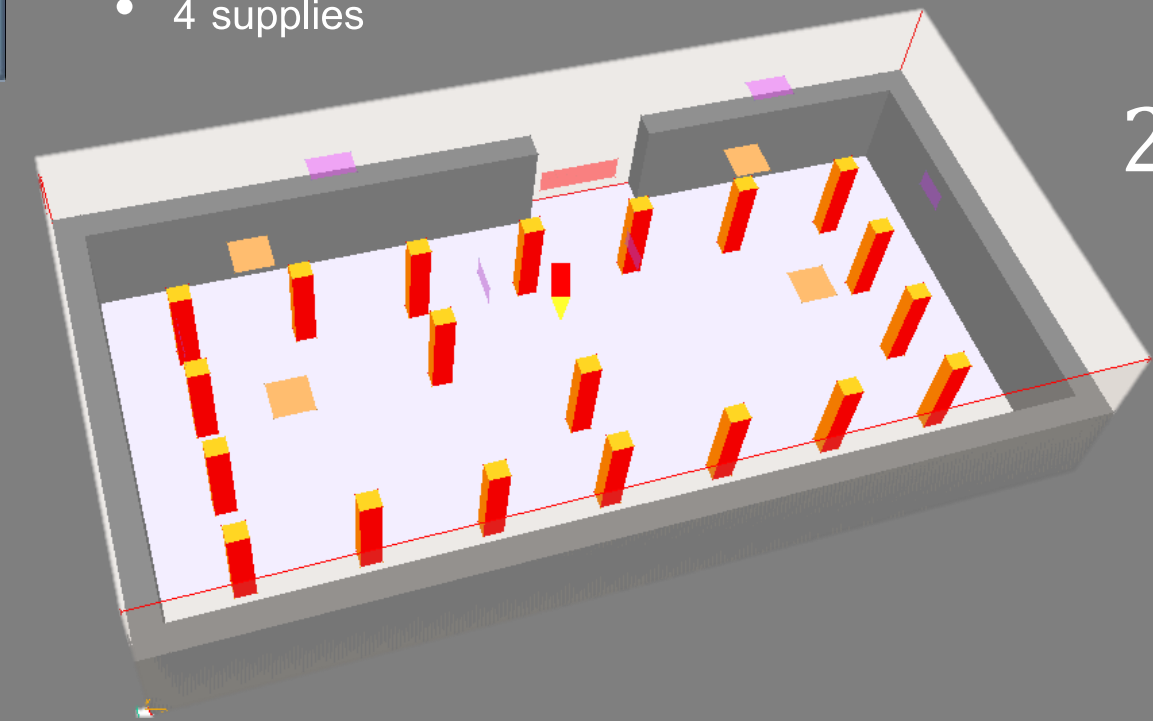
- 20 People : Four surface temperatures of 36.5°C
- Four lights: 15 W
- Transfer grille in door
- 2 exhausts
- 4 supplies

Assumptions:

- Medium activity level
- 30 breaths a minute
- 1.1 liters/breath

$$\dot{m} = 6.6 \times 10^{-4} \text{ kg/s}$$

$$c = 36,000 \text{ ppm}$$



Calculated:

$$PD = 395 \times e^{(-1.83 \times q^{0.25})}$$

$$q = 7.06 \cong 7 \frac{L}{s} \cong 15 \frac{CFM}{olf}$$

$$22 \text{ people} * 10 \frac{olf}{person} * 15 \frac{cfm}{olf} = 3300 cfm$$

$$\cong 2.5 \frac{cfm}{sf}$$

DESIGN CRITERIA		
Ventilation rate	Room Area	CFM/ Difussers
0.5	1365	171
2.5	1365	853





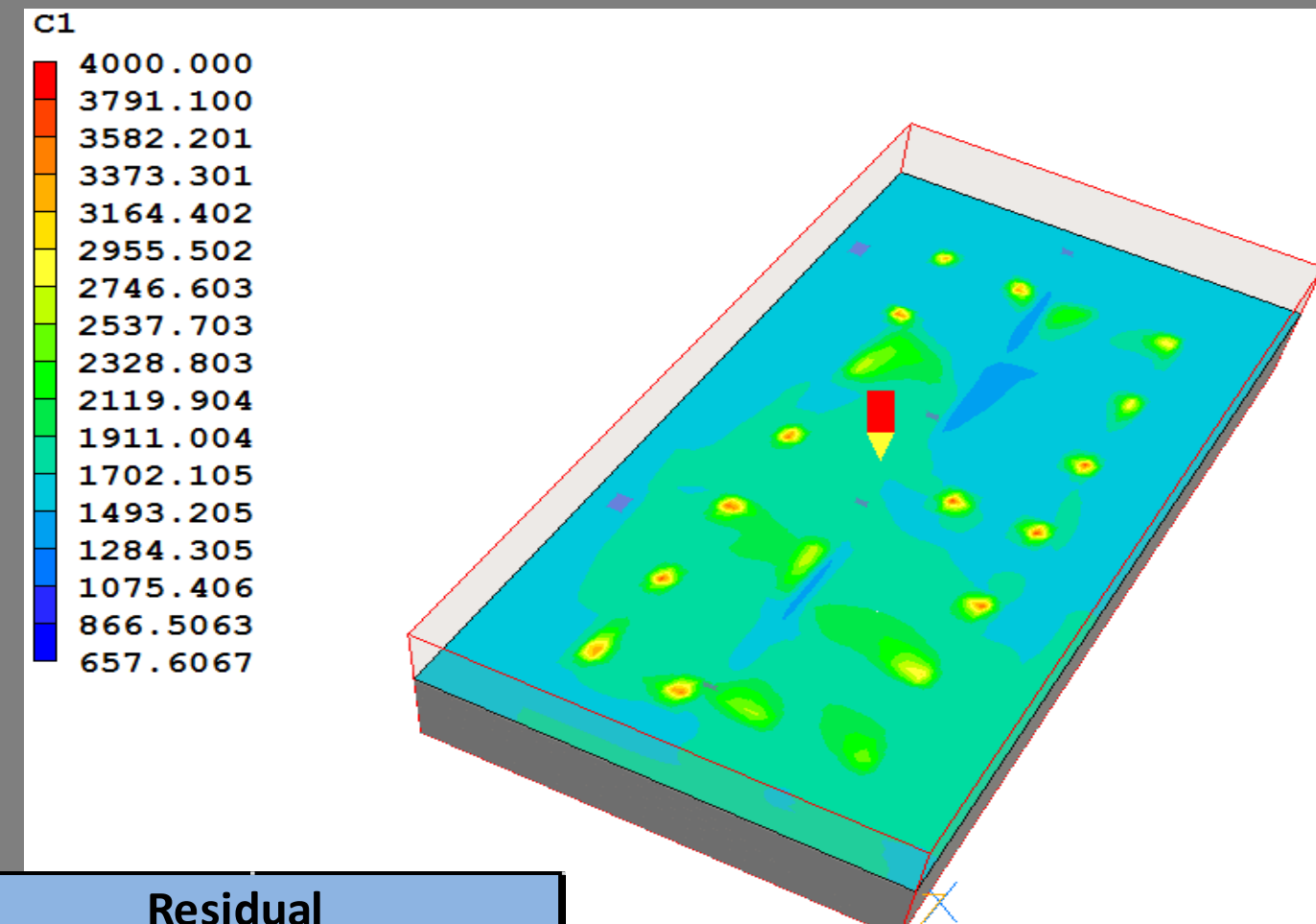
# Appendix

Code: 0.5 cfm/sf

Calculation: 2.5 cfm/sf

Code: 0.5 CFM / SF

8x6	0.33	0.26	cfm	78	104	130	156	182	
			NC	-	-	11	17	21	
			Throw	0°	5-9-16	8-12-19	10-15-21	12-16-23	14-18-25
			(ft)	45°	2-4-7	3-5-8	4-7-9	5-7-10	6-8-11



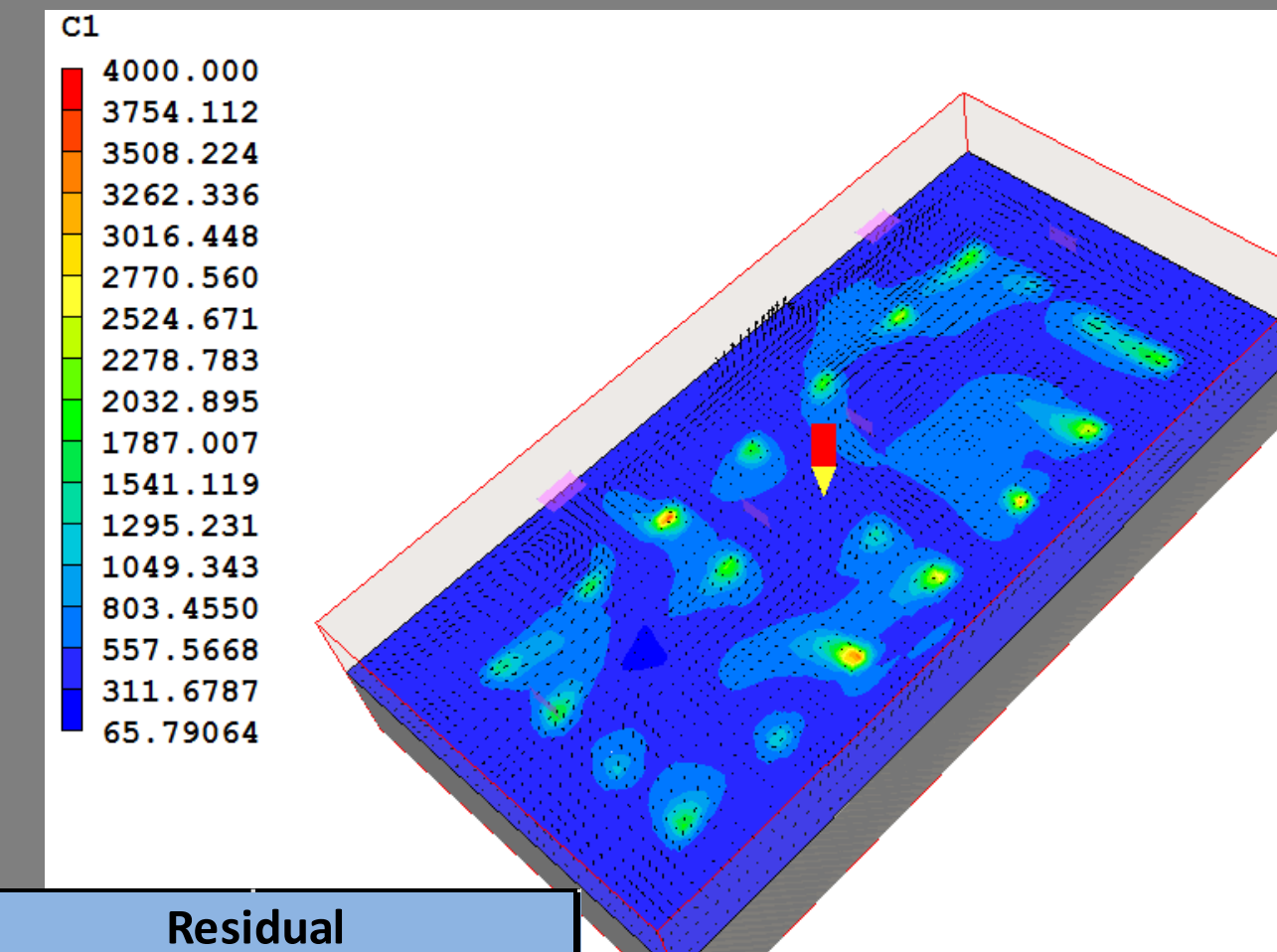
Residual	
Mass	1%
Temperature	0.04%
Concentration	5%

Steady state = 1683.4 ppm



Residual	
Mass	1%
Temperature	0.03%
Concentration	10.7%

Steady state = 527.23 ppm



Code: 2.5 CFM / SF

42x8 24x14	2.33	2.14	cfm	642	856	
			NC	-	13	
			Throw	0°	16-25-47	22-33-54
			(ft)	45°	7-11-21	10-15-24





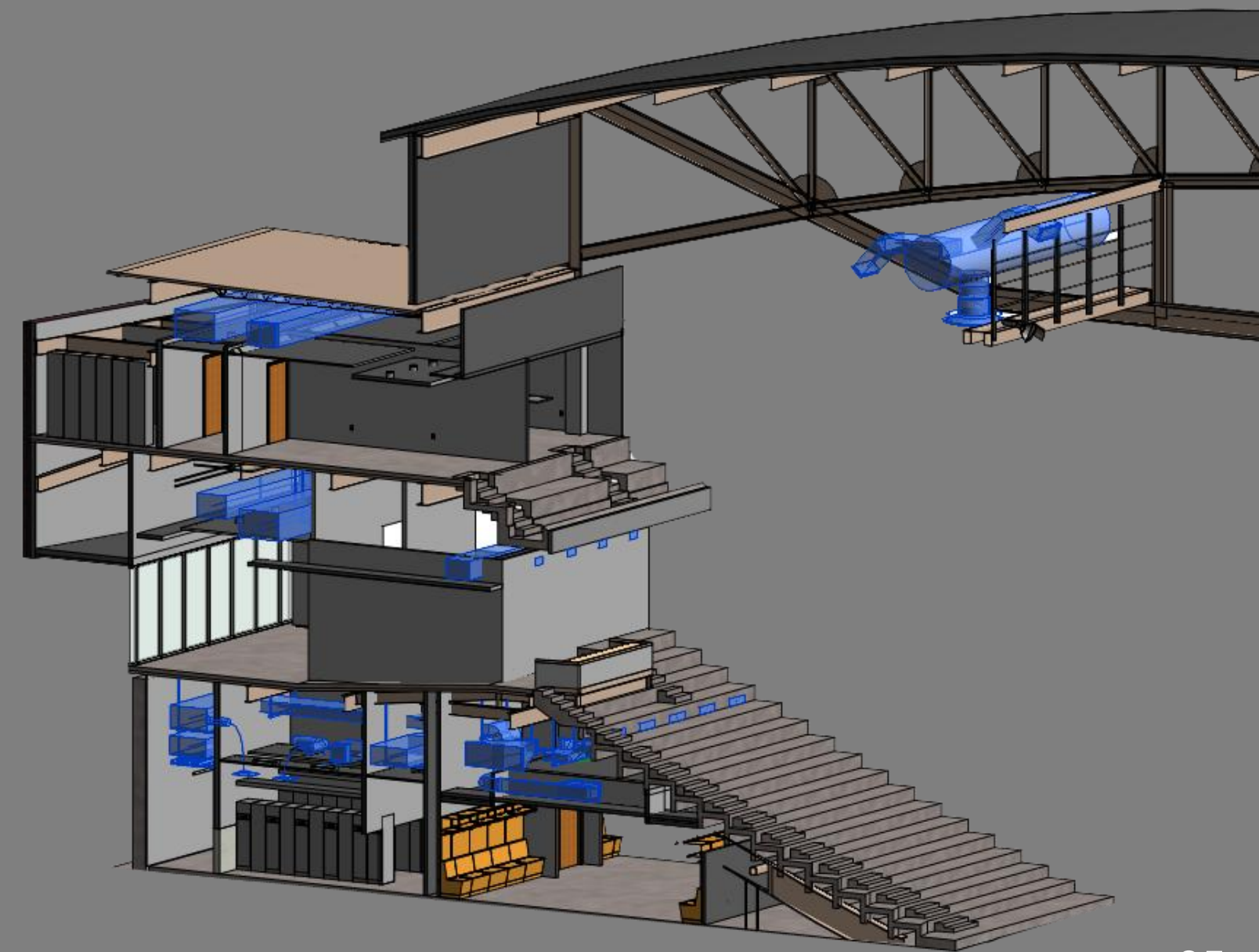
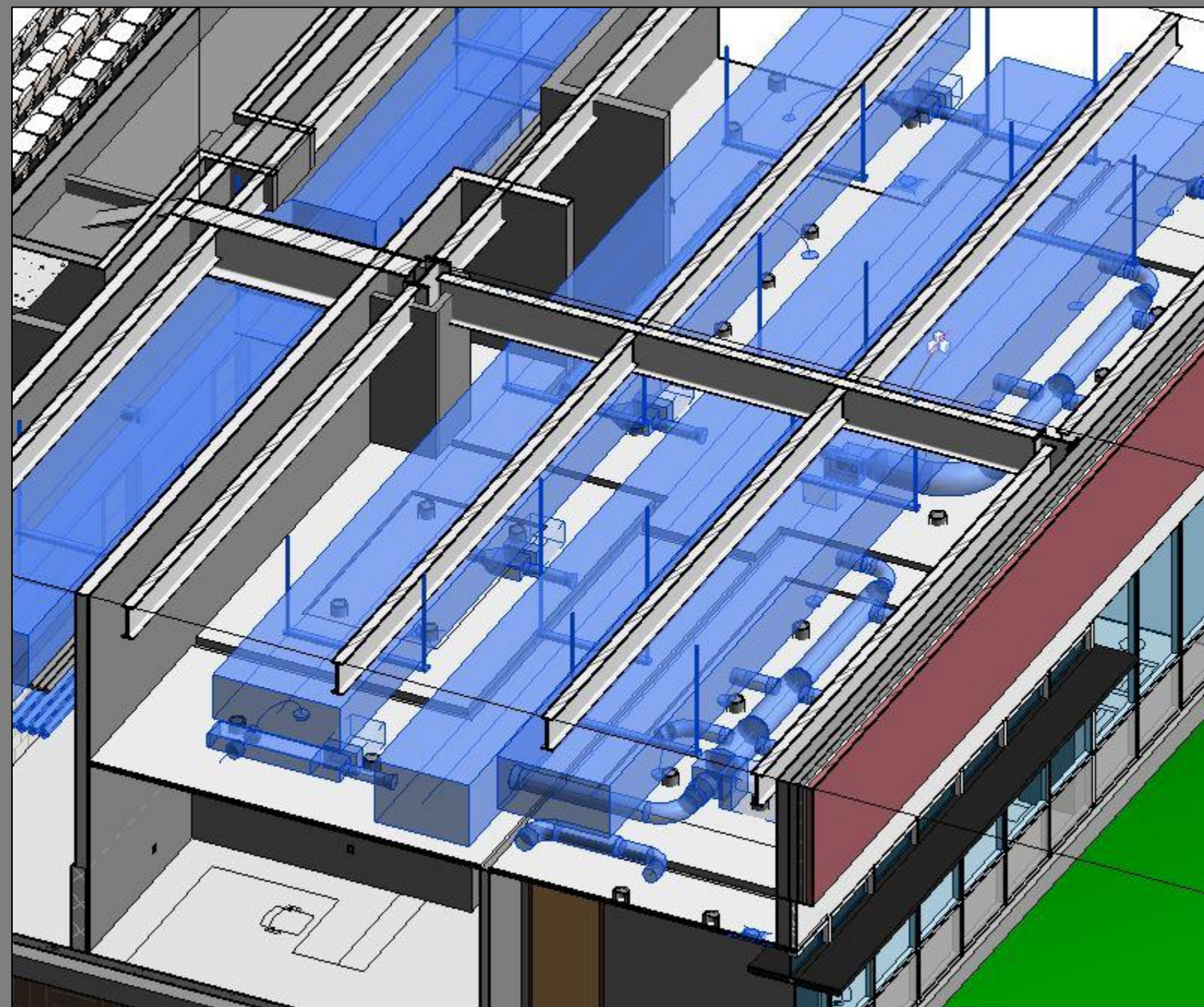
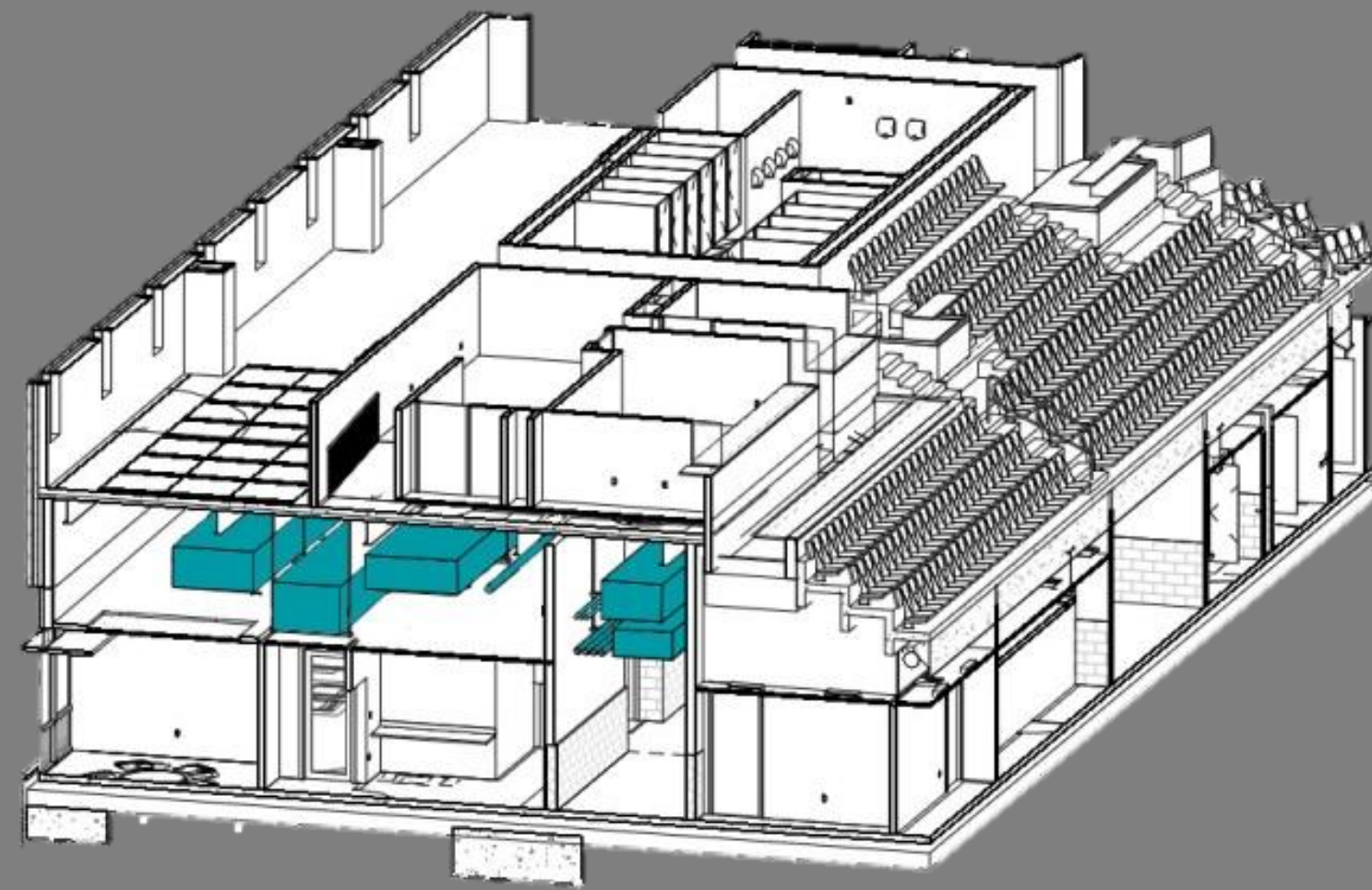
# Appendix

Occupancy Category	Pz (Occ.)	Az (SF)	Rp (CFM/Occ.)	Ra (CFM/SF)	Vbz (CFM)	Vbz Occ	Vbz Area	Ez	Voz (CFM)	Zp	Load	Max (CFM)	Setback	Vpz (CFM)
102A Mens Coach Locker Room	4	188	5	0.5	114	20	94	1.0	114	0.80	143	143	100%	143
105A- Vedio study	4	330	5	0.06	40	20	20	1.0	40	0.96	106	106	39%	41
105B- Storage	0	76	0	0.12	9	0	9	1.0	9	1.01	9	9	100%	9
107- Mens Equipment	0	360	0	0.12	43.2	0	43	1.0	43	0.40	107	107	100%	107
105- Mens Team Lounge	10	600	5	0.06	86	50	36	1.0	86	0.21	406	406	100%	406
100A-Dry Lockers	10	240	5	0.5	170	50	120	1.0	170	1.81	94	94	100%	94
110B-Restrooms	4	205	70	0	280	280	0	1.0	280	4.24	66	66	100%	66
110C-Shower Rooms	16	305	50	0	800	800	0	1.0	800	6.96	115	115	100%	115
F101-Vestibule	0	216	5	0.06	13	0	13	1.0	13	0.50	26	26	100%	26
111B- Restroom	1	61	70	0	70	70	0	1.0	70	1.63	43	43	100%	43
111A-Exam Room	3	161	10	0.12	49	30	19	1.0	49	0.38	131	131	100%	131
111C- Office	2	125	5	0.06	18	10	8	1.0	18	0.16	107	107	100%	107
Q103- Cooridor	0	650	0	0.06	39	0	39	1.0	39	0.50	78	78	100%	78
110D Mens Ice Hockey Locker Room	30	1,332	0	2.5	3330	0	3330	1.0	3330	<b>7.69</b>	433	433	100%	433
110- Corridor	0	640	0	0.06	38	0	38	1.0	38	0.49	78	78	100%	78
102 Mens Coaches Longe	4	186	5	0.06	31	20	11	1.0	31	0.16	193	193	100%	193
109-Main Communication Room	1	100	5	0.12	17	5	12	1.0	17	0.25	68	68	100%	68
Q104- Corridor	0	112	0	0.06	7	0	7	1.0	7	0.48	14	14	100%	14





# Appendix







Opportunity      Goal      Strategy      Results

% Glass	Electric	Heating	Energy Cost	Reduction
100	\$ 335,150.00	\$ 233,366.00	\$ 568,516.00	0.00%
70	\$ 333,878.00	\$ 232,560.00	\$ 566,438.00	0.37%
50	\$ 332,857.00	\$ 231,661.00	\$ 564,518.00	0.70%
30	\$ 331,756.00	\$ 230,837.00	\$ 562,593.00	1.04%
10	\$ 330,471.00	\$ 229,895.00	\$ 560,366.00	1.43%

U-Value : 0.4 & SHGC: 0.16 > ASHRAE min for Climate Zone 5A

Model	Curtain Wall			Brick Wall Total U-Value BTU/h-ft2-F	Cost			
	Total U-Value	SHGC	Cost Per SQFT		Cooling/Electric	Heating	Total Building Energy Cost	Curtain Wall Savings
1601 Wall System	0.4	0.14	\$ 63.00	0.029	\$ 331,785.00	\$ 231,613.00	\$ 563,398.00	0.2%
1602 Wall System 2	0.34	0.21	\$ 63.00	0.029	\$ 335,951.00	\$ 230,487.00	\$ 566,438.00	-0.3%
1603 Wall System 3	0.34	0.14	\$ 63.00	0.029	\$ 331,941.00	\$ 230,412.00	\$ 562,353.00	0.4%
1600 UT 1	0.33	15	\$ 72.50	0.029	\$ 332,529.00	\$ 230,238.00	\$ 562,767.00	0.3%

### TOOL NO. 1 R VALUE ANALYSIS

**MATERIALS**  
rigid ins..(extru.), 3 in.      Help      START/CLR

Add    Delete    Move up    Move dn    Convert

Calc    Graph    Print    WallYb    TOOLBOX

Layer	Generic Material	Thick.	R Val.
1	brick (TTW), 4 in.	4.00	0.64
2	cavity, 2 in.	2.00	0.98
3	rigid ins..(extru.), 3 in.	3.00	15.41
4	paper, stand., (8mil)	0.01	0.12
5	plywood shtg., 1/2 in.	0.50	0.64
6	batt ins., 5-1/2 in.	5.50	16.76
7	gypsum bd., 5/8 in., (#2)	0.63	0.46
8			
9			
10			
11			
12			
		15.63	35.00

CLIMATE CONDITIONS

Winter      Summer

Temp(°F) RH(%)    Temp(°F) RH(%)

Indoor: 70    25    75    50

Outdoor: 2    80    88    59

City: Pittsburgh, PA

CLIMATE CONDITIONS

Winter      Summer

Temp(°F) RH(%)    Temp(°F) RH(%)

Indoor: 70    25    75    50

Outdoor: 2    80    88    59

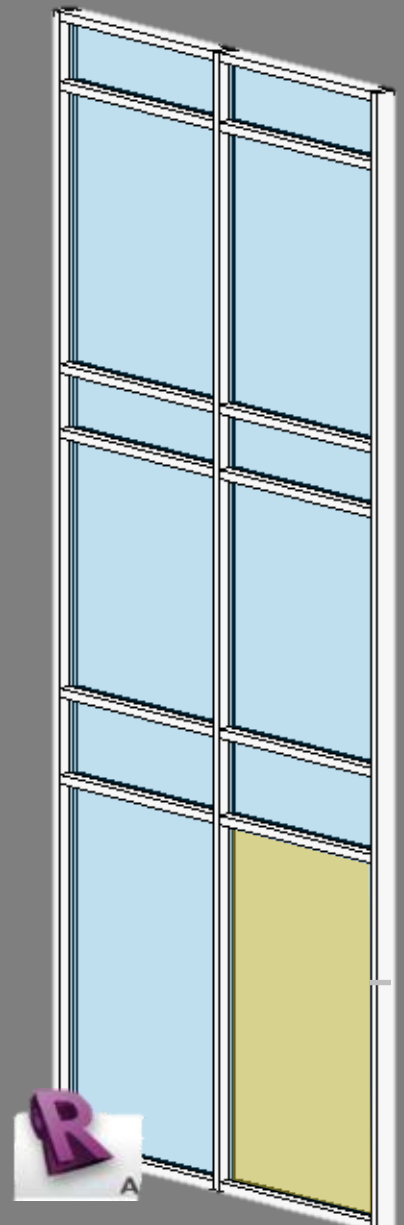
City: Pittsburgh, PA

WALL SECTION & TEMPERATURE GRADIENTS (°F)

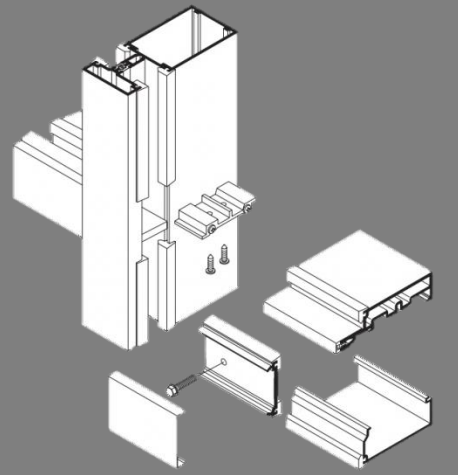
Standard Wall    Wider Wall

WALL SECTION & VAPOR PRESSURE GRADIENTS (in.Hg)

Standard Wall    Thicker Wall



## Kawneer 1600 Wall System ® 3



Thermal Transmittance <sup>1</sup> (BTU/h • ft <sup>2</sup> • °F)	
Glass U-Factor <sup>3</sup>	Overall U-Factor <sup>4</sup>
0.48	0.56
0.46	0.55
0.44	0.53
0.42	0.51
0.40	0.49
0.38	0.48
0.36	0.46
0.34	0.44
0.32	0.43
0.30	0.41
0.28	0.39
0.26	0.37
0.24	0.36
0.22	0.34
0.20	0.32



- Structural Mullion & Glazing Design
- Wind Strength Design (ASTM E1300)
  - Small Missile Impact (ASTM E2025)
- 1/4" Thick Laminated Glass IGU's  
3/8" (7mm) Minimum Mullion Thickness

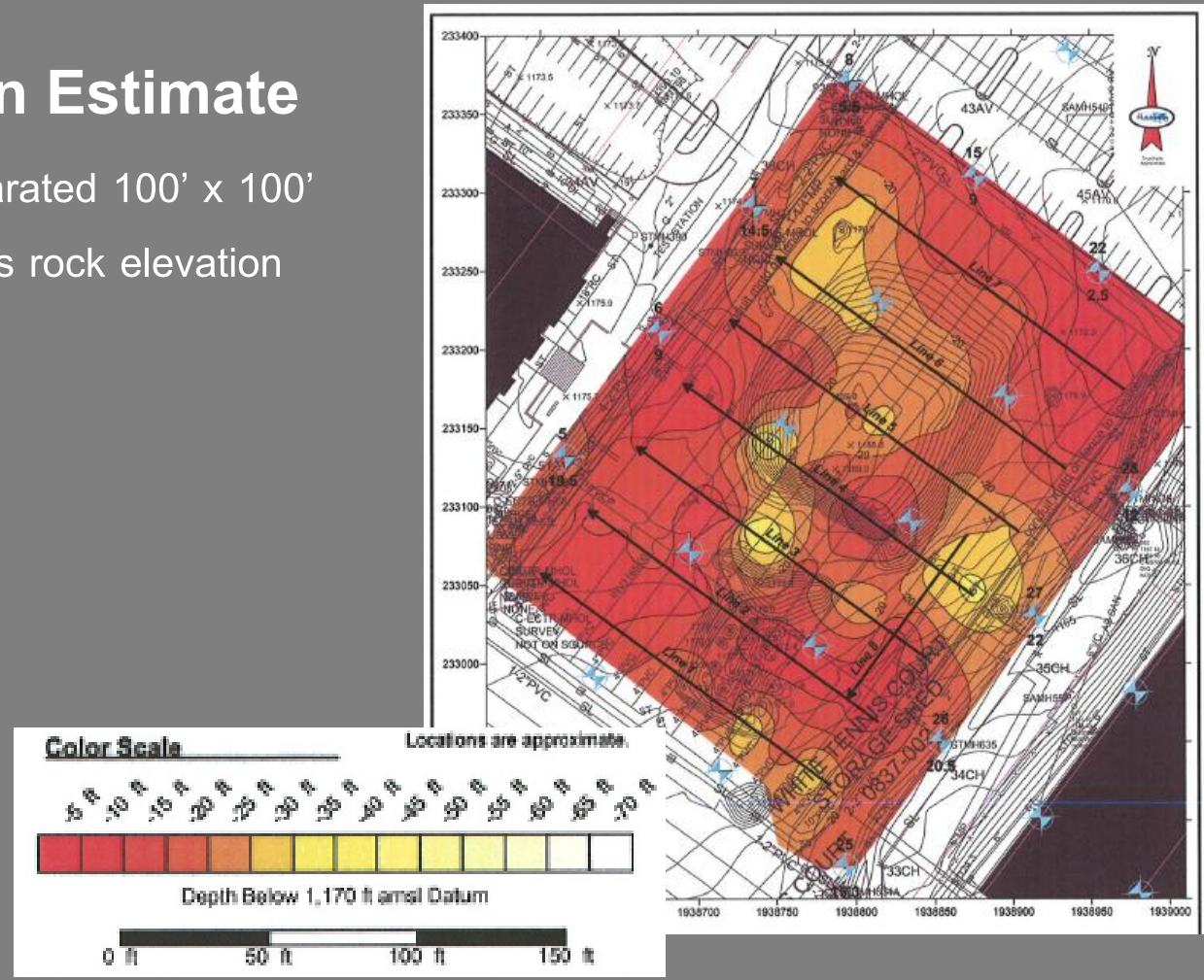




# Appendix

## Rock Excavation Estimate

- Boring locations separated 100' x 100'
- Ave of 4 boring points rock elevation in 100' x 100' section



## Rock Elevation Averages

Bore #	Rock Elev	Exc Elev	Bore #	Rock Elev	Exc Elev	Bore #	Rock Elev	Exc Elev
B-25	15	1159 4/5	B-18	25	1170	B-11	15	1170
B-26	20	1162 1/2	B-19	10	1170	B-12	10	1170
B-18	25	1170	B-11	15	1170	B-4	21	1170 1/2
B-19	10	1170	B-12	10	1170	B-5	16	1170 1/2
<b>AVE</b>	<b>17 1/2</b>	<b>1165 4/7</b>	<b>AVE</b>	<b>15</b>	<b>1170</b>	<b>AVE</b>	<b>15 1/2</b>	<b>1170 1/4</b>
<b>Bore #</b>	<b>Rock Elev</b>	<b>Exc Elev</b>	<b>Bore #</b>	<b>Rock Elev</b>	<b>Exc Elev</b>	<b>Bore #</b>	<b>Rock Elev</b>	<b>Exc Elev</b>
B-26	20	1162 1/2	B-19	10	1170	B-12	10	1170
B-27	15	1165	B-20	15	1170	B-13	25	1170
B-19	10	1170	B-12	10	1170	B-5	16	1170 1/2
B-20	15	1170	B-13	25	1170	B-6	7	1176
<b>AVE</b>	<b>15</b>	<b>1166 7/8</b>	<b>AVE</b>	<b>15</b>	<b>1170</b>	<b>AVE</b>	<b>14 1/2</b>	<b>1171 5/8</b>
<b>Bore #</b>	<b>Rock Elev</b>	<b>Exc Elev</b>	<b>Bore #</b>	<b>Rock Elev</b>	<b>Exc Elev</b>	<b>Bore #</b>	<b>Rock Elev</b>	<b>Exc Elev</b>
B-27	15	1165	B-20	15	1170	B-13	25	1170
B-28	10	1168	B-21	15	1170	B-14	25	1170
B-20	15	1170	B-13	25	1170	B-6	7	1176
B-21	15	1170	B-14	25	1170	B-7	13	1173 1/2
<b>AVE</b>	<b>13 3/4</b>	<b>1168 1/4</b>	<b>AVE</b>	<b>20</b>	<b>1170</b>	<b>AVE</b>	<b>17 1/2</b>	<b>1172 3/8</b>
<b>Bore #</b>	<b>Rock Elev</b>	<b>Exc Elev</b>	<b>Bore #</b>	<b>Rock Elev</b>	<b>Exc Elev</b>	<b>Bore #</b>	<b>Rock Elev</b>	<b>Exc Elev</b>
B-28	10	1168	B-21	15	1170	B-14	25	1170
B-29	7	1169	B-22	2	1170 1/2	B-15	9	1170
B-21	15	1170	B-14	25	1170	B-7	13	1173 1/2
B-22	2	1170 1/2	B-15	9	1173	B-8	8	1172 1/2
<b>AVE</b>	<b>8 1/2</b>	<b>1169 3/8</b>	<b>AVE</b>	<b>12 3/4</b>	<b>1170 7/8</b>	<b>AVE</b>	<b>13 3/4</b>	<b>1171 1/2</b>
<b>Bore #</b>	<b>Rock Elev</b>	<b>Exc Elev</b>	<b>Bore #</b>	<b>Rock Elev</b>	<b>Exc Elev</b>	<b>Bore #</b>	<b>Rock Elev</b>	<b>Exc Elev</b>
B-29	7	1169	B-22	2	1170 1/2	B-15	9	1170
B-30	6	1170	B-23	4	1171	B-16	5	1173 1/2
B-22	2	1170 1/2	B-15	9	1173	B-8	8	1172 1/2
B-23	4	1171	B-16	5	1173 1/2	B-9	2	1174
<b>AVE</b>	<b>4 3/4</b>	<b>1170 1/8</b>	<b>AVE</b>	<b>5</b>	<b>1172</b>	<b>AVE</b>	<b>6</b>	<b>1172 1/2</b>

## Estimated Rock & Soil Excavation

Boring Section	Ave Boring Elevation	Ave Rock Elevation	Sectional Area	Ave Sec Area Rock Depth Below 1170	Rock Above /Below Exc Lvl	Rock Depth to be Rmvd	CF Rock to be Rmvd	CY Rock to be Rmvd	Soil Depth to be Rmvd	CF Soil to be Rmvd	CY Soil to be Rmvd
B-25, 26, 18, 19	1165 4/7	1152 1/2	8500	17 1/2	1 1/6	0	0	0	12	102000	3778
B-25, 26, 32, 33			5100						12	61200	2267
B-26, 27, 19, 20	1166 7/8	1155	10000	15	-1 1/3	2	20000	741	12	120000	4445
B-26, 27, 33, 34			6000		-1 1/3	2	12000	445	12	72000	2667
B-27, 28, 20, 21	1168 1/4	1156 1/4	10000	13 3/4	-2 7/12	3	30000	1112	12	120000	4445
B-27, 28, 34, 35			6000		-2 7/12	3	18000	667	12	72000	2667
Elevator #3 Pit Level 1		1156 1/4	296	13 3/4	-5 3/4	4	1184	44	0	0	0
Elevator #3 Pit Level 2		1156 1/4	76	13 3/4	-7 3/4	2	152	6	0	0	0
B-28, 29, 21, 22	1169 3/8	1161 1/2	11000	8 1/2	-7 5/6	8	88000	3260	8	88000	3260
B-29, 30, 22, 23	1170 1/8	1165 1/4	12100	4 3/4	-11 7/12	12	145200	5378	5	60500	2241
Elevator #2 Pit Level 1		1165 1/4	307	4 3/4	-14 3/4	4	1228	46	0	0	0
Elevator #2 Pit Level 2		1165 1/4	64	4 3/4	-16 3/4	2	128	5	0	0	0
B-18, 19, 11, 12	1170	1155	8500	15	-1 1/3	2	17000	630	15	127500	4723
B-19, 20, 12, 13	1170	1155	10000	15	-1 1/3	2	20000	741	15	150000	5556
B-20, 21, 13, 14	1170	1150	10000	20	3 2/3	0	0	0	17	170000	6297
B-21, 22, 14, 15	1170 7/8	1157 1/4	10000	12 3/4	-3 7/12	4	40000	1482	14	140000	5186
B-22, 23, 15, 16	1172	1165	11000	5	-11 1/3	12	132000	4889	7	77000	2852
B-11, 12, 4, 5	1170 1/4	1154 1/2	5625	15 1/2	- 5/6	1	5625	209	16	90000	3334
B-12, 13, 5, 6	1171 5/8	1155 1/2	8500	14 1/2	-1 5/6	2	17000	630	17	144500	5352
Ice Melt Sump		1155 1/2	353	14 1/2	-2 5/6	1	353	14	0	0	0
B-13, 14, 6, 7	1172 3/8	1152 1/2	8500	17 1/2	1 1/6	0	0	0	19	161500	5982
B-14, 15, 7, 8	1171 1/2	1156 1/4	8500	13 3/4	-2 7/12	3	25500	945	16	136000	5038
Hydro Pit		1156 1/4	1170	13 3/4	-9 2/3	8	9360	347	0	0	0
B-15, 16, 8, 9	1172 1/2	1164	9350	6	-10 1/3	11	102850	3810	9	84150	3117
Elevator #1 Pit Level 1		1164	266	6	-13 1/2	4	1064	40	0	0	0
Elevator #1 Pit Level 2		1164	78	6	-15 1/2	2	156	6	0	0	0
<b>Total</b>							<b>685580</b>	<b>25401</b>		<b>1976350</b>	<b>73207</b>
							CF	CY		CF	CY









# Appendix

## Office Lighting Details

Office Design Criteria – IES 10<sup>th</sup> ed. Lighting Handbook Ch. 32

300 lx Eavg,h @ 3' AFF

75 lx Eavg,v 3' AFF

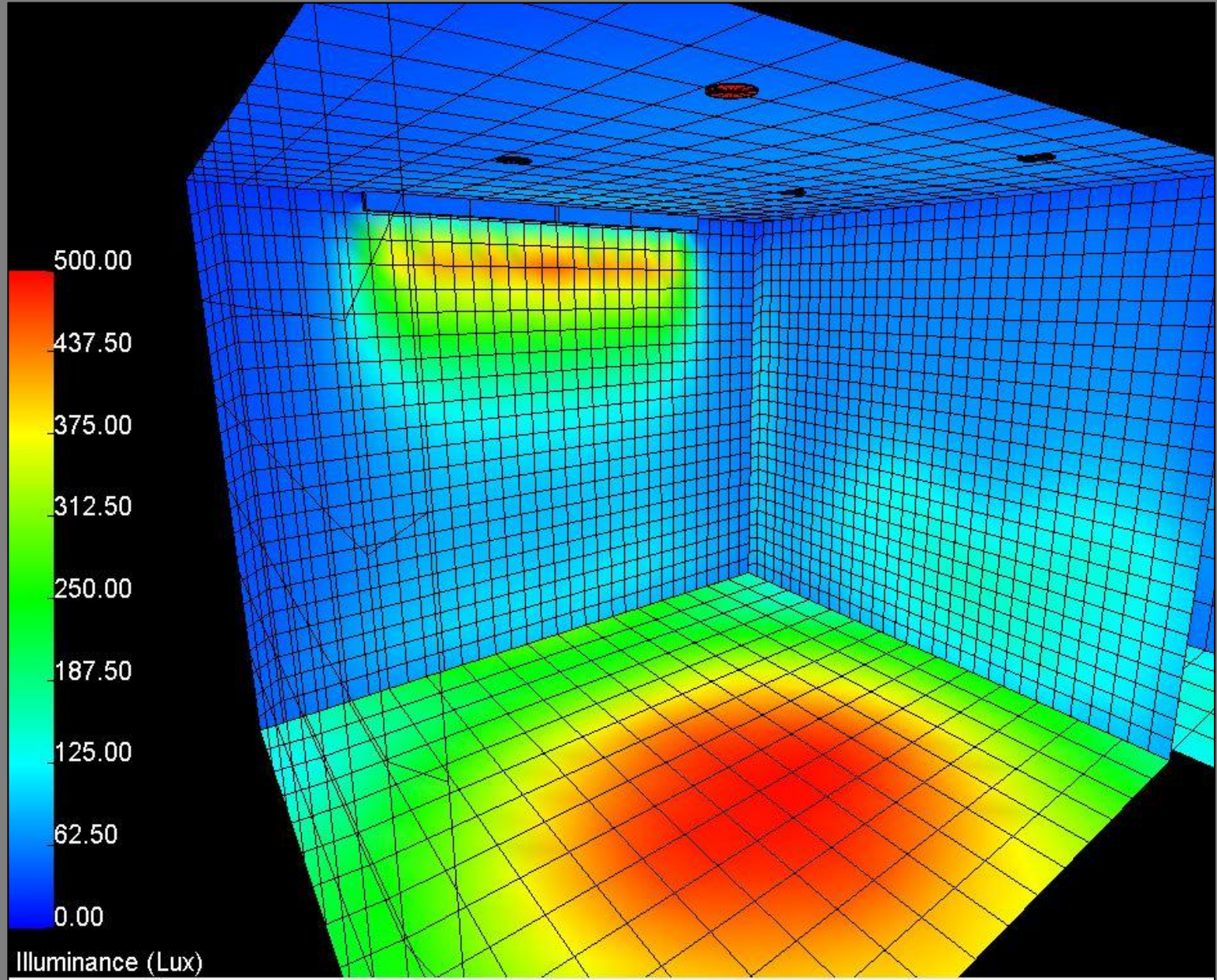
Power Density – ASHRAE STD. 90.1 Section 9

1.11 W/SF

Total Allowable Watts: 158.4 Watts

User Controllability

Multi-zone control



4' Linear LED recessed wall grazer



4 - 6'' round LED downlight

Typical Office Design Results

350 lx Eavg,h @ Floor

83 lx Eavg, v @ Face of Lockers

Power Density

4\*25+37=137 Connected Watts





# Appendix

## Arena Lighting Details

Arena Design Criteria – IES 10<sup>th</sup> ed. Lighting Handbook Ch. 25

& NCAA Broadcast Guidelines

1500 lx Eavg,h @ Ice

400 lx Eavg, v @ 3' – 5' AFF

CV <= 0.13

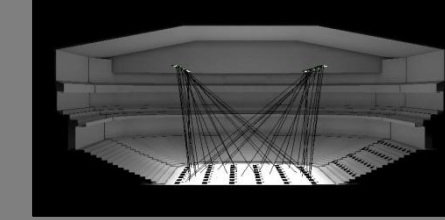
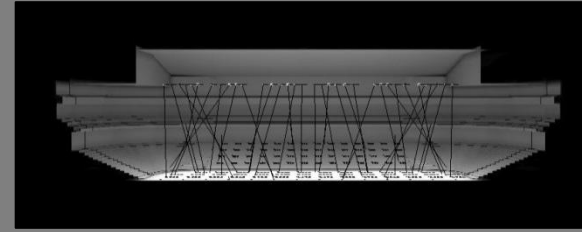
E<sub>max</sub>:E<sub>min</sub> <= 1.7:1.0

Power Density – ASHRAE STD. 90.1 2010

3.1 W/SF - Class 1 Arena

0.43 W/SF – Seating

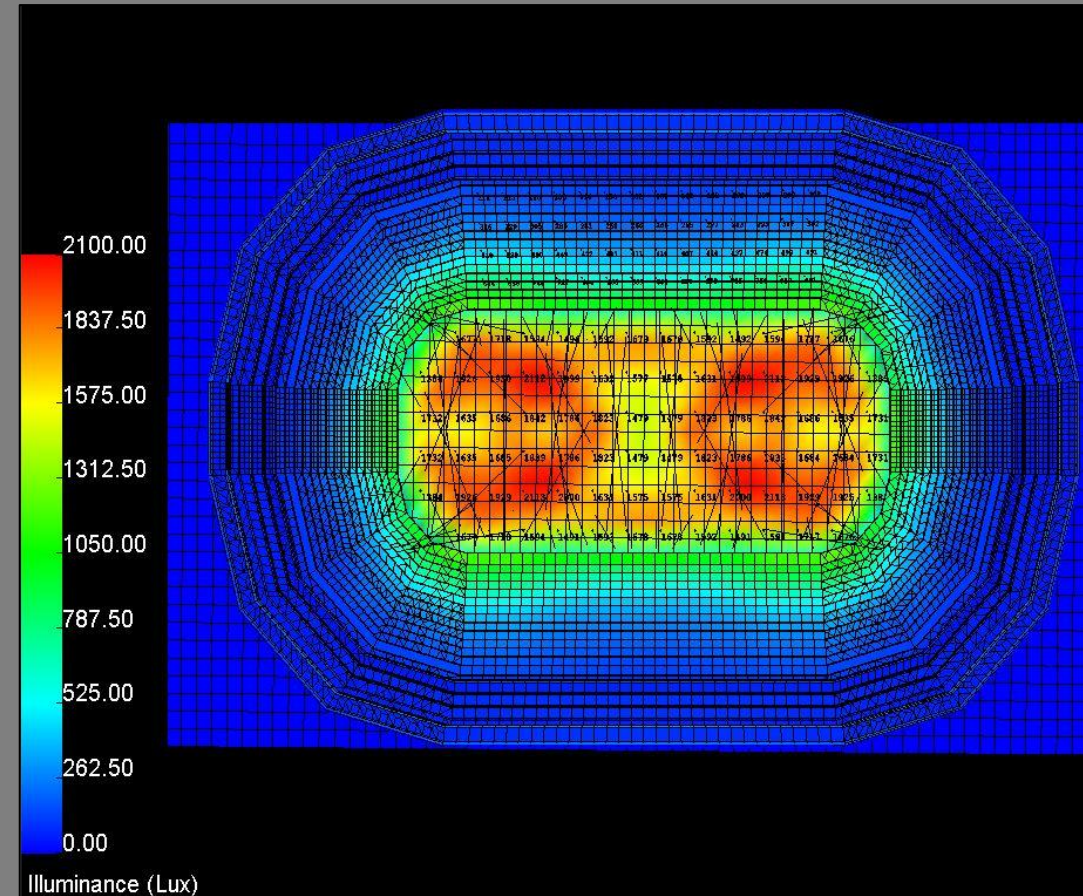
Total Allowable Wattage: 66752 Watts



60 – Indoor Sports Luminaire w/ shutter



20 - 6" round LED downlight



### Arena Design Results

1714 lx Eavg,h @ Ice

1089 lx Eavg,v @ 3' - 5'AFF

CV = 0.10

E<sub>max</sub>:E<sub>min</sub> = 1.39

Power Density

60\*1075+20\*25 = 65000 Connected Watts





# Appendix

## Locker Room Lighting Details

Locker Room Design Criteria – IES 10<sup>th</sup> ed. Lighting Handbook Ch. 22

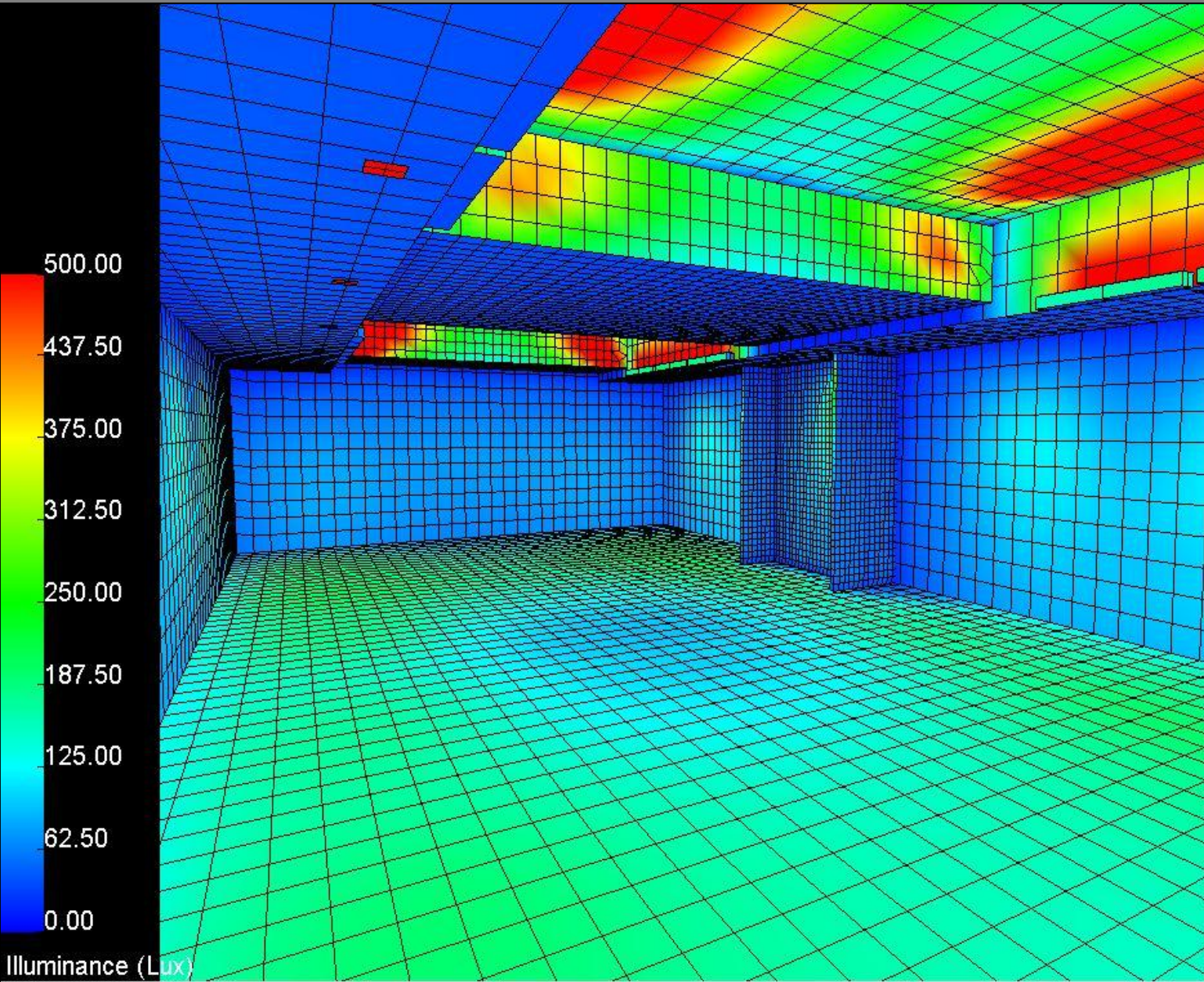
50 lx Eavg,h @ Floor

50 lx Eavg, v @ Face of Lockers

Power Density – ASHRAE STD. 90.1 2010

075 W/SF

Total allowable wattage: 1043.25 Watts



12 – 4.5” LED recessed wallwasher



12 – 4’ T5 linear fluorescent cove

### Locker Room Design Results

153 lx Eavg,h @ Floor

126 lx Eavg, v @ Face of Lockers

Power Density

12\*26\*12\*32= 370 Connected Watts





# Appendix

## Atrium Lighting Details

Atrium Design Criteria – IES 10<sup>th</sup> ed. Lighting Handbook Ch. 22

150 lx Eavg,h @ floor

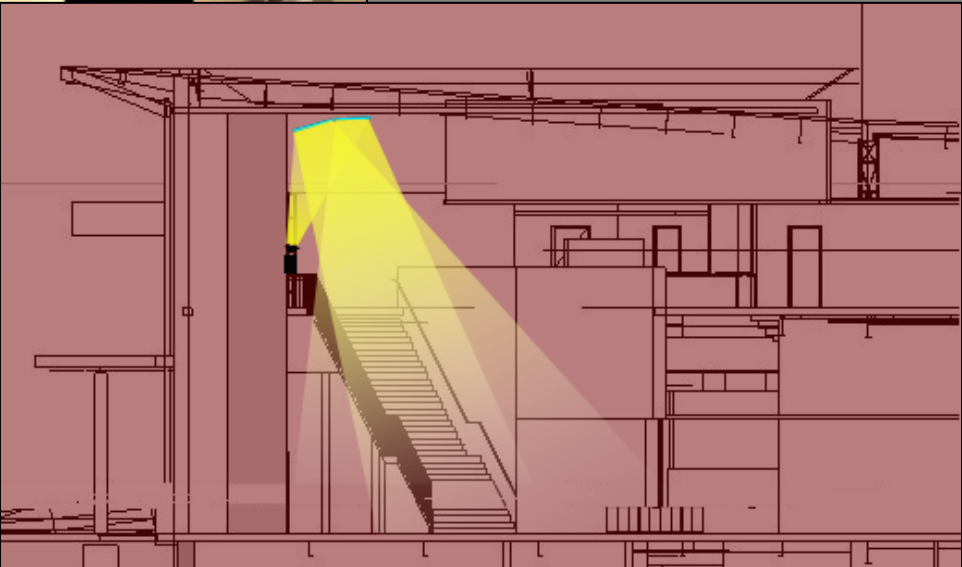
75 lx Eavg,v @ 5' AFF

E<sub>max</sub>:E<sub>min</sub> <= 2:1

Power Density - ASHRAE STD. 90.1 2010

0.73 W/SF

Total Allowable Wattage: 2580 Watts



4 – multifaceted semi specular mirrors



11 – 150 watt parabolic projector

### Atrium Design Results

153 lx Eavg,h @ Floor

126 lx Eavg, v @ Face of Lockers

### Power Density

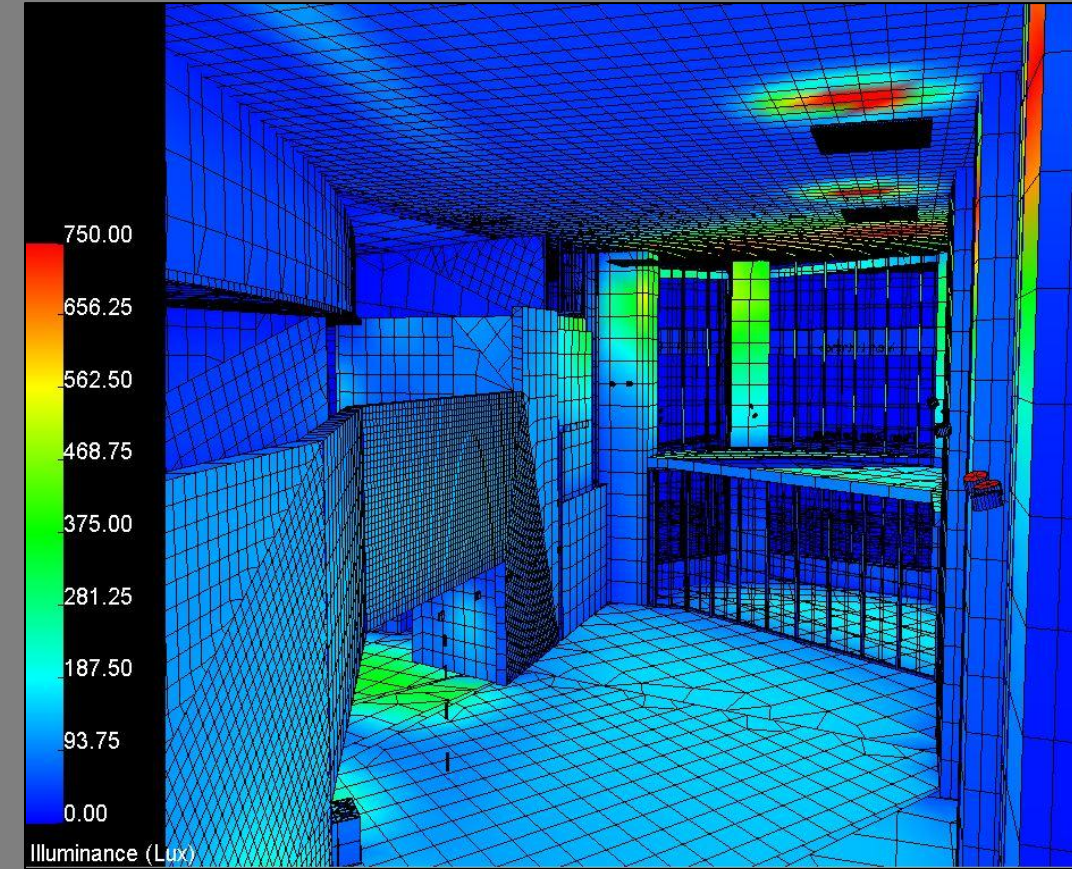
$$9 \times 9W + 14 \times 162W + 8 \times 162W = 3618 \text{ Connected Watts}$$





# Appendix

## Atrium Featured Lighting Details



9 – 1' Cantilever mounted LED asymmetrical luminaire

10 – 150W CMHID track mounted floodlight

