The Millennium Science Complex

University Park, PA

Penn State Integrated Project Delivery / Building Information Modeling Senior Capstone Thesis

KGB Maser

Management. Engineering. Consulting.

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Project Team Members

Jason Brognano
Lighting/Electrical Designer

David Maser
Construction Manager

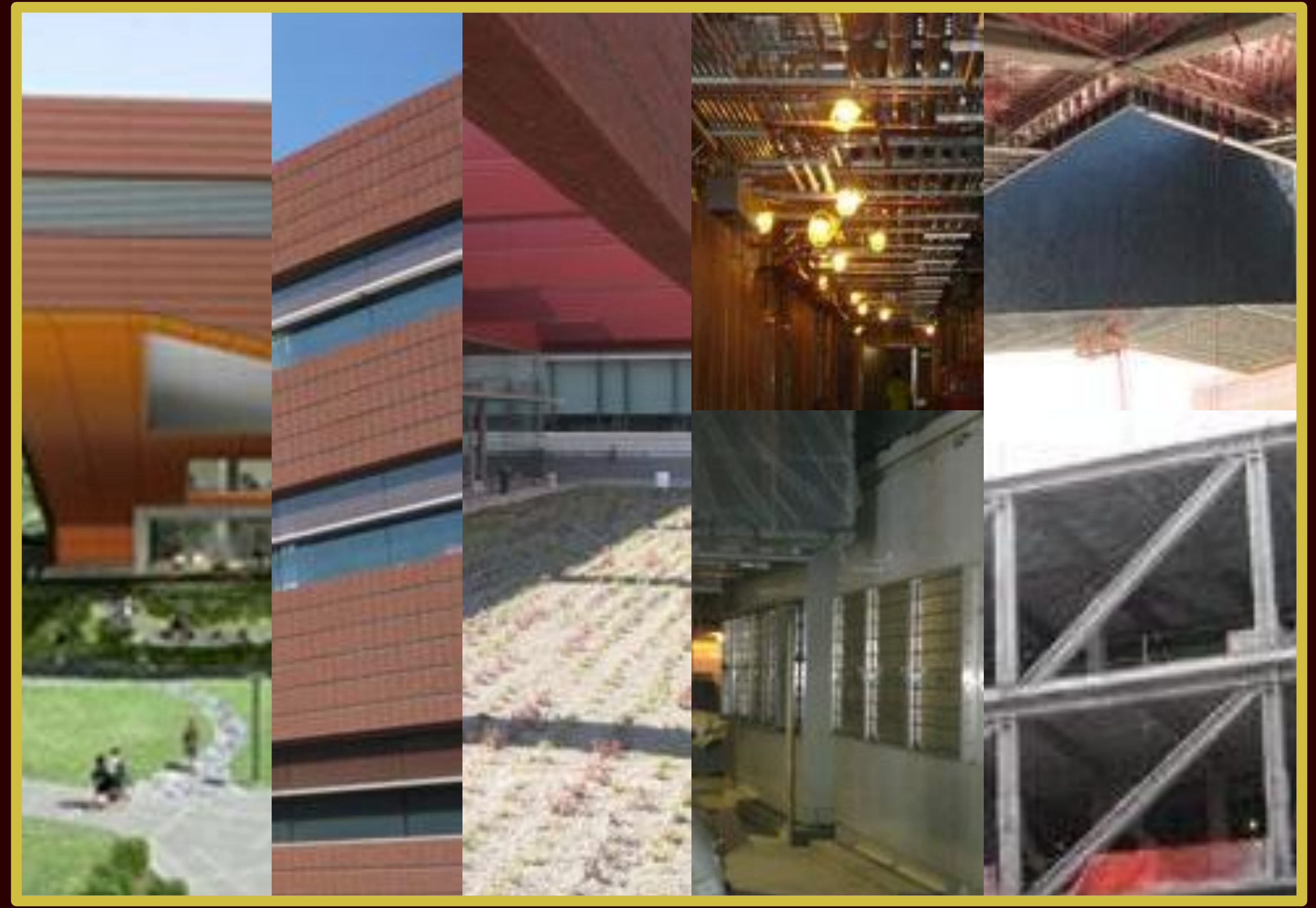
Michael Gilroy
Mechanical Designer

Stephen Kijak
Structural Designer

Project Overview

Location, Size, and Use

- Science Research complex
- 275,600 sq. ft.
- Three above grade floors, penthouse, mezzanine, and basement



Time and Cost

- Design-Bid-Build Delivery
- June 2008 — July 2011 Construction
- $230,000,000 budgeted overall cost
- $175,000,000 building cost

Sustainability Features

- LEED Gold Certification
- Green roofs on both wings
- Low VOC materials on interior
- Daylight integration in perimeter spaces
- CO_2 occupancy density sensors

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Project Overview

Construction

CONSTRUCTION PHASE	DURATION (DAYS)	START	FINISH
Notice to Proceed	1	8-12-08	8-12-08
Foundation	270	2-16-09	2-26-10
Superstructure	274	7-7-09	7-23-10
Enclosure	303	11-9-09	1-5-11
Building Systems & Finishes	345	12-14-09	4-8-11
Construction Duration	758	8-12-08	7-7-11
Substantial Completion	1	7-7-11	7-7-11

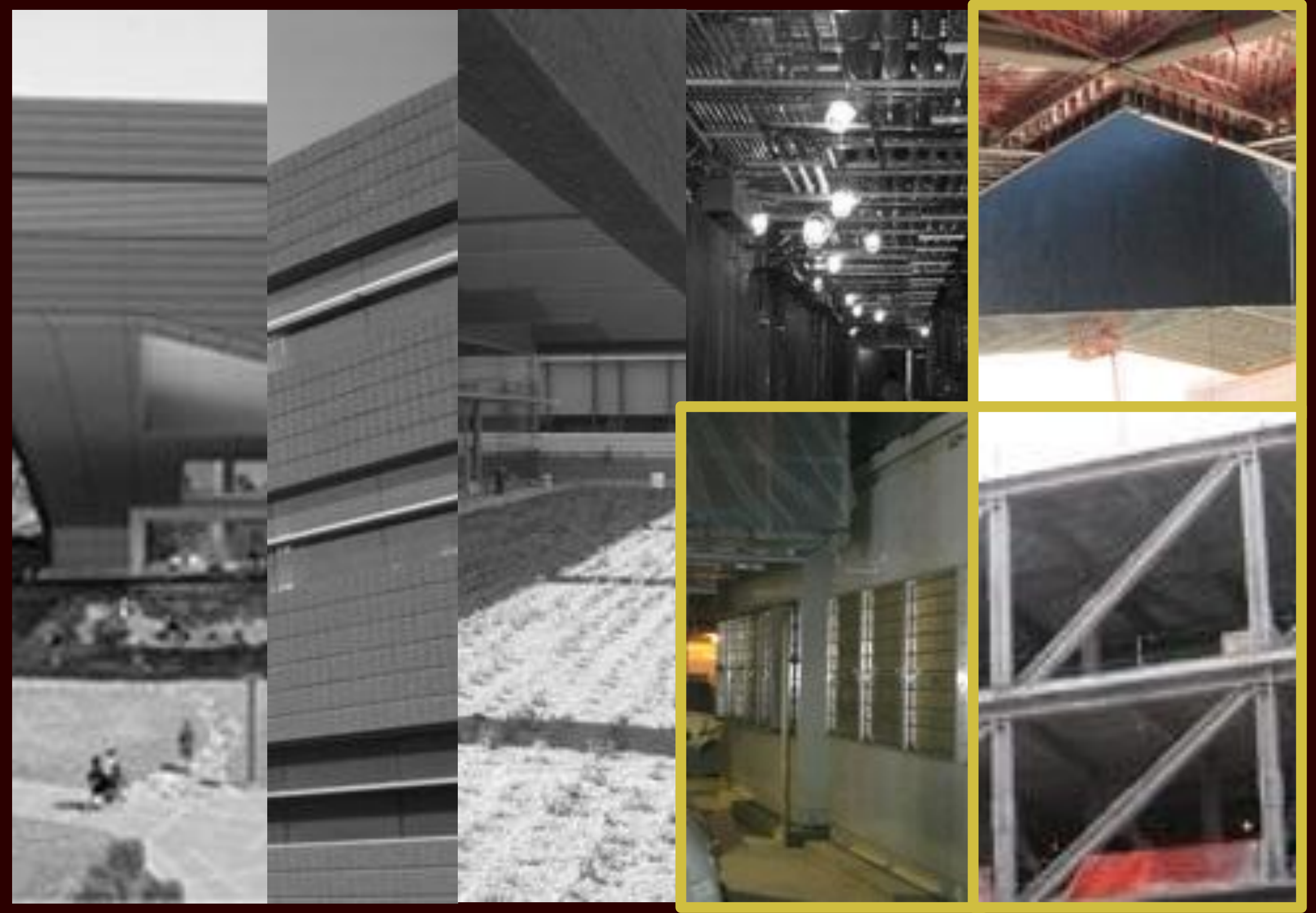
Lighting and Power

- All lighting on 480Y/277V supply
- Receptacle and small loads on 208Y/120V
- Lutron Ecosystem in public perimeter spaces
- Occupancy and daylight sensor control
- Lighting control panels for exterior spaces
- Campus tied, 12.47kV supply voltage
- Dual 5000A main-tie-main switchgear
- Rigid conduit and aluminum cladding in electrical rooms to mitigate EMF interference

Project Overview

Mechanical

- VAV Reheat Air Distribution
  - (5) 50,000 CFM AHUs deliver 100% OA to General Lab Areas
  - (3) 40,000 CFM AHUs serve Office & Common Areas
  - Animal Care, Quiet Lab, and Clean Room AHUs
- High pressure steam from PSU central plant
  - Reduced to medium and low pressure for use
- PSU campus chilled water used for cooling coils AHUs
- Dedicated exhaust system for fume hoods, biosafety cabinets
- CO_2 Sensors throughout to maintain air quality
- 4th floor penthouse and basement mechanical rooms



Structural

- Steel Structure
  - LWT Concrete on 3inch Metal Deck
  - Wide Flange Beams and Girders, 21 and 24 inches deep
  - 22ft. X 22ft. Bays
- 154ft. Cantilever at the North-West corner of the Building
  - 4 Main Supporting Trusses
  - Web Members Oriented for Axial Compression
  - Moment Connected Members for Stiffness
  - Controlled by Deflection - 2 inch Allowance
- Lateral System
  - Shear Walls, Braced Frames, Moment Frames
  - 90% of Lateral Forces Received by Shear Walls
  - Seismic Forces Control
- Foundation
  - Micropiles Beneath Pile Caps
  - Grid of Foundation Beams

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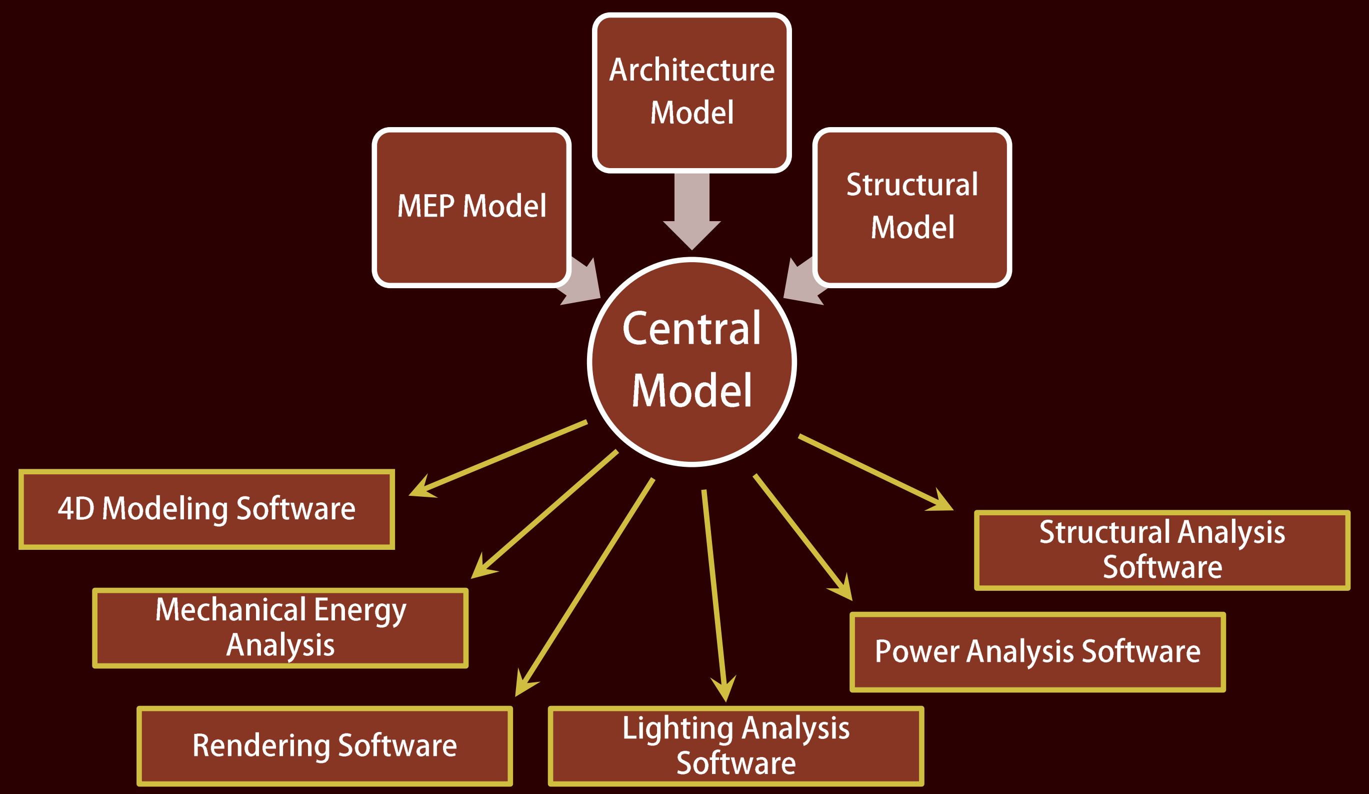
KGB Maser Goals of Analysis

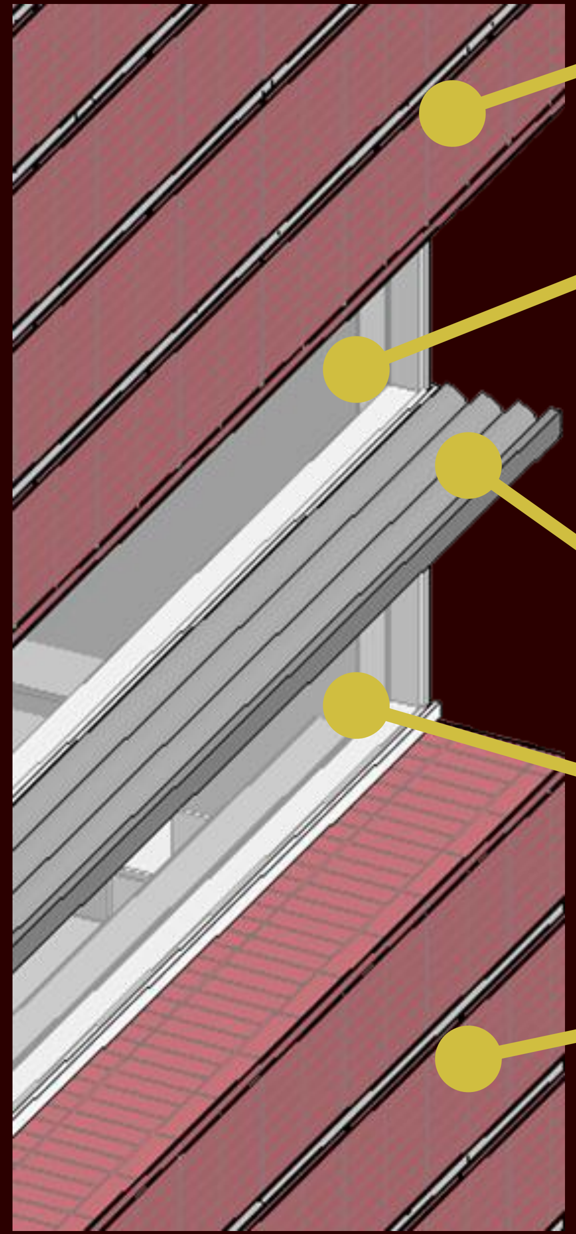
IPD/BIM Goals

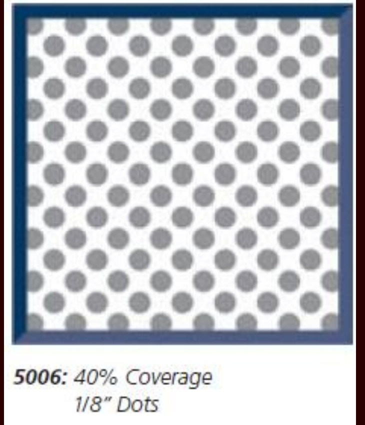
- Update option-specific designs within the appropriate **BIM models**
- Perform analyses using the **central model** as a base
- Document **model sharing processes** to achieve design goals
- Work collaboratively to asses repercussions of design changes on **all disciplines**



Engineering Goals

- Decrease energy consumption by **10%**
- **Reduce size** and **cost** of structural system
- Modify façade to accommodate **multiple disciplines:** daylight delivery, structural efficiency, mechanical system sizing, and constructability





Existing vs. Proposed Facade

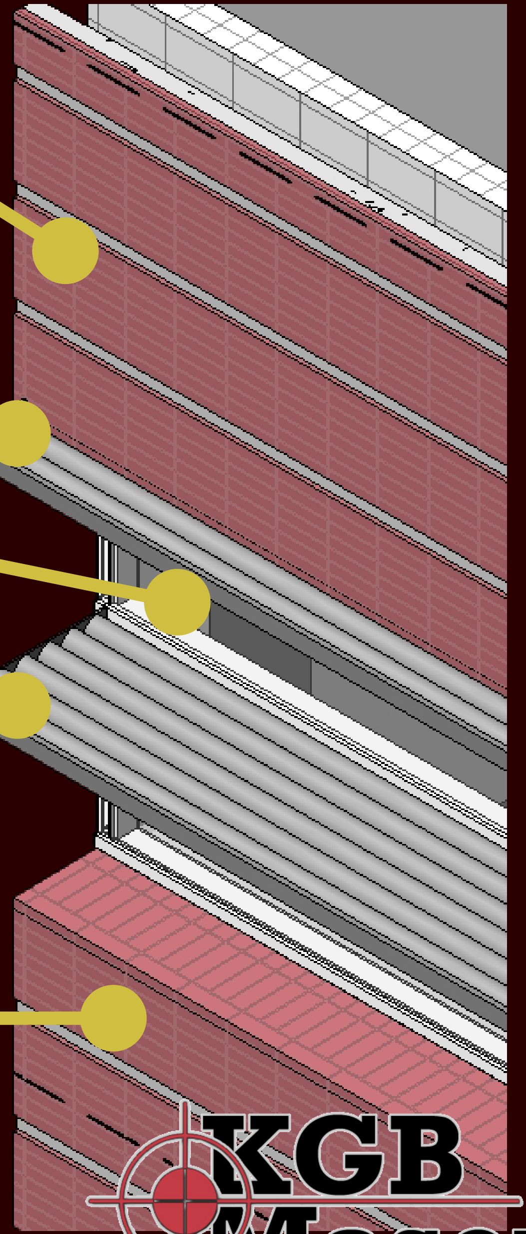
Key Design Issues

How does overhang depth affect **mechanical load?**

How does overhang depth affect **daylight delivery?**

Is it possible to **reduce the weight** of panels?

Can all options come to a conclusion that is **beneficial** and **cost effective?**



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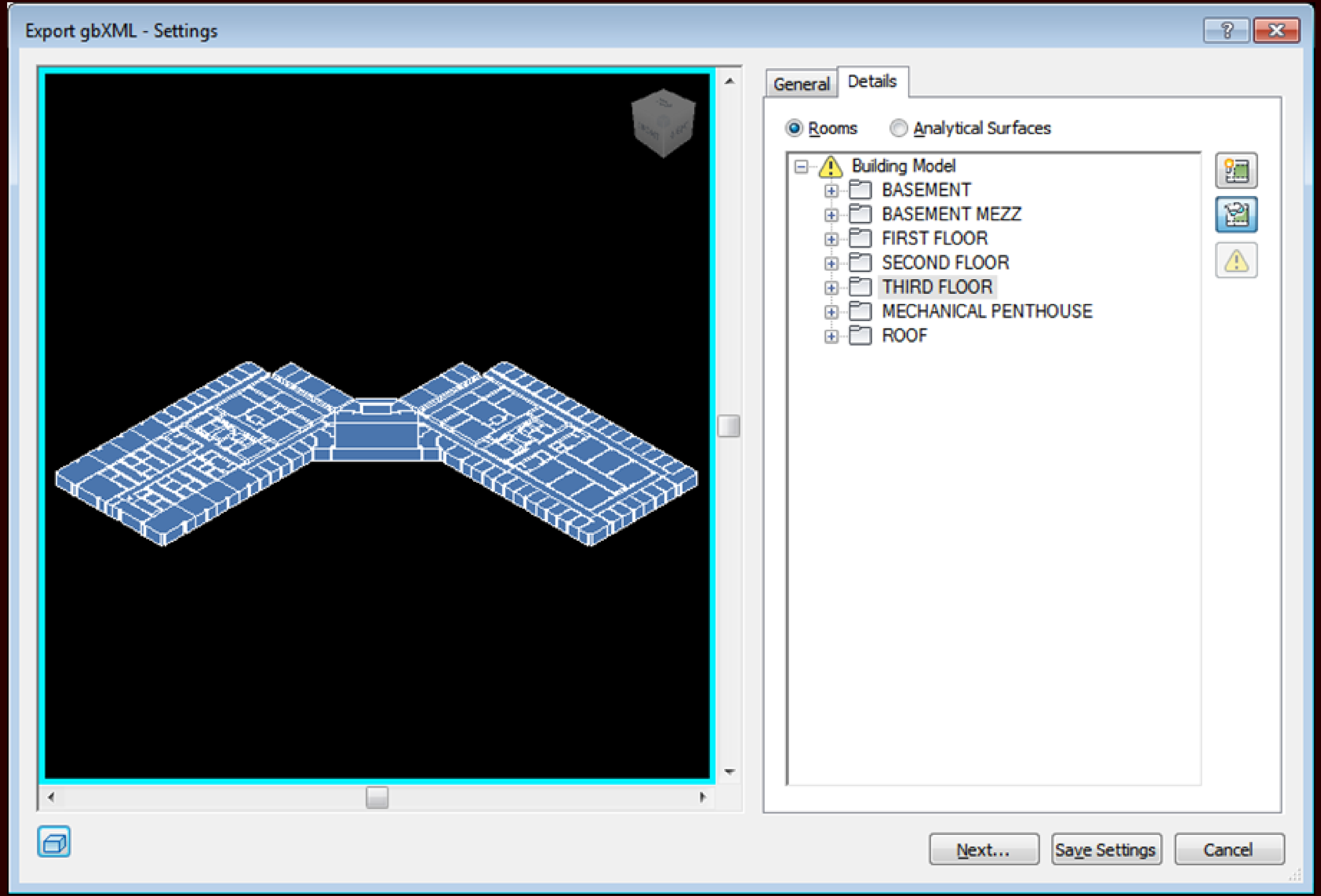
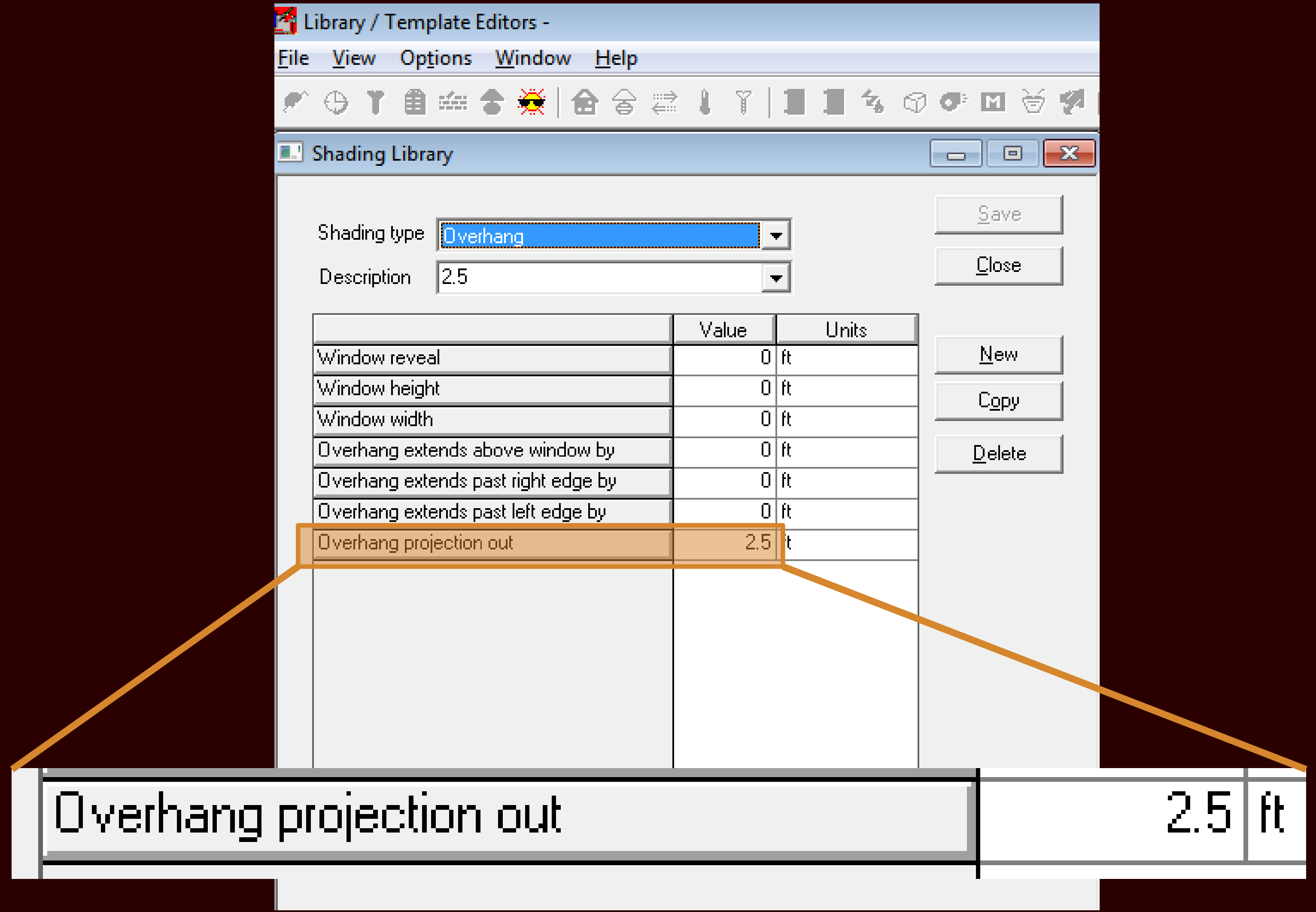
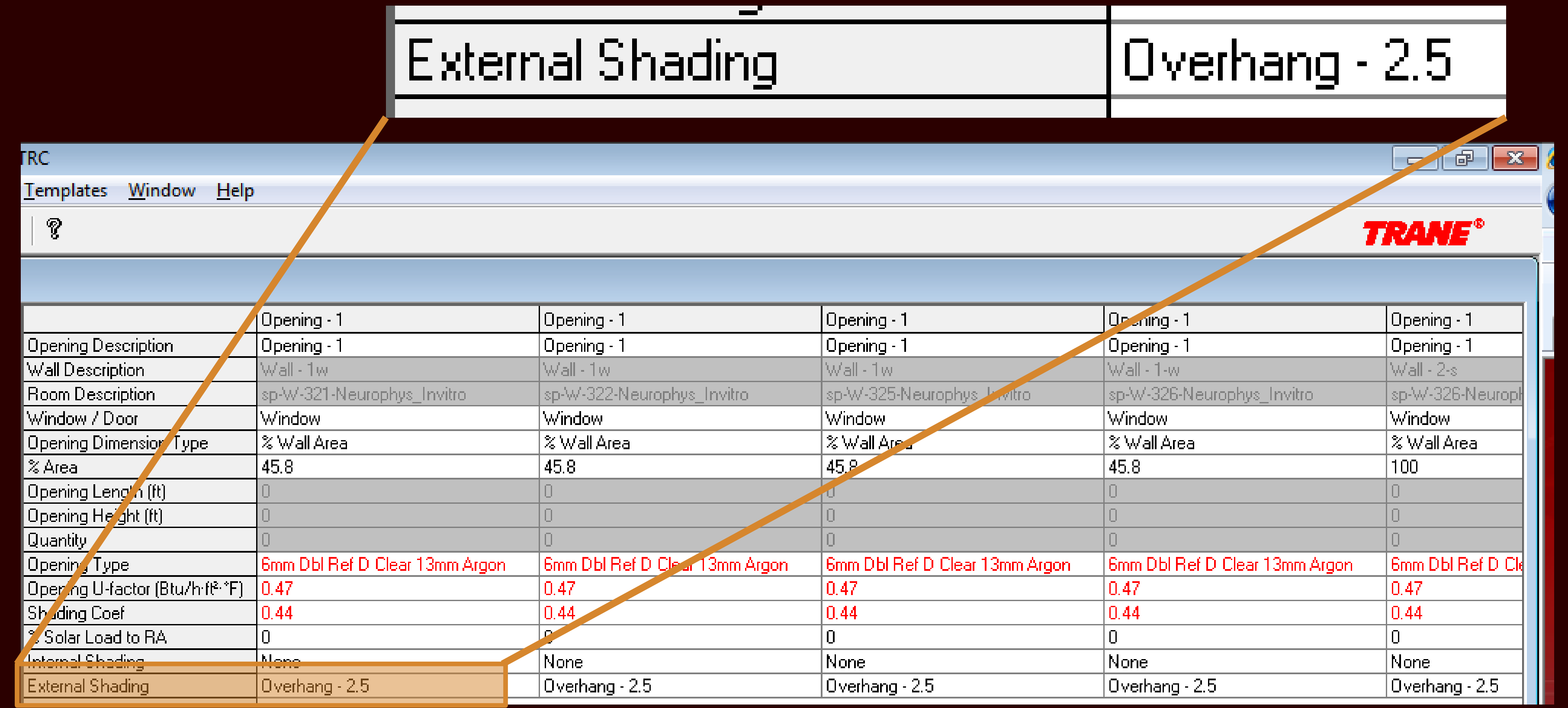
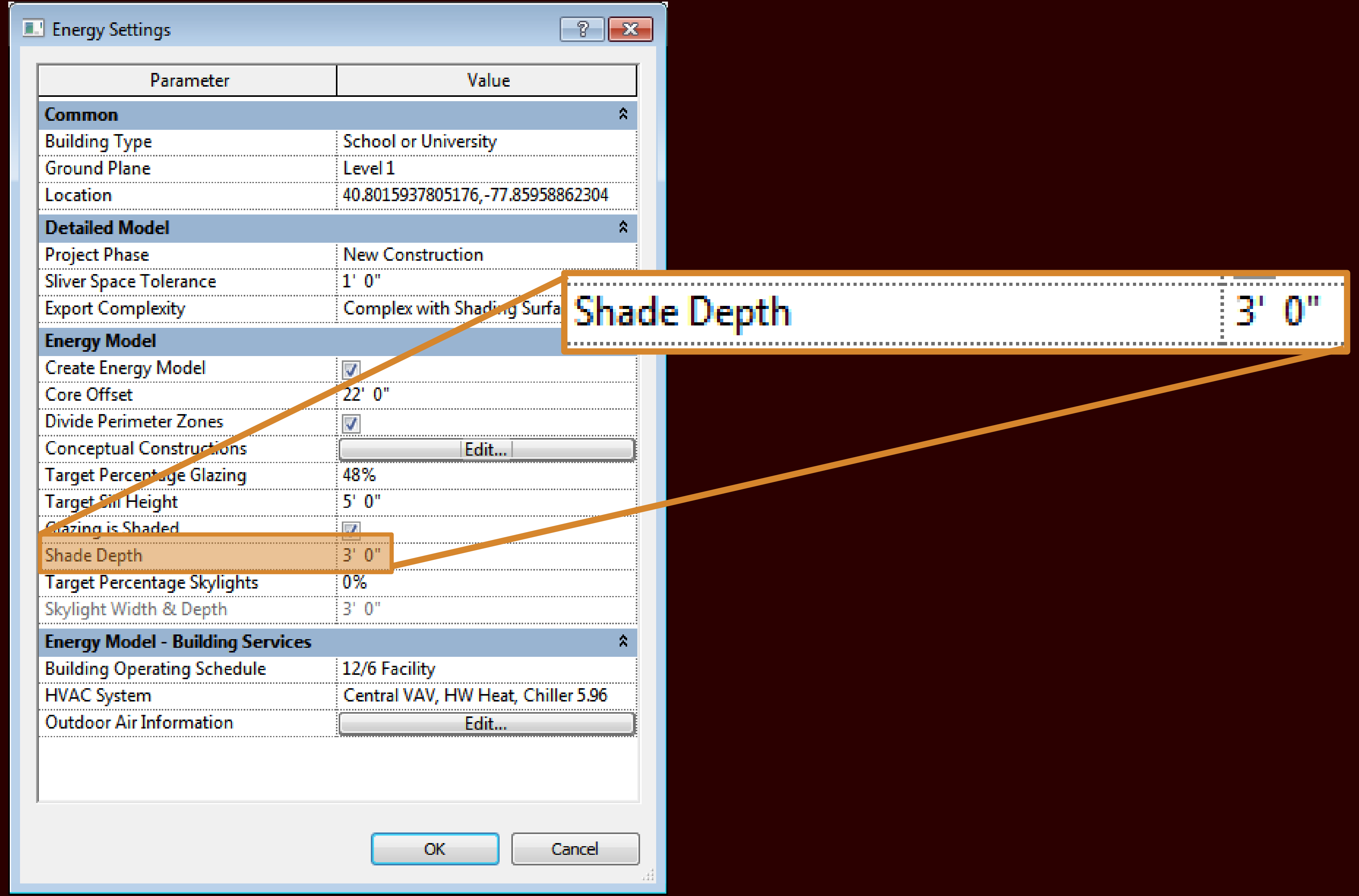
Overhang Investigation: Trane TRACE

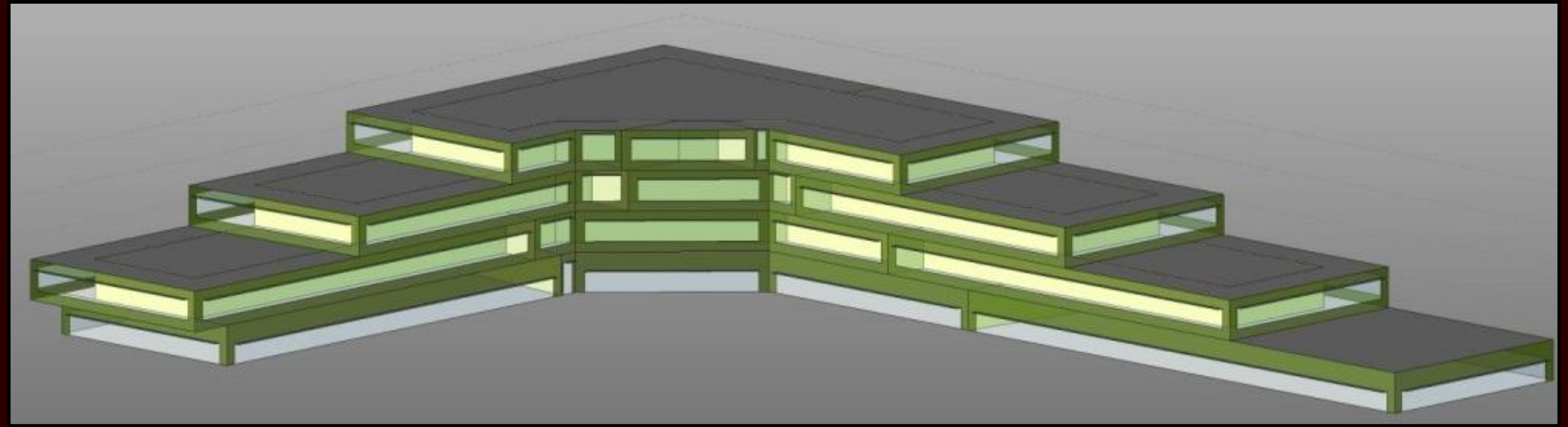


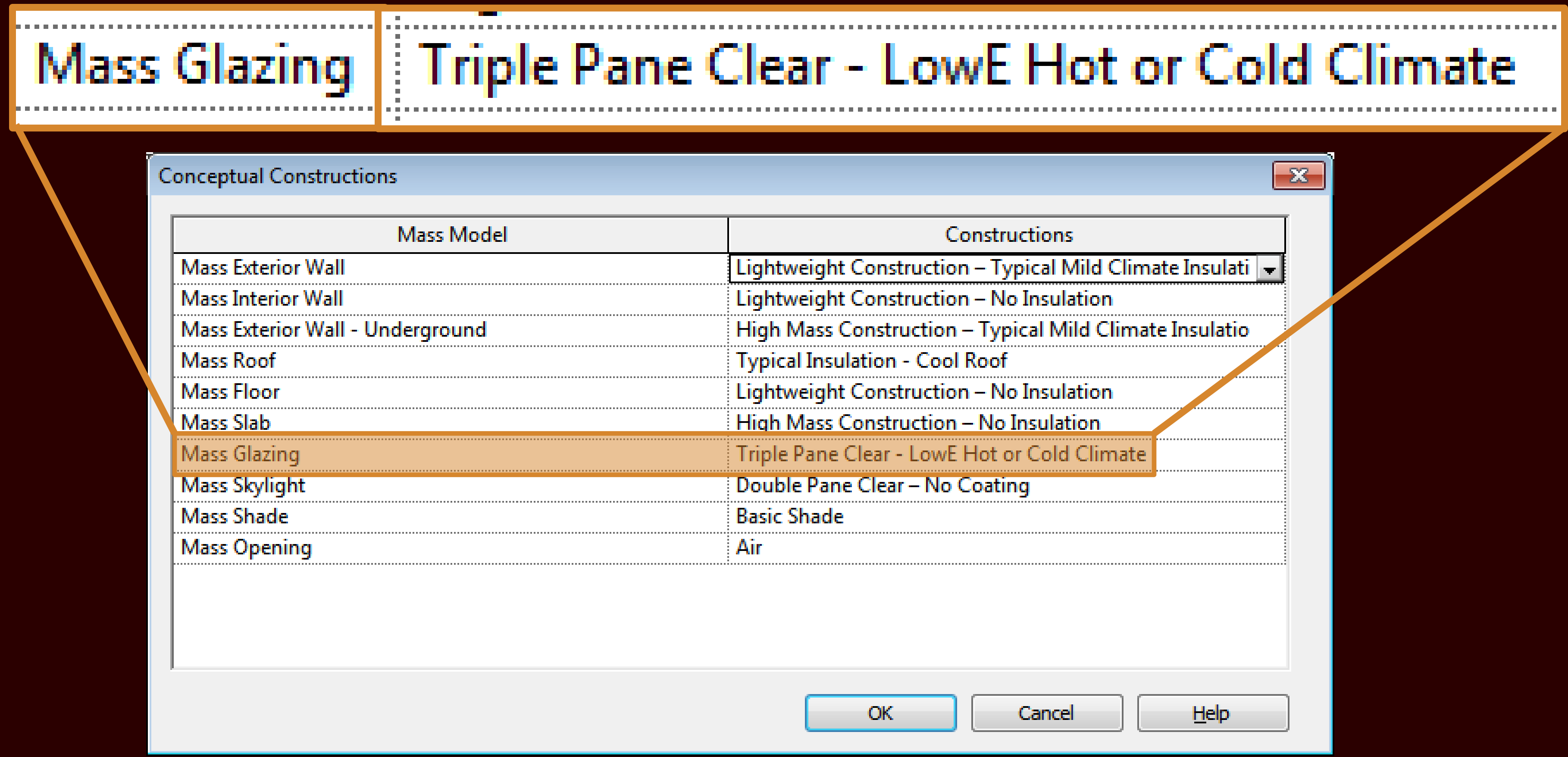




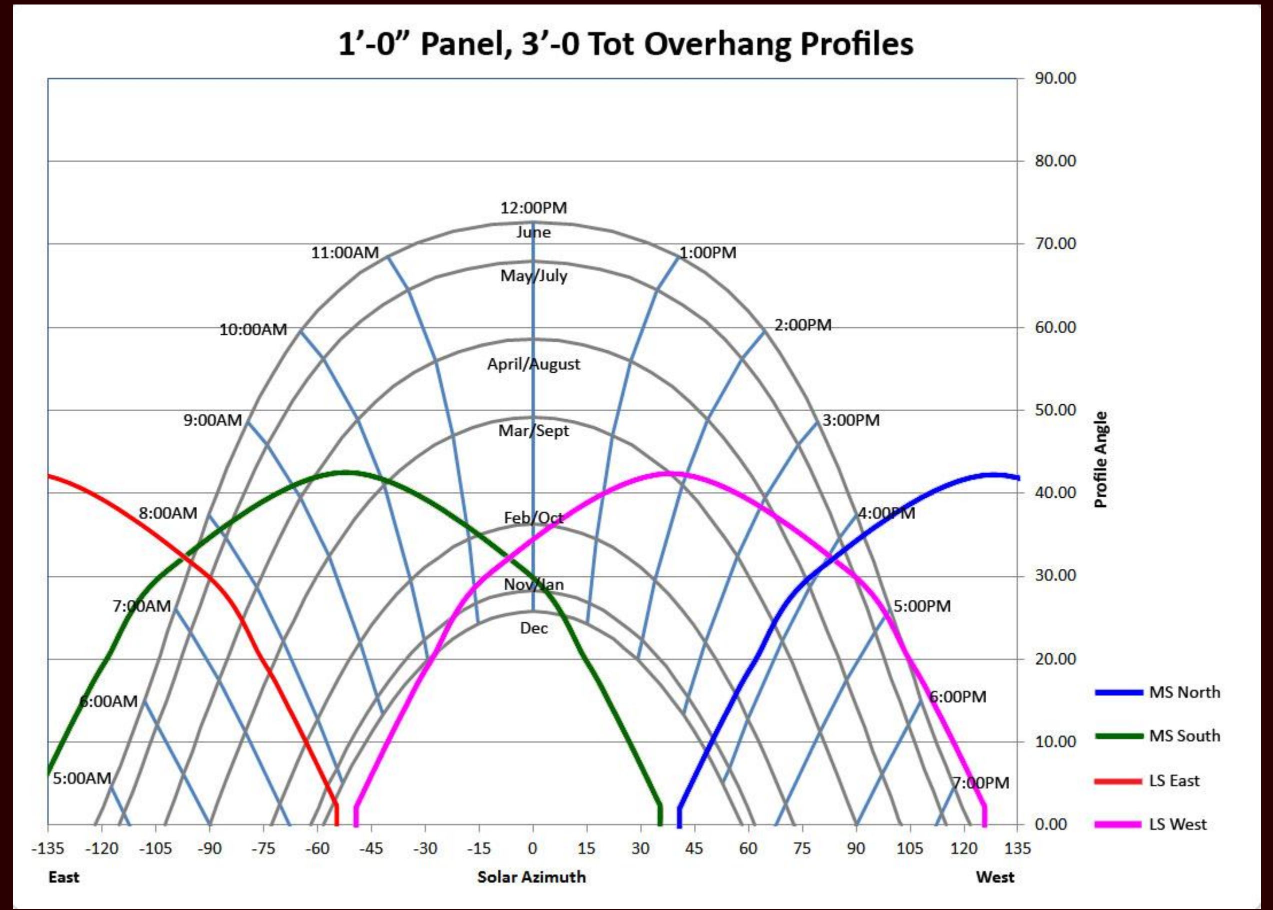
Overhang Investigation: Project Vasari

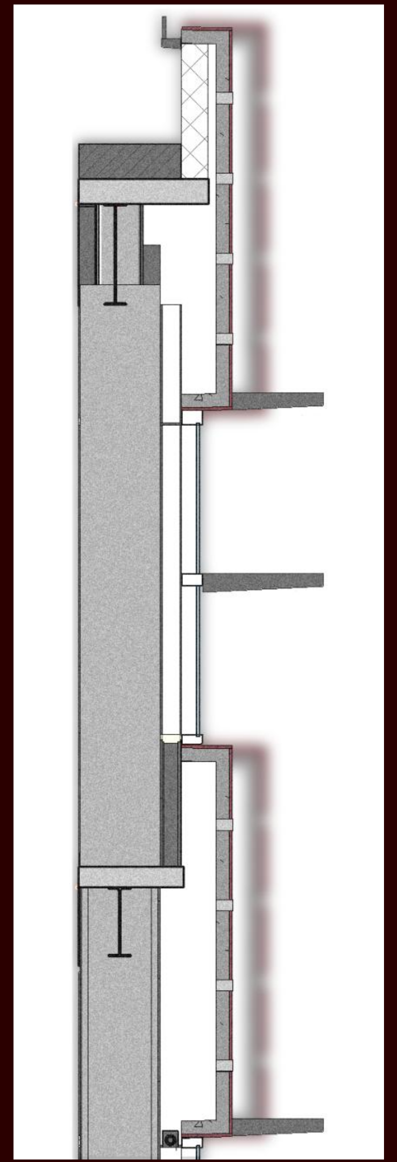


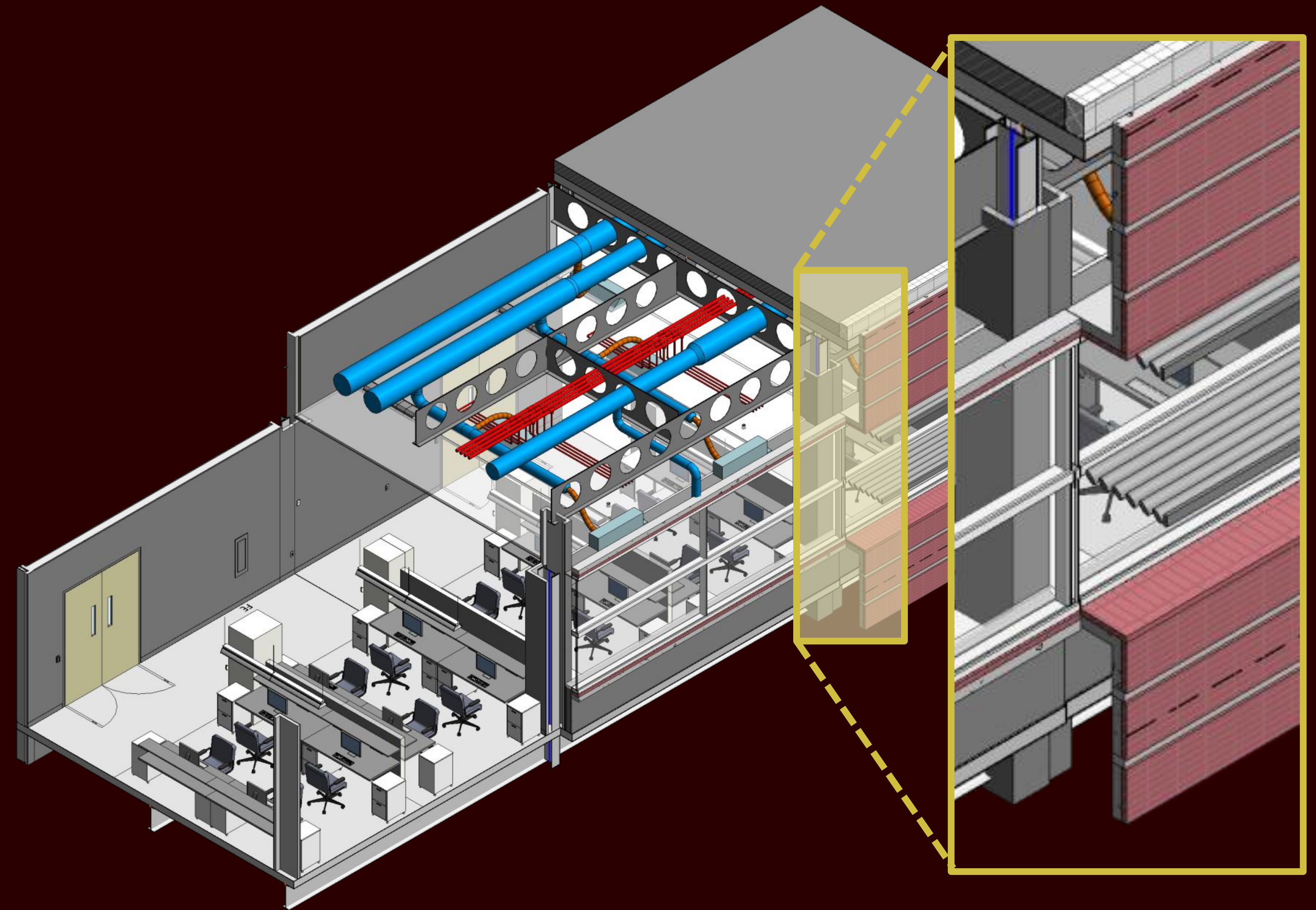


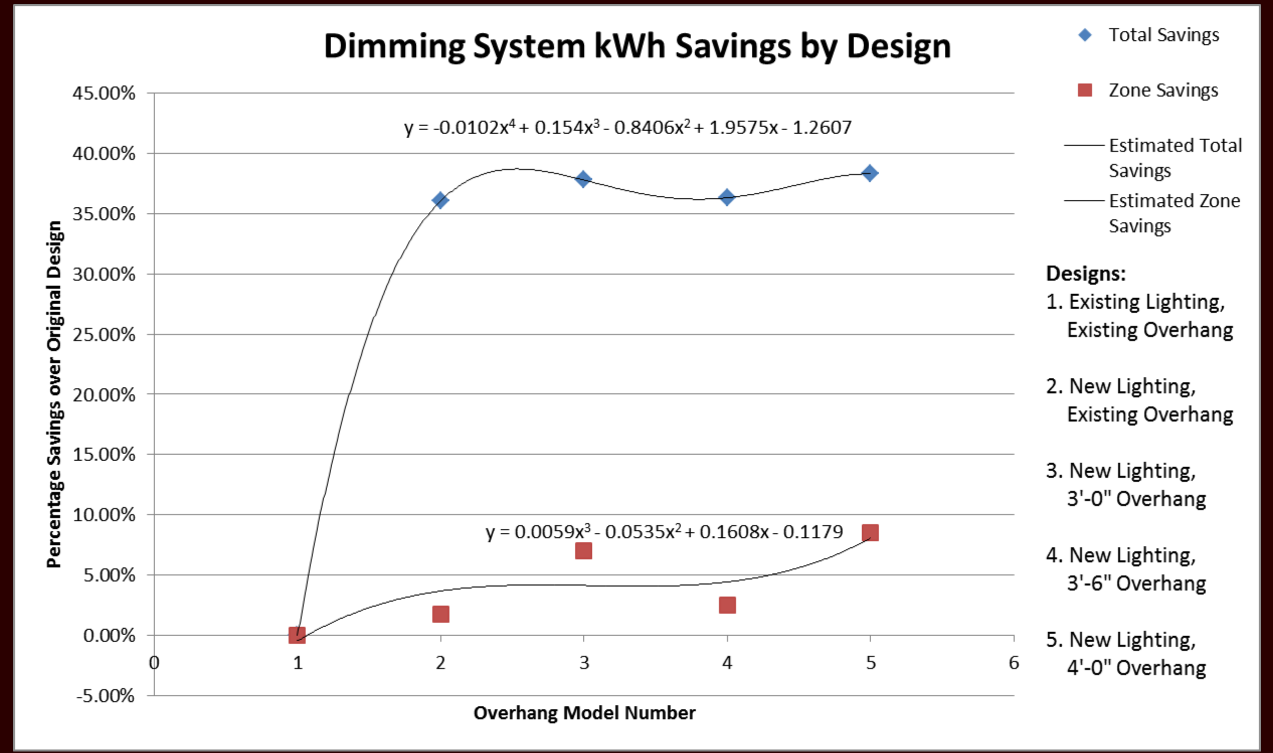


Overhang Investigation: Daysim









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Overhang Investigation: Operating Cost Findings

At 3'-0" the zone savings density is as follows:

Existing System 0.5905 kWh/SF applied to 14115 SF of perimeter area

3'-0" Overhang 0.5494 kWh/SF applied to 14115 SF of perimeter area

Total operating cost savings at $0.08/kWh is **$46.48** for the third floor perimeter spaces

Existing System 8335.34 kWh energy usage

3'-0" Overhang 7754.36 kWh energy usage

Net Difference 580.98 kWh energy usage

Applied building wide, the overhang saves mechanical operating costs by **$23,088**

Overhang and Glazing Analysis: Summary of Effect on HVAC Operating Cost

	Existing Glazing			Proposed Glazing			
Overhang Depth	2.5	3	3.5	0	2.5	3	3.5
TRACE Results	$1,501,728	$1,494,852	$1,490,400	$1,512,576	$1,481,418	$1,478,640	$1,478,268
Decrease	-	0.45%	0.75%	-0.7%	1.35%	1.53%	1.56%
Vasari Results	$953,470	$952,430	$951,956	$888,241	$884,272	$883,823	$883,286
Decrease	-	0.11%	0.16%	6.84%	7.26%	7.30%	7.36%

Energy Savings (kWh)

Design Overhang	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% Savings
Actual Grand	135.01	112.46	118.70	107.26	123.12	117.71	117.71	123.17	113.72	127.98	128.93	125.25	1451.08	0.00%
New Grand	100.58	78.23	73.52	61.91	70.60	63.21	63.13	69.44	70.10	83.76	93.91	99.26	927.72	36.07%
3' Grand	97.35	75.36	70.71	60.18	68.73	62.67	62.82	67.96	67.78	81.56	91.47	96.10	902.75	37.79%
3.5' Grand	100.16	77.80	73.03	61.65	70.54	63.10	63.02	69.23	69.73	83.36	93.51	98.95	924.12	36.32%
4' Grand	96.29	74.55	70.08	59.68	68.31	62.60	62.78	67.51	67.09	80.87	90.47	95.06	895.33	38.30%
Actual Zone	49.61	38.20	37.02	33.01	37.73	36.03	36.03	37.78	35.75	42.59	47.24	47.28	478.33	0.00%
New Zone	60.40	43.29	35.08	26.96	30.42	24.77	24.69	29.25	33.41	43.58	55.47	62.57	469.95	1.75%
3' Zone	57.17	40.42	32.27	25.24	28.55	24.23	24.38	27.77	31.09	41.38	53.04	59.41	444.99	6.97%
3.5' Zone	59.97	42.86	34.59	26.70	30.35	24.66	24.58	29.05	33.04	43.17	55.07	62.26	466.36	2.50%
4' Zone	56.11	39.61	31.64	24.74	28.12	24.16	24.34	27.32	30.40	40.68	52.03	58.36	437.57	8.52%

Orientation Change Summary

Design Overhang	MS South kWh from Table X	Mat. Science North		Life Science East		Life Science West	
		Total kWh	% of MS South	Total kWh	% of MS South	Total kWh	% of MS South
Actual Grand Total	1451.08	1446.46	99.68%	1457.40	100.44%	1447.28	99.74%
Actual Zone Total	478.33	473.70	99.03%	484.65	101.32%	474.53	99.21%

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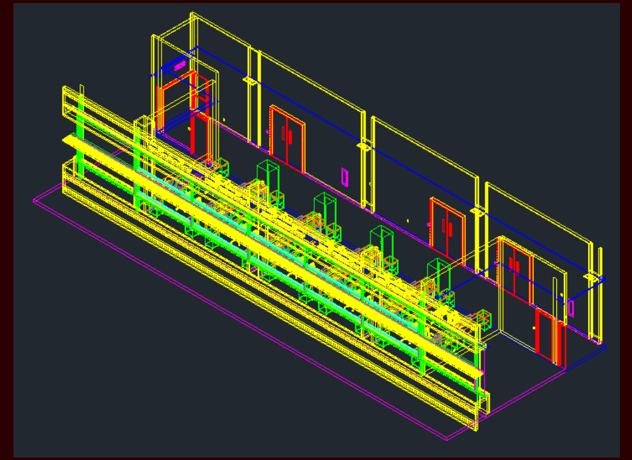
Impact on Lighting Design

StudentExport.rvt

Export parameter change to "ACIS Solids"



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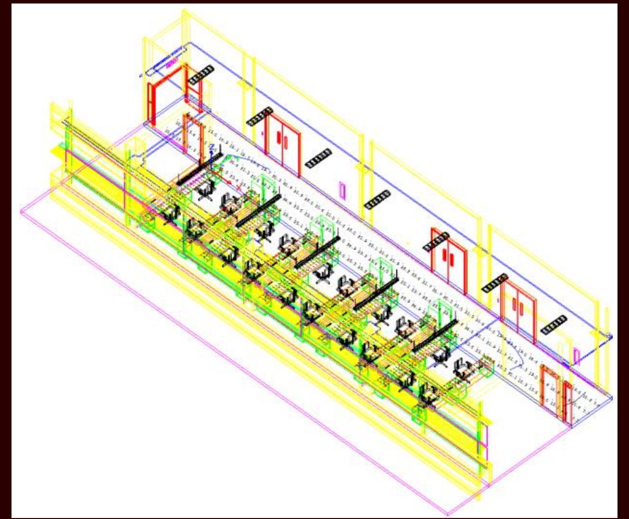
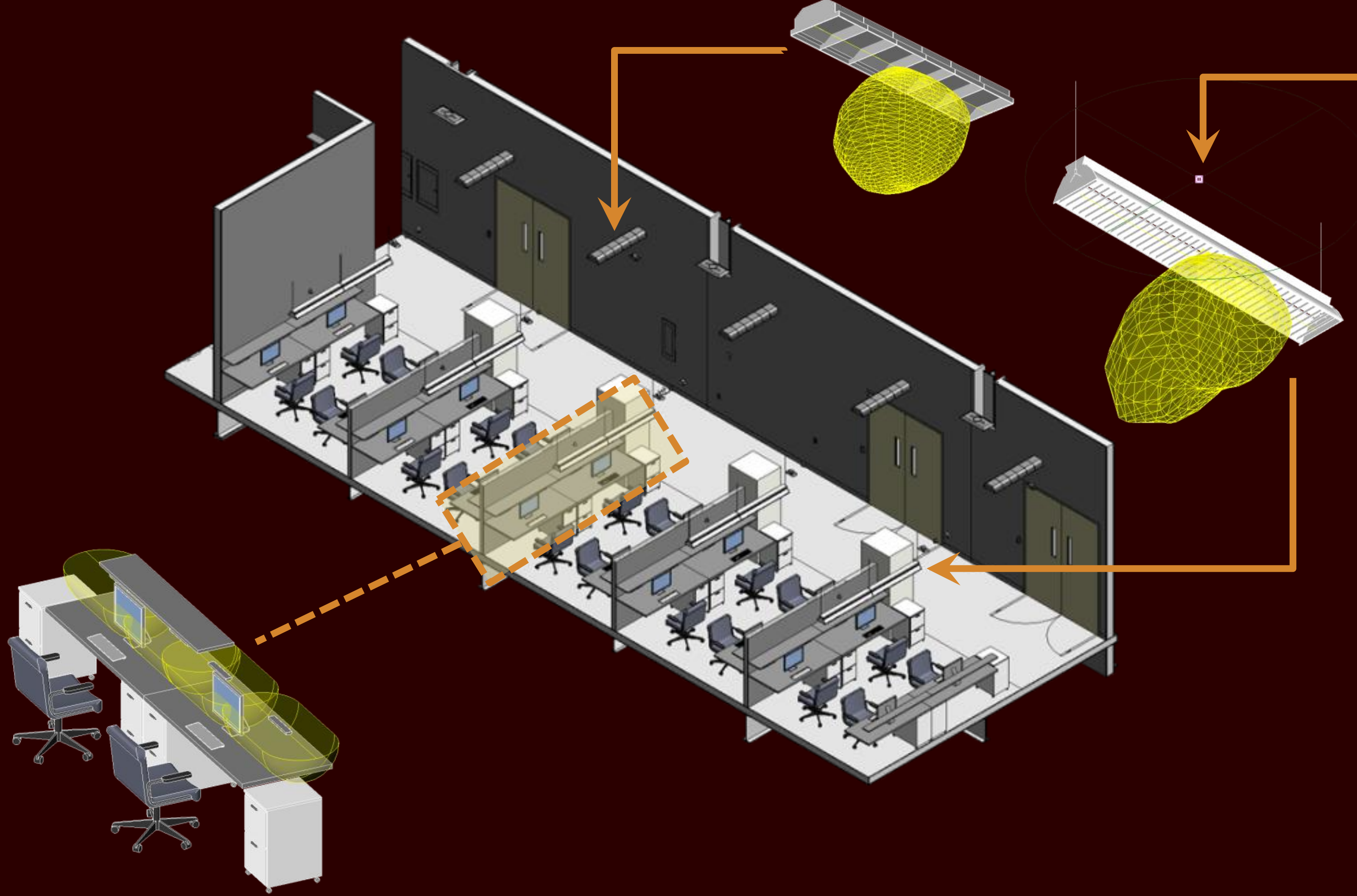
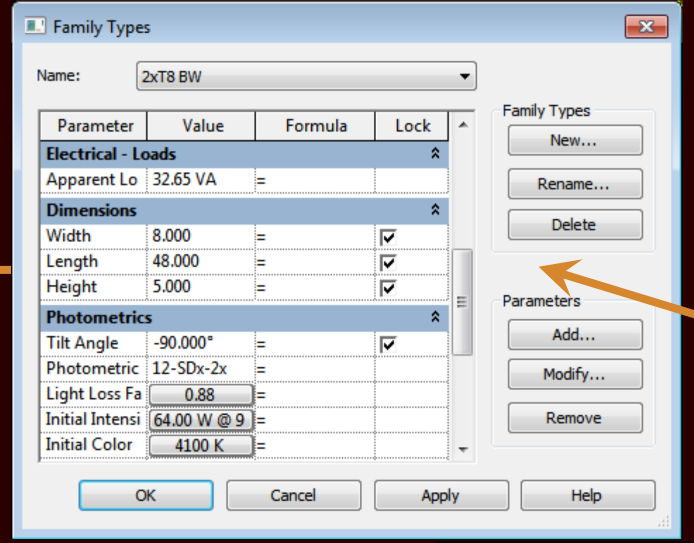
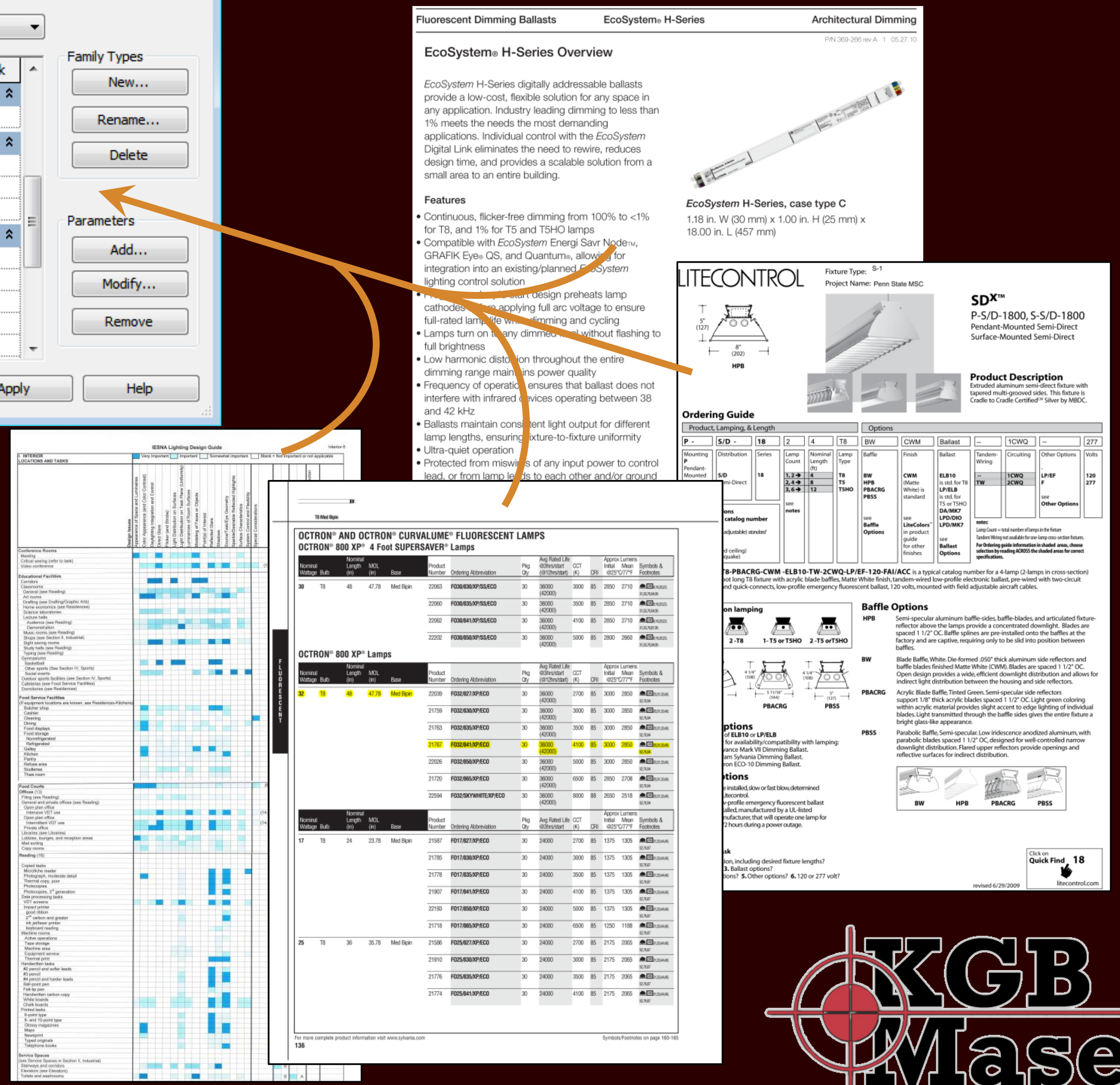


StudentExport.AGI

Import to AGI32 where material properties are assigned

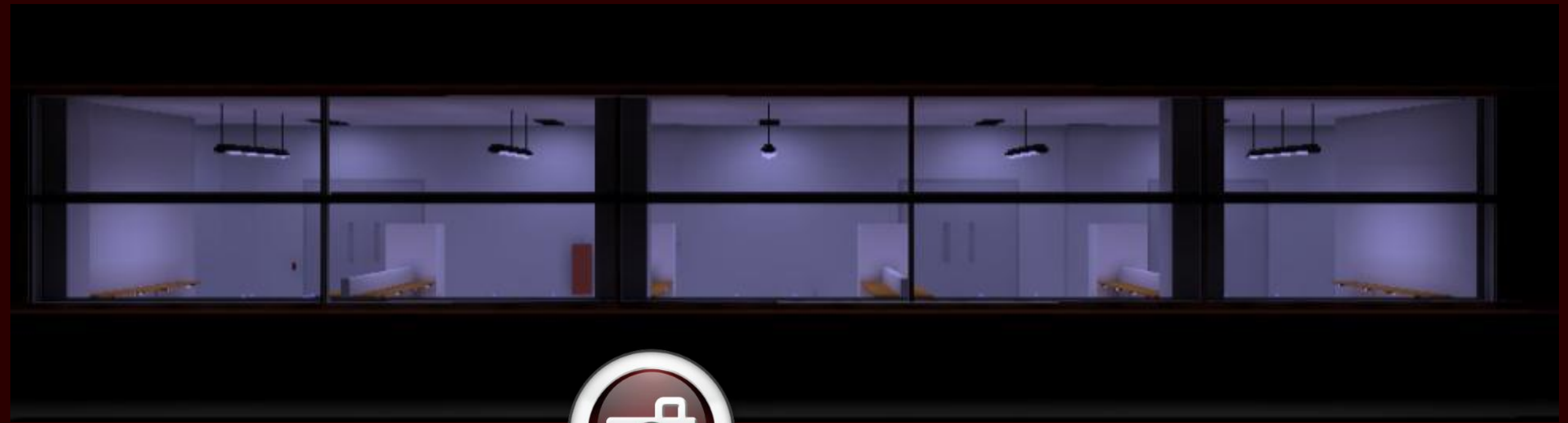






Impact on Lighting Design

Study Area Illuminance Summary						
Space	Illuminance (fc)			Max./Min.	Coeff. Of Variation	Uniformity Gradient
	Min.	Avg.	Max.			
Study Area Only	9.0	36.5	106.0*	11.73	0.47	2.47
Corridor Only	4.5	9.36	10.8	2.40	0.15	1.31
Student Area Combined	15.0	34.3	55.0	3.67	0.27	1.42
Corridor Combined	7.3	20.0	25.3	3.47	0.23	1.38



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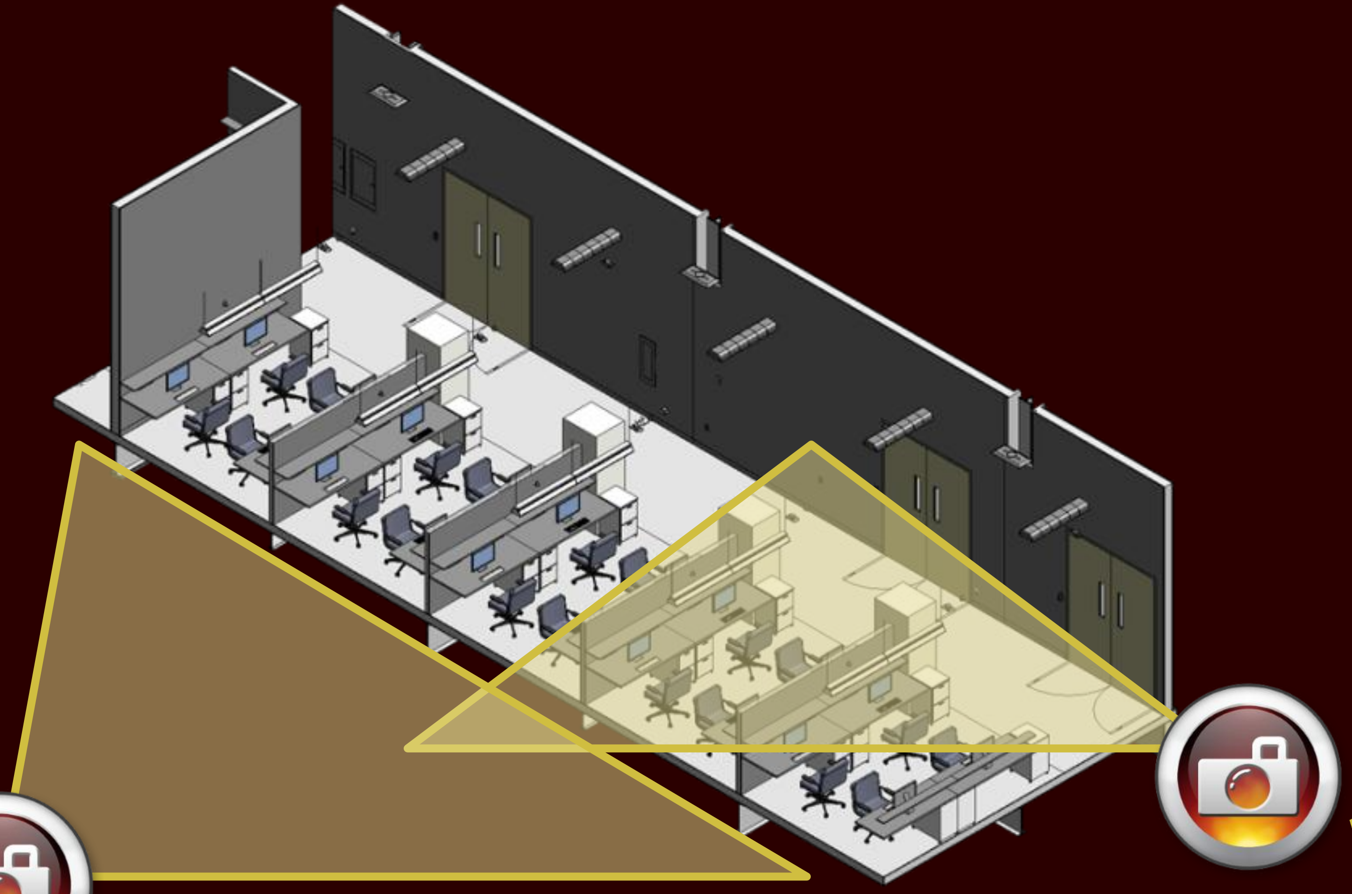

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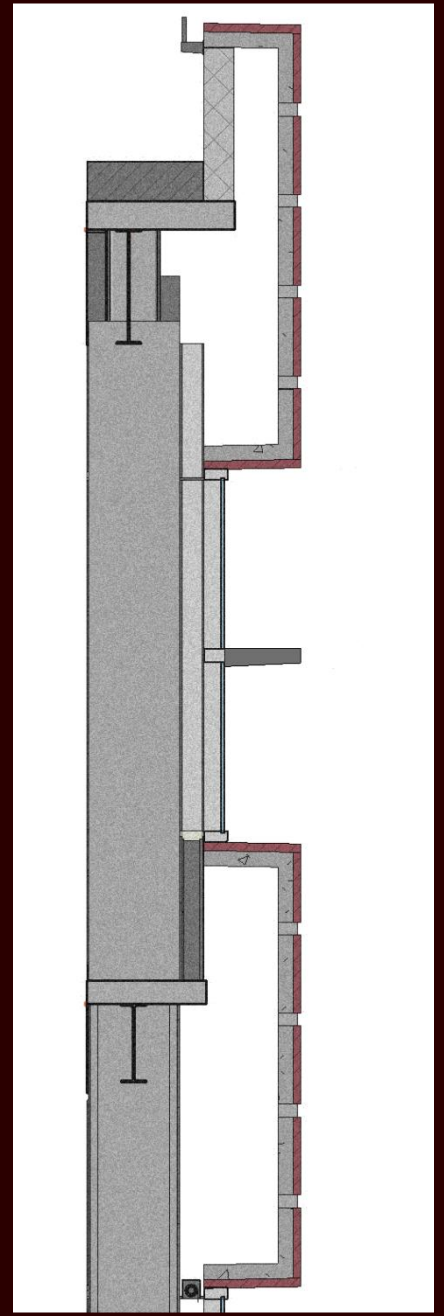


Panel Depth Assessment

Existing Conditions

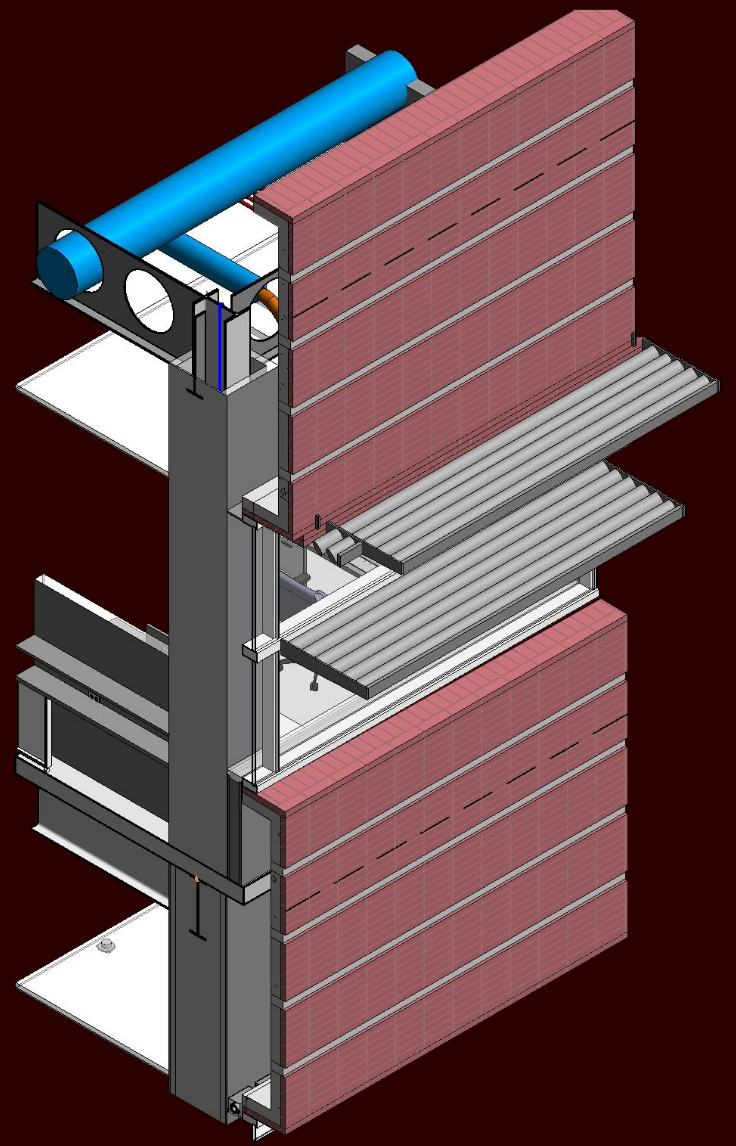
- 27.6" Deep
- 6" Thick Concrete at Face
- 2" Facebrick
- Largest Panel 21ft. Wide by 11ft. Tall

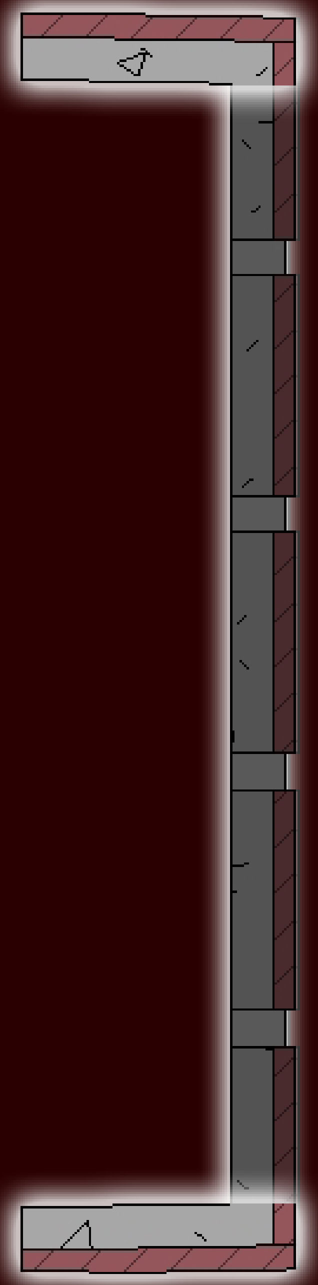
Gravity Controlled Design

- Prone Position Causes Greatest Stress
- 2 Bearing Connections at Either End
- 2 Lateral Connections at Either End

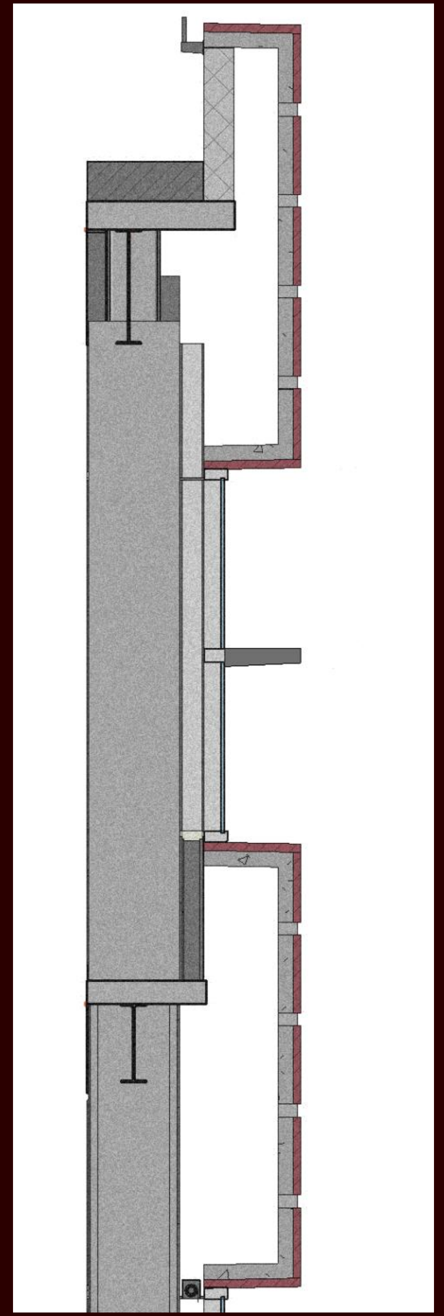
	Cracking Stress	
(factored)	477.2971	psi

Self Weight Check Prone			
Weight/in.	8.53125	lb./in.	(factored)
Inertia of Strip	76.765625	in.4	
Moment	16695.94	lb.in.	
Stress	462.17134	psi.	OK





Panel Depth Assessment



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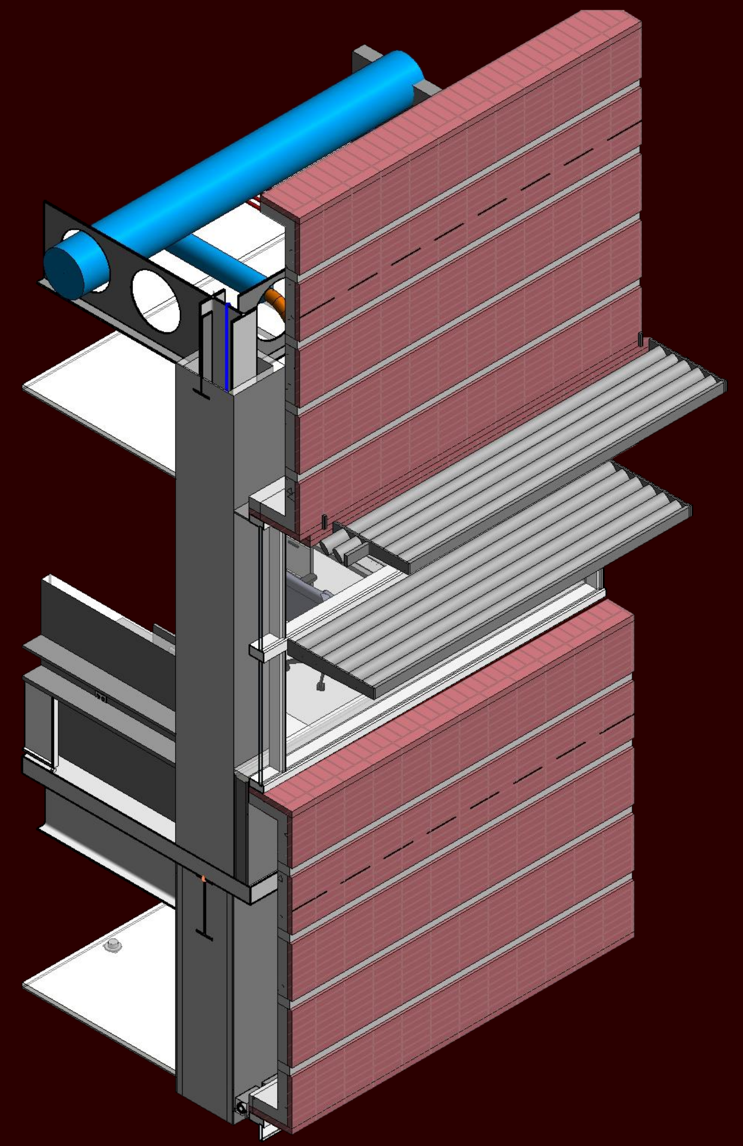
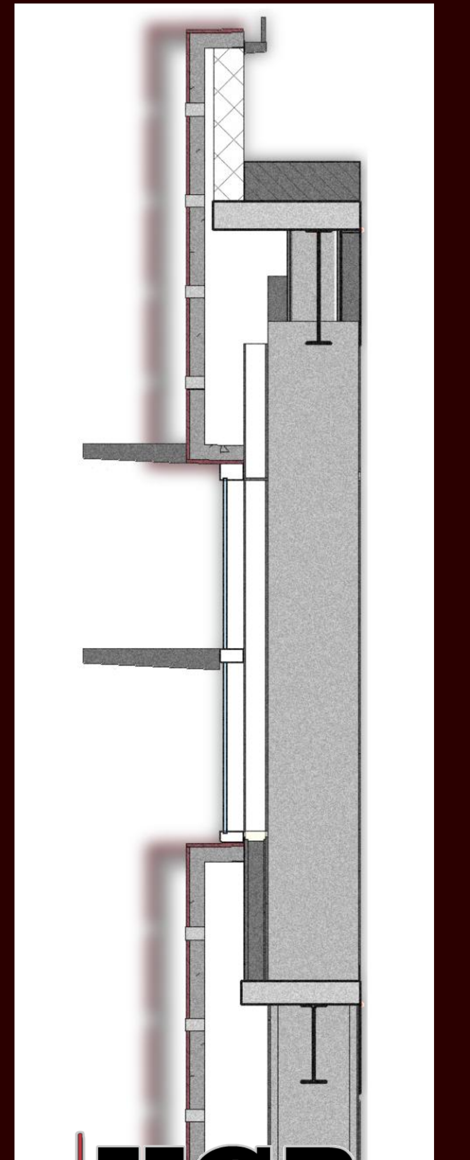
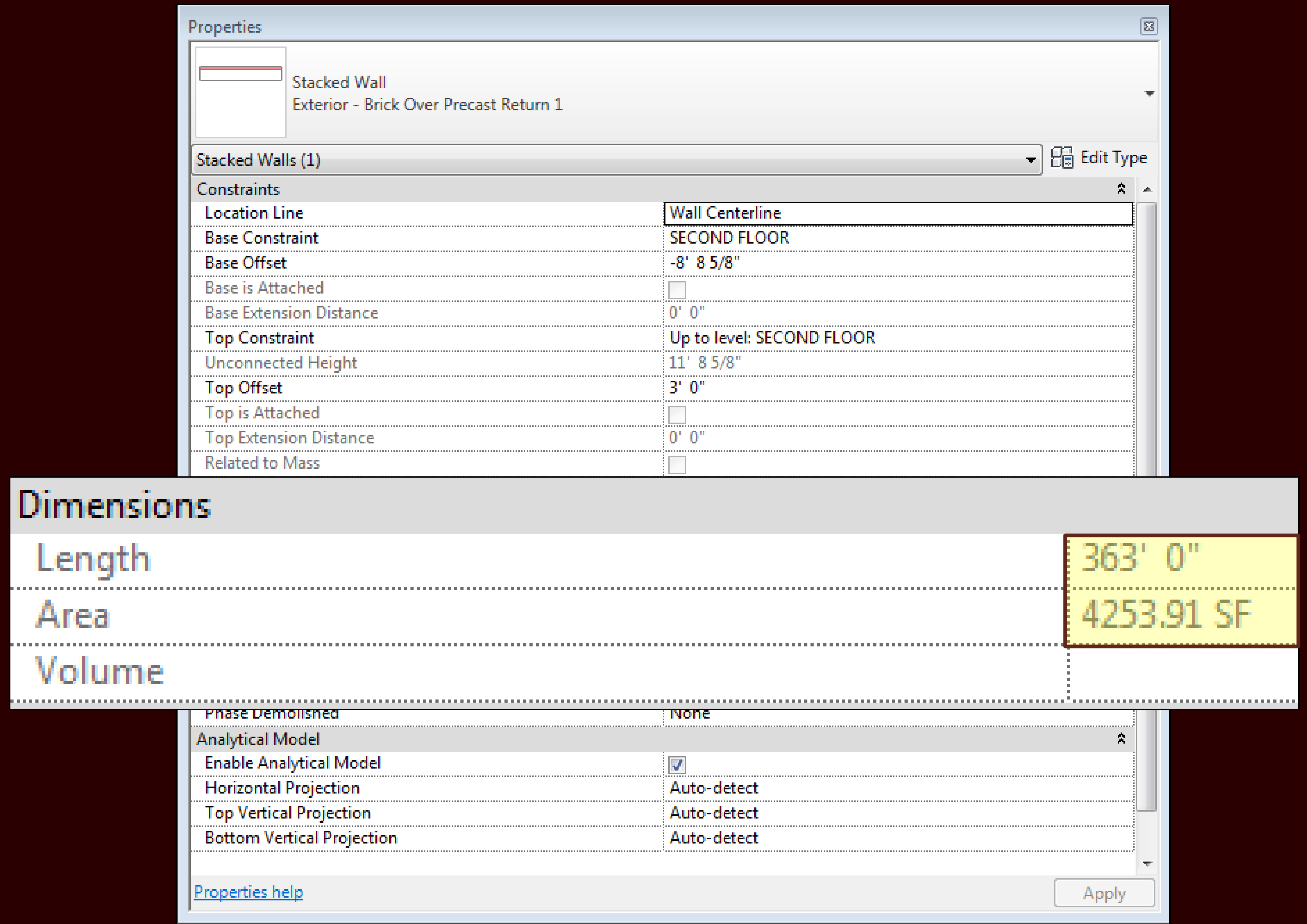


Redesign
- 15.75″ Deep
- 5″ Thick Concrete at Face
- 1/2″ Facebrick
- Largest Panel 21ft. Wide by 11ft. Tall

Wind Controlled Design
- Prone Position Causes Greatest Stress
- 2 Corbel Connections at Either End
- 2 Lateral Connections at Either End

Required Steel		
Vu.max=	189	k.
As.req=	0.44	in.2
μe=	3.4	
As.req=	0.32	in.2
As.min=	0.77	in.2
As=	0.77	in.2
Ah=	0.30	in.2
Ldh=	8.91	in.





Cost Assessment

Existing Pre-Cast							
Total (SF)	Material	Labor	Equipment	Total	Cost	Time	O & P
72319.11	27.3	1.74	1.63	30.67	$2,218,027	$2,816,894	$3,295,766
		TOTAL COST =		$3,295,766.47			
Redesign Pre-Cast							
Total (SF)	Material	Labor	Equipment	Total	Cost	Time	O & P
72319.11	25.03	1.74	1.63	28.4	$2,053,862	$2,608,405	$3,051,834
		TOTAL COST =		$3,051,834.62			

Cost Savings = $240,000

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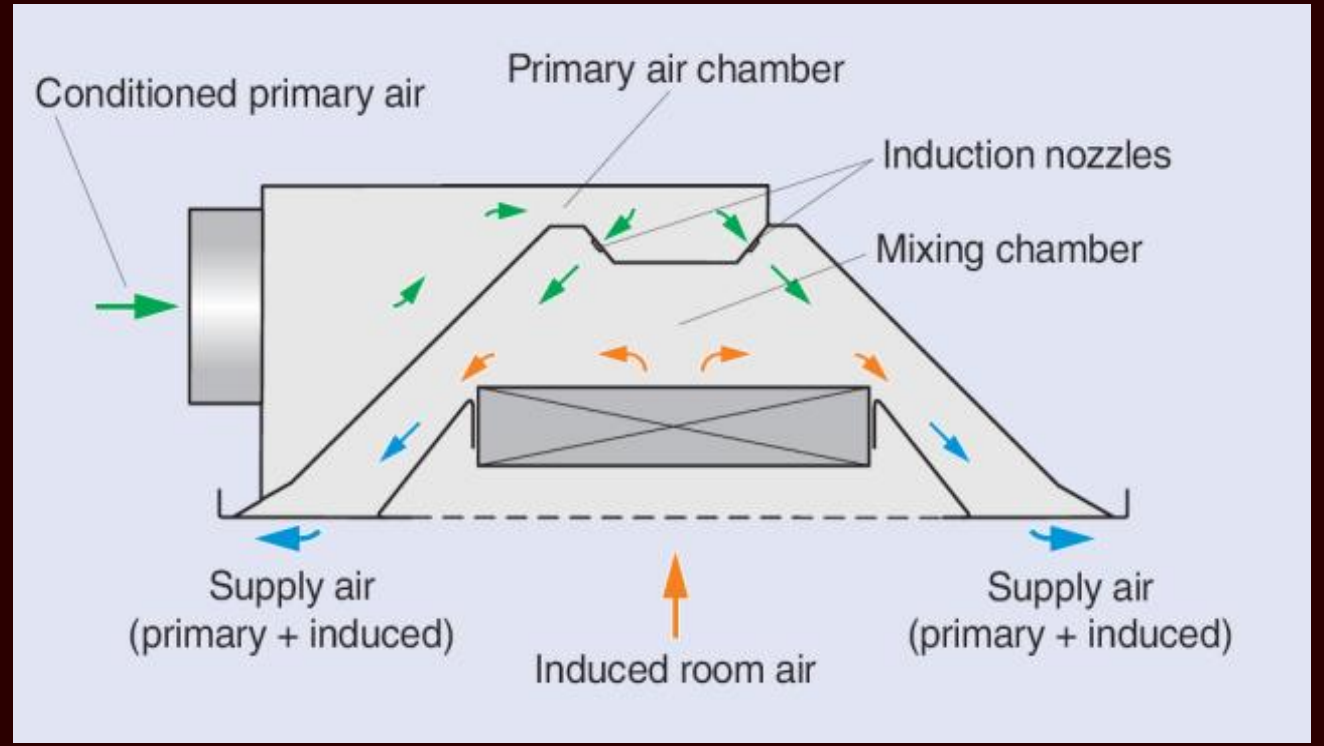
Existing vs. Proposed Distribution

Existing VAV Distribution System

Energy efficient design that can be **easily controlled** to space airflow needs

Familiar system for designers and contractors

Less pumping energy required



Proposed Active Chilled Beam Distribution System

Takes advantage of the higher **specific heat capacity of water**

More concern for handling **latent** loads

Higher **initial cost**

Fan energy saved, pumping energy increased

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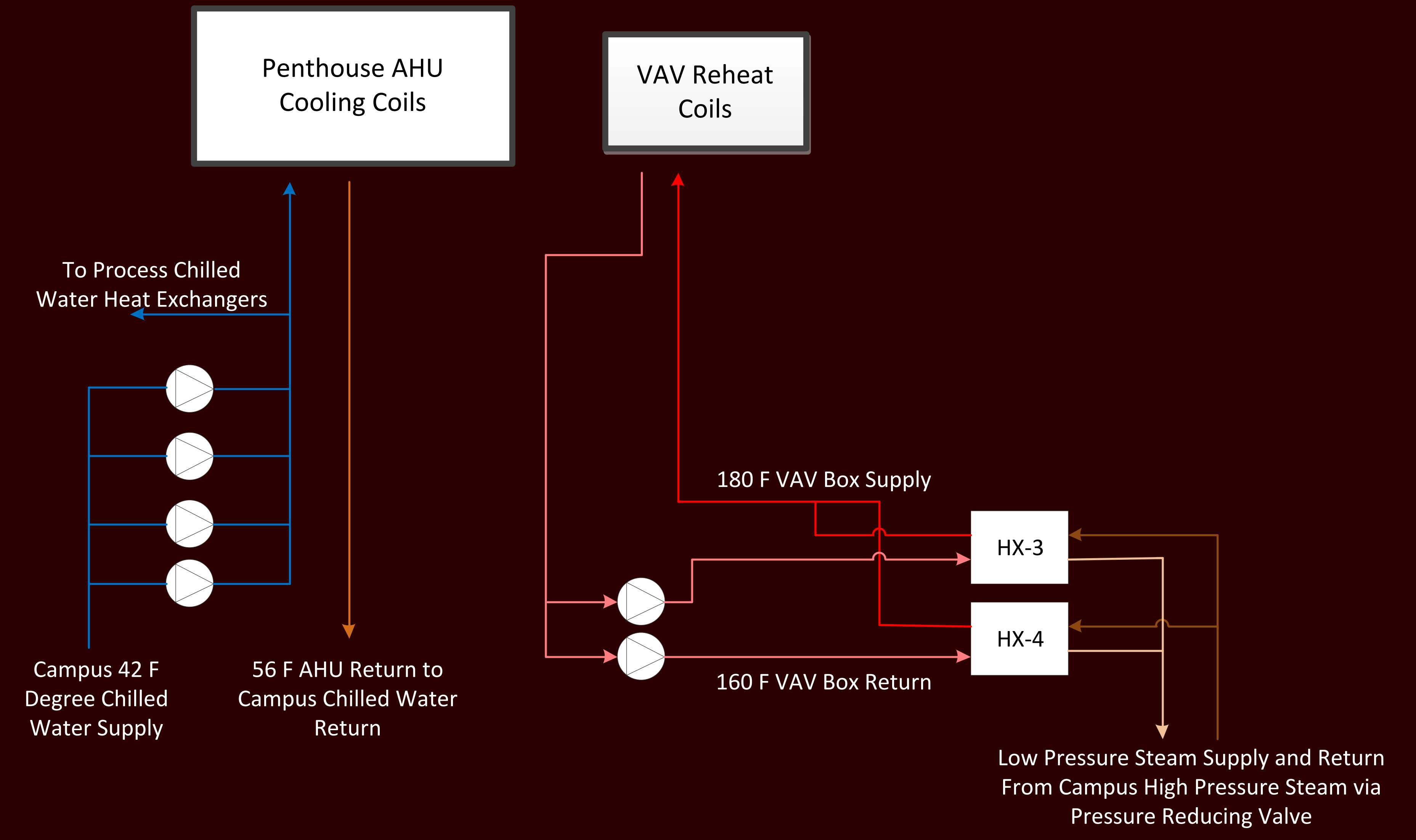
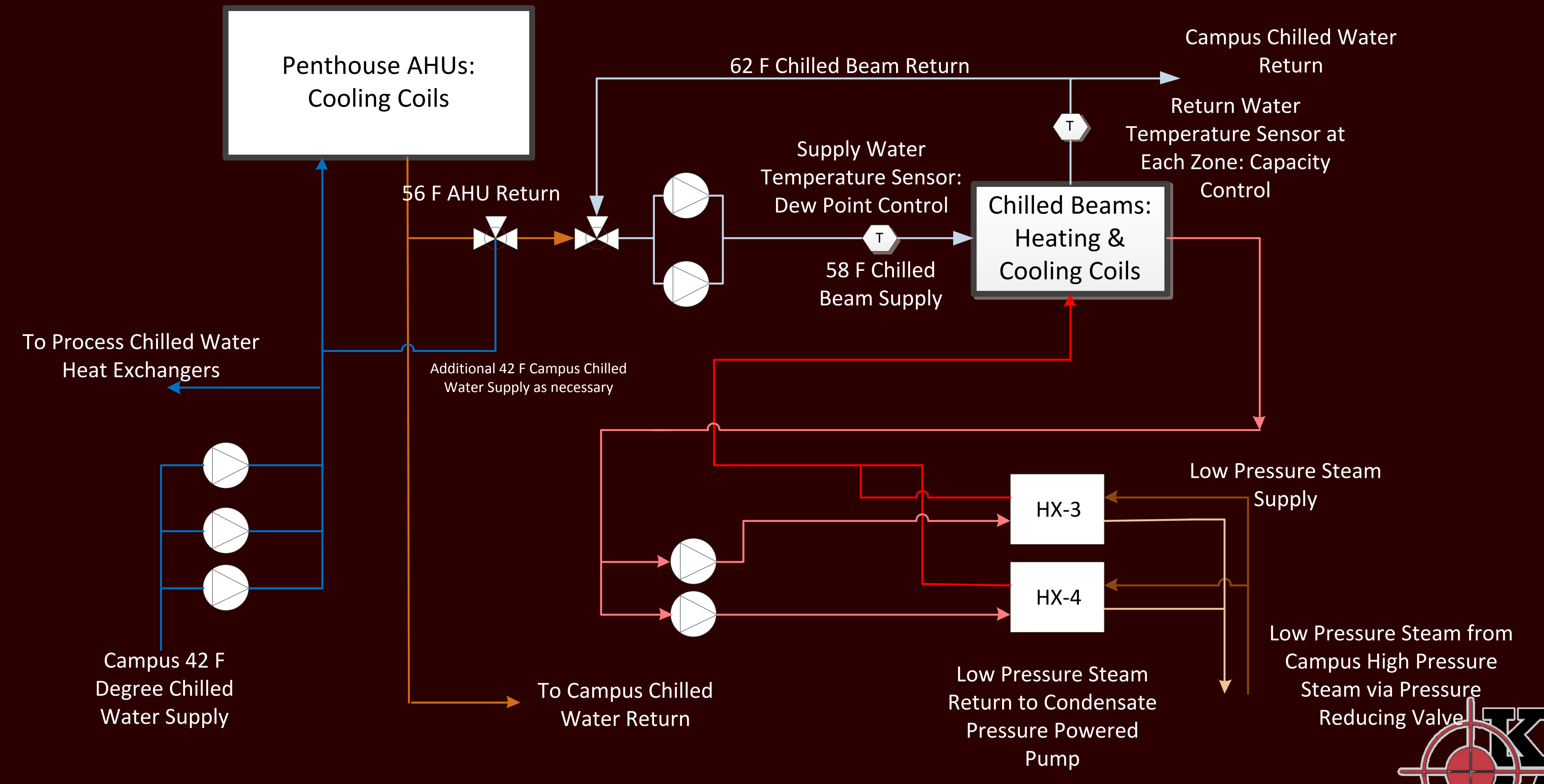
Existing vs. Proposed Distribution

Existing VAV Water Flow Diagram

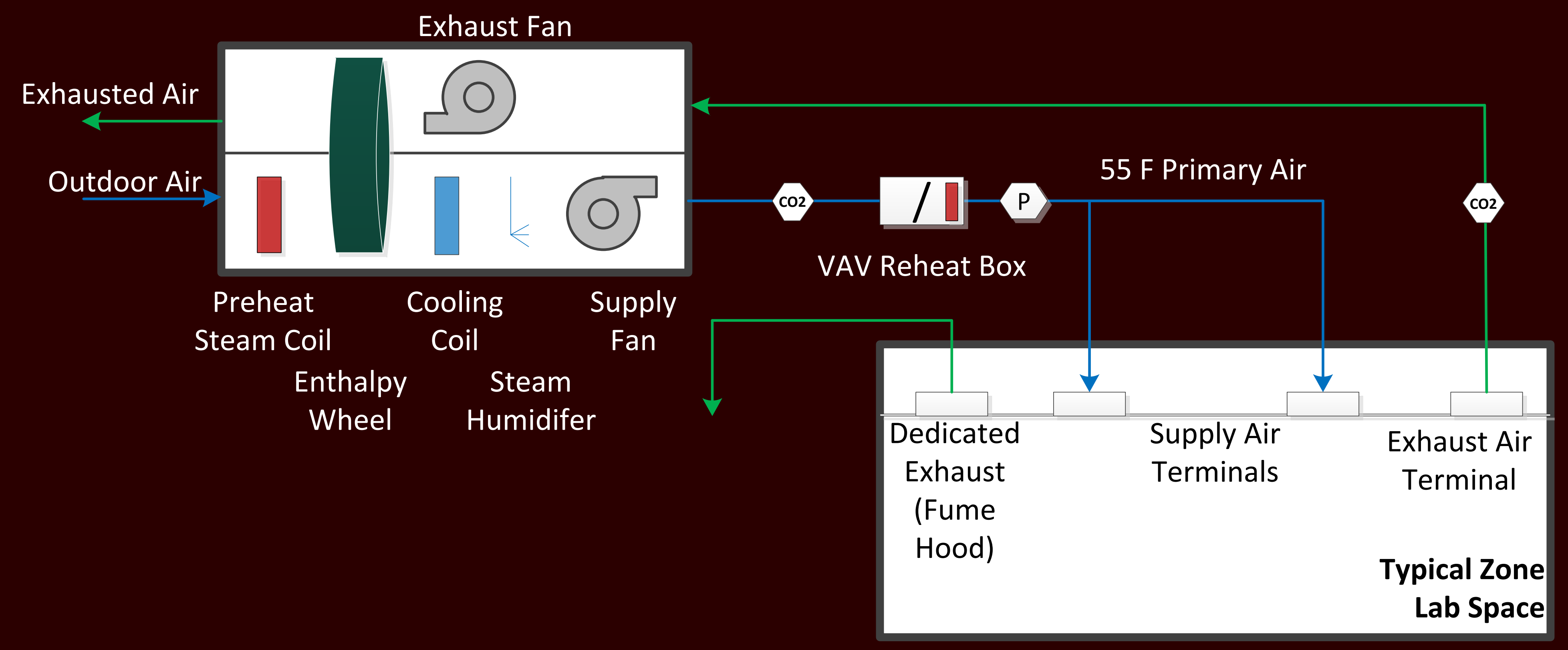


Proposed Chilled Beam Water Flow Diagram

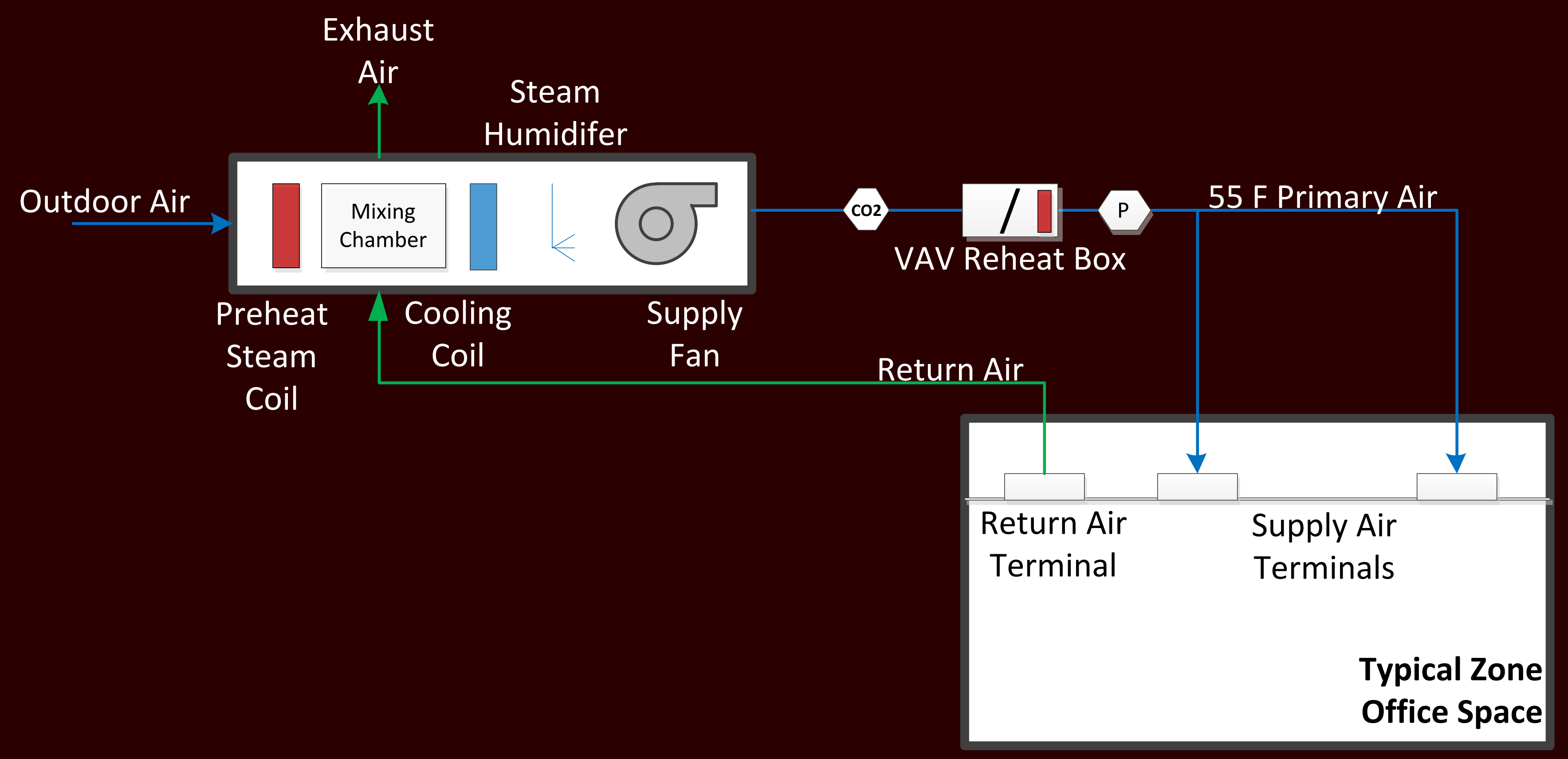


Existing vs. Proposed Distribution

Existing Lab VAV Air Flow Diagram

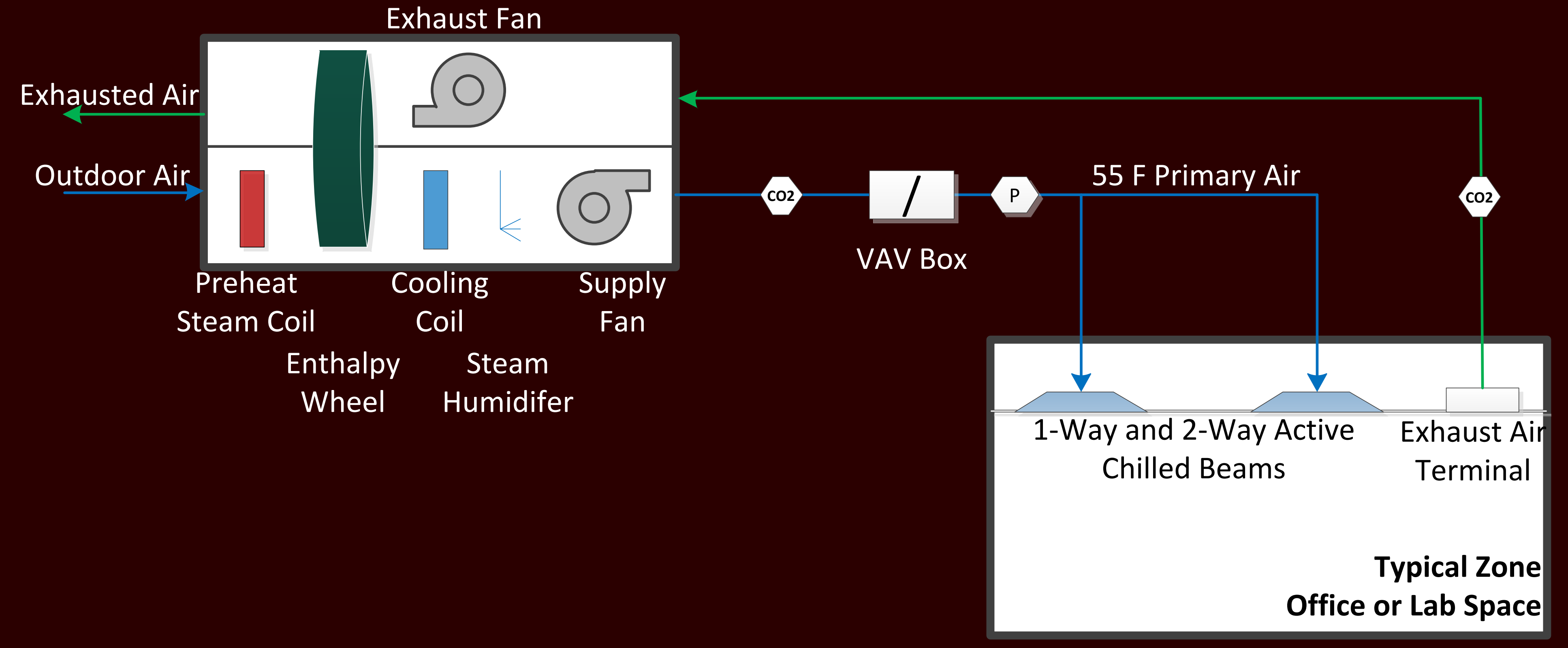


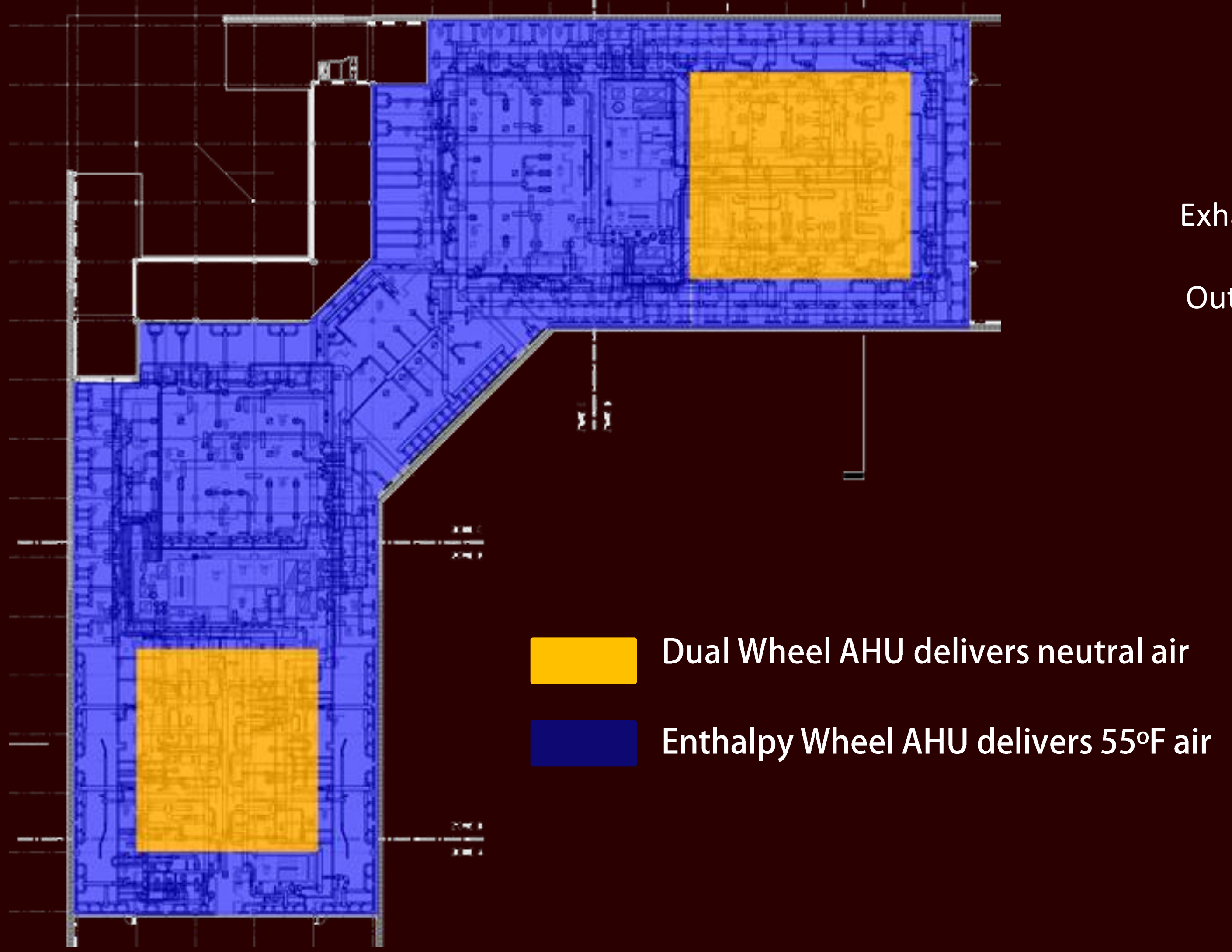
Existing Office VAV Air Flow Diagram



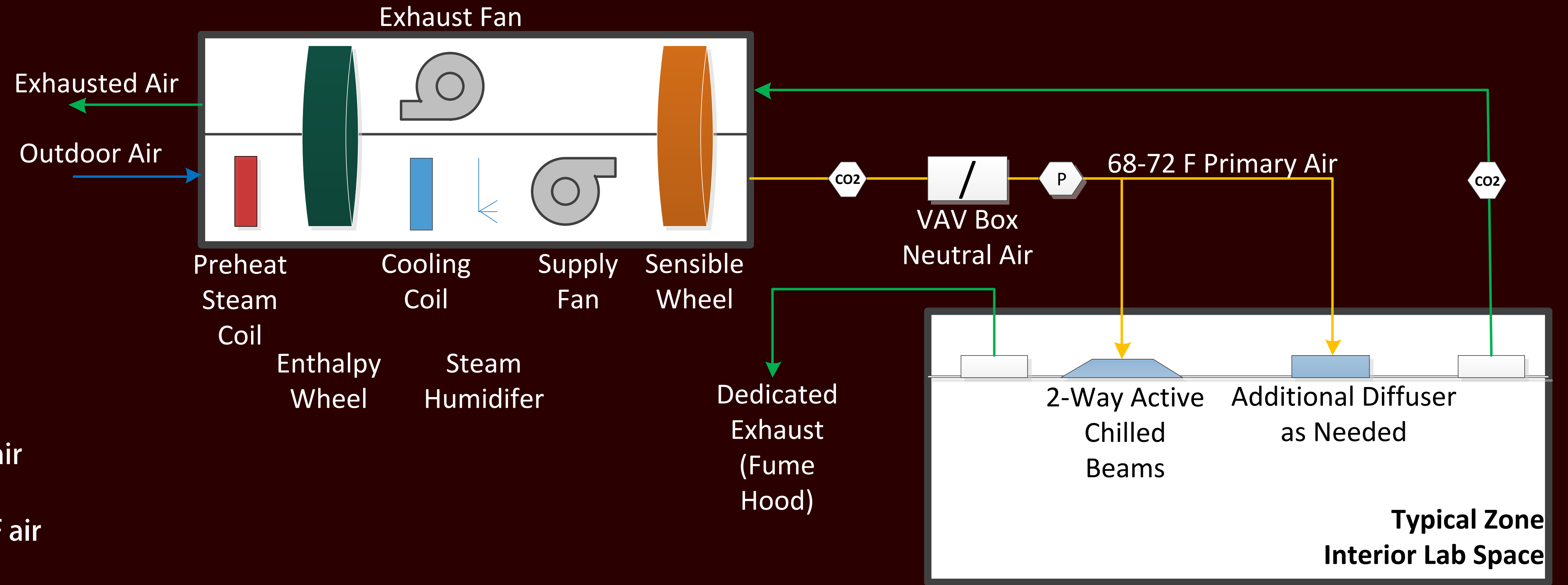
Existing vs. Proposed Distribution

Perimeter Zone Chilled Beam Air Flow Diagram





Interior Lab Chilled Beam Air Flow Diagram



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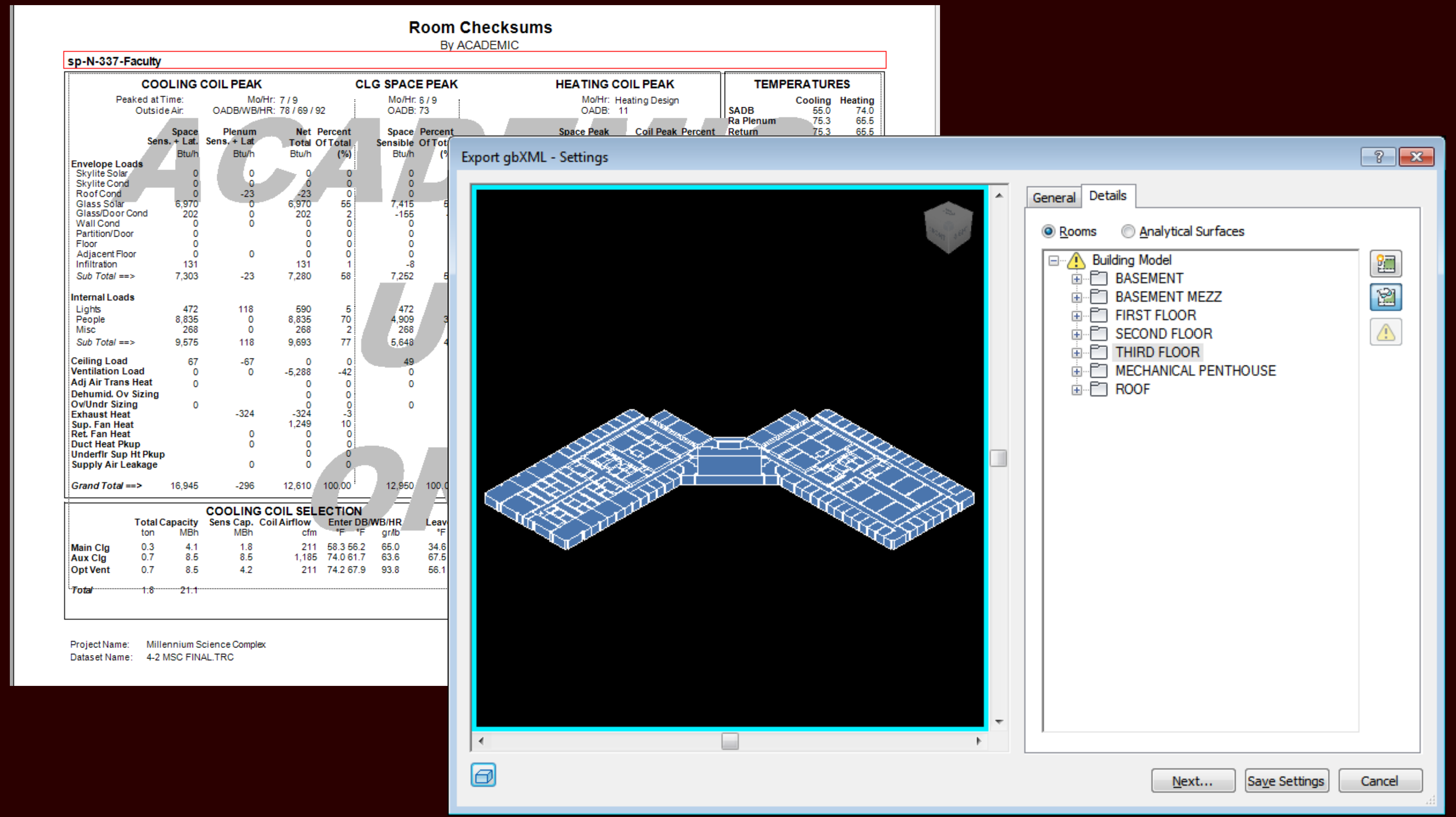
Active Chilled Beam Design Process

1. Obtain room loads from Trane TRACE updated model



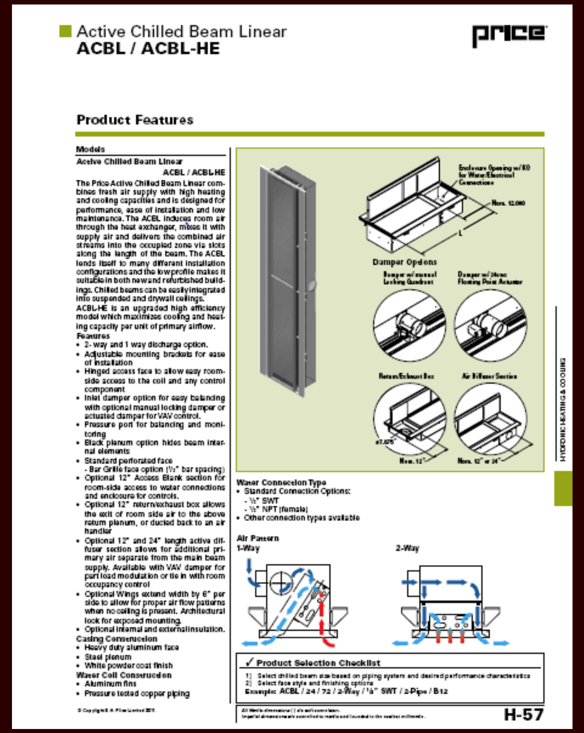
2. Compare ventilation needs: ASHRAE 62.1, Latent, Air Changes

$$Office: 0.06 * SF + 5 * People$$
$$Labs: 0.18 * SF + 10 * People$$

$$Q_{Latent\,CFM} = \frac{q_{latent}}{(0.68\ x\ (W_{room} - W_{Primary}))}$$

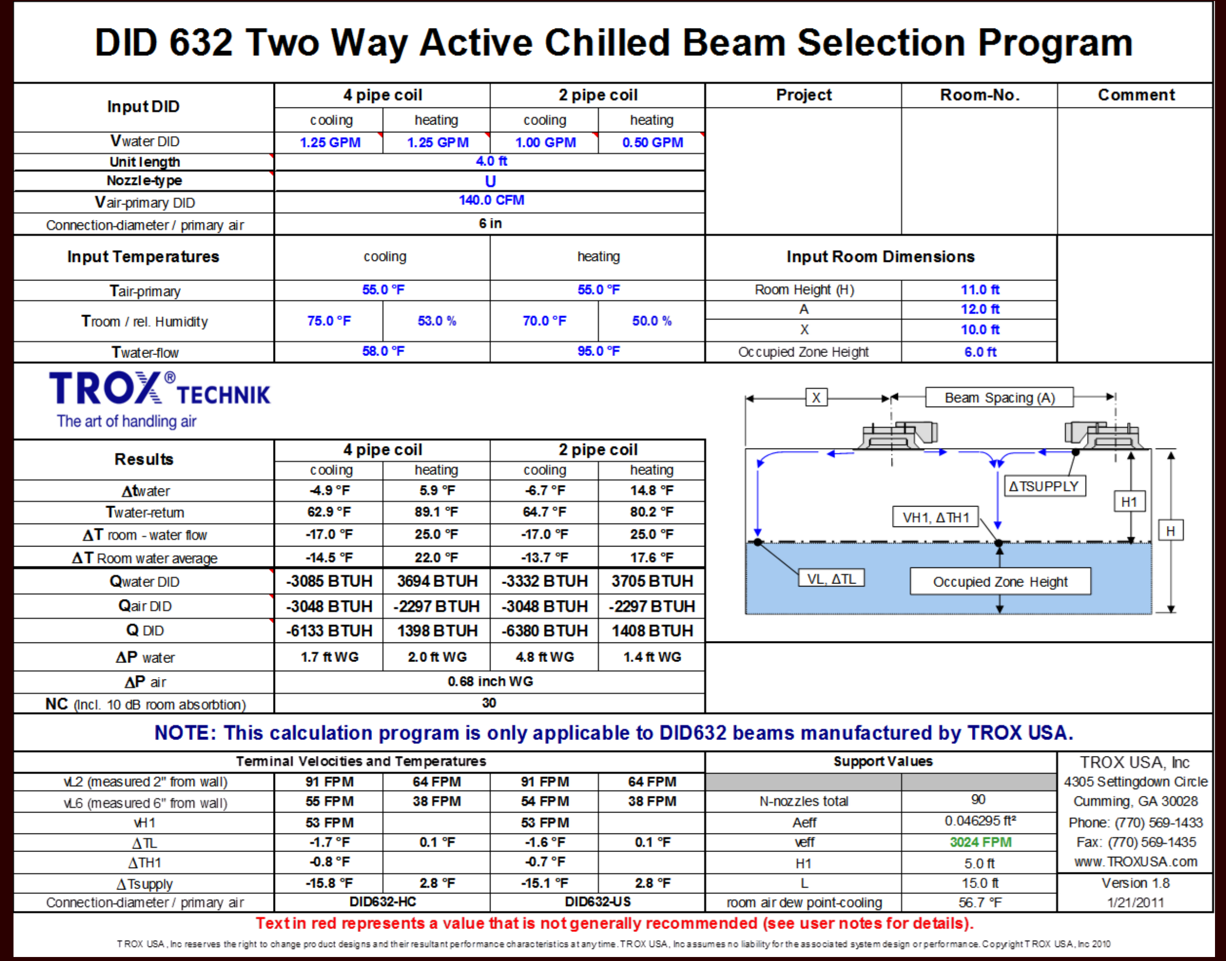
6 Air Change Minimum for Lab Spaces

3. Select Chilled Beam Manufacturer



Active Chilled Beam Design Process

4. Reference RCP & Manufacturer Selection Spacing Program



DID 632 Two Way Active Chilled Beam Selection Program

Input DID	4 pipe coil		2 pipe coil		Project	Room-No.	Comment
	cooling	heating	cooling	heating			
Vwater DID	1.25 GPM	1.25 GPM	1.00 GPM	0.50 GPM			
Unit length	4.0 ft						
Nozzle-type	U						
Vair-primary DID	140.0 CFM						
Connection-diameter / primary air	6 in						

Input Temperatures	cooling		heating		Input Room Dimensions	
Tair-primary	55.0 °F		55.0 °F		Room Height (H)	11.0 ft
Troom / rel. Humidity	75.0 °F	53.0 %	70.0 °F	50.0 %	A	12.0 ft
					X	10.0 ft
Twater-flow	58.0 °F		95.0 °F		Occupied Zone Height	6.0 ft

TROX® TECHNIK
The art of handling air

Results	4 pipe coil		2 pipe coil	
	cooling	heating	cooling	heating
Δtwater	-4.9 °F	5.9 °F	-6.7 °F	14.8 °F
Twater-return	62.9 °F	89.1 °F	64.7 °F	80.2 °F
ΔT room - water flow	-17.0 °F	25.0 °F	-17.0 °F	25.0 °F
ΔT Room water average	-14.5 °F	22.0 °F	-13.7 °F	17.6 °F
Qwater DID	-3085 BTUH	3694 BTUH	-3332 BTUH	3705 BTUH
Qair DID	-3048 BTUH	-2297 BTUH	-3048 BTUH	-2297 BTUH
Q DID	-6133 BTUH	1398 BTUH	-6380 BTUH	1408 BTUH
ΔP water	1.7 ft WG	2.0 ft WG	4.8 ft WG	1.4 ft WG
ΔP air	0.68 inch WG			
NC (Incl. 10 dB room absorbtion)	30			

X
Beam Spacing (A)
ΔTSUPPLY
VH1, ΔTH1
H1
H
VL, ΔTL
Occupied Zone Height

NOTE: This calculation program is only applicable to DID632 beams manufactured by TROX USA.

Terminal Velocities and Temperatures					Support Values	
vL2 (measured 2" from wall)	91 FPM	64 FPM	91 FPM	64 FPM		
vL6 (measured 6" from wall)	55 FPM	38 FPM	54 FPM	38 FPM	N-nozzles total	90
vH1	53 FPM		53 FPM		Aeff	0.046295 ft²
ΔTL	-1.7 °F	0.1 °F	-1.6 °F	0.1 °F	veff	3024 FPM
ΔTH1	-0.8 °F		-0.7 °F		H1	5.0 ft
ΔTsupply	-15.8 °F	2.8 °F	-15.1 °F	2.8 °F	L	15.0 ft
Connection-diameter / primary air	DID632-HC		DID632-US		room air dew point-cooling	56.7 °F

TROX USA, Inc
4305 Settingdown Circle
Cumming, GA 30028
Phone: (770) 569-1433
Fax: (770) 569-1435
www.TROXUSA.com
Version 1.8
1/21/2011

Text in red represents a value that is not generally recommended (see user notes for details).

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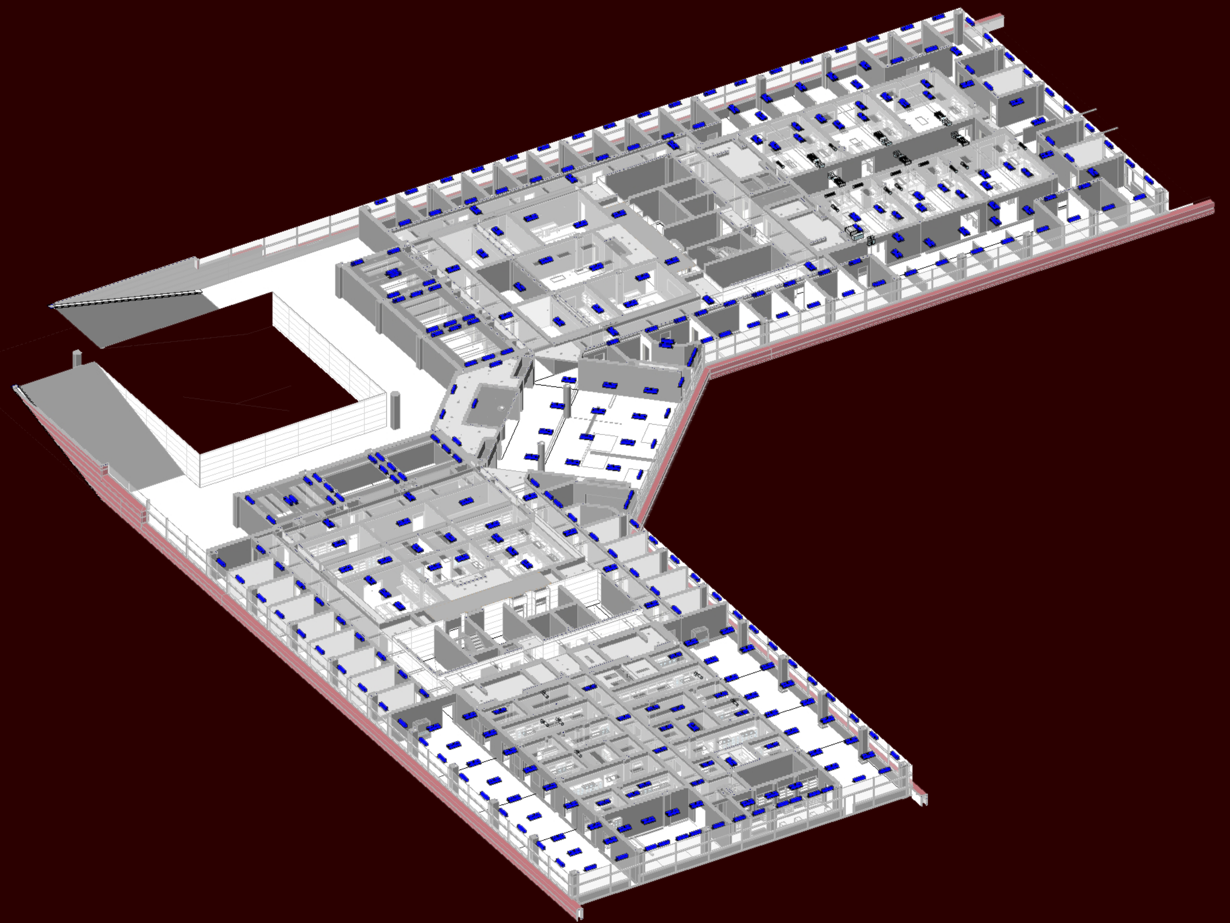
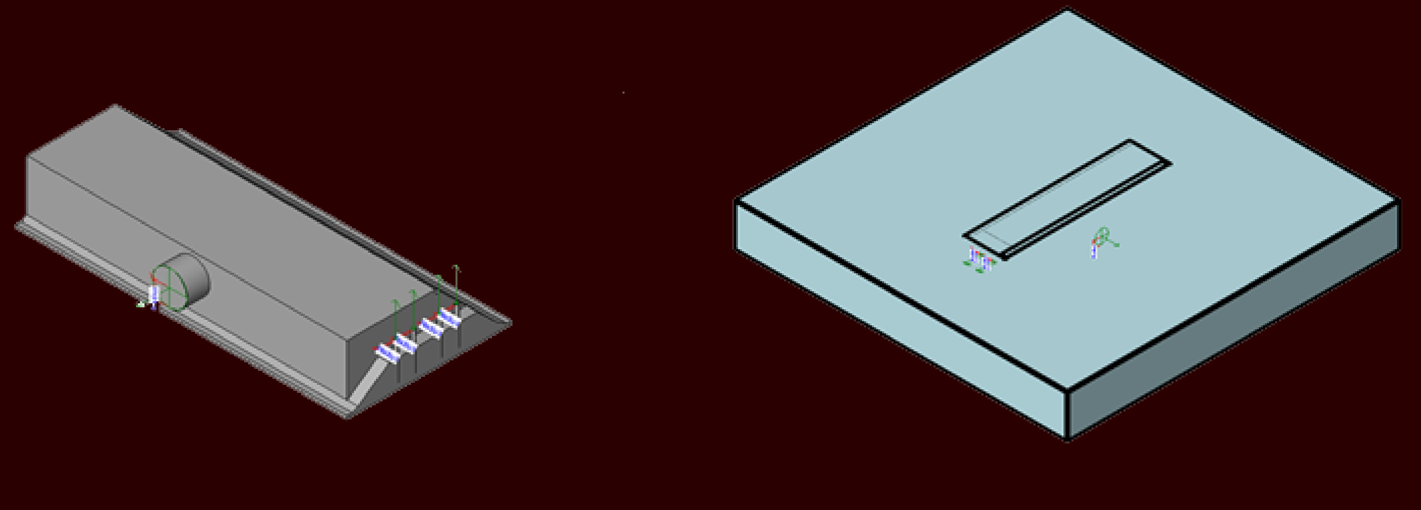
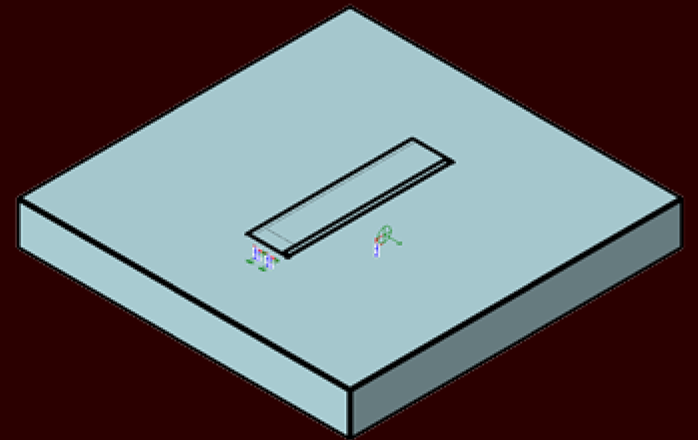
5. Use RCP to place beams in space in Revit MEP model

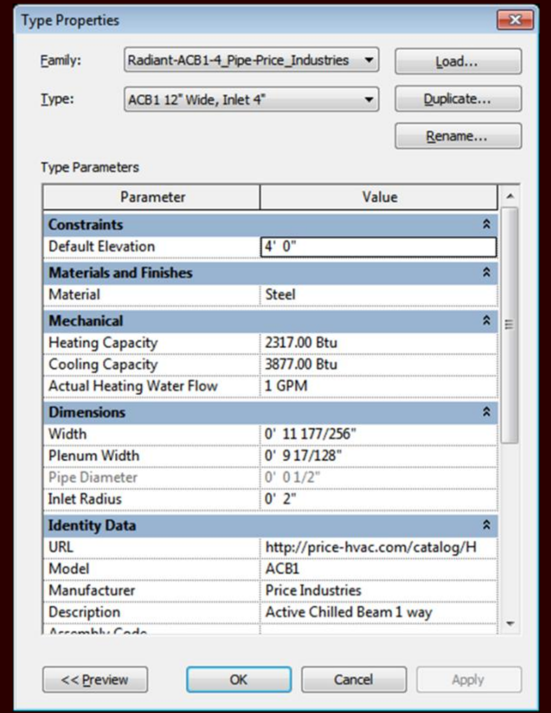


6. Adjust Chilled Beam Families in Revit



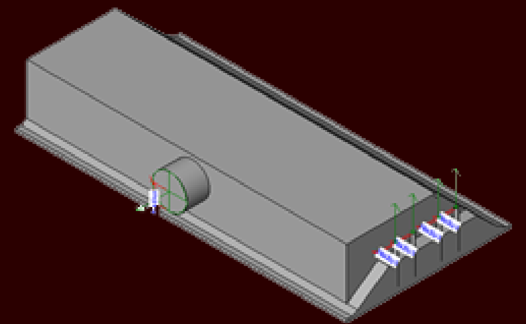
Active Chilled Beam Design Process

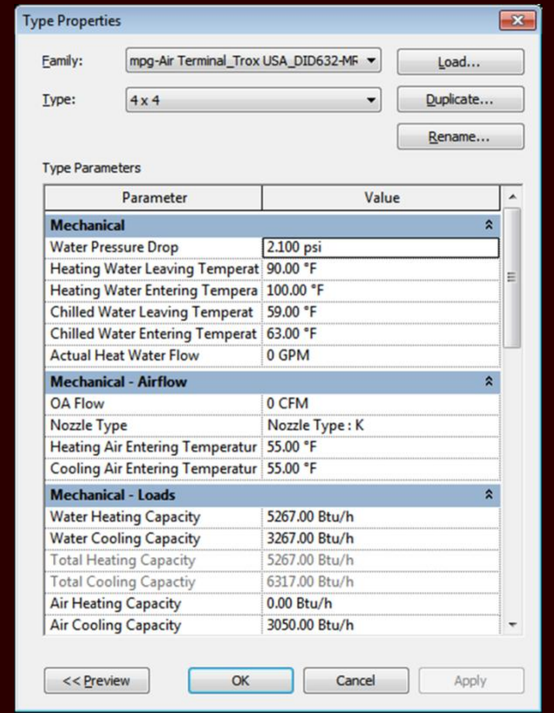




Summary of TROX Chilled Beam Adjustments		
Parameter	Downloaded Setting	Adjusted Setting
Flow Configuration	Calculated	Preset
Flow Direction	In	In
Family	Air Terminal	Mechanical Equipment
Location of Inlet	Side	Top (Cost Option)
Air Flow	Instance: Keeps CFM constant for the same family	Type: Allows different CFM for same family

6. Adjust Chilled Beam Families in Revit





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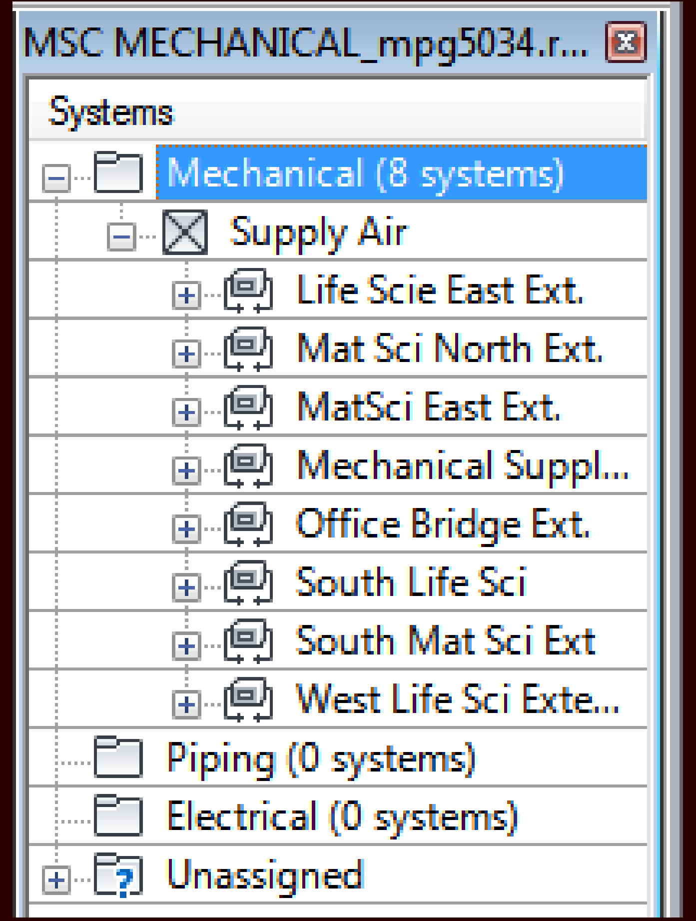
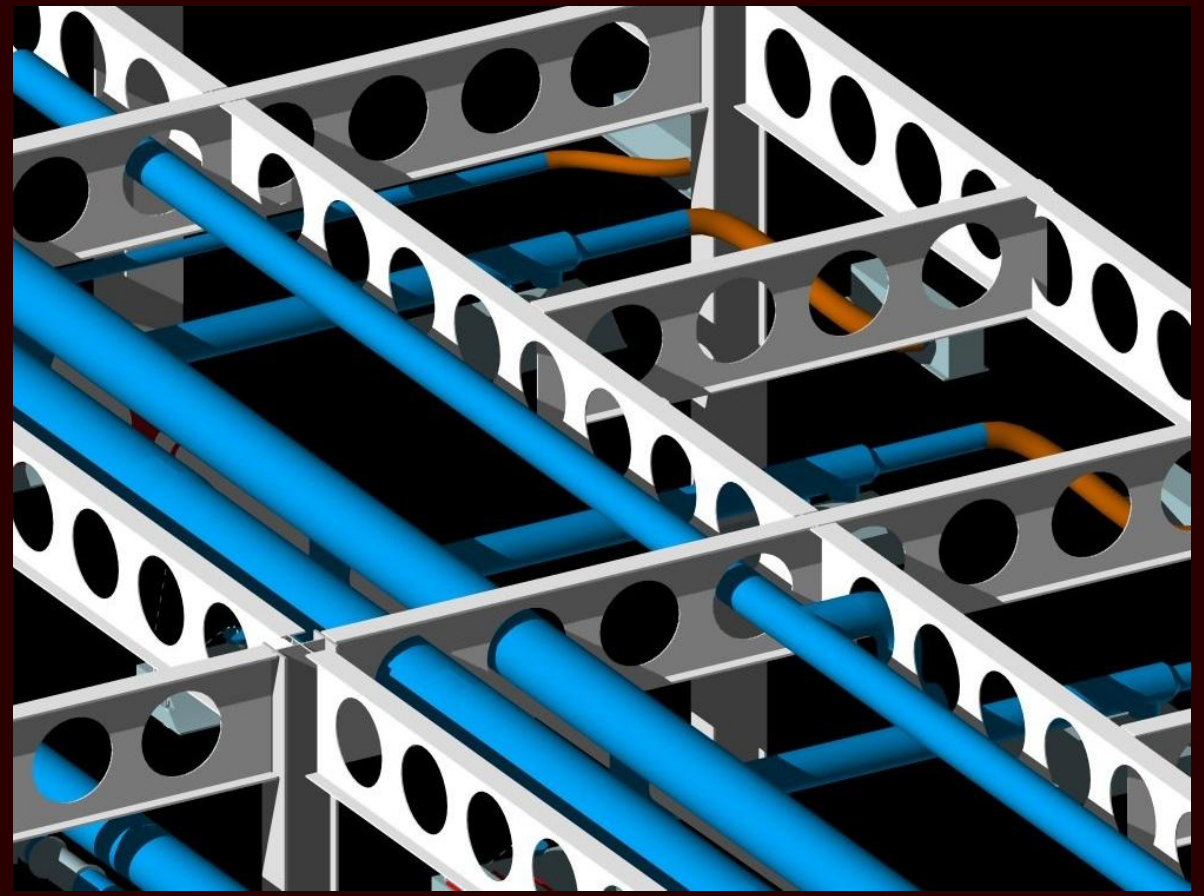
Active Chilled Beam Design Process

7. Create Systems so Revit can calculate Duct, Pipe Sizes

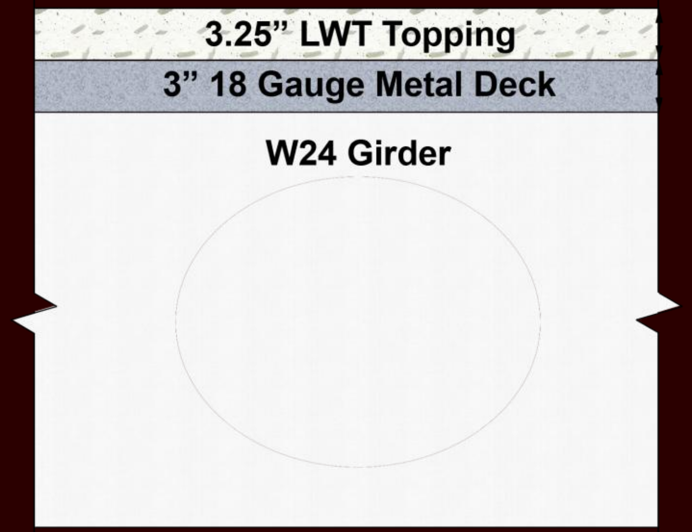


8. Place main duct runs in cellular openings

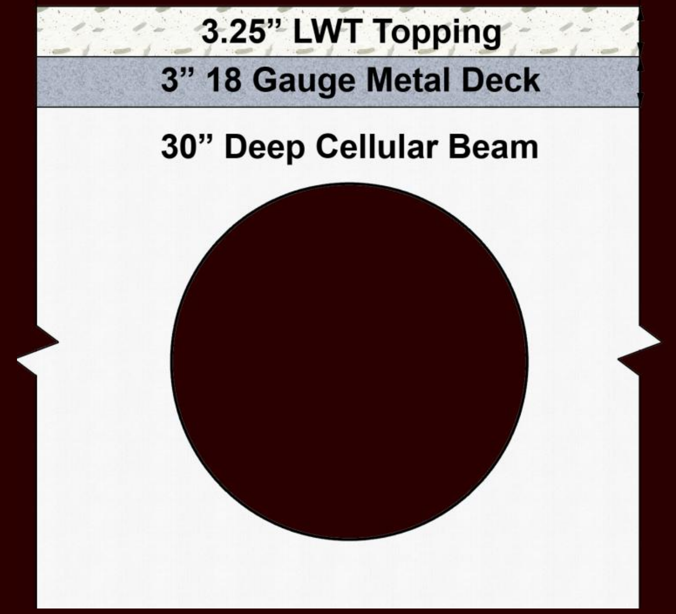


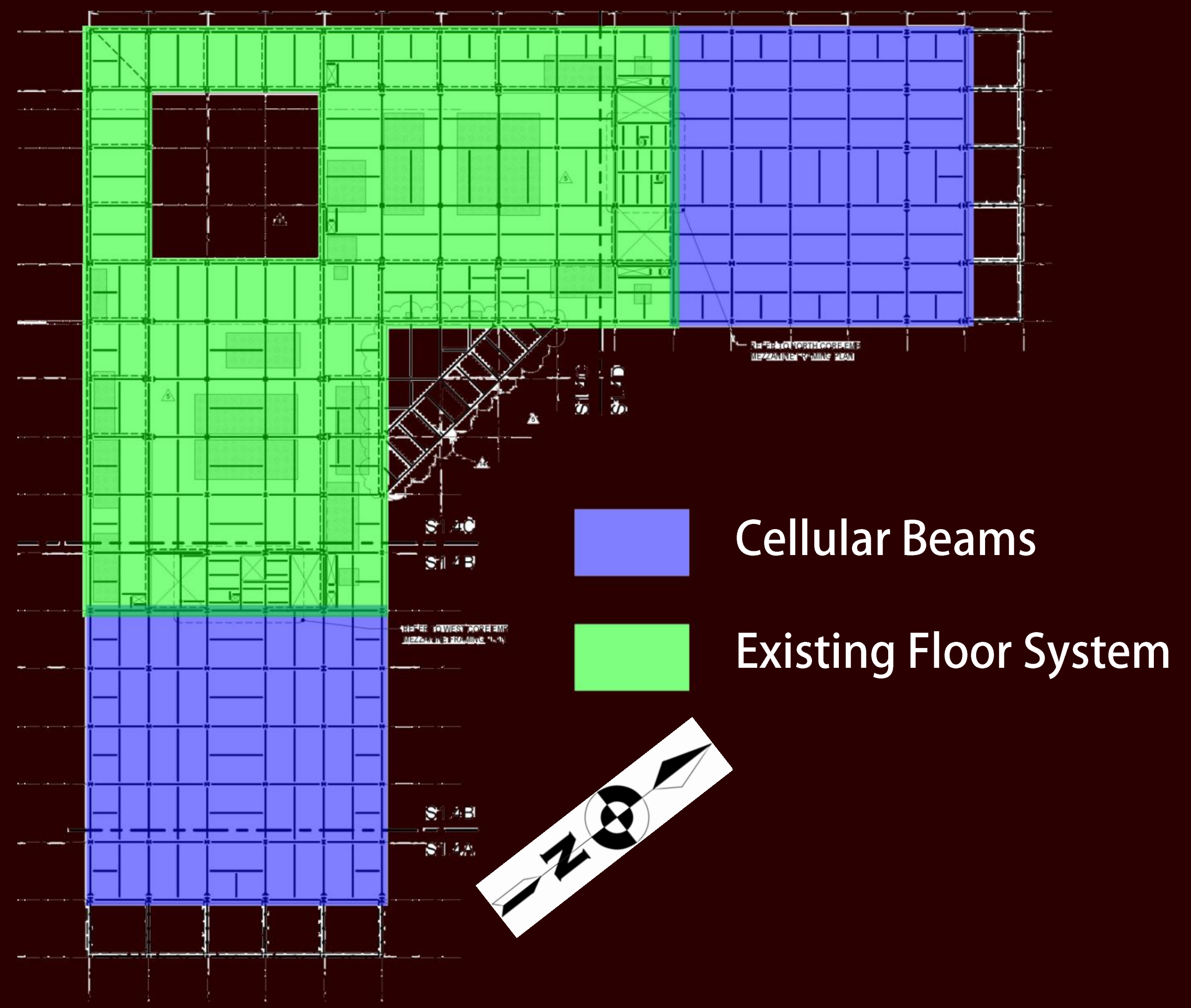
Structural Integration With Chilled Beams

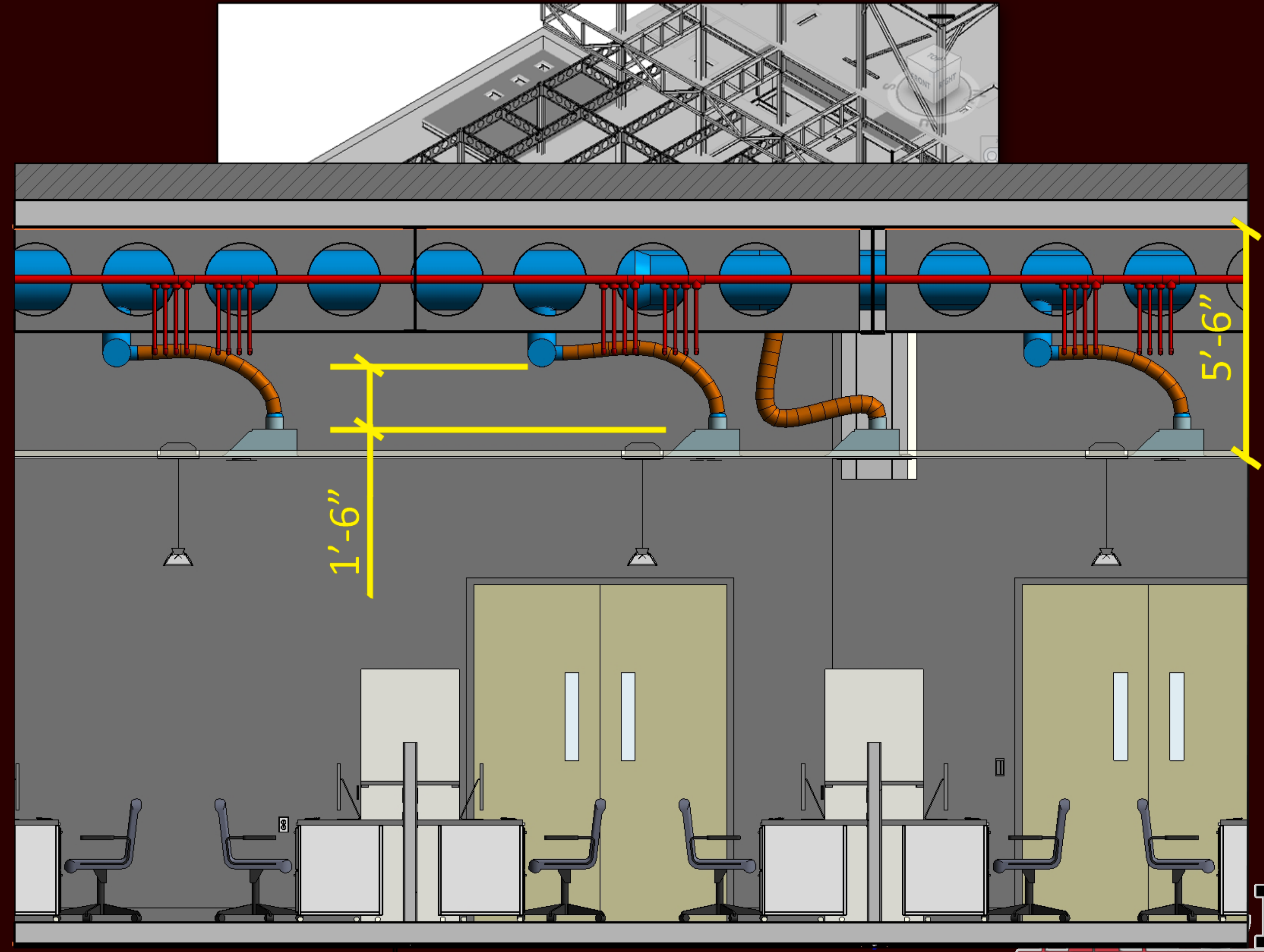
Existing Composite Floor System
- 22ft. X 22ft. Bays
- 21in. Deep Wide Flange Beams
- 24in. Deep Wide Flange Girders
- Floor Supports Green Roof
- NWT Concrete



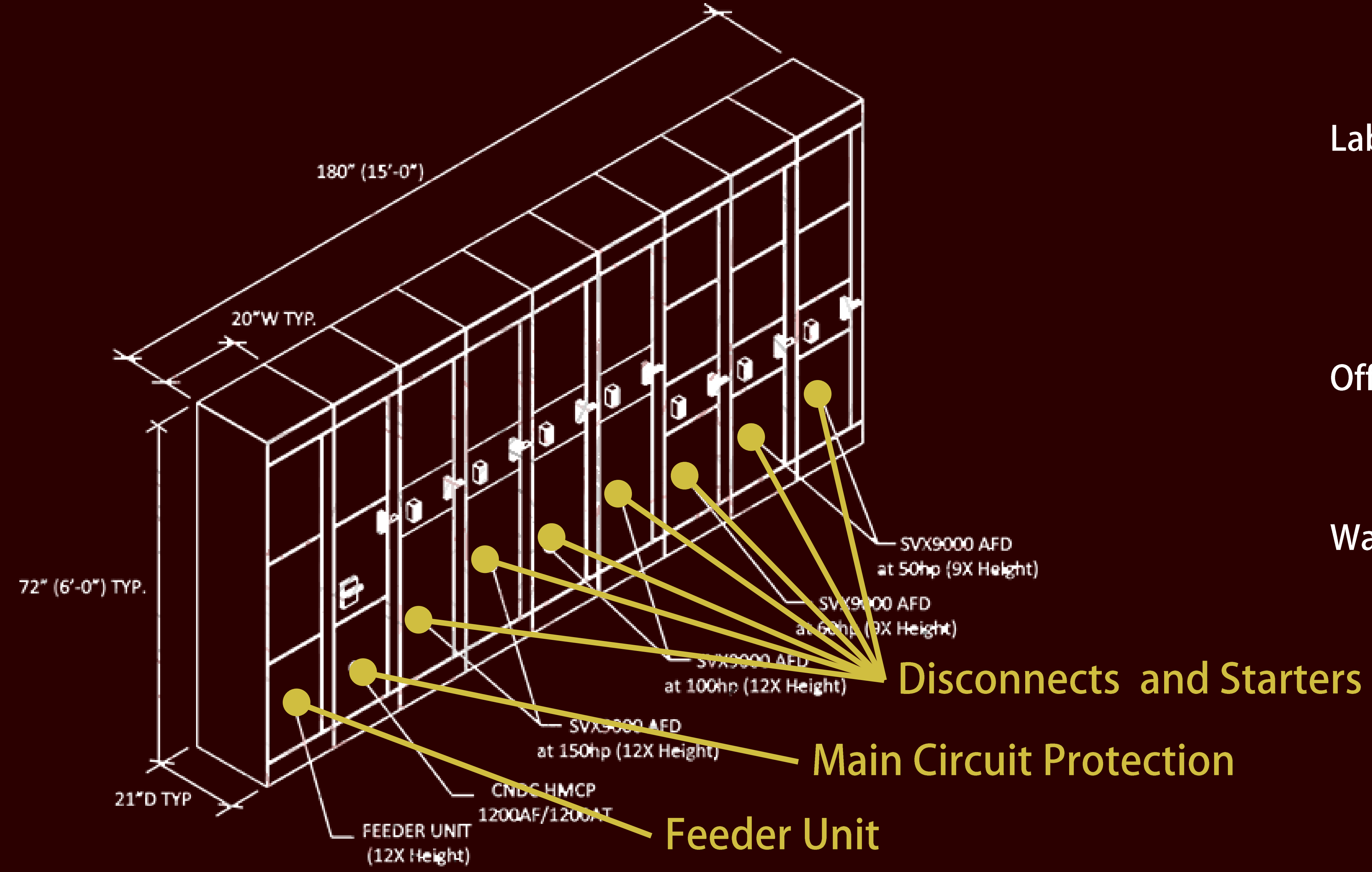
Redesign
- 30in. Deep Cellular Beams
- LB30X44 Beams
- LB30X57 Girders
- Lighter Bays







Chilled Beam Electrical Reaction



Lab Service:
- ACF-1
- ACF-2
- ACF-3
- ACF-4
- ACF-5

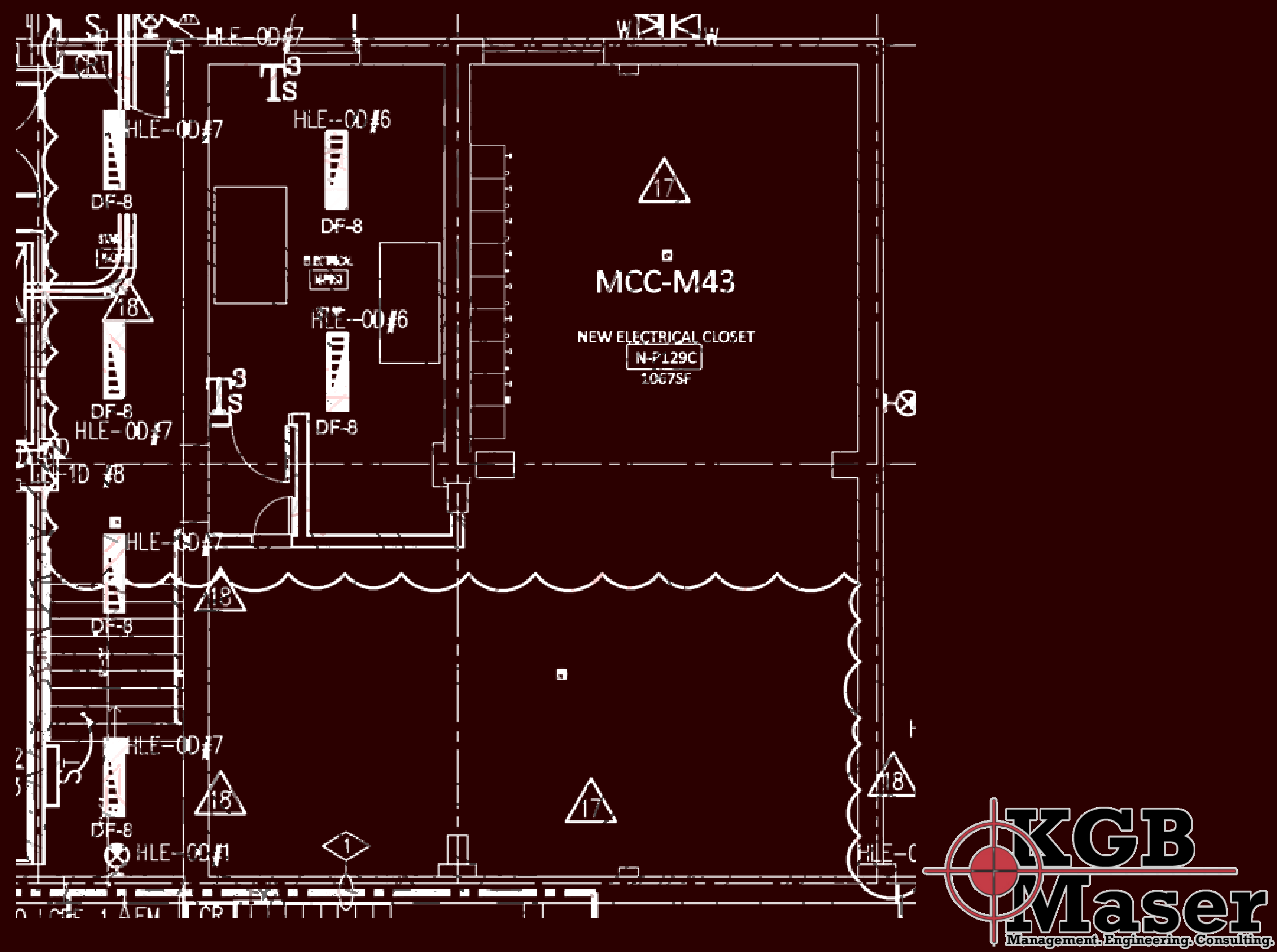
Office Service:
- ACF-6
- ACF-7
- ACF-8

Water Pumps:
- CWP-1
- CWP-2
- CWP-3 (standby)
- CWP-4 (low flow)
- HWP-5
- HWP-6

Labs/Offices:
- AHU-EXT-1
- AHU-EXT-2

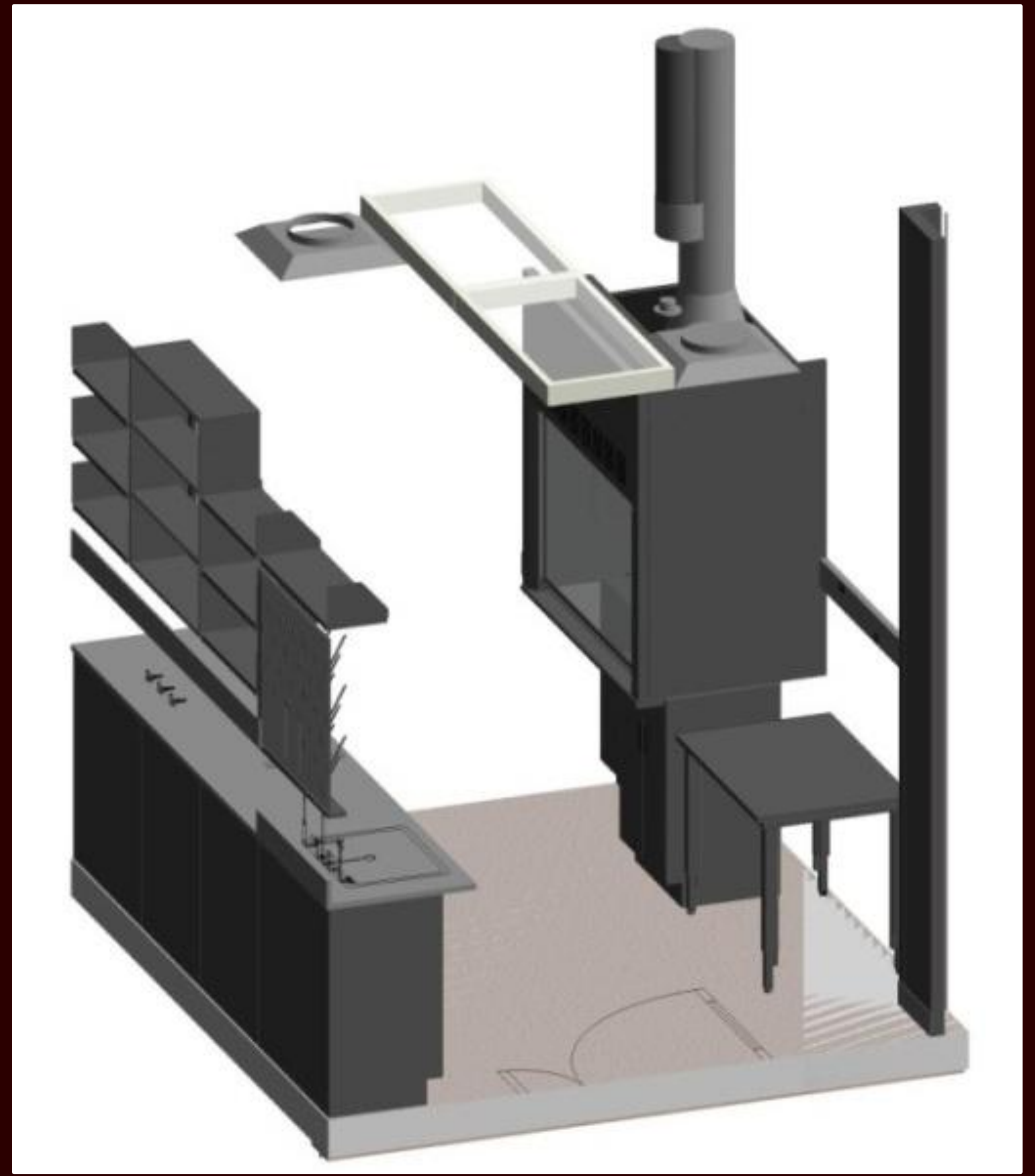
Interior Spaces:
- AHU-INT-LS1
- AHU-INT-LS2
- AHU-INT-MS1
- AHU-INT-MS2

Consolidated to MCC:
- CWP-1
- CWP-2 (standby)
- CWP-3
- CWP-4 (standby)
- CWP-5 (low flow)
- HWP-5
- HWP-6 (standby)

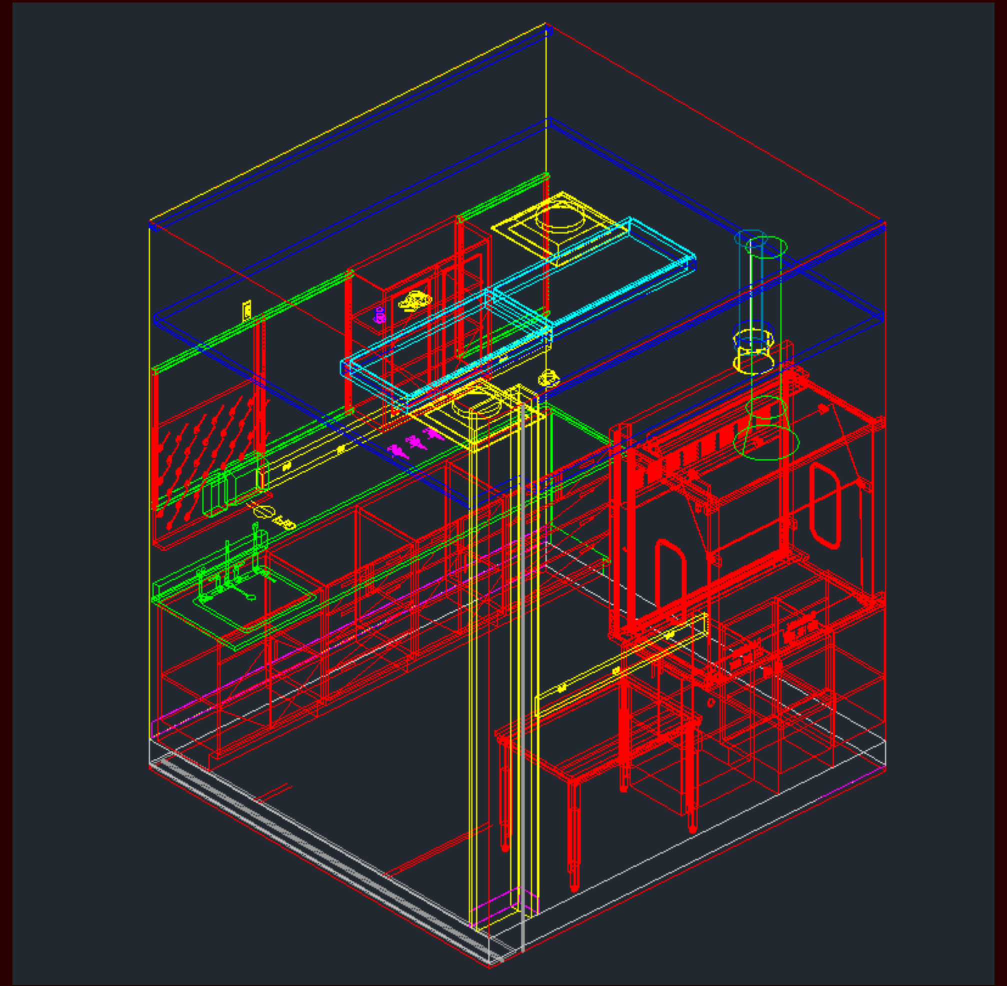


Fume Hood Face Velocity Testing: Software Process

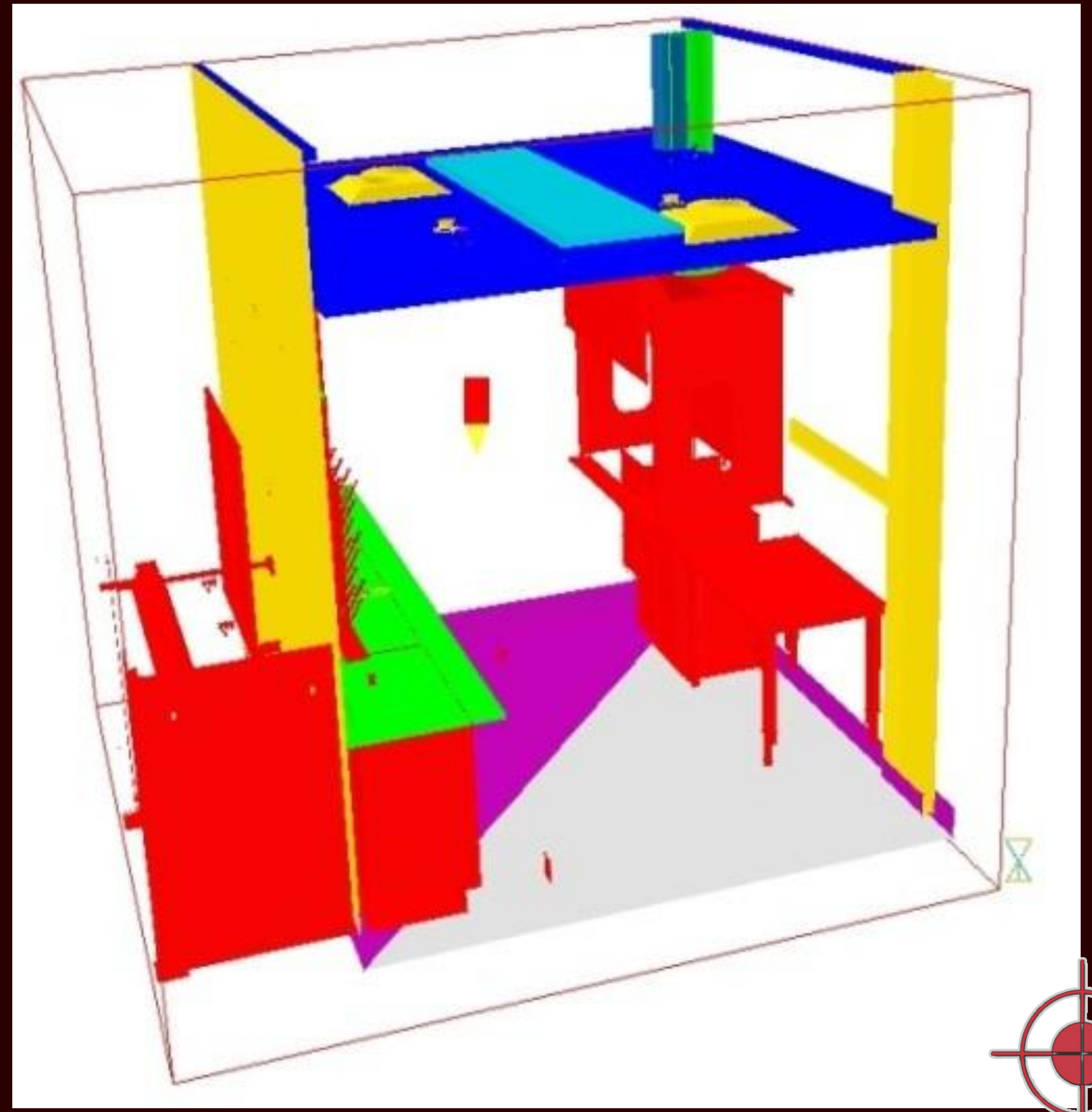
Section Box applied to W324A-Hot Room



DXF Export from Revit Architecture



Attempted import as geometry into Phoenics 2009



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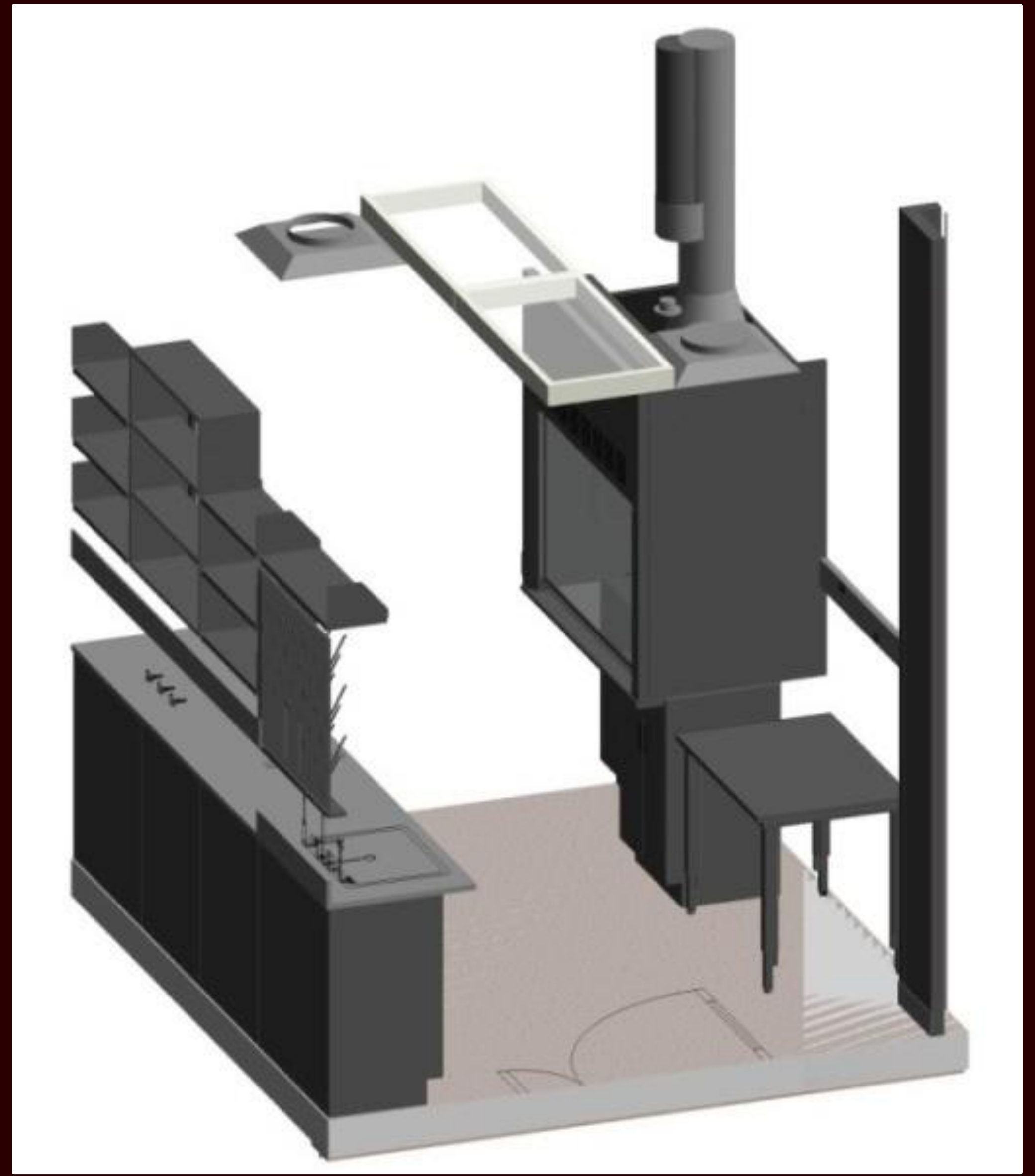
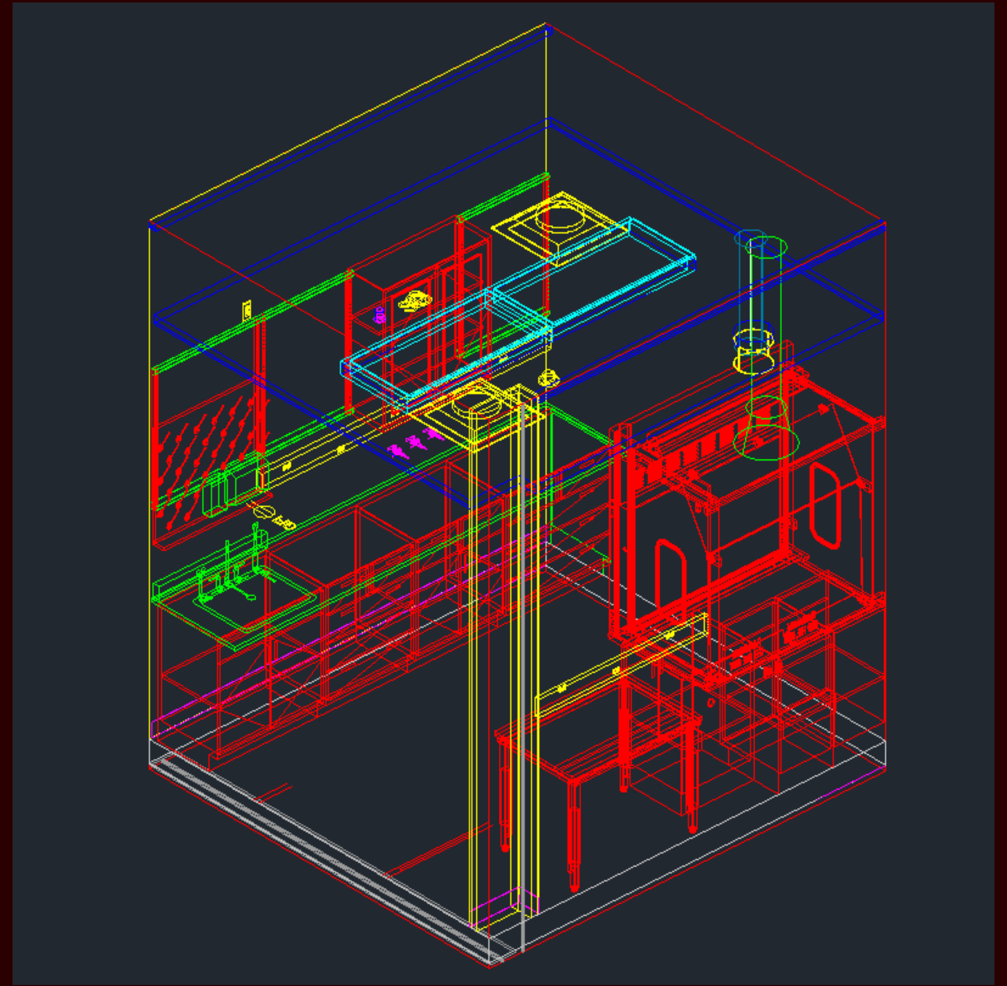
Fume Hood Face Velocity Testing: Software Process

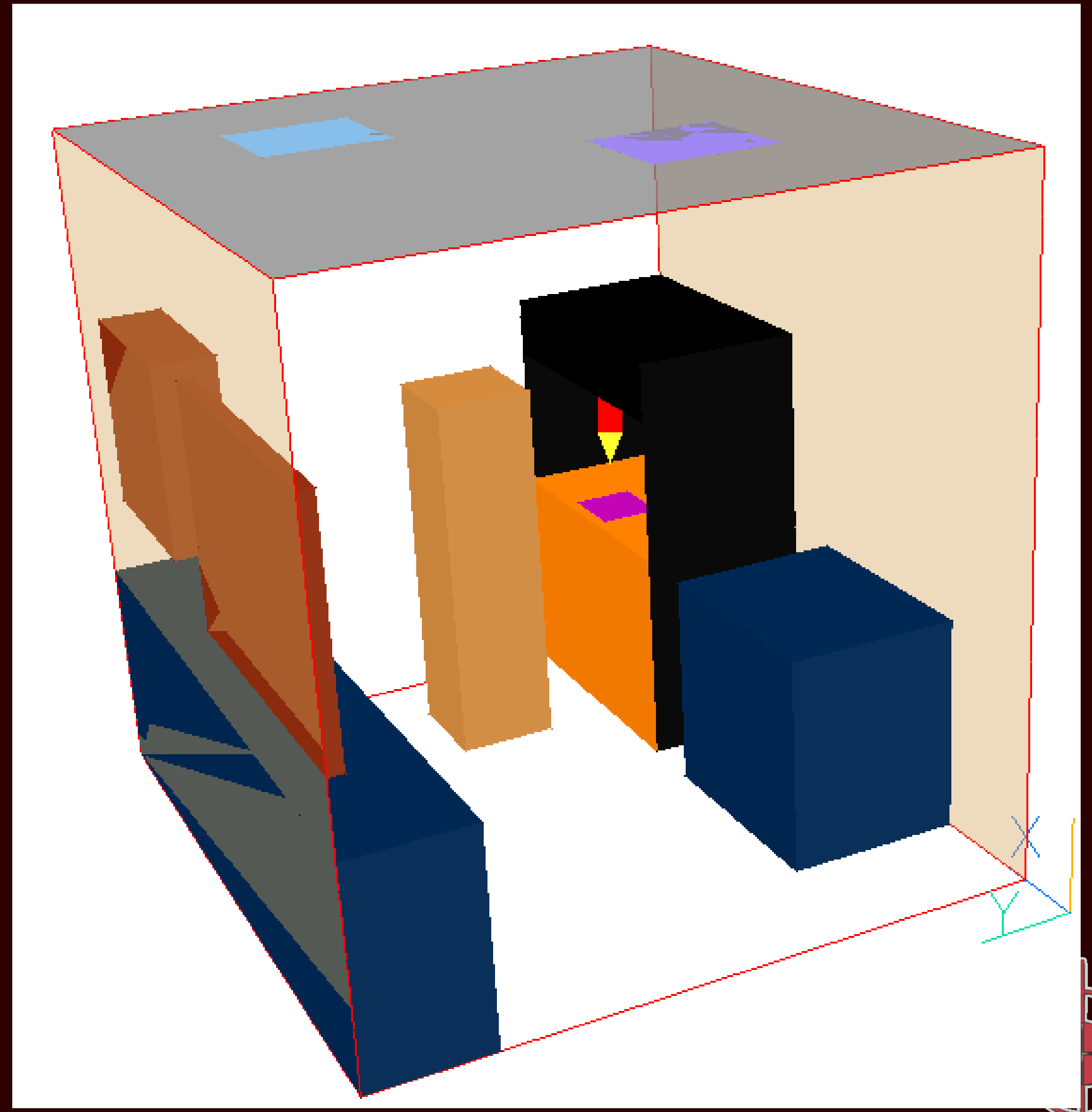
Section Box applied to W324A-Hot Room



DXF Export from Revit Architecture

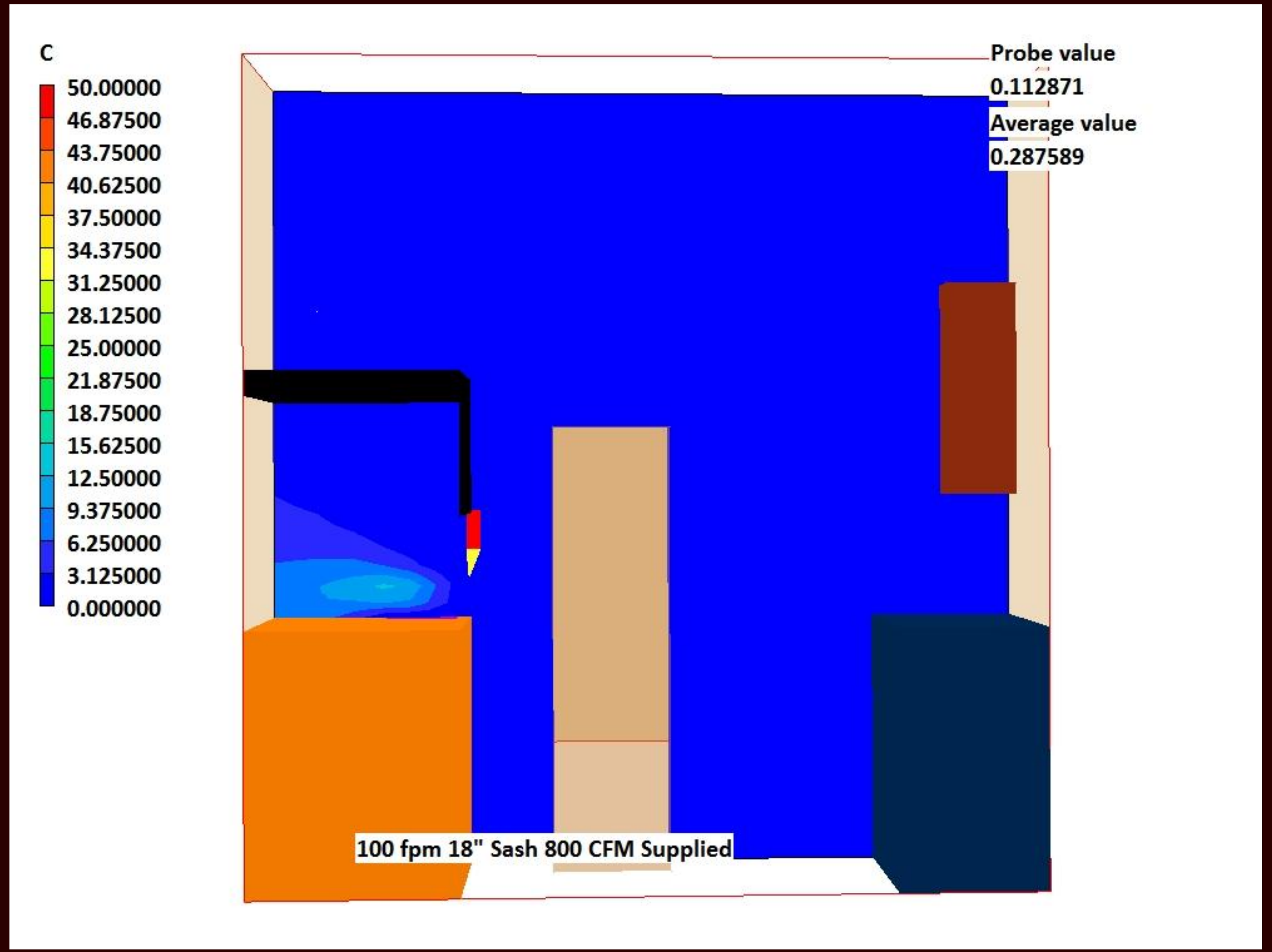


Final Model created with Phoenics elements



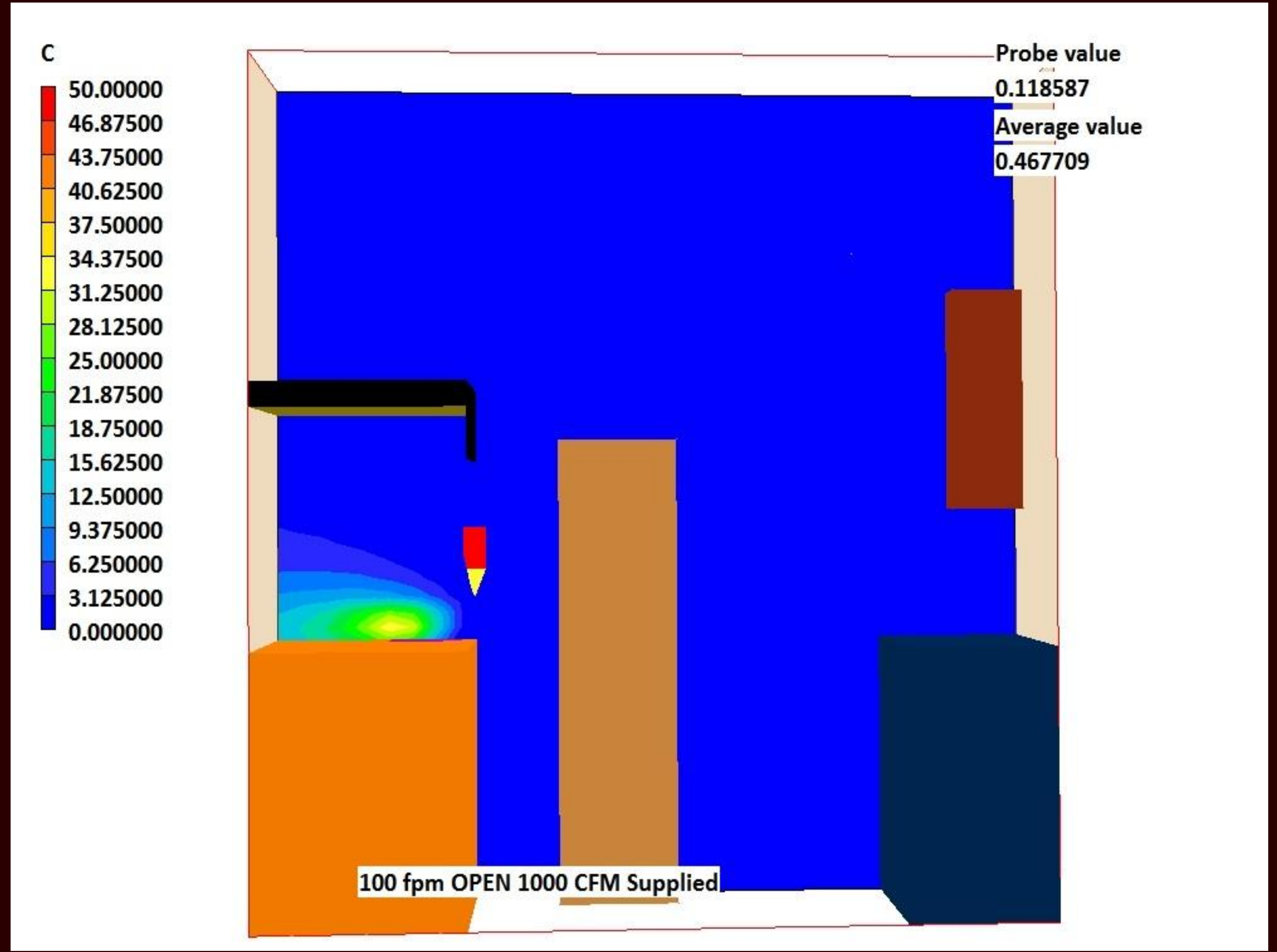
CFD Contaminant Test: 18" Sash Position

100 FPM



80 FPM

CFD Contaminant Test: 30" Sash Position



100 FPM

80 FPM

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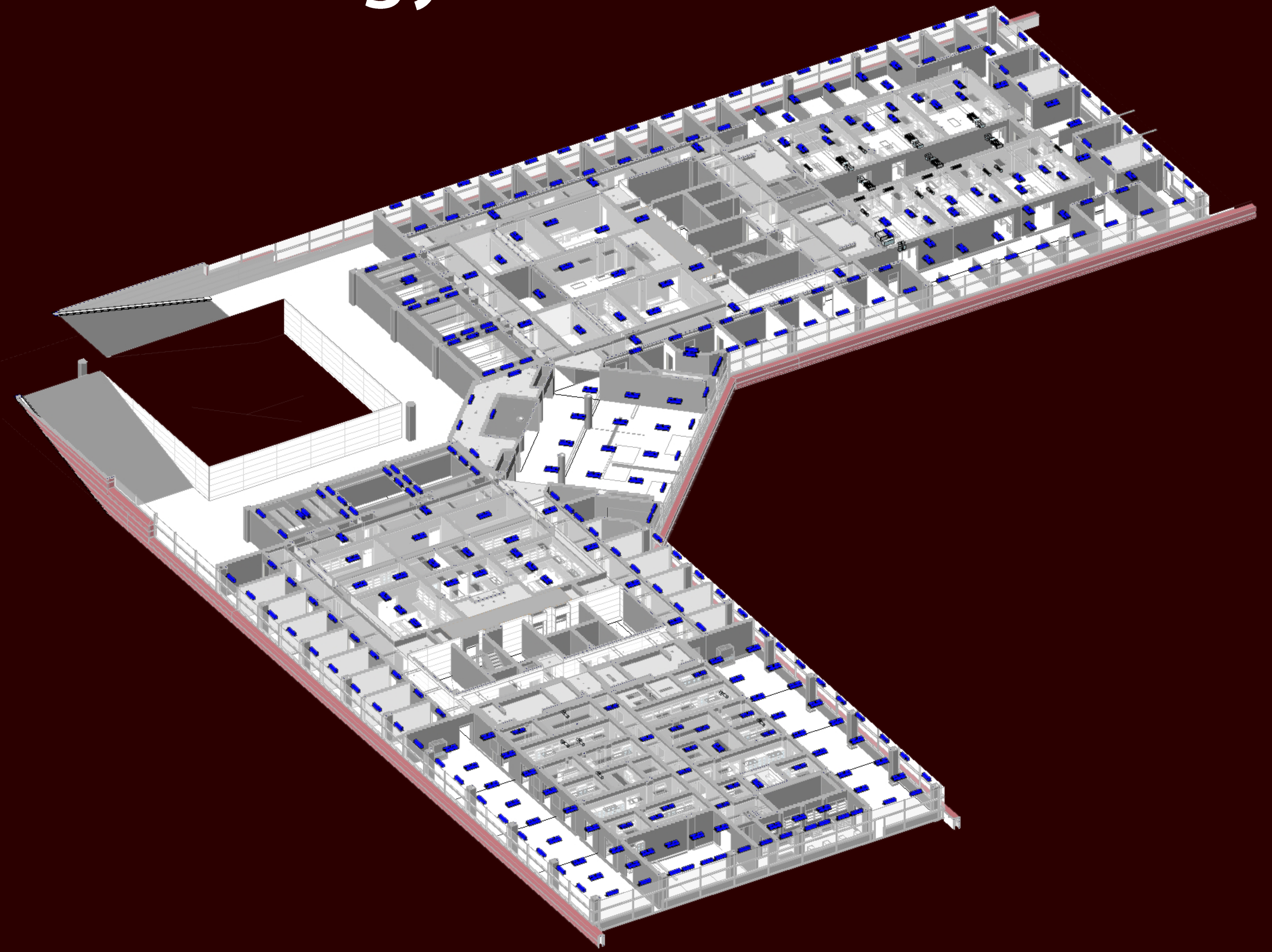
Fume Hood Results

1. Face Velocity **achieved during 18″** simulations, **not 30″**
2. **14.2% more** contaminant present at face of fume hood in 80 fpm, 18″ sash
3. **18.0% more** contaminant present at face of fume hood in 80 fpm, 30″
4. All contaminant readings **less than 0.015% of source,** drop significantly at Human
5. **31.94%** energy savings from conditioning less air

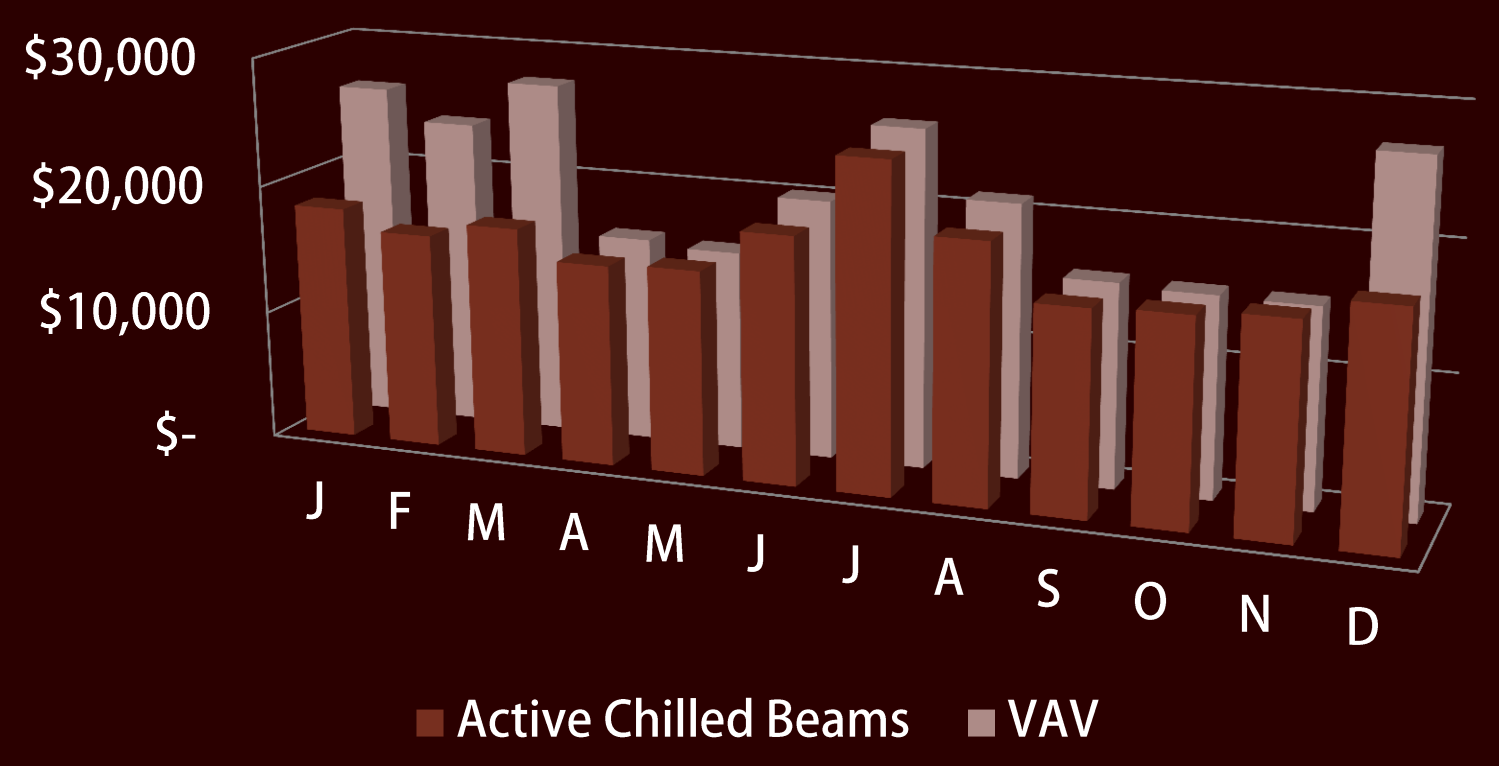
Summary of Fume Hood Makeup Air Costs and Savings		
Metric	100 fpm VAV	80 fpm ACBs
Cooling/Dehumidification	$233,356	$122,597
Heating	$6,479	$13,447
Fan	$110,512	$81,042
Humidification	$17,610	$33,343
CAV Operation Costs	$367,958	$250,431
VAV Multiplier for Operation	0.32	0.32
Adjusted Operation Costs	$116,704	$79,428.
Percent Savings		31.94%

Energy Model Results

3rd Floor and Estimated Building Operating Costs			
		3rd Floor	Building
Existing VAV	Building Energy kBtu/yr	16,478,534	98,871,204
	Operating Costs	\$250,288	\$1,501,728
	Cost/SF	\$5.84/ft²	
Proposed ACB + Triple Pane Glazing	Building Energy kBtu/yr	13,912,786	83,476,716
	Operating Costs	\$214,983	\$1,289,898
	Cost/SF	\$5.02/ft²	
	Percent Savings	14.1%	



Monthly Operating Costs



Mechanical Equipment Schedule

Family and Type	Count	Total	COST
Radiant-ACB1-4: ACB1 12" Wide, Inlet 4"	1	1327.75	$1,327.75
Radiant-ACB1-4: ACB1 12" Wide, Inlet 4"	1	1327.75	$1,327.75

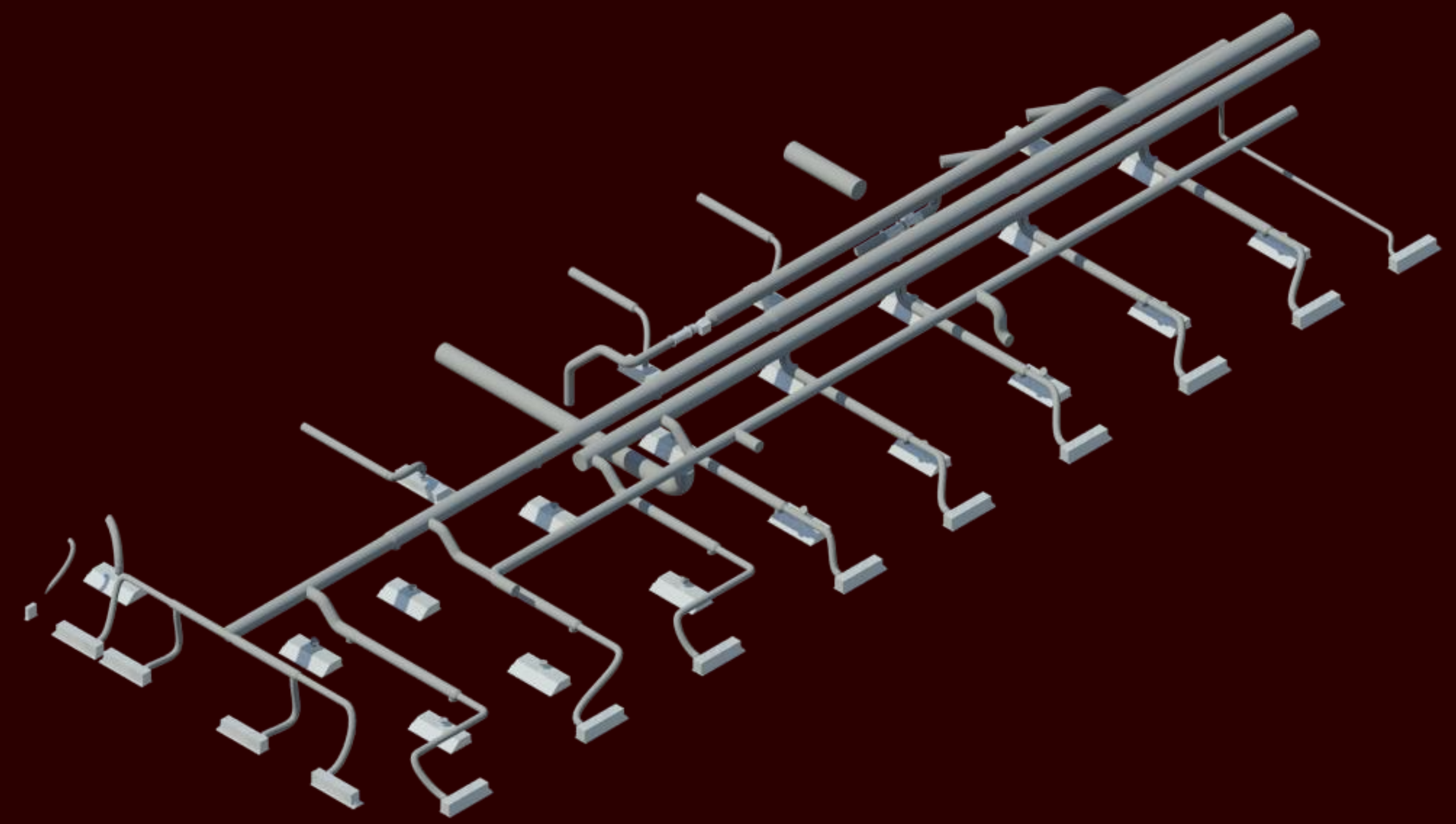
Duct Schedule

Size	Area	Length	Unitless Length	Cross Area	Volume Per FT	Weight
13"x13"	88 SF	20' - 4 1/4"	20.354167	0.022 SF	0.02	70.34
14"ø	4 SF	1' - 0"	1.000001	5.445938	0.03781901	6.54
16"x16"	110 SF	20' - 6 7/8"	20.572917	0.026 SF	0.03	106.65
18"x18"	123 SF	20' - 6 7/8"	20.572917	0.035 SF	0.03	106.65
20"x20"	67 SF	10' - 1 9/32"	10.10551	0.038 SF	0.04	69.85

Pipe Schedule

Family and Type	Size	Length	Unitless Length	Material	Labor	Equipmet	Total	COST
Pipe Types: Standard	1/2"ø	0' - 10 29/32"	0.909167	5.25	5.6	1.25	12.1	$11.00
Pipe Types: Standard	1/2"ø	0' - 7 31/32"	0.662917	5.25	5.6	1.25	12.1	$8.02
Pipe Types: Standard	1/2"ø	1' - 0 29/32"	1.075833	5.25	5.6	1.25	12.1	$13.02

Mechanical Redesign Cost Assessment



CHILLED BEAMS	DUCTWORK	PIPING	PUMPS	AHUs	TOTAL
$9,608,000	$2,966,400	$377,840	$165,484	$2,274,046	$21,035,567

Cost Increase = $1,847,567

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Comparing Life Cycle Costs of Mechanical Systems

Coal Plant Findings			
	Real Rate	2% Inflation	5% Inflation
VAV	$54,813,916	$63,883,395	$63,856,220
ACB	$55,346,191	$62,693,273	$62,647,108
Percent Savings	-0.97%	1.86%	1.89%
NPV Differential	($532,275)	$1,190,122	$1,209,111

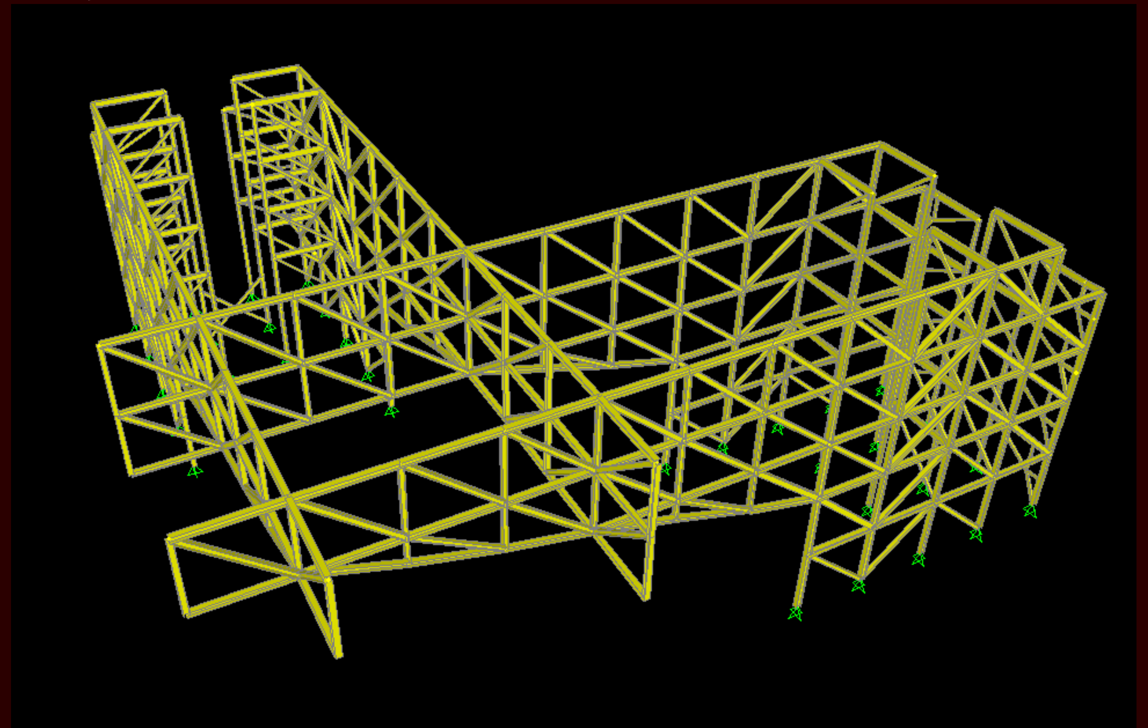
If inflation occurs and PSU remains a coal fired plant, the Active Chilled Beam system should be considered

If PSU changes to a Natural Gas plant, the Active Chilled Beam system should be considered

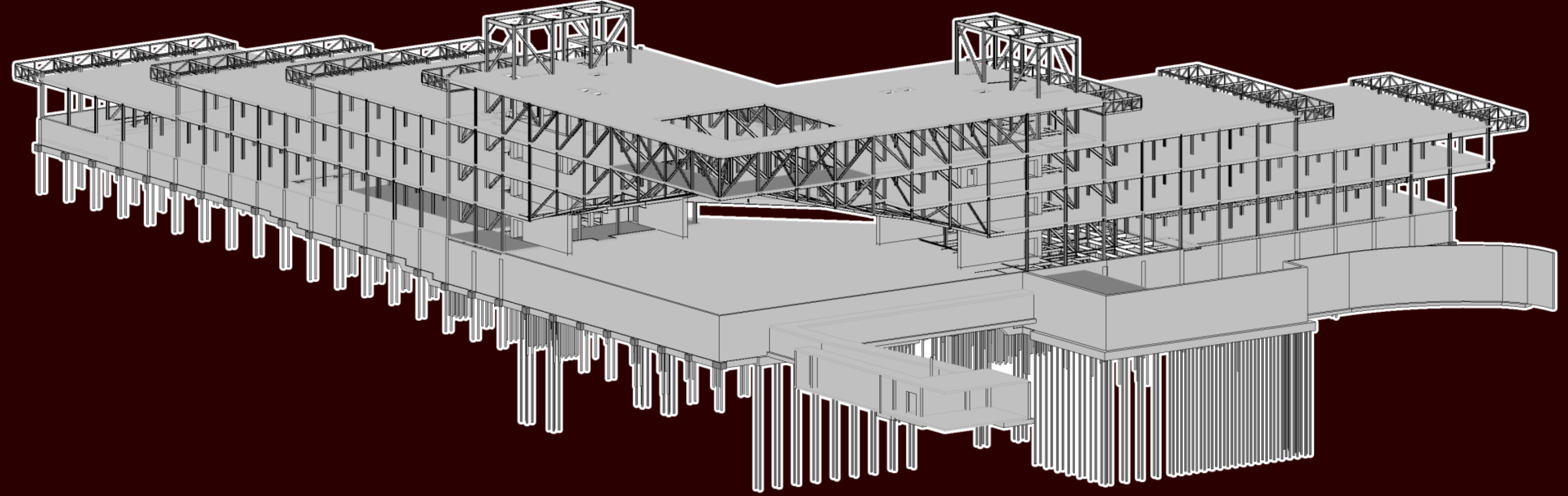
Natural Gas Plant			
	Real Rate	2% Inflation	5% Inflation
VAV	$64,693,985	$72,152,832	$72,110,021
ACB	$59,478,486	$69,307,263	$69,259,831
Percent Savings	8.06%	3.94%	3.95%
NPV Differential	$5,215,499	$2,845,568	$2,850,190

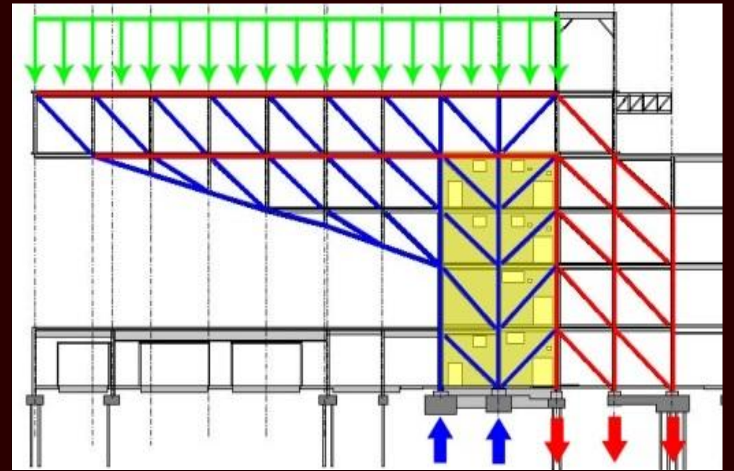
154ft. Overhang

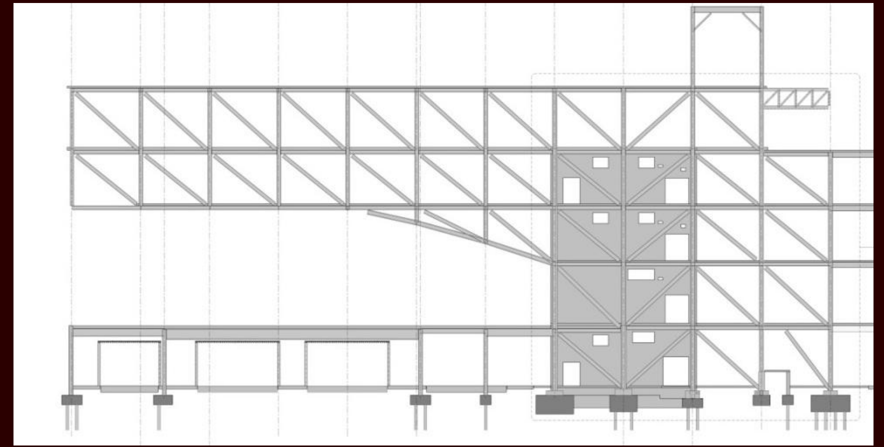
- 4 Main Trusses at Gridlines 2, 5, B, & E
- 11 Bays Lengthwise
- Moment Connections
- Members Oriented for Compression
- Sizes Ranging from W14X90 to W14X550
- Controlled by Deflection

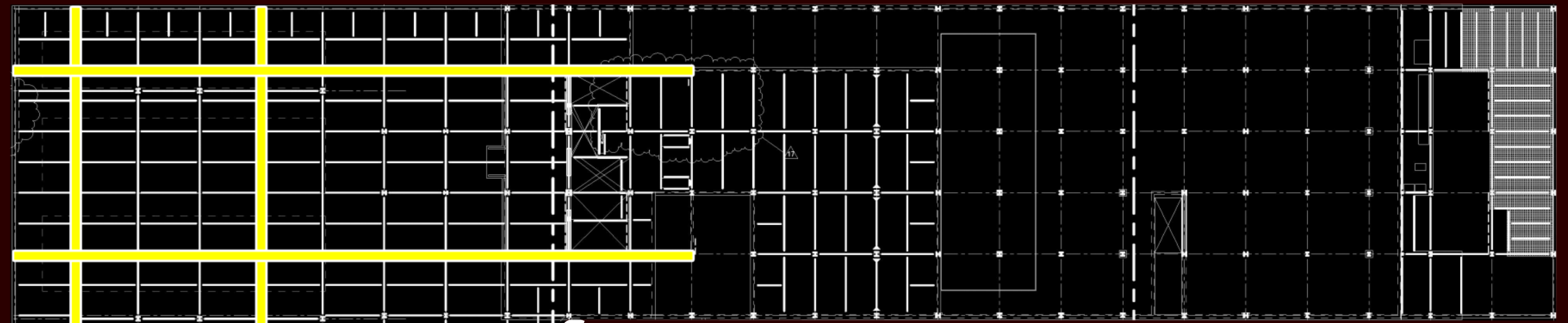


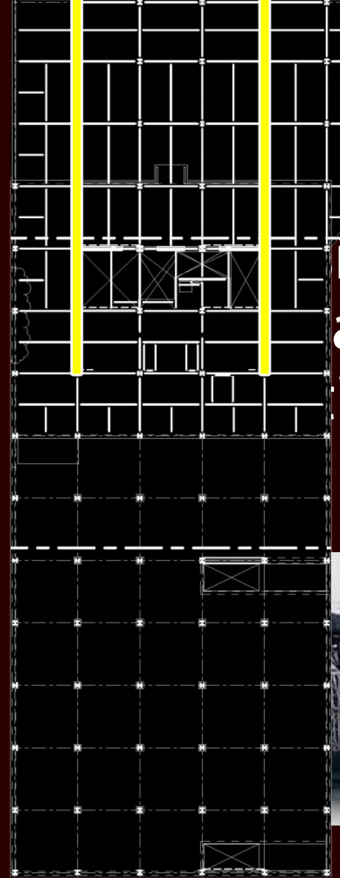
Existing Cantilever











BS

Revit

ntilever Model to Serve as Base

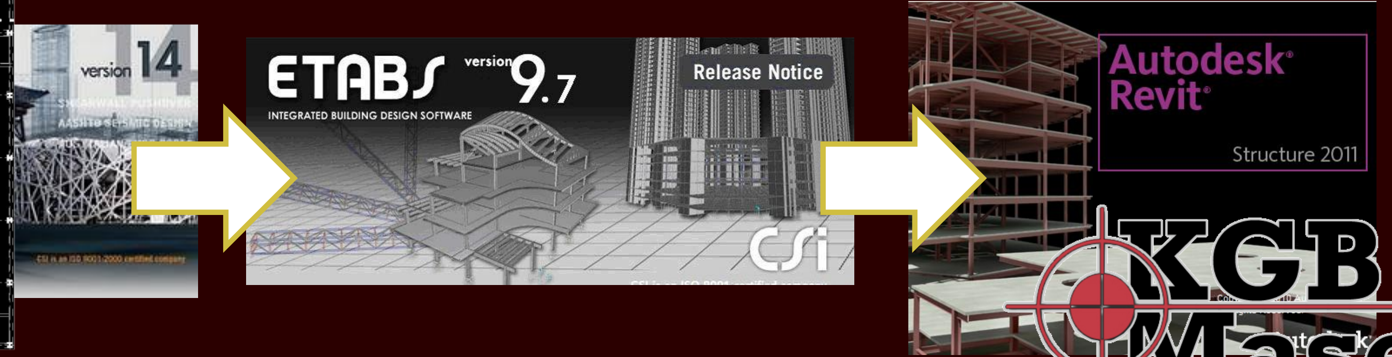
iderations

ation with Lighting and Mechanical

ities to be Take

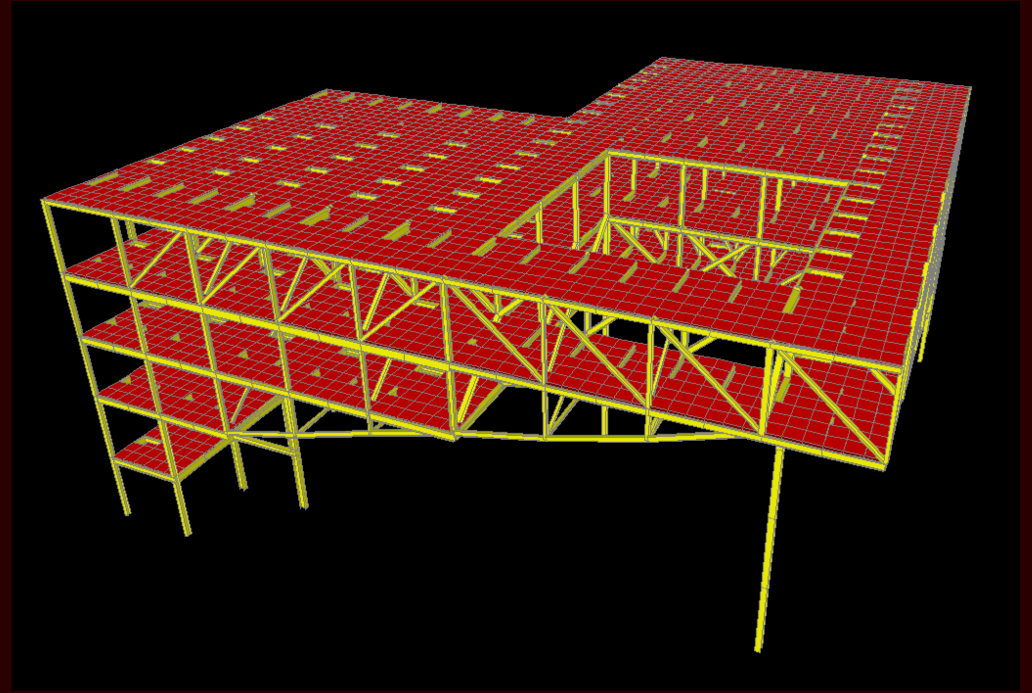
Redesigned Model

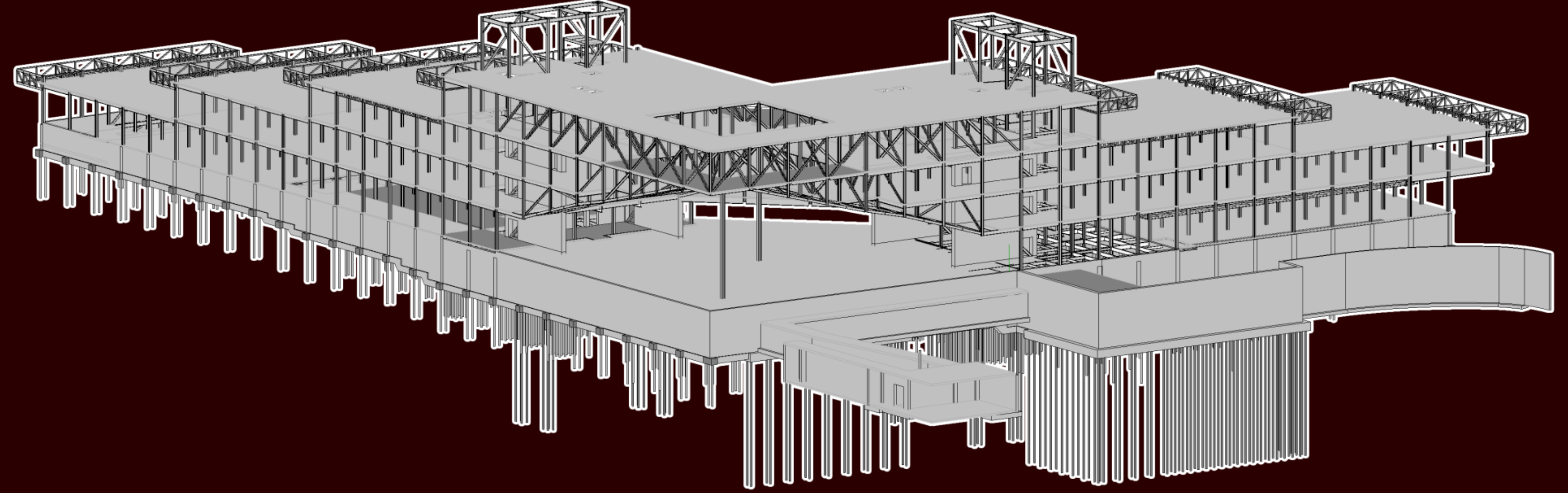
Truss Location

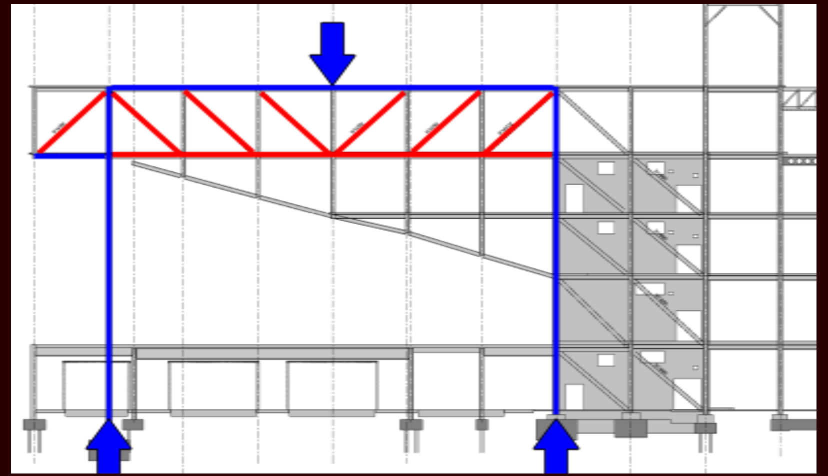


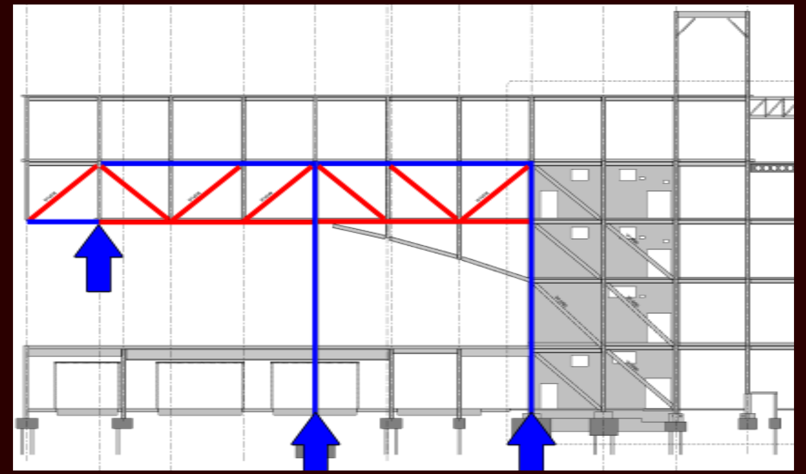
Redesign

154ft. Overhang
- 4 Main Trusses at Gridlines 2, 5, B, & E
- 9 Bays Lengthwise
- Pin Connections
- Members Oriented for Tension
- Sizes Ranging from W14X90 to W14X311
- Controlled by Strength



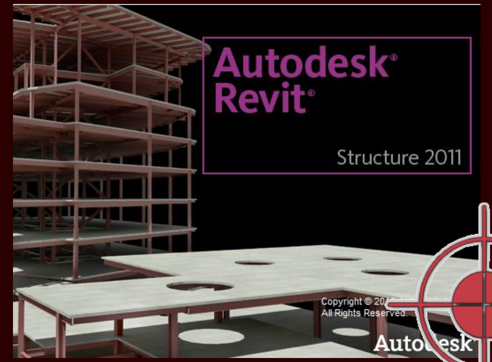


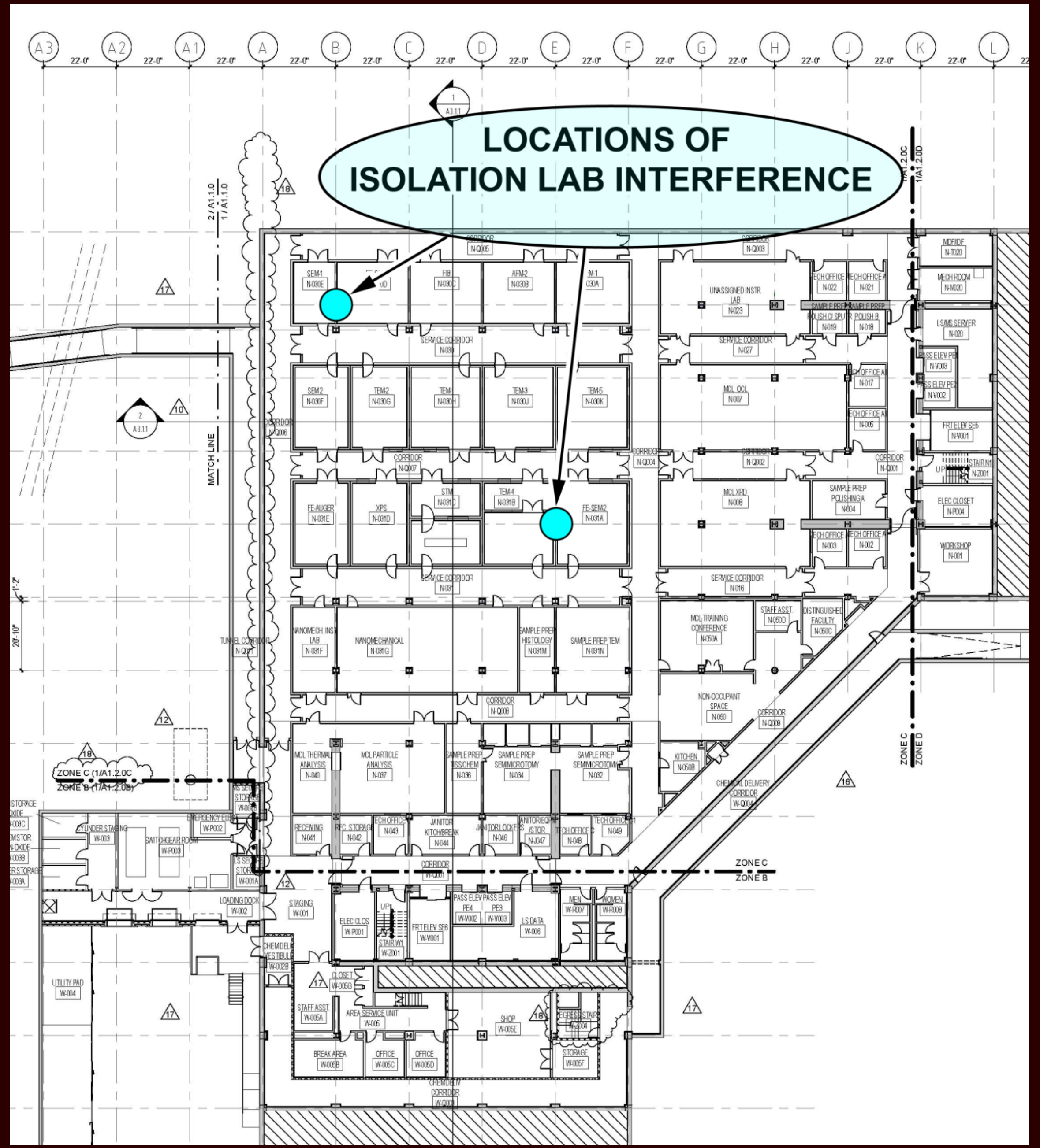




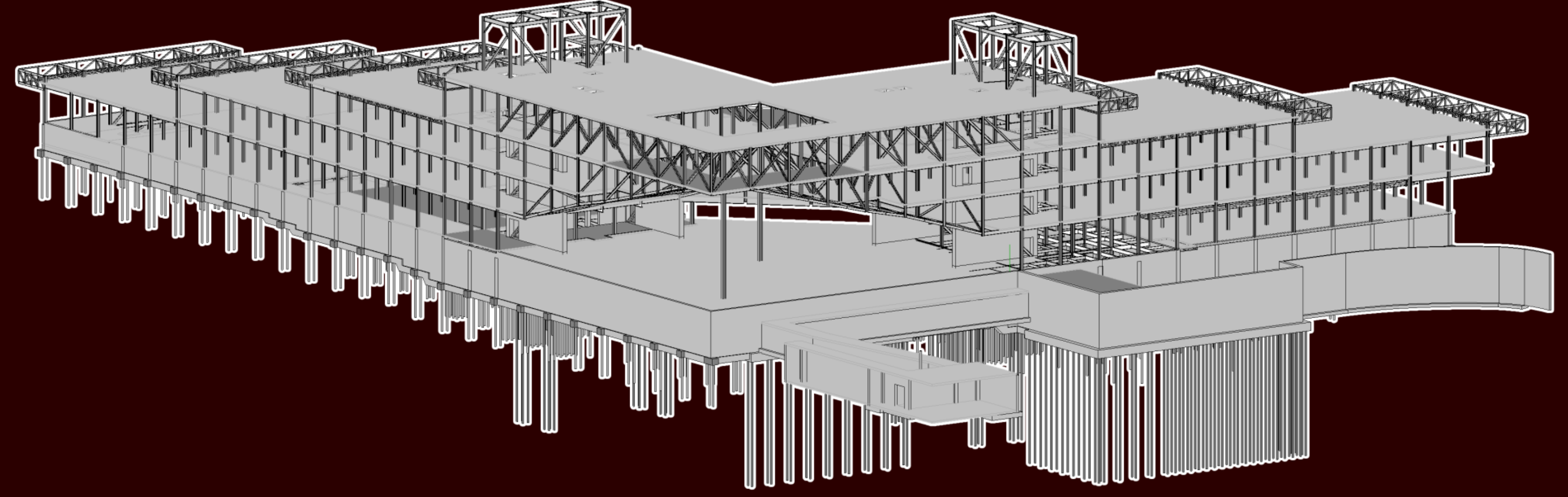
Actual BIM Process
- Build Complete Cantilever in SAP
- Analyze in SAP
- Redesign in SAP
- Replicate in Revit
- Use Existing Conditions Model and Modify

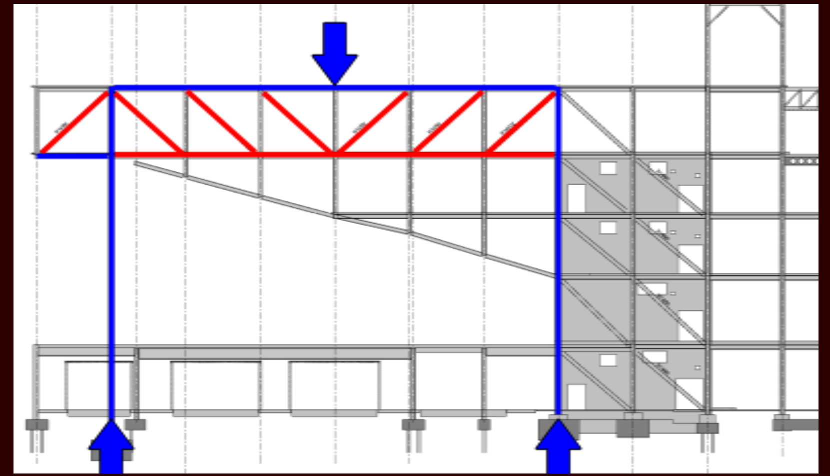
IPD Considerations
- Integration with Lighting and Mechanical
- Quantities to be Taken from Redesigned Model

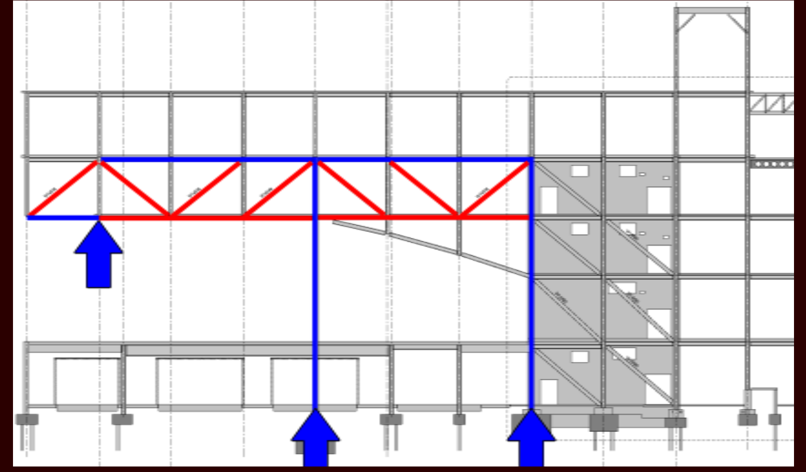


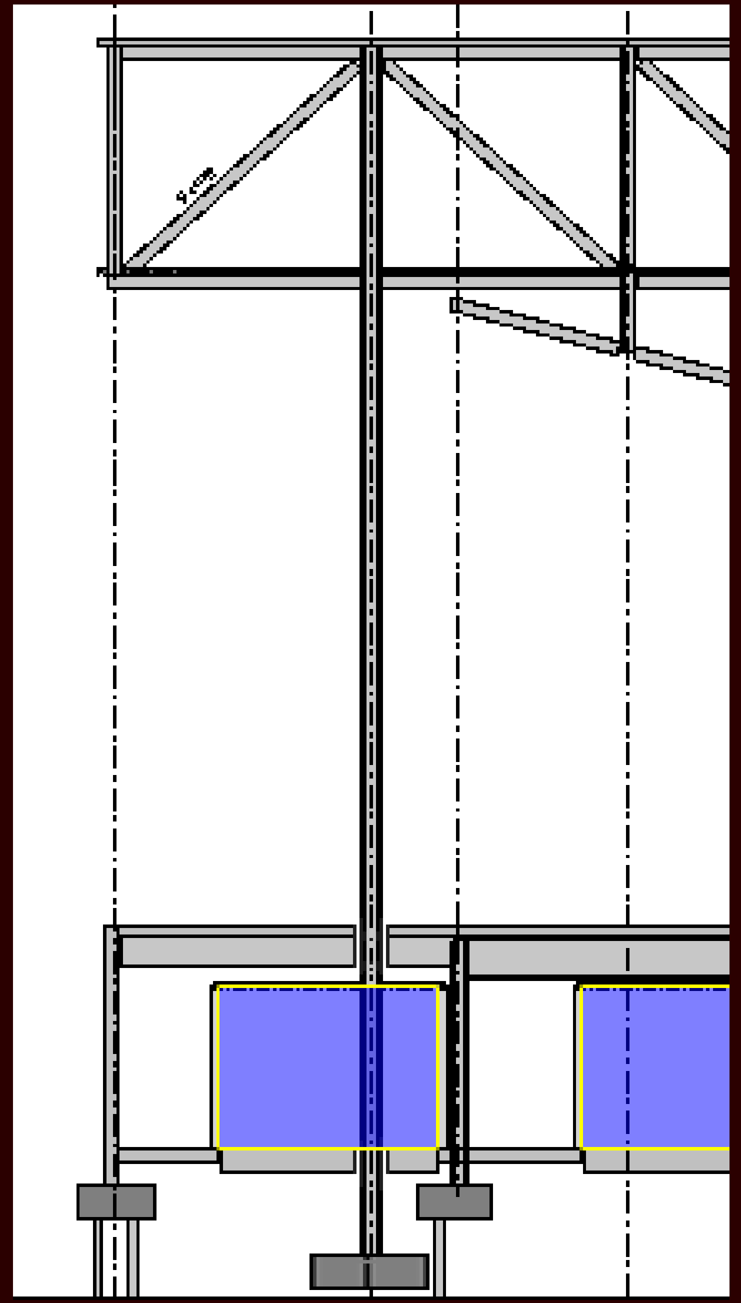


Redesign









Isolation Lab Interference

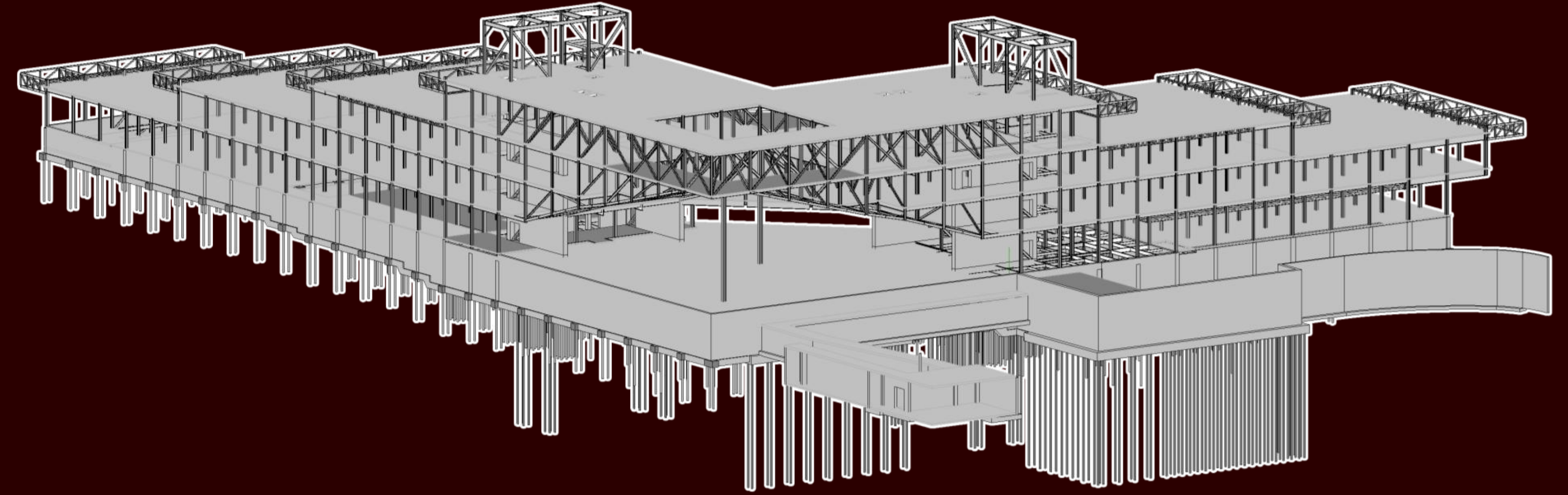
- Column Penetrates Through Slab
- Labs Limited to 130 micro inches/second
- Labs Sequestered from Foundation

Proposed Solution

- Column Pile Caps 3ft. Beneath Bottom of Isolation Slabs
- Isolation Slabs Poured Around Columns
- Compressive Material to Fill Gap

Structural Redesign Cost Implications

Existing Entire Structure				
	Framing Tons	Column Tons	Framing Cost	Column Cost
	3058.7 Tons	953.84 Tons	$8,179,891.34	$2,386,659.20
		Total =	$10,566,550.54	
Existing 3rd Floor Structure				
	Framing Tons	Column Tons	Framing Cost	Column Cost
	595.72 Tons	231.47 Tons	$1,848,680.85	$434,508.19
		Total =	$2,283,189.04	



Cost Savings = $2,290,815

Redesign 3^{rd} Floor Structure				
	Framing Tons	Column Tons	Framing Cost	Column Cost
	459.79 Tons	202.92 Tons	$1,310,896.61	$539,218.72
		Total =	$1,850,115.33	
Cost Implications to Entire Structure				
	Savings/SF	Total SF	Total Savings	Total Cost
	$8.3326/SF	274,922 SF	$2,290,815.05	**$8,275,735.48**

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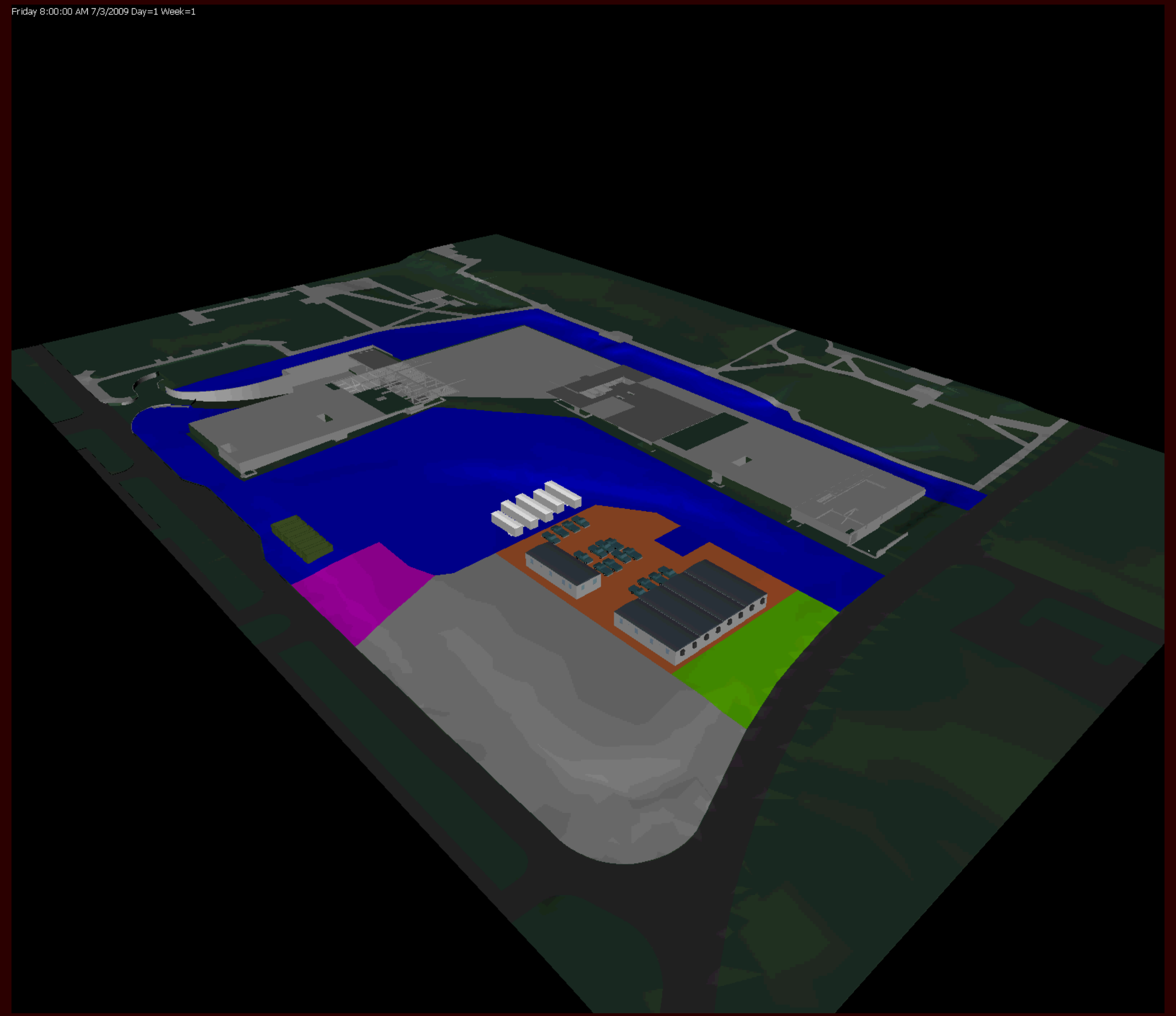
Steel Sequencing 4D Model



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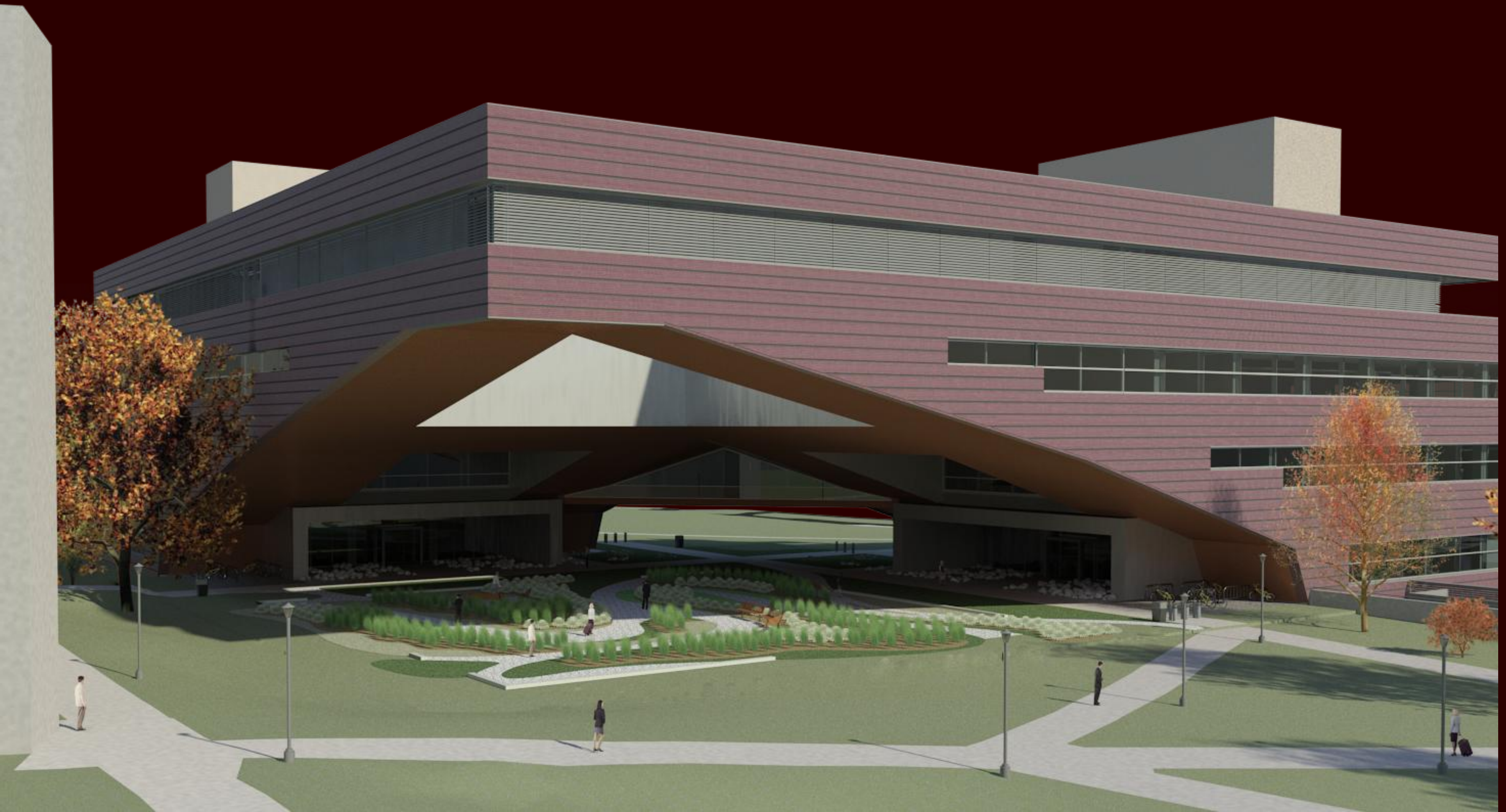
Existing Courtyard Design



Type	Total	Unit	Cost Total	Cost Unit	Cost
RPC Shrub: Century 1'-10"	244	EA	22	EA	$5,368.00
RPC Shrub: Switchgrass (2) 4'-0"	327	EA	17.1	EA	$5,591.70
Basic Wall: Concrete Panel Wall	214.5	FT	11.45	LF	$2,456.03
Custom Park Bench 6'-0"	5	EA	526.5	EA	$2,632.50
Bicycle Racks	8	EA	649	EA	$5,192.00
Stamped Stone Path	4271.75	SF	17.05	SF	$72,833.34
Mulch	4624.63	SF	2.91	SY	$498.43
Bermuda Ornamental Grass	1298.57	SF	50	SY	$2,404.76
Ground Cover Grass	8487.97	SF	220	MSF	$ 1,867.35
Fern/Boulder Area					
Exposed Aggregate Concrete					
Decorative Pea Gravel					
Decorative Boulders					

Total Including O & P, Waste, Delivery, & Time Modifications = **$271,745.24**

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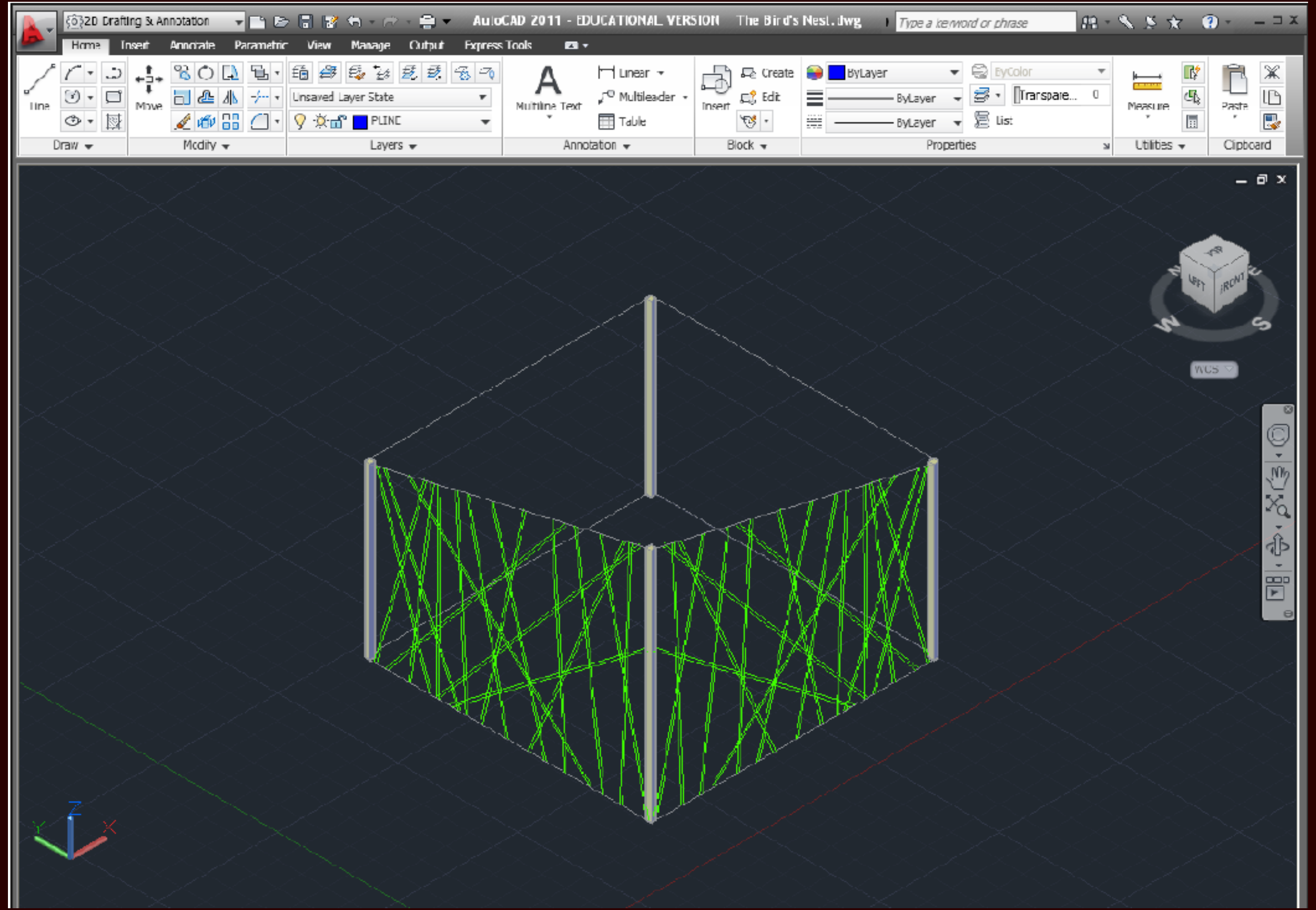
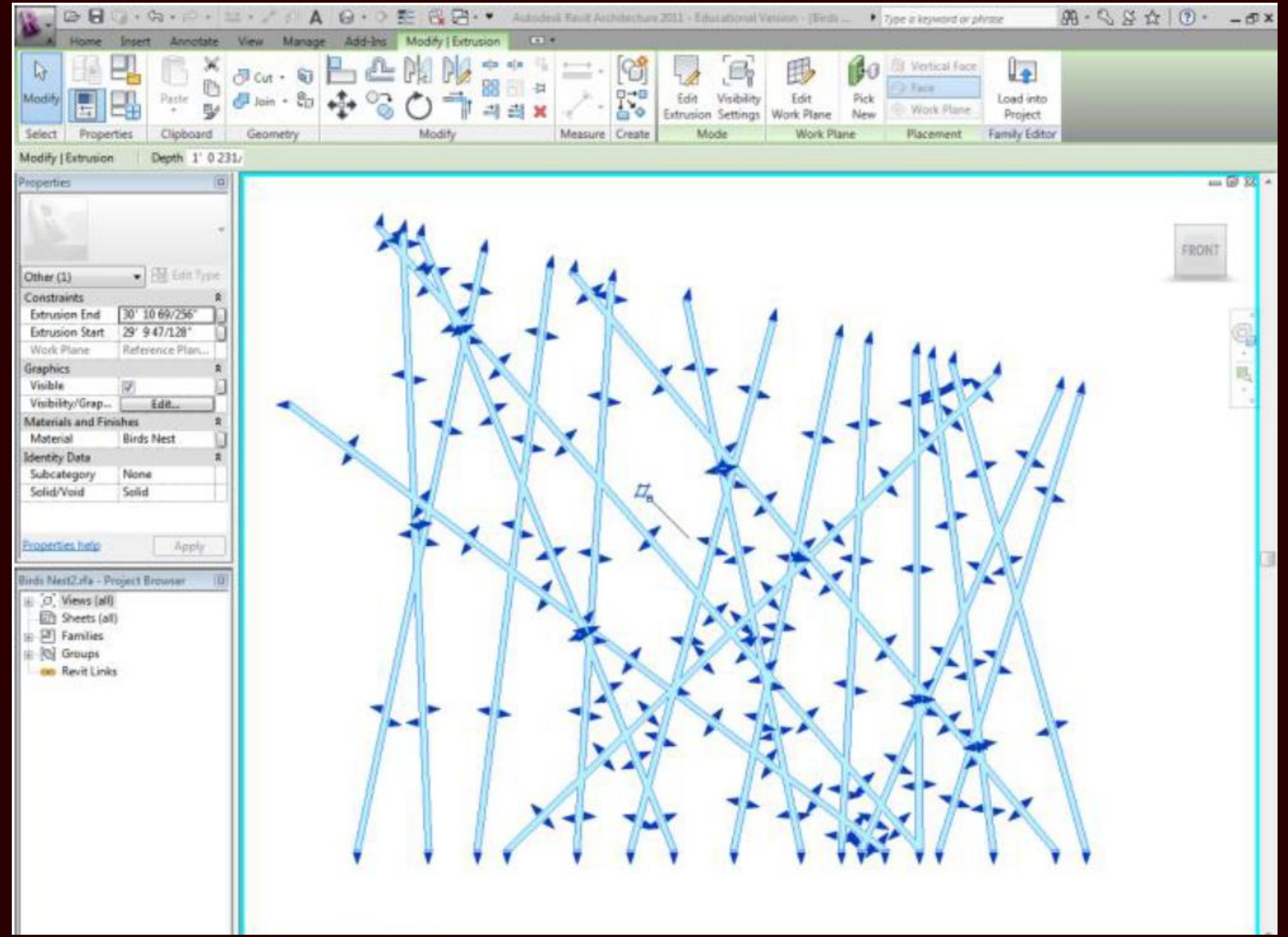
Cage Structure Development





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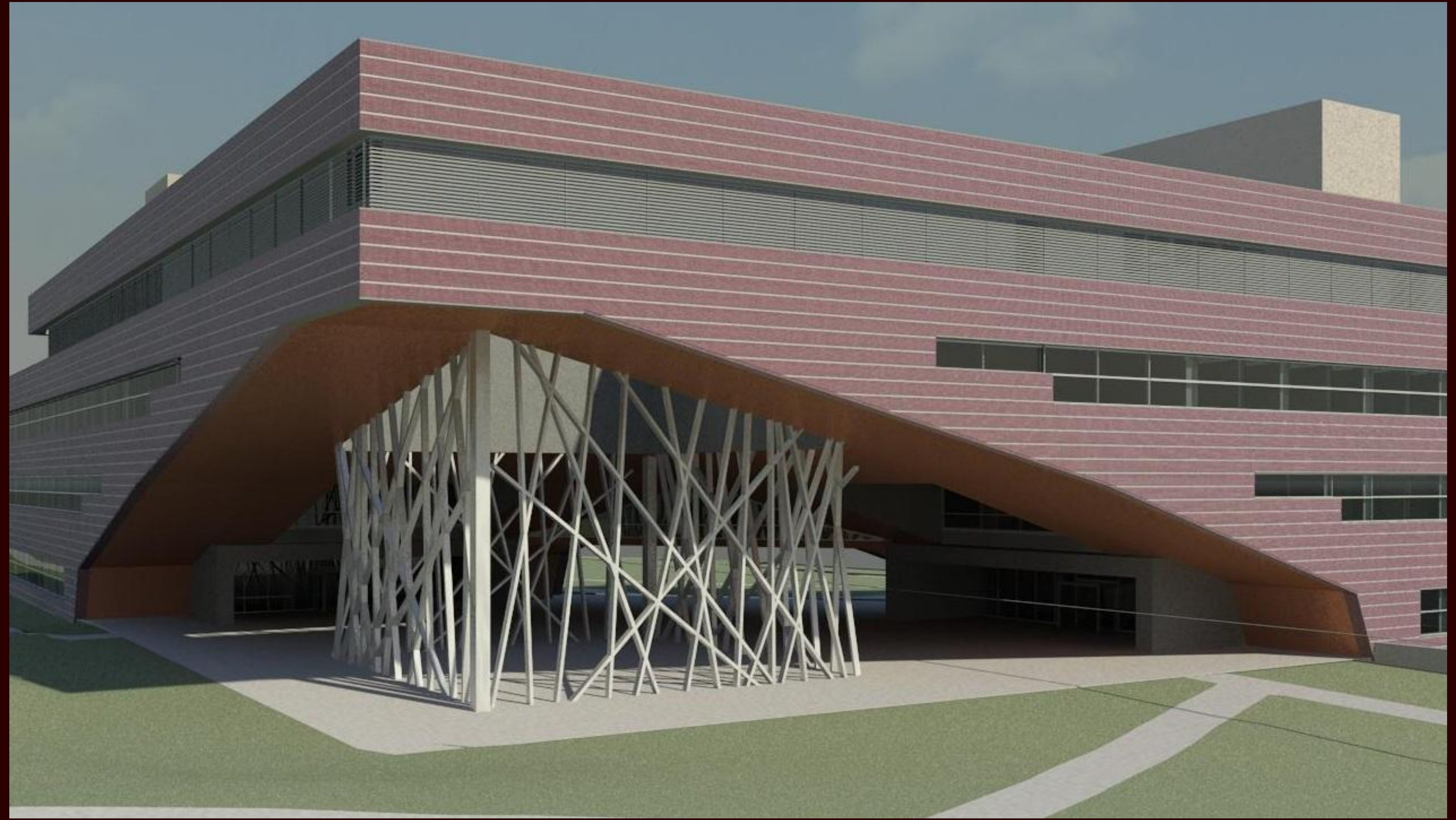
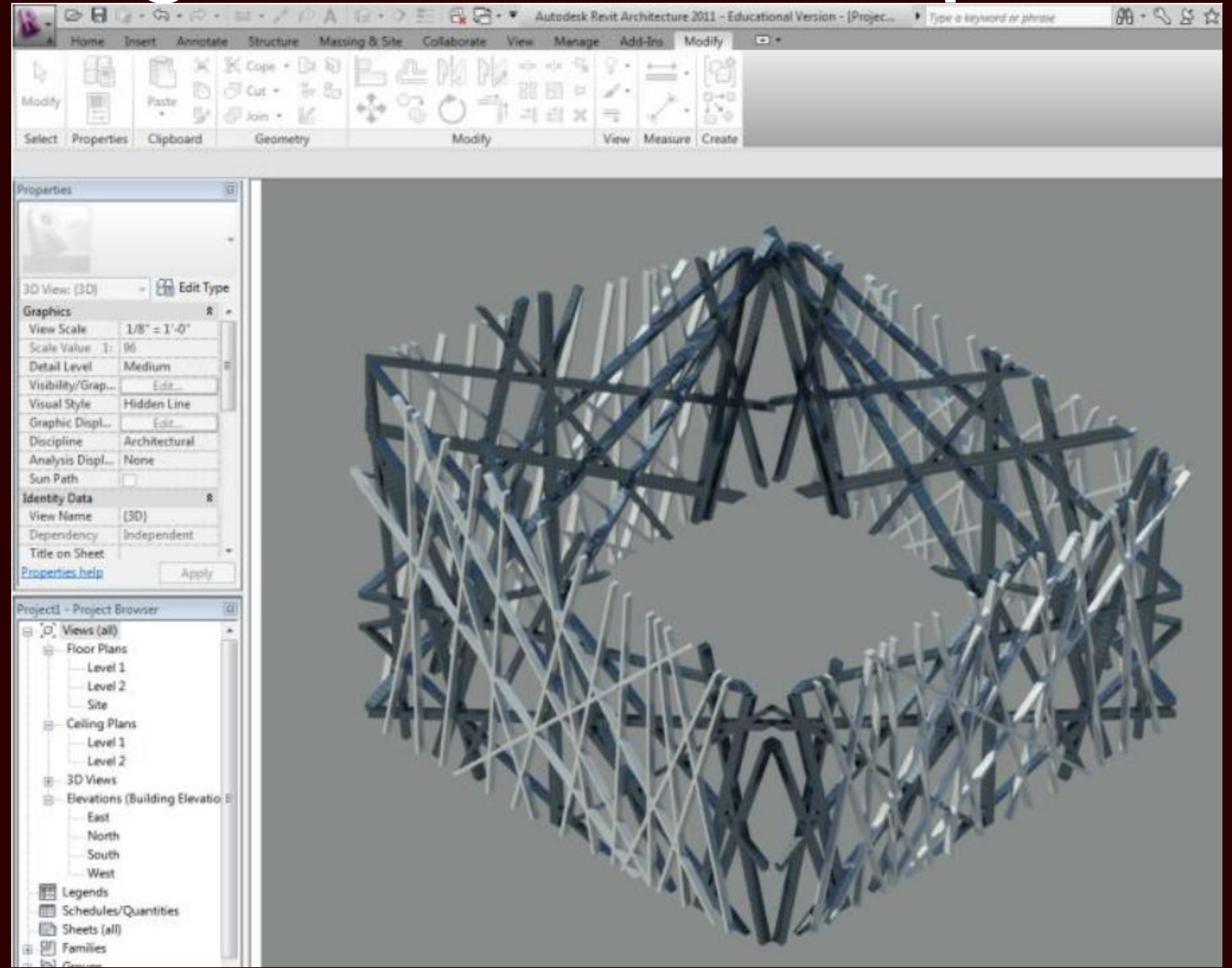
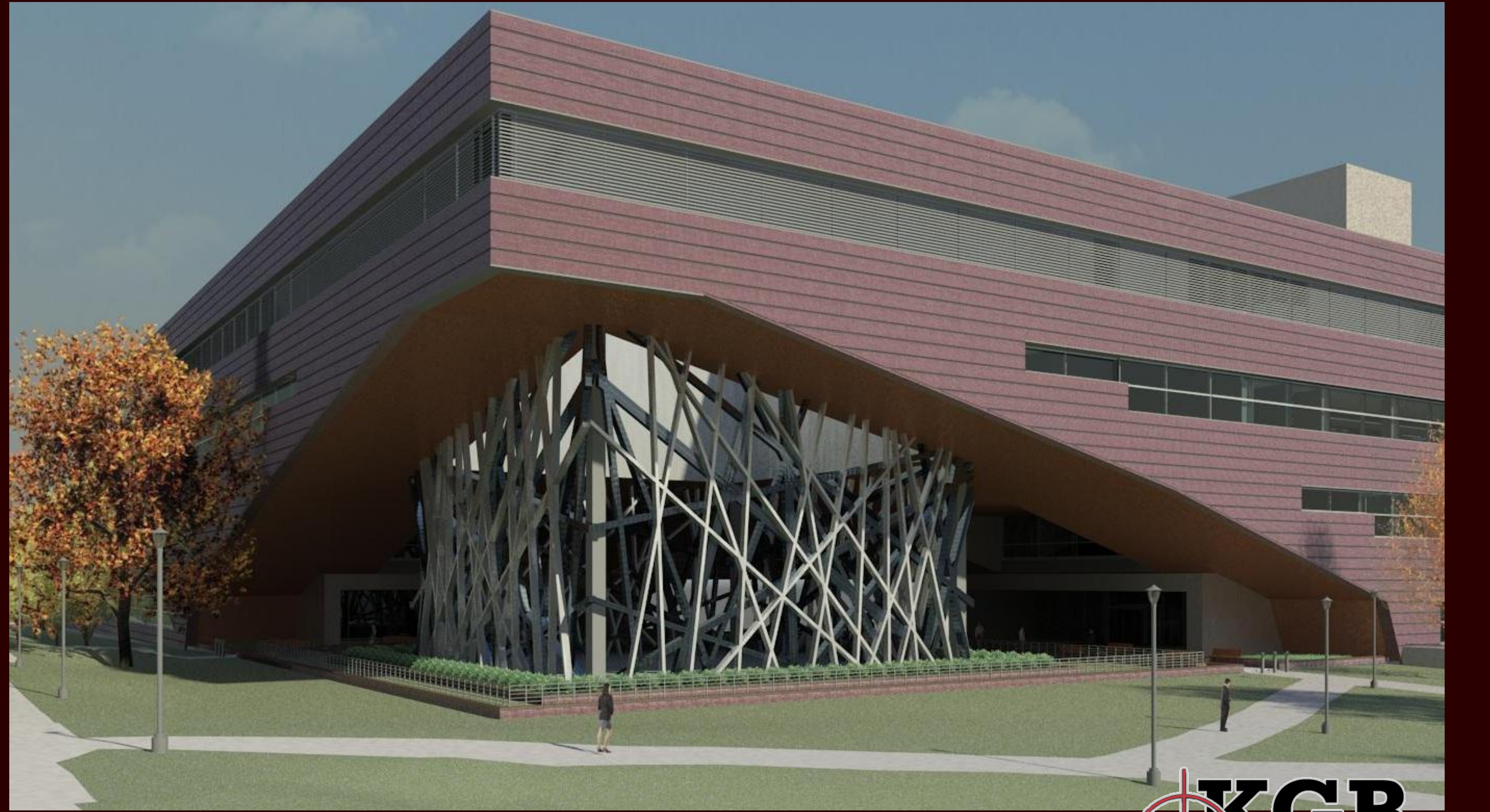
Cage Structure Development







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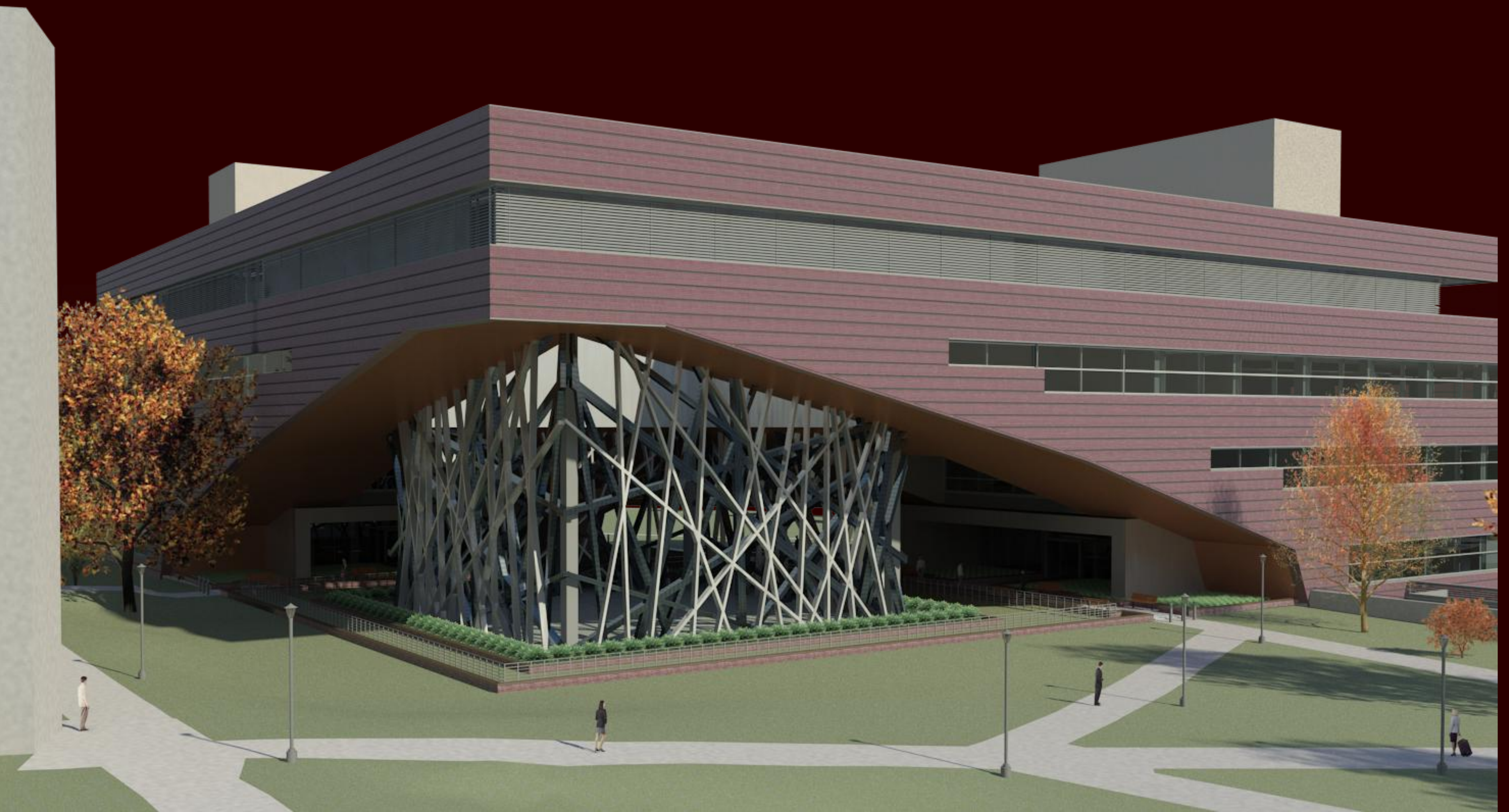
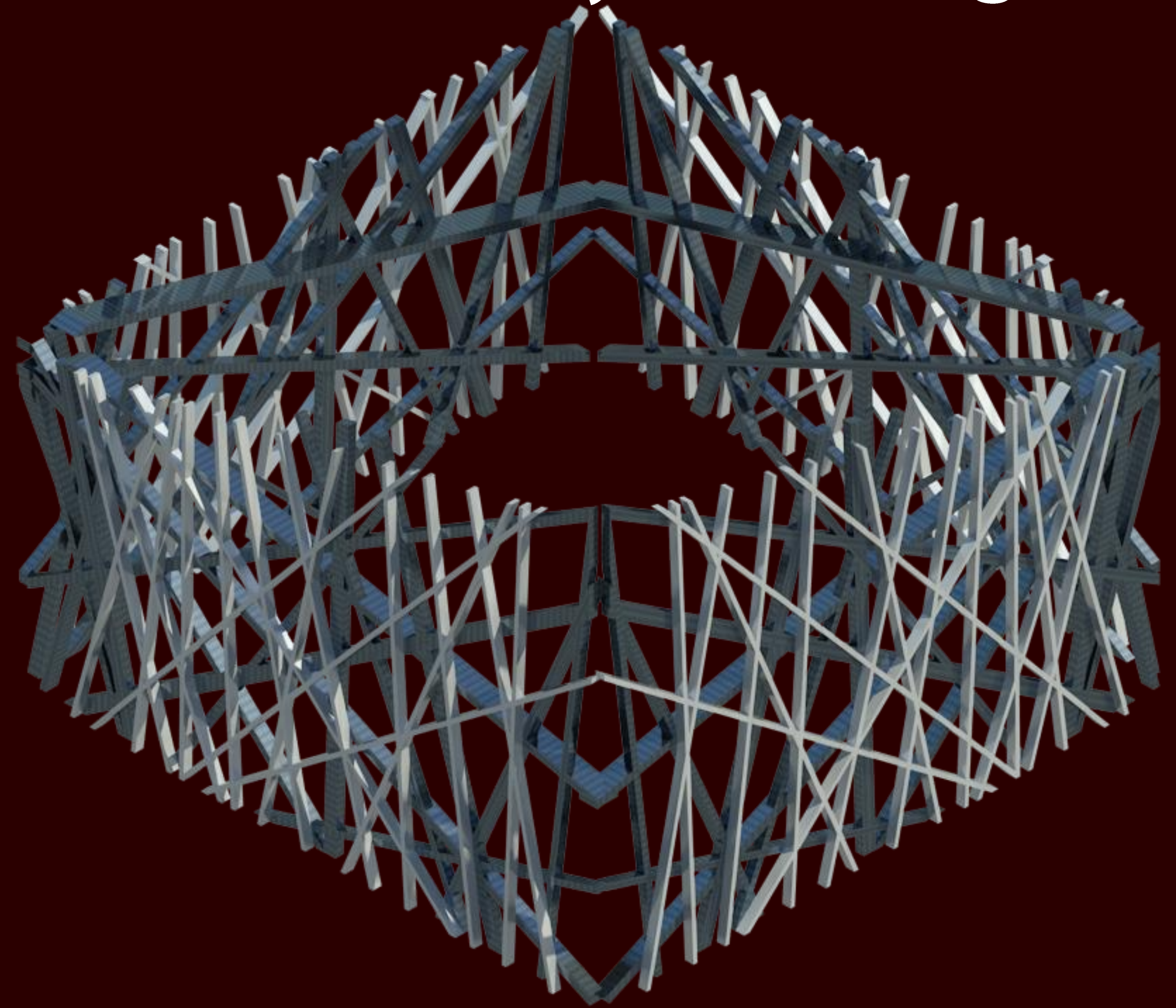
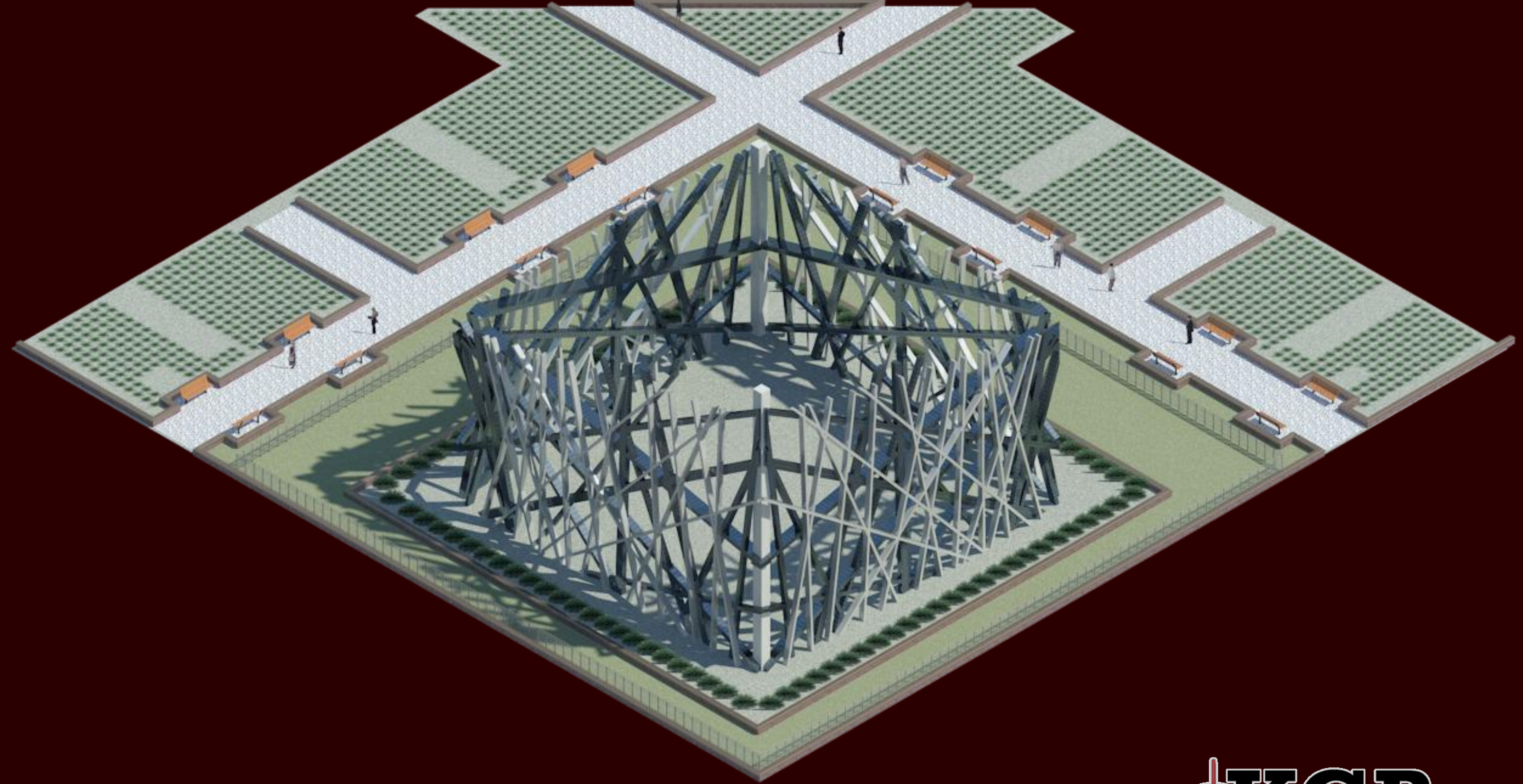
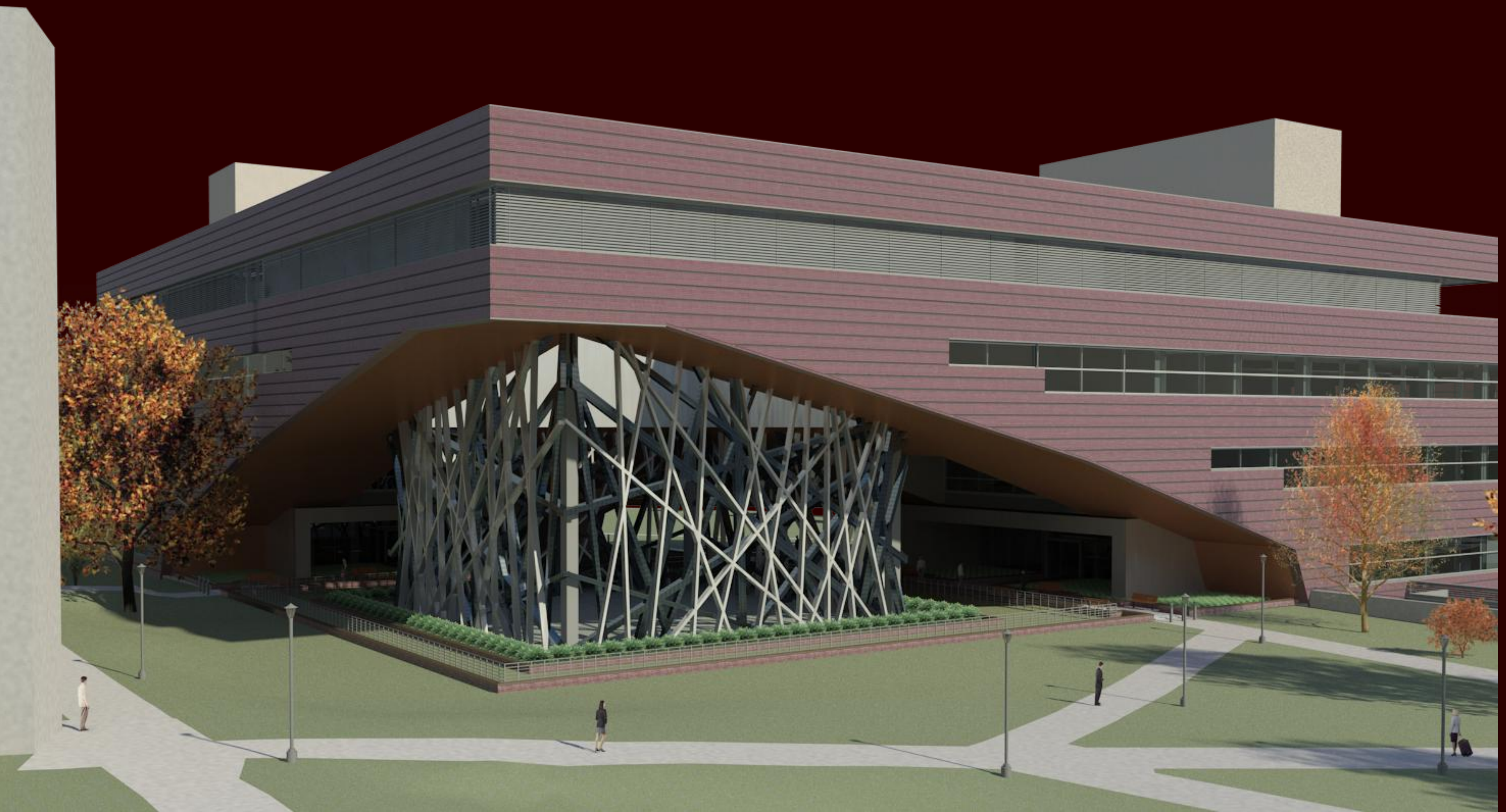
Final Courtyard Design





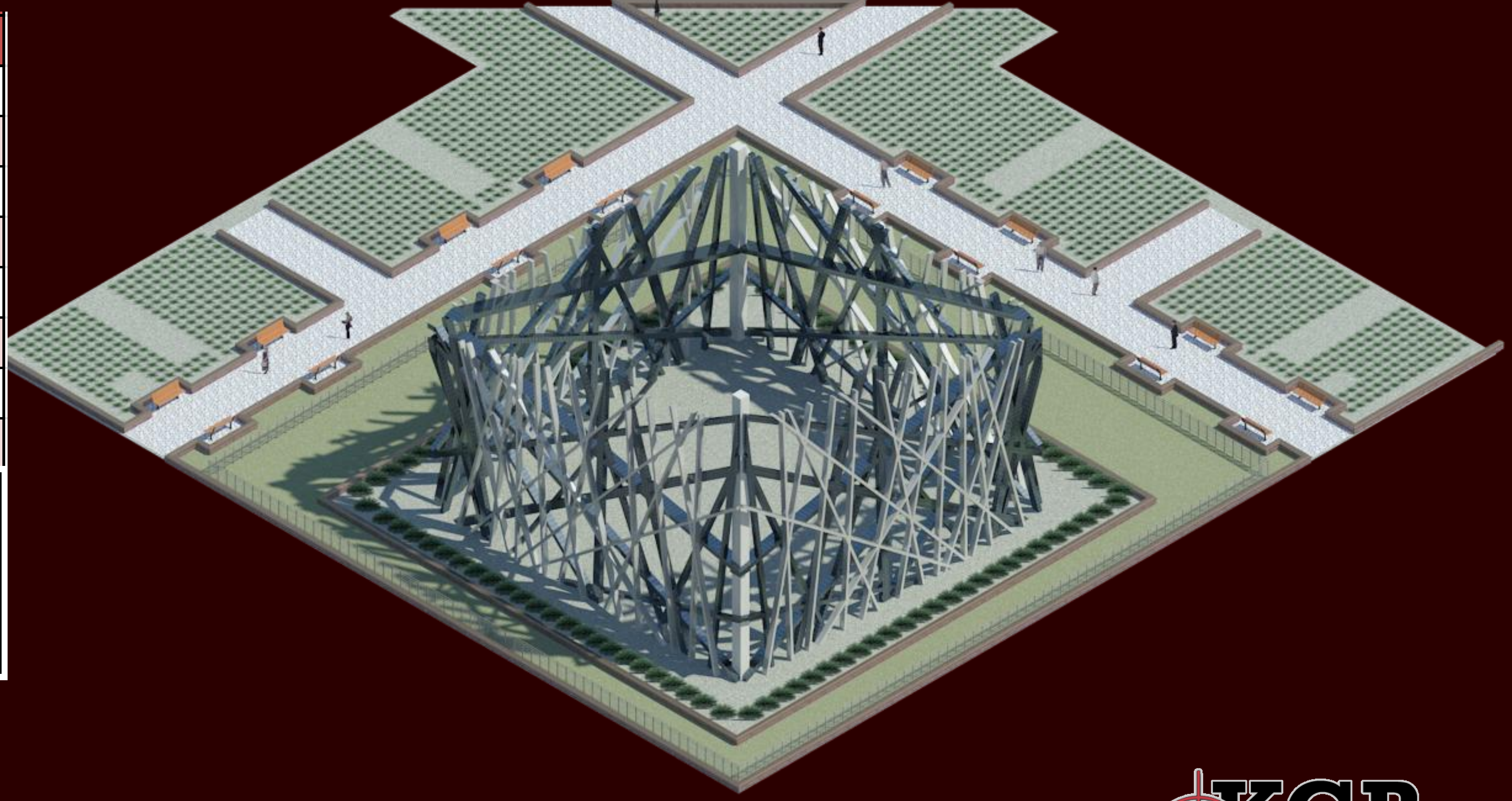


Final Courtyard Design

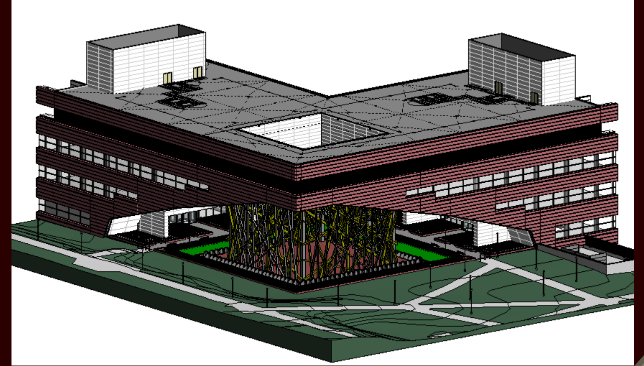


Type	Total	Unit	Total	Unit	Cost
RPC Shrub: Acacia 3'-6"	101	EA	63.8	EA	$ 6,443.80
RPC Shrub: Fountain Grass 1'-6"	733	EA	21.01	EA	$ 15,400.33
Basic Wall: Courtyard Path Wall	1617.89	LF	12.34	LF	$ 19,964.76
Park Bench 6'-0"	16	EA	448.5	EA	$ 7,176.00
Courtyard Railing	486.5	LF	22.92	LF	$ 11,150.58
Mulch	14492.05	SF	2.91	SY	$ 1,561.92
Cage Structure	1	EA	1	EA	$ 500,000.00
Courtyard Sod	9356.29	SF	265.95	MSF	$ 2,488.31

Total Including O & P,
Delivery, Waste, & Time
Modifications = **$866,984.16**

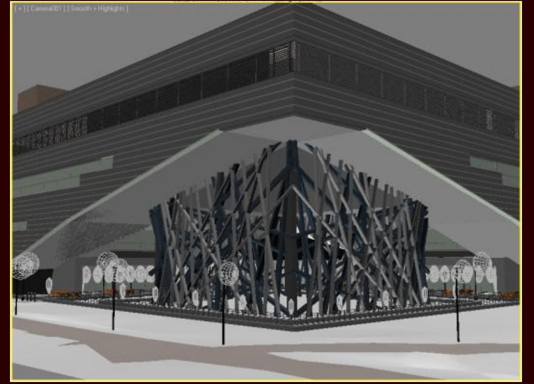


Final Courtyard Design
Lighting

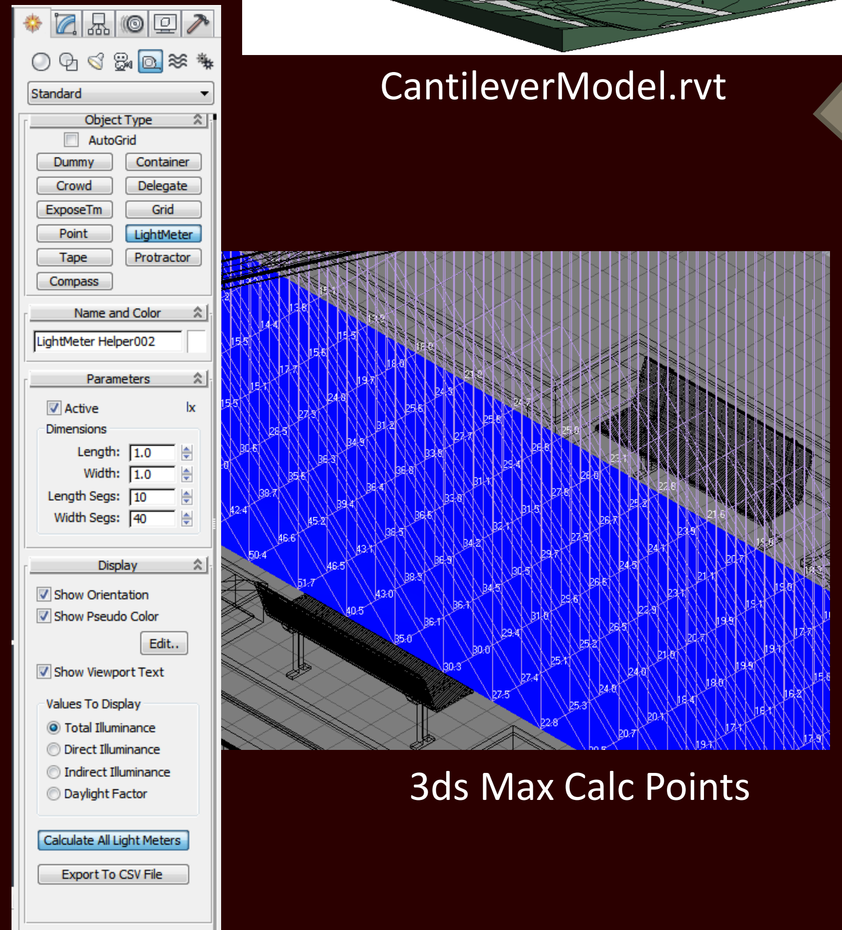


CantileverModel.rvt

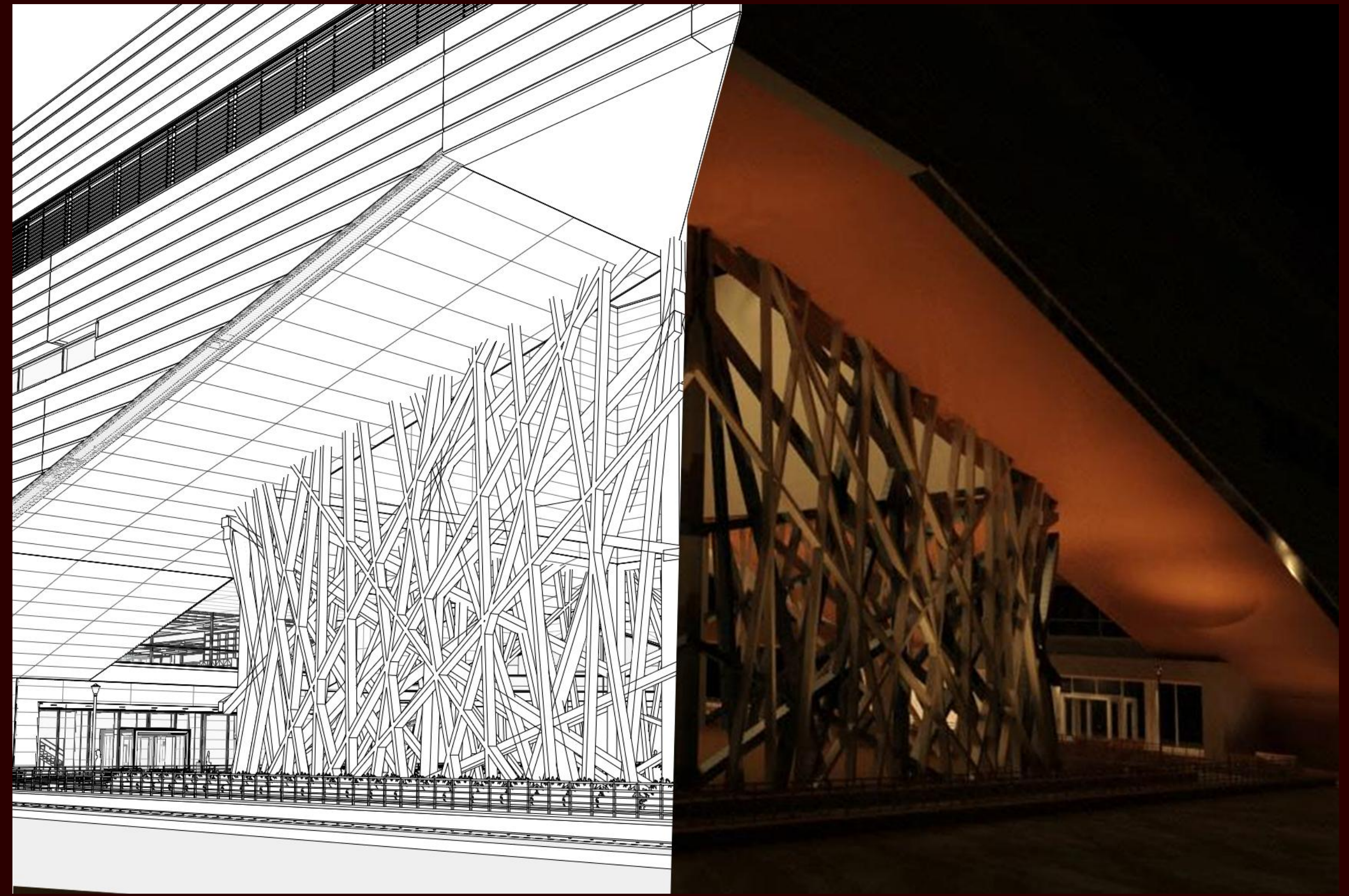
Export from Revit as Cantilever.fbx;
Import to 3ds Max Design with File Link Manager

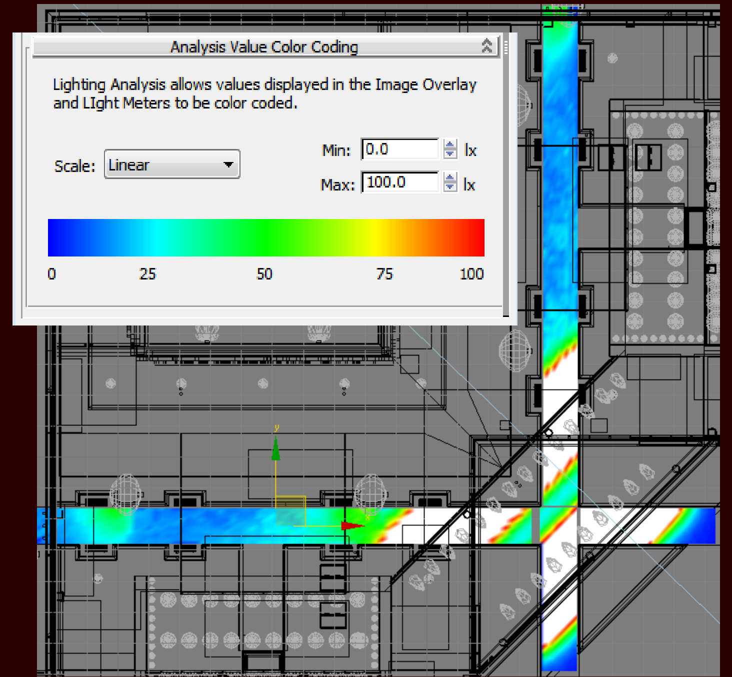


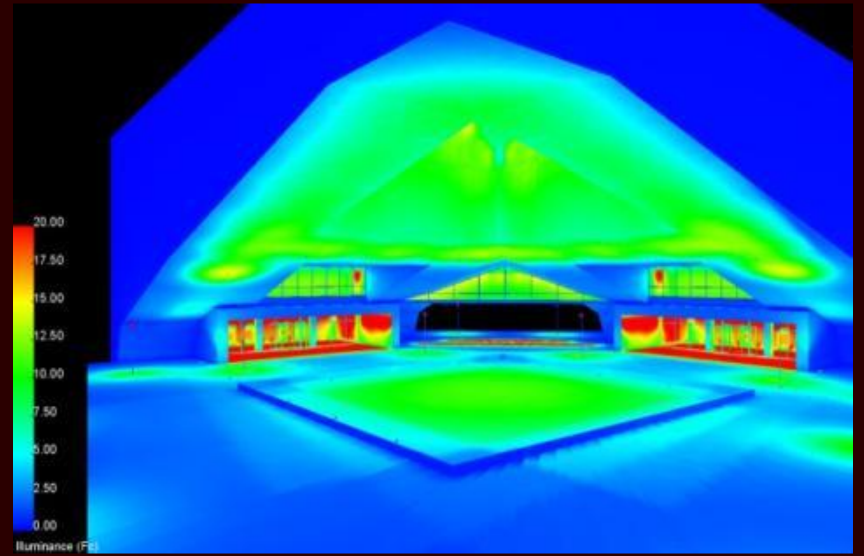
CantileverModel.max



3ds Max Calc Points







Courtyard Illuminance Summary									
Calculation Grid	AGI Illuminance (fc)			3ds Illuminance (fc)			AGI Specific Values		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Max./Min.	Coeff. Of Variation	Uniformity Gradient
Paths	1.10	7.72	63.20	0.102	23.15	59.00	57.45	1.16	3.10
LS Interior Well	1.90	10.32	72.40	Not Measured			38.11	0.59	13.30
LS Exterior Well	1.80	9.33	39.10				21.72	0.41	7.48
MS Interior Well	1.90	9.91	47.60				25.05	0.49	15.03
MS Exterior Well	2.00	9.68	54.10				27.05	0.51	18.03

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Summary of Cost Implications

SUMMARY OF SYSTEM FIRST COSTS				
	FAÇADE REDESIGN	STRUCTURAL REDESIGN	MECANICAL/ENERGY REDESIGN	COURTYARD REDESIGN
EXISTING COST	$3,295,766	$10,566,550	$19,188,000	$271,745
PROPOSED COST	$3,051,834	$8,275,735	$21,040,000	$604,910
SAVINGS/EXPENSE	$243,932	$2,290,815	$1,852,000	$333,165
TOTAL FIRST COST SAVINGS = $349,582				

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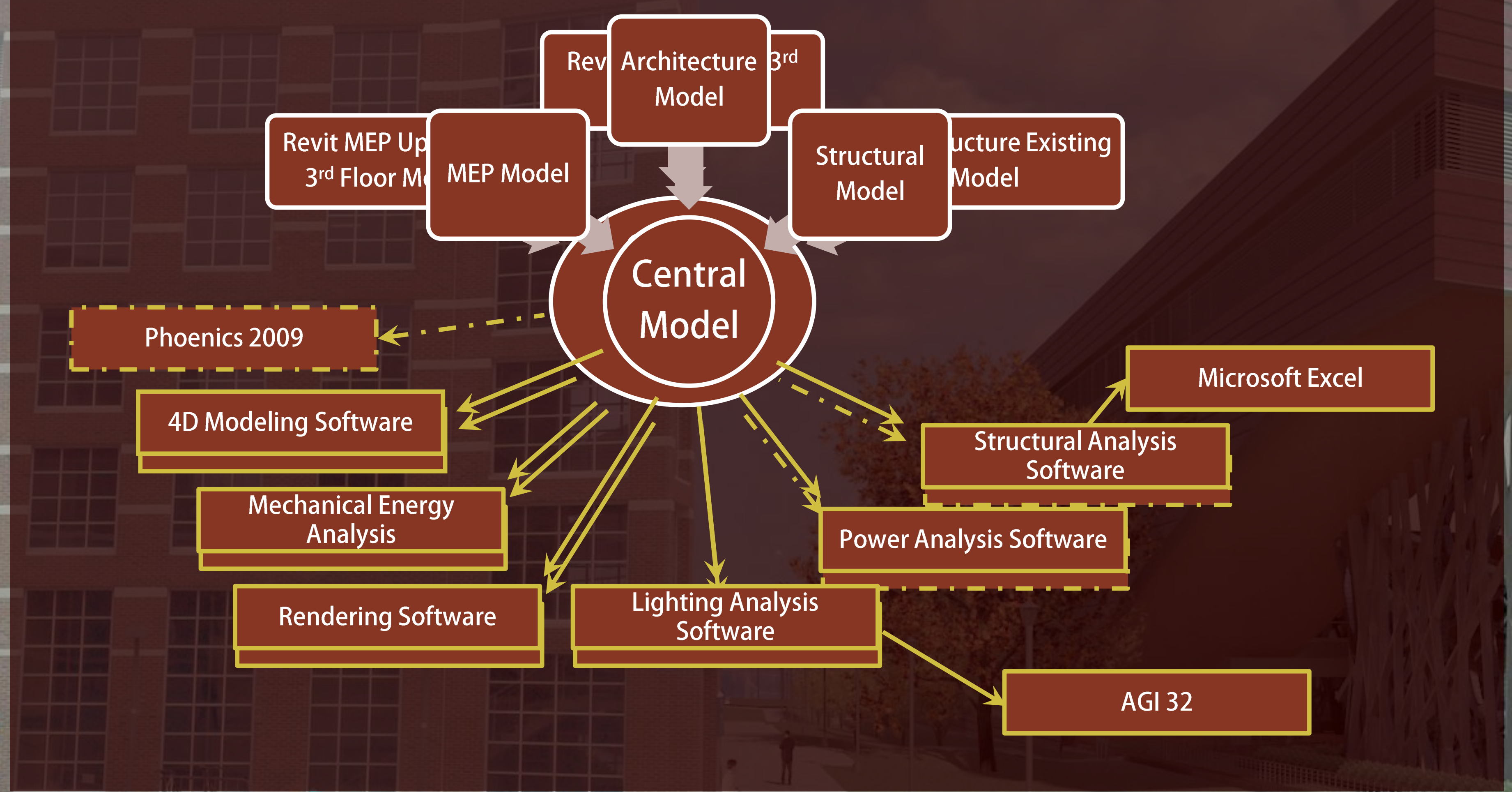
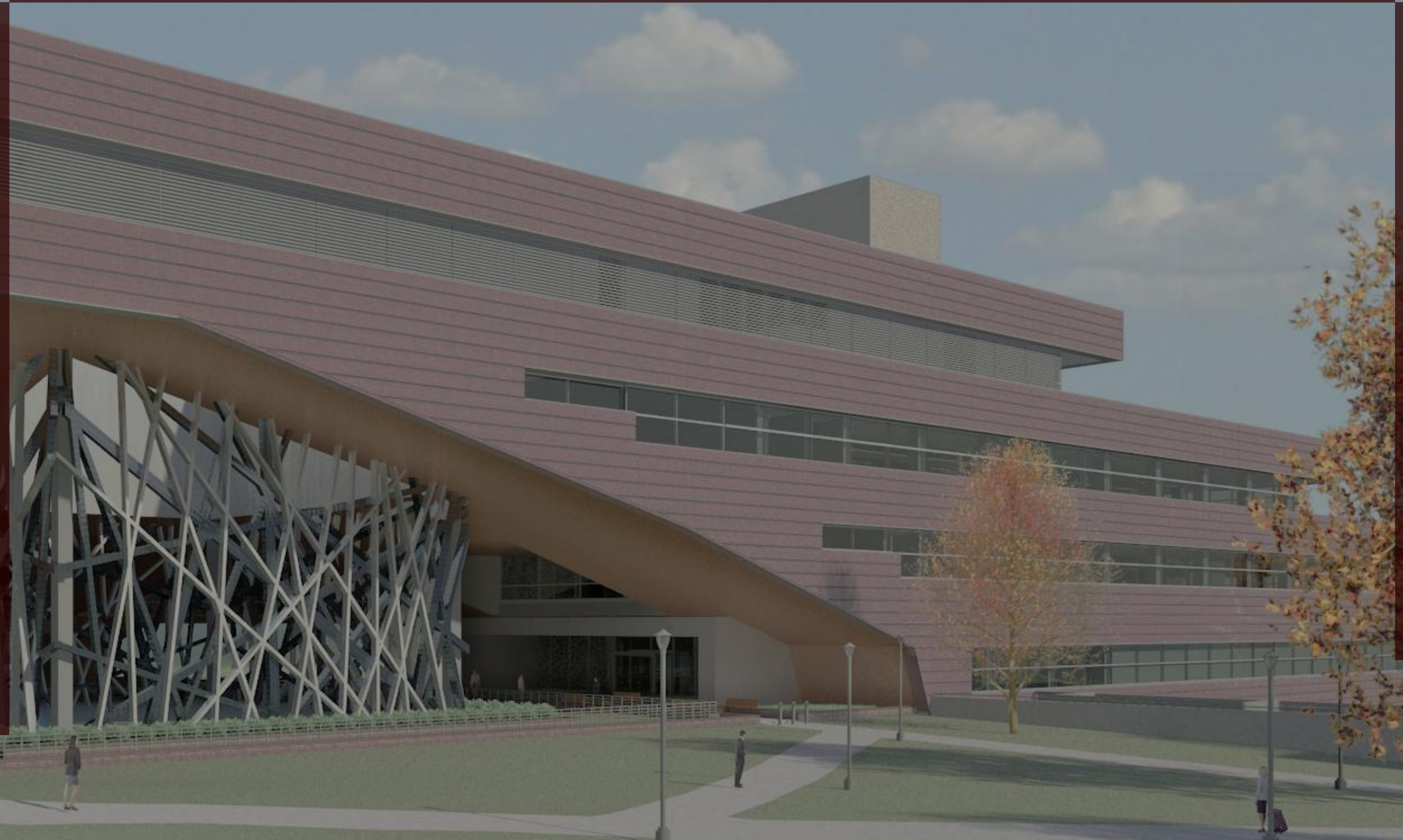
KGB Maser Conclusions





- Decreased energy consumption by 14.2%
- Reduced size and cost of structural system: $2,290,815
- Proposed façade provided marginal operating cost savings and lower initial cost in lighting and structural systems

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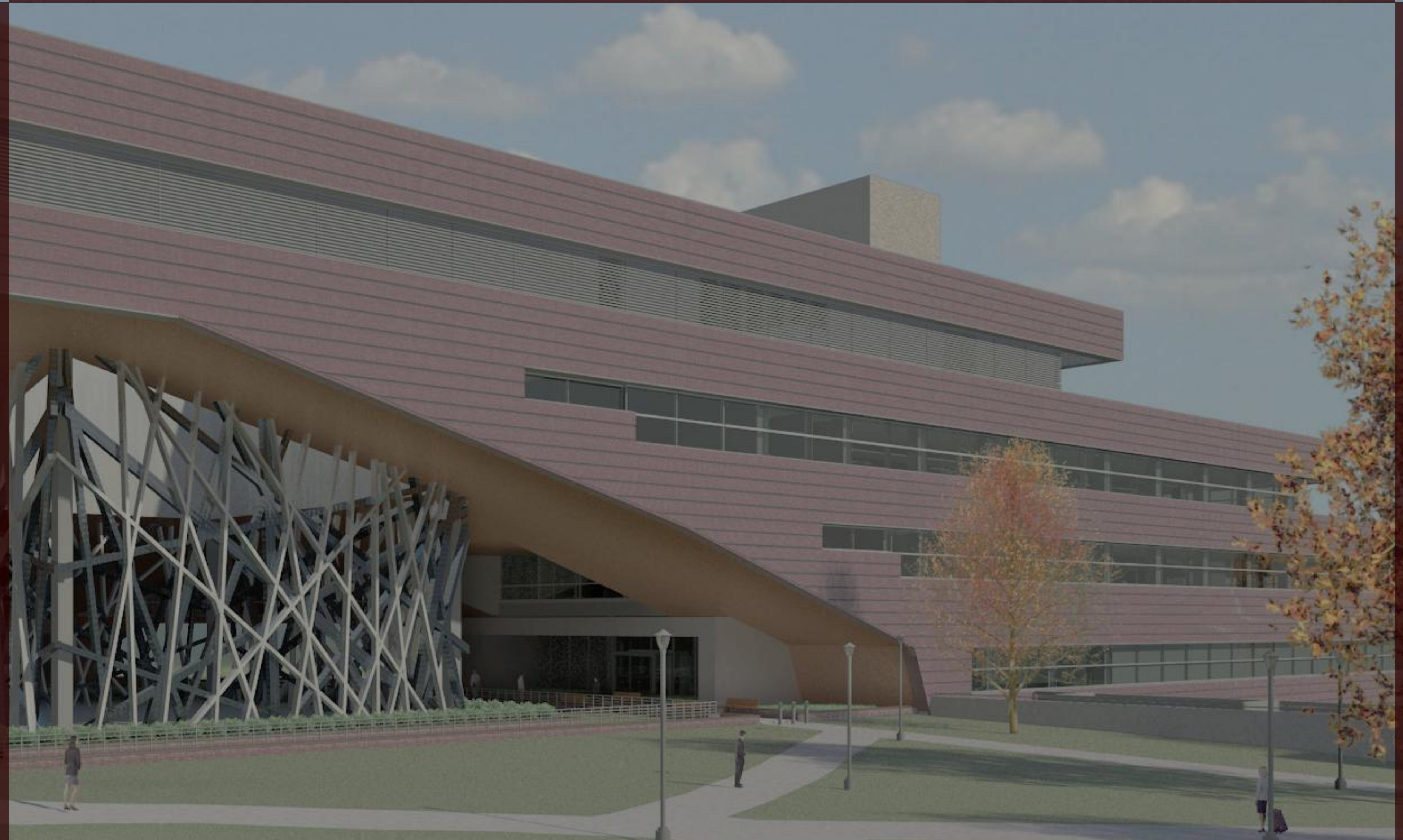
IPD/BIM Lessons Learned

- Must work consistently in **communicative** environment
- Challenging to keep **uniform** group formatting **standards**
- Need to **explain technical reasoning** behind each decision **to all disciplines**



- Adequate time must be allotted for **overcoming** software design issues
- **Not all information** can be shared between modeling platforms; intermediate steps must be taken
- A **higher level of coordination** can be achieved during system designs
- Model sharing is a **one way street** outside of Revit platforms

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Questions and Comments
Thank you for your time
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