The Millennium Science Complex

IPD/BIM Thesis

2010-2011

Team
BIM*ception*

Pfund Russell Stough Villacampa

BIM*ception* Introduction

Stephen Pfund – Structural

Christopher Russell – Lighting/Electrical

Alexander Stough – Mechanical

Thomas Villacampa – Construction Manager

BIM*ception* is dedicated to improving design through innovation and coordination.

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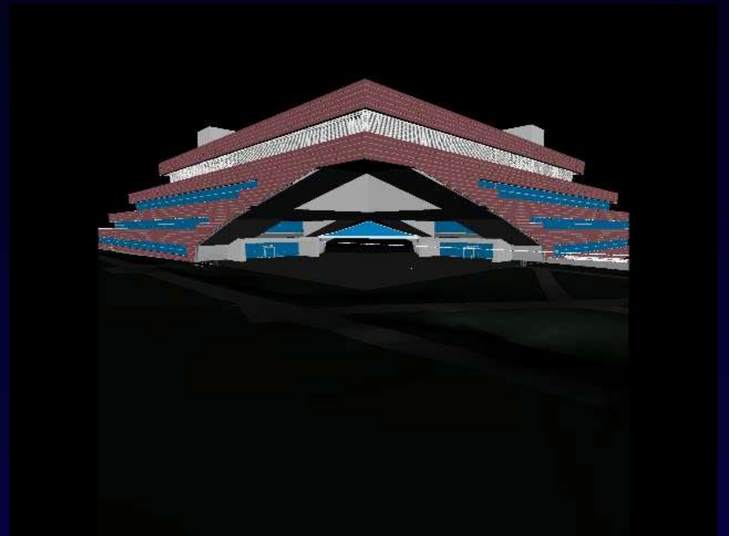
Project Background

- Owner: The Pennsylvania State University
- Location: University Park, Pa
- 275,600 SF Research Facility containing the Huck Institutes for Life Sciences and Material Sciences
- LEED Certification
- 20,000 SF of Vivarium Space
- 40,000 SF of Quiet Lab Space
- 9,500 SF of Nana-Clean Lab Space



BIMception

Building Info
Façade Investigation
Plenum Investigation
Cantilever Plaza
IPD/BIM Reflection

Depth Introduction

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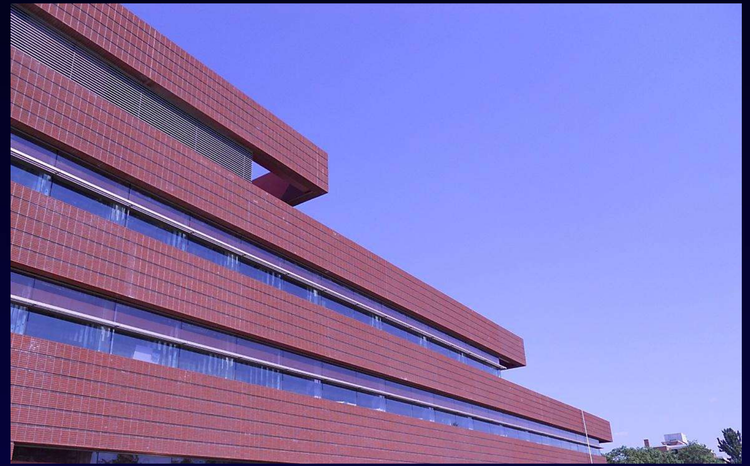
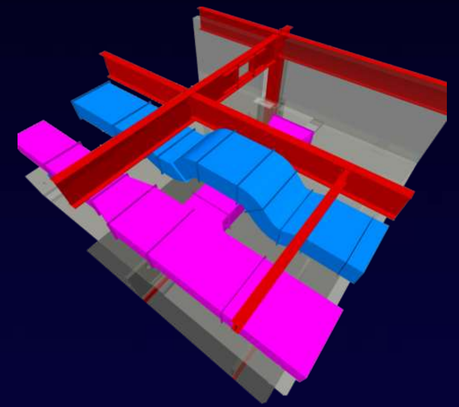
Depth Introduction

- Façade Investigation



Depth Introduction

- Façade Investigation
- Plenum Investigation



Depth Introduction

- Façade Investigation
- Plenum Investigation
- Cantilever Plaza Investigation

Electrical Depth

- (19) Individually Eaton Powerware UPS without Battery Rack
- (1) Eaton Sag Ride Through Central Power Conditioner
- (1) Additional 1200A Panelboard
- First Floor Elec. Closet N-P129

Electrical Depth

- System Cost Comparison
- Voltage Drop Check

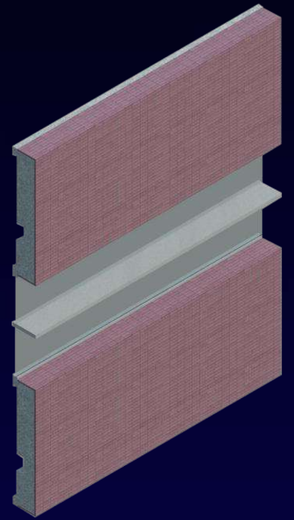
Overall Price Comparison	
System	Total Price
Existing Eaton Powerware UPSs	$794,625.30
New Eaton SRT Central Power Conditioning	$665,540.80

Cost Data Obtained From Eaton and RSMEANS

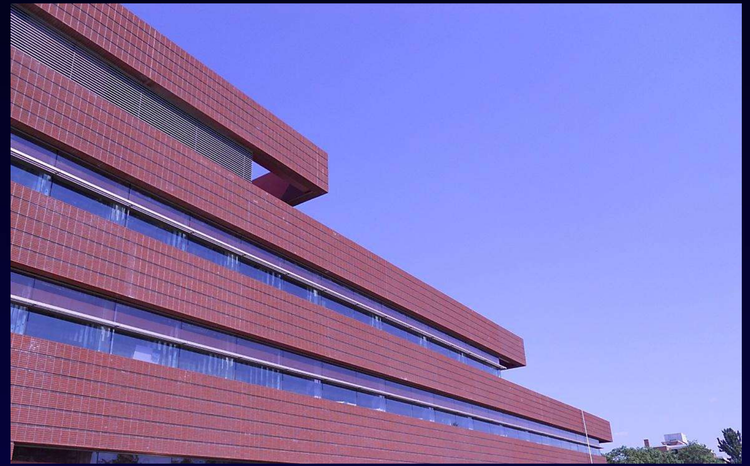
Electrical Depth

- Eaton Powerware without Battery Rack
- Space Limitations
- Future Flexibility and Expansion

Façade Investigation



Facade Analyses



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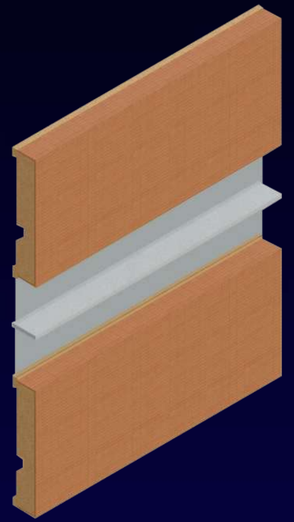

Facade Analyses

- Wall Composition Analysis

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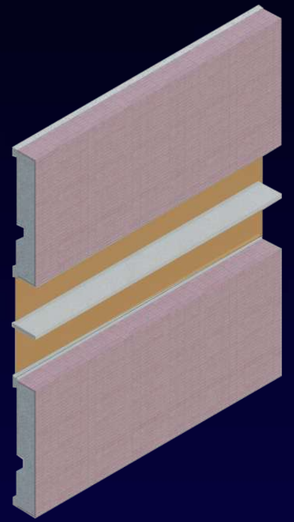
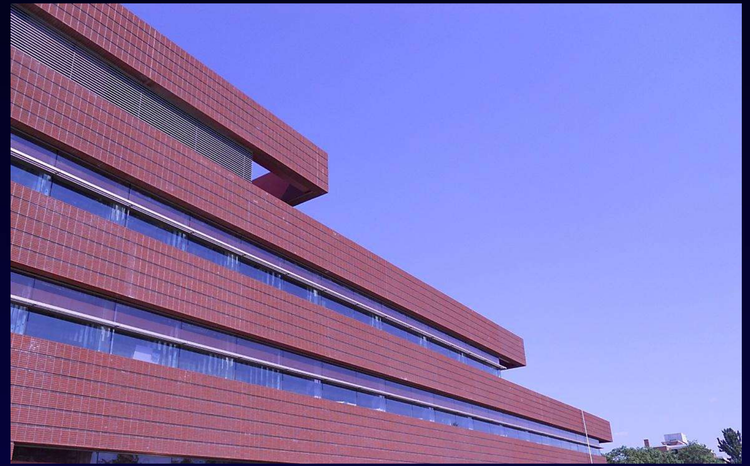


Facade Analyses

- Wall Composition Analysis
- Window to Wall Ratio Analysis



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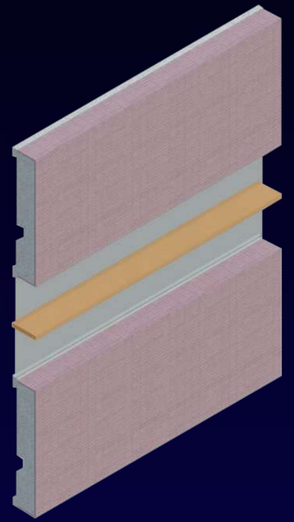
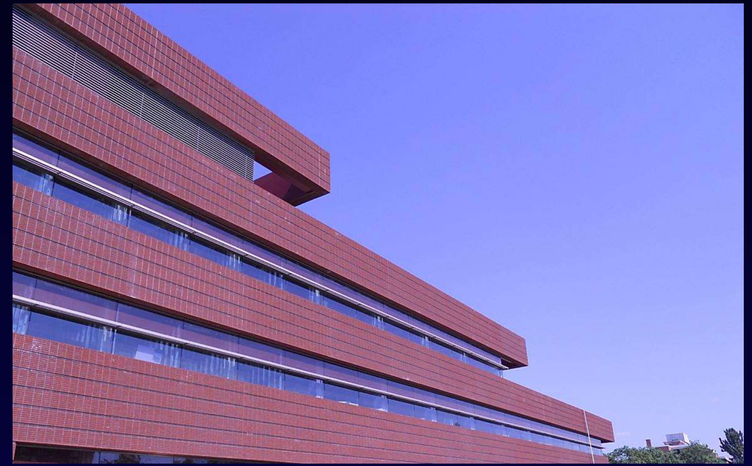
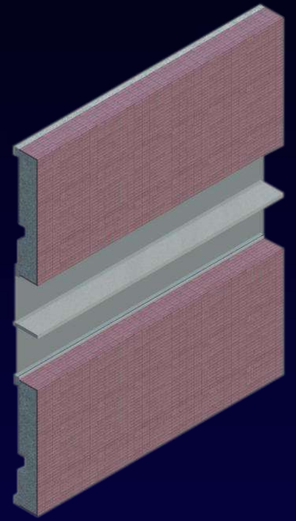


Facade Analyses

- Wall Composition Analysis
- Window to Wall Ratio Analysis
- Shade Analysis



Wall Composition Analysis



Existing Building Enclosure

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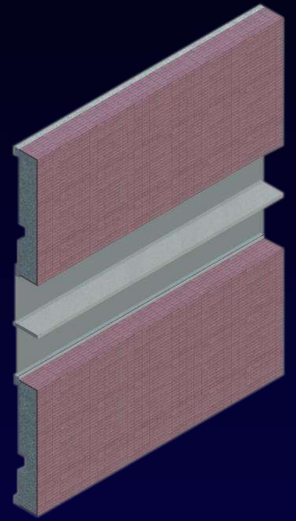
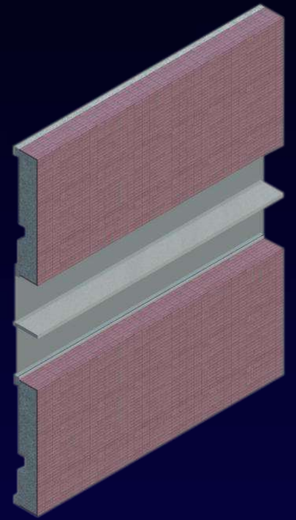


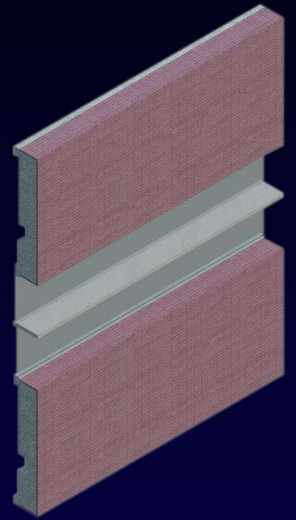
Existing Building Enclosure

- Double Pane Low-e Glazing



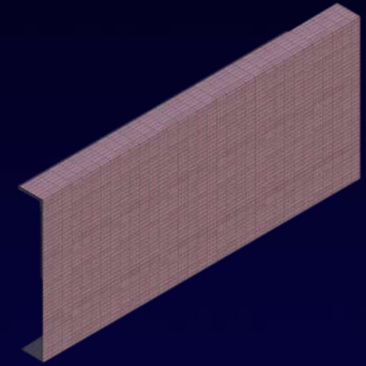
Existing Building Enclosure

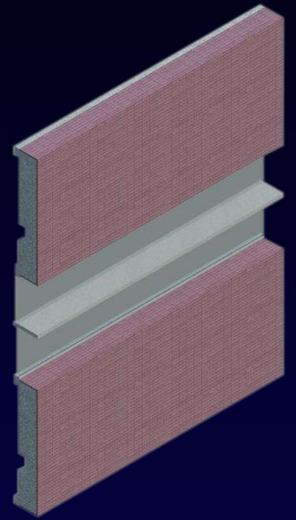
- Double Pane Low-e Glazing
- 24” Overhang and Shelf



Existing Building Enclosure

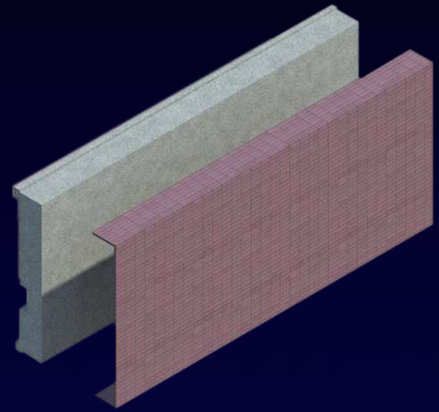
- Double Pane Low-e Glazing
- 24” Overhang and Shelf
- 2” Face Brick

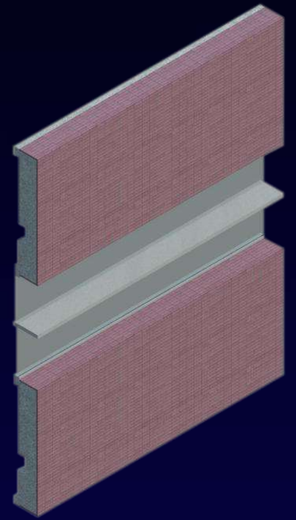




Existing Building Enclosure

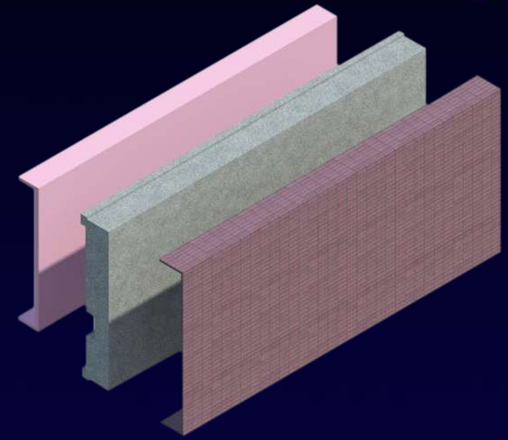
- Double Pane Low-e Glazing
- 24” Overhang and Shelf
- 2” Face Brick
- 6” C-Panel with Side Returns

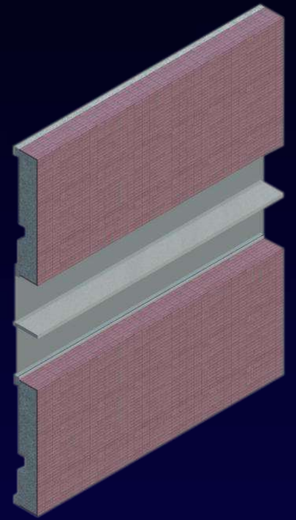




Existing Building Enclosure

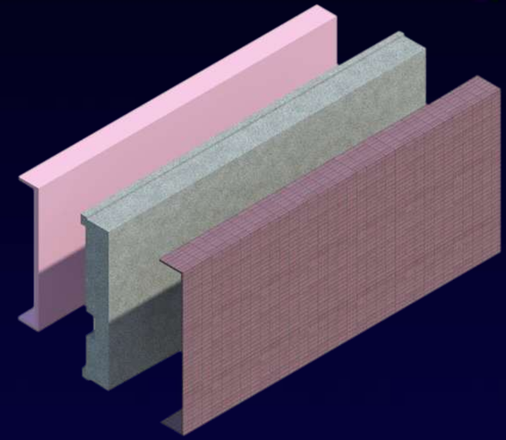
- Double Pane Low-e Glazing
- 24” Overhang and Shelf
- 2” Face Brick
- 6” C-Panel with Side Returns
- 3” Rigid Insulation

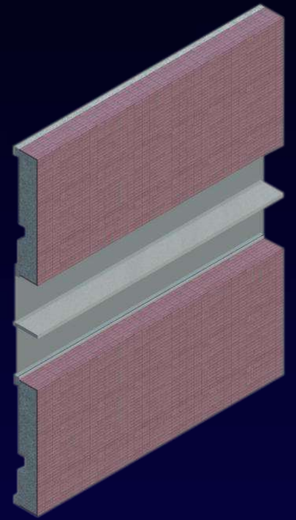




Existing Building Enclosure

- Double Pane Low-e Glazing
- 24” Overhang and Shelf
- 2” Face Brick
- 6” C-Panel with Side Returns
- 3” Rigid Insulation
- Bearing Connections in Side Returns





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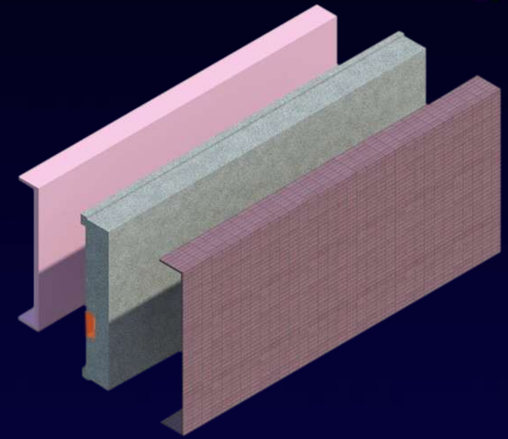
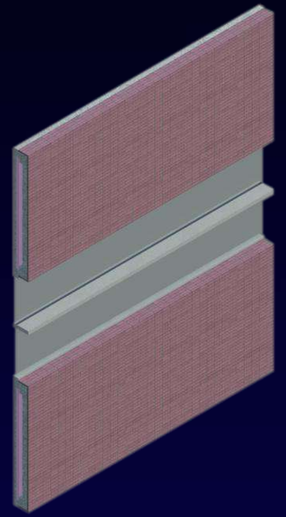
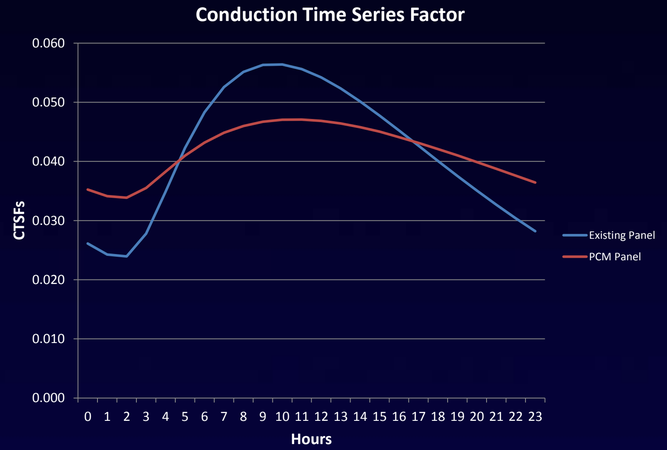
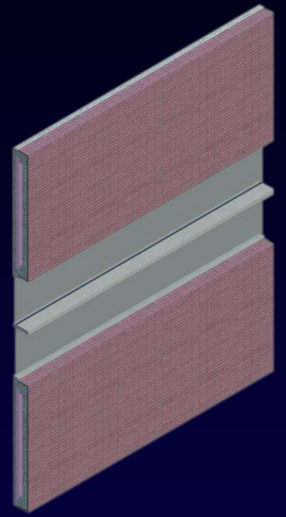




PCM Façade Assembly

- Phase Change Material
  - BASF Micronal PCM
- Improve Energy Performance
- Improve Thermal Heat Capacity
- Flatten External Building Loads





PCM Façade Assembly

- Triple Pane Low-e Glazing

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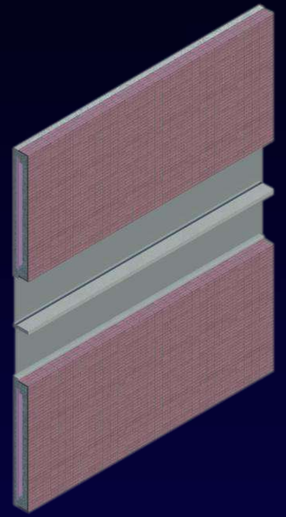
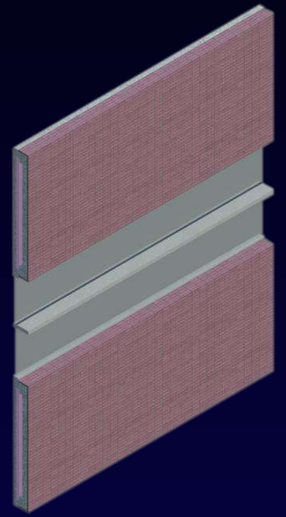


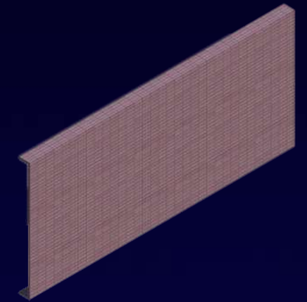
PCM Façade Assembly

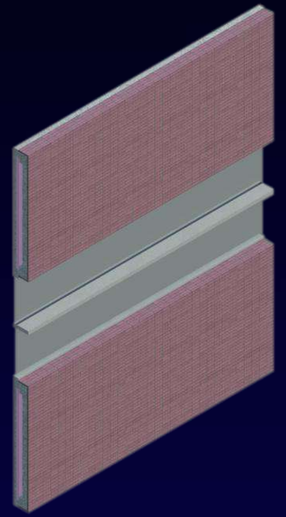
- Triple Pane Low-e Glazing
- 16” Overhang and Shelf



PCM Façade Assembly

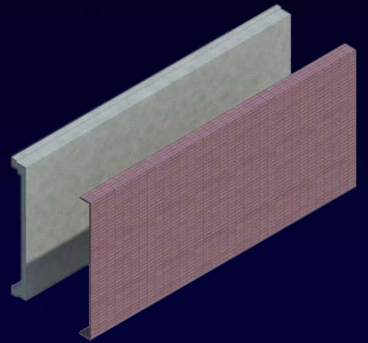
- Triple Pane Low-e Glazing
- 16” Overhang and Shelf
- 2” Face Brick

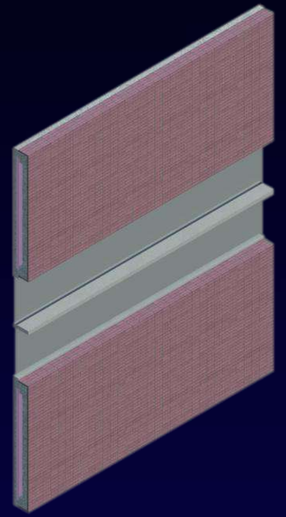




PCM Façade Assembly

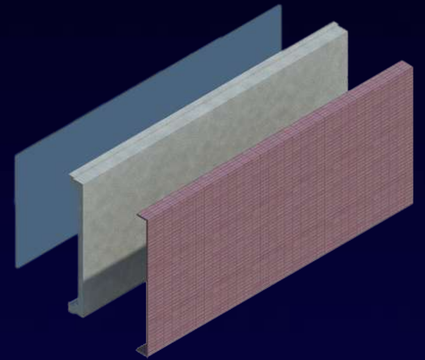
- Triple Pane Low-e Glazing
- 16” Overhang and Shelf
- 2” Face Brick
- 3” Concrete Panel

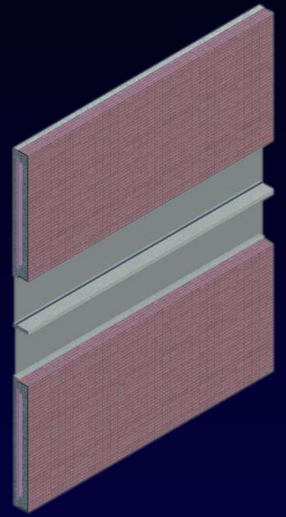




PCM Façade Assembly

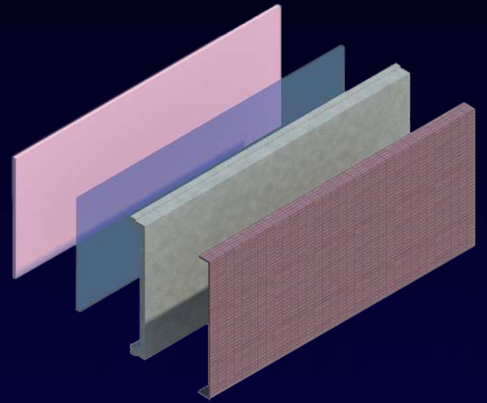
- Triple Pane Low-e Glazing
- 16” Overhang and Shelf
- 2” Face Brick
- 3” Concrete Panel
- 3.5” Air Space

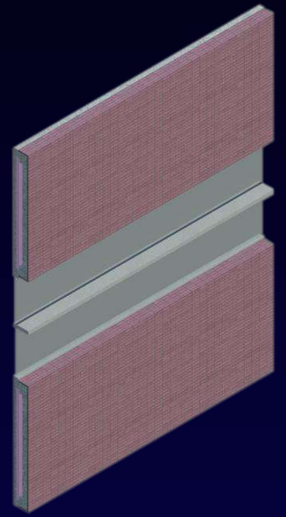




PCM Façade Assembly

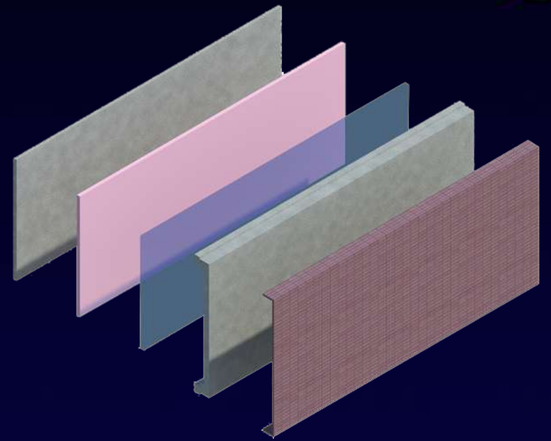
- Triple Pane Low-e Glazing
- 16” Overhang and Shelf
- 2” Face Brick
- 3” Concrete Panel
- 3.5” Air Space
- 3” Rigid Insulation

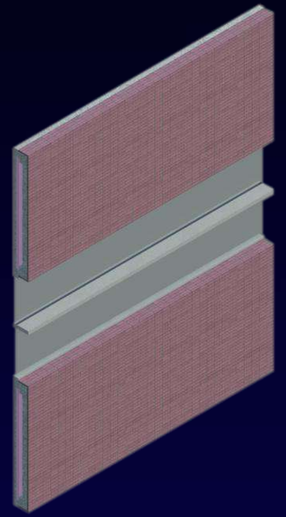




PCM Façade Assembly

- Triple Pane Low-e Glazing
- 16” Overhang and Shelf
- 2” Face Brick
- 3” Concrete Panel
- 3.5” Air Space
- 3” Rigid Insulation
- 3” PCM Panel





Façade energy Analysis

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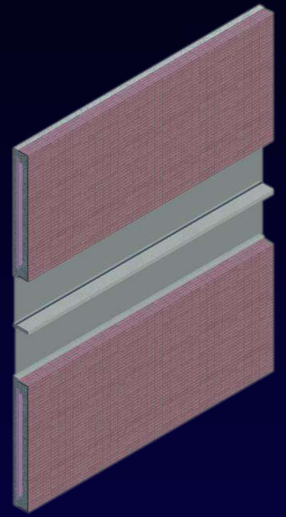
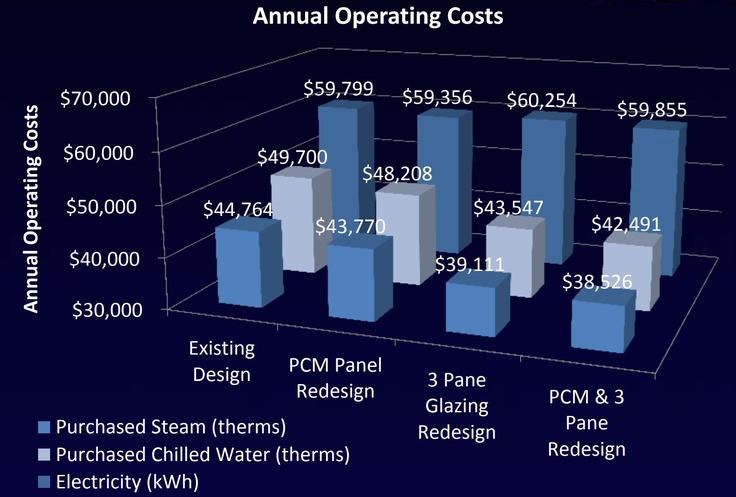


Façade energy Analysis



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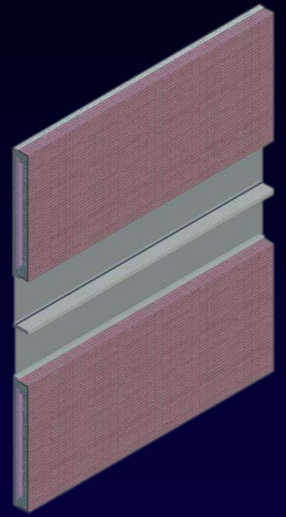
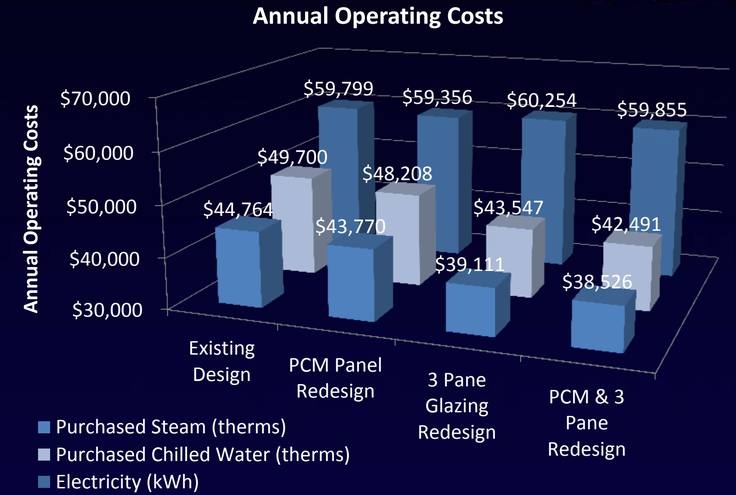
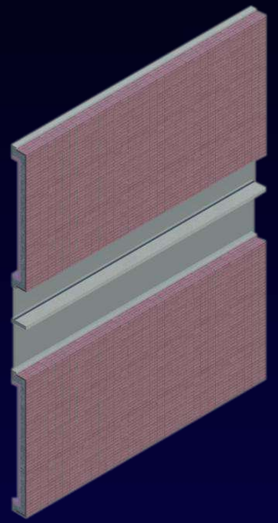


PCM Façade Rejection

- Minimal Energy Savings
- Transportation/ Erection
- Structural Thickness Limitations
- Cost of Additional Materials





Final Assembly Selection

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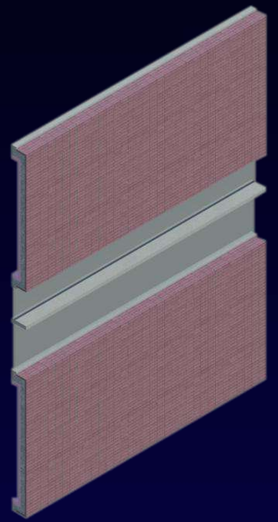
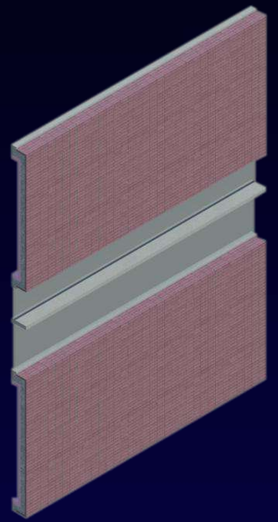


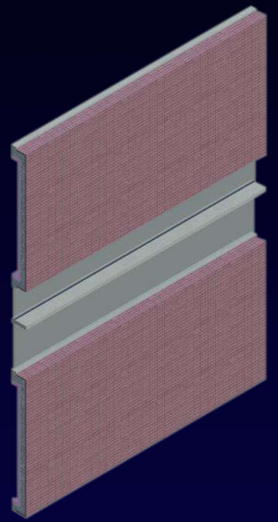
Final Assembly Selection

- Triple Pane Low-e Glazing



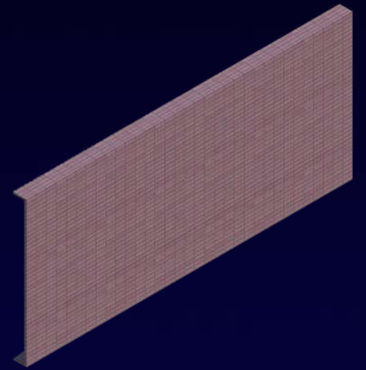
Final Assembly Selection

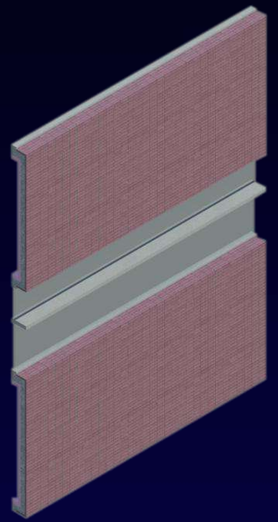
- Triple Pane Low-e Glazing
- 16” Overhang and Shelf



Final Assembly Selection

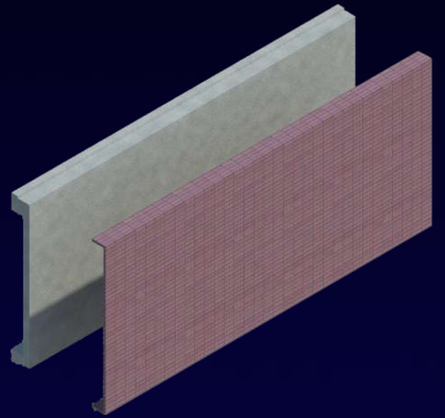
- Triple Pane Low-e Glazing
- 16” Overhang and Shelf
- 2” Face Brick

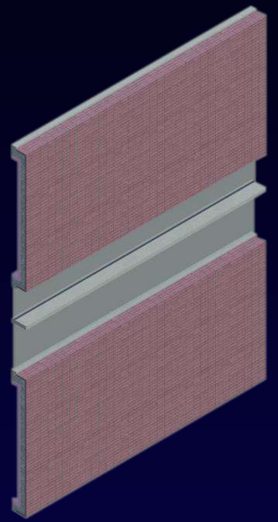




Final Assembly Selection

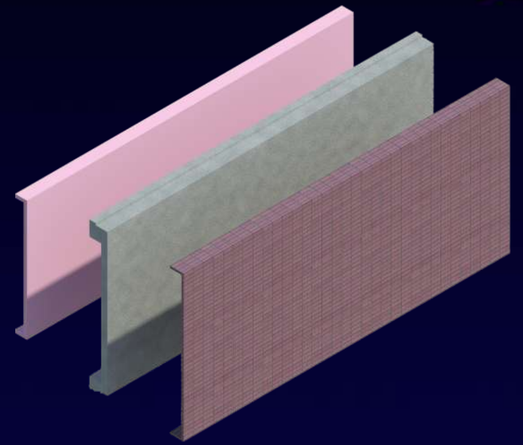
- Triple Pane Low-e Glazing
- 16” Overhang and Shelf
- 2” Face Brick
- 6” C-Panel

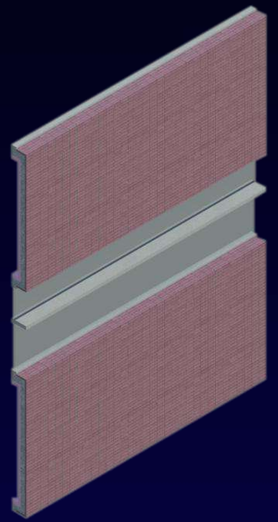




Final Assembly Selection

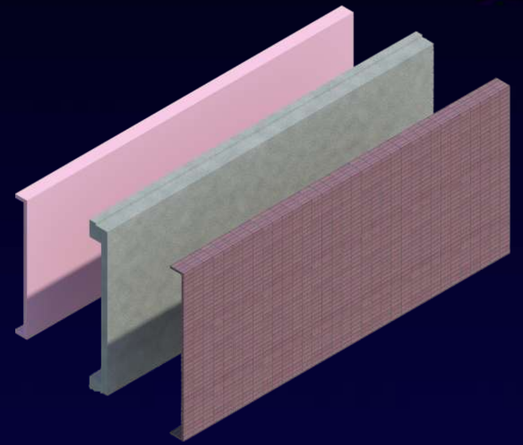
- Triple Pane Low-e Glazing
- 16” Overhang and Shelf
- 2” Face Brick
- 6” C-Panel
- 3” Rigid Insulation

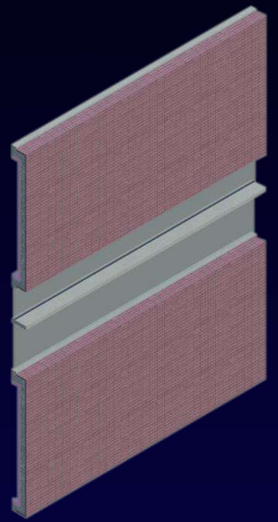




Final Assembly Selection

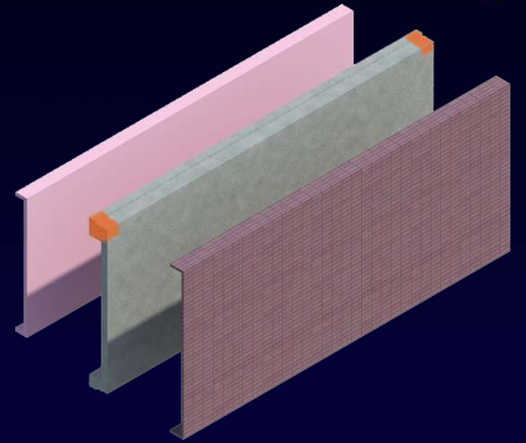
- Triple Pane Low-e Glazing
- 16” Overhang and Shelf
- 2” Face Brick
- 6” C-Panel
- 3” Rigid Insulation
- Bearing Connections Relocated to Top Return

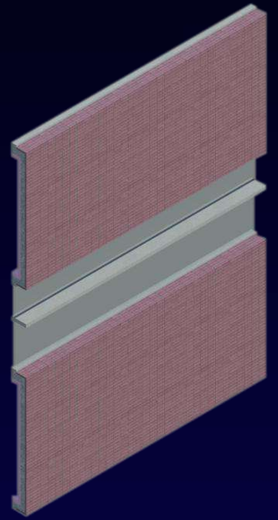




Final Assembly Selection

- Triple Pane Low-e Glazing
- 16” Overhang and Shelf
- 2” Face Brick
- 6” C-Panel
- 3” Rigid Insulation
- Bearing Connections Relocated to Top Return

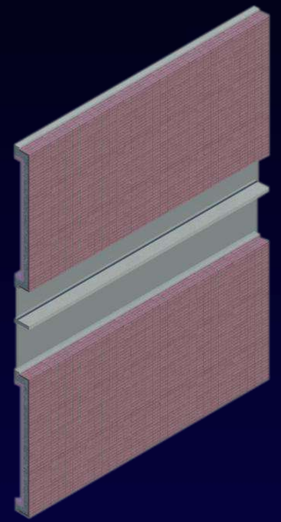




Life Cycle Cost

Third Floor, Existing Panels		
Length of Panel	2-Pane Glass Assembly	3-Pane Glass Assembly
22ft	$1,496,443	$1,587,963
14ft	$41,091	$43,331
31ft	$78,510	$83,470
Total	**$1,616,044**	**$1,714,764**
Increased Cost of 3-Pane	**$98,720**	

$98,720 more for 3-Pane Glazing



Life Cycle Cost

	Existing	*Triple Pane Glazing*	*Savings*
Total Yearly Operating Costs	*$154,262*	*$142,912*	*$11,350*
Installation Costs	*$1,616,044*	*$1,714,764*	*$-98,720*
30 yr Life Cycle Cost	*$5,591,498*	*$5,397,713*	*$193,785*

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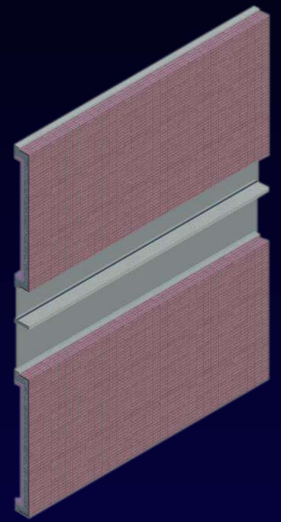
Includes fuel escalation and inflation

Pfund Russell Stough Villacampa



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8.7 Year Simple Payback

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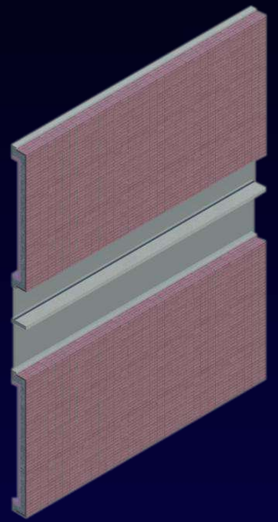
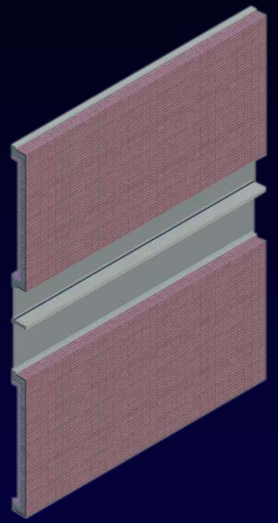
Pfund Russell Stough Villacampa

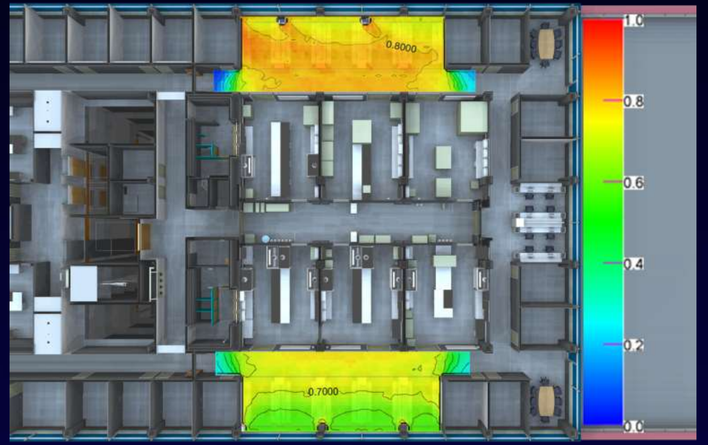


Existing Conditions

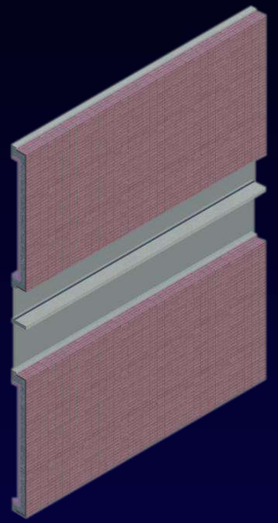
- WWR =70%
- Transmittance = 72%
- U-Value = 0.41
- SHGC = 0.37



Useful Illuminance



Existing Conditions



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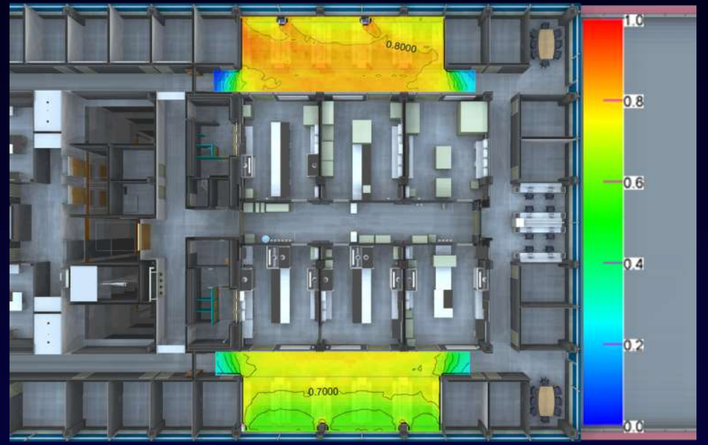

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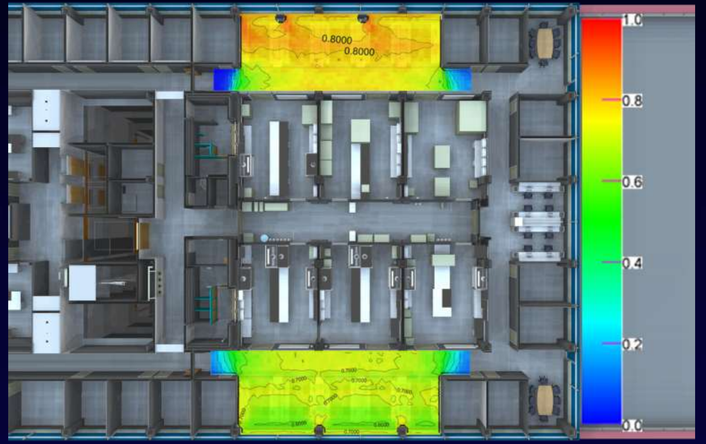
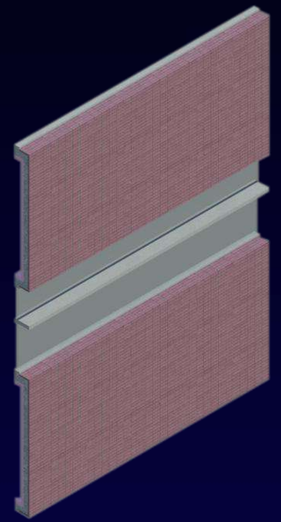


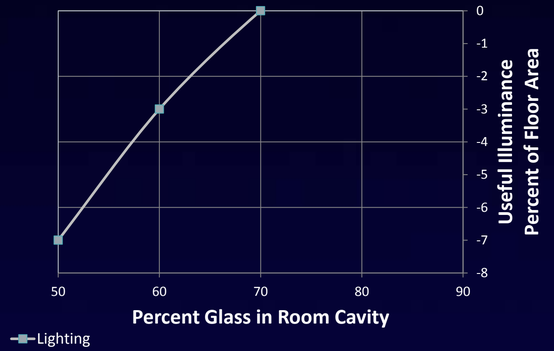
60% WWR

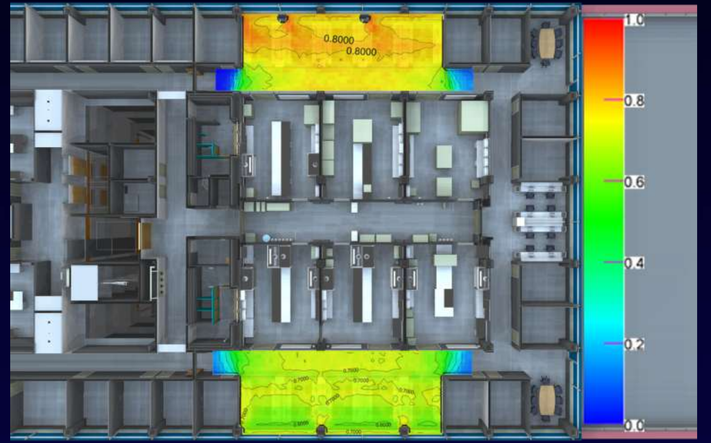
Pfund Russell Stough Villacampa



Useful Illuminance

Window to Wall Ratio Selection





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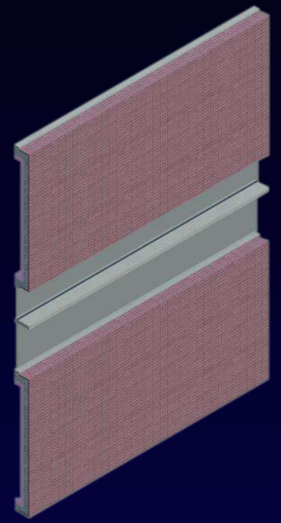
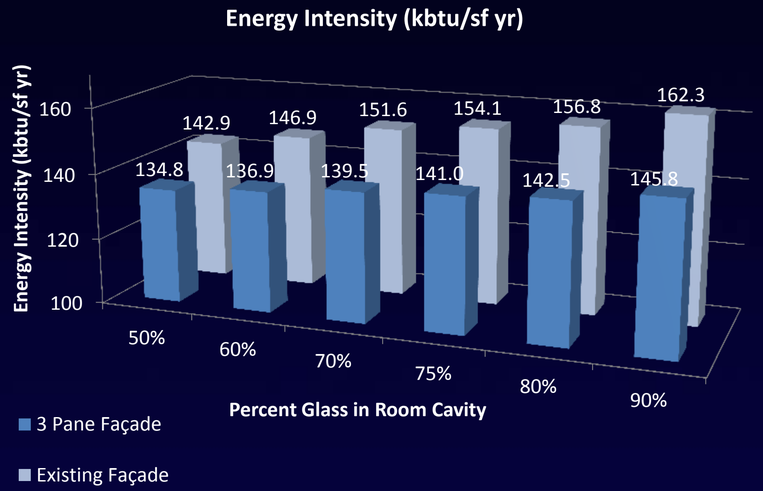
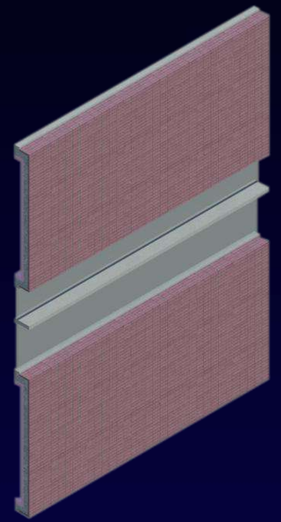
Pfund Russell Stough Villacampa

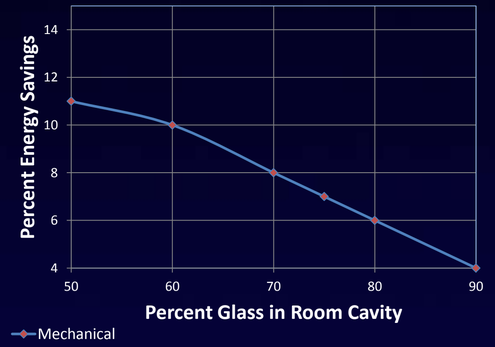


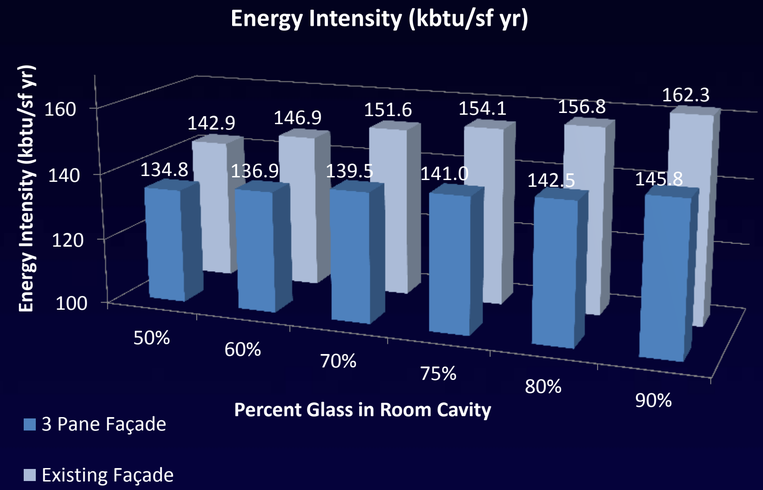
Percent Energy Savings



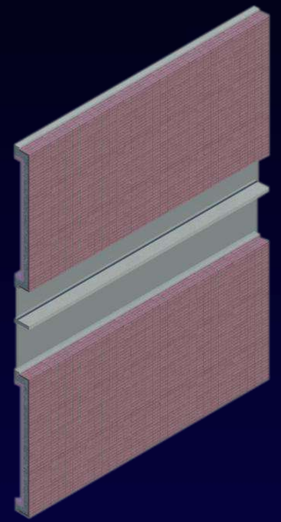


Percent Energy Savings



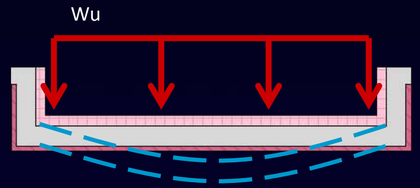


Pfund Russell Stough Villacampa

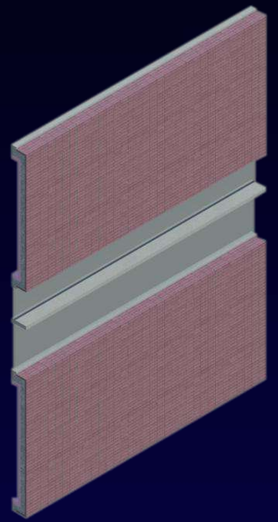


Minimum Concrete Thickness

- Flexure - Self Weight
- 6” Practical for reinforcing conditions



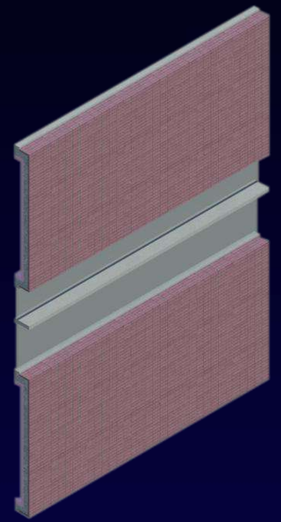
Ratio (%)	Minimum Thickness (in)	M_{cap} (lb-ft)	M_{sw} (lb-ft)	M_{wind} (lb-ft)
50	6	2864	2819	1081
60	5.5	2406	2152	883
70	4.5	1611	1477	706
80	4	1273	1058	550



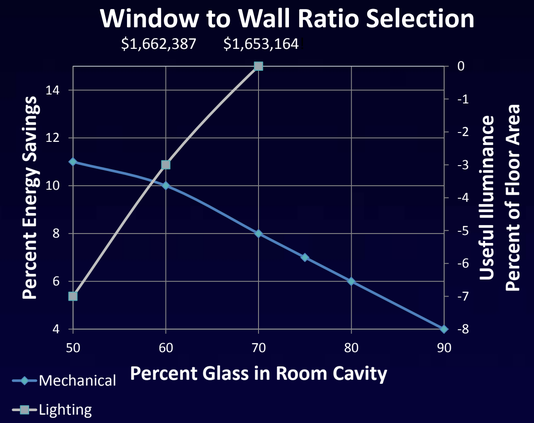
Construction Cost

Third Floor, Redesigned Panel		
Length of Panel	70%	60%
22ft	$1,530,763	$1,539,322
14ft	$41,131	$41,331
31ft	$81,270	$81,733
Total	**$1,653,164**	**$1,662,387**
Increased Cost of 60%	**$9,223**	

$9,223 more for 60% Glass Ratio



WINDOW TO WALL RATIO SELECTION



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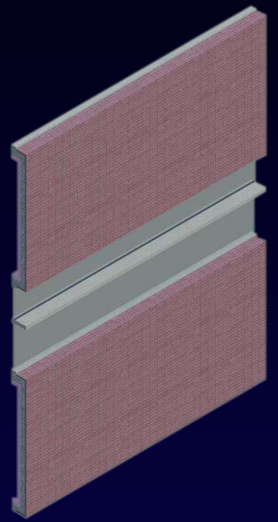

Life Cycle Cost

	70 % Glass	*60 % Glass*	*Savings*
Total Yearly Operating Costs	*$142,912*	*$139,338*	*$3,574*
Installation Costs	*$1,653,164*	*$1,662,387*	*$-9,223*
30 yr Life Cycle Cost	*$5,336,113*	*$5,253,245*	*$82,868*

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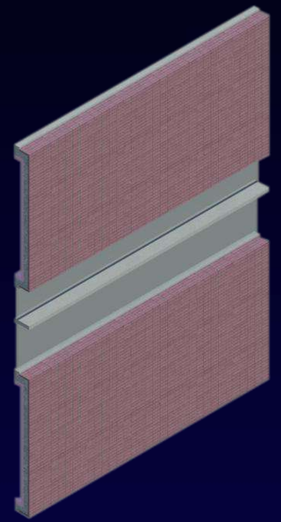

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2.6 Year Simple Payback

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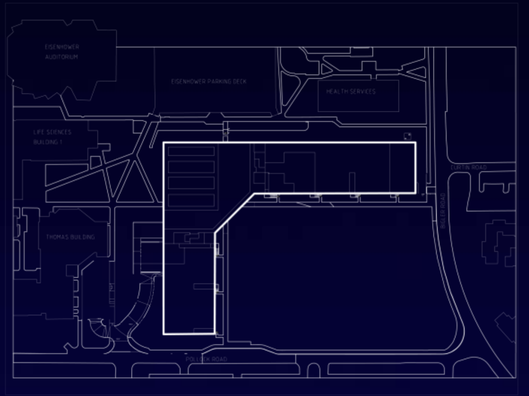
Precast Panel Erection

- Existing Schedule
  - Start: November 16, 2009
  - Finish: May 17, 2010
- New Schedule
  - Start: December 7, 2009
  - Finish: March 4, 2010



Precast Erection Plan

Precast Panel Erection

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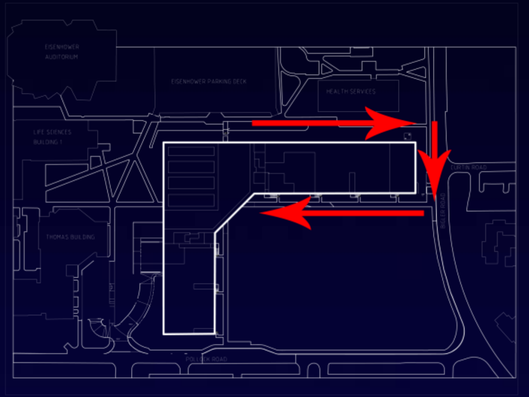

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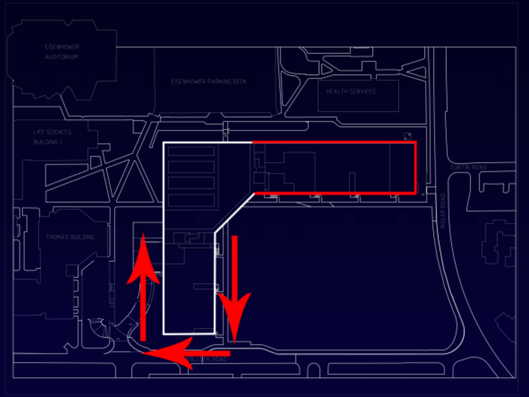

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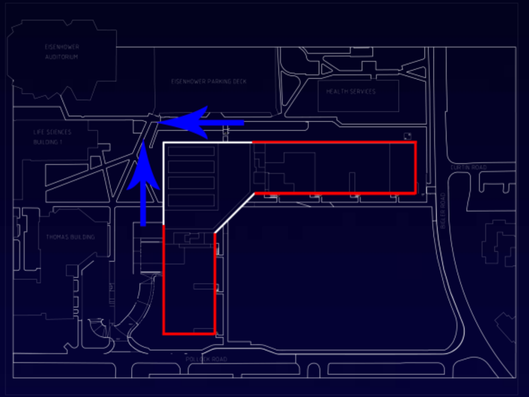

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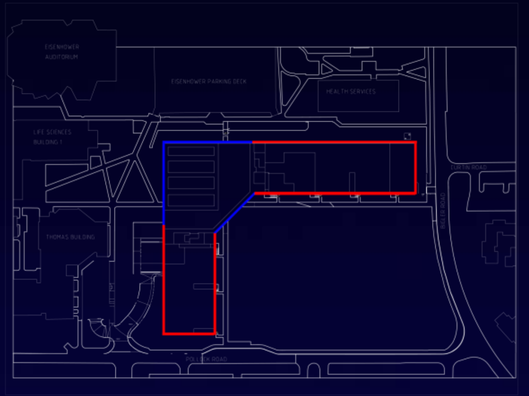
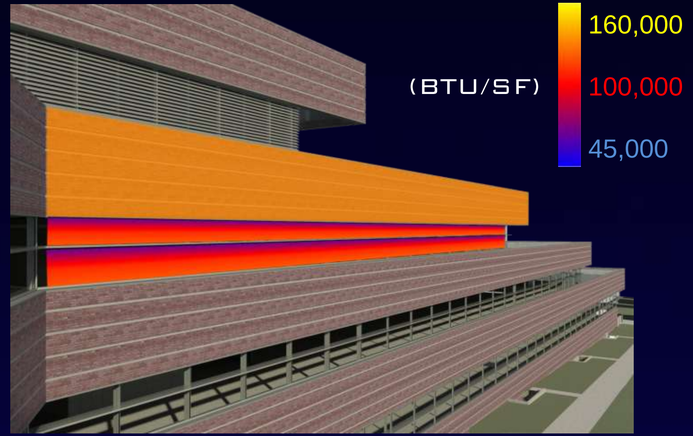


Precast Erection Plan

Shade Analysis

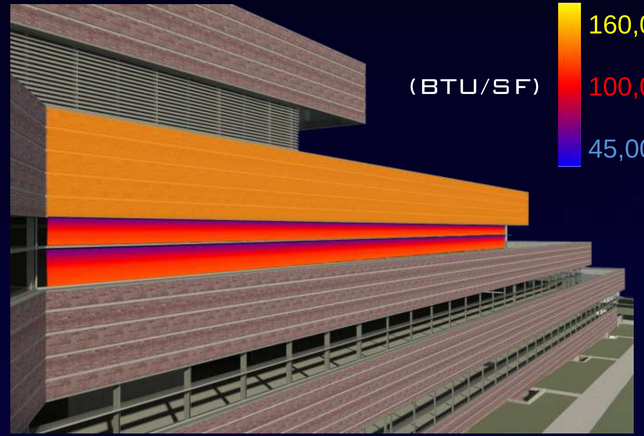
Exterior Shade Analysis

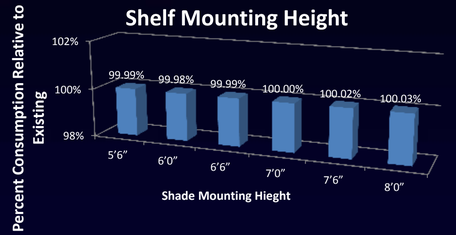


- Analyze Effects of Solar Radiation
- Reduce External Building Loading

Cumulative Yearly Incident Solar Radiation (BTU/SF)

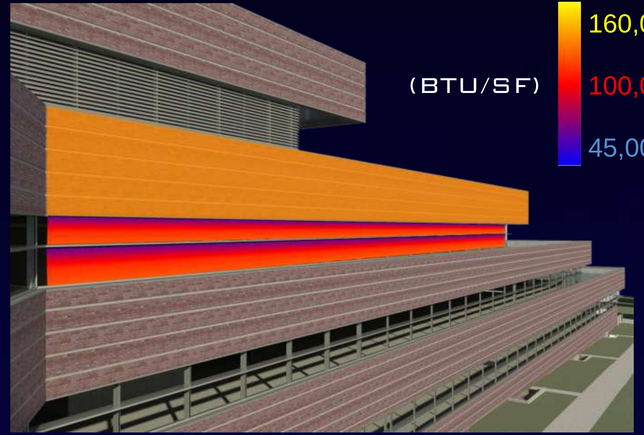
Exterior Shade Analysis



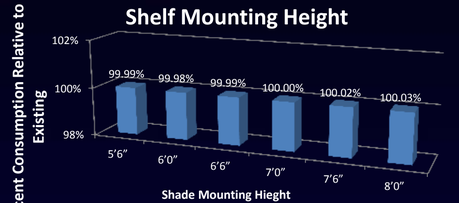


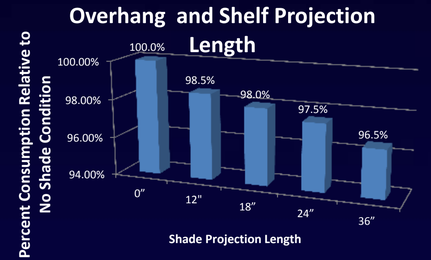
Cumulative Yearly Incident Solar Radiation (BTU/SF)

Exterior Shade Analysis



Cumulative Yearly Incident Solar Radiation (BTU/SF)





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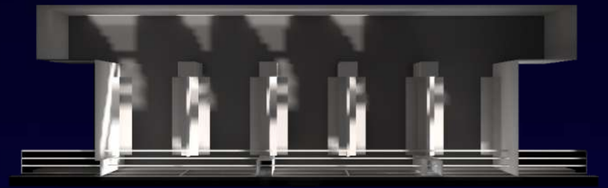
Shade Analysis

Shade Analysis



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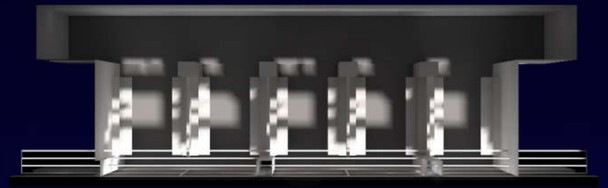

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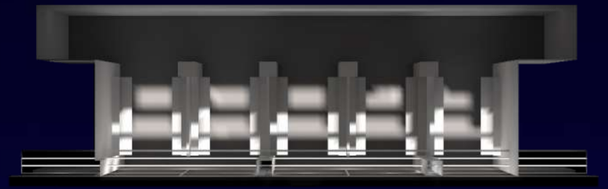

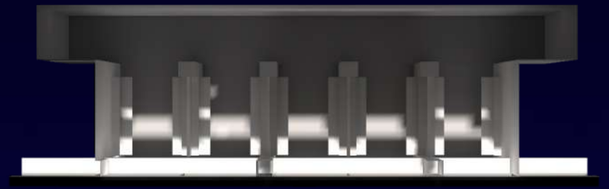

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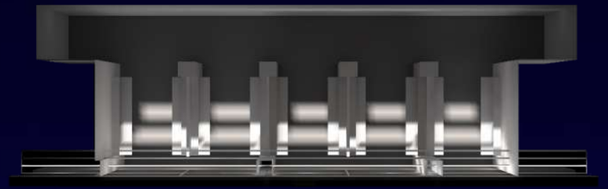

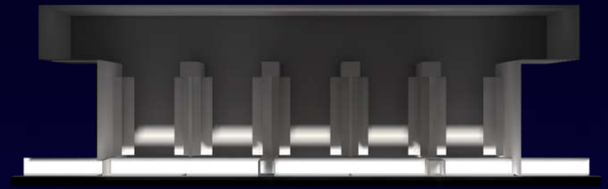

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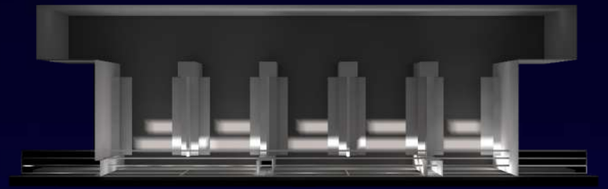

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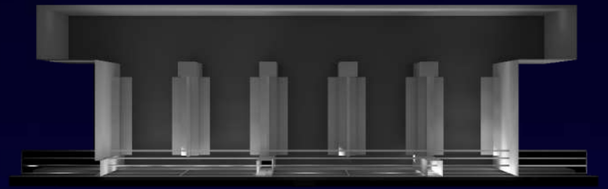
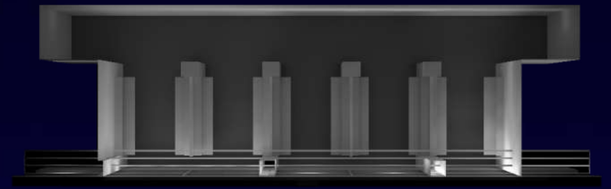
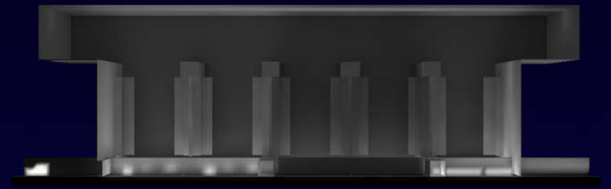
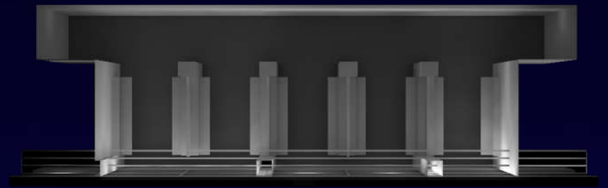


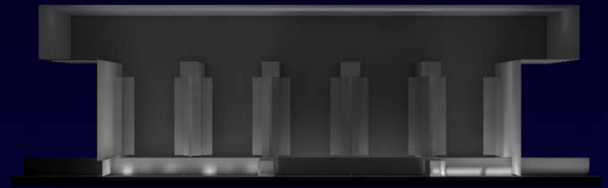
Shade Analysis





Shade Analysis





Lighting Design

Lighting Design

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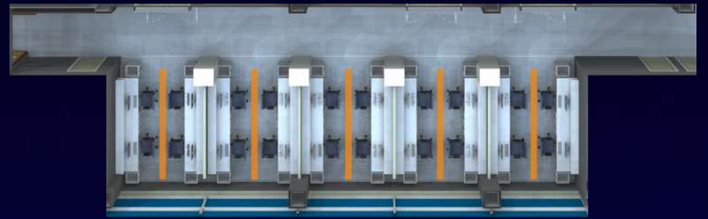
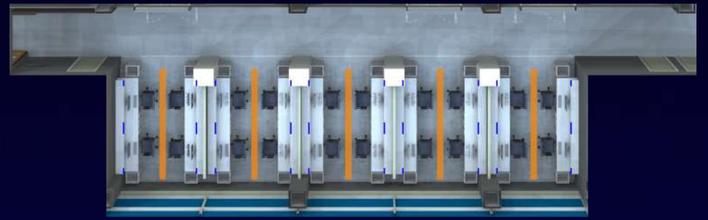
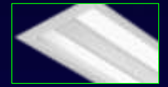
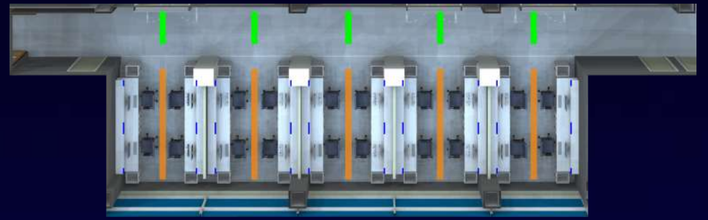


Lighting Design





Lighting Design



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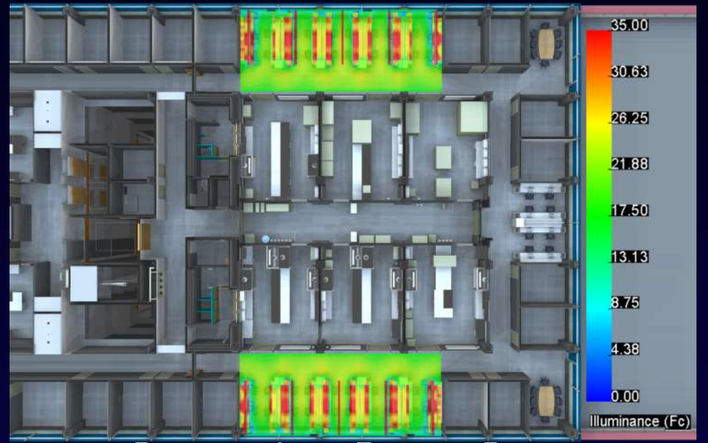
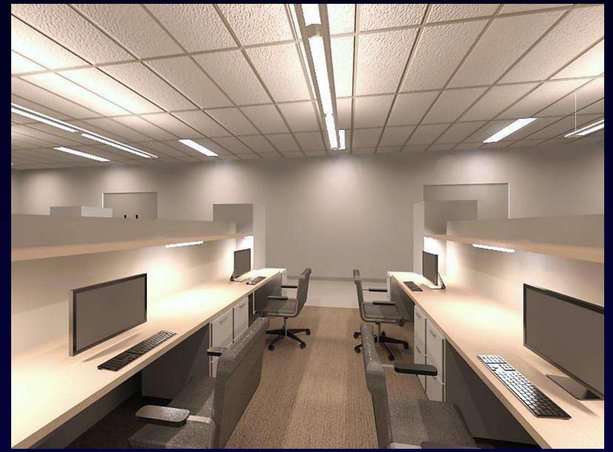
Lighting Design



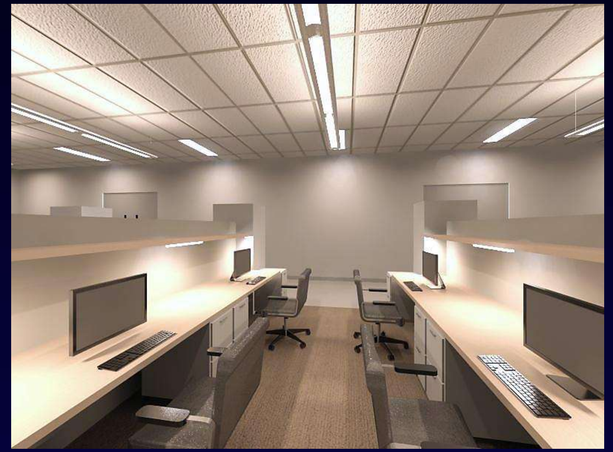
Student Area Pseudo Color



Lighting Design

IESNA Illumination Recommendations for Student Area		
Area	Avg. Horizontal Illuminance	
	Target	Design
Student Area Desk	30 fc	34 fc
Corridor	5 fc	21.7 fc

ASHRAE Power Density Requirements		
Area	Allowable	Design
Student Area	1.2 W / SF	0.86 W / SF
Corridor	0.5 W / SF	0.40 W / SF



Daysim Control Study

Student Area DA_{con} 322.8 lux

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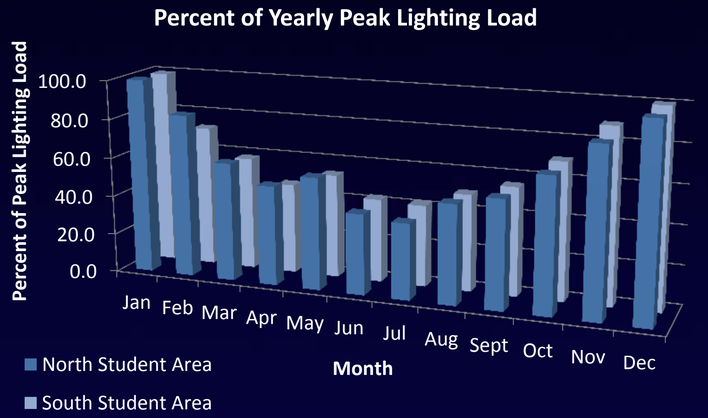

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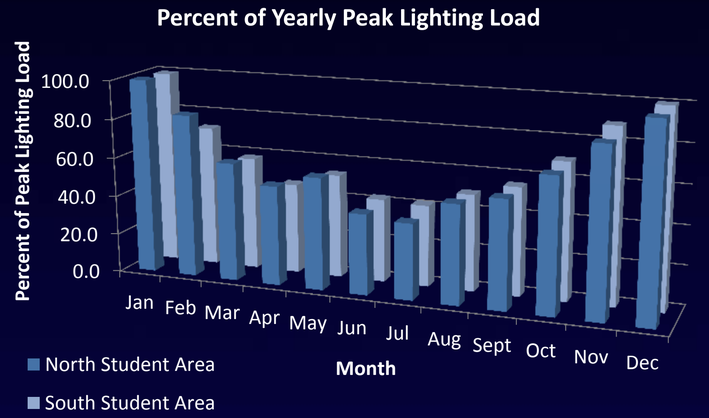
Lighting Energy Analysis

	Existing Design	Lighting Redesign	Savings
Total Yearly Operating Costs	$140,379	$137,859	$2,520
Installation Costs	$42,016	$34,695	$7,321
30 yr Life Cycle Cost	$3,659,698	$3,587,427	$72,271



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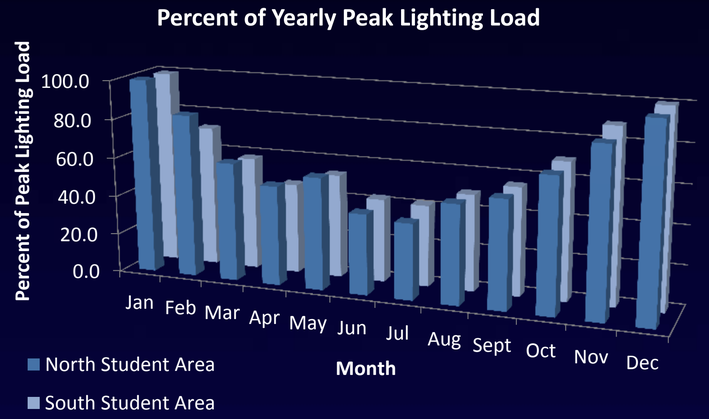
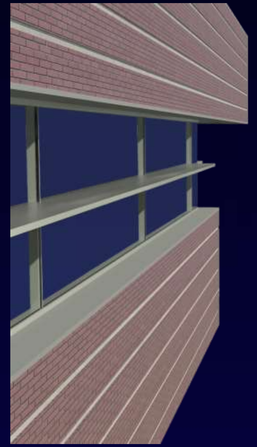
Immediate Return on Investment

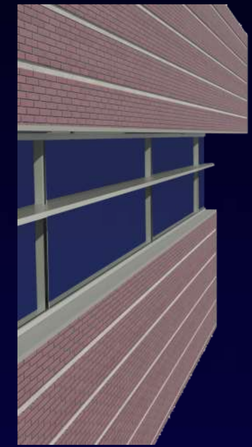


Façade Conclusions

Existing Façade



Façade Redesign



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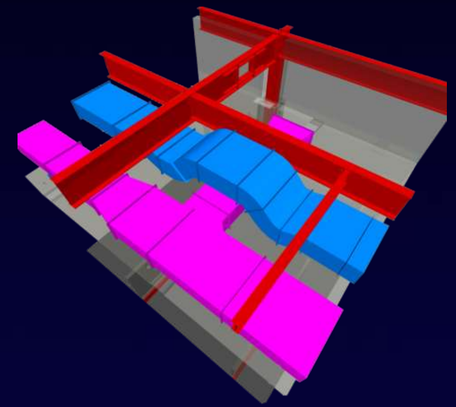
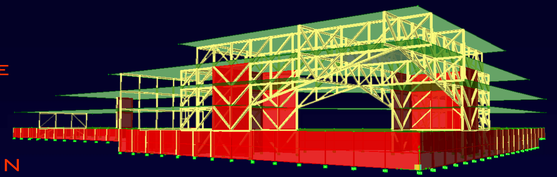
Façade Conclusions

Existing Design

Façade Redesign

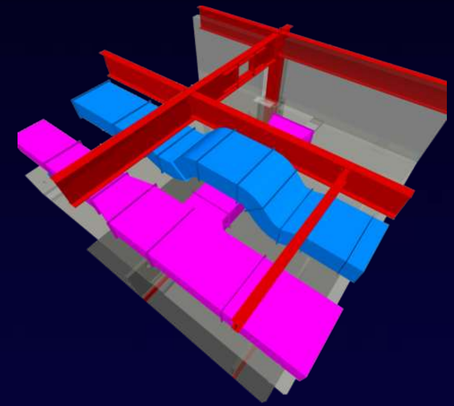
Plenum Investigation



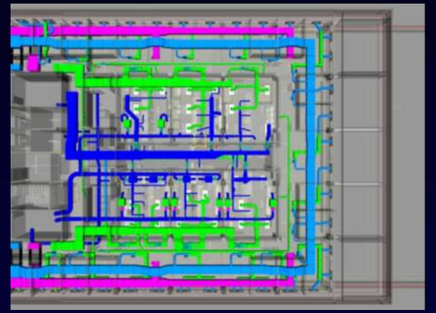


Plenum Analyses

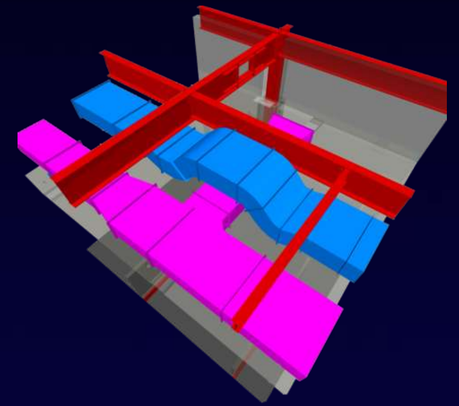
- Floor System redesign/ Vibration Analysis

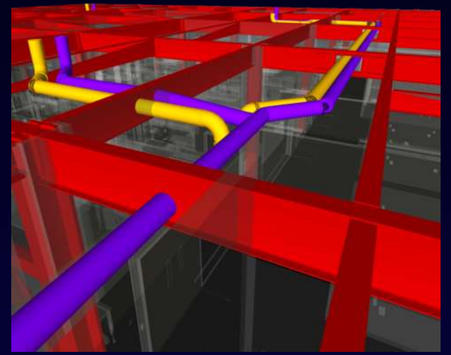


Plenum Analyses



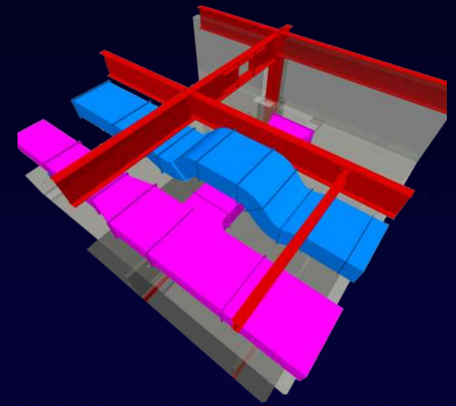
- Floor System redesign/ Vibration Analysis
- Duct System Redesign



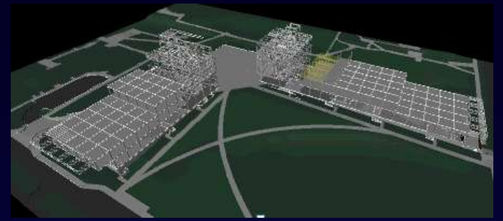


Plenum Analyses

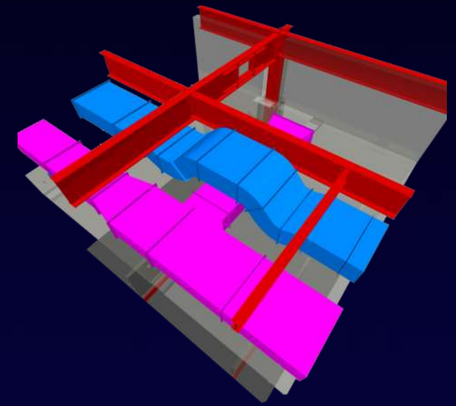
- Floor System redesign/ Vibration Analysis
- Duct System Redesign
- Structural/Mechanical Coordination

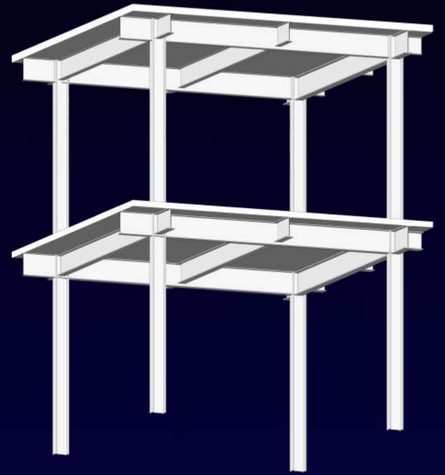


Plenum Analyses



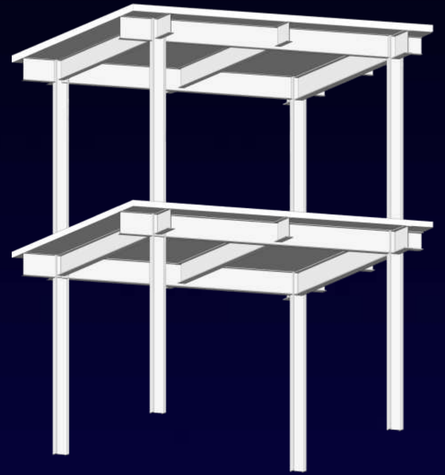
- Floor System redesign/ Vibration Analysis
- Duct System Redesign
- Structural/Mechanical Coordination
- 4D Modeling





Existing Floor System

- One-way composite steel beams
- 22ft square bays
- 11ft Beam spacing
- 6.25” LWC slab, 3” 18ga Deck



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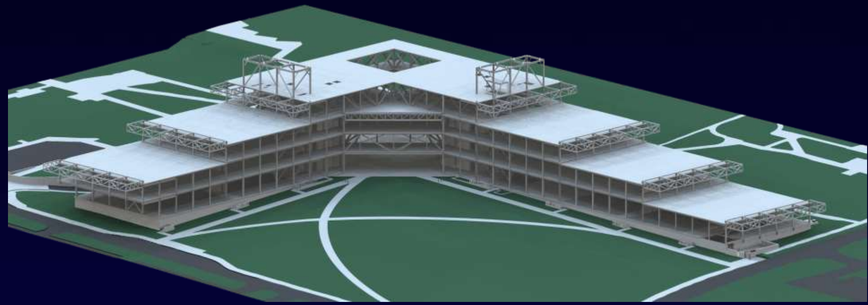
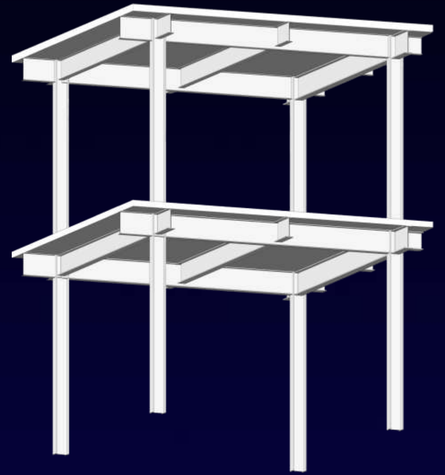
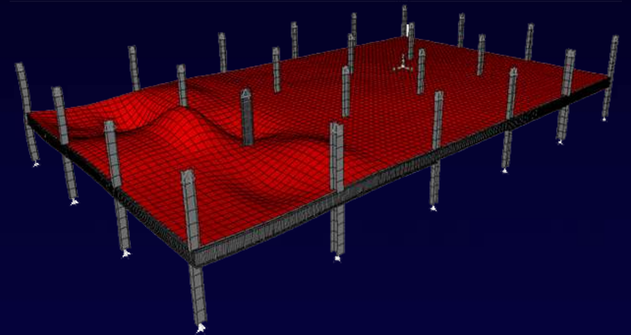




Existing Vibration Analysis

- AISC Design Guide 11- Floor Vibration Due to Human Activity
- SAP2000 model – AE597A
- Point Load – Deflection Analysis
- Period of vibration calculation using Rayleigh method
- Life Science Wing – 4000ui/s

Span/Location	Weight	Uv(lb/sec2)	Δ_p(in/100kip)	T(sec)	Velocity(ui/sec)
A	27.7	5500	1.115	0.0639	3916
B	27.2	5500	1.004	0.0601	3317
C	26.8	5500	1.138	0.0649	4063

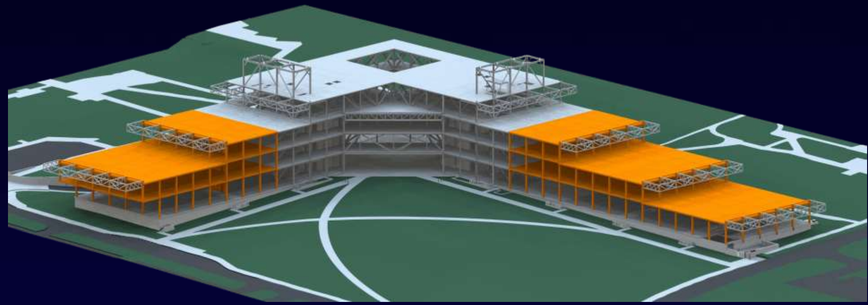


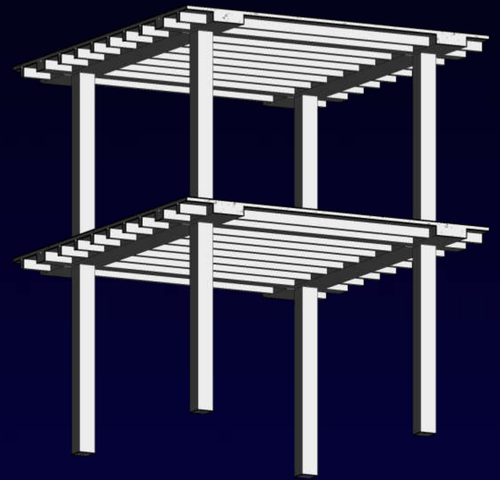
Floor System Alternatives

- Typical Gravity System within Wings
- Save vertical plenum space
- Concrete typically thinner profile

Three Building Mixed System

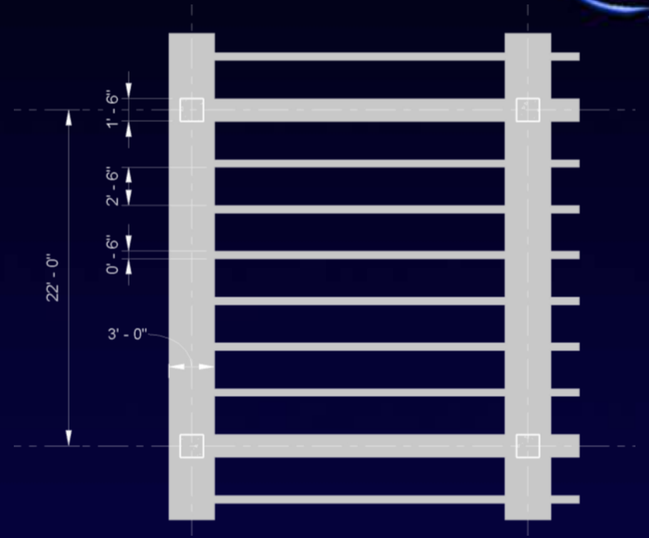
- Seamless Integration at intersection
- Waffle Slab/ One-Way Pan Joist
- Vibrations will determine required stiffness





One-Way Pan-Joist Design

- Designed For Strength
- ACI318-08, Flexural/ Shear Design
- 3ft Module: 30”pans, 6” ribs
- 10” deep pans – Table 9.5a
- 18” Interior Beams on column lines
- 36” Wide Girders
- 18” square columns



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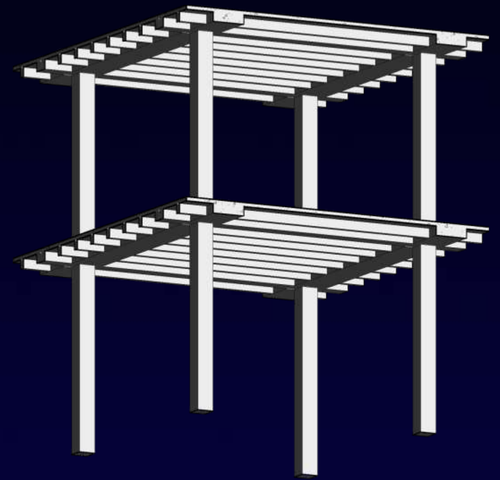
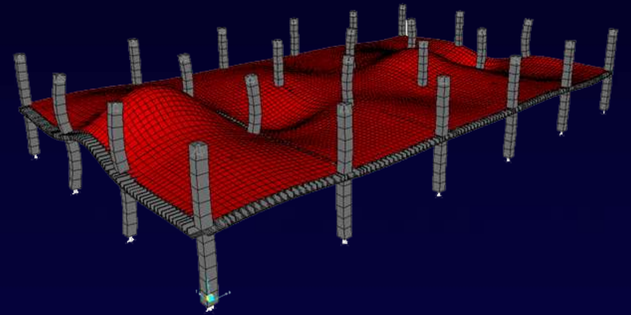


Pan-Joist Vibration Analysis

- AISC Design Guide 11- Floor Vibration Due to Human Activity
- SAP2000 model – AE597A
- Point Load – Deflection Analysis
- Period of vibration calculation using Rayleigh method
- Life Science Wing – 4000ui/s
- More efficient than Waffle Slab

Span/Location	Weight (kip)	Uv (lb/sec2)	Δ_p (in/100kip)	T (sec)	Velocity(ui/sec)
A	41.7	5500	0.584	0.0637	2048
B	41.7	5500	0.541	0.0597	1776
C	41.7	5500	0.541	0.0596	1774



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Structural Cost Comparison

	Material	Labor
Concrete	$403,758	$110,791
Rebar	$277,595	$187,798
Formwork	$1,286,819	$1,787,383
Finishing	$24,606	$49,213
Shoring	$296,521	$6,477.86
Total	$2,289,301	$2,141,664
Cranes	$402,802	
Overall Total	**$4,833,768**	

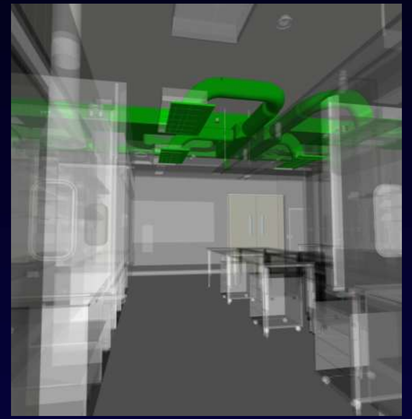
Redesign Structural Cost

	Material Cost	Labor Cost
Steel Framing	$1,722,507	$341,182
Metal Deck	$408,606	$46,170
Concrete	$421,088	$163,810
Total	$2,552,202	$551,163
Cranes	$362,500	
Overall Total	**$3,465,865**	

Existing Structural Cost

Duct System Analysis

- Third Floor Material Science Wing
- Laboratory Supply Duct Runs
  - Use Available Plenum Space
  - Increase Duct Size
  - Reduce Static Pressure
  - Save Fan Energy



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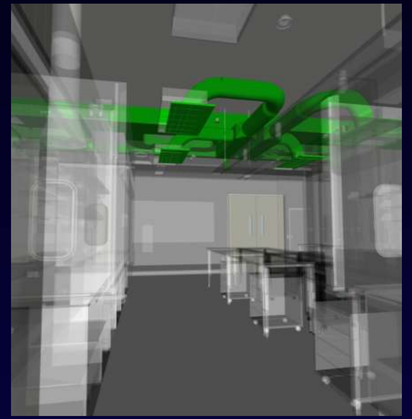

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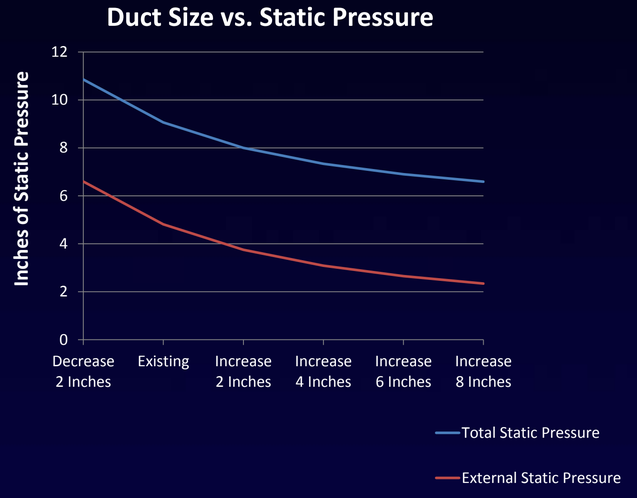
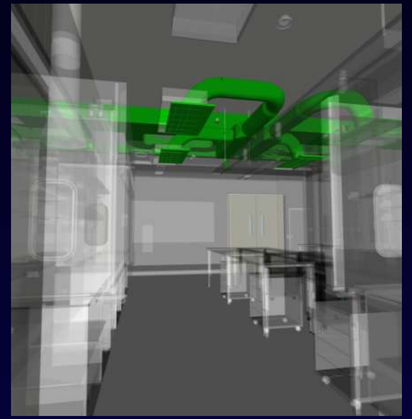
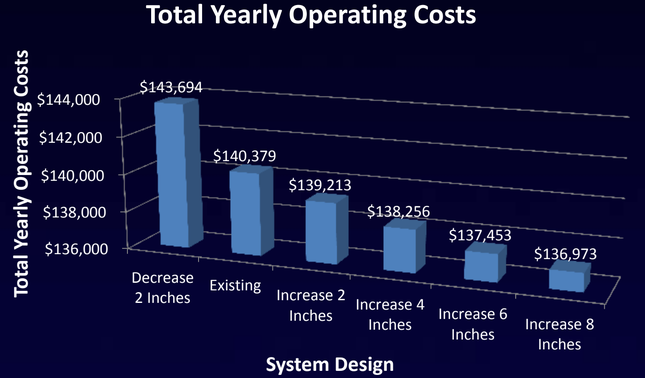




Duct System Analysis



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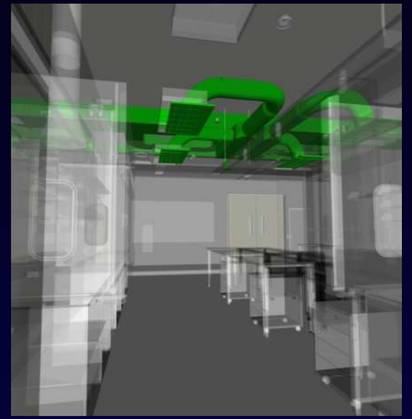
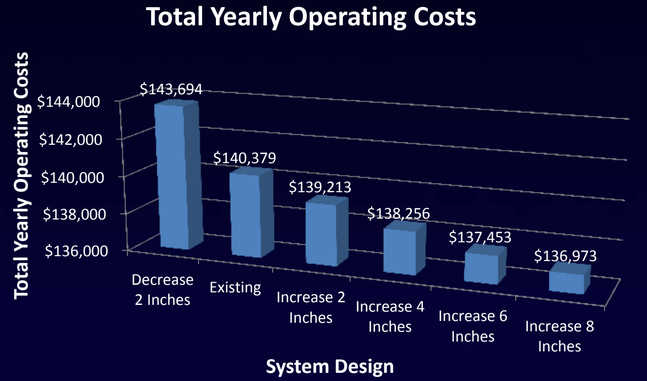
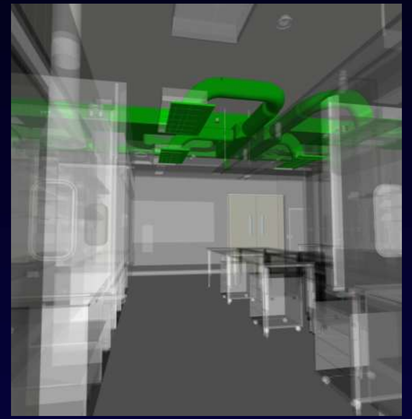
Duct System Analysis



	Decrease 2 Inches	Existing	Increase 2 Inches	Increase 4 Inches	Increase 6 Inches	Increase 8 Inches
Total Yearly Operating Costs	$143,694	$140,379	$139,213	$138,256	$137,453	$136,973
Installed Cost	$28,911	$29,966	$31,021	$32,076	$33,131	$34,161
30 yr Life Cycle Cost	$3,732,024	$3,647,648	$3,618,659	$3,595,055	$3,575,409	$3,564,062



Duct System Analysis



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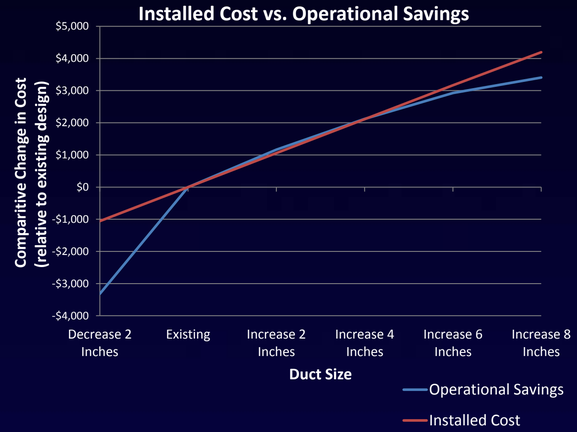
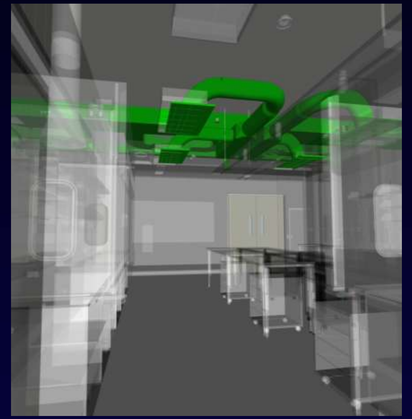
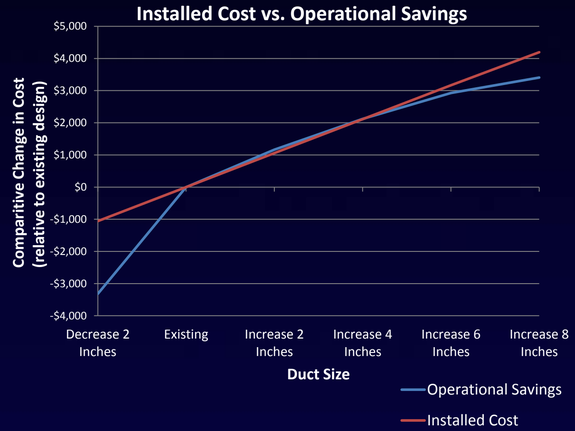


Duct System Analysis



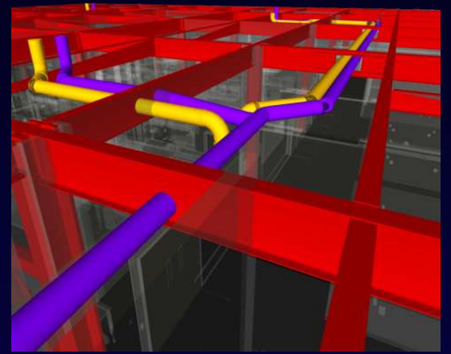
	Existing Design	Increase Duct 6" Design	Savings
Total Yearly Operating Costs	$140,379	$137,453	$2,926
Installation Costs	$29,966	$33,131	$-3,165
30 yr Life Cycle Cost	$3,647,648	$3,575,409	$72,239

1.1 Year Simple Payback

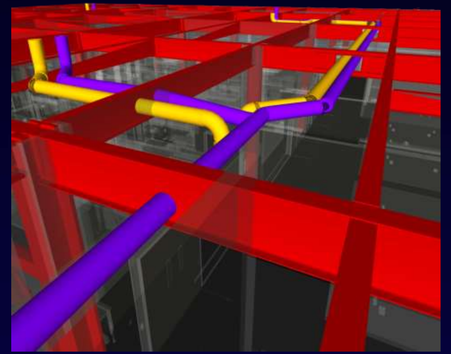


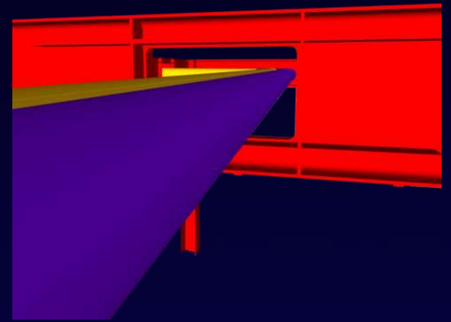
Coordination

Drainage Pipe Collisions

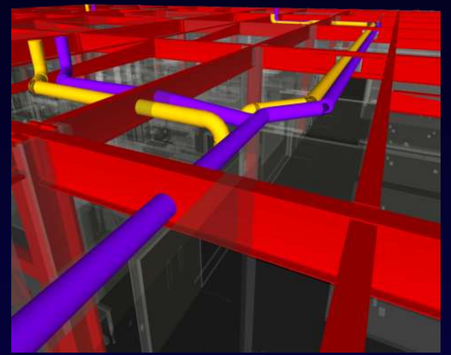


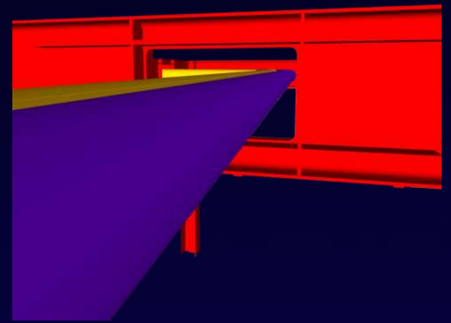
Drainage Pipe Collisions

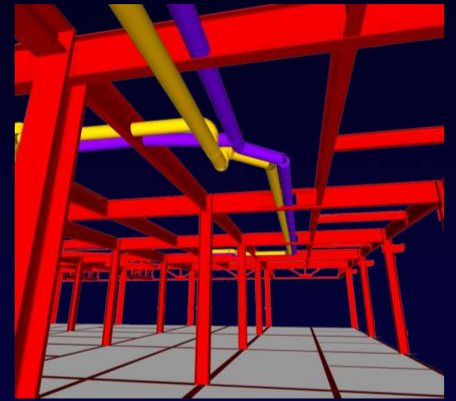




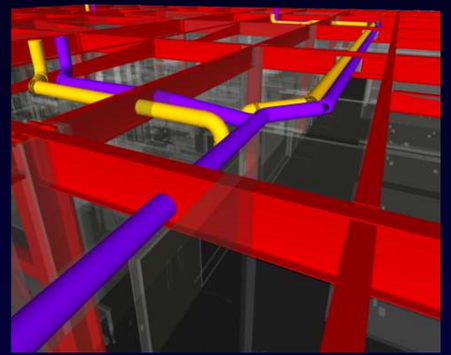
Drainage Pipe Collisions

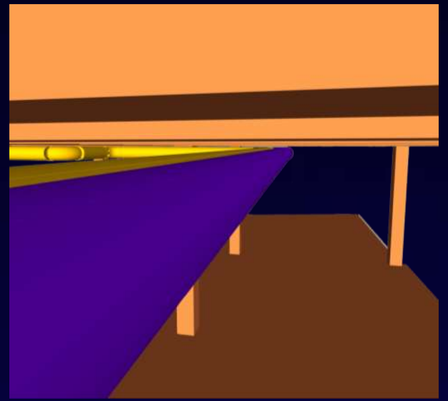


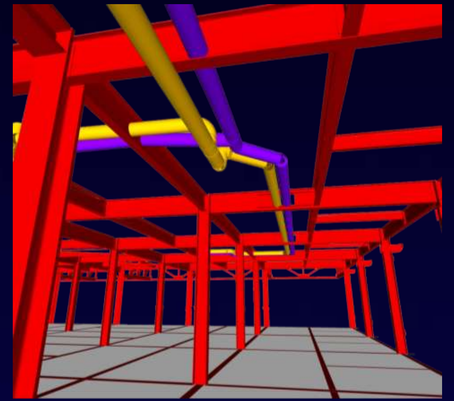




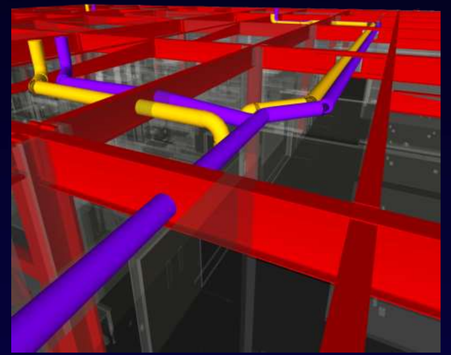
Drainage Pipe Collisions

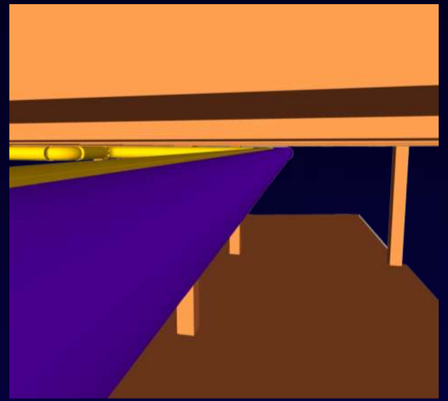


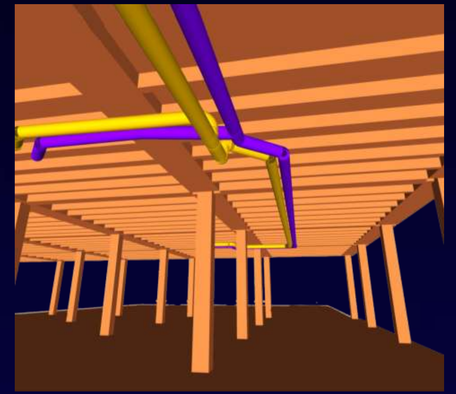




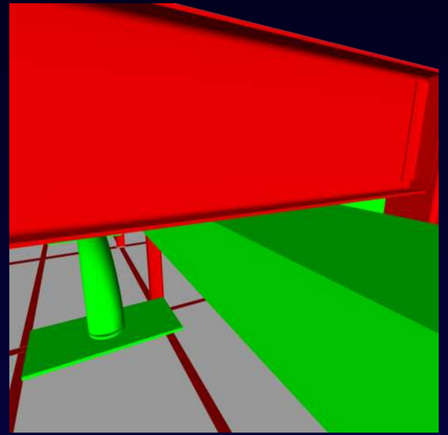
Drainage Pipe Collisions



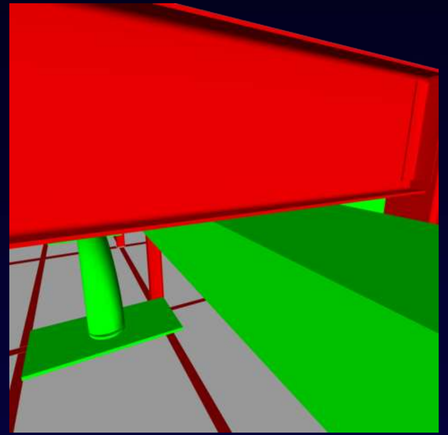


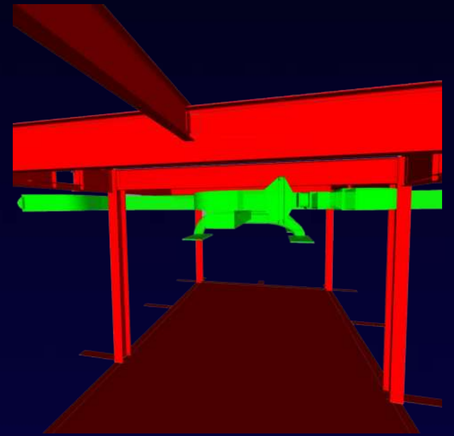


Existing Structure Coordination

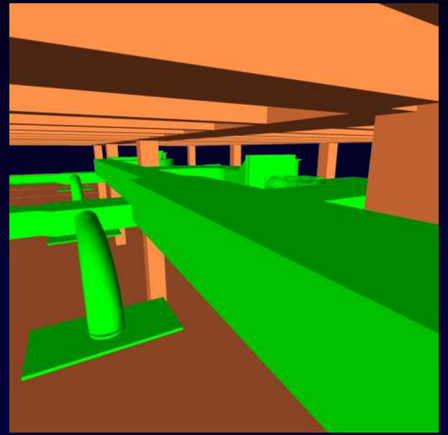


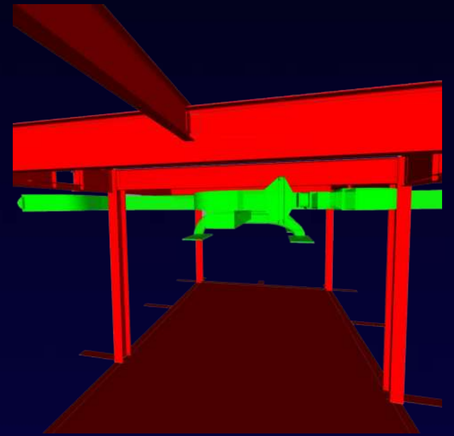
Existing Structure Coordination





Alternative Coordination





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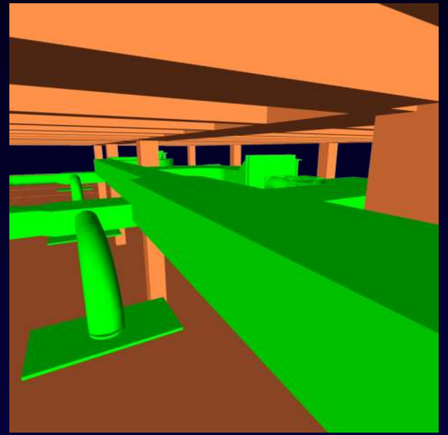
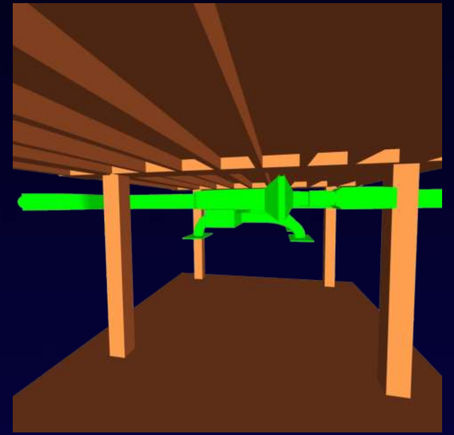
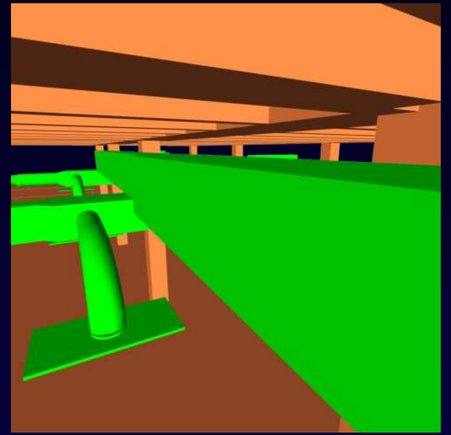
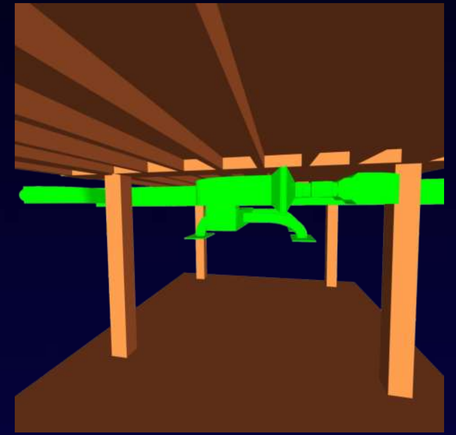


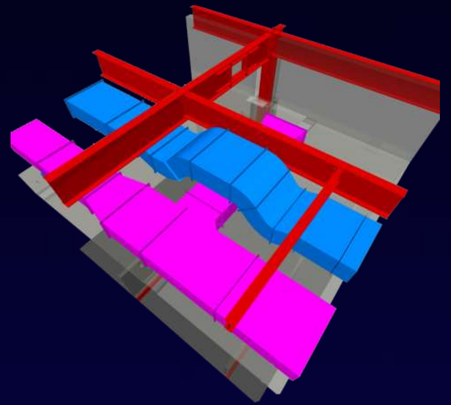


Duct Size Increase

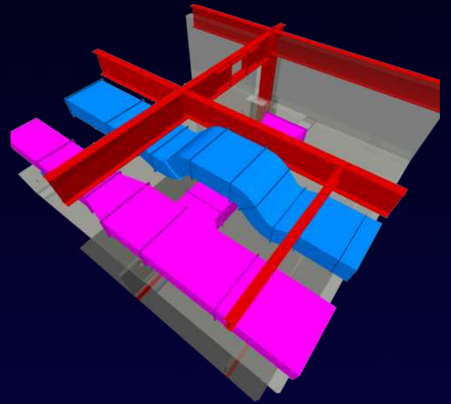


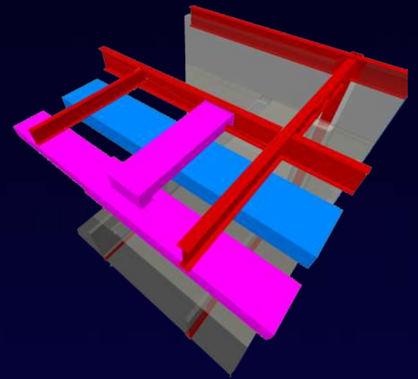


Plenum utilization

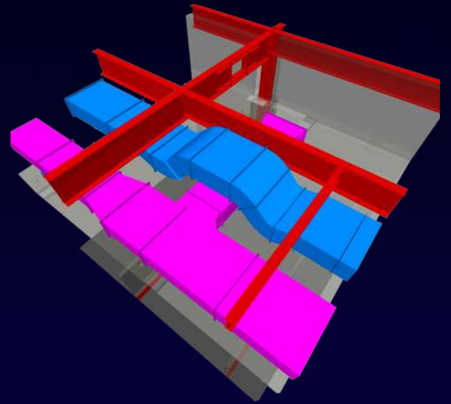


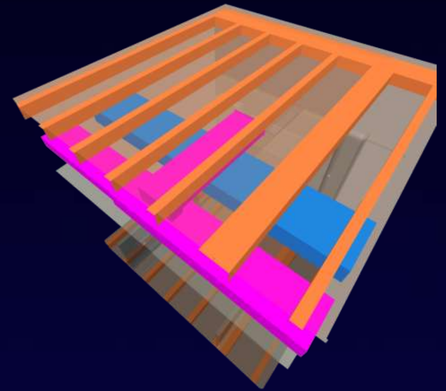
Plenum utilization



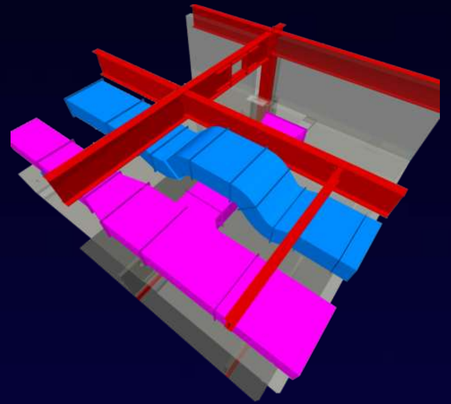


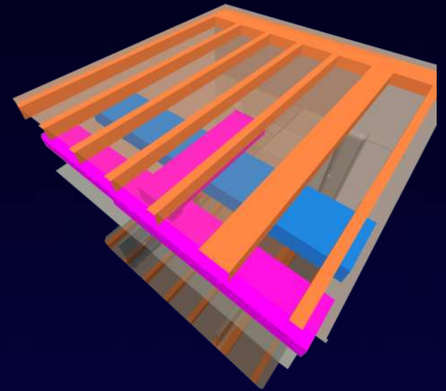
Plenum utilization

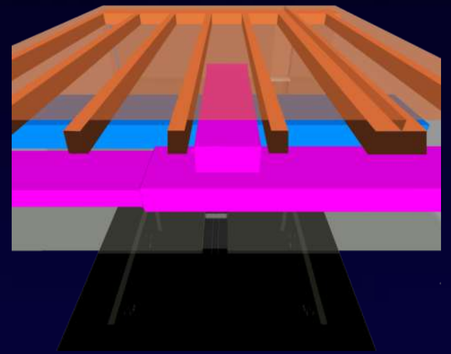




Plenum utilization

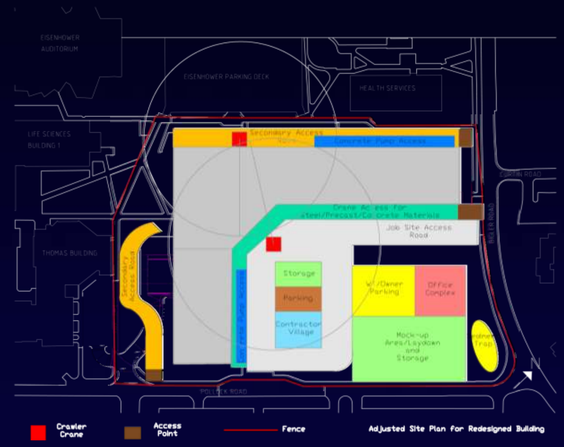






Site Logistics

- Minor Changes to existing Site Plan
- Incorporation of Concrete Pump Truck locations
- Safety is a top priority



Redesign Site Plan

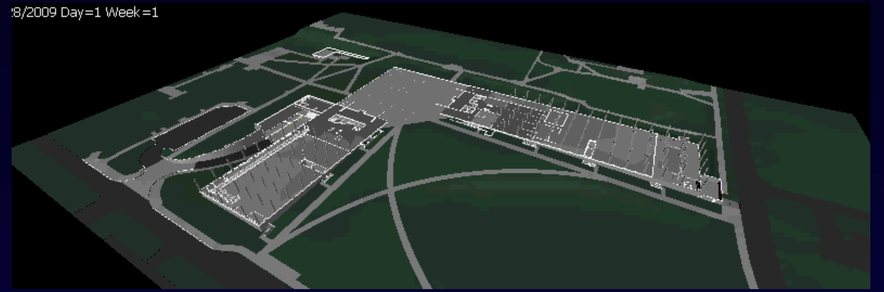
Schedule Impacts

- Re-sequencing of foundation and substructure for concrete structure
- Sequencing of steel and concrete simultaneously
- Acceleration of schedule
- Approximately two month reduction

Task	Duration (Days)	Start	Finish
Material Science Wing Concrete	98	7/29/09	12/11/09
Life Science Wing Concrete	63	8/11/09	11/12/09
Cantilever Steel/Shear Walls	114	8/10/09	1/14/10
Precast Panels	67	12/7/10	3/4/10

Redeveloped schedule

4D Modeling

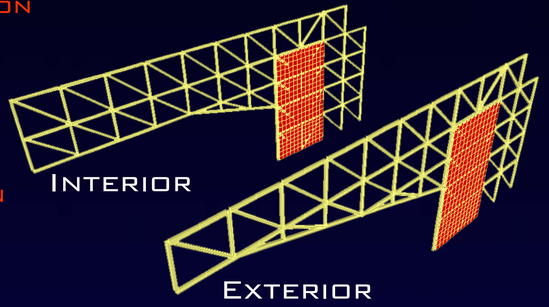


Cantilever Plaza

Pfund Russell Stough Villacampa

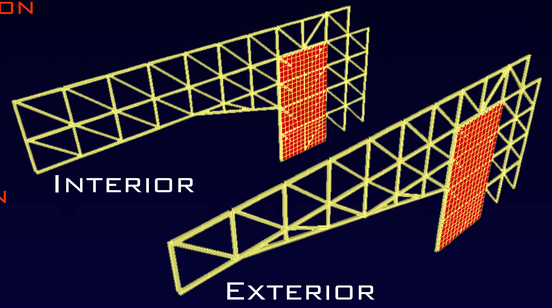
Cantilever Overview

- Structural Analysis/ Redesign
- Structural impacts on architecture
- Lighting Design



Existing Truss System

- 155ft Building Cantilever
- Two Interior Trusses- intersect at 66ft
- Two Exterior Trusses- intersect at 122ft
- All W14 wide flange sections
- Moment Connections
- C-shaped shear wall



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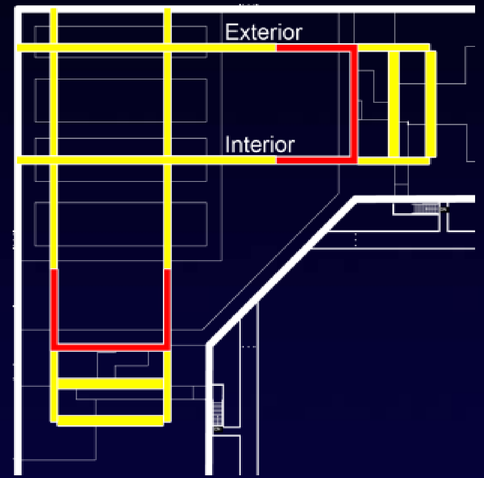

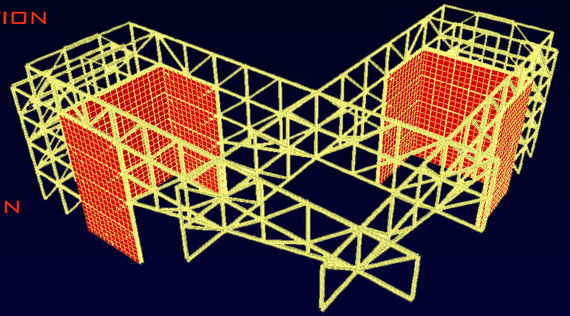

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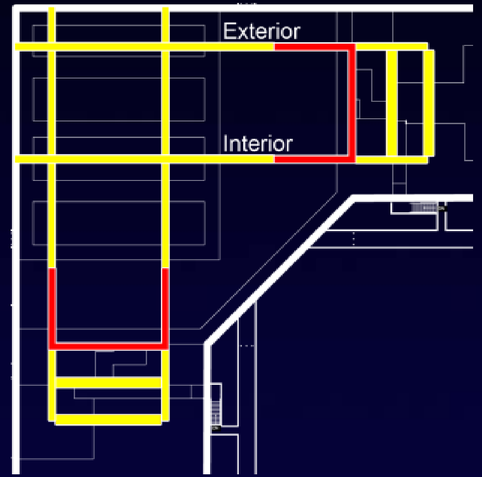
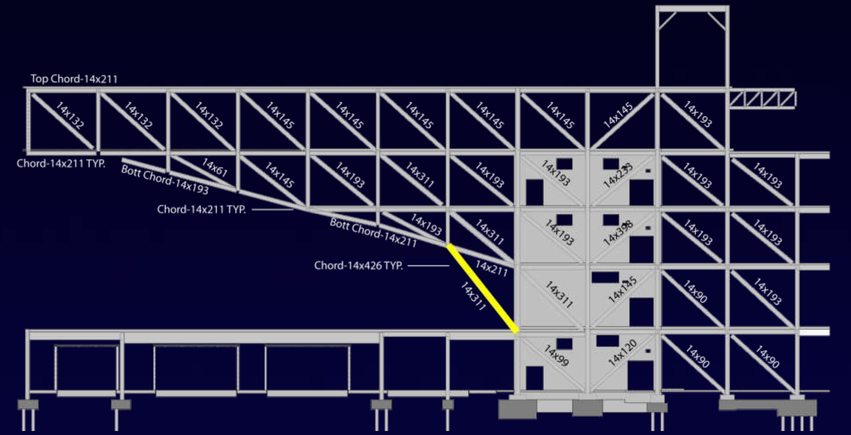
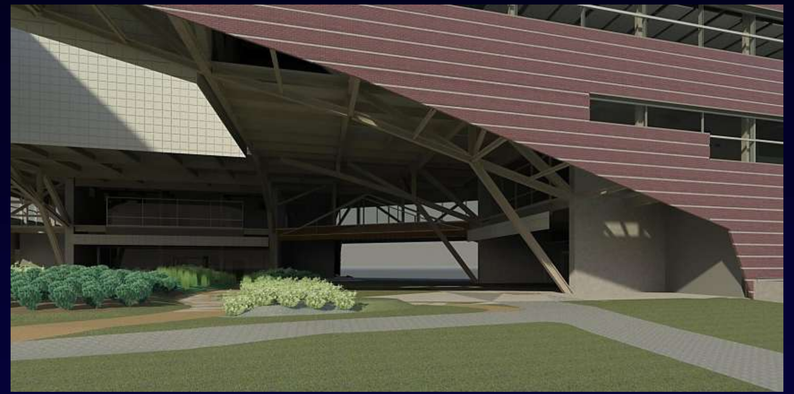


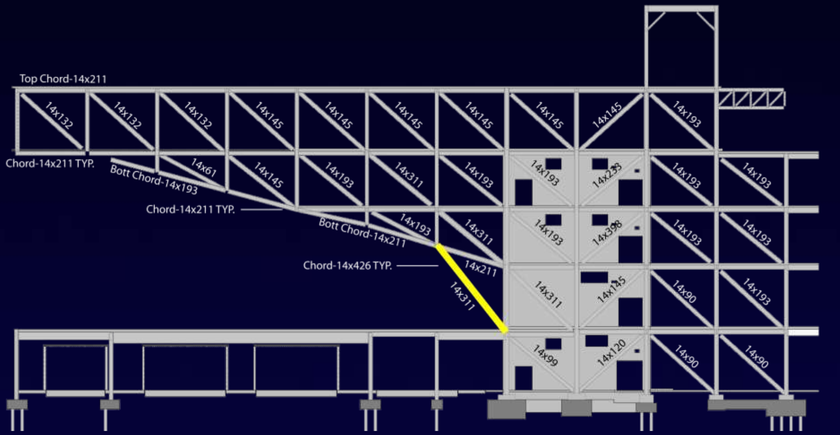
Additional Brace

- Additional Brace – W14X311
- AISC Steel Manual Chapter 6- combined loading
- Added depth to critical section
- Connected Additional compression path
- Saved $52,991 in steel

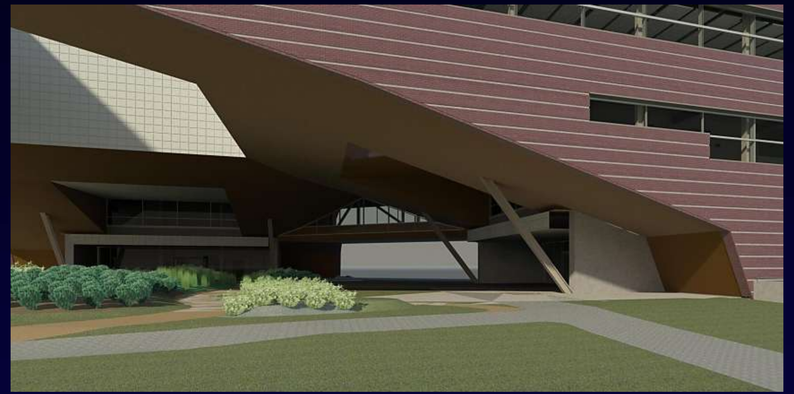


Architectural Impacts

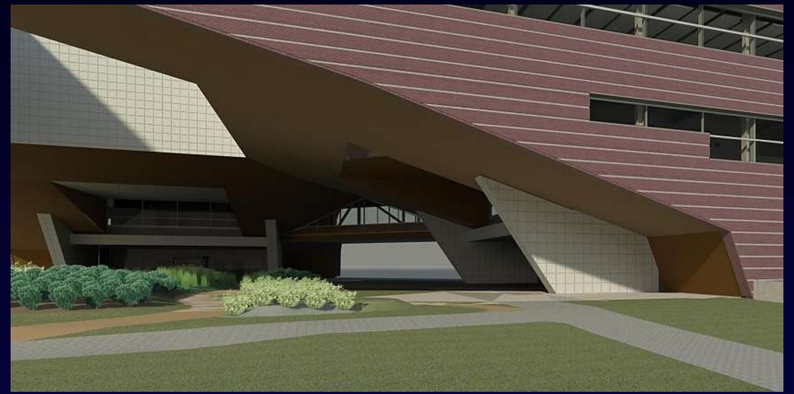




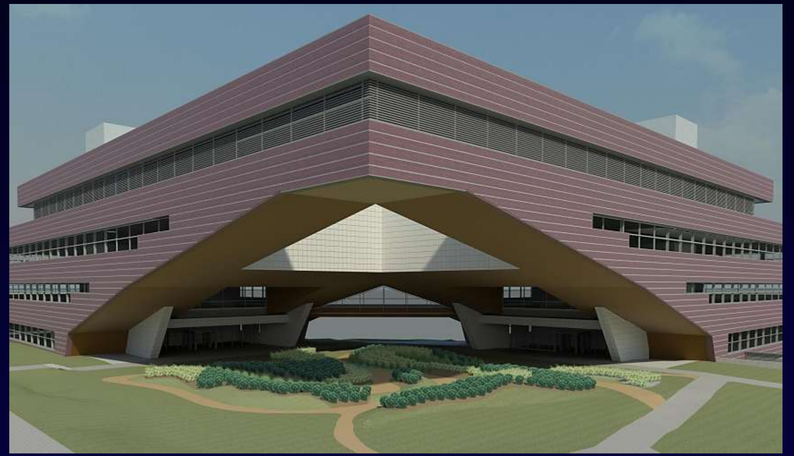
Architectural Impacts



Architectural Impacts



Architectural Impacts



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Lighting Design

Lighting Design

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Lighting Design

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Lighting Design

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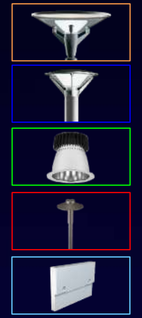

Lighting Design

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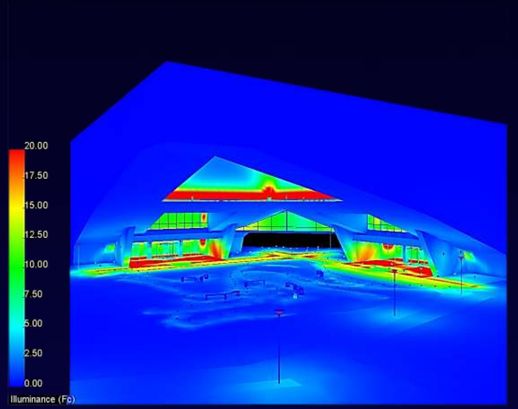


Cantilever Plaza Pseudo Color

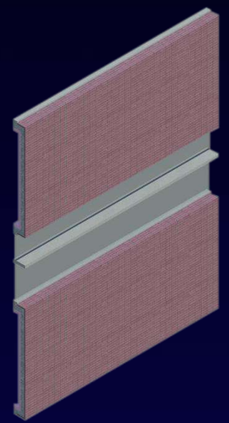
Lighting Design

IESNA Illumination Recommendations for Cantilever Plaza		
Area	Avg. Horizontal Illuminance	
	Target	Design
Sidewalk	5 fc	12.4 fc
Pathway	1 fc	2.3 fc

ASHRAE Power Density Requirements		
Area	Allowable	Design
Cantilever Plaza	1.25 W / SF	0.44 W / SF

IPD/BIM Reflection

Multi-Disciplinary Input



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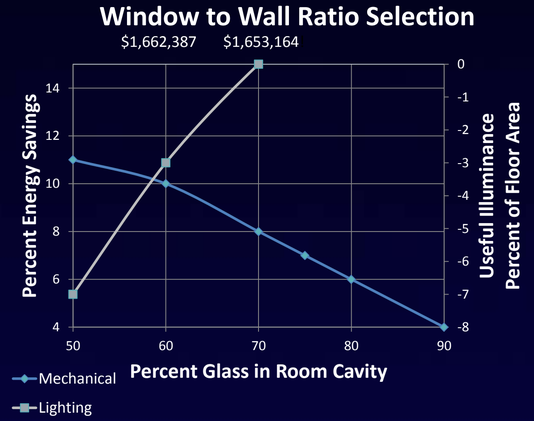
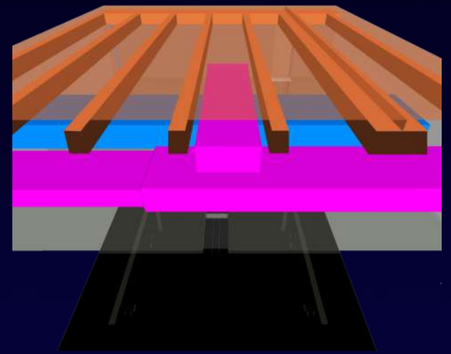
Integrated Selection Criteria

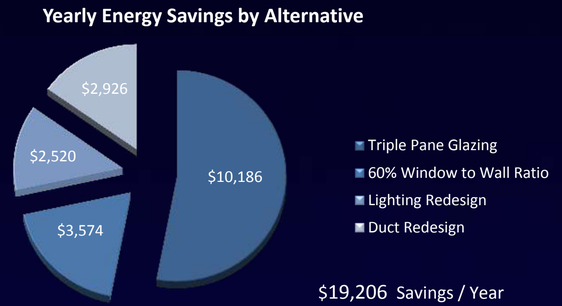


Coordinated Modeling



Unique Interaction

Cumulative Enhancements



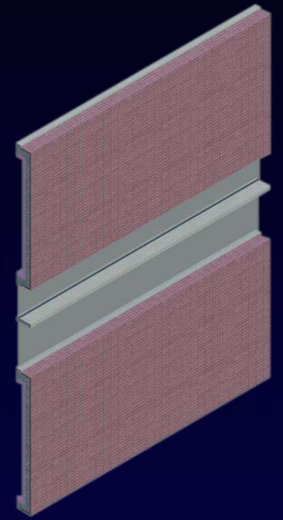
$19,206 Savings / Year

BIM Goals and Uses

Priority (1-3)	Goal Description	Potential BIM Uses
1- Most Important	Value added objectives	
1	Life Cycle Cost / Value Engineer all design decisions	Cost Estimation, Engineering Analysis, Building System Analysis, Design Reviews, Existing Conditions Modeling
1	Optimize Building Performance	Engineering Analysis, Building System Analysis, Design Reviews, Existing Conditions Modeling, Site Analysis
1	Eliminate Field Conflicts	3D Coordination, Design Reviews, Existing Conditions, Modeling, Design Authoring
1	Improve Energy Efficiency	Engineering Analysis, Building System Analysis, Design Reviews, Site Analysis, Existing Conditions Modeling, Design Authoring
1	Improve Daylighting	Engineering Analysis, Building System Analysis, Design Reviews, Site Analysis, Existing Conditions Modeling, Design Authoring
1	Optimize Sequence and Schedule	4D Modeling

Value Engineering - LCC

Priority (1-3)	Goal Description	Potential BIM Uses
1- Most Important	Value added objectives	
1	Life Cycle Cost / Value Engineer all design decisions	Cost Estimation, Engineering Analysis, Building System Analysis, Design Reviews, Existing Conditions Modeling
1	Optimize Building Performance	Engineering Analysis, Building System Analysis, Design Reviews, Existing Conditions Modeling, Site Analysis
1	Eliminate Field Conflicts	3D Coordination, Design Reviews, Existing Conditions, Modeling, Design Authoring
1	Improve Energy Efficiency	Engineering Analysis, Building System Analysis, Design Reviews, Site Analysis, Existing Conditions Modeling, Design Authoring
1	Improve Daylighting	Engineering Analysis, Building System Analysis, Design Reviews, Site Analysis, Existing Conditions Modeling, Design Authoring
1	Optimize Sequence and Schedule	4D Modeling



Optimize Building Performance

Priority (1-3)	Goal Description	Potential BIM Uses
1- Most Important	Value added objectives	
1	Life Cycle Cost / Value Engineer all design decisions	Cost Estimation, Engineering Analysis, Building System Analysis, Design Reviews, Existing Conditions Modeling
1	Optimize Building Performance	Engineering Analysis, Building System Analysis, Design Reviews, Existing Conditions Modeling, Site Analysis
1	Eliminate Field Conflicts	3D Coordination, Design Reviews, Existing Conditions, Modeling, Design Authoring
1	Improve Energy Efficiency	Engineering Analysis, Building System Analysis, Design Reviews, Site Analysis, Existing Conditions Modeling, Design Authoring
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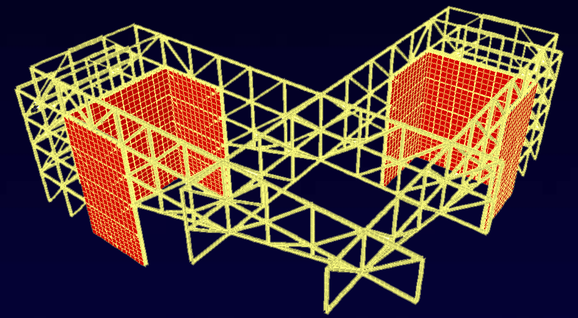
1	Optimize Sequence and Schedule	4D Modeling



Eliminate Field Conflicts

Priority (1-3)	Goal Description	Potential BIM Uses
1- Most Important	Value added objectives	
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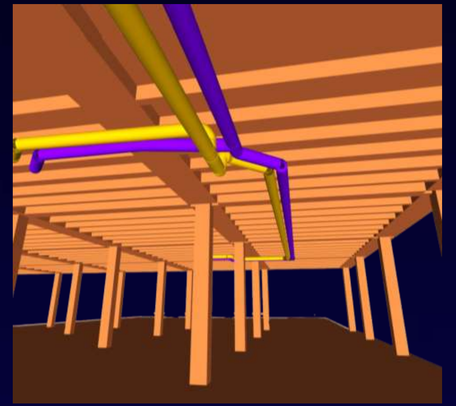
1	Optimize Sequence and Schedule	4D Modeling



Improve Energy Efficiency

Priority (1-3)	Goal Description	Potential BIM Uses
1- Most Important	Value added objectives	
1	Life Cycle Cost / Value Engineer all design decisions	Cost Estimation, Engineering Analysis, Building System Analysis, Design Reviews, Existing Conditions Modeling
1	Optimize Building Performance	Engineering Analysis, Building System Analysis, Design Reviews, Existing Conditions Modeling, Site Analysis
1	Eliminate Field Conflicts	3D Coordination, Design Reviews, Existing Conditions, Modeling, Design Authoring
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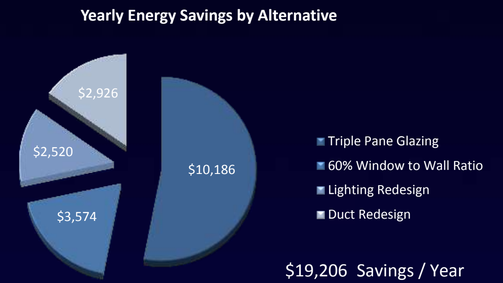
1	Improve Daylighting	Engineering Analysis, Building System Analysis, Design Reviews, Site Analysis, Existing Conditions Modeling, Design Authoring
1	Optimize Sequence and Schedule	4D Modeling



Improve Daylighting

Priority (1-3)	Goal Description	Potential BIM Uses
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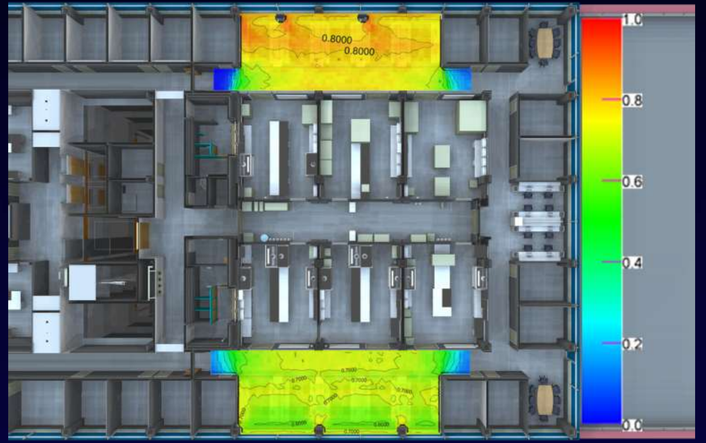
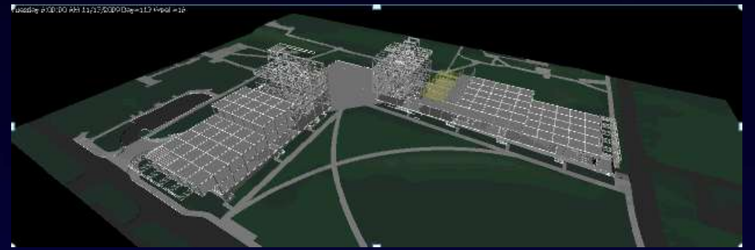
1	Life Cycle Cost / Value Engineer all design decisions	Cost Estimation, Engineering Analysis, Building System Analysis, Design Reviews, Existing Conditions Modeling
1	Optimize Building Performance	Engineering Analysis, Building System Analysis, Design Reviews, Existing Conditions Modeling, Site Analysis
1	Eliminate Field Conflicts	3D Coordination, Design Reviews, Existing Conditions, Modeling, Design Authoring
1	Improve Energy Efficiency	Engineering Analysis, Building System Analysis, Design Reviews, Site Analysis, Existing Conditions Modeling, Design Authoring
1	Improve Daylighting	Engineering Analysis, Building System Analysis, Design Reviews, Site Analysis, Existing Conditions Modeling, Design Authoring
1	Optimize Sequence and Schedule	4D Modeling



Optimize Sequence / Schedule

Priority (1-3)	Goal Description	Potential BIM Uses
1- Most Important	Value added objectives	
1	Life Cycle Cost / Value Engineer all design decisions	Cost Estimation, Engineering Analysis, Building System Analysis, Design Reviews, Existing Conditions Modeling
1	Optimize Building Performance	Engineering Analysis, Building System Analysis, Design Reviews, Existing Conditions Modeling, Site Analysis
1	Eliminate Field Conflicts	3D Coordination, Design Reviews, Existing Conditions, Modeling, Design Authoring
1	Improve Energy Efficiency	Engineering Analysis, Building System Analysis, Design Reviews, Site Analysis, Existing Conditions Modeling, Design Authoring
1	Improve Daylighting	Engineering Analysis, Building System Analysis, Design Reviews, Site Analysis, Existing Conditions Modeling, Design Authoring
1	Optimize Sequence and Schedule	4D Modeling



BIMception

- Building Info
- Façade Investigation
- Plenum Investigation
- Cantilever Plaza
- IPD/BIM Reflection

Acknowledgments

- Professor Robert Holland
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- Professor Theodore Dannerth
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- Dr. Jelena Srebric
- Dr. John Messner
- Dr. Richard Behr
- Dr. Robert Leicht
- Corey Wilkinson
- John Bechtel

Building STIMULUS

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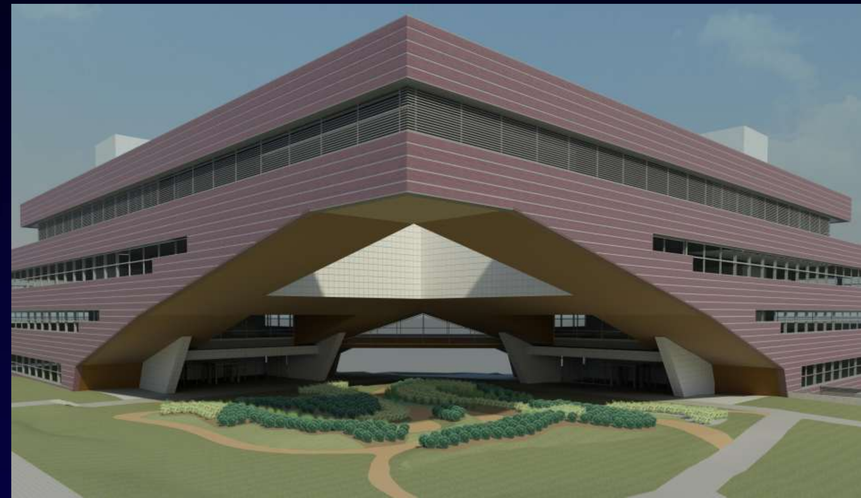

BIMception

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Section	Component		Length (ft)	Airflow (cfm)	Width (in)	Height (in)	Hydraulic Diameter (in)	Round Diameter (in)	Max Diameter (in)	Area (in^2)	Velocity (fpm)	Absolute Roughness (ft)	Relative Roughness (e/D)	Kinematic Viscosity (ft^2/s)	Density (lb/ft^3)	Reynolds Number (Re)	Friction Factor (f)	Pressure Drop Per 100ft (in wg per 100ft)	Velocity Pressure (in wg)	Loss Coefficient (Co)	Pressure Drop (in wg)
1			4.00	600.00	1.00	1.00	1	12.00	12.00	113.10	763.9	0.0100	0.0100000	0.0001580	0.0750000	80584.84938	0.038929176	0.141595			0.0057
	Diffuser	SR4-1									763.9								0.036384669	11.2	0.4075
	90 Diverging Tee	SR5-11									763.9								0.036384669	1.58	0.0575
2			5.00	600.00	14.00	10.00	11.66666667		11.67	106.90	808.2	0.0005	0.0005143	0.0001580	0.0750000	82887.27365	0.020990578	0.087896			0.0044
	90 Rounded Elbow	CR3-1									808.2								0.040724546	0.19	0.0077
3			6.00	600.00	14.00	10.00	11.66666667		11.67	106.90	808.2	0.0005	0.0005143	0.0001580	0.0750000	82887.27365	0.020990578	0.087896			0.0053
	Transition	SR5-13									808.2								0.040724546	0.49	0.0200

Table 2.8b Summary of Energy Costs for Seattle

	Annual Electricity Cost ($/sf)	Annual Gas Cost ($/sf)	Annual Energy Cost ($/sf)	% Reduction in Energy Costs	% Reduction per LEED
Base Case	$3.90	$2.60	$6.50		
Flow Setback (CFM21)	$3.80	$2.60	$6.40	2%	2%
VAV	$3.60	$2.00	$5.60	14%	22%
Supply Static Pressure of 4 in. w.g. (SP4)	$3.60	$2.70	$6.30	3%	4%
Supply Static Pressure of 3 in. w.g. (SP3)	$3.40	$2.70	$6.10	5%	8%
Enthalpy Wheel (Wheel)	$4.00	$1.30	$5.30	18%	28%
Enthalpy Wheel w/ VAV (VWheel)	$3.70	$1.00	$4.70	28%	44%
Heat Pipe (HtPipe)	$4.10	$1.50	$5.60	13%	21%
Run-Around Loop (Loop)	$4.10	$1.50	$5.60	13%	21%
Chiller Energy Recovery (CWER)	$3.90	$2.50	$6.40	1%	2%
Direct Evap. Cooling (Evap)	$3.80	$2.60	$6.40	1%	2%
Water-side Economizer (Econ)	$3.80	$2.60	$6.40	1%	1%
Humidity Controls: Max 60%RH, Min 20%RH (RH26)	$3.90	$2.40	$6.20	4%	6%
Humidity Controls: Max 50%RH, Min 40%RH (RH45)	$4.00	$3.30	$7.30	-12%	-20%
Humidity Controls: Max 50%RH, Min 40%RH w/ Enthalpy Wheel (RH45 Wheel)	$4.10	$1.90	$5.90	8%	13%
Lab Plug Loads 8 W/sf(EPD8)	$3.20	$2.60	$5.80	11%	
Lab Plug Loads 4 W/sf(EPD4)	$2.50	$2.70	$5.20	19%	
Advanced w/Run-Around Loop (ALoop)	$3.50	$1.10	$4.70	28%	44%
Advanced w/Enthalpy Wheel (AWheel)	$3.50	$1.00	$4.50	31%	48%

Utility Charge Rates

Some Departments pay the cost of their utility usage to OPP. These are Departments such as Housing and Food Service and Athletics. The following chart shows the billable rates charged as well as our avoidable costs that are used for Energy Savings Projects for FY 09-10:

Utility	Avoided Costs	Billable Rate	Units	Comments
Electricity	$1.09	$1.09	KW	5 sub-stations only, 1st half
	$0.07781	$0.09648	KWH	5 sub-stations only, 1st half
Electricity	$1.09	$1.09	KW	5 sub-stations only, 2nd half
	$0.07517	$0.09481	KWH	5 sub-stations only, 2nd half
Natural Gas	$8.66	$9.83	MCF	Blended Rate
Steam	$9.85	$21.65	1000 pounds	
Water & Wastewater	$3.32	$8.39	1000 gallons	
Chilled Water	$0.22	$0.22	Ton-Hour	Estimated Cost

Table A-1. SPV factors for finding the present value of future single costs (non-fuel)

	Single Present Value (SPV) Factors		
Number of years from base date	DOE Discount rate 3.0 %	OMB Discount Rates[a] Short term[b] 1.9 %	Long Term[c] 2.7 %
0.25	0.993	0.995	0.993
0.50	0.985	0.991	0.987
0.75	0.978	0.986	0.980
1	0.971	0.981	0.974
2	0.943	0.963	0.948
3	0.915	0.945	0.923
4	0.888	0.927	0.899
5	0.863	0.910	0.875
6	0.837	0.893	0.852
7	0.813	0.877	0.830
8	0.789	0.860	0.808
9	0.766	0.844	0.787
10	0.744	0.828	0.766
11	0.722		0.746
12	0.701		0.726
13	0.681		0.707
14	0.661		0.689
15	0.642		0.671
16	0.623		0.653
17	0.605		0.636
18	0.587		0.619
19	0.570		0.603
20	0.554		0.587
21	0.538		0.572
22	0.522		0.556
23	0.507		0.542
24	0.492		0.528
25	0.478		0.514
26	0.464		0.500
27	0.450		0.487
28	0.437		0.474
29	0.424		0.462
30	0.412		0.450

[a]OMB discount rates as of February 2010.
[b]Short-term discount rate based on OMB discount rate for 7-year study period.
[c]Long-term discount rate based on OMB discount rate for 30-year study period.

Table Ca-1. Projected fuel price indices (excluding general inflation), by end-use sector and fuel type.

Census Region 1 (Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont)

Projected April 1 Fuel Price Indices (April 1, 2010 = 1.00)

Sector and Fuel	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Residential															
Electricity	0.94	0.98	1.01	1.01	1.01	1.02	1.03	1.03	1.04	1.05	1.05	1.06	1.06	1.06	1.05
Distillate Oil	1.00	1.08	1.11	1.18	1.22	1.27	1.31	1.34	1.36	1.37	1.38	1.39	1.41	1.41	1.42
LPG	0.99	1.02	1.06	1.10	1.13	1.15	1.17	1.19	1.20	1.21	1.22	1.23	1.24	1.25	1.26
Natural Gas	1.05	1.07	1.06	1.04	1.04	1.05	1.05	1.05	1.06	1.07	1.08	1.09	1.09	1.09	1.10
Commercial															
Electricity	0.90	0.92	0.94	0.93	0.92	0.92	0.93	0.95	0.96	0.97	0.98	0.99	1.00	1.01	1.01
Distillate Oil	1.01	1.07	1.14	1.19	1.22	1.25	1.27	1.30	1.32	1.34	1.36	1.38	1.40	1.49	1.50
Residual Oil	1.00	1.10	1.23	1.32	1.37	1.42	1.49	1.54	1.60	1.64	1.66	1.68	1.71	1.73	1.75
Natural Gas	1.07	1.09	1.09	1.11	1.11	1.12	1.12	1.12	1.13	1.14	1.16	1.17	1.17	1.17	1.18
Coal	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.96	0.95	0.95	0.94	0.95	0.95	0.95	0.95
Industrial															
Electricity	0.88	0.88	0.90	0.87	0.87	0.88	0.90	0.91	0.91	0.92	0.93	0.94	0.96	0.97	0.97
Distillate Oil	1.00	1.10	1.16	1.22	1.26	1.32	1.36	1.41	1.44	1.47	1.49	1.50	1.52	1.52	1.54
Residual Oil	1.01	1.10	1.21	1.31	1.38	1.42	1.46	1.51	1.57	1.60	1.62	1.64	1.66	1.69	1.71
Natural Gas	1.16	1.17	1.18	1.16	1.16	1.16	1.16	1.16	1.16	1.17	1.19	1.21	1.20	1.20	1.20
Coal	0.99	0.99	0.98	0.98	0.97	0.97	0.97	0.96	0.96	0.95	0.95	0.95	0.95	0.95	0.95
Transportation															
Motor Gasoline	1.04	1.09	1.17	1.23	1.25	1.28	1.31	1.33	1.35	1.37	1.38	1.40	1.41	1.42	1.43

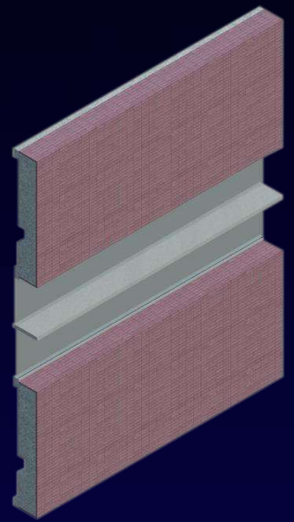
Table Ca-1, continued. Projected fuel price indices (excluding general inflation), by end-use sector and fuel type.

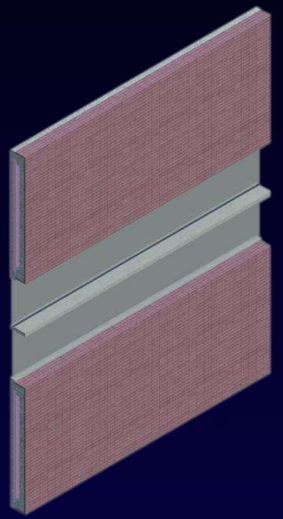
Census Region 1 (Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont)

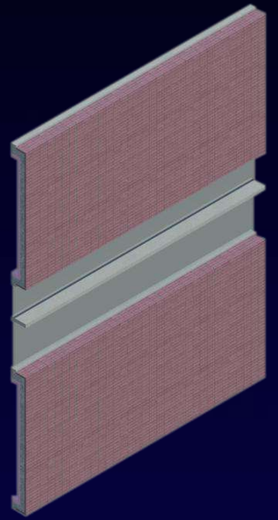
Projected April 1 Fuel Price Indices (April 1, 2010 = 1.00)

Sector and Fuel	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Residential															
Electricity	1.06	1.06	1.07	1.09	1.10	1.11	1.12	1.13	1.13	1.14	1.15	1.15	1.16	1.17	
Distillate Oil	1.44	1.45	1.46	1.48	1.50	1.52	1.54	1.56	1.58	1.60	1.62	1.65	1.66	1.68	1.70
LPG	1.26	1.27	1.28	1.29	1.30	1.31	1.33	1.34	1.35	1.37	1.38	1.39	1.40	1.41	1.42
Natural Gas	1.11	1.12	1.14	1.16	1.18	1.21	1.23	1.24	1.25	1.26	1.27	1.29	1.30	1.31	1.32
Commercial															
Electricity	1.01	1.02	1.03	1.05	1.06	1.08	1.10	1.12	1.13	1.14	1.15	1.15	1.16	1.17	1.17
Distillate Oil	1.52	1.54	1.56	1.58	1.60	1.62	1.64	1.67	1.69	1.72	1.74	1.76	1.79	1.81	1.83
Residual Oil	1.77	1.78	1.81	1.83	1.86	1.89	1.92	1.94	1.98	2.00	2.03	2.06	2.10	2.14	2.17
Natural Gas	1.19	1.20	1.22	1.25	1.28	1.31	1.33	1.35	1.36	1.38	1.39	1.39	1.41	1.43	1.44
Coal	0.95	0.95	0.95	0.96	0.97	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.99	0.99
Industrial															
Electricity	0.97	0.98	1.00	1.02	1.04	1.06	1.08	1.10	1.11	1.12	1.13	1.14	1.15	1.15	1.16
Distillate Oil	1.56	1.58	1.60	1.62	1.64	1.66	1.68	1.71	1.74	1.77	1.79	1.81	1.83	1.85	1.87
Residual Oil	1.72	1.73	1.76	1.78	1.80	1.84	1.86	1.88	1.91	1.93	1.96	1.99	2.02	2.06	2.10
Natural Gas	1.20	1.20	1.41	1.45	1.52	1.54	1.56	1.58	1.60	1.62	1.64	1.66	1.69	1.72	1.75
Coal	0.95	0.95	0.95	0.96	0.96	0.96	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98
Transportation															
Motor Gasoline	1.45	1.46	1.48	1.50	1.51	1.52	1.54	1.56	1.58	1.60	1.62	1.63	1.65	1.66	1.68

	Conductivity (W/m2 K)	Density (kg/m3)	Specific Heat (kj/kg K)	Specific Heat (kj/m3 K)
Insulation	.03	42.4	1.214	51.5
Concrete	1.73	2200	.841	1,850.2
Phase Change Material	.15	900	12.143	10,928.7
15% PCM Concrete	1.49	2005	2.536	5,084.7







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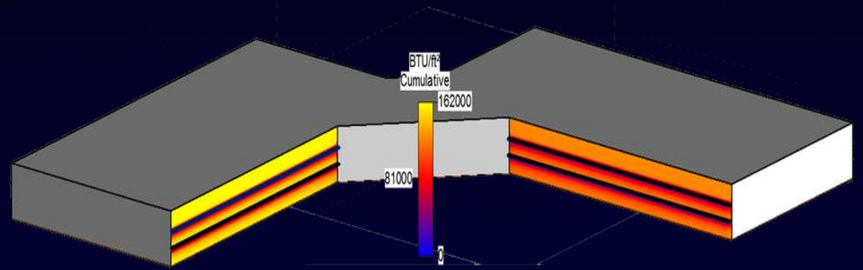

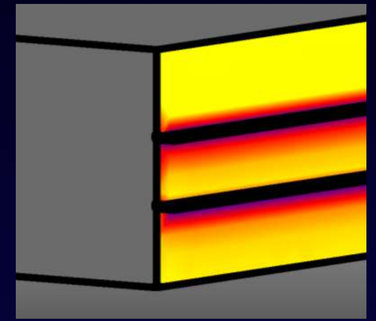

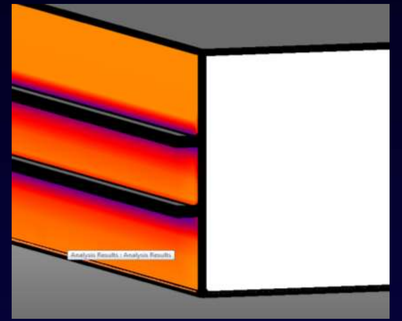

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Cloth Shade Selection

ThermoVeil™ SHADECLOTH		TOTAL SOLAR / VISIBLE					
		T_S	R_S	A_S	T_V	T_{UV}	O_F
■ Open Vertical Weave							
1801	White	0.22	0.63	0.15	0.18	0.13	0.11
1802	Beige	0.14	0.44	0.42	0.12	0.10	0.09
1803	Grey	0.13	0.26	0.61	0.15	0.13	0.12
1804	Blk/Brown	0.15	0.04	0.81	0.17	0.15	0.14
1810	Grey	0.10	0.36	0.54	0.11	0.09	0.09

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Electrical Depth

Panel	Run Length	Phase Conductor	#	Material Cost (lf)	Labor Cost (lf)	Neutral	#	Material Cost (lf)	Labor Cost (lf)	Isolated Ground	#	Material Cost (lf)	Labor Cost (lf)	Conduit Size (in)	Material Cost (lf)	Labor Cost	Total Cost
LB-0C1	150	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 5,901.00
LB-0C3	190	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 7,474.60
LB-0C5	170	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 6,687.80
LB-0C7	190	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 7,474.60
LB-0C9	215	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 8,458.10
LB-0C11	330	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 12,982.20
LB-0C13	230	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 9,048.20
LB-0C17	120	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 4,720.80
LB-1D1	170	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 6,687.80
LB-1E5	360	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 14,162.40
LBS-1E3	210	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 8,261.40
LB-2D1	140	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 5,507.60
LB-2D3	140	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 5,507.60
LB-2D5	60	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 2,360.40
LB-2D6	60	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 2,360.40
LB-2D9	160	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 6,294.40
LBR-0C11	260	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 10,228.40
LB-3D1	70	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 2,753.80
LB-3D5	70	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 2,753.80
																	$ 129,625.30

Equipment	#	Cost/per	Total
Eaton 9390-50 208V IN & Out UPS w/out Battery	19	$ 35,000.00	$665,000.00

Equipment	#	Cost/per	Total
Eaton Sag Ride Through SRT21000208AB	1	$250,000.00	$250,000.00
Pow-R-Line 4 Panelboard (1200A, 120/208V, 65KAIC)	1	$ 5,000.00	$ 5,000.00

Panel	Run Length	Phase Conductor	#	Material Cost (lf)	Labor Cost (lf)	Neutral	#	Material Cost (lf)	Labor Cost (lf)	Isolated Ground	#	Material Cost (lf)	Labor Cost (lf)	Conduit Size (in)	Material Cost (lf)	Labor Cost	Total Cost
LB-0C1	540	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 21,243.60
LB-0C3	510	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 20,063.40
LB-0C5	420	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 16,522.80
LB-0C7	450	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 17,703.00
LB-0C9	470	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 18,489.80
LB-0C11	360	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 14,162.40
LB-0C13	430	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 16,916.20
LB-0C17	580	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 22,817.20
LB-1D1	160	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 6,294.40
LB-1E5	120	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 4,720.80
LBS-1E3	90	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 3,540.60
LB-2D1	200	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 7,868.00
LB-2D3	210	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 8,261.40
LB-2D5	280	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 11,015.20
LB-2D6	290	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 11,408.60
LB-2D9	190	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 7,474.60
LBR-0C11	380	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 14,949.20
LB-3D1	260	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 10,228.40
LB-3D5	270	#2/0	3	$ 2.71	$ 1.39	#2/0	2	$ 2.71	$ 1.39	#6	2	$ 0.55	$ 0.62	2	$ 7.55	$ 8.95	$ 10,621.80
NEW DP	710	#600	6	$ 15.00	$ 3.10	#600	2	$ 15.00	$ 3.10	#1/0	2	$ 3.65	$ 1.22	3.5	$ 21.50	$ 18.30	$166,239.40
																	$ 410,540.80

Electrical Depth

Luminaire Schedule

Fixture Type	Image	Description	Mounting	Lamp	Voltage	Ballast	Wattage	Notes
A2		Linear Lighting Ellipse 27. 1'x4' Indirect/Direct Pendant Fixture, Extruded Aluminum Housing, Baked White finish. Concave louver blades with clear convex insert Catalog #: EL27-B-1-ET5-277-PVI_IC	Pendant 9'-0" A.F.F.	(1) 54W T5 CCT 4100K CRI 85	277V	Electronic Advanced Transformer	63W	
A3		Linear Lighting Ellipse 27. 1'x4' Indirect/Direct Pendant Fixture, Extruded Aluminum Housing, Baked White finish. Concave louver blades with clear convex insert Catalog #: EL27-B-1-ET5-277-PVI_IC-LS	Pendant 9'-0" A.F.F.	(1) 28W T5 CCT 4100K CRI 85	277V	Electronic Dimming Advanced Transformer	32W	
B		Ledalite Voice. Recessed 1'x4' Fixture, Die-Formed Cold Rolled Steel Housing, Flat Acrylic Panels Connected to Prismatic Acrylic Diffuser Catalog #: 9814D1-ST-F128-S-1-2-E	Recessed	(1) 28W T5 4100K CRI 85	277V	Electronic Advanced Transformer	31W	
C1		Philips Alkco Aris Series. 11" Low Profile LED Fixture, Extruded Aluminum Housing, Pearl Finish, Extruded Clear Polycarbonate Lens. Integrated On/Off Swtich Catalog # ARIS-11-40-120-PRL-DWC	Surface	(5) 1W LEDs CCT 4000K CRI 71-73	120V	Integrated Driver	5W	Surface mounted to bottom of shelf at 4'-3" A.F.F.
C2		Philips Alkco Aris Series. 21" Low Profile LED Fixture, Extruded Aluminum Housing, Pearl Finish, Extruded Clear Polycarbonate Lens, Integrated On/Off Switch Catalog # ARIS-21-40-120-PRL-DWC	Surface	(10) 1W LEDs CCT 4000K CRI 71-73	120V	Integrated Driver	10W	Surface mounted to bottom of shelf at 4'-3" A.F.F.
X1		Louis Poulsen Kipp Post Cutoff. Pole Mounted Fixture, White Spun Aluminum Diffuser, Black Injection Molded ASA Top Shade, Clear Polycarbonate Enclosure, Black Die Cast Aluminum Frame Catalog #: KIP-1-70W-CMH-T6 G12	Pole Mounted 27'-0"	(1) 70W CMH CCT 3000K CRI 90	277V	Electronic Advanced Transformer	79W	
X2		Louis Poulsen Kipp Bollard. Pole Mounted Fixture, Injection Molded White Opal Acrylic Diffuser, Injection Molded Clear Polycarbonate Enclosure, Black Die Cast Aluminum Frame. Catalog #: KIB-1-39W-CMH-T6 G12	Pole Mounted 4'-3"	(1) 39W CMH CCT 3000K CRI 90	277V	Electronic Advanced Transformer	45W	

X3		Winona Lighting Spirit. Black Painted Aluminum, 18" Stem, Area Light. Catalog #: SP-0-12V-BKS-18-SM-STD	Surface 18" Stem	(1) 35W MR8 CCT 3000K CRI 100	12V	--	35W	Provide Series TMI 600 Ingrade Transformer
X4		Invue Entri LED Triangle Reveals. Black One Piece Die-Cast Aluminum, Injection Molded AccuLED Optical System. Catalog #: ENT-A01-E1-BL4-BK	Wall Mount	(1) LED Bar 4000K CRI >70	277V	Integrated Driver	26W	Wall mounted at 10' 0"
X5		Lightolier Calculite 6" Recessed Downlight. Array of High Brightness Royal Blue LED's, Phosphoy Lens Assembly Converts Blue Light to White. Catalog #: C6L20-DL-30-M-CL-P	Recessed	LED CCT 3000K CRI	277V	Integrated Driver	39W	
X6		Lightolier Calculite 6" Recessed Wallwasher. Array of High Brightness Royal Blue LED's, Phosphoy Lens Assembly Converts Blue Light to White. Catalog #: C6L20-WW-30-M-CL-P	Recessed	LED CCT 3000K CRI	277V	Integrated Driver	39W	
X7		Bega Floodlight. 3"x4' Floodlight. Black Die-Cast Aluminum Extruded Housing. Catalog #: 7593P.537BLK-28	Wall Mount	(1) 28W T5HO CCT 3000K CRI 85	277V	Electronic Advanced Transformer	31W	Mount Parallel to underside of cantiliver void.
X8		MP Lighting. Black Anodized Aluminum Housing, Polycarbonate Lens. Catalog #: L36-3.5W-W30S-BA	Surface	LED CCT 3000K CRI	12V	Remote Driver	3.5W	Provide Remote TLDDLV60W5000 Driver

Pfund Russell Stough Villacampa

Existing Façade Structure

Self Weight Calculation							
	width(in)	thickness(in)	length(in)	Vol(cf)	pcf	Weight	
Top Return	22.75	6	264	20.9	150	3.13	
Bott Return	22.75	6	264	20.9	150	3.13	
Front Panel	5	125.25	264	95.7	150	14.35	
Side Returns	16.75	125.25	8	9.7	150	1.46	
Brick	141.75	2	264	43.3	120	5.20	
			Totals	7.1	CY	27.26	K

Allowable Thicknesses: Assuming Uncracked Section						
Thickness (in)	I (in4)	C (in)	Fr (psi)	ØM$_{cap}$ (lb-ft)	Mu(SW)	Mu(wind)
2	8	1	530	318	858	694
3	27	1.5	530	716	1096	694
4	64	2	530	1273	1335	694
4.25	77	2.125	530	1437	1394	694
5	125	2.5	530	1989	1573	694
6	216	3	530	2864	1811	694
*Note: Moment due to wind and self-weight are separate cases						

Minimum Reinforcing: ACI 318-08, 10.5.1		
As$_{min}$ =	0.0018*bwd	
Thickness (in)	As$_{min}$ (in2)	Reinforcing
2	0.037	6x6 W2.1/2.1
3	0.056	6x6 W2.9/2.9
4	0.074	6x6 W4.0/4.0
5	0.108	6x6 W6.3/6.3
6	0.130	6x6 W7.4/7.4

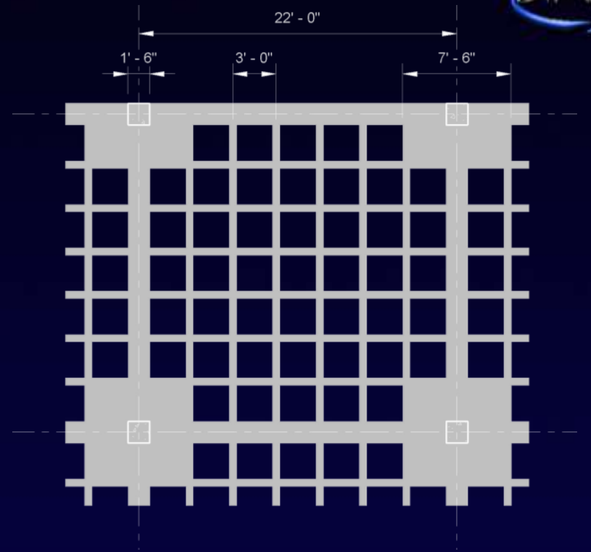
Final Façade Structure

Self Weight Calculation- 60%								
		width(in)	thickness(in)	length(in)	Vol(cf)	pcf	Weight	
Top Return		14	6	264	12.8	150	1.93	
Bott Return		14	5	264	11.8	150	1.76	
Front Panel		6	141.25	264	129.5	150	19.42	
Brick		157.25	2	264	48.0	120	5.77	
				Totals	7.5	CY	28.88	K
				%increase	6.15%			

Allowable thicknesses: Concrete, no reinforcing						
Thickness (in)	I (in4)	C (in)	Fr (psi)	M_{cap} (lb-ft)	Mu(SW)	Mu(wind)
2	8	1	530.33	318.2	1091.101	883.1
3	27	1.5	530.33	715.9	1394.185	883.1
4	64	2	530.33	1272.8	1697.268	883.1
5	125	2.5	530.33	1988.7	2000.352	883.1
5.5	166.375	2.75	530.33	2406.4	2151.894	883.1
6	216	3	530.33	2863.8	2303.436	883.1

Waffle Slab Design

- Designed For Strength
- ACI318-08 Direct Design Method
- 3ft Module: 30”pans, 6” ribs
- 8” deep pans – Table 9.5c
- 18” interior beams
- 90” square drop panels



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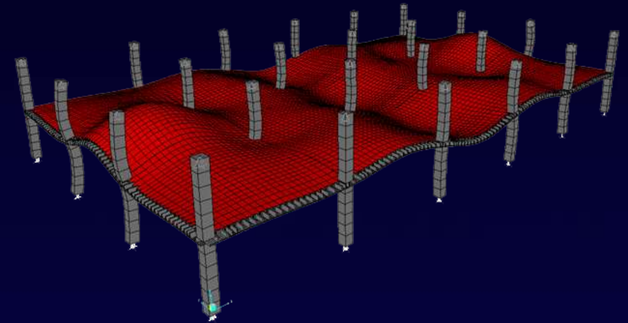
Waffle Slab Vibration Analysis

- AISC Design Guide 11- Floor Vibration Due to Human Activity
- SAP2000 model – AE597A
- Point Load – Deflection Analysis
- Period of vibration calculation using Rayleigh method
- Life Science Wing – 4000ui/s
- Waffle Slab is Too Stiff

Span/Location	Weight(kip)	Uv(lb/sec2)	Δ_p(in/100kip)	T(sec)	Velocity(ui/sec)
A	46.3	5500	0.500	0.0695	1910
B	46.3	5500	0.463	0.0647	1647
C	46.3	5500	0.462	0.0690	1755



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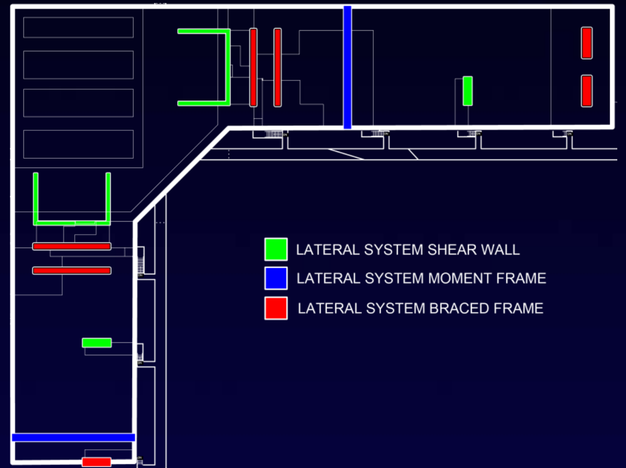
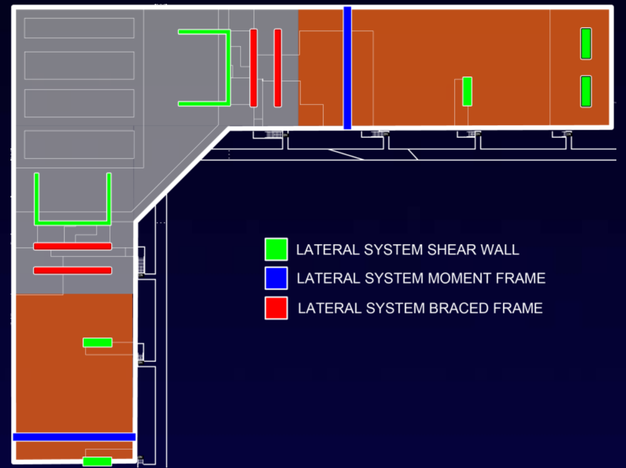
Existing lateral System



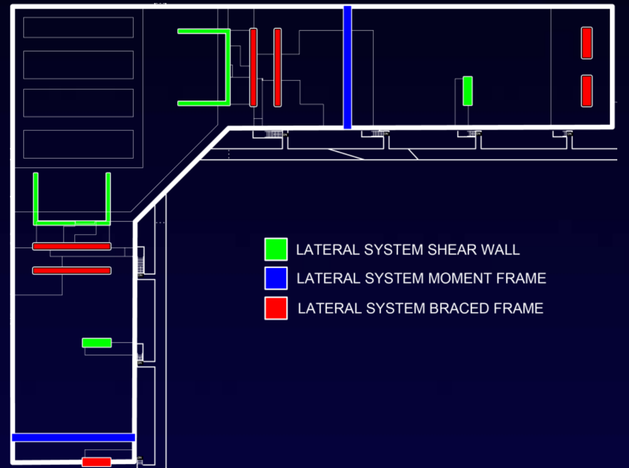
New lateral System



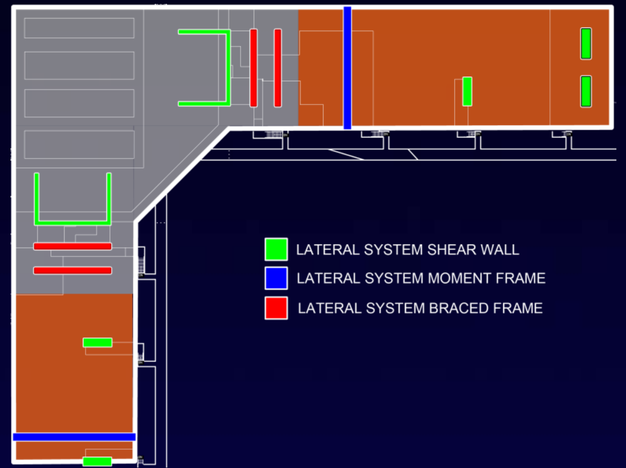
Wind Existing summary

- V = 90mph
- Exposure B: Urban/Suburban
- Construction Type IIIB, Occ. Cat: B

Existing lateral System



New lateral System

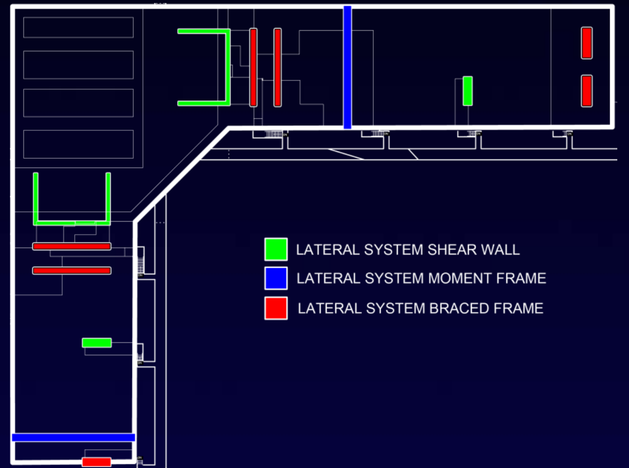


Seismic Existing summary

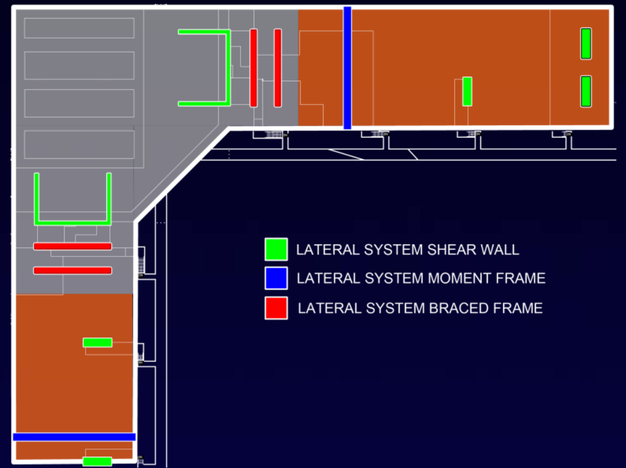
- Torsional Irregularity Type 1a
- SDC: B
- R= 3.25, I= 1.25
- Ta = 0.512s, Cu = 1.7
- Cu*Ta = 0.871s
- Tb = 0.262s
- Cd = 3.25
- New Tb = 0.264s
- Seismic base Shears – 1581K

BIMception

Existing lateral System



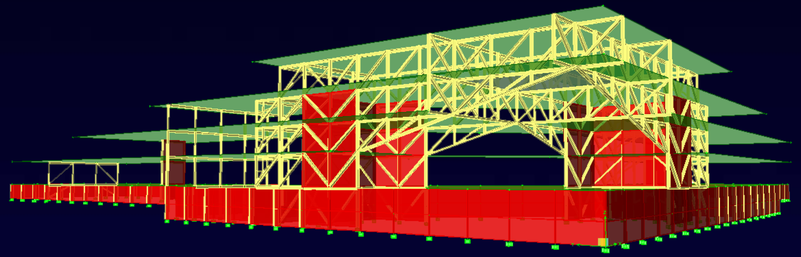
New lateral System



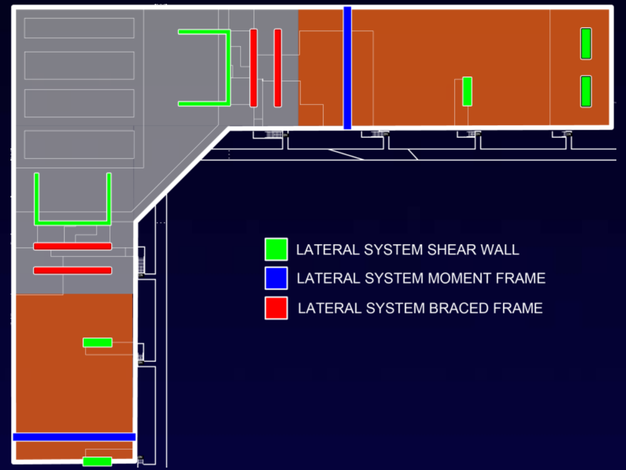
Seismic Redesign summary

- Existing braced frames in wings redesigned as shear walls
- 16” or 18” depending on existing
- R = 3.25, I= 1.25
- Tb = 0.264
- Cd = 3.25
- Seismic Base Shear– 1676k

ETABS Model

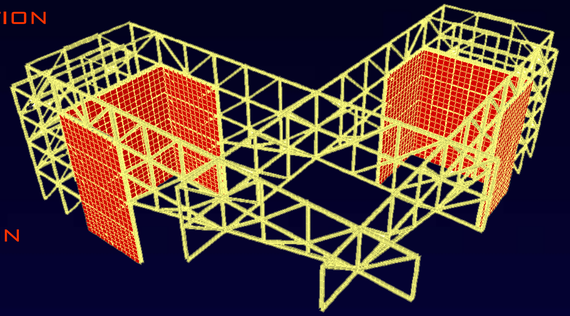


New lateral System



Redesign summary

- Existing braced frames in wings redesigned as shear walls
- 16” or 18” depending on existing



Tension members

- Switch member orientation
- Additional concrete shear wall extension for added stiffness
- Stiffness/ Gravity Analysis