Traditional Design Process

*Linear Information Flow*

- Architect
- Engineer

Integrated Project Delivery

*Shared Responsibility*

- Architect
- Engineer

IPD (+) Data Analytics

*Early Iterative Design*

- Explore
- Adjust
- Score

Architect, Engineer & Contractor

Low Opportunity for Integration

Medium-High Opportunity for Integration

High Opportunity for Integration

Design Process

IPD (+) Data Analytics

Explore

DOAS

Single Zone AHU

VRF

Higher

Lower
Design Process
Parametric Design

<table>
<thead>
<tr>
<th>Input</th>
<th>Analysis</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter 1: x₁ to x₂</td>
<td>Simulation</td>
<td>Objective 1</td>
</tr>
<tr>
<td>Parameter 2: y₁ to y₂</td>
<td></td>
<td>Objective 2</td>
</tr>
<tr>
<td>Parameter 3: z₁ to z₂</td>
<td></td>
<td>Objective 3</td>
</tr>
</tbody>
</table>

Design Process
Brain Power – Computational Methods Relationship

CITATION: ANDREW HEUMANN
Design Process
Brain Power – Computational Methods Relationship

CITATION: ANDREW HEUMANN

COMPUTATIONAL VALIDATION OF "BLOCKS"

FOAM BLOCK EXERCISE

Brain Power – Computational Methods Relationship

CITATION: ANDREW HEUMANN

COMPUTATIONAL VALIDATION OF "BLOCKS"

FOAM BLOCK EXERCISE
Design Process
Ability to Change Design Performance

Impact from Engineered Systems
Impact from Architecture
Missed Opportunity

Traditional Design Process
IPD (+) Data Analytics

Impact from Early Interdisciplinary Design Iterations

Design Process

Tools

BIM

PARAMETRIC

MIRAGE

3D STUDIO MAX

AUTODESK REVIT

VERIFICATION

MECHANICAL

WRF

LIGHTING-ELECTRICAL

Miro Digital Whiteboard

PHYSICAL PLANNING

Miro Digital Whiteboard

CONSTRUCTION PLANNING

AUTODESK CIVIL 3D

Miro Digital Whiteboard

CONCEPTUAL DESIGN PROCESS

Team Collaboration

Physical Pull Planning

Miro Digital Whiteboard

Task Tracking

Trello Task Tracking

Clockify Time Tracking

Microsoft Teams

GoCozy

Office 365

RSMeans

Team Collaboration

Physical Pull Planning

Miro Digital Whiteboard

Task Tracking

Trello Task Tracking

Clockify Time Tracking

Microsoft Teams

GoCozy

Office 365

RSMeans
One GDS Mission

STAKEHOLDER ANALYSIS

EDUCATION BOARD & DONORS

ADMINISTRATION & TEACHERS

SURROUNDING COMMUNITY & ALUMNI

STUDENTS PARENTS & SUPPORT STAFF

Proposed LMS

Existing H.S.

Vertical Connections

Purpose Statement

To... realize an architectural space that integrates with sustainable systems

In a way... that embodies safety, well-being, and function

So that... students are empowered to become forward thinking and socially responsible.
Design Drivers

Responsible Innovation

- $800,000 excavation savings.
- Reduced excavation by 16 days.
- Improved indoor air quality (IAQ) achieve ASHRAE 55 and 62.1.
- Mechanical and Electrical Runs reduced by 27% and 2%, respectively.
**Design Drivers**

**Engage and Empower**

- Building performance display benchmarked energy, water usage, and PV power.
- Color coordinated exposed system engages students.
- Peak Acceleration below 0.5%g provides vibrational comfort.

**Design Drivers**

**Resiliency through Adaptability**

- 150 psf live load and stricter drift requirements promotes flexibility, resiliency.
- Mechanical systems and devices capable of increasing outside air intake to 100% OA for 4500 cfm.
- Packaged AHU located a 3-Step 300kW Natural Gas Generator.
Competition Challenges
Building Performance Enhancement

- >80% sDA in classrooms with low glare conditions
- Enhanced energy performance of 26 site EUI
- Sound isolation from main roadways
- Cost implications of design decisions informed choices

Competition Challenges
Water Retention, Harvesting, & Reutilization

- Saving 620,000 gallons of water through Rainwater Reuse
- Rainwater used for toilets
- Infrastructure for possible potable water treatment
**Competition Challenges**

- Pandemic Resiliency

- Architectural layout remains flexible in pandemic situations
- FC DOAS system equipped with MERV-13 filters.
- Advanced air cleaning methods

---

**Rating Systems**

Use of Categories to Inform Design

- Mind
- Movement
- Nourishment
- Community
- Location and Transportation

**Indoor Environmental Quality**

- LEED – Leadership in Energy and Environmental Design
- CHPS – Collaborative for High Performance Schools
- Site

**Operations and Metrics**
**Overview**

**Design Process**
- Conceptual Design Process
- Schematic Design Process
- Design Audit
- Design Development

**Architectural Evaluation**

**Need for the Study**
- Missed Opportunity
- Impact from Engineered Systems
- Impact from Architecture
- Impact from Early Interdisciplinary Design Iterations

**Traditional Design Process**
- IPD (+) Data Analytics
How does building **form** and **façade** impact overall performance?

**Architectural Evaluation**

**Need for the Study**

- Missed Opportunity
- Impact from Engineered Systems
- Impact from Architecture
- Traditional Design Process
- IPD (+) Data Analytics

**Architectural Evaluation**

**Developing the Design Space**

**Parameters**

- Building Form: 1, 2 & 3
- Building Facade: 0.0 to 1.0

**Analysis**

- Simulation

**Objectives**

- IEQ Performance
- Energy Potential
- Cost and Schedule
- Constructability

**How does building **form** and **façade** impact overall performance?**
### Architectural Evaluation

#### Design Space Parameters

**Parameters**

<table>
<thead>
<tr>
<th>Building Form</th>
<th>1, 2 &amp; 3</th>
<th>1.) AEI PROVIDED DESIGN</th>
<th>2.) MODIFIED DESIGN</th>
<th>3.) RE-ENGINEERED FORM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window Density</td>
<td>0.0 to 1.0</td>
<td>0.0</td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>

- Classrooms: 0.5
- Service/Support: 0.0
- ......

---

**Architectural Evaluation**

**Exploration of Architectural Forms**

- Option: 2
- Window Density: 0.0
- Run: True
Architectural Evaluation

Objective Functions

**Objectives**

- IEQ Performance
- Energy Potential
- Cost and Schedule
- Constructability

- Heating/Cooling Loads
- Radiation Potential
- Aspect Ratio
- Façade Area
- Building Area
- Mechanical & Electrical Runs
- Excavation

Design Space Exploration

- Low Cooling Load Values
- Low Distance Electrical Runs
Architectural Evaluation

Result: 40% Window Density

OBJECTIVES TO BE MINIMIZED

OBJECTIVES TO BE MAXIMIZED

FINAL DESIGN PERFORMANCE TABULATION

<table>
<thead>
<tr>
<th>LOWER PERFORMING</th>
<th>HIGHER PERFORMING</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEI PROVIDED DESIGN</td>
<td></td>
</tr>
<tr>
<td>MODIFIED DESIGN</td>
<td></td>
</tr>
<tr>
<td>RE-ENGINEERED FORM</td>
<td></td>
</tr>
</tbody>
</table>

Excavation and Facade Area

Provided Design
Total Excavation: 51,518 SCY
Total Excavation Duration: 37 Days
Total Excavation Cost: $1,180,148.15

Celsius Design
Total Excavation: 28,591 SCY
Total Excavation Duration: 21 Days
Total Excavation Cost: $1,000,056.3

DESIGN PERFORMANCE TABULATION

<table>
<thead>
<tr>
<th>LOWER PERFORMING</th>
<th>HIGHER PERFORMING</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEI PROVIDED DESIGN</td>
<td></td>
</tr>
<tr>
<td>MODIFIED DESIGN</td>
<td></td>
</tr>
<tr>
<td>RE-ENGINEERED FORM</td>
<td></td>
</tr>
</tbody>
</table>
ARCHITECTURAL EVALUATION

Façade Area and Excavation

AEI PROVIDED DESIGN

RE-ENGINEERED FORM

DESIGN PERFORMANCE TABULATION

<table>
<thead>
<tr>
<th>CONCRETE</th>
<th>STEEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEI PROVIDED DESIGN</td>
<td>20°</td>
</tr>
<tr>
<td>RE-ENGINEERED FORM</td>
<td>10°</td>
</tr>
<tr>
<td>% SAVINGS</td>
<td>62%</td>
</tr>
</tbody>
</table>

SOLAR RADIATION POTENTIAL

AEI PROVIDED DESIGN

RE-ENGINEERED FORM

DESIGN PERFORMANCE TABULATION

AEI PROVIDED DESIGN

MODIFIED DESIGN

RE-ENGINEERED FORM

~320 mWh annual production

409 mWh annual production
Architectural Evaluation
Views to Outdoors

DESIGN PERFORMANCE TABULATION

<table>
<thead>
<tr>
<th>LOWER PERFORMING</th>
<th>HIGHER PERFORMING</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEI PROVIDED DESIGN</td>
<td>AEI PROVIDED DESIGN</td>
</tr>
<tr>
<td>MODIFIED DESIGN</td>
<td>MODIFIED DESIGN</td>
</tr>
<tr>
<td>RE-ENGINEERED FORM</td>
<td>RE-ENGINEERED FORM</td>
</tr>
</tbody>
</table>

Utility Runs

AEI PROVIDED DESIGN

RE-ENGINEERED FORM

DESIGN PERFORMANCE TABULATION

<table>
<thead>
<tr>
<th>LOWER PERFORMING</th>
<th>HIGHER PERFORMING</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEI PROVIDED DESIGN</td>
<td>AEI PROVIDED DESIGN</td>
</tr>
<tr>
<td>MODIFIED DESIGN</td>
<td>MODIFIED DESIGN</td>
</tr>
<tr>
<td>RE-ENGINEERED FORM</td>
<td>RE-ENGINEERED FORM</td>
</tr>
</tbody>
</table>

2% lower electrical runs
27% lower mechanical duct runs
Architectural Evaluation

Acoustic Performance

35% improvement in acoustic comfort

<table>
<thead>
<tr>
<th>DESIGN PERFORMANCE TABULATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOWER PERFORMING</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>AEI PROVIDED DESIGN</td>
</tr>
<tr>
<td>MODIFIED DESIGN</td>
</tr>
<tr>
<td>RE-ENGINEERED FORM</td>
</tr>
</tbody>
</table>

Natural Ventilation Potential

28% improvement in natural ventilation potential

<table>
<thead>
<tr>
<th>DESIGN PERFORMANCE TABULATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOWER PERFORMING</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>AEI PROVIDED DESIGN</td>
</tr>
<tr>
<td>MODIFIED DESIGN</td>
</tr>
<tr>
<td>RE-ENGINEERED FORM</td>
</tr>
</tbody>
</table>
Architectural Evaluation

Cooling and Heating Load

GLAZING AREA: ~14,000 SF

GLAZING AREA: ~13,000 SF

GLAZING AREA: ~19,000 SF

DESIGN PERFORMANCE TABULATION

<table>
<thead>
<tr>
<th>LOWER PERFORMING</th>
<th>HIGHER PERFORMING</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEI PROVIDED DESIGN</td>
<td></td>
</tr>
<tr>
<td>MODIFIED DESIGN</td>
<td></td>
</tr>
<tr>
<td>RE-ENGINEERED FORM</td>
<td></td>
</tr>
</tbody>
</table>

Architectural Evaluation

Quality Daylighting

ANNUAL SUNLIGHT EXPOSURE

80.2%

SPATIAL DAYLIGHT AUTONOMY

6.6%

DESIGN PERFORMANCE TABULATION

<table>
<thead>
<tr>
<th>LOWER PERFORMING</th>
<th>HIGHER PERFORMING</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEI PROVIDED DESIGN</td>
<td></td>
</tr>
<tr>
<td>MODIFIED DESIGN</td>
<td></td>
</tr>
<tr>
<td>RE-ENGINEERED FORM</td>
<td></td>
</tr>
</tbody>
</table>
How can building systems elevate the final deliverable for building occupants?
### Estimate Tracking

#### Celsius Design SF Estimate

<table>
<thead>
<tr>
<th>Level</th>
<th>Major Group Elements</th>
<th>Cost of Level, $</th>
<th>% of Total Cost Level</th>
<th>Cost / SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>SUBSTRUCTURE</td>
<td>$1,227,072.57</td>
<td>4.4%</td>
<td>$162.95</td>
</tr>
<tr>
<td>2.</td>
<td>IME</td>
<td>$12,049,730.83</td>
<td>29.9%</td>
<td>$165.27</td>
</tr>
<tr>
<td>3.</td>
<td>INTERIORS</td>
<td>$9,125,827.90</td>
<td>22.0%</td>
<td>$156.83</td>
</tr>
<tr>
<td>4.</td>
<td>SERVICES</td>
<td>$15,975,368.35</td>
<td>31.2%</td>
<td>$203.77</td>
</tr>
<tr>
<td>5.</td>
<td>EQUIPMENT &amp; FURNITURE</td>
<td>$2,660,078.49</td>
<td>6.4%</td>
<td>$189.08</td>
</tr>
<tr>
<td>6.</td>
<td>SPECIAL CONSTRUCTION &amp; DEMOLITION</td>
<td>$0.00</td>
<td>0.0%</td>
<td>$0.00</td>
</tr>
<tr>
<td>7.</td>
<td>BUILDING ENTRAINMENT</td>
<td>$2,940,941.70</td>
<td>7.5%</td>
<td>$181.48</td>
</tr>
</tbody>
</table>

**Contractor Fees (G & O):** $10,383,183.93

**Architectural Fees:** $5,712,400.92

**Contingency:** $6,213,709.57

**Total:** $43,417,056.42

**Total Estimated Building Cost:** $63,875,023.80

### System Selection

**FINAL SYSTEM**
- Post-Tensioned One-Way Slab and Beam
- Integrated Project Delivery
- DOAS FDU-2 (Air Based)
- Switchboard with Copper Wiring and Natural Gas Generator

**Structural Systems**
- Post-Tensioned One-Way Slab
- Braced Frames

**Construction Systems**
- DOAS FDU-2 (Air Based)
- Integrated Project Delivery
- Switchboard with Copper Wiring and Natural Gas Generator

**Mechanical Systems**
- Switchboard with Copper Wiring and Natural Gas Generator
- Generator

**Electrical Systems**
- Distribution System
- Switchboard
**Structural System Selection**

**Initial Research into Viable Solutions**

**Multi-Bay, Building Level Analysis**

**FINAL SYSTEM**

Post-Tensioned One-Way Slab and Beam

---

**System Selection**

**Structural**

**FTT& Final System**

**Multi-Bay, Building Level Analysis**

**FINAL SYSTEM**

Post-Tensioned One-Way Slab and Beam

---

### Structural System Matrix

<table>
<thead>
<tr>
<th>Category</th>
<th>Metric</th>
<th>Weight</th>
<th>System</th>
<th>Score</th>
<th>PT Slab &amp; Beams</th>
<th>RC Slab &amp; Beams</th>
<th>RC Slab &amp; Pre</th>
<th>Pre-Tensioned</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Steel</td>
<td>Tilt-Up</td>
<td>Hollowcore</td>
<td>One-Way RC</td>
<td>Flat Plate</td>
<td>One-Way Beams</td>
</tr>
<tr>
<td>Material</td>
<td></td>
<td></td>
<td>Steel</td>
<td>Tilt-Up</td>
<td>Hollowcore</td>
<td>One-Way RC</td>
<td>Flat Plate</td>
<td>One-Way Beams</td>
</tr>
<tr>
<td>Torrance</td>
<td></td>
<td></td>
<td>10</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Servicability</td>
<td></td>
<td></td>
<td>10</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Erection Labor</td>
<td></td>
<td></td>
<td>9</td>
<td>3</td>
<td>7</td>
<td>1</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Schedule Impact</td>
<td></td>
<td></td>
<td>10</td>
<td>3</td>
<td>7</td>
<td>3</td>
<td>1</td>
<td>5.5</td>
</tr>
<tr>
<td>Constructability</td>
<td></td>
<td></td>
<td>5</td>
<td>2.5</td>
<td>7</td>
<td>1</td>
<td>3.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Architecture &amp;</td>
<td></td>
<td></td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Integration</td>
<td></td>
<td></td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Aesthetics</td>
<td></td>
<td></td>
<td>7.5</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Durability</td>
<td></td>
<td></td>
<td>7.5</td>
<td>7</td>
<td>6</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Embedded Carbon</td>
<td></td>
<td></td>
<td>20</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Expandability</td>
<td></td>
<td></td>
<td>10</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>2.5</td>
<td>1</td>
</tr>
<tr>
<td><strong>Score</strong></td>
<td></td>
<td></td>
<td>4.3</td>
<td>4.05</td>
<td>3.1</td>
<td>2.95</td>
<td>4.75</td>
<td>3.925</td>
</tr>
</tbody>
</table>
**System Selection**

**Structural**

**FINAL SYSTEM**

Post-Tensioned One-Way Slab and Beam

**Structural System Matrix Score**

<table>
<thead>
<tr>
<th>System Type</th>
<th>Score (Higher is Better)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composite Steel</td>
<td>4.3</td>
</tr>
<tr>
<td>Tilt-Up</td>
<td>4.05</td>
</tr>
<tr>
<td>Hollowcore Plank</td>
<td>3.1</td>
</tr>
<tr>
<td>One-Way RC (System)</td>
<td>2.95</td>
</tr>
<tr>
<td>2-Way PT</td>
<td>4.025</td>
</tr>
<tr>
<td>One-Way PT Slab and Beam</td>
<td>4.75</td>
</tr>
<tr>
<td>One-Way RC Slab and PT Beam</td>
<td>3.925</td>
</tr>
</tbody>
</table>

**System Selection**

**Construction**

**FINAL SYSTEM**

Integrated Project Delivery

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
<th>Score (1:10)</th>
<th>Weighted Score</th>
<th>Score (1:10)</th>
<th>Weighted Score</th>
<th>Score (1:10)</th>
<th>Weighted Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td>20</td>
<td>6</td>
<td>120</td>
<td>7</td>
<td>140</td>
<td>9</td>
<td>180</td>
</tr>
<tr>
<td>Budget</td>
<td>15</td>
<td>7</td>
<td>105</td>
<td>8</td>
<td>120</td>
<td>7</td>
<td>105</td>
</tr>
<tr>
<td>Ability to Deal with Complexity</td>
<td>20</td>
<td>6</td>
<td>120</td>
<td>7</td>
<td>140</td>
<td>9</td>
<td>180</td>
</tr>
<tr>
<td>Delivery Speed</td>
<td>15</td>
<td>6</td>
<td>90</td>
<td>7</td>
<td>105</td>
<td>8</td>
<td>120</td>
</tr>
<tr>
<td>Reduced Risk</td>
<td>5</td>
<td>9</td>
<td>45</td>
<td>8</td>
<td>40</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>Innovation and Integration</td>
<td>25</td>
<td>5</td>
<td>125</td>
<td>6</td>
<td>150</td>
<td>9</td>
<td>225</td>
</tr>
<tr>
<td>Total Weighted Scores</td>
<td>605</td>
<td>695</td>
<td>835</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**System Selection**

**Construction**

**FREE FORM**

Integrated Project Delivery
**System Selection**

**Construction**

**System Selection**

**Mechanical**

**Final System**

DOAS FCU-2 (Air Based)
System Selection  
Mechanical

**Parameters**

- Dedicated Outdoor Air System (DOAS)

**Internal Loads**
- ASHRAE Standards 62.1 & 90.1 - 2013

**Ventilation Per Person (m^3/s)**
- 0.004719

**Ventilation Per Area (m^3/s – m^2)**
- 0.00061

**People Density (Ppl/m^2)**
- 0.25

**Lighting Power Density (W/m^2)**
- 4.304

**Infiltration Rate (m^3/s Per m^2 façade)**
- 0.000227

**Equipment (W/m^2)**
- 10.979

**Construction Type**
- Classroom
- Administration
- Athletics
- Library/Music
- Cafeteria
- Circulation

**Initial Conditions**

- Temperature and Relative Humidity Setpoints
- Construction Type
- Glazing Properties
- System Zones
**Site Logistics**
4D Construction Planning

**PHASE 4**

Jan. 22, 2023 – June 16, 2023

**Design Process**

Overview

- Conceptual Design Process
- Schematic Design Process
- Design Audit
- Design Development

...
Which shading configuration best balances multi-disciplinary needs?

Solutions above 70% sDA and below 50 kBTU/SF/yr EUI resulted in desirable solutions to meet challenges and goals.
Shade Count, Assembly Type and Window to Wall Ratio had the greatest impact on Energy

Window to Wall Ratio had the greatest impact on Daylighting Performance

Each parameter had equal impact on Building Façade Cost

Note: Automatic shading was used which accounts for the lower sDA values.
Building Envelope
Optimize Fenestration

FINAL SHADING DIMENSIONS

U-Factor: 0.25
SHGC: 0.35
VLT: 55%

Building Envelope
Glazing Area

North Façade
WWR: 40%

East Façade
WWR: 35%

West Façade
WWR: 28%

South Façade
WWR: 45%
**Building Envelope**

Hygrothermal Analysis

Plan View of Exterior Wall

Option 1

Option 2

Option 3

Option 4

Option 5

Option 6

Option 7

Option 8

WALL ASSEMBLY EVALUATION MATRIX

**Building Envelope**

Materiality

Wood Cladding

Wood cladding differentiates the second story of the architectural form, providing a low embodied carbon cladding material.

Cost/ft² = $10.17
Material Embodied Carbon = 3.14 kgCO₂eq/ft²

Brick Veneer

Brick veneer on lower levels of the architectural form remain contextually appropriate with surrounding architecture.

Cost/ft² = $9.92
Embodied Carbon = 8.79 kgCO₂eq/ft²

**Materiality**

GLASSROC SHEATHING

BRICK VENEER

GREEN GIRT

4" ROCKWOOL

GLAZING
Building Envelope

Materiality

SAM 100 VS TRADITIONAL MASONRY

TRADITIONAL MASONRY - $212,167
SAM100 MASONRY - $64,484

Wall Connection Detail

SMARTi THERMALLY BROKEN GREEN GIRT
FERO, THERMALLY BROKEN BRICK SUPPORT ANGLE
PROSOCOR CAT’S GUARD PAINT ON WEATHER BARRIER
SECTION AT EXTERIOR WALL
Building Envelope
Acoustic Detailing

68 dBA SOURCE
NC-35
CLASSROOMS

STC 35 GLAZING
METAL STUD CAVITY WALL

Roof and Lobby Integration
Roof Integration

Rainwater and Plumbing

RAINWATER AND PLUMBING SAVINGS

<table>
<thead>
<tr>
<th></th>
<th>Plumbing Fixture Changes</th>
<th>Rainwater Collection Reuse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Savings (Gallons per Year)</td>
<td>360,606</td>
<td>619,862</td>
</tr>
<tr>
<td>Percent Saved</td>
<td>0.2175</td>
<td>-</td>
</tr>
<tr>
<td>Cost per Gallon in DC</td>
<td>0.00622</td>
<td>0.00622</td>
</tr>
<tr>
<td>Cost per Gallon in DC (Sewer)</td>
<td>0.01306</td>
<td>0.01306</td>
</tr>
<tr>
<td>Yearly Savings</td>
<td>6956.35</td>
<td>10621.86</td>
</tr>
<tr>
<td>Payback Period</td>
<td>-</td>
<td>5.65 Years</td>
</tr>
</tbody>
</table>
Roof Integration

Rainwater and Plumbing

- COURSE MESH PLACED AT ROOF DRAIN (TYP).
- 1/8" PIPING SLOPE
- BUILT IN GUTTERS
- OVERFLOW TO STORM SYSTEM
- 50,000 GALLON CISTERN

Filtration System

Parking Structure

Lighting Design

- <0.18 W/SF Lighting Power Density
- >1.0 fc min. Horizontal Illuminance
- 30'-0" Spacing to Match Structure
Roof Integration
Ventilation and Skylight Coordination

- Skylight located above central staircase provides ample daylight
- Smoke exhaust fan removes smoke from lobby and staircase
- Glass smoke curtains ensure smoke is detected in the lobby
- 2-hr fire ratings prevent fire from spreading
- Motorized windows allow outside air to aid in smoke exhaust

Roof Integration
Photovoltaic

ANNUAL PV PRODUCTION

TEAM 2021_03 - AEI COMPETITION

93

94
**Roof Integration**

Photovoltaic

**Lobby Integration**

- Interactive Displays
- Pour Strip
- Security & Access Control

TO FIELD

TO PARKING STRUCTURE

TO CAVESPORT ST.
Pedal Power

- Students can directly take part in generating their own energy
- The energy produced can be used in nearby charging stations

Multi-Media Display

- Media display to highlight the building’s features and act as a teaching tool

Pour Strip

- 9” one-way reinforced concrete, with #6 @ 6” o.c. top and bottom
- Essential to limit and control shrinkage and elastic shortening of tendons
- After 30-60 days, mild steel reinforcement is added to the pour strip
- A shear key is used to help support the new slab
Lobby integration
Security and Access Control

- Main lobby entrances visual monitoring during normal school hours
- Digitally monitored entrances with keycard access and visual intercoms
- Emergency exit doors with electromagnetic door trigger
- Active-shooter sensors that communicate directly with local law enforcement
Flexible Athletic Space
Design Space Exploration

Step 1. Visualize the Design Space
- 47k discrete designs
- Constrained to 20' maximum truss height to satisfy architectural requirements

Step 2. Clean Design Space
- Due to parametric nature, a wide range of truss roof geometries were created.
- Low mass solutions were targeted to remove unrealistic iterations.
### Flexible Athletic Space

#### Design Space Exploration

- **Step 3. Construction Coordination**
  - Design space constrained to only iterations with a maximum mass that is less than the largest mechanical equipment crane pick.

### Flexible Athletic Space

#### Final Selection

**Option 1. Least Embodied Carbon**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Option 1</th>
<th>Option 2</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Trusses</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td># of Panels</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Left/Right Height (ft)</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Truss Height (ft)</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Bottom Chord Height (ft)</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Max Duct Diameter (in)</td>
<td>87</td>
<td>97</td>
</tr>
<tr>
<td>Total Roof Mass (kips)</td>
<td>101</td>
<td>110</td>
</tr>
</tbody>
</table>
Flexible Athletic Space
Final Selection

TAPERED STEEL COLUMNS

HSS4x4x1/4 POSTS

SPUICE

40' PEAK HEIGHT

W8x45 TOP CHORD

W6x25 BOTTOM CHORD

24' CLEAR HEIGHT

HSS3x3x3/8 DIAGONALS

W12x50

W40x249

Flexible Athletic Space
Daylighting

99.6% mDA

1.4% ADE

845 lux
Flexible Athletic Space
Emergency Power

- Generator located within parking structure near emergency electrical room
- Emergency egress lighting, fire alarm system, telecommunications, security, and select HVAC are included on emergency power
- Large HVAC loads are phased to reduce cost
Flexible Athletic Space
Pandemic Testing Facility

- Allows GDS to remain resilient in the event of a pandemic
- Separate entrances/exits
- Winding waiting area to maintain 6ft spacing
- Testing booths to quickly and safely test the community
- Waiting area for community to wait for their rapid results
- Discharge
Theatre
Lighting Design

![Theatre Lighting Design Image]

Theatre
Structural Design

- 24"x24" Reinforced Concrete Exterior Columns
- 24" Wide Post-Tension Beams
- 8" Post-Tension One-Way Slab
- Shallow Spread Foundations
- Reinforced Concrete Shear Walls
- 24"x24" Reinforced Concrete Exterior Columns
- 10" Reinforced Concrete Retaining Walls
- Cold-Form Steel Framed Seating Platform
Classrooms

- Open Structural Layout
- Resilient Mechanical Design
- Daylighting Design
- Enhanced Audio Visual System
- Integrated Takt Time Planning
Structural Design: Classrooms

- 6" PT One-Way Roof Slab
- Flexible Athletic Space
- Roof Truss System
- Parking Structure
- Mechanical Penthouse
- Slab Opening at Skylight
- Cantilevered PT Beam and Slab
- 24" Reinforced Concrete Columns
- Cantilevered Terrace and Demonstration Space
- PT Beam
- Spread Foundations
- 8" PT One-Way Floor Slab

Classrooms Structural Design

- Wood Overhang/Canopy
- Flexible Athletic Space with Long Span Trusses
- Post Tension One-Way Slab
- Pour Strip – One-Way Reinforced Concrete
- One-Way Reinforced Concrete
- Slab Span Direction
- Shear Wall
- Isolation Joint
- 7/8" 7-Strand Low-Relaxation Tendons
- Slab Precompression Target – 125-350 psi
- Beam Precompression Target – 400-800 psi
Classrooms
Structural Design

- 10" thick cast-in-place walls around vertical circulation
- 50' of walls in N/S, 64' of walls in E/W
- H/600 service drifts met for wind loads
- 0.015*H,\textsubscript{w} strength drifts met for seismic loads
- 2" isolation Joint to separate systems

Classrooms
Mechanical Design

Level 2 Floor Plan – Wall Types
Classrooms
Mechanical Design

- Typical DOAS Unit Max. Load = 125,000 CFM
- Typical Classroom Load = 500-1000 CFM
- Each classroom equipped with Fan Coil Unit

Level 2 Floor Plan – Duct Runs

Section View of Multi-Trade Rack
Classrooms
Mechanical Design

Fan Coil Schematic

- Bipolar Ionization Generator located in RA Duct
- MERV 13 Filter
- Heating/Cooling Coils
- RA Duct from DOAS
- RA Duct
- SA Duct
- SA Duct from DOAS
- Pipe Connection

Classrooms
Mechanical Design

- Fan Coil Schematic
Classrooms
Mechanical Design

Use of Natural Ventilation

55°-75°F?
No
Yes

Close Windows
Pandemic?
No
Yes

Open Windows

40 - 60% RH?
No
Yes

Close Windows
Open Windows

Classrooms
Daylighting Performance

ENERGY SAVINGS FROM DAYLIGHT HARVESTING 83%
ANNUAL SUNLIGHT EXPOSURE 6.6%
SPATIAL DAYLIGHT AUTONOMY 80.2%

SUMMER CONDITION
WINTER CONDITION

ENERGY SAVINGS FROM DAYLIGHT HARVESTING
83%
Classrooms
Circadian Lighting

Life-Cycle Cost Analysis

<table>
<thead>
<tr>
<th>LIGHTING SPECIFICATION</th>
<th>NORMAL LAYOUT</th>
<th>CIRCADIAN LAYOUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOAL</td>
<td>STATIC WHITE</td>
<td>TUNABLE WHITE</td>
</tr>
<tr>
<td>LUMEN OUTPUT DIRECT</td>
<td>300 LUMENS/FT</td>
<td>300 LUMENS/FT</td>
</tr>
<tr>
<td>LUMEN OUTPUT INDIRECT</td>
<td>300 LUMENS/FT</td>
<td>600 LUMENS/FT</td>
</tr>
<tr>
<td>FIXTURE QUANTITY PER ROOM</td>
<td>54 LF</td>
<td>72 LF</td>
</tr>
<tr>
<td>CLASSROOM AREA</td>
<td>700 SF</td>
<td>700 SF</td>
</tr>
<tr>
<td>APPROX. FIXTURE COST</td>
<td>$80/LF</td>
<td>$94/LF</td>
</tr>
<tr>
<td>APPROX. CONTROLS COST</td>
<td>$0.25/SF</td>
<td>$0.33/SF</td>
</tr>
<tr>
<td>TOTAL COST PER ROOM</td>
<td>$4,495</td>
<td>$6,999</td>
</tr>
<tr>
<td>LIGHTING POWER DENSITY</td>
<td>0.48 W/SF</td>
<td>0.96 W/SF</td>
</tr>
</tbody>
</table>
### Classrooms

#### Takt Time Planning

<table>
<thead>
<tr>
<th></th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Floor 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zone A - (GRADE 1/2/3)</td>
<td>C1</td>
<td>MECH 1</td>
<td>MECH 1</td>
<td>MECH 1</td>
<td>C1</td>
<td>MECH 1</td>
</tr>
<tr>
<td>Zone B - (GRADE 1/2/3)</td>
<td>C1</td>
<td>MECH 1</td>
<td>MECH 1</td>
<td>MECH 1</td>
<td>C1</td>
<td>MECH 1</td>
</tr>
<tr>
<td>Zone C - (GRADE 4)</td>
<td>C1</td>
<td>MECH 1</td>
<td>MECH 1</td>
<td>MECH 1</td>
<td>C1</td>
<td>MECH 1</td>
</tr>
<tr>
<td>Zone D - (GRADE 5)</td>
<td>C1</td>
<td>MECH 1</td>
<td>MECH 1</td>
<td>MECH 1</td>
<td>C1</td>
<td>MECH 1</td>
</tr>
<tr>
<td><strong>Floor 3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zone A - (GRADE 6)</td>
<td>C2</td>
<td>MECH 2</td>
<td>MECH 2</td>
<td>MECH 2</td>
<td>C2</td>
<td>MECH 2</td>
</tr>
<tr>
<td>Zone B - (GRADE 6/7)</td>
<td>C2</td>
<td>MECH 2</td>
<td>MECH 2</td>
<td>MECH 2</td>
<td>C2</td>
<td>MECH 2</td>
</tr>
<tr>
<td>Zone C - (GRADE 7/8)</td>
<td>C2</td>
<td>MECH 2</td>
<td>MECH 2</td>
<td>MECH 2</td>
<td>C2</td>
<td>MECH 2</td>
</tr>
<tr>
<td>Zone D - (GRADE 8)</td>
<td>C2</td>
<td>MECH 2</td>
<td>MECH 2</td>
<td>MECH 2</td>
<td>C2</td>
<td>MECH 2</td>
</tr>
</tbody>
</table>

#### Systems Coordination

- **C 1** Construction Crew #1
- **MECH 1** Mechanical Crew #1
- **L/E 1** Lighting & Electrical Crew #1
- **OFF** Off Takt Float

*2 Crews*
Systems Coordination
Multi-Trade Rack Fabrication

- POST TENSION BEAM
- HOT/COLD WATER SUPPLY
- CONDUCT
- HVAC DUCTING
- CABLE TRAY
- CONCEALED LIGHTING DETAIL

Offsite Storage Logistics Center
Location: Silver Springs, MD
4000 SF

Multi-Trade Rack
Systems Coordination
Project Overview

Cost Tracking

Construction Cost Tracking

% Cost / Month

% Total Cost

Project Duration

TEAM 2021_03 - AEI COMPETITION
**Celsius Estimate**

- **$63,018,748**
- **$415 / SF**
**Project Overview**

**Schedule**

- **START:** March 1, 2021
- **FINISH:** June 16, 2023
- **TOTAL DURATION:** 28 Months

**Clean Energy DC Amendment Act of 2018**

- 100% renewable energy by 2032

**Air Source Heat Pump**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly efficient source of heat and hot water</td>
<td>Lower output temperature than boilers</td>
</tr>
<tr>
<td>Low maintenance</td>
<td>Expensive to install</td>
</tr>
<tr>
<td>Zero carbon if used with a renewable tariff</td>
<td>Need outdoor space</td>
</tr>
</tbody>
</table>
**Project Overview**

**Energy Consumption**

![Energy Consumption of GDS](image)

- GDS Energy Consumption
- DC Area Average EUI
- ENERGY STAR K-12 Benchmark
- Delaware EUI Goal

**Project Overview**

**Sustainability Plan**

- LEED PLATINUM
- WELL GOLD*
- CHPS VERIFIED

* = CAPABLE OF WELL PLATINUM WITH OWNER INPUT
### Project Overview

#### Highlights

**BUILDING AT A GLANCE**

<table>
<thead>
<tr>
<th>Gross S.F.</th>
<th>151,000 ft²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cost</td>
<td>$63 million</td>
</tr>
<tr>
<td>Cost per S.F.</td>
<td>$415</td>
</tr>
<tr>
<td>Cost of Envelope</td>
<td>$4.7 million</td>
</tr>
<tr>
<td>Occupancy</td>
<td>Mid-June 2023</td>
</tr>
</tbody>
</table>

**PERFORMANCE**

<table>
<thead>
<tr>
<th>LEED v4.1 Platinum</th>
</tr>
</thead>
<tbody>
<tr>
<td>WELL v2 Gold</td>
</tr>
<tr>
<td>CHPS v2.2 Verified</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Site EUI</th>
<th>34 kBTU/SF/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Generation</td>
<td>409 MWh/yr</td>
</tr>
<tr>
<td>Gross Site EUI</td>
<td>25 kBTU/SF/yr</td>
</tr>
<tr>
<td>Savings vs. Energy Standard</td>
<td>54% improvement over ASHRAE 90.1-2013 Primary School Baseline</td>
</tr>
<tr>
<td>Classroom sDA</td>
<td>80.2%</td>
</tr>
<tr>
<td>Cost Saving</td>
<td>$1.0 million</td>
</tr>
</tbody>
</table>

**BUILDING SYSTEMS**

- Delivery Method: IPD (+) Data Analytics
- Mechanical: FCU with DOAS
- Electrical: Switchboard with Natural Gas Generator
- Structural: One-Way Post-Tension Slab and Beam

**QUICK FACTS**

- Structural Layout creates open classroom spaces for flexible layouts.
- Enhanced Glazing allows for views to the outdoors, encouraging a biophilic connection.
- Materiality choices connect with existing context while remaining respectful of environmental impact.