

**Introduction**

**Project Background**

**Analysis # 1: Terra Cotta Rain Screen Redesign**

**Analysis # 2: GPS Material Tracking System – Structural Steel**

**Analysis # 3: Removal of Habitable Green Roof Design**

**Conclusion & Recommendations**

**Acknowledgements**



# **HUB RENOVATIONS & ADDITION**

## **UNIVERSITY PARK, PA**

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**The Pennsylvania State University Architectural Engineering Senior Capstone Project**

**Robert Justin Barlow | Construction Management Option**

**Advisor: Dr. Robert M. Leicht**

**PENNSTATE**

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**Schedule & Cost**

**Mechanical Breadth**

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**Analysis #2: GPS Tracking**

**Just-In-Time**

**RFID Tracking System**

**Schedule & Cost**

**Analysis #3: Green Roof**

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# Overview

**Building Function: Student Union Center**

**Overall Project Cost: \$44.6 Million**

**Size: 40,000 GSF Renovation**  
**64,000 GSF New Construction**

**Schedule:** Start | May 2013  
End | March 2015

**Project Delivery Method: CM at Risk**

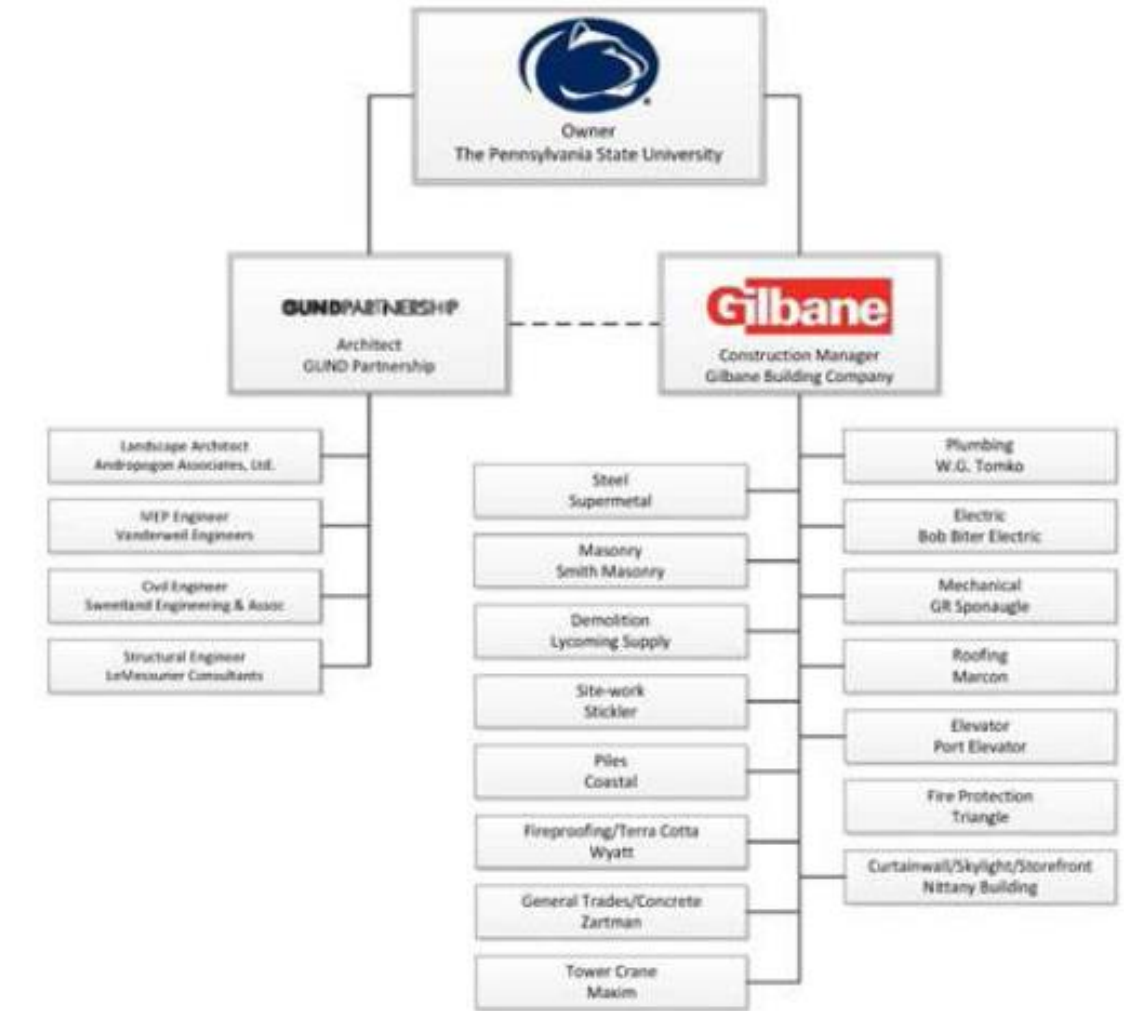


Figure 18: Organizational Chart | RJB

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## Location

**Location: University Park, PA**

**Center of Campus on East Pollock Road**

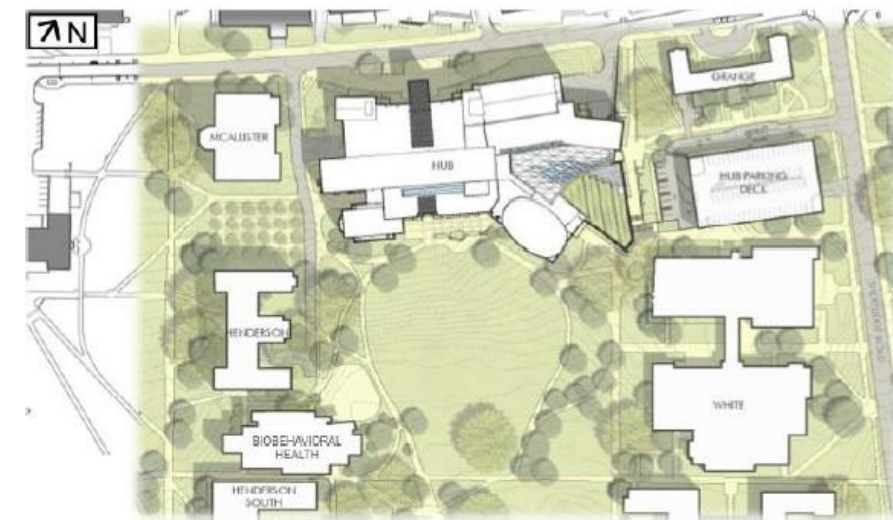


Figure 2: HUB Location on Campus | Image courtesy of Penn State

## Project Features

**Renovated Bookstore & Food Court**

**THON Merchandise Store**

**New Seating & Lounge Space  
Enclosed w/ Aluminum Curtain Wall**

**Terra Cotta Rain Screen System**

**1<sup>st</sup> Habitable Green Roof on Campus**



Figure 4: Rendering of HUB-Robeson Building East Façade | Image courtesy of Penn State

**Analysis # 1: Terra Cotta Rain Screen Redesign**

**Overview of System**

**Schedule & Cost**

**Mechanical Breadth**

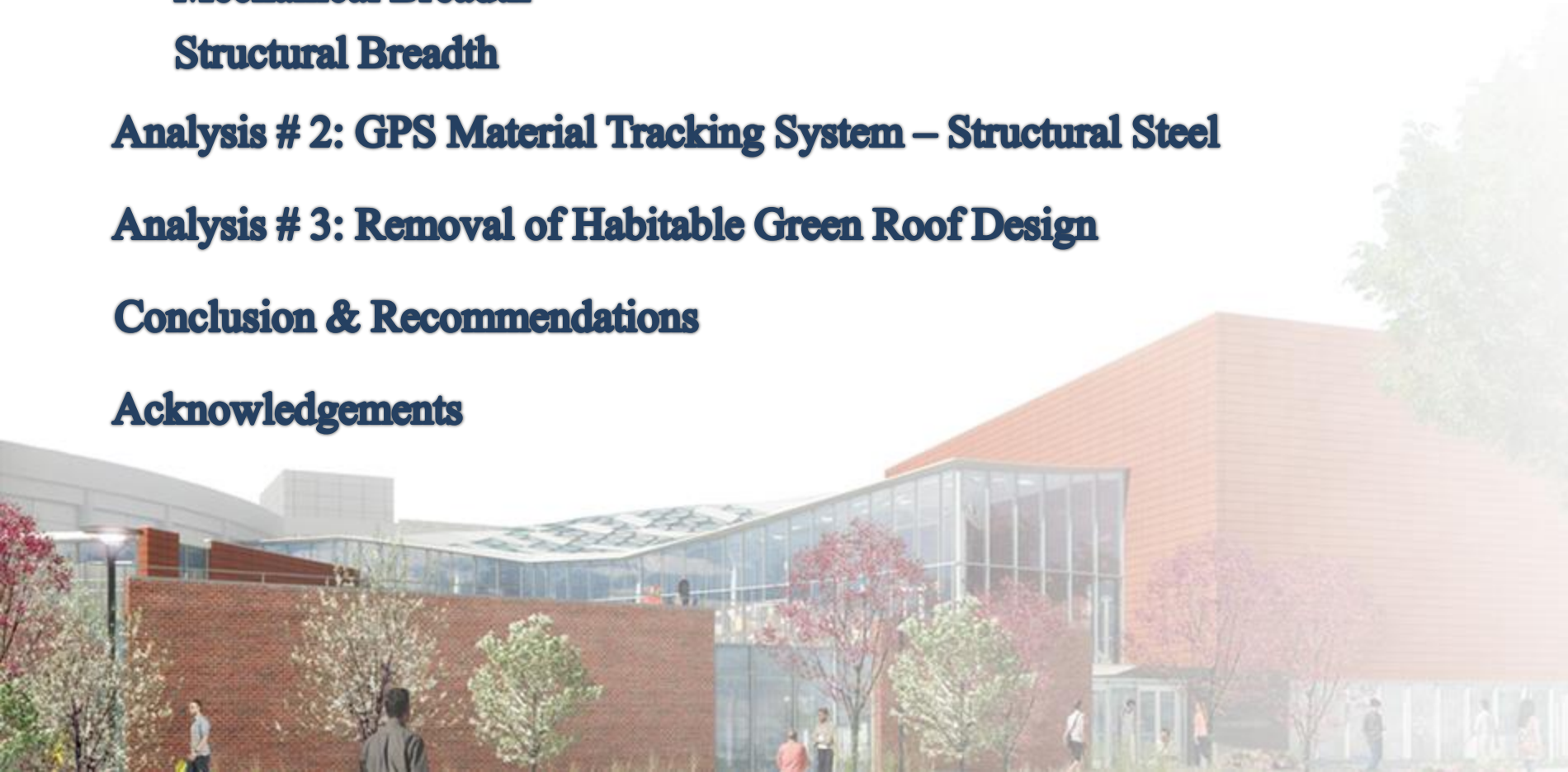
**Structural Breadth**

**Analysis # 2: GPS Material Tracking System – Structural Steel**

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**Overview**

**Façade Study: Nearly 51% of the exterior façade is Terra Cotta**

**Terra Cotta: Installation Issues**

**Focus: Exterior Bookstore Façade**

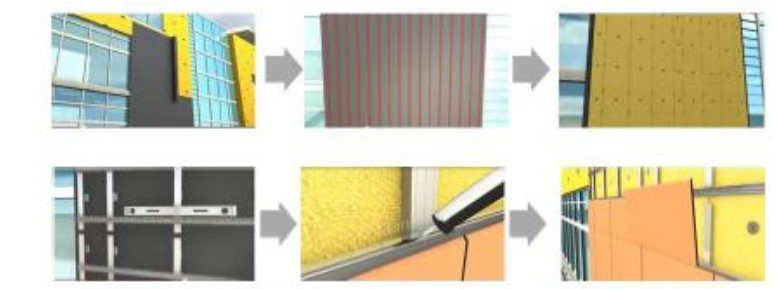


Figure 7: Terra Cotta System Installation Steps - Pictures Courtesy of Cladding Corp. (www.claddingcorp.com)

Table 4: Façade Breakdown | RJB

Façade Description				
Description	Area (SF)	Percentage	Cost / SF	Weight (PSF)
<i>Terra Cotta Rain Screen</i>	13812.03	51%	\$38.00	25
<i>Aluminum Glazed Curtain Wall</i>	6811.56	25%	--	--
<i>Brick Veneer</i>	3776.4	14%	\$5.00	65
<i>Metal Paneling</i>	2658.22	10%	--	--
<b>Total:</b>	27058.21	100%	--	--



Figure 6.3: West Building Façade | RJB



**Analysis #1: Terra Cotta Rain Screen Redesign**

**Analysis # 1: Terra Cotta Rain Screen Redesign**

Overview of System

**Schedule & Cost**

Mechanical Breadth

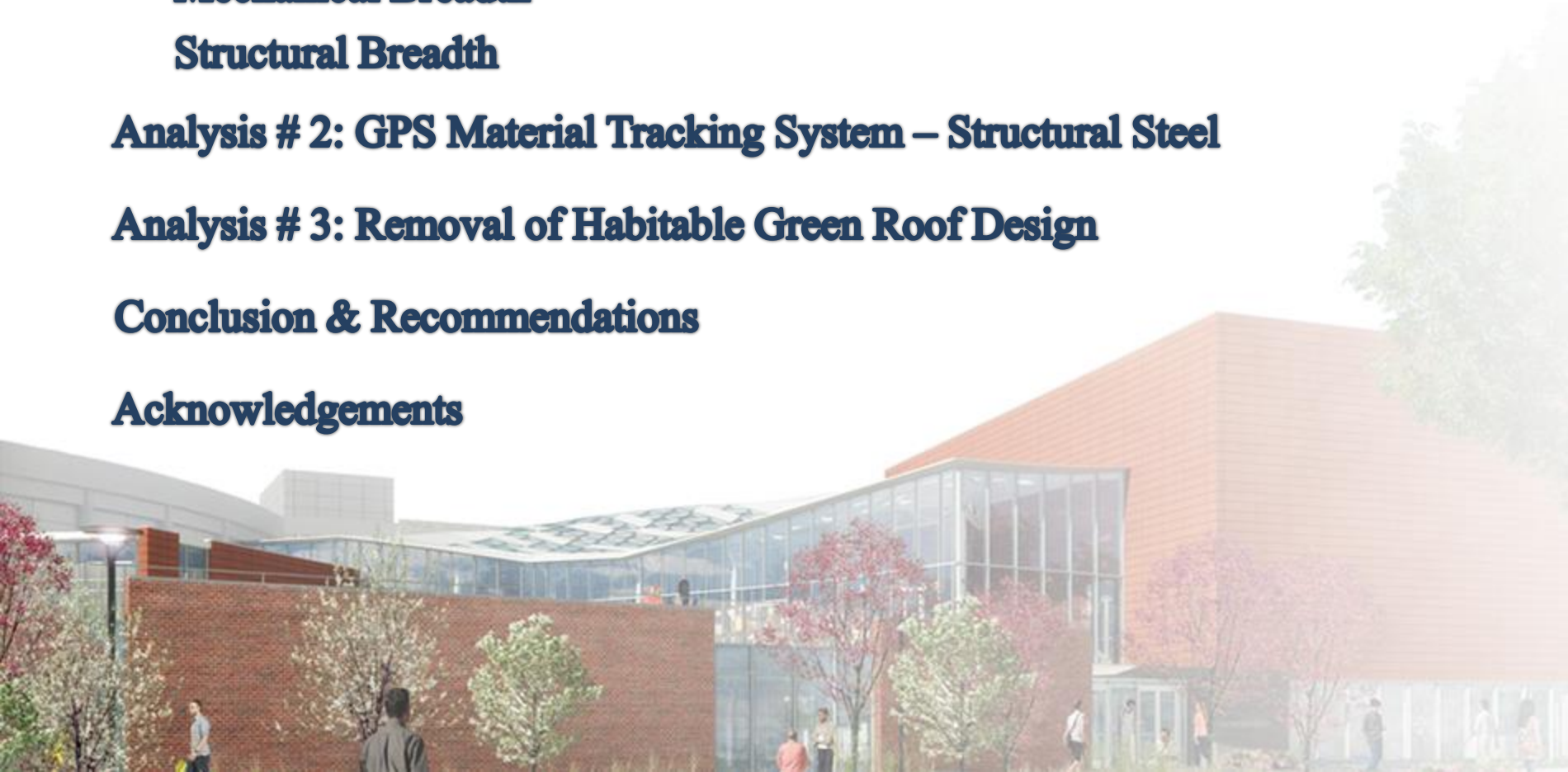
Structural Breadth

**Analysis # 2: GPS Material Tracking System – Structural Steel**

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# Schedule & Cost Evaluation

**Schedule: 6 Day Savings**

**Cost: \$64,142.18 Savings**

**Material Cost: \$455,797.00 Savings (Entire Building Façade)**

Table 12: Bookstore Façade Schedule Comparison | RJB

Schedule Comparison – Bookstore South Façade			
Description	Start Date	End Date	Total Duration
<i>Terra Cotta Rain Screen</i>	<i>02 December 2013</i>	<i>17 January 2014</i>	<i>35 Days</i>
<i>Brick Veneer</i>	<i>02 December 2013</i>	<i>09 January 2014</i>	<i>29 Days</i>

Table 13: Bookstore Façade Cost Comparison | RJB

Cost Comparison – Bookstore South Façade						
Description	Area	Duration	Material Cost	Material Total	Labor Total	Total
<i>Terra Cotta Rain Screen</i>	1777 SF	35 Days	\$38 / SF	\$67,505.48	\$32,200.00	\$99,705.48
<i>Brick Veneer</i>		29 Days	\$5 / SF	\$8,882.30	\$26,680.00	\$35,562.30
<b>Difference:</b>				<b>\$58,623.18</b>	<b>\$5,520.00</b>	<b>\$64,143.18</b>

Table 14: Material Façade Cost Comparison | RJB

Cost Comparison – Material Cost			
Description	Area	Material Cost	Material Total
<i>Terra Cotta Rain Screen</i>	13,813 SF	\$38 / SF	\$524,858.00
<i>Brick Veneer</i>		\$5 / SF	\$69,061.00
<b>Difference:</b>			<b>\$455,797.00</b>

## **Analysis #1: Terra Cotta Rain Screen Redesign**

**Overview**

**51% Terra Cotta Façade  
 Switch TC to Brick Veneer  
 Focus: Bookstore Exterior**

**Analysis # 1: Terra Cotta Rain Screen Redesign**

- Overview of System
- Schedule & Cost
- Mechanical Breadth**
- Structural Breadth

**Analysis # 2: GPS Material Tracking System – Structural Steel**

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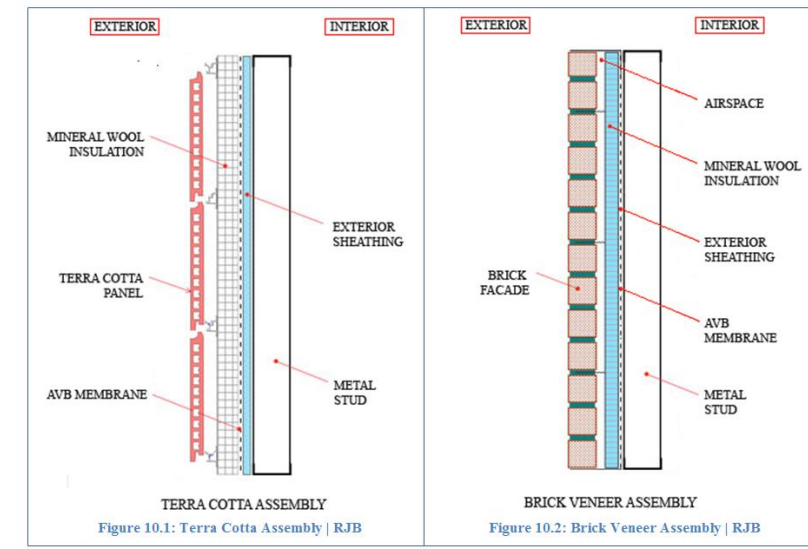
**Acknowledgements**



# Mechanical Breadth

**R-Values: HAM Toolbox**

**Terra Cotta: 10.32**  
**Brick Veneer: 11.40**



**Simple Energy Model : DesignBuilder**

**Terra Cotta: 42948 kBTU**  
**Brick Veneer: 42708 kBTU**  
**Heat Loss Comparison: Brick Veneer 1% more efficient**

Table 7: DesignBuilder Data | RJB

Monthly Heat Loss Comparison (kBTU)												
Description	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Terra Cotta	40812	37224	32648	20913	15063	9355	6902	9500	13583	19298	26098	38967
Brick Veneer	40806	37206	32597	20884	15011	9259	6808	9415	13549	19304	26096	38953

**Analysis #1: Terra Cotta Rain Screen Redesign**

**Overview**  
**51% Terra Cotta Façade**  
**Switch TC to Brick Veneer**  
**Focus: Bookstore Exterior**

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**6 Day Savings**  
**\$64,142.18 Savings**  
**\$455,797.00 Savings**

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# Structural Breadth

**Beam Location: W21x83 2<sup>nd</sup> Floor**

**WebStructural Analytic Software:**

Bending

Shear

Deflection

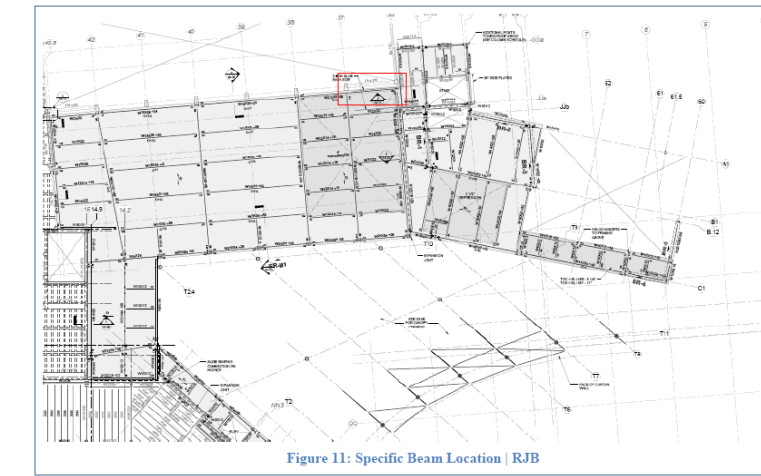


Figure 11: Specific Beam Location | RJB

Table 8: Beam Allowance | RJB

Allowable Limits – Steel Beam				
Beam Type	Length	$\phi$ Mn	$\phi$ Vn	Deflection
W21x83	34' – 10"	529.20 kip-ft.	238.05 kip	0.663" – 1.097"

Table 11: Façade Loading Comparison | RJB

Façade Loading Comparison				
Description	Total Load	Mu	Vu	Deflection
Terra Cotta System	1.15 kip / ft.	219.52 kip-ft.	21.83 kip	0.57"
Brick Veneer System	1.84 kip / ft.	346.41 kip-ft.	34.45 kip	0.94"
<b>Percent Increase</b>	<b>60%</b>	<b>57.8%</b>	<b>57.8%</b>	<b>64.9%</b>

## **Analysis #1: Terra Cotta Rain Screen Redesign**

**Overview**

**51% Terra Cotta Façade  
 Switch TC to Brick Veneer  
 Focus: Bookstore Exterior**

**Schedule & Cost**

**6 Day Savings  
 \$64,142.18 Savings  
 \$455,797.00 Savings**

**Mechanical Breadth**

**Similar:**

**R-Values**

**Thermal Properties**





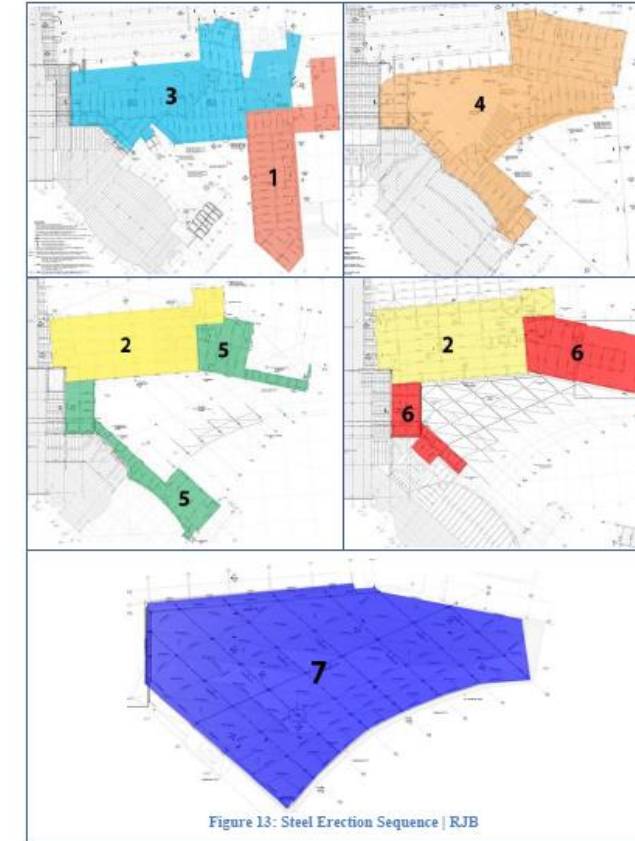
# Just-In-Time Delivery

## Erection Problems:

Site Congestion  
Crane Issues  
Just-In-Time Delivery  
Weather

## Tracking System Needs:

RFID Tags  
Durable  
Battery Life



## Analysis #2: GPS Material Tracking System

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**Just – In – Time Delivery**

RFID Tracking System

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# RFID Tracking System

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  - Just – In – Time Delivery
  - RFID Tracking System**
  - Schedule & Cost
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## Intelliwave Technologies:

**Track: Material, Equipment, Personnel**  
**Durable Design**  
**Designed to Military Specs**



Figure 16.2: RFID Tag |  
intelliwavetechnologies.com

## SiteSense Material Tracking:

**Web-Based Software**  
**7 Year Battery Life**  
**Real Time Location**



Figure 15.1: Tablet Used in Field |  
intelliwavetechnologies.com

## Analysis #2: GPS Material Tracking System

Just-In-Time Delivery  
Needs to:  
**Solve Erection Issues**  
**Durable RFID Tracking**

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# Schedule & Cost Evaluation

## Schedule Benefits:

**Keep Erection on Track**  
**Quality Control**  
**Minimize Project Delays**



Figure 14.3: SiteSense Diagram | intelliwave.com

## Cost:

**215 GPS Units**  
**\$88,150.00 Additional Cost**

Table 15: GPS Cost Breakdown | RJB

GPS Cost Breakdown	
Description	Cost
GPS Tracking Units (215 Units)	\$75,250
GPS Tracking Service Fee	\$12,900
<b>Total:</b>	<b>\$88,150</b>

## Analysis #2: GPS Material Tracking System

**Just-In-Time Delivery**  
**Needs to:**  
**Solve Erection Issues**  
**Durable RFID Tracking**

**RFID Tracking System**  
**Intelliwave Technologies**  
**SiteSense Tracking**

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- Alternative Design
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# Habitable Green Roof

Current Design:

**Extensive Green Roof Assembly**  
**Ultimate Green Roof Assembly**  
**17 Percent Habitable Design**

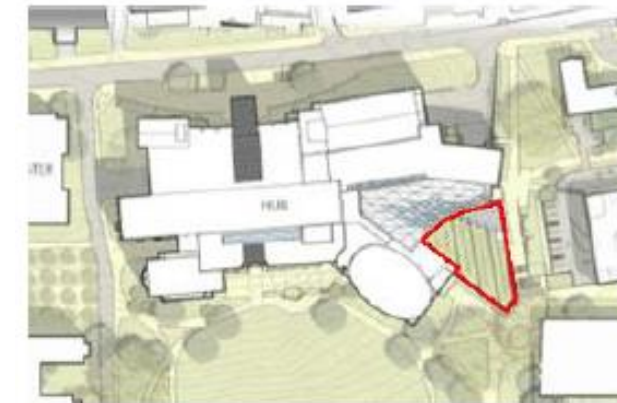


Figure 17: Green Roof Location | RJB

Table 16: Green Roof SF | RJB

Green Roof – Design Breakdown		
Description	Area	Percentage
Extensive Assembly - Vegetation	7972.5 SF	83%
Ultimate Assembly - Pavers	1708.5 SF	17%
<b>Total:</b>	<b>9681 SF</b>	<b>100%</b>

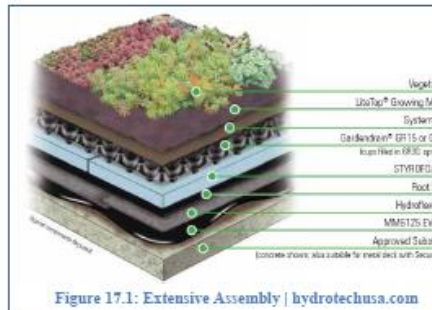


Figure 17.1: Extensive Assembly | hydrotechusa.com

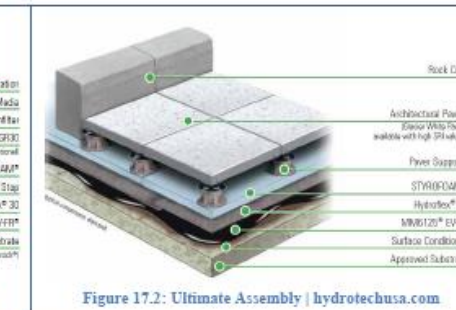


Figure 17.2: Ultimate Assembly | hydrotechusa.com

Analysis #3 Removal of Habitable Green Roof Design

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# Alternative Design

**Alternate Design:**

**Complete Removal of Green Roof  
Duro-Last Cool Zone**

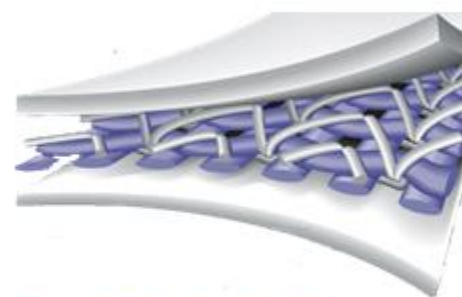


Figure 20: Duro-Last Cool Zone | duro-last.com



Figure 18: Green Roof Design | RJB

**Analysis #3 Removal of Habitable Green Roof Design**

**Habitable Green Roof  
17% Ultimate Assembly  
83% Extensive Assembly  
Existing Bookstore Roof**

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# Carbon Footprint

**Carbon Offset:** (Compared to black roofs)

**Green Roof:** 35 tons of CO<sub>2</sub>

**White Roof:** 90 tons of CO<sub>2</sub>



Figure 19: LEED | google.com

**Green Roof Benefit:**

**Extensive Green Roofs: 0.5-0.8” of water retention**

**Heat Island Effect**



## **Analysis #3 Removal of Habitable Green Roof Design**

**Habitable Green Roof**

**17% Ultimate Assembly**

**83% Extensive Assembly**

**Existing Bookstore Roof**

**Alternative Design**

**Complete Removal**

**Duro-Last Cool Zone Assembly**

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# Schedule & Cost Evaluation

## Schedule:

**40 Day Savings**  
**Green Roof: 55 Day Duration**  
**White Roof: 15 Day Duration**

**Cost: \$154,896.00 Savings**

Table 19: Cost Comparison - Roof Design | RJB

Cost Comparison – Existing Bookstore Roof			
Description	Area	Cost / SF	Total Cost
Hydro-Tech Green Roof Assembly	9681 SF	\$22.00	\$212,982.00
Duro-Last Cool Zone Assembly		\$6.00	\$58,086.00
<b>Difference:</b>			<b>\$154,896.00</b>

Table 17: Green Roof Schedule | RJB

Schedule Breakdown – Current Green Roof Design			
Description	Start Date	End Date	Total Duration
Roof Membrane	02 December 2013	13 December 2013	10 Days
Green Roof / Accessories	16 December 2013	24 January 2014	30 Days
Install Green Roof - Planting	27 January 2014	14 February 2014	15 Days
<b>Total Green Roof Duration:</b>			<b>55 Days</b>

Table 18: New Design Schedule Breakdown | RJB

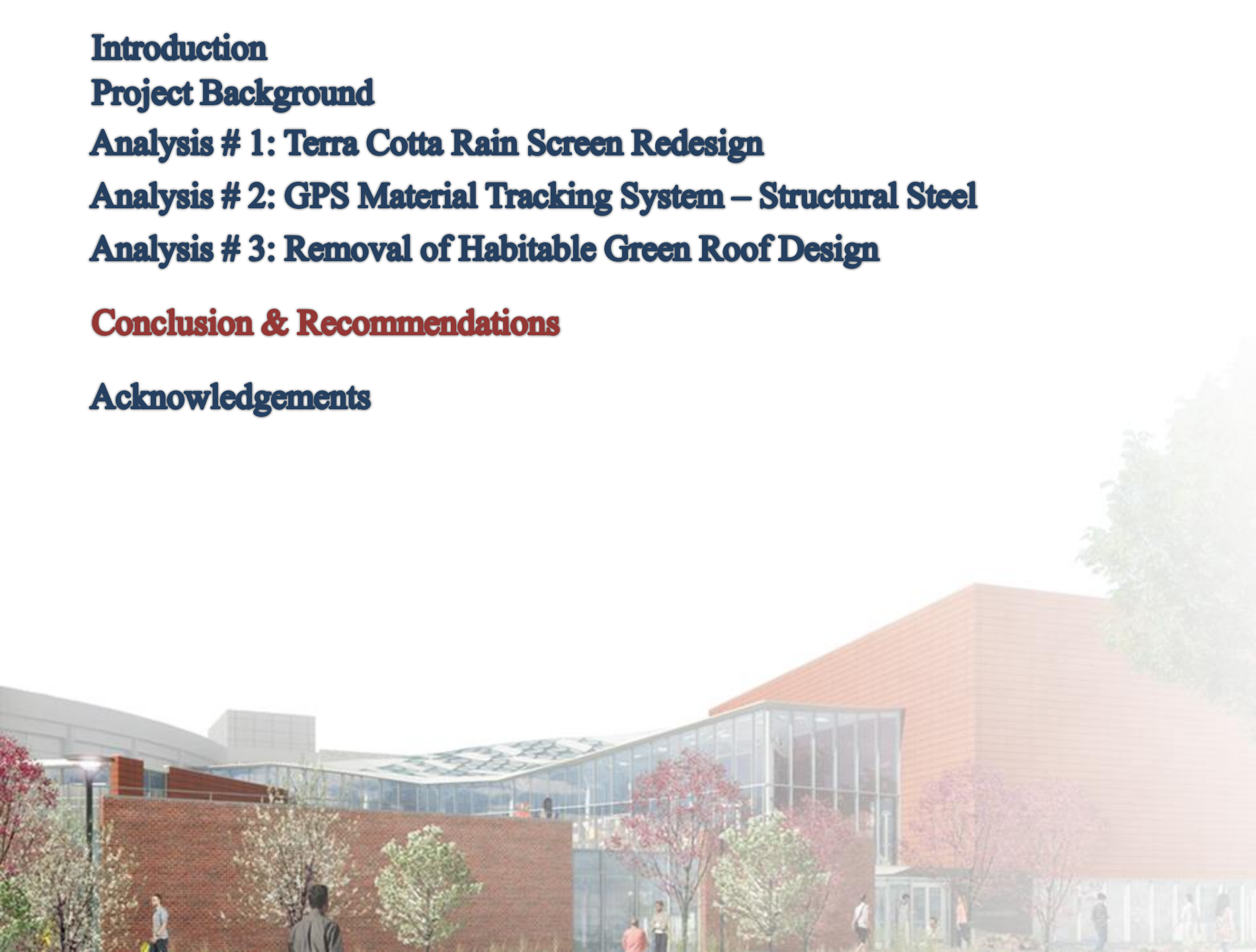
Schedule Breakdown – Duro-Last Design			
Description	Start Date	End Date	Total Duration
Green Roof Assembly	02 December 2013	14 February 2014	55 Days
Duro-Last Assembly	02 December 2013	20 December 2013	15 Days
<b>Total Difference:</b>			<b>40 Days</b>

## Analysis #3 Removal of Habitable Green Roof Design

**Habitable Green Roof**  
**17% Ultimate Assembly**  
**83% Extensive Assembly**  
**Existing Bookstore Roof**

**Alternative Design**  
**Complete Removal**  
**Duro-Last Cool Zone Assembly**

**Carbon Footprint**  
**Green Roof: 35 tons CO<sub>2</sub>**  
**White Roof: 90 tons CO<sub>2</sub>**



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# Conclusion & Recommendations

## Analysis #1: Terra Cotta

**Brick Veneer Alternate Design**

**6 Day Savings**

**\$64,142.18 Savings**

**Similar Thermal Properties**

**Acceptable Loading Difference**

### Recommendation

**The Project Team should Accept**



## Analysis #2: GPS Tracking

**Just-In-Time Delivery**

**Intelliwave Technologies SiteSense**

**215 GPS Units**

**Ensure Quality Control**

**\$88,158.00 Expense**

### Recommendation

**The Project Team should not Accept**



## Analysis #3: Green Roof

**Complete Removal of Green Roof**

**Duro-Last Cool Zone**

**White Roof CO<sub>2</sub> Benefits**

**40 Day Savings**

**\$154,896.00 Savings**

### Recommendation

**The Project Team should Accept**





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# Acknowledgements

## Academic Acknowledgments

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**Ray Sowers**

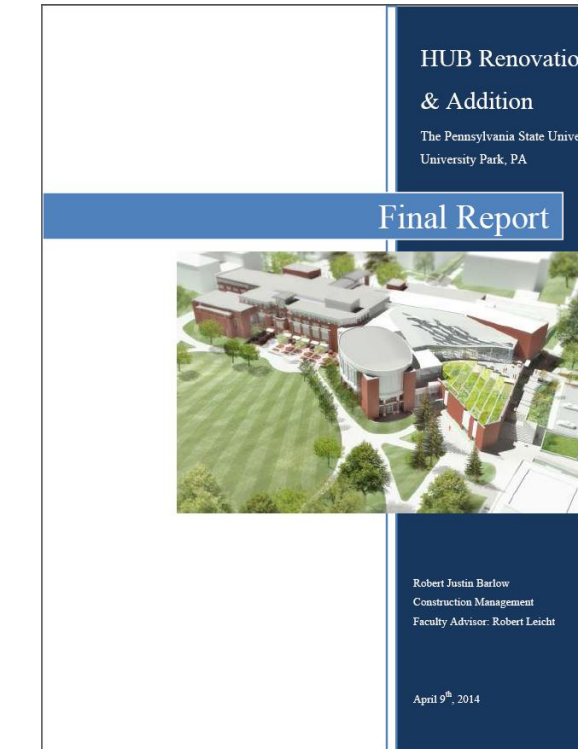
## Special Thanks

**Gilbane Project Team**  
**Dereck Stoeckelin**  
**Family & Friends**



**GUND PARTNERSHIP**

**PENNSTATE**



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