East Coast, USA

Codi Shine

Construction Option

Advisor: Dr. Chimay Anumba



Analysis 1: Analysis 2: Analysis 3: Façade Study Breadths: Analysis 4: Implementation

Alternative Delivery Method Short Interval Production Schedule (SIPS) Architectural & Mechanical Building Information Modeling (BIM)

Statistics

Size: 72,000 GSF Stories: 2 plus a penthouse **Delivery Method**: Design-Bid-Build **Contract Value:** \$41 million **Construction Dates:** 6/1/11-4/22/13

LEED: Platinum Arch Engi Gen Struc Civil



Project Background

Project 1	eam
hitect/MEP ineer	Ewing Cole
neral Contractor	Hensel Phelps
ctural Engineer	Woods Peacock
il Engineer	Alpha Corporation

Schedule Summary	Start
Notice to Proceed	June 1
Earthwork	Nover
Concrete	Nover
Structural Steel	Februa
HVAC	Octob
Electrical	Decer
Plumbing	Decer
Specialty Trades	Decer
Turnover	

	End
1, 2011	
mber 3, 2011	November 1, 2012
mber 7,2011	November 12, 2012
ary 22, 2012	April 23,2012
oer 31, 2011	November 27, 2012
mber 19, 2011	November 30, 2012
mber 21, 2011	October 24, 2012
mber 21,2011	February 22, 2013
	April 22, 2013

Project Background Analysis 1 – Alternative Delivery Method Background Research/Comparisons Schedule reduction Analysis 2 – SIPS Sequence & crews **Different SIPS Options** Schedule Reduction Analysis 3 – Façade Study Background Materials/Research Architectural Breadth Changes Model Mechanical Breadth R-value & Condensation Production & Cost Recommendations Acknowledgements

Analysis Goals

Reduce the schedule by getting the General Contractor in earlier

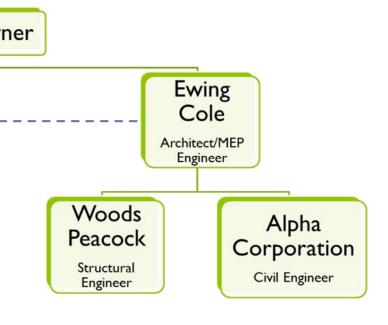
Current: Design-

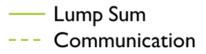
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- Lacks chemis⁻
- Owner acts a
- Owner has to
- Owner holds
- Multiple contr

Background

Analysis 1 – Alternative Delivery Method

	Dropost	
-Bid-Build	Proposed: Design-Build	Own Hensel Phelps
Finish-Start istry as a mediator o find all parties the liability itracts	 GC can be involved earlier Subcontractors assist with design GC and designer are in a joint venture One point of contact Cost effective Shared risk One contract 	General Contractor Joshua Construction Mechanical/Plumbing Contractor Steel LLC Steel Contractor Steel Contractor







Project Background Analysis 1 – Alternative Delivery Method Background **Research/Comparisons** Schedule reduction Analysis 2 – SIPS Sequence & crews **Different SIPS Options** Schedule Reduction Analysis 3 – Façade Study Background Materials/Research Architectural Breadth Changes Model Mechanical Breadth R-value & Condensation Production & Cost Recommendations Acknowledgements

Building Nam

Environmental Stu

Technical Monitori lub

Commercial Hang

Research & Comparisons

Analysis 1 – Alternative Delivery Method

- Design assist subcontractors
- Involved owner
- Owner let Hensel Phelps take control
- Start site work early
- Innovation
- Finalize long lead items early

	Square Foot	Cost/Sq Ft	Intensity	Construction Speed	Delivery Duration
dies	72,000	\$491	\$1,756,192	3576	3473
ng	71,336	\$460	\$2,218,444	4820	
er	60,000	\$329	\$1,768,125		3947

Interviews



Project Background Analysis 1 – Alternative Delivery Method Background Research/Comparisons Schedule reduction Analysis 2 – SIPS Sequence & crews Different SIPS Options Schedule Reduction Analysis 3 – Façade Study Background Materials/Research Architectural Breadth Changes Model Mechanical Breadth R-value & Condensation Production & Cost Recommendations Acknowledgements

ctivity Name	Original	Start	Finish	20	909			2	010
	Duration			Q2	Q3	Q4	Q1	Q2	Q3
ESL:E Environmental Studies Lab: E	1323	23-Mar-09	20-May-14						
📲 ESL:E.2 Pre-Design	75	23-Mar-09	03-Jul-09		7 03-JuH	09, ESL:E.	2 Pre De	sign	
ESL:E.3 Schematic Design	14	29-Jun-09	17-Jul-09	•		109, ESL:1		matic Des	sign
Prepare SD drawings	10	29-Jun-09	10-Jul-09		Prepar	e SD orav	ings		
Fundamental design report	11	29-Jun-09	13-Jul-09		📕 Funda	mental de	sign repo	4	
Issue SD package	0	17-Jul-09			🔶 Issue	SD packa	ge, 17 Ju	609	
ESL:E.4 Design Development 35%	24	10-Aug-09	11-Sep-09			11-Sep-09	, ESL:E.4	Design	Develop
Prepare DD drawings	20	10-Aug-09	04-Sep-09		📥 r	repare D	D drawing	#	
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Prepare DD drawings	25	12-Oct-09	13-Nov-09			📫 Pre	pare DD	drawings	
Prepare DD specs	25	12-Oct-09	13-Nov-09			📫 Pre	pare DD	specs	
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Prepare specs	35	04-Jan-10	19-Feb-10					repare sp	
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Prepare specs	5	12-Apr-10	16-Apr-10					Prep	are spec
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ESL:E.8 Preconstruction	800	04-Apr-11	20-May-14						
Notice of Award	0	04-Apr-11							
 Submittals 		04-Apr-11	20-May-14						
Notice to Proceed	0	01-Jun-11							
Obtain approved permits		01-Jun-11	01-Aug-11						
Prepare & Approve Baseline CPM schedule	75	29-Jun-11	13-Oct-11						

Schedule Reduction

Analysis 1 – Alternative Delivery Method

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13 Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2		
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Environmental Studies Lab: Expansion				Environmental Studies Lab: Expansion												
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Schedule Reduction

Analysis 1 – Alternative Delivery Method



Project Background Analysis 1 – Alternative Delivery Method Background Research/Comparisons Schedule reduction Analysis 2 – SIPS Sequence & crews Different SIPS Options Schedule Reduction Analysis 3 – Façade Study Background Materials/Research Architectural Breadth Changes Model Mechanical Breadth R-value & Condensation Production & Cost Recommendations Acknowledgements

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	Duration			Q2	Q3	Q4	Q1	Q2	Q
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ESL:E.3 Schematic Design	14	29-Jun-09	17-Jul-09		🔫 17-Ju	-09, ESL:	5.3 Scher	natic Des	ign
Prepare SD drawings	10	29-Jun-09	10-Jul-09		Prepar	e SD drav	ingь		
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ESL:E.5 Design Development 65%	49	14-Sep-09	20-Nov-09		-	20	-Nav-09,	ESL:E.Ð I	Desigr
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Schedule Reduction

Analysis 1 – Alternative Delivery Method

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ESL:E.2 Pre-Design 75 23-Mar-09 03-Jul-09	19, E\$L:E.2	Pre-Design
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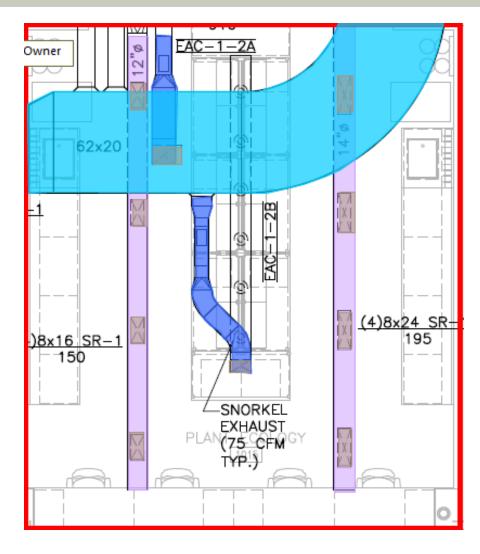
Prepare & Approve Baseline CPM schedule

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Project Background Analysis 1 – Alternative Delivery Method Background Research/Comparisons Schedule reduction Analysis Goals Analysis 2 – SIPS Sequence & crews **Different SIPS Options** Reduce the schedule by Schedule Reduction Analysis 3 – Façade Study construction that will also Background Materials/Research Architectural Breadth Changes Model Mechanical Breadth R-value & Condensation Production & Cost Recommendations Acknowledgements

creating a repetitive manner of improve the quality of the work.



Sequencing & Crews

Analysis 2 – Short Interval Production Schedule (SIPS)

Activity	Crew
Layout	1 Sheet Metal Layout
Install sleeves	1 Sheet Metal Worker
lest all Llangers (an oborg	1 Sheet Metal Worker
Install Hangers/anchors	1 Sheet Metal Apprentice
Layout/Rough-in	1 Sheet Metal Layout
Unload and distribute	2 Sheet Metal Workers
duct sections	
Hang trunk lines	2 Sheet Metal Workers
	1 Sheet Metal Apprentice
Install medium pressure	2 Sheet Metal Workers
branch	1 Sheet Metal Apprentice
	1 Sheet Metal Worker
Install SACs, EACs	1 Sheet Metal Apprentice
Install Low Pressure	2 Sheet Metal Workers
Branch	1 Sheet Metal Apprentice
Hard Duct Taps (Exhaust)	2 Sheet Metal Workers
Hard Duct Taps (Exhaust)	1 Sheet Metal Apprentice
Install RGD	1 Sheet Metal Worker

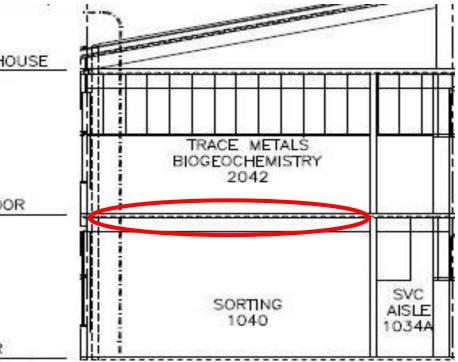
- 8 hour work days

FINISHED MECH PENTHOUSE ELEV 30'-0"

FINISHED SECOND FLOOR ELEV 15'-0"

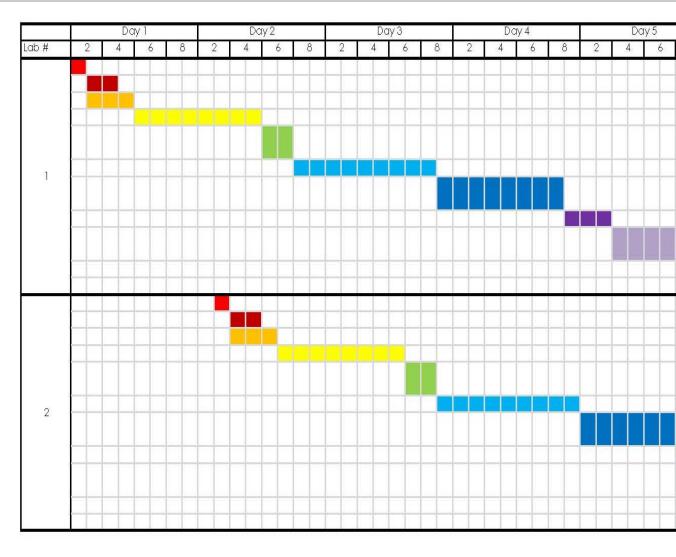
FINISHED FIRST FLOOR

Slightly different sequence on first and second floors





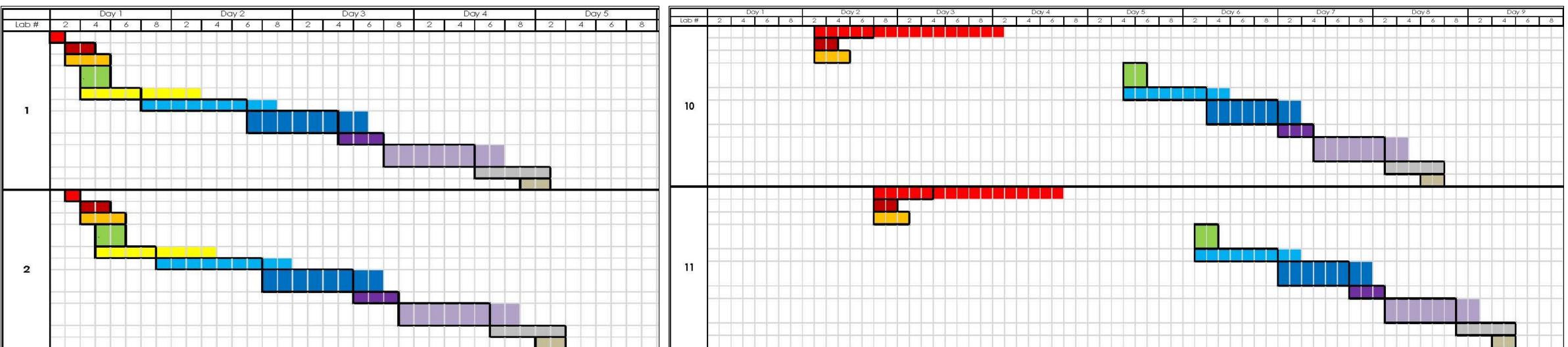
Project Background Analysis 1 – Alternative Delivery Method Background Research/Comparisons Schedule reduction Analysis 2 – SIPS Sequence & crews Different SIPS Options Schedule Reduction Analysis 3 – Façade Study Background Materials/Research Architectural Breadth Changes Model Mechanical Breadth R-value & Condensation Production & Cost Recommendations Acknowledgements



Sequencing & Crews

		Day	6		D	iay 7				Do	ay 8			-			Da	y 10				Day	y 11				Day	12	15		0	 Do	ay 13	21. 			0	Da	y 14					Day	15				Day 1	16				Day 1	7			Do	iy 18	15			D	ay 19	19	
5 8	2	4	6	8 2	4	6	8		2	4	6	8		Lab #		2	4	6	8	2	2	4	6	8	8	2	4	6		8	2	4	(Ś	8	2		4	6	8	8	2	4	4	6	8	4	2	4	6	8	2	4	4	6	8	2	4	6	8	3	2	4		6	8
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Project Background Analysis 1 – Alternative Delivery Method Background Research/Comparisons Schedule reduction Analysis 2 – SIPS Sequence & crews **Different SIPS Options** SIPS 1 Schedule Reduction Analysis 3 – Façade Study Background Materials/Research Architectural Breadth Changes Model Mechanical Breadth R-value & Condensation Production & Cost Recommendations



Different SIPS Options SIPS 1

Analysis 2 – Short Interval Production Schedule (SIPS)

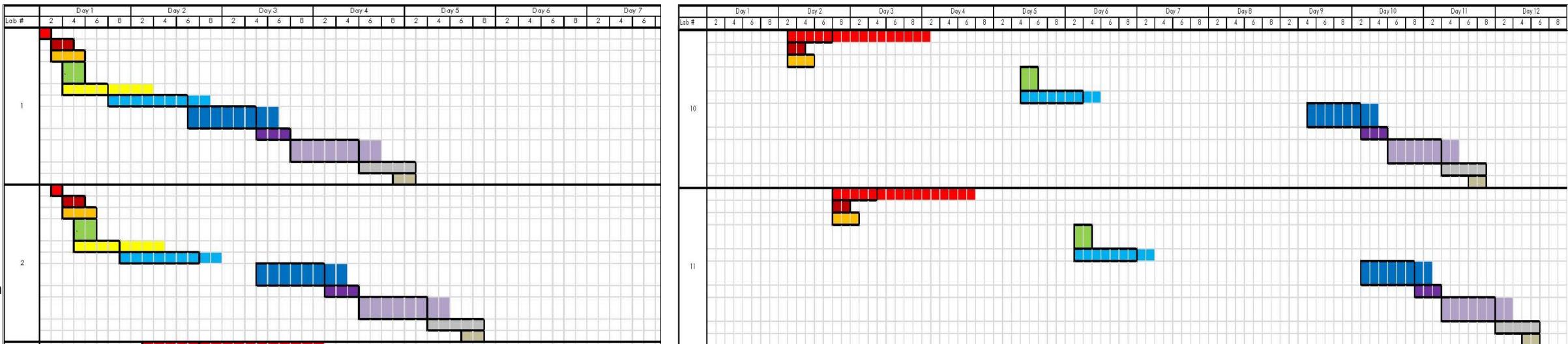
Multiple crews on all activities except for "Layout," "Install sleeves," "Install hangers/anchors."



Project Background Analysis 1 – Alternative Delivery Method Background Research/Comparisons Schedule reduction Analysis 2 – SIPS Sequence & crews **Different SIPS Options**

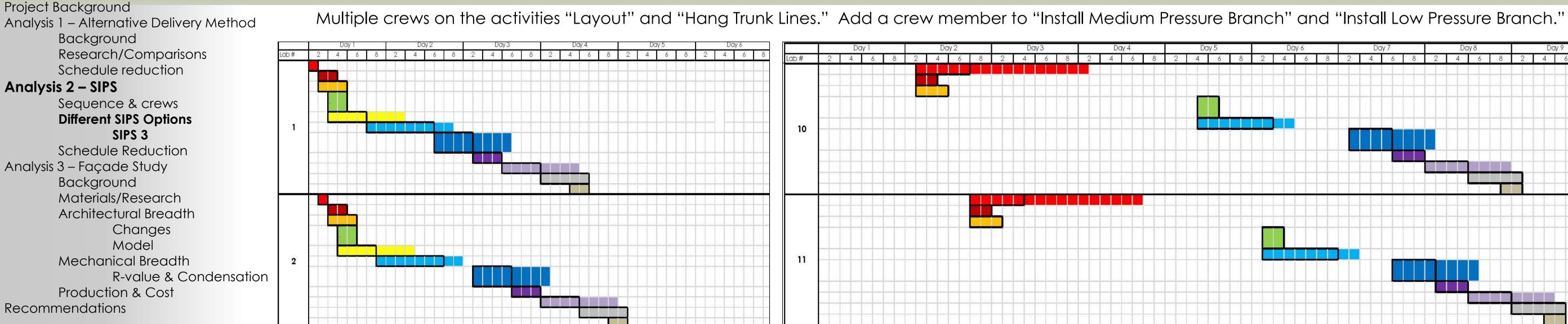
SIPS 2

Schedule Reduction Analysis 3 – Façade Study Background Materials/Research Architectural Breadth Changes Model Mechanical Breadth **R-value & Condensation** Production & Cost Recommendations



Different SIPS Options SIPS 2

Multiple crews on the activities "Layout" and "Hang Trunk Lines"



Different SIPS Options SIPS 3

	Da	ıy 7			Da	y 8			Day	19	
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Project Background		_				
Analysis 1 – Alternative Delivery Method	Schedule 1st	Crew/Lab	Hourly Rate	Hours/lab	Total Cost/lab	Total cost
Background	Original	22	\$39.93	50.22	44,116	\$397,046
Research/Comparisons	SIPS 1	48	\$39.93	40.00	76,666	\$689,990
Schedule reduction	SIPS 2	32	\$39.93	40.00	51,110	\$459,994
Analysis 2 – SIPS	SIPS 3	34	\$39.93	37.60	51,047	\$459,419
Sequence & crews	511 5 5		407.70	57.00	51,047	φ 4 57,417
Different SIPS Options	Schedule 2nd	Crew/Lab	Hourly Rate	Hours/lab	Total Cost/lab	Total cost
Schedule Reduction	Original	21	\$39.93	57.33	48,073	\$432,656
Analysis 3 – Façade Study	SIPS 1	44	\$39.93	40.44	71,050	\$639,449
Background	SIPS 2	32	\$39.93	40.44	51,673	\$465,054
Materials/Research	SIPS 3	32	\$39.93	38.04	48,612	\$437,505
Architectural Breadth	TOTAL	02	<i>\\</i>		10/012	Total cost
Changes		_	_			
Model	Original					\$829,703
Mechanical Breadth	SIPS 1					\$1,329,439
R-value & Condensation	SIPS 2					\$925,047
Production & Cost	SIPS 3					\$896,924
Recommendations						
Acknowledgements						

Schedule Reduction

Schedule	Duration	Days Saved
Original	33	-
SIPS 1	12	21
SIPS 2	17	16
SIPS 3	13	20



_	_				_
Schedule 1st	Crew/Lab	Hourly Rate	Hours/lab	Total Cost/lab	Total cost
Original	22	\$39.93	50.22	44 116	\$397,046
					\$689,990
					\$459,994
					\$459,419
315 3 3		φ07.70	57.00	51,047	\$437,417
Schedule 2nd	Crew/Lab	Hourly Rate	Hours/lab	Total Cost/lab	Total cost
Original	21	\$39.93	57.33	48,073	\$432,656
SIPS 1	44		40.44		\$639,449
SIPS 2	32		40.44		\$465,054
					\$437,505
	02	φσ7.7 σ	00.01	10,012	Total cost
	_	_		_	
	-				\$829,703
SIPS 1					\$1,329,439
SIPS 2					\$925,047
SIPS 3					\$896,924
	Original SIPS 1 SIPS 2 SIPS 3 Schedule 2nd Original SIPS 1 SIPS 2 SIPS 3 TOTAL Original SIPS 1 SIPS 1 SIPS 1	Original22SIPS 148SIPS 232SIPS 334Schedule 2ndCrew/LabOriginal21SIPS 144SIPS 232SIPS 332TOTALJane 1OriginalSIPS 1SIPS 1SIPS 2	Original 22 \$39.93 SIPS 1 48 \$39.93 SIPS 2 32 \$39.93 SIPS 3 34 \$39.93 SIPS 3 34 \$39.93 Schedule 2nd Crew/Lab Hourly Rate Original 21 \$39.93 SIPS 1 44 \$39.93 SIPS 2 32 \$39.93 SIPS 3 32 \$39.93 TOTAL Joriginal Joriginal SIPS 1 Joriginal Joriginal SIPS 2 Joriginal Joriginal SIPS 2 Joriginal Joriginal SIPS 2 Joriginal Joriginal	Original 22 \$39.93 50.22 SIPS 1 48 \$39.93 40.00 SIPS 2 32 \$39.93 40.00 SIPS 3 34 \$39.93 40.00 SIPS 3 34 \$39.93 40.00 SIPS 3 34 \$39.93 37.60 Schedule 2nd Crew/Lab Houriy Rate Hours/lab Original 21 \$39.93 57.33 SIPS 1 44 \$39.93 40.44 SIPS 2 32 \$39.93 40.44 SIPS 3 32 \$39.93 38.04 TOTAL	Original 22 \$39.93 50.22 44,116 SIPS 1 48 \$39.93 40.00 76,666 SIPS 2 32 \$39.93 40.00 51,110 SIPS 3 34 \$39.93 40.00 51,047 Schedule 2nd Crew/Lab Hourly Rate Hours/lab Total Cost/lab Original 21 \$39.93 57.33 48,073 SIPS 1 44 \$39.93 40.44 71,050 SIPS 2 32 \$39.93 40.44 51,673 SIPS 3 32 \$39.93 40.44 51,673 SIPS 1 44 \$39.93 38.04 48,612 SIPS 3 32 \$39.93 38.04 48,612 TOTAL TOTAL TOTAL Total Cost/lab Total Cost/lab SIPS 1 51 51 51 51 SIPS 2 32 \$39.93 38.04 48,612

Schedule Reduction

Analysis 2 – Short Interval Production Schedule (SIPS)

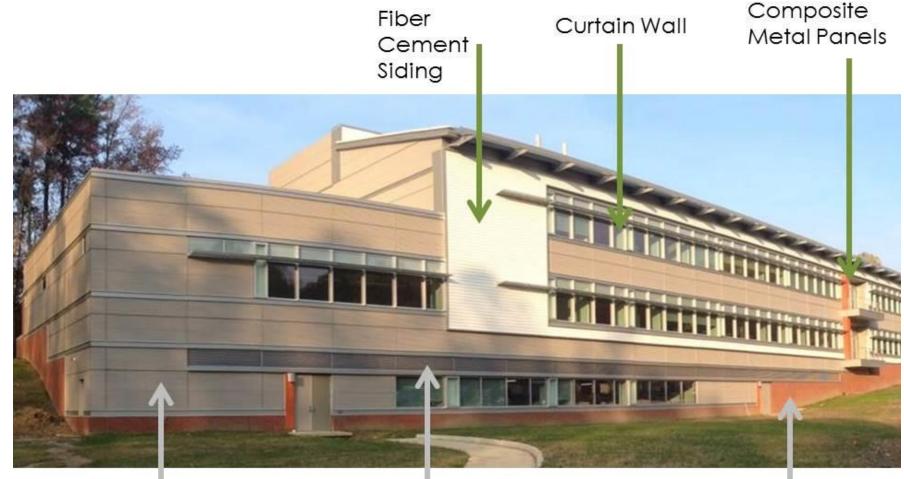
Schedule	Duration	Days Saved
Original	33	-
SIPS 1	12	21
SIPS 2	17	16
SIPS 3	13	20

SIPS 3 saves 20 days and only \$67,000 more for labor

Project Background Analysis 1 – Alternative Delivery Method Background Research/Comparisons Schedule reduction Analysis Goals Analysis 2 – SIPS Sequence & crews Elevation **Different SIPS Options** Reduce the schedule by Analysis 3 – Façade Study reducing the complexity of the North Background façade materials. Materials/Research Architectural Breadth Changes West Model Mechanical Breadth Total **R-value & Condensation** Production & Cost Recommendations Acknowledgements

Background

Analysis 3 – Façade Study



Corrugated Metal Panels

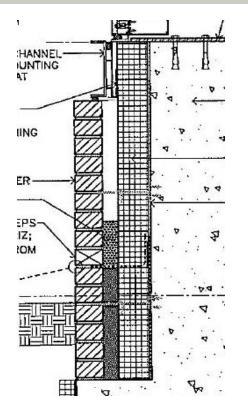
Louvers

		Expansion			
gated	Composite (orange)	Fiber Cement Siding	Louvers	Brick Veneer	Total Square Footage
2,307	0	992	0	818	4,117
14,769	2,412	8,146	1,833	5,737	32,897
490	0	0	0	0	490
3,846	0	0	0	959	4,805
19,105	2,412	9,138	1,833	7,514	40,002

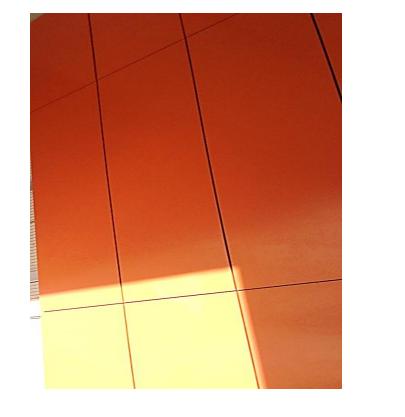
Brick Veneer



Project Background Analysis 1 – Alternative Delivery Method Background Research/Comparisons Schedule reduction Analysis 2 – SIPS Sequence & crews **Different SIPS Options** Analysis 3 – Façade Study Background Materials/Research Architectural Breadth Changes Model Mechanical Breadth R-value & Condensation Production & Cost Recommendations Acknowledgements



Brick Veneer

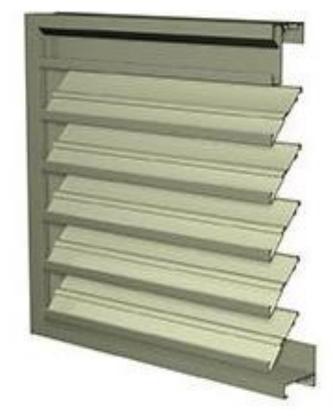


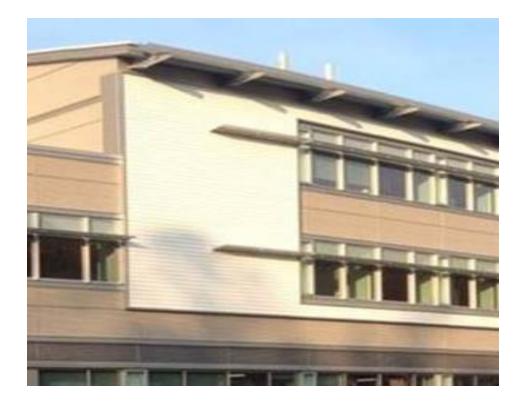
Composite Metal Panels

Materials & Research

Analysis 3 – Façade Study







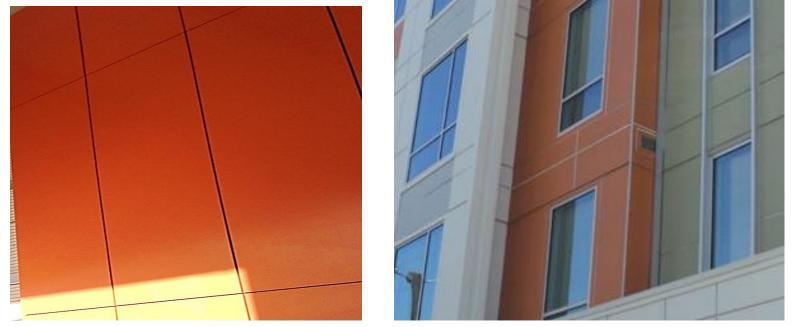


Louvers



Fiber Cement Siding

Project Background Analysis 1 – Alternative Delivery Method Background Research/Comparisons Schedule reduction Analysis 2 – SIPS Sequence & crews **Different SIPS Options** Analysis 3 – Façade Study Background Materials/Research Architectural Breadth Changes Model Mechanical Breadth R-value & Condensation Production & Cost Recommendations Acknowledgements



Change 1: Composite Metal Panels to Fiber Cement Siding

- Same Manufacturer
- Vertical Panels are 4'x10'
- Not fabricated metal look

Architectural Breadth

Analysis 3 – Façade Study

• Difficult installation on metal Z-clips



Change 2: Corrugated Metal Panels to Fiber Cement Siding • Stainless-steel fasteners over hat channels

- Same Manufacturer
- 4" Minimum exposure
- Not fabricated metal look



Project Background Analysis 1 – Alternative Delivery Method Background Research/Comparisons Schedule reduction Analysis 2 – SIPS Sequence & crews **Different SIPS Options** Analysis 3 – Façade Study Background Materials/Research Architectural Breadth Changes Model Mechanical Breadth R-value & Condensation Production & Cost Recommendations Acknowledgements



Change 3: Louvers to Fiber Cement Siding

- Stainless-steel screws
- Same exposure •
- Consistent look

Architectural Breadth

Analysis 3 – Façade Study



4" BRICK VENEER MORTAR NET-FULL JOINT WEEPS HOLD BACK FROM

Change 4: Brick Veneer to Concrete

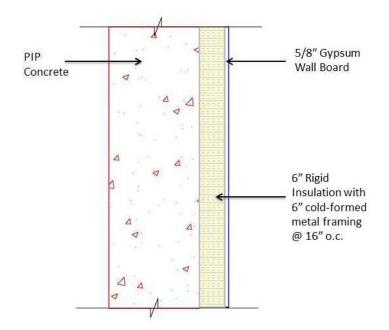
- Dovetail connection to concrete
- Ties into the site

BRACKETS & HAT CHANNELS

MEMBRANE LAP OVER SS FLASHING

AVB TRANSITION

- Hensel Phelps will self-perform
- Fewer wall materials



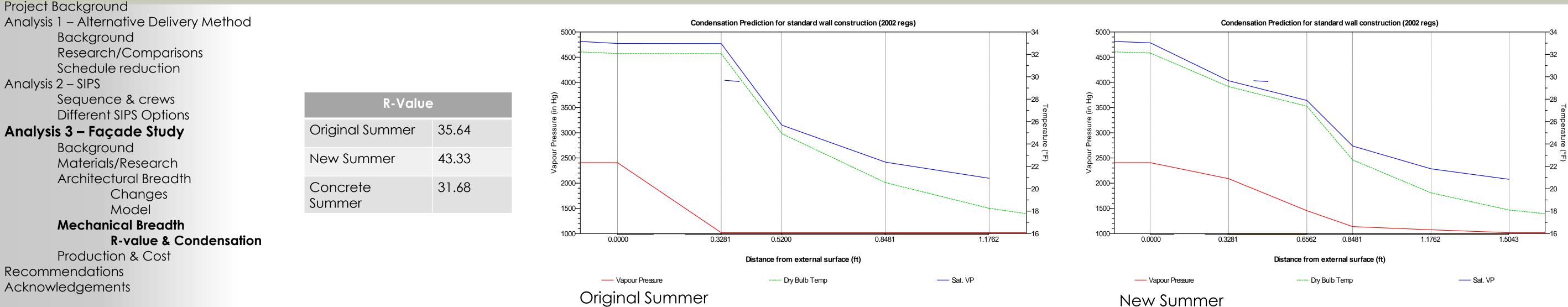


Project Background Analysis 1 – Alternative Delivery Method Background Research/Comparisons Schedule reduction Analysis 2 – SIPS Sequence & crews **Different SIPS Options** Analysis 3 – Façade Study Background Materials/Research Architectural Breadth Changes Model Mechanical Breadth R-value & Condensation Production & Cost Recommendations Acknowledgements

Architectural Breadth

Analysis 3 – Façade Study





Production & Cost Recommendations

Project Background

Analysis 2 – SIPS

Acknowledgements

Original Summer

Mechanical Breadth

Analysis 3 – Façade Study

Project Background Analysis 1 – Alternative Delivery Method Background Research/Comparisons Material Schedule reduction Analysis 2 – SIPS Corrugated Sequence & crews Composite Different SIPS Options iber Cement Analysis 3 – Façade Study Siding Background Louvers Materials/Research Brick Architectural Breadth Total Changes Model Mechanical Breadth R-value & Condensation **Production & Cost** Recommendations Acknowledgements

Production & Cost

Analysis 3	3 – F
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	Original Pro	oduction and Cost			
uare Footage	Duration (Days)	Production Rate (SF/Day)	Cost/Sqft	Cost/Day	Total Cost
19,105	21	940	\$15.00	\$14,100.00	\$296,100
2,412	15	161	\$40.00	\$6,440.00	\$96,600
9,138	10	979	\$13.09	\$12,815.11	\$128,151
1,833	5	367	\$41.50	\$15,230.50	\$76,153
7,514	19	395	\$23.00	\$9,095.89	\$172,822
40,002	70	2,842		\$57,681.50	\$769,826

			New Prod	uction and Cost			
Material	Quantity	Units	Duration (Days)	Production Rate (Unit/Day)	Cost/Unit	Cost/Day	Total Cost
Fiber Cement Siding	32,488	SF	33	979	\$13.09	\$12,815.11	\$425,268
Concrete	509	CY	14	37	\$100.00	\$3,700.00	\$50,928
Total			47	1,016		\$16,515.11	\$476,196

Façade Study

Project Background Analysis 1 – Alternative Delivery Method Background Research/Comparisons Material Schedule reduction Analysis 2 – SIPS Corrugated Sequence & crews Composite **Different SIPS Options** iber Cement Analysis 3 – Façade Study Siding Background Louvers Materials/Research Brick Architectural Breadth Total Changes Model Mechanical Breadth R-value & Condensation **Production & Cost** Recommendations Acknowledgements

Production & Cost

Analysis	3	—	F
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	Original Pro	oduction and Cost			
are Footage	Duration (Days)	Production Rate (SF/Day)	Cost/Sqft	Cost/Day	Total Cost
19,105	21	940	\$15.00	\$14,100.00	\$296,100
2,412	15	161	\$40.00	\$6,440.00	\$96,600
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1,833	5	367	\$41.50	\$15,230.50	\$76,153
7,514	19	395	\$23.00	\$9,095.89	\$172,822
40,002	70	2,842		\$57,681.50	\$769,826

	New Production and Cost														
Material	Quantity	Units	Duration (Days)	Production Rate (Unit/Day)	Cost/Unit	Cost/Day	Total Cost								
Fiber Cement Siding	32,488	SF	33	979	\$13.09	\$12,815.11	\$425,268								
Concrete	509	СҮ	14	37	\$100.00	\$3,700.00	\$50,928								
Total			47	1,016		\$16,515.11	\$476,196								

Façade changes

Façade Study

saves 23 days and \$293,630

Drain at Dalkara und	
Project Background	
Analysis 1 – Alternative Delivery Method	And
Background	
Research/Comparisons	Saves 315
Schedule reduction	
Analysis 2 – SIPS	
Sequence & crews	
Different SIPS Options	Analysis 2
Analysis 3 – Façade Study	Saves
Background	54763
Materials/Research	
Architectural Breadth	
Changes	
Model	Savos
Mechanical Breadth	Saves 2
R-value & Condensation	
Production & Cost	
Recommendations	
Acknowledgements	

Recommendations

nalysis 1: Alternative Delivery Method **5 days with construction starting August 3, 2010** Recommend

2: Short Interval Production Schedule (SIPS) es 21 days with a slight labor cost increase

Analysis 3: Façade Study **23 days with about a \$300,000 cost savings** Recommend

Recommend

Project Background Analysis 1 – Alternative Delivery Method Background Research/Comparisons Schedule reduction Analysis 2 – SIPS Sequence & crews **Different SIPS Options** Analysis 3 – Façade Study Background Materials/Research Architectural Breadth Changes Model Mechanical Breadth R-value & Condensation Production & Cost **Recommendations** Acknowledgements

ivity Name	Original	Start	Finish	2	009			2010				2011				20	12		2	2013
	Duration			Q2	Q3	Q4	Q1 (Q2 Q3	Q4	Q	1 (22 (Q3	Q4	Q1	Q2	Q3	Q4	Q1	
ESL:E Environmental Studies Lab: E	1039	23-Mar-09	10-Apr-13	111										L L						
ESL:E.2 Pre-Design	75	23-Mar-09	03-Jul-09		🛉 03-Ju	1-09, ESL:	E.2 Pre-Des	ign												
ESL:E.3 Schematic Design	14	29-Jun-09	17-Ju⊢09		😽 17-J	uF09, ESL	:E3 Schem	atic Design												
Prepare SD drawings	10	29-Jun-09	10-Jul-09		Prep	are SD dra	wings													Million -
🥃 Fundamental design report	11	29-Jun-09	13-Jul-09		🗖 Fund	lamental d	esign report													
🥃 Issue SD package	0	17-Jul-09			🔷 lssu	e SD pack	age, 17-Jul-	09												
ESL:E.4 Design Development 35%	24	10-Aug-09	11-Sep-09			11-Sep-0	9, ESL:E.4	Design Dev	elopment3	35%										
🥃 Prepare DD drawings	20	10-Aug-09	04-Sep-09			Prepare [D drawings													
🥃 Issue DD package	0	11-Sep-09				Issue DD	package, 1	1-Sep-09												1000
Notice of Award	0	11-Sep-09			•	Notice of	Award, 11-S	ep-09												- Aller
ESL:E.5 Design Development 65%	49	14-Sep-09	20-Nov-09			20	-Nov-09, ES	LE5 Desi	gn Develoj	pment	65%									
Advance DD documents to Construction Document level	20	14-Sep-09	09-Oct-09			📥 Advar	ce DD docu	nents to Co	nstruction	Docu	ment lev	rel								
🥃 Prepare DD drawings	25	12-Oct-09	13-Nov-09			🔲 Pr	pare DD dr	wings												
Prepare DD specs	25	12-Oct-09	13-Nov-09			🔲 Pr	pare DD sp	ecs												1010
🥃 Issue DD package	0	20-Nov-09				Is 🔷	sue DD paci	age, 20-No	v-09											Ditter
ESL:E.6 Construction Documents 95%	835	04-Jan-10	10-Apr-13																	
🥃 Prepare drawings	35	04-Jan-10	19-Feb-10				Prepa	re drawing												
🥃 Prepare specs	35	04-Jan-10	19-Feb-10				Prepa	re specs												Mare -
Notice to Proceed	0	19-Feb-10					Notic	to Procee	l, 19-Feb-	10										
🥃 Submittals	800	22-Feb-10	10-Apr-13								; ; ; 1 1 1							<u> </u>	<u></u>	
💼 Issue 95% CD package	0	01-Mar-10					🔷 İssu	e 95% CD p	ackage, 0	1-Mar-	10									
ESL:E.7 Construction Documents 100%	115	22-Feb-10	03-Aug-10						3-Aug-10,	ËSL:E	7 Con	struction	Docu	mėnts 1	00%					
🥃 Obtain approved permits	43	22-Feb-10	21-Apr-10					Obtain app	oved perr	nits										APARA -
Prepare drawings	5	12-Apr-10	16-Apr-10				0	Prepare dra	wings											
Prepare specs	5	12-Apr-10	16-Apr-10					Prepare spi	cs											
💼 Issue 100% CD package	0	19-Apr-10					٠	lssue 100%	CD pack	age, 1	9-Apr-1	ווס								
🥃 Prepare & Approve Baseline CPM schedule	75	19-Apr-10	03-Aug-10			1111	- i i i 🖻	F	repare &/	Approv	e Basel	inė CPM	scheid	dule						1

Recommendations

tivity Name	Original Start	Finish	2009	I		201	5		2011		2012	201
	Duration		Q2 Q3	Q4	Q1	Q2	Q3	Q4	Q1 Q2	Q3 Q4	Q1 Q2 Q3 Q4	Q1
ESL:E.8 Construction	330 03-Aug-10	16-Nov-11					Y			V	16-Nov-11, ESL E.8 Construction	
ESL:E.9 Earthwork	255 03-Aug-10	02-Aug-11					-			💙 02-Aug-1	I, ESL:E.9 Earthwork	
ESL:E.10 Concrete	260 09-Aug-10	15-Aug-11								15-Aug-	11, ESLE.10 Concrete	
ESL:E.11 Structural Steel	44 17-Nov-10	20-Jan-11						-	🔽 20- Jan-11, ESI	E.11 Structu	Iral Steel	
ESL:E.12 HVAC	254 29-Jul-10	27-Jul-11								1 1 1 1 1	ESL:E.12 HVAC	
									Site HVAC			
	126 29-Jul-10	26-Jan-11						1 1				
Basement HVAC	187 16-Sep-10									asement HVA		
Penthouse HVAC		27-Jul-11					1			Pentriouse		
Eab 1		13-Apr-11							I Lab 1			
Eab 2	4 08-Apr-11	13-Apr-11						1 1	Lab 2	$\begin{array}{cccccccccccccccccccccccccccccccccccc$		
😑 Lab 3		13-Apr-11							∥ Lab3			
Eab 4	5 08-Apr-11	14-Apr-11							□ Labi4			
👝 Lab 5	5 08-Apr-11	14-Apr-11							[]Lab 5			
💼 Lab 6	6 08-Apr-11	15-Apr-11							[]Labi6			
😑 Lab 7	6 11-Apr-11	18-Apr-11							🛛 Lab 7			
🚘 Lab 8	6 11-Apr-11	18-Apr-11		111	111]]Lab 8			<u> </u>
🖨 Lab 9	6 11-Apr-11	18-Apr-11							🛛 Lab 9			
Lab 10	7 11-Apr-11	19-Apr-11							🛛 Lab 10			
🚘 Lab 11	7 12-Apr-11	20-Apr-11							Lab 11			
🚘 Lab 12	6 12-Apr-11	19-Apr-11							Lab 12			
🚘 Lab 13	6 13-Apr-11	20-Apr-11							[] Lab 13			
🚘 Lab 14	6 13-Apr-11	20-Apr-11			111		111		Lab 14			
🚘 Lab 15	6 18-Apr-11	25-Apr-11							🛛 Lab 15			
🚘 Lab 16	6 18-Apr-11	25-Apr-11							🛛 Lab 16			
🚘 Lab 17	6 18-Apr-11	25-Apr-11							🛛 Lab 17			
🚘 Lab 18	6 20-Apr-11	27-Apr-11							🖪 Lab 18			
ESL:E.13 Electrical	244 15-Sep-10	29-Aug-11						3 1 1	133331	29-Aug-1	11, ESL:E.13 Electrical	
ESL:E.14 Fire Protection	100 23-Dec-10	13-May-11						V	13+M	ay-11, ESL.E.	14 Fire Protection	
ESL:E.15 Plumbing	216 20-Sep-10	25-Ju⊦11								25-Jul-11, E	SL:E.15 Plumbing	
ESL:E.16 Facade	43 24-Jan-11	23-Mar-11							23-Mar-11	E\$L:E.16 Fa	acade	
FRP Concrete	14 24-Jan-11	10-Feb-11							FRP Concrete			
👝 Install Fiber Cement Siding	33 07-Feb-11	23-Mar-11			111		111		Install Fibe	r Cement Sidi	ing	
ESL:E.17 Closeout	0 15-Nov-11	15-Nov-11			111					▼ 1	5-Nøv-11, ESL:E.17 Closeout	
Turnover	0	15-Nov-11		111	111	1 1 1	111	111			Furnover,	

Industry:

- Hensel Phelps
- Ewing Cole
- Centria

Acknowledgments

Academic:

- Dr. Chimay Anumba
- Dr. Robert Leicht
- Dr. Craig Dubler
- Dr. David Riley
- Professor Parfitt
- Dr. Cox
- Penn State Architectural

Engineering Facility

Special Thanks to:

- The Project team
- The Owner and Owner's Representative
- Pace Industry Members
- My Family and Friends
- Jessica Weber







Project Outcome Metrics

Metric	Equation
Unit cost (\$/SF)	Actual project cost / Gross square-footage
Cost growth (%)	[(Actual project cost – Initial project cost) / Initial project cost] x 100
Intensity (\$/SF/Month)	Unit cost / (Actual project duration in days / 30)
Schedule growth (%)	[(Actual project duration in days – Initial project duration in days) / Initial project duration in days] x 100
Delivery speed (SF/Month)	Gross square-footage / (Actual project duration in days / 30)
Construction speed (SF/Month)	Gross square-footage / (Actual construction duration in days / 30)
Turnover quality (Sum ratings)	Start-up difficulty + Call back frequency + O&M costs
System quality (Sum ratings)	Structure & envelope expectations met + Interior expectations met + Environmental system expectations met
Design quality (Sum ratings)	Aesthetic expectations met + Functional expectations met
Sustainability	LEED certification level

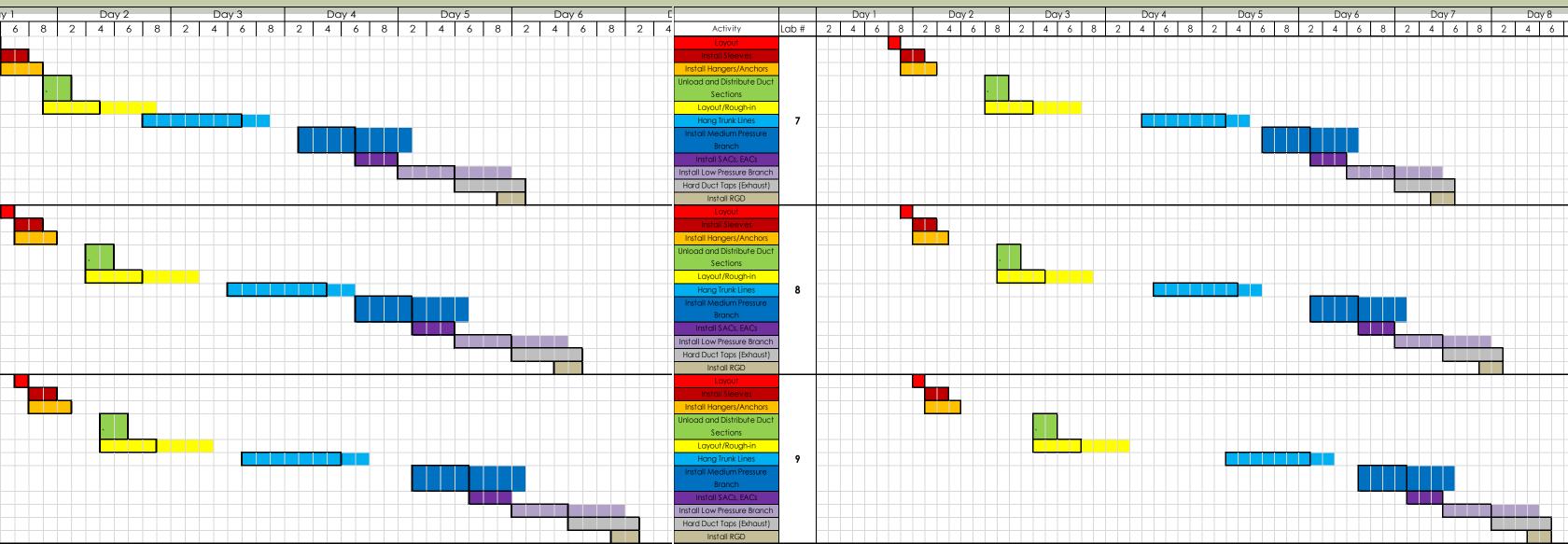
Building Name Environmenta

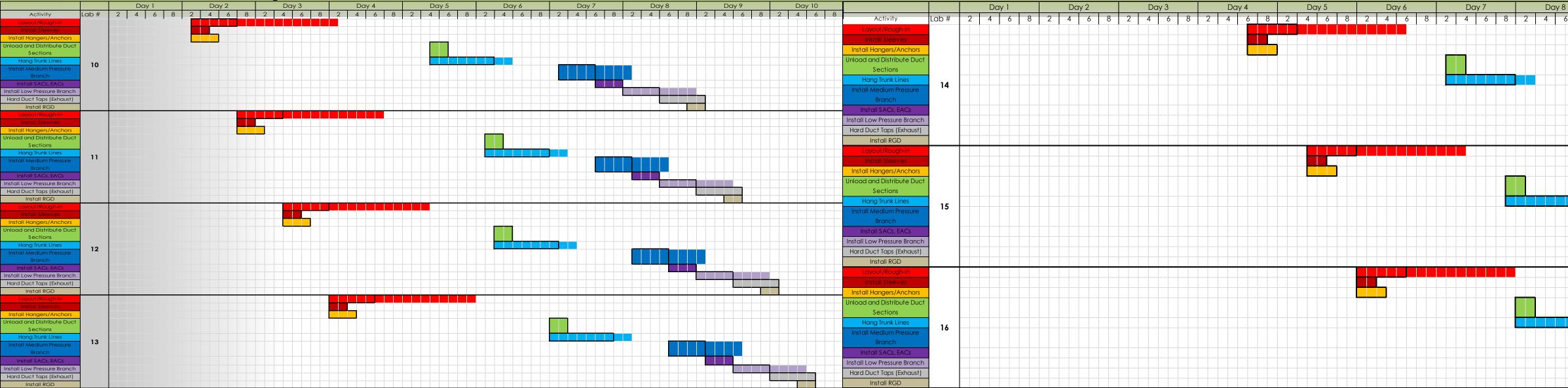
									Finish		Initial	Final				
		Delivery				Project	Start	Finish Plan	Actual	Construction	Construction	Construction			Construction	Delivery
ame	Building Type	Method	Square Foot	NTP	Project End	Duration	Actual Date	date	date	Duration	Cost	Cost	Cost/Sq Ft	Intensity	Speed	Duration
ntal Studies	Lab	DBB	72,000	06/01/11	10/17/13	622	6/15/11	04/22/13	10/07/13	604	33,981,000	35,358,000	\$49 <mark>1</mark>	\$1,756,192	3576	3473
	Naval Base	DB	99,460	04/30/09	05/12/11	531	10/22/09	05/15/11	05/12/11	406	53,787,000	54,518,970	\$548	\$4,028,495	7349	5619
	Health Care	IPD	4,350,100	04/14/08	09/12/12	1153	5/28/09	08/31/12	02/09/12	706	352,852,000	272,892,000	\$63	\$11,595,977	184848	113186
	Municipal building	DB	520,000	12/23/10	08/17/12	432	2/28/11	06/29/12	07/22/12	366	49,177,044	53,396,376	\$103	\$4,376,752	42623	36111
			0_0,000				_/ _0/		•//==/==				+	<u> </u>		
	Transportation	DB	71,336	06/02/11	04/22/13	493	8/10/11	08/01/13	04/22/13	444	25,900,000	32,832,966	\$460	\$2,218,444	4820	4341
	Office/Training/															
	Warehouse	DB	41,155	03/14/12	04/24/13	291	5/21/12	05/31/13	04/24/13	243	8,256,000	10,309,714	\$251	\$1,272,804	5081	4243
	Transportation	DB	2,656,300	10/17/06	06/30/10	967	7/1/07	06/30/10	06/30/10	784	512,771,000	669,456,000	\$252	\$25,616,939	101644	82408
			2,030,300	10/17/00	00/30/10	307	//1/0/	00/30/10	00/30/10	784	512,771,000	009,430,000		ŞZJ,010,939	101044	02400
	Office	DB	250,000	08/01/07	08/01/09	525	8/1/07	06/01/09	06/01/09	479	92,860,000	92,727,765	\$371	\$5,807,584	15658	14286
									On							
		DB	449,000	06/03/11	On Schedule	NA	1/3/12	12/16/15	Schedule	NA	141,231,044	TBD	NA	NA	NA	NA
	Museum	DB	47,000	12/07/09	11/10/12	766	8/7/10	08/23/11	11/09/12	591	11,400,000	12,562,509	\$267	\$637,691	2386	1841
	Hanger-Commercial	DB	60,000	11/03/11	08/01/13	456	3/13/12	06/24/13	06/24/13	335	19,498,000	19,744,063	\$329	\$1,768,125	5373	3947

First Floor														
Activity	Days/Floor	Crew Members	Hours/floor	Hours/lab	Hours/Worker	SIPS 1 & 2 Crew Members	Adjusted Hours/lab	SIPS 3Crew Members	Adjusted Hours/lab					
Layout	1	1	8	0.89	0.89	1	0.89	1	0.89					
Install Sleeves	2	1	16	1.78	1.78	1	1.78	1	1.78					
Install Hangers/Anchors	3	2	24	2.67	1.33	2	2.67	2	2.67					
Unload and Distribute	0			1 70	0.00		1.70	0	1.70					
Duct Sections	2	2	16	1.78			1.78	2	1.78					
Layout/Rough-in	9	•	72	8.00			4.00	2	4.00					
Hang Trunk Lines	10	3	80	8.89	2.96	4	6.67	4	6.67					
Install Medium Pressure	0		70	0.00	0.47		(00	-	4.00					
Branch	9	3	72	8.00			6.00		4.80					
Install SACs, EACs	3.5	2	28	3.11	1.56	2	3.11	2	3.11					
Install Low Pressure Branch	9	3	72	8.00	2.67	4	6.00	5	4.80					
Hard Duct Taps (Exhaust)	6	3	48	5.33	1.78	3	5.33	3	5.33					
Install RGD	2	1	16	1.78	1.78	1	1.78	1	1.78					
Total		22.00	452	50.22		26	40.00	34	37.60					

				Second Flo	or				
						SIPS 1 Crew	Adjusted	SIPS 3Crew	Adjusted
Activity	Days/Floor	Crew Members	Hours/day	Hours/lab	Hours/Worker	Members	Hours/lab	Members	Hours/lab
Layout/Rough-in	18	1	144	16.00	16.00	3	5.33	3	5.33
Install Sleeves	2	1	16	1.78	1.78	1	1.78	1	1.78
Install Hangers/Anchors	3	2	24	2.67	1.33	2	2.67	2	2.67
Unload and Distribute									
Duct Sections	2	2	16	1.78	0.89	2	1.78	2	1.78
Hang Trunk Lines	10	3	80	8.89	2.96	4	6.67	4	6.67
Install Medium Pressure									
Branch	9	3	72	8.00	2.67	4	6.00	5	4.80
Install SACs, EACs	3.5	2	28	3.11	1.56	2	3.11	2	3.11
Install Low Pressure Branch	9	3	72	8.00	2.67	4	6.00	5	4.80
Hard Duct Taps (Exhaust)	6	3	48	5.33	1.78	3	5.33	3	5.33
Install RGD	2	1	16	1.78	1.78	1	1.78	1	1.78
Total		21.00	516	57.33		26	40.44	32	38.04

			Da	y 1			Da	iy 2				Day	/ 3			C	Day -	4			Do	ay 5					Day
Activity	Lab #	2	4	6	8	2	4	6	8	2	4	4	6	8	2	4		6	8	2	4	6	8	Activity	Lab #	2	4
Layout																								Layout			
Install Sleeves																								Install Sleeves			
Install Hangers/Anchors																								Install Hangers/Anchors			
Unload and Distribute Duct																								Unload and Distribute Duct			
Sections			•																					Sections			
Layout/Rough-in																								Layout/Rough-in			
Hang Trunk Lines	1																							Hang Trunk Lines	4		
Install Medium Pressure																								Install Medium Pressure			
Branch																								Branch			
Install SACs, EACs																								Install SACs, EACs			
Install Low Pressure Branch																								Install Low Pressure Branch			
Hard Duct Taps (Exhaust)																								Hard Duct Taps (Exhaust)			
Install RGD																								Install RGD			
Layout																								Layout			
Install Sleeves																								Install Sleeves			
Install Hangers/Anchors																								Install Hangers/Anchors			
Unload and Distribute Duct																								Unload and Distribute Duct			
Sections			`																					Sections			
Layout/Rough-in																								Layout/Rough-in			
Hang Trunk Lines	2																							Hang Trunk Lines	5		
Install Medium Pressure																								Install Medium Pressure			
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Install SACs, EACs																								Install SACs, EACs			
Install Low Pressure Branch																				_				Install Low Pressure Branch			
Hard Duct Taps (Exhaust)	_																							Hard Duct Taps (Exhaust)			
Install RGD																								Install RGD			
Layout																								Layout			
Install Sleeves																								Install Sleeves			
Install Hangers/Anchors																								Install Hangers/Anchors			
Unload and Distribute Duct																								Unload and Distribute Duct			
Sections					`																			Sections			
Layout/Rough-in																								Layout/Rough-in			
Hang Trunk Lines	3																							Hang Trunk Lines	6		\square
Install Medium Pressure																								Install Medium Pressure			
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Install SACs, EACs																								Install SACs, EACs			
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Hard Duct Taps (Exhaust)																								Hard Duct Taps (Exhaust)			
Install RGD																								Install RGD			

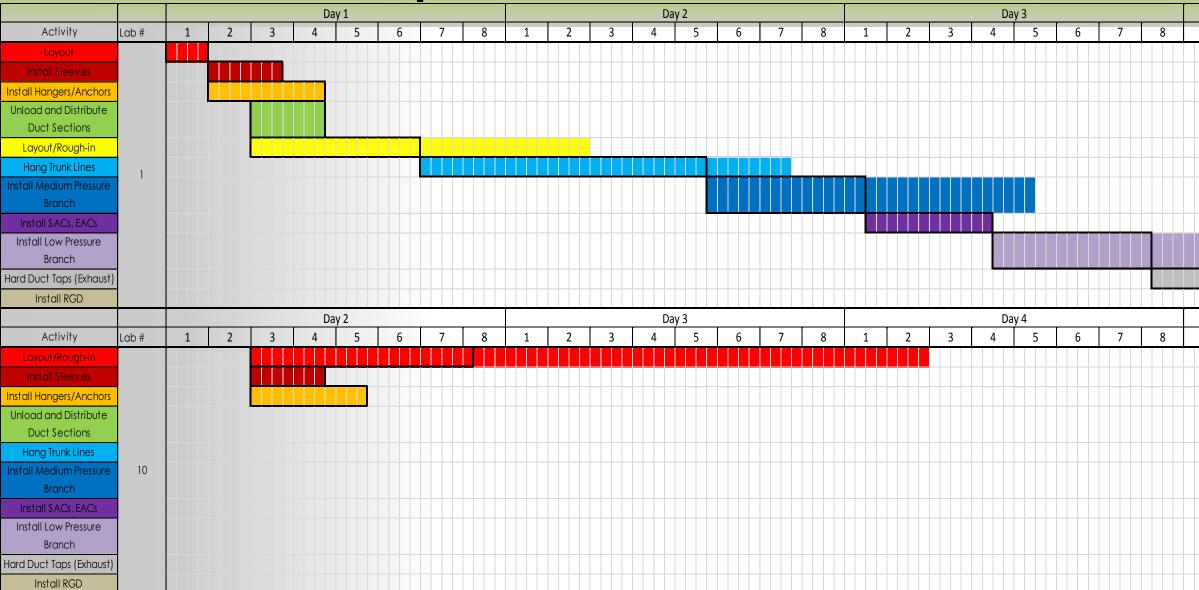




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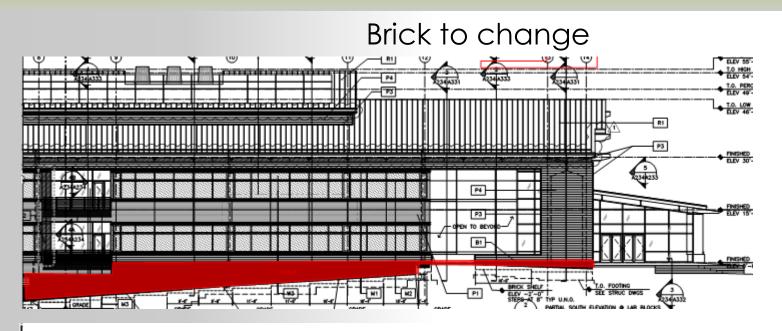
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Install Low Pressure Branch																																			
Hard Duct Taps (Exhaust)																																			
Install RGD																																			

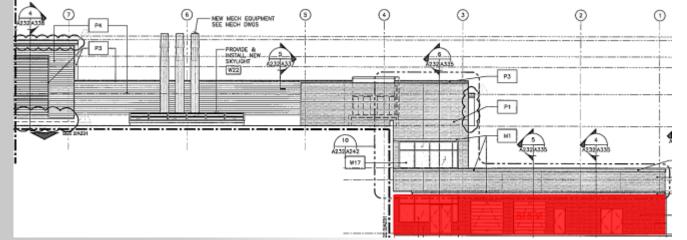


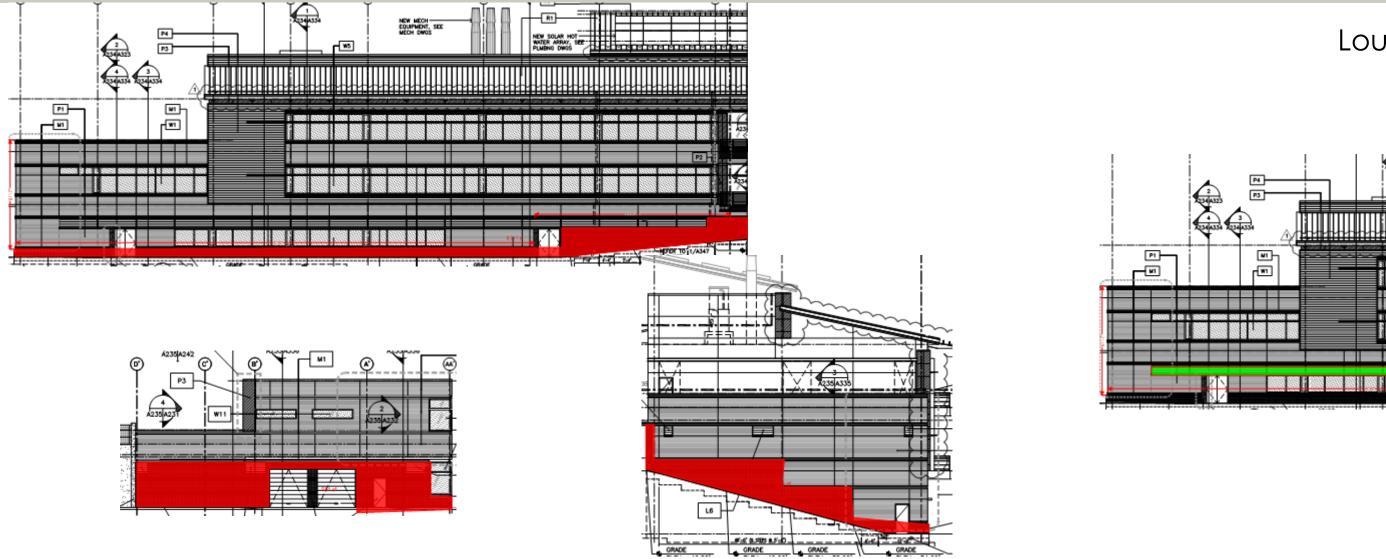


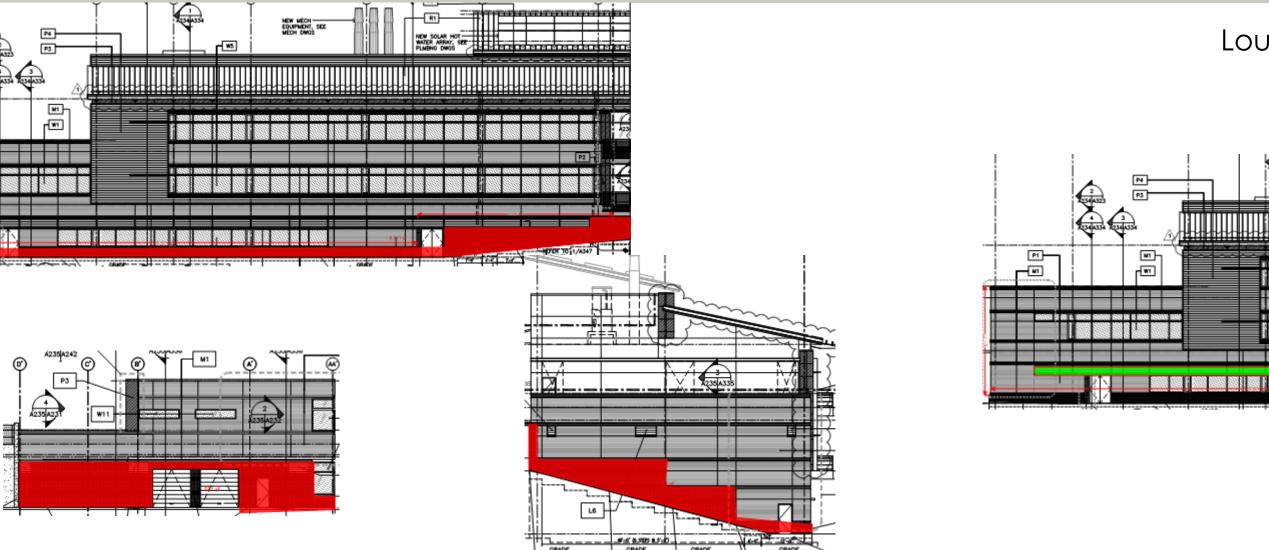


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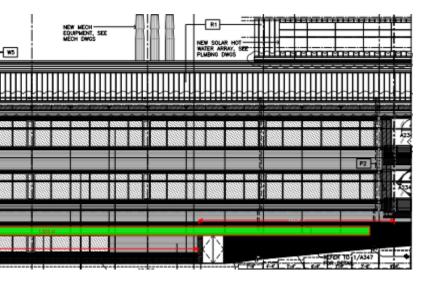




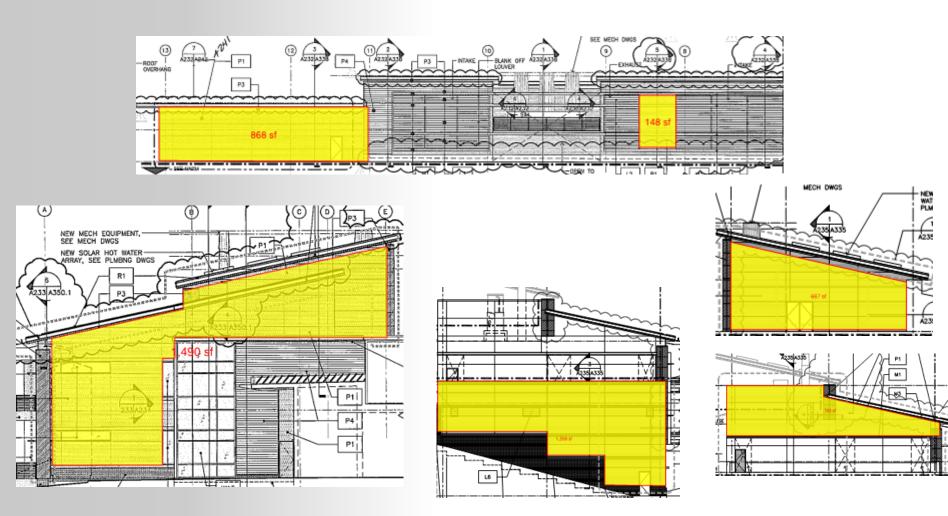
Appendix

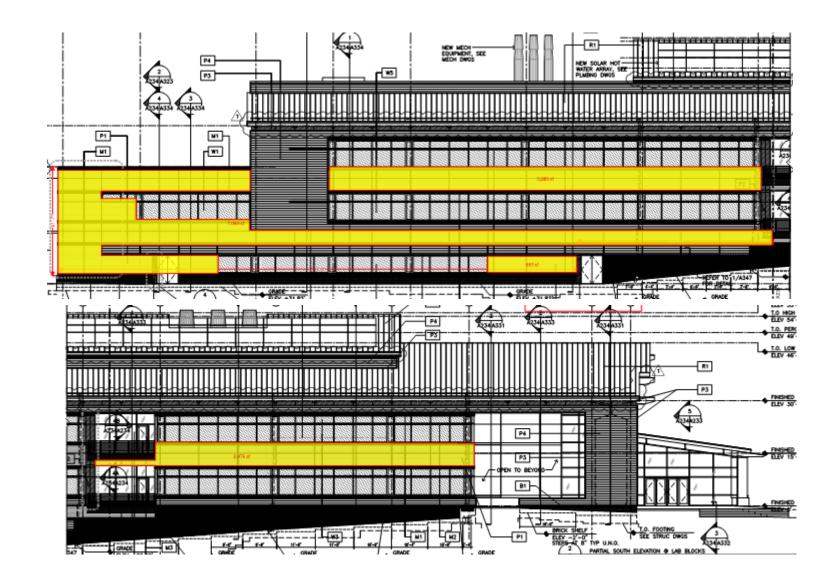
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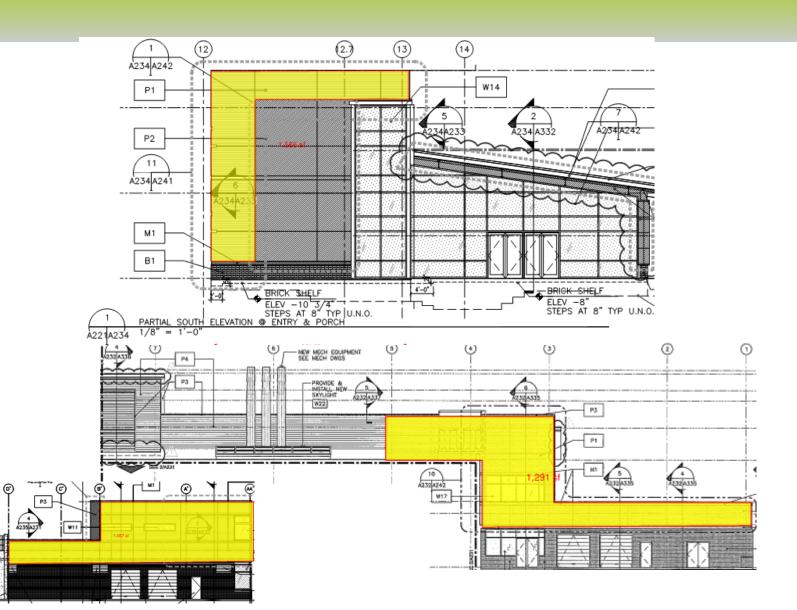
Louvers to change



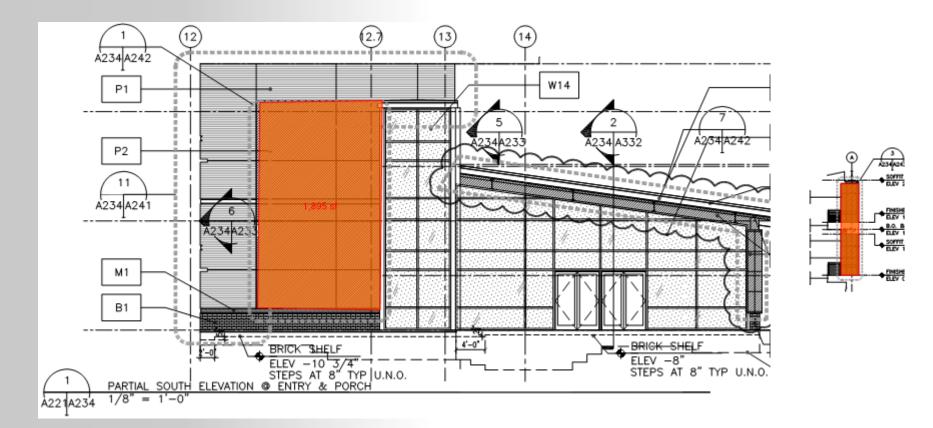
Corrugated to change

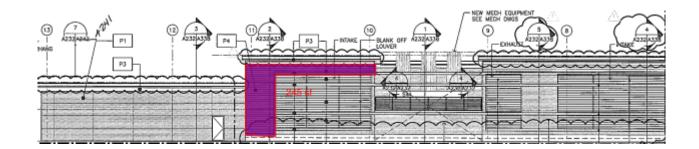






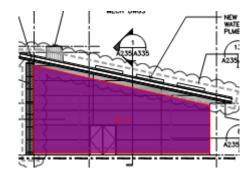
Composite to change

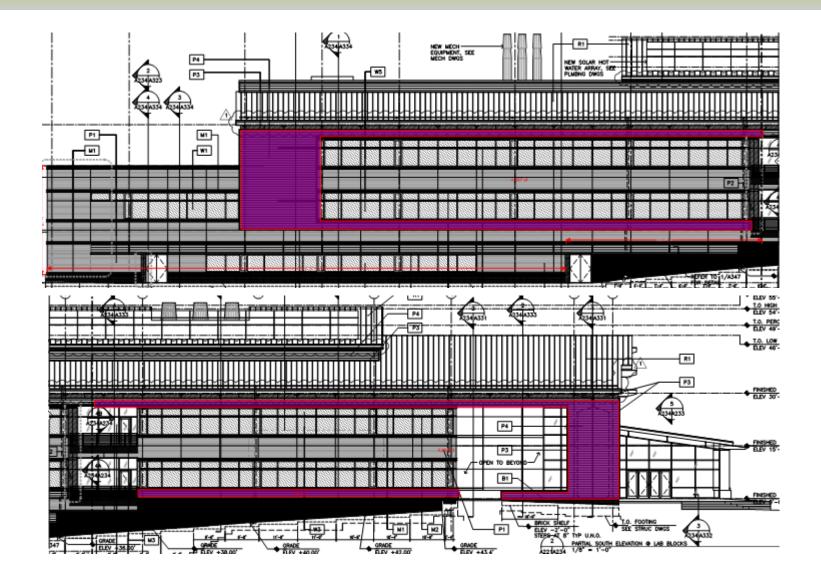




Appendix

Current Fiber Cement Siding





		Whole	e Building (Phase	1 & 2)		
Elevation	Corrugated	Composite (orange)	Fiber Cement Siding	Louvers	Brick Veneer	Total Square Footage
North	2,307	0	5,908	0	818	9,033
South	14,769	2,412	8,146	1,833	5,737	32,897
East	1,788	0	638	0	0	2,426
West	9,333	0	0	0	3,768	13,101
Total	28,197	2,412	14,692	1,833	10,323	57,457

		E	Expansion			
Elevation	Corrugated	Composite (orange)	Fiber Cement Siding	Louvers	Brick Veneer	Total Square Footage
North	2,307	0	992	0	818	4,117
South	14,769	2,412	8,146	1,833	5,737	32,897
East	490	0	0	0	0	490
West	3,846	0	0	0	959	4,805
Total	19,105	2,412	9,138	1,833	7,514	40,002



Material Composite Corrugated Louvers Fiber Cement Siding Total

		Originc	I Production and	Cost		
Martarial		Duration	Production Rate	Coat /S aft	Cost/Day	Tatal Cast
Material	Square Footage	(Days)	(SF/Day)	Cost/Sqft	Cost/Day	Total Cost
Corrugated	19,105	21	940	\$15.00	\$14,100.00	\$296,100
Composite	2,412	15	161	\$40.00	\$6,440.00	\$96,60
Fiber Cement						
Siding	9,138	10	979	\$13.09	\$12,815.11	\$128,15
Louvers	1,833	5	367	\$41.50	\$15,230.50	\$76,15
Brick	7,514	19	395	\$23.00	\$9,095.89	\$172,82
Total	40,002	70	2,842		\$57,681.50	\$769,82

		Fib	er Cement Sidi	ng		
1	Square	Duration	Production	Cost /S off	Cost (Dov	Total Cost
	Footage	(Days)	Rate (SF/Day)	Cost/Sqft	Cost/Day	Total Cost
	2,412	2	979	\$13.09	\$12,815.11	\$31,573
	19,105	20	979	\$13.09	\$12,815.11	\$250,084
	1,833	2	979	\$13.09	\$12,815.11	\$23,994
nt						
	9,138	10	979	\$13.09	\$12,815.11	\$128,151
	32,488	34	3,916		\$51,260.44	\$433,803

			New Productio	n and Cost			
Material	Quantity	Units	Duration (Days)	Production Rate (Unit/Day)	Cost/Unit	Cost/Day	Total Cost
Siding	32,488	SF	33	979	\$13.09	\$12,815.11	\$425,268
Concrete	509	CY	14	37	\$100.00	\$3,700.00	\$50,928
Total			47	1,016		\$16,515.11	\$476,196