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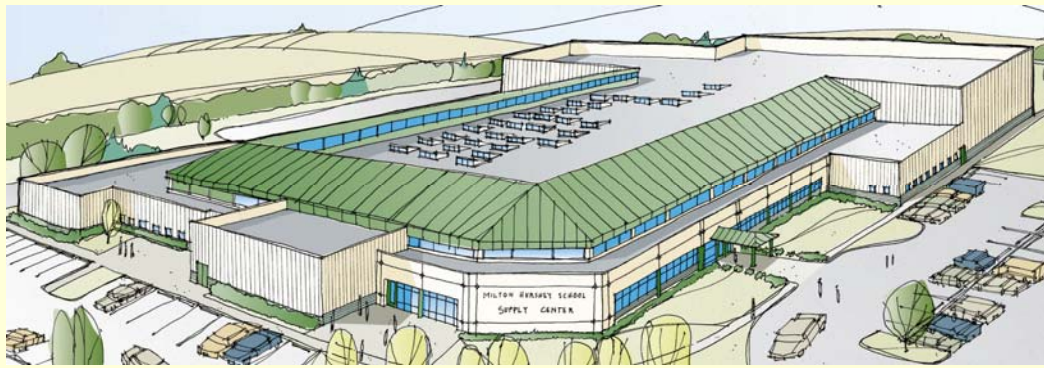
Building Systems Integration - Energy and Cost Analysis

The Milton Hershey School New Supply Center

Justin Bem
AE Senior Thesis – Spring 2007
Mechanical Option
Penn State University



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Presentation Outline

- Project and Building Background
- Existing Conditions
- Mechanical System Redesign
  - DOAS/ Water Source Heat Pumps
  - Condenser Loop Heat Recovery System
  - Absorption Chiller-Heater Technology
  - Redesigned Chiller/Boiler Plants
  - Life Cycle Cost Analysis and Payback
- Structural/Construction Breadth
  - AHU Relocation Roof Structure Impact
  - Mezzanine Floor Detailed Cost Estimate
- Electrical Breadth
  - Redesign's effect on Power Systems
- Conclusions and Recommendations

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Project and Building Background

Owner

- The Milton Hershey School

Location

– The Milton Hershey School Campus, Hershey, PA

Project Size

- 110,000 square feet

Total Cost

- $23,500,000

Design-Bid-Build Contract

Construction Dates

- July 2006 – July 2007

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Project and Building Background

The Supply Center

- General Office and Conference Rooms
- Kitchen/Food Preparation Center
- Bakery
- Clothing Store and Alterations Seamstress
- Mail Distribution Center
- General Building and MHS Campus Storage

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Existing Conditions

Air Side Mechanical System

14 Total Air Handling Units

- 10 VAV Units – Serving General Office and Clothing Areas
- 4 CAV Units – 100% Outdoor Air Make-Up Units for Kitchen/Bakery
- Chilled/Hot Water Coils
- Housed in Elevated Mechanical Mezzanine Floor

McQuay Custom Air Handling Unit

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Existing Conditions

Existing Chiller Plant

(2) 270 ton Water Cooled Centrifugal Chillers

- Primary-Secondary Pumping
- 45°F Chilled Water Serves AHU Coils and Walk-in Freezer Condenser
- Electric Driven Vapor Compression Machines
- Housed in 1st Floor Mechanical Room

Trane Centrifugal Chiller

Existing Boiler Plant

(3) Natural Gas Fired Steam Boilers

- Handles All Building HVAC Heating Demands
- Meets Domestic Hot Water Heating Demands

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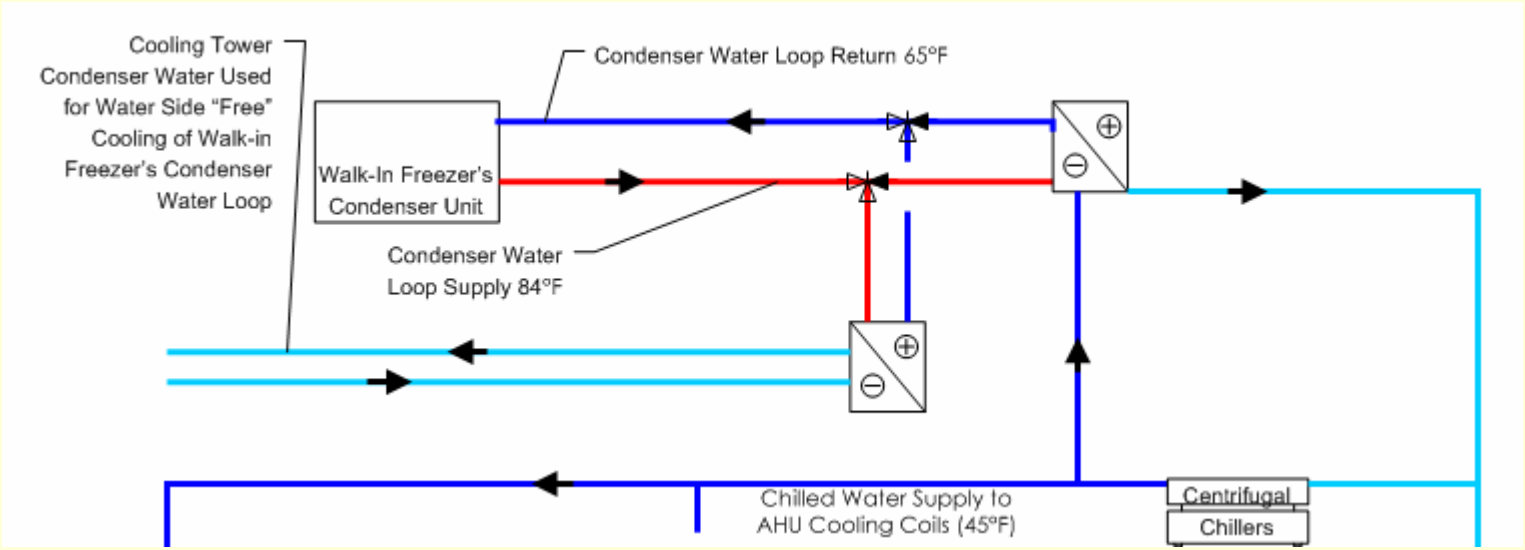
Existing Conditions

Walk-in Freezer Condenser Water Loop

Rejected Heat from Condenser to water loop

- Removes Additional Heating Load from Kitchen Space
- Load Is Met Directly By Chilled Water Plant Via Plate-Frame HX's
- Water Side "Free" Cooling Is Utilized in the Winter for Heat Rejection



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Mechanical System Redesign

Goals and Objectives

- Increase Energy Efficiency
- Low Life Cycle Cost
- Affordable – (Low First Cost or 2-4 Year Payback Period)

Integration of All Building Systems with HVAC System

- Recover Waste Heat
- Perform Multiple Functions from One Fuel Source

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Mechanical System Redesign
DOAS/ Water Source Heat Pumps

DOAS at The Supply Center

-10 Existing VAV Air Handling Units Replaced with 2 DOAS Units

- Saves in First Cost

- Saves in Fan and Chiller Energy

Water Source Heat Pumps at The Supply Center

- Water Source Loop Integrates Other Building Systems

  --Condenser Water Loop Heat Recovery

- Gives Ability to Heat and Cool Simultaneously

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Mechanical System Redesign
Condenser Loop Heat Recovery

Walk-in Freezer's Reject Heat to a Condenser Water Loop

- Must Be Cooled for Continues Operation of Freezers
- Potential for a Large Amount of Energy Recovery

135gpm Flow Rate

84°F Hot Temperature

65°F Operating Temperature

1282 MBH of Possible Heat Recovery

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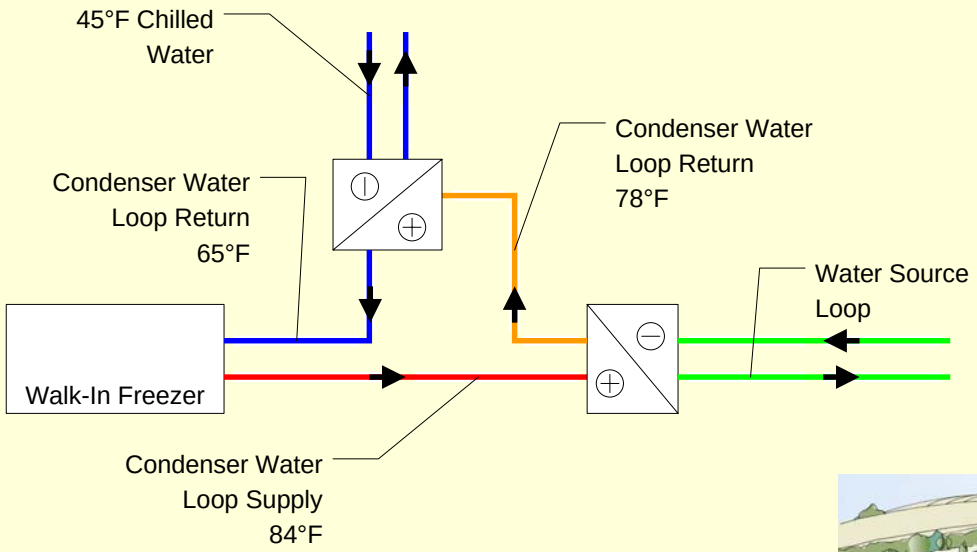
Mechanical System Redesign
Condenser Loop Heat Recovery

Heat Recovery In Water Source Loop

- Water Source Heat Pump Loop Requires Winter Time Heat Addition
- Operating Temperature of 68°F
- Condenser Water Loop Serves as Heat Source Via Heat Exchanger



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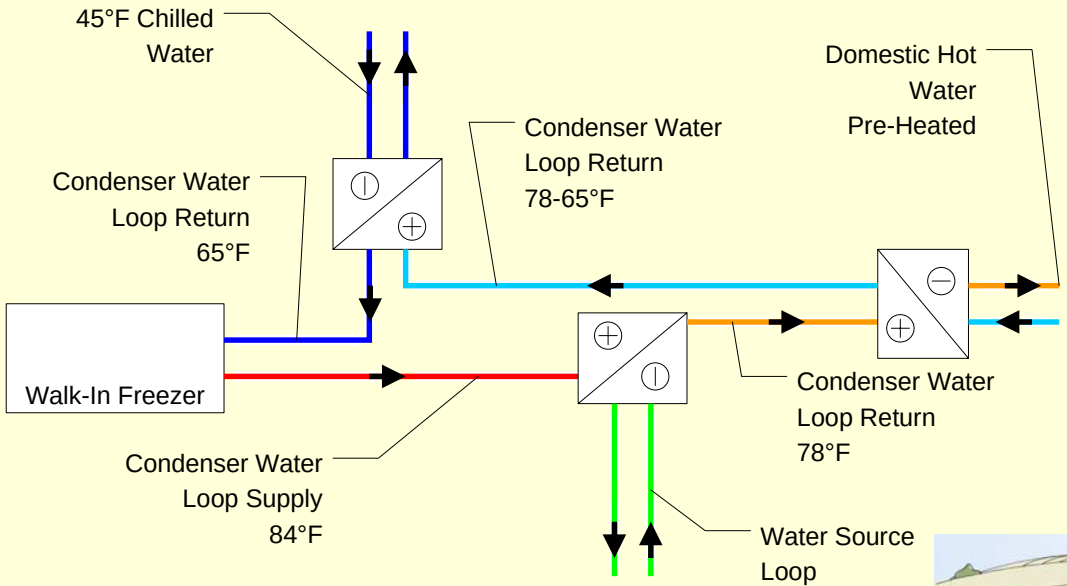
Mechanical System Redesign
Condenser Loop Heat Recovery

Heat Recovery In Domestic Hot Water Pre-Heat

- High Domestic Hot Water Demand at The Supply Center
- Condenser Loop Pre-Heats Water to 76-81°F (Saves 35% Heating Energy)



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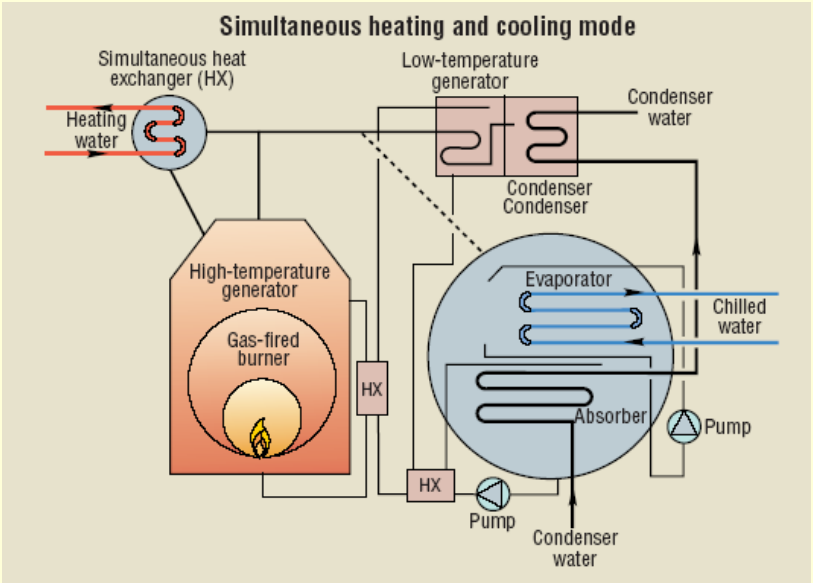
Mechanical System Redesign
Absorption Chiller-Heater Technology

Direct Natural Gas Fired Absorption Chiller-Heaters

- Utilizes Natural Gas Service at The Supply Center

- Typical Single Effect LiBr/Water Absorption Cycle

- Includes Heat Exchanger in High Temperature Generator for Simultaneous Cooling and Hot Water Production (Up to 210°F)



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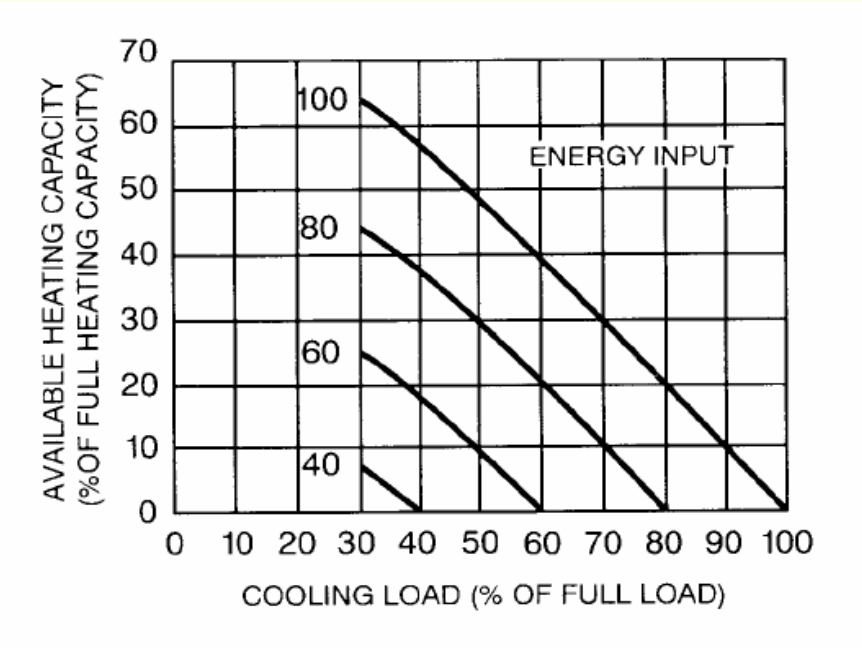
Mechanical System Redesign
Absorption Chiller-Heater Technology

Direct Natural Gas Fired Absorption Chiller-Heaters

- Simultaneous Heating Comes at the Expense of Cooling Production
- Chiller-Heater Must Run at 30% Cooling Capacity Minimum



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Mechanical System Redesign
Redesigned Chiller/Boiler Plants

Chiller-Heater Selection

- Sized to Meet Cooling and HVAC/Domestic Hot Water Needs
- (2) 240 ton Chiller-Heaters Used
- Meets Cooling Load with Enough Capacity to Produce Hot Water

Redundancy

-If one Chiller-Heater Is Off Line, Second Meets Critical Load
    -- Walk-in Freezer's Condenser System
-Back-up Boiler to Meet Heating Demand in This Situation

INTEGRATES HEATING, COOLING, CONDENSER WATER, AND DOMESTIC WATER SYSTEMS!

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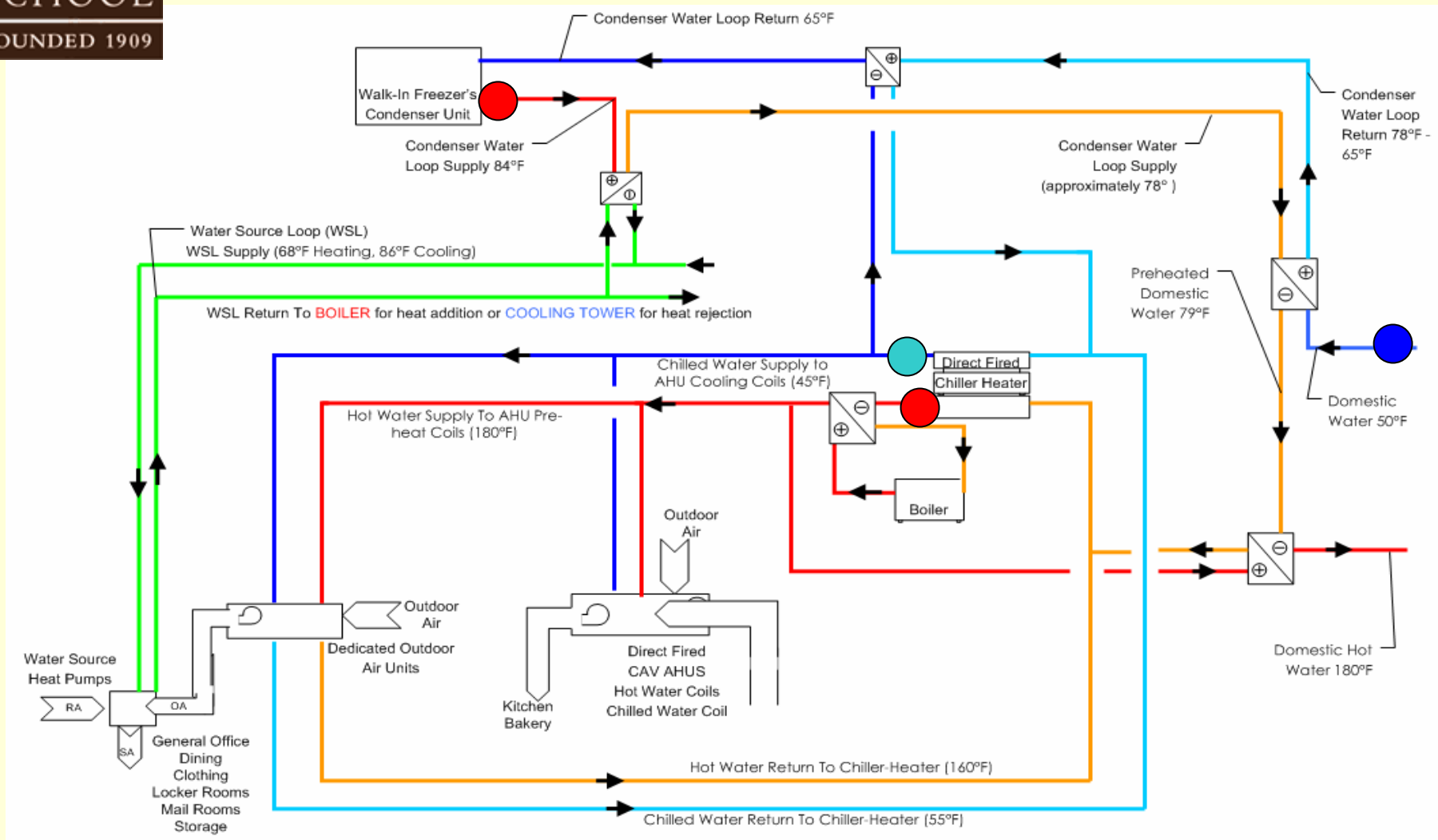
Mechanical System Redesign
Redesigned Chiller/Boiler Plants



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Mechanical System Redesign
Life Cycle Cost Analysis

Annual Operating Cost Comparison

	Existing System	Redesign w/ Chiller-Heater
Cooling Cost	$67,577	N/A
HVAC Heating Cost	$23,016	N/A
Hot Water Heating Cost	$58,371	N/A
Combined Heating and Cooling Cost	N/A	$117,370
Air System Fan Cost	$21,303	$12,318
Pump Cost	$29,274	$20,480
Cooling Tower Cost	$9,920	$16,440
Total	**$209,461**	**$166,608**

$42,800 Annual Cost Savings!

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Mechanical System Redesign
Life Cycle Cost Analysis

Initial Cost Comparison

Equipment (Quantity and Type)	Existing System	Redesign Chiller-heater Option
Chillers (2 Centrifugal)	178,000	-
Chiller-Heaters (2)	-	450,000
HVAC Boiler (1 4500 MBH)	21,800	-
HW Boiler (2 6500 MBH)	61,000	-
Supplemental Boiler (1 9000 MBH)	-	85,000
Heat Exchangers (for HW system)	10,000	-
DOAS AHUs (2)	-	47,840
VAV AHUs (10)	309,310	-
Plate-Frame HX	10,000	20,000
VAV Boxes w/reheat	32,730	-
Heat Pumps	-	60,045
TOTAL	**$622,840**	**$682,885**

$60,000 More Expensive

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Mechanical System Redesign
Life Cycle Cost Analysis

20 Year Life Cycle Cost Comparison

	Existing System	Redesign System
NPW	**$2,266,510**	**$1,829,863**
Initial Cost	$622,840	$682,885
20 Yr LCC	**$2,889,350**	**$2,512,748**

$376,600 Savings Over 20 Years!

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Mechanical System Redesign
Life Cycle Cost Analysis

Mechanical Redesign Conclusions

- Integrates Multiple Building Systems
- More Expensive Up Front
- Cheaper to Operate
- Least Expensive 20 Year Life Cycle Cost

Payback In Just Under 2 Years!

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Structural/Construction Breadth
AHU Relocation

Existing System

14 Total AHUs Housed in Mezzanine Floor

10 VAV 4 CAV

Creates Wasted Space in Mezzanine Floor

Redesigned System

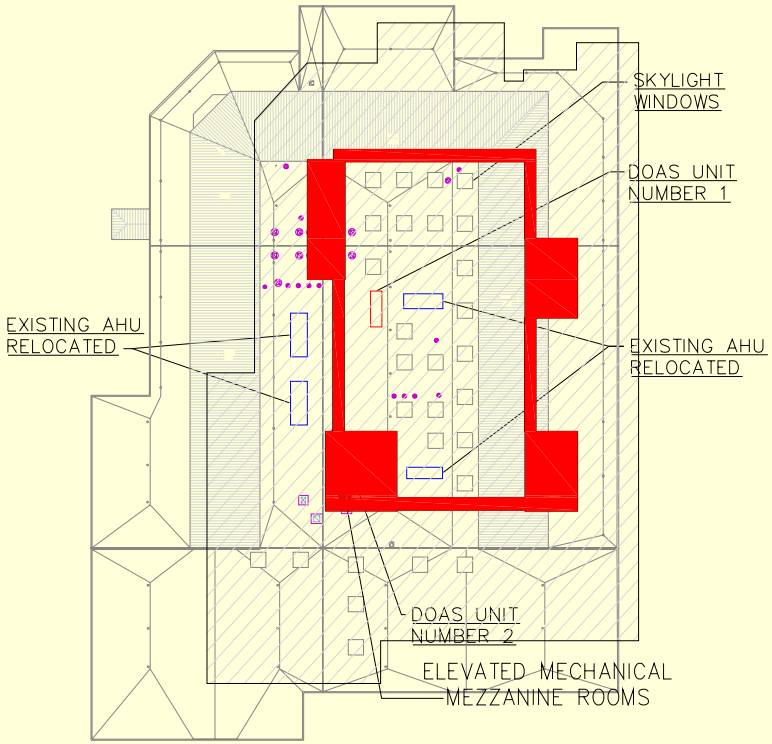
6 Total AHUs

2 DOAS 4 CAV

Move AHUs to Roof

- **Creates Structural Work**

- **Potential to Save Initial Cost**



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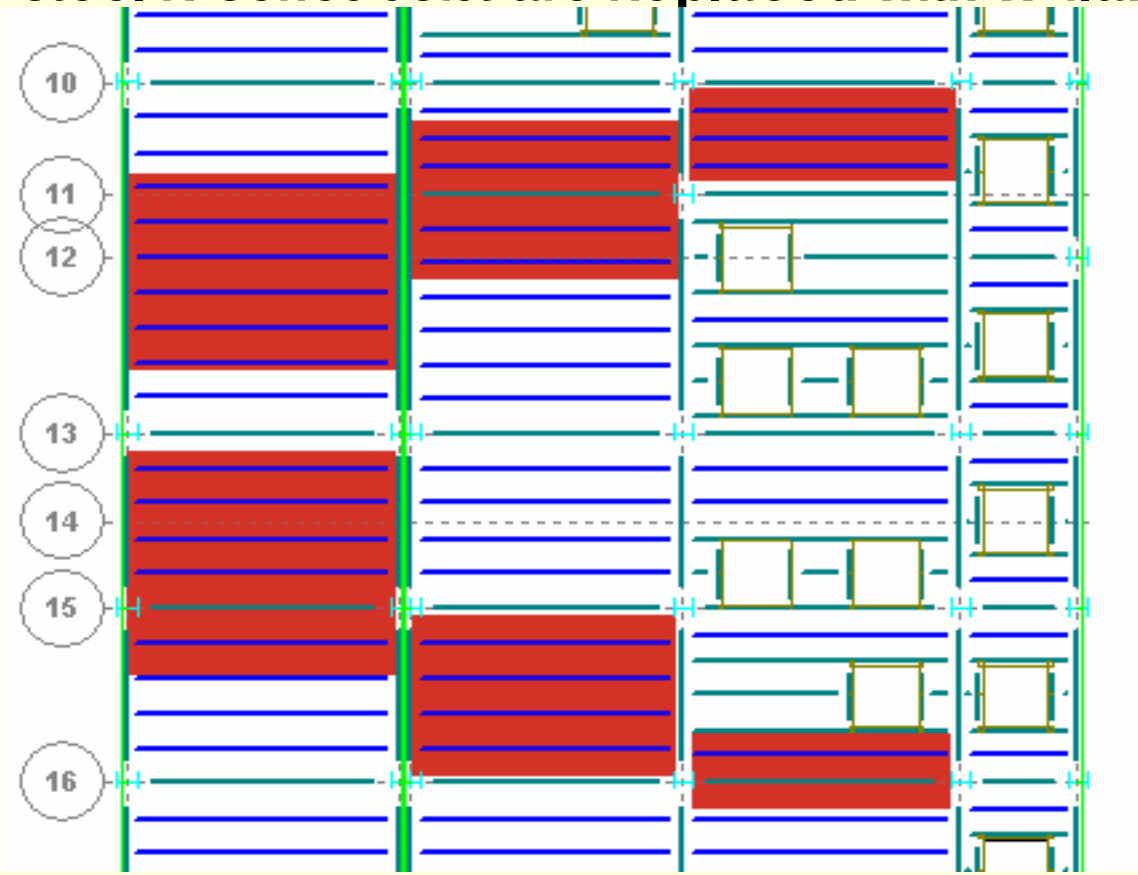
Structural/Construction Breadth
AHU Relocation

Steel K-Series Joist are Replaced with W-flanged Beams



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Structural/Construction Breadth
AHU Relocation

Additional Cost of Redesign Is Small!

BEAM/JOIST	LENGTH	AMOUNT	$COST/LF	TOTAL COST
28KCS5	37	14	11	$5,698
26K7	37	8	6.35	$1,879.6
			JOIST TOTAL COST	$7,577.6
W 8x10	37	22	9.65	$7,855.1
			Difference	**$277.5**

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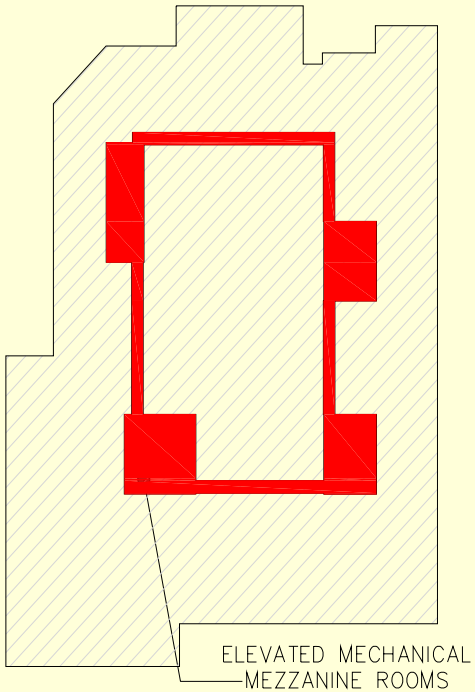
Structural/Construction Breadth
Mezzanine Floor Cost

No Need to Construct Mezzanine Floor
Only Held Air Handling Units



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Structural/Construction Breadth
Mezzanine Floor Cost

Large First Cost Savings for Not Construction Mezzanine Floor

	Total Construction Cost
Steel Members	$122,986.1
1-1/2" Steel Decking	$19,762.75
139 C.Y. of 4000psi Concrete	$11,709.6
TOTAL FLOOR COST	**$154,458.45**

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Electrical Breadth
Power System Alterations

Less Electric Driven Mechanical Equipment

- Chillers, 8 AHUs, Boiler Accessories
- Changes Load on Distribution Panels
- Saves Cost on Feeder and Wire Sizes

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Electrical Breadth
Power System Alterations

Electrical Cost Savings

Electrical Cost Savings	$9,189
New Equipment Electrical Cost	$5,534
Total Electrical Cost Savings	**$3,600**

Mechanical Redesign Creates Electrical Cost Savings!

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Conclusions and Recommendations
Final Cost Analysis

Overall Building System Redesign Cost Analysis

	Existing System	Redesign
Mechanical 1st Cost	$622,840	$682,885
Mezzanine Cost	$154,458	N/A
Additional Structural Cost	N/A	$277
Additional Electrical Cost	$3,600	N/A
Total 1st Cost	$780,898	$683,173

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Conclusions and Recommendations
Final Cost Analysis

Conclusions Compared to Existing System

- Mechanical Redesign Saves Energy and Cost Over 20 Years
- Integrates Other Building Systems
- Creates Overall First Cost Savings!

$ 97,725 Less Upfront!

$ 42,800 Less Per Year!

$ 531,000 Saved Over 20 Years!

Redesign Is Beneficial

Acknowledgments

Thank You!

AE Department

- Advisor Dr. Bahnfleth

H.F. Lenz Company

- Tom Hovan, P.E.

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- Brian Barna & Cynthia Milinichik

Construction Help

- Kyle Conrad

My Great Friends for Their Support!

- Andy, Jess, Kyle, Kevin

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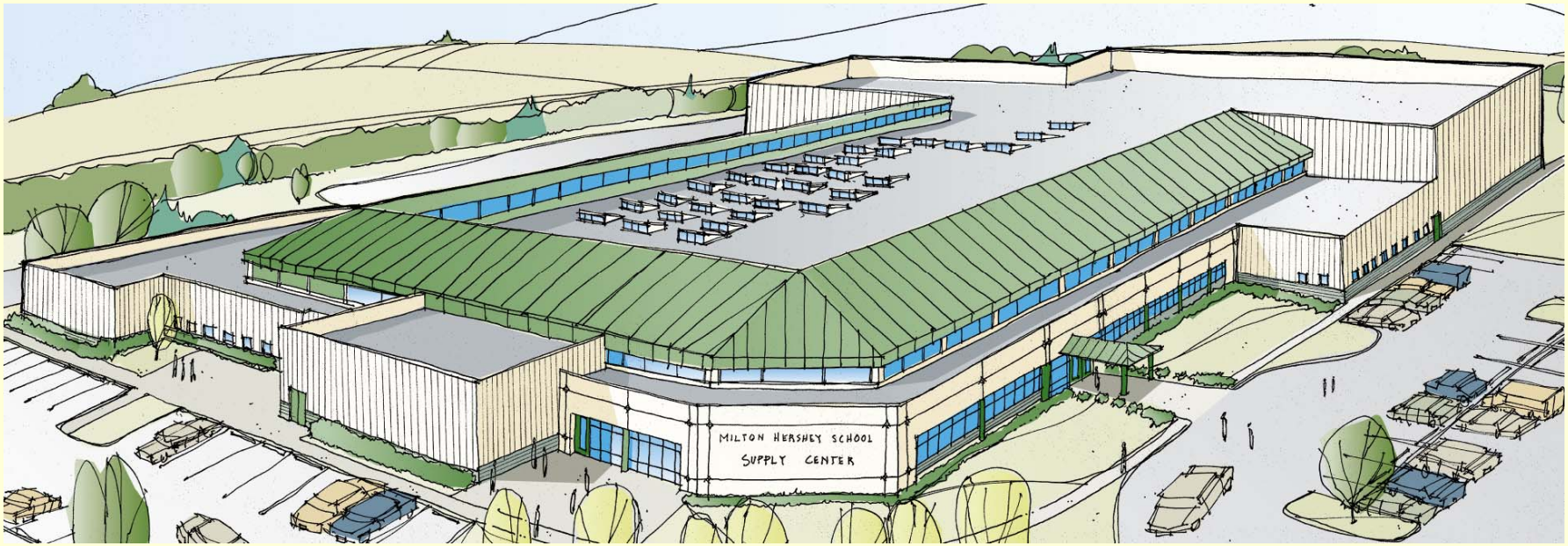
The Milton Hershey School Supply Center

Questions?



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Mechanical System Redesign
Redesigned Chiller/Boiler Plants

Plant Load Analysis

- Walk-in Freezer's Heat Rejection Creates 106 ton Base Load
- Peak Cooling Load at 390 tons
-High Hot Domestic Hot Water Demand
    -- Excellent Opportunity for Simultaneous Heating and Cooling!

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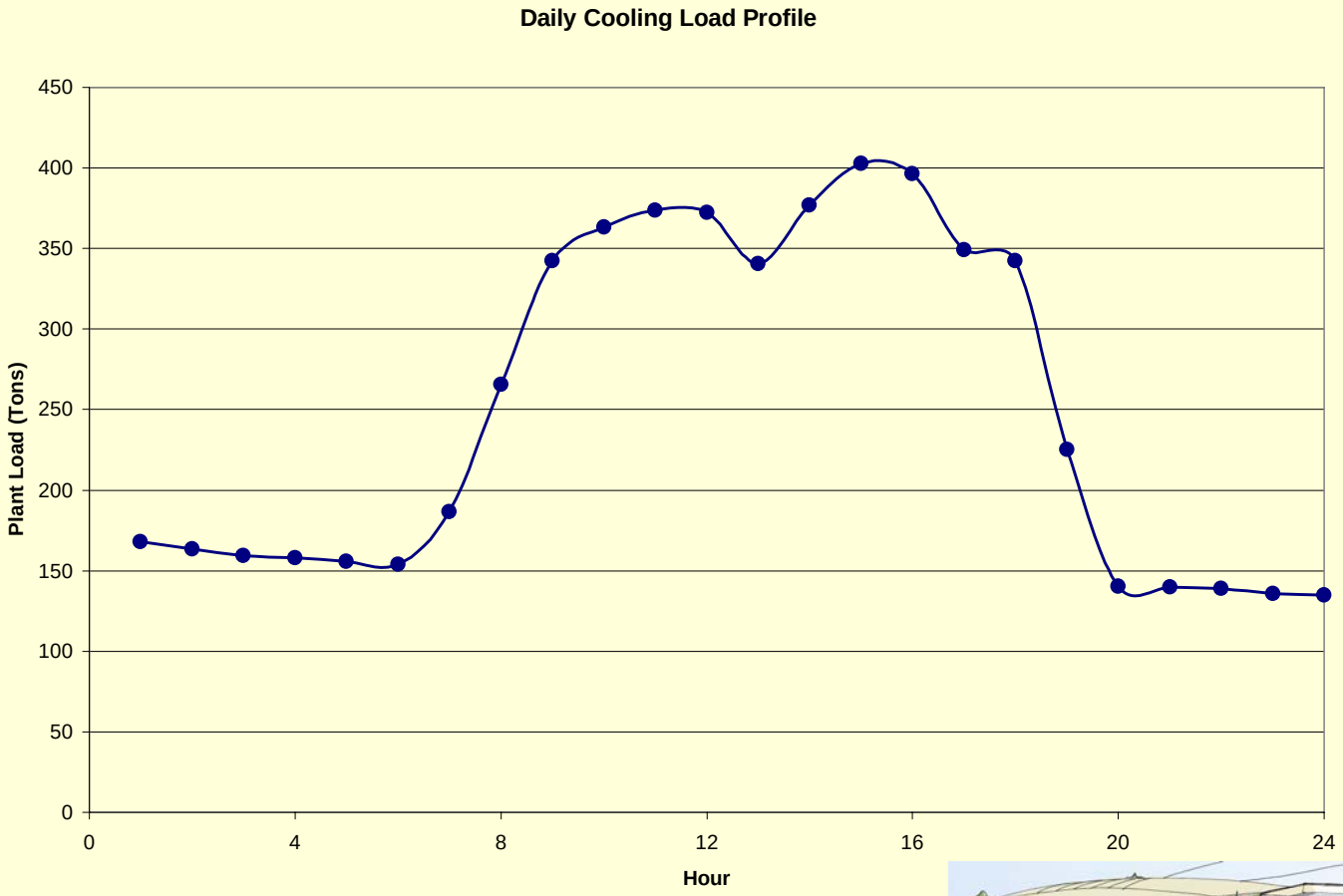
Existing System Chiller Plant Load Profile



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New System Chiller Plant Load Profile