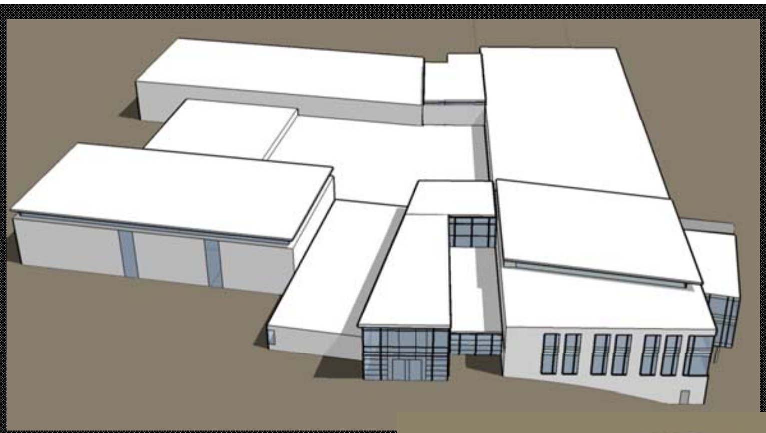
Presentation Outline

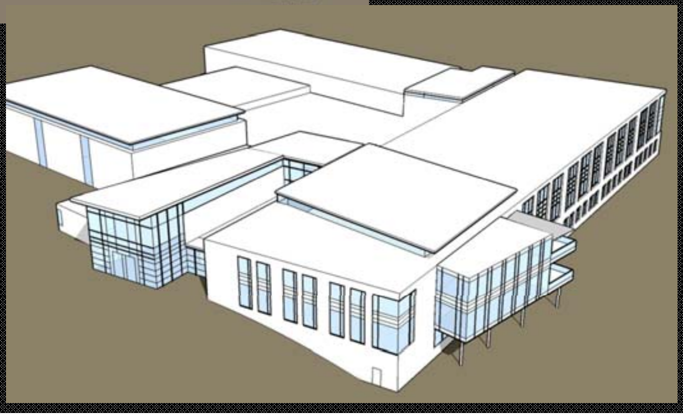
- Introduction
- CHP Analysis
- Thermal Storage Analysis
- System Optimization Analysis
- Electrical Analysis
- Acoustical Analysis
- Conclusion
- Acknowledgements
- Questions

DMA Building
Fort George G. Meade, MD

Pavel Likhonin
Mechanical Option

Thesis Final Presentation

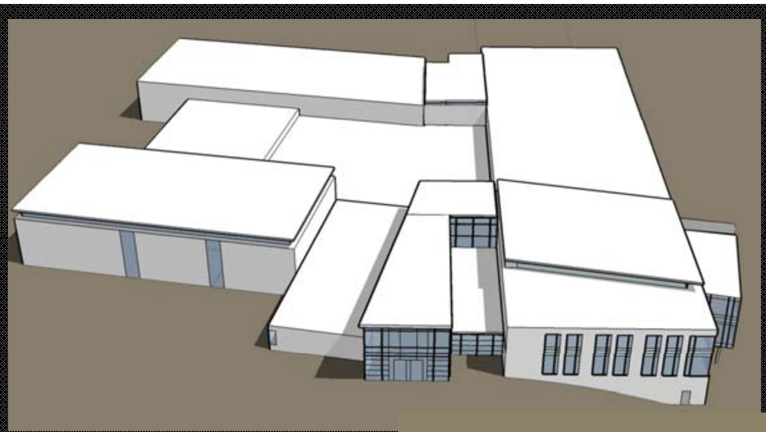


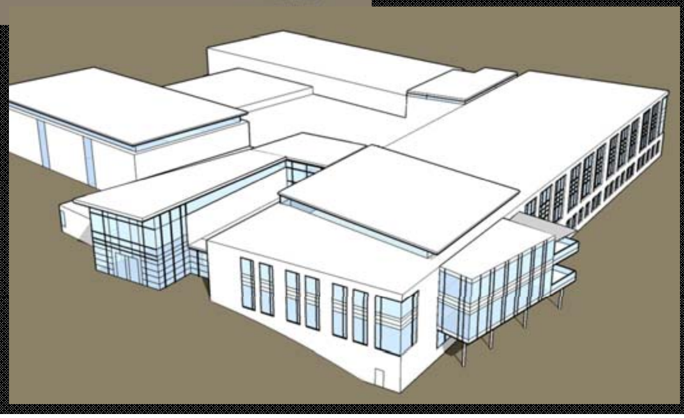


Presentation Outline

Facility Information

Location:	Fort George G. Meade, MD
Total Cost:	$56,000,000
Occupancy:	Office, Media Center
Delivery Method:	Design-Bid-Build
Architect:	HOK
Engineers:	AECOM |HSMM
Owner:	Army Corps of Engineers
Construction Period:	Spring 2009 to September 2011



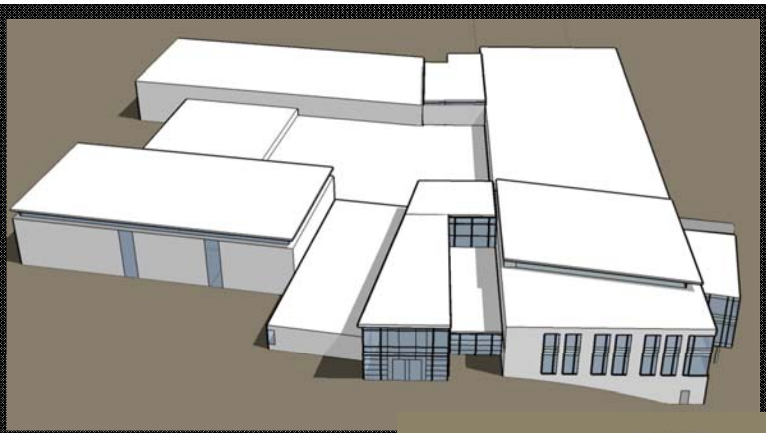


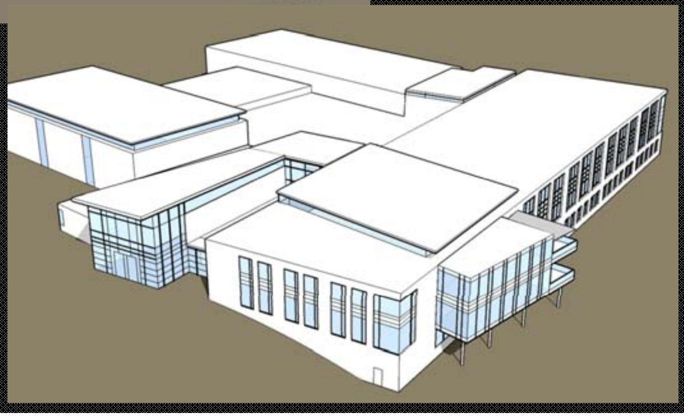
Presentation Outline

- **Introduction**
  - Facility Information
  - **Mechanical Information**
  - Goals
- CHP Analysis
- Thermal Storage Analysis
- System Optimization Analysis
- Electrical Analysis
- Acoustical Analysis
- Conclusion
- Acknowledgements
- Questions

Mechanical Information

Air Delivery System:	Variable Air Volume
Chilled Water System:	(3) 500 Ton Water Cooled Chillers
Economizer:	Waterside Used for Data Center Airside Used in AHU's
Distribution System:	Primary/Secondary Flow
Hot Water System:	(3) 3000 MBH Condensing Boilers
Control System:	Direct Digital Control using BACnet





Presentation Outline

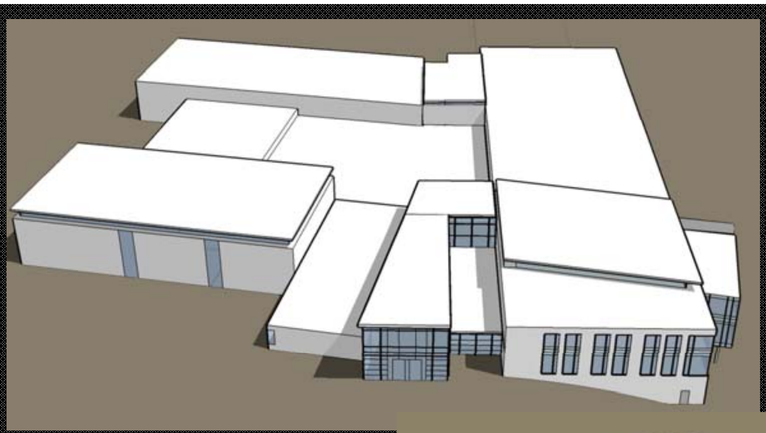
- Introduction
  - Facility Information
  - Mechanical Information
  - Goals
- CHP Analysis
- Thermal Storage Analysis
- System Optimization Analysis
- Electrical Analysis
- Acoustical Analysis
- Conclusion
- Acknowledgements
- Questions

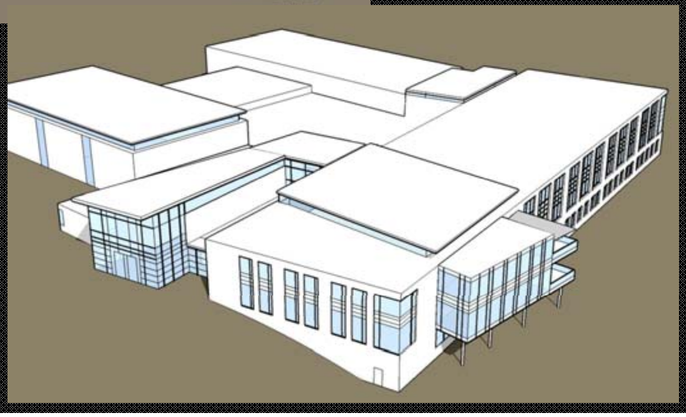
DMA Building
Fort George G. Meade, MD

Pavel Likhonin
Mechanical Option

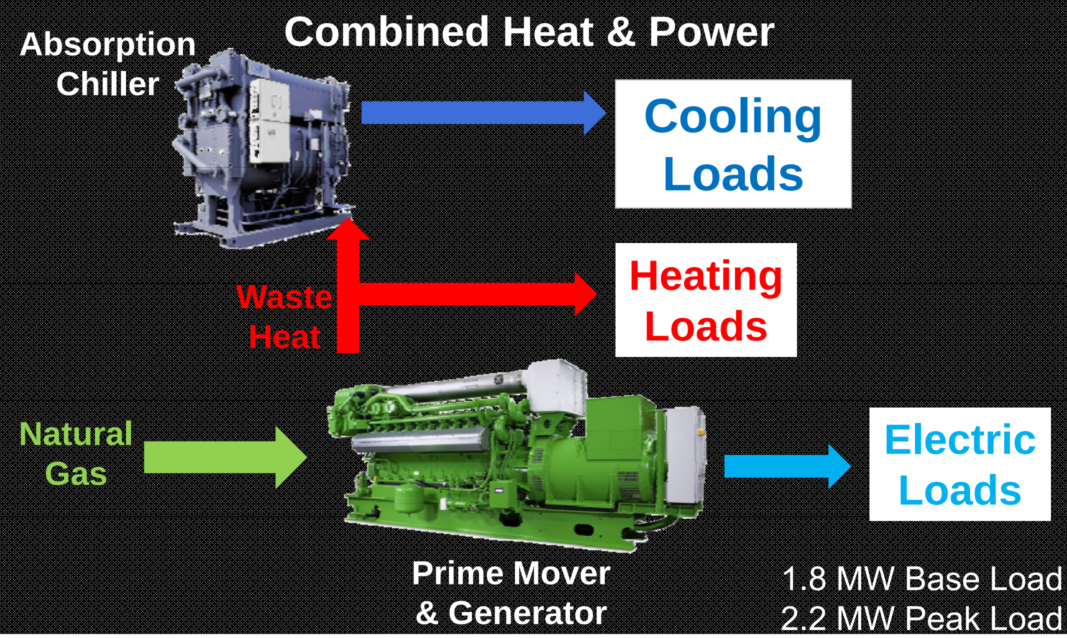
Goal:

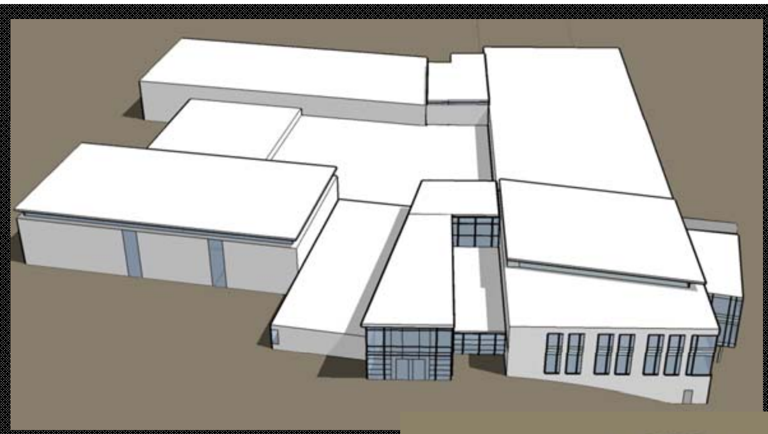
Minimize Costs Spent on Energy Consumption, Making the Building Less Expensive and More Efficient to Operate

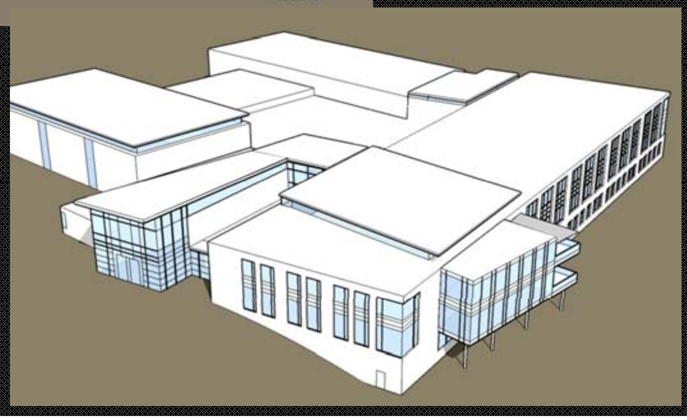




Presentation Outline







Presentation Outline

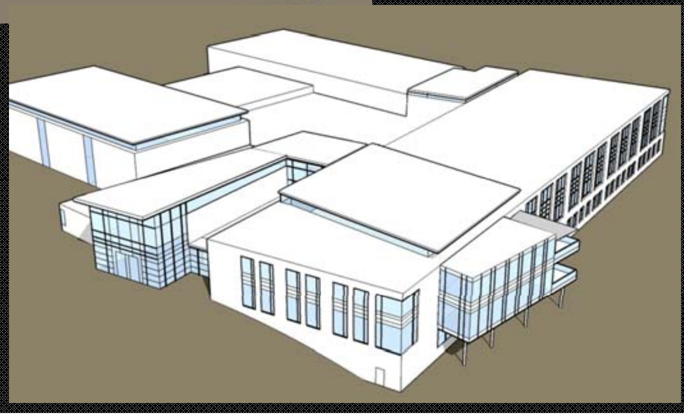
- Introduction
- **CHP Analysis**
  - **Concept**
  - Energy Cost Savings
  - Payback Period
  - Sensitivity Analysis
- Thermal Storage Analysis
- System Optimization Analysis
- Electrical Analysis
- Acoustical Analysis
- Conclusion
- Acknowledgements
- Questions

DMA Building
Fort George G. Meade, MD

Pavel Likhonin
Mechanical Option

CHP Options		
Type	**System**	**Description**
IC Engines	A	2390 kW Jenbacher IC Engine running at full load
		800 Ton Single Stage Absorption Chiller used to cover loads of the building
		A boiler is used to make up needed thermal energy for the Absorption Chiller
	B	2390 kW Jenbacher IC Engine running at full load
		(3) 500 ton Electrical Chillers used to cool the building
		Thermal energy is wasted
	C	2390 kW Jenbacher IC Engine running at full load
		700 ton Single Stage Absorption chiller
		300 ton Electric Chiller used to meet loads not met with an Absorption Chiller
	D	2390 kW Jenbacher IC Engine running to meet electrical load
		800 ton Single Stage Absorption Chiller
		A boiler is used to make up needed thermal energy for the Absorption Chiller
	E	2390 kW Jenbacher IC Engine running to meet electrical load as well as peak electric chiller load
		650 ton Single Stage Absorption Chiller
		300 Ton Electric Chiller meets loads not met by an Absorption Chiller

CHP Options		
Type	**System**	**Description**
IC Engines	F	1801 kW Jenbacher IC Engine running to meet base electrical load
		Buy supplemental electricity from the grid
		800 ton Sing Stage Absorption Chiller
		A boiler is used to make up needed energy for the Absorption Chiller
Gas Turbines	G	1200 kW Saturn 20 Turbine used to meet base load
		Buy supplemental electricity from the grid
		800 ton Single Stage Absorption Chiller
	H	1200 kW Saturn 20 Turbine
		Back Pressure Steam Turbine runs off high pressure steam created by the turbine
		800 ton Absorption Chiller
		A boiler is used to make up needed thermal energy for the Absorption Chiller
	I	1200 kW Saturn 20 Turbine
		Back Pressure Steam Turbine runs off high pressure steam created by the turbine
		400 ton Single Stage Absorption Chiller used to cover loads of the building
		500 ton Electric Chiller used to meet loads not met by an Absorption Chiller

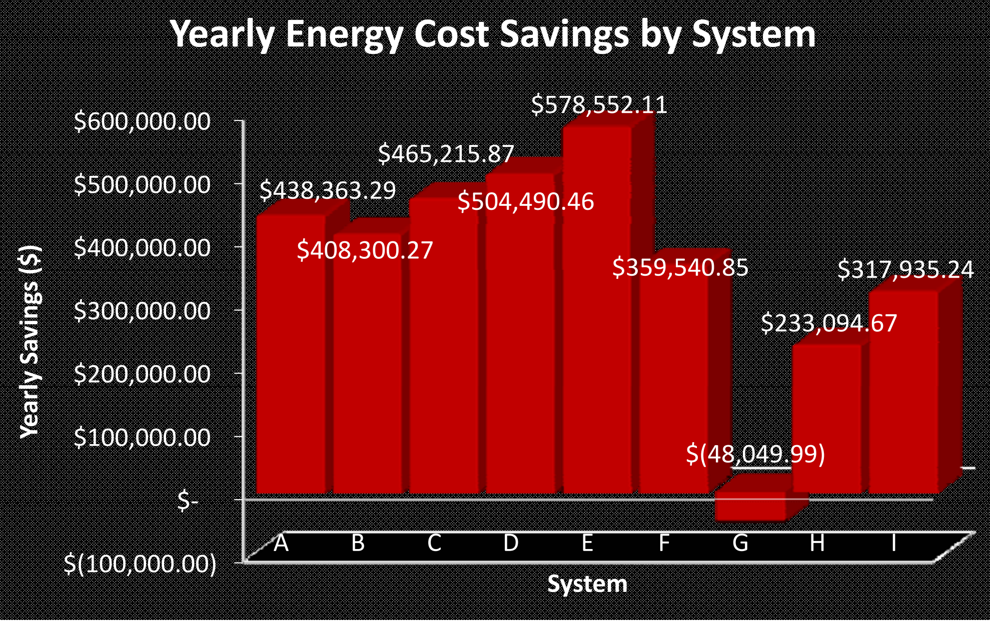


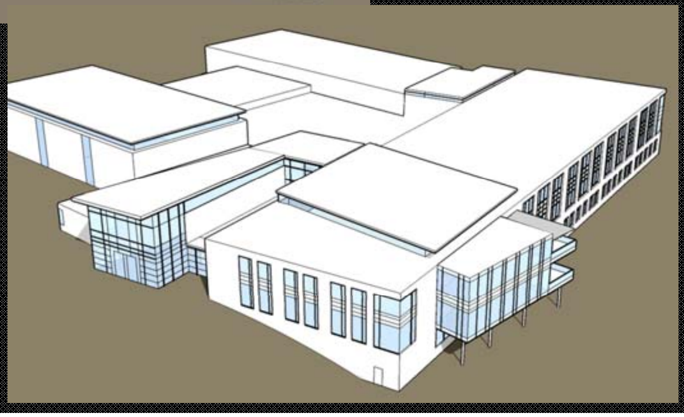
Presentation Outline

- Introduction
- **CHP Analysis**
  - Concept
  - **Energy Cost Savings**
  - Payback Period
  - Sensitivity Analysis
- Thermal Storage Analysis
- System Optimization Analysis
- Electrical Analysis
- Acoustical Analysis
- Conclusion
- Acknowledgements
- Questions

DMA Building
Fort George G. Meade, MD

Pavel Likhonin
Mechanical Option



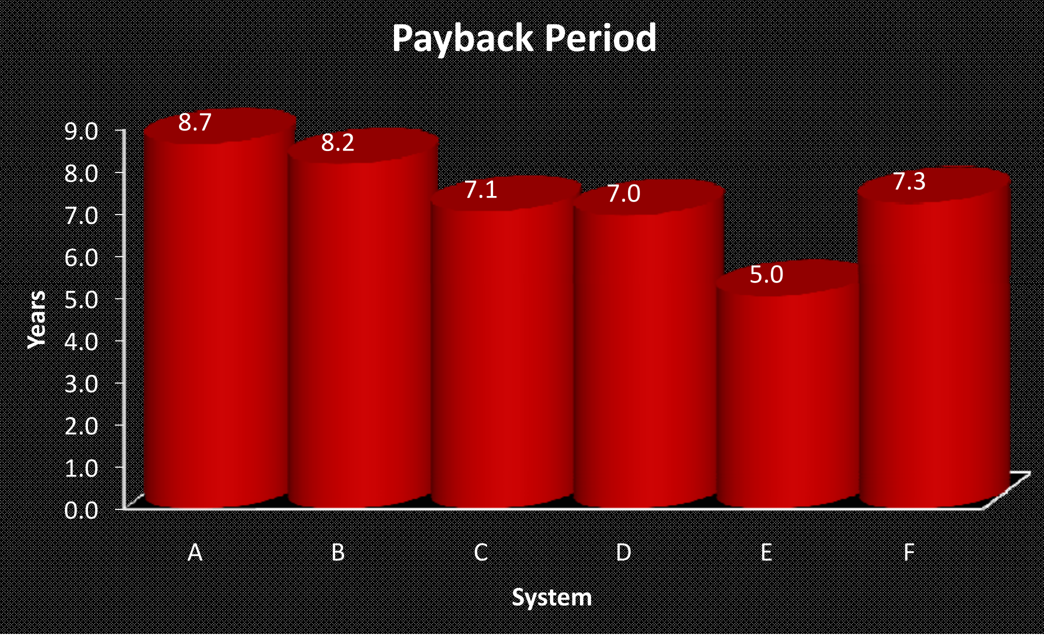


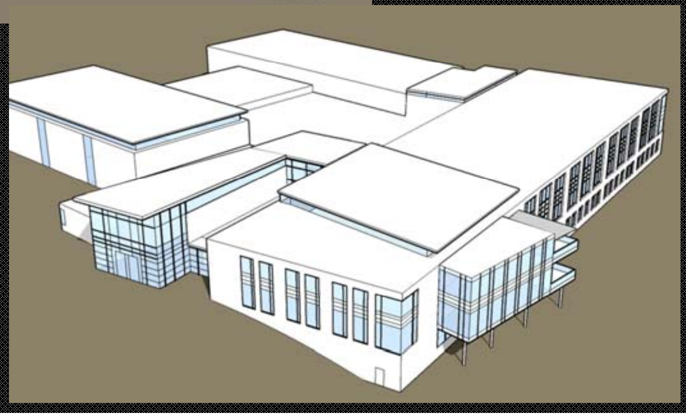
Presentation Outline

- Introduction
- **CHP Analysis**
  - Concept
  - Energy Cost Savings
  - **Payback Period**
  - Sensitivity Analysis
- Thermal Storage Analysis
- System Optimization Analysis
- Electrical Analysis
- Acoustical Analysis
- Conclusion
- Acknowledgements
- Questions

DMA Building
Fort George G. Meade, MD

Pavel Likhonin
Mechanical Option





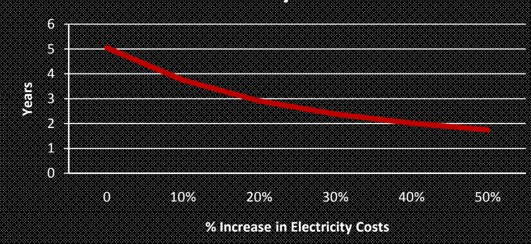
DMA Building
Fort George G. Meade, MD

Pavel Likhonin
Mechanical Option

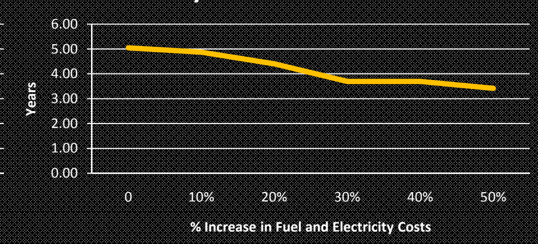
Presentation Outline

- Introduction
- **CHP Analysis**
  - Concept
  - Energy Cost Savings
  - Payback Period
  - **Sensitivity Analysis**
- Thermal Storage Analysis
- System Optimization Analysis
- Electrical Analysis
- Acoustical Analysis
- Conclusion
- Acknowledgements
- Questions

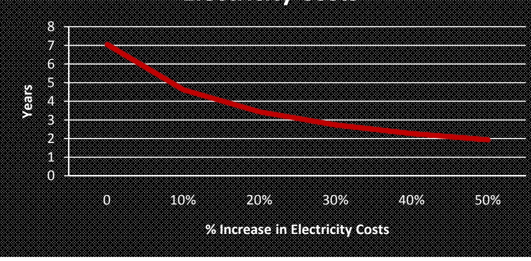
System E Payback with Increasing Electricity Costs



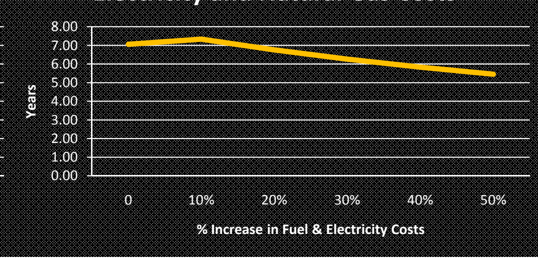
System E Payback with Increasing Electricity and Natural Gas Costs

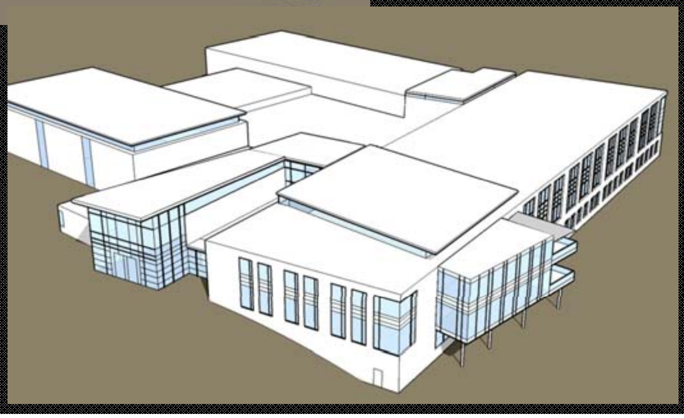


System C Payback with Increasing Electricity Costs



System C Payback with Increasing Electricity and Natural Gas Costs



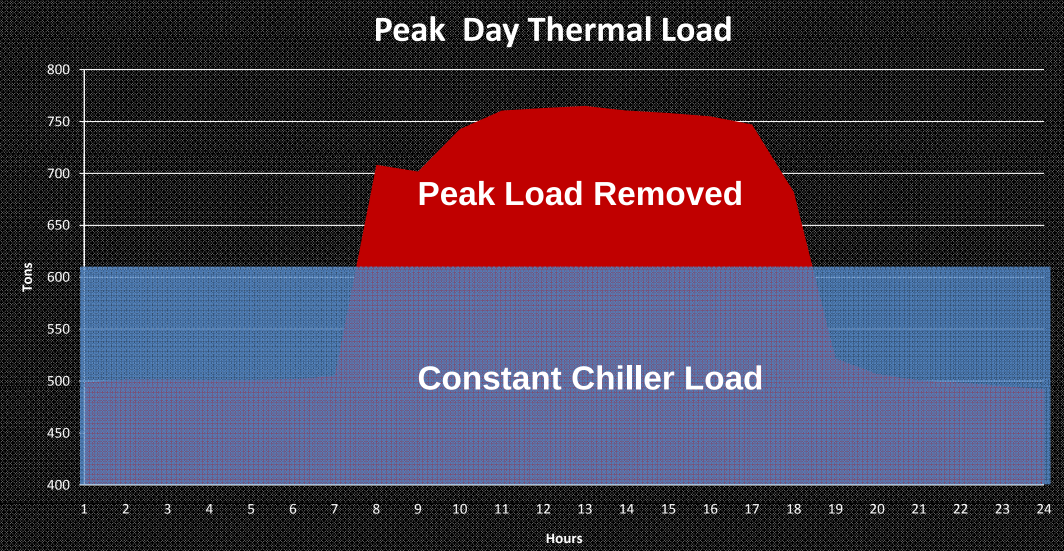


Presentation Outline

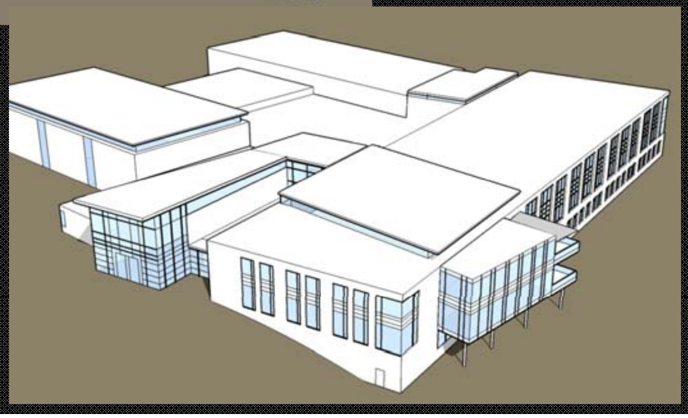
- Introduction
- CHP Analysis
- **Thermal Storage Analysis**
  - Concept
  - Energy Cost Savings
  - Payback Period
  - Sensitivity Analysis
- System Optimization Analysis
- Electrical Analysis
- Acoustical Analysis
- Conclusion
- Acknowledgements
- Questions

DMA Building
Fort George G. Meade, MD

Pavel Likhonin
Mechanical Option



Ice Storage vs. Chilled Water Storage

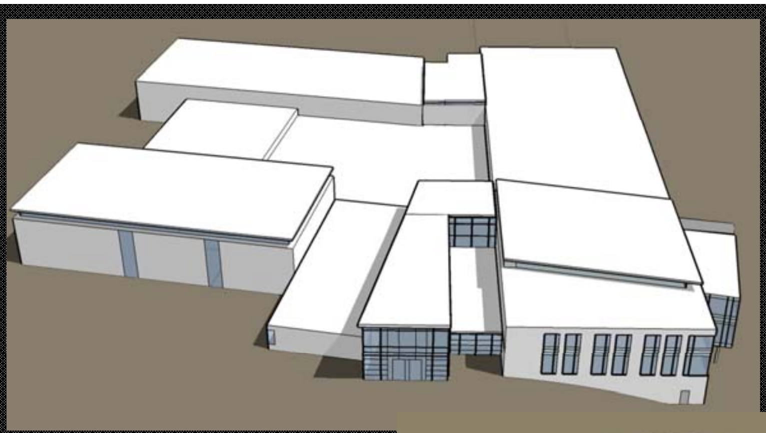


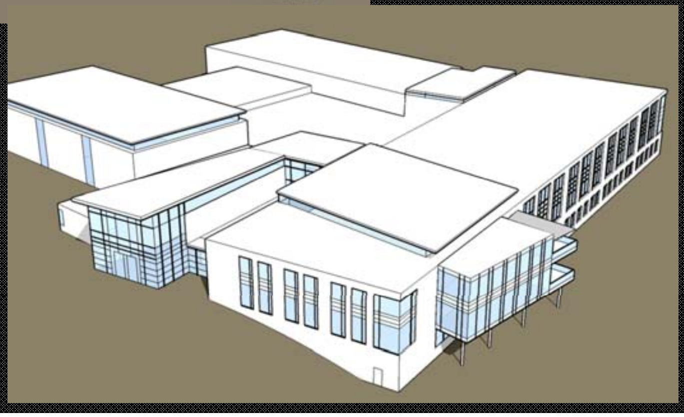
Presentation Outline

Yearly Energy Cost Savings

- Ice storage produced negative savings from this analysis due to inefficiency of making ice and low electric rates.
- Peak demand was determined on a monthly basis.
- On-Peak to Off-Peak shift was determined on a daily basis.

Chilled Water Storage Savings	
Demand Savings:	$3,617.22
On-Peak Savings:	$7,025.21
Total Yearly Savings:	**$10,643.43**



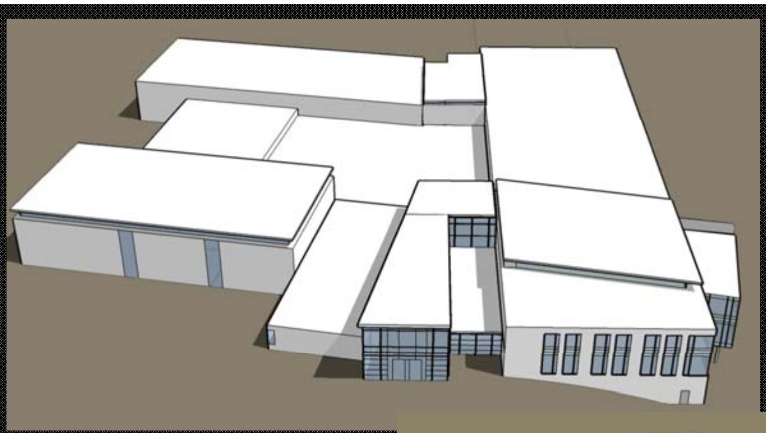


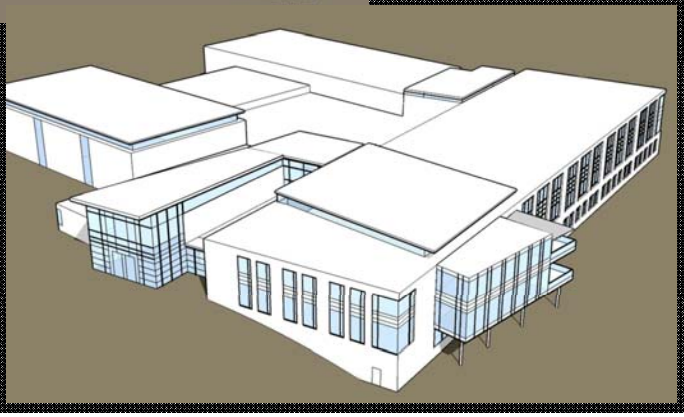
Presentation Outline

Simple Payback Period

- Initial Investment was determined based on a 3,500 Ton-hr, 400,000 Gallon Tank and required accessories such as pumps, piping, etc.
- Due to N+1 Redundancy requirements, One chiller/cooling tower could be removed, and the remaining chillers/cooling towers have to be upsized to 600 tons.

Initial Investment:	$173,666
Simple Payback Period:	16.32 Years



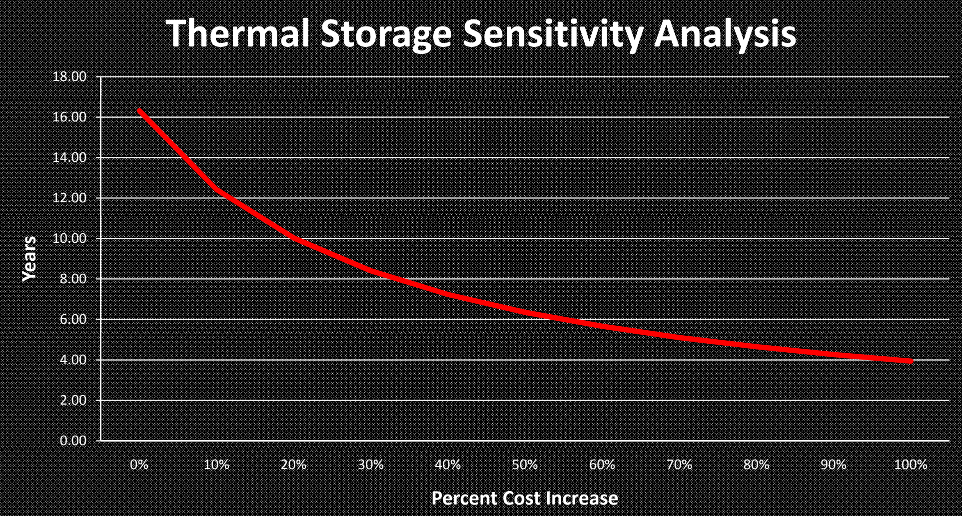


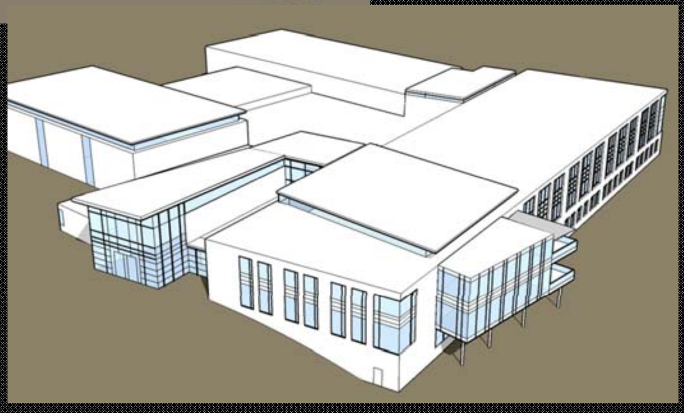
Presentation Outline

- Introduction
- CHP Analysis
- **Thermal Storage Analysis**
  - Concept
  - Energy Cost Savings
  - Payback Period
  - **Sensitivity Analysis**
- System Optimization Analysis
- Electrical Analysis
- Acoustical Analysis
- Conclusion
- Acknowledgements
- Questions

DMA Building
Fort George G. Meade, MD

Pavel Likhonin
Mechanical Option





Presentation Outline

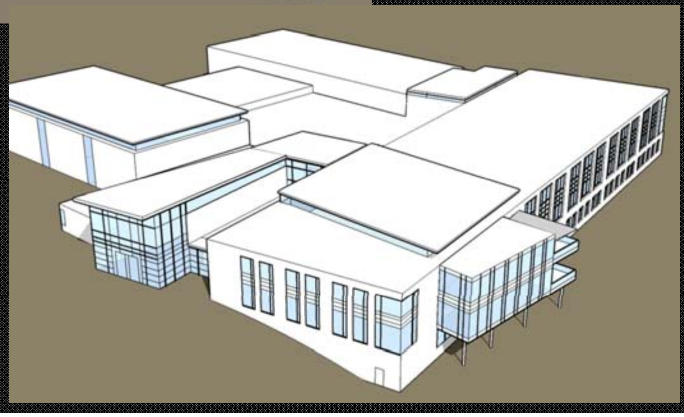
DMA Building
Fort George G. Meade, MD

Pavel Likhonin
Mechanical Option

Yearly Energy Cost Savings

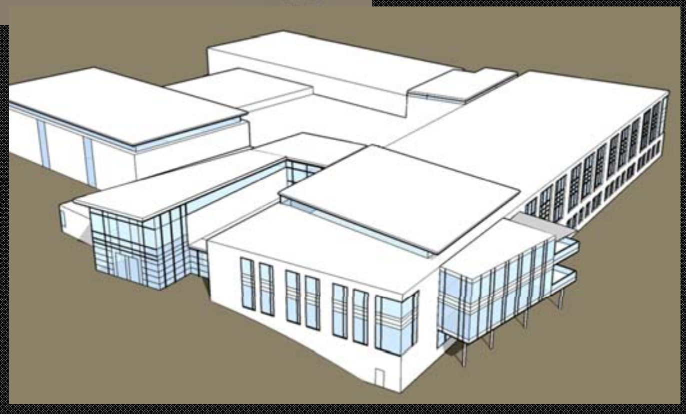
- CHP System A was used for this System Optimization Analysis
  - This system had the largest amount of wasted heat, which makes it a good candidate for integration with thermal storage.
- Hour by hour storage analysis was performed on storage and waste heat from the CHP plant

Yearly Energy Cost Savings: $11,644



Presentation Outline

Initial Investment for Thermal Storage with CHP	
350,000 Gallon Tank	$ 354,200.00
300 Feet of 5" Pipe	$ 10,500.00
300 Feet of 2" Insulation for 5" Pipe	$ 5,874.00
(2) 15 HP Pumps	$ 10,220.00
One Less (500 Ton) Chiller	$ (293,062.50)
One Less (500 Ton) Cooling Tower	$ (50,472.80)
Increasing Size of Original Chiller (500 to 650 tons)	$ 71,200.00
Increasing Size of Original Towers (500 to 650 tons)	$ 14,950.00
Total	**$ 123,408.70**



Presentation Outline

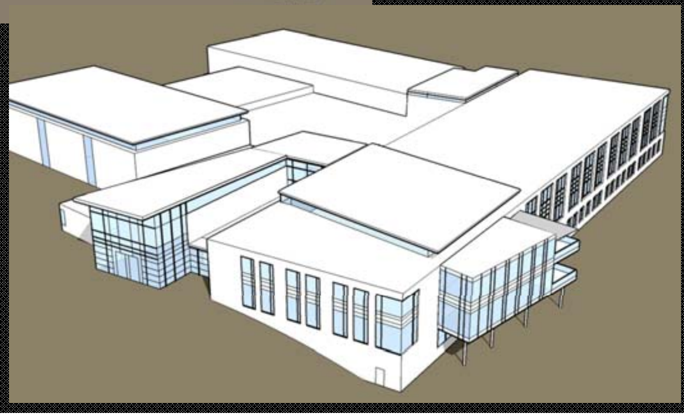
Pavel Likhonin
Mechanical Option

Simple Payback Period

- Integrating thermal storage into a CHP system produced slightly better results than thermal storage on its own.

- Due to a smaller tank, and slightly larger yearly savings, the simple payback period for thermal storage was around:

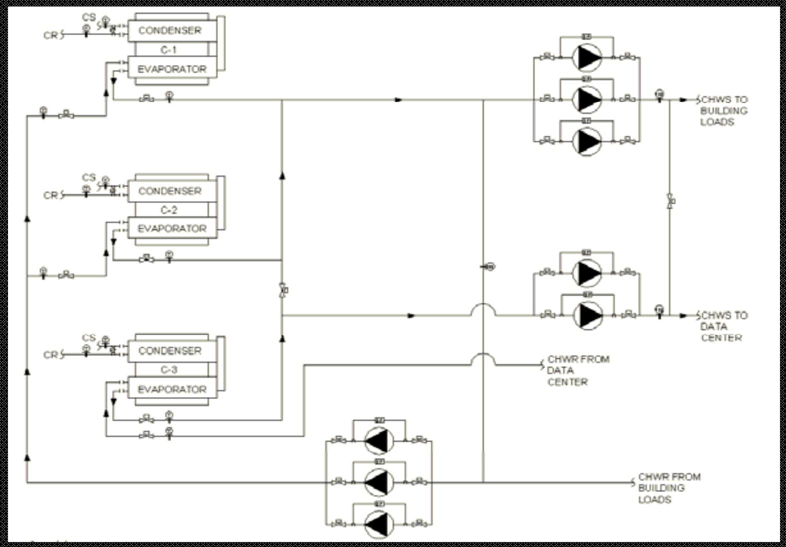
10.6 Years

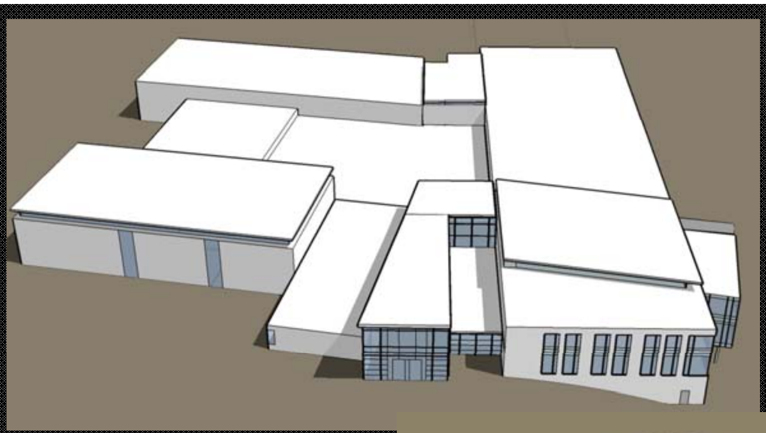


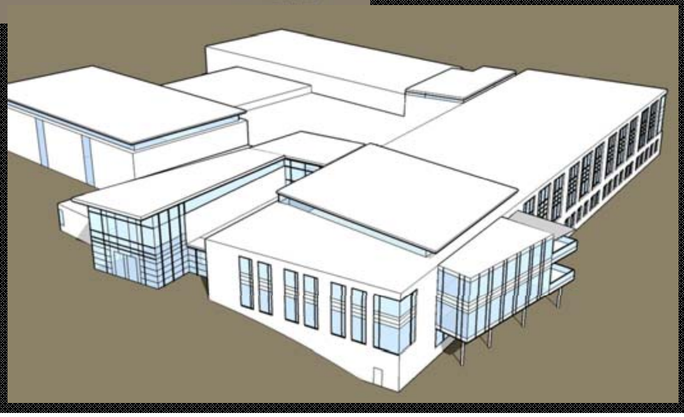
Presentation Outline

- Introduction
- CHP Analysis
- Thermal Storage Analysis
- **System Optimization Analysis**
  - Thermal Storage & CHP
  - Data Center Chiller
    - Concept
    - Energy Cost Savings
    - Payback Period
  - DOAS
- Electrical Analysis
- Acoustical Analysis
- Conclusion
- Acknowledgements
- Questions

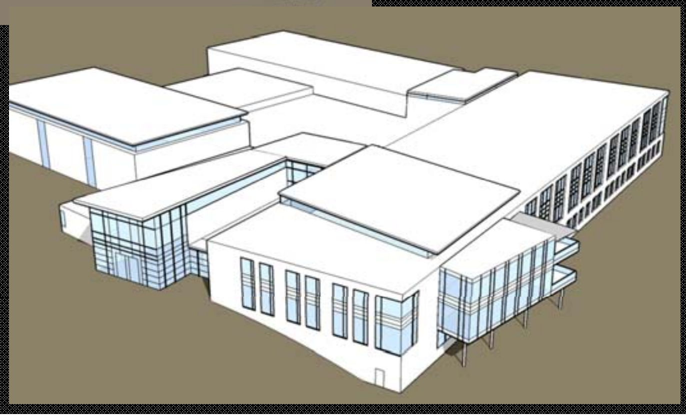
Dedicating a Chiller to the Data Center to Increase Efficiency







Presentation Outline

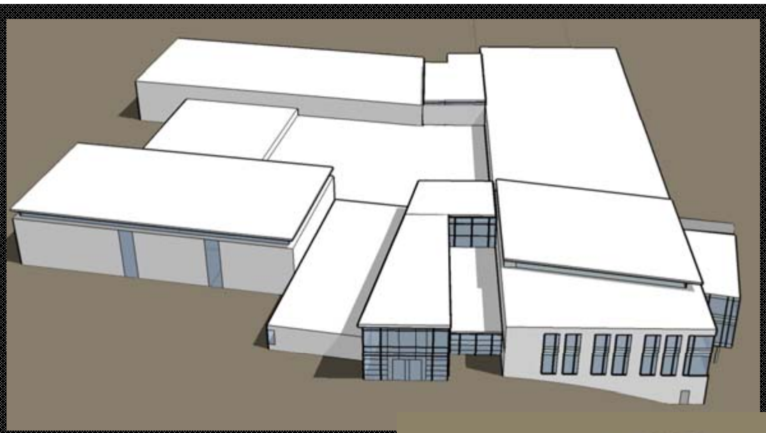


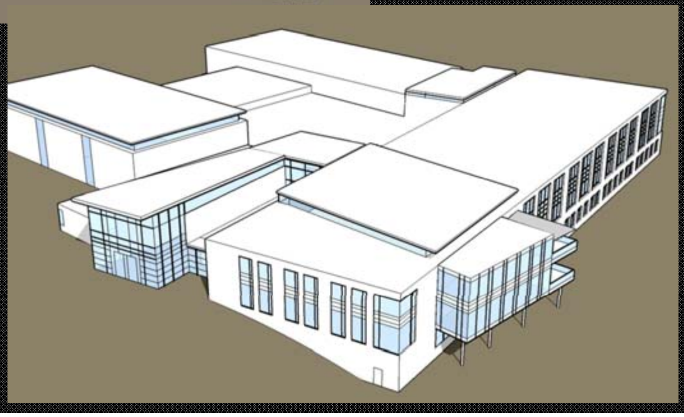
Cooling Cost of the Data Center

Temperature	MMBTU/year	Savings $/yr
44˚ F	15137.0	-
55˚ F	14065.4	$28,155.00
60˚ F	13046.8	$54,946.00

Even with higher pumping costs, the total energy savings from running a chiller at higher temps was substantial

Presentation Outline





Simple Payback Period

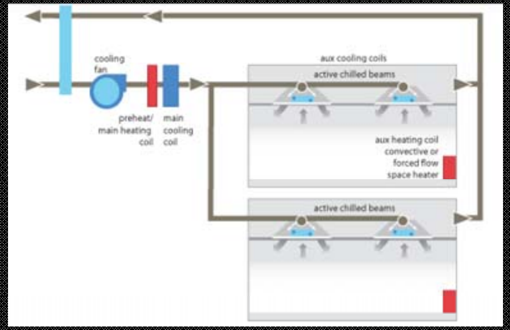
- Initial Investment for dedicating a chiller only involved adding in a few valves, (2) pumps, and some piping.

- •The simple payback period calculated for running a chiller at 55˚ F was less than a year.

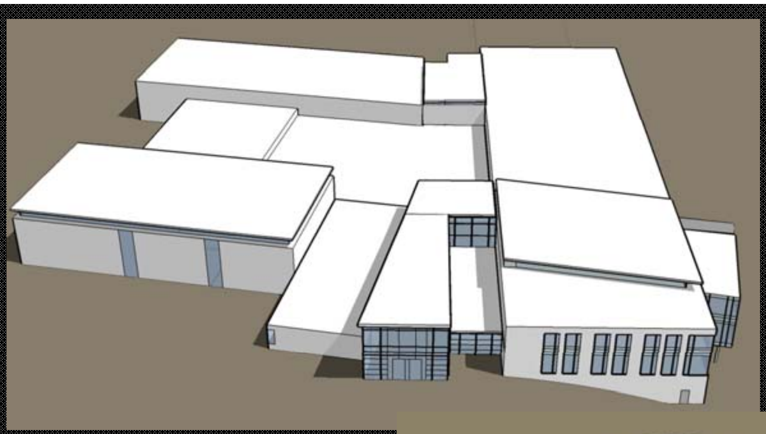
Presentation Outline

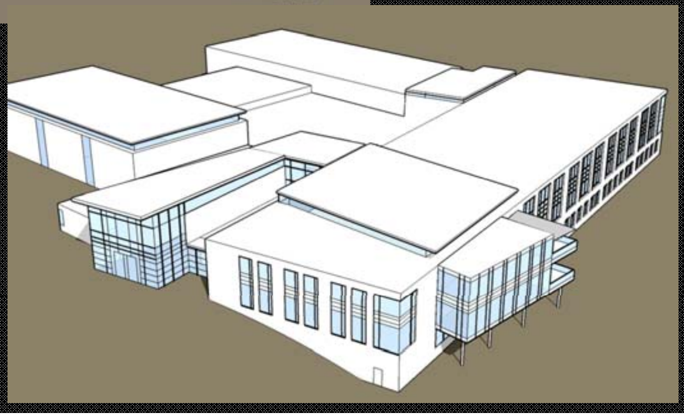
DOAS

- DOAS paralleled with Chilled Beams was modeled in TRACE 700 for annual energy and cost savings
- Only lower energy density areas were modeled as DOAS with Chilled Beams



•Annual Energy Savings: 1,913 x 10^6 [BTU/yr]
•Annual Cost Savings: $46,949





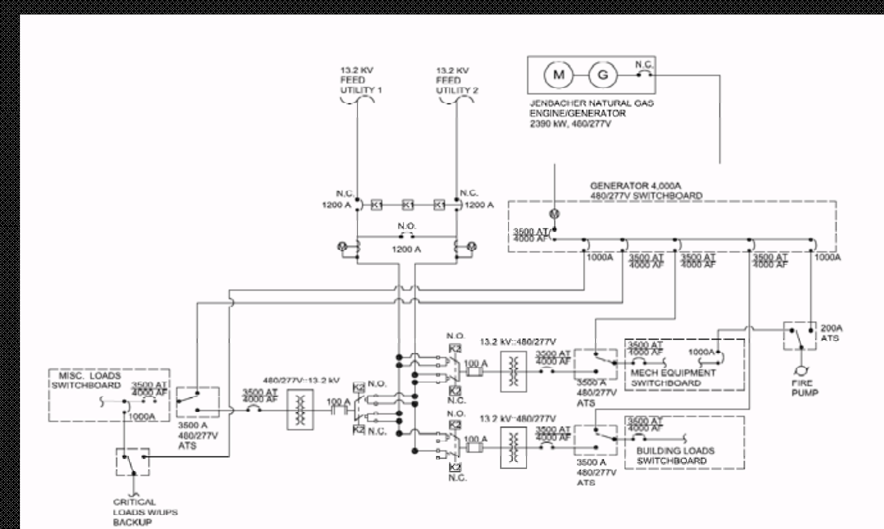
Presentation Outline

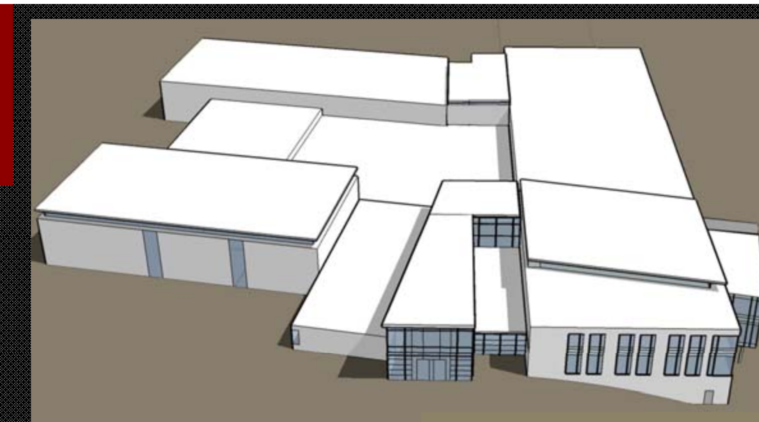
- Introduction
- CHP Analysis
- Thermal Storage Analysis
- System Optimization Analysis
- **Electrical Analysis**
- Acoustical Analysis
- Conclusion
- Acknowledgements
- Questions

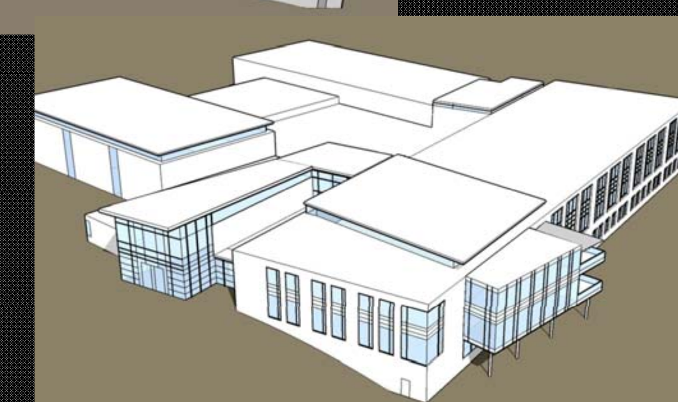
DMA Building
Fort George G. Meade, MD

Pavel Likhonin
Mechanical Option

Electrical Schematic for CHP Interface







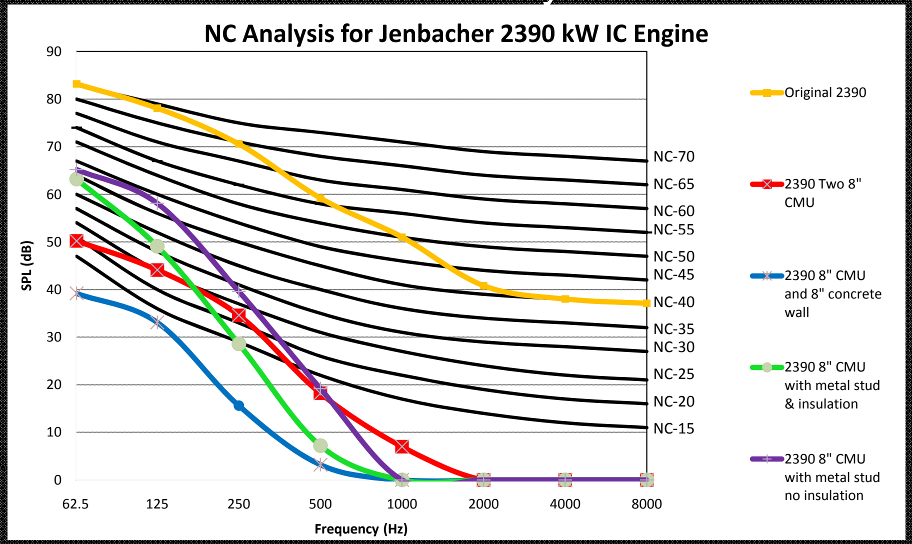
Presentation Outline

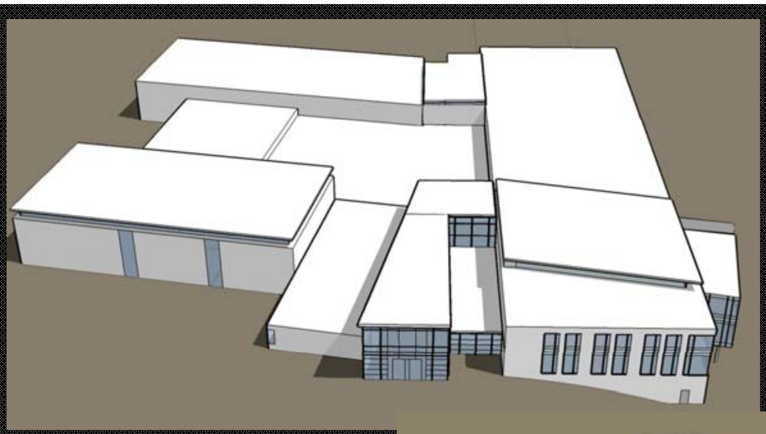
- Introduction
- CHP Analysis
- Thermal Storage Analysis
- System Optimization Analysis
- Electrical Analysis
- **Acoustical Analysis**
- Conclusion
- Acknowledgements
- Questions

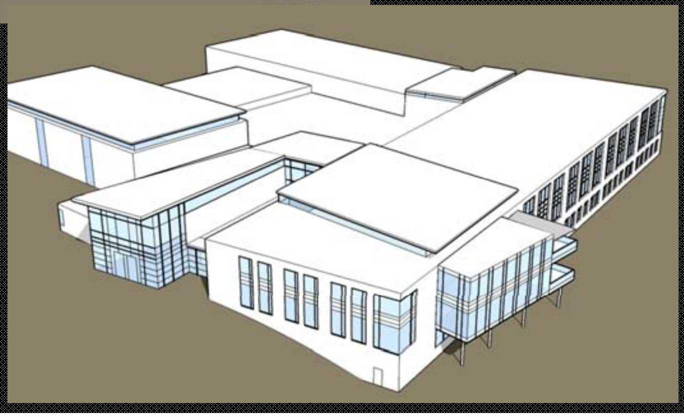
DMA Building
Fort George G. Meade, MD

Pavel Likhonin
Mechanical Option

Acoustical Analysis







Presentation Outline

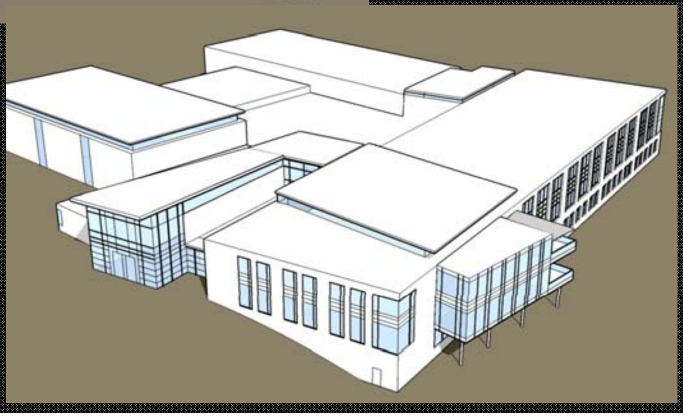
- Introduction
- CHP Analysis
- Thermal Storage Analysis
- System Optimization Analysis
- Electrical Analysis
- Acoustical Analysis
- **Conclusion**
  - Recommendation
- Acknowledgements
- Questions

DMA Building
Fort George G. Meade, MD

Pavel Likhonin
Mechanical Option

Conclusion

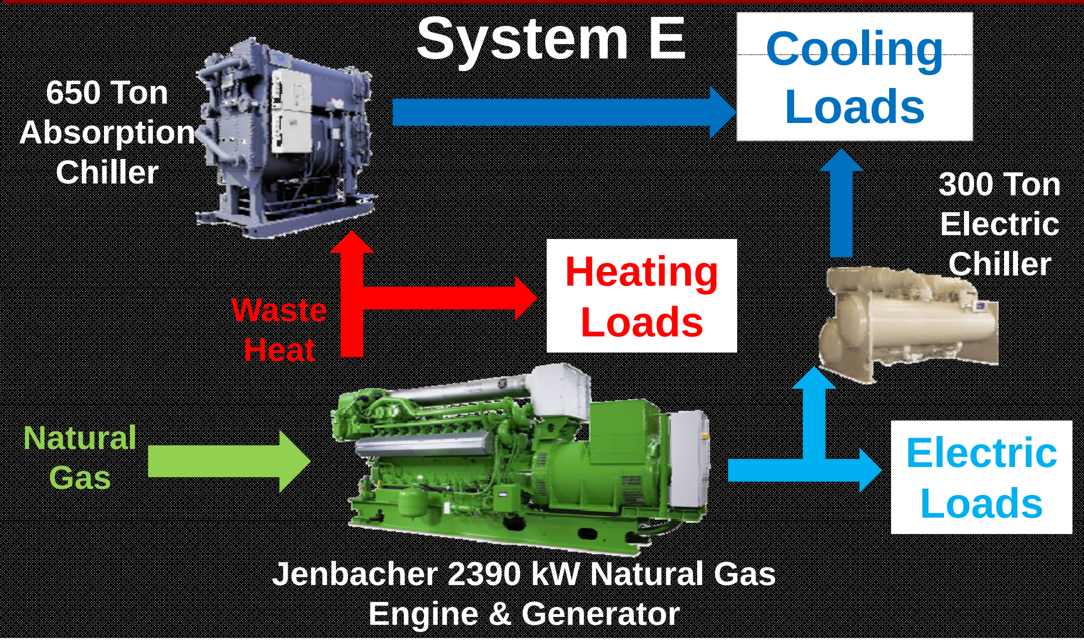
CHP System E Yearly Savings:	$578,552
Chilled Water Storage Yearly Savings:	$10,643
Chilled Water Storage W/CHP System A Savings:	$11,644
Dedicated Chiller to Data Center @ 55˚ F:	$28,155
DOAS (Office) Yearly Savings:	$46,949

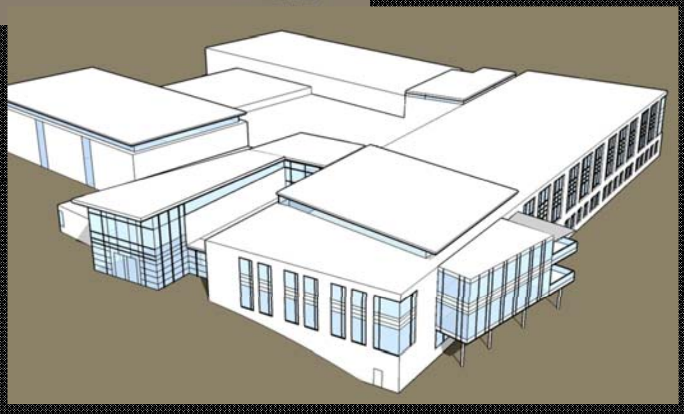


DMA Building
Fort George G. Meade, MD

Pavel Likhonin
Mechanical Option

Presentation Outline





Presentation Outline

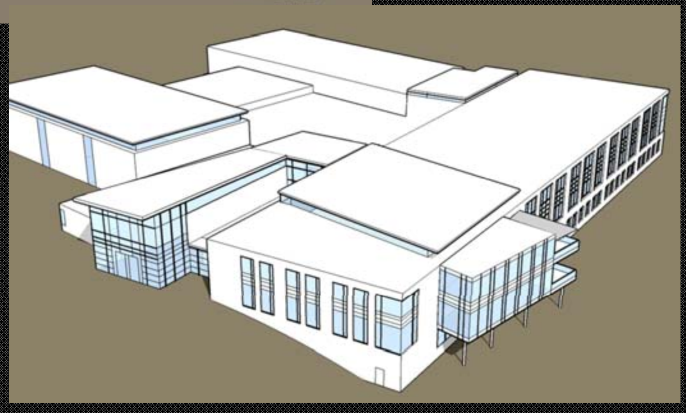
- Introduction
- CHP Analysis
- Thermal Storage Analysis
- System Optimization Analysis
- Electrical Analysis
- Acoustical Analysis
- Conclusion
- **Acknowledgements**
- Questions

DMA Building
Fort George G. Meade, MD

Pavel Likhonin
Mechanical Option

Acknowledgements:

Special Thanks To:
AE Faculty
&
Family and Friends



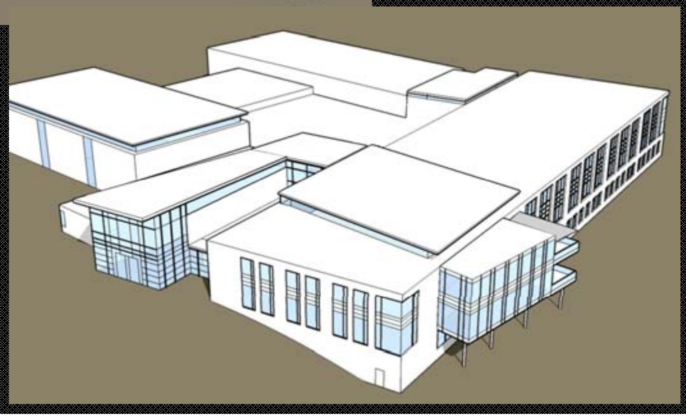
DMA Building
Fort George G. Meade, MD

Pavel Likhonin
Mechanical Option

Presentation Outline

- Introduction
- CHP Analysis
- Thermal Storage Analysis
- System Optimization Analysis
- Electrical Analysis
- Acoustical Analysis
- Conclusion
- Acknowledgements
- **Questions**

Questions



Presentation Outline

- Introduction
- CHP Analysis
- Thermal Storage Analysis
- System Optimization Analysis
- Electrical Analysis
- Acoustical Analysis
- Conclusion
- Acknowledgements
- Questions

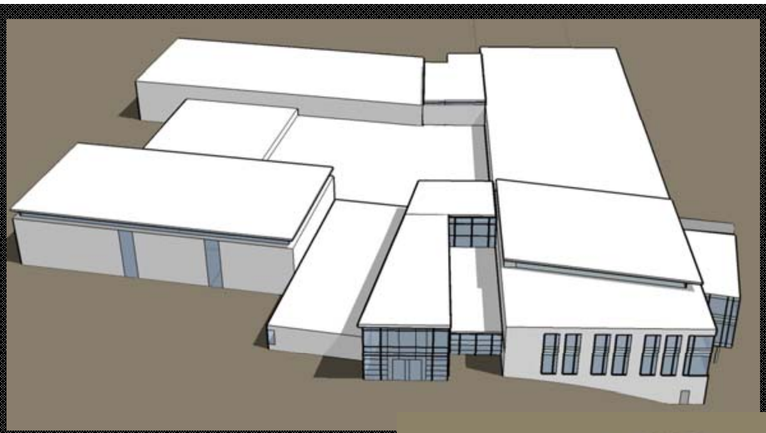
DMA Building
Fort George G. Meade, MD

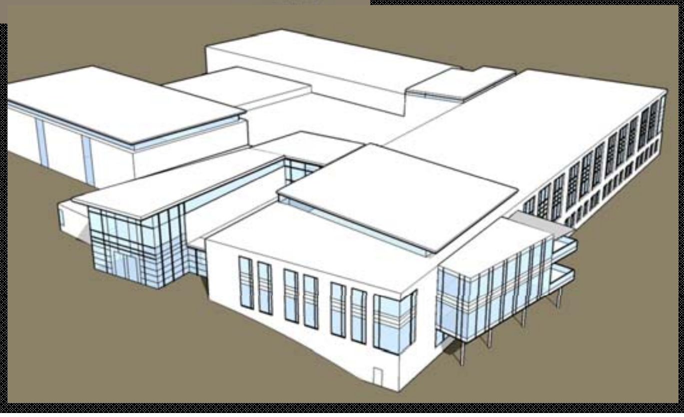
Pavel Likhonin
Mechanical Option

Initial Investment by CHP System	
System	Cost
A	$ 2,754,407.05
B	$ 2,483,717.55
C	$ 2,478,387.55
D	$ 2,800,156.55
E	$ 2,439,842.55
F	$ 2,381,676.53

Initial Investment for Thermal Storage	
400,000 Gallon Tank	$ 382,800.00
300 Feet of 5" pipe	$ 10,500.00
300 Feet of 2" Insulation for 5" Pipe	$ 5,874.00
(2) 15 HP pumps	$ 10,220.00
One Less Chiller	$ (293,062.50)
One Less Cooling Tower	$ (50,472.80)
Increasing size of original Chillers	$ 94,648.00
Increasing size of original Towers	$ 13,160.00
Total	**$ 173,666.70**

Initial Investment for Thermal Storage with CHP	
400,000 Gallon Tank	$ 354,200.00
300 Feet of 5" Pipe	$ 10,500.00
300 Feet of 2" Insulation for 5" Pipe	$ 5,874.00
(2) 15 HP Pumps	$ 10,220.00
One Less Chiller	$ (293,062.50)
One Less Cooling Tower	$ (50,472.80)
Increasing Size of Original Chiller	$ 71,200.00
Increasing Size of Original Towers	$ 14,950.00
Total	**$ 123,408.70**



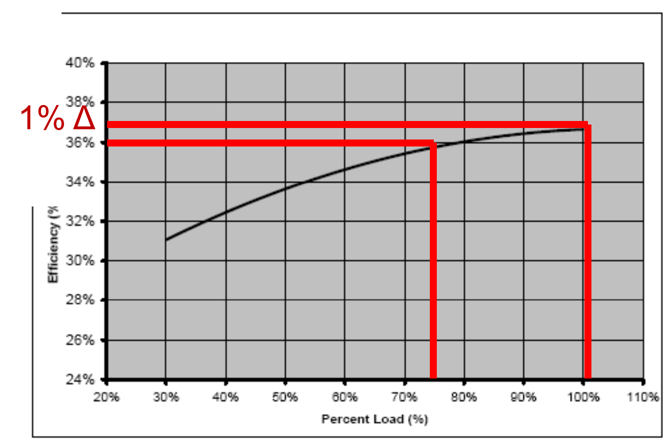


Presentation Outline

CO2e Savings when compared to Grid							
		A	B	C	D	E	F
IC Engine	kWh	20,936,400.00	20,982,933.93	20,936,400.00	16,673,858.17	17,305,591.92	15,776,760.00
	BTU	74,893,389,355.47	71,635,736,437.02	71,476,869,600.00	70,082,301,286.29	59,081,290,819.32	53,861,858,640.00
	CO2e (lb)	10,260,394.34	9,814,095.89	9,792,331.14	9,601,275.28	8,094,136.84	9,011,793.30
Grid	kWh	18,602,443	18,602,443	18,602,443	18,602,443	18,602,443	18,602,443
	CO2e (lb)	33,856,445.42	33,856,445.42	33,856,445.42	33,856,445.42	33,856,445.42	33,856,445.42
	Savings (lb)	**23,596,051.08**	**24,042,349.53**	**24,064,114.29**	**24,255,170.15**	**25,762,308.58**	**24,844,652.12**

- •Equivalent of removing 1,916 cars!
- •Spark Gap: $18.99
- •O&M costs from EPA.gov: $0.005/kWh
- •Assumed 40% Elect. Efficiency at 75% load. From manufacturer, full load electrical efficiency is 42.6%
- •System E never drops below 75% of the load, making load following very efficient
- •Thermal to Electric Ratio of 0.85 to 1.25 during the peak summer months

Figure 1. Part Load Efficiency Performance



Source: Caterpillar, EEA/ICF

Presentation Outline

- Introduction
- CHP Analysis
- Thermal Storage Analysis
- System Optimization Analysis
- Electrical Analysis
- Acoustical Analysis
- Conclusion
- Acknowledgements
- Questions