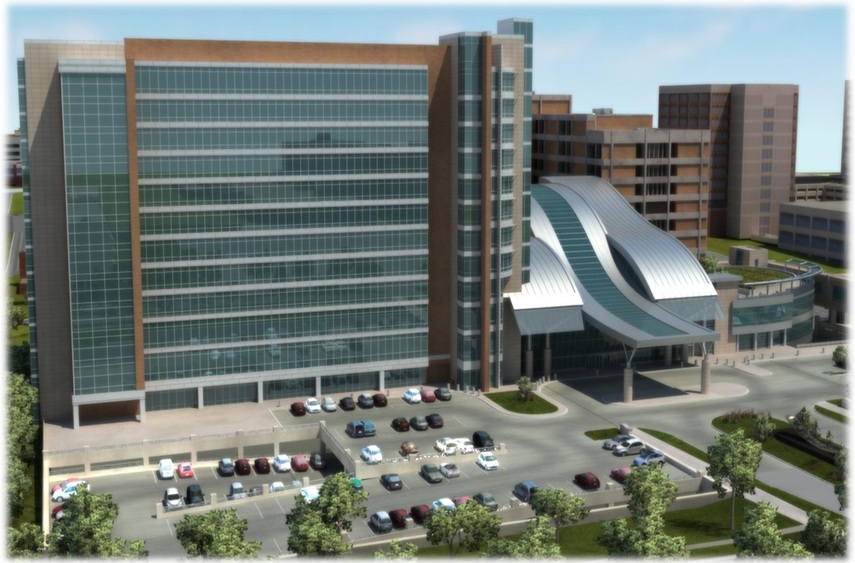


Oklahoma University Children's Medical Office Building

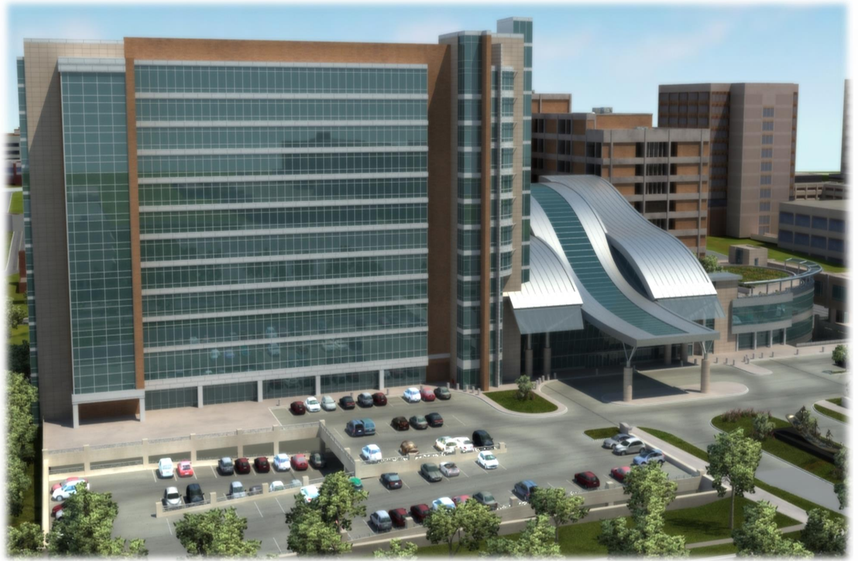
Oklahoma City, O.K.

Alec Canter, BAE
Mechanical Option

Advisor: Laura Miller

Presentation Outline

- Project Background
- Existing Conditions
- Thesis Goals
- Mechanical Depth
  - VRF System
  - Dedicated Outdoor Air System
  - Evaluation
- Acoustics Breadth
  - VRF Indoor Units
  - Design Criteria
  - Room Noise Criteria
- Conclusion

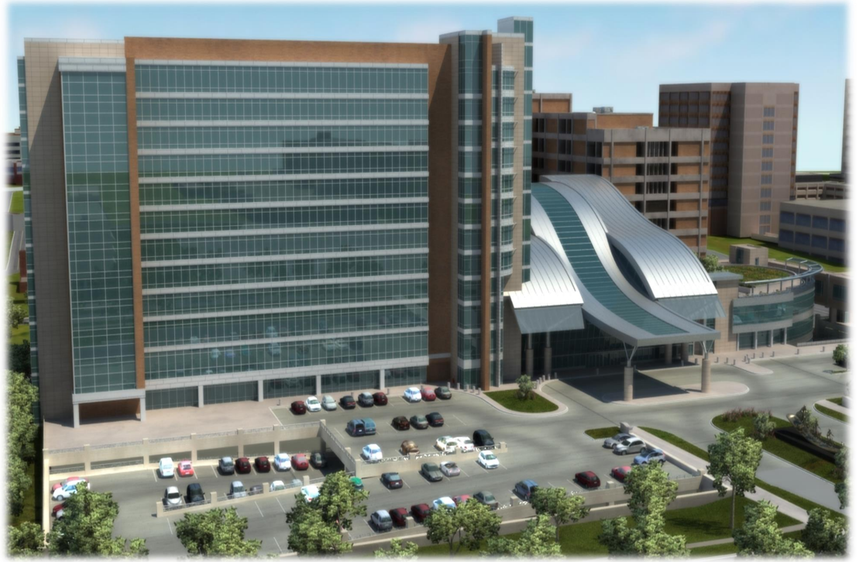


Project Background

- **Project Background:**
  - **Building Statistics**
  - Layout
- Existing Conditions
- Thesis Goals
- Mechanical Depth
- Acoustics Breadth
- Conclusion

Building Statistics

- Location: Oklahoma City, Oklahoma
- Size (Gross Square Feet): 337,000
- 12 Stories Above Grade, 1 Below
- Function: Medical Office Building
- Overall Project Cost: $ 60,000,000
- Construction: Spring 2006 – Spring 2009



Project Background

- **Project Background:**
  - Building Statistics
  - **Layout**
- Existing Conditions
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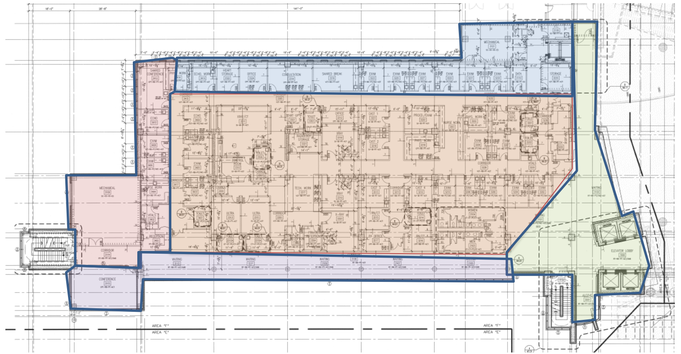
- Mechanical Depth
- Acoustics Breadth
- Conclusion

Floor Layout

N



Room Locations

- Offices, patient Rooms, and conference rooms populate the North and East exterior faces.
- Waiting areas and the main lobby are located on the South and West side
- All other labs, exam rooms, and special equipment rooms such a X-ray rooms dominate the interior

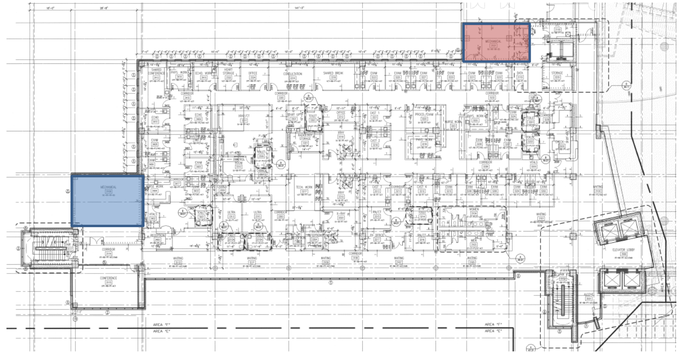
Existing Conditions

- Project Background
- **Existing Conditions:**
  - **Mechanical System**
  - Design Conditions
  - Energy Model Evaluation
- Thesis Goals
- Mechanical Depth
- Acoustics Breadth
- Conclusion

Mechanical Design

- Floor-by-floor air handling systems
- 12 Air Handling Units in Total
- Utilizes hydronic heat and cooling supplied by central plant to main mechanical room in the basement
- VAV terminal units distribute air to each space
- Heating water for zone reheat

Mechanical Room Locations



Existing Conditions

- Project Background
- **Existing Conditions:**
  - Mechanical System
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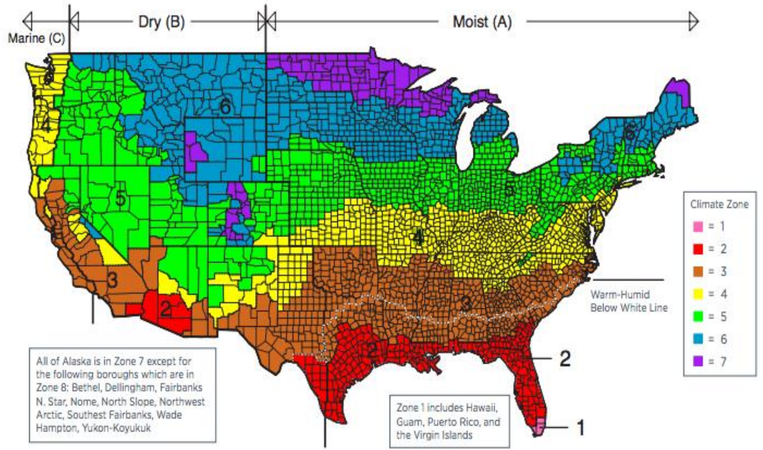
Climate Zone



Design Conditions

Oklahoma City resides in Climate Zone 3A, which is characterized as being Warm-Humid

Design Settings	Summer	Winter
Outdoor Air Dry Bulb [°F]	96	17
Outdoor Air Wet Bulb [°F]	75	-
Relative Humidity [%RH]	50	
Indoor Air Dry Bulb [°F]	75	72
Indoor Air Wet Bulb [°F]	62	60

Existing Conditions

- Project Background
- **Existing Conditions:**
  - Mechanical System
  - Design Conditions
  - **Energy Model Evaluation**
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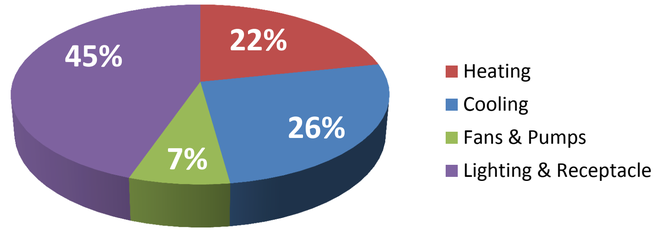
Air Handling Unit Schedule

Floor	Design vs. Calculated Airflow		
	Designed [cfm]	Calculated [cfm]	Percent Error
Basement	15000	10929	27.14
Third	25000	25854	3.42
Fourth	25000	25498	1.99
Fifth	25000	25829	3.32
Sixth	25000	26242	4.97
Seventh	25000	25692	2.77
Eighth	25000	26070	4.28
Ninth	25000	23254	6.98
Tenth	25000	23039	7.84

Energy Summary

Annual Energy Consumption



Existing Conditions

- Project Background
- **Existing Conditions:**
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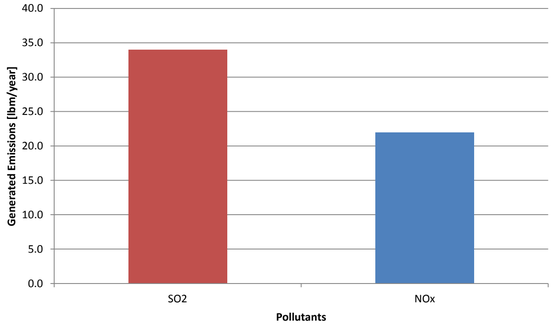
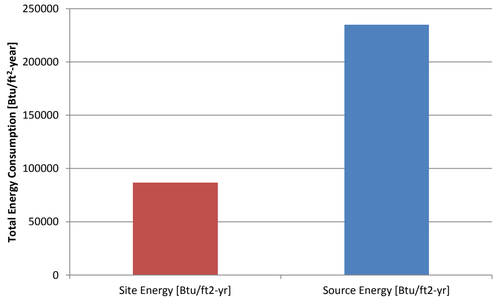
Emissions



- Estimated CO_2 Emissions: 6,152,946 lbm/year
- Estimated No_x and SO_2 Emissions: 56 lbm/year
- **Total CO_2 Equivalent Emissions: 6,153,002 lbm/year**

Energy Consumption



Energy Consumption	
Site Energy [Btu/ft^2-yr]	86724
Source Energy [Btu/ft^2-yr]	234585

Thesis Goals

- Project Background
- Existing Conditions
- **Thesis Goals**
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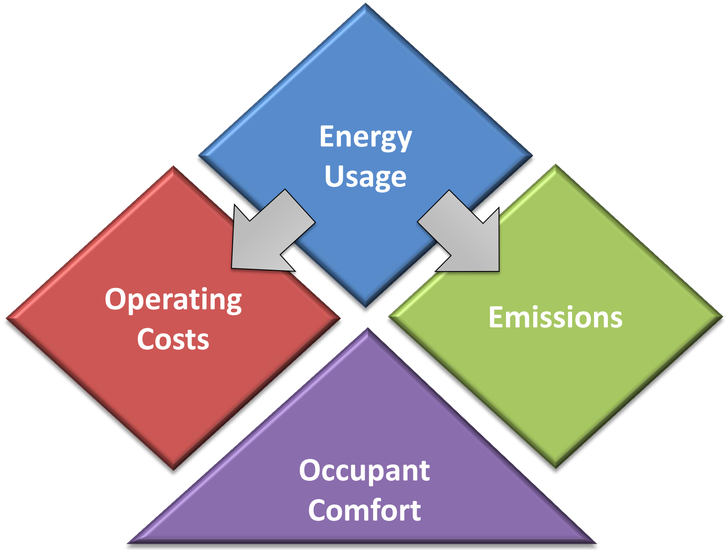
- Conclusion

Propose a system that could:

- **Reduce energy use**
- **Reduce operating costs**
- **Reduce emissions**
- **Improve occupant temperature control**



Mechanical Depth

- Project Background
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- **Mechanical Depth:**
  - **VRF Design**
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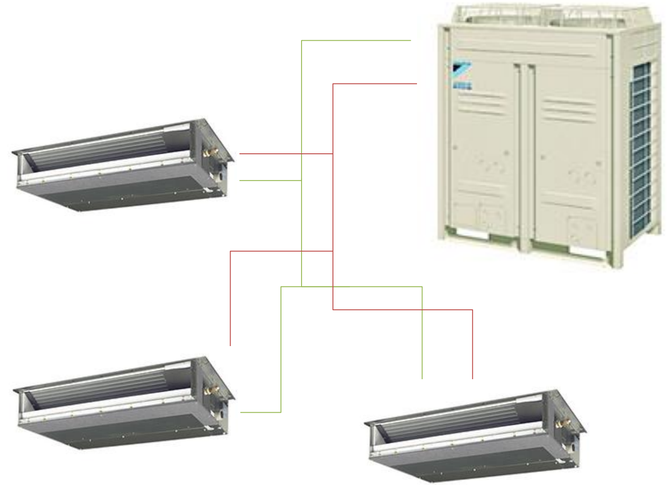
Plan

Design a Variable Refrigerant Flow (VRF) system to serve each floor

- Condenser units will be located on the roof
- Indoor units will be paired with a DOAS

Replace existing air handling units on each floor to serve to zones 100% outdoor air and treat incoming air

- Indoor units will be ducted and served by DOAS



Mechanical Depth

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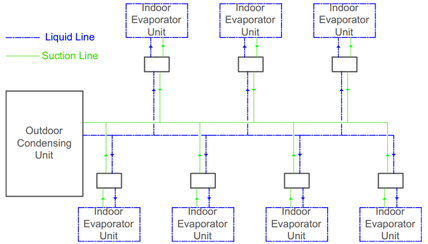
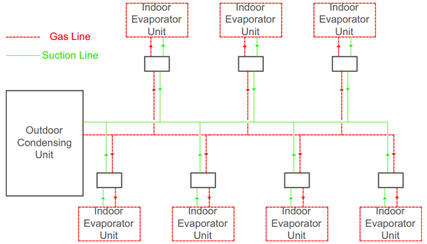
Basic VRF Design

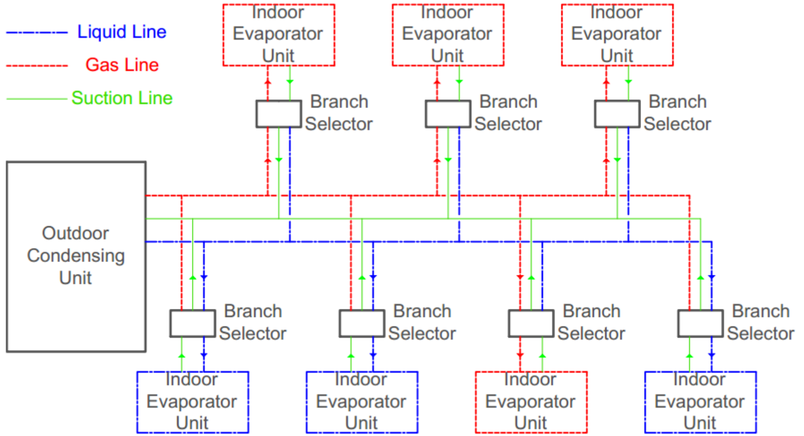


- Cooling Mode
- Basic Refrigeration Cycle



- Heating Mode
- Reverse Heat Pump Cycle
- Outdoor Condensing Unit becomes Evaporator Unit

VRF with Heat Recovery



Mechanical Depth

- Project Background
- Existing Conditions
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- **Mechanical Depth:**
  - **VRF Design**
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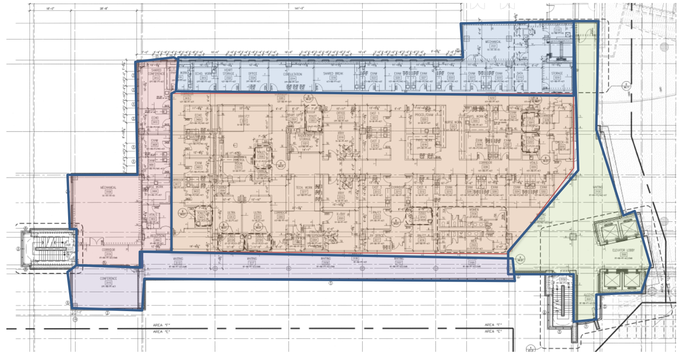
Loads per Floor

Floor	Cooling [tons]	Heating [MBH]
0	20.8	106.9
3	40.4	59.5
4	39.0	60.4
5	39.6	56.2
6	42.9	61.3
7	41.1	60.7
8	40.3	61.1
9	33.8	51.5
10	35.4	53.4

Typical Floor Layout

N



Mechanical Depth

- Project Background
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Loads by Floor

Floor	Cooling [tons]	Heating [MBH]
0	20.8	106.9
3	40.4	59.5
4	39.0	60.4
5	39.6	56.2
6	42.9	61.3
7	41.1	60.7
8	40.3	61.1
9	33.8	51.5
10	35.4	53.4

Zone Design

Basement Floor Zone Designation

Mechanical Depth

- Project Background
- Existing Conditions
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- **Mechanical Depth:**
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  - Dedicated Outdoor Air System
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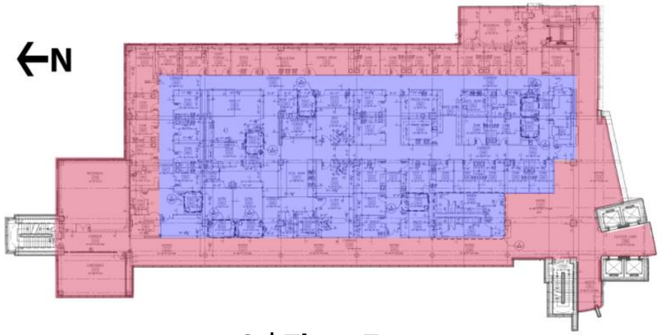
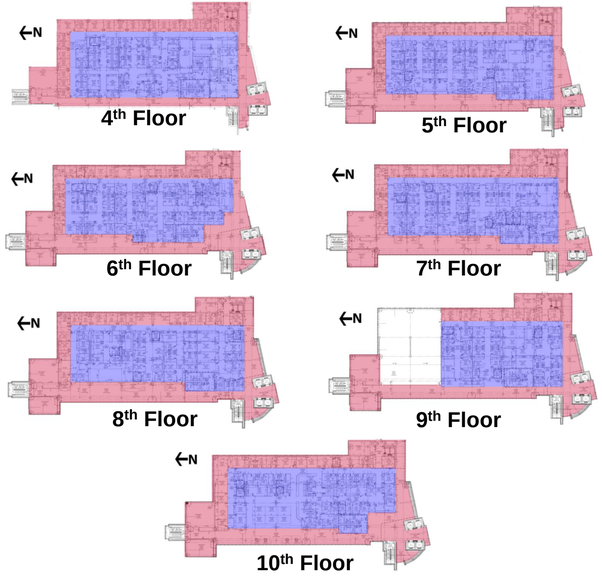
- Conclusion

Typical Zone Layout



3rd Floor Zone Designation



Mechanical Depth

- Project Background
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- **Mechanical Depth:**
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Condenser Schedule

Floor/Units	Condenser Unit Sizes	
	Interior Zone [tons]	Exterior Zone [tons]
F0/CU-1,CU-2	20	-
F3/CU-3,CU-4	10	28
F4/CU-5,CU-6	12	26
F5/CU-7,CU-8	12	26
F6/CU-9,CU-10	12	28
F7/CU-11,CU-12	10	28
F8/CU-13,CU-14	10	28
F9/CU-15,CU-16	8	26
F10/CU-16,CU-17	8	28

General Design Requirements

- 540 linear feet of piping between condensing unit and furthest located fan coil unit or equivalent
- 3,280 total one-way piping in the complete piping network
- 164 feet in vertical separation between the condensing unit and the fan coil units
- 49 feet in vertical separation between fan coil units

Mechanical Depth

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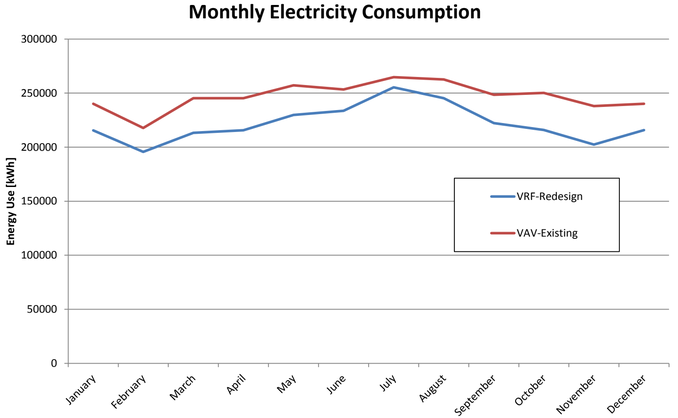
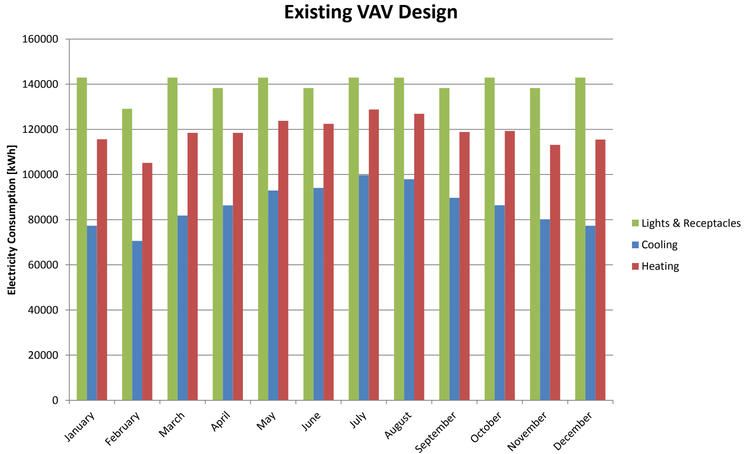
Evaluation



System Power Requirements



Mechanical Depth

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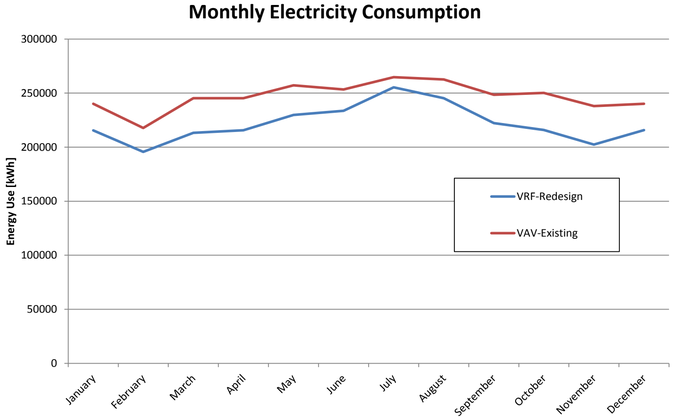
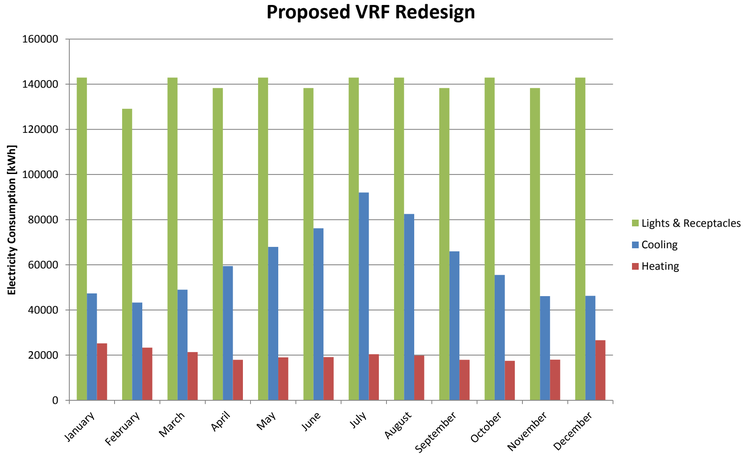
Evaluation



System Power Requirements



Mechanical Depth

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- **Mechanical Depth:**
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  - **Dedicated Outdoor Air System**
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Required Airflow Comparison

Floor	Required Airflow		
	Original Design [cfm]	Redesign [cfm]	Percent Difference
Basement	10929	8912	18.46
Third	25854	25225	2.43
Fourth	25498	18438	27.69
Fifth	25829	21691	16.02
Sixth	26242	23180	11.67
Seventh	25692	21704	15.52
Eighth	26070	25412	2.52
Ninth	23254	19379	16.66
Tenth	23039	20708	10.12
Total	**212407**	**184648**	**13.07**

Fan Utilization

Fan Energy Savings		
Original Design [kBtu/yr]	Redesign [kBtu/yr]	Energy Saved [kBtu/yr]
969,700	741,400	228,300

Mechanical Depth

- Project Background
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Energy

Energy Consumption Breakdown	Existing [kBtu/yr]	Redesign [kBtu/yr]	Reduction [kBtu/yr]
Heating	2796067	98689	2697378
Cooling	3351931	2496724	855207
Fans & Pumps	969706	741378	228328
Lighting & Receptacle	5742841	5742841	-
Total	**12860545**	**9079632**	**3780913**

Total Operating Cost:

- Existing: $298,360/year, $1.55/ft^2
- Redesign: $179,028/year, $0.93/ft^2

Total Annual Savings: $119,332

Emissions

Existing CO_2 Equivalent Production: 6,153,002 lbm/year

Redesign CO_2 Equivalent Production: 3,951,153 lbm/year

Total Reduction: 2,201,849 lbm/year ~64% Decrease

Occupant Comfort

It is implied VRF Heat Recovery system design creates increased controllability by allowing simultaneous heating and cooling for occupant comfort

Acoustics Breadth

- Project Background
- Existing Conditions
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- Mechanical Depth
- **Acoustics Breadth:**
  - **VRF Indoor Units**
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Sound Power Levels

Model FXMQ_PVJU Ducted Concealed			
Cooling Capacity		Sound Levels (dBA)	
BTU/h	Tons	Cooling	Heating
7500	0.6	29	33
9500	0.75	29	333
12000	1	29	34
18000	1.5	37	41
24000	2	38	42
30000	2.5	39	43
36000	3	39	43
48000	4	40	44

Indoor Unit Types

Acoustics Breadth

- Project Background
- Existing Conditions
- Thesis Goals
- Mechanical Depth
- **Acoustics Breadth:**
  - VRF Indoor Units
  - **Design Criteria**
  - Room Noise Criteria
- Conclusion

Existing Sound Power Levels

Octave Band (Hz)	63	125	250	500	1000	2000	4000	8000
Supply Fan Power Level, L_w (dB)	94	94	88	87	85	83	78	72
Return Power Level, Lw (dB)	84	86	77	77	76	74	64	60
Combined Sound Power Level, L_w (dB)	94	95	88	87	86	84	78	72

Octave Band (Hz)	63	125	250	500	1000	2000	4000	8000
VAV Sound Power Level, L_w (dB)	60	60	54	44	42	39	34	34

VRF with DOAS Units

Octave Band (Hz)	63	125	250	500	1000	2000	4000	8000
Supply Fan Power Level, L_w (dB)	90	91	85	84	84	81	76	71
Exhaust Fan Power Level, L_w (dB)	76	77	76	73	71	68	65	60
Combined Sound Power Level, L_w (dB)	90	91	86	84	84	81	76	71

Octave Band (Hz)	63	125	250	500	1000	2000	4000	8000
VRF Sound Power Level, L_w (dB)	44	49	40	37	38	34	22	14

Acoustics Breadth

- Project Background
- Existing Conditions
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- Mechanical Depth
- **Acoustics Breadth:**
  - VRF Indoor Units
  - **Design Criteria**
  - Room Noise Criteria
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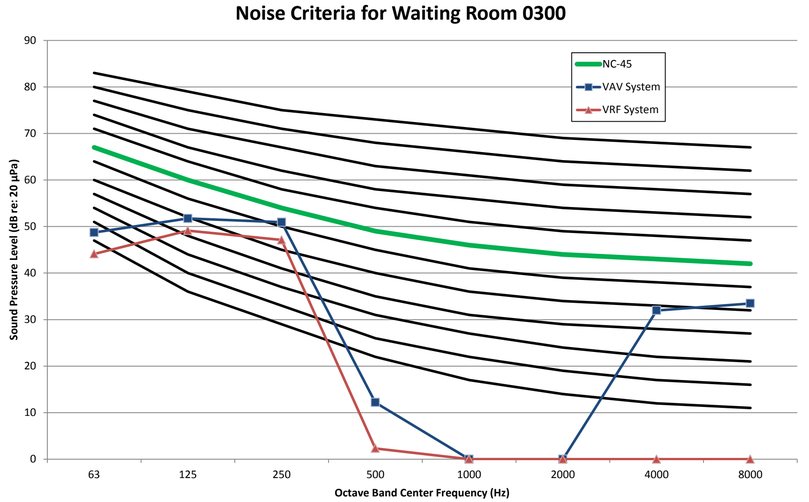
Spectrum Noise Levels

Octave Band (Hz)	63	125	250	500	1000	2000	4000	8000
VAV-AHU Sound Power Level at Room	60	63	62	23	6	0	43	44
VAV-AHU Sound Pressure Level	49	52	51	12	0	0	32	33
VRF-DOAS Sound Power Level at Room	55	60	58	13	0	0	7	6
VRF-DOAS Sound Pressure Level	44	49	47	2	0	0	0	0



Acoustics Breadth

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NC-Ratings by Floor

NC-Rating			
Floor	Room Designation	Existing	Redesign
0	Waiting Room	42	37
3	Exam Room	45	46
4	Faculty Office	45	38
5	Exam Room	44	45
6	Vitals Area	51	55
7	Dictation Room	53	54
8	Consultation	51	49
9	Reception Area	39	33
10	Shared Break Room	50	50

Evaluation

- Noise Criteria levels are based on the background noise present within the space
- Overall, 50% of the rooms investigated with the combine VRF-DOAS system performed better than the existing VAV spectrum levels
- The rooms that performed worse were within the standard Noise Criterion levels
- Additionally, those that performed worse were within 4 NC-values
- Therefore, the design is sufficient without needing any redesign

Conclusion

- Project Background
- Existing Conditions
- Thesis Goals
- Mechanical Depth
- Acoustics Breadth
- **Conclusion**

Overall Evaluation

VRF System with DOAS Investigation:

- **Increased Occupant Control**
- **Decreased Energy Consumption**
- **Decreased Operating Costs**
- **Decreased Emissions**

Recommended

Indoor Unit Acoustic Investigation:

- **Remains consistent with existing design**
- **50% of spaces studied had improved background noise level with the indoor units and DOAS**
- **Meets standard NC rating room requirements**

Conclusion

- Project Background
- Existing Conditions
- Thesis Goals
- Mechanical Depth
- Acoustics Breadth
- **Conclusion**

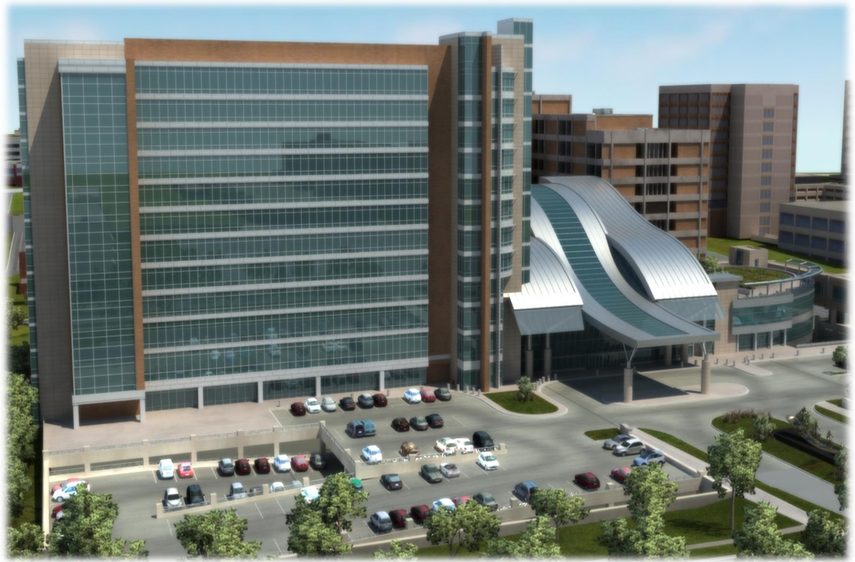
Special Thanks:

The Pennsylvania State University
Architectural Engineering Department

Thesis Advisor: Dr. Laura Miller

Jorge Charneco, AIA; Miles Associates

Thanks to all my family and friends



Questions?