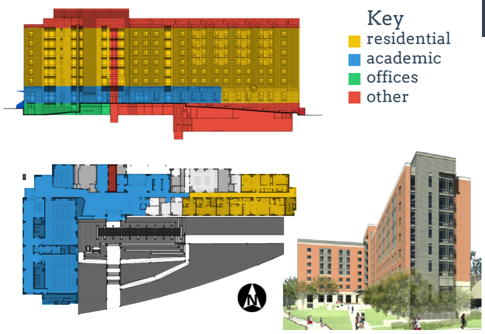
Prince Frederick Hall
university of maryland

Architectural Engineering
2014 senior thesis

Sarah Miller
lighting + electrical



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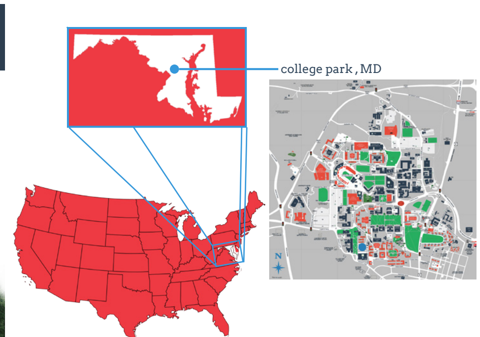

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introduction | lighting | electrical | breadths | conclusion

Design Concept

- public and private spaces
- learning environments

- entry plaza
- lobby
- seminar room
- dormitory suite

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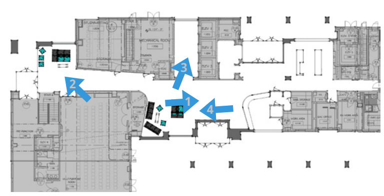
introduction | lighting | electrical | breadths | conclusion

Lobby Lighting

Criteria
- augment wayfinding
- highlight architecture
- juxtapose public & private
- create welcoming entry



discovery occurs through the juxtaposition of public and private spaces

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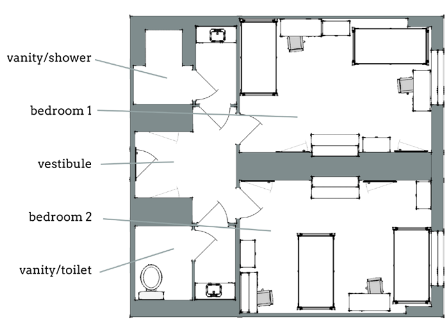
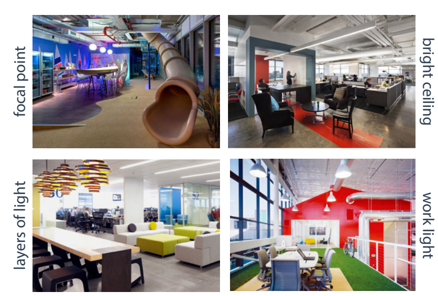
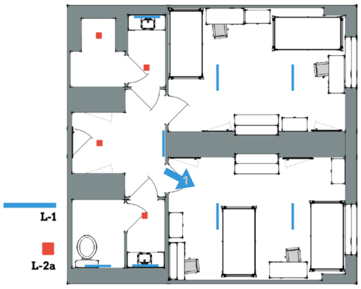


Dormitory Suite Lighting

Initial Criteria
- comfort for occupants
  - layers of light
  - focal point
  - bright ceiling
  - work light
- minimize LPD



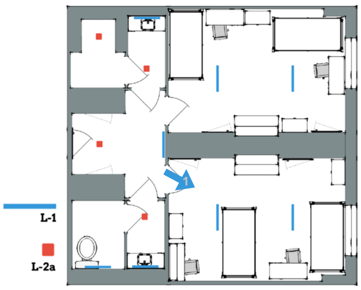


Dormitory Suite Lighting

Criteria: focus on sustainability

- minimize LPD
  - 42 dormitory suites
  - target: 0.34 W/ft²
    (10% less than ASHRAE 90.1 2010)
- maximize controllability
  - comfort for both roommates
  - different scenes

discovery of social life



Dormitory Suite Lighting

Achievements

- minimize LPD
  - target: 0.34 W/ft²
    (10% less than ASHRAE 90.1 2010)
  - achieved: 0.21 W/ft²
- load reduction
  - multiplied across 42 suites
  - design uses 8.8 kW less
- practical
  - coordinates with existing architecture
  - LED fixtures for durability & longevity
- bright ceiling
  - 3-sided lens fixture
  - aesthetic improvement

discovery of social life

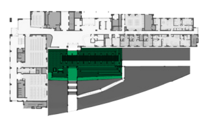
Seminar Room

discover education

Other Lighting Spaces

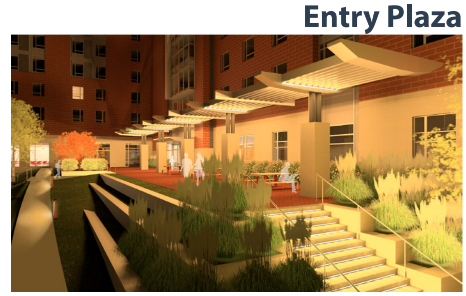
Achievements

- IES Recommendations
  - occupants 25 years old
  - 200 lux on work plane
- peripheral lighting
- flexible controls

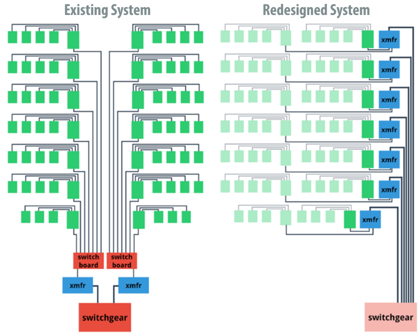


- no upward-facing lights
- trellis highlighted
- social gathering space
- established heirarchy

Entry Plaza



first step of **discovery**



Electrical Depth

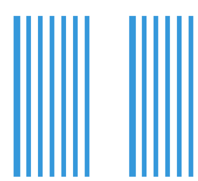
Equipment Savings

branch panels	no changes the loads on these panels are unchanged; equipment is the same
xmfr	-$950 distributed transformers are almost the same cost as centralized
switchboards	$40,000 eliminated (2) 1600A switchboards and associated breakers
draw-out breakers (switchgear)	$275 (2) 800A breakers were changed to several smaller ones

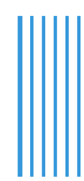
for dormitory distribution system
Total Equipment Cost Savings: **$37,500**

Wire Savings

Existing System	Redesigned System
208Y-120V	480/277V
2 risers	1 riser
250 and 500 kcmil	#1/0 and 250 kcmil

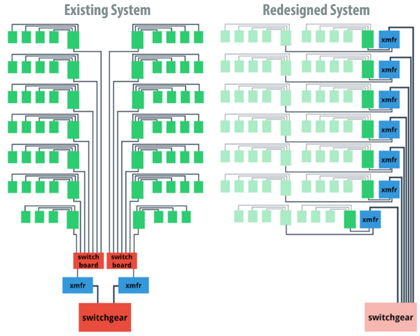


$72,000



$41,000

for dormitory distribution system
Total Wire Cost Savings: **$34,000**



Electrical Depth

System Benefits

- smaller transformers are needed at each floor
- smaller wire sizes
- less voltage drop
  - higher voltage distribution
  - this increases the overall efficiency
- several pieces of equipment eliminated or resized

Total Savings

Total Equipment Cost Savings:	$37,500
Total Wire Cost Savings:	$34,000
Total Savings:	**$71,000**

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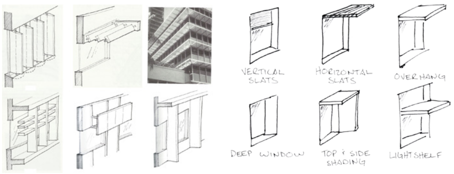
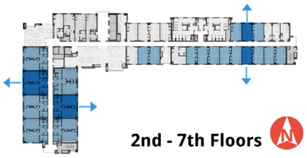
Shading Options



Mechanical + Architectural Breadths

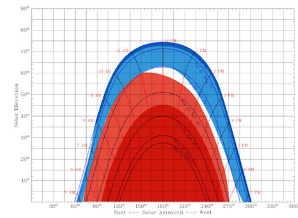
Scope



36 East-facing Suites
18 West-facing Suites

66 South-facing Rooms
18 North-facing Rooms

Design Goal



maximize shading between **June - August**
minimize shading between **October - March**

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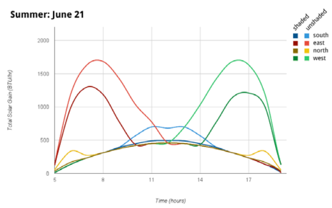
Mechanical Achievements

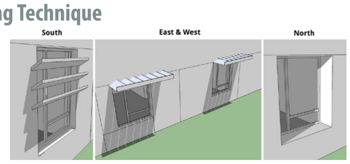


Energy Savings				
	South	East	West	North
Number of Windows	66	36	48	18
Cooling Season Net BTUs	-239192	-165040	-204758	-8004
Heating Season Net BTUs	-347163	-104428	-81834	0
Net BTUs	-107970	60612	122924	8004

Total Reduction: **83,570** BTUs

Mechanical + Architectural Breadths

Shading Technique



Calculation Method

- Compute relevant solar angles (altitude, azimuth, angle of incidence)
- Use solar angles to find the unshaded area (ft^2) of windows
- Calculate direct beam solar heat gain
- Calculate (ground and sky) diffuse solar heat gain

Architectural Achievements

Existing Building

end of presentation

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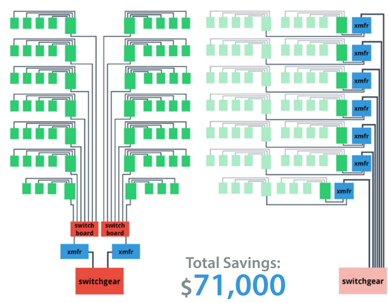
Lighting Depth

Load Reduction:
11,400 Watts

Electrical Depth

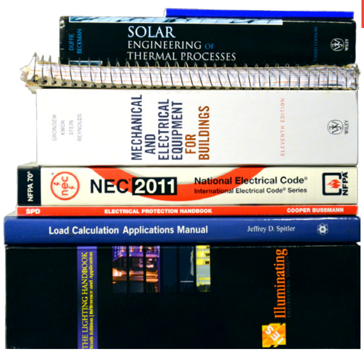


Total Savings:
$71,000

Mechanical + Architectural Breadths

Total Reduction:
83,570 BTUs

end of presentation



Appendix: References

[1] Brownson, Jeffrey R. S. *Solar Energy Conversion Systems*. 1st ed. Oxford, UK: Elsevier, 2014. Print.

[2] Charest, Adrian C. *RSMeans Electrical Cost Data*. Norwell, MA: Construction & Consultants, 2014. Print.

[3] Dilaura, David L., Kevin W. Houser, Richard G. Mistrick, and Gary R. Steffy, eds. *The Lighting Handbook: Reference and Application*. 10th ed. N.p.: Illuminating Engineering, 2011. Print.

[4] Duffie, John A., and William A. Beckman. *Solar Engineering of Thermal Processes*. 3rd ed. Hoboken: Wiley, 2006. Print.

[5] Grondzik, Walter T., Alison G. Kwok, Benjamin Stein, and John S. Reynolds. *Mechanical and Electrical Equipment for Buildings*. 11th ed. Hoboken: J. Wiley & Sons, 2010. Print.

[6] Haggard, Kenneth L., David A. Bainbridge, and Rachel Aljilani. *Passive Solar Architecture Pocket Reference*. Ed. D. Yogi Goswami. London: Earthscan, 2009. Print.

[7] National Fire Protection Association. *NEC 2011*. 2011 ed. Quincy, MA: NFPA, 2010. Print.

[8] Perlin, John. *Let It Shine : The 6,000-year Story of Solar Energy*. Novato, CA: New World Library, 2013. Print.

[9] Spitler, Jeffrey D. *Load Calculation Applications Manual*. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, 2009. Print.

Image Sources

Architect's Renderings:
http://www.resnet.umd.edu/princefrederick/

Dormitory Suite Precedent Images:
http://blogs.edweek.org/edweek/LeaderTalk/2010/11/habits_and_habitats_rethinking.html
http://designermag.org/40-real-creative-workspace-examples/
http://www.nbbj.com/work/russell-investments/
http://www.designboom.com/architecture/camenzind-evolutions-google-office-flourishes-in-dublin/

Shading Options Images:
photos by: Sarah Miller

Tools

revit | autoCAD | AGi32 | photoshop | hand drawing | sketchUp | inDesign

Architecture

Prince Frederick Hall is a new building located on the University of Maryland campus. The building programming provisions space for **academic rooms** on the ground and first floors of the building. Part of the first floor and all of the second through seventh floors are used for **dormitory rooms**. A combination of single, double occupant, and suites provide housing for a little over 450 students.

Red brick dominates the most surface area of the building and is is laid in a traditional running bond pattern. The first floor of the building is wrapped in a **limestone**-colored, special finish masonry unit. **Metal** is also used on the facade; it is used primarily to accent the curtain walls.

Lighting + Electrical

daylighting: Provided to spaces through numerous glazed openings. The lobby and social areas feature large, glass curtain walls. Classrooms are equiped with blackout shades.

lighting: Interior lighting is mostly fluorescent. Many troffers and recessed downlights are applied throughout the building. Exterior lighting is LED.

electrical: Power feeds into the building from the north side. Two 3000 kVA transformers, outside the building, provide 480/277V to the main electrical room. Power is transformed to 208Y-120V for all receptacles and lighting.

Appendix: Abstract

Building Statistics

function: University Housing
size: 185,522 GSF
number of stories: 7 floors + ground floor
construction dates: May 2012-August 2014
project cost: $66.8 million
delivery method: design-build

Project Team

architect: WDG Architecture, PLLC
general contractor: Clark Construction
structural engineer: Cagley & Associates, Inc.
mep consulting: WFT Engineering, Inc.
civil engineer: Site Resources Inc.
landscape architect: Parker Rodriguez Inc.

Mechanical

air distribution: Six air handling units and two roof top units circulate air throughout the building.

central systems: Prince Frederick Hall is connected to the campus' central steam distribution system.

academic spaces: Variable air volume (VAV) boxes are located throughout the ground and first floors. Separate heating and cooling coils provide extra control to individual spaces.

dormitory spaces: Each dormitory room is equipped with its own fan coil unit (FCU) that connects to the building's chilled water and hot water systems.

Structural

foundation: Concrete columns carry the load of the building below grade to footings.

superstructure: The structure of the building is mostly steel-reinforced concrete. Typical 18x30 columns carry 8" concrete decks. Canteleivers on the 2nd floor are supported by post-tensioned concrete beams.

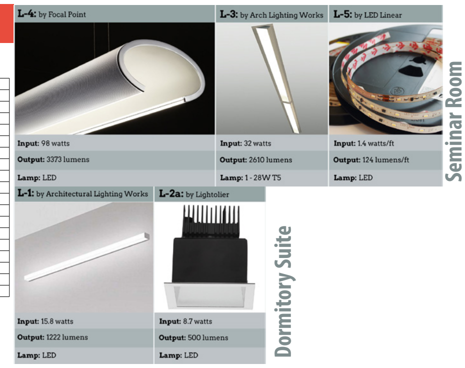
lateral system: Shear walls around stairwells and elevator cores resist lateral loads.

trellis: Located at the north and south entrances, this feature of the building is constructed mainly of hollow steel sections.

Appendix: Lighting

Luminaire Schedule

	Type Mark	Description	Manufacturer	Lamp	Quantity	Input Watts
Lobby	L-5	LED tape	LED Linear	LED (1.4 W/LF)	30	1.4
	L-2b	4" Square Downlight; high output	Lightolier	LED	15	19.8
	L-6a	36" cylinder pendant	Eureka	LED	5	40
	L-6b	54" cylinder pendant	Eureka	LED	8	64
	L-6c	72" cylinder pendant	Eureka	LED	4	87
	L-7	2 cell downlight	iGuzzini	LED	15	4.2
	L-8	Decorative pendant	Eureka	2 - 18W CFL	3	37
Seminar Room	L-3	Semi-recessed linear wall washer	Architectural Lighting Works	1 - 28W T5	4	30
	L-4	Linear pendant 4' direct/indirect	Focal Point	LED	12	98
	L-5	LED tape	LED Linear	LED (1.4 W/LF)	33	1.4
Dormitory Suite	L-1	Surface mounted linear with wrapped lens	Architectural Lighting Works	LED (7 W/LF)	8	15.8
	L-2a	4" Square Downlight; low output	Lightolier	LED	4	8.7
Entry Plaza	LE-1	Exterior 15' UMD Standard LED Pole	LSI Industries	LED	4	138
	LE-2	LED tape; IP67 rated	LED Linear	LED	268	1.4
	LE-3	Bollard	Cooper	LED	7	8.6



Light Levels & Criteria

Appendix: Lighting

Entry Plaza

	General Illumination			Paths to Curb			Seating Areas		
	Criteria	Existing	Thesis	Criteria	Existing	Thesis	Criteria	Existing	Thesis
E (horizontal)	30	30	50	4	11	30	50	31	81
E (vertical)	15						15	3	31
Avg:Min							4:1	1.8:1	2.5:1

Seminar Room

	General Illumination, non-AV			General Illumination, AV			Whiteboard		
	Criteria	Existing	Thesis	Criteria	Existing	Thesis	Criteria	Existing	Thesis
E (horizontal)	200	503	344	25	145	24			
E (vertical)	75	353	304	15	57	14	300	258	295
Avg:Min				2:1	4.34:1	3:1	3:1	1.44:1	2.11:1

Lobby

	General Illumination			Reception Desk			Vestibules		
	Criteria	Existing	Thesis	Criteria	Existing	Thesis	Criteria	Existing	Thesis
E (horizontal)	100	251	251	150	293	205	50	142	79
E (vertical)	30	121	177				30	98	41
Avg:Min	4:1	6:1	2.2:1	4:1	1.7:1	1.6:1	2:1	3.3:1	1.9:1

	Elevator Lobby			Reading/Work Area		
	Criteria	Existing	Thesis	Criteria	Existing	Thesis
E (horizontal)	50	173	60	150	237	244
E (vertical)				50	72	105
Avg:Min	2:1	2.2:1	3:1			

Dormitory Suite

	General Illumination			Desk Areas			Bath Areas		
	Criteria	Existing	Thesis	Criteria	Existing	Thesis	Criteria	Existing	Thesis
E (horizontal)	25	626	290	250	590	268	50	1066	550
E (vertical)									
Avg:Min	3:1	1.2:1	1.3:1				2:1	1.4:1	1.3:1

	Vanities			Foyer		
	Criteria	Existing	Thesis	Criteria	Existing	Thesis
E (horizontal)	150	960	627	50	732	423
E (vertical)	200	1022	628			
Avg:Min	2:1	1.1:1	1.1:1	3:1	1.2:1	1.3:1

LPD & Criteria

Entry Plaza

Existing LPD	Area (SF)	Total Watts	LPD	Target LPD	% Difference
0.09	12,300	987	0.08	0.09	10.80%

Lobby

Existing LPD	Area (SF)	Total Watts	LPD	Target LPD	% Difference
0.70	5,152	1,418	0.28	0.90	69.42%

Seminar Room

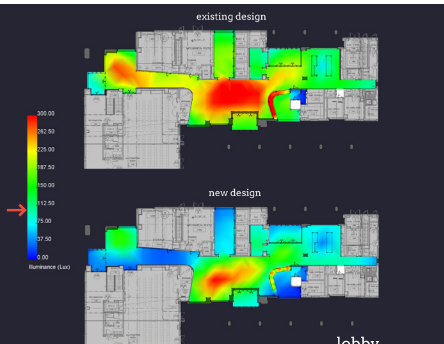
Existing LPD	Area (SF)	Total Watts	LPD	Target LPD	% Difference
0.74	1,750	1,342	0.77	1.24	38.15%

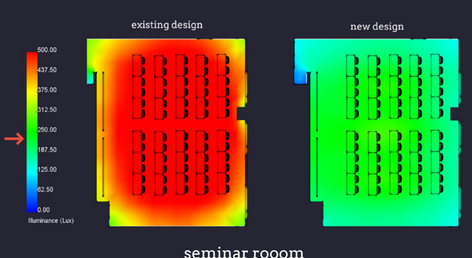
Dormitory Suite

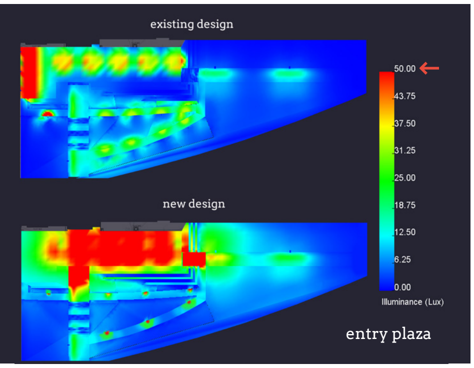
Existing LPD	Area (SF)	Total Watts	LPD	Target LPD	% Difference
0.45	777	161	0.21	0.38	45.40%

Appendix: Lighting

AGi32 Pseudo Color Plans

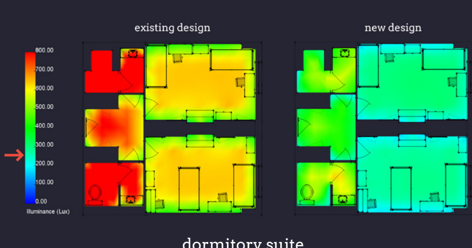




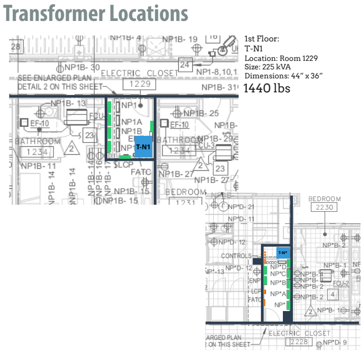


Appendix: Lighting

AGi32 Pseudo Color Plans



Transformer Locations



1st Floor:
T-N1
Location: Room 1229
Size: 225 kVA
Dimensions: 44" x 36"
1440 lbs

2nd - 7th Floors:
T-N*
Location: Room *228
Size: 112.5 kVA
Dimensions: 28" x 23"
where * is the floor number
930 lbs each

Appendix: Electrical

Short Circuit Calculations

X1: Transformer (T-2) Secondary	
I sc sys RMS (A)	1.00E+30
Primary Voltage (V)	13200
Secondary Voltage (V)	480
Impedance	5.75%
Transformer Size (kVA)	3000
	100,000.00
f	4.38E+26
M	0.0000
I sc sys RMS	**62,757.30**

X2: at Switchgear	
I sc (A) from X1	62,757.30
Wire Length	105
Number of Wires per	8
C Value	22185
Voltage (V)	480
f	0.1340
M	0.8819
I sc sys RMS (A)	55,342.95
% motors	0%
I motor contribution (A)	0
I total sym sc RMS (A)	**55,342.95**

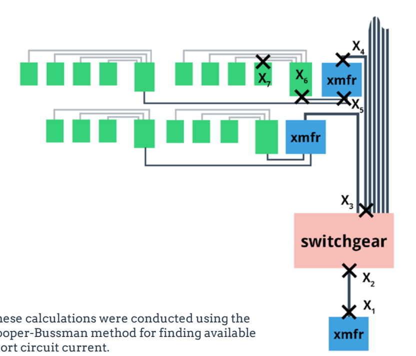
X3: Switchgear	
Main Transformer Size	3000
Voltage at Switchgear (V)	480
Full Load Current (FLA)	3,608.55
I sc (A) from X2	55,342.95
% motors	25%
I motor contribution (A)	3,608.55
I total sym sc RMS (A)	58,951.50
Wire Length	92
Number of Wires per Phase	8
C Value	26706
f	0.0860
M	0.9208
I sc sys RMS (A)	50,960.74
I motor contribution (A)	3,608.55
I total sym sc RMS (A)	**54,569.28**

X4: at Transformer (T-N2) Primary	
I sc (A) from X3	54,569.28
Wire Length	52
Number of Wires per	1
C Value	7493
Voltage (V)	480
f	1.3665
M	0.4226
I sc sys RMS (A)	23,059.29
% motors	0%
I motor contribution (A)	0
I total sym sc RMS (A)	**23,059.29**

X5: Transformer (T-N2) Secondary	
I sc sys RMS (A) from X4	23,059.29
Primary Voltage (V)	480
Secondary Voltage (V)	208
Impedance	2.30%
Transformer Size (kVA)	112.5
	100,000.00
f	3.9193
M	0.2033
I sc sys RMS	**10,817.30**

X6: Panel NP2	
I sc sys RMS (A) from X5	10,817.30
Wire Length	8
Number of Wires per	1
C Value	16483
Voltage (V)	208
f	0.0437
M	0.9581
I sc sys RMS (A)	10,364.20
% motors	0%
I motor contribution (A)	0
I total sym sc RMS (A)	**10,364.20**

X7: Panel NP2A	
I sc sys RMS (A) from X6	10,364.20
Wire Length	8
Number of Wires per Phase	1
C Value	7293
Voltage (V)	208
f	0.0947
M	0.9135
I sc sys RMS (A)	9,467.90
% motors	0%
I motor contribution (A)	0
I total sym sc RMS (A)	**9,467.90**



These calculations were conducted using the Cooper-Bussman method for finding available short circuit current.

Existing Lighting Circuits							
Entry Plaza Lighting							
Fixture Type	Load (VA)	Fixtures per Circuit					
		HL-3	EL-1				
EX-1	138	4					
EX-3	45		3				
EX-4	25	10					
EX-5	24.5	9					
	Existing Load	1022.5	135				
Lobby Lighting							
Fixture Type	Load (VA)	Fixtures per Circuit					
		MP1A-1	MP1A-3	MP1A-4	MP1A-8	EMP1-3	EMP1-5
F-8	42		12		25	7	
F-9	32	10	9	1	17	7	
F-7E	225					3	
F-7F	64				2	2	1
	Existing Load	320	792	32	1722	1321	64
Seminar Room Lighting							
Fixture Type	Load (VA)	Fixtures per Circuit					
		MP1A-7					
F-10	32	21					
F-B1	32	15					
	Existing Load	1152					
Dormitory Suite Lighting							
Fixture Type	Load (VA)	Fixtures per Circuit					
		MP*A-#					
F-1	52	4					
F-2	32	2					
F-3	18	1					
F-4	24	2					
FA	32	1					
	Existing Load	370					

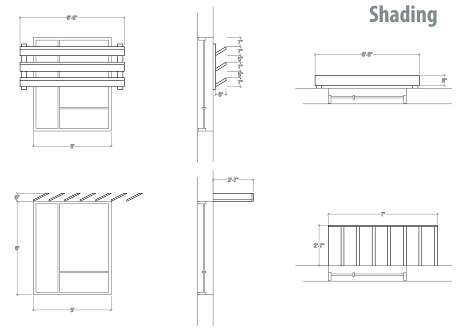
Appendix: Electrical

Lighting Branch Circuit Redesign

Lighting Circuits Comparison			
Circuit Name	Total Circuit Load (VA)		Difference
	Existing	Redesigned	
HL-3	1935	1764.9	-170.1 VA
EL-1	670	670	same
MP1A-1	482	360	-122 VA
MP1A-3	1024	1000	-24 VA
MP1A-4	800	0	combined with MP1A-3
MP1A-8	1806	1041	-765 VA
EMP1-3	1739	831.8	-907.2 VA
EMP1-5	777	717.2	-59.8 VA
MP1A-7	1152	1342.2	+190.2 VA
MP*A-#	370	322.4	reduce from 7 to 4 circuits per floor

Redesigned Lighting Circuits			
Fixture Type	Load (VA)	Quantity	Total Load (VA)
Lobby Loads			
L-5	1.4	30	42
L-2b	19.8	15	297
L-6a	40	5	200
L-6b	64	8	512
L-6c	87	4	348
L-7	4.2	15	63
L-8	37	3	111
Total Lobby Load			1573
Seminar Room Loads			
L-3	30	4	120
L-4	98	12	1176
L-5	1.4	33	46.2
Total Seminar Room Load			1342.2
Dormitory Suite Loads			
L-1	15.8	8	126.4
L-2a	8.7	4	34.8
Total Dorm Suite Load			161.2
Entry Plaza Loads			
LE-1	138	4	552
LE-2	1.4	268	375.2
LE-3	8.6	7	60.2
Total Entry Plaza Load			987.4

Shading



Appendix: Breadths

Solar Heat Gain Calculation Method

First, find direct **beam** solar heat gain:

$$q_{SHG,D} = E_D A_{sunlit} \mathrm{SHGC}(\theta)$$

E_D calculate (see below)
A_{sunlit} is the unshaded area of the window
SHGC(θ) is the manufacturer's SHGC with an angle correction factor applied

where the method to find E_D is:

$$E_D = E_{DN} \cdot \cos(\theta)$$

$$E_{DN} = \frac{A}{\exp(B/\sin(\beta))} \times CN$$

A and B are both coefficients
CN is the clearness number, a regional coefficient
β is the solar altitude

Next, find **diffuse** solar heat gain:

$$q_{SHG,d} = (E_d + E_r)A \cdot \mathrm{SHGC}_{diffuse}$$

E_d calculate (see below)
E_r calculate (see below)
A is the total area of the window
$\mathrm{SHGC}_{diffuse}$ is the manufacturer's SHGC with a diffuse correction factor applied

where E_d (for a vertical surface) is:

$$E_{dV} = Y \cdot E_{DN} \cdot C$$

$$Y = 0.45 \qquad for\ \cos(\theta) \geq -0.20$$

E_{DN} is known from above
C is a listed coefficient

E_r is the ground-reflected diffuse irradiation:

$$E_r = E_{DN}(C + \sin\beta)\rho_g \frac{1-\cos\Sigma}{2}$$

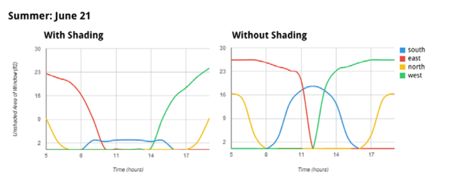
E_{DN} is known from above
C is a listed coefficient
β is the solar altitude
ρ_g is the albedo (ground reflectance)
Σ is the surface tilt angle (90° for vertical surfaces)

Last, combine diffuse and direct solar heat gain to find **total** solar heat gain:

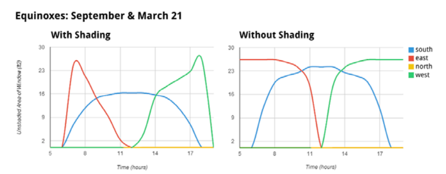
$$q_{SHG} = q_{SHG,D} + q_{SHG,d}$$

Appendix: Breadths

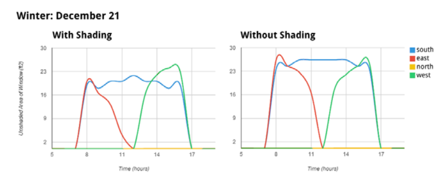
Shaded Area Graphs



Ideal: reduce the unshaded area of each window as much as possible, particularly for peak loads



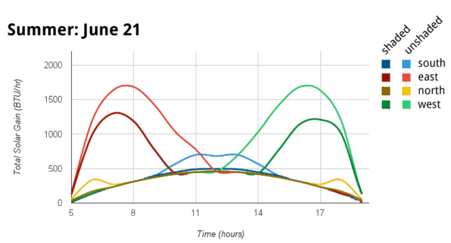
Ideal: these months posed a challenge because September is considered to be a cooling month and March is considered to be a heating month, but the solar angles are identical for both days

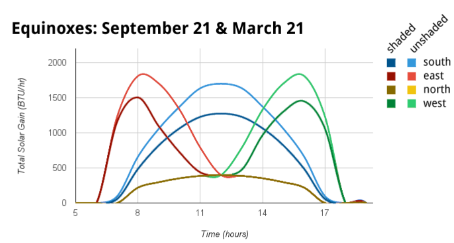


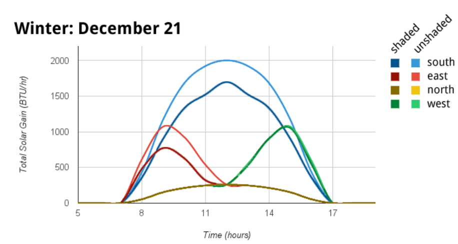
Ideal: maximize the unshaded area of each window as much as possible

Appendix: Breadths

Solar Heat Gain Graphs



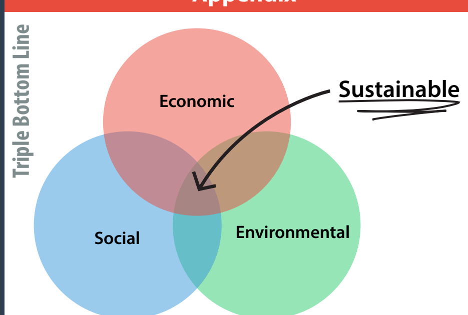




Appendix

on vernacular architecture
"building in response to actual needs, fitted into environment by people who knew no better than to fit them with native feeling [is] for us better worth study than all the highly self-conscious academic attempts at the beautiful throughout Europe."

-Frank Lloyd Wright



on solar design
"The house in which the owner can find a pleasant retreat in all seasons… is at once the most useful and the most beautiful."

-Socrates