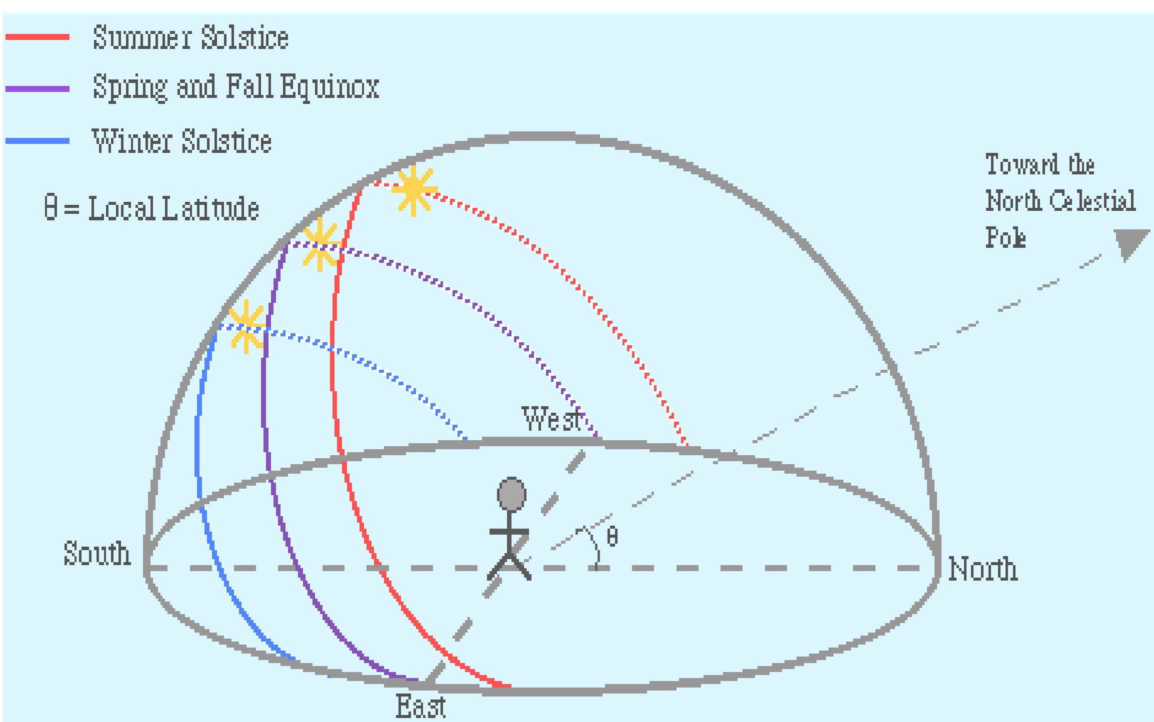
5.0 Daylighting Analysis (Breathe Study)



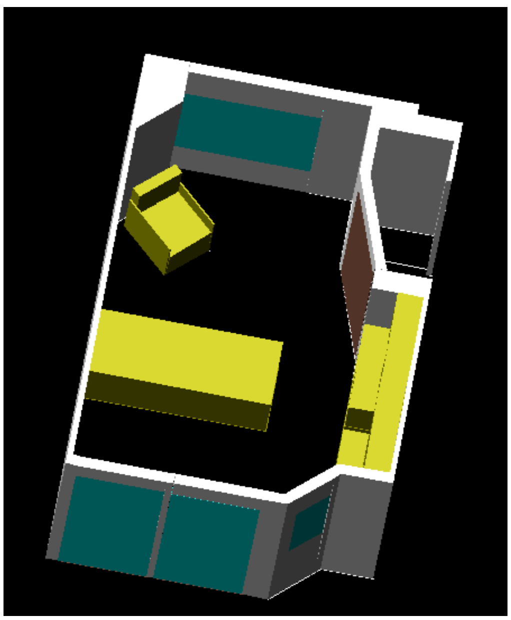
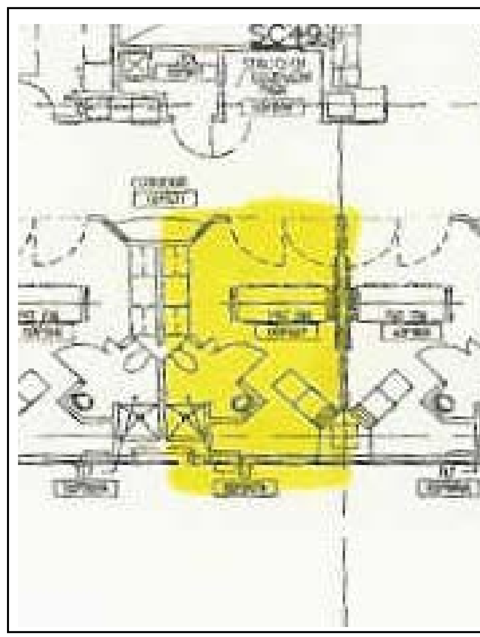
5.0 Daylighting Analysis (Breathe Study)

5.1 Background

The INOVA Heart Institute contains approximately 150 patient recovery rooms. Of these 96 are located around the perimeter of the building and contain acess to windows. Overall the 400,000ft^2 facility contains approximately 22,726 ft^2 of glazing that is exposed to the outside.

5.2 Introducing the Space

Below is a computer rendered image of a typical patient room along with the associated floor plan. Each room contains one bed and has access to one shared bathroom. The approximate area of the patient room is 294 ft^2. The exterior wall area is approximately 84 ft^2 and the window glazing area is approximately 35 ft^2 for each room.

INOVA Rendering 34,35: ***Typical Perimeter Patient Room and Floor Plan***

5.3 Problem/Solution

As stated previously the total exterior glazing area is just under 23,000 ft^2. With such high amounts of glass exposed to the outside an increase in mechanical loads can be expected due to solar gain during the day as well as associated losses of heat during the night. The overall impact on the mechanical system results in wasted energy due to building envelope design especially for a facility that is operating 24 hours a day. The purpose of this study will be to optimize the effects described above without decreasing recommended values of natural daylight. This will be done in hopes of reducing the overall load on the mechanical system which will translate to annual energy savings for the owner. The redesign for the perimeter patient windows may require renovation of the existing curtain wall façade, which will also be studied.

5.4 Plan of Attack

The proposed solution for this study will be to optimize the glazing area of 96 typical perimeter patient rooms which will reduce mechanical load and meet recommend natural daylight illuminances for each space. The following steps will be performed as a result to this investigation.

1. Determine optimal glazing area based on room characteristics and location of Facility.
2. Simulate typical patient room to see if recommended natural daylight values are met.
3. Determine building load and energy usage and estimated HVAC operating cost.
4. Determine impacts of exterior curtain wall façade.
5. Provide cost analysis of redesign
6. Determine feasibility of implementing redesign.

5.5 Determination of Optimal glazing

Much Research was done to determine glazing area that reduces loads while maintains optimal area for daylight transmission into the space. In a study performed by the National Renewable Energies Laboratory (NREL) on passive solar architecture the recommended area of a passive solar feature such as azimuth facing windows is approximately 10% of the floor area for the region of the country nearest to Washington DC. This figure is suppose to account for the reduction solar gains in cooling months (March to September) and increase solar gains in heating months (October to February).

The area of typical patient room is approximately 21’ x 14’ or 294 ft^2. The suggested window glazing area is approximately 29 ft^2 for the patient room

The idea of “ Effective Aperture” for estimates of the optimum glazing area was next used. Effective Aperture is a relationship that is dependent upon both aperture (window area) size and visible transmittance as an effective determinant to measure illumination levels. When the effective aperture, the product of the window to wall ratio and the visible transmittance of the glazing, is approximately 0.18, daylighting saturation will be achieved.

Additional glazing area or light will be counterproductive because it will increase the cooling loads more than it will reduce the lighting loads. In maximizing daylight benefits and minimizing mechanical operating cost the following equation was obtained and used to determine optimal window to wall ratio for window area in the typical patient rooms.

Equation (11):

$$EA = wwr * vt = 0.18$$

(vt) = visible transmittance
(wwr) = window to wall ratio
(EA) = effective aperture

The visible transmittance of the glazing is 55% (Given by Manufacturer, Appendix B.1). This means that the optimal window to wall area is 0.323 or 32%. The current window to wall area for a patient room is (35ft^2)/(84ft^2) or 42%. Multiplying this result by the visible transmittance of 55% gives and effective aperture of 0.23, which is greater than the recommended value of 0.18 and can be reduced. If the window to wall ratio is reduced to the recommended value of 32% producing and effective aperture of 0.18 then the area of the window would be 28ft^2.

This attribute can be useful in evaluating the cost effectiveness and the daylighting potential of a schematic building configuration. The location and height of the window will determine the distribution of the light admitted as well as the depth and penetration. One rule of thumb states that the depth of daylight penetration should be about 2.5 times the distance between the top of a window and the windowsill or approximately ¾ the depth of the room.

5.6 Daylight Simulations

From the results in the previous section, the new window area will be simulated into AGI to see if the minimum recommended daylight factor is met for all perimeter /exterior facing patient rooms. The window area that will be used for each patient room will be approximately 28 ft^2 dimensions: 4’-8” x 6’-2 ¼”.

5.6.1 Daylight Simulations, Daylight Factor

The daylight factor at a point in an interior is the ratio of the illuminance produced at that point by daylight (excluding sunlight) from a sky of known or assumed luminance distribution to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky. No actual information provided that indicates required daylighting for hospitals environment (i.e. patient room). At the recommendation from the lighting advisor patient rooms will liken to bedrooms of house. From the INESA Handbook the a chart recommending daylight factors and sunlight exposures for a bedroom states: "A minimum 0.5% daylight factor should cover at least 5.6 square meters with the penetration of this zone being not less than ¾ of the depth of the room facing the window." In Appendix B.2 the layout of a typical patient room is shown along with the recommended values indicated above.

In a conducted study shown in Daylighting Performance and Design about, "25% of window wall area was the minimum acceptable window size for 50% of the observers but this had to be increased to about 32 % if 85 % of the people were to be satisfied." In general the study recommended that window sizes should be somewhere between 20% and 40% of the window wall area. If below 20% dissatisfaction will arise. If above a 40% level satisfaction with window area will be high but unless special measures are taken, such as a solar control glass, the incidence of thermal and visual discomfort is likely to increase.

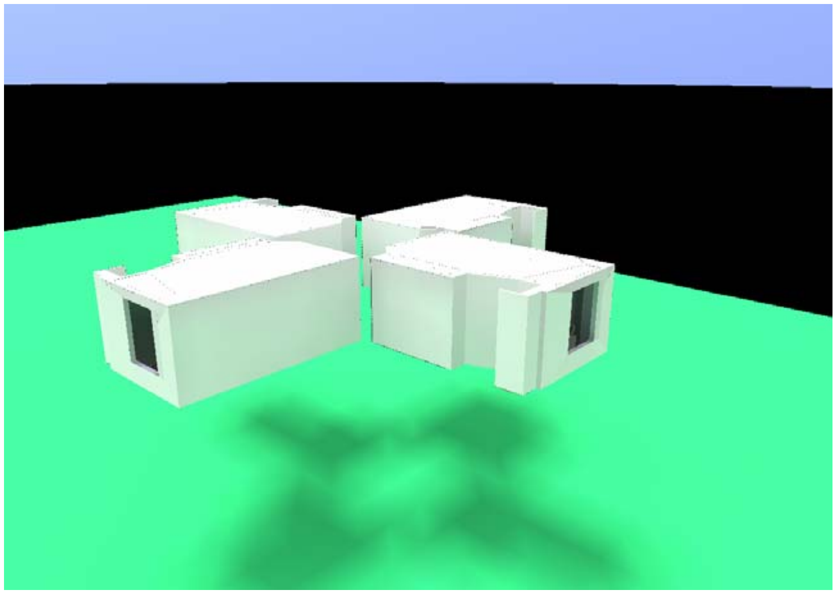
5.6.2 Daylight Simulations, AGI

The purpose of simulating daylight exposure to each room is to determine if the minimum 0.5% daylight factor is met in all of the 96 perimeter patient rooms. The following table illustrates the internal and external reflectance and transmittance values used to perform such simulations.

Room Type:	Perimeter Patient	
Height above ground (ft):	20	
Simulated Room Criteria		
Feature	**Reflectance (%):**	**Transmittance**
Wall:	0.6	-
Floor:	0.3	-
Ceiling:	0.8	-
Furniture:	0.5	-
Window:	0.3	0.55
Ground (outside) :	0.23	-

INOVA Table 15: ***Space Design Characteristics***

The simulated rendering shown below illustrates South East isometric view of (4) patient rooms used to perform the simulations. The rooms will be facing: North, South, East, and West at an elevation of 20 feet (First floor height).



INOVA Rendering 36: ***Typical Perimeter Patient Room***

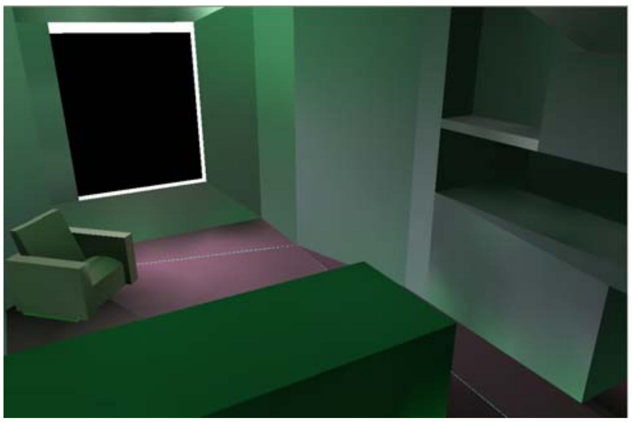
This rendering shows the simulation, which was performed on June 21st or the Summer Solstice (Longest day of the year) at noon. The simulations will also be performed on December 21st or Winter Solstice (Shortest day of the year) and on March 21st or Vernal Equinox (Middle day of the year) also at noontime. For the purpose of this daylight analysis only illuminance levels will be considered at the peak point in the day or noon. The simulated values obtained for external illuminace and the associated internal illuminace needed to meet the minimum daylight factor or shown in the table below. Simulations were also performed at 8am and 4pm and results can be found in Appendix B.3.

Location:	Washington D.C.	
Conditions:	Overcast	
Recommended Daylight Factor (%):	0.5	
Time Performed: 12pm	**External Illumance (fc):**	**Internal Illuminance needed (fc):**
March 21st (*Vernal equinox)	6719	33.595
June 21st (Summer solstice)	8920	44.6
December 21st (Winter solstice)	3133	15.665
**Autumnal equinox will produce the same results as the Vernal equinox and will not be simulated.*		

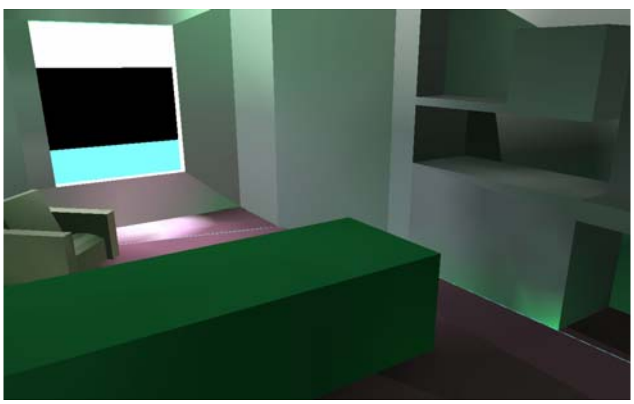
INOVA Table 16: ***Internal and External Illuminaces***

These are a sample of simulated daylight views rendered in AGI for the typical patient room on June 21st at noon.

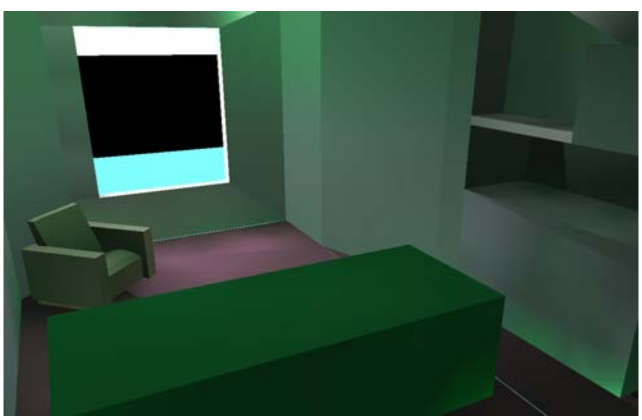
INOVA Rendering 37: *East view (Noon, June 21)*



INOVA Rendering 38: *West view (Noon, June 21)*

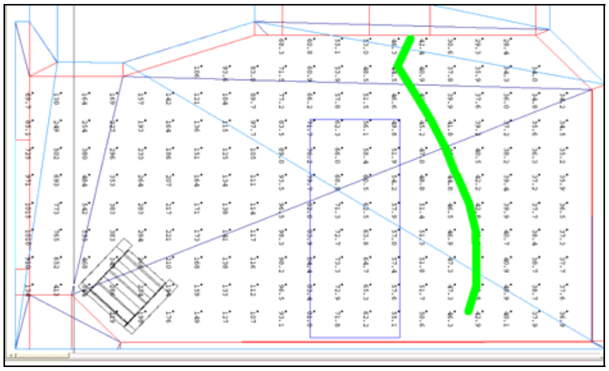


INOVA Rendering 39: *South view (Noon, June 21)*

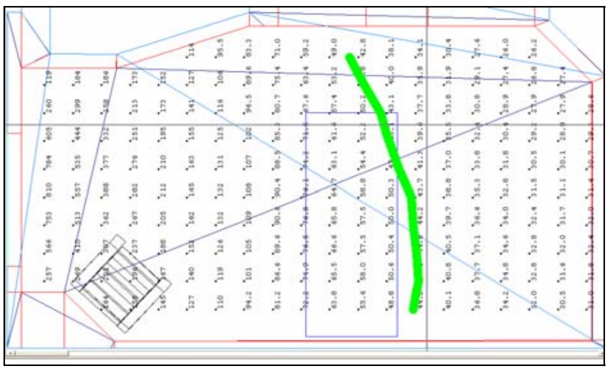


INOVA Rendering 40: *North view (Noon, June 21)*

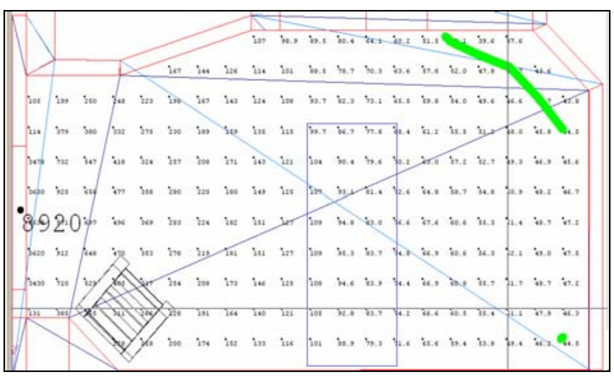
These are illuminace daylight calculations experienced by the room which were performed in AGI for the typical patient room during 3 times of the year at noon. The green contour represents where the minimum internal illuminace values needed no longer meet the recommended values. The window location is locate on the left side of the layout.



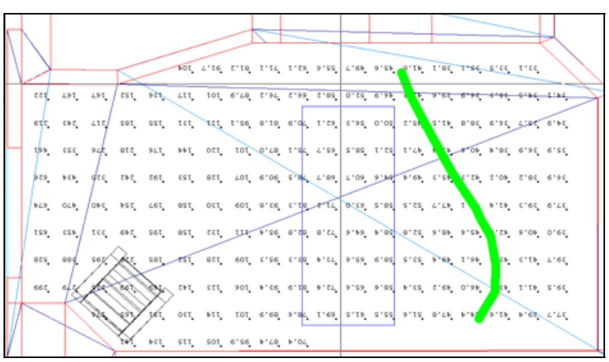
INOVA AGI Calcs. 1: *East View (Noon, June. 21)*



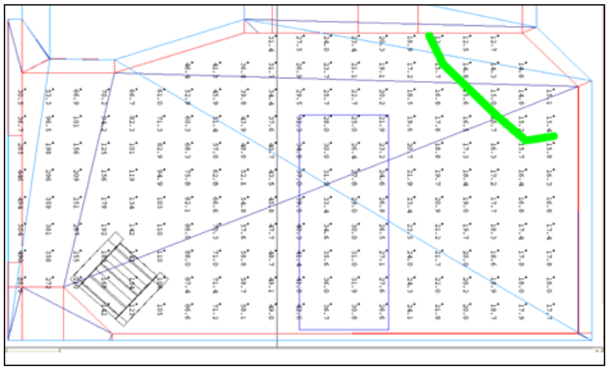
INOVA AGI Calcs. 2: *West View (Noon, June. 21)*



INOVA AGI Calcs. 3: *South View (Noon, June. 21)*

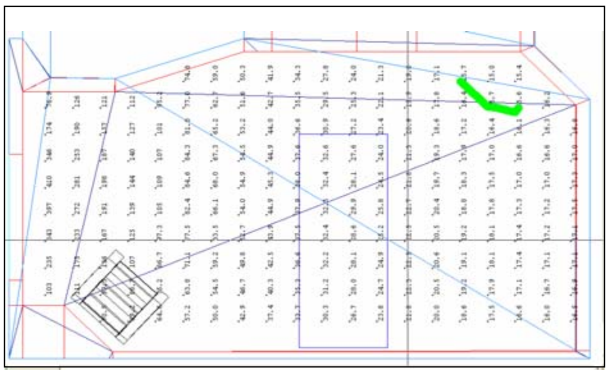


INOVA AGI Calcs. 4: *North View (Noon, June. 21)*

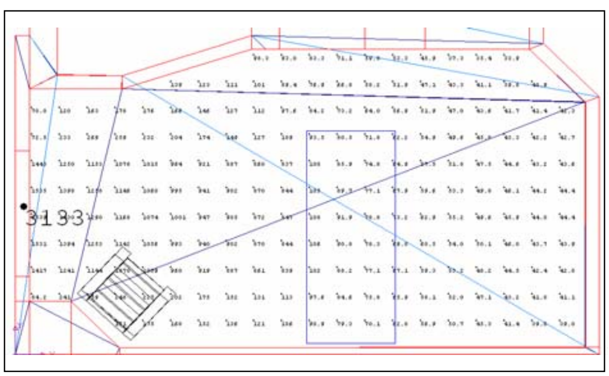


These are illuminace daylight calculations experienced by the room which were performed in AGI for the typical patient room during 3 times of the year at noon. The green contour represents where the minimum internal illuminace values needed no longer meet the recommended values. The window location is locate on the left side of the layout.

INOVA AGI Calcs. 5: *East view (Noon, Dec. 21)*

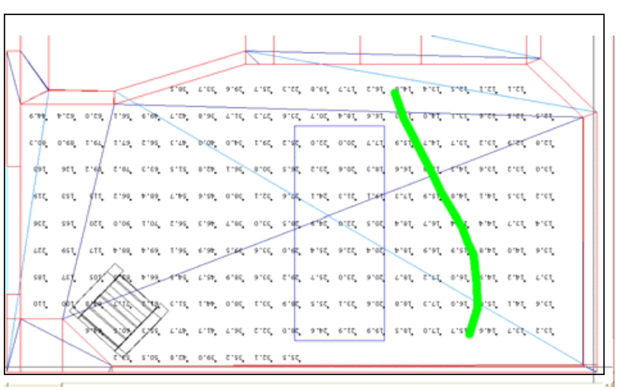


INOVA AGI Calcs. 6: *West View (Noon, Dec. 21)*

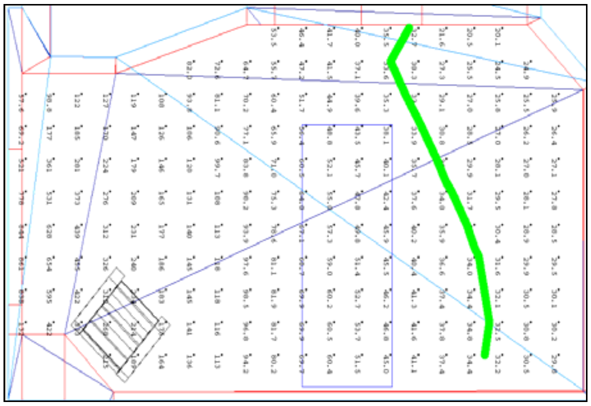


The representative contour for south view is not present because the entire space meets the minimum requirements for daylight.

INOVA AGI Calcs. 7: *South View (Noon, Dec. 21)*

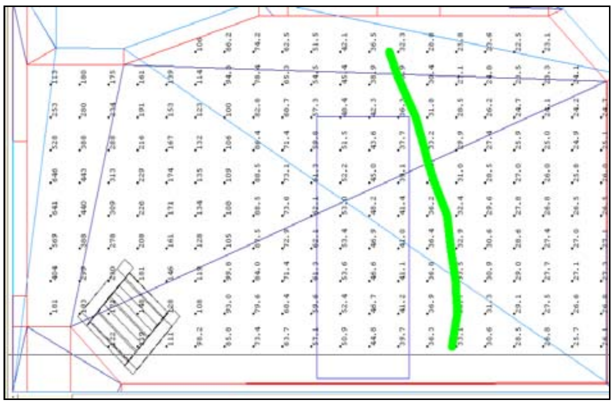


INOVA AGI Calcs. 8: *North View (Noon, Dec. 21)*

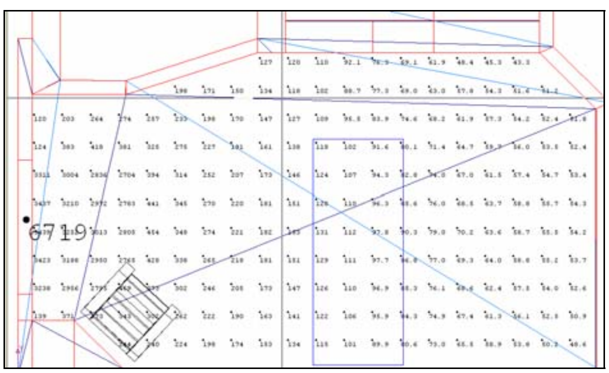


These are illuminace daylight calculations experienced by the room which were performed in AGI for the typical patient room during 3 times of the year at noon. The green contour represents where the minimum internal illuminace values needed no longer meet the recommended values. The window location is locate on the left side of the layout.

INOVA AGI Calcs. 9: *East view (Noon, Mar. 21)*

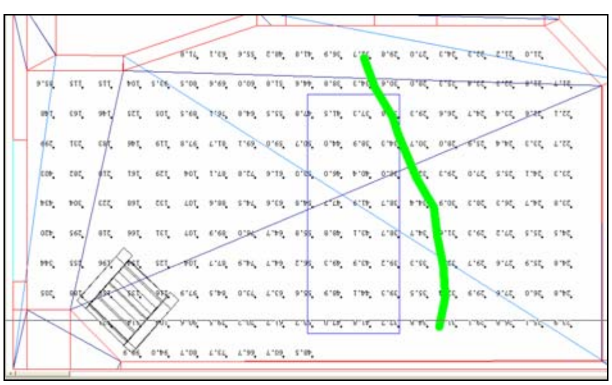


INOVA AGI Calcs. 10: *West View (Noon, Mar. 21)*



The representative contour for south view is not present because the entire space meets the minimum requirements for daylight.

INOVA AGI Calcs. 11: *South View (Noon, Mar. 21)*



INOVA AGI Calcs. 12: *North View (Noon, Mar. 21)*

From the daylight simulation analysis it can be seen that minimum daylight factor requirements are met determined in section 4.6.1 of this study and that the window reduction is possible.

5.7 Building Loads and Operating Cost

From the table shown below the windows that will be involved in the redesign equate to approximately 15% of the the total glazing of the building. The total reduction in actual window area (594ft^2) will be approximately 3%.

Window investigated:	
Direction	**Quantity**
West:	39
East:	15
North:	18
South:	24
Total windows:	96
Total window area (ft^2):	3360
Total Building window area (ft^2):	22,726
Percentage of Building (%):	14.78
Reduction in window area (%):	2.7

INOVA Table 17: ***Windows Investigated***

To determine the building loads, total energy consumed, operating cost by the new facility and entire energy analysis was performed in Carrier's Hourly analysis program for the entire facility (301,967 ft^2).

Annual Site Energy Consumed				
	after window reduct	Before Window Reduction	after window reduct	Before Window Reduction
Component	(kBTU)	(kBTU)	(kBTU/ft²)	(kBTU/ft²)
Air System Fans	21,732,518	21,732,518	71.97	71.97
Cooling	12,166,450	12,116,354	40.291	40.125
Heating	40,509,900	41,592,020	134.153	137.737
Pumps	3,698,295	3,698,203	12.247	12.247
Cooling Tower Fans	3,487,921	3,482,731	11.551	11.534
HVAC Sub-Total	81,595,084	82,621,825	270.211	273.612
	after window reduct	Before Window Reduction	after window reduct	Before Window Reduction
Component	(kBTU)	(kBTU)	(kBTU/ft²)	(kBTU/ft²)
Cooling Coil Loads	81,472,616	81,077,472	269.806	268.497
Heating Coil Loads	33,936,824	34,836,708	112.386	115.366
Grand Total	115,409,440	115,914,180	382.191	383.863
Conditioned Floor Area (ft²)	301967.7			
kBTU/yr Savings with new system implemented:			1,026,741	

INOVA Table 18: ***Annual Energy Consumed***

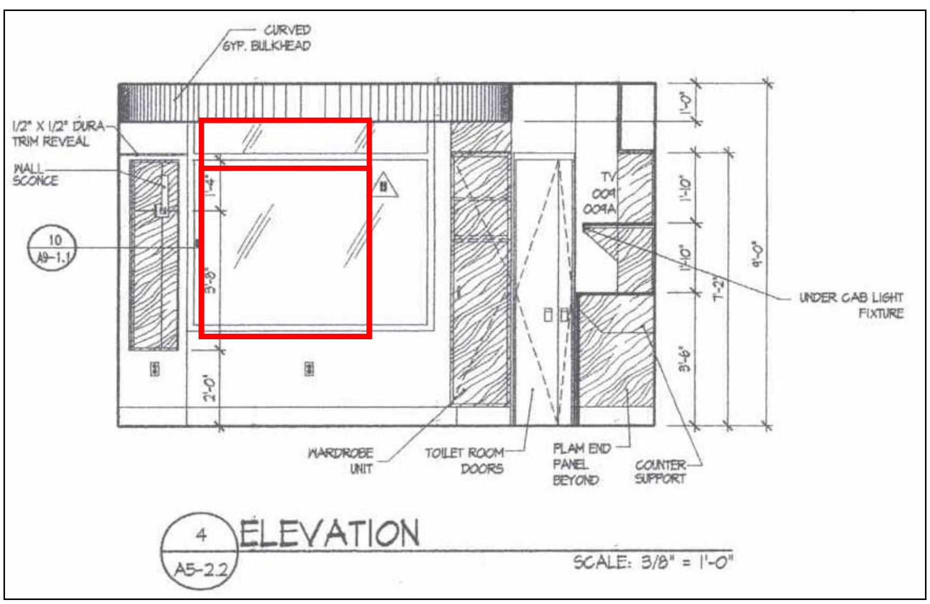
From the table shown in the previous page it can be seen that the annual mechanical load was reduced by approximately a million kBTU/yr. The total mechanical load before window reduction was estimated at 82.6 million kBTU/yr and after approximately 81.6 million kBTU/yr. The total reduction is approximately 2% of the original design. In terms of annual operating cost ($) this translate to approximately $2400 a year. The total mechanical operating cost before window reduction was estimated at $430,100 and after approximately $432,500.

Annual Cost Summary To Operate				
Component	after window reduct ($)	Before Window Reduction ($)	after window reduct ($)/ft^2	Before Window Reduction ($)/ft^2
Air System Fans	189,978	190,311	0.629	0.63
Cooling	102,932	102,787	0.341	0.34
Heating	75,207	77,293	0.249	0.256
Pumps	32,329	32,384	0.107	0.107
Cooling Tower Fans	29,671	29,685	0.098	0.098
HVAC Sub-Total	**430,116**	**432,460**	**1.425**	**1.432**
Conditioned Floor Area (ft^2)	301967.7			
$/yr Cost Savings with new system implemented			2,344	

INOVA Table 19: ***Annual Energy Consumed***

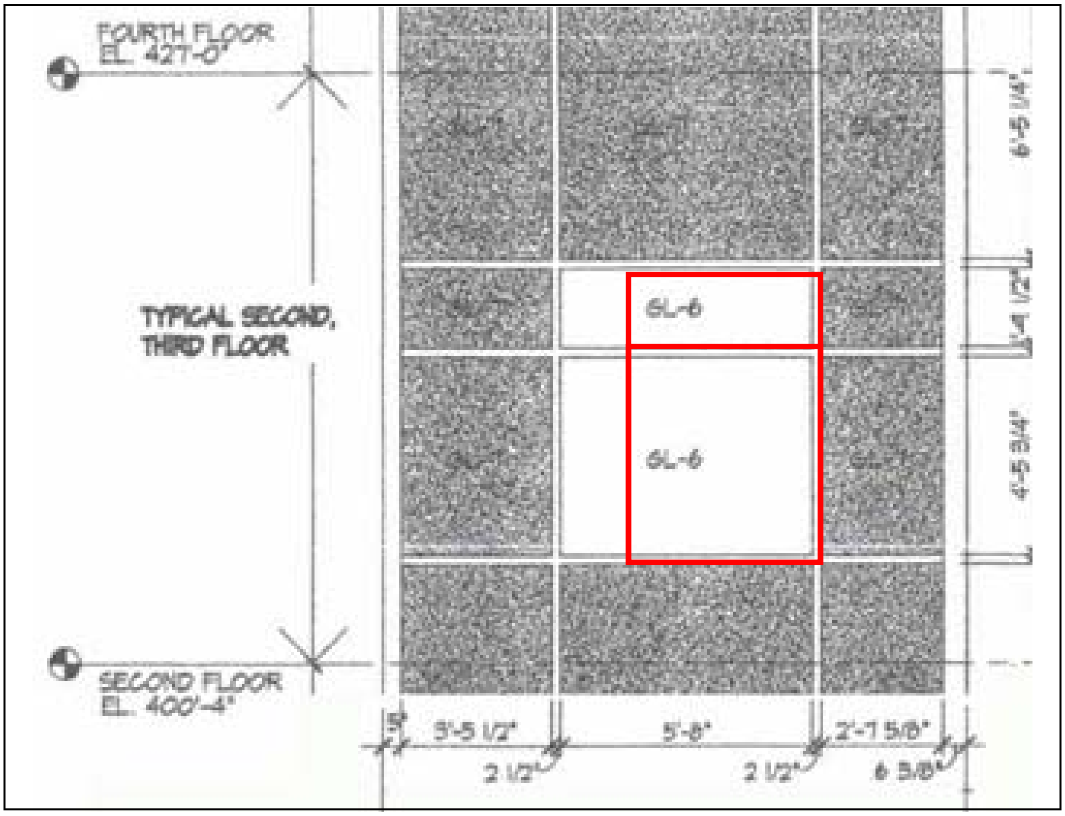
5.8 Impact on Exterior Façade

Below is an elevation of the typical patient room looking at the window exposed to the outside. Highlighted in red is the approximate window reduction from the redesign.



INOVA Rendering 41: ***Interior Patient Room Elevation***

The original dimensions and area of the window are 5'-8" x 6'-2 ¼" and 35 ft^2 Area highlighted in red represents the new window dimensions and area which are 4'-8" x 6'-2 ¼" and 28ft^2. The change in total area per window per room is 6.2 ft^2. The total reduction in window area for the 96 rooms is approximately 594 ft^2. Below is an external view of the elevation for a typical patient room a spandrel glass curtain wall façade surrounds the patient room window. A typical wall section can be found in Appendix B.4.



INOVA Rendering 42: *Exterior Patient Room Elevation*

Structurally the loads for proposed new design do not change relatively much and will not be analyzed at the suggestion of structural advisor. This is primarily due to the fact that in the absence of existing window glass, similar curtain wall spandrel glass and insulation will be replaced along with an extra vertical mullion separating existing spandrel glass and new spandrel glass to secure the replacement. Replacement spandrel glass will be used to reduce the cost of replacing a new oversized piece of spandrel glass.

5.9 Cost Analysis

The following is a cost analysis on the components that will be changed as a result of redesigning the window.

In Appendix B.5 are the associated cost cut sheets provided by RS MEANs.

Window Renovation Cost						
Feature	**$/ft^2**	**$/unit**	**ft^2 replaced**	**$/room**	**# rooms**	**Total cost**
Interior wall:	4.66	-	6.2	28.892	96	2773.632
New window (4'-8" x 6'-2 ¼"):	-	1735	-	1735	96	166560
Old window (5'-8" x 6'-2 ¼"):	-	2107	-	2107	96	202272
Mullion Framing (spandrel Glass):	8.6	-	6.2	53.32	96	5118.72
Painting Interior Walls:	0.84	-	6.2	5.208	96	499.968
Spandrel Glass replacement:	17	-	6.2	105.4	97	10223.8
Curtain wall/Ins. hardware (15% S. Glass):	-	-	-	-	-	1533.57
Total Cost of Original window:						202272
Total Cost of new window and modifications:						186709.69
Cost Savings from Original Design:						15562.31

INOVA Table 20: *Window Renovation Cost*

The new design would have savings on original design if implemented as the original design. The annual savings in HVAC Operating cost would be a year $2344 approx. Based on information provided by local consulting firm based out of Washington DC the typical assumed value for demolition and removal of existing material such as curtain wall and window facades is approximately 25 % of initial cost. This means that if the redesign was implemented after original construction that additional $46,677 would be tacked on to the total cost of the new window and modifications cost of $186,709 or a total cost of $233,387. This is obviously not a wise choice if the annual mechanical operating cost savings is only 1% of the new renovation cost $2344 per year.

5.10 Feasibility of Results.

The only way that the new design would be acceptable is if it was initial implemented as an addendum to the original design before construction. Again, the new design would have saved approximately $ 15,000 and saved on mechanical operating costs which was estimated to be $2344 a year. It must be realized that this is all with respect to loosing 20% of the original window area in the perimeter patient rooms. Values are only estimated and simulated approximations of cost and may vary.

5.11 Summary

The potential for savings through daylighting is affected by location, climate, building use, and building form. Through the investigation of optimizing of natural daylight it was determined that reducing overall glazing area to achieve mechanical operating cost benefits was not effective. This is due to the small fraction of actual glass area that was reduced and the cost of implementation to actually change the windows. The facility in general is rather large is operational all the time, the cost benefits were minimal compared to overall mechanical operating cost and sufficient savings were not realized because of this. It must be noted that the building does have premium quality glazing with Low-E glass which does perform a valid service when saving energy.