CHRISTOPHER NEWPORT UNIVERSITY

Paul & Rosemary Trible Library

Madeline Hess

04.05.2021

Final Report

LIGHTING DEPTH | ELECTRICAL DEPTH | MAE DEPTH | ACOUSTIC BREADTH | STRUCTURAL BREADTH

NOTE: All images used in this report courtesy of Lam Partners, Christopher Newport University, and Glave and Holmes Architecture.

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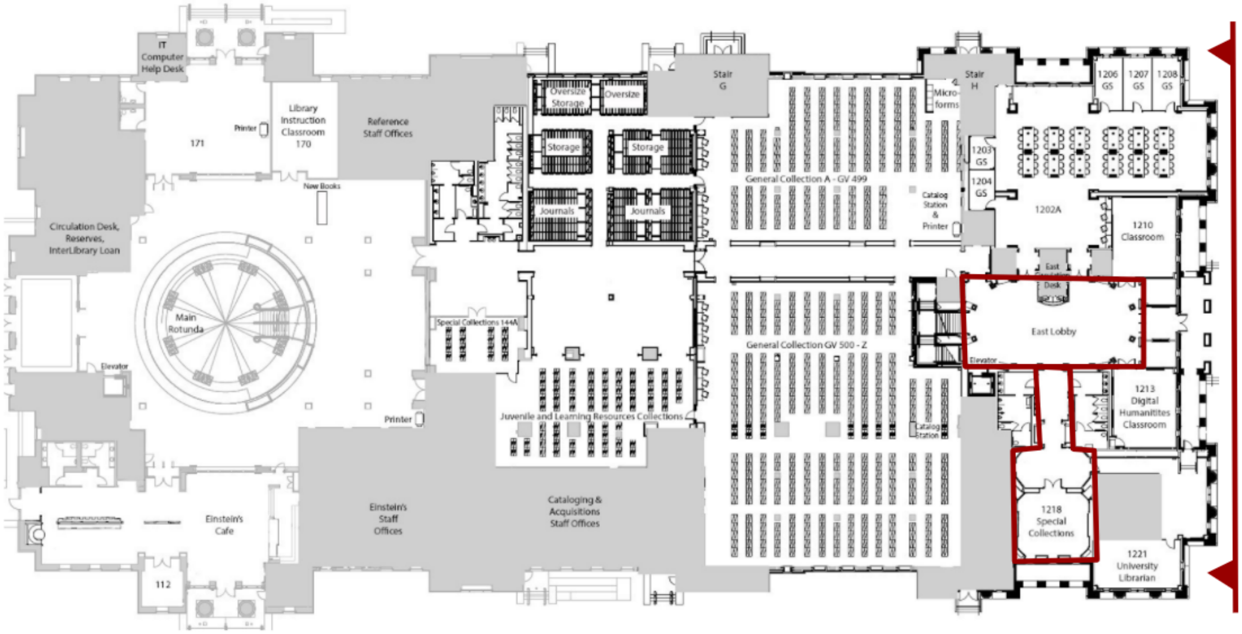
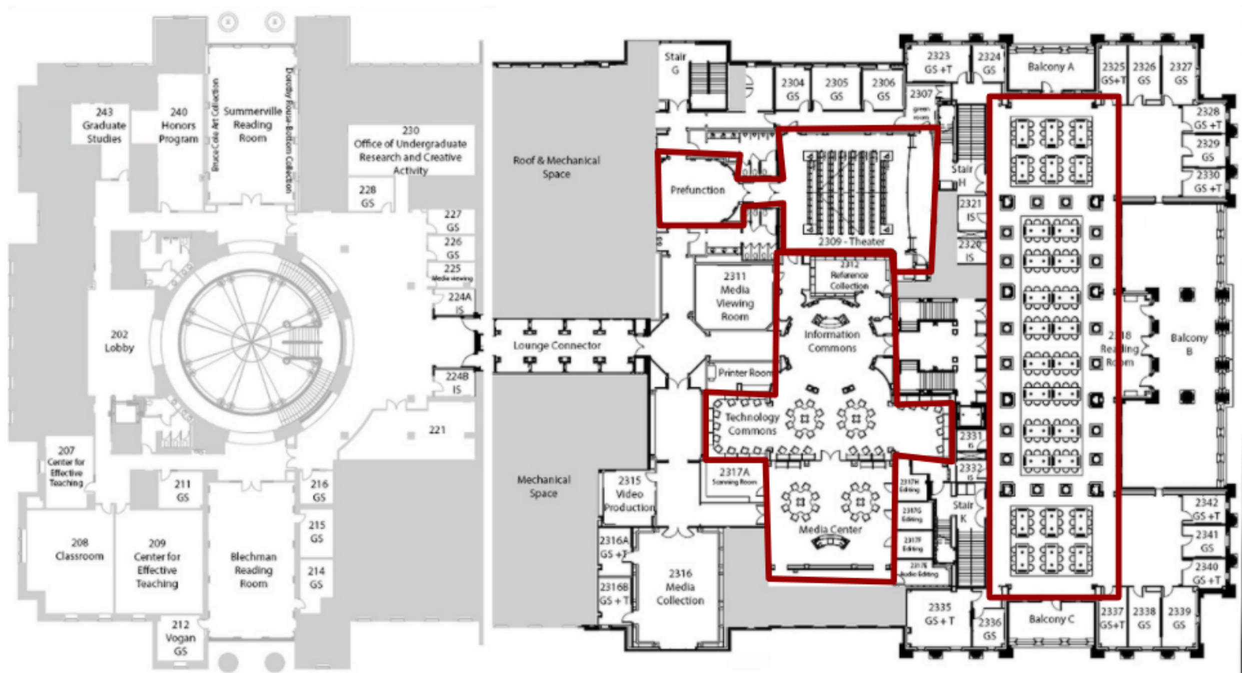
SPACES OF STUDY





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INTRODUCTION

Executive Summary

The Paul & Rosemary Trible Library at Christopher Newport University in Newport News, VA, has served as a focal point of the school's campus since 1966. Successive additions and renovations have kept the building relevant and useful for students, the most recent of which was, up to the point of this project, in 2008. 2016 saw the completion of the 63,000 square foot Phase II renovation, which increased the Library's seating capacity from 200 to 1,000, and included an expanded media center, a café, a lecture hall, and a new two-story reading room, among other improvements. The content of this project focuses on this most recent renovation, which has helped the Library transition into a modern, student-oriented hub.

The following report is a compilation of a year's study into the library's architectural systems, both aesthetic and functional. Included are the analyses listed below.

- Conceptual and schematic lighting designs for selected spaces of importance, conforming to design criteria set forward by IES
- Introduction of daylight to a large, windowless interior space, including analysis of daylight autonomy metrics
- Integration of new skylights with an altered structural roof system
- Qualitative and quantitative acoustical analysis of a theater space, and proposed noise mitigation techniques
- Analysis and redesign of controls systems present in key spaces to respond to daylight and provide dynamic lighting options

As a whole, the proposed design modifications to Trible Library aim to best serve the building's goals of providing a beautiful, pleasant environment which promotes student connection and curiosity, while also promoting modern and energy-efficient design solutions.

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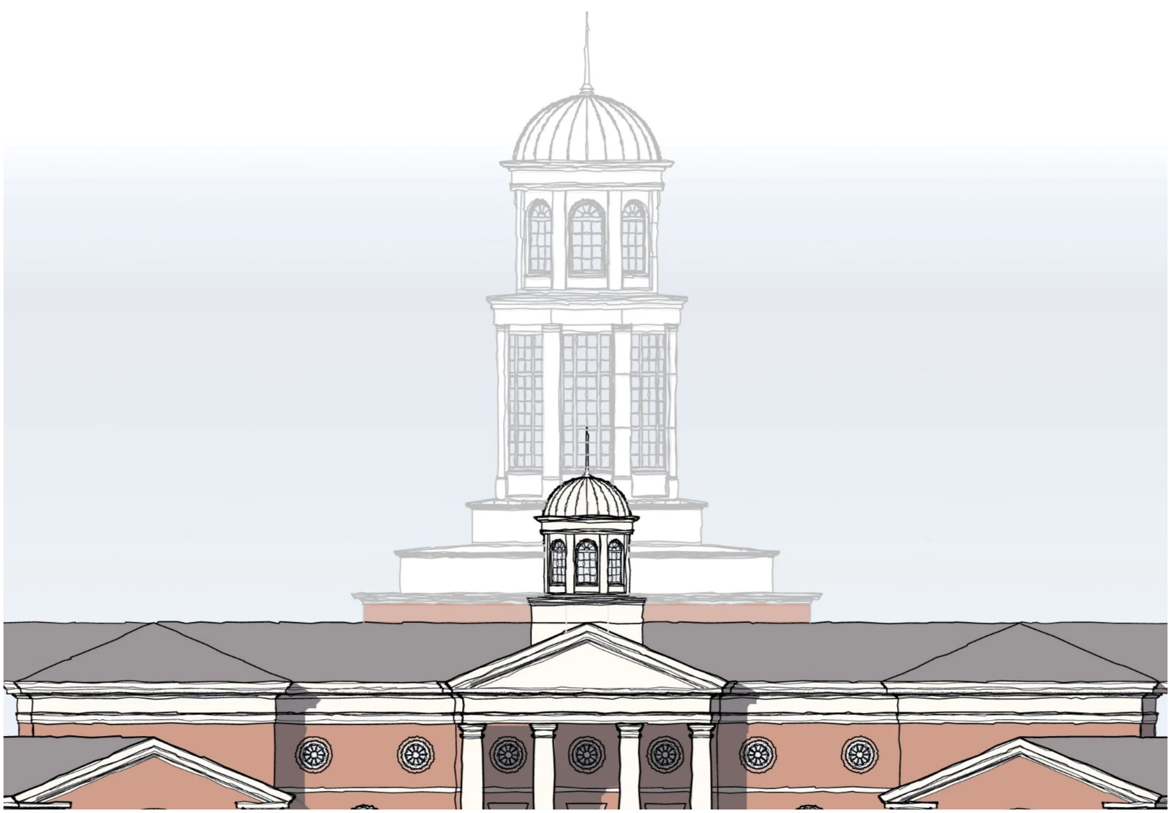
Building Statistics

Building name	Paul & Rosemary Trible Library
Location and site	Newport News, VA
Building Occupant Name	Christopher Newport University
Occupancy / function types	Use types per VUSBC A3 - Assembly (Library), B - Business (Office), S1 - Moderate-Hazard Storage
Size (total square feet)	156,407 SF
Stories above grade / total levels	4 stories above grade (L4 is an attic)
Dates of construction	1966 (original completion), 1978 (addition), 1993 (addition), 2008 (major addition/renovation) 2014-2016 (Phase II renovation)



Project Goals

Despite the many disparate analyses that comprise this year-long study, a unified goal is present as an undercurrent of the project. The best definition of what this building is appears on the Library's website as a mission statement:

> " The Trible Library is the intellectual center of Christopher Newport University. We help students develop research skills and support the **scholarly and personal growth** essential to the study of the liberal arts and sciences. We combine the best of a **traditional library with modern technology** to create an interactive learning experience for the 21st century. "

This marked the project's goal very clearly: encourage the minds of students - their curiosity, their determination, and their love of learning - by synthesizing the past and present. The architectural design of the building lent itself to this, as the neoclassical and colonial elements are already modern echoes of past design languages. But this idea goes beyond the purely aesthetic. In analyzing and designing each system I had chosen to investigate, I focused on the inclusion of distinctly modern elements. This extends from daylighting-based and networked lighting controls to the implementation of an integrated lighting and acoustic system.

Through the creation of spaces which are visually steeped in the past but decidedly modern in function, a contrast appears which emphasizes the positive aspects of both disparate elements. Not only will students be able to inhabit a comfortable, beautiful series of spaces, but they will also be encouraged to engage with the mission statement the University itself put forth for them.

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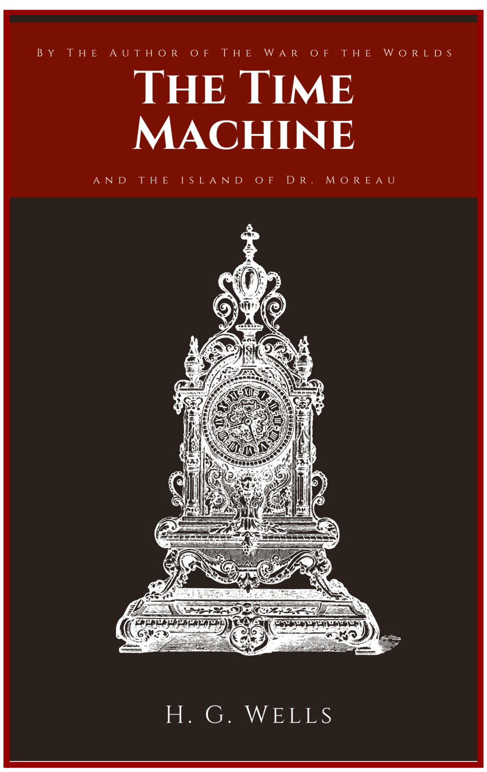
LIGHTING DEPTH

CONCEPT DEVELOPMENT

Books and knowledge as a whole serve as a form of time travel. They are ideas which are encapsulated and sent into the future for us to find. The neoclassical elements woven into the design of the library provide this same time capsule feeling - so what better place to start for this library's design than a book? And, by extension, what better book than H.G. Wells' *The Time Machine*, the story of a man so bent on exploration and discovery that he throws himself into an entirely different world.

The choice to take inspiration from this book wasn't arbitrary; H.G. Wells was not only an author, but a futurist. He wrote many pieces on how man could improve himself, and on predictions concerning technology and human rights. The redesign of the Library's lighting is unified by Wells' futurism, which has been distilled into some of his most important points and applied as design concepts in each space.



These concepts include:

UTOPIA	READING ROOM
NETWORK	100-PERSON THEATER
GENETICS	SPECIAL COLLECTIONS
EXPLORATION	LOBBY
NATURE	MEDIA COMMONS
INCLUSION	EAST FACADE

This translates into a concerted effort to emphasize the Library's neoclassical elements through the contrast of distinctly simplistic, modern lighting design.

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READING GUIDE

As there are many moving parts to the communication of the lighting depth, this guide aims to provide clarity and an idea of what to expect while reading. For each of the six spaces, with the exception of the slightly less-comprehensive facade redesign, there are six main pages of content.

PAGE 1	-	Overview of the space, qualitative / quantitative criteria, key plan
PAGE 2	-	Concept development, precedent images, and / or concept illustrations
PAGE 3	-	Pseudocolor and proof of met quantitative requirements
PAGE 4	-	3D lighting plan with main fixture types highlighted[1]
PAGE 5+	-	Rendered and additional view(s) of final design[2]

Note 1: In an effort to keep this report streamlined and accessible, full fixture schedules and tagged plans have been excluded from the main written portion. For a complete master lighting fixture schedule and tagged lighting plans, please refer to ***Appendix I.***

Note 2: As the facade lighting is not in need of a major redesign, only a rudimentary final rendering will be shown. For rendering base / component image citations, please refer to ***Appendix IV.***

Reading Room

Description

The double-height reading room serves as the focal point of the library both physically and thematically. Students gather here to study, read for leisure, and share ideas.

This space will be the heart of the redesign's concept, the most blatant meeting of past and future.

Qualitative Criteria

Daylight

Respond to and make use of the large amounts of available daylight

Ornament

Call attention to the major decorative elements, including the composite columns and cupola

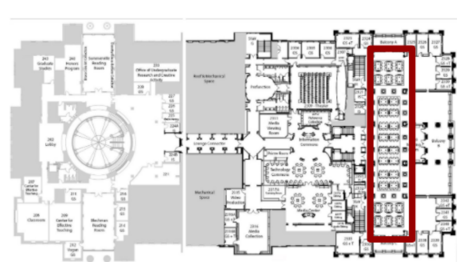
Task

Maintain a sense of individual focus at each student workstation, while creating a cohesive whole

Quantitative Criteria

IES recommendations (lux)	Plane	E_h	E_v	Uniformity
Grand reading room	2'6" AFF	200	75	2:1
Tables & chairs	2'6" AFF	200	100	2:1

Power allowance (ASHRAE 90.1, 2013)	LPD
Library (Reading Room)	1.06



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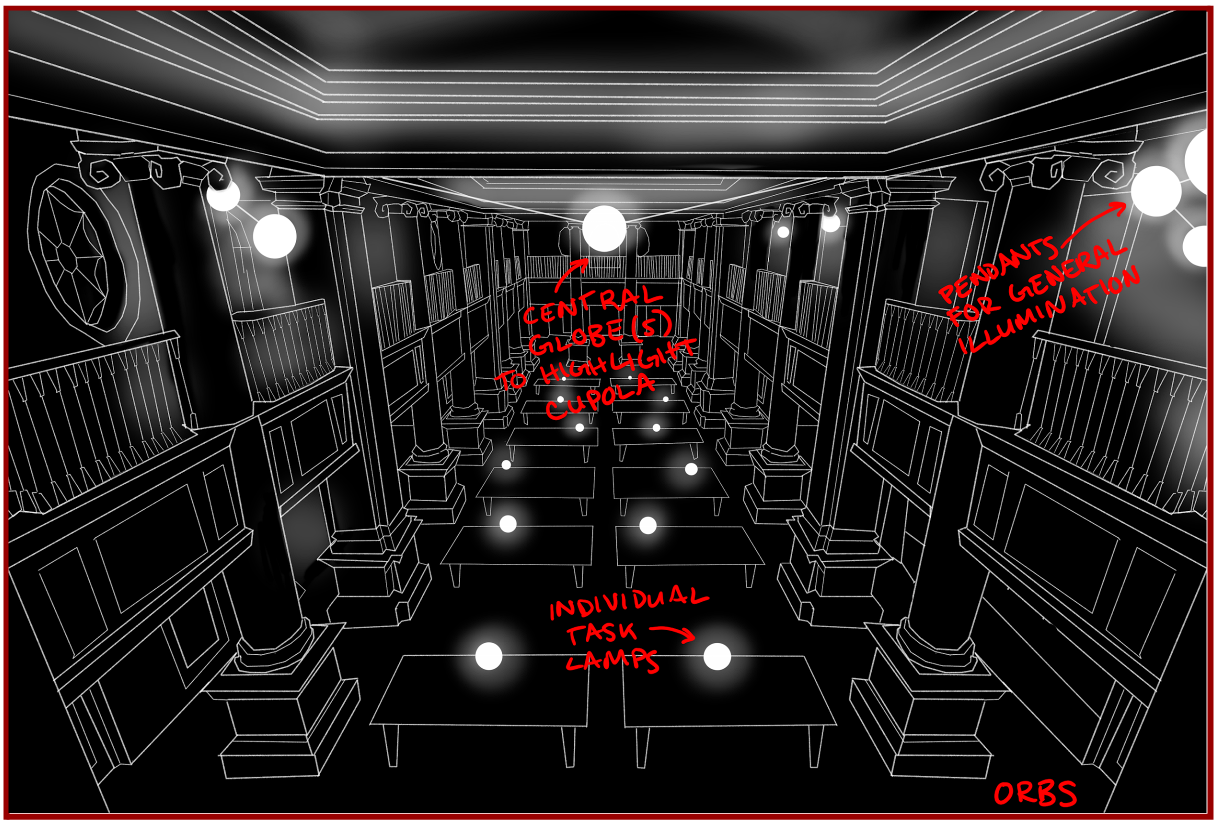
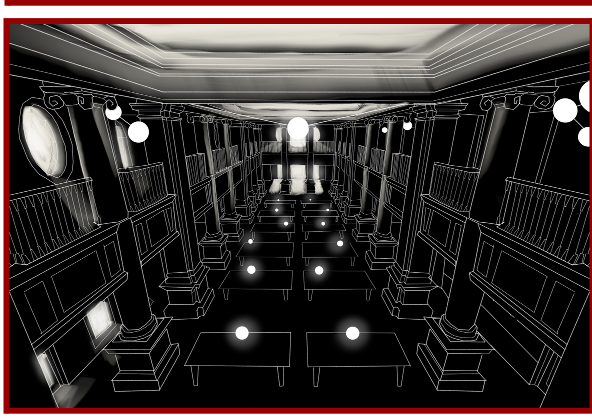
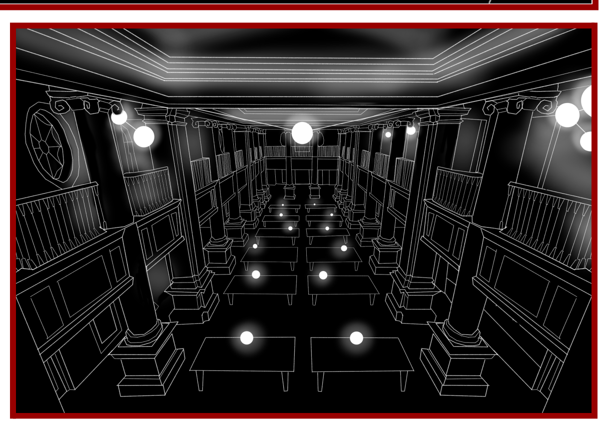
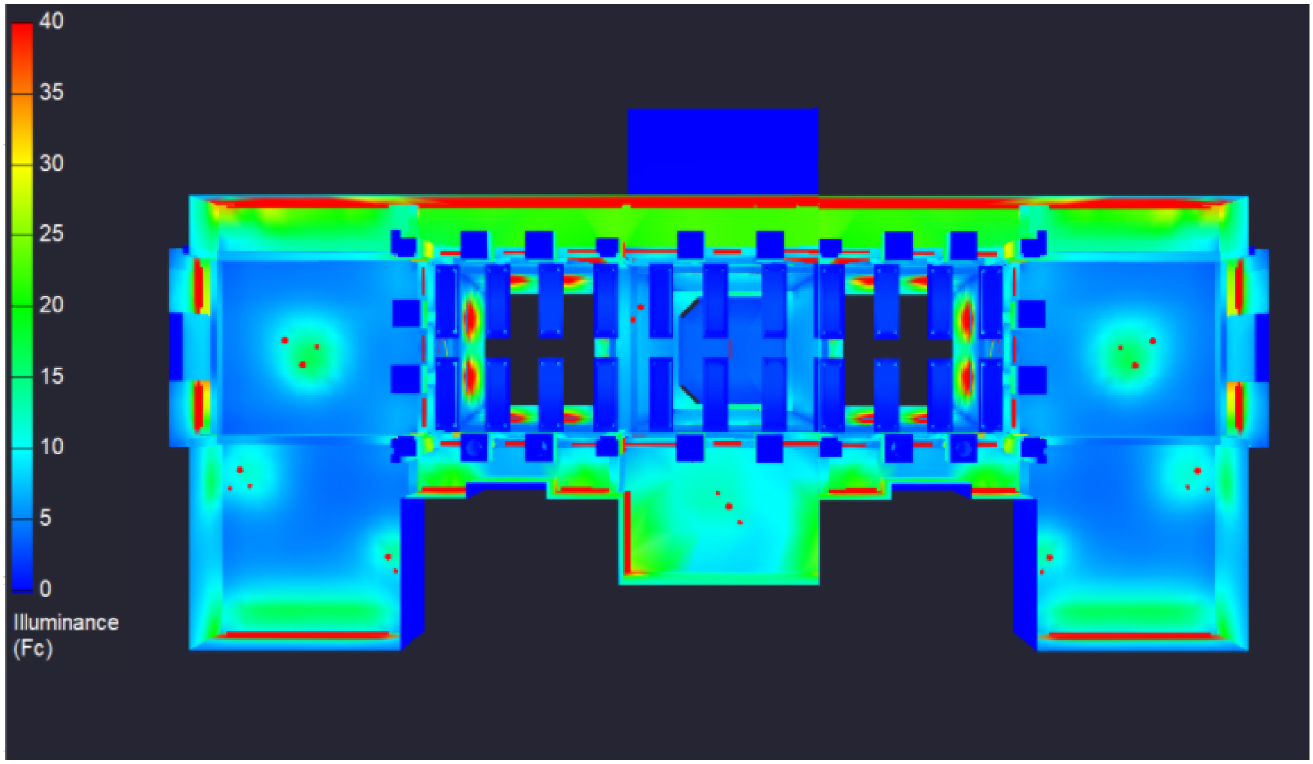
All the futurist writings and musings of H.G. Wells come together in his idea of Utopia, a perfect society of enlightenment, beauty, and freedom from pain. This appears not only in *The Time Machine*, but also in a number of his other works. And it's not just Wells who strives for this idea of Utopia. Whether writers and musicians and architects know it or not, they're all working toward their idea of Utopia, this better world, by putting their best work into our current one. This concept was meant to apply the simplistic round forms often employed to represent a society from which all the rough edges have been smoothed away, highlighting the detailed neoclassicism by contrast to simplicity.









Lighting criteria	IES level	Design level	IES Uniformity	Design Uniformity
Grand reading room / tables - F1	200	234	2:1	2.02:1
Grand reading room / tables - F2	200	161	2:1	1.91:1

Power allowance	ASHRAE LPD	Design LPD
Library (Reading Room)	1.06	0.288

Please note that, due to the complex nature of the roof of the Reading Room, this pseudocolor was taken from beneath the structure.

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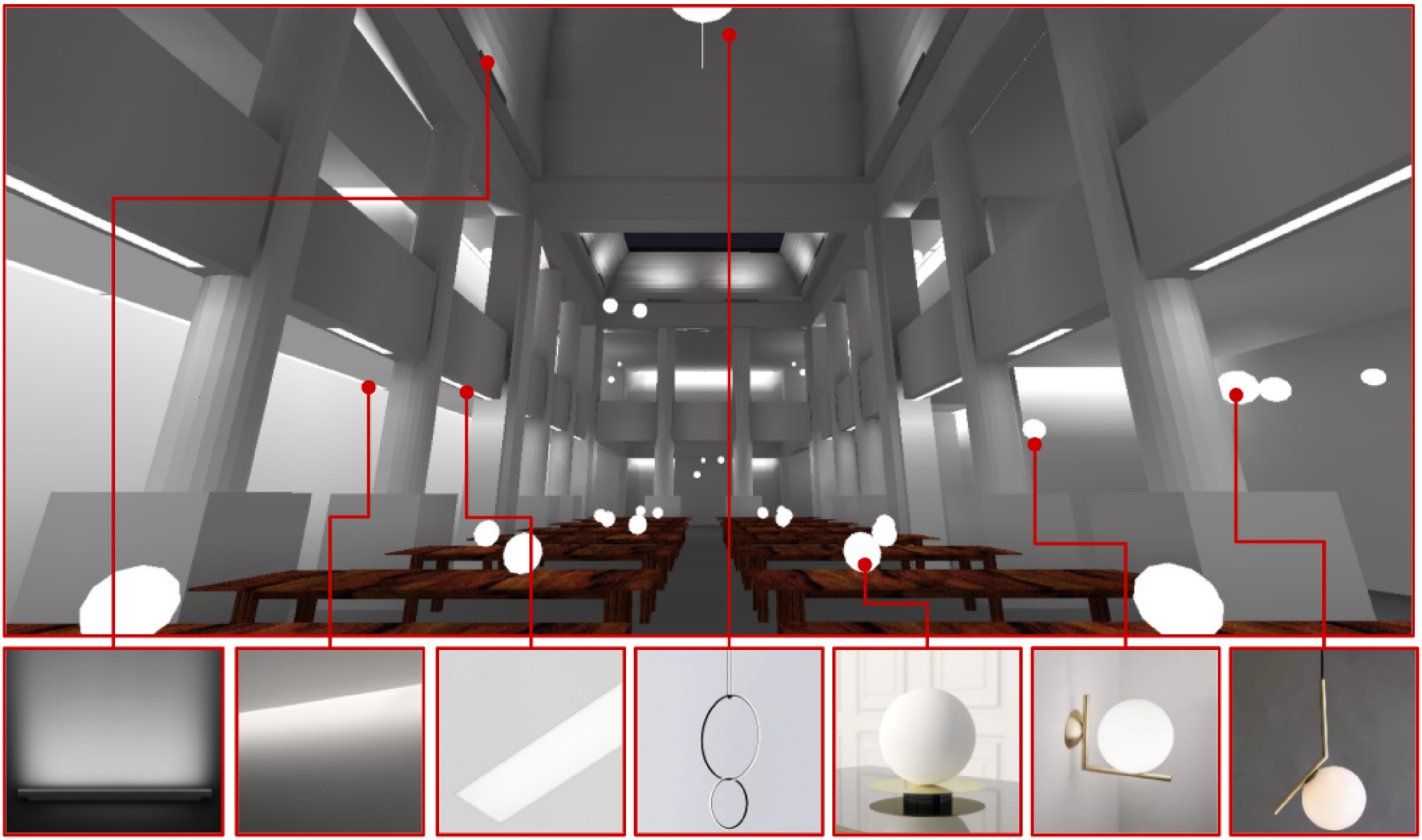
Due to the complex nature of the space, a perspective view is shown, rather than a flat plan.



Multi-part chandelier

12" globe table lamp

12" globe wall sconce

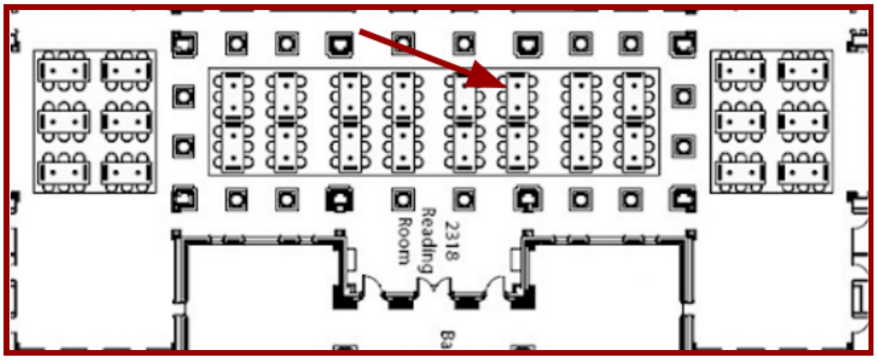
12" globe brass pendant

30x60 linear wall graze

Low-profile wall wash

6" recessed linear

This image shows the Reading Room in daylight. In reality, most lights would be dimmed or off in this scenario. Outputs are exaggerated to show effect.



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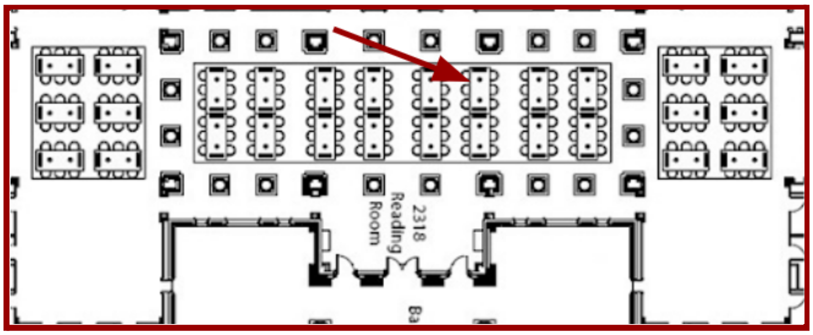
This image shows the Reading Room in the evening or at night. Note that the table lamps have been switched on. The wings and upper level are more subdued study areas, while the center is more brightly lit.



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100-Person Theater

Description

This small theater is available to be used for lectures and visiting guest speakers. Subtle but modern lighting should be used to highlight, rather than mimic, the classical elements present in the theater, while helping provide a psychological impression of spaciousness.

Qualitative Criteria

Spaciousness

Create a feeling of spaciousness should be created in this otherwise crowded space

Controls

Provide responsive, adaptive controls which offer a greater degree of versatility to a small space

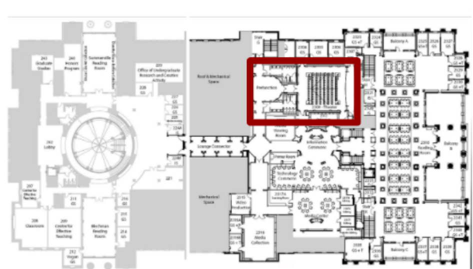
Era

Avoid simple mimicry of the past — help it stand out by including contrasting design choices

Quantitative Criteria

IES recommendation (lux)	Plane	E_h	E_v	Uniformity
Audience (during show) / (pre/post)	Floor	2 / 100	1 / 30	2:1
Circulation	Floor	10	—	3:1
Stage	Floor	50	—	—

Power allowance (ASHRAE 90.1, 2013)	LPD
Auditorium	0.73



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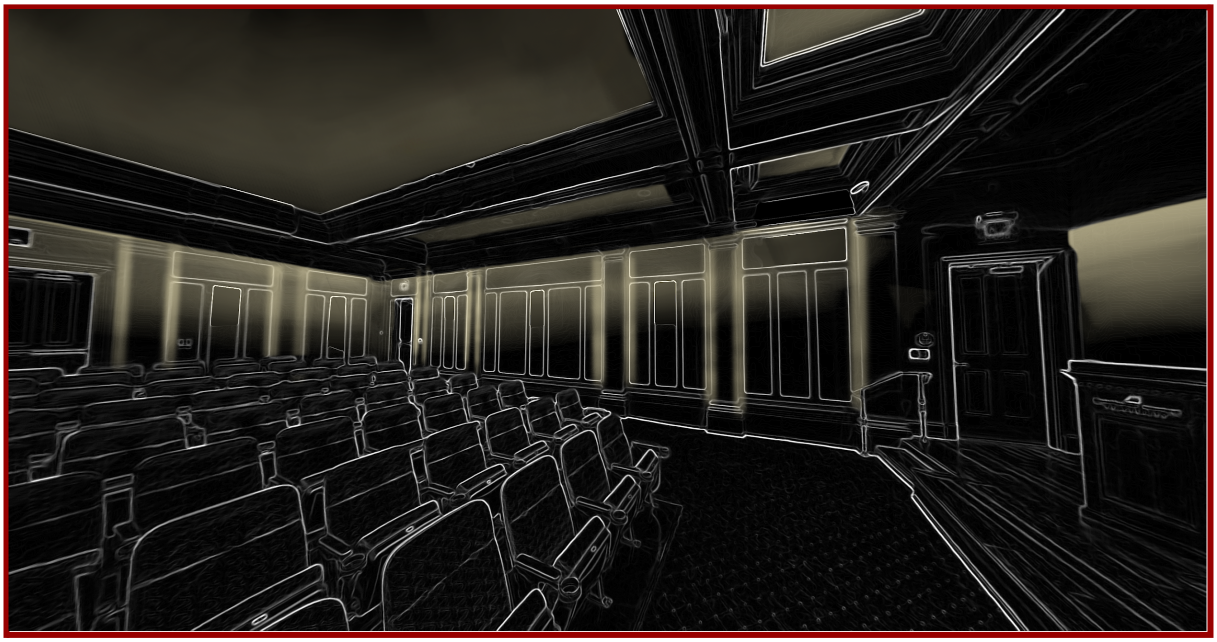
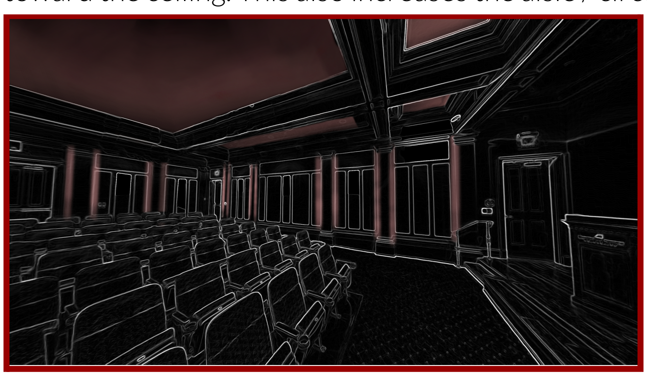
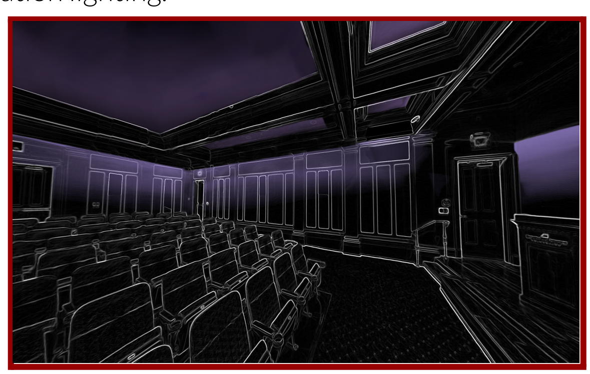
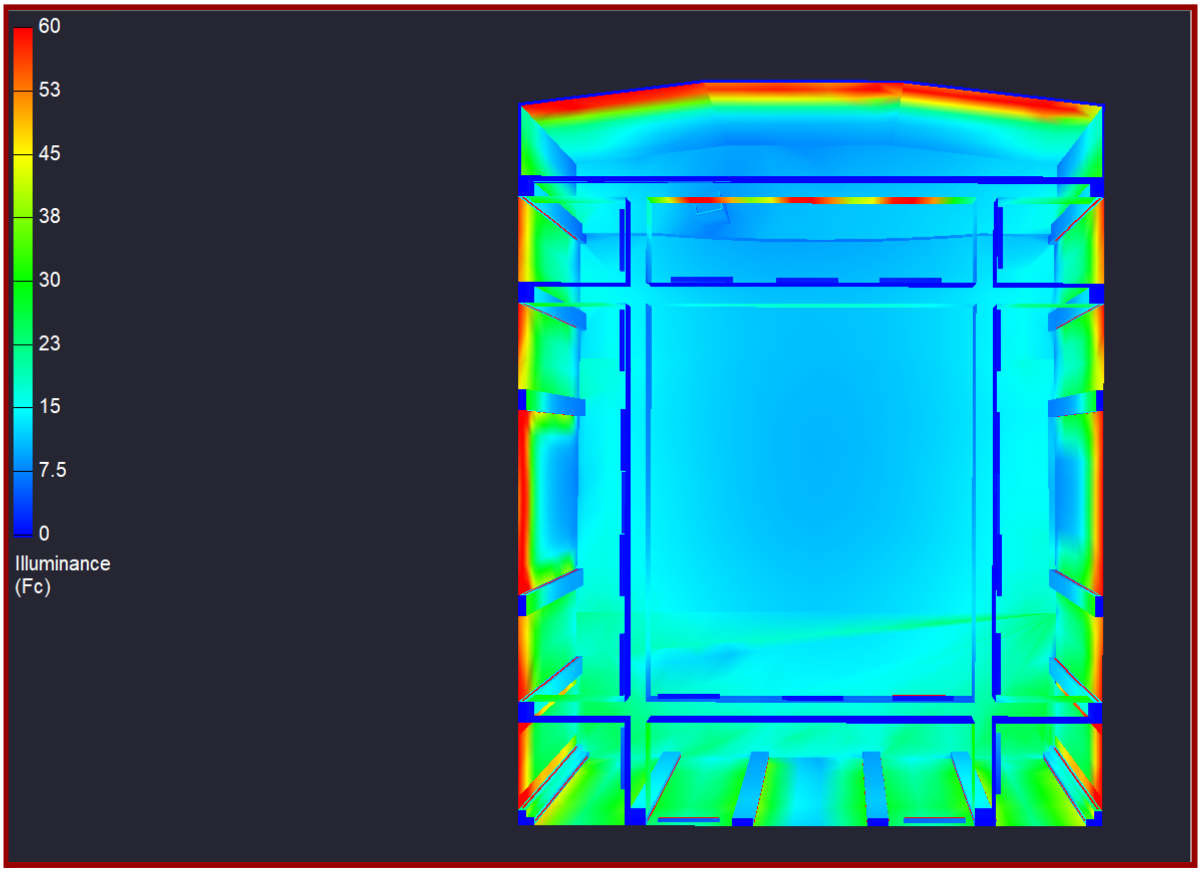


One of HG Wells' most impressive predictions was that we would all one day be connected through a wireless network. That connectedness translates well to a space for speakers sharing knowledge and connection through the arts. It also lends itself well to something I've personally worked with in a theater capacity: DMX networks. In a relatively small space with many functions, DMX can help keep things versatile, especially when coupled with RGBA / RGBW fixtures. This space also promotes a Flynn mode of spaciousness. An open feeling is achieved through perimeter lighting, particularly from the ceiling through wall slots, creating a floating ceiling effect. Additional soft lighting on the ceiling helps to reinforce this. Finally, to highlight the classicism present in the space, backlighting the pilasters emphasizes them cleanly and naturally, while continuing the verticality and sense of lift toward the ceiling. This also increases the aisle / circulation lighting.





The image on the left is an example of a more closed-off, subdued mode of lighting for a serious keynote speaker, while the right is a brighter, more ethereal mode, perhaps for a small music recital.



Lighting criteria	IES level	Design level	IES Uniformity	Design Uniformity
Audience (during show) / (pre/post)	2 / 100	144	2:1	1.25:1
Prefunction (during show) / (pre/post)	50 / 150	163	3:1	2.4:1
Circulation	10	144	3:1	1.25:1
Stage	50 min.	120	–	1.6:1

Power allowance	ASHRAE LPD	Design LPD
Auditorium	0.73	0.716

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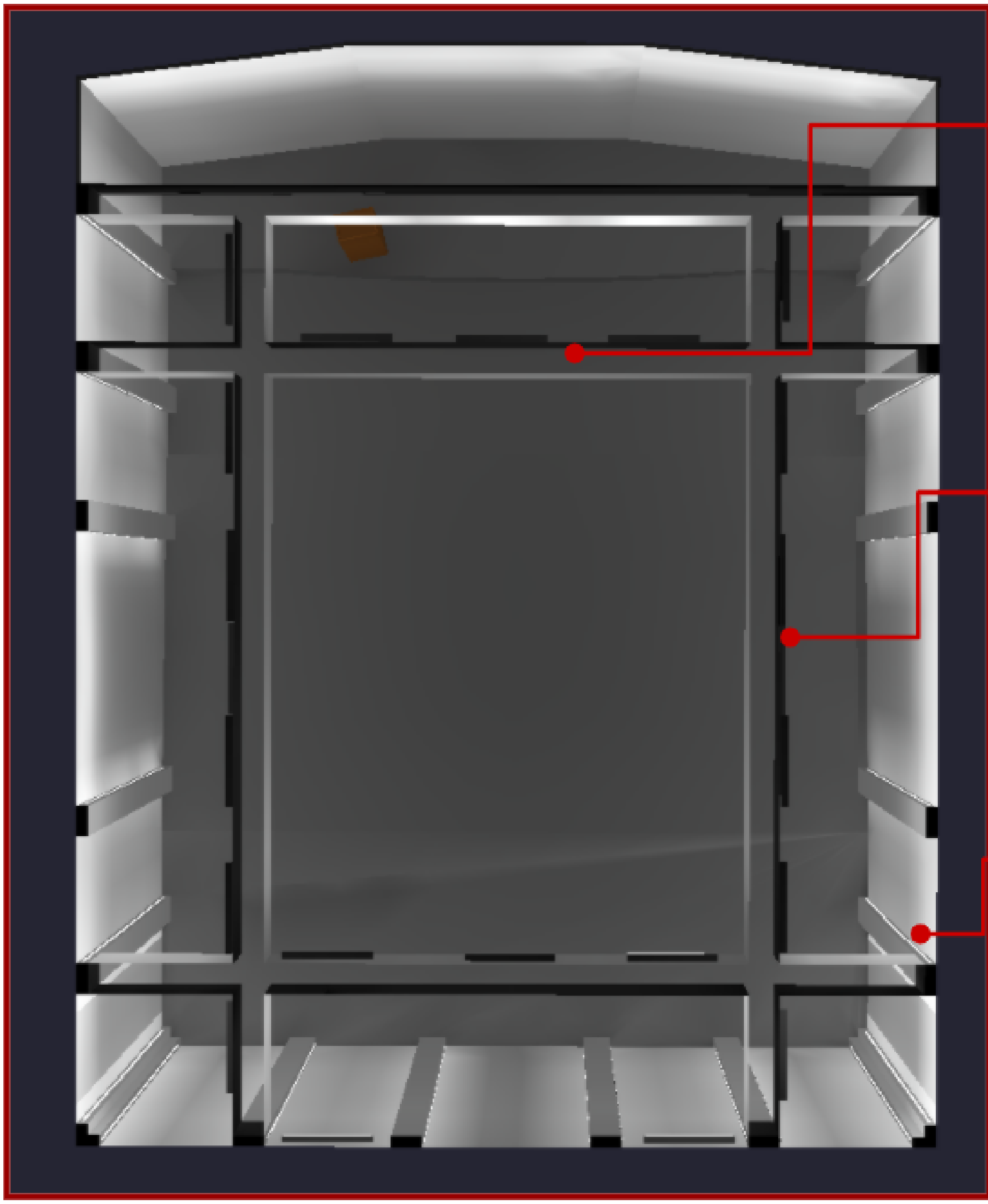
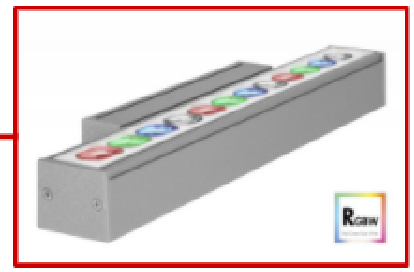
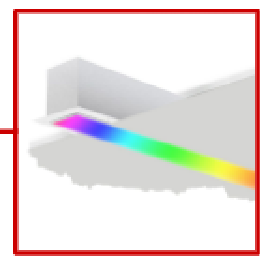


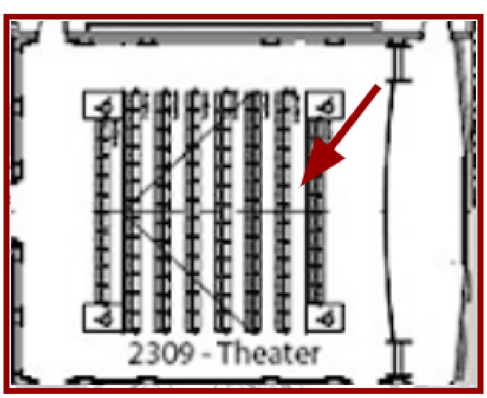
4' linear RGBW with 8x8 distribution to illuminate ceiling



4' linear RGBW with asymmetric wall-wash distribution



1" aperture linear RGBW with frosted lens



The key plan to the left corresponds to the renderings on the following page.

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The top image shows the pre/post show mode; the bottom represents one RGBW option.

Special Collections & Display Gallery

Description

The special collections and display gallery houses paintings and other media, requiring dim lighting, so as not to damage any delicate materials.

A deliberately subdued, delicate design will help highlight the works on display here without distracting from them.

Qualitative Criteria

Delicacy

Protect the works on display from damage due to overexposure

Flexibility

Create a quiet, intimate space to contrast with the lobby, which is directly adjacent and may be loud

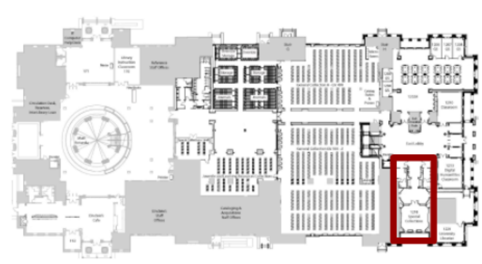
Intimacy

Incorporate the ability to accommodate multiple exhibition types and various collections

Quantitative Criteria

IES recommendation (lux)	Plane	E_h	E_v	Uniformity
Displays (subdued focals)	Floor	0.2x object	0.2x object	4:1
Objects (high sensitivity)	At object	25	25	2:1
Special collections (archival storage)	3' AFF	150	50	2:1

Power allowance (ASHRAE 90.1, 2013)	LPD
Museum	1.05
Library (stacks)	1.71



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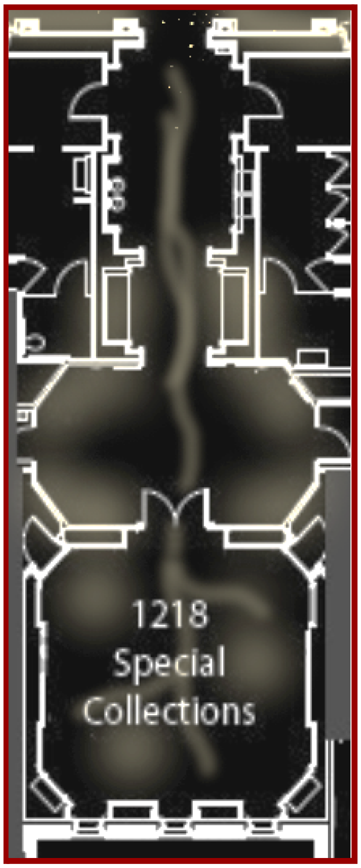
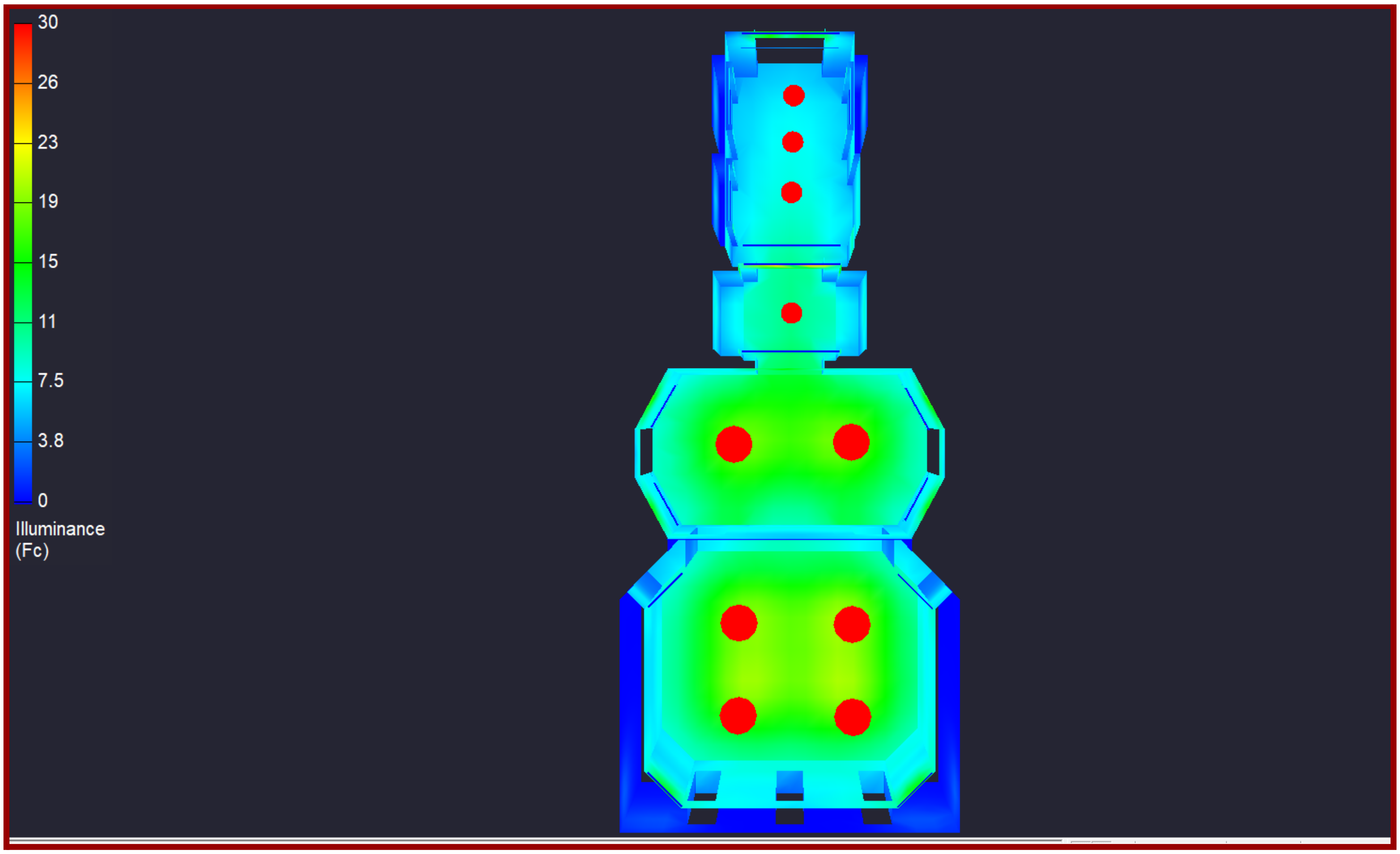


The conceptual development of this space was focused on soft, organic forms in order to echo H.G. Wells' writings on genetics. His interest in the subject makes itself known in *The Time Machine* in the far future, when humans have been refined into gentle, subdued, small beings. That sense of gentleness, as well as the organic forms and smallness of DNA itself, are used here to create a delicate mode of lighting for precious materials.

Quiet, gentle clusters of light are spread through the space, providing both general illumination and decoration. What's more, the amorphous form of this lighting makes it possible to arrange shelves or displays in the Special Collections area in any configuration, while still achieving the same effect. The display lighting inside the cases highlights the exhibits, while the soft general illumination guides guests through the space, creating a decidedly quieter mood from that of the adjacent lobby.



Lighting criteria	IES level	Design level	IES Uniformity	Design Uniformity
Displays (subdued focals)	0.2x object	130		
Objects (high sensitivity)	25 max	23 max	2:1	1.13:1
Special collections (archival storage)	150	130	2:1	1.73:1

Power allowance	ASHRAE LPD	Design LPD
Museum	1.05	0.356
Library (stacks)	1.71	0.356

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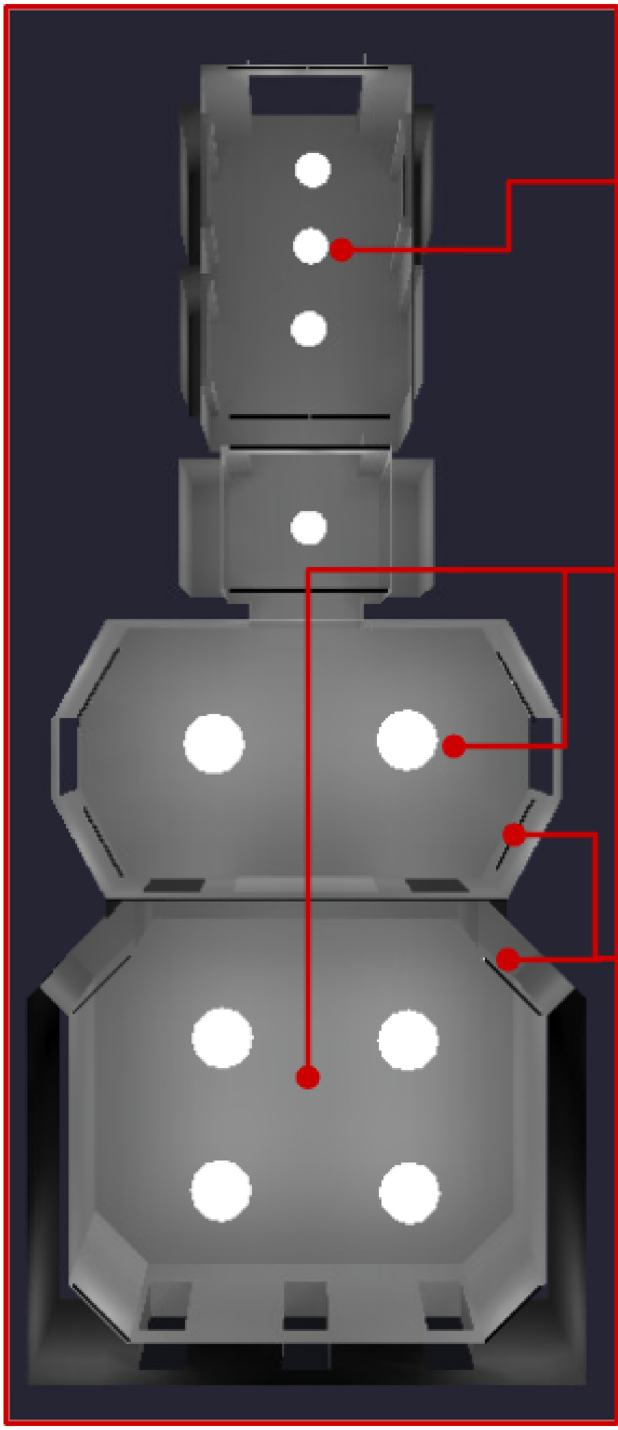

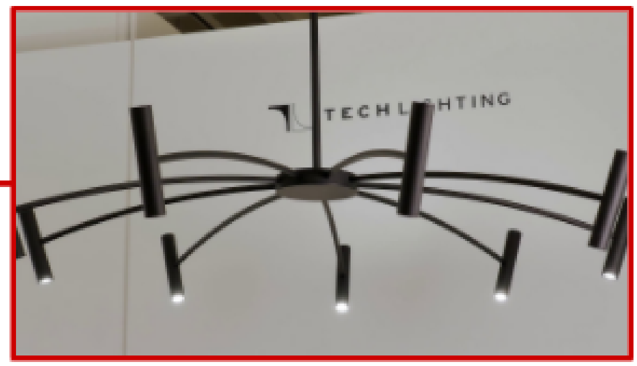

FIRST: Wood pendant lamp with dimmable bulb

SECOND: Simple chandelier with black finish

THIRD: 1" aperture recessed linear

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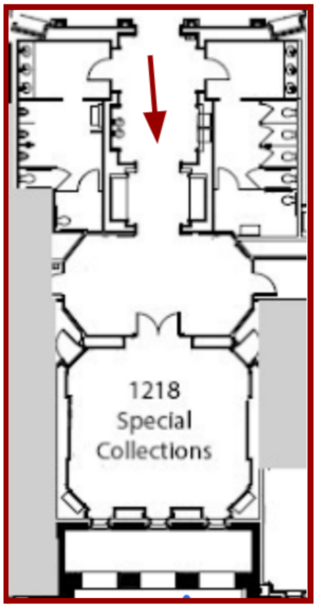
This image is a more conceptual rendering of the display gallery. The organic shapes of the chandeliers and warm wood tones create a relaxed atmosphere in which to appreciate what's on display.



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Lobby

Description

The lobby has many opportunities for accent lighting, particularly on the numerous neoclassical columns. Additionally, the information desk should be addressed.

Because this is the main entrance of the library, the design should promote both lingering and movement, and evoke the overarching theme strongly to set the tone.

Qualitative Criteria

Wayfinding

Provide a design precedent for navigating the building for both students and visitors

Wow factor

Engineer a memorable experience, as this is the main entrance of the library and a main point on campus

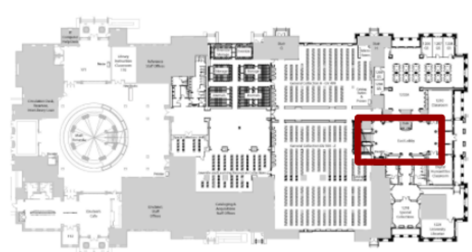
Focal points

Take advantage of the numerous classical elements present in the space as points of interest

Quantitative Criteria

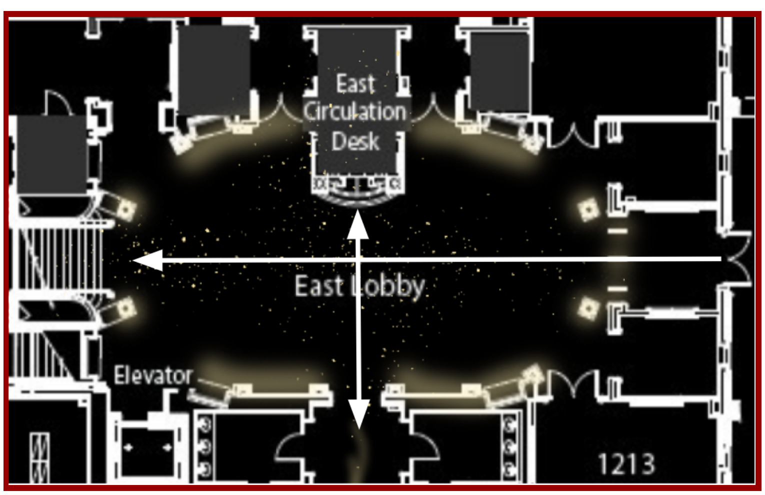
IES recommendation (lux)	Plane	E_h	E_v	Uniformity
Lobby at building entrance (day)	Floor	50	25	4:1
Lobby at building entrance (night)	Floor	15	10	4:1
Lobby desktop	3'6" AFF	75	25	4:1

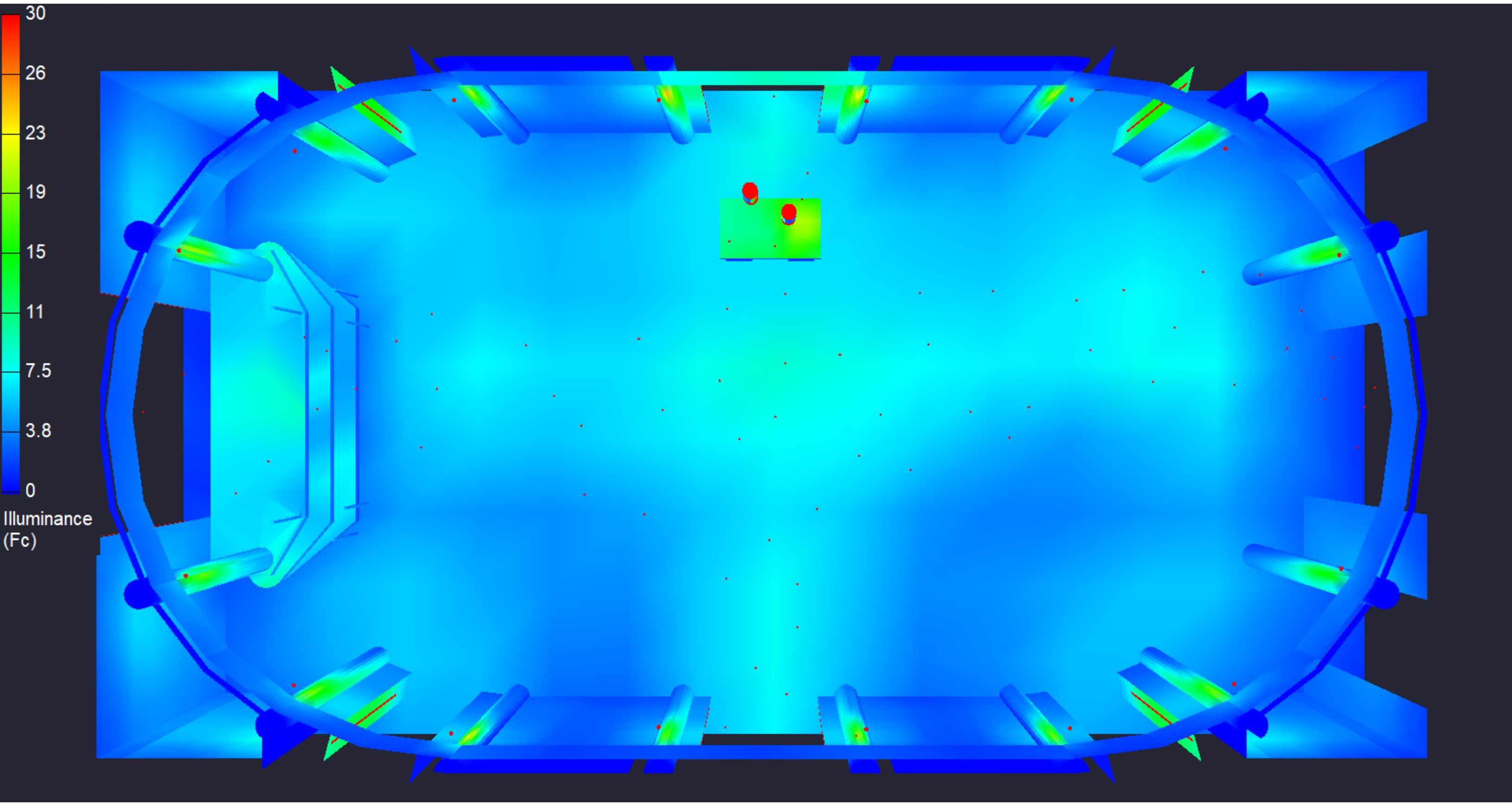
Power allowance (ASHRAE 90.1, 2013)	LPD
Lobby	0.9



An idea many of Wells' writings hinged on, *The Time Machine* most of all, is that of exploration. He wrote a great deal about not only travels through time, but space. As the first room students will encounter, the lobby should foster a desire to explore and learn. Although the space is relatively small, with 12-foot ceilings, it's possible to create a "wow" factor and a sense of wonder through the installation of a fiber optic system.

These precedent images show relatively low ceilings transformed into night skies, with soft perimeter and accent lighting also on display in the left image. These combined modes of lighting, when applied to the lobby, will create an ethereal experience of wonderment for any student - or visitor - that enters. The stars on the ceiling will also be made to provide a subtle wayfinding element, clustered more strongly along the main axes of movement in the space, as can be seen below.





Lighting criteria	IES level	Design level	IES Uniformity	Design Uniformity
Lobby at building entrance (day)	50	65	4:1	2:1
Lobby at building entrance (night)	15	15	4:1	2:1
Lobby desktop	75	150	2:1	1.3:1

Power allowance	ASHRAE LPD	Design LPD
Lobby	0.9	0.265

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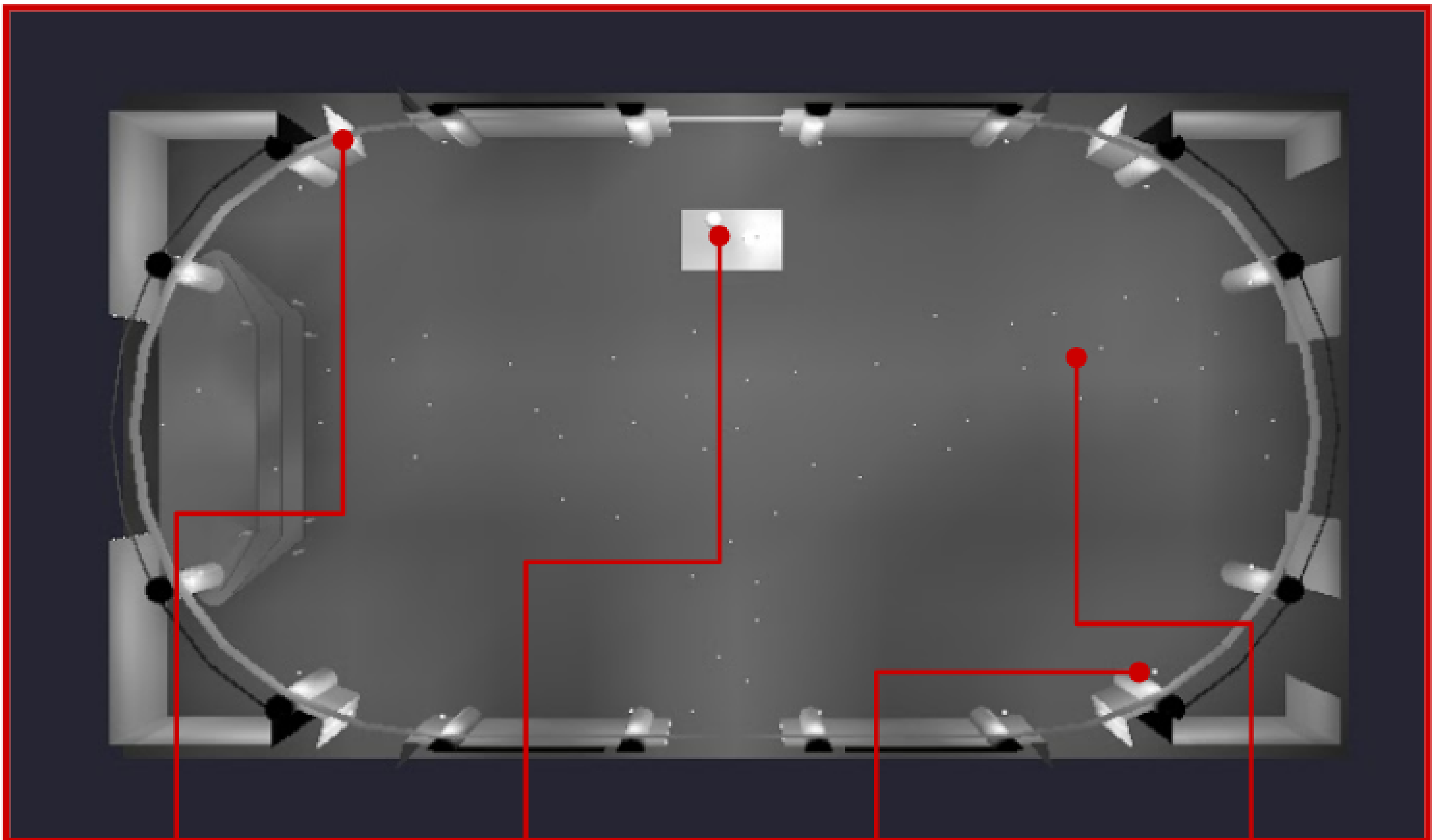
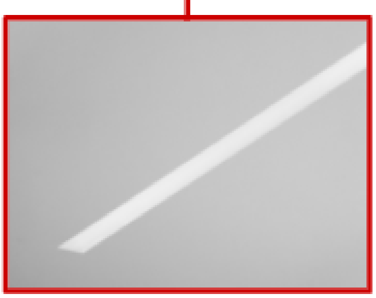
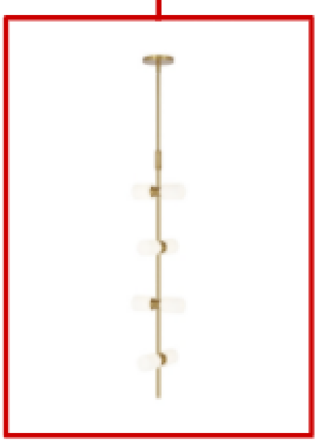




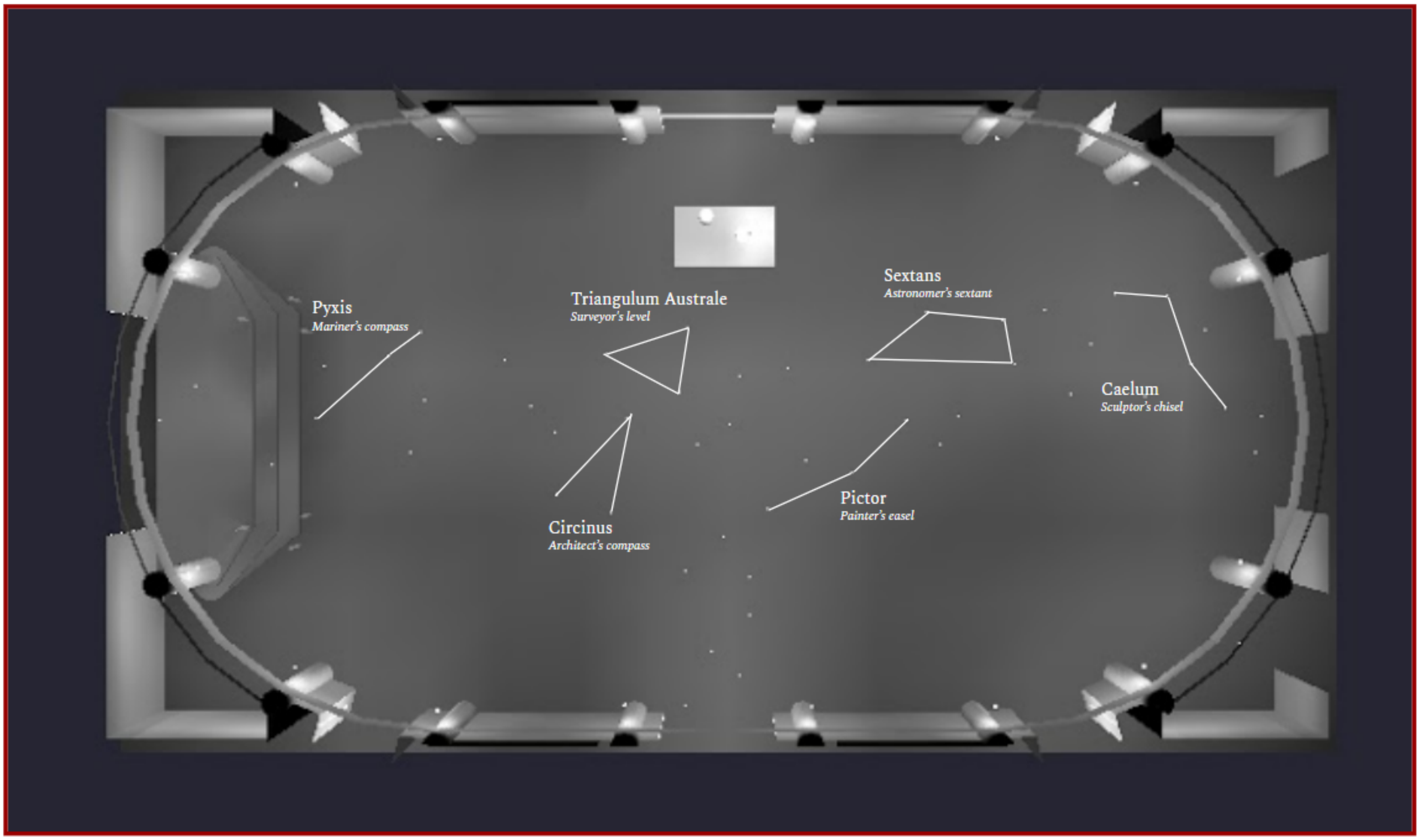


ABOVE: 1" wide recessed linear
RIGHT: Modern decorative pendant

2" adjustable accent downlight

Fiber-optic star system with up to 336 points (64 used)

Before displaying the final rendering, it's apt to note the inclusion of six constellations in the layout of stars on the ceiling of the lobby. Each of these represents a tool of exploration, whether physical, mental, or creative.

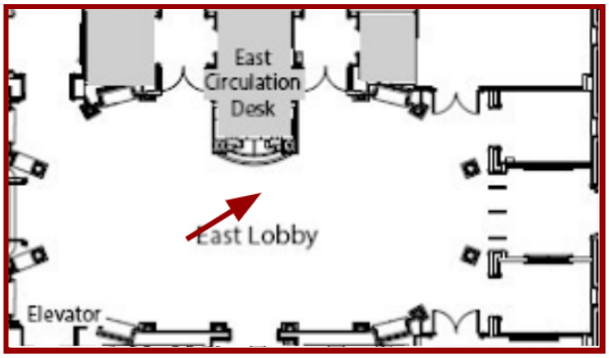


While not explicitly obvious to anyone except (maybe) the most enthusiastic astronomers, these provide a subtle nod to all the ways in which our world can be explored.

From left to right

PYXIS	Mariner's compass
CIRCINUS	Architect's compass
TRIANGULUM AUSTRALE	Surveyor's level
PICTOR	Painter's easel
SEXTANS	Astronomer's sextant
CAELUM	Sculptor's chisel

This image of the lobby is from the perspective of, nearly, the center of the space. Due to the lack of windows, the space will achieve a similar effect at all times of day.



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L/E OPTION, MAE PROGRAM

Media Commons

Description

The large combined spaces of the information and technology commons (media commons) was given a simple 2x4 solution, with high levels of general illumination.

There's a noticeable lack of connection to the outdoors in this windowless space, which will be addressed by the addition of skylights and a more organic design language.

Qualitative Criteria

Collaboration

Promote collaborative work through copious general and circulation illumination

Daylight

Account for the lack of daylight in the space; bring the outside in and respond to new skylights

Focus

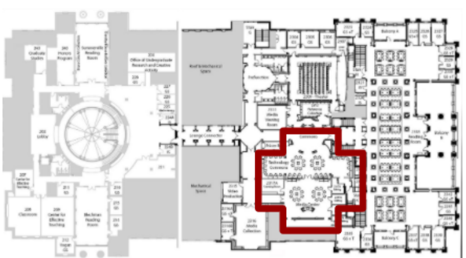
Keep highlights of architectural elements subdued so as not to distract, and provide task light

Quantitative Criteria

IES recommendation (lux)	Plane	E_h	E_v	Uniformity
Computer center	2'6" AFF	150	50	2:1
Open office	2'6" AFF	150	50	2:1
Lobby info desktop	3'6" AFF	75	25	4:1

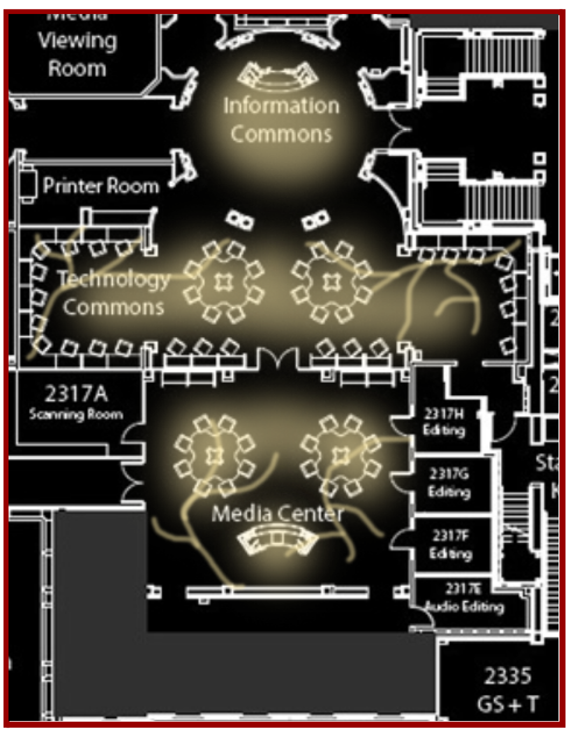
See below for power allowance and key plan.

Power allowance (ASHRAE 90.1, 2013)	LPD
Computer room	1.71
Office (open plan)	0.98



As a futurist, Wells often touted the idea of nature overtaking manmade structures. The narrator of *The Time Machine* finds this himself when he reaches the far future, where plant life has consumed old buildings and people live in harmony with nature. Bringing in organic shapes to this inorganic space devoid of daylight will provide visual interest by contrast, while staying relatively subtle (see precedent image in lower right).

Keeping an eye to the floor and furniture plan, the major clusters of collaboration will be brightly illuminated overhead, not by 2x4 troffers but by daylight, supplemented by subtle LED fixtures. At the fringes of the space are more private workstations, which will be subconsciously indicated by a change in shape language, moving from large patches of light to more subdued, uniform pools. The strips in the design are reminiscent of branches, while the center of the space promotes collaboration with the round / spiral chandeliers.



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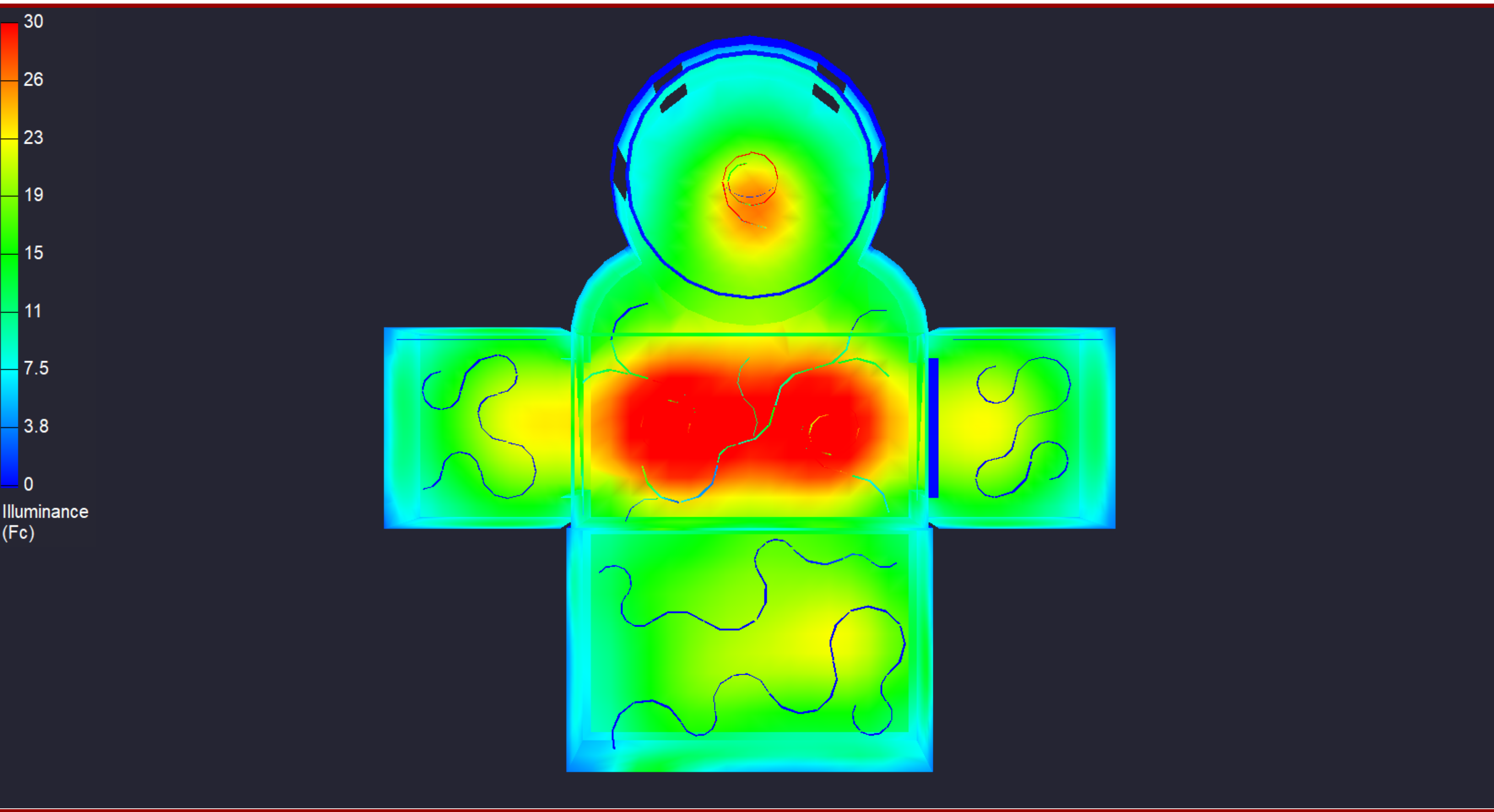

Lighting criteria	IES level	Design level	IES Uniformity	Design Uniformity
Computer center	150	207	2:1	2.55:1
Open office	150	207	2:1	2.55:1
Lobby info desktop	75	372	4:1	1.24:1

Power allowance	ASHRAE LPD	Design LPD
Computer room	1.71	0.495
Office (open plan)	0.98	0.495

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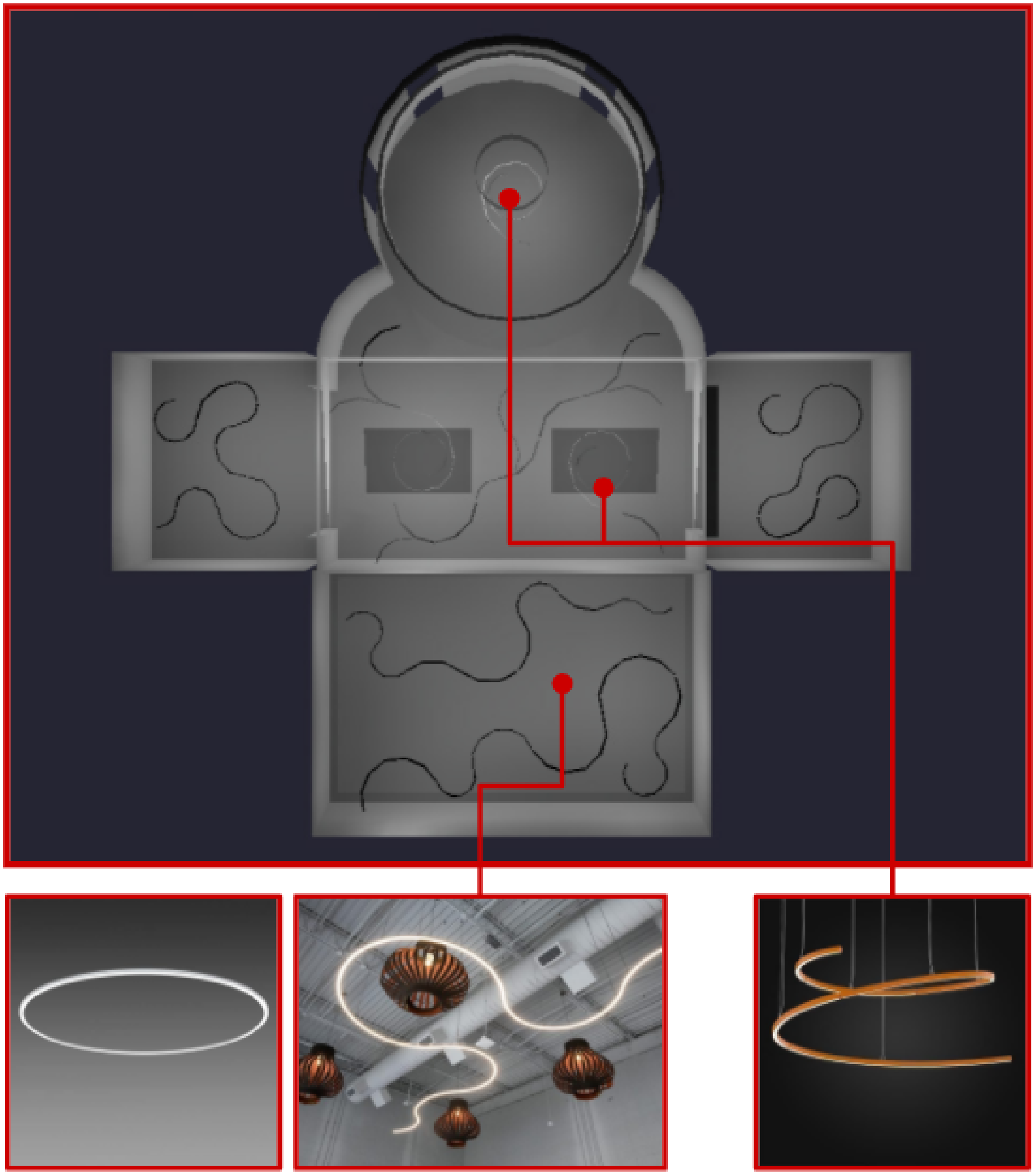
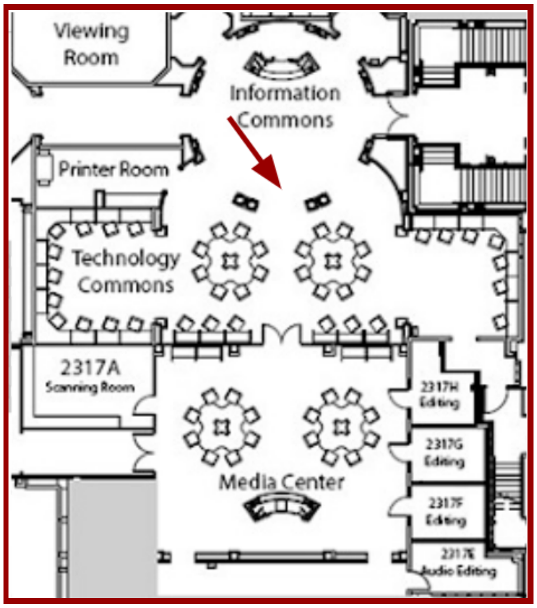


1" aperture configurable surface- and pendant- mounted rings and quarter arcs

1" configurable arcs w/ rotated connectors

This rendering of the Media Commons is meant to emphasize how daylight interacts with the forms of the space. For a large area without any windows, it manages to feel very open and collaborative.



East Facade

Description

The main facade has a multi-faceted design of layered arcades, colonnades, porches, and other ornaments, including precast pediments and columns.

These various layers of design should all be highlighted in some way, without detracting from the modernity and function of the facilities therein.

Qualitative Criteria

Classicism

Emphasize the importance of the facade's neoclassical and colonial revival elements

Cohesion

Ensure cohesion with the existing portion of the library and the surrounding campus structures

Function

Clarify and highlight the usable spaces on the outside of the building, such as porches and arcades

Quantitative Criteria

IES recommendation (lux)	Plane	E_h	E_v	Uniformity
Building entrance, LZ3	Grade	7.5	4	2:1

Power allowance (ASHRAE 90.1, 2013)	LPD
Facade walls	0.15 / wall
Entry canopy	0.4

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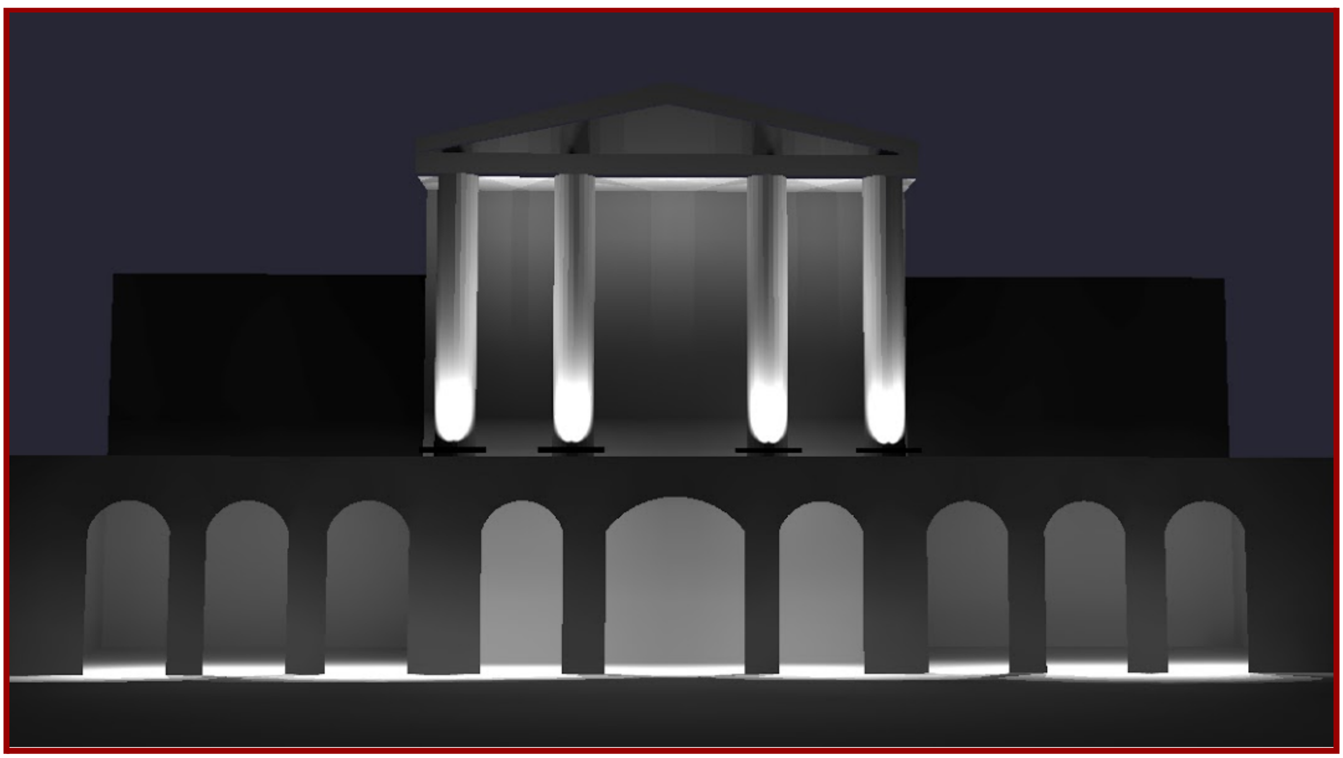
H.G. Wells may be more famous for his fiction, but he was also a prolific writer for human rights and inclusion. His essay on human rights was actually adopted by the UN, and is used as a standard to this day. This design, based on the idea of inclusion, aims to reach out and welcome students into a space of public knowledge.

The design itself illuminates the entry arcade in a wash, making it clear to students where they can enter and that they are welcome. By highlighting the columns from the bottom up, the design is kept more on the pedestrian's level, rather than seeming stately and intimidating. Finally, soft uplights on the pediments and cupola complement the uplighting on the columns.

Lighting criteria	IES level	Design level	IES Uniformity	Design Uniformity
Building entrance, LZ3	7.5	60 (with dimming capabilities)	2:1	2.7:1

Power allowance	ASHRAE LPD	Design LPD
Facade walls	0.15/wall	0.0799
Entry canopy	0.4	0.0849

The above 30x60 accent fixture is the primary one used in this design.



ELECTRICAL DEPTH

Existing Controls Analysis

BUILDING CONTROLS OVERVIEW

Much of the Trible Library is controlled through a facility management system, the Lutron GRAFIK Eye. This consists of programmable wall-mounted control panels, linked to various specified lighting zones in selected spaces by lighting relay panels. These control panels are programmed to respond to assigned time-of-day shutoffs and, in the case of the exterior control panel, photocell signals. Certain spaces in the library are powered by circuits that bypass these panels, and instead have dedicated occupancy sensors, dimming switches, and/or other controls.

As a general note, no occupancy or vacancy sensors are present in any of the selected spaces in the original design. Photocell controls are present, but only on the exterior of the building, in order to relay a general sense of the time of day to some of the designated room lighting control panels.

The following summary details how each space of study in this thesis is linked to the facility management network, as well as any dedicated controls outside of the network.

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READING ROOM

There are multiple room lighting control panels in the two-story reading room, all of which have pre-set scenes, time of day auto shutoff controls, and a corresponding lighting zone override switch.

FIRST FLOOR

The main study space is designated as Zone 6, controlled by RLC6 (room lighting control panel 6). The panel is located along the back wall of a hallway, accessible when exiting the room.

CONTROL PANEL: RLC6				
ZONE	**CIRCUIT**	**RELAY PANEL**	**OVERRIDE**	**DESCRIPTION**
Z6a	EH1-29	LRP2E	S010	Downlights around north and south skylights
Z6b	NH3-16	LRP2	S010	Strip light around skylights
Z6c	NH3-16	LRP2	S010	Linear lighting around central cupola
Z6d	EH1-23	LRP2E	S010	Statement chandelier in central cupola
Z6e	EH1-23	LRP2E	S010	Statement chandelier in north and south skylights
Z6f	EH1-29	LRP2E	S010	Downlights around north and south skylights
Z6g	EH1-29	LRP2E	S010	Downlights around north and south skylights
Z6h	EH1-33	LRP2E	S05	Downlights in hall adjacent to central space
Z6i	EP1-11	LRP2E	S010	Entryway chandeliers
Z6j	EH1-33	LRP2E	S010	Downlights in hall / entryway adjacent to central space
Z6k	EH1-33	LRP2E	S010	Downlights / chandeliers in stairway adjacent to central space

General illumination in the rooms adjacent to the main study space are marked as Zones 7 and 8, controlled by room lighting control panels RLC7 and RLC8. They are controlled in identical manners from the two control panels.

CONTROL PANEL: RLC7 / RLC8				
ZONE	**CIRCUIT**	**RELAY PANEL**	**OVERRIDE**	**DESCRIPTION**
Z7a / Z8a	EH1-33	LRPE2	S05	General illumination recessed downlights
Z7b / Z8b	EH1-33	LRPE2	S05	Recessed downlights in adjacent hall / circulation space
Z7c / Z8c	EP1-7 / EP1-17	LRPE2	S05 / S014	Chandeliers in central north wing
Z7d / Z8d	EP1-7 / EP1-17	LRPE2	S05 / S014	Chandeliers in west portion of north wing
Z7e / Z8e	EH1-33	LRPE2	S05	General illumination recessed downlights

The downlights on circuit EH1-33 are also connected to manual dimmer switches in hallways directly adjacent to the reading room, implying that they can be dimmed separately from scene and timeclock control, according to occupant preference.

SECOND FLOOR

The second floor mezzanine of the Reading Room has two wings, which are designated as Zones 3 and 5. These controls are identical to each other, much like Zones 7 and 8. RLC3 and 5 are located in their respective rooms of control.

CONTROL PANEL: RLC3 / RCL5				
ZONE	**CIRCUIT**	**RELAY PANEL**	**OVERRIDE**	**DESCRIPTION**
Z3a / Z5a	NL3A-3 / NL3A-1	LRPE2	S05 / S014	General illumination recessed downlights
Z3b / Z5b	NL3A-3 / NL3A-1	LRPE2	S05 / S014	Perimeter recessed downlights
Z3c / Z5c	NL3A-3 / NL3A-1	LRPE2	S05 / S014	Chandeliers

The central area of the second floor is designated Zone 4. RLC4 is located centrally on the second floor of the reading room.

CONTROL PANEL: RLC4				
ZONE	**CIRCUIT**	**RELAY PANEL**	**OVERRIDE**	**DESCRIPTION**
Z4a	NL3A-1	LRP3	S09	Recessed downlights in adjacent hall
Z4b	NL3A-1	LRP3	S09	Recessed downlights in adjacent hall
Z4c	NL3A-3	LRP3	S09	Downlights in space adjacent to main area
Z4e	NL3A-3	LRP3	S09	Chandeliers
Z4f	NL3A-3	LRP3	S09	Downlights in space adjacent to main area
Z4g	NL3A-3	LRP3	S09	Downlights in space adjacent to main area
Z4h	NL3A-1	LRP3	S09	Chandeliers in space adjacent to main area
Z4i	NL3A-3	LRP3	S09	Downlights in space adjacent to main area
Z4j	NL3A-3	LRP3	S09	Recessed downlights in adjacent hall
Z4k	NL3A-3	LRP3	S09	Recessed downlights in adjacent hall

Three additional 4-scene control switches are located in the main sections of the second floor of the reading room, next to the room control panels, presumably able to override the scenes dictated by the RLCs.

CONCLUSION: Although the room lighting control panels are attuned to a timeclock and exterior photocells, a form of dimming with respect to the daylight in the space could greatly improve the responsiveness of this design. Energy could be saved with the addition of occupancy / vacancy sensors in the wings, while they may not prove effective in the larger double-height spaces. Greater small-scale controllability in the various spaces could also increase preference for the students who are studying in them.

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100-PERSON THEATER & PREFUNCTION

The theater is designated as control Zone 10, controlled from RLC10, located in the back of the theater adjacent to the exit.

CONTROL PANEL: RLC10				
ZONE	**CIRCUIT**	**RELAY PANEL**	**OVERRIDE**	**DESCRIPTION**
Z10a	NL2C-17	LRP2	S019	Wall sconces
Z10b	EH1-17	LRP2E	S014	Downlights in back aisle
Z10c	EH1-17	LRP2E	S014	Downlights along side aisles
Z10d	EH1-17	LRP2E	S014	Downlights in center of space
Z10e	NL2C-17	LRP2	S019	Chandeliers
Z10f	EH1-17	LRP2E	S014	Downlights on stage
Z10g	EH1-17	LRP2E	S014	Downlights in front of stage
Z10h	EH1-17	LRP2E	S014	Adjustable accent lights in front of stage

The prefunction space is not zoned for specific RLC panel control, but the downlights and chandeliers present in the space are served by circuit NL2C-15, and have dimming controls just outside the prefunction entrance. Circuit NL2C-15 is also designated override switch 18, which is adjacent to the space. Override switch 19 is located next to RLC10, while override switch 14 is located in the Reading Room.

CONCLUSION: The number of zones keeps this space relatively versatile, but it's limited by the type of fixtures (incandescent and fluorescent, rather than RGB). The addition of DMX controls and RGBW or RGBA fixtures would offer a more comprehensive and responsive solution.

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SPECIAL COLLECTIONS & DISPLAY GALLERY

CIRCUIT	RELAY PANEL	OVERRIDE
EP1-3	LRP1E	S06
NL1B-19	LRP1	S06

Because these lights are not zoned for control via a room lighting control panel (RLC), their dedicated controls will be detailed here. Two dimmer switches are located next to the entrance of the Display Gallery. The chandeliers in the Gallery are connected to one dimmer switch, while the spaces' sconces and an additional ceiling fixture are controlled by the other. The downlights and additional chandeliers in the space are controlled by their own dedicated dimmers. In the special collections room, the two modes of lighting (sconces over paintings and general illumination chandeliers) are controlled by dedicated dimmers.

CONCLUSION: There is not a great deal of versatility in this room. A connection to the facility network, as well as a photocontrol device in the special collections room, could prove more effective and a better measure for protecting sensitive materials.

LOBBY

CIRCUIT	RELAY PANEL	OVERRIDE
EP1-3	LRP1E	S06
EH1-7	LRP1E	S05

The chandeliers in the main lobby, as well as in the entry vestibule, are controlled by dimmer switches located beside the front door and in the vestibule. The downlights and linear fixtures providing general illumination are controlled by another dimmer switch next to the front door.

Override switch 6 is located in the Lobby, next to the front entrance; override switch 5 is located in rooms adjacent to the Lobby.

CONCLUSION: The lighting redesign for the Lobby is far more complex than the current design, and will require either a 4-button scene switch or an additional room lighting control panel. The addition of ceiling-mounted vacancy sensors will also be an energy-saving measure.

MEDIA COMMONS

CIRCUIT	RELAY PANEL	OVERRIDE
EH1-19	LRP2E	S016
EH1-21	LRP2E	S017

The Commons are not zoned for control via a room lighting control panel, so the controls are detailed here. Two modes of lighting in the space's dome (downlights and a strip around the perimeter) are controlled via separate dimmers. The rest of the space has a gridded ceiling populated by 2x4s and round perimeter downlights, which are also controlled by separate dimming switches.

Override switch 15 is located in this space.

CONCLUSION: This space has the least comprehensive controls, despite being one of the most heavily-occupied in the library. Vacancy or occupancy sensors, as well as photocells to react to the skylights added in the MAE Daylighting depth, will improve energy consumption and space versatility.

EAST FACADE

The lighting on the east facade (main entry) of the building is controlled by a panel which responds to a programmed timeclock and the exterior photocells. The photocells are mounted on the roof and aimed north.

CONTROL PANEL: RLC0				
ZONE	CIRCUIT	RELAY PANEL	OVERRIDE	DESCRIPTION
Z01	EH1-2	LRP1E	Photocell	Exterior linear fixtures (floor 2, 3)
Z02	EH1-2	LRP1E	Photocell	Exterior linear fixtures (floor 2)
Z06	EH1-2	LRP1E	Photocell	Exterior linear fixtures (floor 3)
Z09	EH1-2	LRP1E	Photocell	Exterior round downlights
Z010	EH1-2	LRP1E	Photocell	Exterior round downlights
Z011	EH1-2	LRP1E	S019	Hanging and wall-mounted lanterns

Controls Redesign

The control goals for each space, while discussed above, are compiled below in a table, along with the devices required to achieve them.

SPACE	GOALS	DEVICES
Reading Room	Daylight dimming, occupancy / vacancy capabilities, greater occupant control	Photocell, occupancy / vacancy sensor, dimmer switches
Theater	Greater versatility, RGBW capabilities, integration with A/V equipment	DMX network / controller, ethernet communication between lights & A/V
Special Collections	Daylight dimming, low exposure of materials, integration with existing facility controls	Photocell, vacancy sensor, dimmer switches, existing facility management device
Lobby	Occupancy controls, greater versatility, integration with existing facility controls	Occupancy sensor, 4-button switch, existing facility management device
Media Commons[1]	Daylight dimming, occupancy control	Photocell, occupancy sensor
Facade	Additional dimming control	Dimmer switch

1: In the case of the Media Commons, ASHRAE 2010, 9.4.1. 5 states that any room with a top lighted area of over 900 ft^2 requires lighting control and dimming by at least one (1) daylight sensor.

CONTROLS MATRICES

The following matrices detail the intended modes of control in the six spaces of study, as well as their sequence of operations. Much of the controllability (time clock, exterior photocell, etc.) is provided by the existing (or newly-connected) room control panel.

*NOTE: See bottom of the controls matrices section for the sequence of operations legend. For a larger version of these tables, refer to **Appendix II.***

READING ROOM

SPACE NAME	ROOM NUMBER	MANUAL ON	MANUAL OFF	DIMMING SWITCH	OVERRIDE SWITCH	TIMECLOCK ON/OFF	OCCUPANCY SENSOR	VACANCY SENSOR	PHOTOCONTROL DIMMING	EXTERIOR PHOTOCELL ON/OFF	FACILITY MANAGEMENT TOOL	4-BUTTON SCENE CONTROL	NETWORKED CONTROLS (DMX)	SEQUENCE OF OPERATIONS
Main Reading Room - F1 / F2	2318B	X	X		X	X	X		X	X	X			1
North Wing - F1	2318A	X	X		X	X	X		X	X	X			1
South Wing - F1	2318C	X	X		X	X	X		X	X	X			1
Entry - F1	2318B	X	X	X	X	X	X		X	X	X			2
North Wing - F2	3001A	X	X		X	X	X		X	X	X			1
South Wing - F2	3001D	X	X		X	X	X		X	X	X			1
Front Study Room - F2	3001C	X	X	X	X	X	X		X	X	X	X		3
Rear Study Room - F2	3001B	X	X	X	X	X	X		X	X	X	X		3

100-PERSON THEATER & PREFUNCTION

SPACE NAME	ROOM NUMBER	MANUAL ON	MANUAL OFF	DIMMING SWITCH	OVERRIDE SWITCH	TIMECLOCK ON/OFF	OCCUPANCY SENSOR	VACANCY SENSOR	PHOTOCONTROL DIMMING	EXTERIOR PHOTOCELL ON/OFF	FACILITY MANAGEMENT TOOL	4-BUTTON SCENE CONTROL	NETWORKED CONTROLS (DMX)	SEQUENCE OF OPERATIONS
Audience	2309	X	X		X	X					X		X	4
Stage	2313	X	X		X	X					X		X	4
Prefunction	L2-C-07	X	X		X	X					X	X		5
Prefunction Hall	2309A	X	X	X	X	X					X			6

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SPECIAL COLLECTIONS & DISPLAY GALLERY

SPACE NAME	ROOM NUMBER	MANUAL ON	MANUAL OFF	DIMMING SWITCH	OVERRIDE SWITCH	TIMECLOCK ON/OFF	OCCUPANCY SENSOR	VACANCY SENSOR	PHOTOCONTROL DIMMING	EXTERIOR PHOTOCELL ON/OFF	FACILITY MANAGEMENT TOOL	4-BUTTON SCENE CONTROL	NETWORKED CONTROLS (DMX)	SEQUENCE OF OPERATIONS
Display Gallery	L1-C-02	X	X	X	X	X	X			X	X	X		7
Display Gallery Hall	L1-C-03	X	X	X	X	X		X		X	X			9
Special Collections	1218	X	X	X	X	X		X	X	X	X	X		8

LOBBY

SPACE NAME	ROOM NUMBER	MANUAL ON	MANUAL OFF	DIMMING SWITCH	OVERRIDE SWITCH	TIMECLOCK ON/OFF	OCCUPANCY SENSOR	VACANCY SENSOR	PHOTOCONTROL DIMMING	EXTERIOR PHOTOCELL ON/OFF	FACILITY MANAGEMENT TOOL	4-BUTTON SCENE CONTROL	NETWORKED CONTROLS (DMX)	SEQUENCE OF OPERATIONS
Main Lobby	L1-C-01	X	X	X	X	X	X			X	X	X		7

MEDIA COMMONS

SPACE NAME	ROOM NUMBER	MANUAL ON	MANUAL OFF	DIMMING SWITCH	OVERRIDE SWITCH	TIMECLOCK ON/OFF	OCCUPANCY SENSOR	VACANCY SENSOR	PHOTOCONTROL DIMMING	EXTERIOR PHOTOCELL ON/OFF	FACILITY MANAGEMENT TOOL	4-BUTTON SCENE CONTROL	NETWORKED CONTROLS (DMX)	SEQUENCE OF OPERATIONS
Info Commons (Dome)	L2-C-13	X	X	X	X	X	X		X	X				10
Technology Commons	2314	X	X	X	X	X	X		X	X				10
Media Center	2317	X	X	X	X	X	X		X	X				10

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EAST FACADE

SPACE NAME	ROOM NUMBER	MANUAL ON	MANUAL OFF	DIMMING SWITCH	OVERRIDE SWITCH	TIMECLOCK ON/OFF	OCCUPANCY SENSOR	VACANCY SENSOR	PHOTOCONTROL DIMMING	EXTERIOR PHOTOCELL ON/OFF	FACILITY MANAGEMENT TOOL	4-BUTTON SCENE CONTROL	NETWORKED CONTROLS (DMX)	SEQUENCE OF OPERATIONS
East Facade	N/A	X	X		X	X				X	X			11

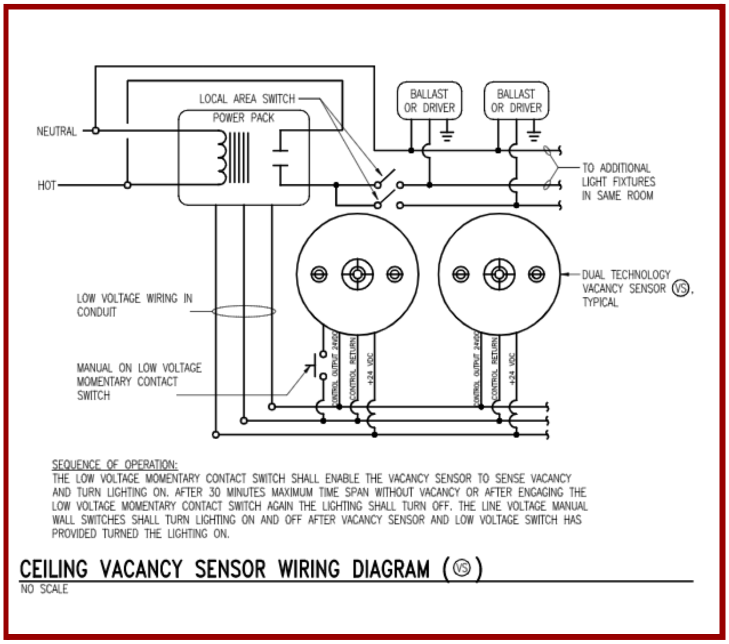
SEQUENCE OF OPERATIONS LEGEND

SEQUENCE OF OPERATIONS LEGEND	
1	At 7:00 AM the timeclock of the facility management system will switch the designated zone ON (if exterior photocell conditions are met); for the duration, the lights may turn OFF if the occupancy sensor detects no movement, turning back ON upon detection. Lights will DIM according to daylight sensors. At 10:00 PM the zone will turn OFF. Overrides include a user-operated manual ON/OFF.
2	At 7:00 AM the timeclock of the facility management system will switch the designated zone ON (if exterior photocell conditions are met); for the duration, the lights may turn OFF if the occupancy sensor detects no movement, turning back ON upon detection. Lights will DIM according to daylight sensors. At 10:00 PM the zone will turn OFF. Overrides include a user-operated manual ON/OFF and user-operated manual dimming.
3	At 7:00 AM the timeclock of the facility management system will switch the designated zone ON (if exterior photocell conditions are met); for the duration, the lights may turn OFF if the occupancy sensor detects no movement, turning back ON upon detection. Lights will DIM according to daylight sensors. At 10:00 PM the zone will turn OFF. Overrides include a user-operated manual ON/OFF, user-operated manual dimming, and user-operated 4-button scenes.
4	At 8:00 AM the timeclock of the facility management system will switch the designated zone ON (if exterior photocell conditions are met); for the duration, the lights may turn OFF if the occupancy sensor detects no movement, turning back ON upon detection. At 8:00 PM the zone will turn OFF. Overrides include DMX network controls and user-operated manual ON/OFF.
5	At 8:00 AM the timeclock of the facility management system will switch the designated zone ON (if exterior photocell conditions are met); for the duration, the lights may turn OFF if the occupancy sensor detects no movement, turning back ON upon detection. At 8:00 PM the zone will turn OFF. Overrides include user-operated manual ON/OFF and a user-operated 4-button scene switch.
6	At 8:00 AM the timeclock of the facility management system will switch the designated zone ON (if exterior photocell conditions are met); for the duration, the lights may turn OFF if the occupancy sensor detects no movement, turning back ON upon detection. At 8:00 PM the zone will turn OFF. Overrides include user-operated manual ON/OFF and a user-operated dimming switch.
7	At 7:00 AM the timeclock of the facility management system will switch the designated zone ON (if exterior photocell conditions are met); for the duration, the lights may turn OFF if the occupancy sensor detects no movement, turning back ON upon detection. At 10:00 PM the zone will turn OFF. Overrides include a 4-button scene switch, a dimming switch, and user-operated manual ON/OFF.
8	At 7:00 AM the timeclock of the facility management system will switch the designated zone ON (if exterior photocell conditions are met); for the duration, the lights may turn OFF if the vacancy sensor detects no movement. At 10:00 PM the zone will turn OFF. Overrides include a 4-button scene switch, a dimming switch, and user-operated manual ON/OFF.
9	At 7:00 AM the timeclock of the facility management system will switch the designated zone ON (if exterior photocell conditions are met); for the duration, the lights may turn OFF if the vacancy sensor detects no movement. At 10:00 PM the zone will turn OFF. Overrides include a dimming switch and a user-operated manual ON/OFF.
10	Upon entrance to the space, the occupancy sensor will turn the zone ON. The lights may turn OFF if the occupancy sensor detects no movement, turning back ON upon detection. Lights will DIM according to daylight sensors. Overrides include a user-operated manual ON/OFF and user-operated dimming.
11	At 5:00 PM the timeclock of the facility management system will switch the designated zones ON (if exterior photocell conditions are met); at 7:00 AM, the system will switch them OFF (again, if photocell conditions are met). Override is a manual ON/OFF switch.

NOTE: for a larger version of these tables, as well as the sequence of operations legend, please refer to ***Appendix II.***

POWER SUPPLY FOR NEW CONTROLS

An investigation of the drawings shows that the existing sensors are powered at 24V DC, connected by low-voltage wiring to a power pack which is, in turn, powered by 120V line voltage. In the case of the vacancy sensor example given in the drawings (pictured below, from Sheet E5.10), there is a momentary contact switch, allowing a form of override.



In keeping with this, the chosen new sensors will operate at a 24V DC input, with line-voltage connected transforming power packs rather than a comprehensive low-voltage panel. This will provide better integration into the existing system, as well as streamlined maintenance for one type of power distribution rather than two different modes.

The other lighting control devices (toggle switches, dimmers, facility management panels) will operate at 120V line voltage, as the existing Lutron Grafik Eye QS system requires 120V input for LED control.

PRODUCT SELECTION

Using the control goals, required devices, and the knowledge of how the existing building controls are powered, product selection is now viable. Section 260923 - Lighting Control Devices of the project manual for Trible Library provides details on the existing controls; in an effort to integrate with the current design, these will be used as guidelines for product selection.

While the existing Lutron GRAFIK Eye QS System is sufficient for facility management and will be used in this redesign (albeit reconfigured), additional devices are also required. The list below details the additional devices selected for each space, as well as if and how they meet the requirements (option offered by chosen device denoted by <u>underline</u>).

See **Appendix II** for manufacturer's data of selected products.

BASICS (needed in most spaces)

Toggle switches (overrides): **Leviton 1223-SW Toggle Switch**

Requirements

- NEMA WD 1, UL 20, and FS W-S-896 compliant ✔
- Rated for 20A at 120/277V AC ✔

120V AC line-voltage power.

Dimmer switches: **Lutron MA-1000-WH**

Requirements

- Solid-state with integral on/off switches ✔
- EMI/RFI suppression filter ✔
- Adjustable slider with single-pole or three-way switching ✔
- Compliant with UL 1472 ✔
- 0-10% dimming for LEDs ✔

Line-voltage input at 120V.

READING ROOM

Daylight sensors (photocells): **Cooper Greengate Open Loop Daylight Sensor**

Requirements

- 1.5 to 10fc range (0.3 to 30fc, adjustable) ✔
- 30s delay minimum (5, 15, or 30 minutes, selectable) ✔
- UL 508 listed ✔

24V DC with class 2 low-voltage wiring; ships with included power pack. Three daylight settings are included: Low (0.3-30 fc), High (3-300 fc), and Direct Sun (30-300 fc). 60 degree view field; acceptable for both sidelight (ceiling mount) and skylight (wall mount) applications.

Occupancy sensors: **Lutron LOS C Series Occupancy Sensor**

Requirements

- Ceiling mounted
  - Solid-state line or low voltage with separate power pack ✔
  - Adjustable delay up to 30 minutes (8-30 minutes) ✔
  - Power pack 20A load rated at 120/277V AC ✔
  - PIR, ultrasonic, and dual-tech type are all acceptable ✔

24V DC with class 2 low-voltage wiring; power pack / transformer required. 360 field of view, 1500 ft^2 coverage when mounted at 8-12'. PIR was chosen as it is better for major motion.

100-PERSON THEATER & PREFUNCTION

DMX System

Requirements

- Integration with digital A/V equipment using RS232 serial communication or over ethernet (included in Lutron Grafik Eye QS system) ✔

Addressable Fixtures

LUMENPULSE Lumenfacade Nano Horizontal Color Changing 8x8
LUMENPULSE Lumenfacade Horizontal Color Changing Wall Wash
ALCON 1" Aperture RGBW Linear
*See **Appendix I** for fixture schedule and cutsheets.*

Auxiliary Devices

DMX controller(s): **Aspect LED Wireless RGBW Multi-Zone Wall Controller**
24V DC power input, with wireless addressing, full RGBW control, and 0-100% brightness control / dimming.
DMX cables: unnecessary due to wireless control.

SPECIAL COLLECTIONS & DISPLAY GALLERY

Daylight sensors (photocells): **Cooper Greengate Open Loop Daylight Sensor**

Requirements: specified above in READING ROOM

Dimmer switch: **Lutron MA-1000-WH**

Requirements: specified above in BASICS

Vacancy and occupancy sensors: **Lutron Maestro Dual Technology Vacancy Sensor Switch**, **Lutron LOS C Series Occupancy Sensor**

Requirements

- Wall-switch sensor
  - 180-degree view field (adjustable from 180 to 40 degrees) ✔
  - Minimum coverage area of 900 ft^2 (900 ft^2 major motion, 400 ft^2 minor motion) ✔
  - Preferably dual technology ✔

LOBBY

4-button switch: **HomeWorks QS Wired seeTouch Keypad**

Requirements

- No visible attachment for faceplate ✔
- Removable button assemblies for configuration needs (replacement kits available) ✔
- Backlighting option ✔
- 4 scenes with raise/lower master and on/off ✔

24V DC with class 2 low-voltage wiring; power pack / transformer required. Compatible with Lutron Grafik Eye QS system.

Occupancy sensors: **Lutron LOS C Series Occupancy Sensor**

Requirements: specified above in READING ROOM

MEDIA COMMONS

Daylight sensors (photocells): **Cooper Greengate Open Loop Daylight Sensor**

Requirements: specified above in READING ROOM

Occupancy sensors: **Lutron LOS C Series Occupancy Sensor**

Requirements: specified above in READING ROOM

EAST FACADE

Dimmer switch: **Lutron MA-1000-WH**

Requirements: specified above in BASICS

DAYLIGHT CONTROLS AND ZONING: MEDIA COMMONS EXAMPLE

In order to provide more comprehensive controls in the Media Commons, a new RLCP (room lighting control panel) must be introduced, and the new lights need to be put on new circuits zoned for control. The current light fixtures in the space are on circuits EH1-19 and EH1-21; this panelboard has ample spare capacity, so these fixtures can be kept on the same panel, albeit in a few more slots. What follows is 1) the original EH1 panelboard schedule and 2) the revised EH1 panelboard schedule, as well as load calculations for the new fixtures. For the spreadsheet version, please refer to **Appendix II.**

PANELBOARD EH1 SCHEDULE

RATED FOR 100 A (REFERENCED FROM RISER DIAGRAM)

LOAD SERVED	LOAD (AMPS)			BKR	CKT	PHASE	CKT	BKR TRIP	LOAD (AMPS)			LOAD SERVED
	A	B	C	TRIP	NO.	A B C	NO.		A	B	C	
LTG 143D	8.5			20/1P	1	A	2	20/1P				LTG EXTERIOR
LTG 143D		8.0		20/1P	3	B	4	20/1P				SPARE
LTG 142,3,154-6			9.0	20/1P	5	C	6	20/1P				SPARE
LTG 1202, 1211-3, L1-C-01, 9	12.2			20/1P	7	A	8	20/1P				SPARE
LTG 1211, 2, 4, 6, 8, 20, L1-C-02		8.2		20/1P	9	B	10	20/1P				SPARE
LTG 2302, L2-C-02, 3			8.6	20/1P	11	C	12	20/1P				SPARE
LTG 2308-10, L2-C-05-09	6.3			20/1P	13	A	14	20/1P				SPARE
LTG ST-G		1.2		20/1P	15	B	16	20/1P				SPARE
LTG 2309			4.2	20/1P	17	C	18	20/1P				SPARE
LTG 2314, 2317	**6.3**			**20/1P**	**19**	**A**	20	20/1P				SPARE
LTG 2316, **L2-C-13**, 12, 3, 6, 7, 8, 4		**10.3**		**20/1P**	**21**	**B**	22	20/1P				SPARE
LTG ST-H			1.9	20/1P	23	C	24	20/1P				SPARE
LTG 2319, ST-J	3.1			20/1P	25	A	26	20/1P				SPARE
LTG ST-L, K		3.2		20/1P	27	B	28	20/1P				SPARE
LTG 3001			3.8	20/1P	29	C	30	20/1P				SPARE
LTG 3001	11.1			20/1P	31	A	32	20/1P				SPARE
LTG 2318B		9.9		20/1P	33	B	34	20/1P				SPARE
LTG ATTIC			6.0	20/1P	35	C	36	20/1P			4.0	GAS SHUT-OFF
SPARE				20/1P	37	A	38	20/1P	26			
SPARE				20/1P	39	B	40	20/1P		14.2		PANEL EP1 VIA XFMR
SPARE				20/1P	41	C	42	20/1P			11.8	
TOTAL	47.5	40.8	33.5						26	14.2	15.8	TOTAL

TOTAL CONNECTED AMPS A: 73.5 B: 55.0 C: 49.3

The load names highlighted in **red** are those that are a part of the Media Commons (Information & Technology Commons combined spaces). All of circuit 19 can be altered; however, circuit 21 contains other loads. The total load of the new space was found to be 9.41 A (refer to **Appendix II** for spreadsheet calculation). Assuming that the designs are comparable, LTG L2-C-13 contributes approximately 3.1 A of load, leaving 7.2 A on circuit 21.

In order to better balance the phases of the panelboard, the new lighting circuits will be strategically placed on phases B and C.

NEW CIRCUIT	LOAD (A)
LTG 2317	2.36
LTG 2314 WEST	1.02
LTG 2314 EAST	1.02
LTG 2314 CENTRAL, LC-2-13	4.96

The space was divided into four separate circuits, which not only promotes ease and clarity of control, but also provides a break where a long and costly span of conduit would have otherwise been required. These new circuit loads were calculated as shown in the image to the right. The fixture types on each circuit were counted, their total wattage summed, then converted to an amperage load by the equation $I_A = P_W / \sqrt{3} * PF * V$, where PF = 0.9 and V = 120V. For the full calculations, again, please refer to **Appendix II.**

The new panelboard is shown below. Note that the phases are slightly more balanced.

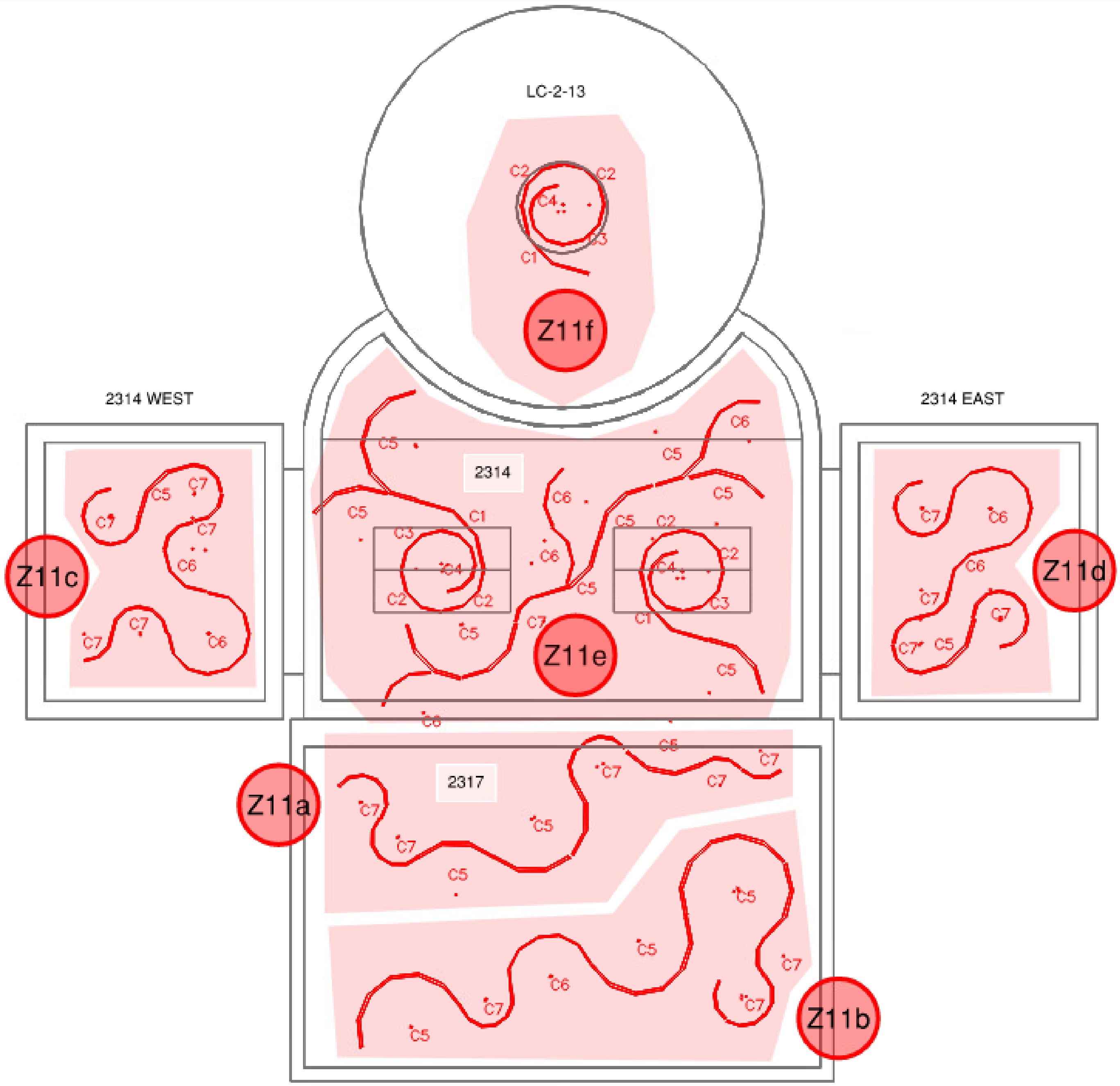
PANELBOARD EH1 SCHEDULE - NEW CONTROLS

RATED FOR 100 A (REFERENCED FROM RISER DIAGRAM)

LOAD SERVED	LOAD (AMPS) A	LOAD (AMPS) B	LOAD (AMPS) C	BKR TRIP	CKT NO.	PHASE A B C	CKT NO.	BKR TRIP	LOAD (AMPS) A	LOAD (AMPS) B	LOAD (AMPS) C	LOAD SERVED
LTG 143D	8.5			20/1P	1	A	2	20/1P				LTG EXTERIOR
LTG 143D		8.0		20/1P	3	B	4	20/1P				SPARE
LTG 142,3,154-6			9.0	20/1P	5	C	6	20/1P				SPARE
LTG 1202, 1211-3, L1-C-01, 9	12.2			20/1P	7	A	8	20/1P				SPARE
LTG 1211, 2, 4, 6, 8, 20, L1-C-02		8.2		20/1P	9	B	10	20/1P				SPARE
LTG 2302, L2-C-02, 3			8.6	20/1P	11	C	12	20/1P				SPARE
LTG 2308-10, L2-C-05-09	6.3			20/1P	13	A	14	20/1P				SPARE
LTG ST-G		1.2		20/1P	15	**B**	**16**	**20/1P**		**2.4**		**LTG 2317**
LTG 2309			4.2	20/1P	17	**C**	**18**	**20/1P**			**5.0**	**LTG 2314 CENTRAL, LC-2-13**
LTG 2314 WEST	**1.0**			**20/1P**	**19**	**A**	20	20/1P				SPARE
LTG 2314 EAST, 2316, L2-C-04, 12, 3, 6, 7, 8		**8.2**		**20/1P**	**21**	**B**	22	20/1P				SPARE
LTG ST-H			1.9	20/1P	23	C	24	20/1P				SPARE
LTG 2319, ST-J	3.1			20/1P	25	A	26	20/1P				SPARE
LTG ST-L, K		3.2		20/1P	27	B	28	20/1P				SPARE
LTG 3001			3.8	20/1P	29	C	30	20/1P				SPARE
LTG 3001	11.1			20/1P	31	A	32	20/1P				SPARE
LTG 2318B		9.9		20/1P	33	B	34	20/1P				SPARE
LTG ATTIC			6.0	20/1P	35	C	36	20/1P			4.0	GAS SHUT-OFF
SPARE				20/1P	37	A	38	20/1P	26			
SPARE				20/1P	39	B	40	20/1P		14.2		PANEL EP1 VIA XFMR
SPARE				20/1P	41	C	42	20/1P			11.8	
TOTAL	42.2	38.7	33.5						26	16.6	20.8	**TOTAL**

TOTAL CONNECTED AMPS A: 68.2 B: 55.3 C: 54.3

MEDIA COMMONS ZONING AND SENSOR LAYOUT



Above is an indication of the new control zones, as well as the room names for the new and altered circuits 16, 18, 19, and 21.

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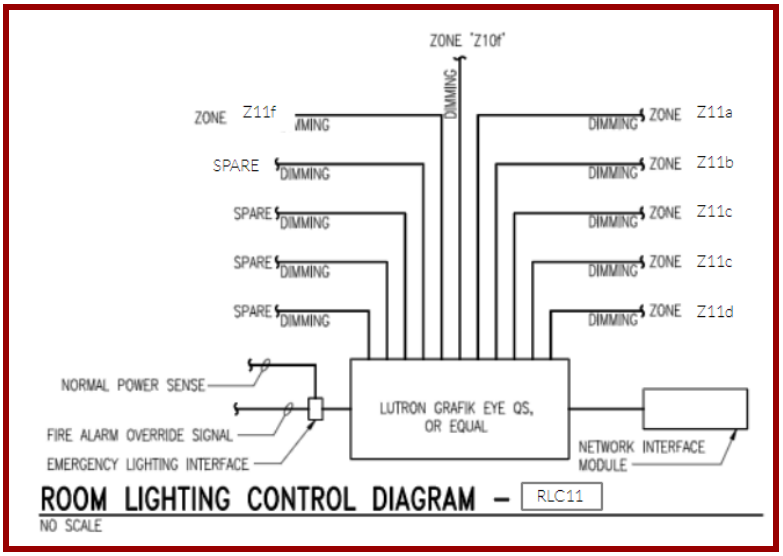
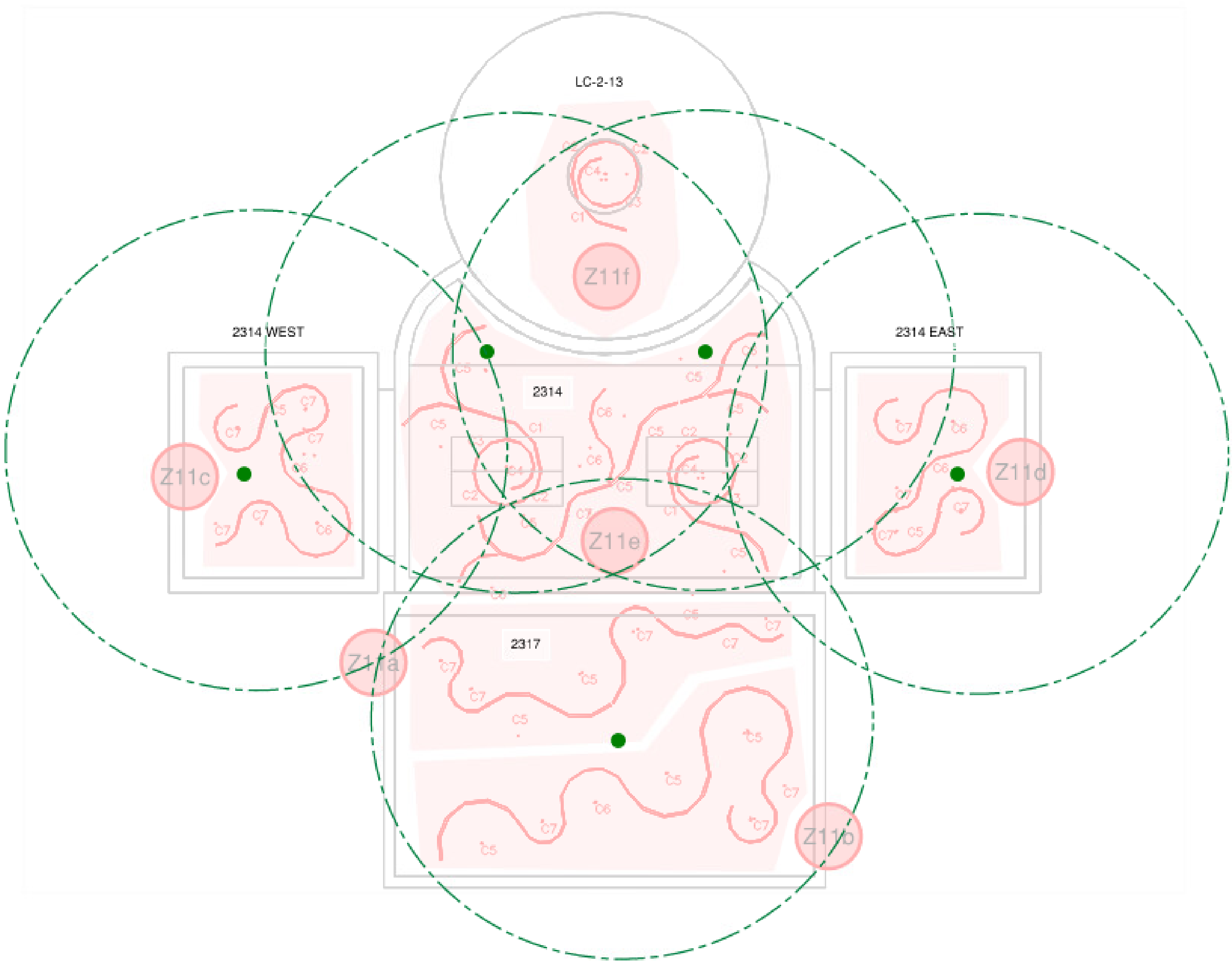
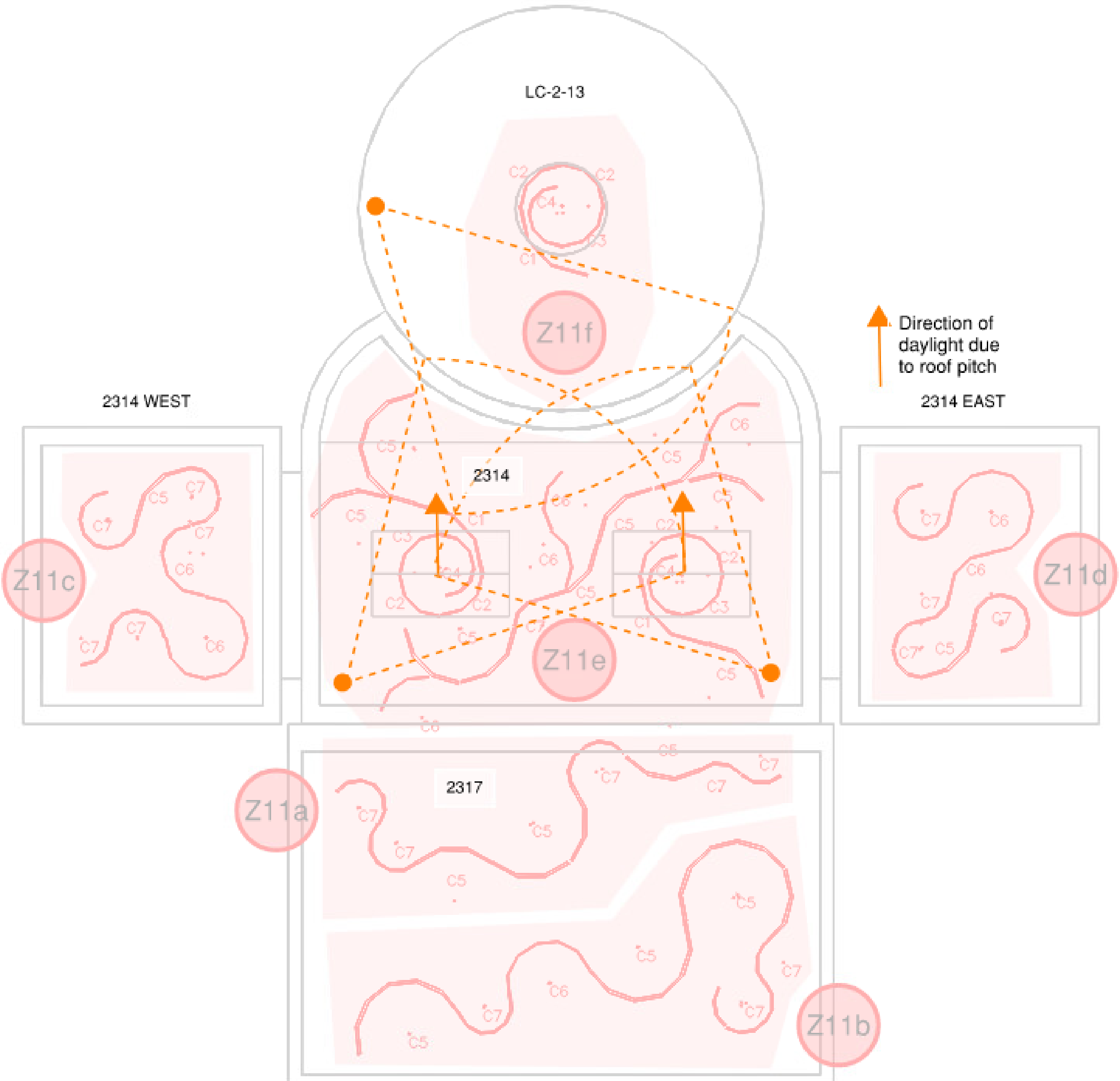


To the left is the control diagram for the new RLC11.

The below image is an occupancy sensor layout diagram, which indicates the proposed locations of five new occupancy sensors. Their coverage of 1500 ft^2 is indicated as a dotted line around the sensor. All are mounted at 12' or below, the requirement for this level of coverage.





The above image is a diagram showing the placement of three new 60-degree daylight sensors. As this space receives a very high amount of daylight (sDA 88.7; see **MAE Depth**), the High (3-300 fc) daylight input setting will be chosen for all three. The two southmost sensors are mounted on the pitched ceiling, behind the skylights in relation to where most of the daylight will enter. Although the high mounting decreases the range of the sensors, this should be mitigated by the sheer amount of daylight in the space. The third sensor, mounted at 12’ on the underside of the dome’s cornice detail, accounts for the large amount of daylight in the southern half of room LC-2-13.

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MAE COMPUTER OPTIMIZATION & DAYLIGHTING DEPTH

INTRODUCTION

The Media Commons (combined Information & Technology Commons) is a large space centrally located in the library that serves a major workspace for students. Despite this, there is no natural light in the space, whether from windows or skylights.

MOTIVATION & SCOPE

Because natural light has been proven to have positive effects on mood, health, and productivity, the addition of skylights to the main roof of the space should be investigated. Number, size, and placement of skylights, as well as roof pitch, play an important role in providing ample daylight. This analysis optimizes the arrangement and roof pitch with respect to the maximum value of sDA (spatial daylight autonomy) achievable in the space.

Optimal skylight layouts can be calculated by hand; however, the efficiency of the process can be vastly improved by an optimization algorithm. This study makes use of the Rhino companion analysis software, Grasshopper, as well as the plugin DIVA and the optimization tools Radical and Galapagos. All tool authors are cited in **Appendix IV** attached to this thesis.

ANALYSIS SUMMARY

In short, this analysis details the construction of the Rhino / Grasshopper model of the Media Commons, the subsequent optimization of sDA with two different algorithms, and the associated interpretations and product selection.

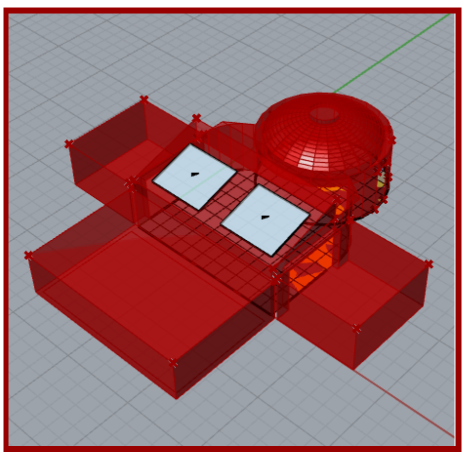
As a note, rectangular skylights were chosen as the objective for optimization. While tubular skylights have comparable energy-saving benefits and daylight capture, their aesthetic and thematic function is different. One of the goals of this study is to connect the Media Commons to the outside; therefore, clear-glazed rectangular skylights were chosen rather than daylight tubes, which mimic artificial light fixtures.

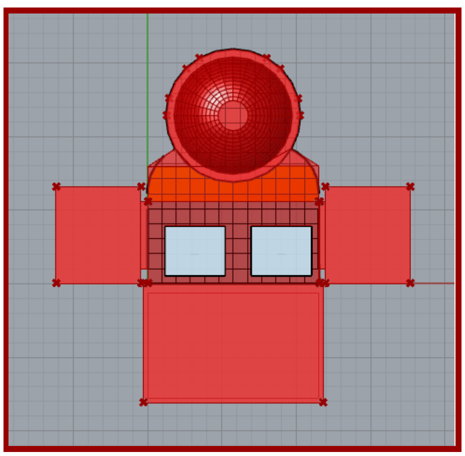
MODEL CONSTRUCTION & PARAMETERS

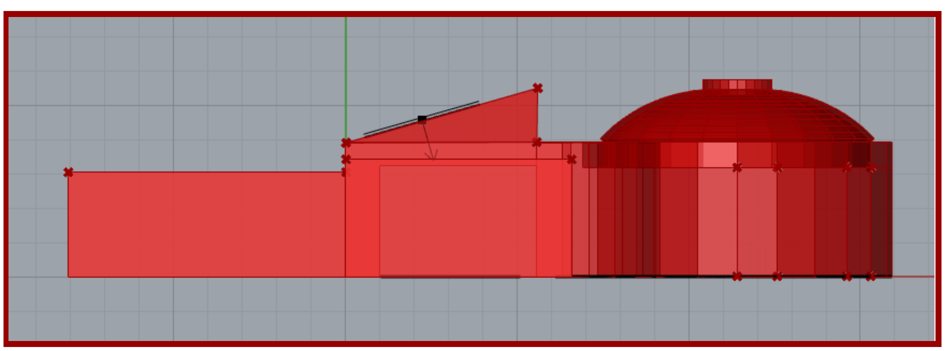
The model of the Media Commons was constructed in Sketchup Pro software, then imported to Rhino. The ceiling was left out and reconstructed in Grasshopper, in order to make it parametrically configurable. The following parametric variables were set forward:

VARIABLE	UNIT	BOUNDS
Rows	--	1 - 5
Columns	--	1 - 5
Left Boundary	% of curve division length	0.1 - 0.4
Right Boundary	% of curve division length	0.5 - 0.9
Upper Boundary	% of curve division length	0.1 - 0.4
Bottom Boundary	% of curve division length	0.5 - 0.9
Roof Height	m (increments of 0.5)	3.9 - 9

These values were used to create a wide array of skylight configurations, with different numbers, sizes, and roof pitches. To give an idea of the model's appearance and orientation, the following images have been included.





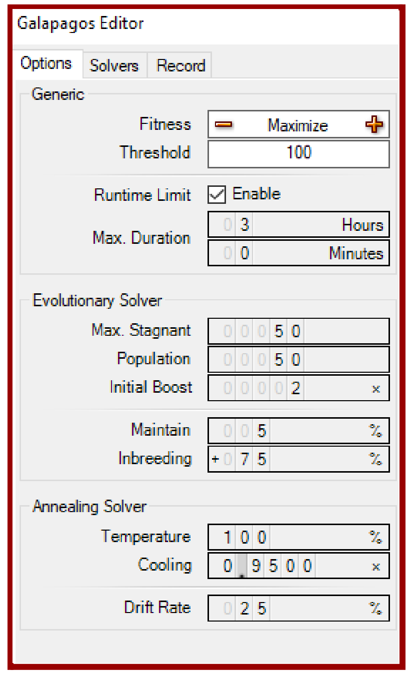


A daylight simulation was set up in DIVA, with the following parameters:

GRID SPACING: 1 meter
GRID PLACEMENT: At finished floor
MATERIAL REFLECTANCES: 80 / 60 / 20
SKYLIGHT GLAZING: Double-glazed; 80% VT
LOCATION: Dulles International Airport (.EPW file)

PRIMARY OPTIMIZATION WITH GALAPAGOS

After ensuring a successful daylighting simulation, an optimization was set up in Galapagos to maximize sDA. The image on the right shows the parameters specified for the optimization. The evolutionary solver algorithm was used, with Fitness (objective function) set to sDA and Genome (variables) set to those referenced in the table on the previous page.



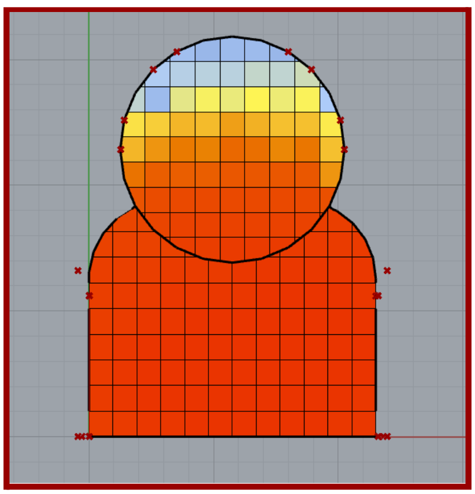
Included below is a table of the starting values of each parametric variable in the simulation.

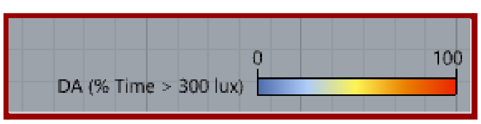
VARIABLE	UNIT	STARTING VALUE
Rows	--	1
Columns	--	1
Left Boundary	% of curve division length	0.4
Right Boundary	% of curve division length	0.5
Upper Boundary	% of curve division length	0.4
Bottom Boundary	% of curve division length	0.5
Roof Height	m (increments of 0.5)	3.9

After the simulation, Galapagos yielded a **maximum sDA of 88.7,** at the following values:

VARIABLE	UNIT	OPTIMAL VALUE (Galapagos)
Rows	--	1
Columns	--	2
Left Boundary	% of curve division length	0.1
Right Boundary	% of curve division length	0.7
Upper Boundary	% of curve division length	0.1
Bottom Boundary	% of curve division length	0.8
Roof Height	m (increments of 0.5)	5.5 (from floor)

As one can see from the sDA grid to the left, the main space has been fully maximized to sDA 100, while the dome (Information Commons) has lower values, dipping into the 50s and below.





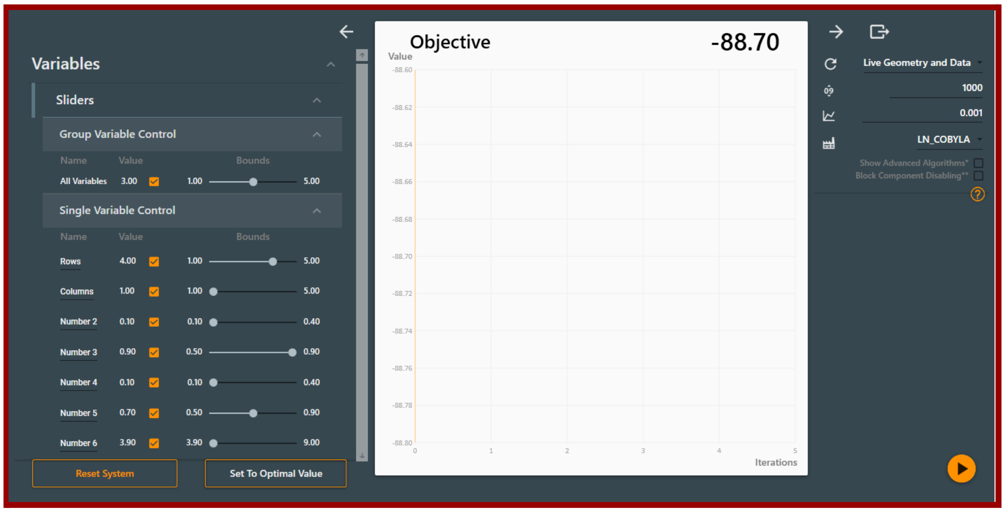
The **optimal roof pitch angle**, using the roof height value, was calculated to be **15.695815 degrees.** This will be referenced later in the Structural breadth.

On the following page is the summary of a secondary analysis using a different tool, as well as the interpretation and implementation of results.

NOTE: Grasshopper and associated Rhino files can be provided upon request of the reader.

SECONDARY OPTIMIZATION WITH RADICAL

A second optimization was conducted with the Radical tool, part of the Design Space Exploration plugin for Grasshopper. This was done to confirm the analysis conducted by Galapagos; below is an image of its output. This tool also yielded a **maximum sDA value of 88.7**.



NOTE:
The value given in the image is negative due to the nature of the Radical tool. It is built to minimize values, rather than maximize. Therefore, the sDA value was multiplied by -1 before being optimized in Radical, yielding a negative maximum value.

INTERPRETATION & IMPLEMENTATION OF RESULTS

This analysis suggests that two large skylights, tilted at an angle of approximately 16 degrees, will provide optimal usable daylight to this space, based on its orientation and solar location. The question now is: can this computer-generated solution be practically implemented?

First, we must determine the actual dimensions of the optimal skylights. Due to the nature of the parametric variables (in percentage of divided curve length), this will need to be done proportionally. The ceiling in the x-direction is 11.5 meters, and in the y-direction is 5.5 meters long. The x-calculation yields: 11.5 / 2 = 5.75 * 0.7 - 5.75 * 0.1 = 3.45 m. The y-calculation yields 5.5 / 2 = 2.75 * 0.8 - 2.75 * 0.1 = 1.925 m. Therefore, skylights of dimensions 3.45 x 1.925 m, or **11.3 x 6.3 ft,** will be needed.

As a rule of thumb, skylights should not take up more than 15% of a given space's floor area. The floor area of the space chosen for study, the Information Commons and main room of the Technology Commons, is 1645.74 ft^2, so the maximum skylight area should be 246.861 ft^2. The current skylight area is **142.38 ft^2,** which is within the 15% window. That said, an 11x6 skylight is very large, and is not practical to specify or install

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Instead, the chosen skylight will be the Wasco SkyMax large-span skylight, with a maximum area of 32 ft^2. Two of these **10' x 3' 2 ½" skylights**, placed side by side, should provide as similar an effect as possible to each of the 11' 3 ⅝" x 6' 3 ⅝" optimal skylights. The chosen skylight is pictured below.

The SkyMax is suitable for roof pitches from 1 to 60 degrees, meets IECC energy code in all climate zones, and its specified glazing is a double layer: one of 1/16″ Solarban 70XL Low-E coated glass and one of clear glass, with a VT of 64% and SHGC of 0.27. See **Appendix II** for the chosen skylight's technical documents and further specifications.

Running the sDA calculation again, with the adjusted VT and glazing properties, the result is **85.0.**

CONCLUSION

Calculating skylight layouts by hand, while possible, can be improved upon through the use of computer optimization, as long as the user has a grasp on what is and is not realistic in terms of implementation.

Upon installation, these skylights will provide ample spatial daylight autonomy to the students in the Media Commons, improving physical wellbeing and productivity. Furthermore, the low solar heat gain coefficient, paired with the new daylighting controls detailed in the electrical depth, will help improve energy consumption.

To investigate the required structural alterations to the designated roof section, please refer to the Structural Breadth on **page 70**.

ACOUSTIC BREADTH

INTRODUCTION

The 100-Person Theater on the second floor, while small, does not have a dedicated system for mitigating the noise from visiting speakers or performances. This analysis aims to evaluate the current ability of the space to absorb this noise, to provide a comprehensive measure of acoustic treatment, and to re-analyze the space's acoustic properties post-noise mitigation.

MOTIVATION & SCOPE

Because most of the Trible Library is devoted to quiet study, a speaker or performance in the 100-person theater could create enough sound trespass to potentially disrupt these endeavors. Measures may need to be taken to keep the library surrounding the theater quiet during these times; this study aims to discern how much mitigation is needed.

This analysis will be done through a calculation of the theater's room sound absorption and reverberation time before and after the new acoustic treatment (if deemed necessary), as well as a study of sound trespass into an adjacent space in the library proper. Three calculation cases will be considered, for three of the standard octave band center frequencies: 500 Hz, 1000 Hz, and 2000 Hz. These frequencies were chosen as they are typically used to calculate the acoustic properties of materials for commercial distribution.

ROOM SOUND ABSORPTION

The tables on the following page detail the absorption coefficient for each major material present in the theater, for the three specified octave band center frequencies. They also indicate the total surface area takeoff for each material region.

These values have been provided both in the Pennsylvania State University's AE 309 (Acoustics) course and by the LEED v4 handbook, used for assigning acoustic points to LEED candidate buildings.

Following the tables is a calculation of the total room sound coefficient for each octave band center frequency.

500 Hz

ELEMENT	MATERIAL	α	AREA (ft^2)
FLOOR	Broadloom carpet	0.15	1027.48
WALLS	Plaster	0.02	1271.88
CEILING	Gypsum	0.05	1519.16
DOORS	Wood	0.1	196.14
STAGE	Wood	0.1	280.96
FURNITURE	Med. upholstered seats	0.70 / 0.82 occupied	493.03

1000 Hz

ELEMENT	MATERIAL	α	AREA
FLOOR	Broadloom carpet	0.3	1027.48
WALLS	Plaster	0.03	1271.88
CEILING	Gypsum	0.04	1519.16
DOORS	Wood	0.07	196.14
STAGE	Wood	0.07	280.96
FURNITURE	Med. upholstered seats	0.72 / 0.85 occupied	493.03

2000 Hz

ELEMENT	MATERIAL	α	AREA
FLOOR	Broadloom carpet	0.5	1027.48
WALLS	Plaster	0.04	1271.88
CEILING	Gypsum	0.07	1519.16
DOORS	Wood	0.06	196.14
STAGE	Wood	0.06	280.96
FURNITURE	Med. upholstered seats	0.68 / 0.86 occupied	493.03

INITIAL ROOM SOUND ABSORPTION (cont.)

$A_T = \Sigma A_i = \Sigma S_i \alpha_i$

	500 Hz	1000 Hz	2000 Hz
A_T (sabins) - UNOCCUPIED	648.35	795.54	1034.84
A_T (sabins) - OCCUPIED	707.51	859.64	1123.59
UNOCCUPIED α	0.135	0.166	0.216
OCCUPIED α	0.148	0.180	0.235

INITIAL REVERBERATION TIME

CONSTANT VALUES

Total volume of space: 22,223.7 ft^3
Total surface area of space: 4,788.65 ft^2
Air attenuation constants:
500 Hz - 0.001 dB / ft
1000 Hz - 0.001 dB / ft
2000 Hz - 0.003 dB / ft

SABINE EQUATION (for $\alpha_T < 0.20$)

$RT_{500} = 0.049V / (S_T\alpha + 4a_aV)$

= 0.049(22223.7) / (4788.65*0.135 + 4*0.001*22223.7)
= **1.48 s, UNOCCUPIED**

= 0.049(22223.7) / (4788.65*0.148 + 4*0.001*22223.7)
= **1.54s, OCCUPIED**

$RT_{1000} = 0.049V / (S_T\alpha + 4a_aV)$

= 0.049(22223.7) / (4788.65*0.166 + 4*0.001*22223.7)
= **1.23s, UNOCCUPIED**

= 0.049(22223.7) / (4788.65*0.180 + 4*0.001*22223.7)
= **1.14s, OCCUPIED**

NORRIS-EYRING EQUATION (for $\alpha_T > 0.20$)

$RT_{2000} = 0.049V / (-S_T \ln(1 - \alpha) + 4a_aV)$

= 0.049(22223.7) / (-4788.65*ln(1 - 0.216) + 4*0.003*22223.7)
= **0.84s, UNOCCUPIED**

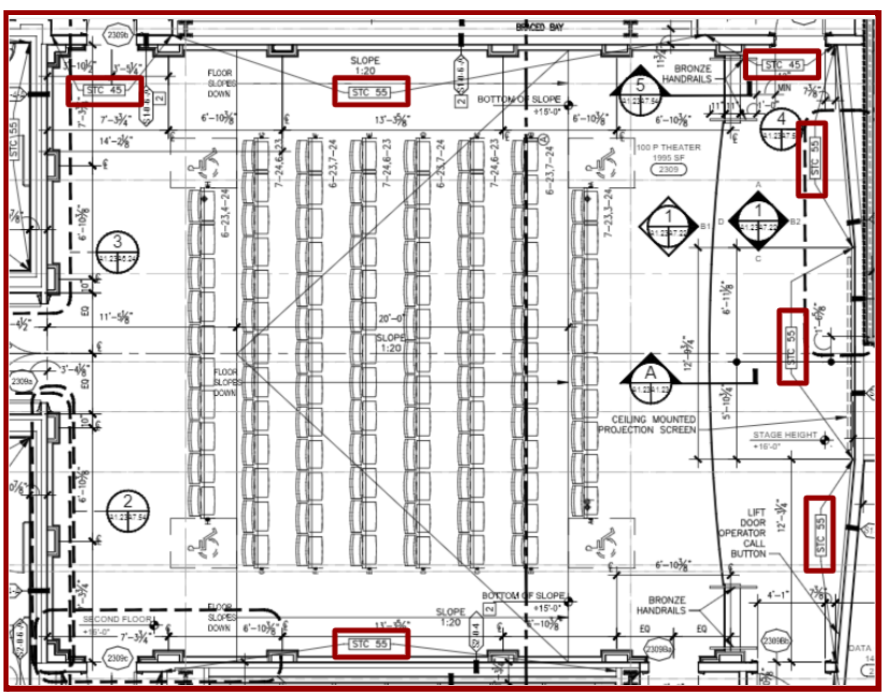
= 0.049(22223.7) / (-4788.65*ln(1 - 0.235) + 4*0.003*22223.7)
= **0.78s, OCCUPIED**

The desired reverberation time for a small auditorium is generally said to be between **1.5 - 2.0 seconds**. As can be seen here, the values are within, or in fact, lower than this threshold. The slightly lower values are ideal for a library where sound absorption is a design goal, so no extra measures will be taken to increase the calculated values for the 1000Hz and 2000Hz octave band center frequencies.

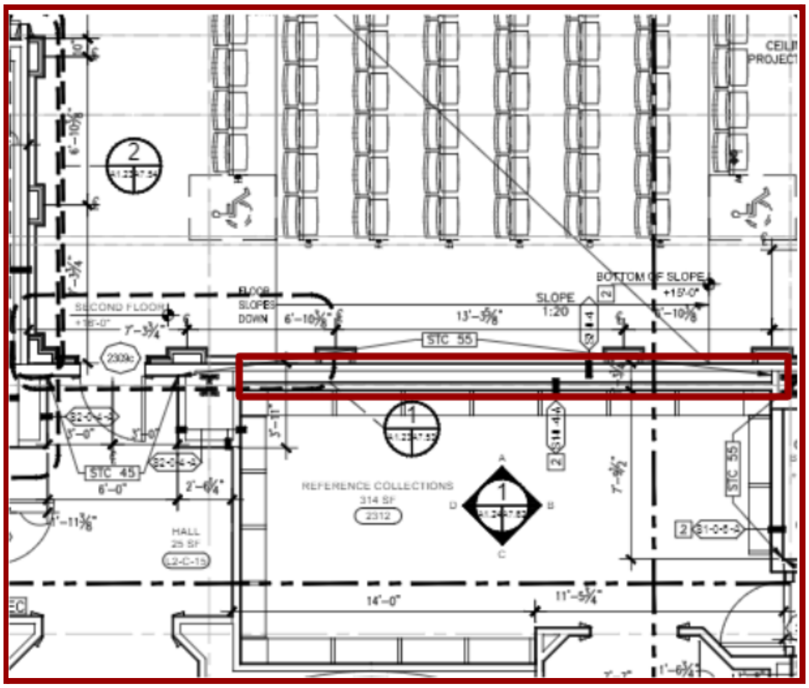
WALL STC RATINGS

The image to the right, taken from the architect-provided drawings (Sheet A1.23) indicates the STC (sound transmission class) rating for the walls of the theater.

For the purpose of this study, we will focus on the south wall, with an STC of 55. This wall borders the Reference Collections



room, a quiet library storage and reading space. The common partition is indicated in the image below, and is 25' 5 ¾" in length.



Converting the STC of 55, the FSTC (field sound transmission class) rating of the current wall is 50. These values are considered minimum quality in terms of acoustic absorbance, and may not be sufficient for this room. Generally, performance and speaking-based spaces should have walls of a minimum STC of 60, or 55 FSTC.

Next, we'll look at the noise criteria set for these two rooms.

	NC	SPL, 500Hz	SPL, 1000Hz	SPL, 2000Hz
Theater (small auditorium, <500 seats)	NC-30	35	31	29
Reference Collections (library)	NC-35	40	37	35

Interestingly, the noise criterion for the Reference Collections is higher than that of the theater. Still, conducting a small study into sound transmission between the spaces will be useful for determining whether STC 55 is high enough for the partition between the spaces.

$$\mathbf{L_R} = \mathbf{L_S} - \mathbf{R} + 10 \log (\mathbf{S_w} / \mathbf{A_r})$$

L_r = Receiving room average SPL (dB)

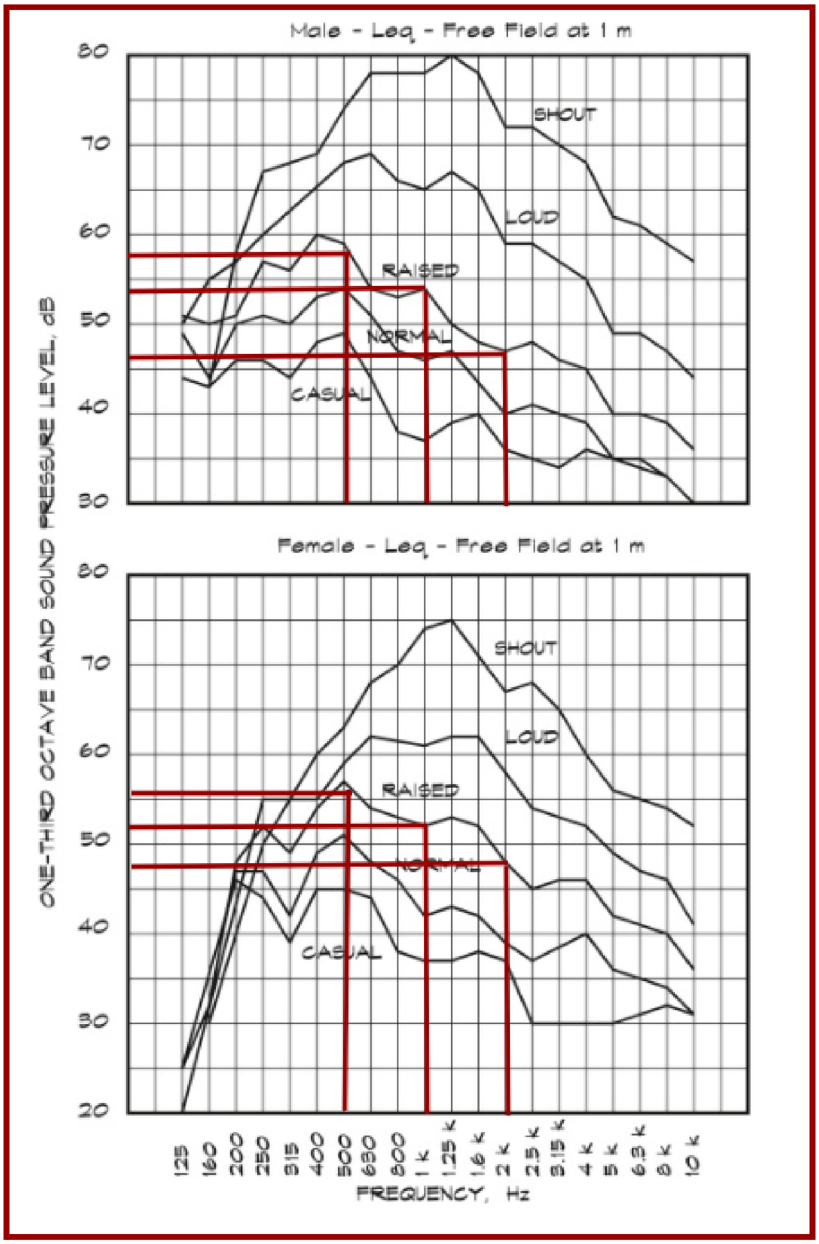
L_S = Source room average SPL (dB)

R = Field transmission loss (dB)

S_w = Common / transmitting surface area (ft^2)

A_r = Room constant of the receiving room (ft^2 sabins)

L_S, the sound pressure level (SPL) in the source room should be determined. The charts below detail sound pressure levels at the three chosen octave band center frequencies, for male and female voices. The *raised* voice curve was chosen as, in this space, most of the use cases will be guest lectures or small performances, implying a voice amplified by a microphone.



The values, averaged between male and female, are as follows:

500 Hz = **56.5 dB**
1000 Hz = **53 dB**
2000 Hz = **46.5 dB**

Field transmission loss, **R**, is calculated by the equation 10 log **τ**, where **τ** is transmission loss. According to the STC 55 contour, transmission loss of the partition is:

500 Hz = 53
1000 Hz = 60
2000 Hz = 61

Using the equation, R is as follows:

500 Hz = **17.24**
1000 Hz = **17.78**
2000 Hz = **17.85**

S_W, the common partition area, is 25' 5 ¾" x 11' 3" (ceiling height) = **286.64 ft^2.**

Finally, **A_r**, the room constant, is calculated as S*α / 1 - α, or the surface area of the room times the average absorption coefficient, over one minus the average absorption coefficient. These values have been calculated assuming that the source room (theater) is occupied.

500 Hz = **829.8**

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1000 Hz = **1047.6**
2000 Hz = **1432.4**

The compiled values:

L_r = *unknown*
L_S = 56.5, 53, 46.5
R = 17.24, 17.28, 17.85
S_w = 286.64
A_r = 829.8, 1047.6, 1432.4

$\mathbf{L_R} = \mathbf{L_S} - \mathbf{R} + 10 \log (\mathbf{S_w} / \mathbf{A_r})$
$L_{R\ 500\ Hz} = 56.5 - 17.24 + 10 \log (286.64 / 829.8) = 34.74$ dB
$L_{R\ 1000\ Hz} = 53 - 17.28 + 10 \log (286.64 / 1047.6) = 30.09$ dB
$L_{R\ 2000\ Hz} = 46.5 - 17.85 + 10 \log (286.64 / 1432.4) = 21.66$ dB

To summarize, the noise criteria of the Reference Collections are detailed below and compared to the found SPLs transmitted by the adjacent room.

	NC	SPL, 500Hz	SPL, 1000Hz	SPL, 2000Hz
Reference Collections (library)	NC-30	40	37	35
Sound received from Theater		35	30	22

These values are within the sound pressure levels given by the noise criteria, so no change in common partition is needed. That said, a reduction could be helpful as the values, especially at 500 and 1000 Hz, do approach the upper limit of acceptability. A slightly higher STC partition, perhaps 60, would be more in line with the typical standards for an acoustically-sensitive space.

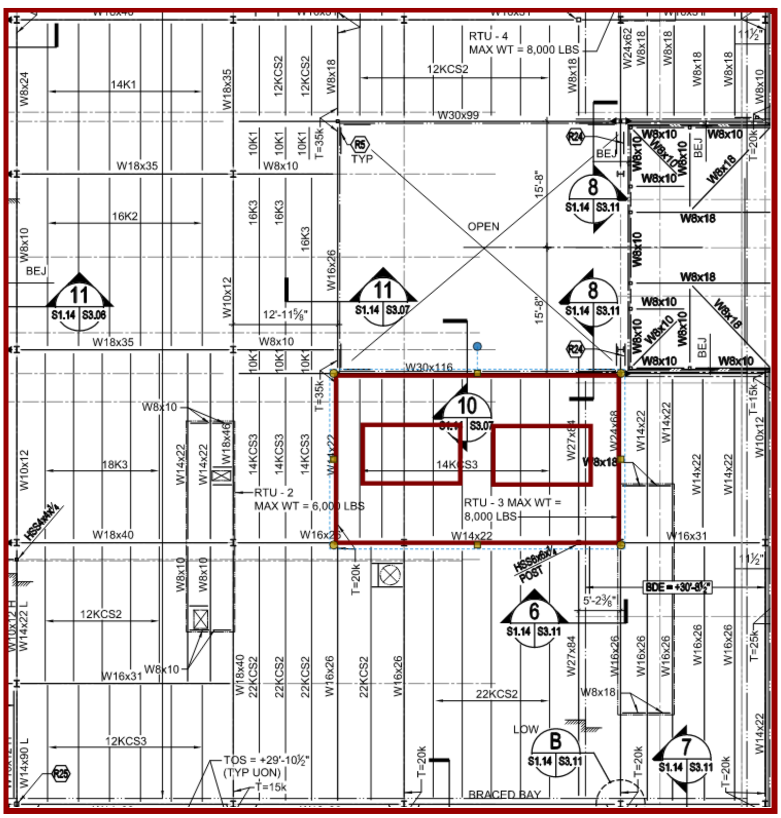
STRUCTURAL BREADTH

INTRODUCTION

In the Daylighting depth, the roof of the Media Commons was altered from effectively flat (a few 2-degree portions were present for drainage purposes) to pitched, in order to accommodate four new large skylights. Load calculations of this new pitched roof are needed in order to ensure it is structurally sound.

MOTIVATION & SCOPE

The portion of the ceiling affected is highlighted in the image below, along with the placement of the new skylights (each rectangular area includes two 10' x 3' skylights). The optimal roof pitch was determined algorithmically in the Daylighting depth to be 15.69 degrees, which has been rounded to 16 degrees here as a worst-case loading scenario. The area of the affected roof is 34.5'x 19.5'.



The following study calculates the adjusted dead, live, snow, wind uplift, and wind downlift loads on the pitched roof. New structural framing is laid out in the adjusted roof and around the skylights. Finally, in the structural loading simulation software ETABS, the required members are sized using these hand-calculated assigned loads.

Because the Trible Library renovation follows IBC 2012, ASCE 710 is applied and referenced throughout the following load adjustment calculations.

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CALCULATION OF ADJUSTED LOADS

The following loads were referenced from Sheet S0.01 of the provided drawings, and can be safely assumed as unaltered by roof pitch.

Load Type	Load	Unit
Live	20	PSF
Dead	10	PSF
Snow	16.5	PSF

The wind load is more complex, as it is altered by an increased roof pitch. Values for the load cases of both wind uplift and wind downlift needed to be calculated. The following is a summarized version of these calculations, the rough hand versions of which are included in **Appendix III** of this report.

A few values given on Sheet S0.01 were necessary for the calculation:

Useful given values
Wind speed: 120 MPH
Exposure category: B
Internal pressure coefficient: +/- 0.18

The wind load equation is as follows for both load cases, uplift and downlift:

$\mathbf{p} = \mathbf{q_z} * G * C_p - \mathbf{q_z} * (G * C_{pi})$

where
$\mathbf{q_z}$ = wind pressure
G = 0.85 (standard)
C_p = pressure coefficient = -0.826 (uplift); -0.16632 (downlift)

This value is found by interpolation of values in Figure 27.4-1 in ASCE 710.
It is partially determined by the ratio of roof height vs. length, or the pitch.
See full calculations for interpolation.

C_{pi} = internal pressure coefficient = +/- 0.18 (uplift/downlift)

Wind pressure, $\mathbf{q_z}$, is calculated by the following equation:

$\mathbf{q_z} = 0.00256K_z * K_{zt} * K_d * V^2$

where

$K_z = 2.01\ (z/z_g)^{2/a} = 0.58$

z = mean roof height, 15.8'; $z_g = 1200$, $a = 7.0$

See full calculations for further information.

$K_{zt} = 1$ (due to mostly flat topography)

$K_d = 0.5$ (standard)

V = wind speed = 120 MPH

q_z = **10.69 PSF**

Reapplying wind pressure to the wind load case equation:

$p = q_z*G*C_p - q_z*(G*C_{pi})$

$p = (q_z*G)*(C_p - C_{pi})$

UPLIFT

$p = (10.69*0.85)*(-0.826 - 0.18)$

$\mathbf{p_{UPLIFT} = -9.141\ PSF}$

DOWNLIFT

$p = (10.69*0.85)*(-0.16632 + 0.18)$

$\mathbf{p_{DOWNLIFT} = 0.1243\ PSF}$

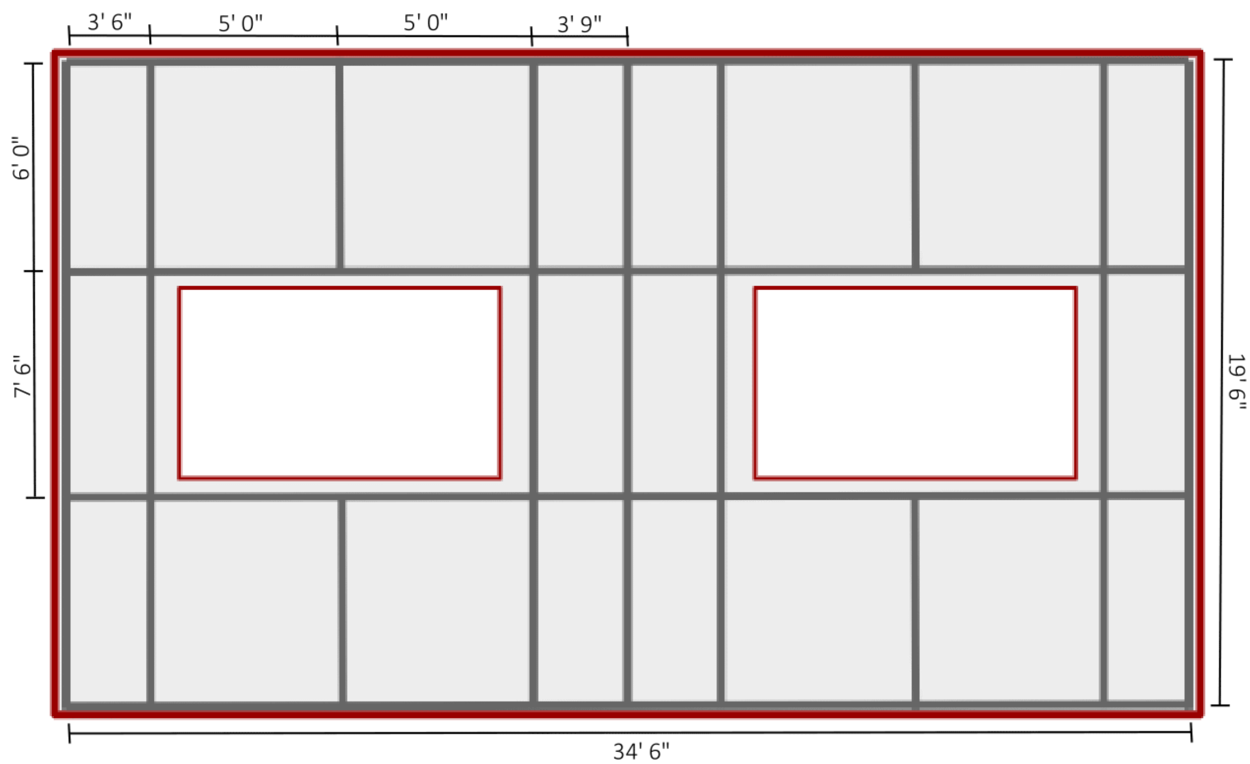
With the new wind loads calculated, the loads were as follows:

Load Type	Load	Unit
Live	20	PSF
Dead	10	PSF
Snow	16.5	PSF
Wind (uplift)	-9.141	PSF
Wind (downlift)	0.1243	PSF

Following this calculation of the raw PSF for each load, tributary width was determined and total loads were calculated in Excel for each member. If desired, please contact msh5424@psu.edu for the full structural calculation operable spreadsheet.

FRAMING DESIGN

Along with the horizontal members of the original design, additional framing was needed around the new skylights. The following design was proposed:



APPLICATION OF LOAD CASES

Four of the load combinations (weighted combinations of individual loads) presented in ASCE 710 were relevant to this roof adjustment. D denotes dead load; L, live load; and $W_{U,D}$, wind uplift and downlift, respectively. Note that snow load is not used - ASCE gives the option of calculating with live or snow load, so the higher of the two was chosen.

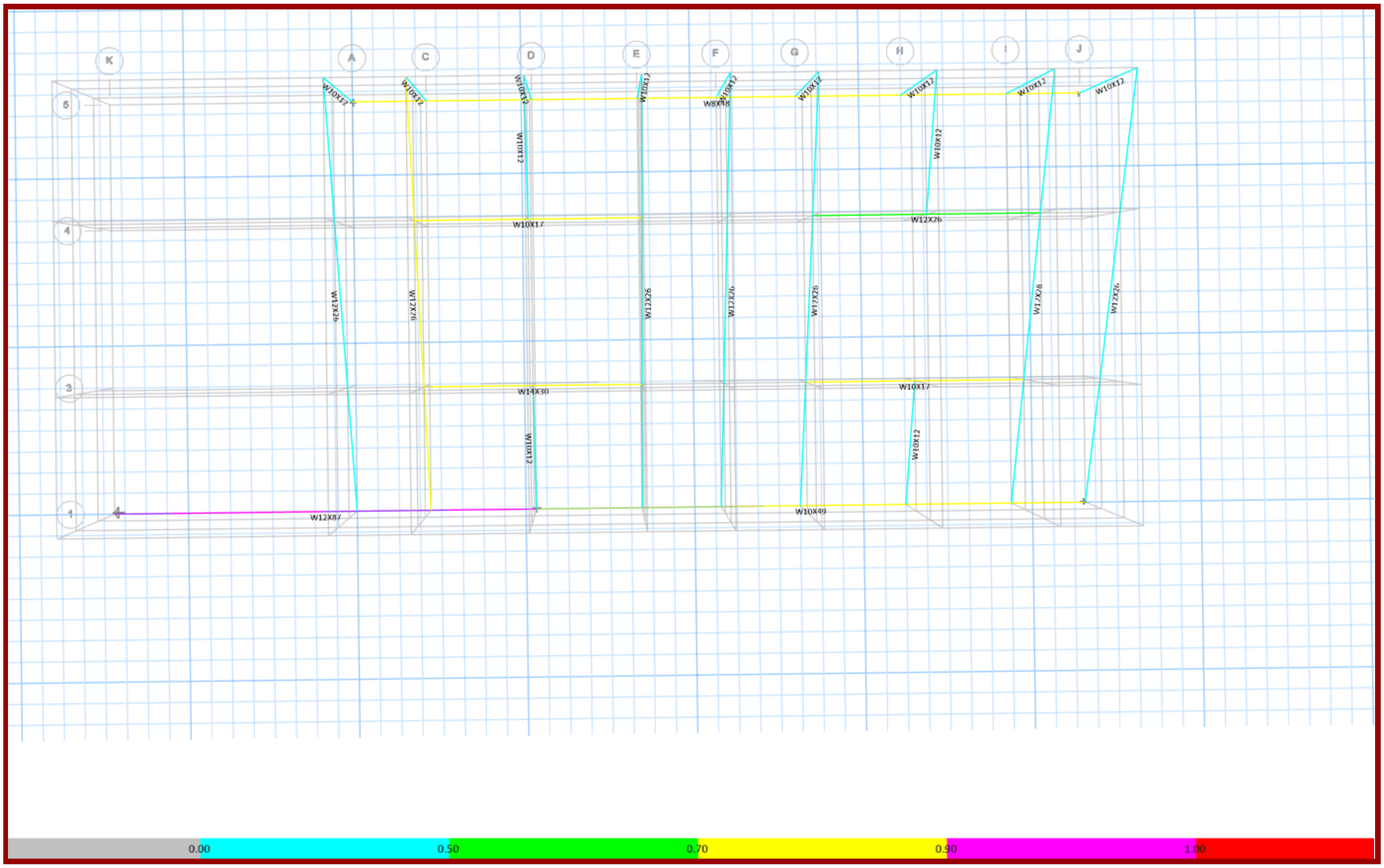
Combo 1	$1.4D$
Combo 3	$1.2D + 1.6L + 0.5W_D$
Combo 4	$1.2D + 1.0W_{U,D} + 0.5L$
Combo 6	$0.9D + 1.0W_U$

The total load values calculated in Excel were applied to these weighted expressions in ETABS, which is detailed below.

MEMBER SIZING IN ETABS SOFTWARE

The ETABS software allowed for the input of the four main load combinations present for this roof. The load values, as calculated in Excel, were also inputted. To see the individual load type applications on each member, see **Appendix III**.

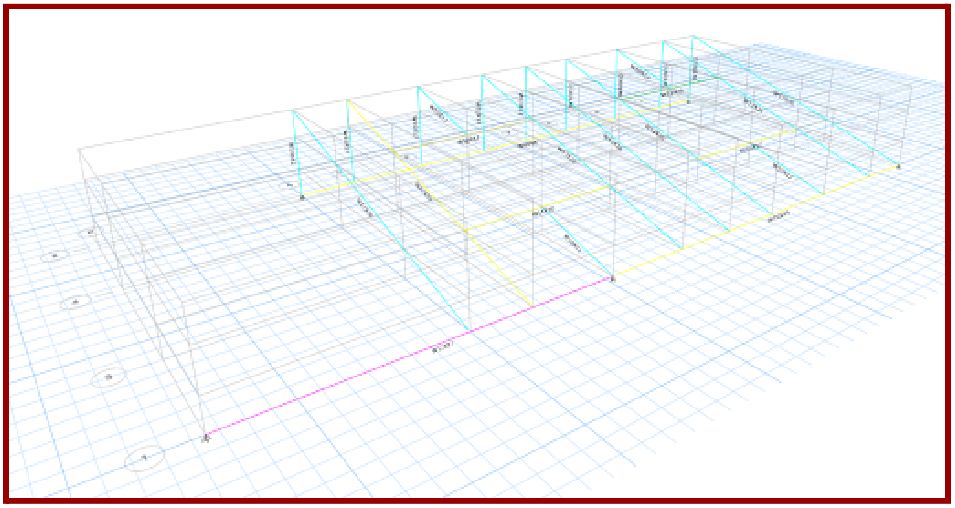
A simulation was then run to find the appropriate size for each member. The following is the output of said simulation. Member sizes are listed adjacent to the member, while color indicates the relative stress in each member.



On the following page is another image which gives a better idea of the mass and layout of the new structural framing design. For a larger version of these images, please refer to **Appendix III**.

Size summary

Horizontal members: W12x26
Roof-height columns: W10x12
Large-span members: W8x48 (back), W10x49 (front), W12x87 (far left)
Skylight framing: W10x17 (upper left, lower right), W12x26 (upper right), W14x30 (lower left)



POTENTIAL ERROR

As can be seen in the simulation output, there is a minor source of error. A member that continued beyond the portion of the roof being renovated was included in the simulation to increase accuracy. Its tributary width of 26' was included in the full Excel calculations of total load. However, the neighboring member (of size W10x49) was treated as if isolated from the other side of its tributary. Assuming a slightly higher total load on that member, then, the size likely would have been nearer to its neighbor, at W12x87.

Despite this, multiple measures were taken that mitigate the error. There existed a continuous effort to round all values up; to assume the highest possible loads; and to include load combinations that may not be applicable except in extreme situations (combination 1, 1.4D).

CONCLUSION

Although the change in roof pitch was dramatic, the sizes of the members and relative stress indicate that the new design is still well within the realm of feasibility. Completely horizontal (rather than pitched with the roof) members were considered, but it was ultimately decided that they would interrupt the daylight and aesthetic flow of the space. This output demonstrates that they were indeed not necessary, providing a new open and airy ceiling with copious daylight to the previously dark and enclosed Media Commons.

CONCLUSION

Closing Remarks

This year-long comprehensive study represents what one person, given the opportunity, would change about an already-beautiful, already-complete project. The takeaway, then, shouldn't be that the proposed redesigns are necessary or superior. Rather, this is proof of the wonderful thing about design work: while there are many viable solutions to any given problem, the person behind a project is what makes it unique. And I should revise that, as well: the *people* behind a project are what makes it unique.

Producing this individual thesis is a radically different experience to anything we as architectural engineers do beforehand in our coursework and afterward in our careers, because the art and science of comprehensive building design is intrinsically collaborative. The total creative control, the cohesive deliverables, the lack of asking the mechanical team to move their diffuser so a luminaire can go there instead, please — all of that is a welcome break at first. However, especially in an isolation and pandemic-driven time, that company is soon missed. I look forward to the day where a project like this can once again be shared with a team.

To speak to the paper itself, the references to H.G. Wells' writings (particularly *The Time Machine*) present in the Lighting Depth echo into the other corners of study. His drive to keep moving forward in technology, human rights, and environmental protection is the same one a fully-developed architectural engineer should strive to have. I hope it's evident that threaded throughout this thesis is a line of curiosity and a desire to hold that drive.

To wrap up, I hope you learned something, felt something, or at least made it through while reading this — now it's your turn! Go and make something!

ABET Accreditation

PSU AE - ABET 2.3

The fixture changes proposed in the Lighting depth, as well as the more comprehensive sensor-based controls introduced in the Electrical depth, will positively affect HVAC loads and energy consumption, as many of the fixtures within the current building design are not LED and occupancy / daylight sensors are few. The switch to more distinctly modern lighting modes will also provide ease of maintenance and installation in terms of construction management.

Additionally, the implementation of skylights in the Daylighting depth will reduce heating loads in the winter and will provide an alternate method of lighting the space, resulting in less power consumption.

PSU AE - ABET 2.4

The redesigns offered in this thesis meet and exceed requirements of all applicable safety codes, ensuring public health, safety, and welfare. This is most pertinent in the Electrical depth, which requires the installation of new electrical items.

The conceptual intent of the design seeks to encourage students to learn and to invite everyone, regardless of who they are, into this public space of learning. This specific emphasis on inclusion may be especially pertinent to the current social climate in a divided America.

Finally, the investigation of more comprehensive daylighting applications and detailed controls is focused on energy conservation. That conservation has been pursued with an eye to sustainability, as well as economic (in the form of energy savings) and environmental factors.

PSU AE - ABET 7.2

In the Lighting depth, an analysis of the light levels of potential designs has been conducted in AGI32, and has been evaluated against the recommendations set forth in the 2010 IES Handbook. Renderings were completed in software including AGI32, Sketchup, and Photoshop.

In the Electrical depth, a detailed understanding of the fixtures and control devices was required, information which was acquired from the manufacturers' provided technical documents. National Electric Code (NFPA 70) was specifically followed.

The MAE Daylighting and Computer Optimization depth

The Structural breadth required calculation of loads by hand. Information about building members and materials were gleaned from the architect's drawings, and the software ETABS was used to assist in new member sizing. ASCE 710 was also referenced.

The Acoustical breadth required additional research into articles regarding small-theater acoustics, as well as independent reading on sound and voice transmission.

Acknowledgements

I must first thank my family. Lucy, my little sister, who was always up for a phone call while I was in the thick of a long simulation or tricky calculation; Joy, my mother, who worked so tirelessly and selflessly to bring me little bits of joy while I was working in my sometimes cave-like apartment; and Roland, my father, who helped me put out so many little fires throughout the process that he should consider changing careers to a fire protection specialist. Thanks for listening to me ramble about footcandles and daylighting simulations, guys.

To my extended family both near and far, thank you for your unwavering support both in this thesis and throughout my degree. I have felt the love from all corners and it's helped bolster me to finish this thing as best as I possibly can. Also, due to a hard drive corruption two weeks from the finish line, I wouldn't have had a computer to finish with at all if it wasn't for the help of my amazing extended family. You're all the very best.

To my friends… gosh, what to say? Thanks for making a global lockdown the most socially-fulfilling year of my life. My dear friends at home who have known me from my 8th-grade days, you are always there to lend an ear and offer truly unconditional support. It's rare that you find a group you can count on with such utter regularity, but I'd say 10+ years is pretty good proof of concept. My AE friends who've sat with me for hours upon hours in classes and thesis, thank you for providing such a fun, wonderfully sarcastic atmosphere in which to work — and play sometimes, too, when we have the time to breathe. Thanks also for encouraging my creative hobbies; the best feeling in the world is bringing others joy with what I make.

Thank you to all those professionals who have helped me on my journey. To my mentors at Lam Partners and AE Works (to name a few: Steve Iski, Olivia Eckard, Tori Roberts, and Beth Kassahun), I have learned more from you than I could have ever hoped to. Your breadth of knowledge, passion for your work, and encouragement of my curiosity helped bring me here.

And finally, to the AE faculty — the professors, instructors, advisors, and everyone else who worked alongside us to help us set out into the AE world — many, many thanks.

I'd like to particularly acknowledge:

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Mr. David Stabler	Professor and Electrical Advisor
Mr. Shawn Good	Instructor and Lighting Advisor

Thank you for being present and understanding during the ups and downs of this strange and difficult remote semester.

And if you read this thesis, a thank-you for you, too!