

Senior Thesis Presentation  
Bucks County Justice Center  
Doylestown, PA

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Lighting/Electrical

Thesis Adviser: Dr. Richard Mistrick

Electrical Adviser: Gary Golaszewski

4/15/2015



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# Introduction

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Bucks County Justice Center  
Doylestown, PA



# Introduction

Presentation Overview

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Building Overview

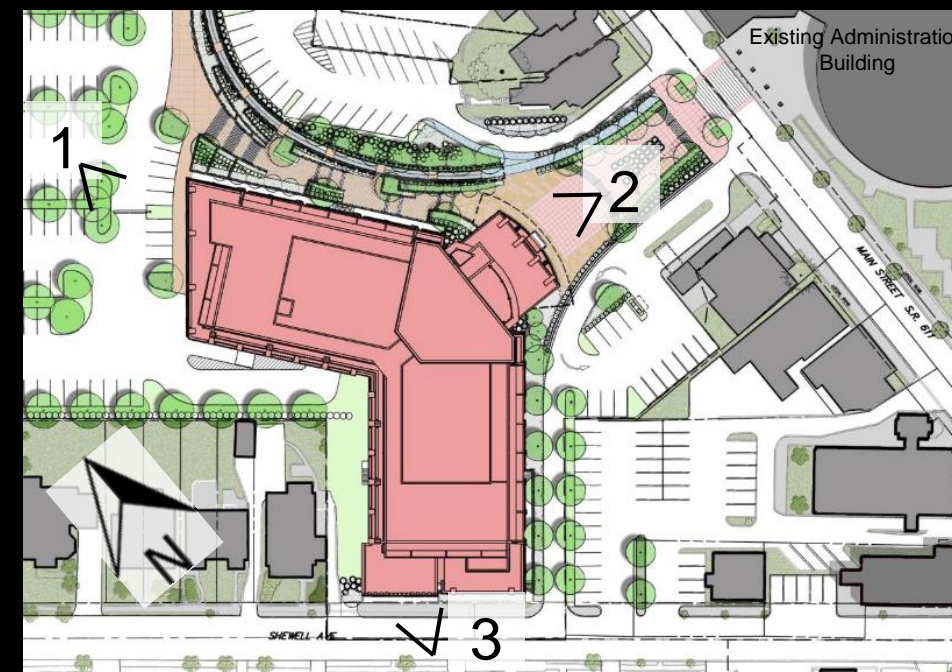
Lighting Depth

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# Introduction

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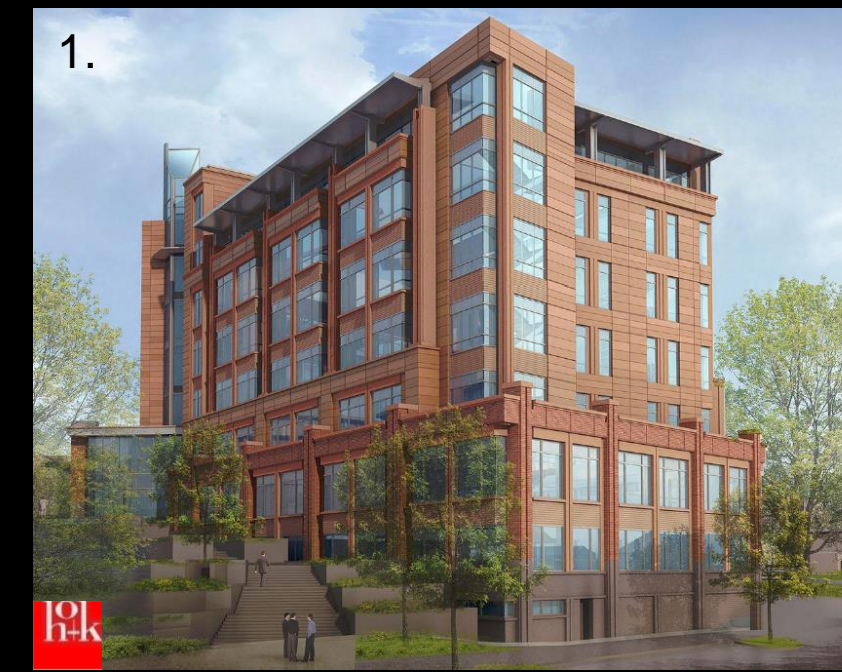
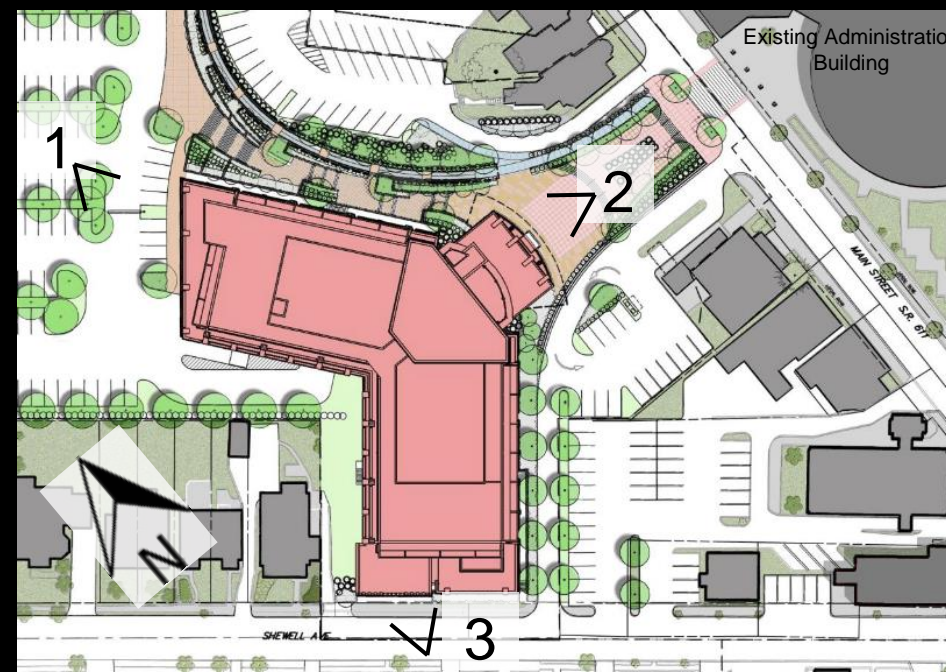
Lighting Depth

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## Building Statistics

Size: 273,000 GSF

Levels: 7 above grade (with penthouse)  
2 below grade

Dates of construction: July 2011-February 2015

Overall Project Cost: approximately \$84 million



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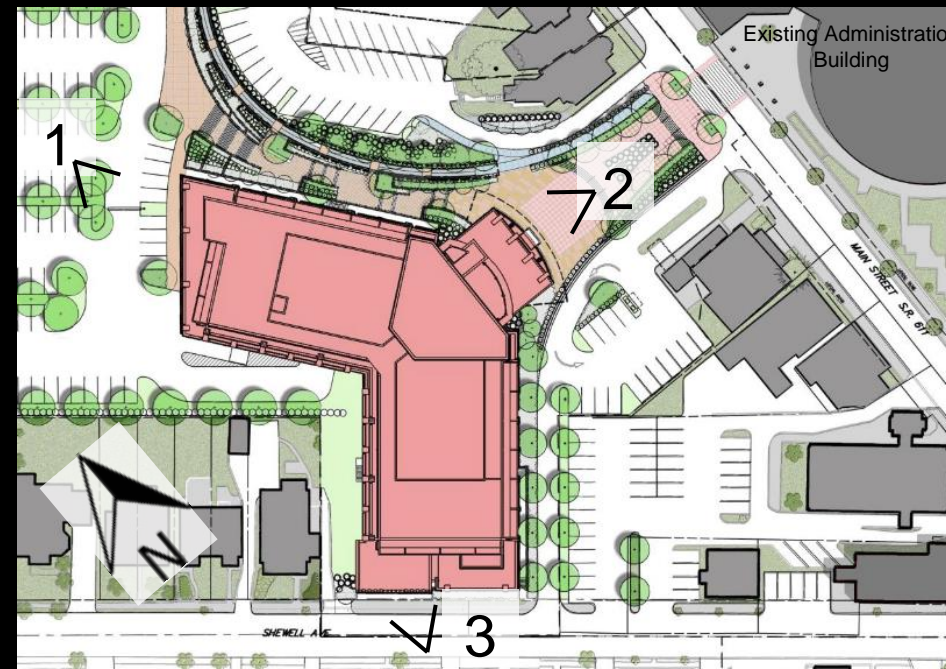
Lighting Depth

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## Project Team

Architect: HOK

MEP: H. F. Lenz

Lighting: Tigue Lighting

Telecom, Data, A/V, and Acoustics: Acentech Incorporated

Civil Engineering: Carroll Engineering Corporation

Structural: The Harman Group

Security and Code Consulting: Brinjac Engineers

General Contractor: Ernest Bock & Sons, Inc.



Introduction

Lighting Depth

Main Lobby

Open Office

Ceremonial Courtroom

Electrical Depth

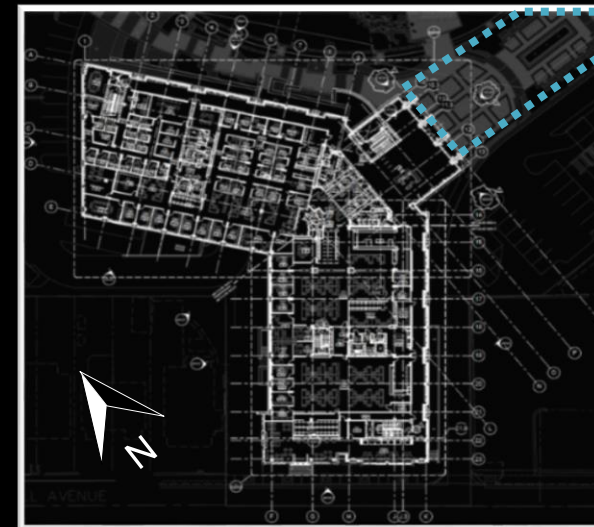
Mechanical Breadth

Acoustical Breadth and MAE Depth

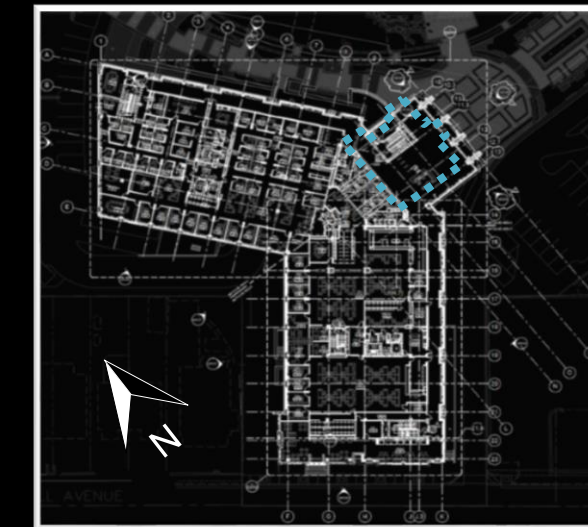
Conclusion

## Spaces

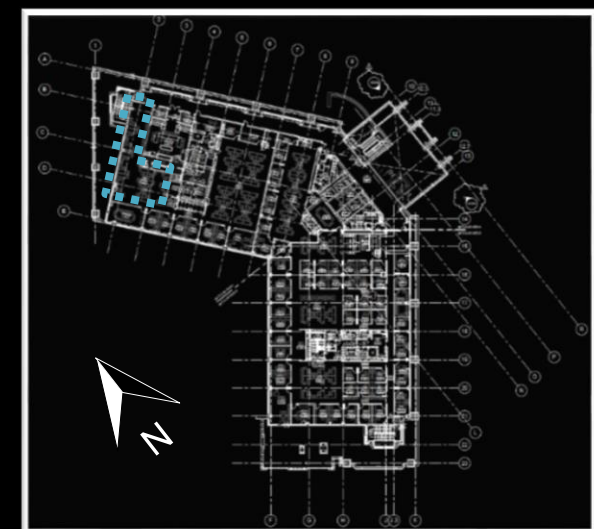
Outdoor Space: Main Plaza



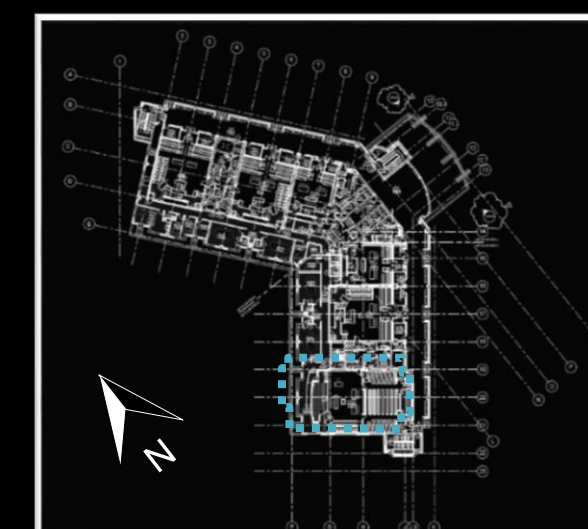
Circulation Space: Main Lobby 1000



Large Workspace: Open Office 2520



Special Purpose Space: Ceremonial Courtroom 4100



## Design Criteria

Qualitative

Professional

Consistency

Quantitative

CRI:80

CCT: 3500K

Target of 20% reduction from ASHRAE maximum LPD

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Open Office

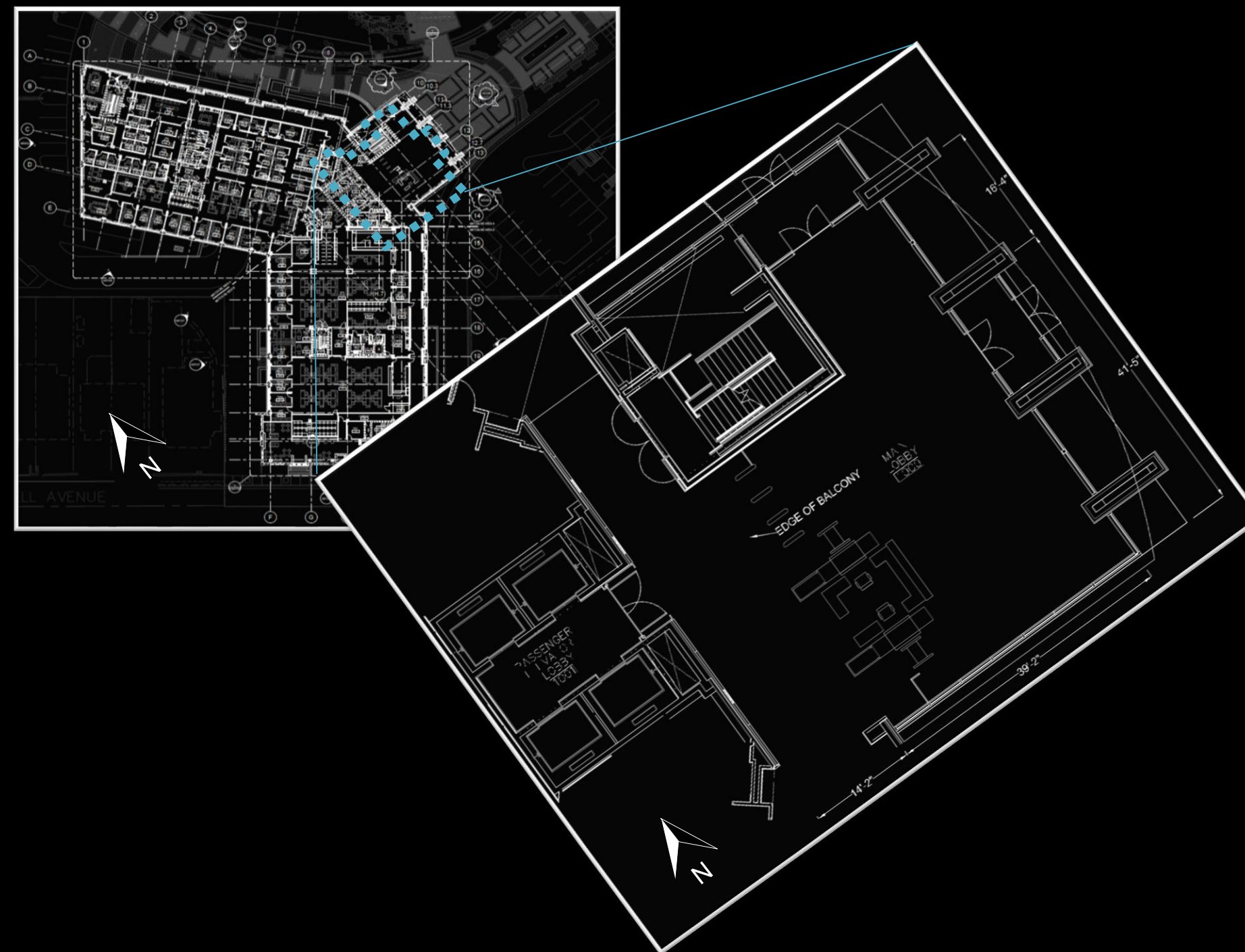
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Main Lobby 1000



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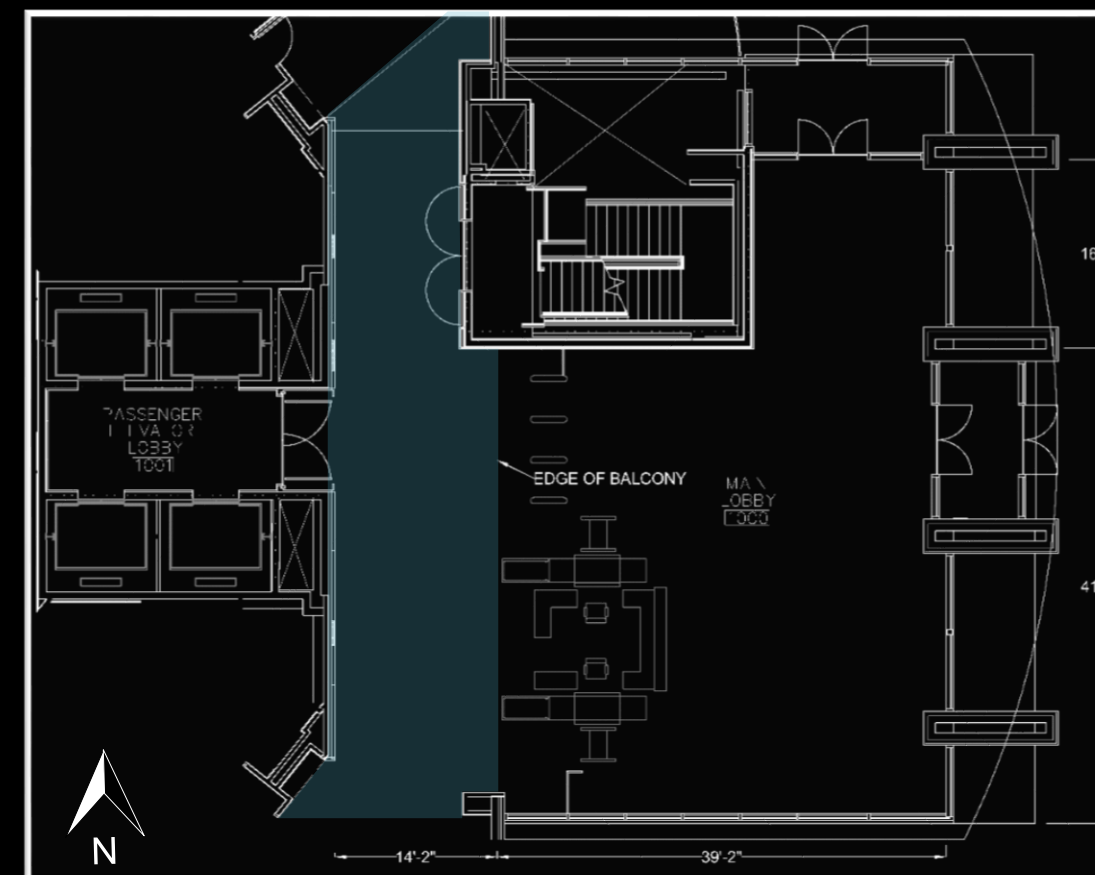
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Main Lobby 1000

Room Area: ~3,000 SF

Ceiling Height: 28'-0"

Balcony



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### Quantitative Criteria

Location	Eh (lux)	Elevation Eh	Avg:Min
Security Screening	200	3'-0"	2:1
Lobbies near entries (day)	100	Floor	4:1

LPD (W/SF)	Local Control	Automatic Daylight Responsive Controls for Sidelighting	Automatic Full OFF	Scheduled Shutoff
0.9	REQ	REQ	ADD2	ADD2

### Qualitative Criteria

Assist Security screening

Spacious and grand

Way finding



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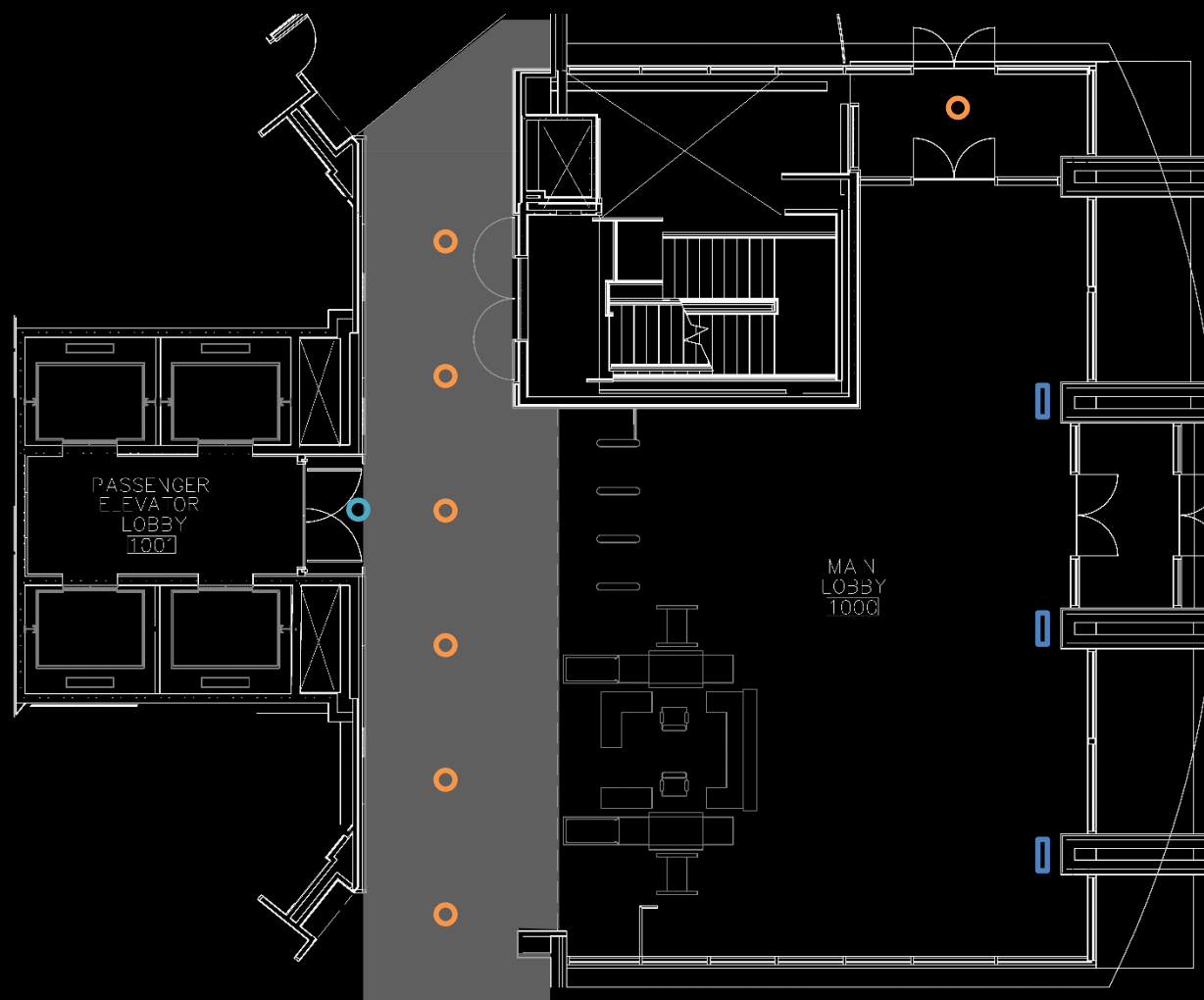
Ceremonial Courtroom

Electrical Depth

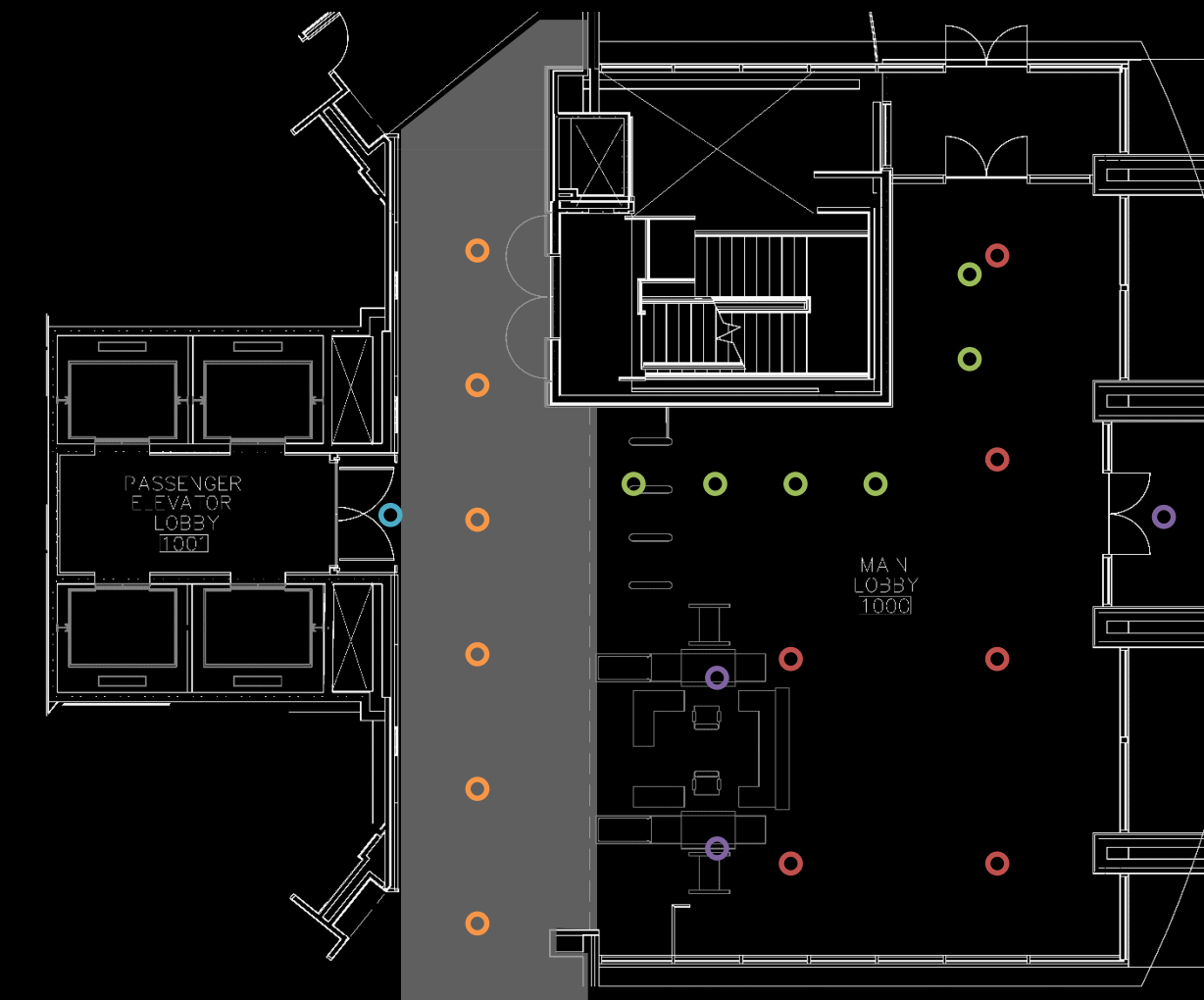
Mechanical Breadth

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Type	Description	CCT (K)	CRI	Life (Hours)	Input (Watts)	Fixture Image
R3	RECESSED CIRCULAR 6 INCH WIDE BEAM DOWNLIGHT 1500 LUMEN	3500	80	50,000 L70	22.4	
R4	RECESSED CIRCULAR 6 INCH WIDE BEAM WALL WASH 1000 LUMEN	3500	80	50,000 L70	14.1	
W1	WALL MOUNTED LINEAR UPLIGHT TWO FOOT, 2000 LUMENS	3500	80	50,000 L70	22.6	



Type	Description	CCT (K)	CRI	Life (Hours)	Input (Watts)	Fixture Image
R7	RECESSED CIRCULAR 8 INCH MEDIUM BEAM DOWNLIGHT 5000 LUMEN	3500	80	50,000 L70	62	
R8	RECESSED CIRCULAR 8 INCH MEDIUM BEAM DOWNLIGHT 3000 LUMEN	3500	80	50,000 L70	42	
R9	RECESSED CIRCULAR 8 INCH WIDE BEAM DOWNLIGHT 3000 LUMEN	3500	80	50,000 L70	42	

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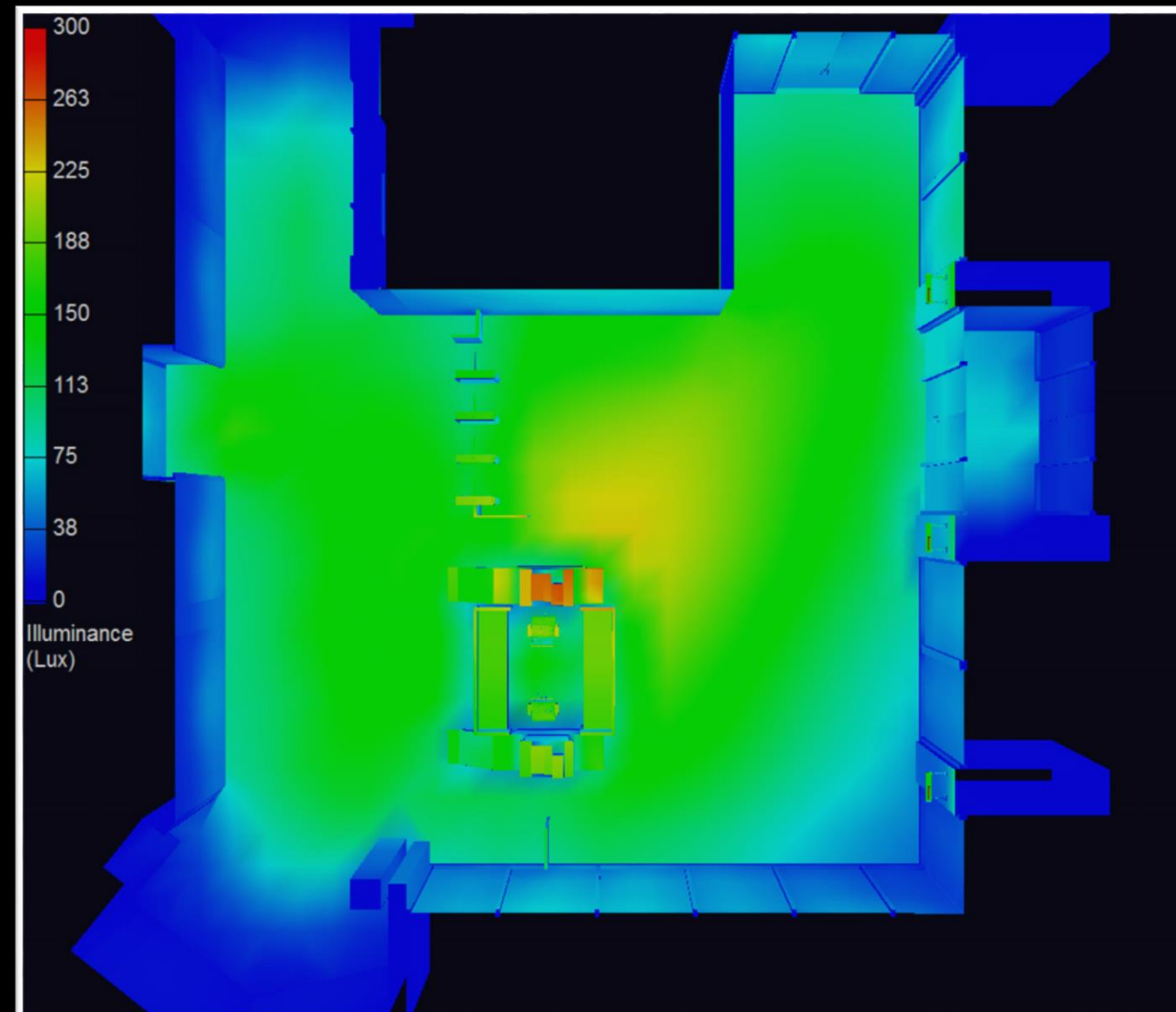
Ceremonial Courtroom

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### Criteria Vs. Design

#### Illuminance

Location		Eh (lux)	Height Eh	Avg:Min
Security Screening	Target	200	3'-0"	2:1
	Design	186	3'-0"	1.7:1
Lobbies near entries (day)	Target	100	Floor	4:1
	Design	139	Floor	3.2:1

#### Power

	W/SF	Percent Reduction
ASHRAE Maximum	0.9	63%
Design	0.33	



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Open Office

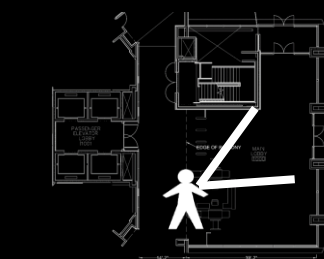
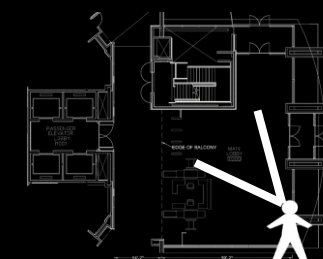
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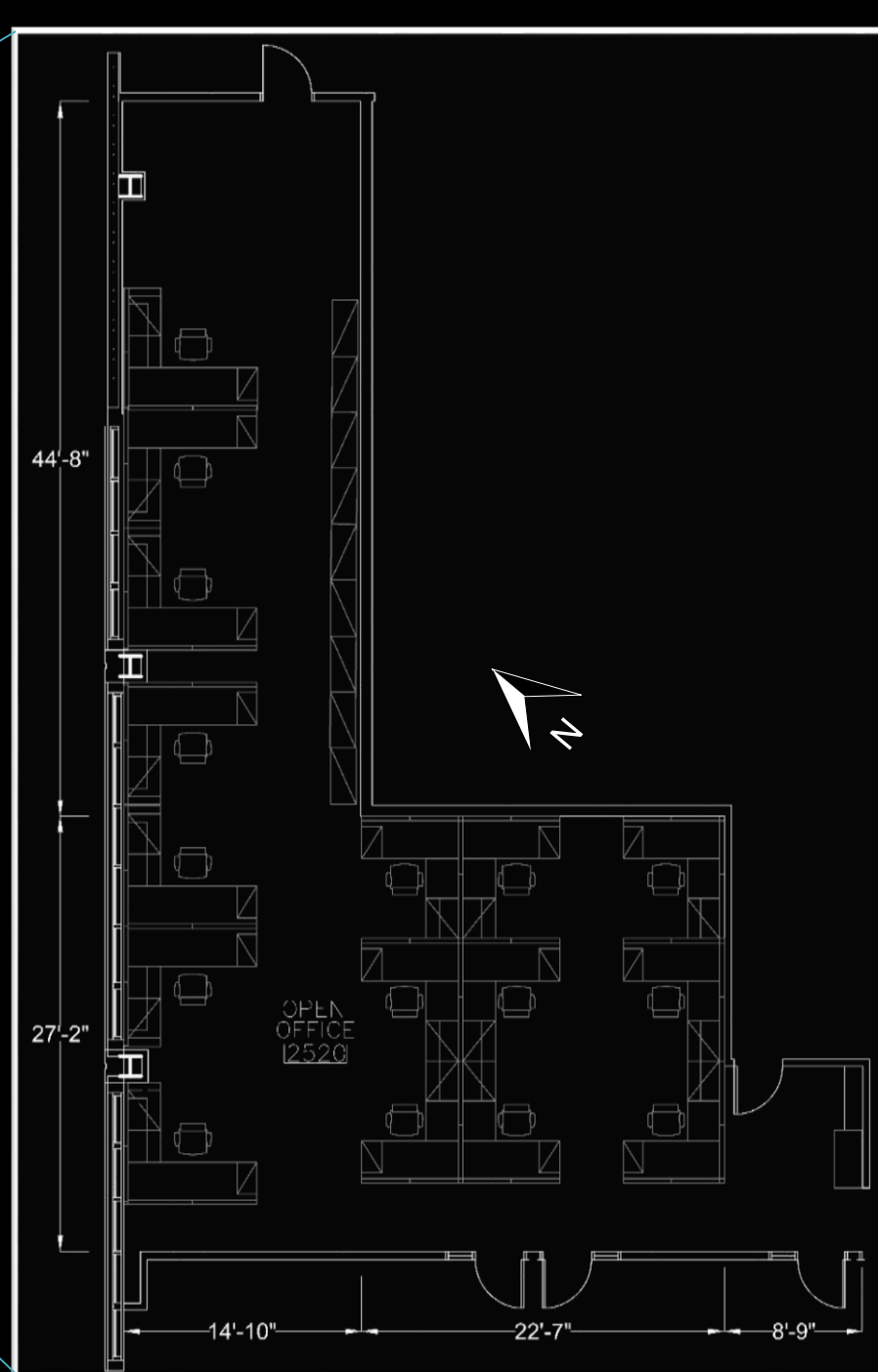
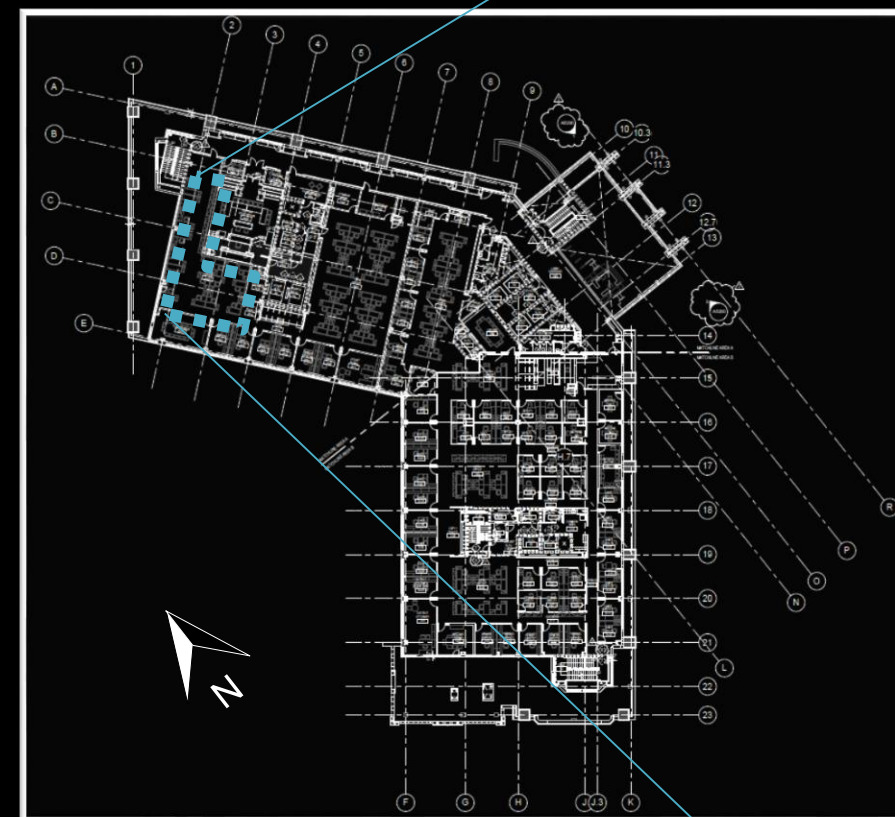
Ceremonial Courtroom

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## Open Office 2520

Room Area: ~1,300 SF

Ceiling Height: 9'-0"

Half height partitions



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### Quantitative Criteria

Location	Eh (lux)	Elevation Eh	Avg:Min
Open Office	300	2'-6"	1.5:1*

\*From Table 12.6

LPD (W/SF)	Local Control	Manual ON	Restricted to Partial Automatic ON	Bilevel Lighting Control	Automatic Daylight Responsive Controls for Sidelighting	Automatic Full OFF	Scheduled Shutoff
0.98	REQ	ADD1	ADD1	REQ	REQ	ADD2	ADD2

### Qualitative Criteria

Openness

Promote community

Views

# Introduction

## Lighting Depth

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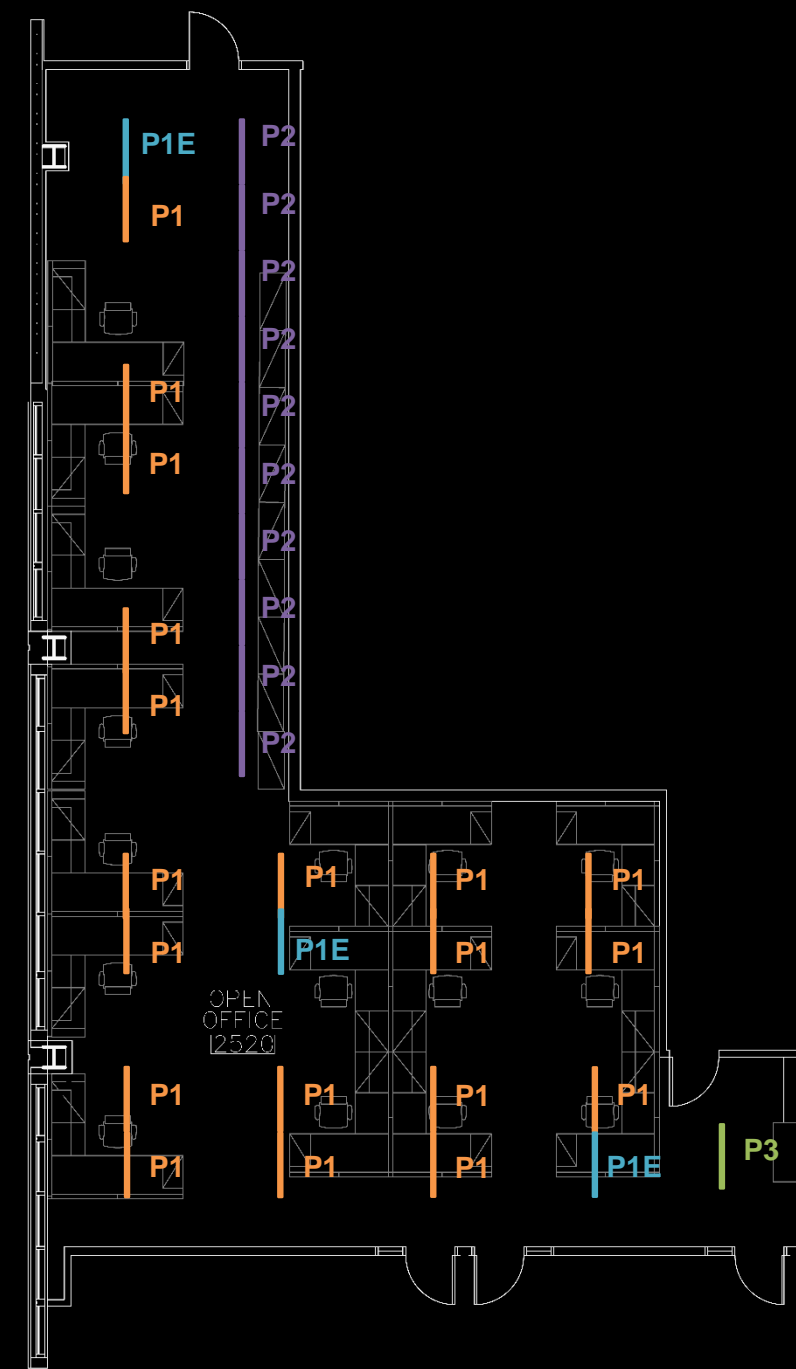
Ceremonial Courtroom

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Type	Description	CCT (K)	CRI	Life (Hours)	Input (Watts)	Fixture Image
P1	CYLINDRICAL LED DIRECT/INDIRECT PENDANT	3500	80+	50,000 L80	40	
P1E	EMERGENCY CYLINDRICAL LED DIRECT/INDIRECT PENDANT	3500	80+	50,000 L80	40	
P2	CYLINDRICAL LED WALL WASHER PENDANT	3500	80+	50,000 L80	20	
P3	CYLINDRICAL LED DIRECT/INDIRECT PENDANT	3500	80+	50,000 L80	60	

Luminaire Type P2 is suspended 8'-0" AFF

All others are suspended 7'-0" AFF



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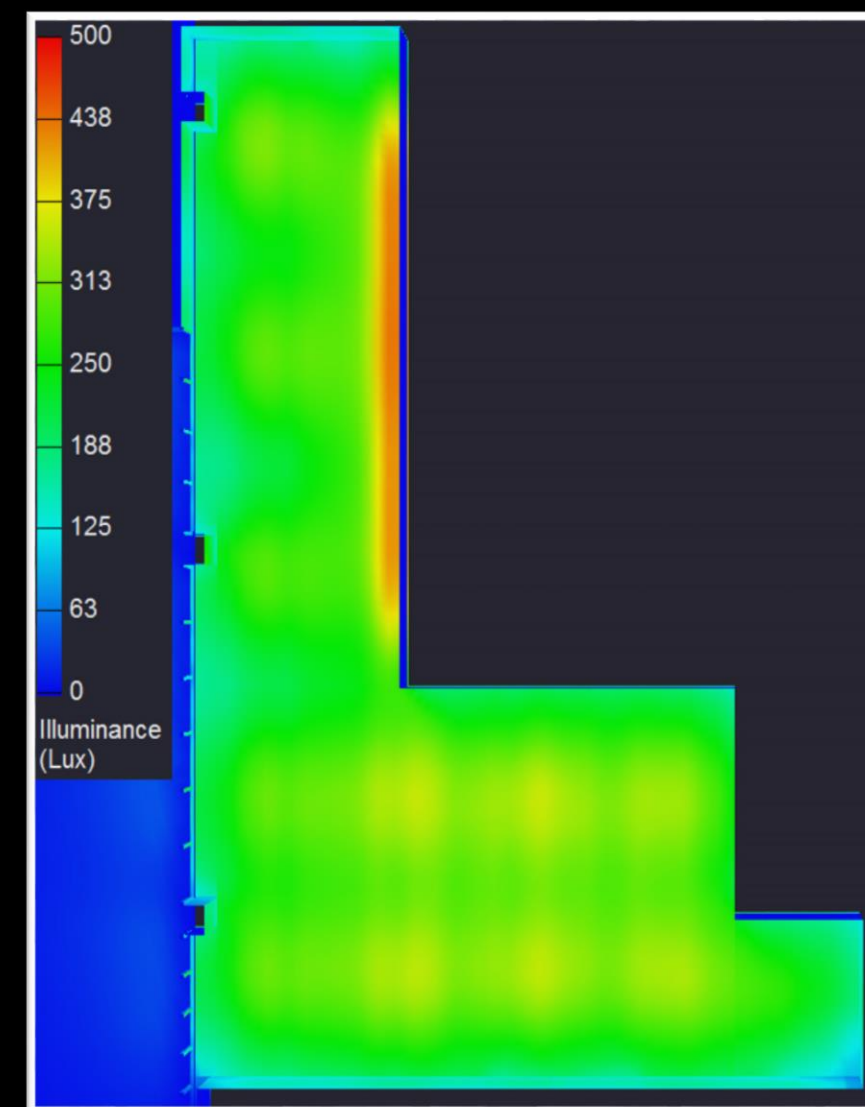
Ceremonial Courtroom

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### Criteria Vs. Design

#### Illuminance

Location		Eh (lux)	Height Eh	Avg:Min
Open Office	Target	300	2'-6"	1.5:1
	Design	329	2'-6"	2.0:1

#### Power

	W/SF	Percent Reduction
ASHRAE Maximum	0.98	28%
Design	0.71	

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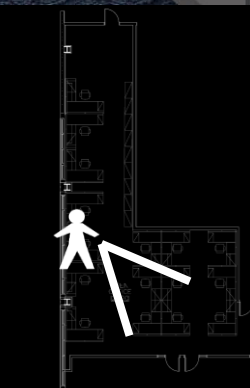
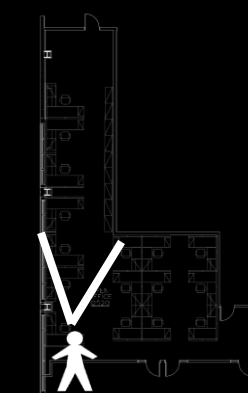
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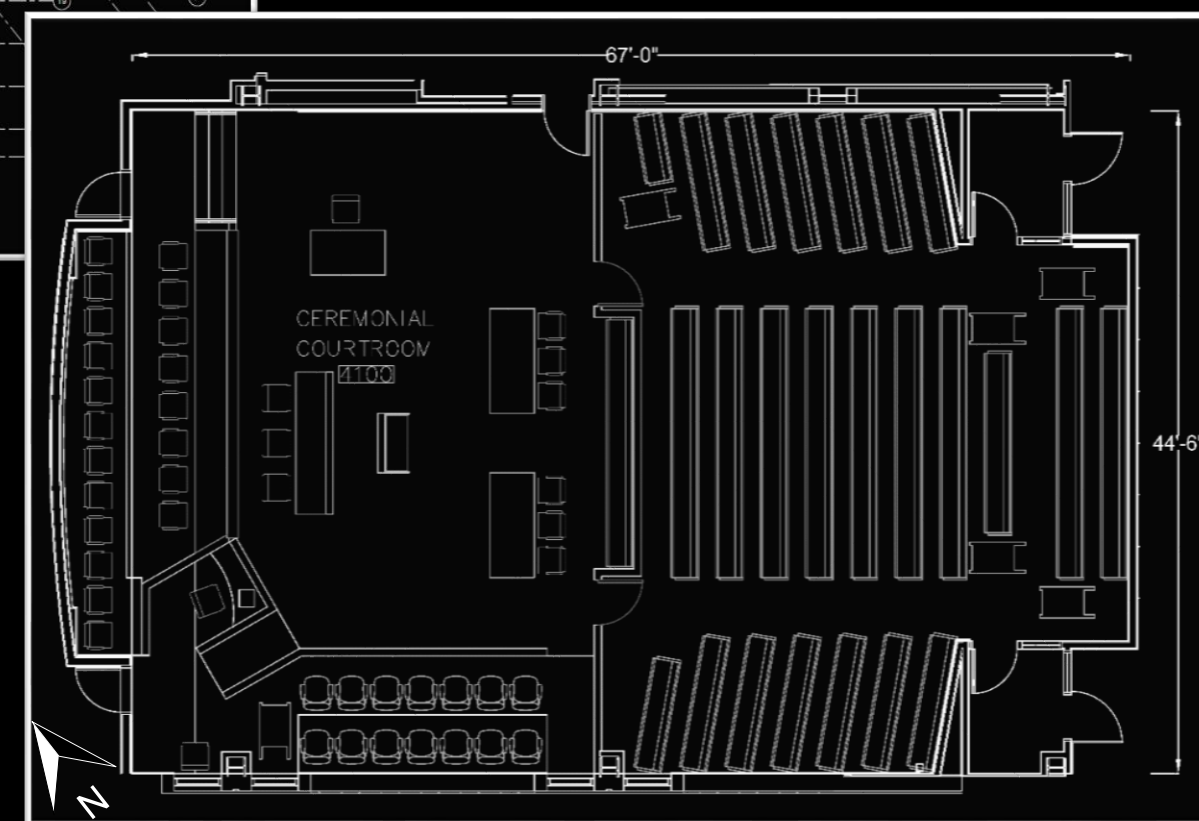
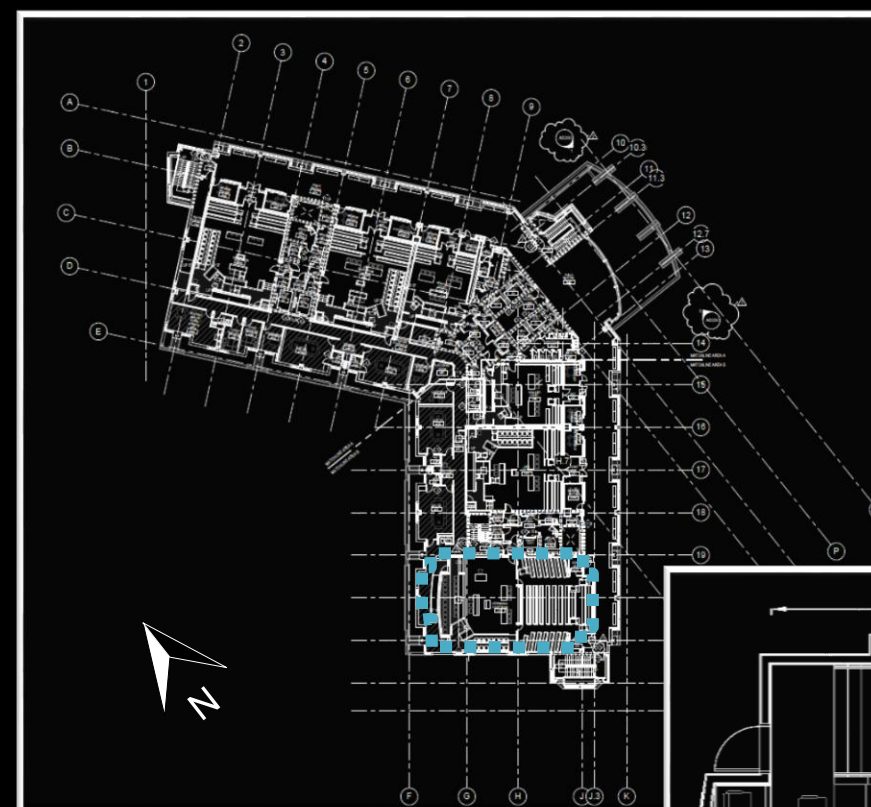
Design Analysis

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## Ceremonial Courtroom 4100

Room Area: ~2,900 SF

Ceiling Height: 10'-6"

Public Seating Capacity: 222

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### Quantitative Criteria

### Qualitative Criteria

Location	Eh (lux)	Elevation Eh	Avg:Min
Attorneys' Tables	500	2'-6"	2:1
Bench and Clerks	500	2'-6"	2:1
Jury Box	300	2'-6"	2:1
Witness Stand	300	2'-6"	2:1
Public Seating	100	2'-6"	2:1

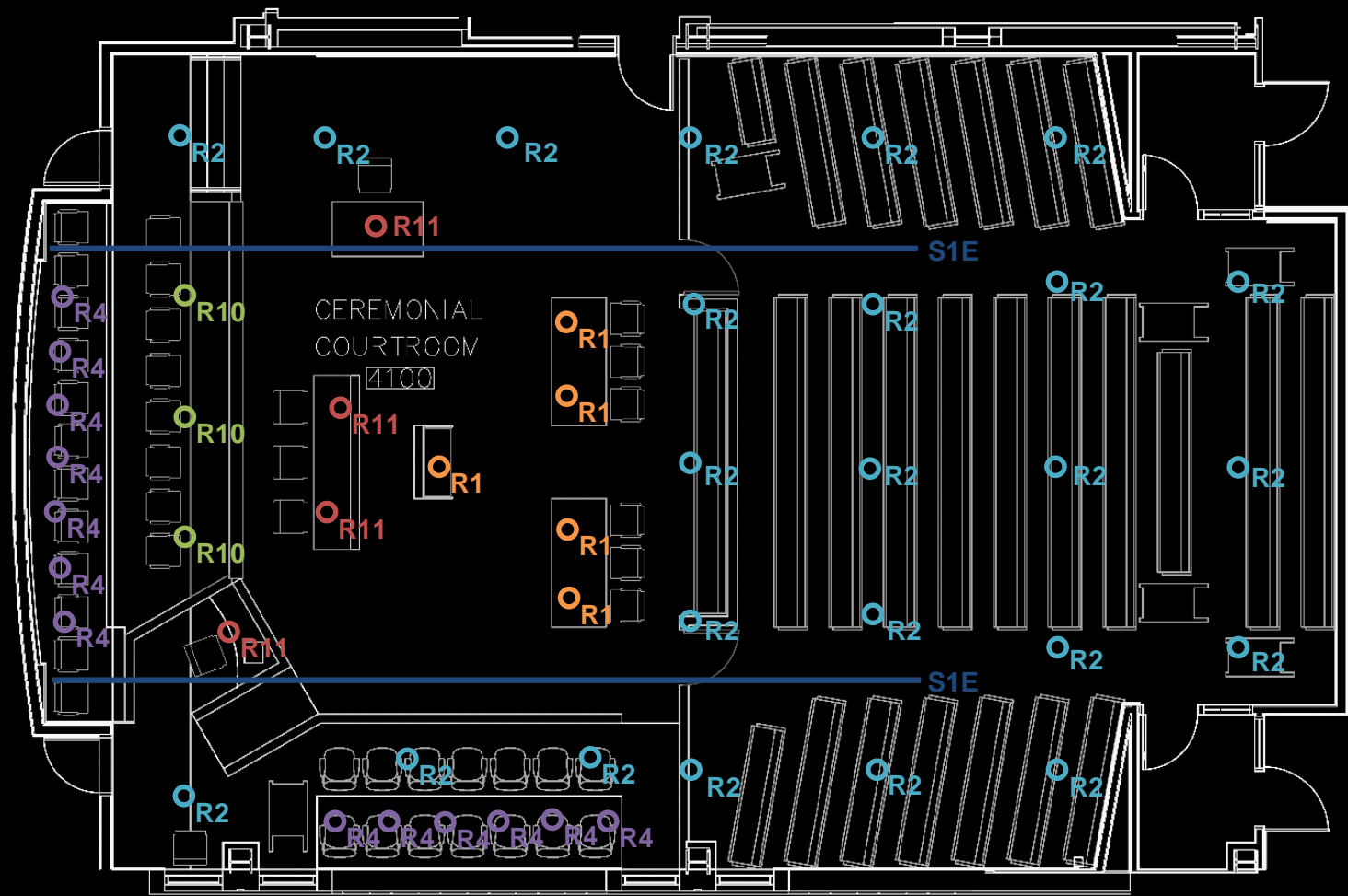
Dignified

Flexibility

Location	Ev (lux)	Max:Avg	Notes
AV Presentation Screen	50	2:1	Max Value

LPD (W/SF)	Local Control	Manual ON	Restricted to Partial Automatic ON	Bilevel Lighting Control	Automatic Daylight Responsive Controls for Sidelighting	Automatic Full OFF	Scheduled Shutoff
1.72	REQ	ADD1	ADD1	REQ	REQ	ADD2	ADD2





Type	Description	CCT (K)	CRI	Life (Hours)	Input (Watts)	Fixture Image
R1	RECESSED CIRCULAR 6 INCH NARROW BEAM DOWNLIGHT 1500 LUMEN	3500	80	50,000 L70	22.4	
R2	RECESSED CIRCULAR 6 INCH WIDE BEAM DOWNLIGHT 1000 LUMEN	3500	80	50,000 L70	14.1	
R4	RECESSED CIRCULAR 6 INCH WIDE BEAM WALL WASH 1000 LUMEN	3500	80	50,000 L70	14.1	
R10	RECESSED CIRCULAR 6 INCH WIDE BEAM DOWNLIGHT 3000 LUMEN	3500	80	50,000 L70	43.6	
R11	RECESSED CIRCULAR 6 INCH MEDIUM BEAM DOWNLIGHT 2000 LUMEN	3500	80	50,000 L70	31.5	
S1E	SURFACE MOUNTED LINEAR CEILING WASH	3500	80+	50,000 L70	63.4	

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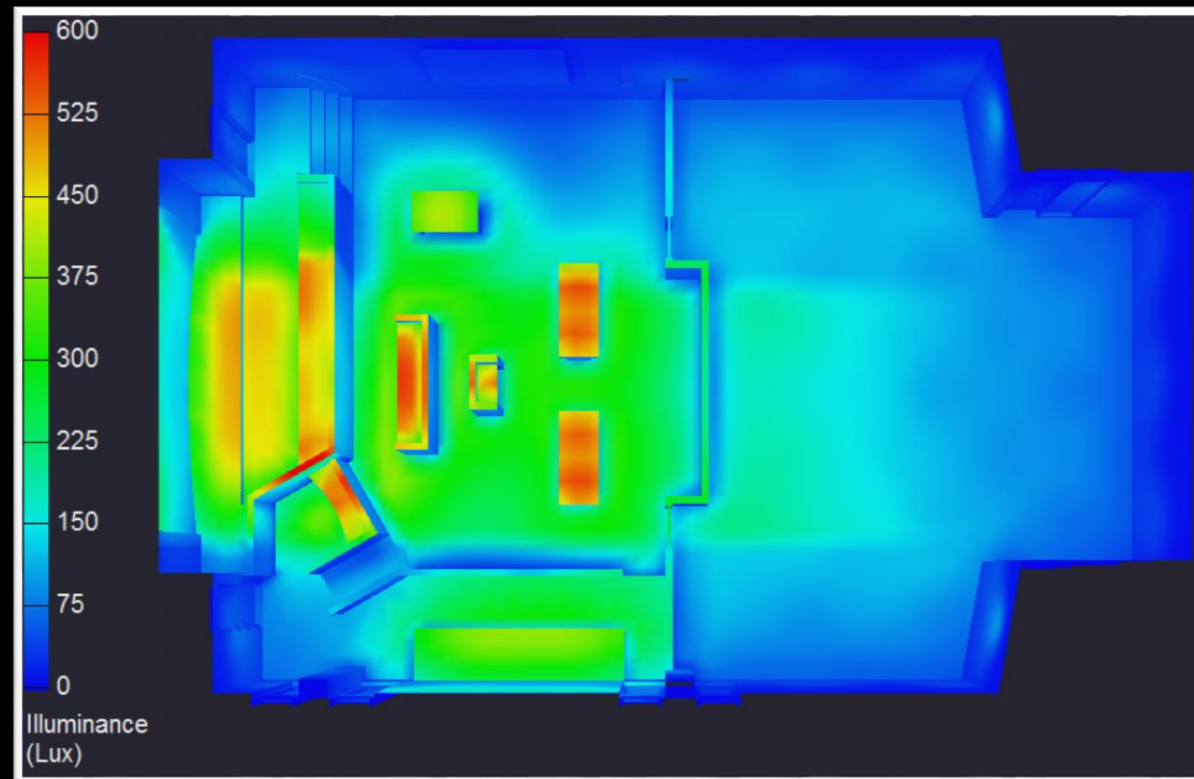
Mechanical Breadth

Acoustical Breadth and MAE Depth

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## Criteria Vs. Design

### Illuminance



Location		Eh (lux)	Avg:Min
Attorney's Tables	Target	500	2:1
	Table 1	454	1.1:1
	Table 2	457	1.1:1
Bench and Clerks	Target	500	2:1
	Design (Bench Upper)	434	1.9:1
	Design (Bench Lower)	460	1.7:1
Podium	Target	500	2:1
	Design	456	1.1:1
Jury Box	Target	300	2:1
	Design	325	2.0:1
Witness Stand	Target	300	2:1
	Design	384	1.1:1
Public Seating	Target	100	2:1
	Design	123	2.1:1

### Power

	W/SF	Percent Reduction
ASHRAE Maximum	1.72	62%
Design	0.66	



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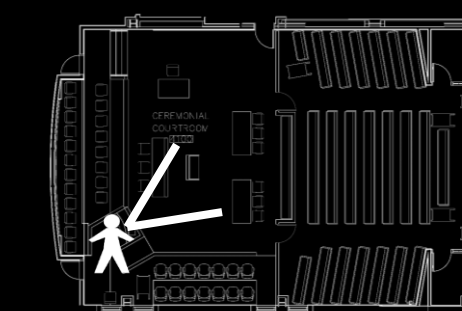
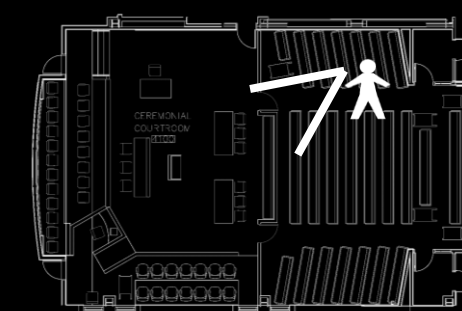
**Design Analysis**

Electrical Depth

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Short Circuit Study

Mechanical Breadth

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Influence of Lighting Depth

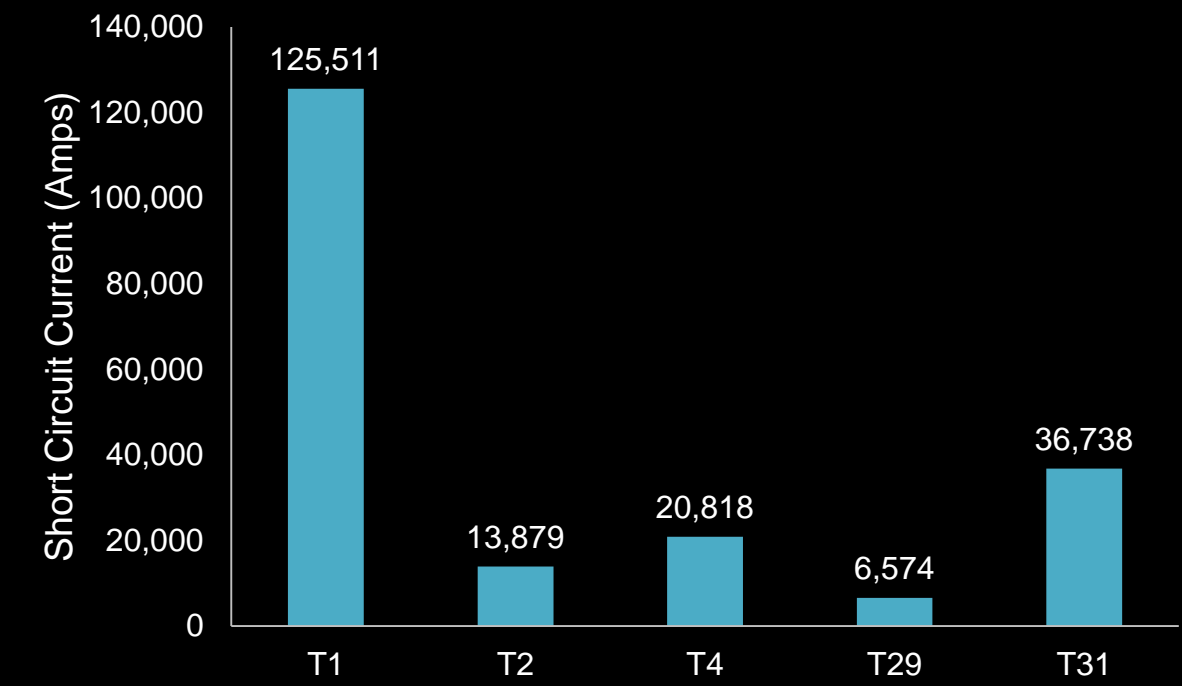
Short Circuit Study

DC Efficiency Analysis

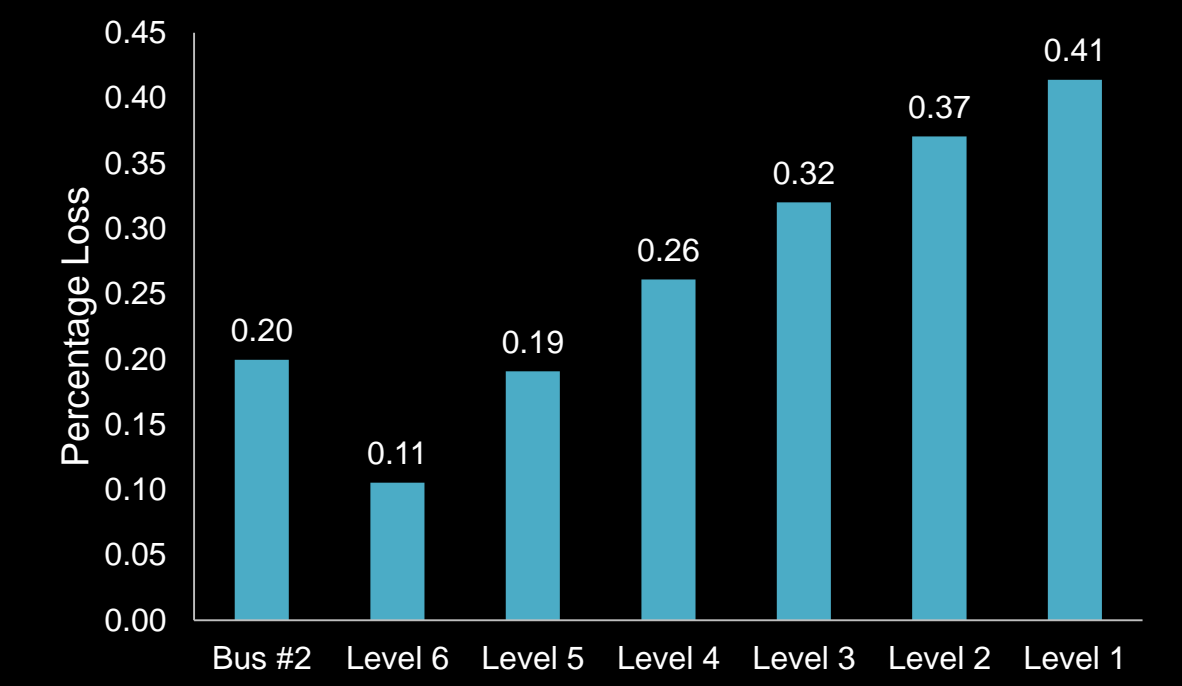


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Transformer Max Let Through Current



Percentage Loss Due to Conductor Impedance



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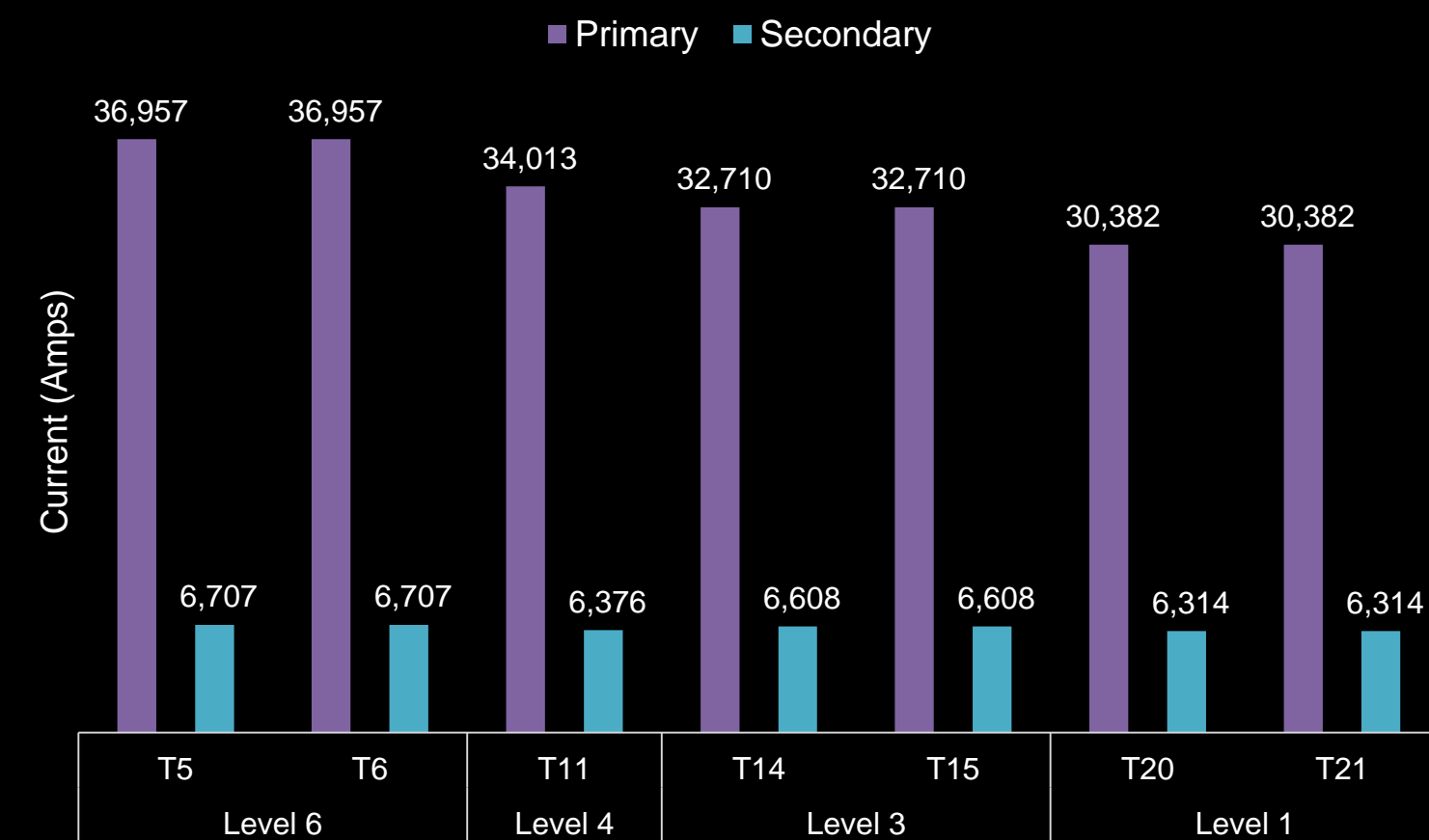
Short Circuit Study

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### Short Circuit Current (Busway #2)



### Conclusion

Branch circuit panels: AIC rating of 10,000 A

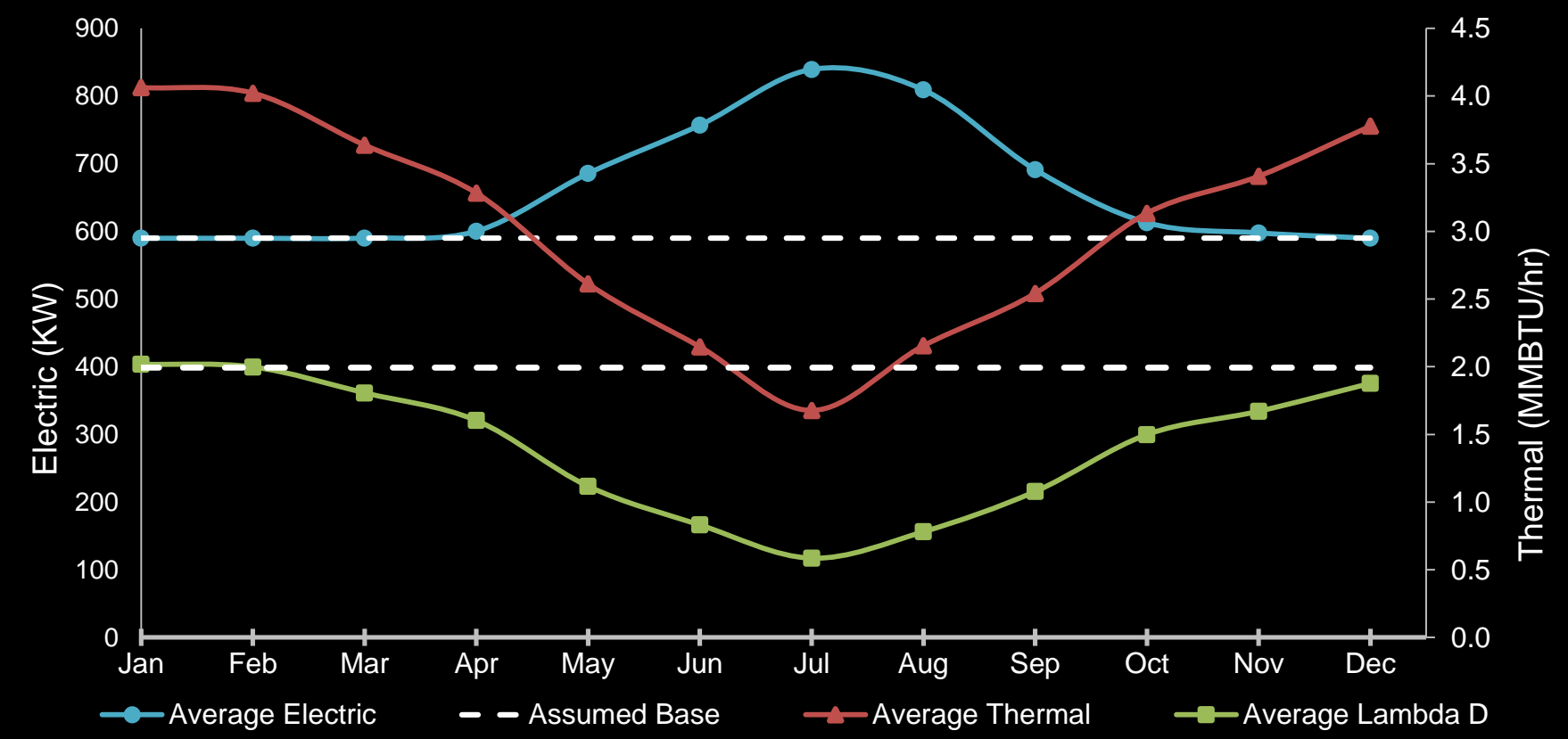
Devices on the primary side of the transformers:  
AIC of 35,000 A or 50,000 A depending on the location



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Mechanical Breadth	<u>Combined Heat and Power (CHP) Feasibility Analysis</u>	<u>Data Sources</u>
	<i>Advantages:</i>	Thermal Demand was exported from a Trane Trace Model
Introduction	Increases primary fuel efficiency	Electric demand data was derived from EIA data for similar buildings
Analysis	Reduces emissions	Natural gas and electric costs came from EIA average data for Pennsylvania
Acoustical Breadth and MAE Depth	Allows “off grid” operation	
Conclusion		

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Monthly Thermal and Electric Demand and Lambda D



Thermal and Electrical Base Loads

Summer Average (June, July, August)		Winter Average (December, January, February)	
Thermal (MMBTU/hr)	1.99	Electric (KW)	590

Results

$\lambda_D$ Annual	Spark Spread
1.34	21.98

Simple Payback
16.3 Years

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Acoustical Breadth (RT Analysis)

MAE Depth (Audio Amplification System Analysis)

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## Speech Intelligibility of Ceremonial Courtroom 4100

Performed a reverberation time (RT) analysis

Analyzed the influence of the audio reinforcement system





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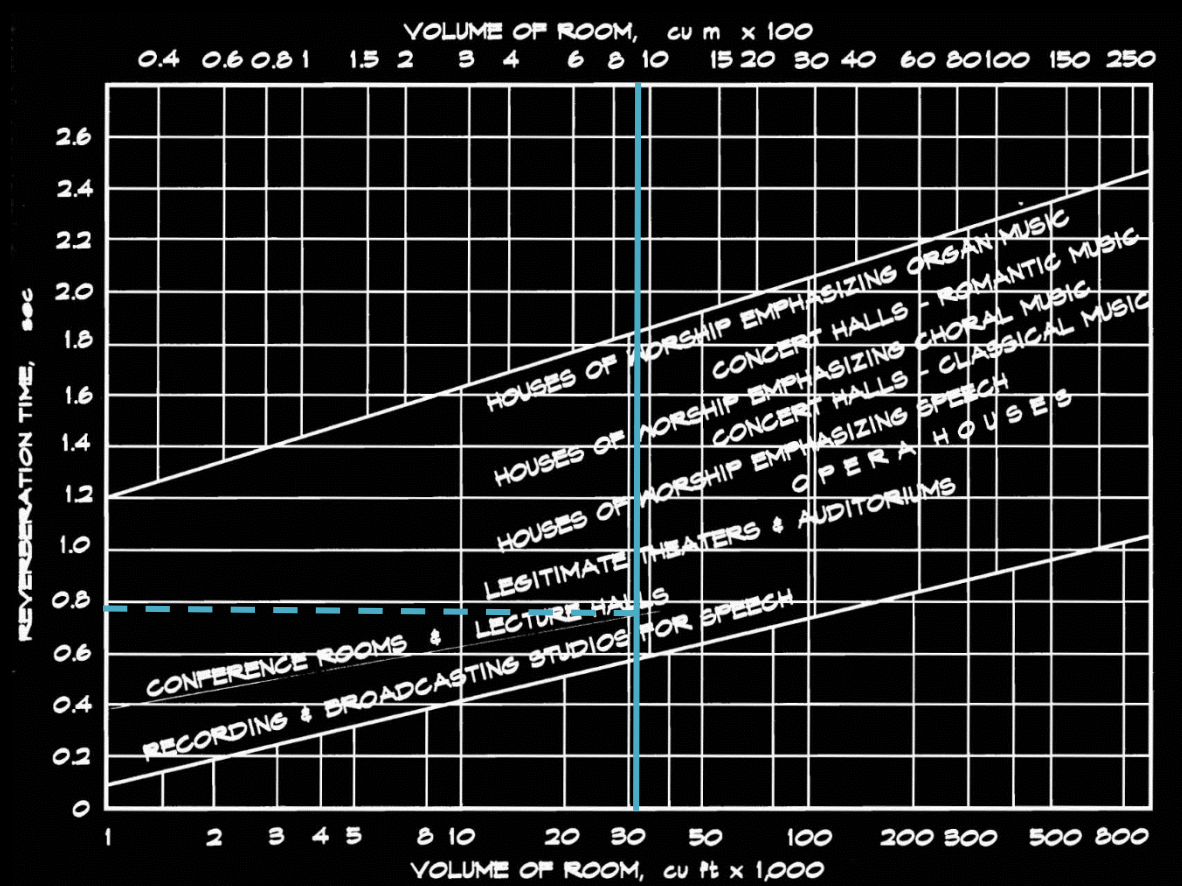
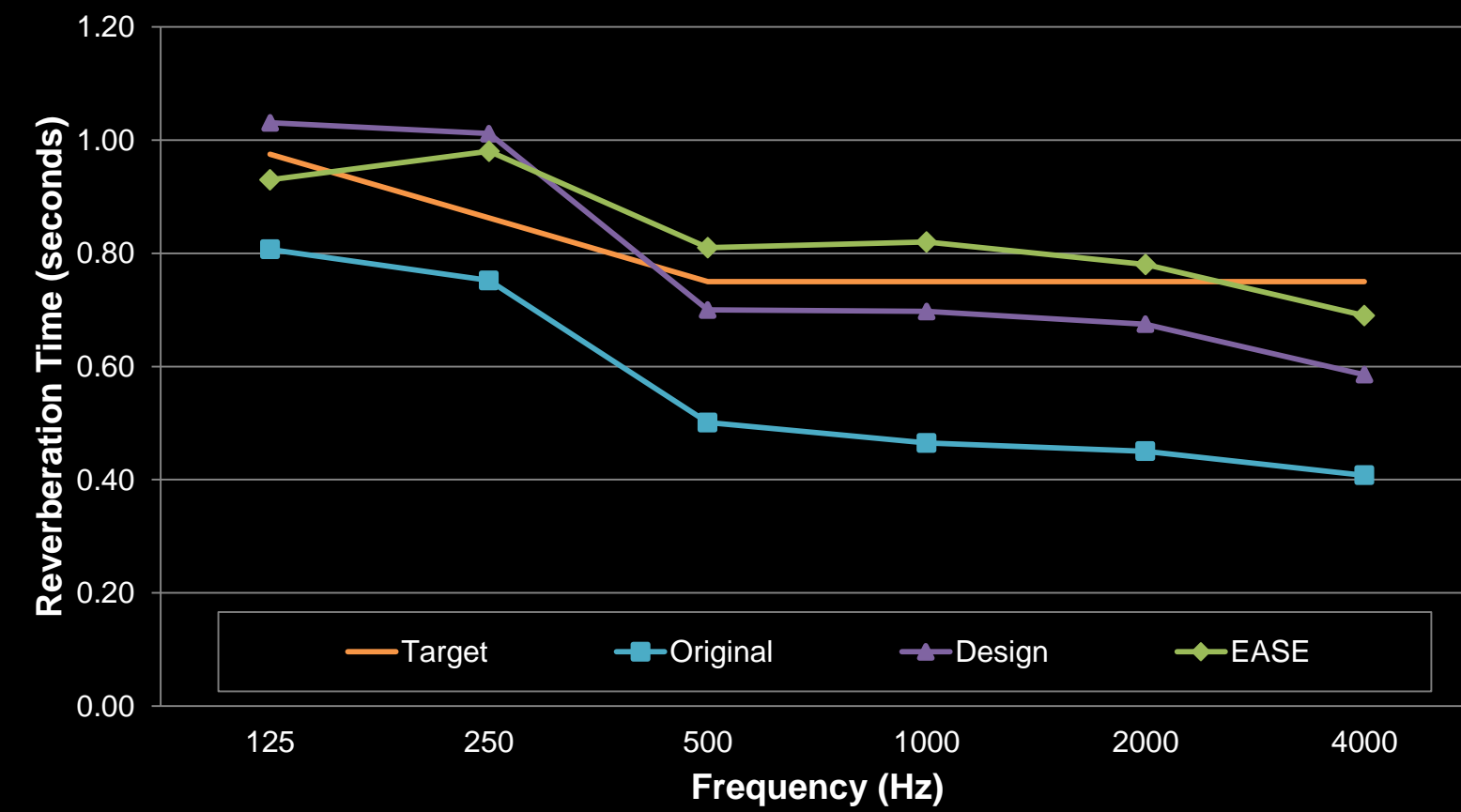


Figure 17.10 from "Architectural Acoustics" by Marshall Long

### Results

#### Ceremonial Courtroom Reverberations Times



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Mechanical Breadth

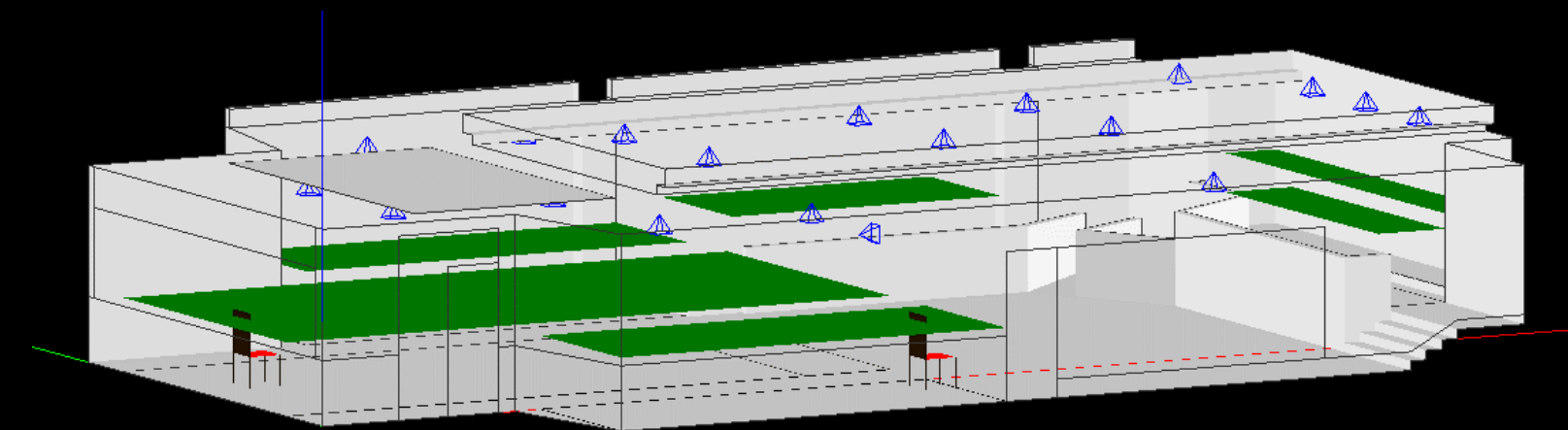
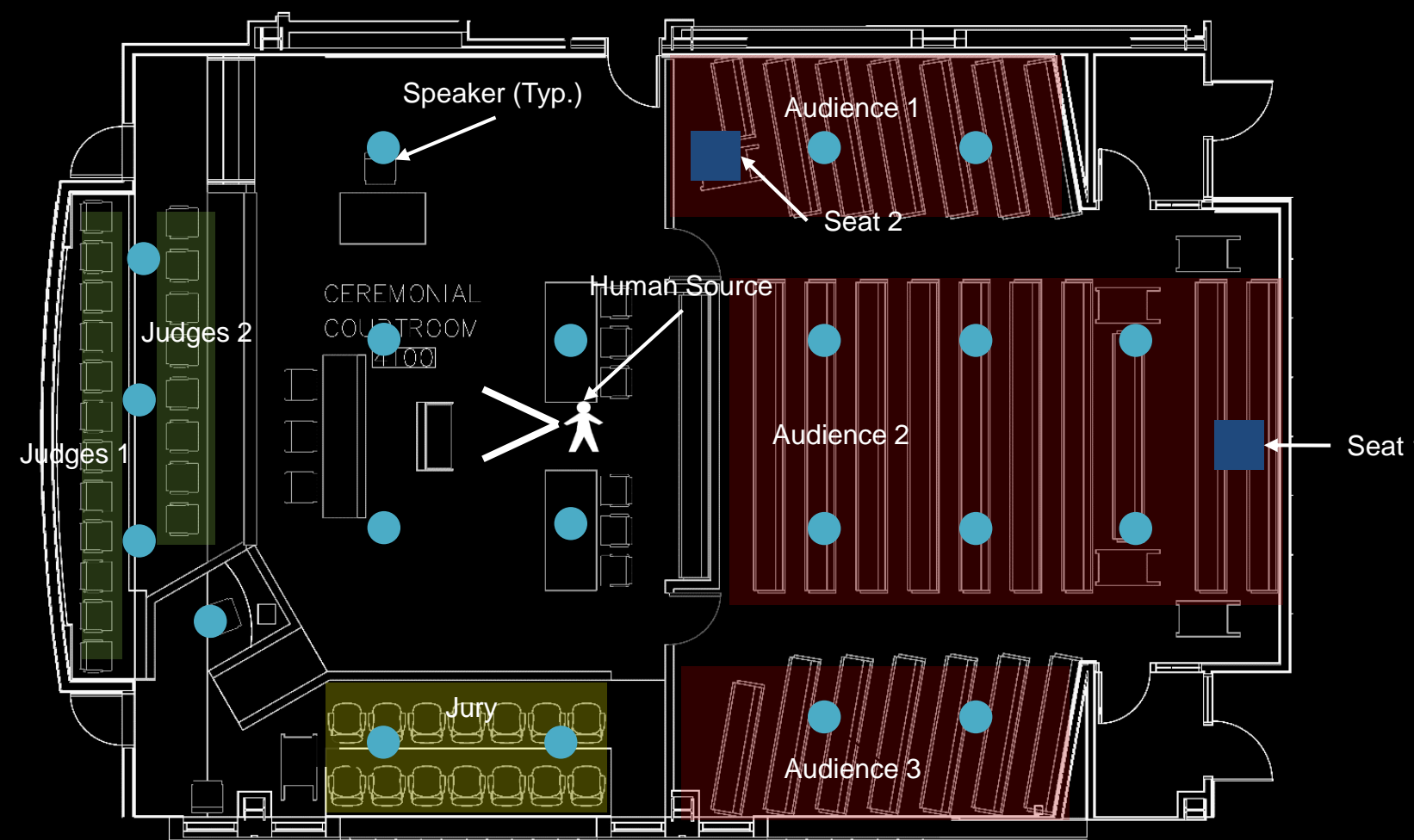
Acoustical Breadth and MAE Depth

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MAE Depth (Audio Amplification System Analysis)

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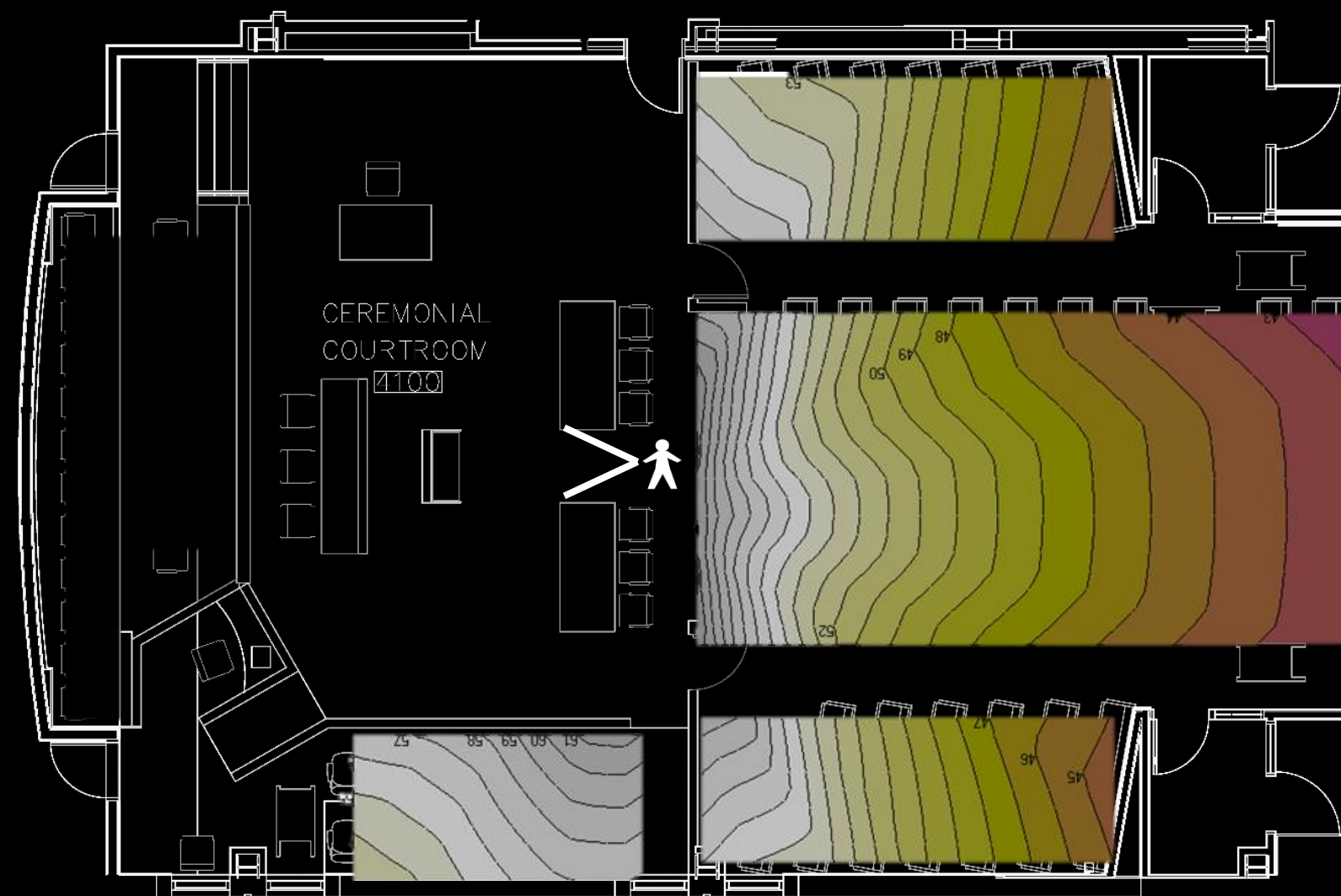
Introduction

Acoustical Breadth (RT Analysis)

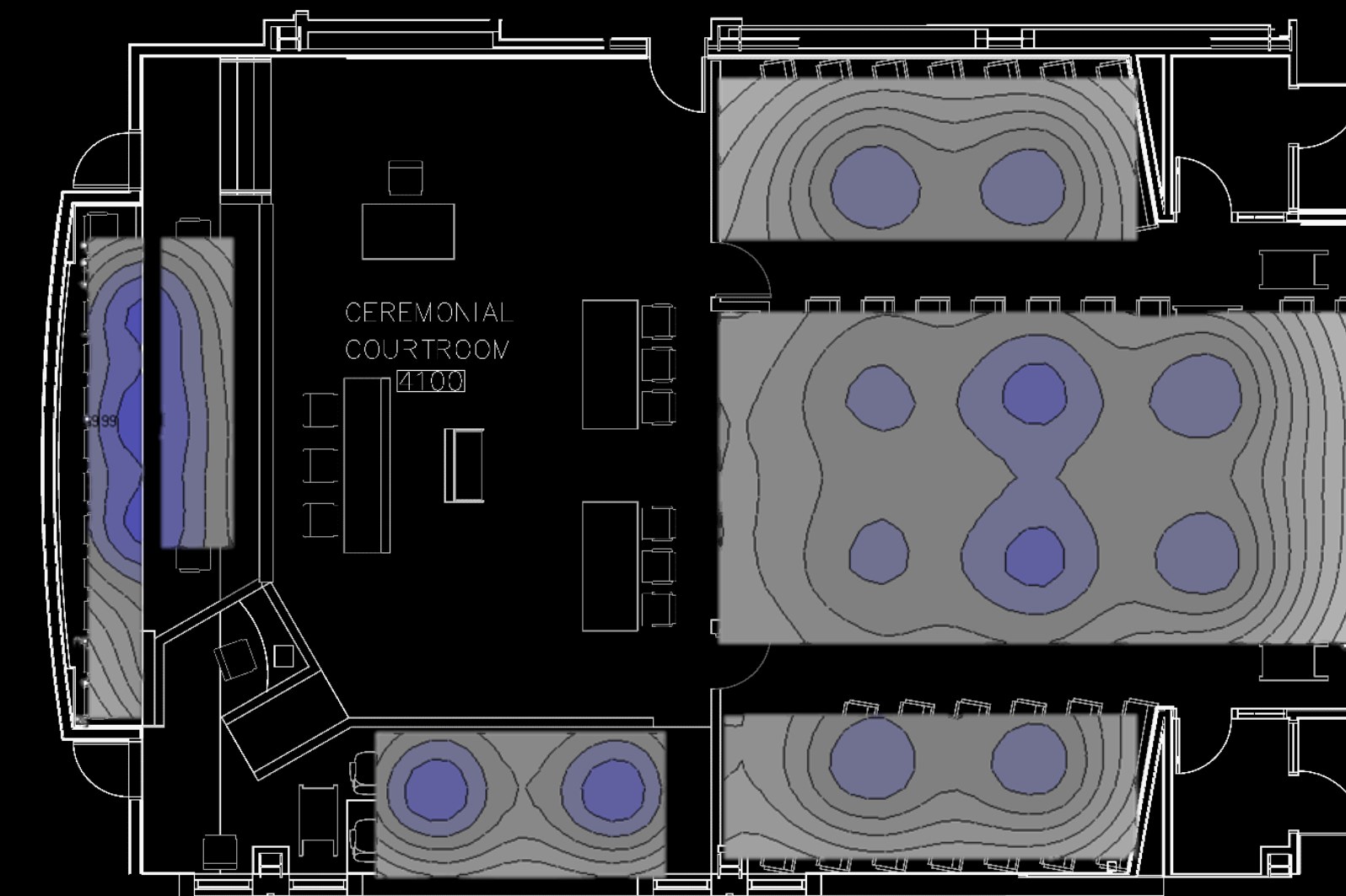
MAE Depth (Audio Amplification System Analysis)

Conclusion

SPL Plot Without Reinforcement



SPL Plot With Reinforcement





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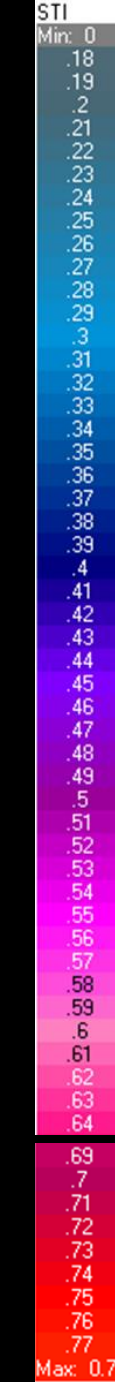
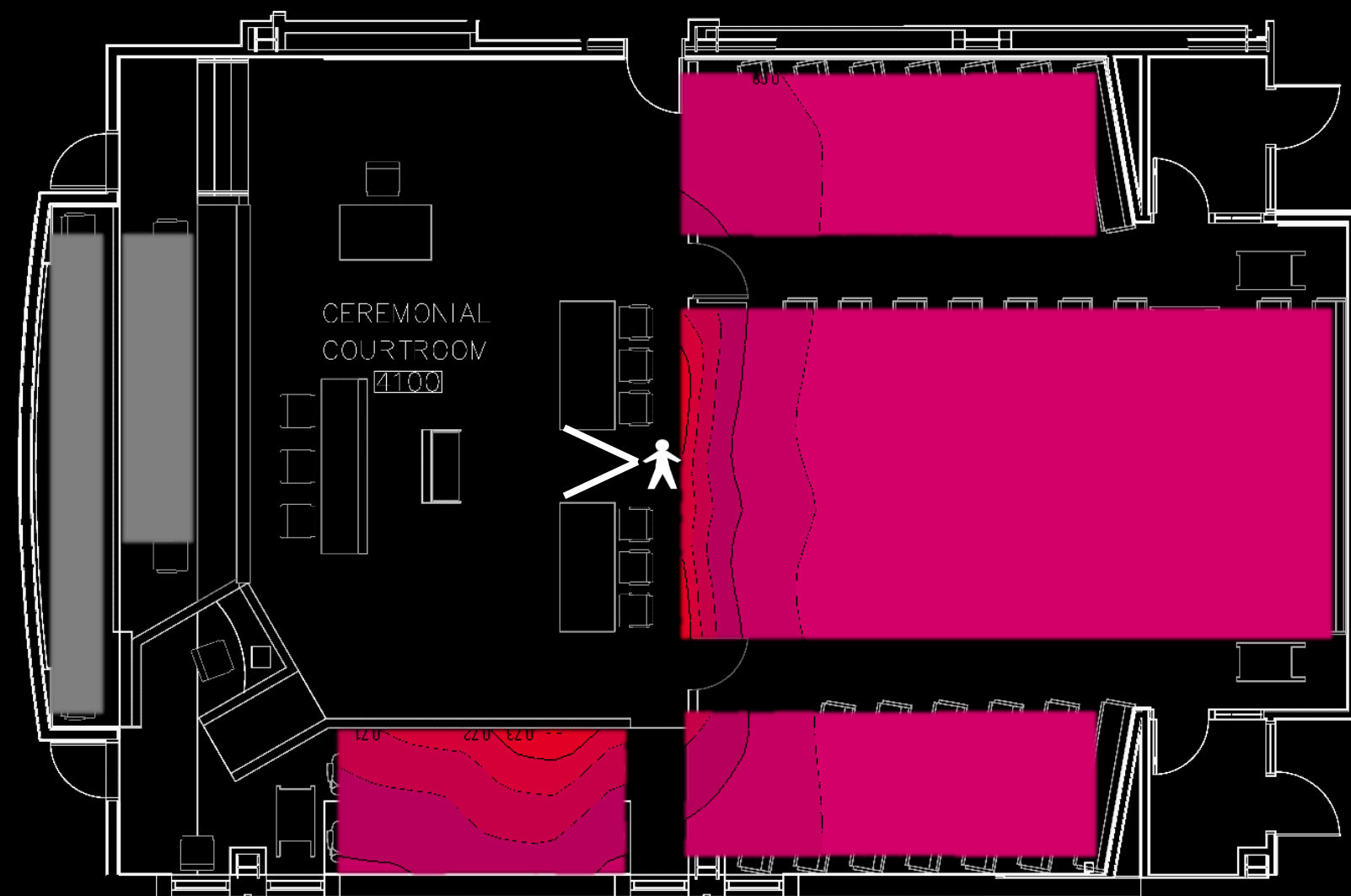
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Acoustical Breadth (RT Analysis)

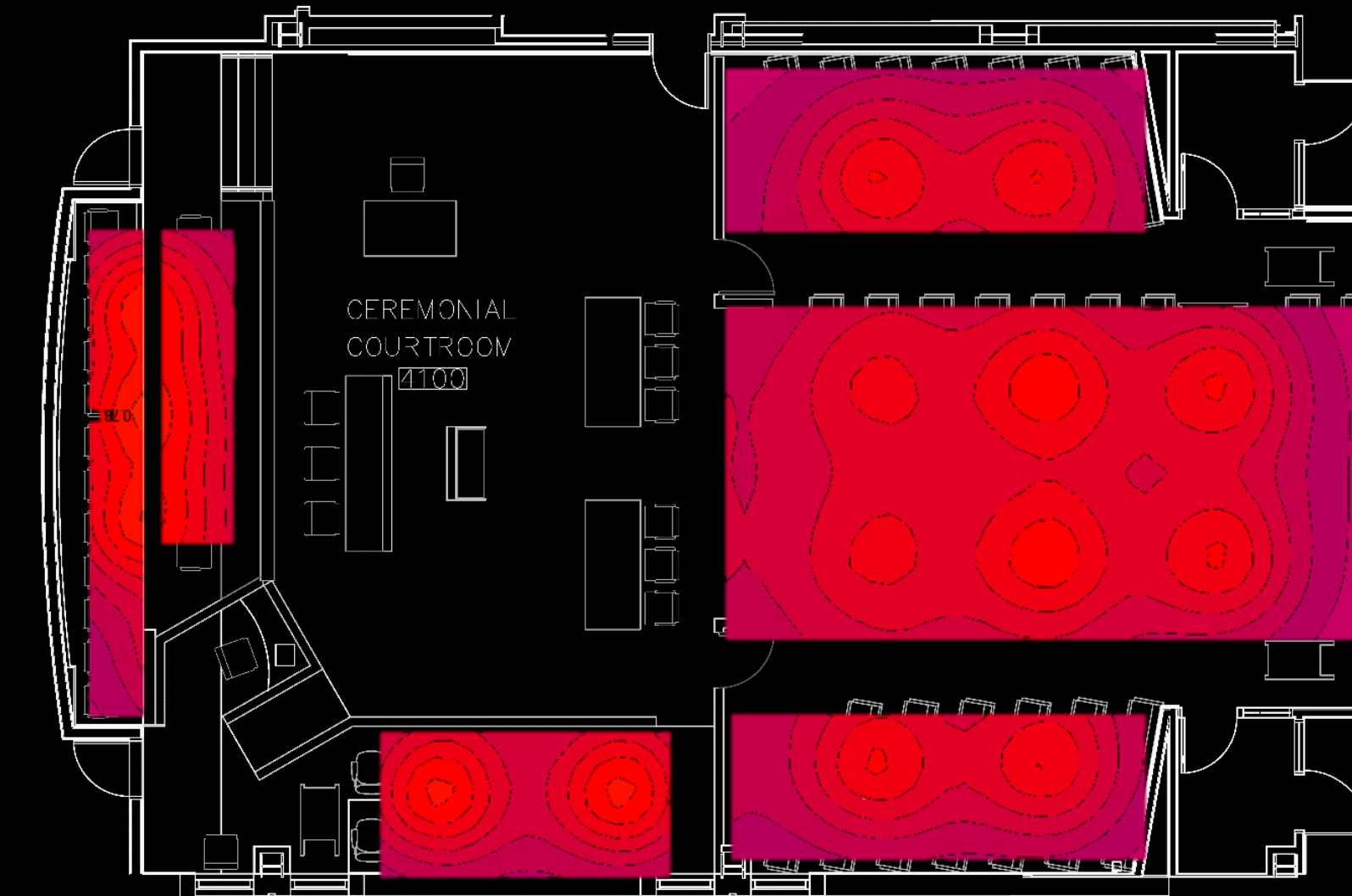
MAE Depth (Audio Amplification System Analysis)

Conclusion

STI Plot Without Reinforcement



STI Plot With Reinforcement



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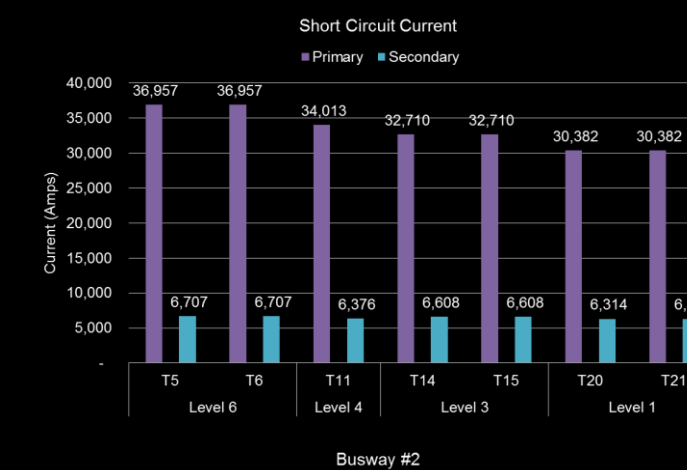
Summary

Acknowledgements

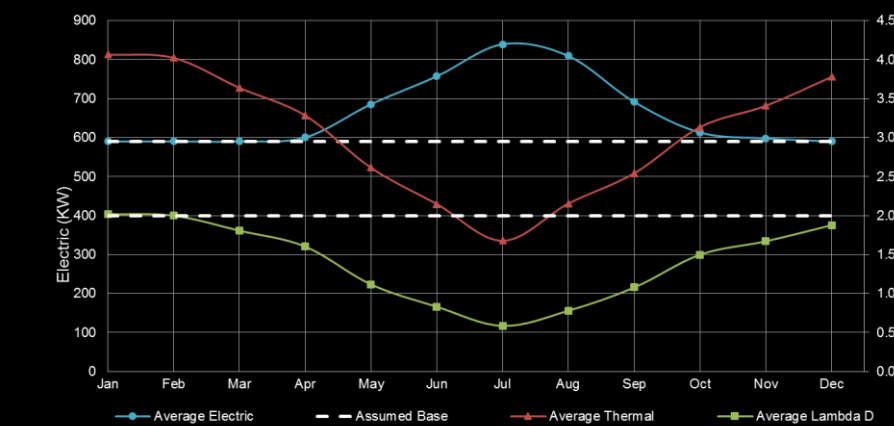
### Lighting Depth



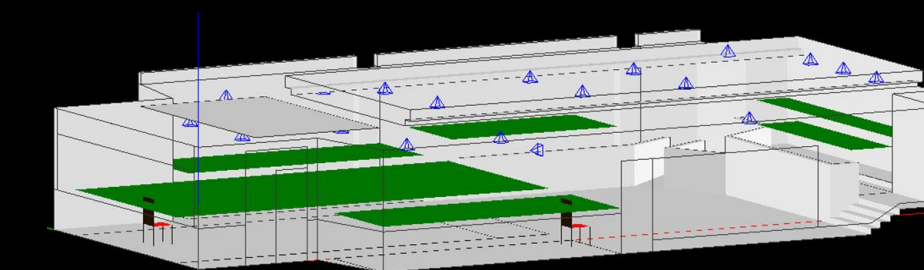
### Electrical Depth



### Mechanical Breadth



### Acoustical Breadth/MAE Depth



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Summary

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# Senior Thesis Presentation

## Bucks County Justice Center

Doylestown, PA

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Joshua Lange

Lighting/Electrical


Thesis Adviser: Dr. Richard Mistrick

Electrical Adviser: Gary Golaszewski





4/15/2015



## Main Lobby 1000

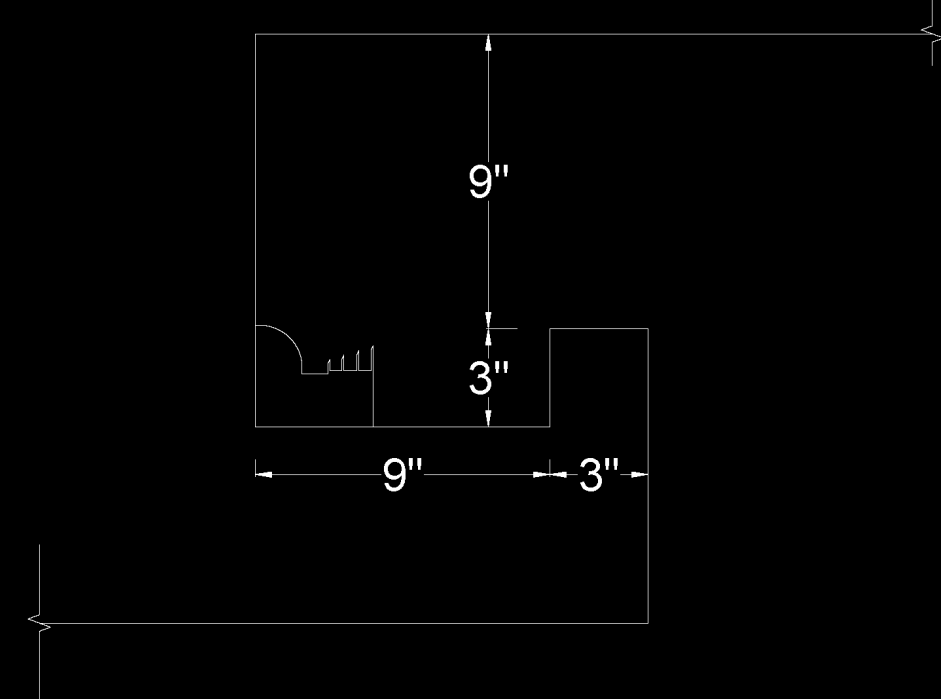
Type	Description	Manufacturer	Model	Lamp	CCT (K)	CRI	Life (Hours)	Ballast	Input (Watts)	Voltage	Fixture Image
R3	RECESSED CIRCULAR 6 INCH WIDE BEAM DOWNLIGHT 1500 LUMEN	COOPER LIGHTING	LD6A15DL3 ERW6A15835 6LW1LI	INTEGRAL	3500	80	50,000 L70	INTEGRAL	22.4	277	
R4	RECESSED CIRCULAR 6 INCH WIDE BEAM WALL WASH 1000 LUMEN	COOPER LIGHTING	LD6A10DL3 ERM6A10835 6LM111LI	INTEGRAL	3500	80	50,000 L70	INTEGRAL	14.1	277	
R7	RECESSED CIRCULAR 8 INCH MEDIUM BEAM DOWNLIGHT 5000 LUMEN	COOPER LIGHTING	LD8A502DL3 ER8A50835 8LMOLI	INTEGRAL	3500	80	50,000 L70	INTEGRAL	62	277	
R8	RECESSED CIRCULAR 8 INCH MEDIUM BEAM DOWNLIGHT 3000 LUMEN	COOPER LIGHTING	LD8A302DL3 ER8A30835 8LW110LI	INTEGRAL	3500	80	50,000 L70	INTEGRAL	42	277	
R9	RECESSED CIRCULAR 8 INCH WIDE BEAM DOWNLIGHT 3000 LUMEN	COOPER LIGHTING	LD8A302DL3 ER8A30835 8LW0LI	INTEGRAL	3500	80	50,000 L70	INTEGRAL	42	277	
W1	WALL MOUNTED LINEAR UPLIGHT TWO FOOT, 2000 LUMENS	COOPER LIGHTING	A02-S1A-2-LED-35K-277-S-AK12-D	INTEGRAL	3500	80	50,000 L70	INTEGRAL	22.6	277	

## Open Office 2520

Type	Description	Manufacturer	Model	Lamp	CCT (K)	CRI	Life (Hours)	Ballast	Input (Watts)	Voltage	Fixture Image
P1	CYLINDRICAL LED DIRECT/INDIRECT PENDANT	PEERLESS	RD4M4 W20/20 8FT R8 277 EZB SCT LP835 F1/24 C110	INTEGRAL	3500	80+	50,000 L80	INTEGRAL	40	277	
P1E	EMERGENCY CYLINDRICAL LED DIRECT/INDIRECT PENDANT	PEERLESS	RD4M4 W20/20 8FT R8 277 EZB 1 EC SCT LP835 F1/24 C110	INTEGRAL	3500	80+	50,000 L80	INTEGRAL	40	277	
P2	CYLINDRICAL LED WALL WASHER PENDANT	PEERLESS	RD4MW W20 40FT R8 277 EZB SCT LP835 F1/24 C110	INTEGRAL	3500	80+	50,000 L80	INTEGRAL	20	277	
P3	CYLINDRICAL LED DIRECT/INDIRECT PENDANT	PEERLESS	RD4M4 W20/40 4FT R4 277 EZB SCT LP835 F1/24 C110	INTEGRAL	3500	80+	50,000 L80	INTEGRAL	60	277	



## Ceremonial Courtroom 4100



Type	Description	Manufacturer	Model	Lamp	CCT (K)	CRI	Life (Hours)	Ballast	Input (Watts)	Voltage	Fixture Image
R1	RECESSED CIRCULAR 6 INCH NARROW BEAM DOWNLIGHT 1500 LUMEN	COOPER LIGHTING	LD6A15DL3 ERN6A10835 6LN1LI	INTEGRAL	3500	80	50,000 L70	INTEGRAL	22.4	277	
R2	RECESSED CIRCULAR 6 INCH WIDE BEAM DOWNLIGHT 1000 LUMEN	COOPER LIGHTING	LD6A10DL3 ERW6A10835 6LW1LI	INTEGRAL	3500	80	50,000 L70	INTEGRAL	14.1	277	
R4	RECESSED CIRCULAR 6 INCH WIDE BEAM WALL WASH 1000 LUMEN	COOPER LIGHTING	LD6A10DL3 ERM6A10835 6LM111LI	INTEGRAL	3500	80	50,000 L70	INTEGRAL	14.1	277	
R10	RECESSED CIRCULAR 6 INCH WIDE BEAM DOWNLIGHT 3000 LUMEN	COOPER LIGHTING	LD6A30DL3 ERW6A30835 6LW1LI	INTEGRAL	3500	80	50,000 L70	INTEGRAL	43.6	277	
R11	RECESSED CIRCULAR 6 INCH MEDIUM BEAM DOWNLIGHT 2000 LUMEN	COOPER LIGHTING	LD6A20DL3 ERN6A20835 6LM1LI	INTEGRAL	3500	80	50,000 L70	INTEGRAL	31.5	277	
S1E	SURFACE MOUNTED LINEAR CEILING WASH	IO LIGHTING	0-08-35KV2HO-1-72-L	INTEGRAL	3500	80+	50,000 L70	INTEGRAL	63.4	277	

Space	Fixture	Quantity	Watts per fixture	Total watts	Room Area	LPD (W/SF)	Space Type	Allowed LPD	Allowed Watts
Ceremonial Courtroom 4100				1905	2900	0.66	Courtroom	1.72	4988
	R1	5	22.4	112					
	R2	24	14.1	338.4					
	R4	13	14.1	183.3					
	R10	3	43.6	130.8					
	R11	4	31.5	126					
	S1	16	63.4	1014					

## Short Circuit Study

Designation	KVA	Primary Voltage	Secondary Voltage	Phase	Type	%Z*	Mounting	I <sub>FLA</sub>	I <sub>SC</sub>
T1	2000	34,500	480Y/277	3	Dry	5.75	Floor	7,217	125,511
T2	30	480	208Y/120	3	Dry	1.8	Hung	250	13,879
T4	45	480	208Y/120	3	Dry	1.8	Hung	375	20,818
T29	15	480	208Y/120	3	Dry	1.9	Hung	125	6,574
T31	75	480	208Y/120	3	Dry	1.7	Hung	625	36,738

$$I_{FLA} = \frac{(kVA)(1000)}{(V_{LL})\sqrt{3}}$$

$$I_{SC} = (I_{FLA}) \left( \frac{100}{\%Z} \right)$$

$$I_{SC \text{ Secondary}} = \frac{V_{primary}}{V_{secondary}} (M) (I_{SC \text{ Primary}})$$

Location	Conductor Type	Length (Feet)	Table 5 C	I <sub>3φ</sub>	Conductors per phase (n)	V <sub>LL</sub>	f 3φ Faults	M	I <sub>sc</sub>	Notes
Bus #2 Feed	3 Sets 300 KCMIL	30	18177	125,511	3	480	0.25	0.80	100,476	Approximate length of conductor from main panel to bus
Level 6	800A Bus	16	49300	100,476	1	480	0.12	0.89	89,898	Length of bus to electrical room based on floor to floor height
Level 5	800A Bus	32	49300	100,476	1	480	0.24	0.81	81,335	
Level 4	800A Bus	48	49300	100,476	1	480	0.35	0.74	74,262	
Level 3	800A Bus	64	49300	100,476	1	480	0.47	0.68	68,320	
Level 2	800A Bus	80	49300	100,476	1	480	0.59	0.63	63,259	
Level 1	800A Bus	96	49300	100,476	1	480	0.71	0.59	58,896	

$$3\phi \text{ faults: } f = \frac{\sqrt{3}(L)(I_{3\phi})}{(C)(n)(V_{LL})}$$

$$M = \frac{1}{1+f}$$