

# **THTR353**

### THEATRE DESIGN REPORT

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### Introduction

Our proposed theatre, the Davin Stone Demi-Dome (henceforth known as 'The Dome'), takes inspiration from architectural movements of the 70s, using mostly natural materials and a brown-orange color scheme. Located in the rainforests of Brazil, The Dome can seat over 1600 people, and has a stage over 100 feet wide. The Dome is constructed mainly of locally sourced granite and basalt, as well as a solid mahogany stage. And most importantly, the main feature of the dome is its sloped moss seating, proving ample space for viewing the stage, as well as comfortable, organic seating. The Dome is best suited for large theatre productions and acoustic music shows; however, any event can find a home at The Dome.

### Acoustic Treatments

#### Overview

Since the roof of the theatre is made of basalt, and the floor is covered with moss, the RT60 for high frequencies was too short, while the RT60 for lower frequencies was too long. Heavy treatment of pegboard was needed on the basalt roof of the theatre to bring the RT60 within the target range of ~1.2 seconds. Reflection paths can be seen in Appendix A.

#### Calculations

Surface area and volume measurements were taken using tools in Rhino3d and can be seen in **Table I**. With over 60000 sq. ft. of moss and around 40000sq. ft. of seatable area, around 5000 people can be comfortably seated with a 9sq. ft. area for each person. Inverse square losses can be calculated using the equation below, along with the distance to the back of the seating in the balcony from center stage, which is about 170ft or 52m.

inverse square = 
$$20 \log \left(\frac{52m}{1m}\right) = 34.32 dB$$

Table I Room Geometry

Room Faces	Surface Area (ft <sup>2</sup> )	Surface Area (m <sup>2</sup> )	Coverage %
A (Seating)	60670.82	18491.56	36.70%
B (Stage)	3299.06	1005.50	2.00%
C (Dome)	54241.96	16532.14	32.81%
D (Side Walls)	44094.53	13439.36	26.67%
E (Other Floor)	2999.06	914.07	1.81%
Total	165305.43		

At a spoken level of 74dB, people seated in the back of the theatre would hear 39.68dB from the performer when unamplified, which is extremely quiet.

Once the individual absorption coefficient for each surface was calculated using **Tables I and II**, the full and empty space RT60 values were calculated using the formula below, where V is the volume of the room, S is the surface area of that surface, and a is the absorption coefficient of that surface.

$$RT_{60} = 0.049 * \frac{V}{-Sln(1-a)}$$

The RT60 value at each frequency was recorded in **Table III**, and a graph showing the space's frequency response can be seen in **Fig. 1**. Lastly, the critical distance for the full and empty theatre was calculated at each frequency using the following equation, with V being the volume of the theatre:

$$d_c = 0.014 \sqrt{\frac{V}{RT_{60}}}$$

The critical distance at each frequency can be seen in Table III.

Table II Absorption	Coefficients
---------------------	--------------

Surface Description	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Wood, Mahogany	0.19	0.23	0.25	0.3	0.37	0.42
Rock, Basalt	0.05	0.18	0.42	0.64	0.74	0.86
Rock, Granite	0.01	0.01	0.01	0.01	0.02	0.02
Moss	0.01	0.03	0.15	0.35	0.44	0.48
Pegboard - 12.7in centers	0.98	1.1	0.99	0.71	0.4	0.2

Table III RT60 and Critical Distance

Critical Distance						
(m)	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
Empty	30.290	33.731	36.676	38.828	37.185	35.927
Full	36.306	40.719	42.479	42.850	40.571	38.682
RT60	125	250	500	1000	2000	4000
Empty	1.900	1.532	1.296	1.156	1.261	1.350
Full	1.322	1.051	0.966	0.949	1.059	1.165

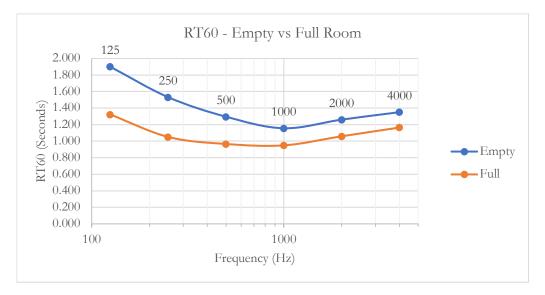


Fig.1. RT60 Curves

#### **Floor Treatments**

Over 95% of the floor is covered in moss for seating, while the remaining ~5% is granite. The moss provides mild attenuation of high frequencies, and this dampening is improved further when the theatre is

full. With plenty of space on the ceiling of the theatre for acoustic treatment, further treatment of the floor would needlessly reduce seating capacity.

#### **Ceiling Treatments**

The surface of the ceiling receives a 70% treatment of pegboard with 6.4mm holes on 2.5cm centers over 12.7in. Since almost a third of the surface are of the theatre is the roof, the basalt caused the theatre to sound too dead at frequencies above 1kHz. The pegboard treatment counteracts this, simultaneously lowering the RT60 for low frequencies and raising the RT60 for high frequencies into our target range of ~1.2s.

### Stage Treatments

The stage makes up only 2% of the surface area of the theatre, and it provides mild absorption across the spectrum, as the stage is mahogany. Ample treatment is provided on the surface of the ceiling, so no further treatment is necessary.

### Loudspeaker Design

#### Overview

The house system is using Meyer's flagship new line array cabinet, Panther. Panther is the ideal array system as it can put out the decibels needed to fill the venue, has 20% less power draw than an average line array cabinet, and allows for pinpoint dispersion control which provides incredible response prediction. In the Davin Demi-Done we have a total of 76 Meyer Panther cabinets; Each of our four main clusters for the orchestra has 10 cabinets while our balcony has 7 cabinets per array. Additionally, spread across the large proscenium we have 8 individual cabinets of Meyer Panthers filling in the gaps. All of this, paired with four arrays of Meyer 900-LFC with a total of 24 cabinets. The block diagram and system connections can be seen in **Appendix B.** This system has an average

Table IV Loudspeaker Specifications

Panth	ier
Freq. Range	55Hz - 16kHz
Max Sound	
Level	150.5dB
LFC-9	00
Freq. Range	31Hz - 125Hz
Freq. Response	30Hz - 85Hz
Max Sound	
Level	140dB

SPL-C weight of 112dB with a maximum linear peak SPL at 138dB at full strength. This allows the Davin Demi-Done to fit the large shows that come through but can still make a single performer show feel full and vibrant but not overpowering. No external amplifiers are needed as all of Meyer's speakers are active. No sensitivity specification is provided by Meyer for their speakers; however, frequency specifications can be seen in **Table IV.** 

With a needed acoustic gain (NAG) of 40.91dB, and a potential acoustic gain (PAG) of 41.27dB after accounting for 6dB of headroom, there is enough room between the PAG and the NAG to reach a level of 85dB in the back of the balcony with a loudspeaker output of 125.91dB.

### Calculations

Due to how Meyer Sound handles their speaker specifications, most of our placement and loudspeaker quantities were determined through simulation trial and error. Pictures showing the results of our simulated system can be seen in **Fig.3-5**.

The measurements used in the calculations for PAG and NAG can be seen below in **Fig.2**, along with the equations for PAG and NAG.

$$PAG = 20 \log_{10} \left( \frac{D_1}{D_s} * \frac{D_0}{D_2} \right) = 47.27 dB$$

PAG with headroom = 47.27dB - 6dB = 41.27dB

 $NAG = 20 \log_{10}(D_2) = 40.91 dB$ 

desired output = 85 dB

loudspeaker output = desired out + NAG = 125.91dB

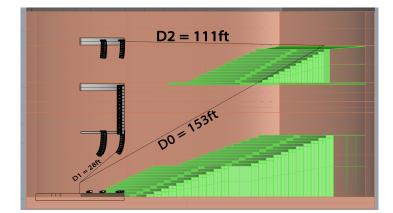


Fig.2. PAGNAG Measurements

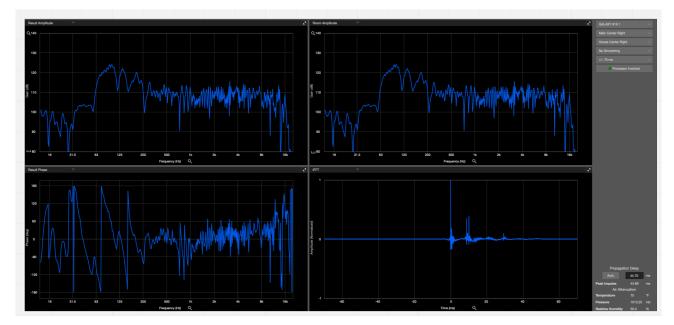


Fig.3. Theatre Sound System Frequency Response

**Table V** Potential and NeededAcoustic Gain

Potential/Ne Acoustic G	
Ds (ft)	0.167
D0 (ft)	153.133
D1 (ft)	27.94
D2 (ft)	111
PAG (dB)	47.27
PAG w/	
FSM(dB)	41.27
NAG (dB)	40.91
Desired	
Output (dB)	85
Loudspeaker	
Output (dB)	125.91

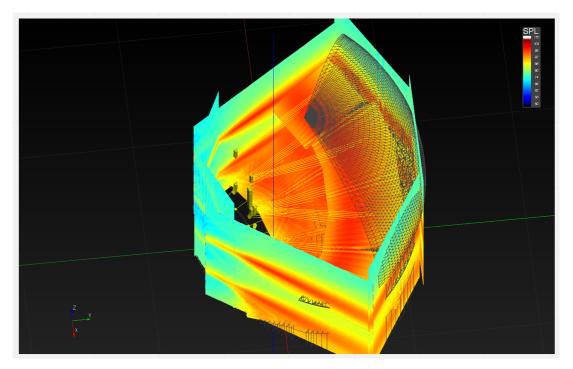


Fig.4. SPL Output at Seating, Side Angle

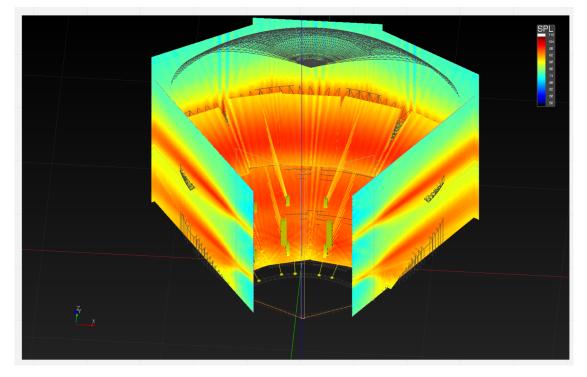


Fig.5. SPL Output at Seating, Front Angle

### Networking and Signal Processing

Our system contains 8 Galileo Galaxy 816 Digital Signal Processors with 7 having control over individual line arrays. Our 8<sup>th</sup> processor is being used as a routing machine with 3 analog inputs and running AVB outputs all hitting an Extreme 440 8 port switch which gives signal to the other processors. The processor settings can be seen below in **Appendix C** in **Fig. 14 - Fig. 20**. While setting up our processor we needed to find delay times to accurately time our system for the ideal audience listen experience. Using this equation, we found that our top boxes  $Delay in ms = \frac{Distance in feet}{1.126}$ of Meyer Panther in our balcony arrays has a delay time of 70.4ms. Going down from there, the bottom box has a delay time of 64ms. The position we calculated from was the center stage position which can be seen in **Fig. 7.** Although this system is very big, using Meyer's equipment, we have been able to simplify the system in a way that allows for easy control, easy access to equipment, and have great user interfaces. A full system schematic can be seen down below in **Appendix B**.

### Mixing Console

### Appendix A – Room Drawings

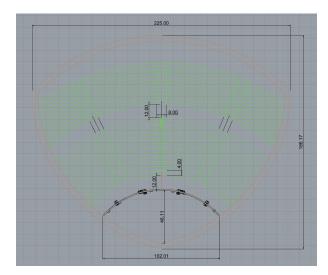
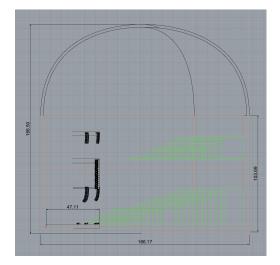


Fig. 6. Annotated Plan (All measurements in feet)



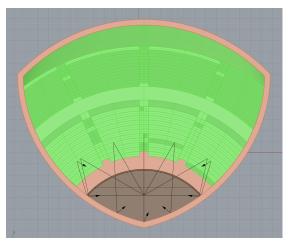


Fig. 7. Plan with Reflections, 30 degrees apart, 2 bounces each

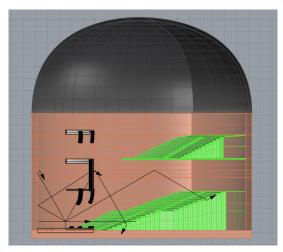


Fig. 9. Section with Reflections, 30 degrees

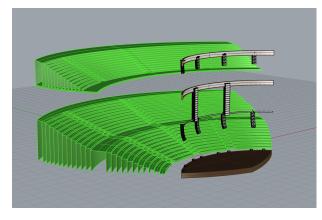


Fig. 10. Stage and seating

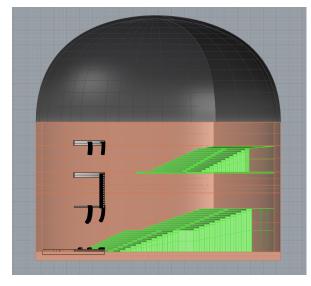


Fig. 12. Half of theatre

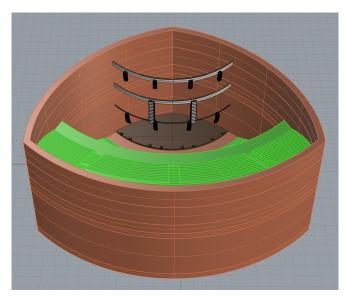


Fig. 11. Back angle of theatre

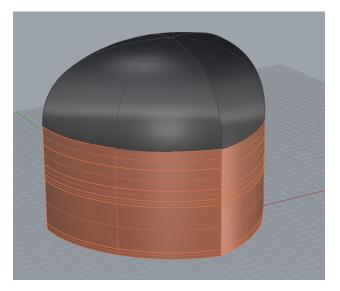
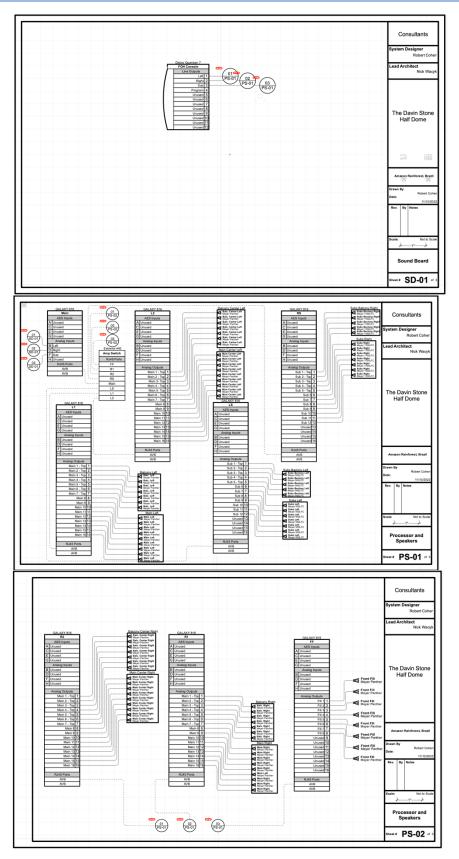


Fig. 13. Fully enclosed dome

# Appendix B - System Diagrams



pg. 9

# Appendix C - Processor Settings



#### Fig. 14. Front Fills

Overview	-	input Proce			Summing Matrix	_		Masters	Output Masters			
Sel Iso	LG		Label		Meter AESOL	Muse	Gain 0.0 d8	Delay 0 mg	Processing		Summing Matrix	14 15 16
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	LG				ACTOL	Mater	0.0 dB	0 m		1234		
		input D			AESOR	Muted	0.0 d3	0 m		1 2 3 4		
		Input E			Notiput	Muled	0.0 dB	0 me				
F F		hext F			Notigut	Muted	0.0 48	0 ms				
G G						Muted	0.0 d3		• •			
нн		input H				Muted	0.0 d3		O H			
Processin		EQ	Product Integration	Atmo	s. Polarity	Delay	Gain		Meter	Mute	Label	Sel Iso Link
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2	=i			Edt			0.0 d8	i 🍎 🎹				
	-1		PWNTHER pc63	Edt			0.0 d0	0				
	-1			Edi			0.0 dB	( <u>)</u>				
	-1			Eat			0.0 dB	0				
	-1	Enabled	PWNTHER pc63	Edt			0.0 d8					
	-1		PWNTHER pc63	Edt			0.0 d0					
	-1		PANTHER pc63	Edt			0.0 dB					
		Enabled	PANTHER po53	Edt			0.0 dB				Main 9	
		Enabled	PWITHER pc63	Edt	I Normal						Main 10	10 10 LG
	_	Enabled	PWNTHER pc63	Edt								
	_ !	Enabled	PANTHER pc63	Edt								12 12 LG
		Enabled	PWNTHER pc63	Edt								
	- 1	Enabled	PWNTHER pc63	Edt			-					14 14 LG
	_	Enabled	PANTHER pc63	Edt							Main 15	15 15 LG
				Edt			0.0 d9				Main 16	16 16 LG

Fig. 15. Line Arrays Left 1

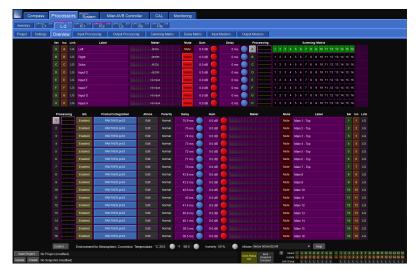


Fig. 16. Line Arrays Left 2

Settings			w	Input Proc	essing	Output Pr	ocessing	Sum	ning Matrix	Delay	Matrix	Input	Masters	Out	put Mar	sters									
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				Input F						Muted	0.0 dB			ms 🔵											
				Input G				Note		Mated	0.0 dB			ms 🤵											
										Mated	0.0 dB			ms 🔵								12 13 14		8	
	Pr	oces	ing		Pro	Juct Integratio		Atmos.	Polarity	Delay		Gain			Mete			Mute			Label				Link
	1	F		Enabled	P																				
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					P	WITHER pc63																			
				Enabled	P	WITHER oc63			Normal	26.2 m															

Fig. 17. Line Arrays Right 1



Fig. 18. Line Arrays Right 2



Fig. 19. Line Arrays Subs Left

Settings	Ow	irvie	w	Input Proce	ssing Output	Processing	Summi	ng Matrix	Delay I	Matrix	Input M	asters	Outpu	t Masters	5							
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				Right			ALSOR		Mused	0.0 dB		0 me						8 9 10 11 12				
				Subs					Mile	85 0.0		0 me						8 9 10 11 12				
				Input D					Muted													
			LG						Muted			0 ms										
				Input F					Mated	0.0 dB		0 ms										
				Input G					Mated	0.0 dB		0 ms										
									Mated								5 6 7					
	Pr		aing		Product Integra	tion	Atmos.	Polarity	Delay		Sain			Meter		Mute		Label	54	i bi	o Link	
	1	E		Enabled		3					00 dB 🌘					Vute	Sub 1 - Top					
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				Enabled		3					0.0 dB 🚺					Mute						
				Enabled	900-LFC pc6	3					0.0 dB 🚺					Mute						
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				Enabled							0.0 dB					Nute	Output 16					

Fig. 20. Line Arrays Subs Right