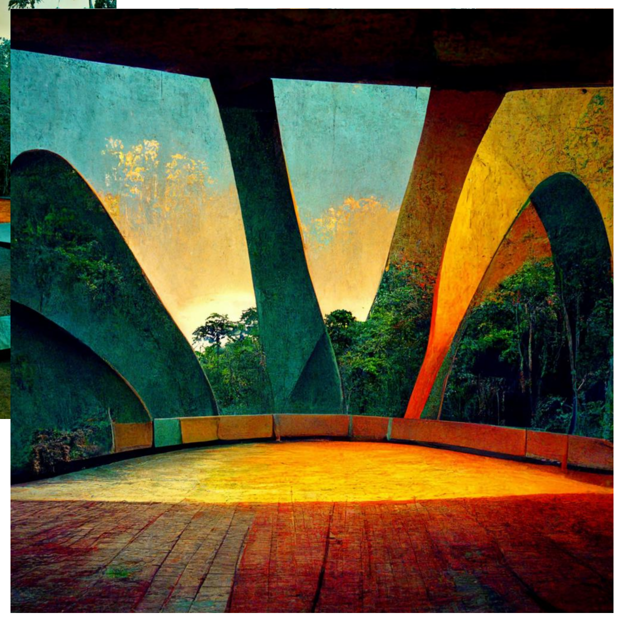
Fall
2022



# THTR353

## THEATRE DESIGN REPORT

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# Contents

# 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.

**Table I** Room Geometry

| Room Faces | Surface Area (ft$^2$) | Surface Area (m$^2$) | 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 | | |

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

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 |

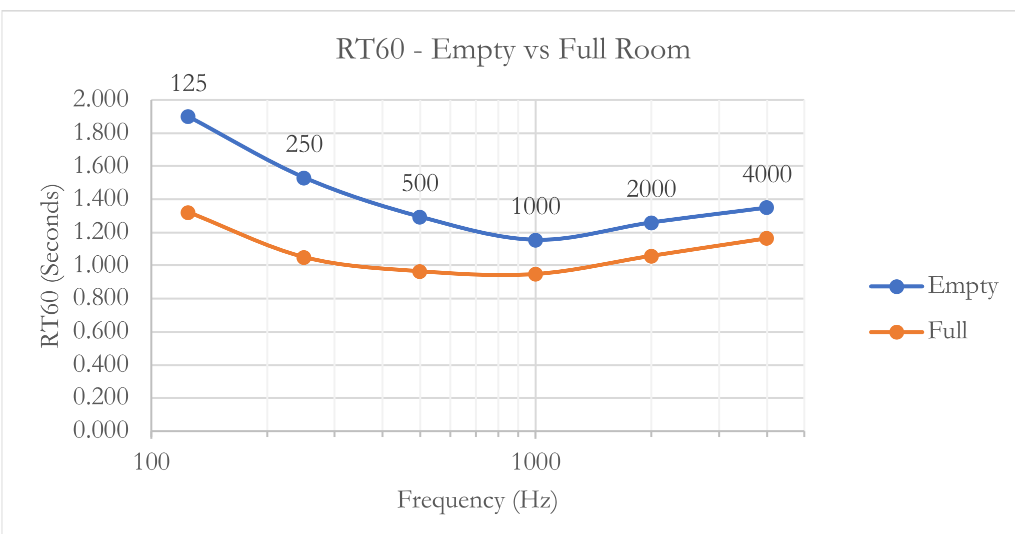



**Fig.1.** RT60 Curves

## 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 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.**

**Table IV** Loudspeaker Specifications

| Panther | |
|---|---|
| Freq. Range | 55Hz - 16kHz |
| Max Sound Level | 150.5dB |
| **LFC-900** | |
| Freq. Range | 31Hz - 125Hz |
| Freq. Response | 30Hz - 85Hz |
| Max Sound Level | 140dB |

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.

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

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

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

$$desired\ output = 85dB$$

$$loudspeaker\ output = desired\ out + NAG = 125.91dB$$

**Table V** Potential and Needed Acoustic Gain

| **Potential/Needed Acoustic Gain** | |
|---|---|
| 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 |

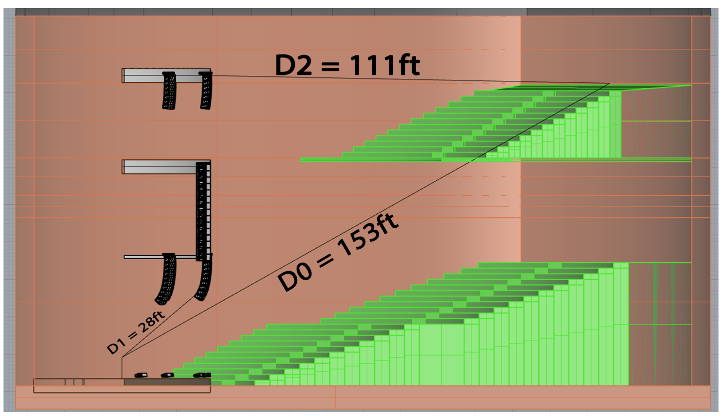



**Fig.2.** PAGNAG Measurements

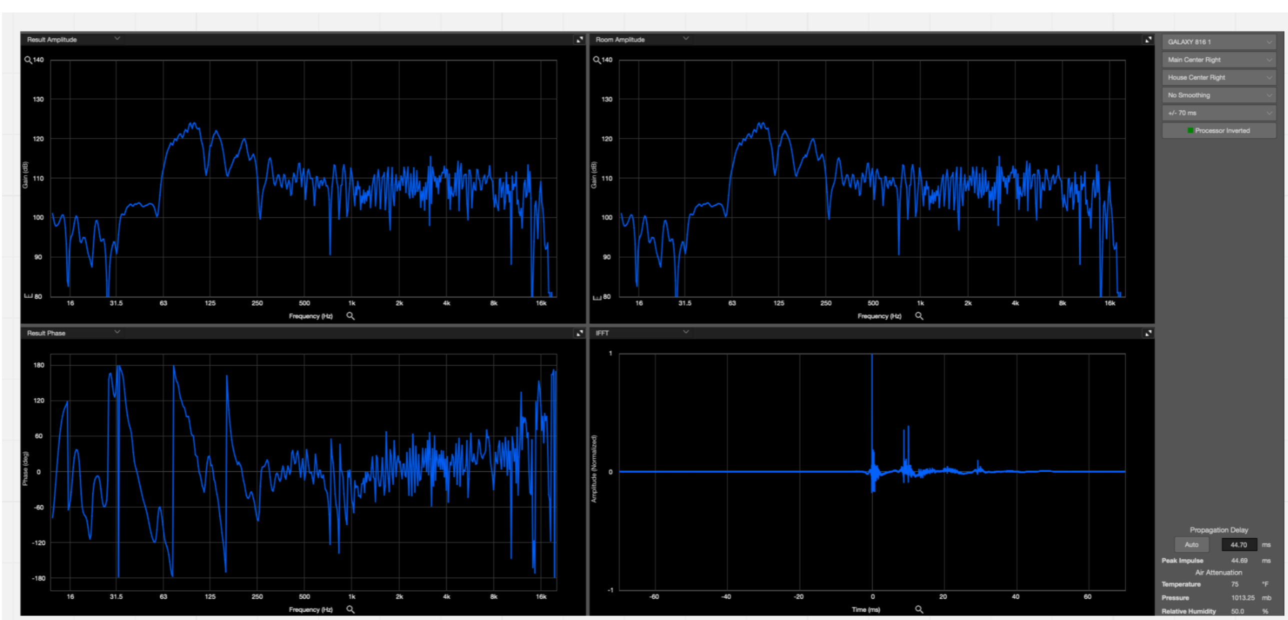


**Fig.3.** Theatre Sound System Frequency Response

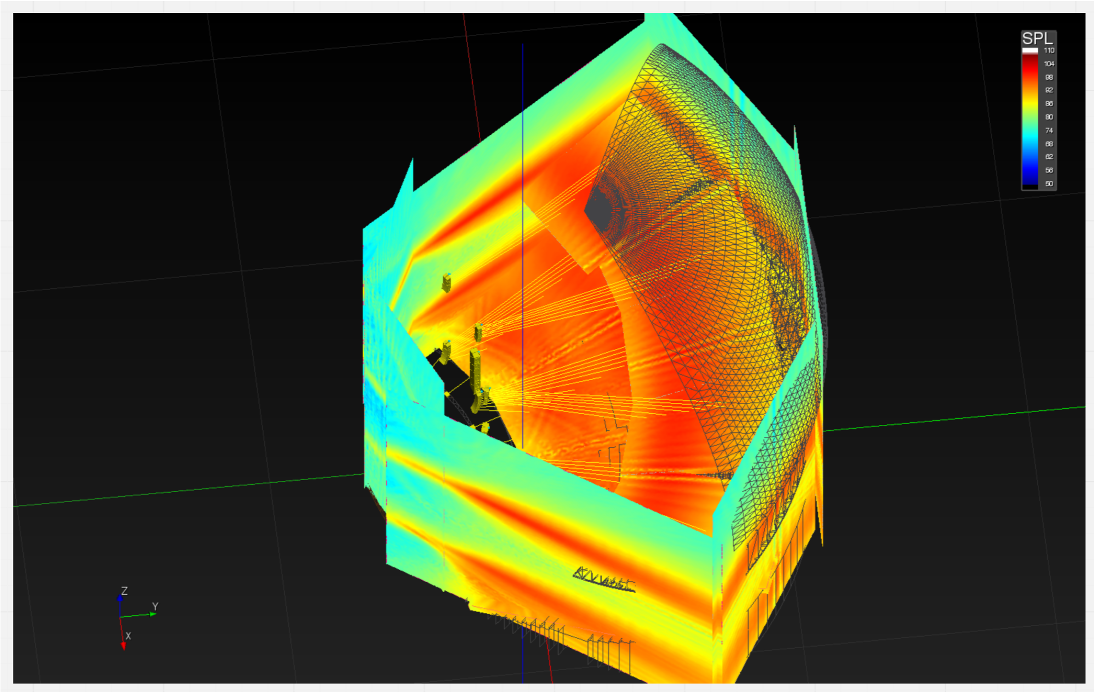



**Fig.4.** SPL Output at Seating, Side Angle

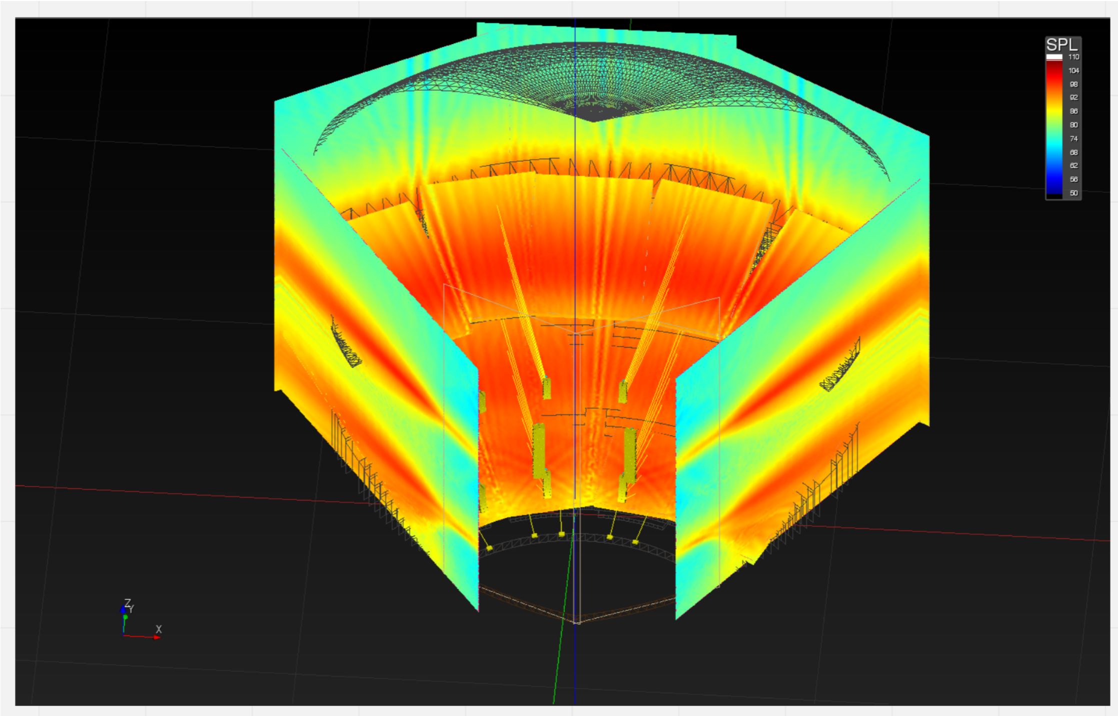



**Fig.5.** SPL Output at Seating, Front Angle

## Networking and Signal Processing

Our system contains 8 Galileo Galaxy 816 Digital Signal Processors with 7 having control over individual line arrays. Our 8th 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 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.**

$$Delay\ in\ ms = \frac{Distance\ in\ feet}{1.126}$$

## Mixing Console

## Appendix A – Room Drawings

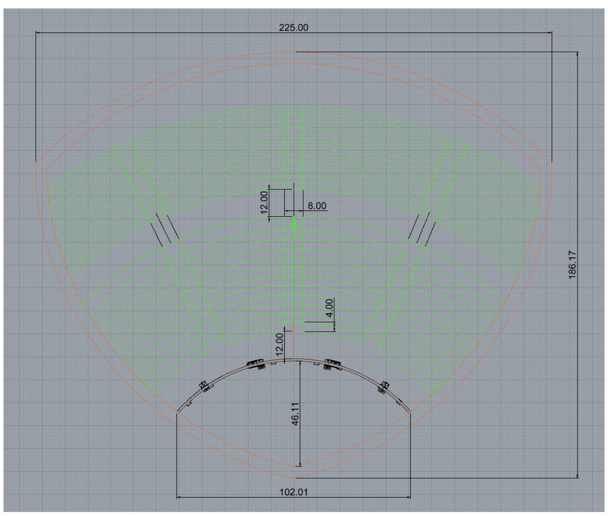



**Fig. 6.** Annotated Plan (All measurements in feet)

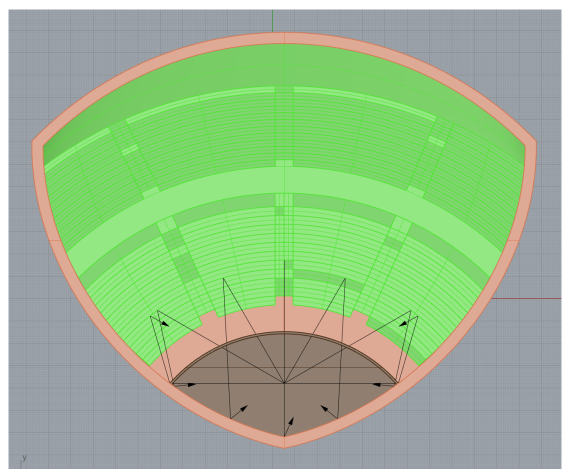
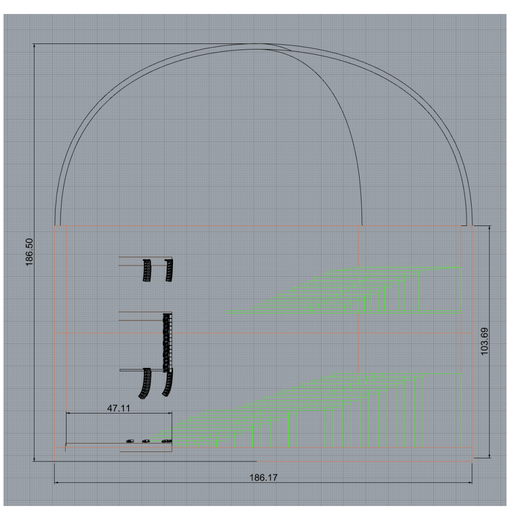


**Fig. 7.** Plan with Reflections, 30 degrees apart, 2 bounces each



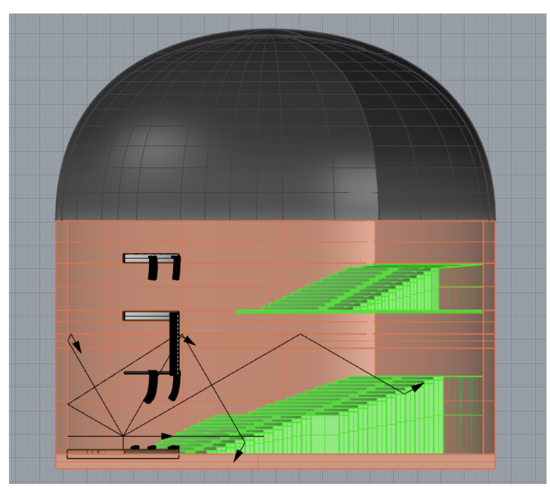



**Fig. 9.** Section with Reflections, 30 degrees

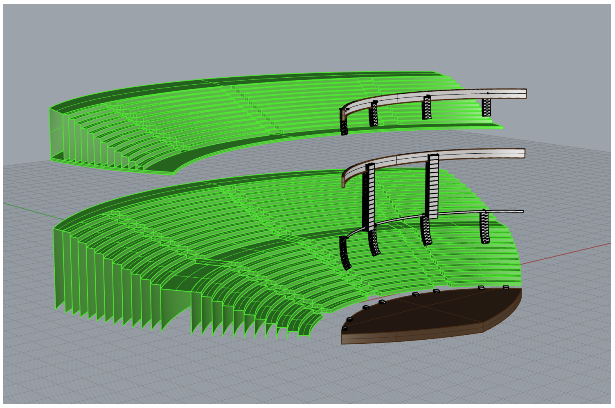


**Fig. 10.** Stage and seating

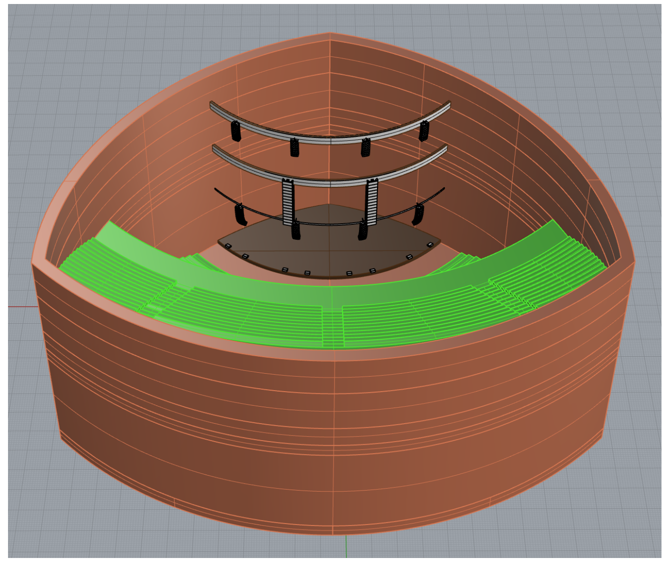


**Fig. 11.** Back angle of theatre

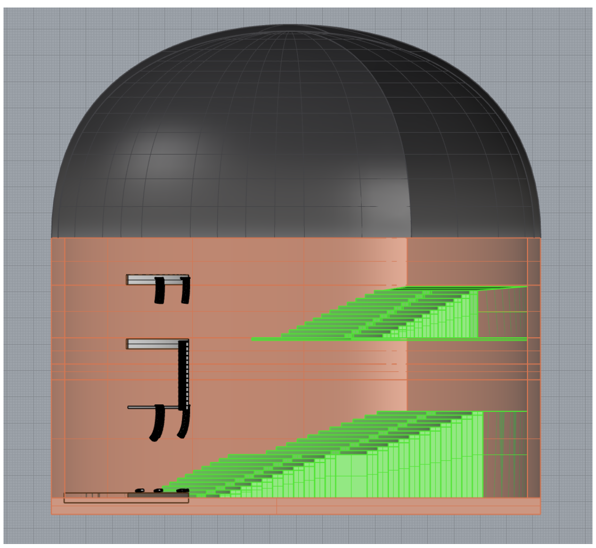


**Fig. 12.** Half of theatre

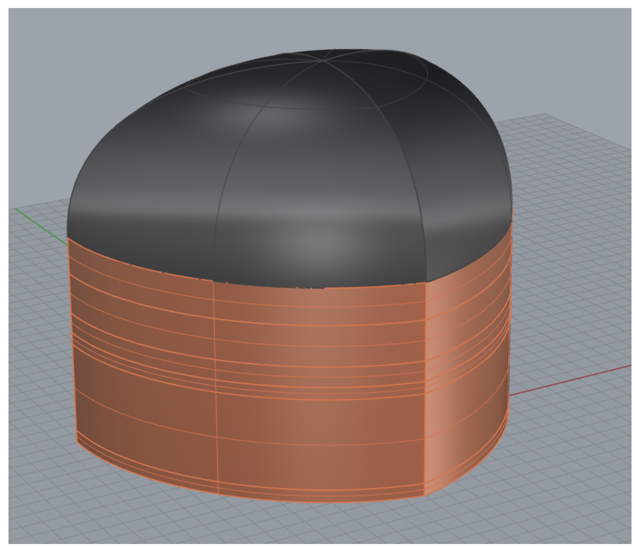
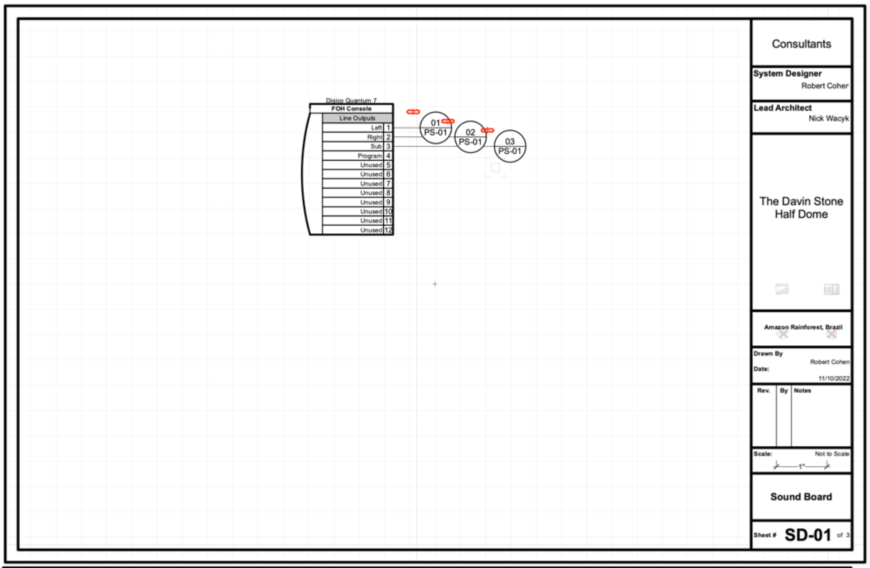
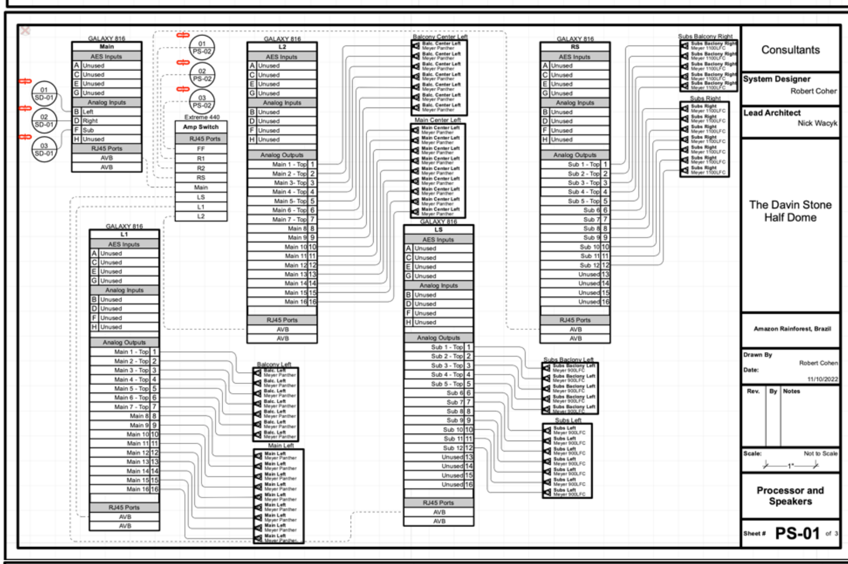
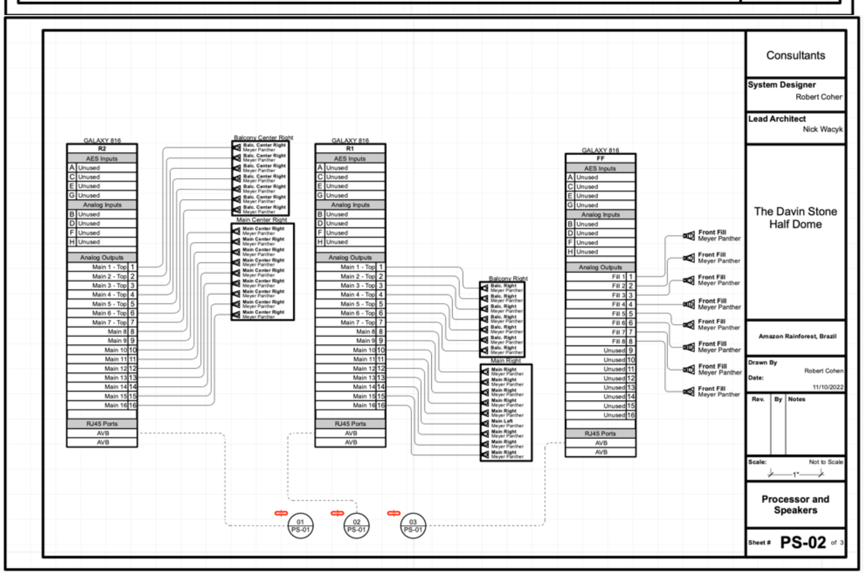


**Fig. 13.** Fully enclosed dome

# Appendix B - System Diagrams



# Appendix C - Processor Settings

**Fig. 14.** Front Fills

**Fig. 15.** Line Arrays Left 1

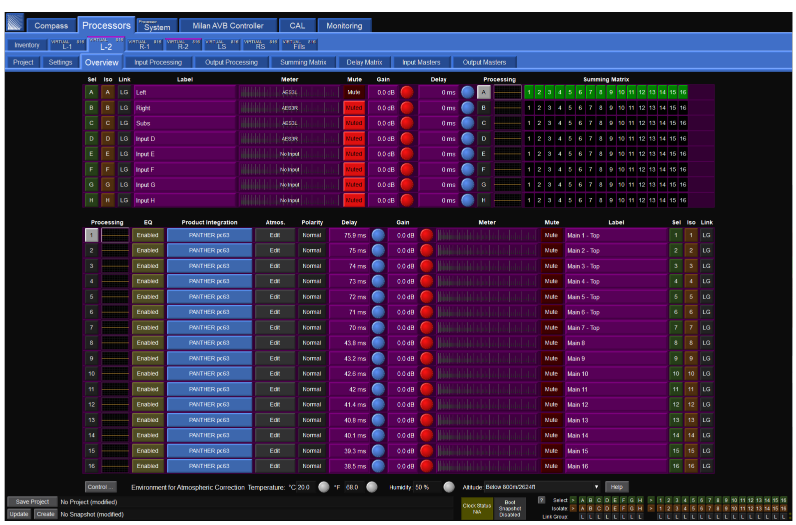


**Fig. 16.** Line Arrays Left 2


**Fig. 17.** Line Arrays Right 1


**Fig. 18.** Line Arrays Right 2

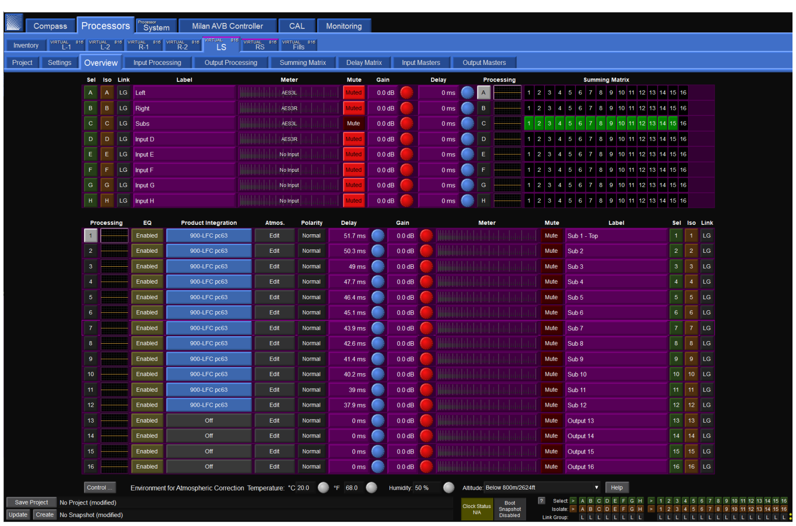



**Fig. 19.** Line Arrays Subs Left

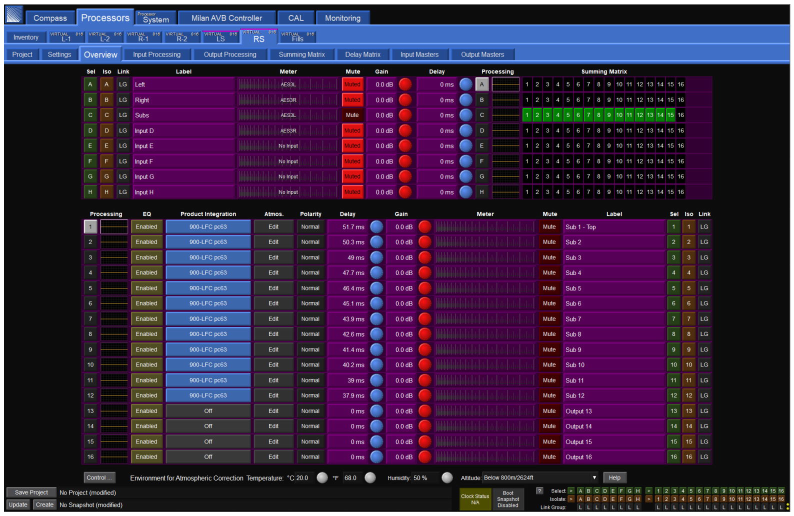



**Fig. 20.** Line Arrays Subs Right