

# Terrestrial Laser Scanning Survey of Haynes Engineering Building, Texas A&M University, College Station, Texas (November 24, 2019): Project Report

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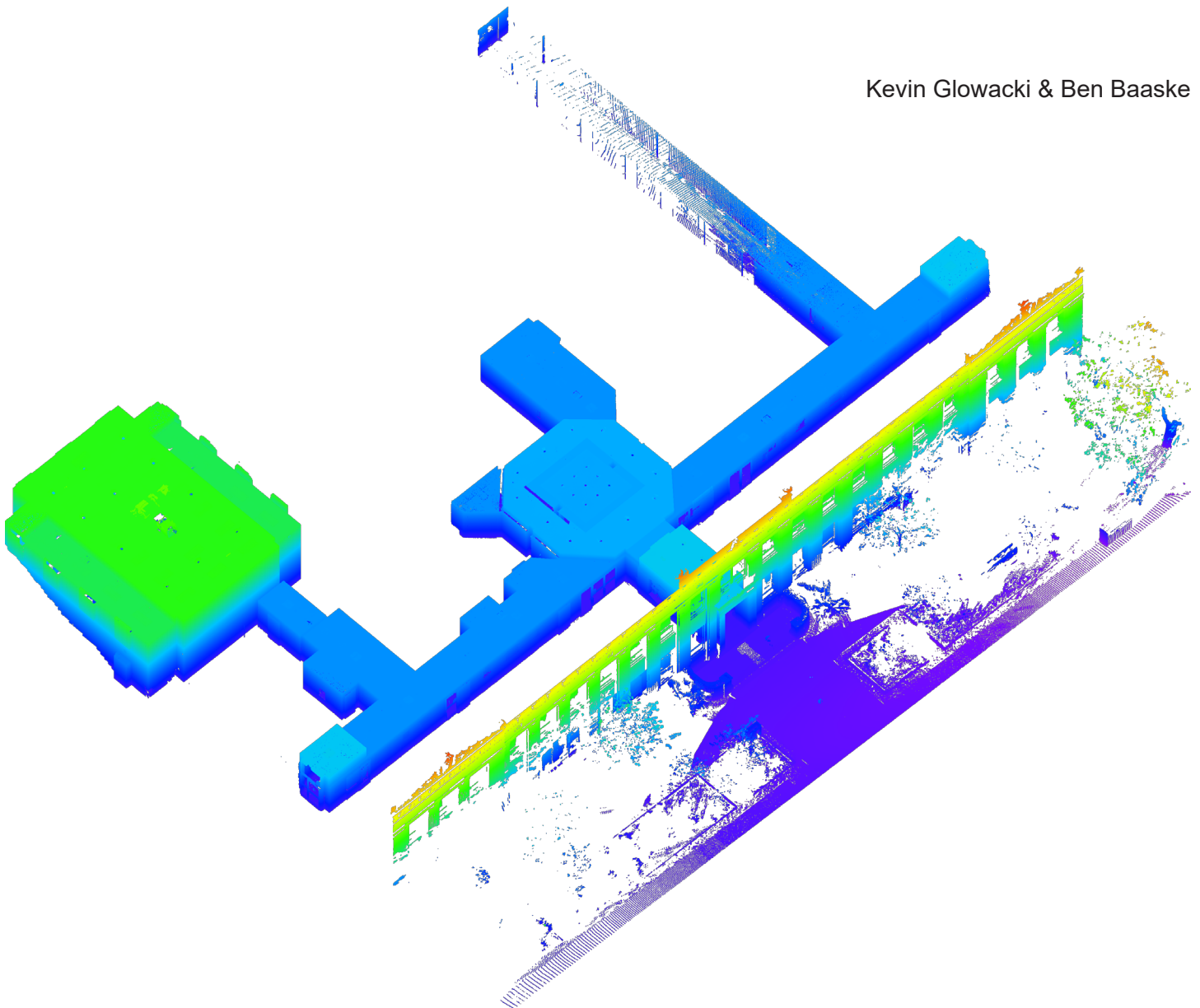


Figure 1:  
Aerial view  
showing location  
of Haynes  
Engineering  
Building in  
College Station,  
Brazos County,  
Texas. Google  
Earth.

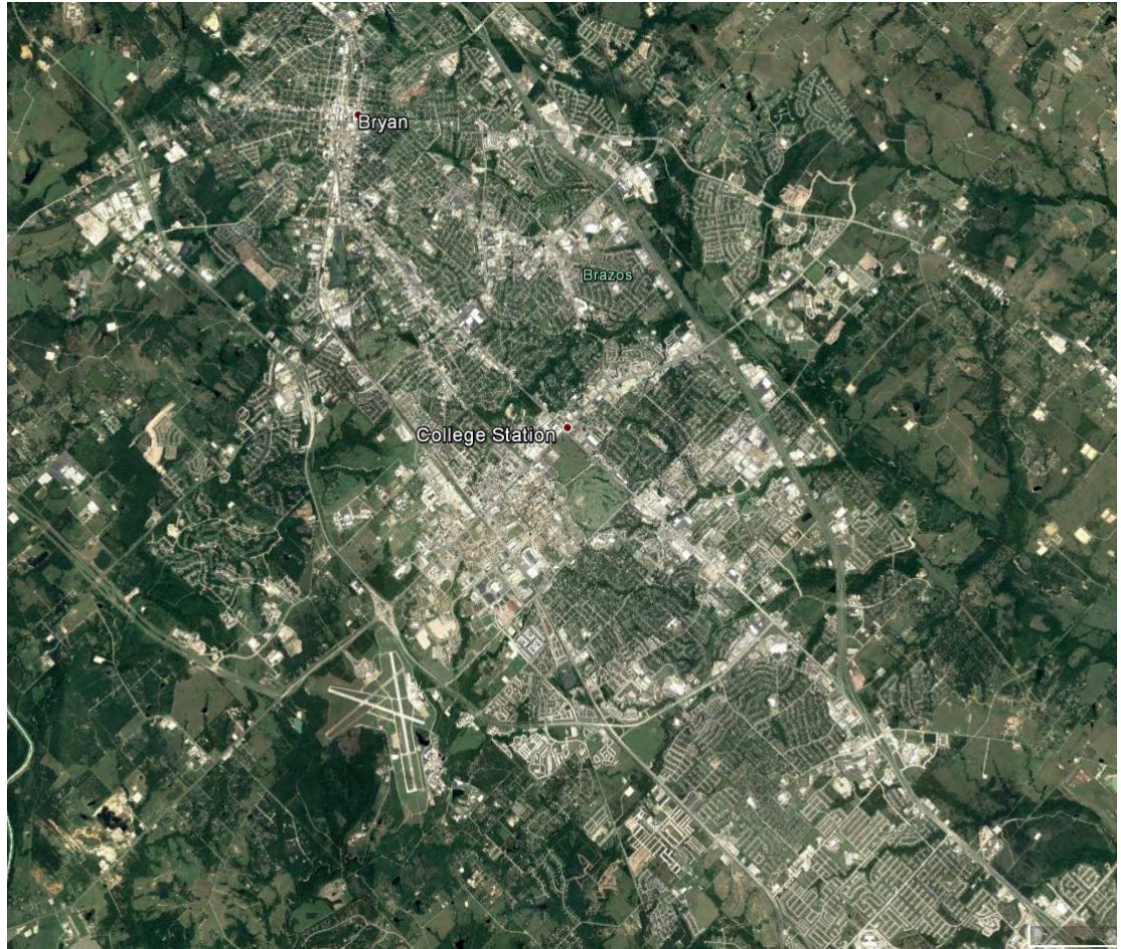


Figure 2:  
Aerial view  
of Haynes  
Engineering  
Building. Google  
Earth.





## **Introduction**

The following is a report on the terrestrial laser scanning survey of the Haynes Engineering Building at Texas A&M University in College Station, Texas, conducted by the Center for Heritage Conservation at Texas A&M University on November 24th, 2019.

The primary objectives of the scanning project were

- 1) to document the current condition of the lobby, main corridor, and auditorium prior to the planned study of material finishes and future renovation/restoration;
- 2) to create a preliminary orthographic images from the recorded point cloud data;
- 3) to prepare archival digital files ready for use in 3d modeling programs.



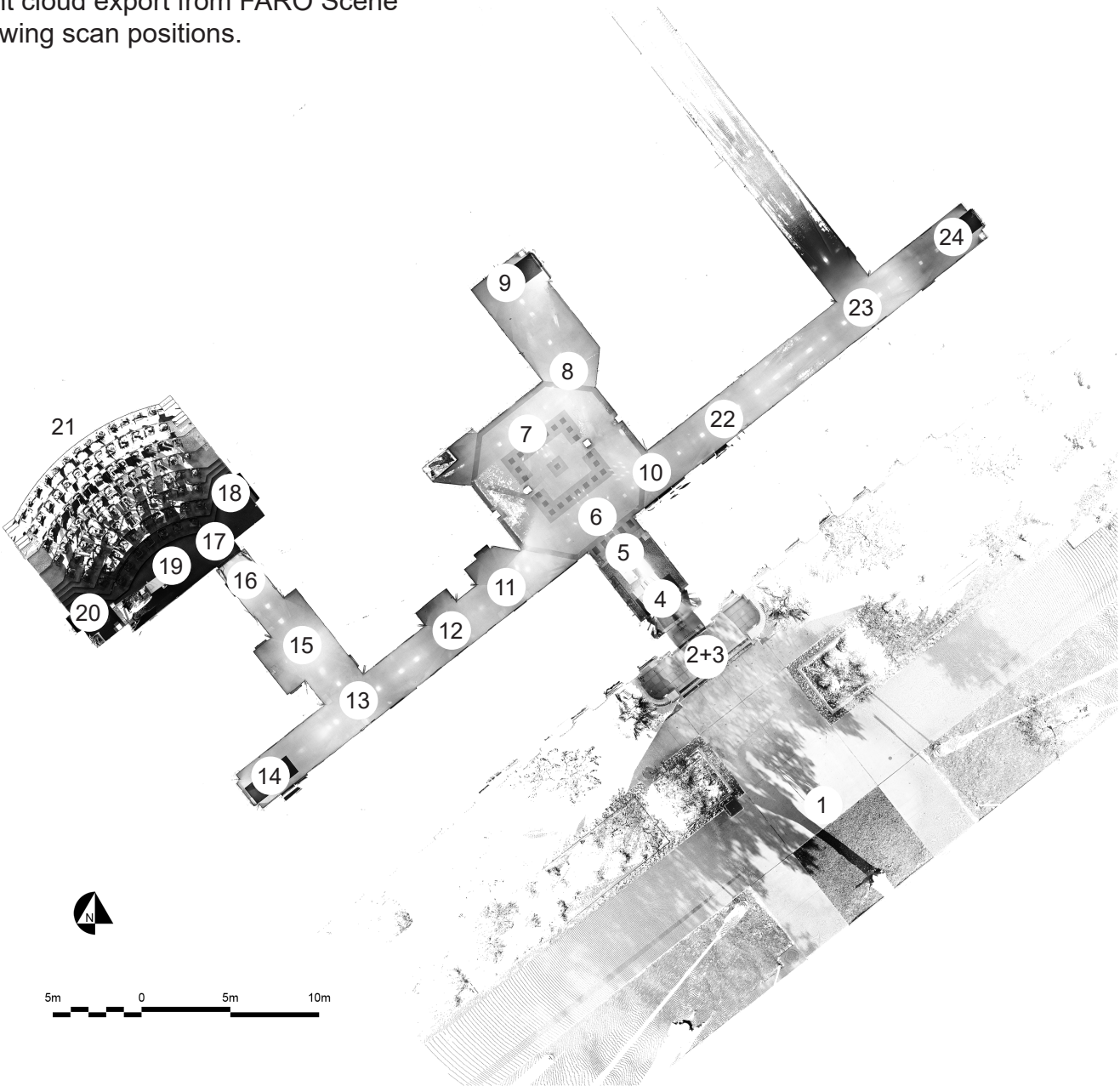
## **The Terrestrial Laser Scanning Survey**

The Center for Heritage Conservation (CHC) at Texas A&M University (TAMU) documented the current condition of the Haynes Engineering Building at Texas A&M University in College Station, Texas, using terrestrial laser scanning (TLS) technology on November 24, 2019.

The team utilized a FARO Focus3D X330, a phase-based laser scanning system. The scan data were initially processed with FARO Scene 2019.0 software.

The scan project resulted in 24 usable scan positions, with each scan duration being around 8 minutes. A scan resolution of  $\frac{1}{4}$  was set; this results in an average point spacing of 6mm at a distance of 10m. The scan quality was set to 3x; this number pertains to the number of measurements of a collected data point. A full 360-degree capture was obtained at each scan position, with a vertical declination range of -60-degree to 90-degrees. Light metering was set to even-weighted and the high dynamic range (HDR) setting was not used for images.

Figure 3. Site Plan. Orthophoto of point cloud export from FARO Scene showing scan positions.



## **Processing & Registration**

The most effective means of aligning adjacent scans correctly proved to be manual alignment using surface planes in the respective scenes. The resulting cluster was then optimized using cloud-to-cloud registration. Initial registration output (using top-view and cloud-to-cloud automatic registration) yielded a mean point error of 2.9mm with a maximum point error of 44.6mm and a minimum overlap of 3.6%. Using manual registration and the fine registration capabilities of Scene, scan point statistics were improved. The mean point error was reduced to 1.2mm with a maximum point error of 3.8mm and a minimum overlap of 13.2%.

Once sufficiently registered, the project point cloud was created; this allowed for export of orthophotos and the project point cloud itself (in various file formats). Overall, the Haynes Engineering Building project point cloud consists of 795,946,704 data points.

Figure 4: Plan view. Screenshot of point cloud in visual registration view from FARO Scene.

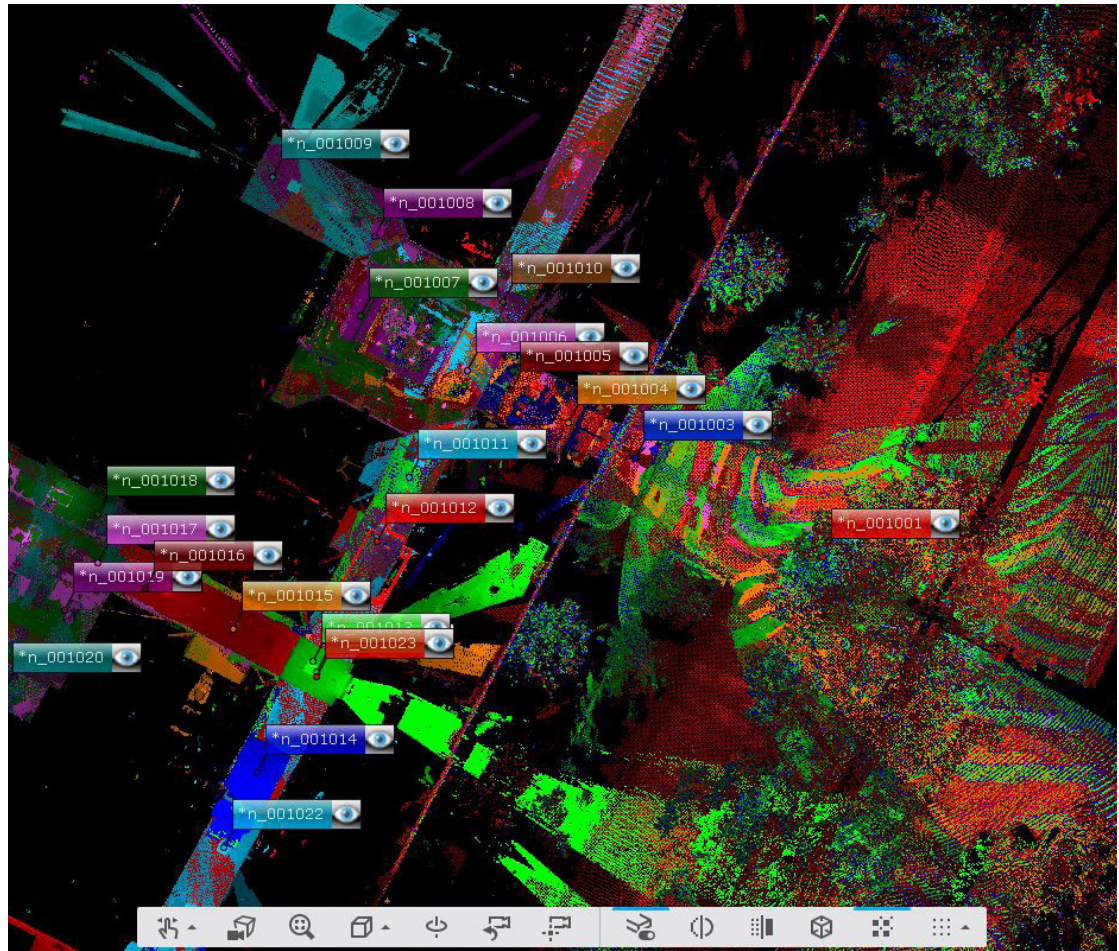
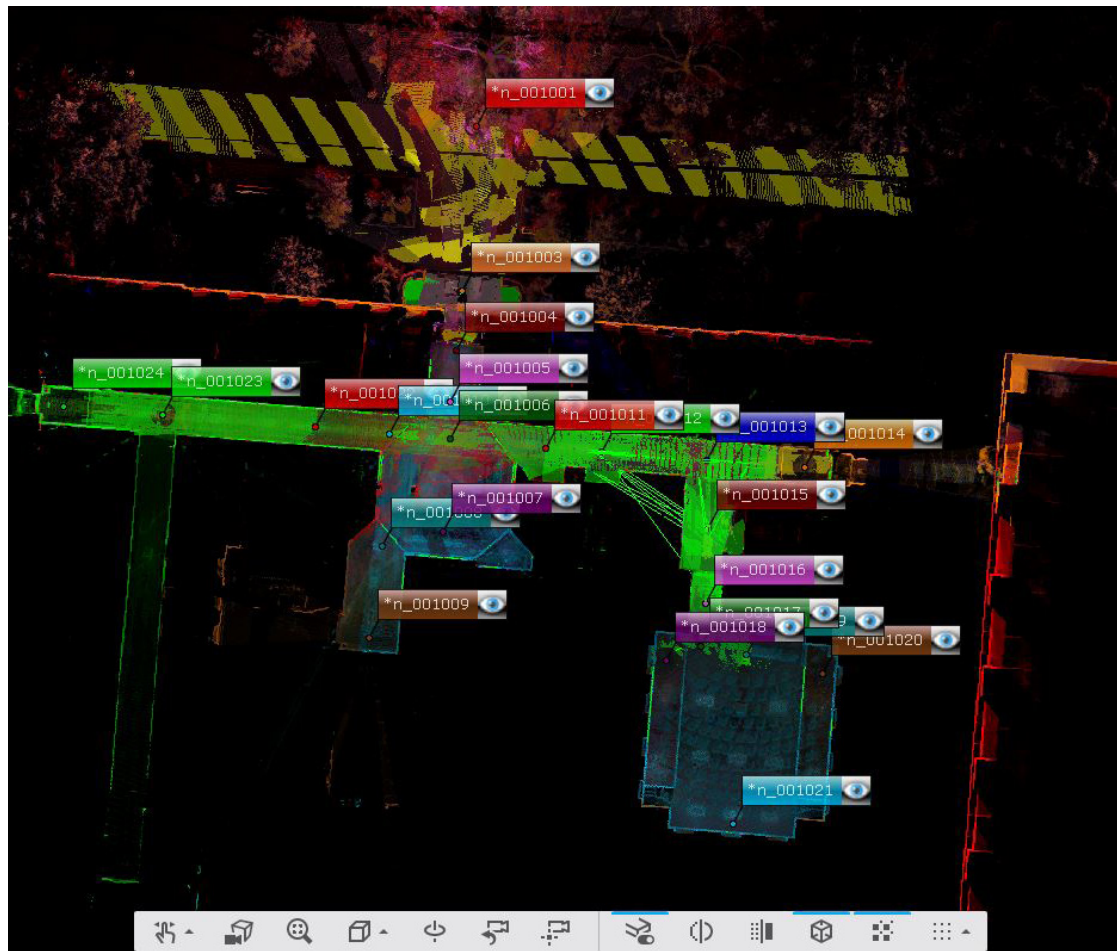


Figure 5: Plan view. Screenshot of point cloud in visual registration view from FARO Scene.





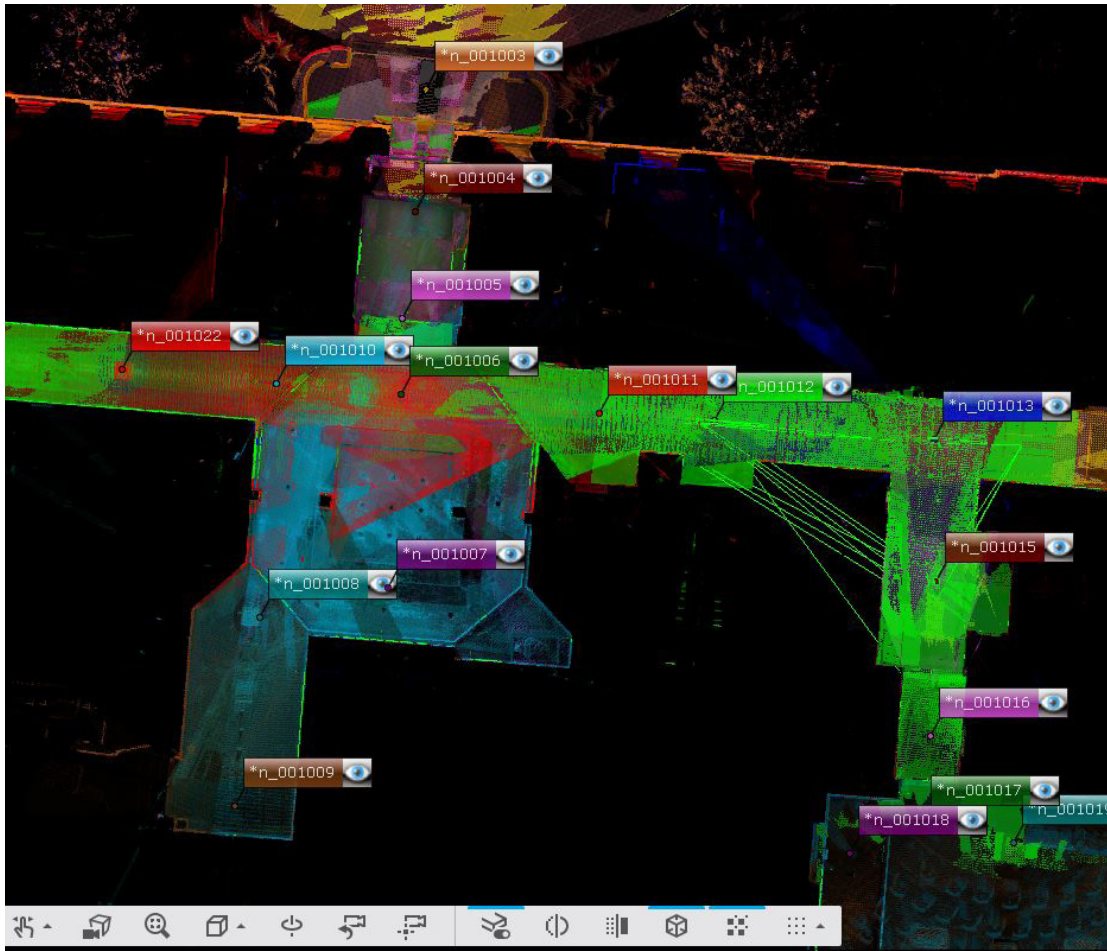


Figure 6:  
Plan view, Main  
Lobby Entrance.  
Screenshot of  
point cloud in  
visual registration  
view from FARO  
Scene.

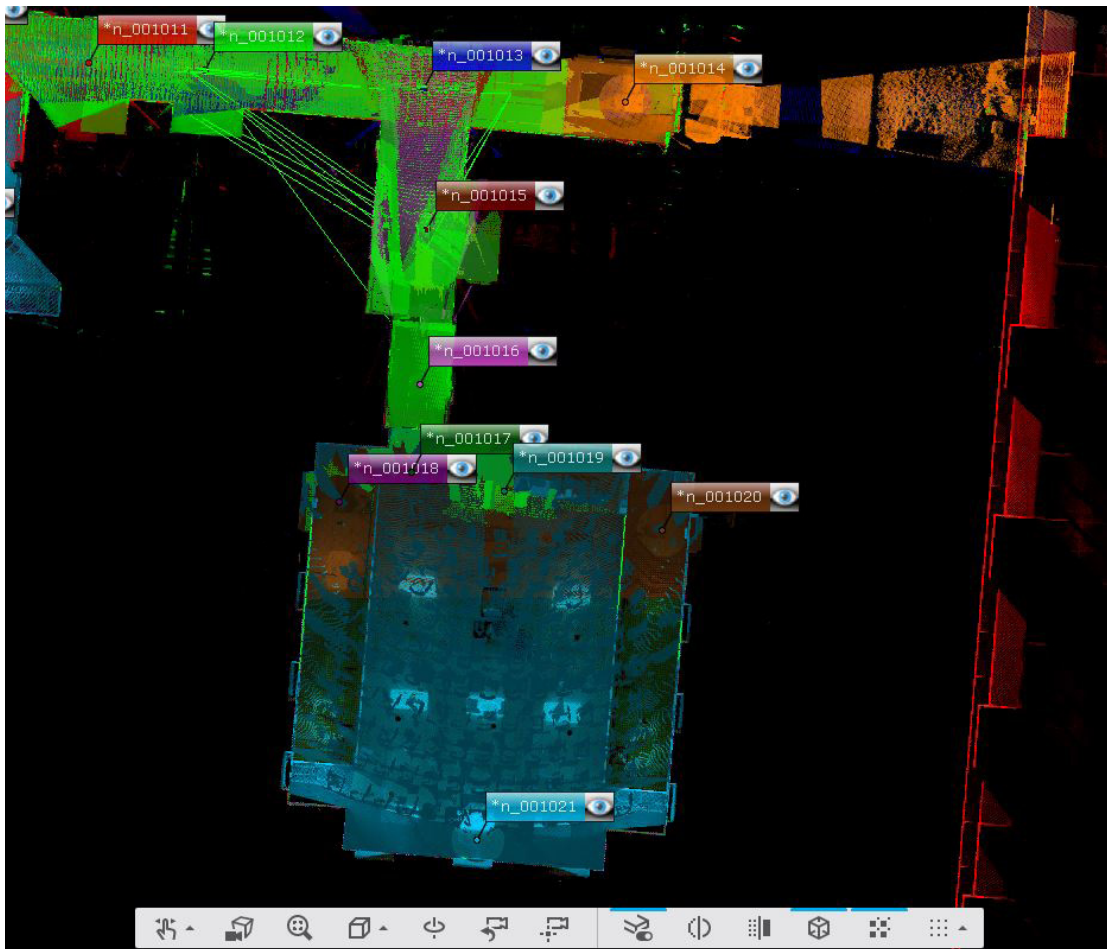
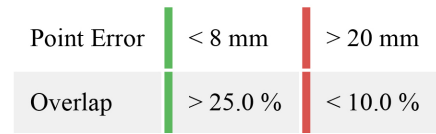


Figure 7:  
Plan view,  
Auditorium.  
Screenshot of  
point cloud in  
visual registration  
view from FARO  
Scene.

Table 1. Scan point statistics from FARO Scene registration report (after 3rd registration).

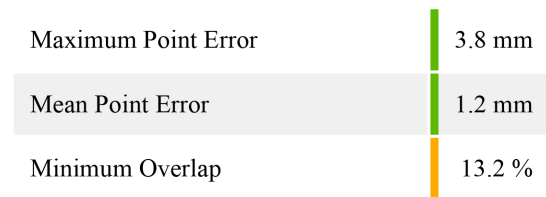
# Registration Report

## Color Coding



## Overview

### Scan Point Statistics



## Scan Errors

### Scan Point Statistics

Cluster/Scan	Connections	Max. Point Error [mm]	Mean Point Error [mm]	Min. Overlap
Haynes01_Scan_001001	3	2.5	2.2	43.9 %
Haynes01_Scan_001024	4	3.3	2.3	38.0 %
Haynes01_Scan_001002	3	2.5	1.6	57.1 %
Haynes01_Scan_001003	3	1.8	1.2	28.6 %
Haynes01_Scan_001004	6	2.4	1.4	28.6 %
Haynes01_Scan_001005	5	2.1	1.1	21.8 %
Haynes01_Scan_001006	12	3.8	1.6	21.4 %
Haynes01_Scan_001007	6	1.3	0.9	28.0 %
Haynes01_Scan_001008	5	1.4	0.9	51.7 %
Haynes01_Scan_001009	4	2.1	1.3	21.4 %
Haynes01_Scan_001010	7	2.4	1.4	44.1 %
Haynes01_Scan_001011	5	2.3	1.3	53.0 %
Haynes01_Scan_001012	4	1.7	1.2	38.2 %
Haynes01_Scan_001013	4	1.2	1.0	53.0 %
Haynes01_Scan_001014	4	3.8	1.8	13.2 %
Haynes01_Scan_001015	4	0.9	0.7	13.2 %
Haynes01_Scan_001016	6	0.9	0.8	33.5 %
Haynes01_Scan_001017	6	0.9	0.7	54.5 %
Haynes01_Scan_001018	5	0.8	0.6	39.8 %
Haynes01_Scan_001019	5	0.7	0.6	43.5 %
Haynes01_Scan_001020	5	0.7	0.6	33.5 %
Haynes01_Scan_001021	5	0.9	0.7	38.7 %
Haynes01_Scan_001022	5	2.3	1.6	40.5 %
Haynes01_Scan_001023	4	2.5	1.8	47.9 %

# Detailed Errors

## Scan Point Statistics

Table 2a. Detailed errors of scan point statistics from FARO Scene registration report (after 3rd registration).

Cluster/Scan 1	Cluster/Scan 2	Point Error [mm]	Overlap
Haynes01_Scan_001024	Haynes01_Scan_001023	1.4	62.1 %
Haynes01_Scan_001024	Haynes01_Scan_001006	3.3	38.0 %
Haynes01_Scan_001024	Haynes01_Scan_001010	2.4	44.1 %
Haynes01_Scan_001002	Haynes01_Scan_001001	2.5	57.1 %
Haynes01_Scan_001002	Haynes01_Scan_001003	0.6	96.1 %
Haynes01_Scan_001003	Haynes01_Scan_001001	1.8	71.1 %
Haynes01_Scan_001004	Haynes01_Scan_001001	2.4	43.9 %
Haynes01_Scan_001004	Haynes01_Scan_001002	1.8	66.7 %
Haynes01_Scan_001004	Haynes01_Scan_001003	1.1	28.6 %
Haynes01_Scan_001004	Haynes01_Scan_001005	1.0	60.7 %
Haynes01_Scan_001004	Haynes01_Scan_001007	1.3	38.3 %
Haynes01_Scan_001004	Haynes01_Scan_001006	0.9	37.5 %
Haynes01_Scan_001005	Haynes01_Scan_001006	0.6	56.7 %
Haynes01_Scan_001005	Haynes01_Scan_001007	0.7	65.7 %
Haynes01_Scan_001005	Haynes01_Scan_001008	1.1	51.7 %
Haynes01_Scan_001006	Haynes01_Scan_001012	1.3	38.2 %
Haynes01_Scan_001006	Haynes01_Scan_001010	1.0	89.0 %
Haynes01_Scan_001006	Haynes01_Scan_001023	2.5	47.9 %
Haynes01_Scan_001007	Haynes01_Scan_001006	0.6	77.9 %
Haynes01_Scan_001007	Haynes01_Scan_001008	0.6	66.3 %
Haynes01_Scan_001007	Haynes01_Scan_001010	1.1	55.6 %
Haynes01_Scan_001008	Haynes01_Scan_001006	1.0	66.2 %
Haynes01_Scan_001008	Haynes01_Scan_001010	1.4	62.8 %
Haynes01_Scan_001009	Haynes01_Scan_001005	2.1	21.8 %
Haynes01_Scan_001009	Haynes01_Scan_001006	1.6	21.4 %
Haynes01_Scan_001009	Haynes01_Scan_001007	0.9	28.0 %
Haynes01_Scan_001009	Haynes01_Scan_001008	0.6	52.4 %
Haynes01_Scan_001010	Haynes01_Scan_001023	1.7	53.8 %
Haynes01_Scan_001011	Haynes01_Scan_001006	1.0	86.9 %
Haynes01_Scan_001011	Haynes01_Scan_001010	1.5	57.0 %
Haynes01_Scan_001011	Haynes01_Scan_001012	0.7	76.4 %
Haynes01_Scan_001011	Haynes01_Scan_001013	1.2	53.0 %

Table 2b. Detailed errors of scan point statistics from FARO Scene registration report (after 3rd registration).

Haynes01_Scan_001011	Haynes01_Scan_001022	2.3	53.8 %
Haynes01_Scan_001013	Haynes01_Scan_001012	0.9	56.2 %
Haynes01_Scan_001014	Haynes01_Scan_001006	3.8	41.1 %
Haynes01_Scan_001014	Haynes01_Scan_001012	1.7	55.6 %
Haynes01_Scan_001014	Haynes01_Scan_001013	1.1	71.6 %
Haynes01_Scan_001014	Haynes01_Scan_001015	0.7	13.2 %
Haynes01_Scan_001015	Haynes01_Scan_001013	0.6	76.0 %
Haynes01_Scan_001015	Haynes01_Scan_001016	0.6	41.4 %
Haynes01_Scan_001015	Haynes01_Scan_001017	0.9	54.5 %
Haynes01_Scan_001016	Haynes01_Scan_001019	0.7	43.5 %
Haynes01_Scan_001016	Haynes01_Scan_001021	0.9	38.7 %
Haynes01_Scan_001017	Haynes01_Scan_001016	0.7	89.9 %
Haynes01_Scan_001017	Haynes01_Scan_001019	0.6	94.8 %
Haynes01_Scan_001017	Haynes01_Scan_001021	0.6	83.0 %
Haynes01_Scan_001018	Haynes01_Scan_001016	0.8	39.8 %
Haynes01_Scan_001018	Haynes01_Scan_001017	0.5	95.9 %
Haynes01_Scan_001018	Haynes01_Scan_001021	0.6	78.9 %
Haynes01_Scan_001018	Haynes01_Scan_001019	0.5	94.9 %
Haynes01_Scan_001020	Haynes01_Scan_001016	0.7	33.5 %
Haynes01_Scan_001020	Haynes01_Scan_001017	0.6	91.4 %
Haynes01_Scan_001020	Haynes01_Scan_001018	0.7	85.7 %
Haynes01_Scan_001020	Haynes01_Scan_001019	0.5	93.7 %
Haynes01_Scan_001020	Haynes01_Scan_001021	0.7	77.5 %
Haynes01_Scan_001021	Haynes01_Scan_001019	0.6	85.2 %
Haynes01_Scan_001022	Haynes01_Scan_001024	2.2	49.1 %
Haynes01_Scan_001022	Haynes01_Scan_001006	1.1	40.5 %
Haynes01_Scan_001022	Haynes01_Scan_001010	0.9	53.9 %
Haynes01_Scan_001022	Haynes01_Scan_001023	1.4	57.5 %

## Inclinometer Mismatches

Table 3.  
Inclinometer  
mismatches from  
FARO Scene  
registration  
report (after 3rd  
registration).

Cluster/Scan	Scan	Mismatch [deg]
Haynes01_Scan_001020	Haynes01_Scan_001020	0.0344
Haynes01_Scan_001009	Haynes01_Scan_001009	0.0130
Haynes01_Scan_001004	Haynes01_Scan_001004	0.0164
Haynes01_Scan_001011	Haynes01_Scan_001011	0.3292
Haynes01_Scan_001014	Haynes01_Scan_001014	0.0327
Haynes01_Scan_001005	Haynes01_Scan_001005	0.0194
Haynes01_Scan_001018	Haynes01_Scan_001018	0.0275
Haynes01_Scan_001015	Haynes01_Scan_001015	0.0370
Haynes01_Scan_001007	Haynes01_Scan_001007	0.0103
Haynes01_Scan_001002	Haynes01_Scan_001002	0.0197
Haynes01_Scan_001017	Haynes01_Scan_001017	0.0334
Haynes01_Scan_001013	Haynes01_Scan_001013	0.1273
Haynes01_Scan_001008	Haynes01_Scan_001008	0.0123
Haynes01_Scan_001022	Haynes01_Scan_001022	0.0294
Haynes01_Scan_001024	Haynes01_Scan_001024	0.0249
Haynes01_Scan_001006	Haynes01_Scan_001006	0.0213
Haynes01_Scan_001016	Haynes01_Scan_001016	0.0343
Haynes01_Scan_001012	Haynes01_Scan_001012	0.4218
Haynes01_Scan_001003	Haynes01_Scan_001003	0.0176
Haynes01_Scan_001001	Haynes01_Scan_001001	0.0311
Haynes01_Scan_001010	Haynes01_Scan_001010	0.0318
Haynes01_Scan_001021	Haynes01_Scan_001021	0.0423
Haynes01_Scan_001019	Haynes01_Scan_001019	0.0274
Haynes01_Scan_001023	Haynes01_Scan_001023	0.0253

Figure 8.  
Auditorium, Floor  
Plan. Orthophoto  
of point cloud  
export from FARO  
Scene.

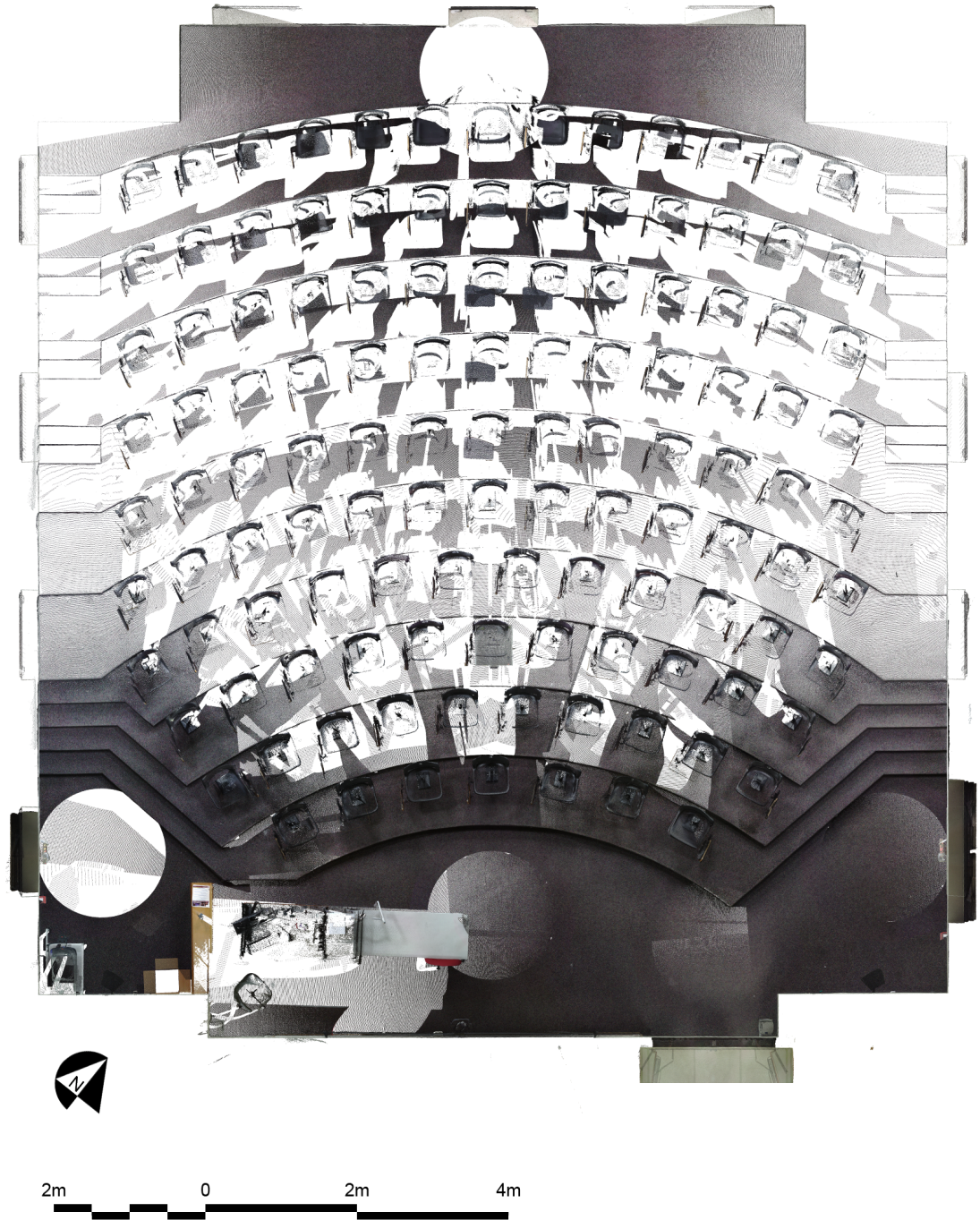


Figure 9. Main Lobby Entrance, Floor Plan. Orthophoto of point cloud export from FARO Scene.

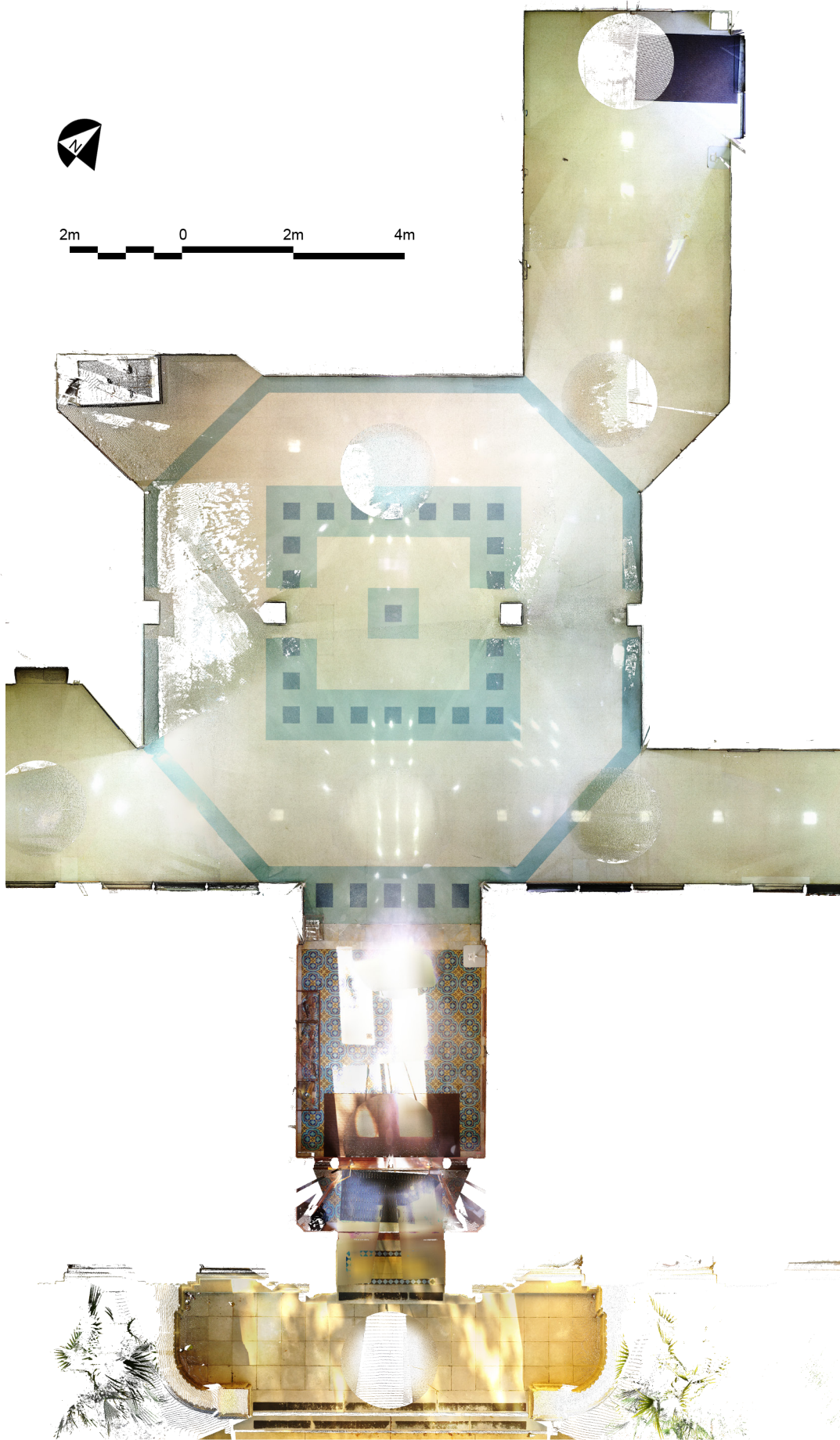


Figure 10. Transverse Section (Northwest-Southeast Axis, looking Northeast). Orthophoto of point cloud export from FARO Scene.



Figure 11. Transverse Section (Northwest-Southeast Axis, looking Northeast). Orthophoto of point cloud export from FARO Scene.

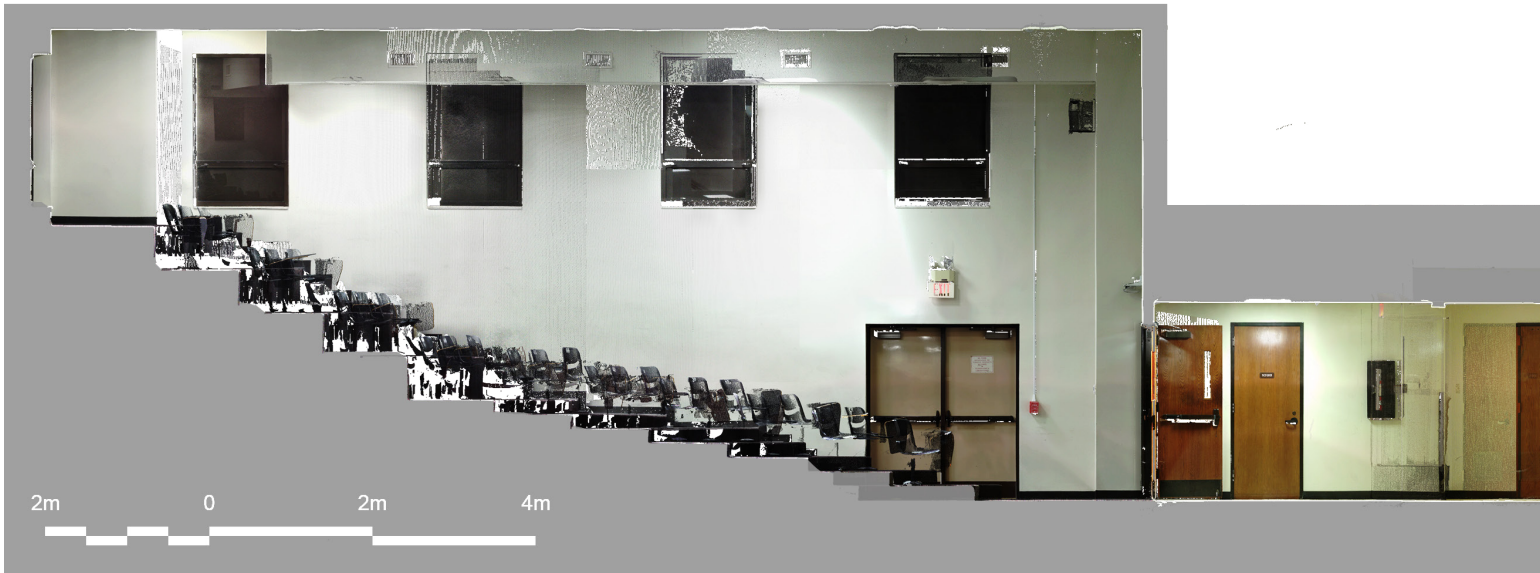






Figure 12.  
Isometric view  
(from South  
looking North).  
Image export from  
Autodesk ReCap.

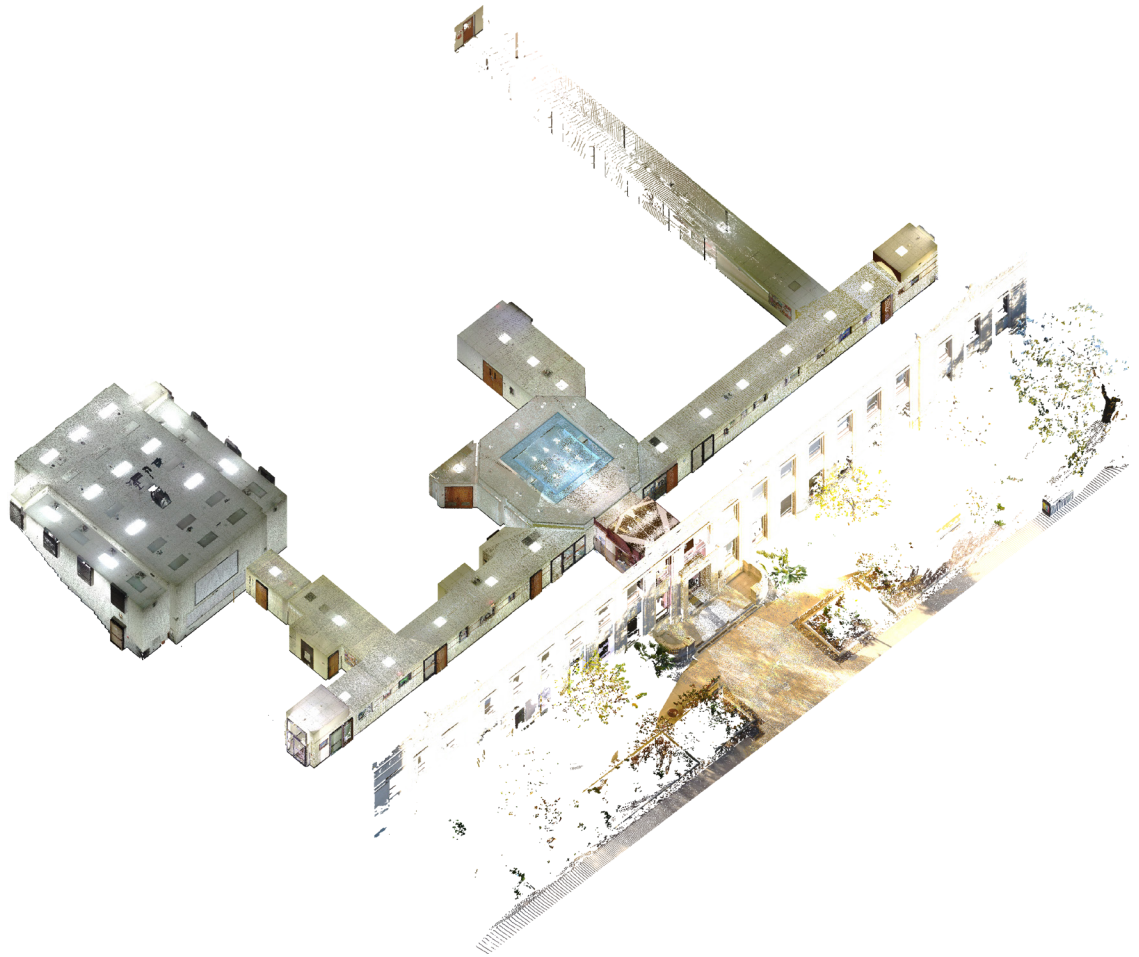
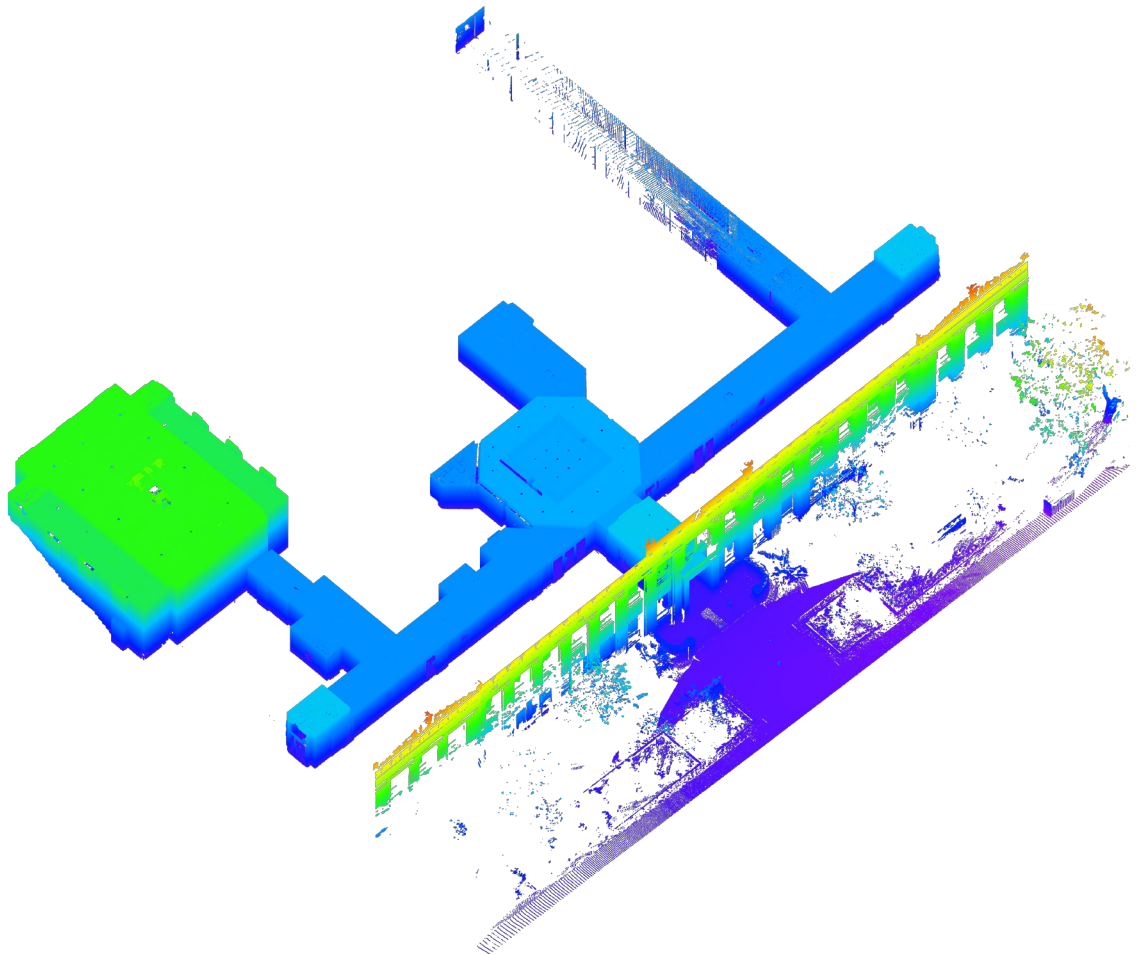


Figure 13.  
Isometric view  
(from South  
looking North).  
Image export from  
Autodesk ReCap  
("heat map"  
filter showing  
topographic  
elevations: high  
[yellow/red] to  
low [violet/blue]  
elevations).



## **Post Processing & Modeling**

Once sufficiently registered, the data was exported to various general formats and brought into secondary software for editing. The project point cloud was exported to E57 and PTS file formats, since either of these formats can be brought into a variety of useful secondary software (e.g., Autodesk ReCap Pro, CloudCompare, Rhinoceros 6, etc.). The scan project was also exported as an Autodesk ReCap Pro project, directly from FARO Scene. In the context of this project, this was done in order to take advantage of that software's "heat map" filter and preset isometric view settings (for image export). This ReCap point cloud can also be linked to AutoCAD and Revit for further modeling, if necessary.

Figure 14. Main Lobby Entrance, Isometric view (from South looking North). Image export from Autodesk ReCap ("heat map" [below] filter showing topographic elevations: high [yellow/red] to low [violet/blue] elevations).

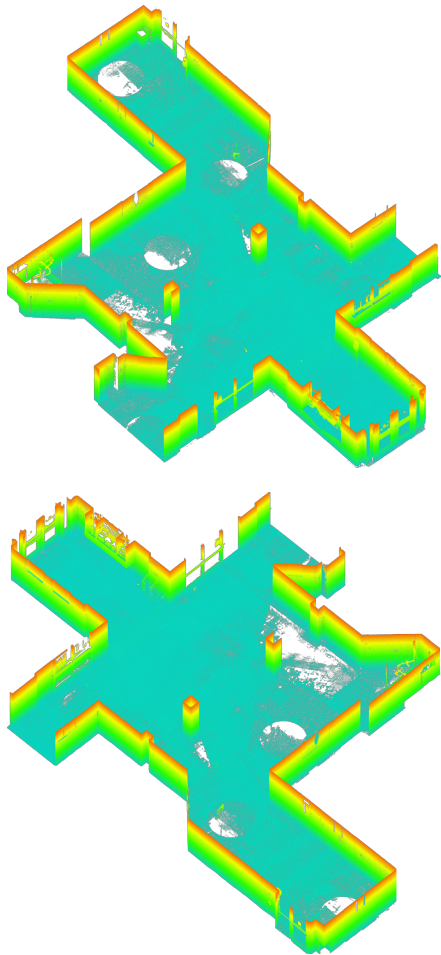
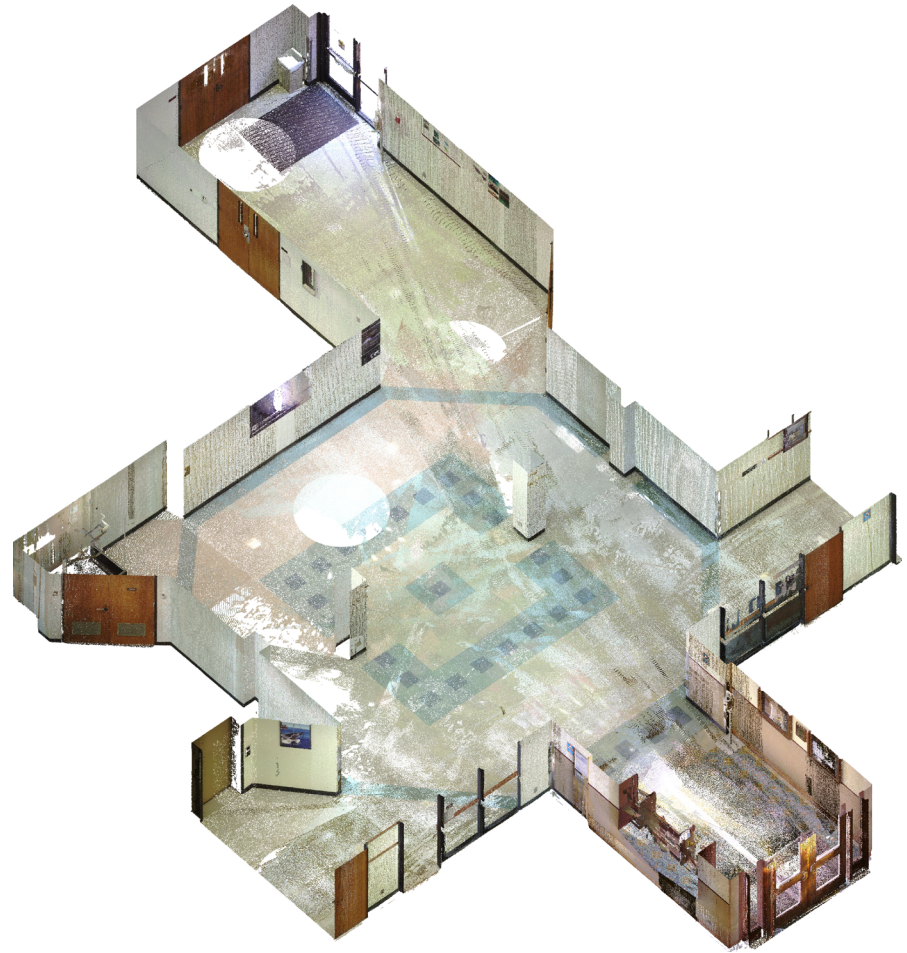
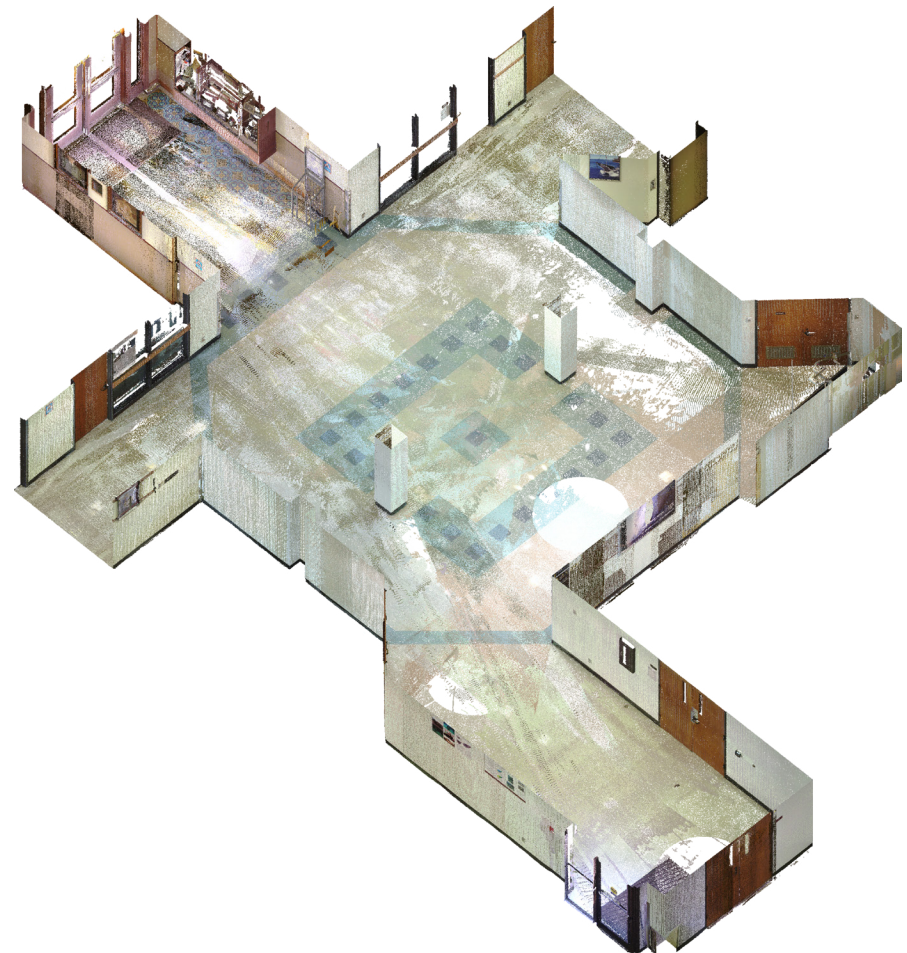


Figure 15. Main Lobby Entrance, Isometric view (from North looking South). Image export from Autodesk ReCap ("heat map" [above] filter showing topographic elevations: high [yellow/red] to low [violet/blue] elevations).



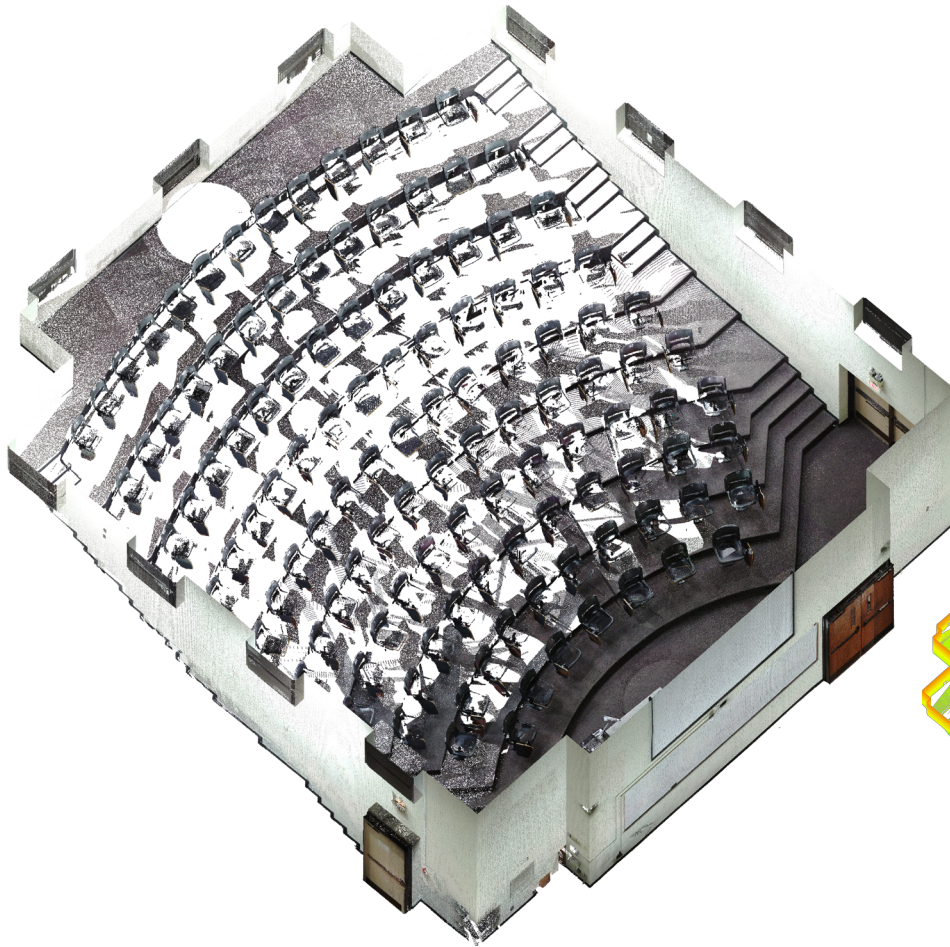


Figure 16. Auditorium, Isometric view (from South looking North). Image export from Autodesk ReCap (“heat map” [below] filter showing topographic elevations: high [yellow/red] to low [violet/blue] elevations).

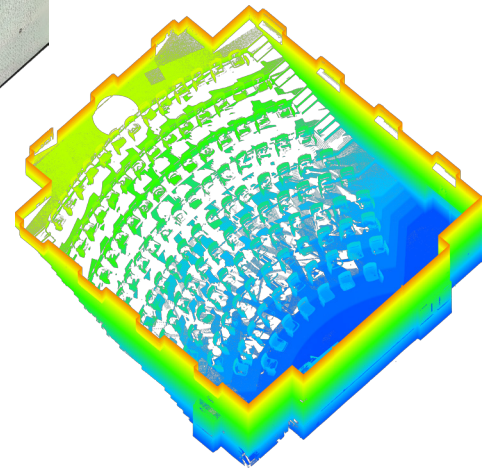


Figure 17. Main Lobby Entrance, Isometric view (from North looking South). Image export from Autodesk ReCap (“heat map” [above] filter showing topographic elevations: high [yellow/red] to low [violet/blue] elevations).

