University Student Services Center

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FPE 596

Culminating Experience in Fire Protection Engineering

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Acronyms and Abbreviations

ASET	Available Safe Egress Time
ASTM	American Society for Testing and Materials
cd	Candela
CO	Carbon Monoxide
DETACT	Detector Actuation
FACP	Fire Alarm Control Panel
FDS	Fire Dynamics Simulator
FED	Fractional Effective Dose
HRR	Heat Release Rate
HRRPUA	Heat Release Rate per Unit Area
IBC	International Building Code
IFC	International Fire Code
ITM	Inspection Testing and Maintenance
LSC	Life Safety Code
NFPA	National Fire Protection Association
RSET	Required Safe Egress Time
SFPE	Society of Fire Protection Engineers

Executive Summary

The building was found to be generally compliant with the requirements set forth in the codes and standards, any discrepancies are addressed within the report in their respective sections. The prescriptive-based analysis was performed using the appropriate NFPA standards, the Life Safety Code (LSC) and the International Building Code (IBC).

The building is three storied and has an overall gross floor area of 101,579 sq ft. It is classified as a mixed occupancy use with a calculated total occupant load of 2,866 occupants and is being evaluated as a Type II-B structure as defined in the IBC. It is protected throughout by an automatic fire sprinkler system and a fire alarm system. The installed fire protection and life safety (egress) systems in this building are evaluated according to NFPA 13, NFPA 72, and NFPA 101.

Hydraulic calculations on the sprinkler system show that the water supply is sufficient for the sprinkler system's remote area. The standpipes in the stairwells appear to be maintained and are available and accessible to emergency responders in the event of an emergency.

The fire alarm system provides adequate coverage for a full-sprinklered facility. Initiating devices placed along the means of egress and at each building exit. Smoke detectors are provided for elevator control functions, releasing of smoke control barriers and releasing automatic closing doors. Duct smoke detectors are placed to shutdown air handling units upon detection of smoke in air supply plenums.

The atrium on the north end of the building connects all three floors. As such, the atrium, requires a smoke control system. The smoke control system was designed in accordance with the smoke management calculations in NFPA 92, Standard *for Smoke Control Systems* – 2015 edition. A beam smoke detector is located in the atrium for control of three smoke exhaust fans and fire vent latch release. This smoke control system was further analyzed in the performance-based design analysis and found to be insufficient for the scenarios chosen.

Based off the results of this building evaluation and walkthrough of the building, the following deficiencies were noted and recommendations proposed:

- The building has two stairwells that are provided 2-hour fire rated walls, large landings, and labeled as "Area of Refuge". These areas are not provided with two-way communication as required by code. Since the buildings is fully sprinklered and areas of refuge are not required, its it recommended that the university remove the signs labeling the stairwells as areas of refuge.
- The third-floor banquet hall is capable of being configured for a large variety of events. It was noted that textile draperies were regularly mounted on the walls and ceilings for aesthetic purposes. A university representative mentioned that the practice was deemed allowable by the local jurisdiction and that the draperies were treated with fire-retardant chemicals. The chemicals, listing or test method used on these draperies was not able to be determined at the time of the walk-through. However, it is recommended that the exit markings are not covered when using the decorative draperies.

- Overflow storage issues in the banquet halls storage room impede on the path of egress from the penthouse mechanical room. It is recommended that the proper housekeeping is performed, and the path kept clear.

For performance-based analysis purposes, notification of building occupants was assumed to occur upon audible or visual signals from the building fire alarm system based of detection time of the fire alarm system. Evacuation modeling estimated the time to evacuate a fully populated building was approximately 180 seconds. Occupant characteristics and premovement time were addressed when doing occupant evacuation simulations for the chosen fire scenarios. The results of occupant evacuation and fire simulations were compared to ensure that tenability performance criteria within the building was maintained and that the available safe egress time (ASET) is greater than the required safe egress time (RSET).

This comparison showed that the ASET of 503 seconds only marginally exceeded the RSET of 500 seconds for scenario #2. Scenario #1 included a scotch pine Christmas tree at the base of the atrium which overpowered the smoke control system in 77 seconds. This time is well before the required egress time of 500 seconds shown in the simulation. From these results, the University was deemed to not provide an adequate level of protection for building occupants in the event of a fire scenario.

The following recommendations are proposed based off the results:

- Discontinue the use of Christmas tree at the base of the atrium for decoration during the holidays.
- Add secondary smoke detection devices in the atrium out coves for earlier detection and notification in the event a fire was to initiate from the outcove.
- Consider replacing exhaust fans with larger capacity fans.

1 Introduction

The purpose of the culminating report was to perform a prescriptive-based evaluation and performance-based analysis of the fire and life safety systems in the University Student Services Center. The objective of this analysis is to determine the degree of compliance with the prescriptive codes in place today as well as compliance with performance-based analysis. The results and conclusions from this evaluation are documents herein and supported by analysis when necessary. This effort has been to perform and document a comprehensive fire protection and life safety evaluation of the University Student Services Center in fulfillment of academic requirements for an advanced degree.

Prescriptive requirements that have been used in this evaluation are those of current versions of the codes. Although these requirements would not have been the basis of design and construction of this building, using the current codes allows possible gaps to be identified and recommendations to be provided to alleviate any property and life safety concerns that may arise. The following is a list of the primary codes and standards that have been used as part of the prescriptive evaluation:

- International Building Code (IBC) – 2015 Edition
- National Fire Protection Association Standards
    - NFPA 10 – Standard for Portable Fire Extinguishers
    - NFPA 13 – Standard for Installation of Fire Sprinkler Systems
    - NFPA 14 – Standard for the Installation of Standpipe and Hose Systems
    - NFPA 20 – Standard for the Installation of Stationary Pumps for Fire Protection
    - NFPA 25 – Standard for Inspection, Maintenance and Testing
    - NFPA 72 – National Fire Alarm and Signaling Code
    - NFPA 92 – Standard for Smoke Control
    - NFPA 101 – Life Safety Code

The performance-based evaluation of the Student Services Center is focused on the three-story atrium at the most prominent entrance of the building. A variety of university groups regularly host events at the base of the atrium such as presentations which includes a large concentration of people. Atriums also pose unique fire challenges which have the capability of impacting a multitude of difference occupancies throughout the building due to the interconnected openings. Fire modeling using Fire Dynamics Simulator (FDS) was performed to characterize the environment of a fire in the atrium for two different scenarios and assess the performance of the fire protection features. An evacuation model was created in Pathfinder and the results were compared to the fire modeling to ensure that tenability criteria was maintained while occupants evacuated the building.

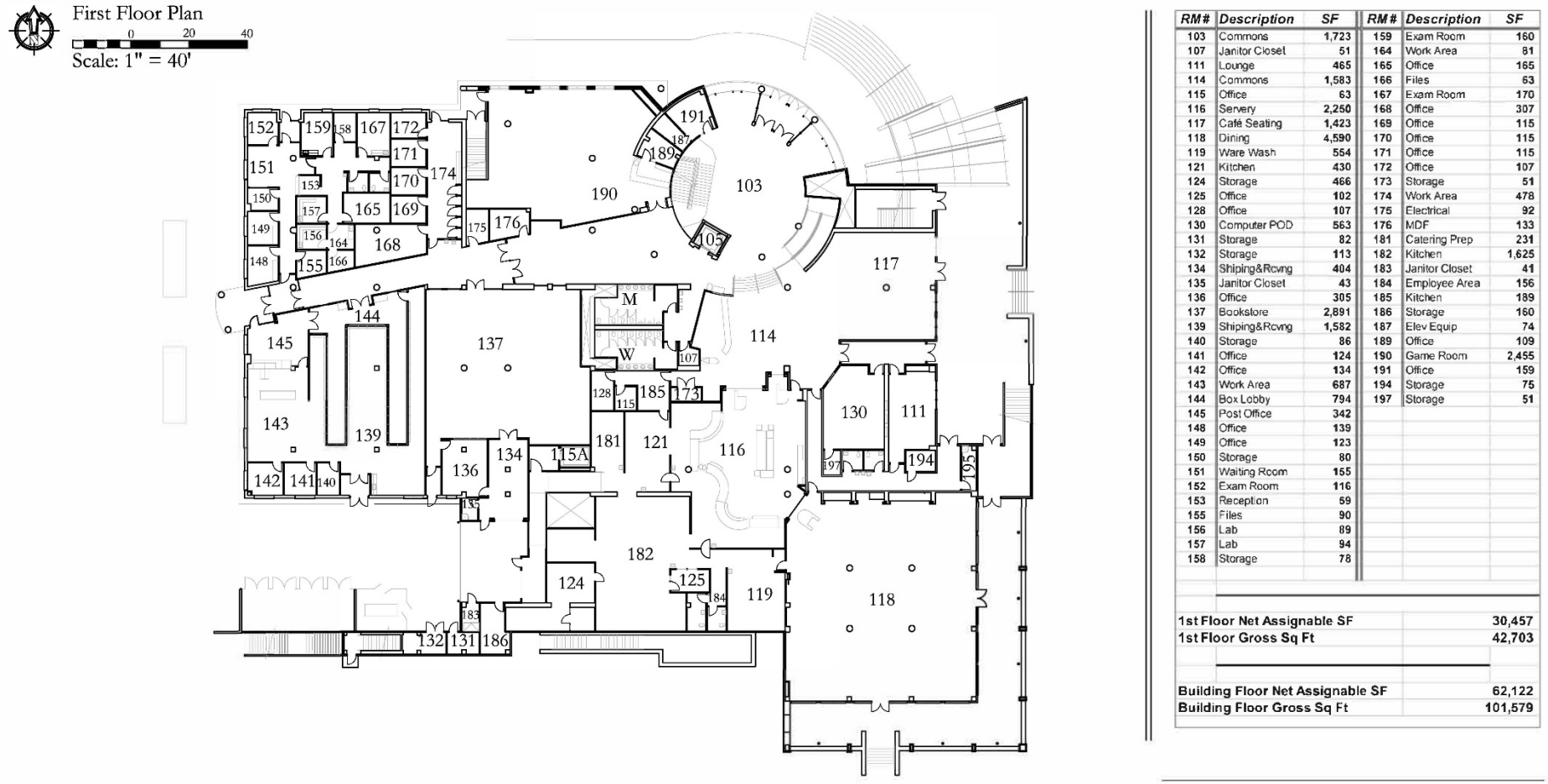
This report starts by evaluating the prescriptive requirements outlined in the codes and ends with the performance-based evaluation and recommendations.

1.1 University Student Services Center Description

The University Student Services Center is a three-story steel frame and concrete structure consisting of approximately 101,000 square feet of business, assembly, and mercantile spaces. The building's construction of complex angles and ellipses is of Type II-B as defined in the IBC. Per the IBC, Type II-B construction types have building elements of noncombustible materials and unprotected, meaning, that no building elements require a rated fire resistance. It is provided with an approved automatic sprinkler system per the IBC Section 903 and NFPA 13, *Standard for the Installation of Sprinkler Systems.*

The center is home to a Dining Hall, Game Room, Counseling and Health Clinic, Coffee Shop, Book Store, the Post Office and a full height atrium on the first floor shown in Figure 1-1. The second floor consisted of several student support service offices such as the Admissions Office, Registrar, Financial Aid, Residential Life and the Center for Student Success among others. In addition to the support services, the building also houses several open areas, conference rooms, a terrace and a ballroom that can be subdivided into three individual sections for different events. Figures 1-2, 1-3, and 1-4 provide general layout information and size of the building and the spaces.

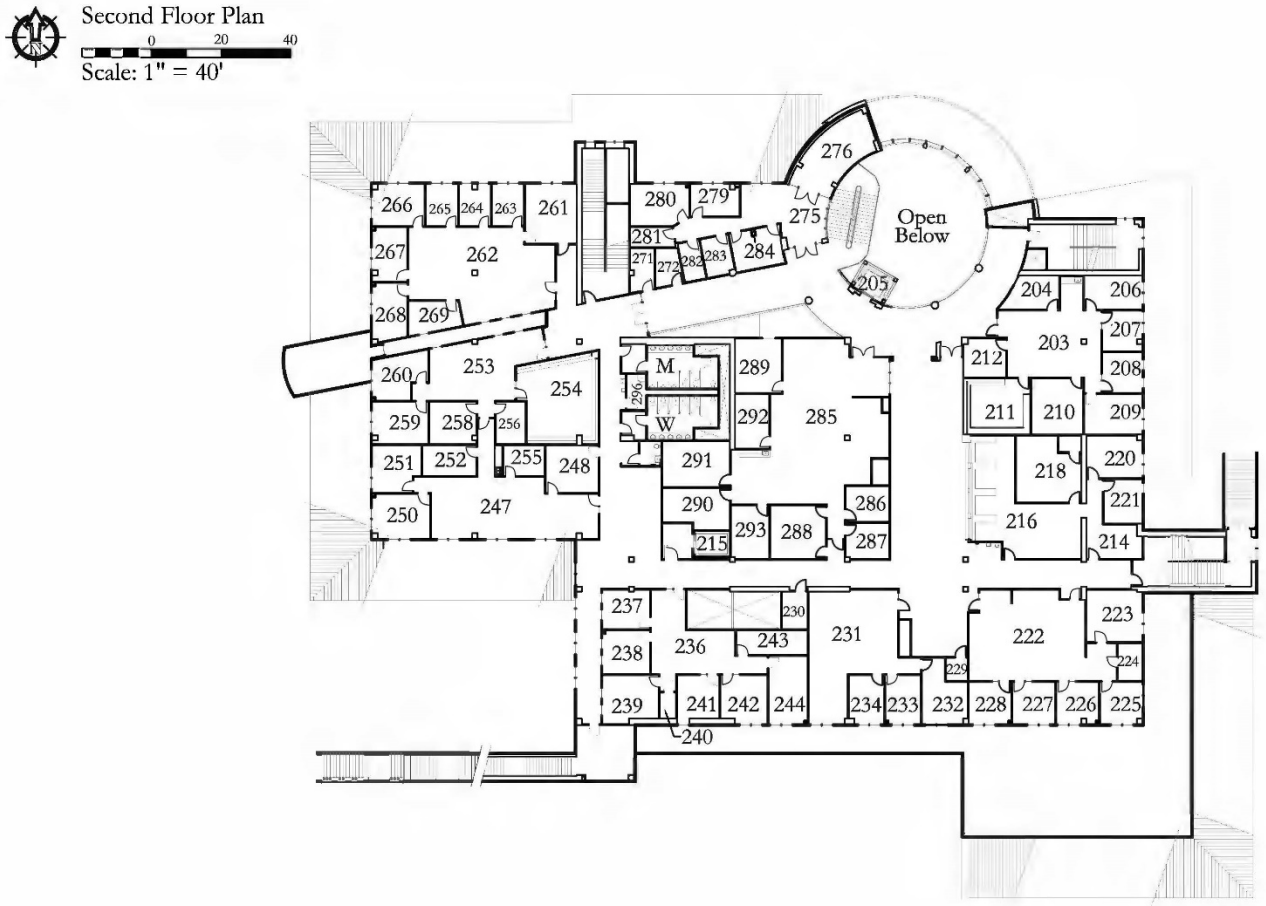
Figure 1-1 - 3 Story Atrium



RM#	Description	SF	RM#	Description	SF
103	Commons	1,723	159	Exam Room	160
107	Janitor Closet	51	164	Work Area	81
111	Lounge	465	165	Office	165
114	Commons	1,583	166	Files	63
115	Office	63	167	Exam Room	170
116	Servery	2,250	168	Office	307
117	Café Seating	1,423	169	Office	115
118	Dining	4,590	170	Office	115
119	Ware Wash	554	171	Office	115
121	Kitchen	430	172	Office	107
124	Storage	466	173	Storage	51
125	Office	102	174	Work Area	478
128	Office	107	175	Electrical	92
130	Computer POD	563	176	MDF	133
131	Storage	82	181	Catering Prep	231
132	Storage	113	182	Kitchen	1,625
134	Shiping&Rcvng	404	183	Janitor Closet	41
135	Janitor Closet	43	184	Employee Area	156
136	Office	305	185	Kitchen	189
137	Bookstore	2,891	186	Storage	160
139	Shiping&Rcvng	1,582	187	Elev Equip	74
140	Storage	86	189	Office	109
141	Office	124	190	Game Room	2,455
142	Office	134	191	Office	159
143	Work Area	687	194	Storage	75
144	Box Lobby	794	197	Storage	51
145	Post Office	342			
148	Office	139			
149	Office	123			
150	Storage	80			
151	Waiting Room	155			
152	Exam Room	116			
153	Reception	59			
155	Files	90			
156	Lab	89			
157	Lab	94			
158	Storage	78			

1st Floor Net Assignable SF	30,457
1st Floor Gross Sq Ft	42,703
Building Floor Net Assignable SF	62,122
Building Floor Gross Sq Ft	101,579

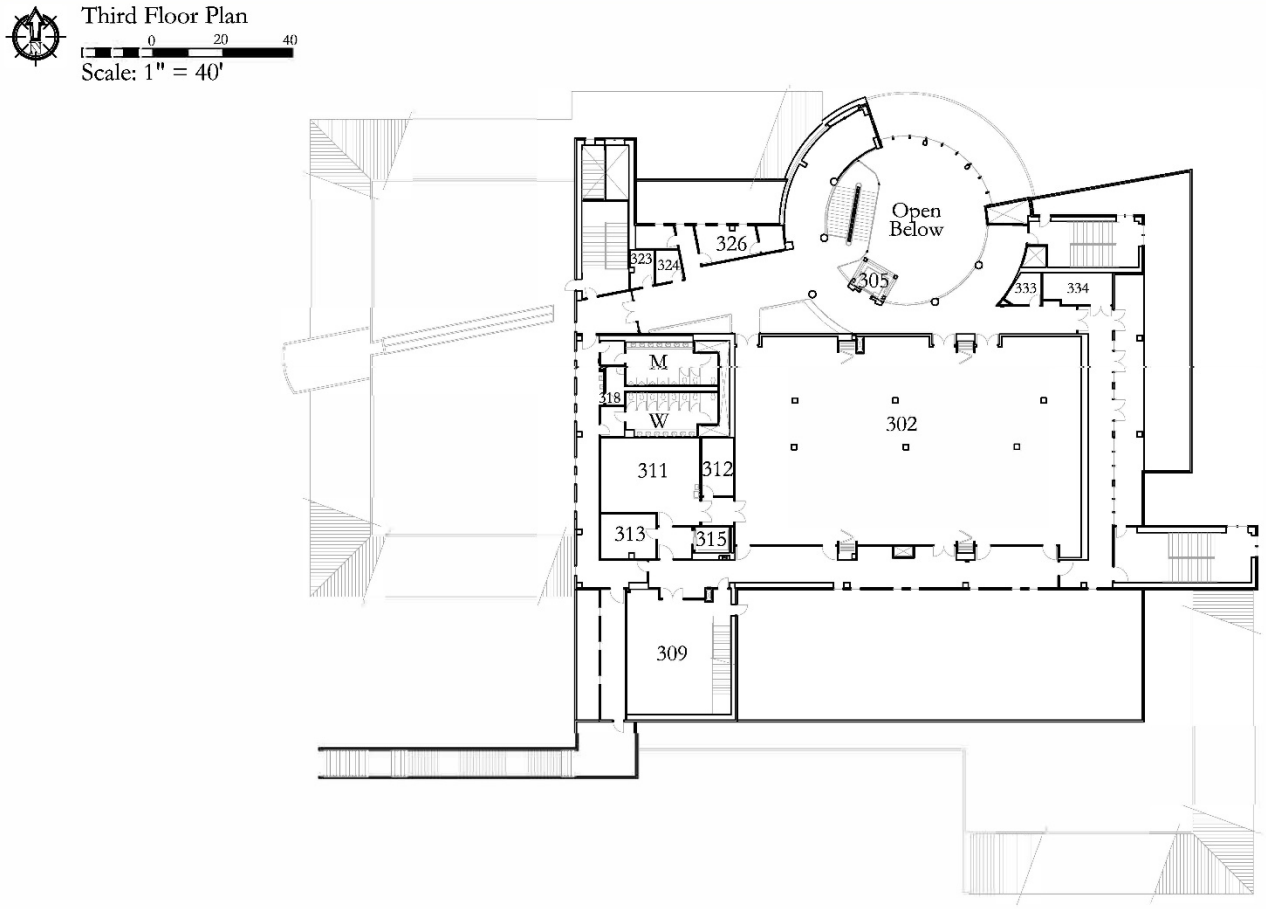
Figure 1-2 - First Floor Layout



RM#	Description	SF	RM#	Description	SF
203	Admission	628	250	Office	208
204	Office	140	251	Office	181
206	Office	162	252	Files	137
207	Office	133	253	Work Area	556
208	Office	136	254	Work Area	540
209	Office	196	255	Storage	106
210	Storage	240	256	Supplies	104
211	Work Room	310	258	Conference	163
212	Office	134	259	Office	194
214	Office	217	260	Office	184
216	Office/Work Area	723	261	Conference	255
218	Files	326	262	Work Area	967
220	Office	240	263	Office	111
221	Office	141	264	Office	109
222	Office/Work Area	936	265	Office	111
223	Files	241	266	Office	180
224	Storage	77	267	Office	155
225	Office	145	268	Office	162
226	Office	145	269	Office	131
227	Office	149	271	Electrical	85
228	Study	148	272	IDF	79
229	Electrical	42	275	Waiting	447
230	IDF	80	276	Library	328
231	Work Area	808	279	Office	128
232	Office	204	280	Office	198
233	Office	143	281	Storage	72
234	Office	141	282	Office	70
236	Work Area	496	283	Office	91
237	Office	156	284	Office	163
238	Office	170	285	Work Area	1,561
239	Office	215	286	Office	128
240	Storage	36	287	Office	128
241	Office	158	288	Conference	245
242	Office	184	289	Office	210
243	Storage	144	290	Storage	212
244	Office	218	291	Storage	254
247	Work Area	894	292	Office	155
248	Conference RM	209	293	Office	168

2nd Floor Net Assignable SF	19,141
2nd Floor Gross Sq Ft	32,704
Building Floor Net Assignable SF	62,122
Building Floor Gross Sq Ft	101,579

Figure 1-3 - Second Floor Layout



RM#	Description	SF
302	Banquet Hall	5,930 sf
309	Storage	844 sf
311	Prep Room	669 sf
312	Storage	157 sf
313	Prep Room	208 sf
318	Janitor Closet	62 sf
323	Electrical	75 sf
324	ISD	69 sf
326	Office	228 sf
333	Copy Room	80 sf
334	Storage	181 sf
3rd Floor Net Assignable SF		8,503
3rd Floor Gross Sq Ft		21,072
Building Floor Net Assignable SF		62,122
Building Floor Gross Sq Ft		101,579

Figure 1-4 - Third Floor Layout

2 International Building Code Analysis

The following analysis is performed using the IBC. A prescriptive-based analysis compares the building to the applicable codes and standards and provides a better understanding of where codes are met and not met within the building. The prescriptive-based analysis does not account for occupant characteristics as well as proposed uses for specific rooms. This analysis typically considers the worst-case scenarios in order to ensure all future uses of the building will meet the code.

2.1 Occupancy Classification

Structures or portions of structures have to be classified with respect to occupancy per one or more groups as listed in Section 302 of the International Building Code (IBC). For mixed use facilities applicable provisions of IBC Section 508.2, 508.3 or 508.4 must be followed. This building will comply with IBC Section 508.3.

Four different occupancies are present within this multistory building:

Assembly Group A-2 for the game room, banquet hall and dining facilities (including associated kitchen)
Business Group B for the offices, computer rooms, clinic, and post office.
Mercantile Group M for the bookstore.
Storage Group S-1 for storage areas greater than 100 sq. ft. in area. Per section 311.1.1 (IBC, 2015) rooms used for the purposes of storage with less than 100 sq. ft. in area and accessory to another occupancy were classified as part of that occupancy.

The floor levels, areas and occupancies are as follows in Table 2-1:

Table 2-1 - Building Occupancies and Areas

Level	Gross Floor Area (sq. ft)	Occupancy Descriptions
1	42,703	Assembly A-2, Business B, Storage S-1, Mercantile M
2	32,704	Business Group 2, Storage Group S-1
2	21,072	Assembly A-2, Business B, Storage S-1

2.2 Types of Construction

The Student Services Center was designed and constructed as Type II-B, unprotected, non-combustible, as defined by the IBC.

2.3 Building Heights and Areas

2.3.1 Requirements

The IBC provided limitations for building heights and allowable areas in Sections 504 and 506. These limitations are based on the type of construction and the occupancy classification. Table 2-2 indicates the allowable building height above grade. For our main occupancies A and B, with Type II-B construction, the building is limited to a height of 75 feet for a fully sprinklered building.

Table 2-2 – IBC Allowable Building Height in Feet

OCCUPANCY CLASSIFICATION	TYPE OF CONSTRUCTION									
	SEE FOOTNOTES	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
A, B, E, F, M, S, U	NS[b]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60

Table 2-3 indicates the allowable number of stories above grade. For our main occupancies A and B, with Type II-B construction, we are limited by the most restrictive requirement which in this case would be 3 stories.

Table 2-3 - IBC Allowable Number of Stories

OCCUPANCY CLASSIFICATION	TYPE OF CONSTRUCTION									
	SEE FOOTNOTES	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
A-1	NS	UL	5	3	2	3	2	3	2	1
	S	UL	6	4	3	4	3	4	3	2
A-2	NS	UL	11	3	2	3	2	3	2	1
	S	UL	12	4	3	4	3	4	3	2
B	NS	UL	11	5	3	5	3	5	3	2
	S	UL	12	6	4	6	4	6	4	3
M	NS	UL	11	4	2	4	2	4	3	1
	S	UL	12	5	3	5	3	5	4	2
S-1	NS	UL	11	4	2	3	2	4	3	1
	S	UL	12	5	3	4	3	5	4	2

506.2.4 *Each story of a mixed-occupancy building with more than one story above grade plane shall individually comply with the applicable requirements of Section 508.1*

For Mixed-occupancy, multistory buildings, the allowable area is calculated using the following equation.

$$A_a = [A_t + (NSxI_f)] \text{ (IBC, Equation 5-3)}$$

Where:

A_a = Allowable Area (sq. ft)
A_t = Tabular allowable area factor
NS = Tabular allowable area factor for nonsprinklered building
I_f = Area factor increase due to frontage

The area factor increase based on frontage is determined in accordance with the following equation

$$I_f = [F/P - 0.25]\,W/30 \text{ (IBC, Equation 5-5)}$$

2.3.2 Compliance

The Student Services Center is equipped throughout with an approved automatic sprinkler system, as such, an increase in the overall height, number of floors and floor area is allowable. Per Section 506.3 of the IBC, the building area can be increased and additional 200%, up to a total of 69,000 sq. ft. per story.

Being a three storied building with overall height of ~55 feet above ground level with the largest floor area being 42,703 sq. ft., the building is in compliance with building height, stories, and area requirements of the IBC.

2.4 Incidental Uses

2.4.1 Requirements

IBC Section 509.1 *General Incidental uses located within single occupancy or mixed occupancy buildings shall comply with the provisions of this section. Incidental uses are ancillary functions associated with a given occupancy that generally pose a greater level of risk to that occupancy and are limited to those uses listed in Table 509.*

2.4.2 Compliance

There are no incidental use areas present in this building listed in Table 509 of the IBC.

2.5 Area of Refuge

An area of refuge is an area where persons unable to use stairways can remain temporarily to await instructions or assistance during emergency evacuation. Although fully-sprinklered, the Student Services Center is supplied with two areas of refuge. An area of refuge has a temporary use during egress and generally serves as a staging area that provides relative safety to its occupants while potential emergencies are being assessed, decisions are made, and mitigating activities are begun. Taking refuge within these areas is a stage of the total egress process prior to egress to a public way.

The first area of refuge is located on the south west corner of the second floor near the Advancement Office and has an estimated 256 sq. ft. floor area. The second area is located on the south-east corner of the third floor near the exits to the banquet hall and the exterior balcony. It has a 234 sq. ft floor area. The areas are outlined in Figure 2-1 and Figure 2-2.

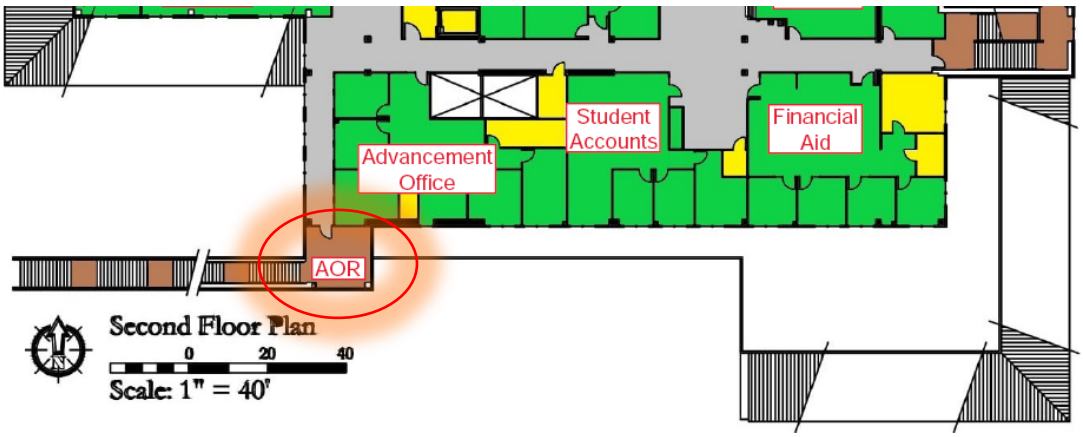


Figure 2-1 - Second Floor Area of Refuge

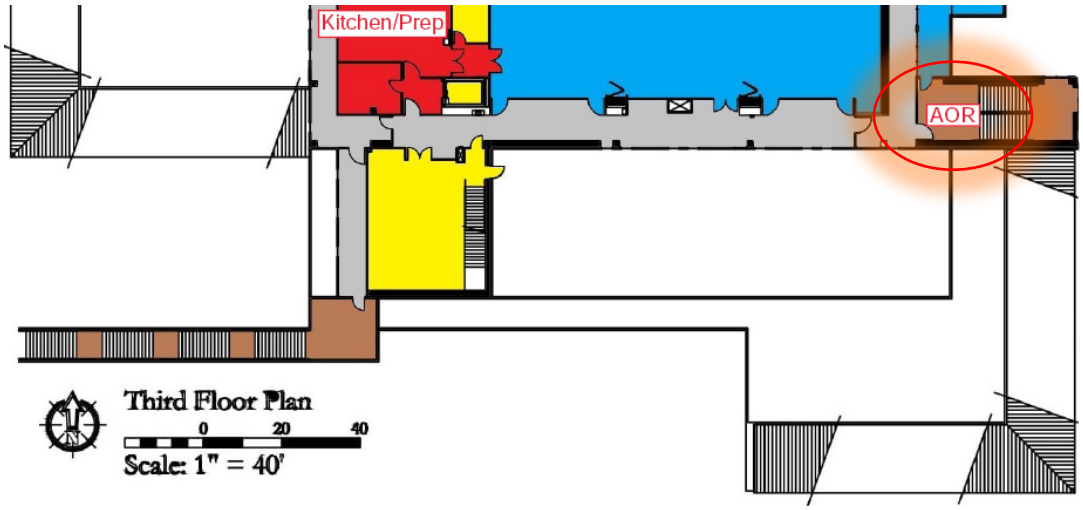


Figure 2-2 - Third Floor Area of Refuge

2.5.1 Requirements

The maximum travel distance from any accessible space to an area of refuge is not allowed exceed the exit access travel distance permitted for the occupancy. Each area of refuge is also required to be separated from the remainder of the story by a smoke barrier complying with Section 709 of the IBC. Each area of refuge must be designed to minimize the intrusion of smoke and shall be provided with a two-way communication system complying with Sections 1009.8.1 and 1009.8.2 of the IBC.

2.5.2 Compliance

The maximum travel distance to the area of refuge does not exceed the most stringent travel distance for the building occupancy types and is separated via the use of fire rated construction and door assemblies. However, the areas are not supplied with a two-way communication system as outline in Section 1009.6.5 of the IBC.

2.6 Summary

The overall structure of the University Student Services Center was found to follow the prescriptive requirements of the IBC. The limits for a Type II-B sprinklered building is 75 feet in height, 3 stories, and 69,000 sq ft per story. It extends roughly 55 ft in height at 3 stories and the largest floor expands to approximately 43,000 sq. ft. As a fully sprinklered building areas of refuge are not required, however, two unique areas are labeled as such. Upon review of the areas, they appear to meet all structural requirements but lack two-way communication systems. Discussion with a building occupant revealed that the original plans called for a system to be installed but was later removed. Its recommended that the University add communication systems or remove the signs labeling these Areas of Refuge as it could cause confusion for building occupants in case of an emergency.

3 Structural Fire Protection

This section addresses the requirements for structural fire protection. Generally, provisions for structural fire protection are found in Chapter 4, 5, 6, and 7 of the 2015 IBC. Chapter 4 provides specific requirements for various occupancies, buildings types, and building features. Limitations on building heights, floor areas, and mixed occupancies are given in Chapter 5. Chapter 6 provides requirements for types of construction and Chapter 7 provides specific requirements for ensuring the building element is adequately fire rated.

The building’s construction type, requirements for fire resistance for building elements and fire separation for multiple occupancies and the atrium are addressed below.

3.1 Fire Resistance Requirements

IBC Section 602.2 defines Type II construction as construction in which building elements listed in Table 601 are of noncombustible materials. Table 601 of the IBC is shown below in Table 3-1 - IBC Fire Resistance Rating of Building Elements.

Table 602 of the IBC shown below provides fire rating requirements for exterior walls and partitions and is shown in Table 3-2 - IBC Fire Resistance Rating of Exterior Walls.

Table 3-1 - IBC Fire Resistance Rating of Building Elements

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A	B	A	B	HT	A	B
Primary structural frame[f] (see Section 202)	3[a]	2[a]	1	0	1	0	HT	1	0
Bearing walls Exterior[e, f] Interior	3 3[a]	2 2[a]	1 1	0 0	2 1	2 0	2 1/HT	1 1	0 0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and associated secondary members (see Section 202)	1½[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

Table 3-2 - IBC Fire Resistance Rating of Exterior Walls

FIRE SEPARATION DISTANCE = X (feet)	TYPE OF CONSTRUCTION	OCCUPANCY GROUP H[e]	OCCUPANCY GROUP F-1, M, S-1[f]	OCCUPANCY GROUP A, B, E, F-2, I, R, S-2, U
X < 5[b]	All	3	2	1
5 ≤ X < 10	IA Others	3 2	2 1	1 1
10 ≤ X < 30	IA, IB IIB, VB Others	2 1 1	1 0 1	1[c] 0 1[c]
X ≥ 30	All	0	0	0

Each Area of Refuge is required to be separated from the remainder of the story that it serves by a barrier with a minimum of 1-hour fire resistance rating with door assemblies having a minimum of 20-minute fire resistance rating.

3.1.1 Compliance

From IBC Table 601, it is noted that building elements are not required to have a fire resistance rating.

The fire separation distance between the building and the surrounding buildings is greater than 30 ft (X > 30) on all sides other than the east most exterior wall. The fire resistance rating for these 3 exterior sides is 0 hours for all occupancy classifications and types of constructions.

On the east most side, the corresponding fire resistance rating for separation distances greater than 10 ft but less than 30 ft (10<x<30) for Group A, B, and M occupancy types is also 0 hours. As such, exterior walls of this building are not required to be fire rated per the IBC.

The two Areas of Refuge and atrium were found to be in compliance with the fire resistance requirements outlined above.

3.2 Interior Finishes

Section 803 of the IBC details the interior finish requirements based on the use and occupancy. Table 3-3 depicts the allowable finish for wall and ceilings. For the atrium, section 404.8 of the IBC requires that the interior finish of "*walls and ceilings of the atrium shall be not less than Class B with no reduction in class for sprinkler protection.*" Lastly, IBC 806.3 limits the amount of combustible decorative material such as curtains, draperies, fabric hangings and similar combustible decorative materials suspended from walls or ceilings to 10 percent of the specific wall or ceiling area to which such materials are attached.

Table 3-3 - Interior Wall and Ceiling Finish Requirements by Occupancy (IBC Table 803.11)

Group	Sprinklered		
	Interior exit stairways, interior exit ramps and exit passageways	Corridors and enclosure for exit access stairways and exit access ramps	Rooms and enclosed spaces
A-1 & A-2	B	B	C
B, E, M, R-1	B	C	C
S	C	C	C

3.2.1 Compliance

The materials used as interior finishes in the Student Services Center are in compliance with the requirements outlined within the IBC. However, the limits for the amount of combustible material that is allowed to be used has been seen to exceed the code allowable 10 percent of the wall area during events such as banquets. Figure 3-1 shows an example were the draperies hung from the walls and ceilings cover more than 10 percent of the respective areas. In addition to not complying with Section 806.3, the draperies and curtains also block sprinkler heads, smoke detectors and illuminated exit signs.

Figure 3-1 - Decorated Banquet Hall

3.3 Summary

Review of the building construction elements are believed to meet or exceed the structural fire protection requirements of a Type II-B building. Areas with required separation such as the area of refuge have walls marked as “Fire Rated Wall” and penetrations are seen to be supplied with approved fire-stop caulking and assemblies. In terms of interior finishes, the buildings are in compliance for the majority of the calendar year. During special events, the third-floor banquet hall’s use of decorative finishes has been seen to exceed the 10% of wall/ceiling area limitation. During this time, exit signs and sprinklers are obstructed which could compromise their operation. Exceeding the code limitation of 10% area has been approved by the local jurisdiction for special events. As such, it is recommended that University use caution to not block exit signs or sprinklers in future special events.

4 Life Safety Evaluation

This assessment of the Student Services Center used the building general arrangements and architectural design documents to evaluate the facility for compliance with the means of egress requirements of NFPA 101. This evaluation consists of a review of the egress arrangement, travel distance, exit capacity, number of exits and other building components including stairs, doors and lighting.

4.1 Occupancy Classifications

The Student Services Center is a multiple occupancy building. Table 4-1, Table 4-2, and Table 4-3 below compare the occupancy classification for the building per the IBC to the occupancy classification per the LSC for each story of the building.

Table 4-1 - First Floor Occupancy Classifications

Area Name	Occupancy Classification (LSC)	Occupancy Classification (IBC)
Health Clinic	Business	B
Post Office	Business	B
Game Room	Casinos and similar gaming areas	A-3
Bookstore	Mercantile	M
Offices	Office	B
Kitchen	Kitchens	A-2
Cafeteria	Less concentrated	A-2
Commons	Less concentrated	A-2
Computer Pod	Concentrated Business	A-2
Shipping & Receiving	Shipping & Receiving	M
Storage	Storage	S-2

Table 4-2 - Second Floor Occupancy Classifications

Area Name	Occupancy Classification	Occupancy Classification (IBC)
Admissions	Office	B
Registrar	Office	B
Res Life	Office	B
Advance. Office	Office	B
Financial Aid	Office	B
Center for Student Success	Office	B
Cashiers	Office	B
Student Accounts	Office	B
Career Center	Office	B
Auxiliary Services	Office	B
Storage	Storage	S-2

Table 4-3 - Third Floor Occupancy Classifications

Area Name	Occupancy Classification	Occupancy Classification (IBC)
Banquet Hall	Less concentrated	A-2
Kitchen	Kitchens	A-2
Office	Office	B
Storage	Storage	S-2

4.2 Occupant Load

The occupancy load was calculated using the Occupant Load Factors provided in Table 7.3.1.2 of NFPA 101. The spaces areas were divided by their respective use within the building and the corresponding occupant load factor. The total for each space and each floor was added up to obtain the total occupancy load for the entire building. The occupancy type and load factors used for calculations are shown in Figure 4-1, Figure 4-2, Figure 4-3, Table 4-5, Table 4-6, and Table 4-7.

Table 4-4 - Building Occupant Load

Student Services Center	
Floor	Number of Occupants
First	1838
Second	169
Third	859
Total	2,866

The occupant loading of the building was determined to be approximately 2,866 people at full capacity as shown in Table 4-4 - Building Occupant Load. Although the building has a maximum capacity of 2,866, it is unlikely that the building will be occupied to this extent. However, this worst-case scenario for occupant load will be used for all remaining analysis for conservatism.

4.2.1.1 First Floor

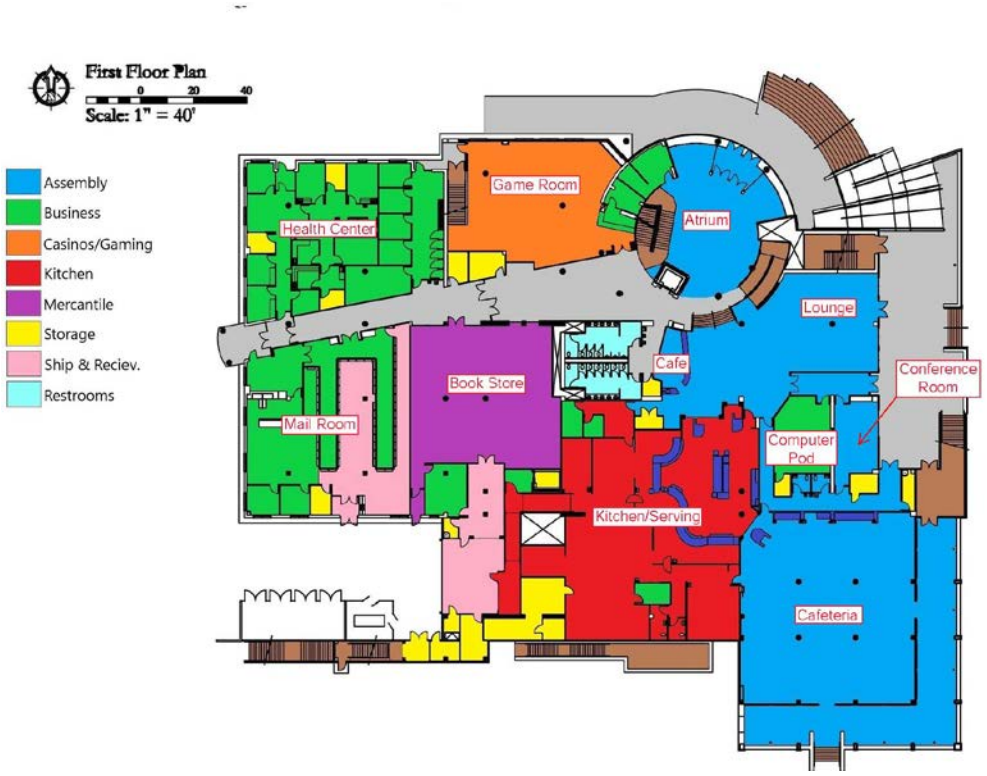


Figure 4-1 - First Floor Occupancy Uses

Table 4-5 - First Floor Occupant Load

First Floor				
Area Name	Occupancy Classification	Occupant Load Factor (sq.ft/person)	Area Space (sq.ft)	Number of Occupants
Health Clinic	Business	100	924	9
Mail Room	Business	100	1,823	18
Game Room	Casinos and similar gaming areas	11	2,455	223
Bookstore	Mercantile	30	2,891	96
Offices	Office	100	2,767	28
Kitchen	Kitchens	100	5,435	54
Cafeteria	Less concentrated	7	4,590	656
Commons	Less concentrated	7	5,194	742
Computer Room	Concentrated Business	50	563	11
Shipping & Receiving	Shipping & Receiving	300	1,986	15
Storage	Storage	500	1,755	4
Total			30,383	1838

4.2.1.2 Second Floor

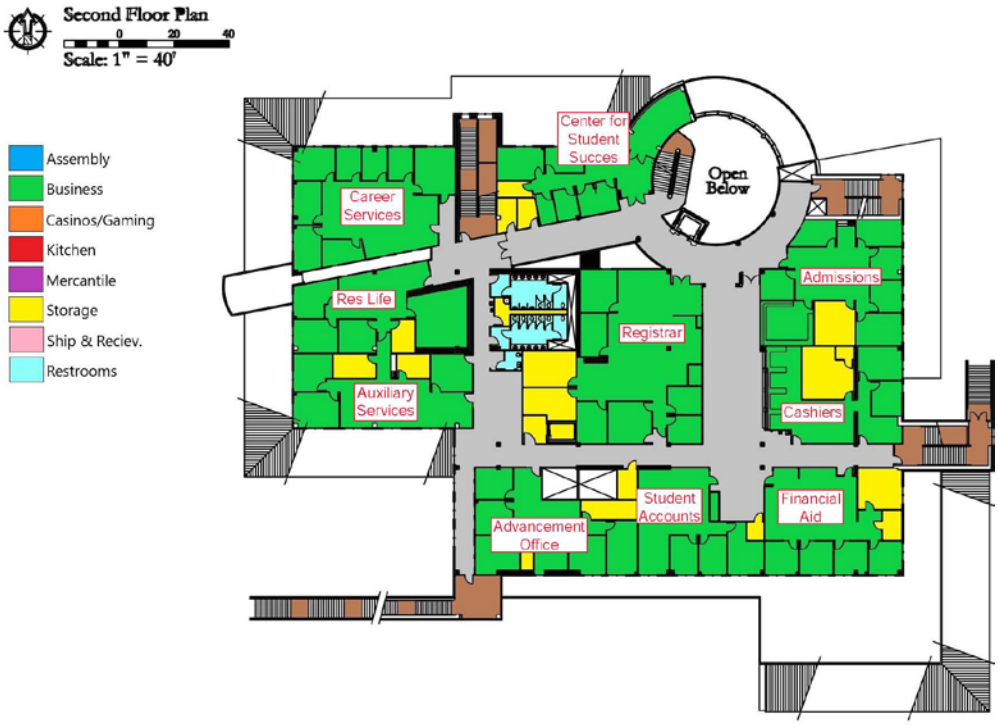


Figure 4-2 - Second Floor Occupancy Uses

Table 4-6 - Second Floor Occupant Load

Second Floor				
Area Name	Occupancy Classification	Occupant Load Factor (sq.ft/person)	Area Space (sq.ft)	Number of Occupants
Admissions	Office	100	1,839	18
Registrar	Office	100	2,595	26
Res Life	Office	100	1,637	16
Advance. Office	Office	100	1,597	16
Financial Aid	Office	100	1,523	15
Center for Student Success	Office	100	1,492	15
Cashiers	Office	100	1,321	13
Student Accounts	Office	100	1,296	13
Career Center	Office	100	2,181	22
Auxiliary Services	Office	100	1,425	14
Storage	Storage	500	2,235	4
Total			19,141	169

4.2.1.3 Third Floor

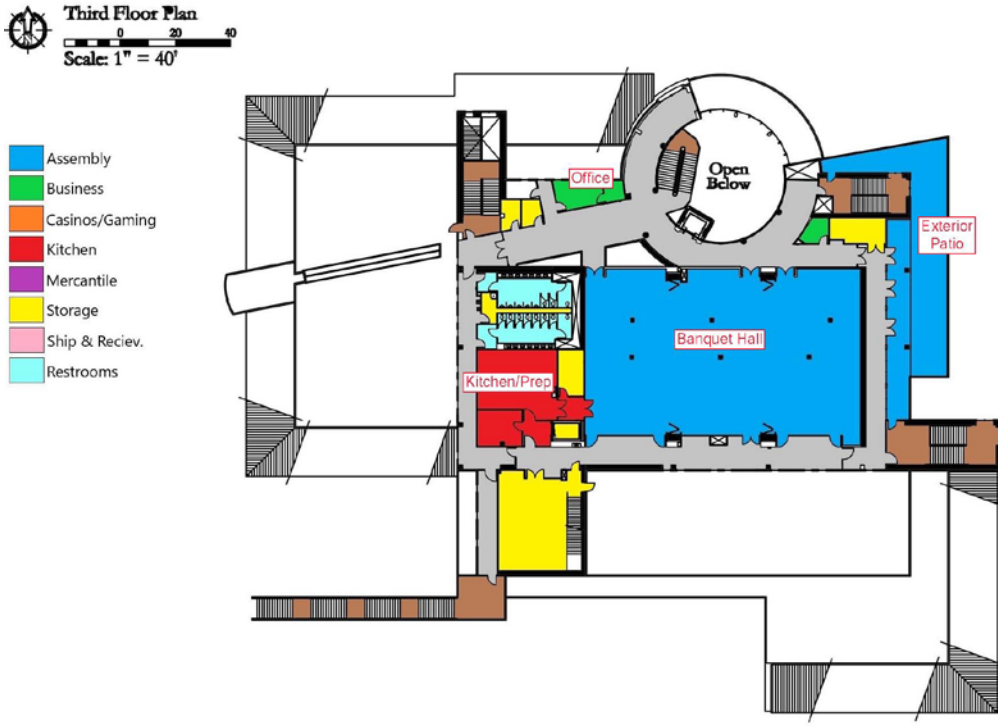


Figure 4-3 - Third Floor Occupancy Uses

Table 4-7 - Third Floor Occupant Load

Third Floor				
Area Name	Occupancy Classification	Occupant Load Factor (sq.ft/person)	Area Space (sq.ft)	Number of Occupants
Banquet Hall	Less concentrated	7	5,930	847
Kitchen	Kitchens	100	877	9
Office	Office	100	308	3
Storage	Storage	500	1,388	3
Total			8,503	859

4.3 Number of Exits

4.3.1 Requirements

LSC Section 7.4 requires that all portions of a building, including mezzanines and stories shall have a minimum of two egress exits, unless a single means of egress is permitted in Chapters 11 through 43. The minimum number of exits from any balcony, mezzanine, or portion thereof, shall be two. Building occupant loads more than 500, but more than 1000 shall not have less than three means of egress and occupant loads over 1,000 shall not have less than four means of egress.

4.3.2 Compliance

The University Student Services building meets or exceeds the minimum number of means of egress from all occupancies and floors. Detail explanations of compliance are outlined in sections 4.3.2.1, 4.3.2.2, and 4.3.2.3 below.

4.3.2.1 First Floor

The bookstore, being a mercantile occupancy, requires that not less than two separate exits shall be accessible from every part. The store has two exits, one on the north end and one on the south end and satisfies the requirements set forth in the code.

The Health Store, Mail Room, Computer Pod, and sporadic offices are designated as business occupancies and all have an occupant load less than 50 people. These areas meet the criteria set forth in the code for a permitted single exit. All areas other than Computer Pod and some of the small offices are serviced by two unique exits.

The common spaces such as the atrium, lounge, café, and cafeteria as classified as assembly occupancies and are all below the occupant load of 500 which would require them be served by two exits.

All occupancies have their own separate exits to the exterior of the building except for the computer pod and small office spaces. However, each discharge into areas that have more than one path of travel to an exit. These areas meet the criteria set forth in the code for permitted two exits and all are provided with at least two.

Exits and occupancies are labeled and shown on the floor plan provided in Figure 4-4.

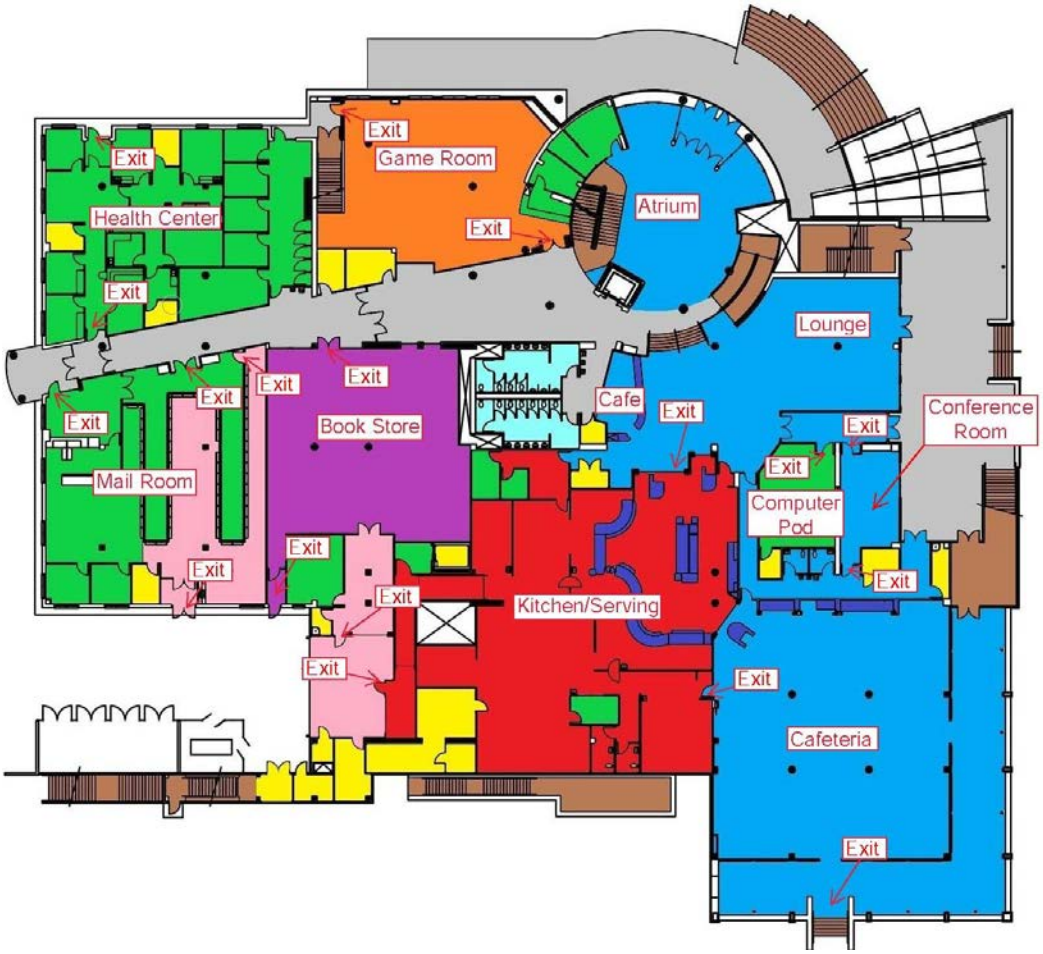


Figure 4-4 – First Floor Occupancy Exits

4.3.2.2 Second Floor

The second floor is comprised entirely of business and storage occupancies. No single portion/area of this floor has an occupant load greater than 50 people. As such all areas meet the criteria for a permitted single exit as provided.

Exits and occupancies are labeled and shown on the floor plan provided in Figure 4-5.

Figure 4-5 - Second Floor Occupancy Exits

4.3.2.3 Third Floor

The banquet hall is the main occupancy on the third floor and has a total of 8 exits. All auxiliary occupancies including the offices and storage areas have a single exit.

Exits and occupancies are labeled and shown on the floor plan provided in Figure 4-6.

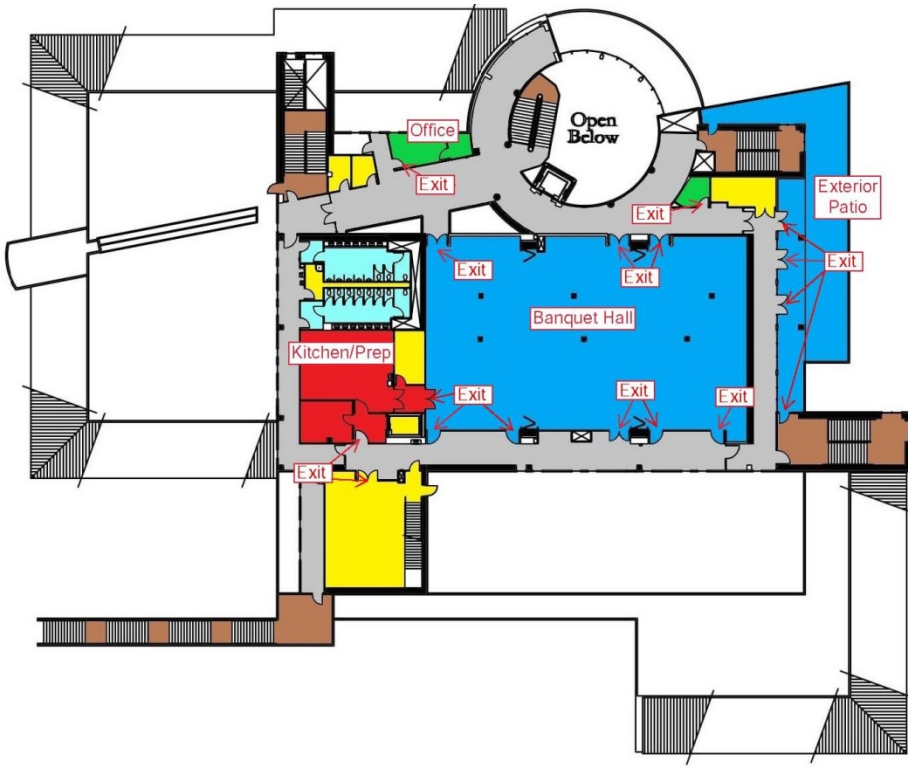


Figure 4-6 - Third Floor Occupancy Exits

The banquet room is configured with permanently mounted folding partition walls as shown in Figure 4-7 that allows the entire hall to be divided into 3 separate spaces. When subdivided the occupant load may be greater than 50, as such, a minimum of two doors for each subdivided space is required. A swinging door leaf is not required to be provided in the folding partitions since every space has a minimum or two means of egress when fully subdivided.

Figure 4-7 - Banquet Hall (Partitioned)

4.4 Egress Capacity and Minimum Width

4.4.1 Requirements

The minimum width of egress routes is based on the occupancy load served. However, the minimum egress routes shall not be reduced to less than 36 inches.

4.4.2 Compliance

All credited egress routes from the first, second and third floor meet the minimum width requirements of 36 inches. Detailed dimensions and total egress capacity per means of egress and floor level are provided in Table 4-8, Table 4-9, and Table 4-10 below.

4.4.2.1 First Floor

The first floor is supplied with a total on 6 main exits which have a combined egress capacity of 2372 people. Every portion of the floor met the requirements set forth in Section 7.4 of NFPA 101.

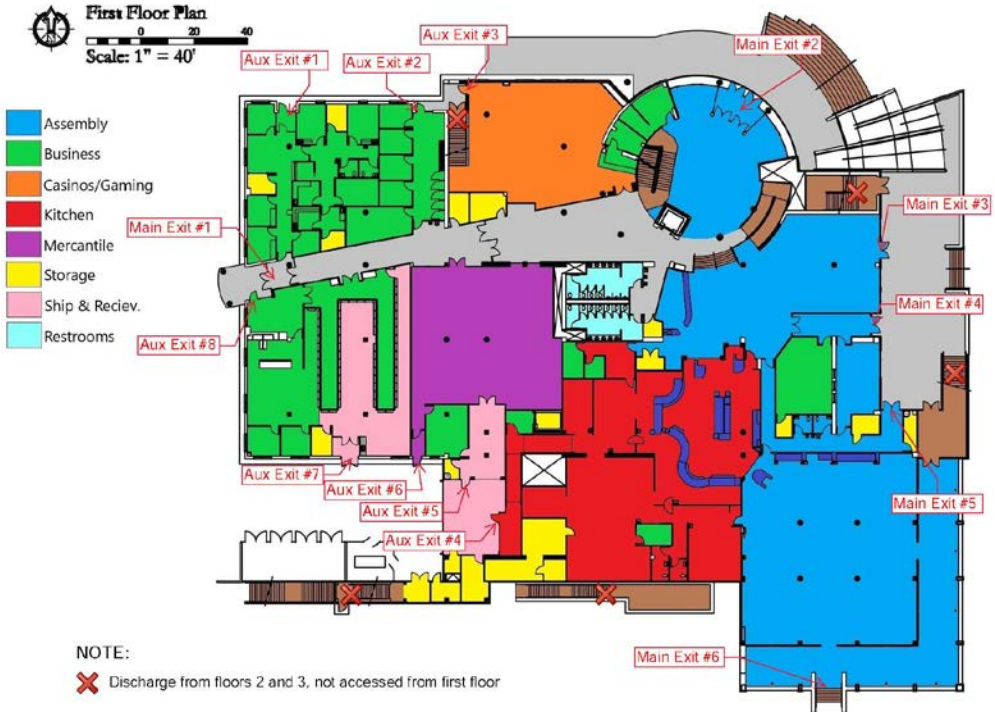


Figure 4-8 - First Floor Exits

Main Exits #2, 3, 4, and 5 do not discharge directly onto a public way, therefore, the path of travel from the termination of the exits to the public way is considered an external "exit discharge" as defined in NFPA 101 – 2015. Calculations showed that the stairs serving Main Exit #2 are sufficiently sized as to not limit exit capacity. However, the door exit capacity for Main Exits #3, 4, and 5 have a combined total of 1080 occupants, while the stairs serving these exits are limited to a capacity of 752 occupants. Egress capacity for all exits and stairways are shown below in Table 4-8 and have a combined egress capacity of 2372 occupants from the first floor.

Table 4-8 - First Floor Egress Capacity

First Floor							
Exit	Stair Width (in)	Exit Width Factor	Exit Capacity (Exit Width/Width Factor)	Door Width (in)	Exit Width Factor	Exit Capacity (Exit Width/Width Factor)	Limiting Exit Capacity
Main Exit #1	-	-	-	72	0.2	360	360
Main Exit #2	354	Eq. 7.3.3.2	1568.7	144	0.2	720	720
Main Exit #3	176	Eq. 7.3.3.2	752.2	72	0.2	360	752.2
Main Exit #4	176	Eq. 7.3.3.2	Shared with Exit #3 and #5	72	0.2	360	
Main Exit #5	176	Eq. 7.3.3.2	Shared with Exit #3 and #4	72	0.2	360	
Main Exit #6	113	Eq. 7.3.3.2	463.2	72	0.2	360	360.0
Aux Exit #1	-	-	-	36	0.2	180	180.0
Aux Exit #2	-	-	-	36	0.2	180	180.0
Aux Exit #3	-	-	-	36	0.2	180	180.0
Aux Exit #4	-	-	-	36	0.2	180	180.0
Aux Exit #5	-	-	-	36	0.2	180	180.0
Aux Exit #6	-	-	-	36	0.2	180	180.0
Aux Exit #7	-	-	-	72	0.2	360	360.0
Aux Exit #8	-	-	-	36	0.2	180	180.0
						Total Egress Capacity	2372

4.4.2.2 Second Floor

The second floor is supplied with a total on 5 means of egress (stairways) which have a combined egress capacity of 922 occupants. All stairways with the exception of stairway #2 discharge to the exterior of the building.

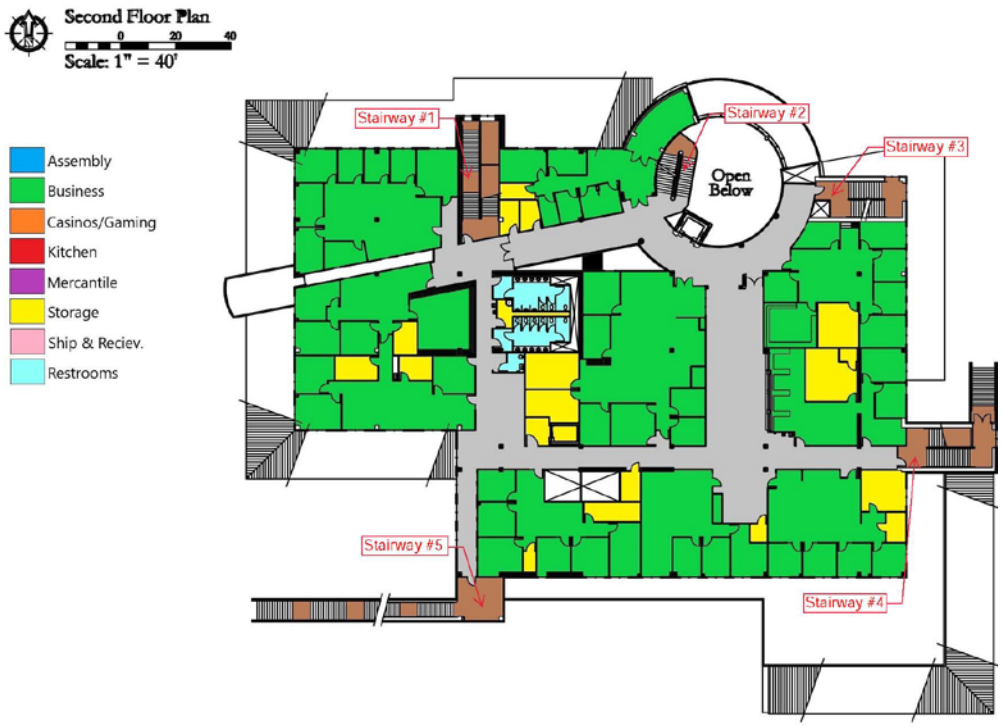


Figure 4-9 - Second Floor Exits

Table 4-9 - Second Floor Exit Capacity

Second Floor							
Exit	Stair Width (in)	Exit Width Factor	Exit Capacity (Exit Width/Width Factor)	Door Width (in)	Exit Width Factor	Exit Capacity (Exit Width/Width Factor)	Limiting Exit Capacity
Staircase #1	72	Eq. 7.3.3.2	275.1	36	0.2	180	180.0
Staircase #2	56	Eq. 7.3.3.2	201.7	-	-	-	201.7
Staircase #3	72	Eq. 7.3.3.2	275.1	36	0.2	180	180.0
Staircase #4	80	Eq. 7.3.3.2	311.8	36	0.2	180	180.0
Staircase #5	60	Eq. 7.3.3.2	220.1	36	0.2	180	180.0
						Total Egress Capacity	922

4.4.2.3 Third Floor

Similar to the second floor, the third floor is supplied with a total of 5 stairways for egress all of which discharge to the exterior of the building with the exception of stairway #2. The entry door to Stairway #4 on the third floor was increased to 48 inches in order to accommodate ADA wheelchairs or other individuals that may require assistance. For this reason, the exit capacity for the third-floor increases to 982 occupants.

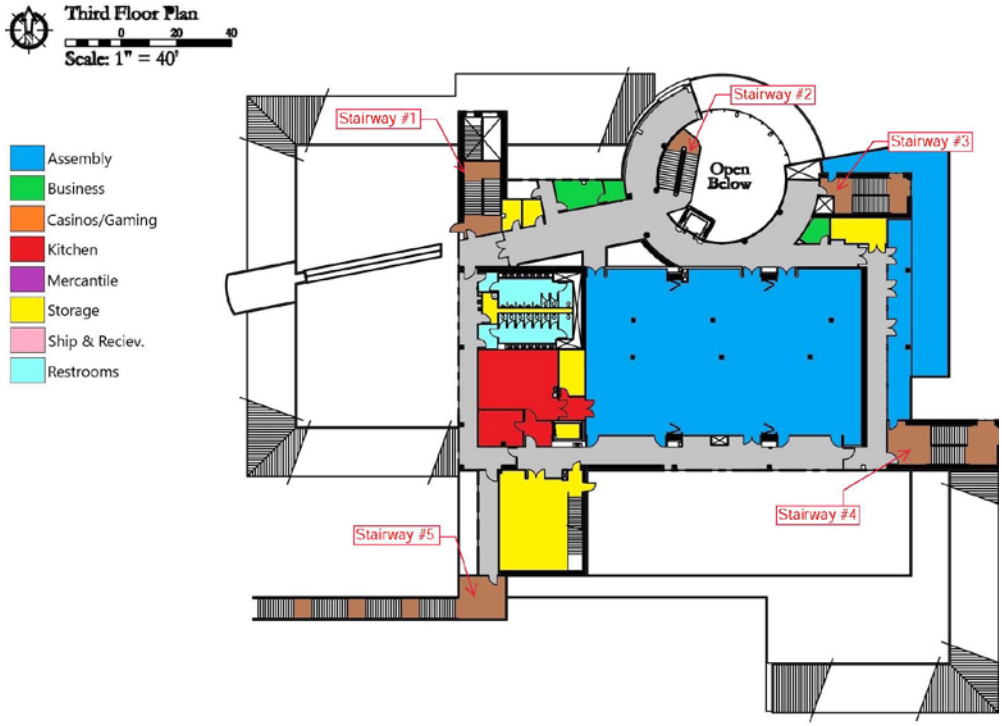


Figure 4-10 - Third Floor Exits

Table 4-10 - Third Floor Exit Capacity

Third Floor							
Exit	Stair Width (in)	Exit Width Factor	Exit Capacity (Exit Width/Width Factor)	Door Width (in)	Exit Width Factor	Exit Capacity (Exit Width/Width Factor)	Limiting Exit Capacity
Staircase #1	72	Eq. 7.3.3.2	275.1	36	0.2	180	180.0
Staircase #2	56	Eq. 7.3.3.2	201.7	-	-	-	201.7
Staircase #3	72	Eq. 7.3.3.2	275.1	36	0.2	180	180.0
Staircase #4	84	Eq. 7.3.3.2	330.2	48	0.2	240	240.0
Staircase #5	84	Eq. 7.3.3.2	330.2	36	0.2	180	180.0
						Total Egress Capacity	982

4.5 Arrangement of Exits

4.5.1 Requirements

Exits shall be located, and exit access shall be arranged, so that exits are readily accessible at all times. Where exits are not immediately accessible from an open floor area, continuous passageways, aisles, or corridors leading directly to every exit shall be maintained and shall be arranged to provide access for each occupant to not less than two exits by separate ways of travel. Dead-end corridors shall not exceed 30 ft (9.1m). Common Path of Travel shall not exceed 100 ft (30m).

(NFPA 101 -2015, Section 7.5)

Remoteness in buildings protected throughout by an approved, supervised automatic sprinkler system in accordance with Section 9.7, the minimum separation distance between two exits, exit accesses, or exit discharges, measured in accordance with 7.5.1.3.2, shall not be less than one-third the length of the maximum overall diagonal dimension of the building or area to be served.

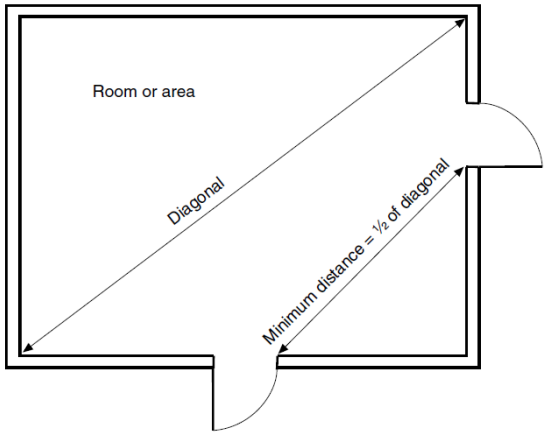


Figure 4-11 - Diagonal Rule for Exit Remoteness

4.5.2 Compliance

All areas on all floors of the building meet the arrangement requirements set forth in the code.

Marked up floor plans can be found in Appendix A.

4.6 Travel Distance to Exits

4.6.1 Requirements

The travel distance to an exit shall be measured on the floor or other walking surface as follows:

(1) Along the centerline of the natural path of travel, starting from the most remote point subject to occupancy
(2) Curving around any corners or obstructions, with 12 in. clearance therefrom
(3) Termination at one of the following:
    a. Center of the doorway
    b. Other point at which the exit begins

Where the measurement includes stairs, the measurement shall be taken in the plane of the tread nosing.

The travel distance in any occupied space with not less than one exit, is measured in accordance with the above shall not exceed the limits as specified in the Table 4-11 below:

Table 4-11 - Allowable Exit Travel Distance

Occupancy		Travel Distance to Exit (NTE)
Assembly	Section 12.2.6.1	250 ft
Mercantile	Section 36.2.6.2	250 ft
Business	Section 38.2.6.3	300 ft

4.6.2 Compliance

All areas and floors of the building meet the maximum travel distances set forth in the code.
A summary of paths of travel that were used to calculate travel distances is summarized in Appendix B

4.7 Common Path of Travel

4.7.1 Requirements

Requirements for common path of travel are outlined throughout the Life Safety Code based of the occupancy type. Table A7.6 provides a compilation of all the requirements for each occupancy type for new and existing buildings. For the fully-sprinklered Student Services Center, the most stringent common path of travel limit is 75 ft in Assembly occupancies serving greater than 50 people.

4.7.2 Compliance

Any part of the exit path that must be traveled prior to two separate and distinct paths to two different exits is considered a common path of travel. A review of the floor plans show that the common path of travel does not exceed the most stringent requirement of 75 ft for any of the various occupancies within the Student Services Center.

4.8 Dead End Corridors

4.8.1 Requirements

Table A7.6 of the Life Safety Code also provides the limit for dead ends of each occupancy type. The most stringent dead-end limit for the facility is 20 ft for Assembly occupancies.

4.8.2 Compliance

A review of the floor plan shows that the assembly occupancies within the building do not exceed the dead-end limit of 20 ft. Within the office spaces on the second floor, the maximum measured dead-end distance reaches 27 ft in the Center for Student Success. However, these office spaces are classified as Business occupancy have a maximum dead-end limit of 50 ft.

4.9 Marking of Means of Egress

4.9.1 Requirements

LSC, Marking of Means of Egress. Signs designating exits or ways of travel thereto shall be provided in accordance with section 7.10.

a. Section 7.10.1.2. Exits shall be marked by an approved sign readily visible from any direction of exit access.
b. Section 7.10.1.5. Signs shall be placed such that no point in the access corridor is more than 100 ft from the nearest sign, in areas where the exit is not readily apparent.

c. Section 7.10.5.2. Every sign required by section 7.10.6.3, 7.10.7 and 7.10.8.1 shall be continuously illuminated.

4.9.2 Compliance

Markings, exit illumination and signs designating exits or ways of travel comply with the LSC.
Sign placement can be viewed in Appendix C.

4.10 Summary

No deficiencies were discovered when reviewing the structure of the Student Services Center against the prescriptive requirements of the Life Safety Code. Based off the occupant load factors found within the code, the maximum occupant load as calculated to be 2,866. This calculation aligns with the building's posted sign of 2,865 at the west entrance. In terms of means of egress, the building either meet or exceeds the requirements for number of exits, arraignment, travel distance, common path of travel, dead end corridors and marking. When performing a building walkthrough, it was noted that the Banquet Hall Storage room was cluttered with chairs and tables which impeded the width of the means of egress. It is recommended that the occupants organize the storage room in order to provide a clear path for egress.

5 Fire Suppression

The building is equipped throughout with a wet-pipe sprinkler system for automatic fire suppression. This section will evaluate the water-based suppression system against the requirements in NFPA 13, *Standard for the Installation of Sprinkler Systems.*

5.1 Water-Based Fire Suppression System

The areas in the building have been designated with their respective occupancy classifications. Based off their classification, different density/area criteria are required. Table 5-1 below documents these relationships with classification and design criteria.

Table 5-1 - Sprinkler Design Criteria

Space	NFPA 13 Classification	Density (gpm/ft^2)	Area (ft^2)	HSA (gpm)	Duration (min)
Offices	Light Hazard	0.10	1,500	100	30
Institutional	Light Hazard	0.10	1,500	100	30
Restaurant seating areas	Light Hazard	0.10	1,500	100	30
Restaurant services areas	Ordinary Hazard 1	0.15	1,500	250	60-90
Mercantile	Ordinary Hazard 2	0.20	1,500	250	60-90
Post Offices	Ordinary Hazard 2	0.20	1,500	250	60-90

5.2 Water Supply

The underground loop at the Student Services Center is fed from the local city water supply. Location of fire hydrants surrounding the building as shown below in Figure 5-1.

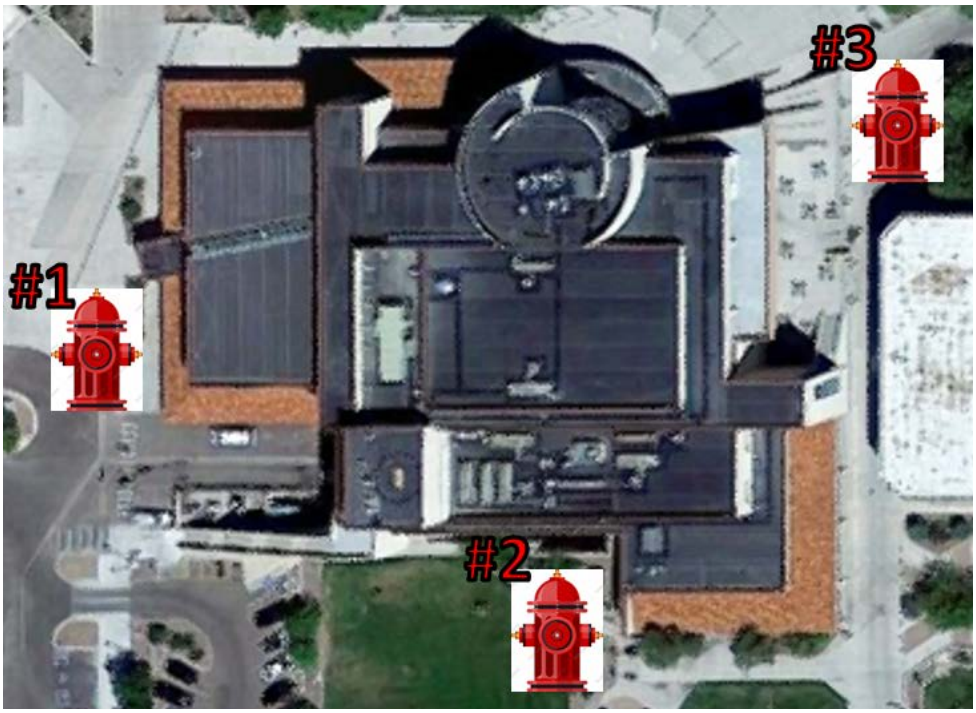


Figure 5-1 - Fire Hydrant Locations

The latest water flow test from hydrant #1 is as follows:

City Water Pressure
Static: 60 psi
Residual: 20 psi
Flow: 750 gpm

5.2.1 Standpipes

The facility is outfitted with two class 1 standpipes which 2.5” hose connections for use by the fire department as required. They are located in stairway #1 and #3 and are not provided with hoses. The standpipes are readily accessible and are within 100 ft of a fire hydrant.

5.2.2 Water Flow Alarm

The sprinkler system is supervised with tamper switches on all control valves including the exterior post indicator valves that are locked at all times. The riser is provided with a pressure type waterflow switch to indicate when a sprinkler has begun flowing water.

5.2.3 Backflow Preventers

Code requires that the sprinkler system piping be protected against backflow into potable water supplies in accordance with the International Plumbing Code. Presence of backflow preventer was verified; however, the model of the device was not obtained.

5.2.4 Fire Department Connection

There are two fire department connections provided for the facility. The first is on the southwestern corner of the mail room which feeds in the main sprinkler riser. The second fire department connection is located on the east end of the building below the exterior patio as shown in Figure 5-2.

Figure 5-2 - Fire Department Connection

5.3 Hydraulic Calculations

For this project, a hydraulic analysis will be performed on the south east end of the third-floor banquet hall. The classification for this area per NFPA 13 is light hazard. The design criteria of 0.10 gpm/ft^2 over 1500 ft^2 with a hose stream allowance of 100 gpm for a duration of 30 minutes was chosen for this space.

5.3.1 Number of Sprinkler Heads

The number of sprinkler heads in the design area were determined using the following equation

$$\#\ of\ heads = \frac{Design\ Area}{Coverage\ per\ sprinkler}$$

The maximum protection area for upright/standard spray pendants in light hazard applications is 225 ft^2 with a maximum space of 15 ft between sprinklers and between branch lines.

$$\#\ of\ heads = \frac{1500\ ft^2}{225\ ft^2} = 6.67\ \approx 7\ sprinkler\ heads$$

5.3.2 Water Demand at Sprinkler Head

The minimum water demand (Q) at the most remote head must meet the max coverage per head multiplied by the density from the design criteria.

$$Q = (\max coverage\ per\ head) * (Density\ from\ desity\ curve)$$

$$Q = 225\ ft^2 * \frac{0.10\ gpm}{ft^2} = 22.5\ gpm$$

$$22.5\ gpm\ minimum\ for\ each\ sprinkler\ head$$

5.3.3 Water Pressure at Sprinkler Head

The make and model of the sprinklers installed in the facility are unknown. For this analysis a sprinkler with a k-factor of 5.6 was chosen. The water pressure required at the most remote sprinkler head can be calculated using the following equation.

$$P = \left(\frac{Q}{K}\right)^2$$

Where:
P = pressure (psi)
Q = water flow are sprinkler head (gpm)
K = k-factor for the sprinkler head

$$P = \left(\frac{22.5}{5.6}\right)^2 = 16.1\ psi$$

The minimum water pressure required at the most remote head in the system is 16.1 psi.

5.3.4 Sprinkler Layout

The following inputs were taken into account when choosing sprinkler layout:

Maximum distance between heads and branchlines:	15 ft
Minimum distance between heads and branchlines	6 ft
Minimum distance to walls:	4 in
Maximum distance from walls:	7.5 ft

The sprinkler layout that was used for the hydraulic calculation is shown below in Figure 5-3.

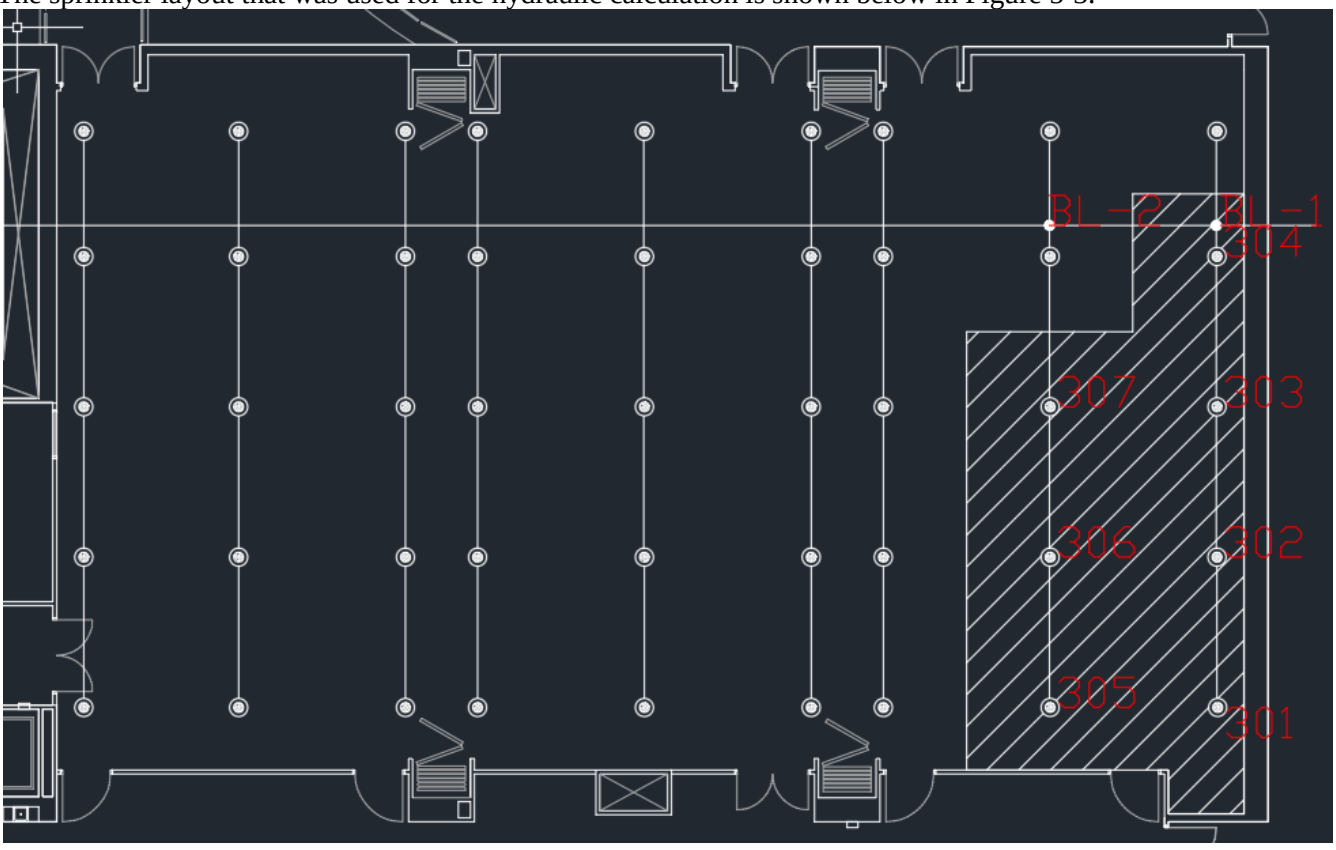


Figure 5-3 - Remote Area 1

Remote area number:	1
Remote area location:	3rd level
Occupancy classification:	Light Hazard
Density:	0.10 gpm/sq.ft
Area of application:	1500 sq.ft
Coverage of sprinklers:	225 sq.ft
No. of sprinklers:	7
Hose steam:	100 gpm
Total required:	212 gpm @ 35.4 psi

The results of the hydraulic calculation demonstrate that the banquet hall requires 212 gpm at a pressure of 35.4 psi with an additional 100 gpm for the hose stream allowance. The water supply at the nearest hydrant to the riser is static pressure of 60 psi with a residual of 20 psi at 750 gpm. The supply is capable of delivering the water required to the remote area calculated as shown below in Figure 5-4 - Water Supply vs Demand.

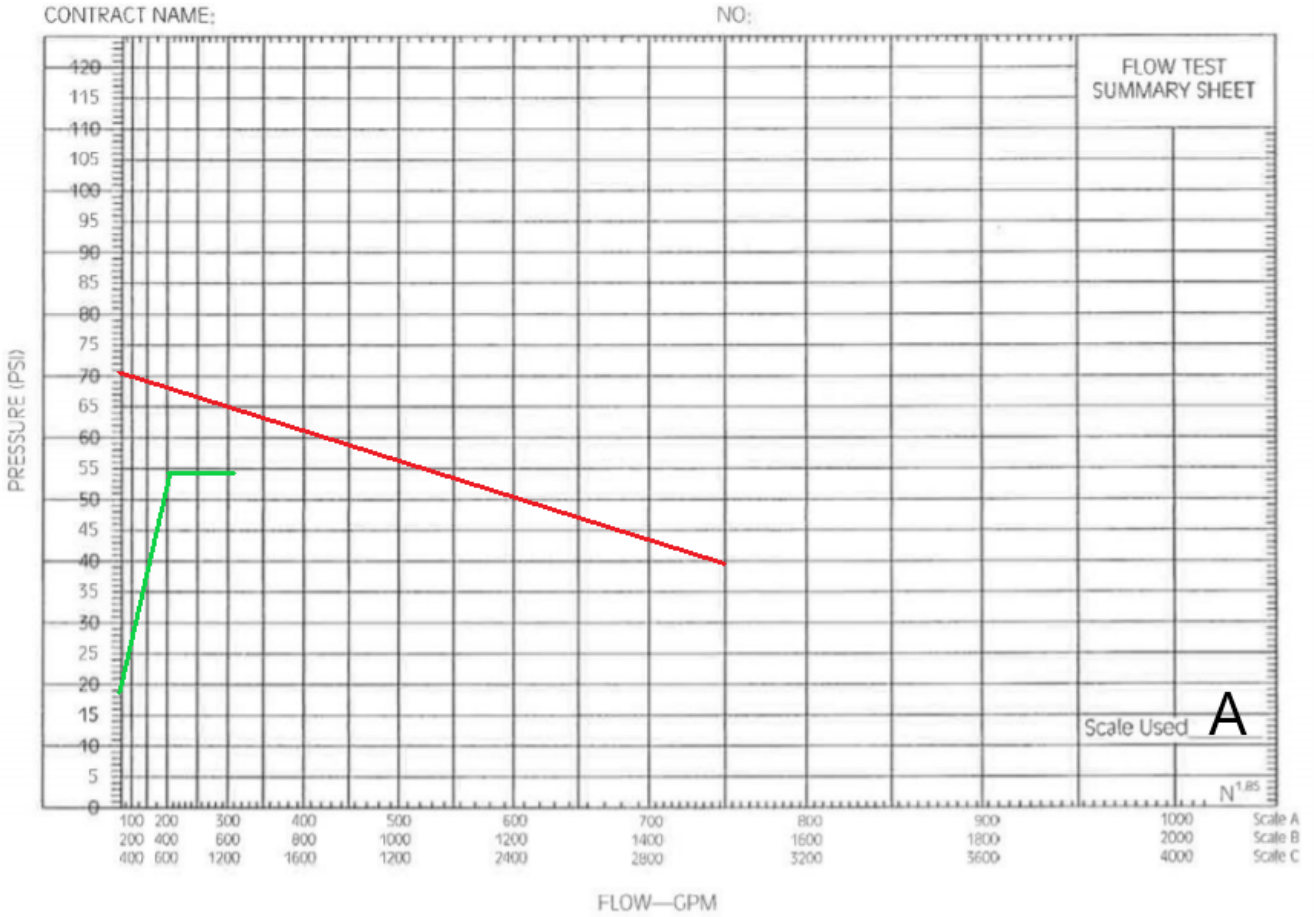


Figure 5-4 - Water Supply vs Demand

5.4 Inspection Testing and Maintenance (ITM)

Inspection, testing and maintenance for the water-based systems are performed periodically as required by NFPA 13. NFPA 13 requires that the property owner or an authorized representative perform and document the inspection, testing and maintenance in accordance with NFPA 25, *Standard for Inspection, Testing and Maintenance of Water-Based Fire Protection Systems*.

5.5 Summary

The facility was reviewed for its supplied water-based fire suppression systems in accordance with NFPA 13 requirements. Hydraulic calculations were performed to determine the system demand requirements for a remote area located on the top floor of the building. The results of the calculation were compared to the results of a recent hydrant flow test and the city water supply was found to be adequate for the system as installed. The standpipes provided in stairwells #1 and #3 were found to located near fire hydrants and readily accessible to fire trucks in needed. Specific equipment selection for valves and accessories was not able to be determined at time of review, however it's assumed that the equipment supplied is listed and labeled for use in the system.

6 Fire Detection and Alarm System

The fire alarm and control system for the facility is designed to detect fires, provide notification, summon the fire department and inform a main control room of the fire's location. The system also monitors the status fire protection system and annunciates actuation of the water-based suppression system (water flow).

This section will evaluate the fire detection and alarm system against the requirements in NFPA 72, *National Fire Alarm and Signaling Code*.

6.1 Fire Alarm Control Panel (FACP)

The Student Services Center is provided with a Notifier NFS-640 fire alarm control panel which is located in an electrical room near the east entrance of the facility. The NFS-640 is an intelligent, field-programmable Fire Alarm Control Panel. Field-programming the control panel lets you customize the fire alarm system by selecting and setting program options for intelligent/addressable detectors and modules, Panel Circuits, and Notification Appliance Circuits (NACs). In addition to the FACP, the facility is equipped with a Notifier FDU-80 annunciator which is housed in the west entrance vestibule.

6.2 Detection and Initiating Devices

The facility is supplied with a variety of different detection and initiating devices that provide direct input to the main FACP for a variety of functions from activation of an alarm state to shutting down equipment. Each type of device and its function is addressed in the sections below.

6.2.1 Smoke Detectors

The facility is fully sprinklered and as such does not require full coverage of smoke detection Smoke detectors are provided in selected areas, including equipment rooms, the bookstore, the dining hall and the area immediately above the FACP.

Some of the smoke detectors are tied into the system to release automatically closing doors on the first, second and third floors as well was lowering the roll up door on the second floor to minimize the propagation of smoke into other areas of the building from the atrium. Other smoke detectors are also used for elevator recall. All smoke detectors will initiate an alarm condition at the FACP.

The smoke detectors are Notifier FSP-851. Locations for all smoke detectors are shown in Appendix D

6.2.2 Duct Smoke Detectors

The facility is equipped with air-handling units (AHU) that provide comfort cooling during the summer months. In an attempt to minimize the amount of smoke that cascades through the air ducting system into other areas, the

AHUs in the facility are equipped with smoke duct detectors. The detectors are wired to shut down their respective AHU when activated and send a supervisory signal to the FACP.

The smoke duct detectors are Notifier FSP-851R.

6.2.3 Beam Smoke Detector

The facility's three-story atrium is equipped with a beam smoke detector that is placed approximately 8 ft above the third-floor walking surface. The equipment is positioned in a manner as to have the beam project directly across the atrium to the reflector as depicted in Figure 6-1 and Figure 6-2 below. When the detector is activated, the detector will initiate an alarm as the FACP as well as transmit signals for the initiation of the smoke removal system that will be discussed in Section 7**,** Smoke Control**,** of this report.

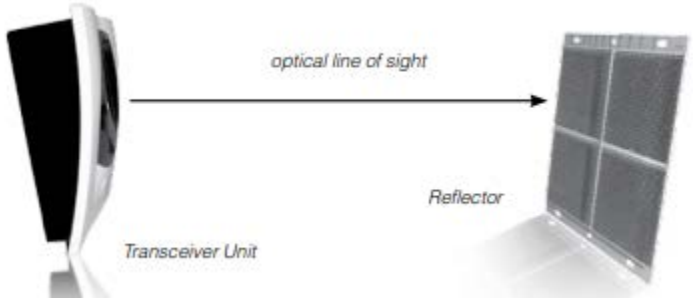


Figure 6-1 - Beam Smoke Detector Example

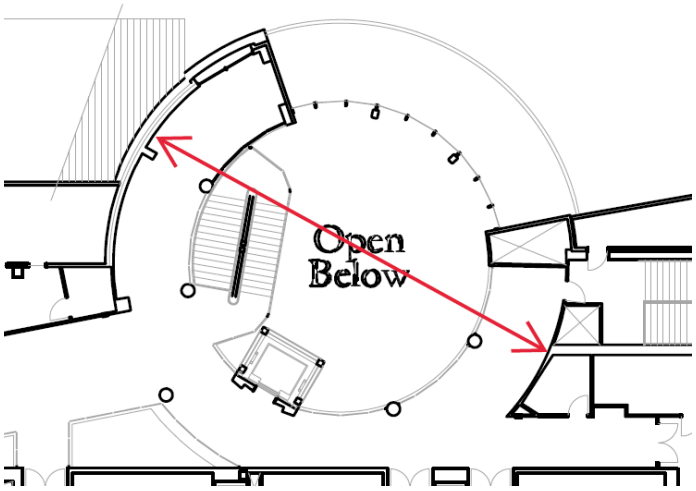


Figure 6-2 - Beam Orientation

6.2.4 Manual Pull Stations

Manual pull stations are provided throughout the facility near all the exits. All are mounted at 40" AFF in accordance with NFPA 72, Section 17.14.5. The activation of a pull station will also initiate an alarm condition at the FACP.

The manual pull stations are Notifier NBG-12LX. Locations for all pull stations are shown in Appendix D

6.3 Notification Appliances

The facility is fully equipped with notification appliances that are activated by an alarm condition at the FACP.

These devices ensure that the occupants of the building are notified in the event of an emergency so that they may evacuate the building to safety. The notification devices consist of horns and strobes designed and located in accordance with NFPA 72.

6.3.1 Horn Strobe Combinations

All horn/strobe combination are mounted in accordance with NFPA 72, Section 18.5.5.1 “Wall-mounted appliances shall be mounted such that the entire lens is not less than 80 in. (2.03 m) and not greater than 96 in. (2.44 m) above the finished floor.” The horn/strobe combination devices are Wheelock MT-24MCW-FR multitone strobe, 24 VDC, multi-candela strobe. Locations for all notification appliances are shown in Appendix D.

6.3.2 Strobes

Certain areas within the facility such as stairwells and restrooms are provided with only visual notification. All strobes are mounted in accordance with NFPA 72, Section 18.5.5.1, The strobe only models are Wheelock RSS-24MCW-FR, 24 VDC, multi-candela strobe. Locations for all notification appliances are shown in Appendix D.

6.4 Secondary Power Supply Requirements

The fire alarm control panel and auxiliary power supplies are required to have secondary power supply in the event of a loss of primary power. The secondary power supply for emergency voice/alarm communication systems are required to be capable of operating the system under quiescent load for a minimum of 24 hours and be capable of operating the system during fire or other emergency condition for a period of 15 minutes.

Table 6-1 - FACP System Power Requirements

Current Draw		Time (hours)	Total (AH)	
Secondary Standby Load 1.613 A	x	Required Standby Time		
		24 hours	38.71	
Secondary Alarm Load 1.990 A	x	Required Alarm Time		
		0.250 hours	0.50	
		Total Secondary Load	39.21	
		Derating factor	x 1.2	
		Secondary Load Requirements	**47.05**	AH

Two 55-amp hour batteries are installed in the FACP which are wired together to provide redundancy. This provides 7.95-amp hours, 14.5% more than the minimum required after the code required 20% derating factor has been accounted for. Both are maintained and tested per NFPA Code requirements.

6.5 Sequence of Operations

Figure 6-3 below shows the matrix provided for the facility by the installing contractor. All alarm, trouble and supervisory messages are transmitted to the annunciator. Fire alarms associated with area smoke or heat detectors, manual pull stations and sprinkler waterflow activate the NACs for facility evacuation. In addition to NAC activation, the fire alarm panel also releases all magnetic door holders upon activation of any fire alarm. Horns are silencable and strobes are capable of being turned off until a new initiating event is received, or the fire alarm is cleared and the panel reset.

When the atrium smoke detector is activated, the detector will initiate an alarm as the FACP as well as transmit signals for the initiation of the smoke removal system components. Activation of duct smoke detectors does not initiate a fire alarm but rather shuts down the associated air handling unit and provides a supervisory signal.

Activation of any smoke detector in a passenger elevator lobby and/or elevator equipment room causes the recall of that elevator to the first floor and lockout elevator controls. In the event of recall initiation by the detector in the first-floor lobby, the recall is to the second floor. The elevator shaft heat detector will shunt the elevator.

SYSTEM INPUT	SYSTEM OUTPUT: ANNUNCIATION — DISPLAY STATUS AT FACP (A)	INDICATE ALARM AT FACP (B)	INDICATE TROUBLE AT FACP (C)	INDICATE SUPERVISORY AT FACP (D)	DISPLAY STATUS AT OTHER NODES (E)	ACTIVATE EVACUATION MESSAGE (F)	TRANSMIT POINT SPECIFIC ALARM TO CS (G)	TRANSMIT POINT SPECIFIC TROUBLE TO CS (H)	TRANSMIT POINT SPECIFIC SUPERVISORY TO CS (I)	SHUTDOWN ASSOCIATED A.H.U. (J)	INITIATE SMOKE REMOVAL (K)	NOTIFICATION — RECALL ELEVATOR TO 1ST FLOOR (L)	RECALL ELEVATOR TO ALTERNATE FLOOR (M)	SHUNT ELEVATOR POWER (N)	CONTROL FUNCTION — RELEASE DOOR HOLDERS (O)	
MANUAL STATION	•	•			•	•	•									1
WATERFLOW	•	•			•	•	•				•				•	2
VALVE TAMPER	•			•	•				•							3
DUCT DETECTOR	•			•	•				•	•						4
ATRIUM SMOKE DETECTOR	•	•			•	•	•				•				•	5
1ST FLOOR ELEVATOR LOBBY SMOKE DETECTOR OR PIT SMOKE	•	•			•	•	•						•		•	6
ELEVATOR LOBBY SMOKE DETECTOR (ALL OTHER FLOORS)	•	•			•	•	•					•			•	7
ELEVATOR TOP-OF-SHAFT SMOKE DETECTOR	•	•			•	•	•					•			•	8
ELEVATOR SHAFT/EQUIPMENT ROOM HEAT DETECTOR	•	•			•	•	•							•		9
ANY OTHER SMOKE DETECTOR	•	•			•	•	•								•	10
ANY OTHER HEAT DETECTOR	•	•			•	•	•									11
SMOKE CONTROL IN MANUAL MODE	•			•	•				•							12
AC FAILURE	•		•		•			•								13
LOW BATTERY	•		•		•			•								14
OPEN CIRCUIT	•		•		•			•								15
SHORT CIRCUIT	•		•		•			•								16
GROUND FAULT	•		•		•			•								17

Figure 6-3 - Sequence of Operation Matrix

6.6 Inspection Testing and Maintenance (ITM)

The property or building or system owner or the owner's designated representative shall be responsible for inspection, testing, and maintenance of the system and for alterations or additions to this system.
The inspection, testing and maintenance of systems, their initiating devices, and notification appliances shall comply with the requirements of NFPA 72, Chapter 14.

The purpose for periodic inspections is to assure that obvious damages or changes that might affect the system operability are visually identified. The purpose for reacceptance tests is to ensure system operation is in accordance with design documents.
Equipment includes but is not limited to:

- Initialing Devices
- Control Equipment
- Supervising Station Alarm Systems
- Batteries and Power Supplies

6.7 Summary

The University Student Services Center was found to be generally in compliance with the requirements set forth in the code. Manual Pull stations are supplied near all exits and do not exceed the maximum distance for placement. Smoke Detectors are supplied for general area protection, elevator and smoke control functions. Notification appliances provide sufficient visual coverage for the facility but minimal decibel levels above ambient were not able to be confirmed. Placement of all devices was also found to be in compliance with the established code requirements.

7 Smoke Control

The International Building Code (IBC) requires that any atrium that connects more than 2 stories be equipped with a smoke control system in accordance with the requirements set forth in NFPA 92B, Standard for Smoke Management Systems in Malls, Atria, and Large Spaces.

This section will discuss the smoke control features of the Student Services Center atrium shown in Figure 7-1.

Figure 7-1 - Atrium

Per NFPA 92B, all portions of active or engineered smoke control systems shall be capable of continued operation after detection of the fire event for a period of not less than either 20 minutes or 1.5 times the calculated egress time, whichever is greater.

7.1 Exhaust Calculations (NFPA 92)

7.1.1 Assumptions

1) Atrium is of uniform circular cross section
2) Fire is located in the center of the atrium (axisymmetric plume)
3) Smoke Density of 0.075 lb/ft^3. (Equivalent to smoke at 70^{o}F)
4) Smoke is instantly and uniformly distributed over the atrium area
5) The base of the fire is 1.5 ft above the base of the atrium
6) No heat loss from the smoke layer to the atrium boundaries

7.1.2 Smoke Plume Calculation

Height	50 ft
Area	1623.8 ft^2
A/H^2	0.64
Design Fire (Unsteady)	4174 kW [1]
Highest walking surface	30 ft

Time when the first indication of smoke is 6 ft above the highest walking surface

$$\frac{z}{H} = 0.67 - 0.28 \ln\left(\frac{\frac{tQ^{1/3}}{H^{4/3}}}{\frac{A}{H^2}}\right)$$

Equation 6.1.2.1 from NFPA 92

where:

z = 36 ft
H = 50 ft
Q = 4174 kW [1]
Q$^{1/3}$ = 16.10
H$^{4/3}$ = 184.2

$A/H^2 = 0.64$

$$0.72 = 0.67 - 0.28 \ln\left(\frac{\frac{16.10t}{184.2}}{0.64}\right)$$

$$0.05 = -0.28 \ln(0.135t)$$

$$-0.179 = \ln(0.135t)$$

$$0.836 = 0.135t$$

$$t = 6.19\ seconds$$

Axisymmetric Plume - A plume that rises above a fire, does not come into contact with walls or other obstacles, and is not disrupted or deflected by airflow.

For an axisymmetric plume, NFPA 92 methodology for calculating the required exhaust rate can be summarized as:

1. Calculate the plume mass flow rate per Equation 5.5.1.1b
2. Calculate the average plume temperature from Equation 5.5.5
3. Calculate the average plume density from the ideal gas law and the average plume temperature calculated in Step 2.
4. Calculate the required volumetric exhaust rate by converting the plume mass flow rate calculated in Step 1 to volumetric flow rate using the plume density calculated in Step 3.

The equations for the methodology described above as displayed below:

1. $$\dot{m}_p = 0.071 Q_c^{1/3} z^{5/3} + 0.0018 Q_c$$ Equation 5.5.1.1b from NFPA 92
2. $$T_s = T_o + \frac{Q_c}{m_p C_p}$$ Equation 5.5.5 from NFPA 92
3. $$\rho_p = \frac{P_0 M}{R T_p}$$ Ideal Gas Law
4. $$\dot{V} = \frac{m_p}{\rho_p}$$ Conversion to volumetric

Where:

$\dot{m}_p$ = mass flow rate in plume at height z (kg/sec)
Q_c = convective portion of heat release rate (kW)
z = distance abive the base of the fire to the smoke layer interface (m)
T_s = average smoke layer temperature (K)
T_o = ambient temperature (K)
C_p = specific heat of plume gases (1.0 kJ/kg-K)
P_0 = ambient pressure adjusted for the locations density altitude (101558 Pa)
M = molecular mass of air (~ 0.029 kg/mol)
R = ideal gas constant (8.314 J/mol-K)
$\dot{V}$ = volumetric exhaust rate required to maintain smoke layer at height z (m^3/s)

Per IBC Section 909.8.1, the height of the lowest horizontal surface of the smoke layer interface shall maintain not less than 6 feet above the walking surface that forms a portion of a required egress system within the smoke zone.
The base of the atrium is 0'-0", and the 3rd floor walkway is +25'-0", i.e. Level 2 is 25'-0" above Level 0. The smoke layer must be maintained at a height of 29'-6" above the base of the atrium.

This height was calculated as follows:

25'-0"	+	6'0"	-	1'-6"	=	29'-6"
height difference between level 2 and level 0	+	height of smoke layer above level 2	-	height of base of fire above level 0	=	smoke layer height

Using Equations 1 thru 4 above for a total heat release rate of 4000 kW as established in the Methodology. (Convective heat release rate of 2800 kW using a radiative fraction of 0.3), the required exhaust rate is calculated as:

Step 1:

$$\dot{m}_p = 0.071 Q_c^{1/3} z^{5/3} + 0.0018 Q_c = 0.071\ x\ (0.7\ x\ 4174)^{1/3}\ x\ 9^{5/3} + 0.0018\ x\ (0.7\ x\ 4174) = 44.01\ kg/s$$

Step 2:

$$T_s = T_o + \frac{Q_c}{m_p C_p} = 21\ C + \frac{2800}{44.01\ x\ 1.0} = 84.62\ \text{C}$$

Step 3:

$$\rho_p = \frac{P_0 M}{R T_p} = \frac{101558\ x\ 0.029}{8.314\ x\ (84.62+273)} = 0.99\ kg/m^3$$

Step 4:

$$\dot{V} = \frac{m_p}{\rho_p} = \frac{44.01}{0.99} = 44.45\ m^3/s$$

Thus, the required exhaust rate is 44.45 m^3/s

7.1.3 Equipment

A variety of equipment is installed in the facility to achieve the performance required per the calculation above. This section will touch on this equipment in detail.

7.1.3.1 Fire Vents

The atrium is provided with two (2) Bilco double leaf fire vents on the roof of each of the two out coves at the base as shown in Figure 7-2 below.

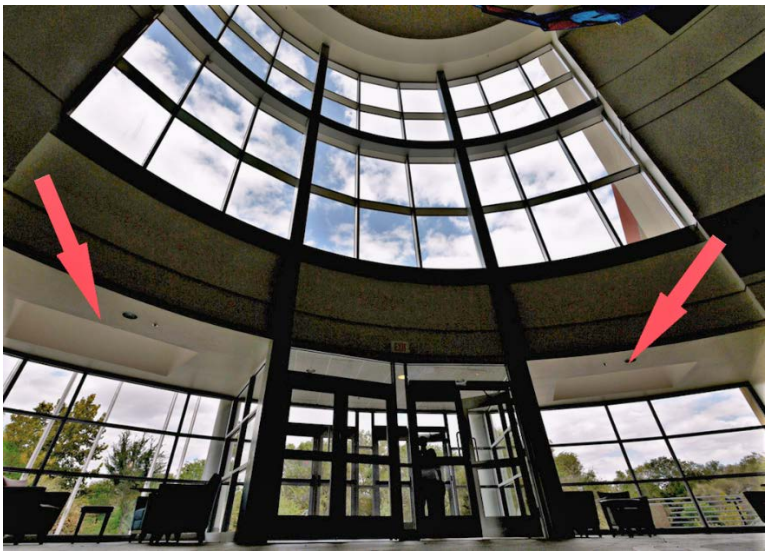


Figure 7-2 - Fire Vent Locations

Although similar vents typically have heat links and used for the venting of air to the exterior of the building, these are used to allow make-up are to enter the building during operation of the exhaust fans. These fire vents are equipped with gas spring operators that are capable of opening the covers in snow and wind conditions. The vent's motor actuators are tied into the fire detection and alarm system to release upon the detection of smoke in the atrium via the beam detector. An example of a Bilco Fire vent is shown on the left of Figure 7-3 and the right is an image of the vent installed in the atrium.

Figure 7-3 - Bilco Fire Vent

7.1.3.2 Exhaust Fans

The atrium has been provided with three (3) 15,000 cfm smoke exhaust fans on the roof of the atrium as shown in Figure 7-4 below. At the time of this report the exact make and model of the exhaust fans was unavailable. Confirmation of installation and style (Figure 7-5) was performed using satellite images of the facility and

discussions with building personnel. The exhaust fans are tied into the fire detection and alarm system to turn on upon the detection of smoke in the atrium via the beam detector.

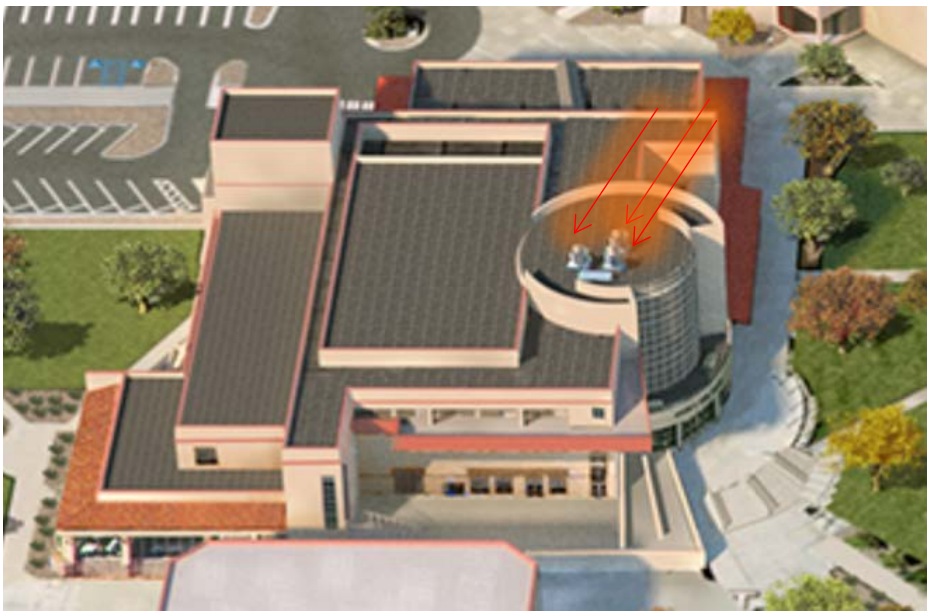


Figure 7-4 - Roof Mounted Exhaust Fans

Figure 7-5 - Exhaust fan

7.1.3.3 Magnetic Closing Doors

The first, second, and third floor are provided with magnetically closing doors in the west wing of the corridor. Upon detection of smoke, the magnetic door holders would release, and the doors would close limiting the smoke spread further into the interior of the building from the atrium.

7.1.3.4 Roll-Up Door

The second floor is provided with a large roll up door which is also tied into the Fire Detection and Alarm system to close upon the detection of the smoke via the smoke detectors that are installed on either side of the roll up

door. This door would section off the second floor limiting smoke from the atrium to propagate further into the south end of the building and to prevent smoke from spilling into the atrium from the interior of the building.

7.2 Summary

The smoke control system as currently supplied in the University Student Services Center meets the general intent of the code. The beam detector provides initial detection and initiation of smoke control sequence. The 3 supplied smoke exhaust fans provide the minimal capacity required per the NFPA 92 calculations that were performed while the intake louvers at the base provide make up air.

Slightly larger capacity exhaust fans that provide a larger margin of safety would have been ideal as mechanical equipment's performance tends to degrade overtime. It's recommended that the university take into consideration upsize the exhaust fans as part of their aging equipment and obsolesce program. Also, the orientation of the beam detector could cause the fire to go undetected for an extended amount of time. It's recommended that secondary smoke detection such as that depicted in Figure 7-6 be added in the atrium for earlier detection and smoke control sequence initiation.

Figure 7-6 - Recommended Secondary Smoke Detector Placement

8 Performance Based Design

8.1 Disclaimer

The following performance-based analysis uses hypothetical scenarios to analyze the building for life safety. The scenarios are intended to be representative of hazards that exist in buildings in general. The scenarios are not intended to identify the size and location of actual hazards. The information in this report is meant to supplement frequent inspections of the building fire protection system and good housekeeping habits to maintain the optimum level of safety for the occupants and the building. The fire hazards, calculation assumptions, and pass/fail criteria used for each scenario are conservative to provide a factor of safety to the occupants.

8.2 Objectives and Performance Criteria

The objectives to be achieved over the design interval time are as follows:

- Notification and protection of occupants not in the immediate area of fire.
- Maintain a tenable environment within all exit access and smoke refuge access paths for the time necessary to allow occupants to reach an exit or smoke refuge area.

Table 8-1 - Performance/Tenability Criteria

Fire Protection Goal	Stakeholder Objective	Design Objective	Performance Criteria
Minimize fire-related injuries and prevent undue loss of life	Allow safe egress for all occupants	Maintain tenable conditions/Prevent flashover	Visibility > 10 m
			Smoke Layer Height > 6 ft
			Temperatures < 120 C
Minimize fire-related damage to the building and its contents	Prevent thermal damage	Minimize spread beyond the room of the fire origin	Upper Layer Temperature < 250 C
Minimize undue loss of operations due to fire-related damage	Minimize smoke spread	Limit smoke spread and exposure	Upper Layer Temperature < 250 C

Table 8-1 - Performance/Tenability Criteria was established using data provided within the 5th edition of the SPFE Handbook. Table 61.3 of the handbook documents that people familiar with the building are capable of evacuating with 4 meters of visibility whereas people unfamiliar require 13 meters. Table 61.4 contains fire researcher proposed data for allowable visibility in fire escape. From this table a value of 10 m was chosen. In addition, data shows that air temperature above 120°C drastically increase the possibility of skin burns and pain to occur.

8.3 Occupant Characteristics

Being such a large public building that houses a wide variety of uses and amenities, the occupants that maybe present in the building ranges significantly. Table 8-2 - Occupant Characteristics below outlines some of the characteristics and attributes that were considered during the evaluation and simulations.

Table 8-2 - Occupant Characteristics

Characeristic	Visitors	Event Patrons	Students	Employees
Familiarity	Transitory	Transitory	"Semi" Permanent	Permanent
Training	None	None	None	Yes
Ages	Adults; children possible	Adults; children possible	Adults	Adults
Disabilities	Wide Range Possible	Wide Range Possible	Wide Range Possible	Small Range Possible
Vulnerabilities	Possible	Possible	Possible	Possible
Level of intoxication	Intoxication Possible	Intoxication Likely	Intoxication Possible	Conscious
Awake	Awake	Awake	Awake	Awake
Social Groupings	Individuals, couples, families, groups	Individuals, couples, families, groups	Individuals, groups	Idividuals, co-workers
Role	Guest (expects assistance)	Guest (expects assistance)	Students	Manager/subordinate

Occupants of the building would be mostly university students and staff. These occupants would be relatively familiar with the layout of the building. During an emergency, its typical for occupants to seek confirmation prior to gathering their belongings and commencing evacuation. Activities such as these are being considered when determining pre-movement times. To minimize this pre-movement time, certain staff members have been designated as building wardens and located throughout the facility by the university in order provide instructions and guide occupants to the closest available exit.

8.4 Estimation of Evacuation Time

8.4.1 SFPE Hydraulic Model

Chapter 59 of the 5th edition of the SFPE handbook provides a hydraulic model for estimation of the time it takes for occupants to reach safety. This time is also commonly referred to as the Required Safe Egress Time. This

model uses values for population movement from egress components to egress components such as doorways, stairs, ramps, etc… This estimation typically tends to be on the optimistic side based off the assumptions that are within the calculations.

The assumptions used for the calculation are as follows:

1. The building is at full capacity. The building being at the maximum occupant load means that the means of egress are being analyzed under the worst-case scenario.
2. Occupants evacuate simultaneously. All occupants evacuating simultaneously means that the limiting portions of the means of egress are being tested and queuing at the door ways will occur on each floor. Queuing means that the specific flow will be at its maximum.
3. Optimization of Exits. This assumption is that the occupants will optimize the use of the stairways and number of exits in each space.
4. Capabilities. Occupants are healthy and able to self-egress

Boundary Layer Widths of egress components:

Table 59.1 of the SFPE Handbook Provides boundary layer widths for several exit route elements. The two main elements in the Student Services Center is that of stairways and doors. According to this table, doors and stairways both have a boundary layer width of 6 inches per side.

From Table 59.5, we gather that the maximum specific flow for a corridor, aisle, ramp, or doorway is 24.0 persons/min/ft of effective width and that the maximum specific flow for a stairway, assuming 7.5 in. treads and 11 in risers is 17.1 persons/min/ft of effective width.

Calculations for individual floors:

Each floor was analyzed to estimate the time to evacuation based off the maximum occupant load calculated earlier in Section 4 this report.

The first floor of the Student Services Center has the largest concentration of occupants and the largest number of available exits. Following the assumptions outlined above, the total time for the first floor to evacuate is calculated at 1.4 minutes or 84 seconds as shown in Table 8-3 – First Floor RSET.

Table 8-3 – First Floor RSET

First Floor								
Exit	Stair Width (in)	Effect. Width (in)	Specific Flow (pp/min/ft)	Max Flow (pp/min)	Door Width (in)	Effect. Width (in)	Specific Flow (pp/min/ft)	Max Flow (pp/min)
Main Exit #1	-				72	60	24	120
Main Exit #2	354	342	18.5	527.3	144	132	24	264.0
Main Exit #3	176	164	18.5	252.8	72	60	24	120.0
Main Exit #4	176	164	18.5	252.8	72	60	24	120.0
Main Exit #5	176	164	18.5	252.8	72	60	24	120.0
Main Exit #6	113	101	18.5	155.7	72	60	24	120.0
Aux Exit #1	-				36	24	24	48.0
Aux Exit #2	-				36	24	24	48.0
Aux Exit #3	-				36	24	24	48.0
Aux Exit #4	-				36	24	24	48.0
Aux Exit #5	-				36	24	24	48.0
Aux Exit #6	-				36	24	24	48.0
Aux Exit #7	-				72	60	24	120.0
Aux Exit #8	-				36	24	24	48.0
							Floor Occupants	1838
							Max Flow (pp/min)	1320
							Time to Empty (min)	1.4

The second floor is all business occupancy and thus has the smallest concentration of occupants and can evacuate in just 0.7 minutes or 42 seconds as shown Table 8-4.

Table 8-4 – Second Floor RSET

Second Floor								
Exit	Stair Width (in)	Effect. Width (in)	Specific Flow (pp/min/ft)	Max Flow (pp/min)	Door Width (in)	Effect. Width (in)	Specific Flow (pp/min/ft)	Max Flow (pp/min)
Staircase #1	72	60	18.5	92.5	36	24	24	48.0
Staircase #2	56	44	18.5	67.8	-			
Staircase #3	72	60	18.5	92.5	36	24	24	48.0
Staircase #4	80	68	18.5	104.8	36	24	24	48.0
Staircase #5	60	48	18.5	74.0	36	24	24	48.0
							Floor Occupants	169
							Max Flow (pp/min)	260
							Time to Empty (min)	0.7

Lastly, Table 8-5 shows that the third floor can evacuate in 3 minutes or 180 seconds.

Table 8-5 – Third Floor RSET

Third Floor								
Exit	Stair Width (in)	Effect. Width (in)	Specific Flow (pp/min/ft)	Max Flow (pp/min)	Door Width (in)	Effect. Width (in)	Specific Flow (pp/min/ft)	Max Flow (pp/min)
Staircase #1	72	60	18.5	92.5	36	24	24	48.0
Staircase #2	56	44	18.5	67.8	-			
Staircase #3	72	60	18.5	92.5	36	24	24	48.0
Staircase #4	84	72	18.5	111.0	48	36	24	72.0
Staircase #5	84	72	18.5	111.0	36	24	24	48.0
							Floor Occupants	859
							Max Flow (pp/min)	284
							Time to Empty (min)	3.0

8.4.2 Pathfinder Simulation

Pathfinder is an agent-based evacuation simulation software that allows modeling of occupant movement throughout a building. The floor plan of the building was imported and all geometrical features such as door widths, stairways and ramps defined. The simulation model was then populated at max capacity with a random distribution of agents (occupants) based off the occupant load calculations per area. This occupant load is seen as the worst-case scenario for occupant loading of the building. Figure 8-1 below shows the three floors loaded with the 2866 occupants as calculated in Table 4-4 - Building Occupant Load.

Figure 8-1 - Pathfinder Layout

The model was run with the building at full capacity and all exits available for use, the simulation resulted in an evacuation time of approximately 167 seconds for all occupants to exit to safety. These results do not take into consideration pre-movement occupant behaviors but rather provide an estimate of movement time to safety. As expected, Figure 8-2 shows large ques at the exits to the most populated areas such as the banquet hall and cafeteria. These results were used as a baseline. The model was altered to properly account for the fire scenarios which were analyzed later in this report.

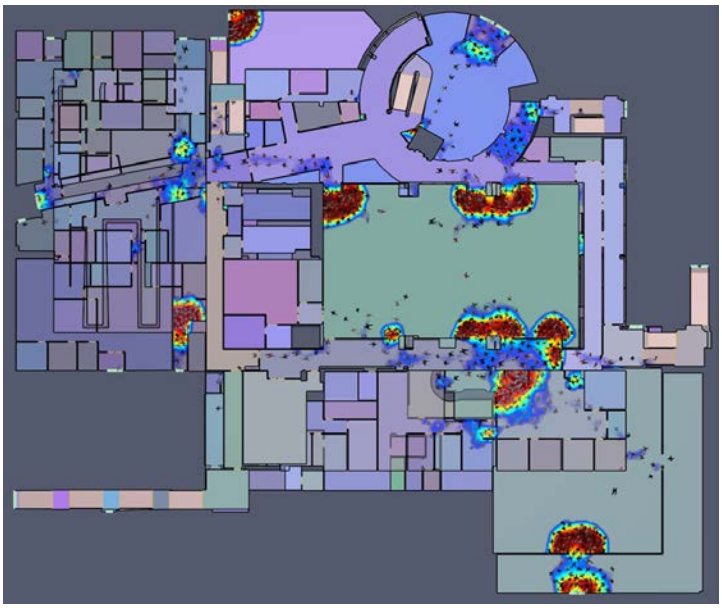


Figure 8-2 - Queuing in Pathfinder Simulation

8.4.3 Pre-Movement Time

The time that occupants take to initiate their movement towards an exit is difficult to estimate. The SFPE Handbook chapter, "Engineering Data" contains several pre-evacuation data-sets collected from buildings ranging in size and occupancy types. These data sets were reviewed to find one that closely resembled the University Student Services Center. The data set chosen was of a 3 storied University building in New Zealand with a different number of occupants on each floor. The results of this data set show a mean pre-evacuation time of 28 seconds[8]. The Pathfinder model will be altered to randomly distribute a range of pre-evacuation time to all the building occupants ranging from 0-15 seconds to people in proximity of the fire and 15-40 seconds for people separated from the origination point. In addition to the pre-movement time, a factor of safety of 20% will also be added.

8.5 Fire Scenarios

Section 5.5.3 of the Life Safety Code outlines the different design fire scenarios which should be considered when developing appropriate design fires to analyze. In total there are 8 different scenarios outlined as shown below:

1) Fire typical of occupancy type
2) Ultrafast-developing fire blocking means of egress
3) Fire in normally unoccupied room
4) Concealed space fire adjacent to a large occupied room
5) Slowly developing fire, shielded from fire protection systems
6) Most severe fire consisting of largest possible fuel load
7) Outside Exposure Fire
8) Ordinary combustibles/Ineffective fire systems system

8.6 Considered Design Fires

The following design fire scenarios were considered for the performance-based analysis on this facility.

8.6.1 Atrium Scotch Pine Christmas Tree Fire

It is holiday season and the school has decided place a Christmas display in the center of the atrium (**Error! Reference source not found.**). The atrium is one of the main entry ways to the facility. This proposed design fire aligns with scenario #2 where an ultra-fast developing fire blocks a means of egress. The display is comprised of a Scotch Pine Christmas tree and several fake gifts comprised of wrapped cardboard boxes.

Figure 8-3 - Scotch Pine Tree

8.6.2 Atrium Furniture Fire

The outcoves at the base of the atrium are provided with upholstered furniture year-round (Figure 8-4). These areas are typically used by students to read, do homework, or collaborate with other students in between classes. This proposed design fire scenario also aligns with #2.

Figure 8-4 - Atrium Furniture

8.6.3 Banquet Hall

The third-floor banquet hall regularly holds events such as standardized testing, research presentations and even receptions as shown in Figure 8-5. Figure 8-5 shows a configuration where textile draperies are hung from the walls and ceilings. These draperies block both sprinkler head as well as obstructs exits signs. Looking at Life Safety Code scenario #3, where a fire starts in an unoccupied room such as the supply storage room shown in Figure 8-6. However, during special events the tables and chairs are being used in the banquet hall and not in storage. When the items are in the storage room, the number of occupants on the third floor is limited and access is typically closed. For these reasons, the scenario was not analyzed.

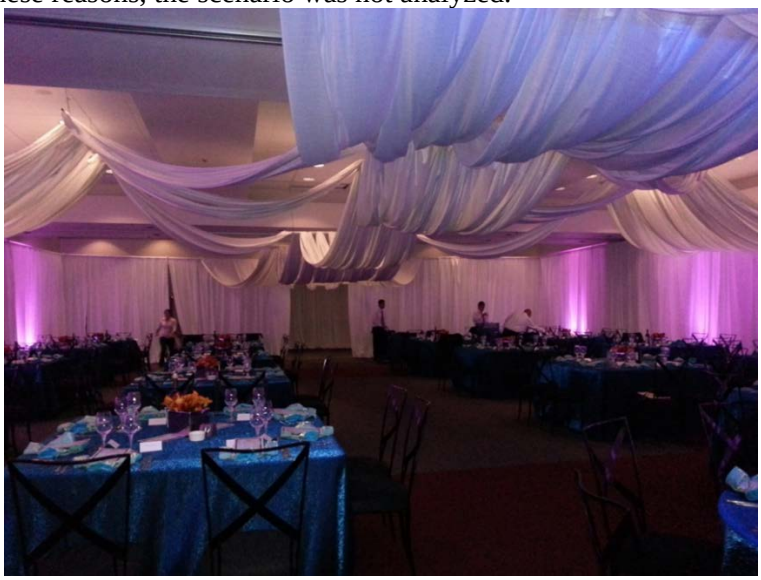


Figure 8-5 - Sample Banquet Hall Configuration

Figure 8-6 - Banquet Hall Supply Storage Room

8.6.4 Mechanical Room (Scenario 3)

There is a mechanical room shown below in Figure 8-7 located on the penthouse (fourth floor) above the banquet hall storage room. It is filled with boilers, pumps, heat exchangers and other equipment. This scenario would look at combustible materials being stored improperly in the mechanical room. Prolonged exposure to the radiative heat from the equipment raises the temperature of the material until it ignites creating a small fire. Again, this scenario looks at life safety code's scenario three, where a fire originates in a normally unoccupied room.

The room is relatively small in size and of fire rated construction. Being located above any floor that is normally occupied and equipped with smoke detection, this mechanical room scenario was deemed as a lower risk of exposing the occupants to hazards conditions and not analyzed.

Figure 8-7 - 4th floor Mechanical Room

8.7 Design Fire Scenario 1

The first design fire that was selected to be analyzed is the Christmas display placed at the base of the atrium. Atriums present significant challenges due to their size when it comes to fire protection. Also, the location of this atrium in one of the most popular entrances to the facility make it "worst case" scenario in terms of losing a primary means of egress. This section will cover the details regarding inputs to the FDS model such as geometry and fuel load.

8.7.1 Inputs

The atrium has a unique tiered ceiling that needs to be modeled for accurate representation of smoke movement. This ceiling creates a reservoir in which smoke can be collected and delay the smoke propagation into the third floor in the event that the smoke exhaust system does not operate. The vents to the smoke extraction system are located above a circular "dish" that is suspended in the center of the ceiling, which is shown in Figure 8-8. As such, this "dish" was added into the model to show the smoke spilling over and into the smoke extraction vent.

Figure 8-8 Atrium Ceiling

The fuel information for the scotch pine Christmas tree that was selected for the design fire are shown below in Table 8-6 and Figure 8-9. This data was obtained from a NIST report of Test FR 4010 issued in 1999.

Table 8-6 - Design Fire Fuel Inputs[4]

Scotch Pine Tree	
Weight =17.2 Kg Height = 2.6 m Width = 1.7 m	PEAK HRR = 4173.6 kW HHRPUA = 919.25 kW/m^2 Soot Yield = 0.07 Co Yield = 0.005

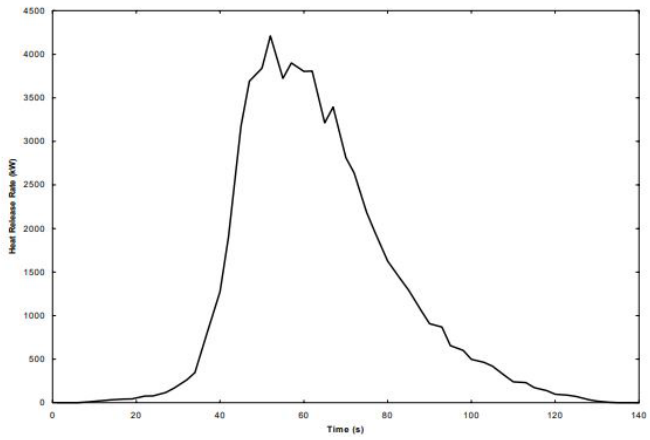


Figure 8-9 - Heat Release Rate of Scotch Pine Trees[1]

8.7.2 Modeling

The focus of the design fire being analyzed is the three-story atrium at the main entrance of the building. As such, the building geometry that was created in FDS was limited to the atrium and the open areas on each floor up to the automatic closing doors. A mesh was applied to the model and refined to properly capture the geometry and does not create holes through any surfaces. Various slice files were finally placed throughout the model in order to gather information on parameters of interest such as smoke density, velocity and temperature. The geometry, mesh and slice files are depicted in Figure 8-10 and Figure 8-11 below.

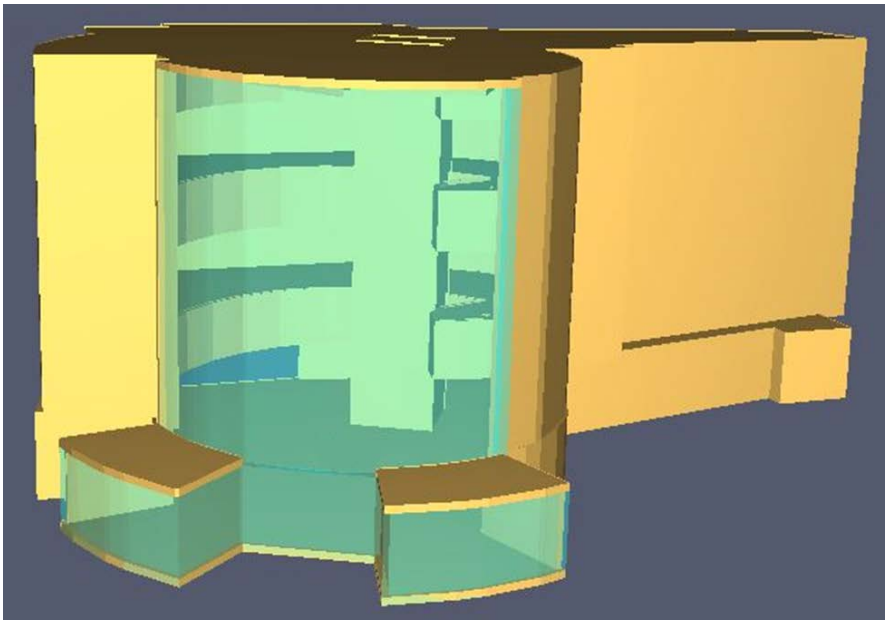


Figure 8-10 - FDS Model Geometry

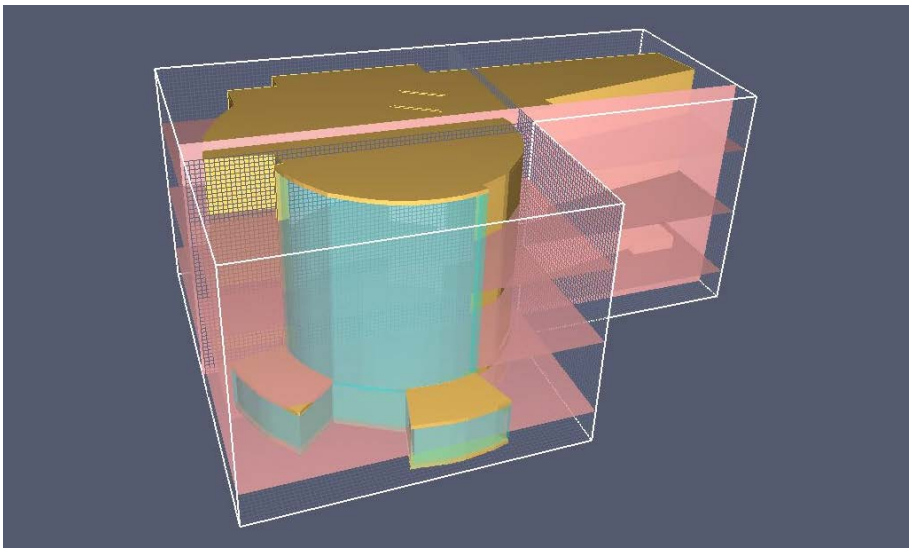


Figure 8-11 - FDS Model with Mesh and Slices

8.7.3 Design Fire Scenario 1 Results

The FDS model was run using the input parameters from 8.7.1 for a total of 700 seconds. At approximately 7 seconds into the simulation, the smoke layer has reached over 6 feet above the third-floor walking surface. At 12 seconds, Figure 8-12, the smoke detector has alarmed and activated the smoke exhaust vents and opened the air intake louvers.

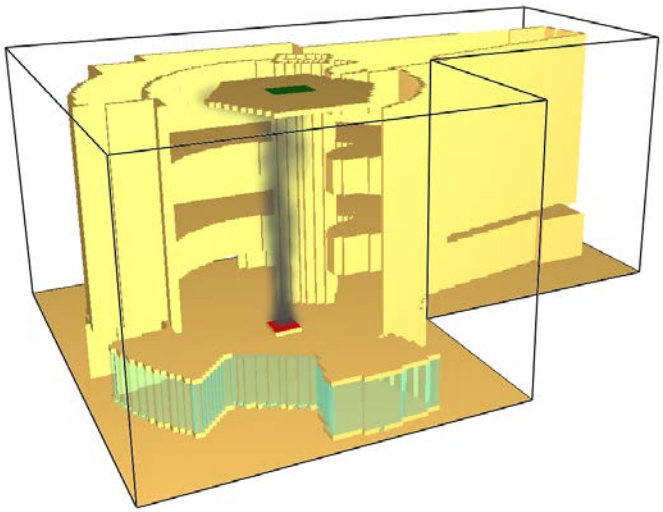


Figure 8-12 - Detector Activation 12 seconds

At 54.8 seconds, Figure 8-13, the smoke is starting to flow under the ceiling of the third floor. This walking surface is part of the main path of egress for many of the occupants in the banquet hall. Smoke density at this point has not met the failure criteria.

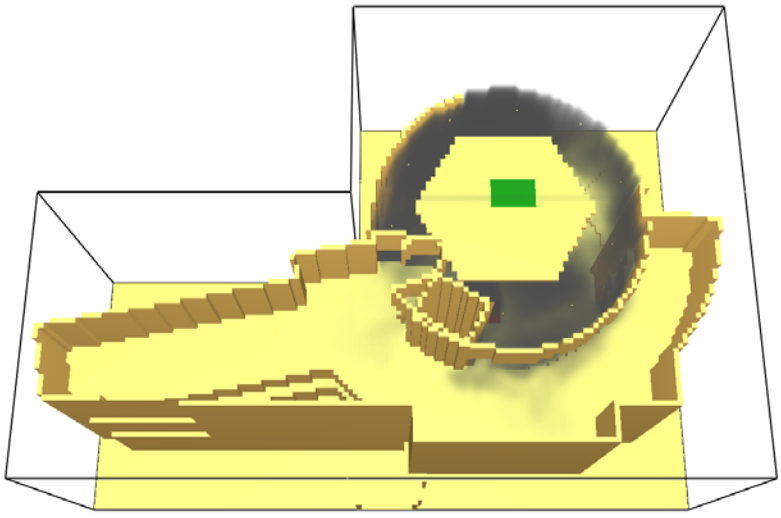


Figure 8-13 - Smoke flow into 3rd floor walkway at 54.8 seconds

Figure 8-14 below shows the areas 6-feet above third floor walking surface where the smoke density has increased to such a level that the visibility has decreased to l0 meters or less. At 65 seconds, occupants in this area will be exposed to a smoke density that exceeds the acceptable performance criteria established of 10 m.

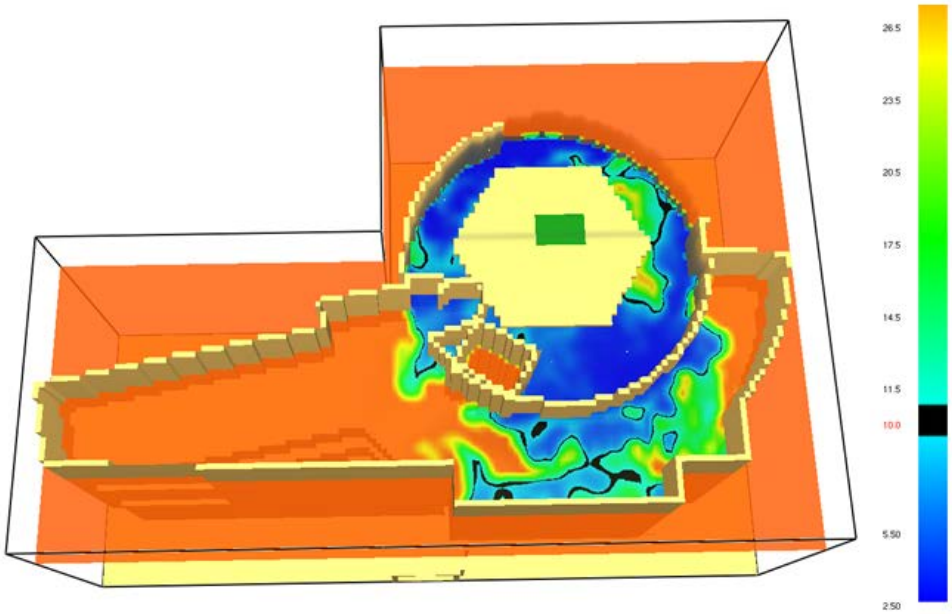


Figure 8-14 - Tenability Failure at 65 seconds

At 77 seconds, Figure 8-15 shows the entire third floor walking area has been engulfed with smoke and reduced the visibility to well below the 10 m criteria at the 6-feet above the walking surface.

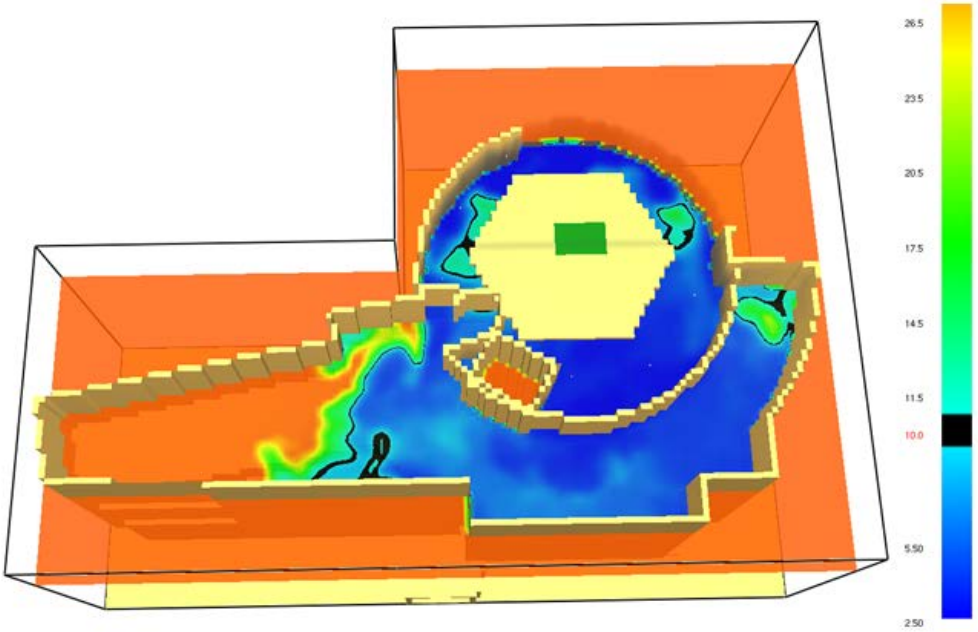


Figure 8-15 - Third Floor completely engulfed in dense smoke 77 seconds

Section 8.4 documented a minimum of 167 seconds without pre-evacuation time for all occupants to exit the building. As the third floor has become engulfed with smoke at the 6 ft above floor finish at 77 seconds in the FDS model, it is clear that the fire protection systems in place would not be capable of maintaining tenable

conditions for occupants to safely egress from the building. Upon failure of the visibility criteria, no other parameters were analyzed.

8.8 Design Fire Scenario 2

The atrium seating areas are provided with five upholstered furniture chairs for occupants to use during normal business hours. A single chair ignites and the radiative heat flux causes a second chair in close proximity to ignite.

8.8.1 Inputs

Figure 8-16 below shows the typically furniture layout for the out coves at the base of the atrium. The fuel parameters are shown in Table 8-7 and Figure 8-17.

Figure 8-16 - Atrium Furniture

Table 8-7 - Design Fire Fuel Inputs

Upholstered Furniture
PEAK HRR = 695 kW
HHRPUA = 1241.17 kW/m^2
Soot Yield = 0.198
Co Yield = 0.042

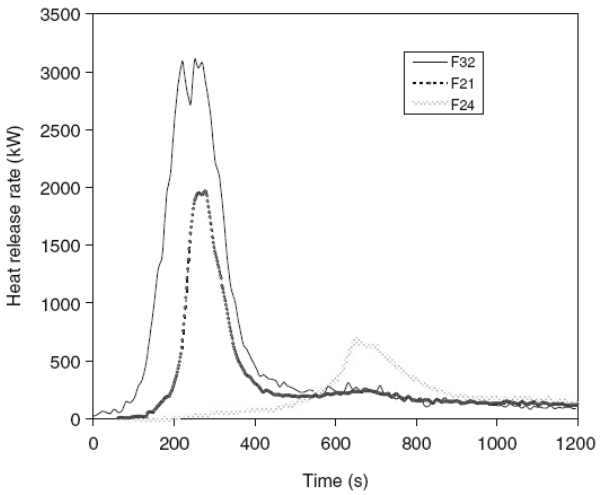


Figure 8-17 - Heat Release Rate of upholstered furniture items tested at NIST, (F24)[2]

Heat release rate ‘F24’ was selected. For this scenario, the “2chairs unmitigated” curve from Figure 8-18 was input into FDS.

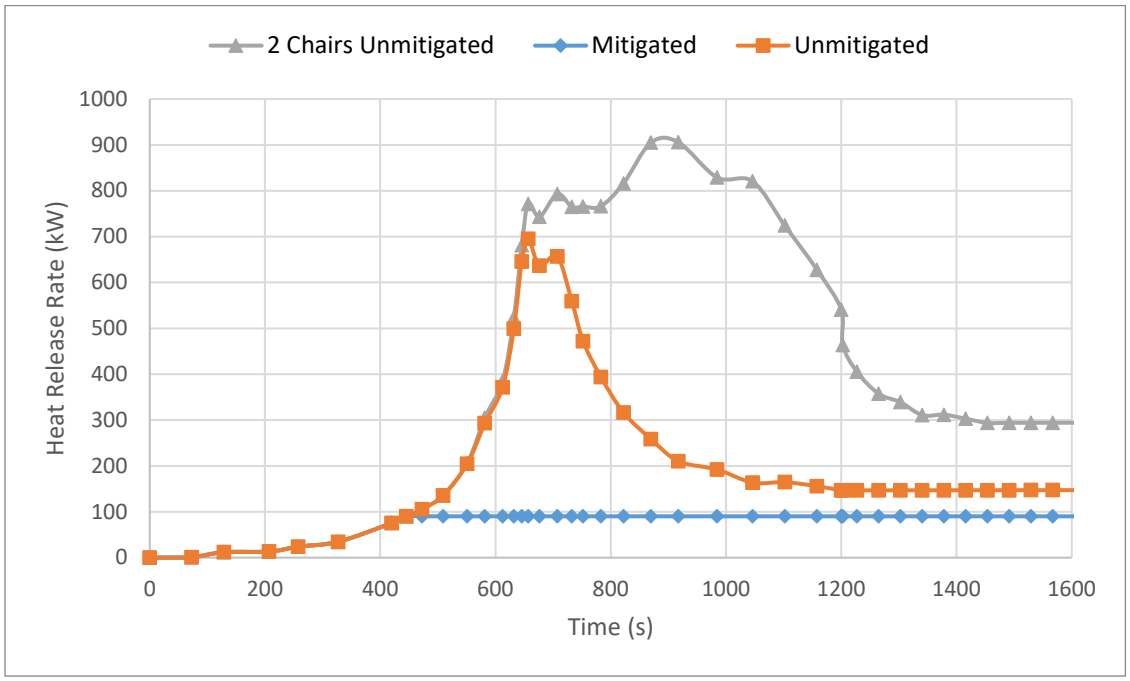


Figure 8-18 - Combined HRR for two upholstered chairs

8.8.2 Modeling

The location of the fire and the fuel sources was changed for this simulation. The rest of the model for this fire scenario is the same as the first scenario. The FDS input file can be found in Appendix E.

The original full evacuation model was altered for design fire scenario #2 to account for the placement of the fire within the atrium. The main doors next to the location of the fire were closed in the model as it is assumed that people would likely travel in the direction away from the fire and smoke rather than towards it.

8.8.3 Design Fire Scenario 2 Results

In fire scenario #2, the fuel source is off to the side under one of the outcoves versus right in the center as in scenario #1. Due to this change, the smoke no longer travels up the atrium directly in the path of the beam detector. Rather, it spills from the outcove and up from the windows into the reservoir. Figure 8-19 shows a

epresentation of smoke movement in the atrium during this scenario. As the reservoir fills, the smoke level eventually reached the height of the beam and was detected at 203 seconds as shown in Figure 8-20 below.

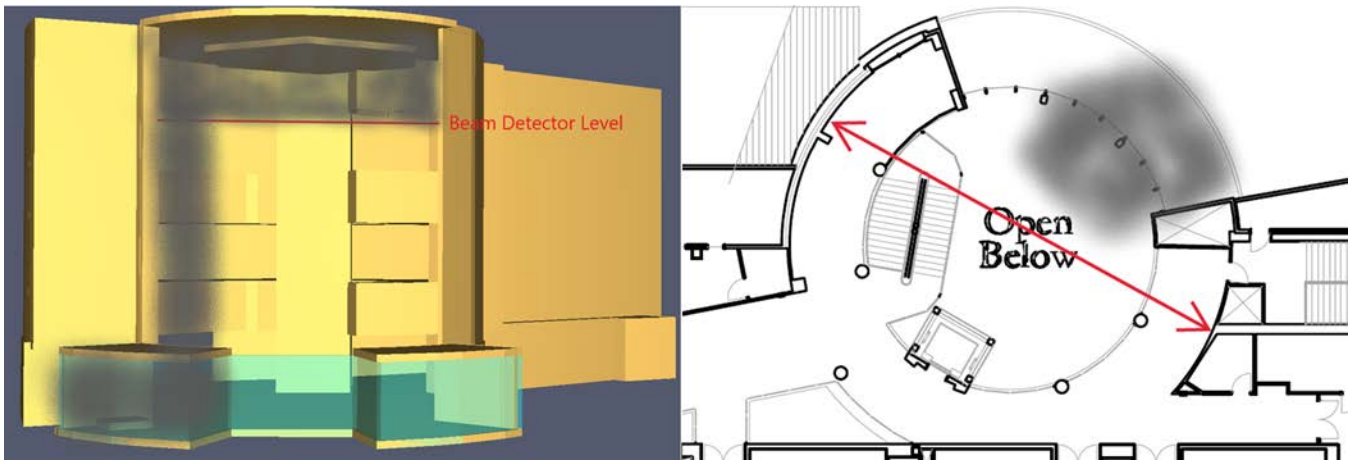


Figure 8-19 - Smoke Movement vs Beam Detector Orientation

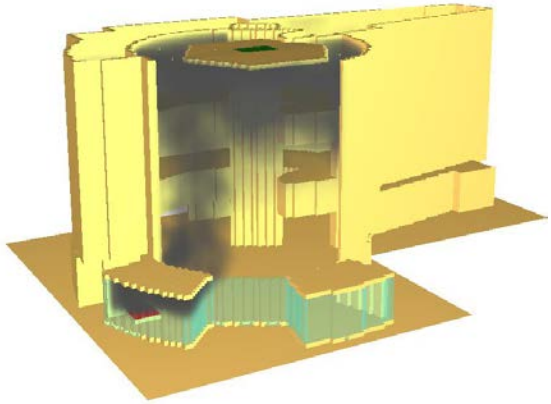


Figure 8-20 - Detector Activation at 203 seconds

Upon detection, the smoke control features such as exhaust fans, air vents and fire doors all activate. Figure 8-21 shows a large disturbance in the smoke upon the activation of these systems just seconds after initial detection of the smoke.

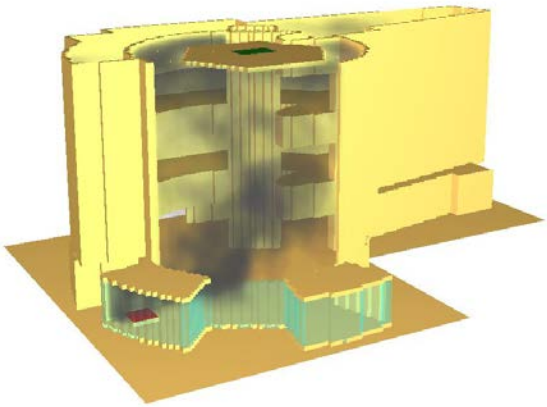


Figure 8-21 – Smoke Control System Activation

Slices files for visibility and temperature were placed at 6-feet above each of the walking surfaces. If at any point in the simulation the temperature were to increase above, or the visibility decrease below their respective tenability criteria, the simulation is considered as having failed to protect the occupants.

The pathfinder model (Figure 8-22) shows that the occupants that used the third-floor walking surface open to the atrium have all cleared at 322 seconds into the simulation. Looking at the FDS results in Figure 8-23 for visibility on the third-floor at this same time shows that the tenability criteria is still being met as no portion of the path has been reduced below 10 m.

Figure 8-22 - Evacuation Model at 322 seconds

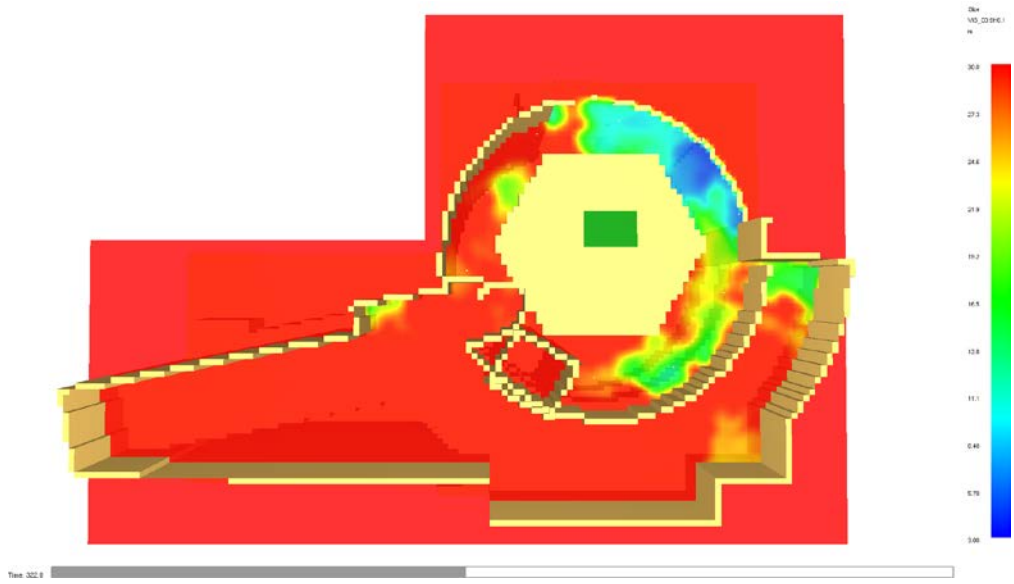


Figure 8-23 - Smoke flow into 3rd floor walkway at 322 seconds

At 451 seconds, Figure 8-24 shows in the FDS simulation that a small portion of this walking surface has fallen below the 10 m tenability criteria. This area is shown as blue outlined in black on the figure.

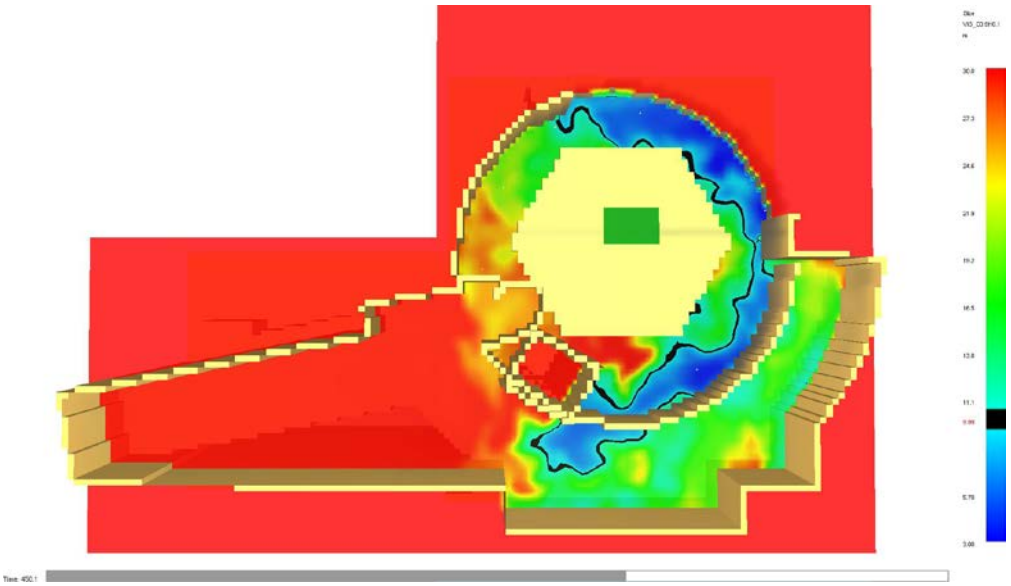


Figure 8-24 – Partial Visibility Failure at 451 seconds

At this point of failure, all of the occupants have been able to successfully evacuate the facility to safety. The simulation calculated a total of 417 seconds from the time of ignition for a full evacuation a as shown in Figure 8-25 below. This time includes the 203 seconds that it took for the beam detector to alarm, pre-movement time and the blocked off egress doors in the atrium. When the 20% factor of safety is added to the evacuation time, the RSET is totaled at 500 seconds.

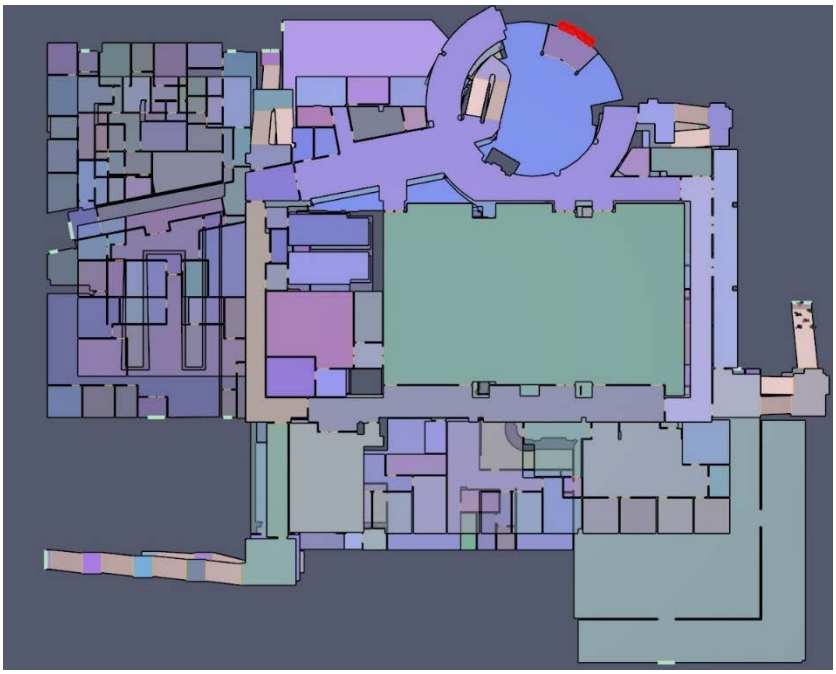


Figure 8-25 – Evacuation Model at 417 seconds

The temperature does not increase above 60 C at 6-feet above any of the first, second, or third floor walking surfaces at any point before the RSET is reached. Figure 8-26 show shows the temperature at 6-feet above the walking surface at 700 seconds into the simulation.

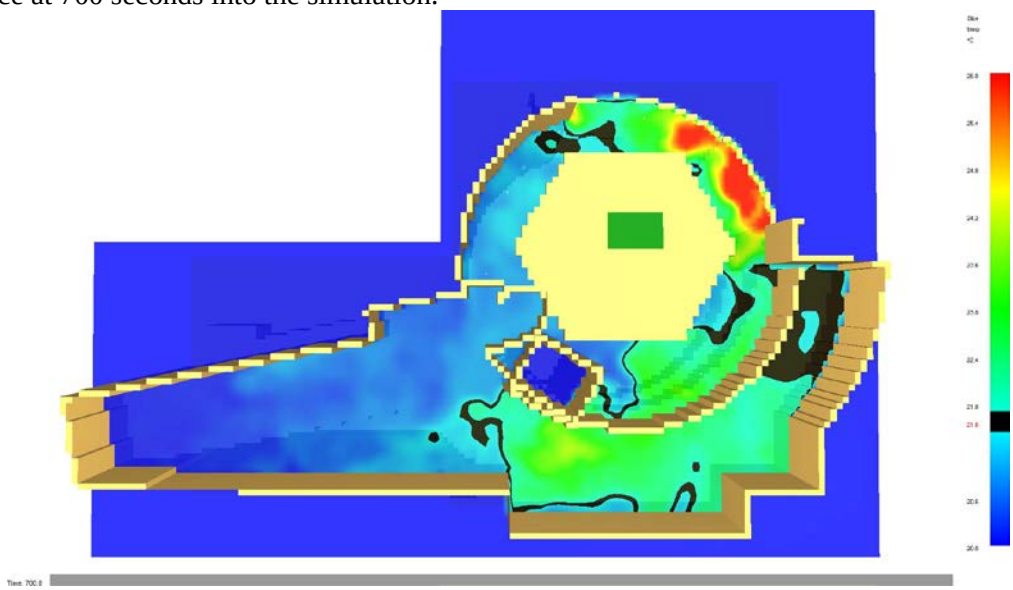


Figure 8-26 - Max temperature on path of egress

At 503 seconds into the simulation, Figure 8-27 shows complete failure of the visibility criteria on the third floor.

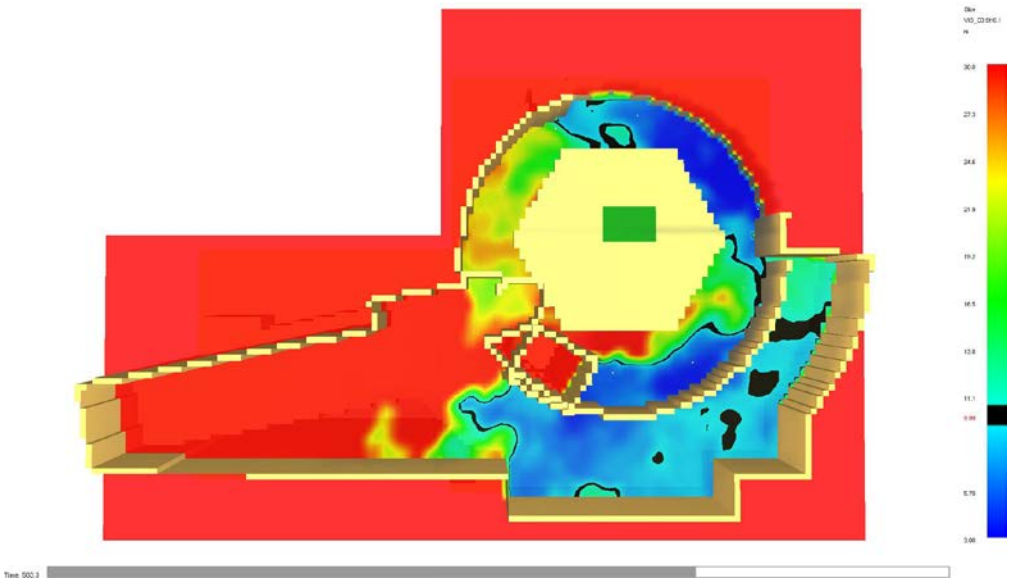


Figure 8-27 - Complete Visibility Failure on 3rd Floor Walkway

8.8.4 Summary

Visibility dropped below the tenability criteria for both Design Fire Scenarios #1 and #2. In design fire scenario #1, the failure occurred at 65 seconds which is well before the occupants have been able to safely evacuate. In design fire scenario #2, visibility began to drop below the tenability criteria of 6-feet above the third-floor walking surface at approximately 451 seconds. This is after the evacuation models calculated time to evacuation of 417 seconds. However, after we add 20% margin of safety, the RSET becomes 500 seconds. Thus, scenario also failed to meet the tenability criteria for visibility. No floors other than the third failed to maintain the established criteria for either simulation.

In a fully occupied facility of 2,866 people, it's extremely unlikely that the fire would go unnoticed for 203 seconds until the beam smoke detector alarmed and notification was sent to the building occupants to evacuate. If we assume that an occupant notices the fire and initiates a manual pull station in approximately 90 seconds from origin, the RSET with the margin of safety would be 364 seconds. At 364 seconds, design fire scenario #2 would have maintained tenability criteria and passed.

Temperature for both Design Fire Scenarios #1 and #2 was maintained well below the tenability criteria on all levels for the duration of the simulations.

9 Conclusions

A comprehensive fire protection and life safety evaluation was performed for the University Student Services Center. The evaluation considered both prescription and performance-based design aspects. The building was evaluated against current codes and not necessarily the codes of record that were used during its construction in 2003. The use of current codes rather than the codes of records was strictly for academic purposes. However, it was found that the fire protection and life safety systems installed in the facility are mostly compliant with the provisions in the current codes and standards.

Deficiencies noted during a walk-through of the facility revealed the following:

- The building has two stairwells that are provided 2-hour fire rated walls, large landings, and labeled as "Area of Refuge". These areas are not provided with two-way communication as required by code. Since the buildings is fully sprinklered and areas of refuge are not required, its it recommended that the university remove the signs labeling the stairwells as areas of refuge.
- The third-floor banquet hall is capable of being configured for a large variety of events. It was noted that textile draperies were regularly mounted on the walls and ceilings for aesthetic purposes. A university representative mentioned that the practice was deemed allowable by the local jurisdiction and that the draperies were treated with fire-retardant chemicals. The chemicals, listing or test method used on these draperies was not able to be determined at the time of the walk-through. However, it is recommended that the exit markings are not covered when using the decorative draperies.
- Overflow storage issues in the banquet halls storage room impede on the path of egress from the penthouse mechanical room. It is recommended that the proper housekeeping is performed, and the path kept clear.

The University Student services center is a three-story building with an atrium that connects all three floors at the main entrance. Per code, when an atrium connects more than two stories, the atrium is required to have a smoke control system. Performance of the smoke control system was evaluated using fire modeling. The time to evacuation for a fully occupied University Student Services Center with all exits available for use was calculated at approximately 180 seconds. For Scenario #1, the established tenability criteria failed at 65 seconds from when the fire was initiated which is well before the minimum time it would take the occupant to evacuate. In scenario #2, the tenability criteria failed partially failed at 451 seconds, 49 seconds prior to the 500 second RSET calculated. As currently installed and with the design fire scenarios evaluated, the smoke control system is not capable of maintaining tenable conditions throughout the required safe egress time

The following recommendations are proposed based off the results:

- Discontinue the use of Christmas tree at the base of the atrium for decoration during the holidays.
- Add secondary smoke detection devices in the atrium out coves for earlier detection and notification in the event a fire was to initiate from the outcove.
- Consider replacing exhaust fans with larger capacity fans,

10 References & Sources

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3. NFPA, NFPA 13: Standard for the Installation of Sprinkler Systems. Quincy. MA: National Fire Protection Association (2016)

4. NFPA, NFPA 25: Standard for Inspection, Testing and Maintenance of Water-Based Fire Protection Systems. Quincy. MA: National Fire Protection Association (2017)

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6. NFPA, NFPA 92: Standard for Smoke Control Systems. Quincy. MA: National Fire Protection Association (2015)

7. NFPA, NFPA 101: Life Safety Code. Quincy. MA: National Fire Protection Association (2015)

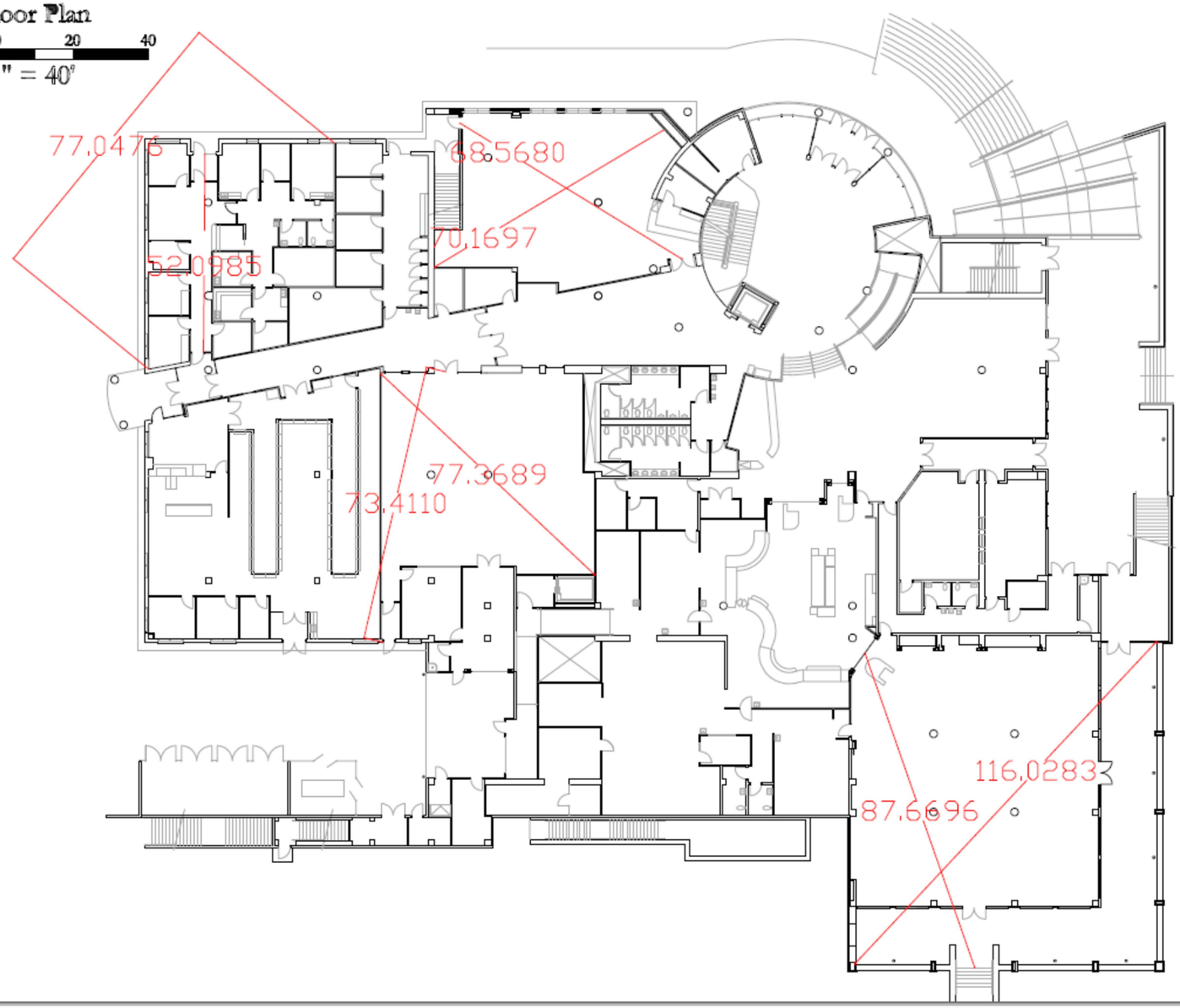
8. Olsson PA° , Regan MA (1998), A comparison between actual and predicated evacuation times. In: Proceedings of the first international symposium on human behaviour in fire. University of Ulster, pp 461–468. ISBN 1 85923 103 9.

Appendix A – Exit Remoteness

First Floor Plan

0 20 40

Scale: 1" = 40'



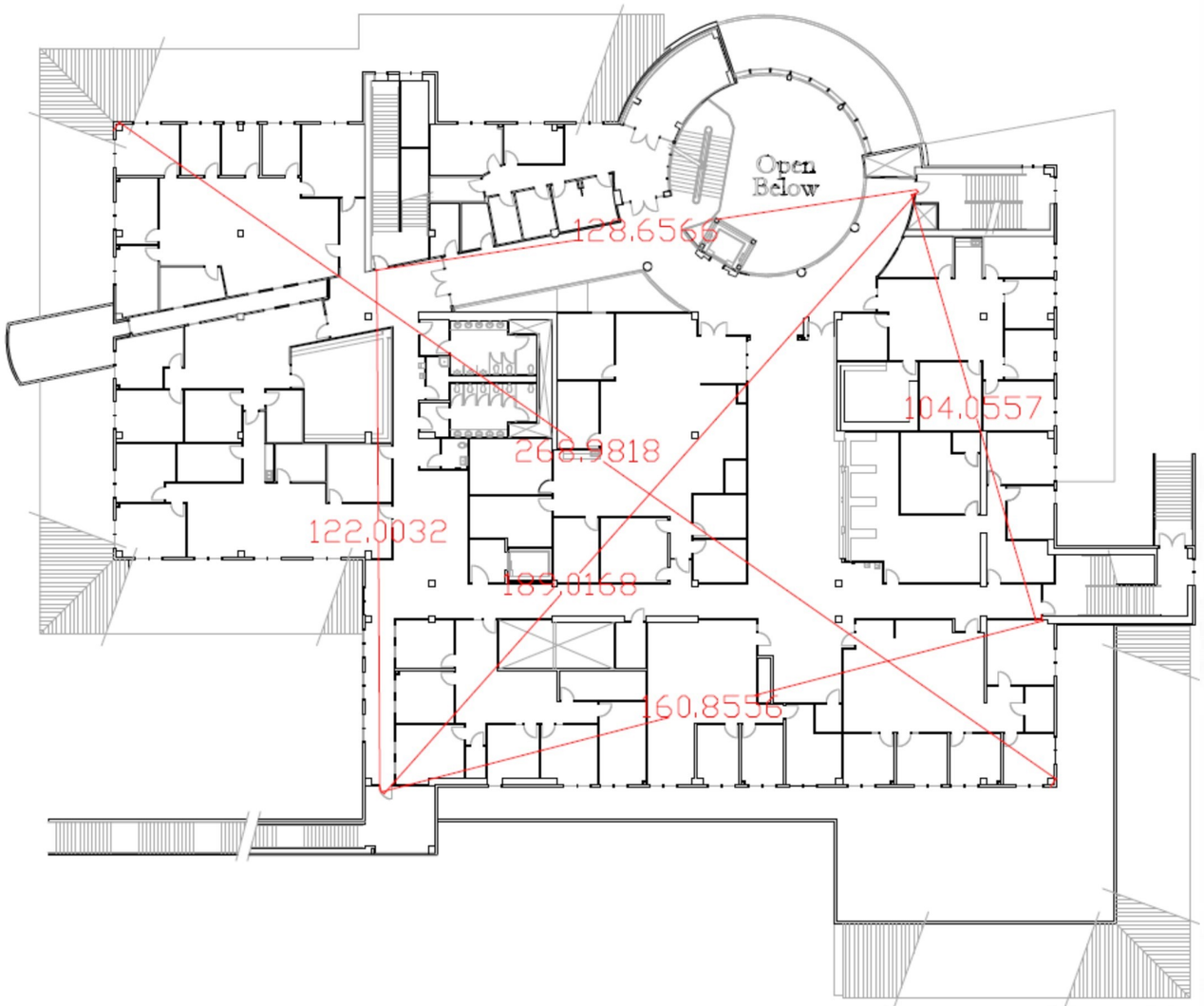
RM#	Description	SF	RM#	Description	SF
103	Commons	1,723	159	Exam Room	160
107	Janitor Closet	51	164	Work Area	81
111	Lounge	465	165	Office	165
114	Commons	1,583	166	Files	63
115	Office	63	167	Exam Room	170
116	Servery	2,250	168	Office	307
117	Café Seating	1,423	169	Office	115
118	Dining	4,590	170	Office	115
119	Ware Wash	554	171	Office	115
121	Kitchen	430	172	Office	107
124	Storage	466	173	Storage	51
125	Office	102	174	Work Area	478
128	Office	107	175	Electrical	92
130	Computer POD	563	176	MDF	133
131	Storage	82	181	Catering Prep	231
132	Storage	113	182	Kitchen	1,625
134	Shiping&Rcvng	404	183	Janitor Closet	41
135	Janitor Closet	43	184	Employee Area	156
136	Office	305	185	Kitchen	189
137	Bookstore	2,891	186	Storage	160
139	Shiping&Rcvng	1,582	187	Elev Equip	74
140	Storage	86	189	Office	109
141	Office	124	190	Game Room	2,455
142	Office	134	191	Office	159
143	Work Area	687	194	Storage	75
144	Box Lobby	794	197	Storage	51
145	Post Office	342			
148	Office	139			
149	Office	123			
150	Storage	80			
151	Waiting Room	155			
152	Exam Room	116			
153	Reception	59			
155	Files	90			
156	Lab	89			
157	Lab	94			
158	Storage	78			

1st Floor Net Assignable SF	**30,457**
1st Floor Gross Sq Ft	**42,703**
Building Floor Net Assignable SF	**62,122**
Building Floor Gross Sq Ft	**101,579**

Second Floor Plan

0 20 40

Scale: 1" = 40'



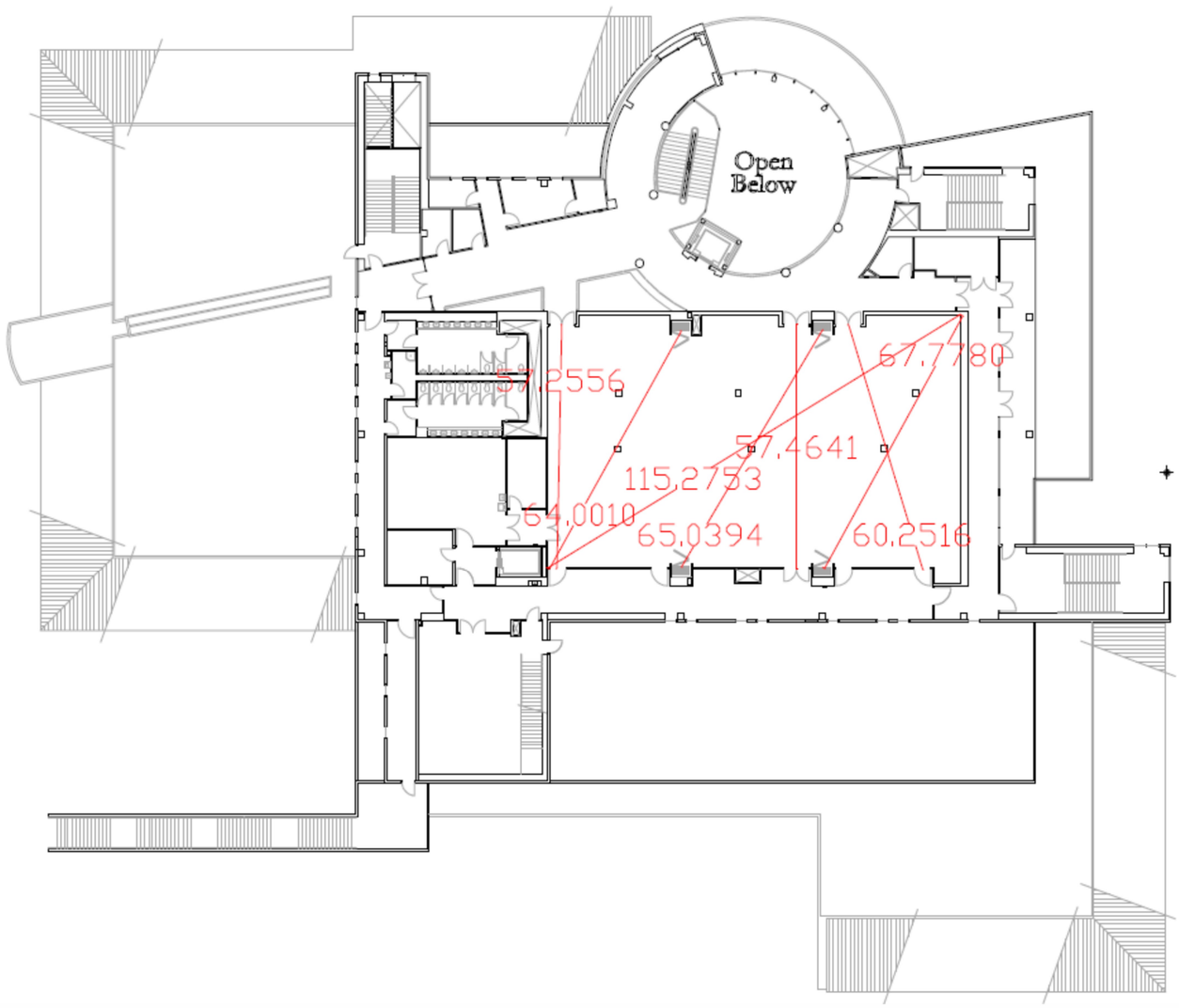
RM#	Description	SF	RM#	Description	SF
203	Admission	628	250	Office	208
204	Office	140	251	Office	181
206	Office	162	252	Files	137
207	Office	133	253	Work Area	556
208	Office	136	254	Work Area	540
209	Office	196	255	Storage	106
210	Storage	240	256	Supplies	104
211	Work Room	310	258	Conference	163
212	Office	134	259	Office	194
214	Office	217	260	Office	184
216	Office/Work Area	723	261	Conference	255
218	Files	326	262	Work Area	967
220	Office	240	263	Office	111
221	Office	141	264	Office	109
222	Office/Work Area	936	265	Office	111
223	Files	241	266	Office	180
224	Storage	77	267	Office	155
225	Office	145	268	Office	162
226	Office	145	269	Office	131
227	Office	149	271	Electrical	85
228	Study	148	272	IDF	79
229	Electrical	42	275	Waiting	447
230	IDF	80	276	Library	328
231	Work Area	808	279	Office	128
232	Office	204	280	Office	198
233	Office	143	281	Storage	72
234	Office	141	282	Office	70
236	Work Area	496	283	Office	91
237	Office	156	284	Office	163
238	Office	170	285	Work Area	1,561
239	Office	215	286	Office	128
240	Storage	36	287	Office	128
241	Office	158	288	Conference	245
242	Office	184	289	Office	210
243	Storage	144	290	Storage	212
244	Office	218	291	Storage	254
247	Work Area	894	292	Office	155
248	Conference RM	209	293	Office	168

2nd Floor Net Assignable SF	**19,141**
2nd Floor Gross Sq Ft	**32,704**
Building Floor Net Assignable SF	**62,122**
Building Floor Gross Sq Ft	**101,579**

Third Floor Plan

0 20 40

Scale: 1" = 40'



RM#	Description	SF
302	Banquet Hall	5,930 sf
309	Storage	844 sf
311	Prep Room	669 sf
312	Storage	157 sf
313	Prep Room	208 sf
318	Janitor Closet	62 sf
323	Electrical	75 sf
324	ISD	69 sf
326	Office	228 sf
333	Copy Room	80 sf
334	Storage	181 sf

3rd Floor Net Assignable SF	**8,503**
3rd Floor Gross Sq Ft	**21,072**
Building Floor Net Assignable SF	**62,122**
Building Floor Gross Sq Ft	**101,579**

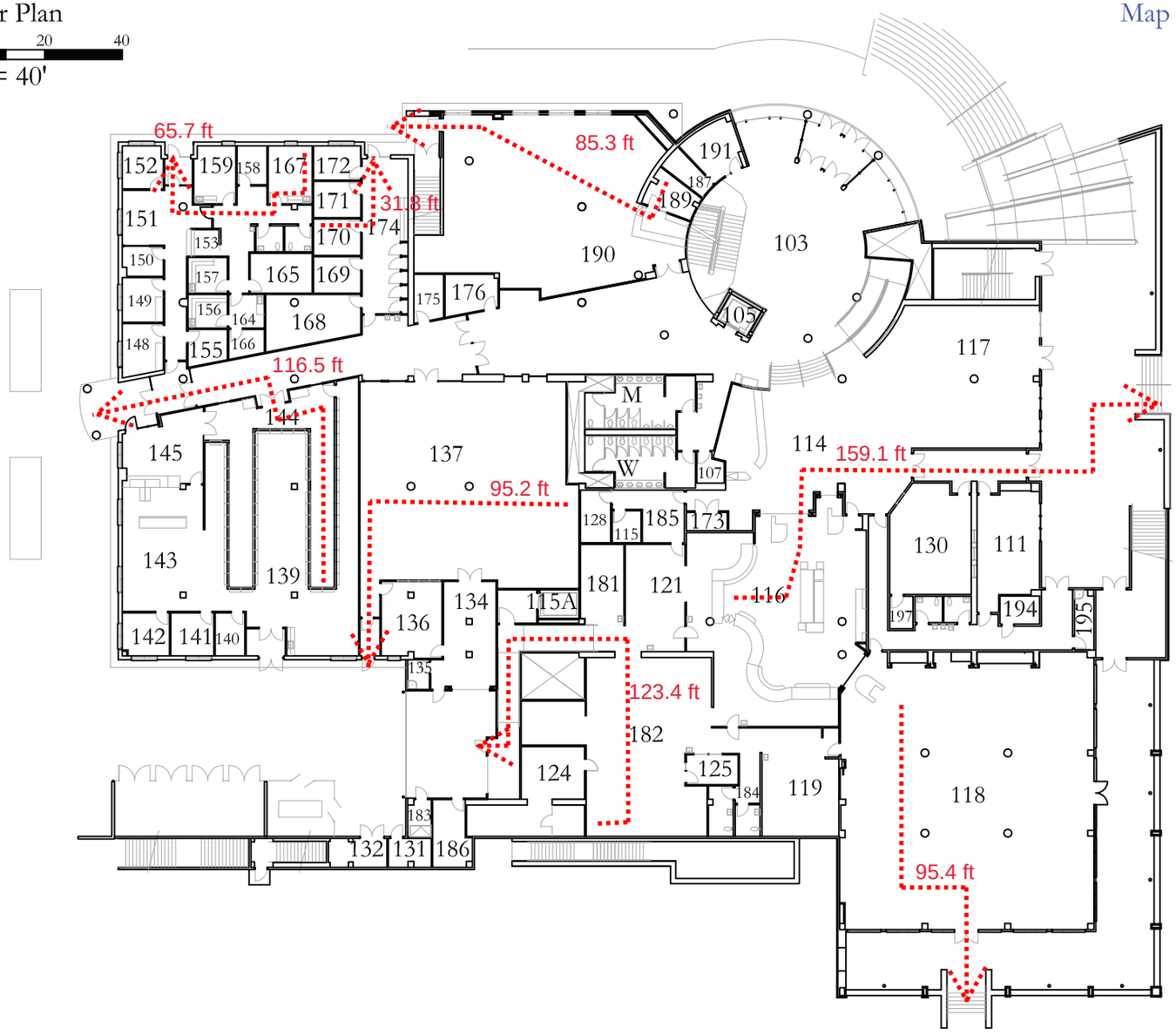
Appendix B – Travel Distance to Exits

First Floor Plan

0 20 40

Scale: 1" = 40'

Map Grid: I-19



RM#	Description	SF	RM#	Description	SF
103	Commons	1,723	159	Exam Room	160
107	Janitor Closet	51	164	Work Area	81
111	Lounge	465	165	Office	165
114	Commons	1,583	166	Files	63
115	Office	63	167	Exam Room	170
116	Servery	2,250	168	Office	307
117	Café Seating	1,423	169	Office	115
118	Dining	4,590	170	Office	115
119	Ware Wash	554	171	Office	115
121	Kitchen	430	172	Office	107
124	Storage	466	173	Storage	51
125	Office	102	174	Work Area	478
128	Office	107	175	Electrical	92
130	Computer POD	563	176	MDF	133
131	Storage	82	181	Catering Prep	231
132	Storage	113	182	Kitchen	1,625
134	Shiping&Rcvng	404	183	Janitor Closet	41
135	Janitor Closet	43	184	Employee Area	156
136	Office	305	185	Kitchen	189
137	Bookstore	2,891	186	Storage	160
139	Shiping&Rcvng	1,582	187	Elev Equip	74
140	Storage	86	189	Office	109
141	Office	124	190	Game Room	2,455
142	Office	134	191	Office	159
143	Work Area	687	194	Storage	75
144	Box Lobby	794	197	Storage	51
145	Post Office	342			
148	Office	139			
149	Office	123			
150	Storage	80			
151	Waiting Room	155			
152	Exam Room	116			
153	Reception	59			
155	Files	90			
156	Lab	89			
157	Lab	94			
158	Storage	78			

1st Floor Net Assignable SF	30,457
1st Floor Gross Sq Ft	42,703
Building Floor Net Assignable SF	62,122
Building Floor Gross Sq Ft	101,579

Second Floor Plan

0 20 40

Scale: 1" = 40'

Map Grid: I-19

RM#	Description	SF	RM#	Description	SF
203	Admission	628	250	Office	208
204	Office	140	251	Office	181
206	Office	162	252	Files	137
207	Office	133	253	Work Area	556
208	Office	136	254	Work Area	540
209	Office	196	255	Storage	106
210	Storage	240	256	Supplies	104
211	Work Room	310	258	Conference	163
212	Office	134	259	Office	194
214	Office	217	260	Office	184
216	Office/Work Area	723	261	Conference	255
218	Files	326	262	Work Area	967
220	Office	240	263	Office	111
221	Office	141	264	Office	109
222	Office/Work Area	936	265	Office	111
223	Files	241	266	Office	180
224	Storage	77	267	Office	155
225	Office	145	268	Office	162
226	Office	145	269	Office	131
227	Office	149	271	Electrical	85
228	Study	148	272	IDF	79
229	Electrical	42	275	Waiting	447
230	IDF	80	276	Library	328
231	Work Area	808	279	Office	128
232	Office	204	280	Office	198
233	Office	143	281	Storage	72
234	Office	141	282	Office	70
236	Work Area	496	283	Office	91
237	Office	156	284	Office	163
238	Office	170	285	Work Area	1,561
239	Office	215	286	Office	128
240	Storage	36	287	Office	128
241	Office	158	288	Conference	245
242	Office	184	289	Office	210
243	Storage	144	290	Storage	212
244	Office	218	291	Storage	254
247	Work Area	894	292	Office	155
248	Conference RM	209	293	Office	168

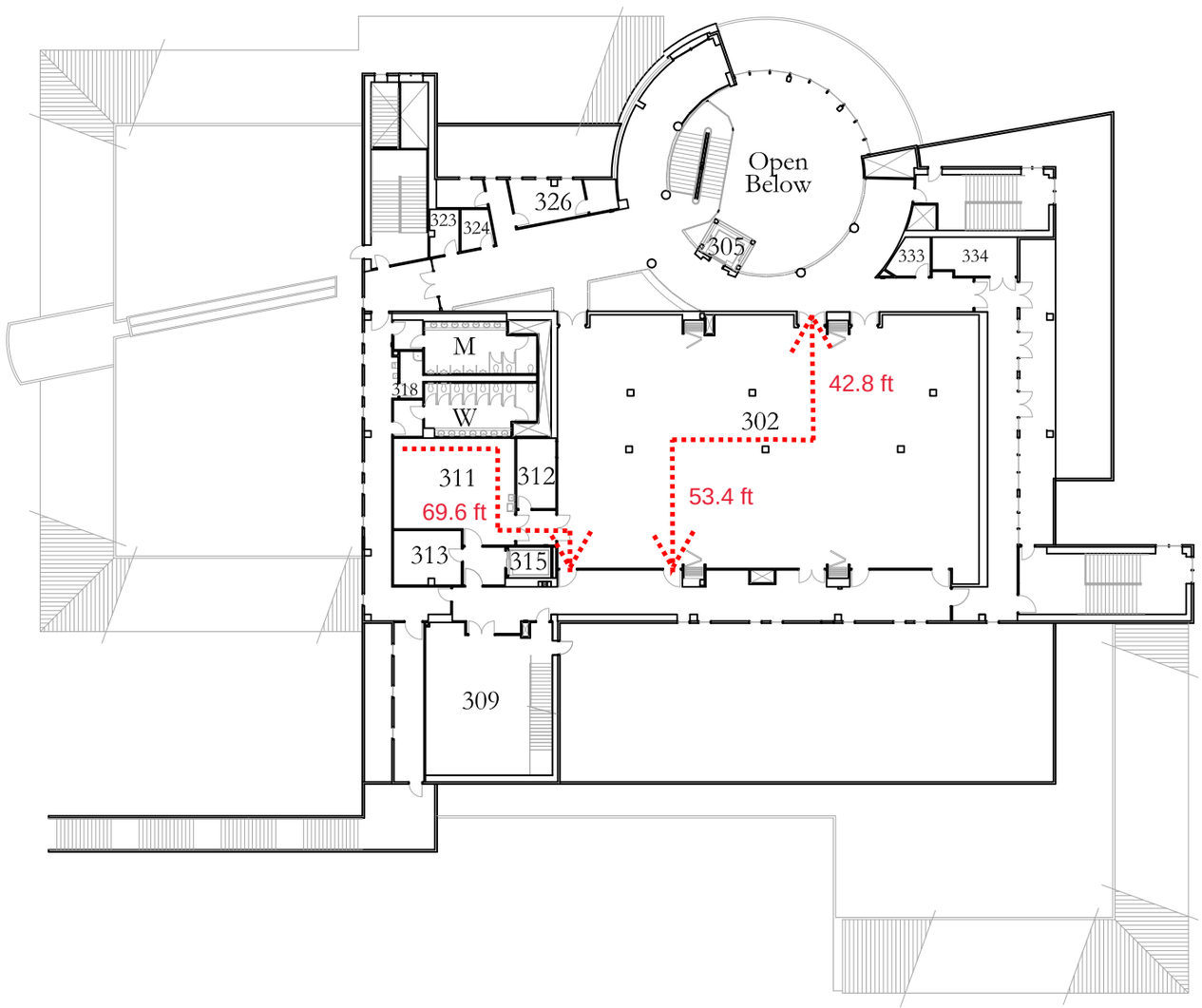
2nd Floor Net Assignable SF	19,141
2nd Floor Gross Sq Ft	32,704
Building Floor Net Assignable SF	62,122
Building Floor Gross Sq Ft	101,579

Third Floor Plan

0 20 40

Scale: 1" = 40'

Map Grid: I-19



RM#	Description	SF
302	Banquet Hall	5,930 sf
309	Storage	844 sf
311	Prep Room	669 sf
312	Storage	157 sf
313	Prep Room	208 sf
318	Janitor Closet	62 sf
323	Electrical	75 sf
324	ISD	69 sf
326	Office	228 sf
333	Copy Room	80 sf
334	Storage	181 sf

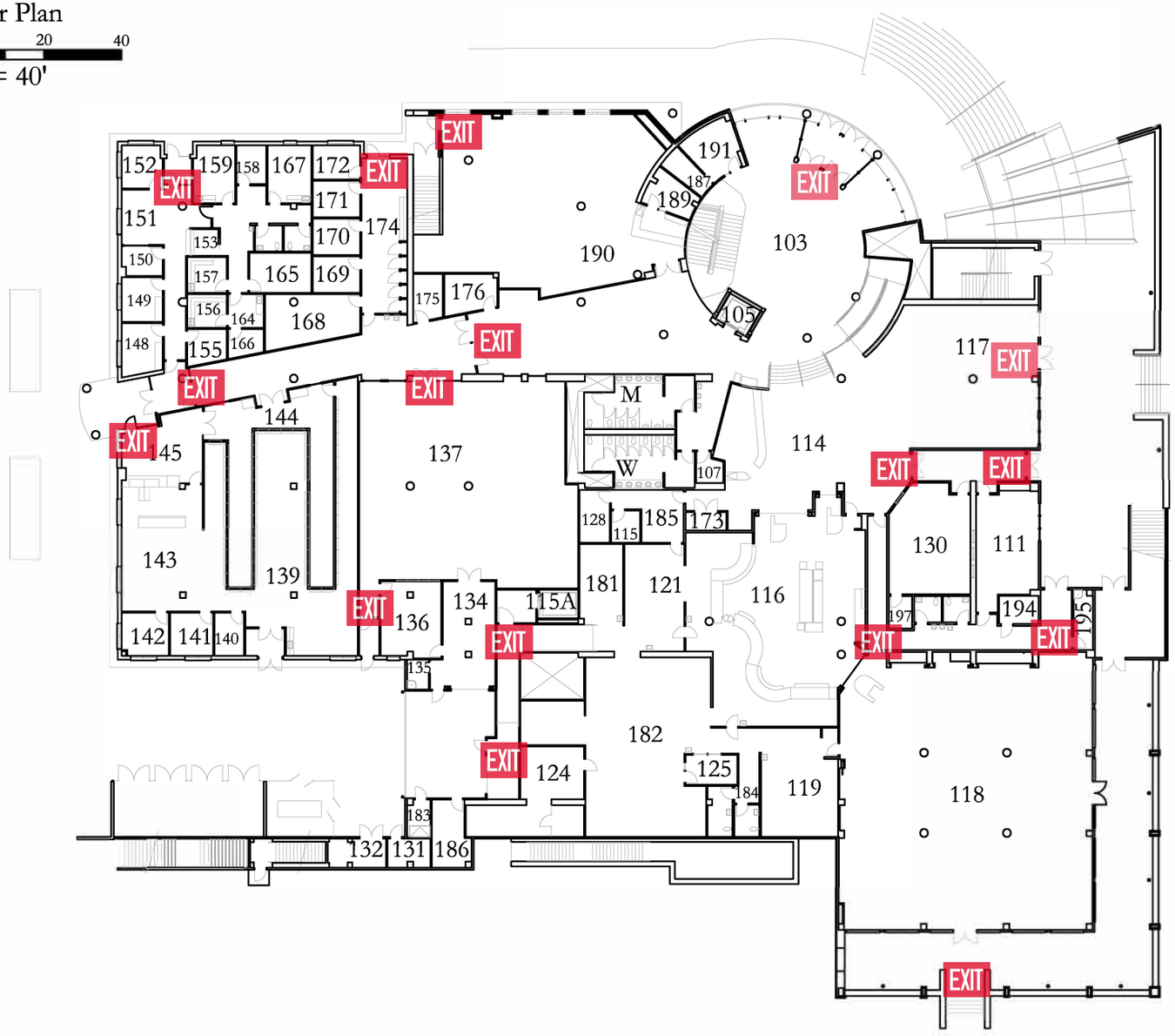
3rd Floor Net Assignable SF	**8,503**
3rd Floor Gross Sq Ft	**21,072**
Building Floor Net Assignable SF	**62,122**
Building Floor Gross Sq Ft	**101,579**

Appendix C – Exit Sign Location

First Floor Plan

0 20 40

Scale: 1" = 40'



RM#	Description	SF	RM#	Description	SF
103	Commons	1,723	159	Exam Room	160
107	Janitor Closet	51	164	Work Area	81
111	Lounge	465	165	Office	165
114	Commons	1,583	166	Files	63
115	Office	63	167	Exam Room	170
116	Servery	2,250	168	Office	307
117	Café Seating	1,423	169	Office	115
118	Dining	4,590	170	Office	115
119	Ware Wash	554	171	Office	115
121	Kitchen	430	172	Office	107
124	Storage	466	173	Storage	51
125	Office	102	174	Work Area	478
128	Office	107	175	Electrical	92
130	Computer POD	563	176	MDF	133
131	Storage	82	181	Catering Prep	231
132	Storage	113	182	Kitchen	1,625
134	Shiping&Rcvng	404	183	Janitor Closet	41
135	Janitor Closet	43	184	Employee Area	156
136	Office	305	185	Kitchen	189
137	Bookstore	2,891	186	Storage	160
139	Shiping&Rcvng	1,582	187	Elev Equip	74
140	Storage	86	189	Office	109
141	Office	124	190	Game Room	2,455
142	Office	134	191	Office	159
143	Work Area	687	194	Storage	75
144	Box Lobby	794	197	Storage	51
145	Post Office	342			
148	Office	139			
149	Office	123			
150	Storage	80			
151	Waiting Room	155			
152	Exam Room	116			
153	Reception	59			
155	Files	90			
156	Lab	89			
157	Lab	94			
158	Storage	78			

1st Floor Net Assignable SF	30,457
1st Floor Gross Sq Ft	42,703
Building Floor Net Assignable SF	62,122
Building Floor Gross Sq Ft	101,579

Second Floor Plan

0 20 40

Scale: 1" = 40'

RM#	Description	SF	RM#	Description	SF
203	Admission	628	250	Office	208
204	Office	140	251	Office	181
206	Office	162	252	Files	137
207	Office	133	253	Work Area	556
208	Office	136	254	Work Area	540
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211	Work Room	310	258	Conference	163
212	Office	134	259	Office	194
214	Office	217	260	Office	184
216	Office/Work Area	723	261	Conference	255
218	Files	326	262	Work Area	967
220	Office	240	263	Office	111
221	Office	141	264	Office	109
222	Office/Work Area	936	265	Office	111
223	Files	241	266	Office	180
224	Storage	77	267	Office	155
225	Office	145	268	Office	162
226	Office	145	269	Office	131
227	Office	149	271	Electrical	85
228	Study	148	272	IDF	79
229	Electrical	42	275	Waiting	447
230	IDF	80	276	Library	328
231	Work Area	808	279	Office	128
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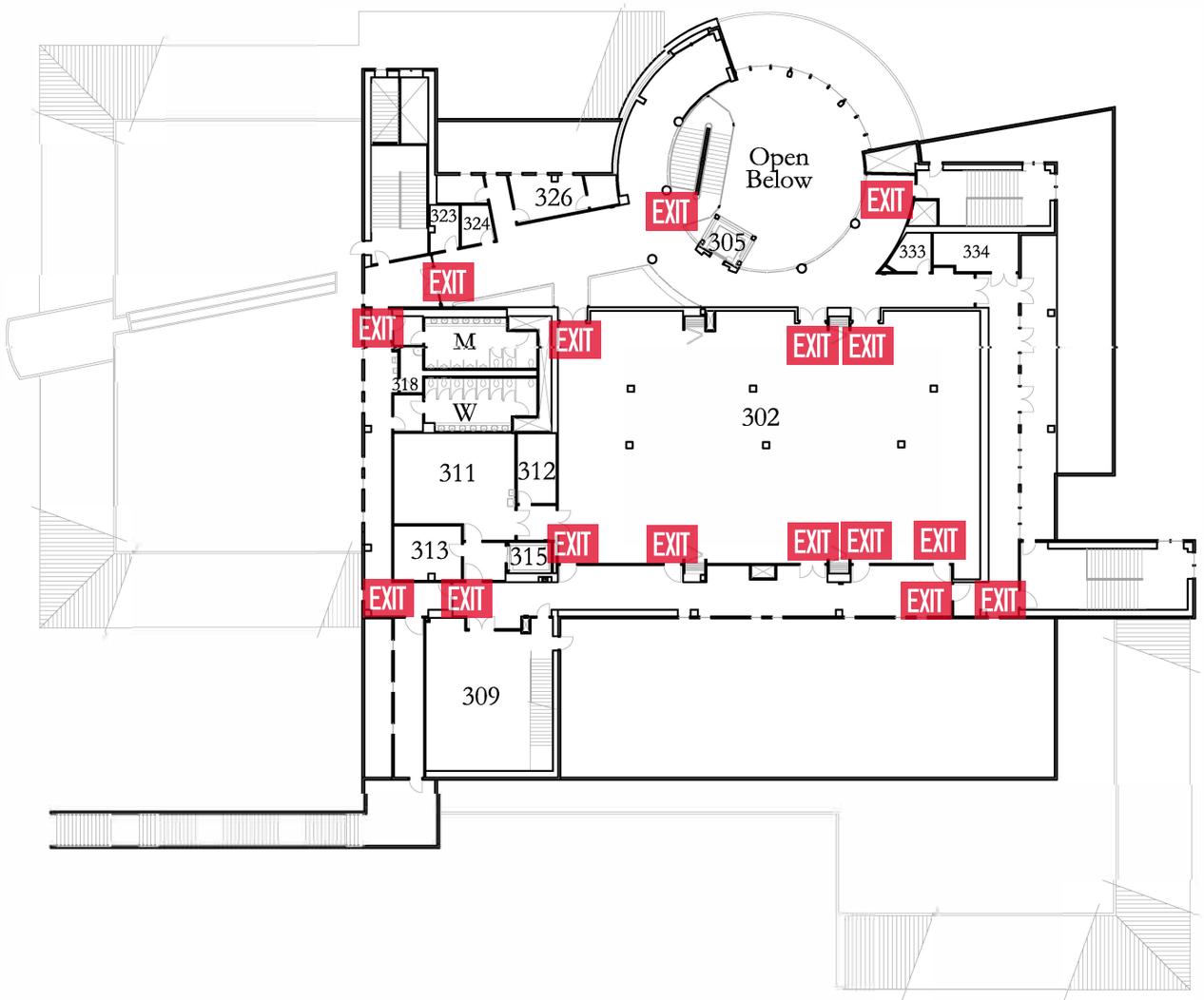
237	Office	156	284	Office	163
238	Office	170	285	Work Area	1,561
239	Office	215	286	Office	128
240	Storage	36	287	Office	128
241	Office	158	288	Conference	245
242	Office	184	289	Office	210
243	Storage	144	290	Storage	212
244	Office	218	291	Storage	254
247	Work Area	894	292	Office	155
248	Conference RM	209	293	Office	168

2nd Floor Net Assignable SF	**19,141**
2nd Floor Gross Sq Ft	**32,704**
Building Floor Net Assignable SF	**62,122**
Building Floor Gross Sq Ft	**101,579**

Third Floor Plan

0 20 40

Scale: 1" = 40'



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309	Storage	844 sf
311	Prep Room	669 sf
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313	Prep Room	208 sf
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323	Electrical	75 sf
324	ISD	69 sf
326	Office	228 sf
333	Copy Room	80 sf
334	Storage	181 sf

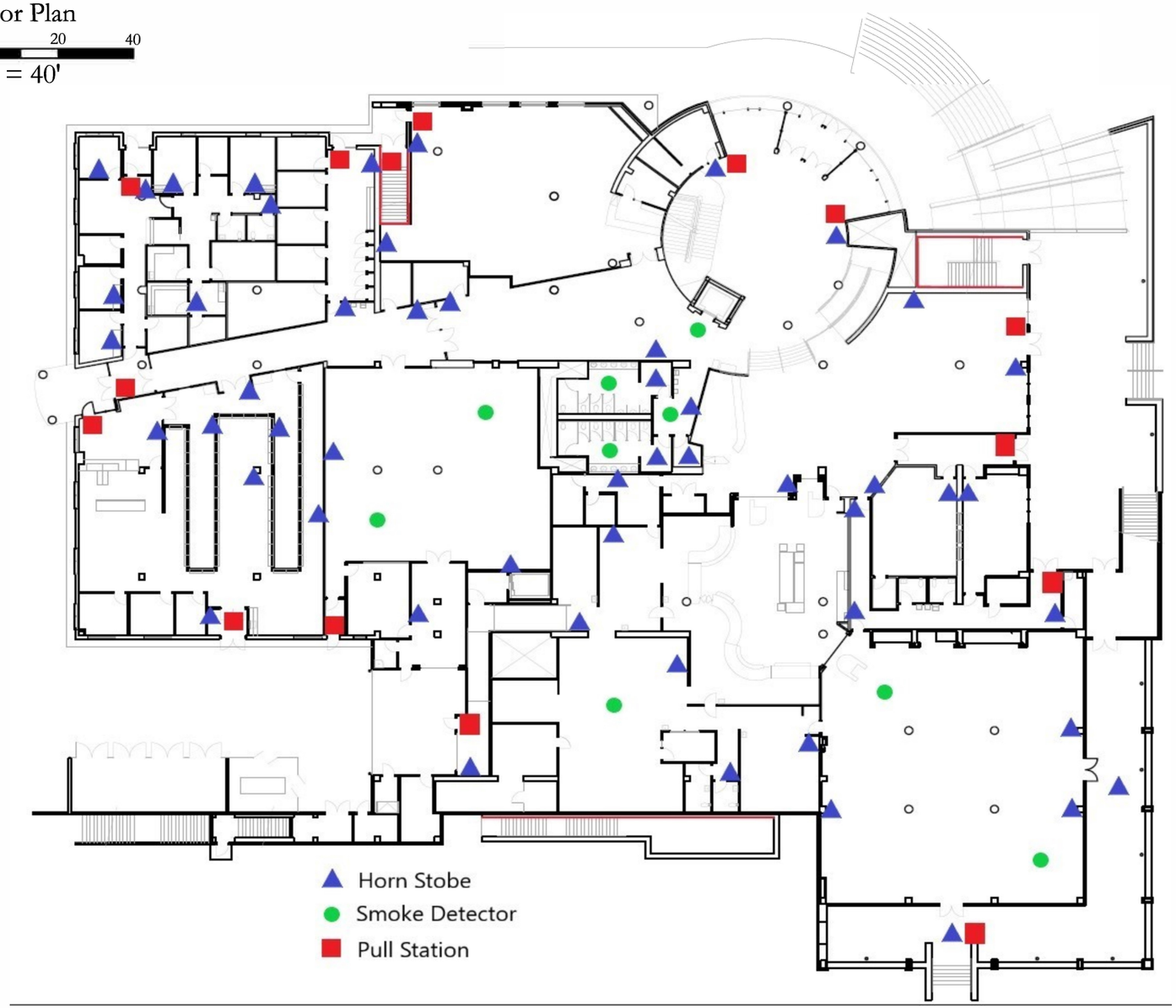
3rd Floor Net Assignable SF	**8,503**
3rd Floor Gross Sq Ft	**21,072**
Building Floor Net Assignable SF	**62,122**
Building Floor Gross Sq Ft	**101,579**

Appendix D – Fire Alarm System Layouts

First Floor Plan

0 20 40

Scale: 1" = 40'



RM#	Description	SF	RM#	Description	SF
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107	Janitor Closet	51	164	Work Area	81
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121	Kitchen	430	172	Office	107
124	Storage	466	173	Storage	51
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132	Storage	113	182	Kitchen	1,625
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135	Janitor Closet	43	184	Employee Area	156
136	Office	305	185	Kitchen	189
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143	Work Area	687	194	Storage	75
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145	Post Office	342			
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150	Storage	80			
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153	Reception	59			
155	Files	90			
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157	Lab	94			
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1st Floor Net Assignable SF	30,457
1st Floor Gross Sq Ft	42,703
Building Floor Net Assignable SF	62,122
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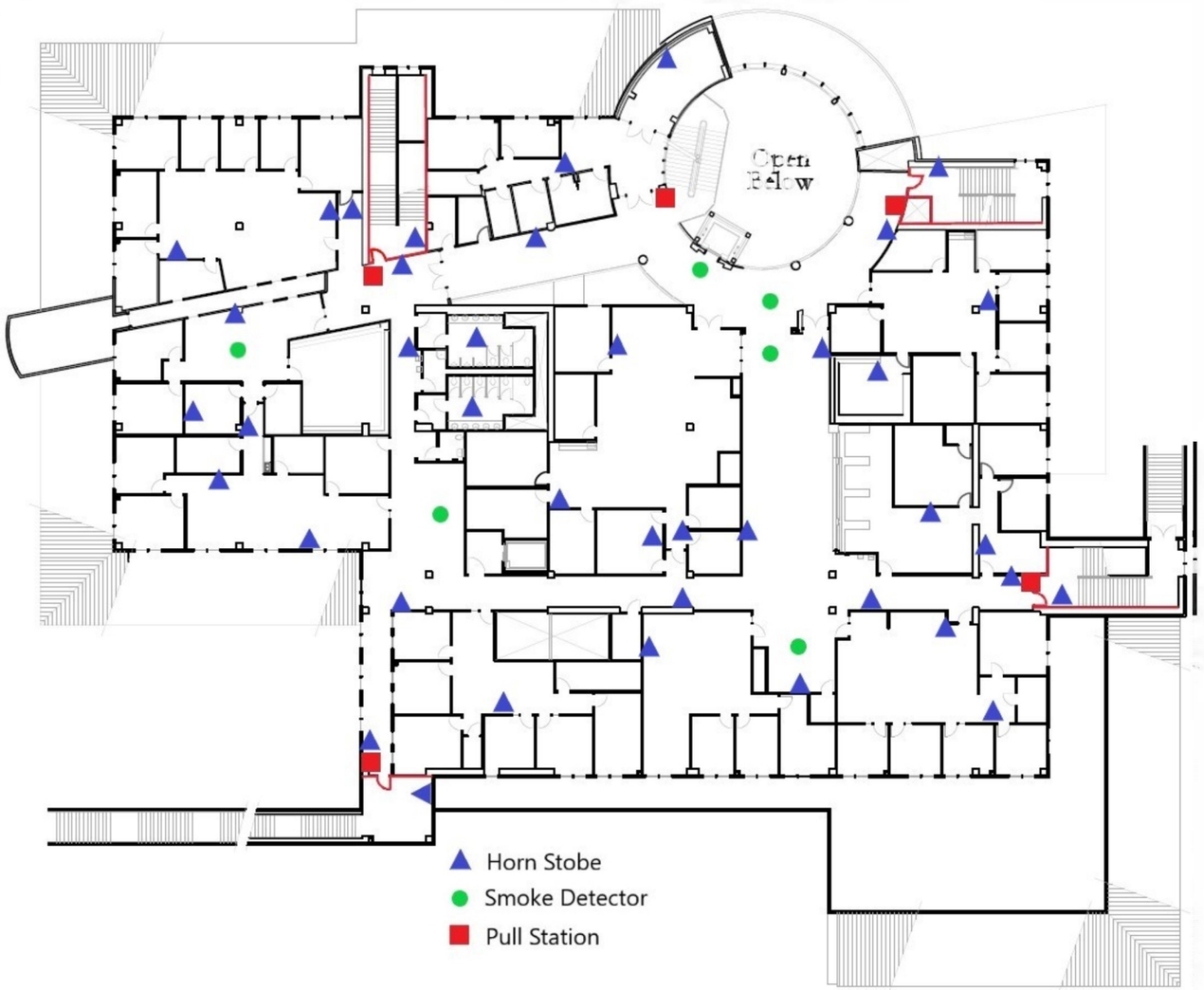
Second Floor Plan

0 20 40

Scale: 1" = 40'



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223	Files	241	266	Office	180
224	Storage	77	267	Office	155
225	Office	145	268	Office	162
226	Office	145	269	Office	131
227	Office	149	271	Electrical	85
228	Study	148	272	IDF	79
229	Electrical	42	275	Waiting	447
230	IDF	80	276	Library	328
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2nd Floor Net Assignable SF	**19,141**
2nd Floor Gross Sq Ft	**32,704**
Building Floor Net Assignable SF	**62,122**
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Third Floor Plan

0 20 40

Scale: 1" = 40'

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3rd Floor Net Assignable SF	**8,503**
3rd Floor Gross Sq Ft	**21,072**
Building Floor Net Assignable SF	**62,122**
Building Floor Gross Sq Ft	**101,579**

Appendix E - Fire Scenario 1 Code

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Generated by PyroSim - Version 2018.1.0329
May 9, 2018 8:33:40 PM

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--------------------PyroSim-generated Section--------------------

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SURF_ID='INERT'/
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&VENT ID='Vent', SURF_ID='Smoke Extraction',
XB=56.457862,58.68277,51.922211,53.601005,14.266,14.266, CTRL_ID='Control01'/
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&SLCF QUANTITY='TEMPERATURE', VECTOR=.TRUE., PBZ=6.7508/
&SLCF QUANTITY='TEMPERATURE', VECTOR=.TRUE., PBZ=11.3228/
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&TAIL /
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Appendix F - Fire Scenario 2 Code

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Atrium_couch_supply_air.fds
Generated by PyroSim - Version 2018.1.0329
Aug 1, 2018 6:12:31 PM

-------------User Section (not generated by PyroSim)-------------

&VENT SURF_ID='OPEN', MB='XMIN'/
&VENT SURF_ID='OPEN', MB='XMAX'/
&VENT SURF_ID='OPEN', MB='YMIN'/
&VENT SURF_ID='OPEN', MB='YMAX'/
&VENT SURF_ID='OPEN', MB='ZMAX'/

--------------------PyroSim-generated Section--------------------

&HEAD CHID='Atrium_couch_supply_air'/
&TIME T_END=700.0/
&DUMP RENDER_FILE='Atrium_couch_supply_air.ge1', COLUMN_DUMP_LIMIT=.TRUE.,
DT_RESTART=300.0, DT_SL3D=0.25/

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&MESH ID='Mesh03-c-b', IJK=78,56,60, XB=49.5,69.0,38.5,52.5,0.0,15.0/
&MESH ID='Mesh03-d', IJK=78,42,60, XB=49.5,69.0,52.5,63.0,0.0,15.0/

&SPEC ID='WATER VAPOR'/

&PART ID='Water',
      SPEC_ID='WATER VAPOR',
      DIAMETER=500.0,
      MONODISPERSE=.TRUE.,
      AGE=60.0,
      SAMPLING_FACTOR=1/

&REAC ID='POLYURETHANE_GM27',
      FYI='SFPE Handbook, GM27',
      FUEL='REAC_FUEL',
      C=1.0,
      H=1.7,
      O=0.3,
      N=0.08,
      CO_YIELD=0.042,
      SOOT_YIELD=0.198/

&PROP ID='Default_Water Spray',
      QUANTITY='SPRINKLER LINK TEMPERATURE',
      ACTIVATION_TEMPERATURE=74.0,
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      FLOW_RATE=1.0,
      PARTICLE_VELOCITY=5.0,
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SETPOINT=0.14/
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&DEVC ID='SPRK07', PROP_ID='Default_Water Spray', XYZ=54.514271,56.795348,14.266/
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&DEVC ID='SPRK11', PROP_ID='Default_Water Spray', XYZ=62.421547,50.049331,14.266/
&DEVC ID='SPRK12', PROP_ID='Default_Water Spray', XYZ=61.222205,56.561651,14.266/
&DEVC ID='SPRK13', PROP_ID='Default_Water Spray', XYZ=63.072822,53.389165,14.266/
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      TRANSPARENCY=0.254902/
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      RGB=26,128,26,
      VOLUME_FLOW=45.5/
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      HRRPUA=919.29,
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