Appendix

The appendix expands on three significant topics introduced Part II of the FCMP. Each topic grows out of an emerging priority initiative contained therein. Each requires ambitious planning efforts to inform and complement laboratory planning processes. Together, these complex, interrelated and interdependent issues are vital components to developing and implementing a complete and consistent 20 year laboratory plan. The three are:

- Strategically assess campus buildings
- Strategically assess campus utilities
- Establish design guidelines

The appendix is a means to kick start an organizational process to guide further study. Ultimately, by the year 2020, the laboratory hopes to publish each topic as a freestanding institutional companion document to the Fermilab Campus Master Plan.

Index

1.0 Strategically Assess Campus Buildings

1.1 Introduction

Fermilab currently has 364 individual buildings totaling 2.49 million square feet constructed over a period of 115 years. One-hundred twenty-seven of these building 35% were already on site at the 1967 founding of the laboratory. At that time they were repurposed for laboratory use. From 1969-1970, 21 temporary buddings were constructed on the site for laboratory usage. During the Wilson Years, 163 new building were constructed on the site. As of this writing, 1.4 million square feet of building area, making up 60% of Fermilab's total, are over 40 years old.

Relationship to the Fermilab Campus Master Plan - As Fermilab celebrated its 50th anniversary in 2017, the laboratory is clearly embracing its next era of science. Important global particle physics research initiatives are under way, and others are well along in their planning and development. In response to these circumstances, the Fermilab Campus Master Plan (FCMP) was developed to guide the transition of laboratory facilities to support the next era. The FCMP is a "twenty-year transformational plan creating a state of the art, open inviting and collaborative international research community for 21st century science.

The FCMP presents several initiatives to realize that transition. One vital initiative, and the subject of this part of the appendix, is the assessment and strategic alignment of the buildings on the campus with the 20 year vision.

Ready for the future? Accomplishing this transformation requires that a substantial number of legacy buildings be strategically assessed to determine their suitability and readiness for the next era of science. As described in Part I of the FCMP, construction of the campus buildings has been 115 years in the making. Development both surged and declined at various periods, leading to a phenomenon referred to as block obsolescence, a condition resulting from large numbers of buildings reaching their usable end simultaneously.

Repurpose, replace, retire, renovate? Questions about these aging facilities need to be answered. To frame and kick off an effort to find those answers, the campus planning team created this appendix for the FCMP. Providing bulk building data, as well as a first pass at assessment criteria, it creates a foundation for a soon-to-be convened team to build upon.

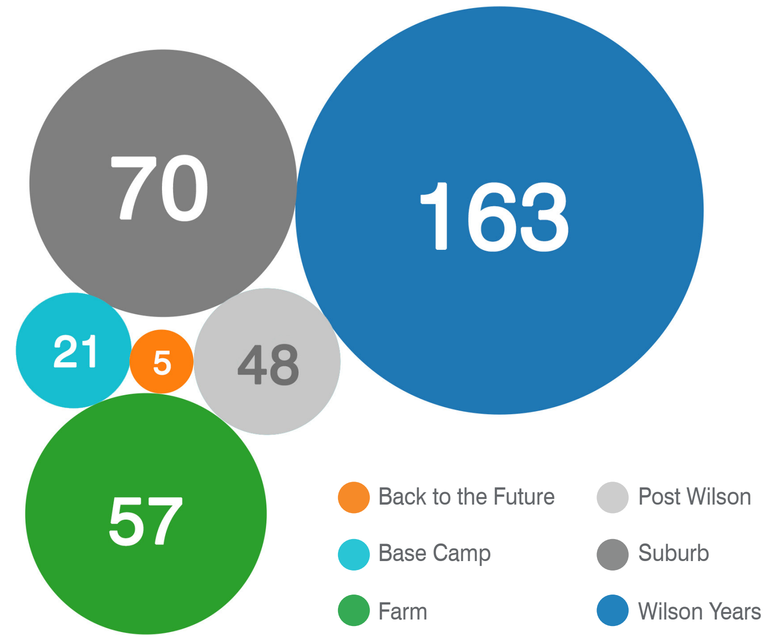
The teams work will ultimately result in a formalized long-term planning document. The document is imagined as a one-stop, core, institutional resource documenting the plan and a companion document to the FCMP.

The pages that follow describe the above referenced building data and assessment criteria. Part 4 at the end of this appendix illustrates the proposed timeline for development and publication of the Strategic Facility Assessment Plan.

1.2 Building Data

Composition by era constructed	Quantity	
	Total / Era	**%**
Farm *(1912 - 1962)*	57	16%
Suburb *(1963)*	70	19%
Base Camp *(1969 - 1970)*	21	6%
Wilson Years *(1971 - 1993)*	163	45%
Post Wilson *(1994 - 2008)*	48	13%
Back to the Future *(2009 - Now)*	5	1%
Totals	**364**	

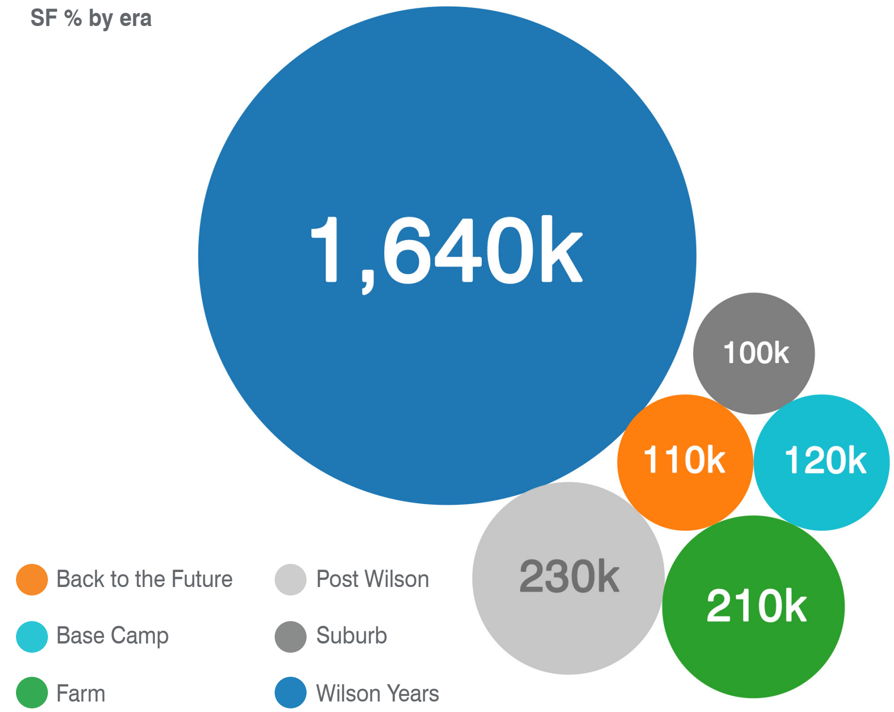
Quantity by era



Color indicates. Size shows sum of quantity.

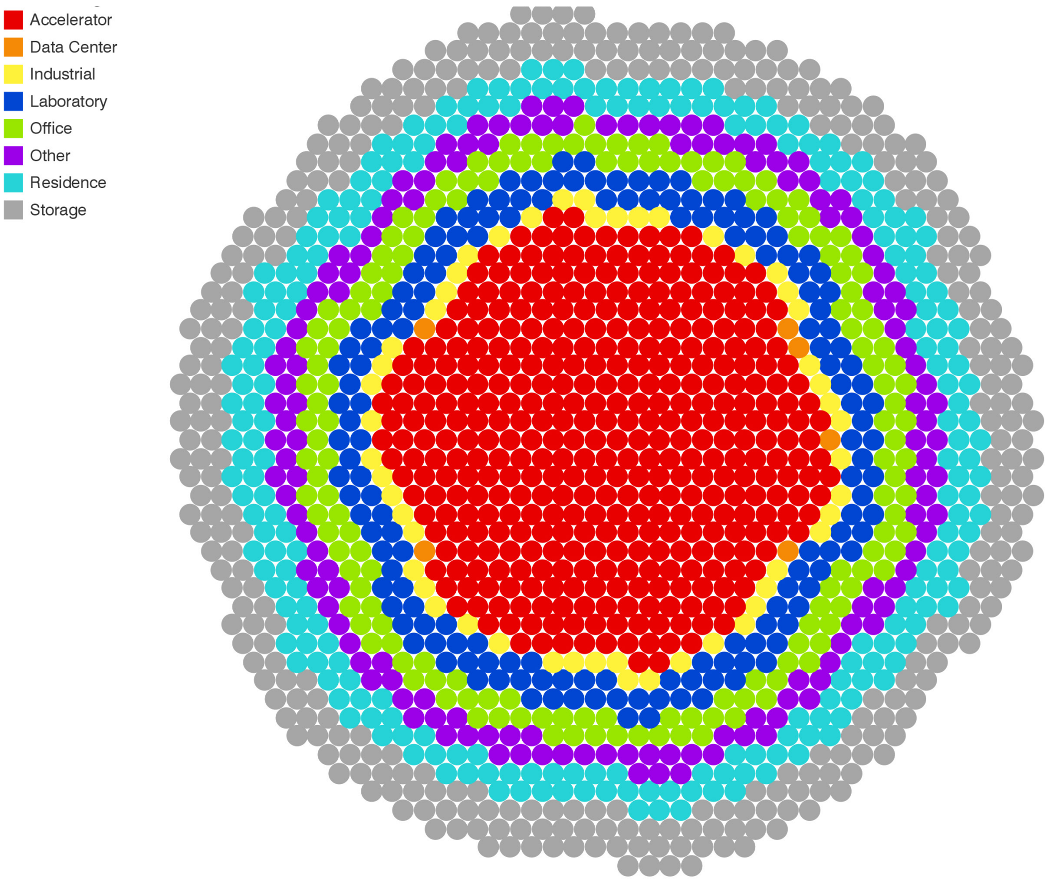
Composition by era constructed	Area	
	SF	%
Farm *(1912 - 1962)*	210K	9%
Suburb *(1963)*	100K	4%
Base Camp *(1969 - 1970)*	120K	5%
Wilson Years *(1971 - 1993)*	1,640K	67%
Post Wilson *(1994 - 2008)*	230K	10%
Back to the Future *(2009 - Now)*	110K	5%
Totals	**2,410K**	

SF % by era

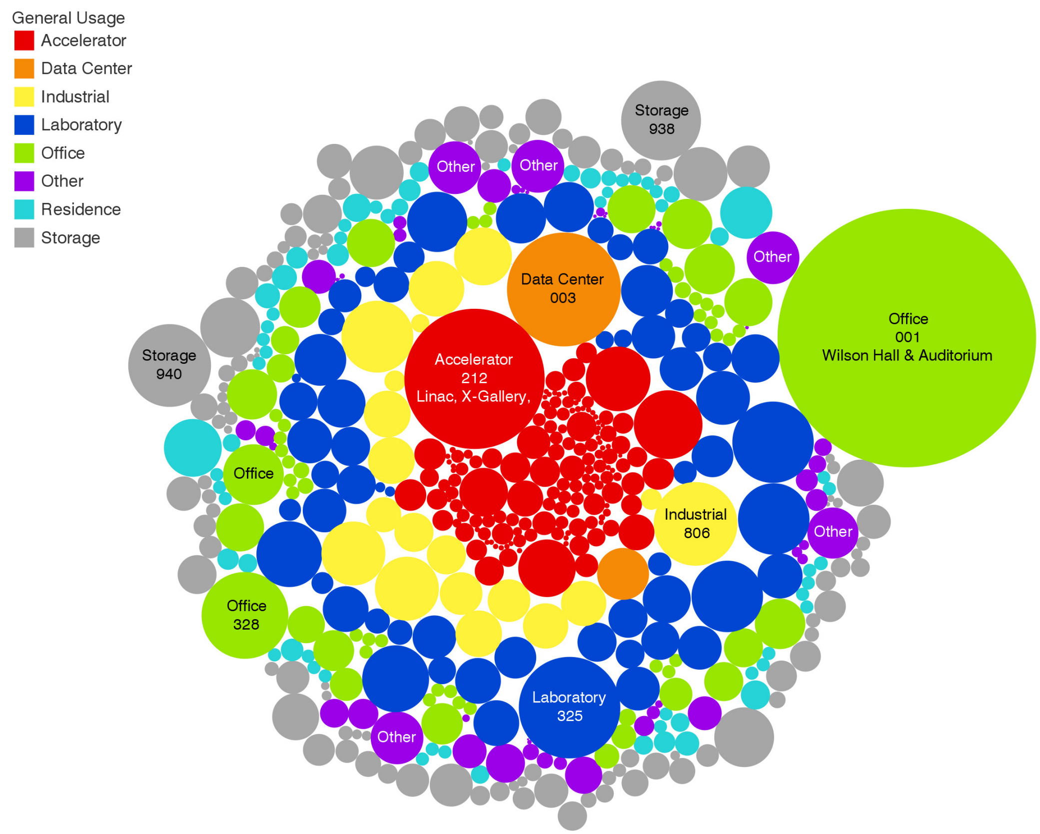


Color indicates era. Size shows sum of area.

Composition by function	Number	% of total
Offices	34	27%
Data Centers	2	4%
Residences	64	6%
Storage	80	15%
Industrial	13	9%
Physics Labs	37	20%
Accelerator	95	15%
Other	39	5%
Totals	**364**	**100%**



Composition by usage	Total area (SF)	% of total
Offices	640,000	27%
Data Centers	100,000	4%
Residences	140,000	6%
Storage	350,000	15%
Industrial	220,000	9%
Physics Labs	470,000	20%
Accelerator	360,000	15%
Other	120,000	5%
Totals	**2,410,000**	**100%**



1.3 Assessment Criteria

The FCMP *Guiding Principles* and Emerging Priorities cut across several interrelated facility issues. Responding to these issues, the planning team created the following starter list of questions to aid in evaluating existing facilities.

Science Need	Is it currently used for ongoing science? If not, is it reasonably adaptable for other usage? Is it part of experiments or beamlines that have ended or are scheduled to end?
Location	Does its location support the vision of consolidation and centralization into a core campus and the associated goals of pedestrianizing, reduction of vehicle usage, and collaboration through proximity? Does it reinforce community? Is it optimally located for current functions relative to the lab at large?
Condition	Does its condition enhance or detract from the campus experience? Is it inviting and informative to international and local visitors? Is it consistent with the envisioned state-of-the-art laboratory? Is it past its realistic useful life?
Quality, Design, Character and Identity	Does it contribute to quality of life and sense of place? Is it desirable place to work? Will it aid in attracting and retaining future researchers and staff? Is it, or can it be, renovated to become a state-of-the-art facility? Is it optimally design and suited to current usage? Is it purpose-built or was it originally designed and built for a different function? Does it contribute to or detract from character identity of Fermilab? Is it historically significant? Does it enhance or detract from the natural setting?
Flexibility and Life Cycle Value	Is it of a quality, scale and durability conducive to continued use or long-term adaptive reuse? Can it support cutting-edge research? Can it use space efficiently?
Stewardship	Dose it pose any environmental or safety hazards or risk? Is it safe for long-term habitation? Does it facilitate efficient use resources? Does it use energy efficiently? Does it require excessive maintenance efforts and cost? Is it, life cycle efficient and justifiable?
Long-Term Validity and relevance	Is it a facility Fermilab wants to be using 20 years from now?

2.0 Strategically Assess Campus Utilities

2.1 Introduction

A fully integrated, holistic approach to planning necessitates looking beyond buildings, site layout, roads and landscaping. Planning must consider the utility systems that provide the campus buildings, experiments and accelerators with electricity, heating, cooling and water. Fermilab has an extensive network of utility infrastructure throughout its 6,800-acre site. Significant portions date to the early years of the laboratory. As the future unfolds, new buildings and experimental facilities will require effective and reliable site infrastructure to support the future facilities vital to achieve Fermilab's mission.

As Fermilab celebrated its 50th anniversary in 2017, it had clearly embarked on its next era of science. Important global particle physics research initiatives are under way, and others are well along in their planning and development. To insure cohesive planning and guide future developments, the Fermilab Campus Master Plan (FCMP) has been developed to guide the transition of laboratory facilities to support the next era. The FCMP is a "20 year transformational plan creating a state of the art, open inviting and collaborative international research community for 21st-century science".

The FCMP presents several initiatives to realize that transition. One vital initiative, and the subject of this part of the appendix, is the strategic assessment of the campus utility infrastructure to determine systems' suitability and readiness for the next era of science. Many questions about these aging facilities need to be answered. To frame and kick-off an effort to find those answers, the campus planning team created this appendix the FCMP.

This appendix provides an overview of the utility systems currently on site. They are domestic water, industrial cooling water, sanitary sewer, natural gas, electrical power, telecommunication and computing. The site has one central utility plant, the CUB, that provides both hot and chilled water to Wilson Hall and associated buildings in the campus's central region.

Using the information herein, an infrastructure evaluation team will be assembled. The teamwork will ultimately result in a formalized long-term planning document. The document will be a one-stop, core, institutional resource used as a companion document to the FCMP. Part 4 at the end of this appendix illustrates the proposed time line for development and publication of the Strategic Utility Assessment Plan.

2	27	14	241
Primary electrical substations	Miles of underground industrial cooling water piping	Miles of underground sanitary piping	Secondary substations

2.2 Utility Systems Overview

Electrical System Overview: The Fermilab electrical system is owned and operated by the laboratory. Its primary source is provided by two 345,000-volt transmission lines feeding two electrical substations that contain four 40-MVA power transformers each and distribute power at 13,800 volts. The substations contain buildings housed in metal enclosed switchgear with vacuum circuit breakers for feeder protection. The feeders distribute throughout the main campus through underground concrete-encased ductbank type.

The laboratory Village area is a separate electrical system served by a single distribution feeder at 12,470 volts. The distribution feeder is provided by the local investor-owned electrical utility, ComEd. The distribution in the Village is primarily overhead construction and owned and operated by the laboratory. A backup tie from the main campus electrical system is available.

Distribution: Power is distributed throughout the laboratory medium voltage feeders, primarily at 13,800 V on the main laboratory campus and 12,470 V in the Village area. Two on site electrical substations are used as primary distribution: Kautz Road Substation (KRS) and Master Substation (MSS).

Kautz Road Substation was built in 1998 as part of the Main Injector facility. The station is designed to provide power to two separate types of users: pulsed power and conventional power. This is accomplished with six separate 13,800 volts busses-four for pulsed and two for conventional power. The pulsed-power busses have space for up to 28 vacuum circuit breakers that feed the Main Injector power supplies along with the harmonic filters to reduce any adverse effects of the connected pulsed power supplies on the electrical system. These feeder breakers are dedicated to the power supplies and are an integral part of the operations of the Main Injector to isolate power sources via LOTO for maintenance. The conventional power busses have space for up to 12 vacuum circuit breakers that feed conventional facilities such as buildings and miscellaneous industrial loads.

The Master Substation was built in 1969 as part of the original laboratory construction and was fully renovated in 2017 with state-of-the-art equipment and a new enclosure building. The station is designed to provide power to two separate types of users: pulsed power and conventional power. This is accomplished with five separate 13,800 Volts busses-two for pulsed and three for conventional power. The pulsed power busses have space for up to 14 vacuum circuit breakers. While pulsed-power is no longer connected to Master Substation, the separate pulsed-power busses are used to isolate and feed the sensitive programmatic facilities in the original footprint area. The conventional-power busses have space for up to 32 vacuum circuit breakers that feed conventional facilities such as buildings and miscellaneous industrial loads in the original footprint area.

Feeders: The feeders that provide power across the site originate at the substation vacuum circuit breakers. They exit the substations and route around the site in underground conduit ductbanks. The feeder system is designed as an open-loop sectionalized system. The feeders use air switches and available connections with each other for redundancy, allowing sections to be isolated for maintenance without requiring full feeder outages. Several feeders are dedicated to a backfeed system between Master Substation and Kautz Road Substation. This backfeed system allows the two substations to provide limited redundancy to each other to maintain power distribution during maintenance periods. Feeder technology has changed in the 50 years of the laboratory, and all of the original cables have been replaced. A small number of older cables exist that are not in use, but the feeder may be used in the future. The cables are anticipated to be replaced at that time. Current cable technology enables an expected useful life of 40 years.

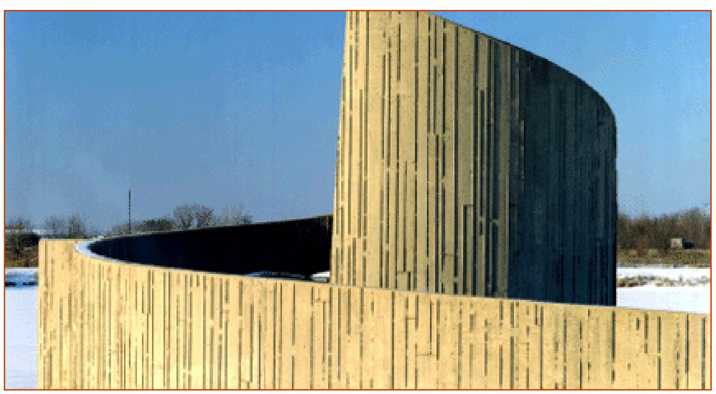
Unit Substations: Fermilab is made up of complexes of large industrial-type electrical loads. With this type of load, the electrical system generally uses 480-volt,three-phase services to the buildings with a typical transformer size of, 1500 KVA. Because many of the buildings are built in cluster areas, the unit substation configuration with large circuit breakers to feed multiple services was installed at the inception of the laboratory in 1969 and into the 1970s. These unit substations were constructed with sections for high-voltage switchgear, transformer and low-voltage switchgear. The technology of low voltage switchgear has changed over time, and the usefulness of this multipart configuration has become obsolete. As site improvements have allowed, the unit substations have been replaced with modern pad-mounted transformers.

Switching Equipment: As described above, the feeders are sectionalized using 15-kilovolt-rated switches. The original equipment installed for this purpose used a dielectric oil tank technology that enclosed the mechanical components of the switch. Over time, this technology has proven to be obsolete and has been slowly replaced by an air-insulated switch technology. The replacement of the oil switches is nearly complete, with four remaining switches to be replaced.

Industrial Cooling Water: The industrial cooling water system at Fermilab has a dual purpose. It is used to supply water to the various fire protection sprinkler systems located in buildings across the site. It is used in many of the experimental areas as a source for conventional-magnet cooling. The distribution system for ICW extends from the main pumping station at Casey's Pond to the support area, Wilson Hall and footprint area, and most of the experimental areas located on the Fermilab site.

The main storage reservoir for the ICW system is Casey's Pond, which is in the northern portion of the Fermilab site. Two sources provide water to the reservoir. A sitewide network of lakes and ditches is used to collect runoff water, as well as heat exchanger and sump discharge water, and return it to the main reservoir at Casey's Pond. Water is also collected in the Main Ring Lake, located within the main accelerator ring, and Lake Law, located in the southeast portion of the site. The water from these lakes is then transferred to the main reservoir by means of a pumping station located at the Main Ring Lake. It is important to note that the whole of the 6,800-acre Fermilab site provides runoff to this network of ditches and lakes, and thus even open areas of the site contribute to the experimental effort of the laboratory. Another source, under certain circumstances, may be used to supply water to the main reservoir. A contract with the state of Illinois allows Fermilab, when water levels are sufficient, to pump water from the nearby Fox River to supplement and maintain water levels at Casey's Pond.

The present total capacity of the on-site ICW supply system is 185.7M million gallons based on existing lake and ditch sizes and average rainfall. Building 855, the pumping station at Casey's Pond, contains three 5,000-gpm variable-speed primary pumps and four 1,000-gpm single-speed secondary pumps that supply water to the sitewide distribution system. The average pumping output of the Casey's Pond pumping station is primarily dependent on the water temperature of the reservoir supply. This temperature varies with the time of year and the amount of experimental equipment requiring cooling. In the winter months, with minimum cooling demand from equipment, the output may be as low as 4,000 gpm. In the summer months, with a maximum cooling demand, the output could exceed 11,000 gpm. There are three other supplemental pumping stations: C-4 on the Main Ring, Swan Lake and CMTF pump stations.



Domestic water: Water for the entire site is sourced from the City of Warrenville. Two separate 8-inch-diameter taps connect to the Warrenville system along the east boundary of the site. Two separate sources allow redundancy in the system in case of a failure in one of the feeds. The consumption rate for the entire laboratory ranges from 0 to 90 gpm depending on the time of day. The pressure of the system is 35 psi.

There are about 20 miles of DWS pipe on site. Much piping, especially in the Village, is ductile iron and about 50 years old. Piping that has been installed more recently is HDPE material. Separate from the city of Warrenville distribution lines, there are four shallow water wells that serve individual buildings at Sites 29, 52, 56 and 58. These facilities are used for residential purposes, storage and care for the bison barn.

Sanitary Sewer: Two underground sewage collection systems are at the laboratory. One serves the main site, and the other serves the Village. The main site collection system has six lift stations; the Village system has one. No sewage is treated on site. Sewage from the main site is treated on a fee basis by the city of Batavia. Sewage from the Village is handled by the city of Warrenville under a similar arrangement.

There are approximately 16 miles of sanitary piping across the site. The collection system that serves the main-site facilities is in generally good working condition. For the Village system, there has been an increase in the infiltration rate in recent years primarily due to the age of the system. A portion of this system has been repaired. Investigation continues to identify and remedy the remainder of this problem.

Natural Gas: There are approximately 20 miles of natural-gas piping across the site. Gas is delivered to Fermilab by the Northern Illinois Gas Company from two separate source points. The primary gas supply is an 8 inch line that is metered at the Wilson Road boundary. Two branch lines then extend south. One serves the Village while the other terminates at the Central Utility Building. A second 4 inch back-up feed supplies gas through a meter station at the west boundary of the site, adjacent to Giese Road.

Through a system of sectioning valves, gas supply can be maintained to the site in the event of an interruption of service from the 8-inch primary supply. The sitewide pressure is regulated to maintain 90 psi and is considered high pressure. There are no identifiable problems with the gas distribution system.

Central Utility Building: The Fermilab Central Utility Building (CUB) was constructed in the early 1970s and has been remodeled numerous times to support the lab's mission. Housing the comfort chilled water system, the process chilled water system, the Linac chilled water system and the hot water heating system, its 16,000 square feet contain equipment that produces process chilled water, comfort chilled water, Linac chilled water, 95-degree low-conductivity water (LCW) for muon delivery ring and for Booster, deionized (DI) water, condenser water for chillers, condenser water for 95 LCW heat exchangers, and tower water system to reject condenser water heat to ambient air.

The comfort chilled-water systems' primary function is to provide comfort cooling to Wilson Hall, Ramsey Auditorium, Cross Gallery, Transfer Gallery, Cross Gallery, Booster towers and other area buildings. The system consists of chillers CH-1 and CH-5 (each with a 4,160-volt, 800-ton capacity and 1,800-gpm evaporator), primary pumps CP1, 2/3 (each with 40-horsepower, 1,800-gpm flow) and a secondary loop that contains secondary pumps CP-4/5 with variable speed drives (each with 40-horsepower variable-speed drive and 3,600-gpm flow) and a heat exchanger, HX-2 of nominal 800-ton capacity with pumps, 30 horsepower each CP12/13. The primary loop has various operating modes. Two chillers and two pumps operate during peak summer months. HX-2 provides cooling during the winter months. The secondary loop's normal operating mode is one pump. HX-2 provides cooling from the process chilled-water system to the comfort system and will normally carry the light winter loads. HX-2 may be used in an emergency to transfer heat in either direction between the comfort and process systems.

The process chilled-water system provides cooling water for process loads at remote locations. It consists of a primary system with chillers CH-2 (800 Tons), CH-4 (800 Tons), free cooling HX-1 (1,800 tons) and primary pumps CP-10/11 with variable speed drive controls (6,720, 300 horsepower each). The primary system flows water through a bridge capable of feeding (1) the process secondary chilled water system, (2) the Linac secondary low-conductivity water chilled-water system through a heat exchanger HX-3, LP-13/14 and (3) the comfort chilled-water system through heat exchanger HX-2, CP-12/13. The process secondary chilled water system temperature, flow and pressure are dictated by process requirements.

The Linac chilled-water system provides low-conductivity water (for cooling) to the Linac loop. Chiller CH-3 and primary pump CP-9 operate in the primary loop. Secondary pumps LP-4/5, an emergency operation heat exchanger HX-3 tied to the process chilled water primary bridge and HX pumps LP-13/14 operate in the secondary loop. The secondary loop serves Linac Chilled-water (HX-7) and 55 LCW loads.

The heating hot water system provides comfort conditioning for the various footprint area buildings. Two boilers in CUB operate individually. Three 25 horsepower boiler pumps, two running and one standby unit-pump water through system and back to the boilers. There are over a dozen heating zones that have airhandlers, terminal units and radiation. The zones predominantly have three-way valves for control, and many have dedicated zone pumps.

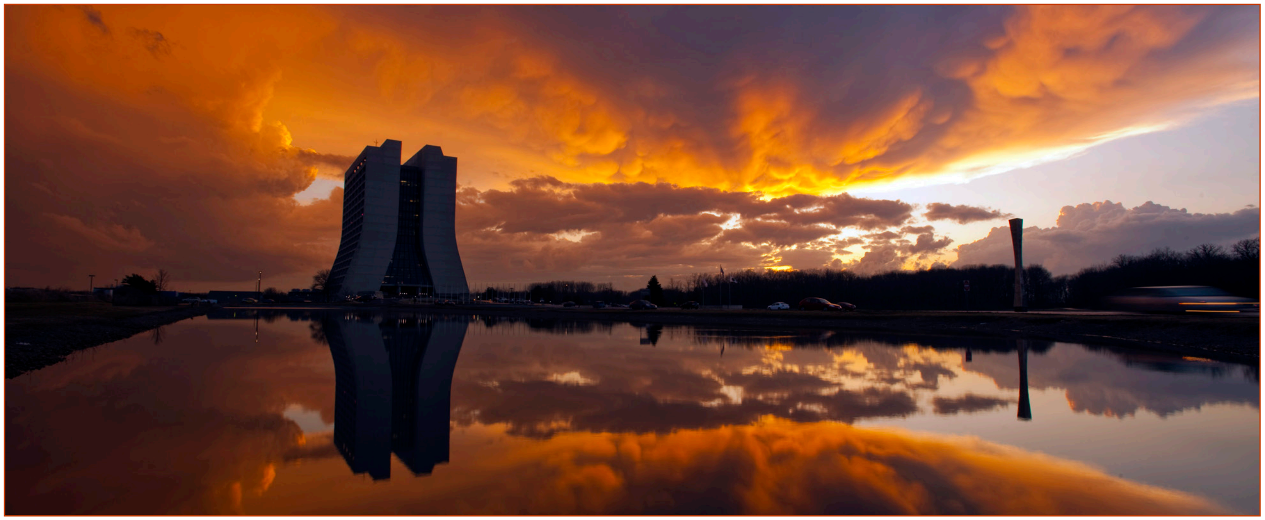
3.0 Establish Design Guidelines

3.1 Introduction

The Fermilab Campus Master Plan (FCMP) presents goals and aspirations to guide the transition of laboratory facilities to support the next era of science and discovery. The plan sets forth guiding principles and planning initiatives, providing the framework for the process. One of these initiatives, Establish Design Guidelines, is the subject of this appendix.

As described in the FCMP, Fermilab has a legacy of distinctive buildings and structures created out of the founder's vision for the laboratory. The result is a place with a character and identity unique among the world's research laboratories. Upholding that unique identity while responding to the vastly different sociological and technological landscape of the current and future eras is the aim of creating design guidelines.

To frame and kick off this effort, the campus planning team created this appendix to the FCMP. The content herein provides design history and general design guidelines. A design guidelines development team composed of subject matter experts, will be charged to create formalized, long-term, detailed design guidelines. The outcome of their work will be a freestanding *Fermilab Design Guidelines* document. It will be an institutional document serving as a companion publication to the FCMP. Part 4 at the end of this appendix illustrates the proposed timeline for development and publication of the *Fermilab Design Guidelines.*



3.2 Design History

"A Utopian place where physicists from all parts of the country, and from all countries, would be doing their creative thing in an ambience of well-functioning and yet beautiful instruments, structures and surroundings that would reflect the magnificence of their discoveries and theories."

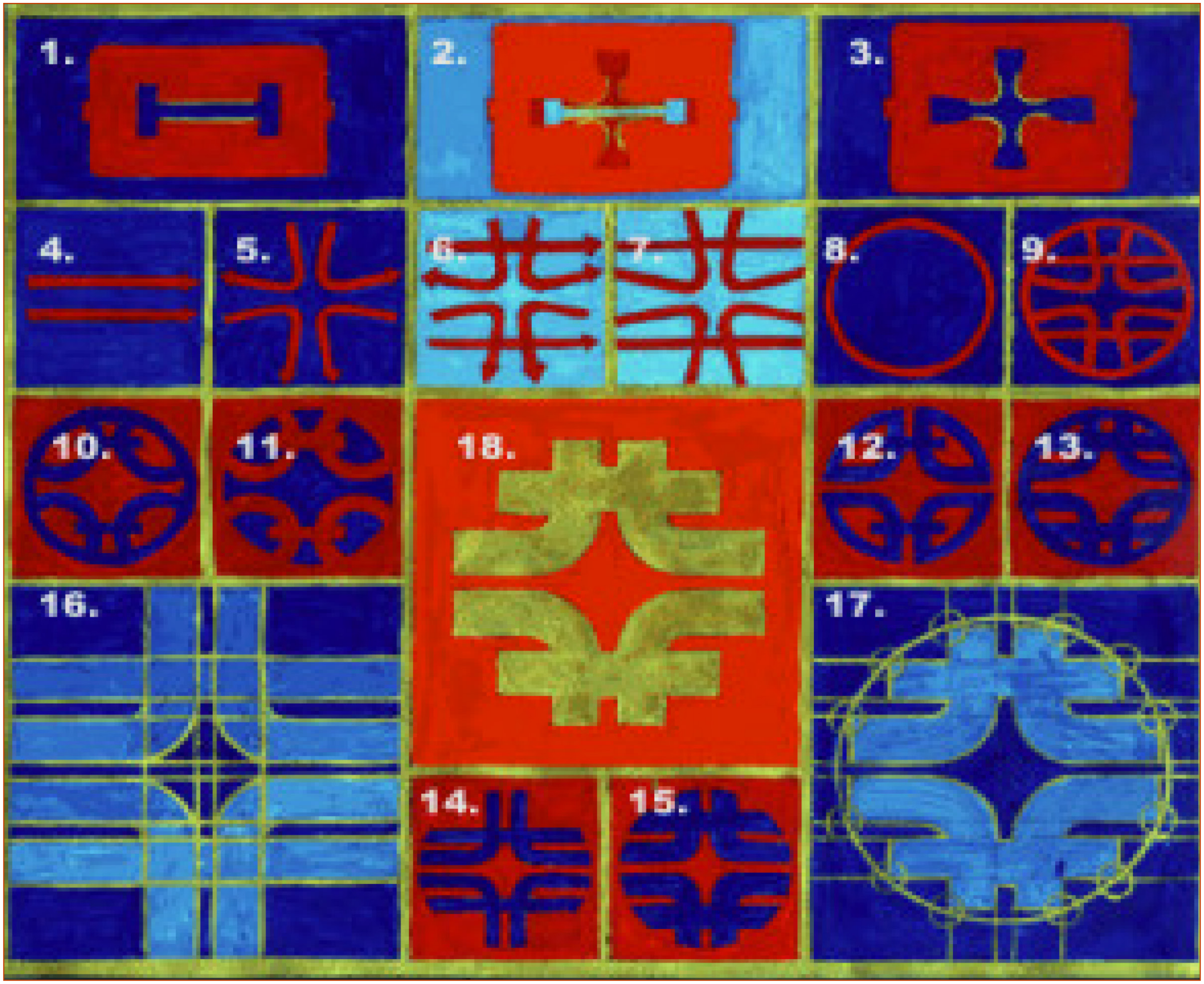
This quote from laboratory founder Robert R. Wilson embodies his vision for Fermilab. He imagined scientists from around the world gathering in a place of natural beauty, amid architectural grandeur and cultural splendor.

The interplay of art, science and technology formed the basis for the design approach to the laboratory. Sculptural forms became a prominent feature. Landmark buildings were distinguished simple sculptural shapes, materials, colors and textures. Playful, colorful geometry, squares and circles, became emblematic of the laboratory and were painted on buildings throughout the campus.

Robert Wilson helped design the centerpiece of the site, the stately 16-story Robert Rathbun Wilson Hall, inspired by a Gothic cathedral in Beauvais, France. The building serves as a central meeting place, housing the laboratory's cafeteria and the campus's largest concentration of offices. Adjoining Wilson Hall to the south is the 830-seat Norman F. Ramsey Auditorium, which hosts numerous talks and cultural events.

Wilson also influenced the unique design and character of several other founding-era buildings and structures on campus and created several of the site's iconic sculptures.

Assisting Wilson at the founding was artist and designer, Angela Gonzales. She was a major influence in forming the laboratory's distinct character. Her work created the color palette and bold geometric approach to architecture and graphic design, exemplified by the images below and on the facing page.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Beginning with the canvas of farmland, farmhouses, barns and the small town of Weston, a physics laboratory was imagined that would embody Dr. Wilson's vision while deriving inspiration from the existing context.

Colors, Forms and Textures: Robert Wilson drew inspiration from the surrounding farmland and farm equipment, the local flora and fauna, the sky, the horizon and surrounding fields, and the materials and textures of the existing buildings and barns. These inspirations would form the color and texture palette for the laboratory. The laboratory buildings would take on these colors and textures and be scattered throughout the site-like colorful toy blocks scattered about, forming the "Physics Playground."

"I have always felt science, technology and art are importantly connected; indeed, science and technology seem to many scholars to have grown out of art.

"I had better pay close attention to the architecture of the project, for I was determined that it be significant yet affordable. If we produced a dowdy site with shabby buildings, then the technical people we wanted to work with us would not come and the statesmen, who might judge us in part by appearances, would not in the long run give us the funds that we would need for our physics / My fantasy of a Utopian laboratory clearly required a setting of environmental beauty, of architectural grandeur, of cultural splendor..."

Robert R. Wilson, founder

3.3 General Design Guidelines

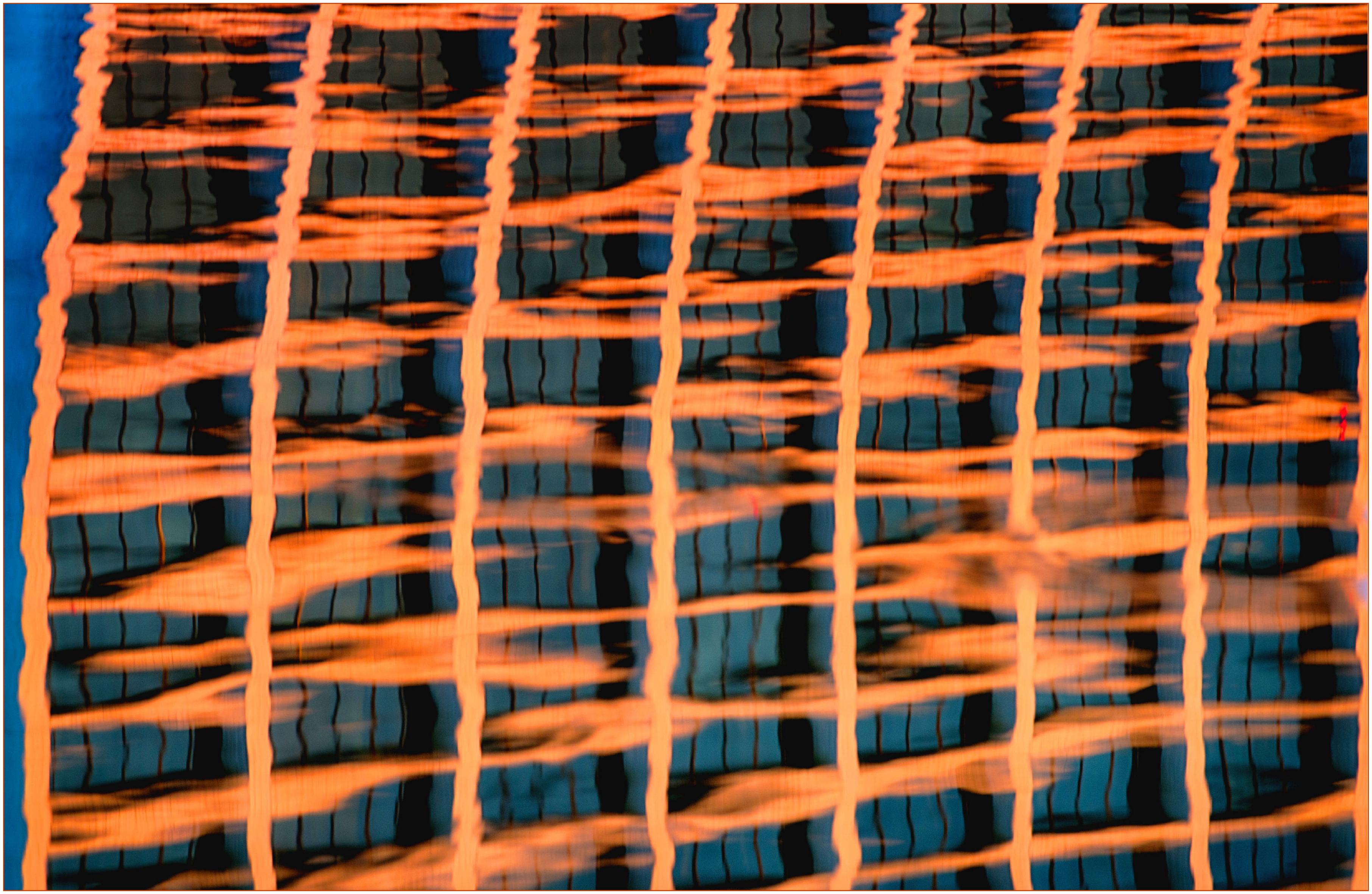
The design of buildings and open spaces should encourage interaction, creating the settings to bring staff, users and visitors together, becoming vibrant centers of laboratory life.

Entrances and Ground Floors: Buildings should be welcoming, strengthen existing gathering spaces and provide new opportunities for social interaction. Entrances should be evident in the daytime and at night. The ground floor of buildings should emphasize transparency. Service and utility areas should be located so as not to negatively affect pedestrian paths, important streets or building entrances.

Public Spaces: Public spaces should be generous, promote interaction and be visible to those using the buildings or walking past them. Outdoor and indoor public spaces should be designed to allow for informal gatherings and social interactions during both daytime and evening hours. Lighting and security of public spaces are critical for their success. Rooftops and terraces should be considered participatory spaces for the campus community, accommodating social spaces, conferencing and unique offices. Buildings should provide universal access so they are not encumbered unnecessarily by level changes, ramps and stairs.

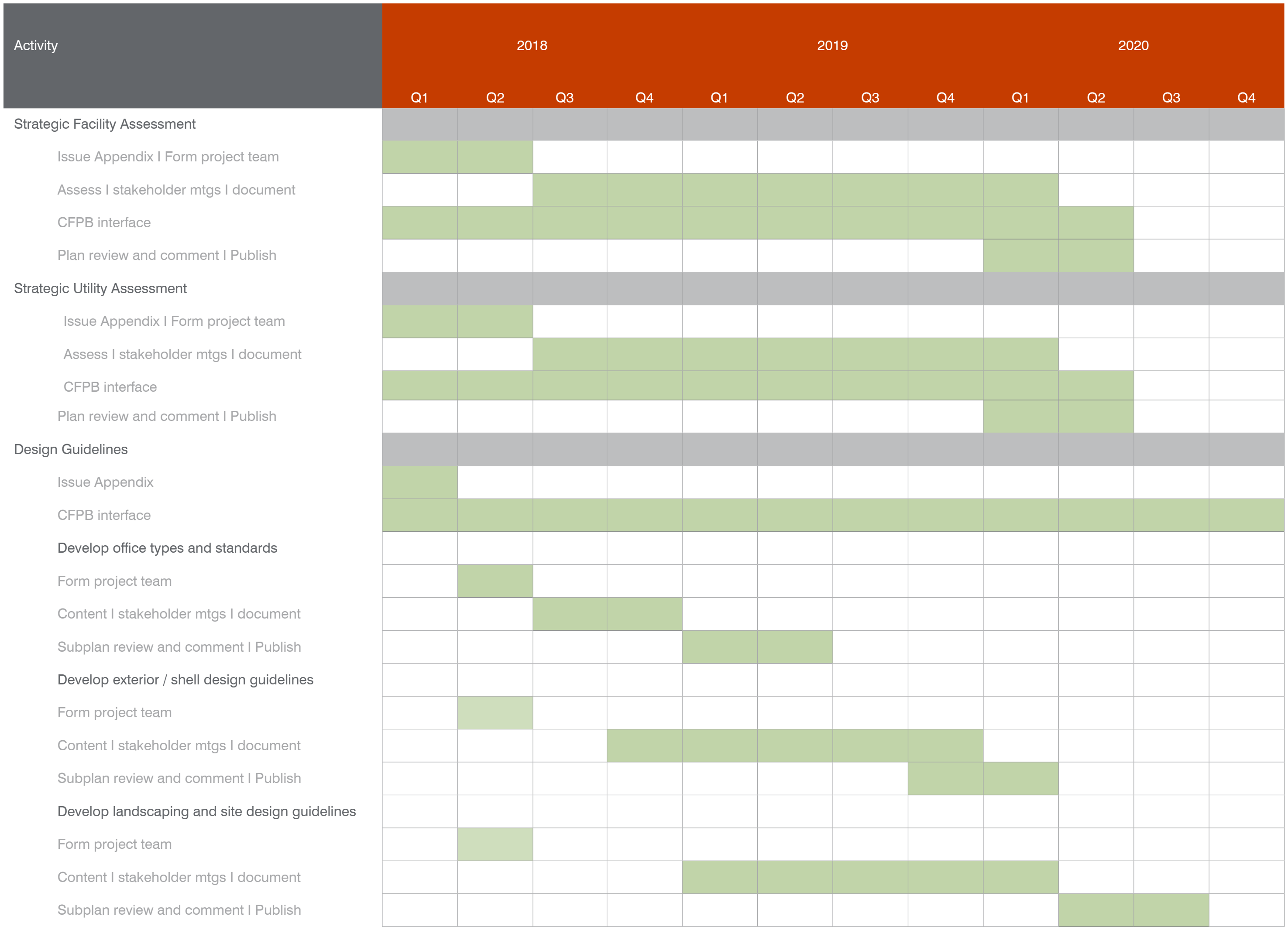
Long-term flexibility and life cycle value: Buildings on campus should have the inherent capacity and flexibility to outlive the original program. Appropriate attention to the design of floor plates, floor-to-floor heights and structural systems will enable a high degree of flexibility for unanticipated future uses. Over time, campus buildings should anticipate a variety of programs and uses, responding to new needs and unanticipated demands. New projects should be designed with a commitment to flexibility, quality and durability to provide long-term usefulness. Building design should also anticipate future changes in technology and scientific methods in the planning and design of buildings and research spaces. They should incorporate building systems and support infrastructure, facilitating easy adaptation for new programs and future demands. When making building system decisions, consider initial capital investments as they affect long-term operational costs in the full life cycle of the project.

Uphold the unique character of Fermilab: The Fermilab campus is rooted in the tradition of architectural innovations and excellence representing the architectural innovations of the time in which they were built. A strong component of the campus includes architecture significant for and symptomatic of its time. Design of new and renovated facilities should acknowledge this legacy while pursuing design excellence appropriate and symptomatic of the current era, continuing the tradition of design excellence. The collection of landmark buildings within the community can be captured into a community of architectural styles resulting in a dynamic relationship between the past and the future. Buildings contributing to the legacy of the campus should be retained and revitalized when feasible. Open spaces and significant landscapes should be identified and respected as critical components of the campus experience.



4.0 Next Steps

4.1 Planing Documents Development Timeline



4.2 Planning Documents Relationship Grid