SOUTH POLE STATION

MASTER PLAN

— 2025 —

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Cover: Sunrise beyond IceCUBE. Source: NSF, Johannes Werthebach, 2018.

Table of Contents: Skiway grooming. Source: NSF, Johannes Werthebach, 2018.

Geographic South Pole Marker. Source: NSF, 2018.

Executive Summary

Amundsen-Scott South Pole Station (referred to as "SPS" in this document) provides a platform for Earth and space observation and polar field work that is unparalleled anywhere else on the planet. Science conducted from SPS provides valuable insights into the past and future of our planet. This South Pole Station Master Plan (referred to as "SPS Master Plan") establishes the National Science Foundation's (NSF) long-range vision for ensuring SPS infrastructure can continue to support a world-leading science program.

In preparation for creating the SPS Master Plan, the planning team conducted an analysis of several SPS population and energy growth scenarios. The estimated total cost of ownership of each scenario was weighed against Antarctic Treaty and USAP requirements and national research priorities. It is in the nation's best interest to modernize SPS infrastructure and operations while maintaining the 150-bed capacity. While this will limit the overall volume of individuals SPS can support at any one time, implementation of the recommendations of this SPS Master Plan can reduce operational demands and maximize future scientific support at SPS.

Large-scale infrastructure recapitalization will be necessary at SPS over the coming decades to prevent critical primary infrastructure and service failures. Several currently funded, USAP resource-dependent scientific research projects are approved for completion at SPS during this same period.

This SPS Master Plan presents a summary of current conditions, constraints, and opportunities for the SPS area. It identifies projects that will require capital-funding levels for completion, presents a site plan for redevelopment of infrastructure in need of replacement, considers conceptual building forms and design considerations for those replacement structures, and establishes a phasing plan for accomplishing these improvements.

As demands for research based out of SPS are growing, the master planning process is critical to maintaining a functional and safe station at the Amundsen-Scott SPS over the next 30 to 50 years. This SPS Master Plan is the first such plan developed for the Amundsen-Scott SPS. This plan, like all other USAP station master plans, will be routinely reviewed and updated as infrastructure conditions, USAP requirements, and national priorities warrant.

SECTION 1

Summer Camp. Source: NSF, 2018-2019.

Purpose of the SPS Master Plan

The purpose of the SPS Master Plan is to establish an actionable recapitalization plan in support of the vision to modernize infrastructure and operations to continue scientific support at the South Pole, maintaining the 150-bed capacity of the station for the next 30 to 50 years. The SPS Master Plan will serve as a guide for future development at the SPS.

Prior to the development of this SPS Master Plan, a scientific community engagement charrette was conducted to identify the broad needs and future priorities of the scientific research community across all major South Pole-based scientific fields. The information gathered through this outreach was compared to the impact and feasibility of any additions and/or major renovations to primary infrastructure required to support future priorities while maintaining operations at the station.

This SPS Master Plan, resulting from the community charrettes, presents a cohesive integrated approach to future redevelopment of the South Pole area based on current (2025) supportable levels of scientific activity and support operations.

This SPS Master Plan provides an overview of existing station conditions and phasing for completing the large infrastructure projects necessary to continue supporting scientific research at SPS. This SPS Master Plan does not include structural or architectural designs, energy modeling and design, snowdrift modeling, or project initiation schedules or pricing.

Methodology

The SPS Master Plan was developed through a process of: discovery, assessment, validation, planning, and projections. The graphic below illustrates the master planning process.

During the discovery phase, all available existing infrastructure assessments and historical data were collected to understand the baseline conditions at SPS. From the baseline, an integrated needs assessment was undertaken to ascertain existing deficiencies and identify improvements that could be made to maintain SPS science research capabilities over the next 30 to 50 years.

The primary focus of the assessment phase was to understand the concerns of the science community who conduct research at the South Pole. A four-day virtual charrette was conducted with science disciplines who have interest in the South Pole area. Participants were given time to express their concerns with the existing SPS infrastructure and design, share their desired future projects, and discuss preferred solutions for the SPS area.

The master planning team then completed the validation phase by way of gathering information during the discovery and assessment phases and cross-referencing collected information and with supporting documentation and empirical data. Once validation of concerns and existing conditions was complete, the master planning team began the planning phase of the process.

During the planning phase, focus groups were established and work sessions were conducted with subject matter experts (SMEs), SPS personnel, Antarctic Support Contractor (ASC) personnel, and NSF personnel. The focus group sessions allowed SMEs to verify information, ask exploratory questions, and identify best practices for specialty areas. As the SPS Master Plan was drafted, iterations of the document were submitted to the focus groups for review and comment. The review comments were used to further refine the contents of the SPS Master Plan. In completion of the final phase, developing projections, the wants and needs of the station based were ascertained based upon the feedback received resulted in the development of the SPS Master Plan and capital infrastructure projects list.

A Regulating Plan was created to establish land use districts, overlay districts, and easements to guide the placement of future large structures and facilities based on the impacts created by their associated uses. Subareas were established for focused Subarea plans, and three overall master plan concepts were developed. Validation of supporting information and identification of the potential benefits and impacts of these three concepts was continued throughout the drafting process.

Capital projects required to support this master plan were assigned to one of four future completion phases to maximize efficiencies in construction processes and reduce risk and impact to life safety and science activities at SPS. Rough Order of Magnitude (ROM) costs for projects anticipated to occur within the next 20 years were established to support resource planning during each phase.

MASTER PLANNING PROCESS FLOW

DISCOVERY
Data Collection
Map Review
Baselining

ASSESSMENT
Charrette Sessions
Document Review
Interviews

VALIDATION
Focus Groups
SME Interviews
External Research
Content Editing

PLANNING
Building Types
Needs Assessment
Sub Area Plans
Master Plans

PROJECTIONS
Capital Projects
Costing
FY Planning

FACTS & ASSUMPTIONS

- The South Pole is an extremely cold, logistically constrained, and remote environment. The physical elements impose environmental strains on buildings and equipment, limiting the lifespan of infrastructure at SPS.
- The Sectors at the South Pole (Dark Sector, Clean Air Sector, Quiet Sector, Downwind Sector) are defined by the Antarctic Specially Managed Area Number 5 (ASMA). Any proposed edit to the ASMA will require approval by the Antarctic Treaty parties before formal adoption and implementation.
- The Operations Zone provides support facilities and sustaining environmental systems for scientific research.
- New infrastructure and substantial upgrades to scientific research projects are funded independently. Shared infrastructure and support systems are funded by the NSF Office of Polar Programs (OPP).
- SPS plans to continue to support a 150-bed capacity for the foreseeable future.

The following baseline planning assumptions form the foundation of this SPS Master Plan:

- New support facilities will be programmed and right-sized to maintain current operations.
- Desire to consolidate facilities and centralize logistics and storage of existing infrastructure.
- Desire for improvement of efficiencies and realization of cost savings through the alteration of operations.

Vision

VISION STATEMENT

Modernize infrastructure and operations to continue scientific support at the South Pole.

MISSION

The SPS Master Plan aims to ensure SPS remains a viable platform for supporting Antarctic science for the next 30 to 50 years by:

- Supporting future redevelopment of SPS that optimizes support of local and deep field science;
- Supporting predictable operational costs, personnel requirements, and improved operational efficiency;
- Supporting improved energy efficiency for facilities and operational support;
- Providing a reliable, safe, and healthy working environment for USAP personnel, researchers, official guests, and visitors;
- Providing the flexibility to adapt to the evolving needs of U.S. scientific research in Antarctica over the planning horizon;
- Ensuring an “active and influential presence” in Antarctica in a manner consistent with U.S. stature in the international research community; and
- Preserving the professionalism and the scientific activities carried out at SPS.

GOALS

The primary goals of the SPS Master Plan are to:

- Guide future development decisions by documenting existing and projected conditions, infrastructure needs, and science support requirements;
- Create a conceptual site design and station layout by identifying land use designations and general building placement for future scientific and support requirements;
- Integrate the planning of future national science priorities; and
- Provide a general sequence for identified work to facilitate the efficient and effective use of resources.

OBJECTIVES

The primary objectives of the SPS Master Plan are to:

- Identify gaps in services, facilities, and information at SPS;
- Articulate goals for future SPS operations to support research;
- Identify long-term energy efficiencies at SPS;
- Determine priorities for the long-term viability of SPS; and
- Identify capital project completion phasing the long-term viability of SPS.

History & Background

DISCOVERY AND DEVELOPMENT OF THE SOUTH POLE

The Amundsen and Scott expeditions of 1911-1912 marked the first known human activity at the geographic South Pole. In 1956, in preparation for the 1957-1958 International Geophysical Year (IGY), the U.S. established SPS as the first permanent Antarctic scientific research station located near the geographic South Pole. The IGY was an intensive, multi-national, multi-disciplinary, global research effort designed to study a wide range of geophysical processes. The IGY led to the Antarctic Treaty, which was signed by the 12 original signatory nations, including the U.S., in 1961. The treaty reserves the area south of 60 degrees south latitude as a zone of peace and prohibits measures of a military nature (including fortifications), nuclear explosions, and the disposal of radioactive waste. It gives international treaty parties the right to inspect all areas of Antarctica, including the stations, installations, equipment, ships, and airplanes of other member states to ensure adherence to the treaty.

The U.S. has maintained a permanent presence at the geographic South Pole continuously since the IGY. As of 1982, Presidential Memorandum 6646 has directed NSF to:
"Maintain the U.S. Antarctic Program (USAP) program at a level providing an active and influential presence in Antarctica designed to support the range of U.S. Antarctic interests. This presence shall include the conduct of scientific activities in major disciplines; year-round occupation of the South Pole and two coastal stations; and availability of related necessary logistics support."

The treaty nations have since agreed to several addenda, including the 1991 Environmental Protocol to the Antarctic Treaty (referred to as "the Protocol"), which reserves Antarctica for peace and science purposes, designates Antarctica as a natural preserve, sets forth principles regarding human activities, and restricts activities related to mineral resources. The Protocol was ratified and went into effect in 1998 and may not be modified before 2048 without unanimous agreement of all Consultative Parties of the Antarctic Treaty.

The first station, known as "Old Pole," was created for the IGY by the U.S. Navy and was later abandoned due to structural failure caused by snow and ice accumulation and differential movement of the ice sheet. Old Pole is now irretrievably buried beneath the ice sheet surface and is considered a restricted zone in the greater station area. It was replaced in 1974 by a geodesic dome main station structure with supporting fuel and logistic arches. Additional garage shop and power plant arches were added in 1998 and 1999, respectively, in advance of construction of a new station. The dome was removed after completion of the current "Elevated Station" in 2010.

In July 2012, the report, titled the U.S. Antarctic Program Blue Ribbon Panel, More and Better Science in Antarctica through Increased Logistical Effectiveness was completed at the request of the White House Office of Science and Technology Policy and the NSF. The report identified demands placed on the logistical enterprise to support future scientific efforts at all USAP locations and the Antarctic region, discerned any mismatches with currently projected capabilities, and proposed opportunities and corrective actions for exploration. Although the report included many logistics, operations, and facility recommendations for SPS, creation of a master plan for the future of SPS was beyond the scope of the document.

SPS is supported by McMurdo Station. All logistical support runs through McMurdo Station. All people, material, equipment, and waste to and from SPS transit through McMurdo.

The Elevated Station was uniquely designed to provide clearance beneath the structure to reduce the rate of annual wind-driven snowdrift accumulation. The 65,000 square-foot structure was built on a network of columns as two connected pods, and it was designed to be lifted incrementally over time to prevent burial beneath the ice and extend the structure's lifespan. The Elevated Station currently provides housing, dining, recreation, and medical services for approximately 150 scientific research and support personnel in the austral summer (November to February) and approximately 50 scientific research and support personnel in the austral winter (February to October). The structure contains mission support offices, a computer laboratory, and a hydroponic greenhouse. The Elevated Station is connected to the previously constructed fuel, power plant, garage shop, and logistics arches for primary power, heat, and additional support services.

During construction and following completion of the Elevated Station in 2008, the footprint of the SPS campus continued to grow. Remote science facilities and freestanding storage solutions transformed the SPS campus into a large assembly of structures; the current configuration does not reflect optimized placement for efficient, long-term energy efficiency of science-supporting operations. A wide range of integrated, large-scale recapitalization projects are now required to address normal wear and tear, environmental challenges (such as snow accumulation and plateau movement), aging infrastructure, and evolving scientific research interests.

The Elevated Station and current SPS infrastructure were designed to provide mission support to world-class U.S. scientific and international collaborations at the South Pole and surrounding field areas under the leadership of the USAP, which is managed as a national program by NSF on behalf of the U.S. The inter-agency collaborations for scientific activities involve a variety of U.S. Federal agencies, such as:

- Cold Regions Research and Engineering Laboratory (CRREL)
- Department of Energy/Office of Science (DOE-Science)
- Department of the Interior, United States Geological Survey (DOI-USGS)
- Joint Task Force-Support Forces Antarctica (JTF-SFA)
- National Oceanic and Atmospheric Administration (NOAA)
- National Aeronautics and Space Administration (NASA)
- Naval Information Warfare Center (NIWC)
- New York Air National Guard (NYANG)
- U.S. Army Corps of Engineers (USACE)
- United States Air Force (USAF) Reserve Command
- United States Space Force (USSF)

ASMA NO. 5: AMUNDSEN-SCOTT SOUTH POLE STATION, SOUTH POLE

The 1991 Protocol on Environmental Protection to the Antarctic Treaty (Environmental Protocol) established rules and procedures specifically designed to protect the Antarctic environment across the continent and created the Committee for Environmental Protection (CEP). The CEP is composed of representatives from the countries that are party to the Environmental Protocol and is tasked "to provide advice and formulate recommendations to the Parties in connection with the implementation of this Protocol, including the operation of its Annexes, for consideration at Antarctic Treaty Consultative Meetings [ATCM]" (Environmental Protocol Article 12). The CEP generally convenes alongside the ATCM once a year. Since the adoption of the Environmental Protocol in 1991, additional Antarctic Specially Managed Areas (ASMAs) and Antarctic Specially Protected Areas (ASPAs) were established to further define standards, protections, and restrictions specific to various geographical areas of the continent. The Management Plan for ASMA No. 5: Amundsen-Scott South Pole Station, (referred to as "the ASMA" in this document) conserves and protects the environment surrounding the South Pole by managing and coordinating human activities in the area. The ASMA is reviewed by the CEP every five years, or when circumstances warrant a change in the ASMA. A consensus of the Treaty Parties is required for the formal adoption of any proposed changes to the ASMA.

The ASMA divides the greater South Pole area into three management zones: Scientific, Operations, and Restricted. The established objectives and allowed activities for each management zone are described in the ASMA. The ASMA No. 5 Management Plan defines the geometry of each Sector. Brief details about each Sector are included below.

The ASMA describes the Operations Zone as the area containing the "primary human activity in the Area, including science support activities, main station services (e.g., living facilities), skiway operations, and on-ground support facilities for non-governmental visitors (NGVs)." The Downwind Sector of the Scientific Zone "was established to provide an area free from obstructions for balloon launches, aircraft operations, and other activities. Scientific and Operations Zone activities are allowed in the Downwind Sector." In practice, the Downwind Sector has been used for aircraft operations and overland transportation activities that support SPS. Balloon launches currently occur in the Operations Zone and not the Downwind Sector.

ASMA No. 5 Zones	Zone Objectives	Interior Zones and Sectors
Operations Zone	To ensure that science support facilities and related human activities within the Zone are contained and managed within a designated area.	Operations Zone
Scientific Zone	To ensure those planning science or logistics within the Zone, and all visitors to the Zone, are aware of sites of current or long-term scientific investigation that may be sensitive to disturbance or have sensitive scientific equipment installed, so these may be taken into account during the planning and conduct of activities within the Area. A particular objective of the Scientific Zone is to minimize conflicts between different types of use.	Clean Air Sector, Quiet Sector, Dark Sector, Downwind Sector
Restricted Zone	To restrict access into a particular part of the Zone and/or activities within it for a range of reasons; e.g., owing to special scientific values because of sensitivity, presence of hazards, or to restrict emissions or constructions at a particular site. Access into Restricted Zones should normally be for compelling reasons that cannot be served elsewhere within the Zone.	Aircraft Operations Zone, Old Pole Station Zone, ARO "No Vehicle" Zone, ARO "Meteorological Tower" Zone, Antenna Field Zone, Communications Zone

DARK SECTOR
The Dark Sector was established to preserve the conditions of low light pollution and low electromagnetic interference (EMI) at SPS that are important to facilitate many types of astrophysical, astronomical, and aeronautical research.

CLEAN AIR SECTOR
The Clean Air Sector (CAS) was established to preserve the unique conditions that are required for atmospheric research at SPS.

QUIET SECTOR
Sound noise and mechanical equipment activities are limited within the Quiet Sector to minimize vibration effects on seismological and other vibration-sensitive research.

DOWNWIND SECTOR
The Downwind Sector was established to provide an area free from obstructions for balloon launches, aircraft operations, and other activities. Both scientific and operations activities are allowed in the Downwind Sector.

OPERATIONS ZONE
The Operations Zone contains the science support facilities and human activity areas.

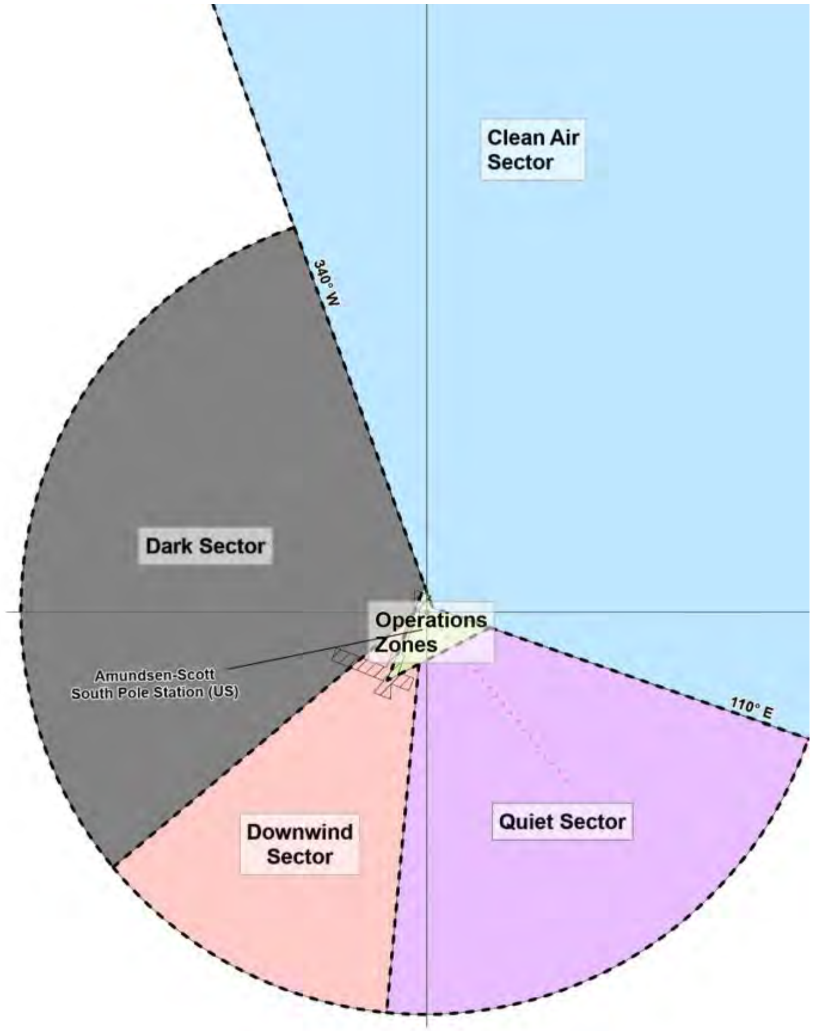
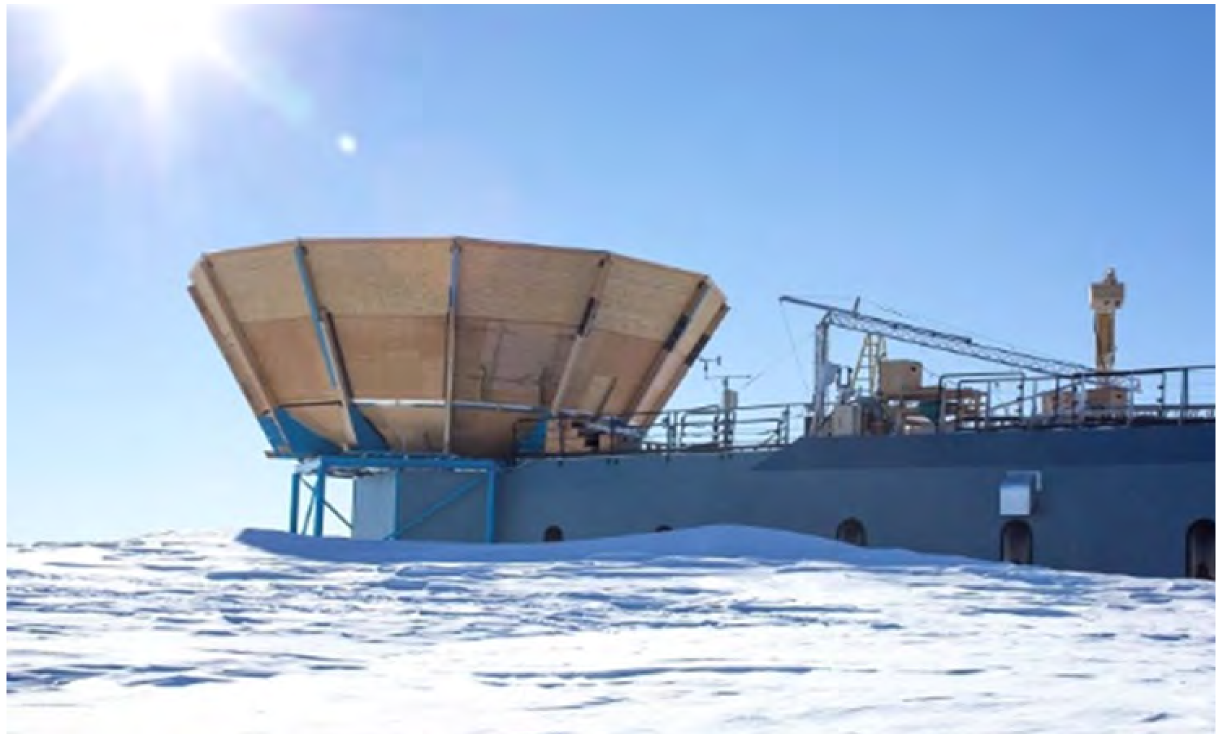


Figure 4.1 ASMA No. 5 Sectors.

MAPO Buried by Snowdrift. Source: NSF, Robert Schwarz, 2018.



MAPO buried by snowdrift. Source: NSF, Andrea Dixon, 2018.

South Pole Station Aerial. Source: Andrew V. Williams, Undated.

LANDSCAPE AND CLIMATE

The South Pole occupies a gently sloping and relatively featureless ice sheet approximately 9,300 feet above sea level. The ice sheet under the South Pole is approximately 8,850 feet thick and rests on the bedrock of the underlying Antarctic continental mass. The surface of the ice sheet is characterized by sastrugi (windblown snow). The area is not crevassed.

The ice sheet and all infrastructure upon or buried within the ice sheet move at a rate of approximately ten meters per year. As such, Global Positioning System (GPS) coordinates for all infrastructure change over time, complicating traditional mapping efforts. To help alleviate this issue, a local grid system is used to define boundaries and building locations.

The South Pole is a bitterly cold, dry, and windy polar desert. The average annual temperature has varied between minus (-) 13.6 degrees (°) Celsius (C) (-7.5° F) and -82.8° C (-117.0° F). Annual mean temperature is -49° C (-56.2° F), and the air holds little to no humidity (average relative humidity is less than 10%). Snowfall is minimal, and persistent winds averaging between 5 to 15 knots cut across the area, primarily from Grid northeast/east. The winds create deep drifts and wells around anything protruding from the flat surface of the ice, burying structures over time. Snowdrift mitigation is a continual maintenance activity at SPS, which currently requires hundreds of labor hours and more than 25,000 gallons of AN8 fuel to complete each year. Over time, nature prevails and structures throughout the South Pole area must be lifted or relocated to prevent complete burial beneath the ice surface.

The altitude and snowy surfaces, which reflect sunlight, create a blindingly bright austral summer at SPS. During this time, the South Pole experiences 24 hours of sunlight, with the sun peaking at a maximum elevation of 23.5° above the horizon. SPS is isolated during the austral winter due to extreme weather conditions that prevent air and overland travel to the South Pole. Although the winter months bring 24 hours of darkness, the austral winter brings the Aurora Australis (or southern lights), which shimmers across the sky as charged particles from the sun, channeled by Earth’s magnetic field, bombard the atmosphere.

Polar Lights. A stunning display of the southern lights over South Pole Station's satellite communications infrastructure.
SOURCE: NSF, Matt Smith, Undated.

SCIENCE ACTIVITIES AT THE SOUTH POLE

Under the U.S. presidential mandate (February 1982) to occupy the South Pole, the current Elevated Station primarily exists and was designed to maintain the influential U.S. scientific presence in the international community. The South Pole is uniquely defined by its level of isolation and environmental constraints that are only common to the east Antarctic plateau. High, dry, cold, and clean desert characteristics coupled with nearly two miles of ice depth provide some of the best field science conditions in the world for supporting a wide variety of sciences.

SPS supports the operation of world-class science experiments on the cutting edge of discovery in their respective fields. Due to its isolation, the South Pole is relatively free from anthropogenic inputs that could compromise the integrity of data in other locations on the planet. Support for remote science field camps only occurs during the austral summer months as harsh weather conditions prevent access to the camps in the austral winter. However, the presence of modern laboratory facilities at SPS allows observations in the station area to continue year-round. SPS is internationally renowned as a premiere field laboratory site on the planet and supports multiple areas of scientific exploration.

According to the ASMA, the major areas of scientific exploration in the South Pole ASMA Zones and Sectors are listed below:

ATMOSPHERIC SCIENCES

Atmospheric science activity occurs primarily in the Clean Air Sector and Operations Zone. Scientists conduct research from the Atmospheric Research Observatory (ARO) and Meteorological Tower along the Clean Air Sector boundary, measuring stratospheric ozone depletion via scientific and operational balloon launches from the Balloon Inflation Facility (BIF) in the Operations Zone.

ASTROPHYSICS AND COSMOLOGY SCIENCES

Astrophysics and Cosmology research primarily occur in the Dark Sector, where light and electromagnetic interference are reduced.

GEOSPACE SCIENCE

Geospace research occurs in a restricted area within the Operations Zone.

GLACIOLOGY

The properties of the Antarctic ice sheet are studied via scientific ice core drilling.

SEISMOLOGY

Seismometers at the South Pole measure and record energy created by seismic events elsewhere on earth. The primary science facility associated with seismology is the South Pole Remote Earth Science and Seismological Observatory (SPRESSO), which is in the Quiet Sector and can detect vibrations up to four times quieter than other seismic observatories on the earth.

MEDICAL RESEARCH

Social behavior, human physiology, psychology, and medical illnesses related to isolated settings, high altitude, and sleep pattern disruption are periodically performed at SPS due to the uniquely isolated environment.

DISCOVERY ASSESSMENT


South Pole Station Aerial. Source: NSF, Undated.

Existing Conditions

EXISTING SOUTH POLE STATION

The following describes the existing conditions, delineated by management zone, to outline current baseline conditions at SPS. Figure 5.1 depicts the existing SPS site plan and identifies the airfield, restricted areas, and primary buildings. Each ASMA Sector contains either science specific facilities or operational facilities and infrastructure. A summary of the existing conditions for each Sector and the primary components in the Sector are described in this section.

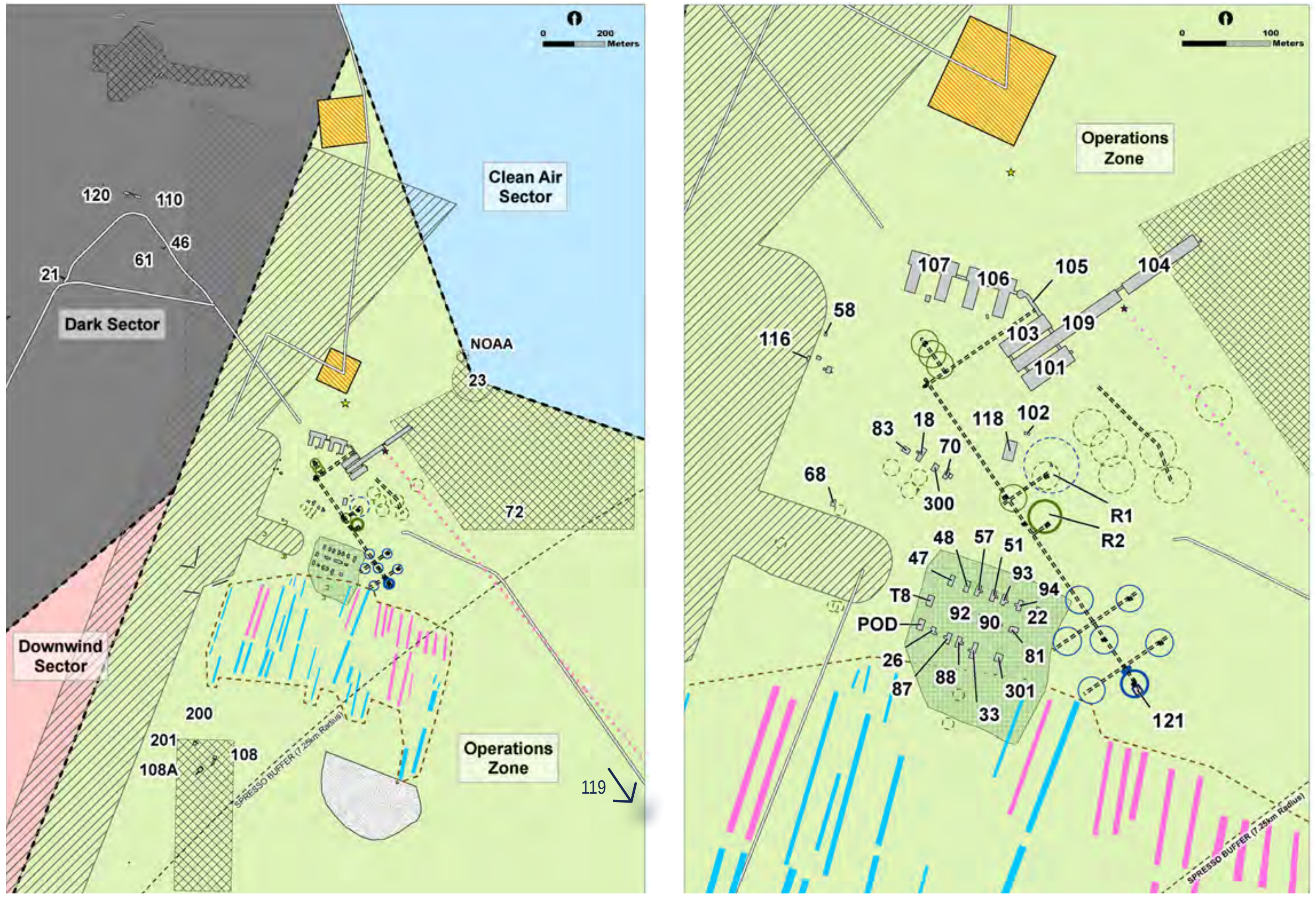
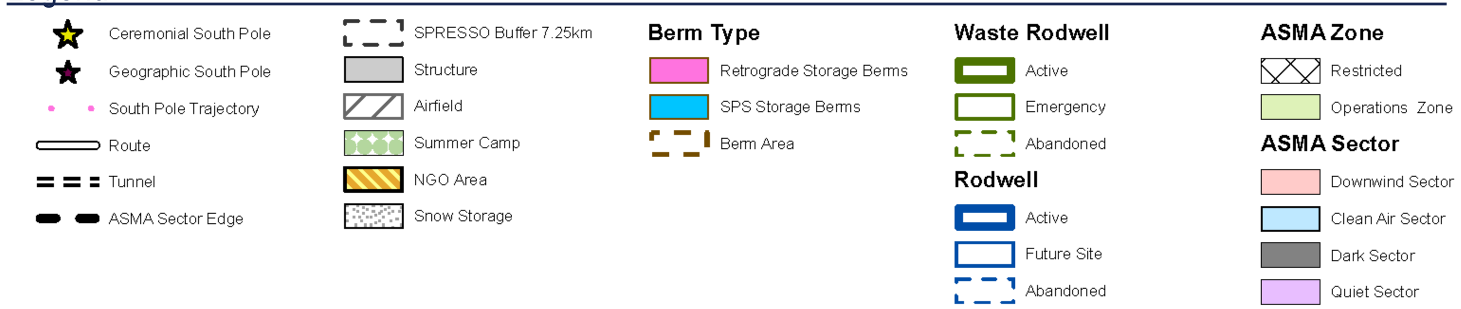


Figure 5.1 Existing Conditions

Legend

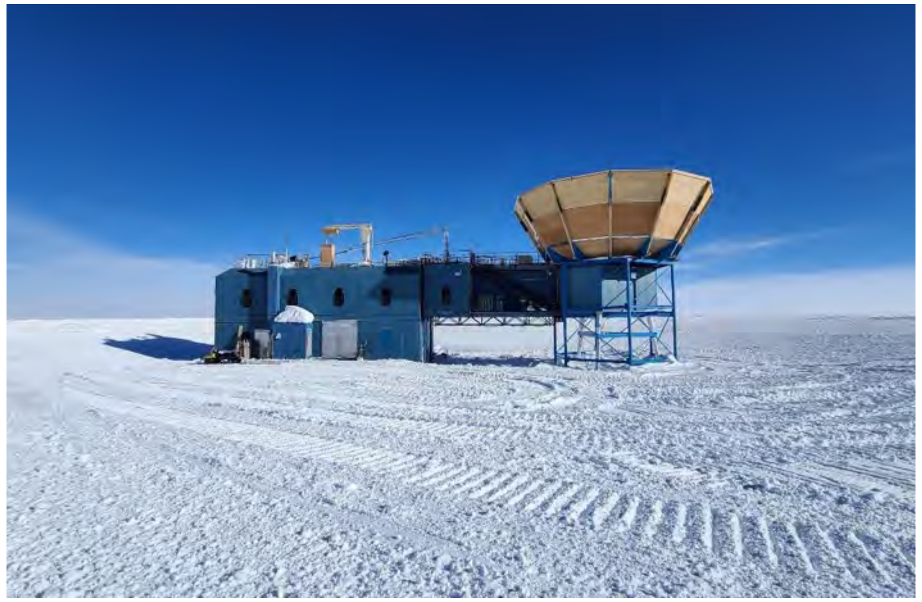


#	BUILDING NAME	INTENDED USE	CURRENT USE
18	Storage Tent	Do Not Freeze Storage	Do Not Freeze Storage
22	Summer Camp Hazardous Waste	Temp. Hazardous Materials Storage	Storage
21	IceCube Laboratory	Science	Science
23	Atmospheric Research Observatory (ARO)	Science	Science
26	Summer Camp Smoking Lounge	Temporary (Temp.) Housing Support	Storage
33	Summer Camp Berthing Tent J-9	Temp. Housing Support	Storage
47	Summer Camp Hypertat No.1	Temp. Support	Storage
46	Martin A. Pomerantz Observatory (MAPO)	Science	Science
48	Summer Camp Hypertat No. 2	Temp. Support	Storage

#*	BUILDING NAME	INTENDED USE	CURRENT USE
51	Summer Camp Hypertat No.3	Temp. Support	Surge Housing
57	Summer Camp Hypertat No.4	Temp. Support	Surge Housing
58	Passenger Terminal	Transportation	Transportation
61	Dark Sector Electrical Substation	Utility	Utility
68	Summer Camp Electrical Substation	Utility	Utility
70	Hazardous Materials Van	Hazardous Materials Storage	Hazardous Materials Storage
72	SuperDARN (Dual Auroral Radar Network)	Science	Science
81	Summer Camp Climbing Wall/Gym	Temp. Recreation	Recreation
83	Cargo Facility	Storage	Storage
87	Summer Camp Berthing Tent J-11	Temp. Housing Support	Storage
88	Summer Camp Berthing Tent J-10	Temp. Housing Support	Storage
90	Summer Camp Restroom	Temp. Housing Support	Decommissioned
92	Summer Camp Carpentry Shop	Temp. Logistics & Operations	Logistics & Operations
93	Summer Camp Berthing Tent J-12	Temp. Housing Support	Storage
94	Summer Camp Berthing Tent J-13	Temp. Housing Support	Storage
101	Garage Shops and Arch	Mixed Use	Mixed Use
102	Vehicle Fueling Module Mobile	Fuel	Fuel
103	Power Plant Arch	Utility	Utility
104	Fuel Pump House and Arch	Utility	Utility
105	Vertical Tower	Passenger Elevator	Cargo Elevator
106	Elevated Station Pod A	Mixed Use	Mixed Use
107	Elevated Station Pod B	Mixed Use & Emergency Pod	Mixed Use & Emergency Pod
108	RF Facility	Communications	Communications
108A	Radome - SPMGT	Communications	Communications
108C	South Pole TDRSS Relay (SPTR)	Communications	Communications
109	Logistics Cargo Facility and Arch	Logistics & Operations	Storage
110	Dark Sector Laboratory	Science	Science
116	Aircraft Fuel Module	Fuel	Fuel
118	Cryogen Facility	Science	Science & Aviation Support
119	SPRESSO	Science	Science
120	10 Meter Telescope	Science	Science
121	Rodwell No. 3 (Water Supply)	Utility	Utility
201	Radome - SPTR	Communications	Communications
300	Beverage Barn (Do Not Freeze)	Do Not Freeze Storage	Do Not Freeze Storage
301	Solar Garage	Temp. Transportation	Storage
POD	Rodwell No. 2 Building	Temp. Utility	Decommissioned
T8	Summer Camp Electrical Warehouse	Utility	Storage
R1	Rodwell No. 1 Building	Utility	Decommissioned
R2	Rodwell No. 2 (Wastewater)	Utility	Utility
NOAA	NOAA Tower	Utility	Utility

SECTOR AND ZONE CONDITIONS

Existing science facilities are maintained to continue support of the research hosted at SPS. Known structural deficiencies of buried vaults, the snow burial of five remote scientific structures, and the stretching of critical utility cabling between core infrastructure and existing scientific facilities due to the movement of the ice are current risks to research at SPS.



MAPO. Source: NSF, Gabe Nerf, 2021.

Scientific activities in the South Pole area are primarily housed in blue-colored, remote Science Research Facilities, which provide laboratory and shelter space for researchers in the Operations Zone and the Dark Sector and Clean Air Sector. The first Science Research Facility constructed was used as a dormitory and was later relocated to its current location for use as a Science Research facility. The insulated, metal-panel-clad buildings were assembled from expanded polystyrene panels and placed on steel-constructed elevated substructures. The Science Research Facilities were originally designed to have skids so they could be transportable; however, the skid system was not completed. In order to remain above ice, the expectation remains for regular intervals of building lifts, though these lifts have yet to occur.

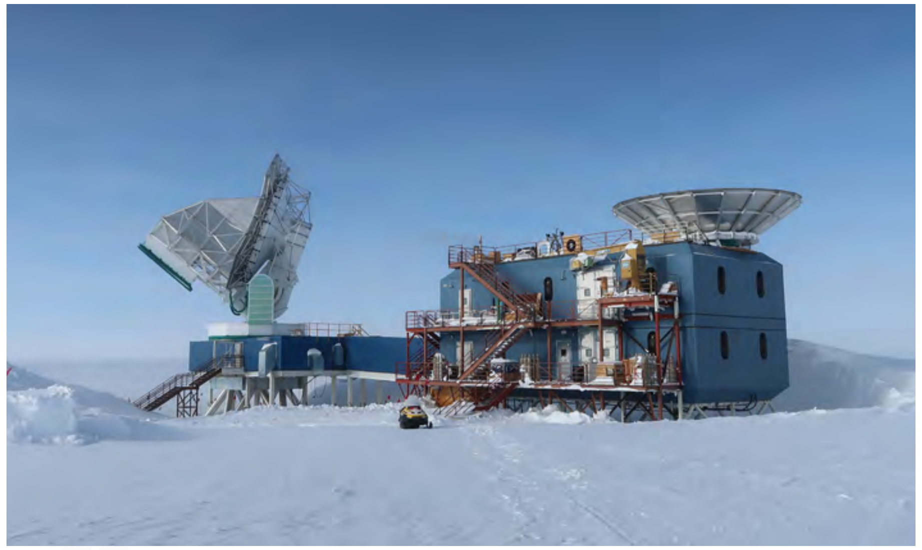
The Science Research Facilities include the Martin A. Pomerantz Observatory (MAPO, built in 1994), IceCube Laboratory (ICL, built in 1993 as a dormitory and re-purposed and relocated in 2004), and Dark Sector Laboratory/South Pole Telescope (DSL/SPT, built in 2005 and 2006, respectively) in the Dark Sector; the Super Dual Auroral Radar Network (SuperDARN, placed in its location in 2013) and the modular cryogen building (built in 2005, then relocated and remodeled in 2015) in the Operations Zone; the Atmospheric Research Observatory (ARO, built in 1996) in the Clean Air Sector, and the SPRESSO (built in 2003) in the Quiet Sector.

DARK SECTOR AND CLEAN AIR SECTOR

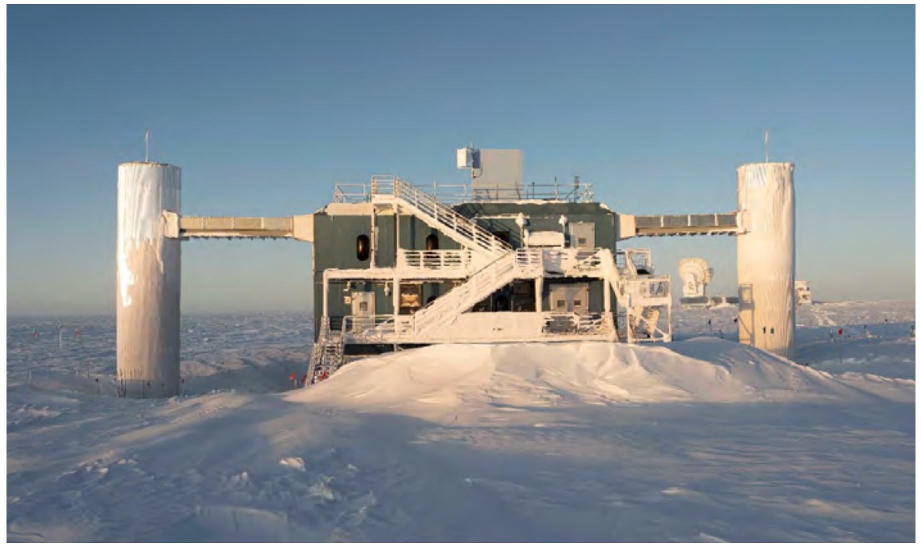
The structures within the Dark Sector and Clean Air Sector are in extreme need of lifting or relocation due to ice accumulation and burial in snowdrifts. MAPO currently has the deepest level of burial. The immediate concern of the MAPO burial is the potential loss of egress of the first story doors, difficulty servicing with fuel and cargo, and increased maintenance costs of snow removal. In the near future, there is a high potential of structural damage due to the snow loading on the building. ARO is substantially buried and at high risk for similar issues as MAPO, and it is currently being planned for a lift in an upcoming season. Based on current snow levels, DSL/SPT would be the next in line for lifting after MAPO and ARO, and they would be followed by ICL.

QUIET SECTOR

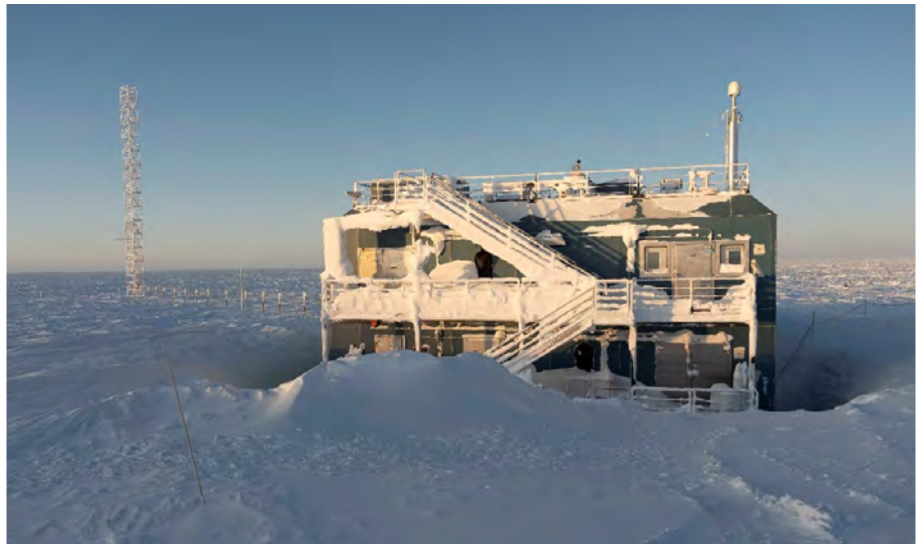
In the Quiet Sector, SPRESSO sustains large forces from the ice sheet due to its depth 20 feet beneath the surface. The structure was only designed for 15 years of use and is now 20 years old. The SPRESSO vault is encased in a crush wall exterior frame. SPRESSO is approximately 5.0 miles (8 kilometers [km]) from the Elevated Station, and its associated utility cabling now strains under the pressure and differential movement of the ice sheet, which moves the facility farther from the Elevated Station each year. Fiber-optic cabling and other utilities need to be comprehensively evaluated for replacement, as the annual movement of the ice sheet is predicted to stretch the cabling beyond its specified limit. As the current SPRESSO structure exists only to meet the needs of a specific research project, any future modifications or rebuilds of the structure are dependent on the continuation and infrastructure needs of that project. Neither the remaining life span of the structure nor the recurrence of the current research have been determined, therefore the current plan for SPRESSO is not yet resolved.



DSL. Source: Troftgruben, Undated.



ICL. Source: NSF, 2023.



ARO. Source: NSF, 2023.

OPERATIONS ZONE

The Operations Zone of the South Pole houses all primary support structures (the Elevated Station, the arches, and the primary utility infrastructure). All permanent facilities at SPS were constructed by USAP. For a multitude of reasons, many auxiliary structures exist outside of the main Elevated Station structure and the support arches. Many of these structures, such as the "Summer Camp" buildings, were intended to be temporary and removed from SPS following the completion of the Elevated Station construction. As indicated by name, these structures were only intended for seasonal summer use. However, each structure has been re-purposed over time to serve needs that the Elevated Station is unable to accommodate, such as adequate warehousing, surge housing space, and field science staging.

ELEVATED STATION

The Elevated Station was designed as a lift-able megaplex composed of two pods (Station Pod A / Building (Bldg.) No. 106, and Station Pod B / Bldg. No. 107) containing primary lodging, dining services, recreation and social spaces, a hydroponic greenhouse, limited warehousing, and emergency services. In the event of a critical power failure in the winter, Pod B can be sealed off from the rest of the structure until evacuation is possible. Pod B contains an emergency power generator, lodging, dining, and service spaces to support a winter population until rescue/resolution. The Elevated Station is connected to a network of arches containing support infrastructure and warehousing for station operations via a vertical tower / Bldg. 105. The vertical tower holds all utility connections between the Elevated Station and the arches.

Elevated Station Entrance. Source: NSF, 2023.

SOUTH POLE POPULATION: BY THE NUMBERS

SPS population falls into two distinct categories: support staff (personnel responsible for SPS logistics, safety, and operation) and science staff (all scientific research team staff whose presence is associated with specific science initiatives).

ELEVATED STATION BASIS OF DESIGN (BOD):

- Population: 150 maximum and 0 surge
- Population Ratio: 1-1 support staff to science staff
- Support Services: All sized for 150 people maximum.

ELEVATED STATION ACTUAL POPULATION:

- Baseline summer population: 150 permanent and 36 surge
- Average summer population (past 5 years, excluding FY21 COVID response): 128
- Median summer population (past 5 years, excluding FY21 COVID response): 147
- Average summer population ratio: 2-1 support staff to science staff
- Average winter population: 42
- Average winter population ratio: 4-1 support staff to science staff

CHANGES IMPACTING THE 1-1 BOD RATIO:

Assumptions made within the BOD for the Elevated Station were based on the function of the previous dome station and existing technology and regulations available in the 1990s. Since the 1990s design phase of the Elevated Station, significant advancements in technological and scientific research capabilities have occurred, creating a higher demand for data, energy, and field research staging at SPS. Large, long-standing science projects, such as IceCube and South Pole Telescope (SPT), did not exist before the design of the Elevated Station, and their associated staffing, power, and information technology (IT) support needs were not anticipated. As a result, higher levels of support services at SPS are required, including, but not limited to, IT and power generation technicians, fuel and cargo staff, and dining and emergency service personnel. Regulations and contractual requirements have progressed during this time, including the requirement for additional on-site Aircraft Rescue Fire and Fighting (ARFF) and waste management personnel. Due to the evolution of support requirements, the ratio of support staff to science personnel has yet to align with the BOD 1-1 ratio following completion of the Elevated Station in 2008.

STRUCTURAL DESIGN

The current Elevated Station was designed to provide clearance beneath the structure to reduce the rate of annual wind-driven snow drifting and accumulation. The 65,000-square-foot structure was built on a network of columns as two connected pods (A and B) and designed to be lifted twice during its lifetime to prevent burial beneath the ice and extend the structure's lifespan. Each raise is designed to lift the station 13 feet (approximately one story). However, the structure has not been lifted since initial construction was completed in 2008. A survey is completed every 1-2 years to assess the rate of settlement between the 32 columns supporting the Elevated Station, and the structure is incrementally leveled and shimmed based on the movements recorded. The ability to shim the facility is nearing capacity in some areas and a major building lift event must be completed in the future to keep it above the snow surface.

All structures in the SPS area rely on the previously constructed fuel, power plant, logistics, and garage shop arches for primary power generation and critical station support services. All surface-built arches containing these critical services are now completely submerged below the ice, complicating structural repairs to the buildings within them and increasing maintenance requirements. Although the engineering design for the Elevated Station included proposed plans to lift one pod at a time during lift events, a complete analysis of BOD lift process and the project plan is needed before the proposed lift can be confirmed as feasible or practical. The study of the associated project demands is necessary to determine several key impacts on SPS activities and amenities, including the impact on connections to utilities in the arch structures, and whether the Elevated Station can be safely occupied during the lift process.

ARCHES

Since 1974, corrugated metal arches at SPS have provided a protective covering from snowdrift and wind for the buildings under the arch structures. Over time, all the arches have been subject to deformation as snow accumulates and have become buried. Ice-floor surfaces are subject to gradual upward deflection (or "doming"), arch footings settle as the snow load exerts more downward pressure, arch ceilings press downward and arch sidewalls begin to deform by crumpling near the footings. Arch floors are subject to the differential movement of the ice sheet. These foundational settlements and movements result in the gradual elimination of clearance space between the arch ceiling and the internal building roofs. Buildings within the arches were originally constructed with approximately three feet of clearance between the arch ceiling and the interior building roofs. Arches are subject to gradual crushing due to the enormous weight of ice accumulation, and the clearance space will eventually decrease to the point where the arches will press on building structures. Arches last for decades when installed on the ice surface, then slowly begin to fail as they are buried in the ice. The fuel and logistics arches, originally built in 1974 as supporting structures for the dome station, are now beyond any set precedence for service life. These arches were retained from the previous station due to their serviceable condition at the time of the Elevated Station construction. However, they are now at the end of their service life and need replacement.

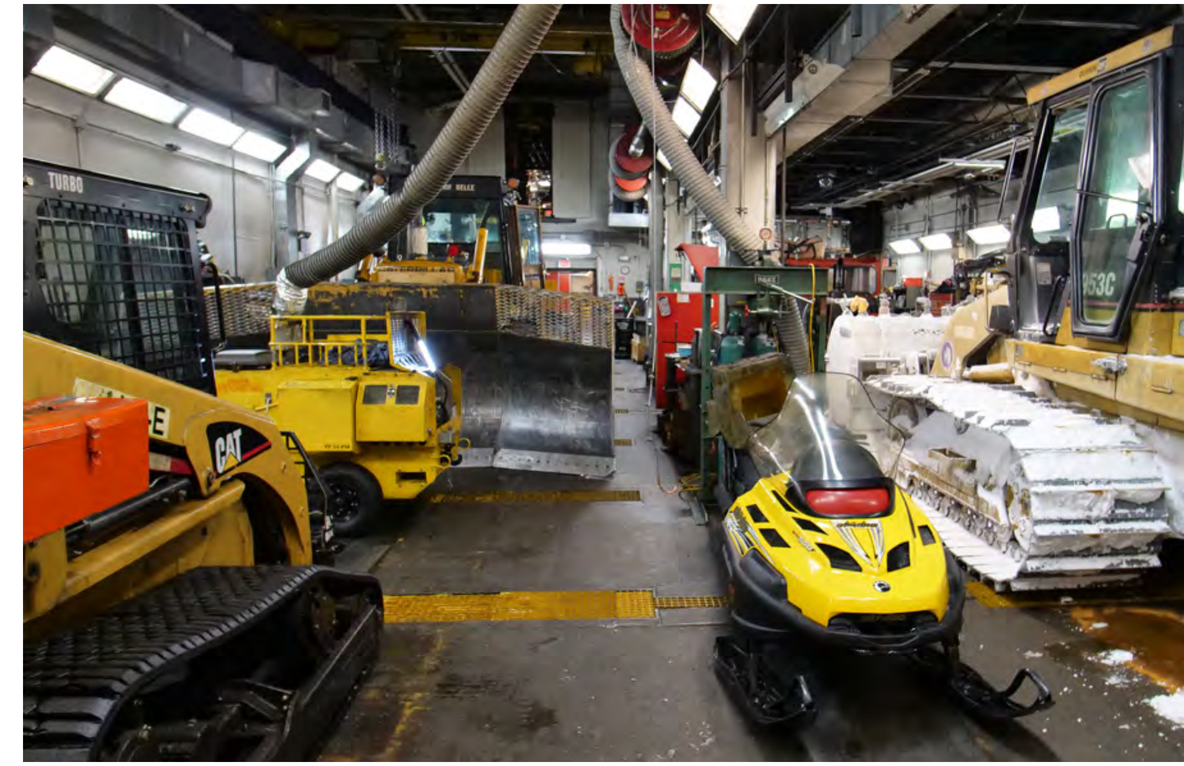
When the garage shop (also known as the Vehicle Maintenance Facility, or VMF) and power plant arches were built along the sides of the existing fuel and logistics arches in 1998 and 1999, respectively, their foundation planes were excavated to match that of the existing arches. The pre-burial of the newer arches has significantly reduced their lifespans compared to the original fuel and logistics arches.


Excavated Covered Arch Entries. Source: NSF, Bill Coughran, 2023.

GARAGE AND SHOPS / BLDG. NO. 101

The garage shop (or "VMF") arch was built in 1999 and is the arch most immediately at risk for contact between the arch ceiling and the buildings inside. The garage shop arch houses the VMF, which services vehicles and heavy equipment for SPS and contains a small facilities maintenance workshop. The VMF now services more fleet vehicles than it was designed to accommodate. The need to keep large vehicles heated over the winter was not considered in the low-bay and high-bay design of the arch or VMF, causing winter vehicle storage and maintenance activity constraints. The garage shop building is in need of significant leveling. However, due to the proximity of the arch ceiling to the interior building, raising, jacking, or shimming is no longer possible without arch ceiling contact. According to the engineering analysis completed in 2020 by DH Glabe & Associates, the VMF was projected to make contact with the arch ceiling as early as 2025, based on the current average linear encroachment rate of approximately 1.3 inches per year. The original three-foot allowance "crush zone" now measures at six inches. An interim mitigation effort to remove a corner of the VMF building and relocate roof-based heating, ventilation, and air conditioning (HVAC) systems is currently under way to prevent imminent building failure. However, this is only a temporary solution as the VMF structure and contents must be wholly replaced to continue maintaining vehicle and facilities maintenance capabilities at SPS.

Figure 5.1 indicates the condition of all inventoried fleet vehicles as of December 2023. Vehicles and equipment need to be maintained and winterized. Currently, there is not adequate heated interior space to winterize all equipment. Many vehicles in the fleet at SPS have reached the end of their life expectancy and are often in disrepair, causing constraint on operations. In efforts to replace the aging fleet, two (2) new loaders and 20 new snowmobiles will arrive at SPS in 2025. However, as shown in Table 5.1, 65% of the existing fleet at SPS is beyond its service life.



Winter Vehicle Storage. More vehicles and a greater variety of vehicles are stored in the VMF over the winter than the original station design had anticipated. Source: NSF, Josiah Heiser, 2021.

Figure 5.1 SPS 2023 Equipment Conditions as of February 2024..

Winterized Tracked Vehicle. Source: NSF, Bill Coughran, 2023.

Snowmobile Spool Storage. Source: NSF, Elyse Dinnocenzo, 2023.

POWER PLANT ARCH / BLDG. NO. 103

The power plant arch, built in 1998, contains the primary power generators, waste heat recovery equipment, electrical switchgear, and associated power and hot water distribution lines. Snow is removed annually with a South Pole Traverse (SPoT) tractor to maintain a snow overburden no greater than five feet. This approach is intended to extend the arch's lifespan for a limited time, as the natural grade is rising at roughly eight inches per year. The current location of exhaust stacks creates a safety risk, as escaping heat creates wells (or deep voids) in the snow. Infrastructure in the power plant arch is projected to make contact with the arch ceiling in less than ten years. The power plant arch and associated infrastructure must be replaced in advance of this structural failure to prevent critical loss of power and heat, which would impact all buildings serviced by the power plant, including the Elevated Station itself. The reciprocating internal combustion engine (RICE) generators (originally installed in 1999) have recently been and are projected to continue functioning dependably, beyond the life of the arch that contains them. It is estimated that the engines themselves are approximately halfway through their service life, assuming continued maintenance in accordance with the manufacturer's requirements.

FUEL ARCH / BLDG. NO.104

The fuel arch, built in 1974, is one of the oldest arches at SPS. The arch is in its original 1974 construction, however, the tank infrastructure within the arch was refit in 1999. The arch has traveled 1640.42 feet (500 meters) horizontally with the movement of the ice cap since its construction and is now completely buried by snowdrifts. The fuel arch contains 45 fuel-storage tanks, secondary tank containment, piping, and primary pumping infrastructure. The snow floor currently exhibits significant doming due to differential movement, heavy ice load and associated pressures along the wall footings. These movements negatively affect the alignment and fixed-point connections of the tanks, structures, and piping systems comprising the SPS fuel delivery system. Tank leveling, shoring and pipe system adjustments and/or replacements are typically performed as annual maintenance. The remaining leveling and adjustment capacity of the system components and remaining fuel delivery system lifespan is unknown. However, fuel tank safety relief valves are estimated to make contact with the arch ceiling in less than ten years. Safety railings on top of fuel storage tanks are a contact risk as the tank maintenance access area above the tanks is quickly diminishing. The fuel arch and associated infrastructure must be replaced in advance of this structural failure to prevent critical power failure at the station.

LOGISTICS CARGO BUILDING / BLDG. NO. 109

Like the fuel arch, the logistics arch was built in 1974, has provided extended effective service, and is nearing its end-of-life expectancy. The logistics arch contains a single heated warehouse/logistics building and open cold storage areas with vertical pallet racks for bulk box storage on a structural floor. The warehouse is inadequately sized to house the entire stock of supplies and materials now needed to maintain the technologies and infrastructure of the Elevated Station and Science Research Facilities. As a result, more than half of the station's supplies are stored outside on snow berms and across a slew of disparate auxiliary structures in the immediate SPS area.

A vertical tower containing a service elevator connects the Elevated Station to the arch system and warehouse via an under-snow tunnel. The existing elevator fails to serve as a cargo movement device because it is improperly sized to handle the standard cargo packaging delivered to SPS. It is unable to move people due to the the lack of annual recertification required to meet occupancy code standards. As of January 2025, the elevator is no longer in service. The plywood floor of the cold storage area rests on a floating steel frame that is subject to the doming of the ice surface beneath it. In 2023, the centerline of the floor was nearly ten inches higher than the outer edges. The smooth plywood finish and the slightly uneven slope of the floor has created a slip risk for personnel and forklift operation. Additionally, the shelving racks have begun to tilt as the floor buckles.

The buildings in the logistics arch are projected to make contact with the arch ceiling in less than ten years, as the original three-foot "crush zone" space is now approximately 18 inches. The infrastructure inside the logistics arch must be replaced in advance of structural failure or floor buckling.

Power Plant Generators. The power plant arch connects to the Elevated Station tower and to the logistics arch via interior arch system corridors. Source: NSF, Josiah Heiser, 2021.

Warehousing in the Logistics Arch. The logistics arch and heated warehouse building have a structural steel and plywood floor to allow the forklift use and pallet storage; the floor is beginning to dome. Source: NSF, Josiah Heiser, 2021.

SNOW BERM STORAGE

Due to the lack of adequate indoor storage space, supplies are stored in a complex of snow berms adjacent to the airfield and cargo staging areas. The manual labor required to confirm inventory across the disparate locations significantly increases the level of difficulty in confirming and retrieving inventory. Recorded material condition of items stored in berms is unreliable as the items are subject to fluctuating, unknown environmental conditions, reducing inventory of ready use material accuracy. Projects cannot reliably rely on materials stored outside the logistics arch to remain in issuable condition for project and construction use. Outdoor snow berm storage carries potential risk to damage of materials as mission support personnel must dig out materials to confirm status of inventory , introducing risk of damage to material during excavation. Storage berms logistics footprint is approximately 68 acres.

As of 2024, spare and remnant construction materials from the Elevated Station, IceCube, and SPT construction projects from the early 2000s remain buried in snow berms. Removal of materials is an annual requirement. Progress has been incremental due to the volume of the materials and the labor hours associated with their retrieval from the berms. As of the 2023 rate of material movement and with the assumption necessary resources were available, the removal of materials from all berms would be a seven-year evolution. Snow berms of remnant material encompass approximately 62,227 sf and 497,819 cubic feet of material. Berms must be rebuilt every four years to remain above snowdrift.

AUXILIARY STRUCTURES

More than 20 auxiliary buildings, tents, and huts are located outside the Elevated Station, providing storage and staging areas outside of the Elevated Station and arches. These uses include, but are not limited to, storing cargo, DNF supplies, waste, fuel, summer skilled trade shops, snowmobile parking, and Dark Sector and field science staging.

“Summer Camp,” which was originally created to support the construction of the Elevated Station and was slated for removal upon completion, remains on station despite construction completion in 2008. Most of the structures in the Summer Camp area are now used for storage. These structures were generally built on-site and not equipped with skis, which reduces the ability to move them to new locations without structural damage.

Four (4) “Hypertat” structures were included as temporary housing in Summer Camp. Two (2) of the these buildings were later converted into storage structures and are now being renovated to restore their use for surge housing. A single Hypertat can provide nine beds. Two (2) Hypertats are equipped with solar panels that produce enough energy to support themselves and add a small amount of energy to the power grid. Hypertat bedspace is not accounted for in annual bedspace planning, as these beds exist to provide necessary redundancy during weather or other event-related flight groundings during periods of peak population.

A snow pile created in the summer camp area awaits relocation to the snow storage area. Snow pile scale: flat edge is approx. 4ft tall. Source: NSF, Elyse Dinnocenzo, 2023.

Auxiliary Structures. The area surrounding the Elevated Station is occupied by a variety of auxiliary structures serving a wide variety of storage and operational needs. Source: NSF, Ian McEwan, 2016.

INFRASTRUCTURE

ENERGY

POWER GENERATION

The SPS power plant is housed in an arch that is now below the surface of the snow. Fuel to support SPS operations is located in the nearby sub-surface fuel arch, and an emergency power plant is located in Pod B of the Elevated Station to provide emergency power in the event of a power failure.

Waste oil produced by SPS activities is currently filtered and used as fuel for power production. Expanding the use of waste for energy and heating is a desirable direction for future energy production at SPS. Incorporation of waste-to-energy and micro gasification systems could drastically reduce the amount of waste that must be removed from the continent via existing waste retrograde procedures or deposited into the sewer outfalls (decommissioned Rodriguez Well, or “Rodwell”), where it will remain beneath the ice surface for thousands of years. A Rodwell is a well drilled into the ice sheet for water and used as an outfall for human waste when water wells are decommissioned.

The two (2) Hypertat structures currently used for surge housing have solar panels. Although the South Pole is subject to 24 hours of continuous sunlight in the austral summer, the angle of the sun is not ideal for the solar technology currently present at SPS. Production levels are low, though the panels do provide energy to the structures they rest upon and contribute a small amount of additional energy into the electrical grid. Expanding solar power production at SPS may be feasible, but it requires additional research on currently available technologies.

Wind energy has a small presence at SPS; at one point, one wind turbine generator was positioned near the Rodwell. That turbine no longer works, however serves as an example of an application for harnessing wind energy. Wind speeds at SPS are typically less than ideal for extended periods of time to capture wind energy and surge storm winds can exceed turbine limitations. Wind gusts can over-torque the blades, which triggers a mechanism that prevents the blades from spinning. The static blades are then subject to icing that often requires manual removal before energy production can resume. Expanding wind power production at SPS may be feasible with current available technologies, but additional research is needed before these technologies can be incorporated.

FUEL TRANSPORT AND STORAGE

Approximately 300,000 gallons of fuel are transported to SPS by three overland traverses each year. The remaining annual fuel (approximately 150,000 gallons) is delivered by LC-130 aircraft. While fuel transport capacity is a factor in the amount of existing fuel storage at SPS, it is not the only limiting factor. Fuel capacity in the arch is 468,000 gallons of fuel in tanks, with a safe fill of 95%. The actual amount of volume available is less, as the pick-up lines do not extend to the bottom of the tanks and thus cannot utilize that fuel. Additionally, 68,000 gallons of emergency reserve fuel is kept in surface tanks separately from the fuel arch.

SPS must be able to sustain itself without fuel resupply annually from February 15 through November 15 (roughly 274 days). Approximately 425,000 gallons of fuel must be on hand at SPS at the close of summer operations to sustain winter operations, maintain a contingency buffer for emergencies, and for SPS reopening the following summer. This amount of fuel is subject to fluctuation based on summer and winter power consumption. Increases in power demand increase fuel consumption, which affects the amount of fuel that must be delivered each summer. The price for combined air- and overland- delivered fuel varies year over year. The projected price for AN8 fuel in FY30 is $24.85 per gallon.

Power Plant Generators. Source: NSF, Josiah Heiser, 2021.

POWER PLANT CAPACITY AND INFRASTRUCTURE

The current power plant was designed for a maximum capacity of approximately one megawatt (MW). It consists of three CAT 3512B diesel-fired RICE generators, each with an on-site prime power rating of 750 kilowatts (kW), and a CAT 3406C peaking unit with an on-site prime rating of 239 kW (all engines are de-rated due to high altitude). The normal power consumption target is no more than 680 kW for the 3512Bs. “Prime power” is 600 kW, which is the maximum power accessible for an unlimited number of hours per year in the variable load setting (80% of the generator capacity). Prime power assumes an average load under 80% of prime capacity to maintain the lifespan of the system and the ability to operate at a higher level in an emergency. Power usage above prime power decreases generator efficiency; therefore, 680 kW is considered the high end of the range for acceptable continuous operation. If the power consumption reaches 712 kW, the peaking unit activates to carry the additional load. Generally, only one 3512B runs at a time, except during transfer operations.

AVERAGE CURRENT POWER CONSUMPTION

Current power consumption ranges have been compliant with energy consumption targets, with an average of 600 kW from 2013-2019. The prime power is 600 kW for each generator and running the peaking generator continuously is not necessary. If the peaking generator were needed the maximum additional capacity would be 30 to 50 kW.

The current SPS power consumption level is maintained at the optimal capacity of the existing power plant. Power consumption rates would be expected to rise with any facility expansions beyond the current footprint of the Elevasted Station, aches, and existing science facilities, which would exceed the optimal capacity of the current power plant. Gradual increases in fuel demands have occurred as aging infrastructure requires more maintenance to remain functional and the volume of snowdrift to be relocated each summer season increases.

POWER PLANT EFFICIENCY

The average power plant fuel efficiency at SPS is approximately 14 kW-hour (hr.)/gallon (gal) (per data from June 2023). The current cost of energy at SPS, based on the current plant and fuel cost, is $1.80/kW-hr, assuming $1.00/kW-hr:

$25.45 ($/gal) /14 (kW-hr/gal) = $1.80/kW-hr

UTILITY CABLING

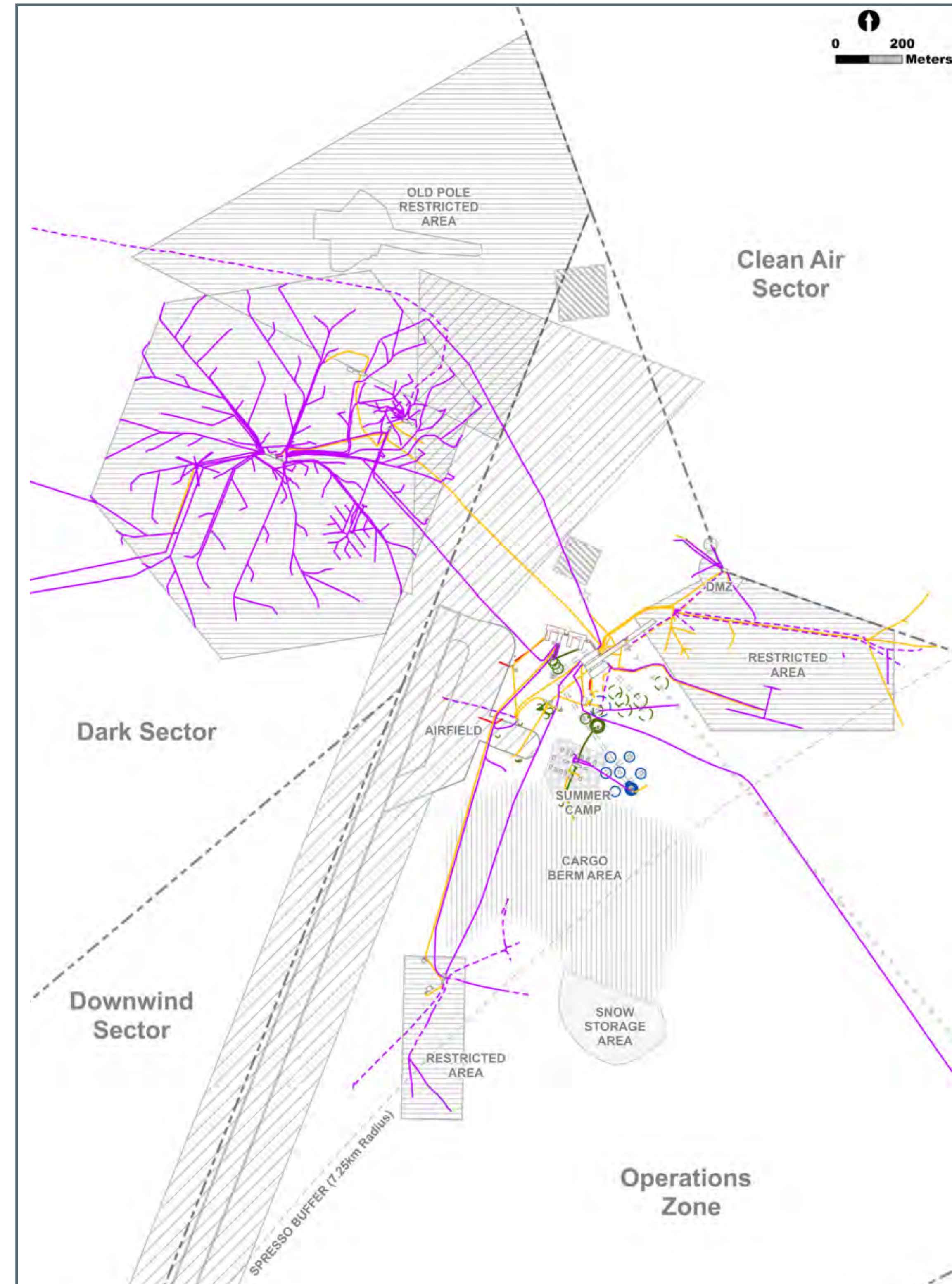
The subsurface utility cabling running throughout the SPS area forms a sprawling network of cables that were placed from utility source to end on a project-to-project basis without a comprehensive utility plan or a detailed record of placement. As a result, many utility lines are difficult to locate, and the Operations Zone area immediately adjacent to the Elevated Station has become a crowded subsurface network. A substantial portion of the existing SPS immediate area contains scattered subsurface vaults, decommissioned Rodwells, and antennas, further complicating future structural placements within the area.

Exact locations of utility lines are unknown in many areas, and locations are not surveyed annually. Buried utility cable locations shift within the ice sheet over time, complicating utility location efforts. Cabling repairs and location is typically accomplished via hot water trenching.

Of particular concern is the stretching that occurs throughout a cable line due to the annual, uneven, differential movement of the ice sheet. The power and data cables running to SPRESSO, for example, are currently stretched nearly to capacity in several areas. A coordinated trenching and cabling effort may be combined with the SPRESSO vault replacement, as the vault itself has reached the end of its designed lifespan.

Critical cabling in the immediate SPS area runs through abandoned building sites, buried vaults that get increasingly deeper, and structures that are approaching the end of their service lives due to structural strain or burial. The airfield beacon lights, for example, are currently fed via cabling through an abandoned building site.

Building 61 houses the electrical distribution module and primary cabling hub for the Dark Sector. The structure is becoming increasingly buried and in need of lifting or replacement to ensure uninterrupted power to Dark Sector science.



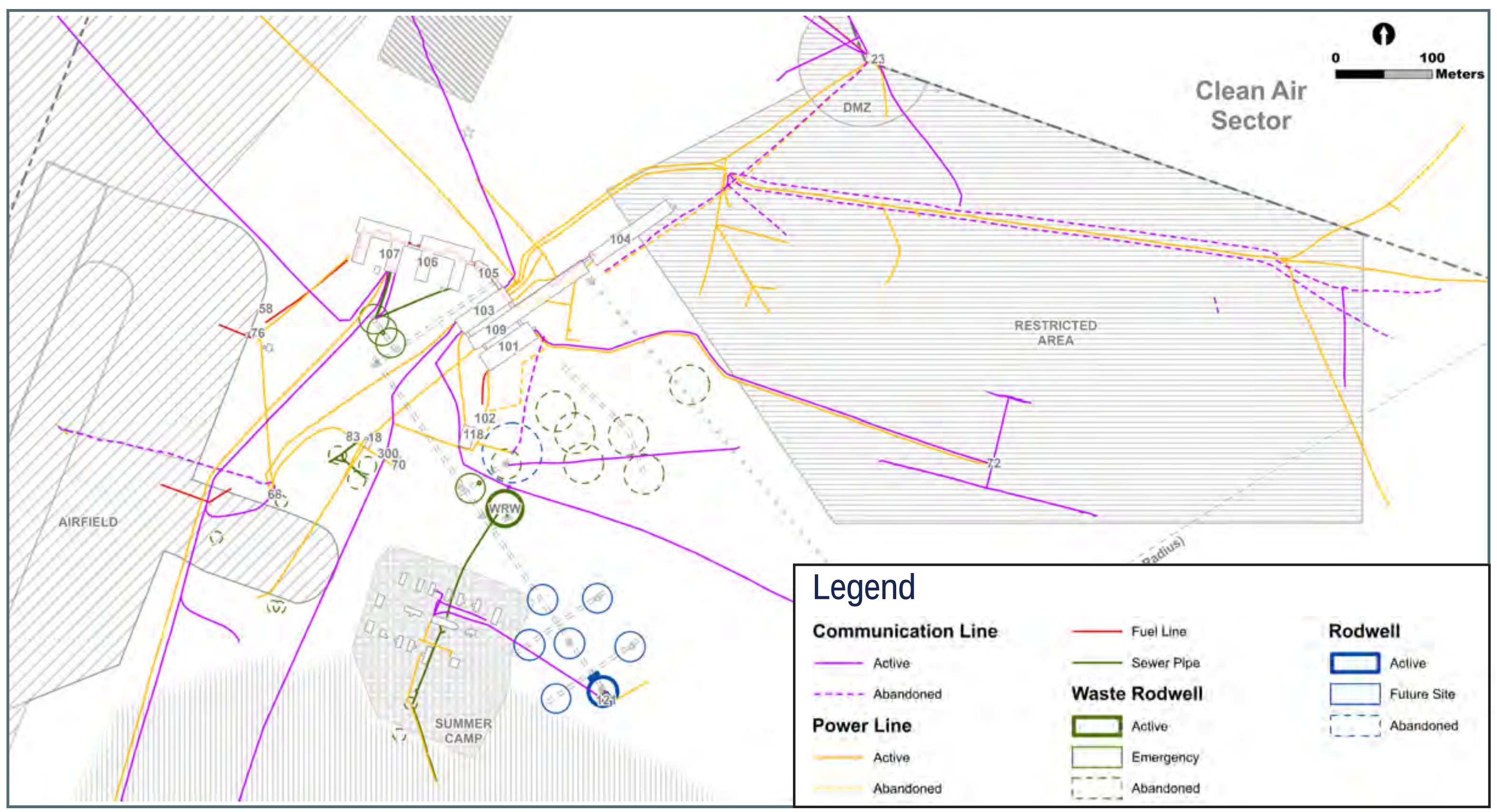


Figure 5.2 Approximate Cabling Map. The SPS area has an overlapping network of cables running under the ice. Source: NSF, Undated. Not to scale.

INFORMATION TECHNOLOGY (IT) & TELECOMMUNICATIONS

Communications and science demands are currently subject to the following data/IT bandwidth and restrictions at SPS.

- Satellite Constellations:
  - Two satellite constellations are used by the U.S. Antarctic Program (USAP) for communication:
    - NASA Tracking and Data Relay Satellite System (TDRSS): Not expected to be available in the future.
    - Defense Satellite Communications System (DSCS): Owned and operated by the U.S. military. USAP does not have a written commitment for continued service, and its availability is subject to change. DSCS is expected to be available to South Pole until 2043.
  - Coverage:
    - The two satellite constellations combined provide approximately 16 hours of coverage each day.
    - Adding another DSCS satellite would increase coverage to nearly 20 hours of satellite connectivity.
  - Data Load:
    - The daily allowable science data load is 450 gigabytes, dedicated to scientific data transfers within a four-hour window.
    - Business, personal, and aviation uses are allocated outside of the science data transfer period.
  - Two Iridium Certus systems are installed with antennas and antenna electronics mounted on top of the RF Building (with built-in heaters) to provide backup and gap-filling Internet access when TDRSS and DSCS are not visible.
- Wi-Fi:
  - Wi-Fi is currently available only inside the Elevated Station.
  - There are concerns that Wi-Fi signals could interfere with Dark Sector research.
- Emergency and Aviation Communications:
  - Emergency Medical Services: Relies on the Land Mobile Radio (LMR) system.
  - Aviation:
    - South Pole monitors VHF 129.7 (Common Traffic Advisory Frequency, CTAF) for arrival and departure intentions.
    - UHF/AM air-ground radios are used.
- Telephone Services:
  - Telephone services are facilitated through Iridium connections routed through a Call Manager.
  - These Iridium connections are made via externally mounted Iridium antennas.

Multiple private entities are launching low Earth and polar orbiting systems that may enhance communication availability, increase capacities, and improve capabilities at SPS.

WASTE

Current solid waste management practices at SPS involve on-site packaging and shipping to McMurdo Station via South Pole Traverse (SPoT) or LC-130, for onward shipment to the continental U.S. via refrigerated vessel to Port Hueneme, California. This process is referred to as “waste retrograde.” Waste material removed through this process must remain refrigerated on-site and during transit until it reaches its final destination to minimize mold and bacteria growth. Once the waste reaches the continental U.S., it is incinerated or otherwise disposed of by fee-based private companies and fee-based public systems that have contractual agreements with the USAP. The required infrastructure for moving refrigerated cargo and the number of transfers currently involved in the process restricts the speed and efficiency of waste removal from SPS. Investment in a modernized process would alleviate multiple logistical challenges and reduce supply, transportation, and labor costs.

Human waste is handled via a sewer outfall system that re-purposes decommissioned Rodwells. When the sewage outfall reaches capacity, waste deposits are redirected to another decommissioned Rodwell and the timeline for its life cycle begins again. The current sewer outfall has approximately 2.8 million gallons of capacity and has reached capacity. A new waste Rodwell must be established to enable a sewage management transition before overflow occurs. An intermediate sewer outfall is being constructed to collect human waste until water production can be transitioned to a new Rodwell and the decommissioned Rodwell can become the new waste outfall.

DSCS. USAP satellite infrastructure provides approximately 9.5 hours of communications coverage per day. Source: NSF, Gabe Nerf, 2020.

Waste Retrograde. Packaged retrograde materials are set outside over winter and staged along the SPoT route and airfield to be loaded onto the SPoT platform or an LC-130 in the austral summer. Source: NSF, Austin Danicic, Undated.

WATER

Approximately 650,000 gallons of fresh water are provided to the station each year via a Rodwell and water treatment system. A well pump is lowered into the Rodwell and runs continuously. When the water well gets too deep (approximately 500 feet to water's surface), the Rodwell is decommissioned and water sourcing moves to a new Rodwell. A set of future Rodwell locations is planned in the immediate SPS area, organized in a honeycomb pattern adjacent to the ice tunnel system to minimize relocation impacts on the Elevated Station's water supply infrastructure. To maintain operation of the Rodwell, the pump must be pulled and the access hole re-bored annually.

Complete installation of a new Rodwell can take up to six years, including component delivery and installation. Design generally requires pre-fabrication prior to shipment to Antarctica. Engineering and conceptual review requires specialized expertise and participation of subject matter experts in polar well construction. The next water Rodwell is expected to be ready for use between 2028 and 2030.

Back-up water supply is provided for the population via a portable, glycol-heated snow melter that is staged outside of the existing power plant arch. Snow must be manually loaded into the system and melted before being treated in the water treatment plant. The back-up snow melter is adequately sized for winter populations, however is unsuitable for support of summer season populations.

The plans for the Elevated Station initially included a wastewater treatment plant to reduce demand on water supply and sewage outfall Rodwells. The plant was removed from project scope before construction.

TUNNELS

The ice tunnel system has functioned well as a utility corridor (utilidor). Ongoing maintenance is required to keep the tunnel walls square because they slowly bulge inward due to ice build up. Ice tunnels work well and can be utilized in the future as utility locations as new buildings are added.

SCIENCE STRUCTURES IN THE OPERATIONS ZONE

A variety of scientific research projects are located within the Operations Zone, grid-east and grid-northeast of the Elevated Station. These long standing projects create potential for conflict between operational activities and machine operation and scientific instrument sensitivity. However, proximity to the Elevated Station is important for these projects due to their pedestrian winter servicing requirements.

The positioning of scientific research facilities and vaults in the Operations Zone has created the need for Restricted Zones in operational space. This limits the area within the Operations Zone where support operations may occur without conflicting with scientific measurement and communications tools. Although these science projects may change over the years, the vaults that may be left behind create potential building hazards in the Operations Zone.

Ice Tunnel Utilidor. Source: NSF, 2023.

FIELD SCIENCE

Support services for field science are supported by McMurdo Station, allowing for continuity in mobilization and demobilization and a provide a central location for returned equipment that can be prepared for re-issuance. SPS was not originally designed to serve as a support hub for field science. Due to the absence of adequate supply storage space at SPS and the changing locations of scientific interest that exclude SPS as a support hub, this has been the most efficient model for maximizing field support and Search and Rescue assets thus far. However, this model of field science deployment currently requires shipping supplies for each project to and from SPS via LC-130 aircraft, SPoT, or science traverse which creates logistical challenges when field equipment competes with other equipment and supplies for delivery space on the LC-130s and traverses.

SPS currently operates as a staging base for field science expeditions to eastern Antarctica. Existing field science staging space is located in the Cryogen/Balloon Inflation Facility (BIF) building, B2 laboratory, and in a Hypertat hut in the old Summer Camp area. However, field science staging areas are not adequately sized to stage the volume of deep field science gear that moves through SPS. In the Elevated Station, there is no indoor space dedicated for field gear storage or for briefing field teams. Due to the short nature of planned stays, temporary lodging for transient field science teams is often provided in the Hypertat structures located in the Summer Camp area. It is important to note that not all field science teams depart from the station to field camps for the entirety of the summer, and there are frequent weather-related delays due to reliance on aircraft transportation. To account for these delays, bed space occupancy periods must be reserved for field science visitors beyond the proposed official dates of each field science expedition. These teams compete for bed space with other SPS-based researchers and operational and infrastructure-project personnel.

A recent summer project used polar equipped wheeled vehicles and proved out a concept of using the technology for future field teams based out of SPS.

EMERGENCY SERVICES

On-site emergency response capability consists of a medical clinic with two qualified medical staff, a gymnasium space for mass casualty and emergency response staging and treatment, and a brigade-based response to emergencies. Aircraft Rescue and Fire Fighting (ARFF) capability is are required per U.S. Air Force Aircraft Fire Protection for Exercises and Contingency Response Operations (Air Force Pamphlet 32-2004) for military LC-130 aircraft operations during the austral summer.

The SPS emergency services brigade that operates in the summer is staffed by the winter-over team. This provides year-round consistency for primary response to all manner of emergency situations, with the exception of Air Force aircraft under ARFF jurisdiction. The brigade responsibility turns over once each year in November, when the previous team departs the station at the end of the winter and is replaced by the next year's group. The presence of the professional ARFF contingent during the short summer allows the new brigade to train and drill for readiness to cover station needs through the long austral winter.

Search and Rescue capability is managed from McMurdo Station to provide continuity and centralized command and control, and it is reliant on airlift availability (currently provided via LC-130, Basler, and Twin Otter aircraft). Primary emergency response resources for field or remote response are sent from McMurdo Station via airlift. SPS houses a limited cache of emergency equipment and supplies in the Elevated Station to be used for off-station emergency response. If future Search and Rescue responses are to be coordinated and staged out of SPS for near-field science, additional dedicated storage space and personnel will be necessary.

Field Camp Planning. Field camps vary in size, based on the scale of the research support requirements. Each camp must plan for limited supplies and transportation options. Source: NSF, Howard Conway, Undated.

Emergency Services. Source: NSF, Undated.

For significant events, emergencies are managed at a program level by the McMurdo Emergency Operations Center, which makes resource distribution decisions. Incident command of the SPS brigade remains local. Examples of large events include aircraft emergencies, Search and Rescue operations for field groups, aid to other nationality programs or private expeditions, humanitarian aid, international diplomacy, and medical evacuations.

Medical facilities at SPS are in the Elevated Station for on-station medical needs, but the location of emergency service equipment, supplies, and servicing areas does not provide ease of access. Medical supply storage, for example, is located on the lower level of the station, while the substantially undersized medical center is located on the upper level. Storage space for emergency response team gear was not included in the Elevated Station plans. The gymnasium provides adequate space for staging and response in the event of a mass-casualty or large-scale emergency response. However, none of the medical servicing areas are located for ease of access during patient transport.

The Elevated Station and facilities within arches primarily employ a water sprinkler fire suppression system. Auxiliary structures outside of the Elevated Station employ localized fire suppression systems that are meant to protect only specific high-value equipment. Arches are ambient or colder, so no fire suppression is provided under arches. The under arch Power Plant and the Emergency Power Plant in the Elevated Station have CO2 fire suppression systems, and the under-arch VMF is sprinklered. These systems are subject to annual maintenance and testing to ensure code compliance and reliability.

Emergency service personnel rely on the Land Mobile Radio system for communication of emergency events and needs, while aviation-related coordination relies on UHF/AM air-ground radio systems. New technologies may resolve this issue, but there is an overall lack of variation in the existing systems to prevent multiple failures. All emergency communications systems require periodic upgrades, based on military requirements, equipment condition, obsolescence, and technological capabilities, and all systems are currently in need of system updates.

TRAVERSES

Overland traverse platforms are a well-established technology in Antarctica and are used by many other national programs with a permanent presence on the continent, such as Australia, France, and Russia. A South Pole Traverse (SPoT) platform was established between McMurdo Station and SPS in the mid-2000s to increase fuel and cargo delivery capacity and reduce reliance on LC-130 aircraft. The SPoT fleet delivers fuel and cargo to SPS and transports waste retrograde materials back to McMurdo Station to be shipped via vessel to the continental U.S. for disposal. After the first mission proved to be a successful alternative to LC-130 delivery of supplies, the number of SPoT missions per year has gradually increased to three over the course of the austral summer. The result has been a significant reduction in LC-130 supply chain constraints related to restocking the station and a higher potential delivery capacity for fuel and cargo overall. Due to the short length of the austral summer, additional SPoT missions are not currently possible.

The heavy science traverse (HST) fleet, which generally supports large field projects out of McMurdo Station, has started several seasons of East Antarctic operations through SPS, including pre-staging fuel and cargo. The HST has proven to be an effective and efficient solution to delivering field supplies as it is not subject to the same restrictions and constraints as small aircraft in Antarctic weather and climate. The SPoT fleet has been used to support East Antarctic science from SPS in addition to its normal resupply mission. SPoT has assisted HST with moving science cargo to and from various locations along the McMurdo-SPS route. In crevasse-free regions, this has allowed the HST to move forward in accordance with scientific research schedules without costly weather-related delays. Similarly, light science traverse systems could improve access to East Antarctica research sites from SPS.

Due to aircraft and science activity restrictions caused by the COVID-19 pandemic, the SPoT and HST fleets were combined to deliver all fuel and cargo to SPS for the 2020-2021 season. This was the first total resupply of the station by traverse platform, and it was highly successful. The efforts demonstrated both the feasibility and utility of traverse as a means of annually resupplying SPS. It drastically reduced delivery costs, increased the efficiency of waste retrograde efforts, and reduced the population impact on SPS. Traverse platforms are preferable for population and bed space management at SPS, as the fleet includes integrated bed space for its operators and does not rely on external bed space at SPS.

Traverse platform efficiencies could be bolstered by SPS cargo handling upgrades. Cargo slated for delivery by traverse or LC-130 must currently be palletized in Christchurch, New Zealand (if delivered to McMurdo Station by ship or LC-130 under special circumstances) and/or McMurdo Station (if delivered to SPS by LC-130 or traverse before shipment).

The existing SPoT fleet can deliver full 20- and 40-foot shipping containers, but there is no infrastructure available at SPS to unload or reload these containers onto the traverse platform. The lack of such infrastructure increases staging, packaging, and storage demands throughout the cargo supply chain. Adding such infrastructure to SPS could assist in alleviating these issues. The supply storage inherently provided by the containers during on-site inventory and sorting efforts would help foster a sustained departure from the current snow-berm storage model, eliminating the demand for personnel devoted to digging out and relocating buried supplies.

According to the 2014 CRREL report Economic Analysis of the South Pole Traverse, "SPoT's net economic benefits of $2.0M/ year [using 2011 dollars] result from significantly lower delivery costs per pound compared with LC-130 airlift ($3.60/pound (lb.) versus $6.10/lb.), respectively." In addition, current projections estimate that expanded SPoT capabilities could further reduce the reliance on LC-130s for fuel delivery and significantly reduce long-term fuel delivery costs. The relative ease of platform scalability (an expanded fleet) supports the development of an expanded traverse platform.

Fuel Bladders pulled by SPoT. Source: J. Lever, 2008.

Station Approach. The traverse route curves around the skiway before heading grid-north to the Elevated Station. Source: NSF, Colin Whitmore, Undated.

TOURISM

The ASMA defines areas of the Operations Zone as historical markers and for Non-Governmental Organization (NGO) tourism activities. These areas are intended for use as NGO tourism campgrounds and related vehicle or aircraft parking. A NGO parking area and associated visitors camp is located grid-north of the Elevated Station and only used in the summer months.

In the 2011-2012 summer, over 300 tourists visited the South Pole in honor of the station's centenary. The number of annual tourists continues to increase over time. Approximately 300 tourists now visit the South Pole each year on NGO expeditions with private tour operators. Visits to the geographic South Pole are the pinnacle of trips to the South Pole, and most visitors walk or ski to both the Ceremonial South Pole and the geographic South Pole, both of which are within the immediate station area.

The USAP allows use of the airfield for NGO aircraft and designates a separate groomed parking area grid-north of the station for NGO aircraft. The USAP allocates a small, mobile, modular visitor's center and outhouse, though does not provide supplies, use of the Elevated Station facilities, or any other non-emergency support to private expeditions. A fixed number of limited tours of the Elevated Station are apportioned among the tour operators through a pre-season, off-continent agreement between NSF and the operators, coordinated through the International Association of Antarctic Tour Operators (IAATO).

If tourism continues to grow, the potential for impacts on the operations and infrastructure at SPS will increase. Separation of uses, especially surrounding the geographic South Pole, is becoming more important each year.

The designated approach routes avoid scientific sectors and hazard areas encroachment. Current access to the Non-Governmental Visitor (NGV) sites is as follows:

DO NOT ENTER CLEAN AIR SECTOR OR QUIET SECTOR

- To avoid entry into Clean Air Sector, do NOT travel south of S88° 39' between longitude lines W020 and E110.
- To avoid entry into Quiet Sector, do NOT travel south of S89° 49' between longitude lines E110 and W170.

WEST APPROACH – FROM HERCULES INLET, MESSNER START, RONNE ICE SHELF

- Expeditions approaching between W020 and W110, call ALE Communications 24 hours before arrival and advise intentions.
- Aim for 'West Waypoint' S89° 59.0' W016° 00.0'. Look for a 'Welcome to the South Pole' sign. Do not enter the Clean Air Sector.
- From West Waypoint, continue about 1 km to the NGV campsite at approximately S89° 59.45' W004° 15.0'. Do not cross the flag line that marks the Clean Air Sector boundary.

SOUTH APPROACH – FROM AXEL HEIBERG, LEVERETT, BEARDMORE GLACIER, ROSS ICE SHELF.

- Expeditions approaching between E110 and W110 aim for 'Pole Turn 1 Waypoint' S89° 55.29' W132° 00.00'. Avoid entering Quiet Sector.
- Call ALE Communications when you arrive at 'Pole Turn 1 Waypoint'. DO NOT PROCEED beyond Waypoint until advised by ALE Communications. Be prepared to camp as air operations may delay onward passage to South Pole.
- When approved to continue, proceed 5.2 km to waypoint S89° 57.78' W149° 45._', West of skiway threshold.
- Continue 4 km along west side of skiway, to the crossing beacon at S89° 59.65' W047° 53.45'. Stay at least 30m from the flagged edge of the skiway.
- Cross skiway at designated crossing point, marked by a red beacon, and proceed towards South Pole markers and NGV campsite.
- Do not cross the skiway if beacon is flashing.

NGO Camp. Source: NSF, 2023.

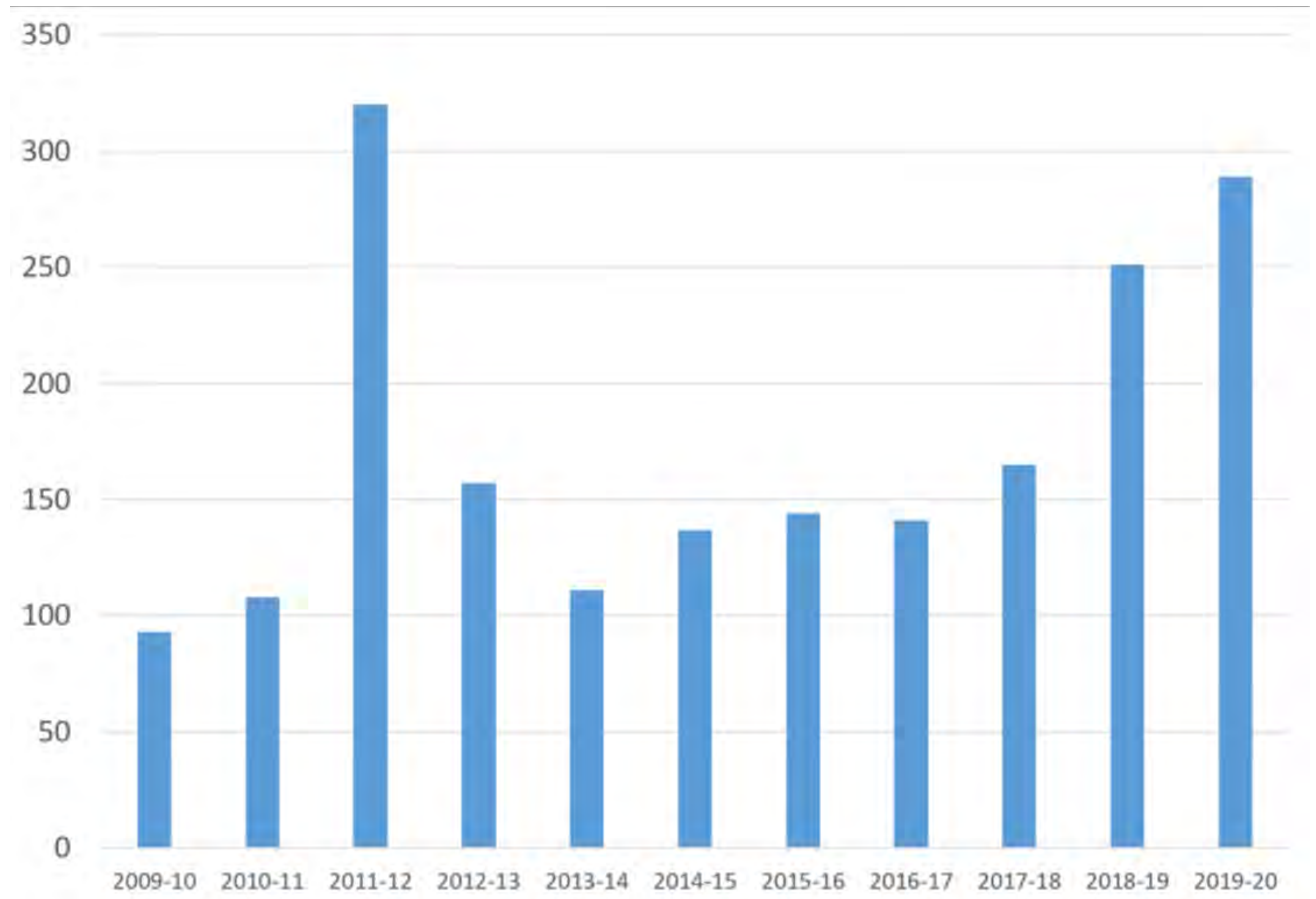


Figure 5.3 NGO Visitors by Summer Season. The number of tourists who visit SPS has continued to grow over the past decade. The 2011-2012 Centenary summer season population may soon be surpassed. Source: IAATO, 2020.

DOWNWIND SECTOR

AIRFIELD

The airfield is in the Operations Zone where airfield support activities (e.g., aircraft landing and parking, refueling, and cargo staging) occur. The airfield requires proper separation from other station service activities in order to prevent cross contamination of supplies and mitigate air and sound pollution to protect the health of station personnel. The airfield contains the skiway, aircraft parking areas, refueling stations and a variety of structures and infrastructure used to support airfield operations. The position of the airfield (specifically the clearance zones for departing planes) has been a concern for Clean Air Sector research operations in the past. Future development within the SPS area may require the airfield to shift further grid-southwest along its existing axis. Siting of all future Air Support facilities and services will require a site study and environmental analysis, where applicable, before final placement.

The skiway is a groomed snow surface that runs along the Dark Sector and Operations Zone boundaries. Routes to the Dark Sector currently cross the skiway threshold. Incoming passengers disembark at a parking apron along the side of the airfield and walk to the Elevated Station.

Air support to SPS is provided by a mix of LC-130 and Basler DC-3 aircraft that transport people and supplies from McMurdo Station. Twin Otter aircraft supports SPS on a limited basis, though they must refuel at a fuel cache in the Transantarctic Mountains while en route from McMurdo Station to SPS. Twin Otters are primarily used for close support of field science and East Antarctica sites.

The 109th Air National Guard (ANG), based out of Stratton, New York, provides LC-130 support for the USAP. Historically, SPS has relied primarily on near-daily LC-130 missions during the austral summer to transport fuel, cargo, and passengers to and from SPS and deep-field camps. In the past decade, the traverse fleet has been developed to enable overland movement of more fuel and heavy materials to SPS, which has lowered the overall reliance on LC-130s. In recent seasons, the LC-130 presence at the South Pole dropped to a historical low of 65 to 80 missions per season. As traverse capabilities continue to grow, dependency on LC-130s for cargo and fuel delivery are further reduced. However, reliance on LC-130 support for personnel transport is anticipated to continue.

Using Basler aircraft to move passengers and baggage is increasing. A limiting factor of the Basler is the requirement of a larger good-weather window to fly from McMurdo Station to SPS as its unpressurized cabin limits its capability to fly above weather when crossing the Transantarctic Mountains. The lower takeoff weight limit at the South Pole's altitude makes the northbound leg of the trip less cargo efficient. Current use of Twin Otter aircraft for near-field transportation of scientific and support personnel often results in delays due to multiple-location weather conditions. Twin Otters experience no-fly days at SPS due to unfavorable forecasts, which make it difficult to get into the field to conduct research. This results in adverse effects on scientific research and places an additional bed space and resource burden on SPS. An operational model of near-field overland travel may reduce the frequency of these issues, as the traverse is not as sensitive to adverse weather conditions. Baslers, Twin Otters, and traverse platforms must all refuel at SPS, inherently depleting fuel supplies at SPS that must be restocked by additional LC-130 flights or traverses.

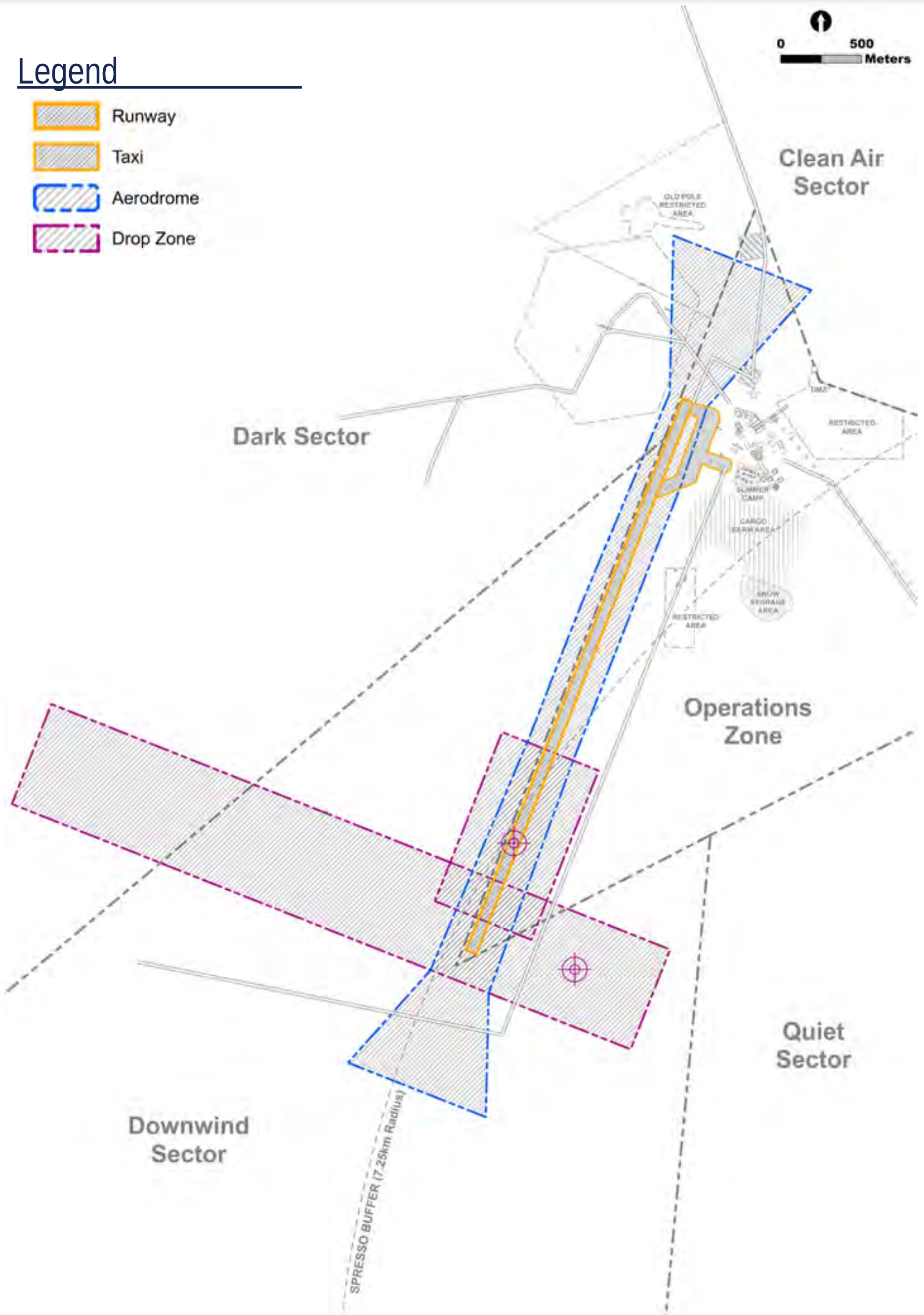


Figure 5.4 Airfield Configuration.

Twin Otter. A modified Twin Otter aircraft owned and operated by Kenn Borek Air in support of the U.S. Antarctic Program sites at SPS. Source: NSF, Unknown, 2018.

LC-130 Disembarkation. Scientists and support staff arrive at SPS after a three-hour flight from McMurdo Station. Source: NSF, Mike Lucibella, 2019.

Basler. A modified DC-3 Basler aircraft owned and operated by Kenn Borek Air in support of the USAP sits at SPS. Source: NSF, Luis Gonzalez, 2018.

LOGISTICS AND TRANSPORTATION

The logistics of transporting personnel, fuel, and cargo to the SP can be an arduous effort. Maintaining an efficient supply chain system is critical to the operations at the SP. Material commodities (cargo) destined to the South Pole are delivered to the USAP cargo hub at Port Hueneme, CA. Once in the USAP Supply Chain, materials are transshipped from Port Hueneme to Christchurch, NZ via a variety of modes, including charter vessel, commercial vessel, and commercial air.

A chartered, U. S.-flag cargo vessel sails annually from Port Hueneme to New Zealand, and on to McMurdo Station, usually arriving the last week of January. The ship carries resupply items for McMurdo Station and SPS and returns retrograde cargo and waste to the United States. To meet this timeline, cargo for this ship must be received in Port Hueneme by November. This vessel is the preferred mode of transport for delivering materials to McMurdo Station, as well as for ongoing transport to SPS. When possible, cargo should be planned to be positioned in Antarctica the season before scheduled field work. Vessel-delivered materials that are to traverse overland to South Pole must arrive on-continent the season before the traverse due to the late arrival of the vessel and the early departure of traverses relative to the vessel arrival. In other words, materials being delivered overland must be on the cargo ship two seasons before planned construction or by the fiscal year before the planned construction.

Cargo destined for vessel shipment to the South Pole must be received in Port Hueneme in November. In December, the ship is loaded and sails for Antarctica via New Zealand. The ship arrives at McMurdo Station for offload in late January or early February. Cargo destined for the South Pole can then be transferred to an LC-130 aircraft for same-season delivery to SPS or staged for aircraft or traverse delivery to SPS the following austral summer. Staging prior to delivery to the South Pole must occur at McMurdo. The ship's arrival at McMurdo Station occurs near the end of the austral summer season, thus only prioritized cargo can be shipped on to the South Pole in the same year due to the limited remaining weather window for the LC-130 to reach the South Pole. The end of the LC-130 season is driven by temperatures at the South Pole and closes in mid-February and opens again in early November. The first traverse is slated to arrive in late November following a 30-day trip from McMurdo Station.

Science Cargo personnel at McMurdo Station and SPS determine cargo plans and schedules. Cargo to and from SPS is transported by LC-130s, Basler aircraft, and South Pole Traverses from McMurdo Station only during the summer. South Pole Traverse transports cargo, most often fuel. The station is isolated the remainder of the year.

Nearly all USAP personnel reach SPS via a three-hour flight from McMurdo Station aboard LC-130 aircraft operated and maintained by the Air National Guard's 109th Airlift Wing based out of Stratton Air National Guard Base, New York.

The annual fuel tanker vessel delivers approximately six million gallons of fuel, purchased through the Defense Fuels Agency, to McMurdo Station, which provides the forward supply of fuel for SPS, delivered from McMurdo Station to SPS by traverse and LC-130.

As with all coastal locations in the southern Ross Sea region, heavy icebreaking is needed to open the roughly ten-mile channel from the sea ice edge to McMurdo Station to enable the offload of cargo and fuel.

McMurdo Station operates two airfields that are used at different times of summer because of seasonal conditions and aircraft type. The primary means of moving USAP participants from Christchurch, NZ, to McMurdo Station is via C-17 Globemaster III, operated by the U.S. Air Force 62nd Airlift Wing,Joint Base Lewis McChord. located near Lakewood, Washington. USAP airlift refers to the scheduled movement of cargo and passengers from Christchurch, NZ, to McMurdo Station via aircraft capable and certified to operate in Antarctica. The airlift period is generally from late August to the end of the operating season. Although rare, winter flights may occur.

Commercial surface vessel shipments to Christchurch (via Port Lyttelton) are the preferred transport mode for cargo. In general, airlift cargo needs to arrive at Port Hueneme by established shipping dates (December 1).

Commercial Air Cargo can be used if circumstances prohibit shipment by sea. In this scenario, ASC may be authorized to ship cargo by commercial air to Christchurch, NZ. This is a more costly method of cargo transportation and is exercised for essential materials that cannot go by sea. Commercial air shipments must provide sufficient cost to benefit to warrant the added cost of this mode of transport. Air cargo is not authorized as a substitute for inadequate advance planning.

Commercial Surface Cargo (COMSUR) voyages are a more economical method for the program to position cargo over the use of commercial airlines. ASC books multiple voyages on oceangoing commercial vessels to position cargo at Punta Arenas, Chile, and Christchurch, NZ.

A Continental Acquisition Schedule provides the shipping deadlines and required delivery dates to meet the associated Required on Site (ROS) dates for the operating seasons. These schedules are built to accommodate the long lead time presented during ocean voyages between the continental U.S. (CONUS) and the foreign ports.

Figure 5.5 illustrates the typical duration and mode of transportation for materials to make the journey from Port Hueneme, CA, to their destination at the South Pole.

Figure 5.5 Logistics and Transportation Route to South Pole Overview Map. Source: NSF, Undated.

LOCATION	AIRCRAFT	DATES OF TYPICAL OPERATION	LIMIT TO OPERATIONS
McMurdo	C-17	Late Aug; 1 Oct - Late Feb	Seasonal Tasking
McMurdo	LC-130	Late Oct - Late Feb	Seasonal Tasking
McMurdo	Small Fixed-Wing	Mid Nov - Mid Feb	Seasonal Tasking
McMurdo	Helicopter	Early Oct - Early Feb	Seasonal Tasking
South Pole	LC-130	Early Nov - Mid Feb	Temperature
South Pole	Small Fixed-Wing	Late Oct - Late Feb	Seasonal Tasking
Deep Field Camps	LC-130	Early Nov - Mid Feb	Temperature
Deep Field Camps	Small Fixed-Wing	Mid Nov - Mid Feb	Seasonal Tasking

Table 5.2 Air support operations periods

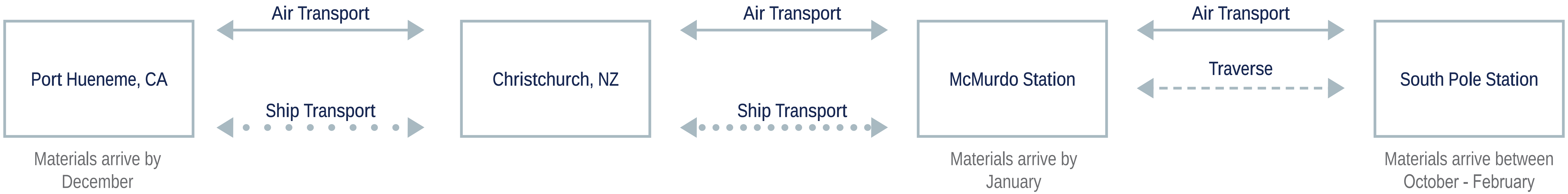


Figure 5.6 Transportation journey to SPS.

LC-130 Air Cargo. Source: USAP, 2020.

Ocean Giant cargo vessel. Source: NSF, Lauren Lipuma, 2023.

Aurora Australis Blends into Milky Way over Dark Sector. Source: NSF, Robert S, Undated.

SPS Area Plans

STATION AREA PLANNING

Area planning examines subareas of concern at SPS in more detail. Subarea designations in the SPS Master Plan align with the sectors and zones established by ASMA No. 5, and each has a primary function dedicated to either science or operations. This section compiles concerns identified through existing conditions reviews, community engagement efforts, and subject matter expert reviews within the SPS Master Plan process for transparency and to highlight the consideration of these concerns in the planning process. These concerns were primarily identified during four public outreach science community charrettes held by the master planning team in spring of 2024, which included open commentary allowance from ASC and NSF on SPS Master Plan drafts. All concerns and commentary were vetted by the master planning team for applicability and reasonableness at SPS.

A list of recommendations to address the concerns for each subarea was then developed by the master planning team. The recommendations fall within the following categories:

1) physical site recommendations,
2) action items to be undertaken, or
3) items that require further study outside of the scope of this master plan.

Recommendations that require funding to complete are identified as capital infrastructure projects and studies in Section 8.

Aurora Australis near IceCube. Source: Sven Lidstrom, 2012.

SOUTH POLE STATION

SPS functions as a complex to support a variety of science research facilities. There are concerns that apply generally to the station area as a whole. The following are the concerns and recommendations identified for the overall SPS area:

CONCERNS

- Snow is accumulating atop Scientific research facilities . These facilities need to be raised.
- Electro Magnetic Interference (EMI) emitting from the NGO sites and the Operations Zone can negatively affect scientific research.
- The frequency and volume of personnel movements and cargo in and out of SPS is lower than desired.

RECOMMENDATIONS

SPS 1 Conduct a cost-benefit analysis regarding lifting or full replacement of Science Research Facilities and communications facilities.

- Raise all scientific research and communications facilities in the near future to prevent structural failure and maintain researcher access to the buildings.
- Evaluate if structural skids or skis can be attached to building foundations to simplify snowdrift management and allow regular building relocation via towing.

SPS 2 Develop an EMI governance/management plan with implementation procedures for SPS to include EMI screening criteria for the selection of future electro-mechanical systems, facility UPS systems, and other EMI-emitting infrastructure and equipment. Implement a sustainable Radio Frequency (RF) spectrum monitoring system to track background noise emissions and to provide a real-time aid for finding and resolving spurious EMI events.

SPS 3 Conduct a cost-benefit analysis of use of other airframes to continued use of LC-130s, Baslers, and Twin Otters for potential cost savings and improved air travel reliability. (AIR 2)


Crossing Airfield from Dark Sector to Elevated Station. Source: NSF, 2023.

DARK SECTOR

The Dark Sector contains three primary scientific research facilities that must be lifted or relocated due to ice accumulation and burial in snowdrifts. The following are the concerns and recommendations identified for the Dark Sector:

CONCERNS

- Building 61 is at the deepest level of burial. The immediate concern is loss of telecommunications and electrical power to the Dark Sector.
- MAPO is experiencing burial by snowdrifts. The immediate concern of the MAPO burial is the potential loss of egress from the first story doors, difficulty servicing with fuel and cargo, increased maintenance costs of snow removal, and potential for structural damage from snow drifts.
- The ICL and DSL buildings need to be raised.
- EMI emissions from the NGO camps causes interference with Dark Sector scientific research.
- Personnel crossing the skiway to access the Dark Sector can cause conflicts with airfield operations.

RECOMMENDATIONS

D1 Raise Building 61 to maintain telecommunications and electrical power distribution to the Dark Sector.

D2 Raise MAPO, ICL, and DSL buildings in the near future.

D3 Conduct engineering evaluations in cooperation with the radio astronomers to devise safe distance estimates for typical RF emitting devices (e.g., consumer grade equipment and satellite communications earth stations).

D4 Study ways to deconflict crossing the skiway for personnel accessing the Dark Sector.

CLEAN AIR SECTOR

The Clean Air Sector contains the ARO building, two Automatic Weather Stations, and the NOAA scaffold tower. ARO and the two Automatic Weather Stations are structurally independent of each other, but operation and data collection cabling must be maintained between each structure. The following are the concerns and recommendations identified for the Clean Air Sector:

CONCERNS

- The NGO camp can cause emissions and contamination interference with atmospheric testing in the Clean Air Sector.
- Uncontrolled access by pedestrians or vehicles into the Clean Air Sector can contaminate the snow and air quality.
- Snowdrift maintenance is an ongoing challenge and impacts the ARO building.

RECOMMENDATIONS

CAS 1 Locate a new NOAA science building up to 1 km northeast of the current ARO building to add operational space, deconflict NGO activities, and ensure air quality.

CAS 2 Identify an access control easement along the 110-degree and 340-degree line to manage access into the Clean Air Sector.

CAS 3 Draft a management plan to regulate access into the Clean Air Sector.

CAS 4 Raise the ARO building to prevent structural failure and maintain research access to the building.

QUIET SECTOR

The Quiet Sector contains the SPRESSO, built in 2003. This facility was designed for a life span of 15 years and is nearing 20 years in service. The SPRESSO vault was originally designed as a crush wall exterior frame and was pre-buried in the ice with its access at surface level. However, the building is now 29 feet under ice and the facility needs to be raised or moved for continued use. SPRESSO is approximately five (5) miles (8 km) from the Elevated Station. The SPRESSO utility cabling is strained due to differential movement of the ice sheet, which moves the facility farther from the station each year. Fiber-optic cabling and other utilities need to be comprehensively evaluated for replacement as the annual movement of the ice sheet is stretching the cabling beyond its specification limits. Replacement of SPRESSO would simultaneously address the facility age and cabling replacement concerns. There is an opportunity to move the facility to a more optimal location when replacing the existing SPRESSO facility. The following are the concerns and recommendations identified for the Quiet Sector:

CONCERNS

- SPRESSO experiences various forms of interference from the Operations Zone.
- SPRESSO poses access challenges during servicing events.
- SPRESSO utility cables are being stretched beyond reliability limits.
- Communications technology for SPRESSO needs improvement.

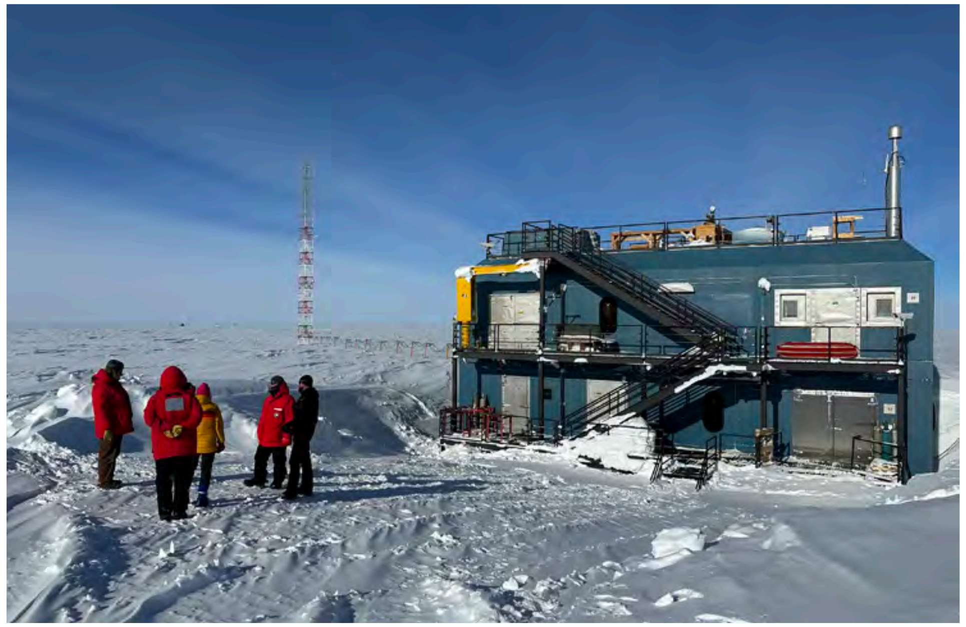
RECOMMENDATIONS

QS 1 Conduct a study to evaluate the end-of-life for the SPRESSO vault. If the SPRESSO vault is to be replaced, evaluate the cost-benefit of relocating it northeast of the current location (closer to Clean Air Sector) to deconflict interferences with the Operations Zone.

QS 2 If the SPRESSO program will continue, establish a SPRESSO buffer to restrict interference.

QS 3 Continue monitoring the quality and function of SPRESSO power and data cables to anticipate when cables need to be replaced.

ARO. Source: NSF, Gabe Nerf, 2020.



ARO Entrance Excavated. Source: NSF, Elyse Dinnocenzo, 2023.

SPRESSO cabling. Source: NSF, Jack Corbin, 2008.

OPERATIONS ZONE

All SPS support facilities are located in the Operations Zone. The primary structures include the Elevated Station and the arches. A variety of other auxiliary structures are scattered within the Operations Zone but are not organized for efficiency as many auxiliary structures have been re-purposed from their original intented use.

Several research projects have been located within the Operations Zone to enable ease of winter technician access. The positioning of Scientific Research Facilities in the Operations Zone has created the need for Restricted Zones within operational space. These Restricted Zones have thus limited the area within the Operations Zone where support operations may occur without conflicting with scientific measurement and communications tools. Although science projects may change over the years, the structures and vaults that are left behind are re-purposed and can create potential building hazards.

Although vaults are primarily unoccupied and unheated, the V8 vault, located near SuperDARN, now contains scientific projects that require heated instrumentation and regular servicing. However, V8 was not designed to be heated or used for scientific research purposes and does not have an air turnover system, creating a safety concern.

The Cryogen building supports the Balloon Inflation Facility (BIF) and houses the liquid helium and nitrogen production plants, temporary scientific research projects, and field staging. The Cryogen building was dragged to its current location in 2013 and will need to be relocated in the future to stay above the ice. However, the Cryogen building must be evaluated prior to relocation in order to to determine if the structure;s integrity will remain with the strain of another relocation or if it will require replacement.

The SuperDARN building remains above the snow surface, but will need to be lifted in the future.

Additional laboratory space is contained within the Elevated Station is now fully subscribed for existing scientific projects. As each project is completed, the space that it occupied in the Elevated Station laboratory is reallocated to newly funded research projects.

The following are the concerns and recommendations identified for the Operations Zone:

CONCERNS

- The ongoing impacts of snowdrift is enveloping the Elevated Station. The Elevated Station needs to be raised.
- The arches are buried beyond the design assumptions. The arches are forecasted to come into contact with interior structures in coming years. The facilities within the arches must be relocated.
- Various auxiliary buildings need to be moved or raised to higher elevations out of the snow accumulation.
- Cargo storage is inefficient and inadequate. More cargo capacity is needed to consolidate materials for better efficiency.
- The vehicular circulation is inefficient within the Operations Zone.
- The storage of waste materials on berms is excessive and inefficient.
- Summer Camp needs to be removed.
- The Operations Zone has a limited capacity for the staging of a field science hub.
- Utilities are not managed as part of a master utility plan.
- The effects of the ice sheet movement on subsurface fiber optic cable and utilities needs to be managed.
- The number of flights to support personnel rotations does not meet demand.
- The number of current flights and traverses for cargo delivery may not be able to support future capacity demands for major construction and infrastructure needs.
- Snow management continues to be a challenge.
- The practice of dumping snow grid-south of the Elevated Station is causing an increase over natural rates of drifting and burial of the HF Radio long-haul antennas used for aircraft and emergency communications.

RECOMMENDATIONS

OZ 1 Construct replacement structures for all facilities and uses within existing arches. Additional storage and warehouse spaces should be included in future structure designs. Auxiliary structure storage should be consolidated into a new structure to reduce the energy demands of disparate, decentralized structures serving similar purposes.

OZ 2 Evaluate moving some science functions to new facilities or locations to reduce EMI.

OZ 3 Designate vehicular circulation organized within an efficient station layout.

OZ 4 Inventory all berm contents to determine materials available for re-purpose to reduce retrograde, storage, and shipping demands. Retrograde reduction plans should be included with each new project to maintain a compact station footprint and prevent future berm growth and warehousing overruns.

OZ 5 Raise the Elevated Station, communications buildings, and SuperDARN facilities.

OZ 6 Demolish old buildings and retrograde the remnants of the old Summer Camp.

OZ 7 Conduct a cost-benefit analysis for providing facilities to support a field science hub.

OZ 8 Develop a utility master plan that establishes utility rights-of-way for routing of fiber optic telecommunications cables, electrical lines, and water and sewer lines. The utility master plan should monitor geospatial locations of the rights-of-way from year to year to account for ice sheet movement.

OZ 9 Determine the future demands for SPoT and other traverse options for improving personnel rotations, as well as cargo and fuel deliveries.

OZ 10 Conduct a retrograde initiative to reduce snow drift accumulation, maintenance costs, labor and resource demands, and the environmental impact of SPS.

OZ 11 Expand the current area for snow storage to ensure snow accumulation does not impact the Operations Zone activities.

OZ 12 Relocate HF Antennas to deconflict long-term snow drift challenges..

OZ 13 Evaluate the timing for the first Elevated Station lift and the remaining life expectancy of the Elevated Station if no action is taken.

Arch Construction. Source: NSF, Jack Corbin, 1990s.

PRIMARY INFRASTRUCTURE

WATER SYSTEM

The water supply at SPS is provided by a Rodwell and water treatment system. The system has functioned well for SPS. The following are the concerns and recommendations identified for the water system in the Operations Zone:

CONCERNS

- The logistics of reconnecting the water system to a raised Elevated Station and replacement buildings needs to be engineered.
- A new Rodwell is needed at this time and will be needed again in the next 10-15 years.
- Maintaining utility service tunnels accessibility and function is becoming difficult.
- The water lines may need to be upgraded when buildings are raised.
- The capacity of the back-up snow melt system for emergencies in summer season may not be adequate.
- There may be ways to extend the life of the Rodwell.

RECOMMENDATIONS

WS 1	Replace water distribution lines and associated infrastructure to avoid critical points of failure in the piping system.
WS 2	Replace the existing Water Rodwell by 2030. Locate the replacement Rodwell building relative to the ice tunnel beneath the structure so that a ladder shaft from the ice tunnel to the building can be configured for easier waterline and utility maintenance.
WS 3	Evaluate utility tunnel replacement options.
WS 4	Design piping systems, appendages, and structures to enable periodic building raises.
WS 5	Conduct an analysis to determine if the back-up snow melt system capacity needs to be upgraded to support the summer population at SPS in the event of a Rodwell outage.
WS 6	Evaluate the existing Rodwell building to determine its lifespan and ability to be relocated.
WS 7	Investigate and recommend grey-water treatment options and re-use solutions to be used to extend Rodwell lifespans and reduce long-term Rodwell planning and installation costs.

HUMAN AND SOLID WASTE

Human waste storage at SPS is provided by the sewer outfall system via a decommissioned Rodwell. The waste system has functioned well for SPS. Solid waste, known as retrograde, has been stored on snow berms waiting to be removed from SPS. The South Pole Retrograde Initiative (SPRI) is encouraged to continue for the removal of retrograde material.

The following are the concerns and recommendations identified for the human and solid waste systems in the Operations Zone:

CONCERNS

- The logistics of connecting the human waste system to a new Elevated Station and other structures needs to be engineered.
- The maintenance and upgrades of sewer lines when buildings are raised needs to be engineered.
- The timing of moving to a new sewer outfall is of concern.
- The long-term environmental impacts of human waste disposal in the sewer outfalls is of concern.
- Maintaining utility service tunnels accessibility and function is becoming difficult.
- The disposal of solid waste retrograde to CONUS is a long-term and costly supply chain concern. The solid waste supply chain backlog of retrograde materials has resulted in increased bermed storage.

RECOMMENDATIONS

HSW 1	Design piping systems, appendages, and structures to enable periodic building raises.
HSW 2	Replace the sewer outfall Rodwell immediately.
HSW 3	Conduct an analysis of alternatives study for a wastewater treatment plant to mitigate environmental impacts.
HSW 4	Investigate grey-water treatment and reuse solutions for future station designs to extend Rodwell lifespans and reduce long-term Rodwell planning and installation costs.
HSW 5	Investigate black water and waste technology as potential alternative fuel sources in future station designs to reduce the environmental impacts of SPS activity.
HSW 6	Evaluate utility tunnel replacement options. (WS 3)
HSW 7	Continue the South Pole Retrograde Initiative (SPRI) to reduce accumulation, maintenance costs, labor and resource demands, and the station’s environmental impact. (OZ 10)

ENERGY

SPS energy systems are not only necessary for the continued operation of the scientific research facilities, but are essential from a life safety standpoint. The energy facilities at SPS rely on the existing power plant, which provides both electrical and thermal energy to the surrounding facilities. The power plant consists of reciprocating internal combustion (diesel) engines and associated waste heat recovery equipment. Electrical energy is distributed from the plant to most buildings at SPS. The thermal energy is utilized for building heating in the Elevated Station as well as several outbuildings. The power plant, along with its fuel storage facility, are located in the power plant and fuel storage arches, respectively. As with the other arches located at SPS, these arches are currently buried under snow and sinking. The arches are expected to reach end of life within ten years.

The following are the concerns and recommendations identified for the energy systems in the Operations Zone:

CONCERNS

- The power plant and fuel storage arches are completely buried and interior structures are at risk of caving.
- Replacements for power plant and fuel storage arches are needed.
- Reliable power and heat generation cannot be interrupted at any time during the transition to the new facilities.
- New science projects are requiring higher power levels and energy consumption rates than in the past.
- Fuel delivery costs continue to increase.

RECOMMENDATIONS

E 1 Augment the power plant and fuel storage with energy efficient proven technologies.

E 2 Conduct a comprehensive study of the life expectancy of all main power plant components, including the structures beneath the arch and the arch itself, to dictate replacement timelines.

E 3 Conduct a comprehensive study of energy production feasibility to determine the appropriate energy production portfolio for a replacement power plant.

E 4 Conduct on-site proofing of current renewable energy technologies to determine suitability for the South Pole environment.

E 5 Engage in future partnerships with other national Antarctic programs in the continued study of and/or creation of alternative energy production systems that could reliably perform in the South Pole environment.

UTILITY CABLING

Utility cabling supplies the electrical and communications cables throughout SPS and the Sectors. Many of the cables are aging and being stretched due to differential movement of the ice sheet. New cables will be installed as buildings are raised, moved, or replaced. A cabling master plan could provide guidance for consolidating lines, looping networks, and exploring methods for dealing with differential movement.

The following are the concerns and recommendations identified for utility cabling in the Operations Zone:

CONCERNS

- Buildings 61 and 68 need to be maintained to ensure electrical power distribution to current facilities.
- Cabling is nearing end of life due to the ice sheet movement.
- Existing fixed cable connections are susceptible to damage from the ice sheet differential movement.
- Utility cables are not easily located due to a lack of surveyed utility mapping.

RECOMMENDATIONS

UC 1 Evaluate timing for the replacement of the main trunk fiber optic cables and local Dark Sector fiber optic cables.

UC 2 Discontinue fixed-point connections for cabling and implement a connection system that accounts for ice sheet movement.

UC 3 Proactively account for network expansion at precise locations to prevent future ad hoc cabling decisions.

UC 4 Explore options for colocation of utility cables.

Fixed point connections experiencing deformation due to ice sheet movement.
Source: NSF, Bill Coughran, Unknown.

INFORMATION TECHNOLOGY & TELECOMMUNICATIONS

Station communication systems are critical life safety infrastructure. Communications systems at SPS require reliable data transmissions.

The following are the concerns and recommendations identified for Information Technology & Telecommunications in the Operations Zone:

CONCERNS

- The existing RF Building is undersized to meet mission need.
- The distance from the Elevated Station to locations beyond the RF Building pose a heightened risk to wintering communications technician personnel traveling to the RF Building area to conduct corrective maintenance.
- Radio communications systems are out of date.
- The existing 9 meter (m) satellite antenna underneath the large radome is obsolete, decommissioned, and could be removed.
- The existing Land Mobile Radio presents a life safety concern.
  - System is obsolete, losing parts support, and at high risk of failure.
  - System coverage areas within the elevated and sub-surface station, as well as the outdoor operating area, must be preserved for safety-of-life communications in addition to station operations
- EMI interference in the Dark Sector continues
  - The Land Mobile Radio system has demonstrated harmful interference to Dark Sector science (radio astronomy).
  - Satellite communications earth station operations and Starlink testing in proximity of the RF Building have been documented to cause EMI with Dark Sector radio telescopes.
- The existing HF radio long-range curtain antennas are buried by snowdrifts with risk of permanent damage, exacerbated by snow clearing/dump activities for annual snow maintenance of Operations Zone.
- The existing antenna structures (especially the South Pole TDRSS Relay antenna platform) are constrained by the airstrip safety height restriction zone perpendicular to the airstrip centerline.

Communications facilities. Source: NSF, 2023.

RECOMMENDATIONS

ITT 1 Conduct right-sizing assessment on RF Building size to support future requirements to include space for needed equipment redundancy to minimize the need for high-risk winter personnel visits.

ITT 2 Identify potential site for a future communications complex.

ITT 3 Upgrade the existing UHF/AM air-ground radio systems to maintain aviation communication capabilities.

ITT 4 Conduct a cost-benefit analysis of the emergent broadband polar orbiting, satellite-based, communications systems to evaluate the viability of emerging technologies for science data.

ITT 5 Uninstall and retrograde the 9m antenna, evaluate potential reuse of the radome, and preserve the antenna platform as a future resource to support future wideband low Earth orbit satellite systems for Enterprise-scale high speed communications.

ITT 6 Upgrade the Land Mobile Radio system to maintain communications availability for timely emergency response.

ITT 7 Research communication methods that rely on updated technologies and therefore not subject to the same failure points to increase resiliency and redundancy of emergency communications.

ITT 8 Coordinate spectrum selection and waveforms (i.e., occupied spectrum) of Land Mobile Radio system with the Dark Sector research community to harmonize on emissions that minimize harmful EMI while maximizing safety/operational needs..

ITT 9 Conduct engineering assessments in coordination with the Dark Sector research community to identify safe operating ranges for existing and expected future wideband satellite earth stations (per ITT 5) and define site facility requirements (support buildings, utility runs, radiation hazard safe zones, etc.) for future site build-out.

ITT 10 Conduct engineering studies to find optimum trade-off between distance from airstrip centerline to main Elevated Station for winter personnel safety and utility runs vs. isolation distance needed to minimize EMI risks to Dark Sector (especially radio astronomy) to acceptable levels.

ITT 11 Refresh HF antenna requirements (design, number, purpose) to align with near-term NIWC HF Radio Modernization Capital Project for NIWC project to implement needed replacements.

ITT 12 Research new technologies that may reduce data and communications service gap hours each day and be installed at SPS to reduce communication-related safety risks and meet growing science data requirements.

FIELD SCIENCE

Field science expeditions from SPS are supported with field equipment by McMurdo Station. Although field science expeditions use SPS as a staging base, there is not adequate supply storage space and staging support facilities to support field science independent of McMurdo Station. SPS currently is not equipped as a field science hub.

The following are the concerns and recommendations identified for field science in the Operations Zone:

CONCERNS

- Providing field science staging areas, temporary housing, and logistics support needs to be evaluated if SPS will serve as a field hub in the future.
- Field science is often delayed when Basler and Twin Otter aircraft are grounded due to weather.
- Emergency rescue equipment and support needs for expeditions need to be allocated for SPS.
- The number of flights to support field science does not meet demand.

RECOMMENDATIONS

FS 1 Conduct a cost-benefits analysis for operating a field science hub based out of SPS for access to Eastern Antarctica science sites.

FS 2 Continue to centrally manage field support and Search and Rescue assets from a centralized location at McMurdo Station to provide continuity, efficiency, and a smaller footprint at SPS.

FS 3 Evaluate providing remote emergency response equipment storage structure adjacent to the airfield to enhance resiliency of the emergency response program.

FS 4 Re-purpose the existing arches, once vacated, for field science supplies as a temporary location until replacement facilities are constructed.

FS 5 Include dedicated VMF/warehouse space in a future station for staging the large and often voluminous equipment for multi-year, field science projects.

EMERGENCY SERVICES

SPS on-site emergency services lacks adequate storage and staging space. The emergency services are supported by a qualified medical team and fire brigade team.

The following are the concerns and recommendations identified for emergency services in the Operations Zone:

CONCERNS

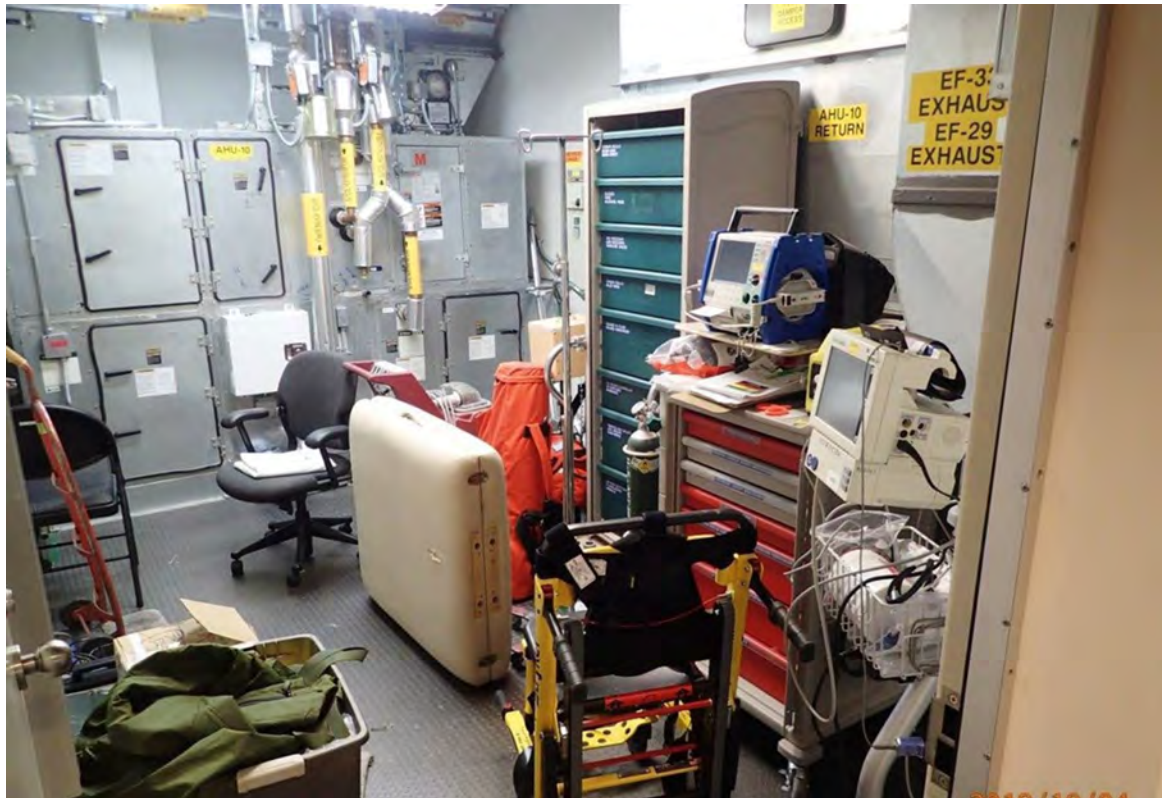
- Emergency operational spaces may be inadequate and could impact response efficiency at the station.
- Emergency equipment storage space is inadequate and could impact response efficiency at the station.
- Radio communications systems need to be upgraded for emergency services.

RECOMMENDATIONS

EMS 1 Consolidate emergency services storage and staging space in the Elevated Station and provide space directly adjacent to or integrated with field and aircraft staging areas.

EMS 2 In a future station, account for gurney maneuverability to and from emergency services treatment and airfield areas.

EMS 3 Upgrade the Land Mobile Radio system to maintain communications availability for timely emergency response. (ITT 6)



Shortage of emergency supply storage space. Overflow medical and emergency supplies are stored in a fan room due to lack of adequate space in the medical facilities. Source: NSF, Unknown, 2018.

TRAVERSES

SOUTH POLE TRAVERSE (SPoT)

Traverse platforms are a well-established technology in Antarctica. The SPoT platform is used annually for fuel and cargo delivery, reducing reliance on LC-130 aircraft missions. The SPoT fleet is used to transport waste retrograde materials back to McMurdo Station to be shipped back to the U.S.

The following are the concerns and recommendations identified for SPoT in the Operations Zone:

CONCERNS

- The existing SPoT fleet has limitations on capacity, which impacts costs and efficiencies.
- The current fuel offloading process has limitations on turnaround time for the SPoT platform.
- The anticipated increase in construction projects at SPS will increase fuel and cargo capacity needs.

RECOMMENDATIONS

SPoT 1 Conduct a cost-benefit analysis of increasing traverse capacities and capabilities to reduce the reliance on and costs related to using LC-130s.

SPoT 2 Evaluate infrastructure upgrades to allow for loading and unloading full 20- and 40-foot shipping containers to and from the SPoT platform at McMurdo Station and SPS to expedite cargo delivery and reduce reliance on berms.

SPoT. Source: NSF, Unknown

OVERLAND SCIENCE TRAVERSE

The heavy science traverse (HST) fleet and the SPoT fleet are occasionally used to support field science departing from SPS. The Traverse platforms have proven to be effective and efficient solutions to delivering field supplies to field camps as traverse platforms are not subject to the same restrictions and constraints as small aircraft in Antarctic weather and climate. Cargo traverse platforms have been proven to bolster SPS cargo and fuel delivery capabilities.

The following are the concerns and recommendations identified for the overland science traverse in the Operations Zone:

CONCERNS

- Many field science experiment teams are delayed when Basler and/or Twin Otter aircraft are not able to fly due to weather.
- The lack of storage and staging areas at SPS places limitations on overland science traverse capabilities.

RECOMMENDATIONS

TR 1 Conduct a cost-benefit analysis of the procurement, operation, and storage of light science, polar equipped, wheeled vehicles at SPS for access to field science sites.

TR 2 Provide storage space in a future warehouse and VMF building for wheeled vehicles.

Agile Overland Traverse. Small overland traverse vehicles have been used in Antarctica in the past and may be a cost- and time-saving alternative to field flights in crevasse-free areas. Source: ASC, Unknown.

NGO/TOURISM

The potential for impacts on SPS operations and infrastructure will continue to increase as tourism presence grows at the South Pole. Separation of uses, especially surrounding the geographic South Pole, is becoming more important each year.

The following are the concerns and recommendations identified for NGO/Tourism in the Operations Zone:

CONCERNS

- NGO operations have EMI impacts on Dark Sector and other science facilities.
- Current NGO approach corridors and operations can conflict with both Dark and Clean Air Sector science.
- The geographic South Pole trajectory needs to be protected for NGO access.

RECOMMENDATIONS

NGO 1 Encourage NGO operators to evaluate new communications equipment and deploy solutions that minimize EMI conflicts.

NGO 2 Maintain current practices and protocols while adapting approach corridors to the geographic South Pole that account for the movement of the geographic South Pole to the grid-east of the archway systems.

NGO 3 Transition the NGO campsite to an area closer to the Elevated Station and relocate the NGO aircraft parking area to increase the buffer between the campsite and the Clean Air Sector.

NGO 4 Create an easement over the geographic South Pole trajectory to prevent future operational and facility conflicts with NGO-visitor foot, ski, and vehicle traffic.

NGO 5 Designate an NGO camp site grid-east of the future site of a replacement SPS. The relocated NGO camp will be located immediately adjacent to the geographic South Pole trajectory for ease of visitor access and elimination of potential conflicts with operational activities. This would not occur until a new station is built.

Geographic South Pole. Source: NSF, Unknown.

DOWNWIND SECTOR

AIRFIELD

The Downwind Sector provides protected airspace for the airfield and airfield operations. The position of the airfield (specifically the clearance zones for departing planes) has been a concern for Clean Air Sector research operations in the past. The clearance zones created by the imaginary surfaces, which overlap areas of the Dark Sector and the Operations Zone, limit development potential within the clearance zone.

The following are the concerns and recommendations identified for the airfield in the Downwind Sector:

CONCERNS

- The airfield clear zone requirements within the Dark Sector and Operations Zone limit the ability to develop areas for new scientific research or support operations.
- Conflicts with aircraft flying over the Clean Air Sector need to be addressed to eliminate contaminations.
- The LC-130 airframe has experienced a high rate of mechanical delays in recent years and reliance on the airframe needs to be studied.
- Existing limitations on crossing the skiway to and from the Dark Sector during flight operations should be studied to reduce the conflicts.

RECOMMENDATIONS

AIR 1 Evaluate ways to minimize skiway crossing conflicts to and from the Dark Sector. Conduct a cost-benefit analysis on shifting the skiway to deconflict crossings and prevent Clean Air Sector contamination.

AIR 2 Conduct a cost-benefit analysis to compare other airframes to continued use of LC-130s, Baslers, and Twin Otters for potential cost savings and improved air travel reliability. (SPS 3)

AIR 3 Explore alternative methods of field fuel cache restocking currently supported by LC-130 airdrops to reduce the number of small aircraft flights required to recover the dropped supplies for each primary flight to the field.

SECTION 7

PLANNING

NOAA Balloon Release Time Lapse. Source: NSF, 2016.

Station Master Plan

The master planning process began with understanding the history (Section 4) and current conditions (Section 5) of SPS. This provided a foundation from which area-specific concerns were identified (Section 6). A collection of community-based, subject matter expert, and master planning team recommendations to address these concerns were devised (Section 6). These recommendations were then further evaluated through the development of the Station Master Plan (Section 7). Not all recommendations from the SPS Area Plans were selected for inclusion in the Station Master Plan; refer to Appendix B for a complete list of recommendations considered in the creation of the Station Master Plan.

Subsections of the Station Master Plan focus on energy efficiency; natural, historic, and cultural resources; community health; and security and safety. Each subsection provides best practices and guidance in protecting and promoting a viable SPS future. The last subsection of the Station Master Plan, physical planning, includes physical site arrangements and use relationships for SPS infrastructure and activities. The capacity section conveys the space requirements and building forms that will replace the arches. A conceptual future site plan depicting the vision for the future of SPS is provided in this section.

The Station Master Plan section of the SPS Master Plan presents guidance on how the SPS area could be developed in an organized manner over the next 30 to 50 years. Station Master Plans should be updated in parallel as improvements are made at SPS. The SPS Master Plan will therefore be reviewed every 10 years.

ENERGY EFFICIENCY

EFFICIENCIES AND ADJACENCIES

SPS is an assemblage of buildings, structures, and connected underground utility lines that was constructed over decades without a master plan to guide efficient placement for optimum operations. Past location criteria for new structures was based on a generalized “close proximity” to existing buildings, as clustering facilities minimized travel distances. As more science projects were added to the SPS area, use adjacency challenges emerged. These challenges are addressed by proposing future building and operational function siting to:

- Minimize exterior exposure.
- Reduce utility runs and distance for logistics movements.
- Reduce snowdrift removal demand.
- Minimize EMI by increasing distances from emitting sources.
- Provide acceptable distances from NGO activities.
- Maintain orientation to the geographic South Pole.

STATION ENERGY EFFICIENCY

A community-produced 2018 report provided preliminary guidance on how to promote Energy Efficiency at SPS. The report addressed Community, Environment, and People as areas for improved management.

Key goals for Energy Efficiency include:

- Introduction of readily available energy sources.
- Provision of remote monitoring and automation technologies to reduce energy consumption.
- Increased compliance with environmental regulations.
- Improvements to window insulation.
- Improvements to human waste management systems.
- Implementation of lower-energy tech (i.e. LED lights, high efficiency appliances, electric equipment, and vehicles) and associated interfaces compatible with extreme cold weather conditions and science demands with consideration of EMI implications of low power devices to minimize conflict with EMI reduction objectives.
- Replacement of the arches with more energy efficient facilities.
- Consolidation of storage items into a single building to reduce human and building energy consumption.
- Provision of a heated parking facility for winterizing electric components of vehicles.

STATION RESILIENCE

Over the 30 to 50 year time frame covered in the SPS Master Plan, environmental conditions throughout the continent are projected to change and pose a threat to the continued operation of the station and the upstream suppliers on which SPS depends.

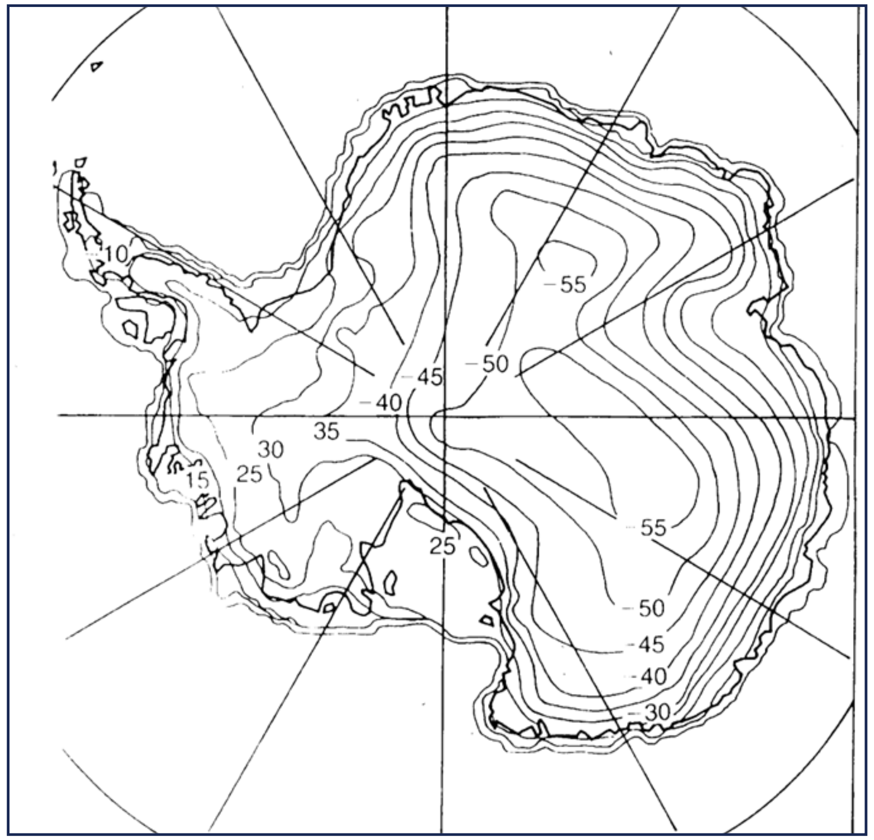


Figure 7.1 Annual mean surface temperature. (Linacre & Geerts, 1999) Source: Linacre & Geerts, 1999.

Antarctic and SPS operations are experiencing profound impacts from shifting environmental conditions, with observable changes in temperature, ice melt, and sea level. The continent of Antarctica has warmed by between 1°C and 3°C, or approximately three times faster than the global average over the past 50 years (British Antarctic Survey). Additionally, ocean currents that transport warm water from the equator to Antarctica have warmed, resulting in the degradation of the coastal ice network around the continent (Convey & Peck, 2019). Satellite observations confirm this trend and reveal a substantial decrease in sea ice extent around the continent (NASA Earth Observatory, 2009). Modeled projections indicate that these trends are expected to persist (Tewari, Mishra, Salunke, & Dewan, 2022; Comiso, 2000). This could result in over a meter of global sea level rise by the end of the century, the effect of which is only compounded by the continued degradation of the continental ice mass (Davies, 2020).

While environmental impacts to the Antarctic continent are significant, the location of SPS at 9,000 feet above sea level and 800 miles inland mitigates some of these impacts (National Science Foundation). In terms of temperature, the inland location lessens the threat of localized ice melt even in the face of warming, as annual mean temperatures drop from -10°C on the coast to -60°C at the highest inland elevations (Antarctic Weather, 2019). Additionally, the inland location will not be affected by the combined threat of coastal degradation and sea level inundation. However, while such a remote location may be a benefit in terms of resilience to these hazards for SPS infrastructure, the remoteness enhances the vulnerabilities that may exist amongst key nodes within the supply and operational network. The environmental threats across all upstream operational sites, such as McMurdo Station, should be evaluated using a scenario analysis of the latest modeled projection data to inform localized resilience strategies for each. A similar approach can confirm the vulnerabilities, or lack thereof, that may exist to SPS from changes in environmental conditions like temperature and precipitation.

A preliminary investigation into future conditions at and around the South Pole found that studies to date have focused on the Antarctic continent as a whole or on regions such as the Antarctic Peninsula, Western Antarctic, or the Eastern Antarctic. Studies generally focused on temperature and precipitation trends, while there was a lack of study with a geographic focus on the South Pole and no studies were identified that focused on future ice sheet movement. Findings from the preliminary investigation are summarized on the next page.

Temperature-related findings for Antarctica parallel those in the rest of the world, with Antarctic temperatures projected to increase in the coming decades. For example, using the latest modeled projection data, Bracegirdle et al. (2020) indicate that the end-of-century Antarctic surface-air temperature is expected to increase between 1.3°C and 4.8°C when compared to the time period of 1995–2014. Tewari et al. (2022) project about a 5°C increase by the end of the century under a high emission scenario (RCP8.5 or SSP5-8.5), as shown on Figure 7.2 and Figure 7.3. Similar changes are indicated by other authors as well (Beaumet et al. 2021; Zhu et al. 2023).

Precipitation is expected to increase due to an increase in the water holding capacity of the warming air. Palerme et al. (2017) projects between a 9.6% and 39.6% increase in annual precipitation for the continental interior (with elevation above 7,380 feet [2250 m]) by the 2080-2099 time period when compared to 1986-2005. Meanwhile, Krinner et al. (2019) indicate a 41% increase in precipitation by the end of the century based on a global atmospheric model under a high emissions scenario. Using the latest modeled projections, precipitation rate changes are projected to be between 8% and 31% by the end of the century by Bracegirdle et al, (2020). Beaumet et al. (2021) indicate an increase, and Tewari et al. (2022) project a 44% to 50% rise in precipitation under a high emissions scenario.

Snow accumulation depends on the amount of precipitation and a variety of processes such as sublimation, evaporation, meltwater run-off, and blowing snow (Palerme et al. 2017). In the interior of the Antarctic, ice sheet precipitation is usually very light due to very low temperatures (Palerme et al. 2017). A large fraction of the precipitation there "falls in the form of 'diamond dust' (ice crystals) under clear sky conditions" (Bromwich 1988; Fujita and Abe 2006, cited in Palerme et al. 2017). Snow accumulation is expected to increase in the future. Krinner et al. (2019) found that continental-scale snow accumulation (precipitation minus sublimation) is projected to increase by approximately 6.9% per degree (Celsius) of warming. Similar results of about 5% per degree Celsius (+/- 1%) are indicated by Frieler et al. (2015).

While these studies aid in the understanding of environmental trends, data geographically tailored to SPS may be able to inform a more detailed vulnerability assessment that can be used to determine the adaptations necessary for SPS operation to continue unabated in the face of shifting environmental conditions.

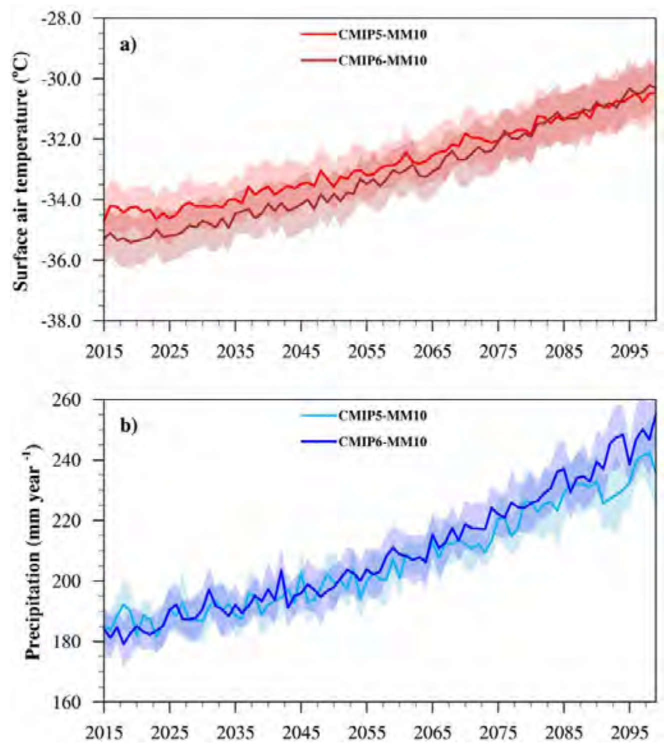


Figure 7.2 Time series of a) annual mean surface air temperature and b) annual precipitation rate over the Antarctic landmass. Source: Tewari et al., 2022.

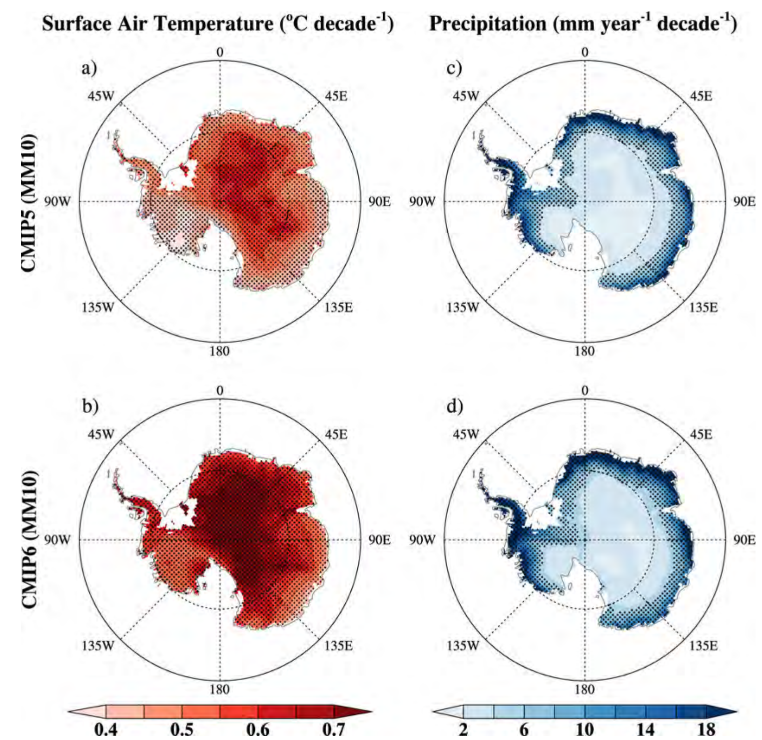


Figure 7.3 Decadal change in a) mean annual surface air temperature and b) annual precipitation over Antarctica. Texture indicates values are significant at a 99% confidence level. Source: Tewari et al., 2022.

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Zhu, J., Xie, A., Qin, X., Wang, S., Xu, B., & Wang, Y. (2023). Projection on Antarctic Temperature Extremes from the CMIP6 Multimodel Ensemble under Different Scenarios. Journal of Applied Meteorology and Climatology, 62(8), 1129-1146.

CIRCULATION

SPS is primarily managed as a pedestrian campus in both the summer and winter seasons. Circulation routes are not defined by paved roads, but rather by plowed corridors and marker flags. Circulation must be efficient and direct to conserve vehicular fuel consumption. Due to the extreme climate conditions, minimizing pedestrian exposure outside is critical. One (1) kilometer is generally regarded as the maximum safe distance to walk between heated buildings or facilities, especially during the austral winter. Safe vehicular or motorized distances are based on the type of vehicle; vehicles with heated compartments may safely travel for a longer period of time than a snowmobile operator or person traveling on skis.

Establishing efficient, direct routes and safe distances will remain a primary basis of station design.

Road to Berms. Source: NSF, 2023.

NATURAL, HISTORIC, AND CULTURAL RESOURCES

MISSION COMPATIBILITY

HISTORIC SOUTH POLE SITE PRESERVATION

Preservation of the location of the historic South Pole is governed by ASMA No. 5.
Located grid north of the MAPO blue building in the Dark Sector, the historic site is protected within a Restricted Area. This area will continue to be protected in the SPS Master Plan.

Historic Significance:

- Historic Sites and Monuments No. 1 (1972) to memorialize the flag mast erected by the First Argentine Overland Polar Expedition in 1965.
- Historic Sites and Monuments No. 80 to recognize Amundsen's tent, which was erected by the Norwegian expedition upon their arrival in 1911; the first expedition to reach the South Pole.

PROTECTION OF GEOGRAPHIC SOUTH POLE TRAJECTORY

The geographic south pole appears to "move" due to the constant flow of the ice sheet on which SPS is located. The ice sheet shifts approximately 32.81 feet (10 meters) per year. To protect the path of the geographic south pole, the SPS Master Plan will provide an easement along the trajectory of the geographic south pole. The easement will prevent any buildings or structures from being constructed within the easement and will stipulate that all buildings and structures be setback a specified distance from the easement.

PROTECTION OF CEREMONIAL SOUTH POLE

The "Ceremonial South Pole" established by the United States commemorates the 1957/58 International Geophysical Year and all expeditions that have reached the South Pole. The ceremonial location will continue to be a prominent feature, and will be relocated as the geographic south pole moves and a future main station is constructed.

NATURAL ENVIRONMENT

SNOWDRIFT MANAGEMENT

One of the primary natural environmental determinants at SPS is snowdrift. Snowdrift clearance is a constant management operation required to keep the buildings and structures from being buried. The following is an excerpt from a Snowdrift Guidance study, 2006, that summarizes how snowdrift is analyzed and the importance of placing buildings and structures to minimize snowdrift impacts.

"Various snow simulation 'tools' are available to predict snowdrift patterns around buildings. The selection of the 'right' analytical tool is not only driven by the level of detail required in the results, but also by budgetary constraints. Physical scale model tests in water flumes and wind tunnels are well suited to short duration and repetitive investigations of wind and snowdrift patterns. For example, the effects of changes to a building mass or feature on local wind or snowdrifting can be readily assessed. Computer simulation techniques are more labor intensive to perform and are more appropriate when an increased precision in the prediction of detailed wind flow and snowdrift patterns is required.

Key design guidance derived from the snow simulation studies included the need to sufficiently elevate buildings above the snow surface and to orient a row of linked buildings perpendicular to the prevalent winds. Of equal importance is to understand that snowdrifting will invariably occur and that sensitive activities should be located away from the snow deposition area."

Source: Waechter, B. and Williams, C. 2006, "Snowdrift Design Guidance for The New South Pole Station." Pg. 68

Design recommendations for future work at SPS were included in the 2006 Snowdrift Guidance Study with the following recommendations:

- Additional computer modeling undertaken to refine the design. C-shape Buildings, links, and vertical circulation tower concept tested should be retained in the design of the replacement Science Facilities at the South Pole.
- Snowdrift deposition around the entire future station (buildings, tower, and links) should be predicted through finite area element and computational fluid dynamics computer modeling techniques.
- Long-term (5-year, 10-year, etc.) snow deposition around the entire future station should be predicted through computer modeling techniques.

Another study, "Effects of Support Structures Porosity on the Drift Accumulation Surrounding an Elevated Building", Song, A. and Haehnel, R. 2012, provides additional guidance for future buildings at SPS.

"In austere environments, such as Antarctica, snowdrift accumulation around buildings not only presents safety hazards to personnel, but also can significantly shorten the service life of the building. Elevated structures are a common and effective design strategy to combat drift accumulation in proximity to buildings. However, the foundation structure or substructure that is used to elevate the building above grade may impede or choke off the flow thereby increasing the drift accumulation and reducing the effectiveness of elevating the building."

"Some features under the building, such as the support structure, can promote drifting close to the building and cause the drift to rapidly encroach on the building. This is a potentially dangerous drifting behavior that may also lead to a shorter building service lifespan. We observed that a substructure composed of a dense matrix of support posts increased the rate that the drift approached the front of the building by 1.5 times. But, porosity was not the only factor affecting drift encroachment. The support structure may have span-wise cross members. These will serve as nucleation points for drift formation and allow the drift to form much closer to the building than would occur for a substructure clear of these features. Careful thought during the design phase needs to be given to avoiding such structural features that promote drifting. The results of this study suggest that applying such care in the design could prolong the life of a building having the same configuration as the MAPO by 2 or more years."

The "Amundsen-Scott South Pole Station Snow Drift Simulation Overview," CRREL, 2021, presented the following conclusions:

Though changes in drift volume vary with extents of region chosen to calculate volume, overall trends change little with region extents shown here.

- *West drift volume increases when Pod B is raised (either independently or with entire station).*
- *Total drift volume is reduced when the station is lifted (all lift scenarios).*
- *Total drift volume is reduced the most when Pod A is lifted first (5 – 8%).*
- *Drift Volume over arches is reduced the most (5 – 9%) when Pod A is raised (either independently or with entire station).*
- *Changes in drift volume for all cases, in comparison to baseline, is generally less than 10%.*

Future buildings at SPS, such as the arches and a Main Station replacement, must be located with snowdrift mitigation as a primary basis of design.

COMMUNITY HEALTH

MORALE, WELFARE, AND RECREATION

Maintaining physical and mental health and providing a safe environment is critical to sustaining a healthy station environment. A key part of maintaining a healthy, safe work environment is providing support services for both mental and physical health. Each year, an Amundsen-Scott SPS Guide is issued that outlines all the services and resources available at SPS. Contained in the guide are resources for emergency response, safety, medical services, recreational resources, faith-based services, and mental counseling.

Within the Elevated Station, there are various facilities that are accessible to residents to be utilized for maintaining physical, mental, and emotional health. These include a library, lounge, café / bar, dining room, workout room, a gymnasium, and a green house. All these facilities should be maintained, and personnel encouraged to use them as they see fit to foster good physical, mental, and emotional health. The following spotlight on Health and Wellbeing highlights some best practices for personnel stationed at SPS to consider.

SPOTLIGHT ON HEALTH AND WELLBEING

GREEN SPACE FOR IMPROVED WELLBEING

The ability to directly view and/or interact with green spaces has been proven to improve mental wellbeing and recovery rates, as shown in a variety of international medical studies since the 1980s. Green space, in the context of the built environment, traditionally refers to areas partially or completely covered with vegetation, such as parks, green roofs, and community gardens. In absence of the ability to provide outdoor green space at the South Pole, the internal green space provided by the SPS greenhouse should be leveraged to the fullest extent practical.

Slater SJ, Christiana RW, Gustat J. "Recommendations for Keeping Parks and Green Space Accessible for Mental and Physical Health During COVID-19 and Other Pandemics." Prev Chronic Dis 2020; 17:200204. https://pubmed.ncbi.nlm.nih.gov/25874859/

Snowdrift Formation on Rodwell Building. Source: NSF, Bill Coughran, 2023.

Snowdrift Pile behind Elevated Station. Source: NSF, Bill Coughran, 2023.

Elevated Station Greenhouse. Fresh vegetables are an important addition to SPS personnel diets. The greenhouse and hydroponic system provides fresh produce throughout the winter and is a highly successful contribution to the livability of the station and management of isolation-related factors. The greenhouse has become a popular small social or quiet space for SPS personnel, providing green space respite in the otherwise lifeless surroundings of the station. Source: NSF, Felipe Pederos-Bustos, 2013.

Lounge. Source: NSF, Bill Coughran, Unknown.

DAYLIGHTING FOR IMPROVED WELLBEING

Exposure to natural light generally improves mental health and feelings of wellbeing across all ages, cultures, and geographic locations. When sufficient natural light is not available (as is the case during the austral winter at the South Pole), daylighting technologies may help reduce the impacts of the loss of natural light exposure. However, the color of the artificial light is critically important, as blue lights have been shown to be more disruptive to circadian rhythms. Sleep deprivation and sleep disorders due to the unusual natural light experienced at the South Pole is a serious year-round concern. In the winter, reduced exposure to natural light and subsequent low-quality sleep has been linked to the development of mental health disorders, such as anxiety and seasonal affective disorder (SAD). In the summer, 24 hours of light can disrupt sleep patterns in a similar fashion if the population is unable to reduce their exposure to the light before sleep. Reducing or eliminating natural light exposure at least two hours before sleep has been shown to improve sleep quality and reduce the chances of developing a sleep disorder.

Marqueze EC, Vasconcelos S, Garefelt J, Skene DJ, Moreno CR, Lowden A (2015). "Natural Light Exposure, Sleep and Depression among Day Workers and Shift workers at Arctic and Equatorial Latitudes." PLoS ONE 10(4): e0122078. https://doi.org/10.1371/journal.pone.0122078

PRIVACY FOR IMPROVED WELLBEING

The ability for people to control their immediate surroundings has been shown to reduce feelings of helplessness, anxiety, and depression. Private bed spaces allow SPS personnel to control their level of personal social engagement, which helps reduce feelings of irritability and anxiety. The rooms offer a respite in an often crowded and isolated area that may otherwise become overwhelming.

Evans GW. "The built environment and mental health." Journal of Urban Health. 80(4):536-555, 2003. https://www.ncbi.nlm.nih.gov/pmc/ articles/PMC3456225/ pdf/11524_2006_Article_257.pdf | Basic Information about Sleep and Fatigue: Effects of light. The National Institute for Occupational Safety and Health (NIOSH). 2020. https://www.cdc.gov/niosh/emres/longhourstraining/sleepfatigue.html

PHYSICAL ACTIVITY FOR IMPROVED WELLBEING

Physical activity provides a plethora of health benefits beyond body composition and weight management. Regular activity lowers blood pressure, cholesterol, and the risk of a wide variety of chronic illnesses, such as Type 2 diabetes and certain cancers. Bursts of moderate-to-vigorous activity stimulate the brain to release endorphins that can help manage feelings of anxiety and depression in adults, and regular activity of this intensity has been proven to help regulate sleep cycles—a critical health concern for the SPS population.

"Benefits of physical activity." Center for Disease Control & Prevention. 2021. https://www.cdc.gov/physicalactivity/basics/pa-health/index. htm?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fphysicalactivity%2Feveryone%2Fhealth%2Findex.html

SOCIAL INTEGRATION FOR IMPROVED WELLBEING

Building a positive sense of community is essential for isolated populations that depend on each other to survive. Social interactions remain positive when they are integrated into people's daily lives but easily controlled on an individual level. In residential built environments, having a wide variety of social spaces of various sizes has been shown to give residents a sense of community and stability. This helps create a positive environment where each person can develop a sense of security and belonging within a larger group.

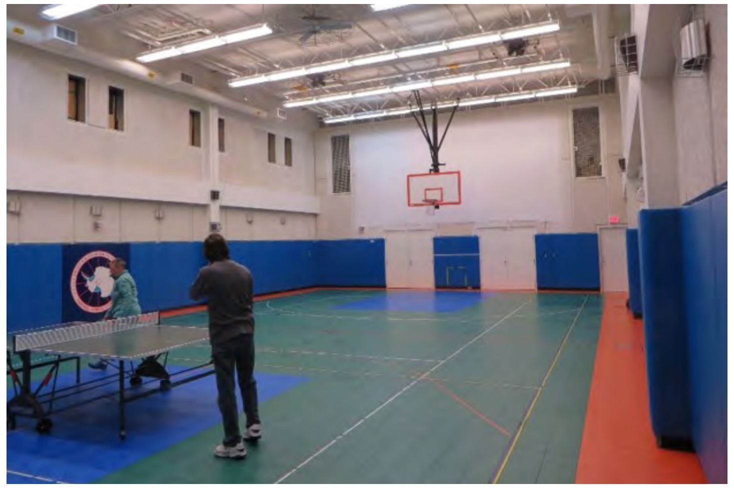
Evans GW. "The built environment and mental health." Journal of Urban Health. 80(4):536-555, 2003. https://www.ncbi.nlm.nih.gov/pmc/ articles/PMC3456225/ pdf/11524_2006_Article_257.pdf

REDUCED NOISE POLLUTION FOR IMPROVED WELLBEING

While extremely loud noises are often considered to have the biggest impact on physical wellbeing, sustained levels of noise pollution can have a similarly disruptive effect on the populations. Reactions to noise pollution include, but are not limited to, heightened levels of anxiety, frustration and annoyance, cognitive impairment, and poor sleep quality. Prolonged poor sleep quality can contribute to the development of insomnia and the related physical and mental impacts of chronic fatigue. Sound-proofing or dulling materials should be considered in the construction of spaces that will be regularly occupied, and ear plugs or white noise machines should be recommended or made available as sleep aids while on station.

World Health Organization. "Healthy Environments for Healthier People." 2018. https://www.euro.who.int/__data/assets/pdf_ file/0006/367188/eceh-eng.pdf

Single Bed. The elevated station contains 103 single bedrooms. Source: NSF, Bill Coughran, Unknown.



Gymnasium. The gymnasium hosts a variety of physical exercise and recreation activities. Source: NSF, Joe Rottman, Unknown.

Ruth Siple Library. Source: NSF, Elaine Hood, 2013.

SECURITY AND SAFETY

SITE SECURITY AND SAFETY CONSIDERATIONS

Physical access to SPS facilities is based on key control, and standard operating procedures for all visitors affiliated with tour operators and other national programs that have the capability to reach the station. Key control includes locked and limited masters to dorm rooms, hypertat rooms, work centers, offices and other warehouses and locations. Enhanced security measures are in place for life safety systems including additional key controls and cameras. All management and emergency response teams have 24/7 radio access. If an incident required law enforcement resources, the McMurdo Station Manager is a Special Deputy U.S. Marshal who works in close coordination with the Marshal's Service, the Department of Justice, and the NSF Office of the Inspector General.

SPS has a comprehensive emergency operations plan that covers a wide range of incidents for management on site as well as coordination off-station with McMurdo or back to the U.S. Emergency response capabilities are extensive with procedures that cover many possible scenarios and are followed by a designated incident commander and emergency response teams (ERT). ERT includes four main teams – first responder, fire brigade, logistics (transport and gathers materials needed from around station), and medical. All teams train individually on a weekly basis and each month a station-wide drill is conducted. Each summer and winter season, one of those drills is a mass casualty incident. Trainings are conducted before each summer season for both the trauma team and the fire brigade from experts in their field.

Medical facilities at SPS are in the Elevated Station for on-station medical needs, but the location of emergency service equipment, supplies, and servicing areas does not provide ease of access. Medical supply storage, for example, is located on the lower level of the station, while the medical center is located on the upper level. Storage for emergency response team gear was not included in the Elevated Station plans. The gymnasium provides adequate space for staging and response in the event of a mass-casualty or large-scale emergency response. However, none of the medical servicing areas are located for ease of access during patient transport.

Personnel safety at the SPS is governed by the NSF OPP Safety and Occupational Health Policy (SOH-POL_2000.10), and building/premises safety is regulated by the USAP Building Code (USAP-BC) and Fire Code (USAP-FC). These documents are based on nationally recognized model safety, building, and fire codes and are routinely updated. Individual buildings will include features such as fire alarm or suppressions systems as defined by the safety and building codes. The Elevated Station and arches primarily employ a water sprinkler fire suppression system. The power plants and certain information technology spaces are equipped with gas-led suppression systems. Auxiliary structures outside of the Elevated Station employ localized fire suppression systems that are meant to protect only specific high-value equipment. These systems are subject to annual maintenance and testing to ensure code compliance and reliability.

The safety of all personnel, grantees, and visitors at SPS is paramount. Should someone be harmed or experience victimization, specific safety measures will be implemented to safeguard and support the individual. The following built environment strategies will be incorporated into the design of new structures at SPS wherever feasible to ensure the safety of the living environment and enhance the ability to respond effectively to victims' needs.

- Provide single-occupancy locked bedrooms
- Reduce dead-end corridors and identify alternate path/emergency use options to mitigate contact between individuals when there are safety concerns
- Improve lighting
- Improve communications tools, including providing locations with adequate privacy when individuals wish to confer with off-ice professionals
- Configure the medical clinic to administer sexual assault forensic examinations with confidentiality and privacy

South Pole Station Aerial. Source: NSF, Undated.

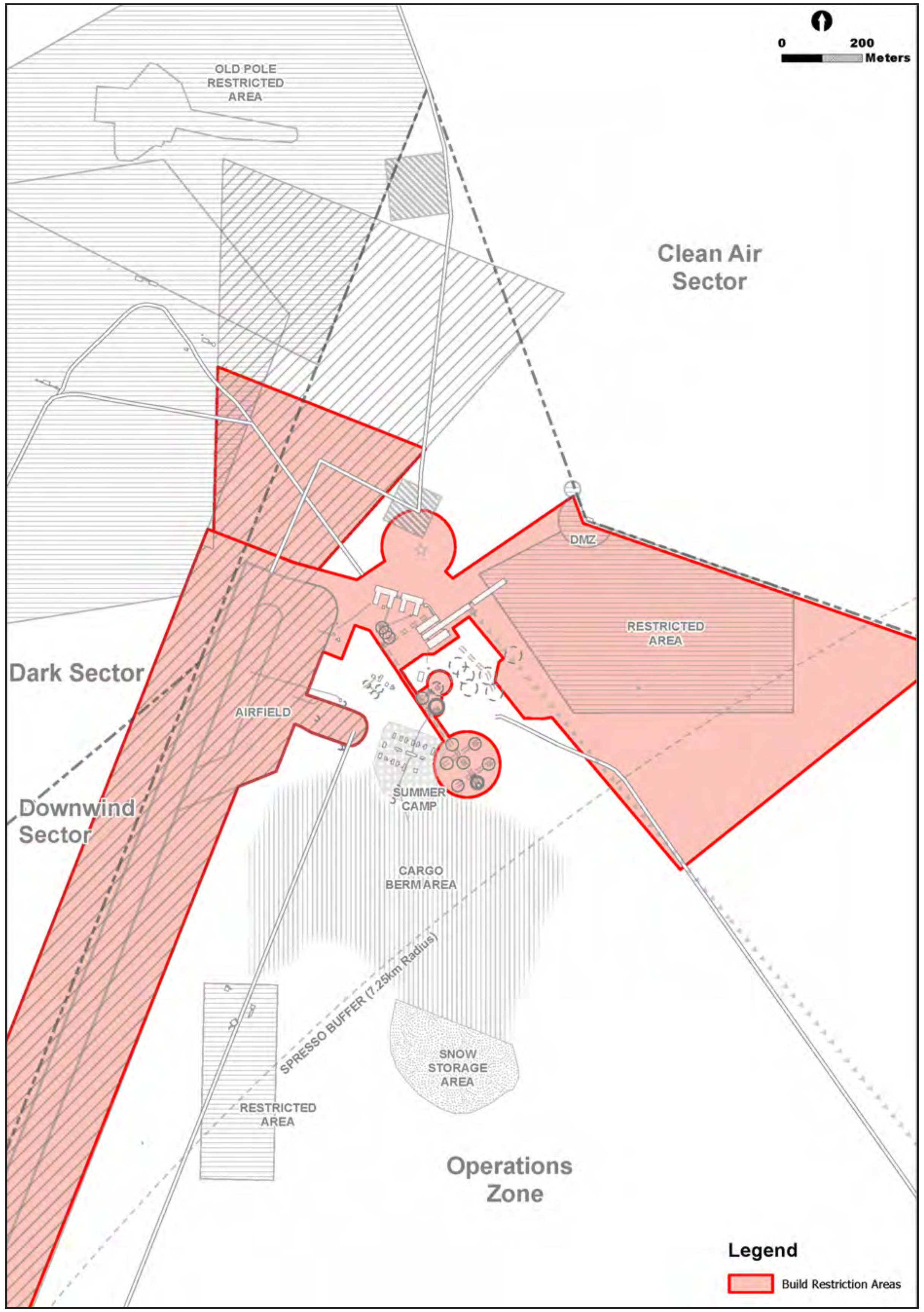


Figure 7.4 Build Restriction Areas.

CONCEPTUAL BUILDING FORMS

All existing arches and interior arch buildings at SPS require replacement. The SPS Master Plan has considered the approach to replacing each of these buildings. The replacement structures should be sized to meet current and projected needs. A square footage assessment was conducted for each building to determine a proposed footprint size. Different building types were initially explored for their suitability in Antarctic conditions. Once a preferred building type was selected, building templates were developed and used to create the conceptual site plan of the SPS Master Plan.

SQUARE FOOTAGE ASSESSMENT

The gross square feet of each of the existing arches footprints are summarized below. Table 7.2 summarizes the estimated total square footage of stored materials and equipment in the SPS area. Aisles, common areas, and offices are not included. Table 7.3 provides the estimated amount of materials recommended to be relocated to covered storage areas and the amount of materials that may remain at current outdoor locations.

To determine the size for replacement buildings the following assumptions were made:

- The size of a replacement power plant building assumes the same amount of area as required by the existing generators. A new building would increase by 10% for additional storage and office space. The building size used for the SPS Master Plan concepts is 12,675 square feet.
- The replacement fuel facility sizing assumes the same footprint as the existing structure, plus 15% for additional storage, and access. The footprint size used for the SPS Master Plan concepts is 16,612 square feet.
- The size of a replacement garage shops (VMF) structure was determined based on the desired number of bays, vehicle parking stalls, storage, and office space. The footprint size used for the SPS Master Plan concepts is 18,000 square feet. An additional new building was recommended for the storage of vehicles and equipment over winter months. A heated parking structure is not proposed for the SPS Master Plan, but for future planning a footprint size of a heated parking structure is estimated to be +/-30,000 square feet.
- The size of a replacement logistics/warehouse structure was determined by assessing the estimated square footage of items currently stored in outbuildings and snow berms that would be better protected within a covered storage arch (identified as “Move to Arches” in Table 7.3). The net footprint of a single stack storage on a snow berm yields approximately 8,563 square feet of material. A double stacked storage height produces a net footprint of 19,281 square feet of stacked open storage area. A multiplier of 1.38 was used to account for additional space for aisles and offices within a replacement arch. An additional 4,000 square feet for heated and cold storage structures inside a replacement warehouse was added. The estimated building footprint assumes storage racks will be stacked 2.5 pallets high, will be approximately 20 feet long, and will maintain a 12-foot access aisle. The loss of stack height due to the curvature of the ceiling was accounted for in the estimated sizing of this replacement structure. The footprint size used for the SPS Master Plan concepts is 31,000 square feet.

Existing Arches Square Foot Assessment

BLDG #	NAME	USE	STRUCTURE	ARCH GSF	REPLACEMENT GSF
101	Garage Shops	Vehicle Maintenance	Metal Arch	13,134	18,000
103	Power Plant	Power Generation	Metal Arch	11,542	12,675
104	Fuel Facility	Fuel Storage	Metal Arch	14,445	16,612
109	Logistics (Warehouse)	Cargo Storage	Metal Arch	22,090	31,000

TABLE 7.1 Existing Arches Gross Square Feet (GSF) Assessment

Current Stored Material Inventory

	SQUARE FEET OF STORAGE					
STORAGE TYPE	BERMS	OUT-BUILDINGS	ARCHES	ELEVATED STATION A	ELEVATED STATION B	TOTALS
Construction	12,160	0	0	0	0	12,160
Emergency Management	160	0	180	100	0	440
Fleet	6,400	0	3,760	0	0	10,160
Food/Dry Good	0	560	0	91	0	651
Fuels	160	320	0	0	0	480
Greenhouse	0	0	0	68	0	68
IT/Communications	160	0	0	124	237	521
Janitorial	4,000	0	0	102	99	4,201
Lodging Supplies	0	563	0	48	55	666
Maintenance	22,960	2,922	56	8	118	26,064
Medical	0	0	0	0	66	66
Miscellaneous	176,914	0	0	38	0	176,950
Postal Service	0	0	0	12	0	12
Recreation	0	0	0	0	100	100
Science	640	1,126	0	0	0	1,766
Store Stock	160	0	0	0	0	160
Utilities	4,800	0	624	0	0	5,424
Waste	62,227	0	0	0	0	62,227
TOTAL	290,741	5,491	4,620	591	675	301,932

TABLE 7.2 Current Stored Material Inventory
The square footage shown represents the actual footprint of the material, i.e. the size of a pallet.

Stored Material Potential Location

MOVE TO ARCHES (SF) Includes 560 sf DNF

28,560	Berms
5,135	Outbuildings
102	Elevated Station A
176	Elevated Station B
4,620	Arches
38,593	TOTAL

OPTIONAL MOVE/STAY (SF)

10,720	Berms
36	Outbuildings
201	Elevated Station A
192	Elevated Station B
0	Arches
11,149	TOTAL

REMAIN IN CURRENT LOCALE (SF)

251,461	Berms
320	Outbuildings
288	Elevated Station A
307	Elevated Station B
0	Arches
252,376	TOTAL

TABLE 7.3 Stored Material Potential Location

Logistics Operations Building Inside Arch. Source: NSF, Bill Coughran, 2023.

REPLACEMENT BUILDINGS

As new facilities replace the existing structures at the SPS, the existing arches may be temporarily re-purposed before removal from SPS. The existing arches will be replaced with new arches.

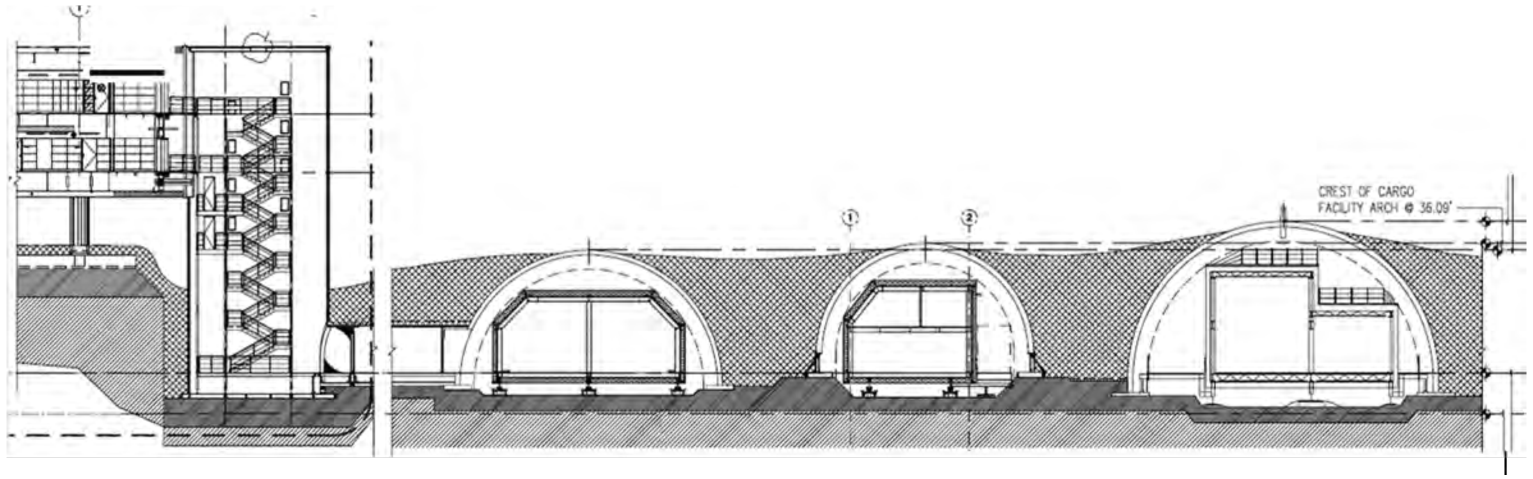
BUILDING TYPE - ARCHES

The arch structure remains a practical and effective option for construction at the SPS, combining simplicity, cost-efficiency, and proven durability in the extreme environment. With a SPS construction history dating back to the 1970s, arches are a well-established and reliable building form for this location. The modular design and lightweight materials used to construct arches make transportation and assembly easier compared to other building types, while relatively low upfront costs allow for the efficient allocation of resources to other critical station needs.

The versatility of this building type makes arches an ideal choice for supporting diverse SPS functions. The straightforward assembly process and predictable performance of arches in this environment make them a dependable solution for maintaining critical infrastructure under extreme conditions. By addressing known drawbacks with modern design improvements such as elevated snowpack pads, wider footings, and structurally rigid floors, the arches offer the best balance of efficiency, durability, and adaptability for the SPS's ongoing facility upgrades.

PROS

- Compared to other building types (such as elevated or jackable structures), arches provide a simple, time-tested solution.
- Arches can be constructed relatively quickly, allowing for timely replacements of aging infrastructure and reducing disruption to station operations.
- The individual ribs used to construct the arches nest within themselves during transportation. Arch materials are lightweight and support efficient shipment (relative to other structure types).
- Construction costs are lower compared to elevated structures.
- Arches have a long and successful use history at SPS. Arch performance and snow drift maintenance requirements are therefore predictable.
- Arches can be oriented to minimize drift impacts and reduce the maintenance burden of snow removal.
- Interior structures remain protected from exterior climate conditions, including periodic storm conditions.
- Snow floors can be regraded periodically to counteract long-term snowpack settlement along arch bearing lines.



Existing Arches Cross-Section showing buildings inside Arches. Source: NSF, Undated.

CONS

- Arch clear spans have a maximum width, which is a limiting factor in overall building dimensions.
- Due to the covered nature of the arch, interior building access to natural light is limited.
- Entry points are generally limited to the open face of the arch.
- Surface structures become buried over time from snow drifts.
- Historically, snow drift loading on the arches has caused structural damage in the form of local buckling of the steel ribs. However, this can be mitigated in future designs by increasing the steel gauge and adjusting the profile of the steel ribs.
- Snow floors experience "doming" over time, where the center portion of the snow floor appears to be crowning. This causes the interior overhead clearance to reduce significantly over time. Interior structures will eventually make contact with the arch ceiling, compromising the integrity of both structures.
- The snow floor of an arch experiences settlement at the bearing lines due to long-term deformation, or "creep," of ice and snow under sustained loading. Settlement-related doming can be partially mitigated by providing wider footings at the arch bearing lines. Additionally, a structurally rigid floor that spans from beneath the sides of the arch may better distribute the arch load and lessen differential settlement at the bearing lines.
- Floors constructed directly on top of the ice surface eventually become uneven, creating unsafe conditions for pedestrians and the operation of equipment such as forklifts. While the doming rate can be slowed, it cannot be eliminated and re-leveling of the floor will be required as a periodic maintenance item.
- Significant labor is required to clear snow drifts at the entries.

Arches and Covered Buildings during Construction. Source: NSF, 1999.

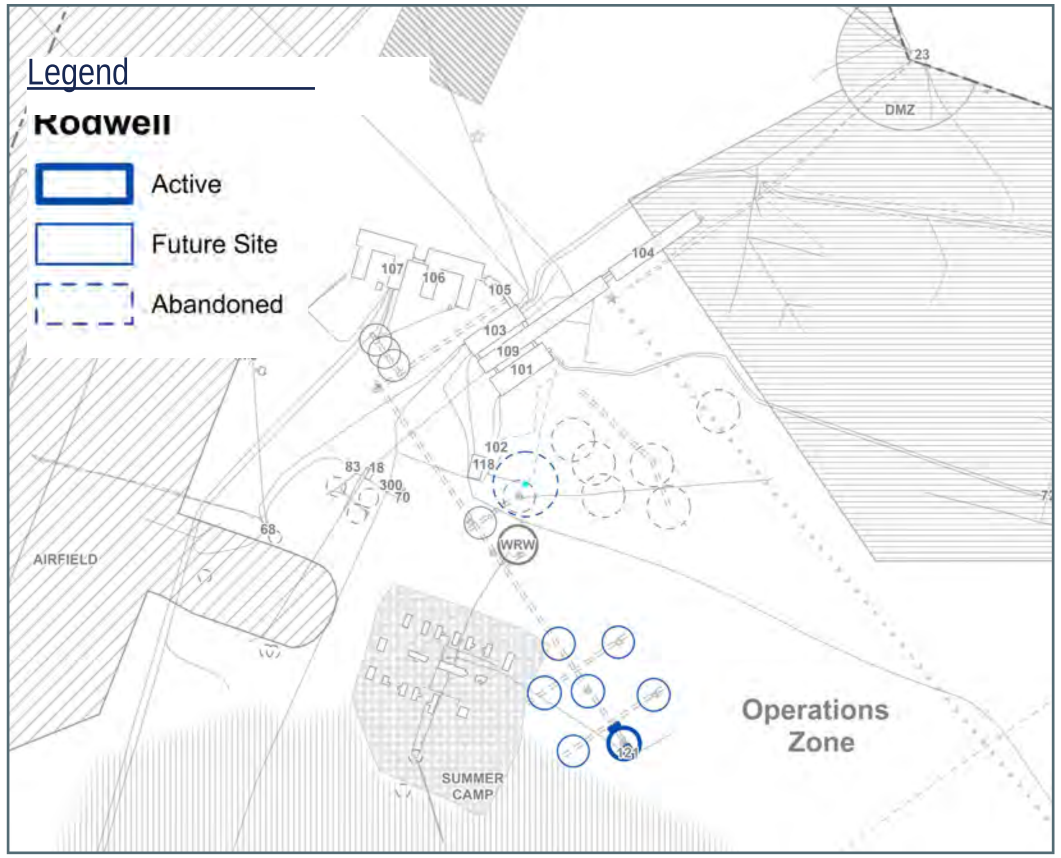


Figure 7.5 Water System.

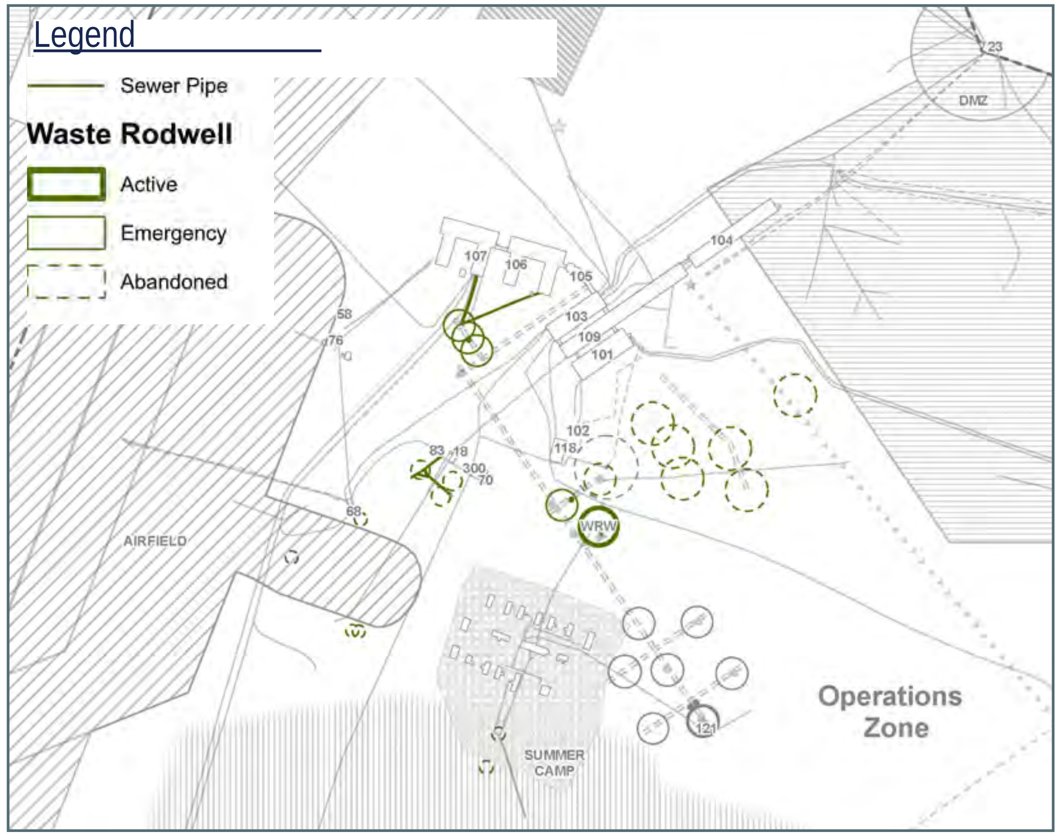


Figure 7.6 Human Waste System.

SYSTEMS

PRIMARY INFRASTRUCTURE

WATER SYSTEM

The current water treatment system will continue to serve the Elevated Station. Locations for future Rodwells have been identified along the existing utility tunnel corridor, as shown in Figure 7.5. A new water Rodwell is forecasted to be completed in early 2029.

When a new power plant is built, a new water treatment system will be installed and connected to the current water distribution system. Existing utility tunnels will be expanded as needed to connect future Rodwell locations to the new power plant.

If temporary outbuildings for surge bed facilities are constructed, water lines will be extended from the current water system to these facilities.

SEWER SYSTEM

When an existing sewer Rodwell reaches its capacity, the current water supply Rodwell will be transitioned to become the next sewer outfall. The existing sewer outfall is forecasted to be full in 2028, and a new intermediate sewer outfall is planned for completion in 2026. The intermediate sewer outfall will be used until a new water Rodwell is completed and the existing water Rodwell is transitioned into the new sewer outfall.

As new buildings are constructed, the existing utility tunnel will be expanded to connect new buildings to planned sewer outfall locations. Waste sewer lines will be expanded and connected to the active sewer outfall distribution system through existing and future utility tunnels.

If temporary outbuildings for surge bed facilities are constructed, localized waste outfalls will be installed for these facilities.

ELECTRICAL NETWORK.

FUEL FACILITY

A new fuel storage building will provide the same fuel capacity as the current facility. However, new technology and storage tanks could yield improvements to capacity and distribution. The new fuel storage building will be located next to the new power plant.

POWER PLANT

A new power plant needs to be constructed. The new power plant will contain the following new equipment:

- Three similarly sized (750 kW prime rating at site) diesel engine generators, including:
    - » Heat recovery heat exchangers
    - » Engine cooling systems (radiators)
    - » Engine exhaust systems
    - » Liquid fuel day tanks
- One similarly sized (239 kW prime rating at site) diesel engine generator, including:
    - » Heat recovery heat exchangers
    - » Engine cooling systems (radiators)
    - » Engine exhaust systems
    - » Liquid fuel day tanks
    - » ALTERNATE: Replace the new peaking generator with one of the existing 750 kW generators
- Electrical switchgear
- Motor control centers
- Plant control system and operator interface
- Heating fluid circulating pumps and expansion tanks
- Piping, valves, instruments, and cable as required

ELECTRICAL LINES

As electrical lines are scheduled to be replaced or added, every attempt will be made to collocate lines in a utilidor. As part of a future utility master plan, utilidors should located within utility easements.

The following actions will maintain a high-quality electrical system at SPS:

- As part of the arch replacement projects, a new consolidated utilidor from the new power plant to the existing SPS electrical connections will be created.
    - » When the new power plant is ready to come online, temporary outages will occur during the switch over.
    - » As existing and new structures are renovated or developed, new electrical utilidors will be constructed from the new power plant to those structures. Existing splices will be abandoned and then removed over time.
- Electrical cabling will be looped at both ends of utilidor to allow for ice sheet shifts that stretch the cables.

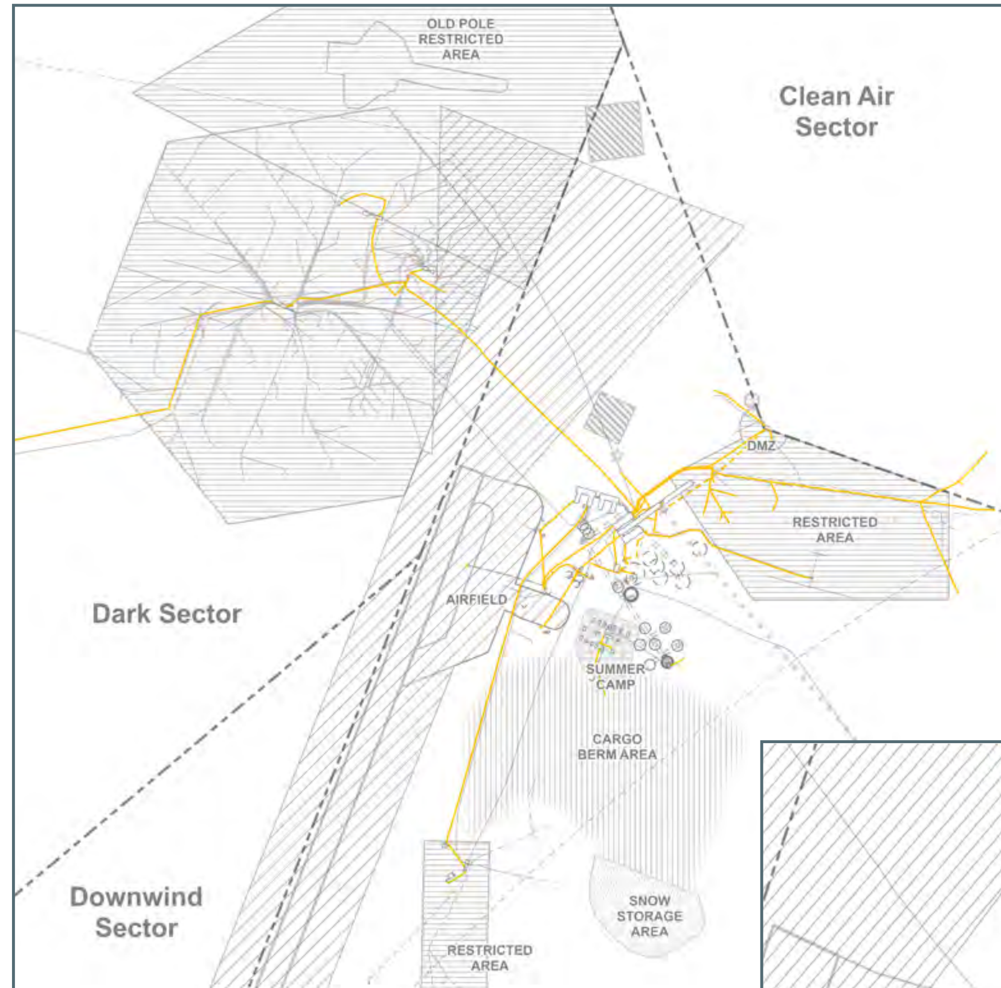


Figure 7.8. Electrical Cabling: Overall Station.

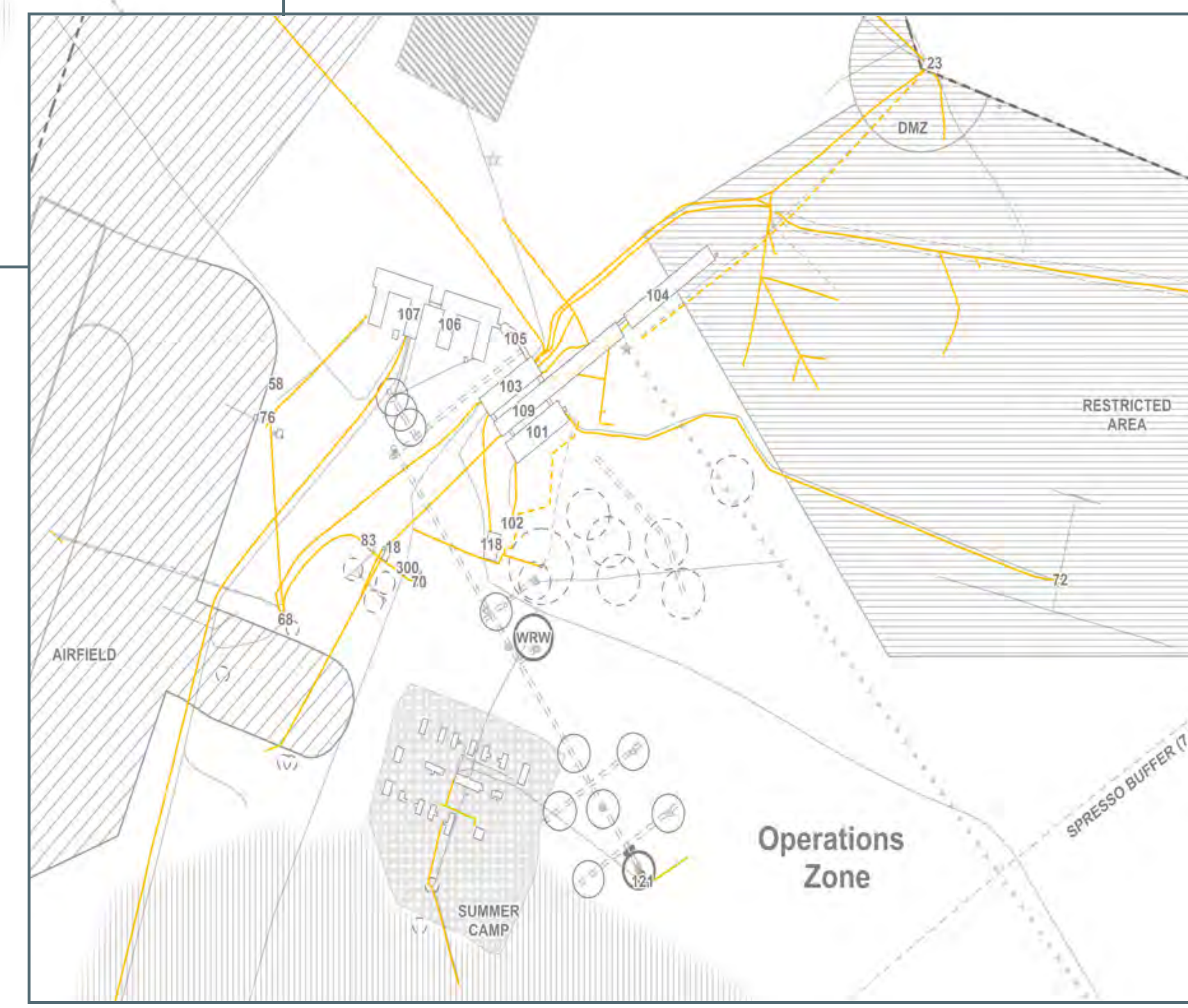


Figure 7.9. Electrical Cabling: Core Area.

COMMUNICATIONS NETWORK

Communications systems connect all SPS service and science facilities. IT and Communications systems are vital to maintaining daily communications and data links from SPS to points around the world. Minimizing EMI, maintaining reliable radio communications, and maximizing satellite connections are imperative to the continues success of SPS.

As communications lines are scheduled to be replaced or added, every attempt will be made to collocate lines in a utilidor. As part of a future utility master plan, utilidors should located within utility easements.

The following actions will maintain a high-quality communications system at SPS:

Spectrum Coordination and Optimization:

- Land Mobile Radio system spectrum selection and waveforms will be coordinated with all existing Sector science facilities.
- EMI and RF will be minimized where practical while ensuring safety and operational requirements are met.
- Ongoing collaboration mechanisms will be established to adapt to emerging spectrum-related challenges and advancements.
- Technology strategies will be researched and adopted where practical to minimize or localize RF emissions to necessary-only levels. Example: widespread use of Distributed Antenna Systems interconnected by fiber optic cables for localized low power emissions where needed; sector antennas for broadcast service to direct energy away from Dark Sector, etc.

Modernization of HF Radios and Antennas:

- Collaboration with NIWC will continue for the modernization of HF radios.
- Antenna refreshes will be pursued to enhance overall system performance and reliability.
- Industry advancements will be monitored for potential upgrades to HF communication technologies.

Space Assessment for RF Building Redesign:

- A thorough space assessment of RF Building size will be conducted to support future facility redesign.
- Provisions for equipment redundancy will be included to minimize high-risk winter personnel visits.
- Spatial requirements for emerging technologies and adaptability to evolving communication needs will be evaluated.
- Technology advancements will be researched and adopted where practical to reduce equipment footprint and enhance use of redundancy and automation, minimizing the need for high-risk winter technician calls for corrective maintenance.

Permanent Utility Right-of-Ways for Fiber Optic Cables:

- Utility easements will be established for the routing of fiber optic telecommunications cables.
- Geospatial documentation of easement locations will be maintained to account for ice sheet movement and changes over time.
- Protocols for regular inspections (locating) and maintenance will be implemented to prevent unplanned disruptions due to changing environmental conditions.
- Telecom industry best practices and technology innovations will be researched and adopted where practical to enable geolocation and dynamic protection of buried cable routes (e.g., use of Distributed Acoustic Sensing for cable protection).

SATCOM Construction. Source: NSF, Jack Corbin, Undated.

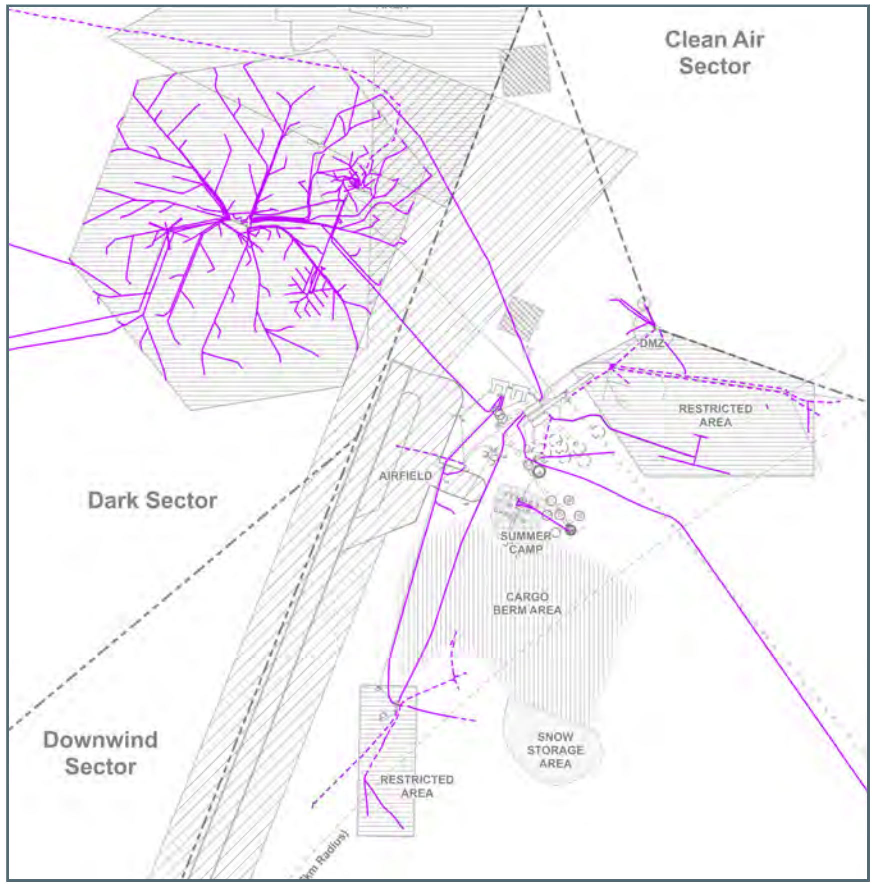


Figure 7.10 Communications Network.

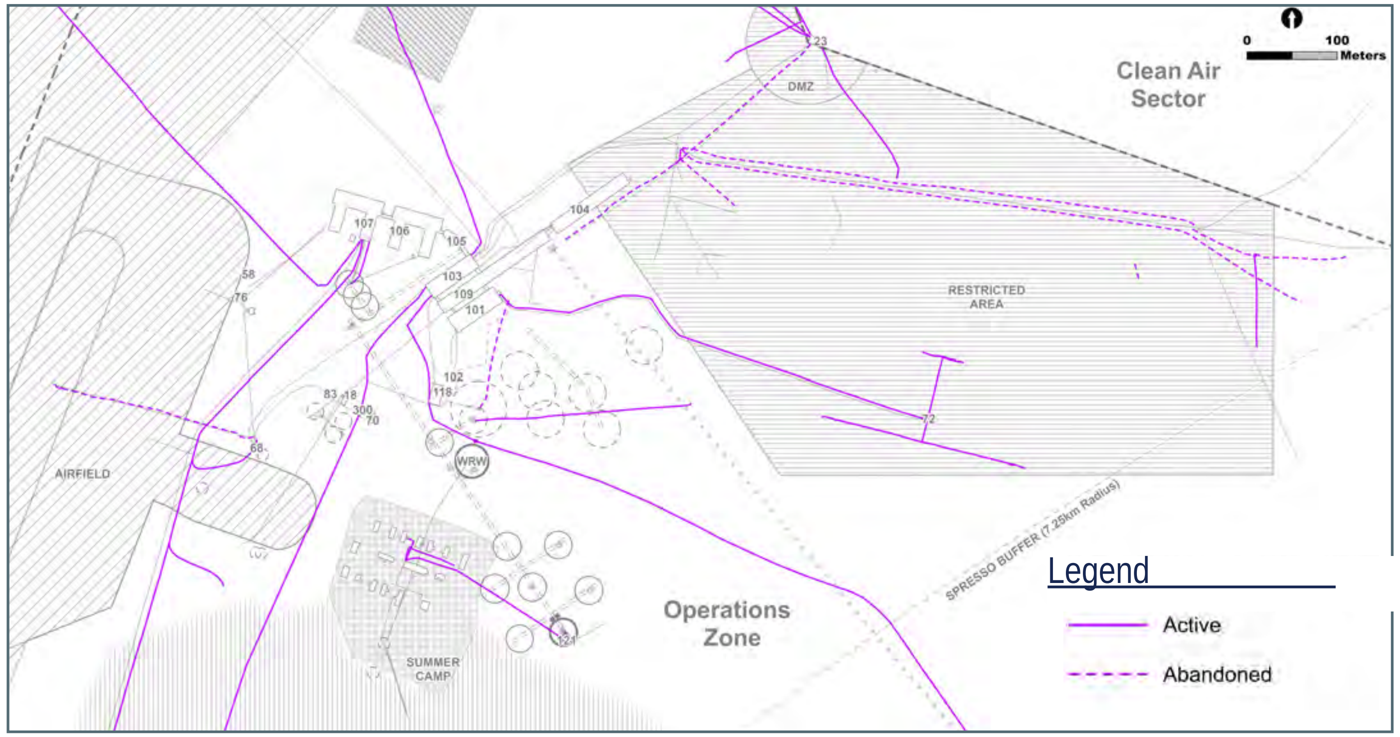


Figure 7.11 Communications Network Core Area.

Adopting New Technological Developments:

- New technological developments in the telecommunications field will continue to be evaluated for potential benefits to SPS operations and science communications and data transfers.
- Innovations that allow for additional throughput in network bandwidth will be prioritized.
- Adoption of new technologies will not disrupt the scientific communities in the Dark Sector where practical, and will aligns with Dark Sector operational requirements.
- A proactive communication strategy will be developed to keep stakeholders informed about technology changes and potential impacts on ongoing operations.
- High reliability and low labor “touch-factor” design with redundancy, automation, and remote operations/management will be prioritized.

REDUCED CONSUMPTION OF DELIVERED FUEL

Use of freely available on-site energy sources at SPS will be evaluated to reduce the consumption of delivered fuel. Reduction of delivered fuel consumption at SPS will result in increased flexibility for delivery of materials and supplies to SPS via SPoT and LC-130 platforms. Use of multiple energy sources will improve resiliency of the overall power production system, allowing better fuel cost and resource management and emergency planning. A techno-economic analysis for implementation of a hybrid energy system at SPS, which currently hosts several high-energy physics experiments with nontrivial power needs, should be conducted. A cost-benefit analysis of different energy production portfolio combinations with and without traditional diesel energy generation should be completed.

The SPS Master Plan identifies preliminary potential sites for future on-site energy production fields. These sites are conceptual locations based on available geography. The final location of any future on-site energy production fields will require additional research and testing for optimum performance, minimal EMI and vibration, and consideration of energy loss due to the distance of transmission lines to the SPS.

A parhelic circle, or “sundog,” over the geographic South Pole. Source: NSF, Peter Rejcek, 2015.

AIRFIELD

The airfield is an instrument flight rules (IFR) certified skiway designed under Federal Aviation Administration (FAA) guidelines and the Department of the Air Force Manual (DAFMAN) 13-217, dated 19 April 2022. It currently serves LC-130s on the 20 skiway with the 02 approach only used in emergencies. Two primary concerns with the airfield include the 02 approach/departure contaminating the air quality in the Clean Air Sector and the development limitations imposed by the height restrictions with the Imaginary Surfaces on the 02 skiway. The imaginary surface for the skiway is depicted on Figures 7.12 as red rectangles. The contours shown on the figure represent the imaginary surfaces elevation above the skiway elevation. The heights of all physical objects within the imaginary surface areas must not exceed the contour elevation. The contour elevations are shown as individual lines. A secondary concern is the need for personnel walking to and from the Dark Sector to cross the skiway. Pedestrians and vehicles are required to wait until the aircraft have cleared the flight path before crossing. In extreme temperatures, this wait is not preferred.

The SPS Master Plan recommends no change to the skiway at this time for the following reasons:

1. Flight patterns can be adjusted to avoid flying over the Clean Air Sector.
2. The development areas north of the skiway are not being considered as viable sites for SPS and science expansion.
3. Policies and procedures are already in place to manage pedestrian and vehicular crossing of the skiway.
4. Logistics challenges of shifting the skiway.

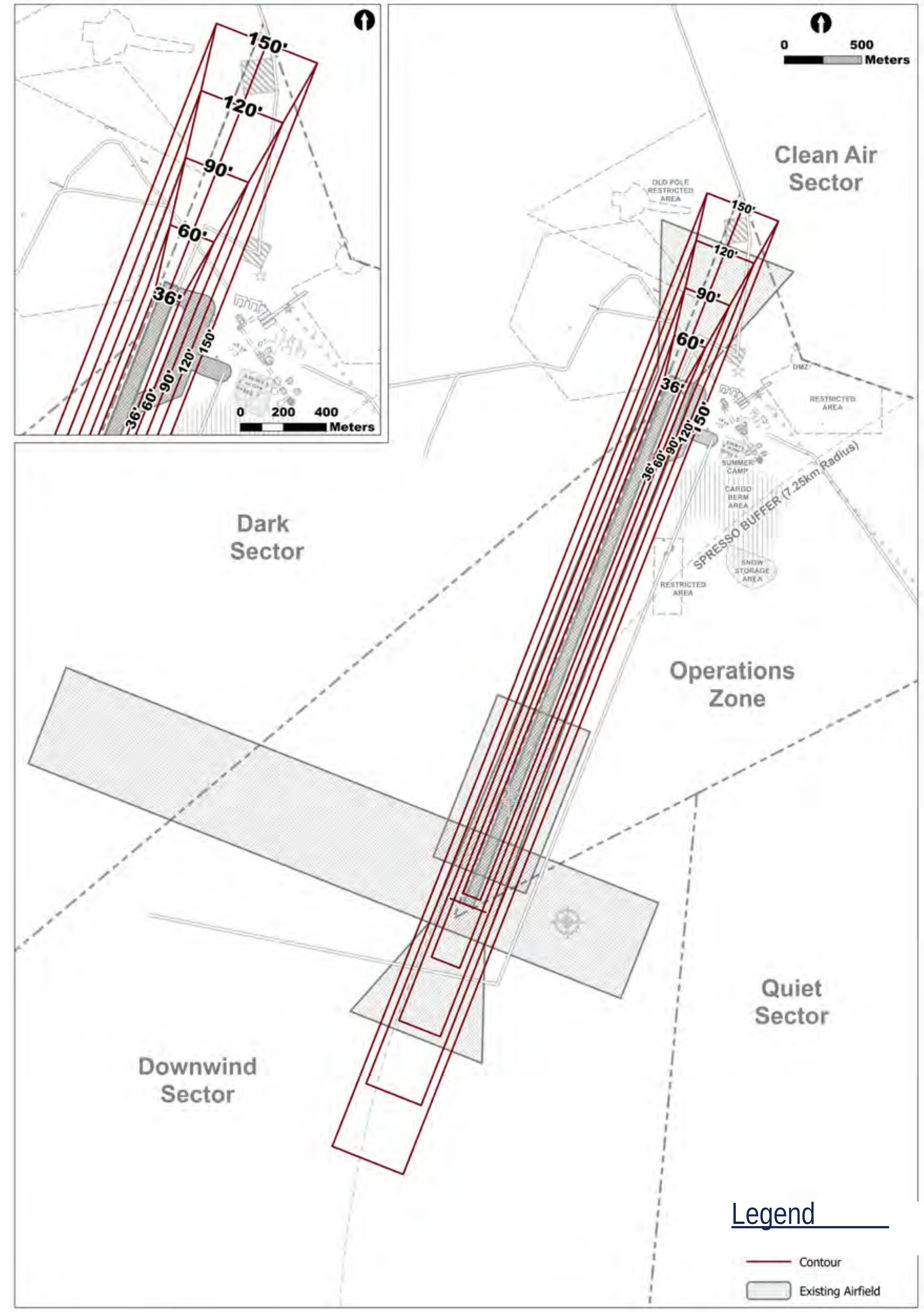
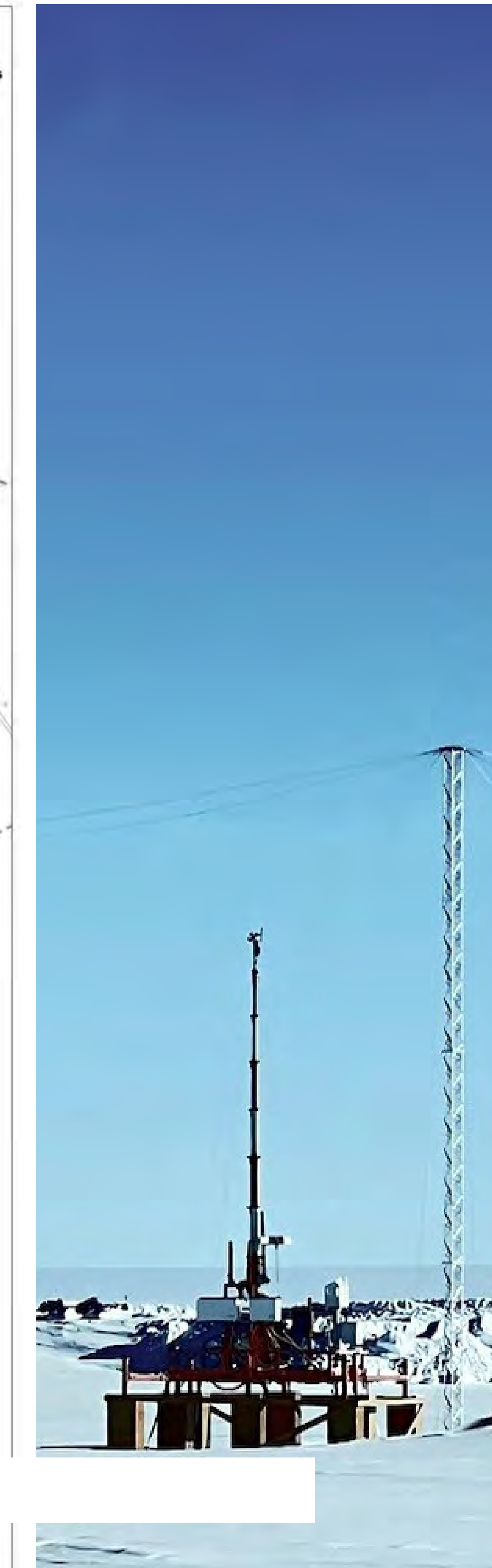


Figure 7.12. Existing Airfield Imaginary Surfaces.



FMQ23 for Airfield. Source: NSF, Undated.

REGULATING PLANS

The South Pole Sectors and Operations Zone remain regulated by ASMA No. 5. However, the SPS Master Plan Regulating Plans provides USAP-internal guidance for future development within the Operations Zone. The SPS Master Plan Regulating Plans contain additional planning tools to organize future development, including design principles, land use districts, district overlays, and easements. These tools will assist in the alignment of USAP resources; encourage a more efficient, orderly, and aesthetically pleasing station design; and eliminate potential conflicts between scientific research activities and the infrastructure activities needed to support science.

DESIGN PRINCIPLES

Design principles are foundational land use and master planning ideals that both guide the design of the built environment and are applicable across a wide variety of recommendations and objectives for maintaining, replacing, and operating current and future buildings and infrastructure at SPS. Design principles are not planning mandates. No hierarchy of application is assigned to the design principles. In the event that multiple design principles are applicable to the planning and execution of an action but are found to be in conflict during the design and completion of an infrastructure project, conflicting design principle(s) may be omitted.

SAFETY & RELIABILITY

The safety of personnel and visitors is the single most important goal of station operations. Future building and infrastructure designs should improve SPS operations and disaster response and recovery capabilities. Reducing single-point failure risks and promoting fail-soft systems to improve system reliability should be encouraged where possible.

SIMPLICITY & STANDARDIZATION

Simplicity and standardization of systems and components promotes ease of installation, operation, and maintenance of station buildings and infrastructure. Where possible, structural and functional systems should be designed in a way that reduces the variety of specialty parts, tools, and labor needed to operate, maintain, and service them. Easily duplicable and easily serviced buildings and infrastructure that can be built off-site should be encouraged. For example, modular, stackable building components (such as prefabricated wall panels) that conform to the size and weight requirements of available transportation methods could standardize shipping and installation processes.

FLEXIBILITY & ADAPTABILITY

Future SPS buildings and infrastructure should be flexible and adaptable in order to support the evolving nature of scientific inquiry in Antarctica, while at the same time considering potential future needs or constraints. Easily scalable structures and infrastructure systems should be encouraged. Infrastructure that can be adapted or reconfigured based on current needs should be considered where appropriate.

RIGHT-SIZED & COMPACT

To increase logistical and resource efficiencies, future buildings, infrastructure, and vehicles should be appropriately right-sized for the scale and intensity of each use, which may result in a reduced or increased structure or service footprint at the station. Spatial relationships between uses should be intentionally planned to encourage compact operational nodes throughout the station area. Compact nodes encourage local walkability, energy efficiency, and reduced reliance on vehicular traffic.

INTEROPERABILITY

Ensuring interoperability of mission support and scientific activities is paramount to the continued success of SPS continuing efforts and status in international leadership in scientific research and exploration. This includes continuing enforcement of Sector boundaries and regulations, preventing interferences or contaminations in accordance with Antarctic Treaty provisions, and mitigating impacts of large-scale infrastructure and science projects on small-scale science resources. Future designs should evaluate potential adverse impacts of one infrastructure or science project on other functions in the area. Where possible, these impacts should be mitigated during the design of large projects to allow continuous station operation and scientific exploration for all fields of research.

ENERGY EFFICIENCY

Energy Efficiency refers to the pursuit of freely available, on-site energy production systems and adaptive re-use of climate-appropriate materials to maximize energy efficiencies, reduce fuel consumption and its associated delivery costs, and maximize the life of SPS, while complying with all environmental regulations. Fossil fuel delivery is one of the largest current annual logistics constraints for the station. Future designs should consider the potential for reducing resupply demands and re-using materials wherever possible. Final siting of new structures identified in this SPS Master Plan should consider walkability to reduce the reliance on vehicular traffic and its associated staffing, maintenance, and fuel consumption.

ENVIRONMENTALLY RESPONSIVE

Buildings, infrastructure, and vehicles should be designed to respond appropriately to the environmental, terrain, and weather conditions of the South Pole. Special consideration of snowdrift implications should be included in the siting and structural design of all infrastructure. Where possible, easily elevated structures and technologies to combat snow accumulation and maximize the life of station infrastructure should be pursued. Potential uses for snow removed during the annual snow removal efforts should be explored.

LIVABILITY

Building and infrastructure designs should ensure that SPS provides a habitable, healthy environment for personnel and visitors, which includes ensuring healthy indoor air quality, supporting mental and physical health by means of spatial programming and architectural design, and integrating social spaces to support collaboration and a sense of community. The use of architectural design features that improve privacy at SPS should be pursued, and the provision of single-occupancy rooms wherever possible should continue. All future designs should take particular care to ensure livability for the winter-over population, including adequate emergency facility planning.

AESTHETICALLY INDICATIVE OF THE NSF'S STATURE

Future modernization and designs should include an orderly, intentionally planned site layout and forward-thinking, and cost-effective architectural design. The appearance of the SPS campus and structures should be aesthetically indicative of the professionalism, world-class science conducted in Antarctica, and the professionalism of the staff supporting SPS operations.

OPERATIONAL EFFICIENCY

The operational efficiency design principle encompasses several concepts that would improve spatial organization and use of the SPS area, but may require process modifications beyond the scope of this document to achieve. Storage and warehousing, for example, are currently drastically undersized at SPS. Robust life cycle planning of resources, including pre-planning of retrograde or re-use of materials, should be encouraged to reduce resupply demands and the required warehousing footprint. This may include pursuing regulatory waivers for staffing requirements where health and life-safety standards would not be compromised.

Elevated Station Vertical Tower. Source: NSF, 2021.

LAND USE DISTRICTS

Land use districts are planning tools that help organize uses and operations within a defined area. Each district has development standards to mitigate the impacts of incompatible activities by separating land uses and organizing land use adjacencies in each area. The land use districts, district overlays, and easements presented in this document have been created for USAP-internal guidance of future development at SPS and are not intended to replace, supersede, or conflict with any existing Antarctic Treaty, Environmental Protocol, or ASMA agreement, directive, or requirement. A land use district matrix listing the permitted uses for each district is provided in Appendix C.

AIR SUPPORT DISTRICT

The Air Support District denotes areas in the Operations Zone where airfield support activities (e.g., aircraft landing and parking, refueling, and cargo staging) may occur and should be reasonably separated from other SPS service activities to prevent cross contamination of supplies and mitigate air and sound pollution to protect the health of SPS personnel. This district will contain the skiway, aircraft parking areas, and a variety of structures and infrastructure used to support airfield operations. Siting of all future Air Support District facilities and services will require a site study and environmental analysis, where applicable, before final placement.

- Structure Setback: Governed by U.S. Air Force regulations and USAP building codes.
- Existing, non-conforming structures and infrastructure in the Air Support District may continue current operations as long as those operations do not conflict with existing U.S. Air Force regulations, but those operations may not be expanded or replaced.

STATION AREA SCIENCE DISTRICT

The Station Area Science District sets aside an Operations Zone area for scientific research activities that require immediate SPS proximity for year-round pedestrian access. The boundaries of the Station Area Science District reflect Operations Zone space that is already used for this purpose. Dedicating a specific area in the Operations Zone to scientific activities and infrastructure de-conflicts operational and scientific activities and promotes improved interoperability with the necessary functions of the Operations Zone. Delineating a specific area prevents sprawl and preserves the Operations Sector for future operational development, such as renewable energy production fields and heavy equipment operations that may otherwise interfere with scientific equipment or measurements. Access to the Station Area Science District is restricted to USAP personnel and researchers. All personnel working in this district should coordinate with the scientific research organizations working in the area to avoid disturbing any areas where sensitive scientific or antenna infrastructure may be affected by vehicular or pedestrian activity. This district is proposed to eventually take the place of the ASMA Antenna Field Restricted Zone, as that zone no longer matches the actual footprint or extent of scientific activities in the Operations Zone. Siting of all future Station Area Science District structures will require a site study and environmental analysis, where applicable, before final placement.

- Structure Setback: 150 feet from any previously established Primary Infrastructure District uses and as required by USAP building codes.
- Existing non-conforming structures and infrastructure in the Station Area Science District may continue current operations as long as those operations do not conflict with existing funded scientific research activity. Conflicting non-conforming structures and infrastructure should work toward relocation and may not be expanded or replaced.

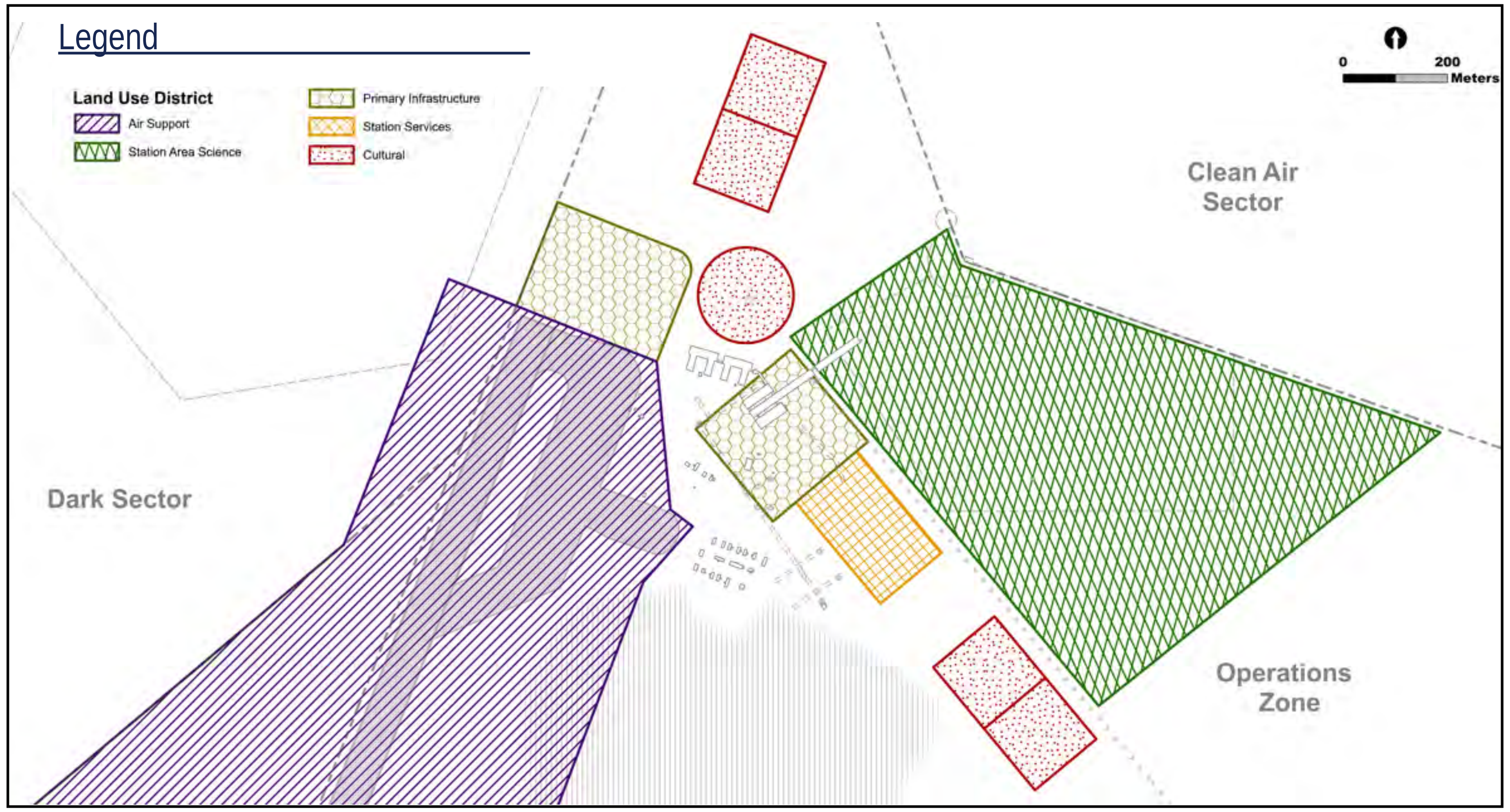


Figure 7.13. Land Use Districts.

PRIMARY INFRASTRUCTURE DISTRICT

The Primary Infrastructure District denotes areas within the Operations Zone where critical infrastructure uses such as power generation, fuel storage, heavy equipment operation, and equipment warehousing may create byproducts that hinder or otherwise negatively impact station services and scientific activities and, therefore, should be reasonably separated from these activities to prevent cross contamination of food and life safety supplies. Separation of these uses will mitigate air and sound pollution to protect the health of station personnel. This district will contain the primary infrastructure arches and its associated utility grid. Siting of all future Primary Infrastructure District facilities and services will require a site study, plume analysis, and environmental analysis (where applicable) before final placement. A utility master plan should be developed before future cabling in the district is completed.

- Structure Setback: 100 feet from any previously established Station Services District uses and as required by USAP building codes within the district.
- Existing non-conforming structures and infrastructure in the Primary Infrastructure District may continue current operations but not be expanded or replaced.

STATION SERVICES DISTRICT

The Station Services District denotes the proposed area for a future Elevated Station that will provide lodging, dining, recreation, medical, and office services to SPS personnel. These uses are sensitive to the byproducts of industrial processes, such as power generation and fuel storage, and should be reasonably separated from such processes to prevent cross contamination of supplies and mitigate air and sound pollution to protect the health of SPS personnel. A central and compact location of station services within the district increases visitor safety by de-conflicting the heavy equipment traffic in the Primary Infrastructure District and the pedestrian and light vehicle traffic associated with the Station Services District. The Station Services District has been located for future adjacency to the projected 2070 location of the geographic South Pole. A new campus-specific master plan and a complete siting study and environmental analysis must occur before final siting of the future station.

- Structure Setback: 150 feet from any previously established Primary Infrastructure District uses and as required by USAP building codes within the district.
- Existing non-conforming structures and infrastructure in the Station Services District may continue current operations but not be expanded or replaced. Relocating existing station services structures to the Station Services District should not occur until a campus-specific master plan for a future station has been completed.

CULTURAL DISTRICT

The Cultural District is intended to set aside areas of the Operations Zone for historical markers and NGO tourism activities. Cultural District areas noted with a Temporary Structure Overlay are intended for use as NGO tourism campgrounds and related vehicle or aircraft parking. Siting of all future Cultural District facilities and services will require a site study and environmental analysis, where applicable, before final placement. The placement of an NGO camp grid-east of the Station Services District would only be implemented if SPRESSO moves further from the Elevated Station.

- Structure Setback: None.
- Existing non-conforming structures and infrastructure in the Cultural District may continue current operations but not be expanded or replaced.

DISTRICT OVERLAYS

District overlays, depicted in Figure 7.14, are land use organization tools applied to areas where complex and varied activities occur. District overlays are used to identify areas where additional development standards or restrictions apply to the underlying Land Use District to maintain proper adjacency and operational relationships.

TEMPORARY STRUCTURE OVERLAY

The temporary structure overlay identifies areas where temporary, movable structures may be located to serve a specific and non-permanent use. The locations of the temporary structure overlay correspond to future anticipated temporary uses, such as tourism campgrounds. Temporary structures placed within a temporary structure overlay should be modular or otherwise easily reconfigured, re-purposed, or dismantled. Once all temporary uses have ceased within a structure, the structure must be removed from the overlay district, and may be stored in a covered location for future use. Existing non-conforming temporary structures outside the temporary structure overlay may continue current operations but not be expanded or replaced. Relocating such structures to an applicable temporary structure overlay area is encouraged.

CONSTRUCTION HAZARD OVERLAY

The construction hazard overlay area indicates where new construction/structures may be subject to construction conflicts resulting from snow settlement, existing structures, or buried obstacles. Construction activities in this overlay will require siting studies that identify construction impacts of buried hazards. Potential hazards within the area include, but are not limited to, existing buried structures and building foundations, science and utility vaults, current or decommissioned Rodwells and sewer outfalls, utility lines, and fuel lines.

SNOW STORAGE OVERLAY

The snow storage overlay indicates the area where snow from drift removal may be deposited. Within the overlay, snow deposits must be located far enough away from existing structures to prevent additional snowdrift accumulation around those structures. Existing non-conforming structures and infrastructure may continue current operations but not be expanded or replaced within the snow storage overlay. This includes, but is not limited to, snow berm storage of supplies.

EASEMENTS

Easements are land use organization tools commonly applied to areas that require specific regulation. Typically, easements are used for granting or protecting access. Easements can be applied across Land Use Districts or ASMA Zones. They are similar in nature to the ASMA Restricted Zones. See Figure 7.14 for general locations of SPS easements.

CLEAN AIR SECTOR (CAS) BUFFER EASEMENT

The Clean Air Sector (CAS) Buffer Easement follows the boundary of the CAS and extends 1 km into the CAS from the boundary. All CAS structures should be located a minimum of 100 feet into the CAS to prevent contamination and emissions interference with CAS scientific operations. Existing non-conforming structures and infrastructure (including CAS structures) may continue current operations but not be expanded or replaced within the easement.

CLEAN AIR SECTOR (CAS) ACCESS CONTROL EASEMENT

To minimize contamination in the CAS, access into the CAS may be managed by an access control easement. The access control easement would be placed along the 110-degree and 340-degree CAS boundary for a distance of 2 km originating at the intersection of the 110- and 340-degree lines. Access across this easement into the CAS is not permitted without approval from SPS management and/or the science community conducting research in the CAS. Access into the CAS beyond the access control easement will still require pre-approval. Routes to the point of access into the CAS shall follow the CAS boundary. Return routes shall follow the exact same route.

GEOGRAPHIC SOUTH POLE EASEMENT

A 100-foot easement shall be established along the trajectory of the geographic South Pole to maintain unobstructed pedestrian and vehicular access to the geographic South Pole, which is a popular destination for South Pole visitors and which experiences frequent summer foot traffic. No structures may be placed within this easement. Existing non-conforming structures, infrastructure, and station area science may continue current operations, but may not be expanded or replaced within the easement.

UTILITY ACCESS EASEMENTS

Utility access easements are defined as surveyed corridors used for installing, constructing, and maintaining utility lines and infrastructure. Permanent buildings and structures shall not be constructed over a utility access easement. Utility access easements may be established in any Sector or Zone of the SPS area. These easements may contain wet and dry utilities. The easements must provide sufficient width to allow for required utility separations, access in the case of ice tunnels, and snow storage during trenching. Existing non-conforming utility lines and infrastructure may remain in current locations, but may not be expanded or replaced without relocation to a utility access easement. Siting of all future utility access easements may require a site study and environmental analysis, where applicable, before final placement.

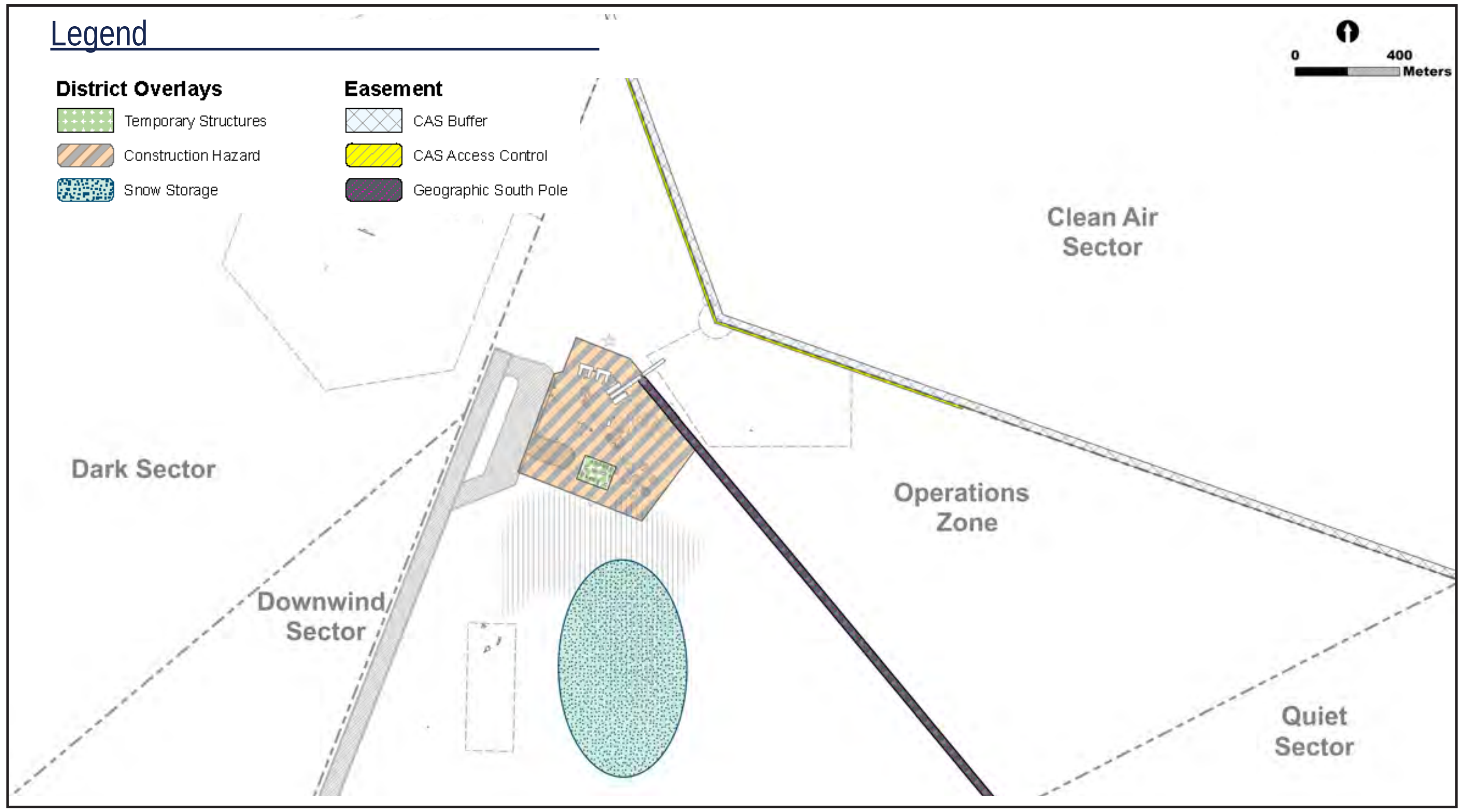


Figure 7.14. District Overlays and Easements.

SNOWDRIFT EASEMENT

Snowdrift Easements are defined as general easements placed around new buildings denoting potential areas of snow accumulation from drifting snow. Snowdrift easements discourage improvements from being constructed adjacent to any existing structures that would result in increased snowdrift accumulation around an existing building. Figure 7.15 depicts known drift areas around the Elevated Station. Figure 7.16 depicts wind roses used for snowdrift modeling at the South Pole. The prevailing wind direction is 10 to 30 degrees grid east.

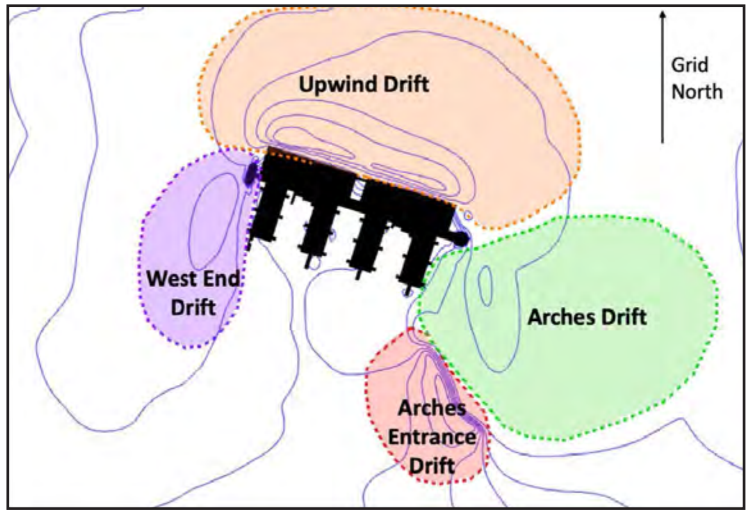


Figure 7.15. Snowdrift Areas
Source: South Pole Station Drift Model, ERDC/CRREL TR-22-7, August 2022.

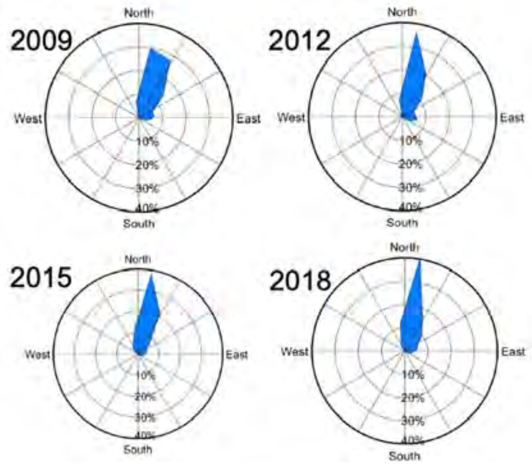


Figure 7.16. South Pole wind roses used for snowdrift modeling.
Source: South Pole Station Drift Model, ERDC/CRREL TR-22-7, August 2022.

MASTER PLAN

The SPS Master Plan is a guide for redevelopment and modernization of station buildings, structures, and improvements to the SPS campus over the next 30 to 50 years. The SPS Master Plan reviewed existing SPS conditions, identified existing, evaluated recommended actions, and developed a list of capital projects and studies to be considered in support of the implementation of the SPS Master Plan vision. The SPS Master Plan illustrates how the SPS campus can be organized to achieve efficiencies and aesthetic and mitigate use conflicts. However, the SPS Master Plan does not propose final or exact locations for future structures or utilities at the SPS; comprehensive siting studies, including environmental assessments per Article 8 of the Protocol on Environmental Protection to the Antarctic Treaty, must be completed prior to placing any new structures or relocating existing structures in the SPS area. A snowdrift analysis should be completed before any structure placements or relocations occur on the SPS campus to avoid unforeseen snowdrift impacts.

The recommendations presented in Section 6: SPS Area Plans were evaluated for applicability and alignment with the SPS Master Plan vision. Not every recommendation was adopted in the SPS Master Plan or selected for implementation via a capital infrastructure project or study. Additionally, not every recommendation has a physical site location. The bulleted SPS Master Plan initiatives outlined in this section reference Section 6 identifying numbers in parenthesis where applicable. A consolidated Section 6 recommendations list is provided in Appendix B.

Recommendations that were selected for implementation via a capital infrastructure project or study in Section 8 are identified with an asterisk. Section 8 provides consolidated project descriptions and prioritization of project and study completions.

Figures 7.17, 7.18, and 7.19 illustrate the physical changes to the SPS area resulting from implementation of the SPS Master Plan.

SECTORS

DARK SECTOR

- The Dark Sector ASMA boundary will not change.
- The Dark Sector will continue to function as it is currently. New science facilities will be added and expanded over time as part of continued science projects. As part of the SPS Master Plan, MAPO, ICL, DSL, and Building 61 will be raised. (SPS 1*, D1*, D2*)
- Study ways to deconflict crossing the skiway. (D4, AIR 1)

CLEAN AIR SECTOR

- Changes to the Clean Air Sector ASMA boundary not proposed.
- The ARO building will be raised. (CAS 4*)
- The contamination of air quality by emissions from aircraft, NGO camps, and unauthorized pedestrian or vehicular access into the Clean Air Sector has been a concern. To help mitigate these issues, three actions are proposed.
  - » The NGO camp site will be moved closer to the Ceremonial South Pole, placing it farther away from the Clean Air Sector boundary. Increasing separation from the boundary should reduce air contamination. (D3*, CAS 1)
  - » NOAA has expressed support for the placement of a replaced ARO building further into the Clean Air Sector to reduce contamination. The location of this building would be determined by NOAA. If a new ARO building is constructed, the existing ARO building will remain for other Clean Air Sector uses. (CAS 1)
  - » An access control easement may be placed along the 340- and 110-degree lines for 1km in each direction originating from the existing ARO building. The access control easement is defined in the Section 7: Regulating Plans. (CAS 2, CAS 3)

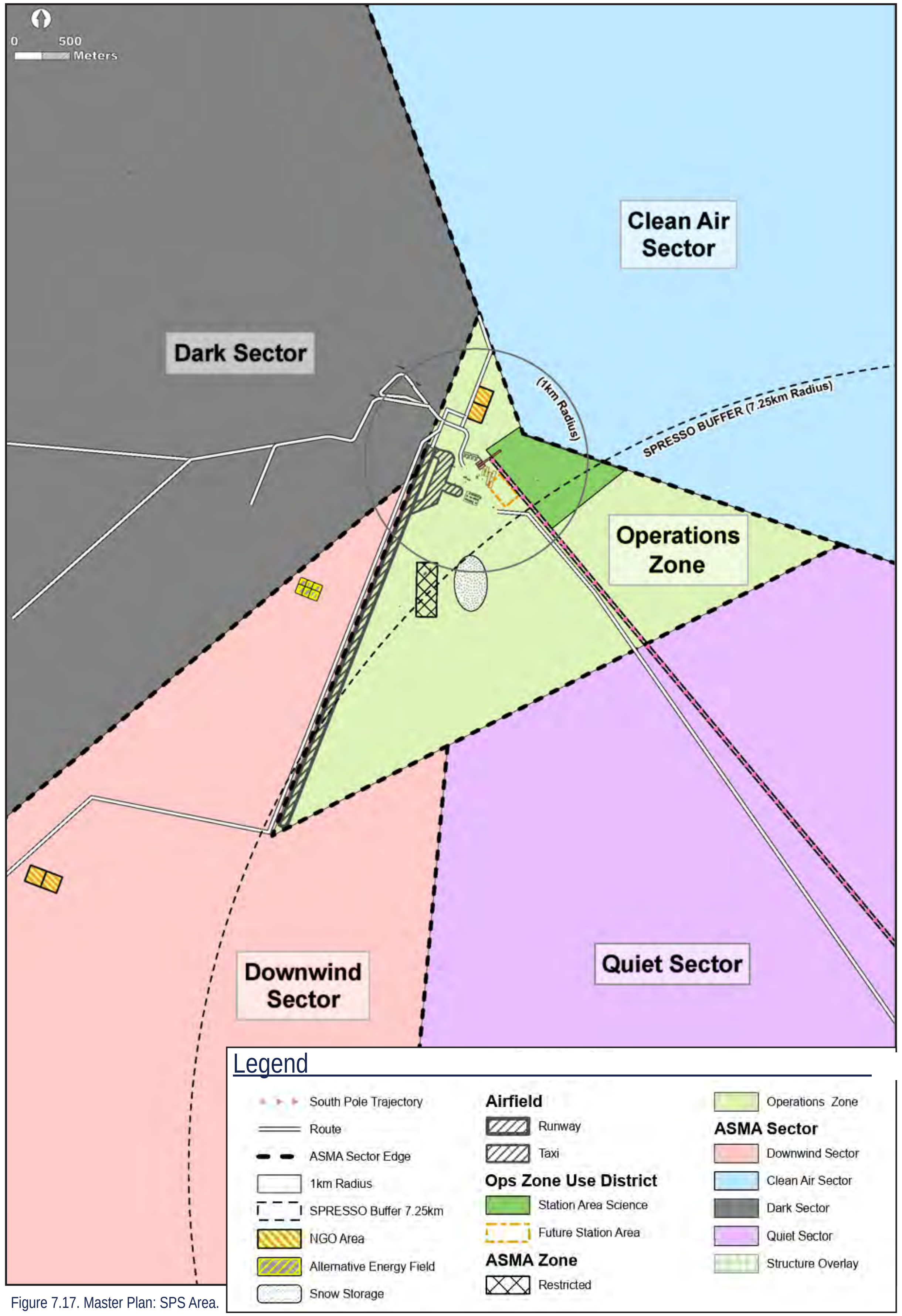


Figure 7.17. Master Plan: SPS Area.

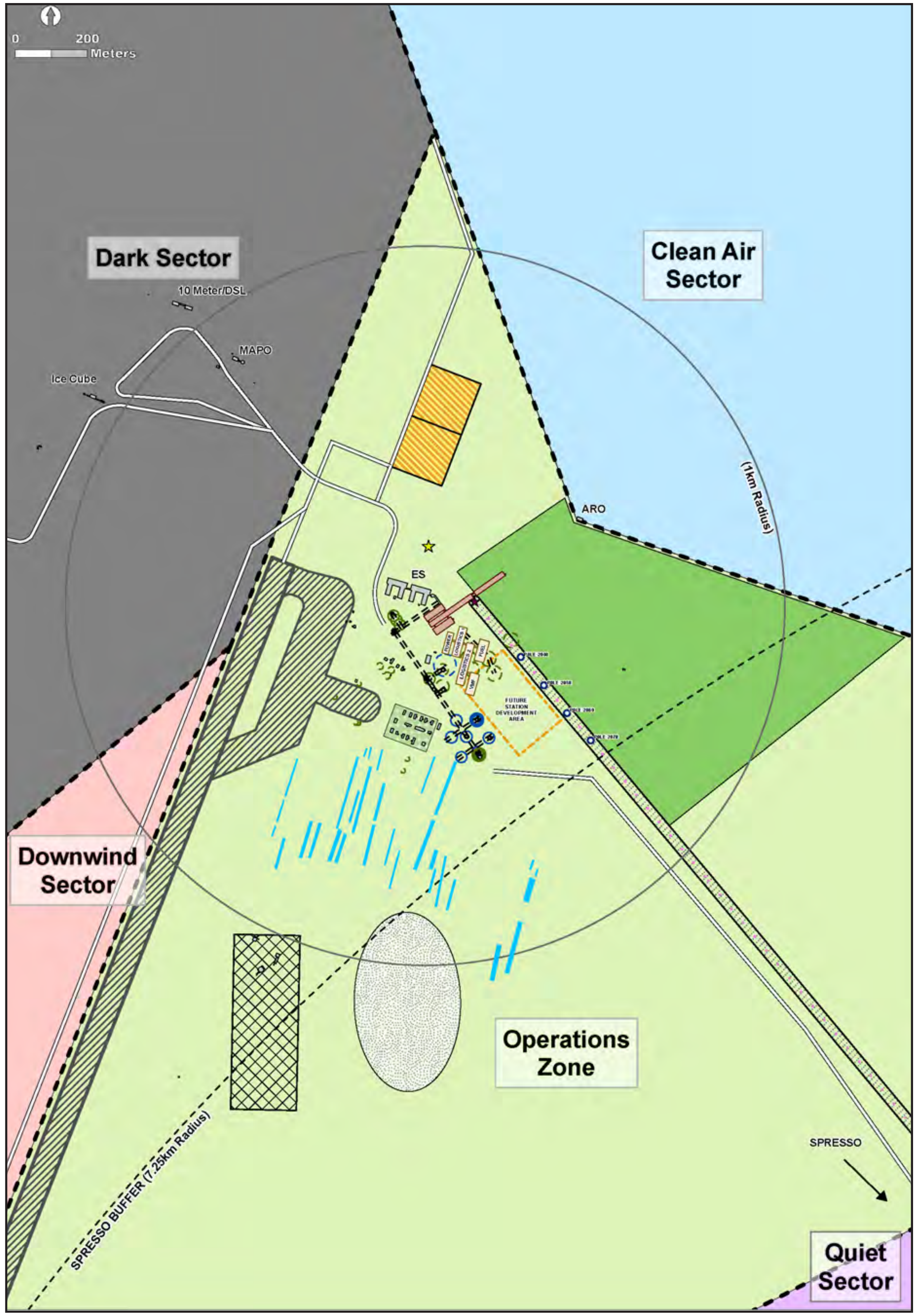


Figure 7.18. Master Plan: Operations Zone.

QUIET SECTOR

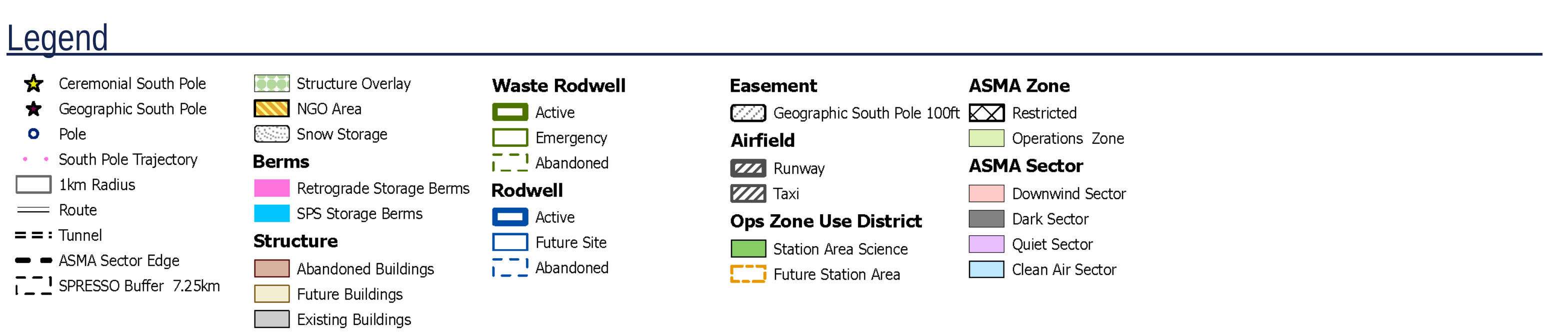
- When SPRESSO is replaced, the new SPRESSO facility may be located closer to the Clean Air Sector boundary at a similar or greater distance from the SPS core area. SPRESSO operations must not result in any negative impacts on the Clean Air Sector. The SPS Master Plan does not propose a final location, as the location will be determined by science. When SPRESSO is moved, a new buffer radius will be established. The new location of SPRESSO would result in a greater distance from the SPS core area, which would allow for the Operations Zone boundary to be revised providing new areas for operations if desired. (QS 1*, QS 2, QS 3)

DOWNWIND SECTOR

- No new facilities are proposed in the Downwind Sector.
- The skiway, aircraft parking, apron, and flight line to remain in the current location.
- A cost-benefit analysis to be conducted comparing additional airframes to the continued use of the LC-130, Basler, and Twin Otter aircraft. (AIR 2*)

OPERATIONS ZONE

- Land Use Districts, Overlays, and Easements will be established as USAP-internal guidance to be managed by operations.
- The existing arches and interior infrastructure will be replaced. (OZ 1*)
- The Elevated Station and SuperDARN will be raised. (SPS 1*, OZ 5*)
- The Radome building, RF building, HF Antennas and TDRSS platform will be raised. (OZ 5*, SPS 1*)
- The 9m antenna will be deconstructed and retrograded. (ITT 5*)
- The DNF cargo Jamesway may be replaced. (OZ 1*, OZ 6)
- Water and Waste: A new Rodwell, outfall, and waterline will be established. Utility ice tunnels will be upgraded. Retrograde waste will be shipped to CONUS for disposal. (WS 1* to 7*, HSW 1* to 7*)
- An analysis of alternatives study may be completed to determine the best course of action for a waste water treatment plant. (HSW 3)
- Movement of the north NGO site closer to the Ceremonial South Pole to increase separation from the Clean Air Sector will be proposed. As the geographic South Pole migrates along its projected alignment, it will eventually be located closer to the New Station Area. A new NGO camp site will be proposed southeast of the new station facility when a new station facility is constructed. (NGO 5)
- New/revised NGO operations guidance will be proposed. (NGO 1, NGO 3)
- An EMI governance/management plan will be developed with implementing procedures for SPS, to include EMI screening criteria for the selection of future electro-mechanical systems, facility UPS systems, and other EMI-emitting infrastructure and equipment. A sustainable RF spectrum monitoring system will be studied to determined feasibility of tracking background noise emissions and providing real-time aid for finding and resolving spurious EMI events. (SPS 2*, ITT 8)
- Communications technology will be upgraded. (ITT 3*, ITT 4*, ITT 6, ITT 7*, ITT 11)
- An assessment of ways to improve safe operating ranges around the skiway will be completed. (ITT 9*, ITT 10*)
- A snow storage overlay has been identified south of the Elevated Station. This area will accommodate future snow disposal needs. (OZ 11)



- A primary route will be identified to simplify circulation through the SPS campus. This route connects to the SPoT south of the airfield and extends to the northeast providing access to the Downwind Sector and the north NGO camp. (OZ 3)
- Emergency services will be provided ample storage and staging space in the Elevated Station and directly adjacent to or integrated with field and aircraft staging areas. (EMS 1, EMS 2)
- A utility master plan will be developed to establish utility rights-of-way for routing of fiber optic telecommunications cables, electrical lines, and water and sewer lines. The utility master plan will monitor geospatial locations of the rights-of-way from year to year to account for ice sheet movement. (OZ 8*, UC 1* to UC 4)
- An on-site energy production system design and construction effort will be initiated to reduce reliance on delivered fuel sources and reduce fuel delivery costs. The SPS Master Plan proposes a site for an on-site energy field, but the final location will be determined at the time of design. (E 4, E 5)
- Relocation of the communications facilities south of the Elevated Station (RF and Radome) will be evaluated to reduce EMI and improve satellite orientations. Several studies to determine viable options for improving communications and reducing EMI are included in this SPS Master Plan. (OZ 12*, ITT 1*, ITT 2*, ITT 12*)
- The four arch buildings will be replaced. This includes the Power Plant, Fuel Storage, Logistics/Warehouse, and VMF, as well as all internal arch infrastructure and buildings. (SPS 1*, OZ 2*, E 1*, E 2*, E 3*)
- A cost-benefit analysis will be completed for operating a field science hub based out of SPS. (FS 1*, FS 2, FS 3*, FS 4, FS 5, TR 1*, TR 2*)
- Ways to improve the capacity and capabilities of transporting cargo and personnel to and from SPS will be evaluated. (SPoT 1*, SPoT 2*, AIR 3*)

Once replaced, the existing arches will be evaluated to serve as temporary storage and heated parking space while awaiting removal.

Replacement arches will be located in an area where abandoned Rodwells, ice tunnels, and small exterior facilities are currently located. Extensive surveys and studies will be conducted to verify constructibility and prepare the site prior to development. By re-purposing these existing areas of development (brownfields) for the replacement buildings, SPS will preserve surrounding undeveloped areas (greenfields). This adheres to the SPS Master Plan design principle of "Rightsized & Compact."

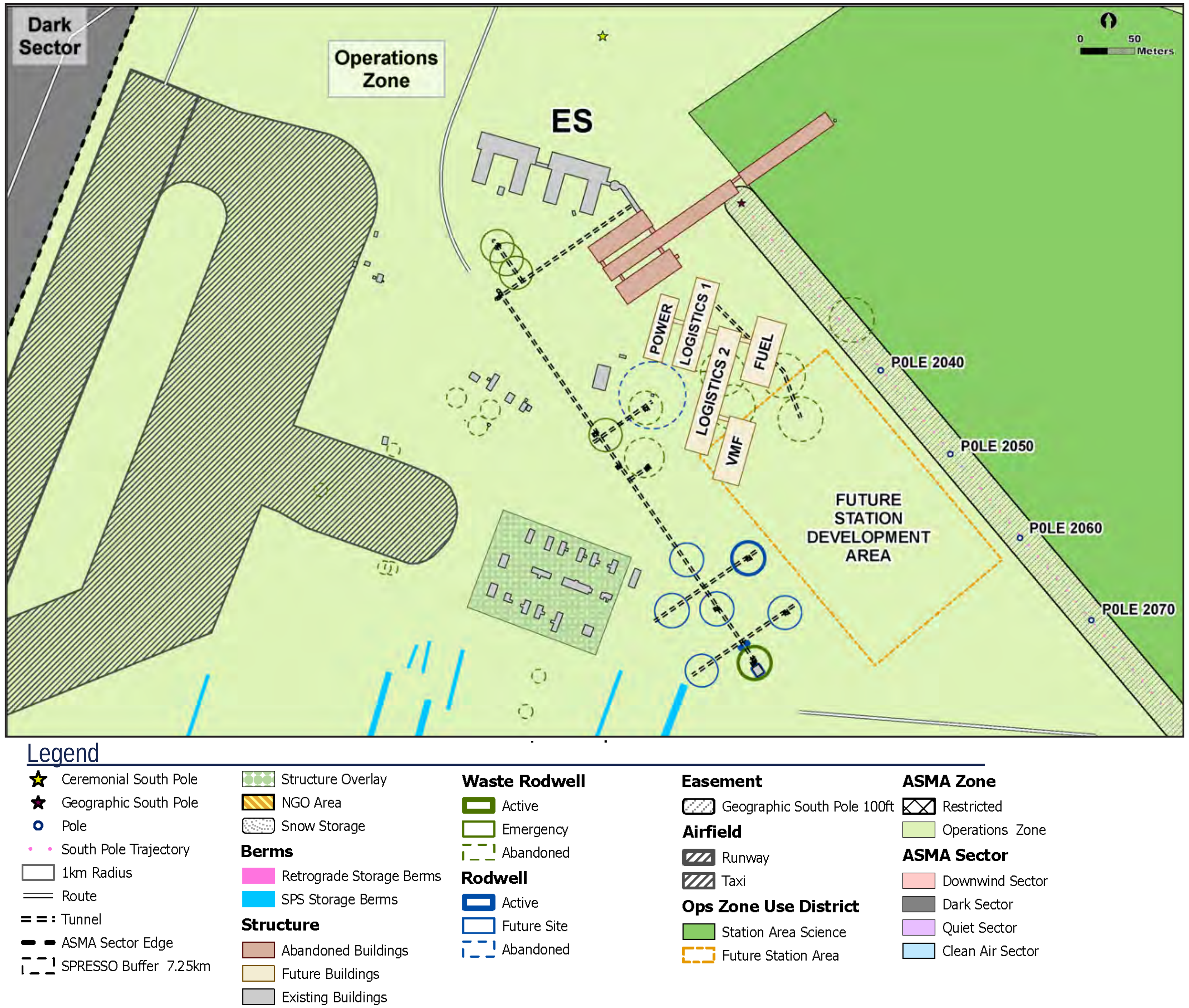


Figure 7.19. Master Plan Operations Zone Core: For illustrative purposes only; the arch replacement facilities layout requires additional study prior to finalization.

BUILDING TYPES

New arches will be constructed to replace the existing arches. The longevity of the new arches will be improved over the current application of this construction method by developing a compacted snow pad that elevates the floor of the arches above the surrounding grade. Figure 7.20 depicts the conceptual location of the elevated snow pad for the new arches. The final snow pad elevation and location will be determined during the design of the arches.

POWER PLANT (POWER)

- Building form: Arch Building Type

  Arches are relatively quickly constructed and could be assembled on elevated snow base foundations to slow the burial process.

FUEL STORAGE (FUEL)

- Building form: Arch Building Type

LOGISTICS & WAREHOUSING (LOGISTICS 1 & 2)

- Building form: Arch Building Type

  A maximum of two logistics arches are envisioned. One arch may be used for unheated storage; DNF materials will be consolidated to the heated arch.

VEHICLE MAINTENANCE FACILITY (VMF)

- Building form: Arch Building Type

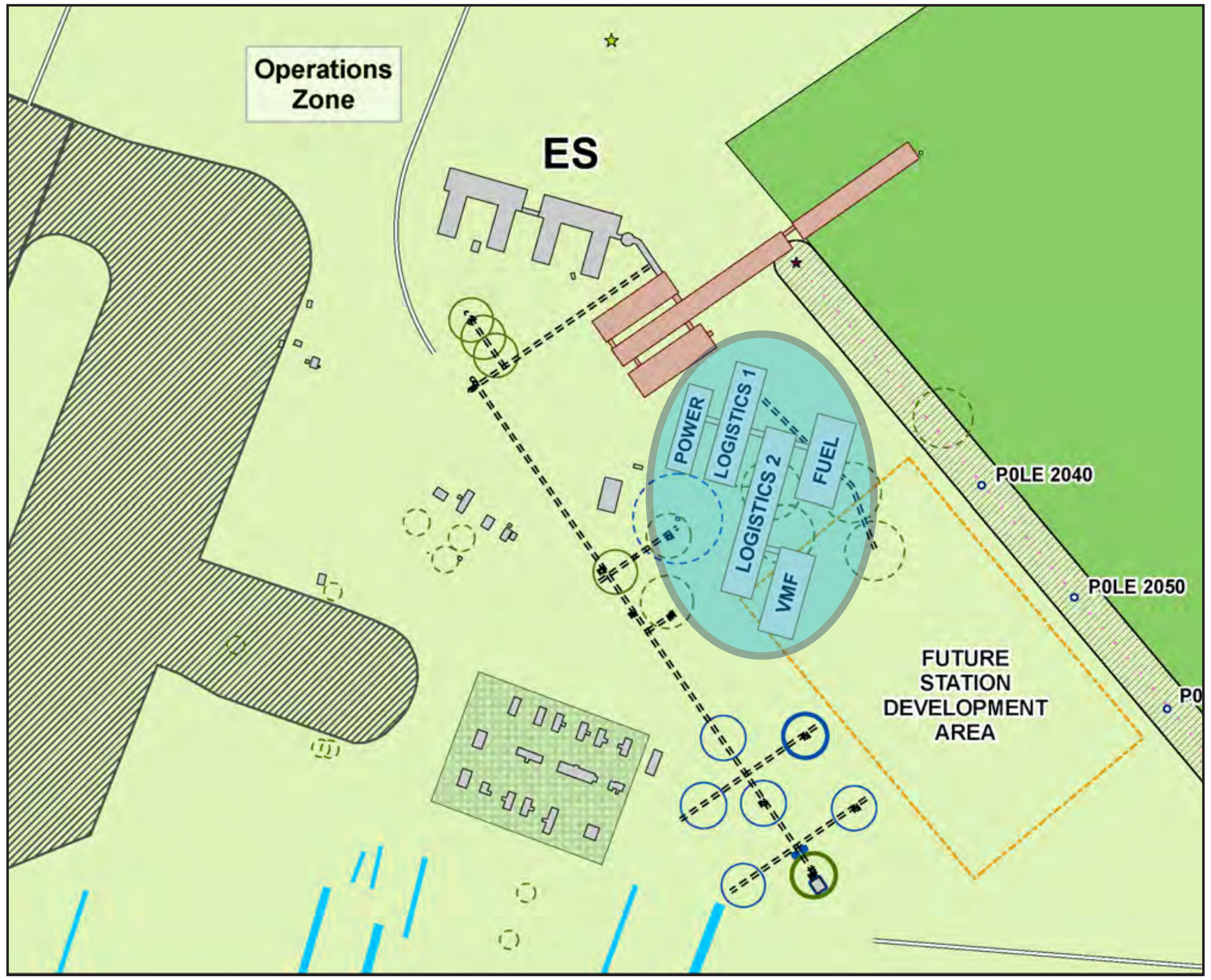


Figure 7.20.Master Plan Operations Zone Core: General area for an elevated snow pad. For illustrative purposes only; the arch replacement facilities layout requires additional study prior to finalization.

SPS MASTER PLAN CONCEPT RENDERINGS

The following renderings depict conceptual views of the SPS Master Plan final state. The arch replacement facilities layout requires additional study prior to finalization.

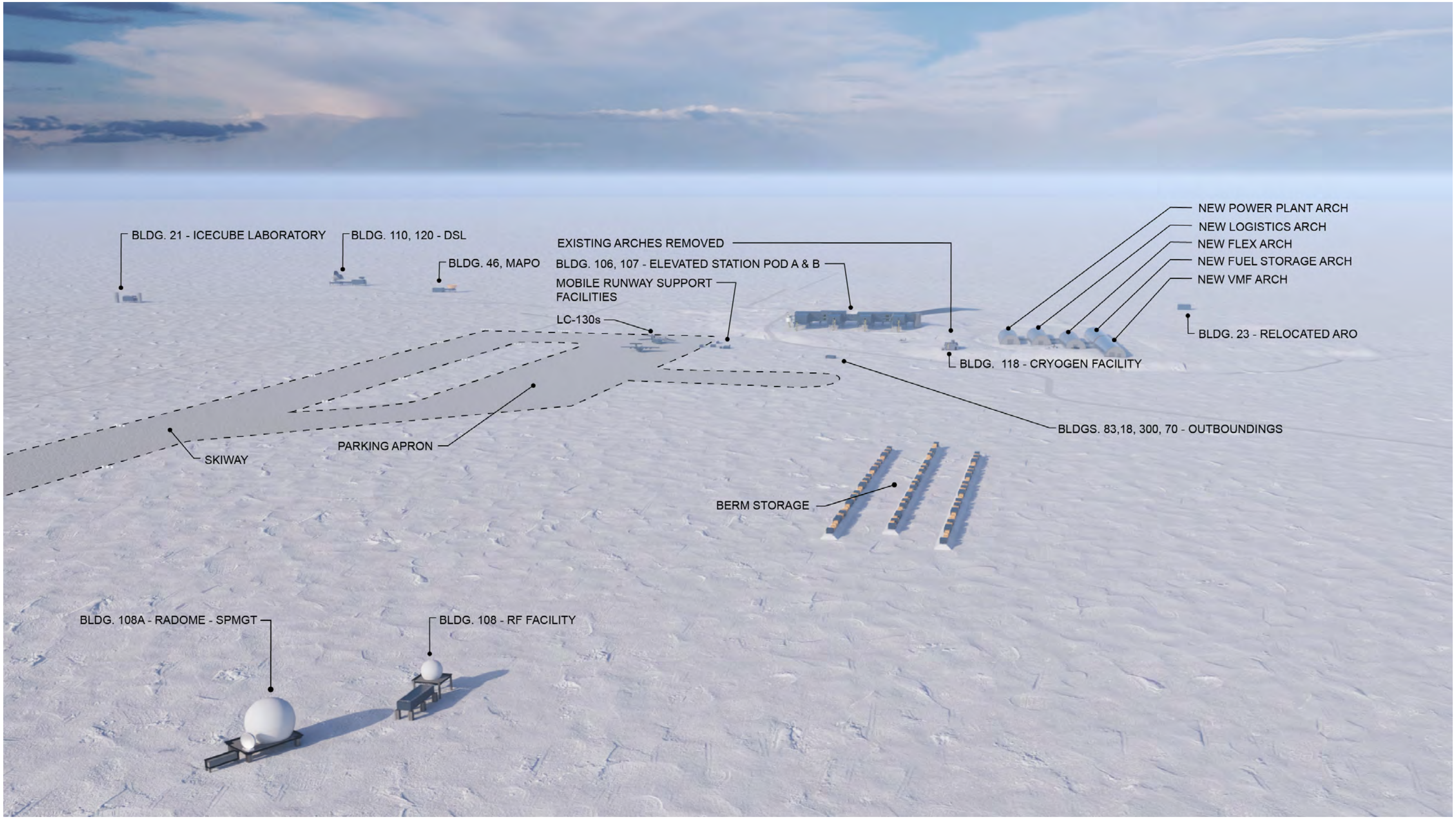


Figure 7.21. 3D rendering of master plan concept: Aerial view looking grid north.

SPS MASTER PLAN CONCEPT RENDERINGS

The following renderings depict conceptual views of the SPS Master Plan final state. The arch replacement facilities layout requires additional study prior to finalization.

Figure 7.22. 3D rendering of Elevated Station: Grade view looking grid south. Existing ceremonial South Pole depicted in foreground.

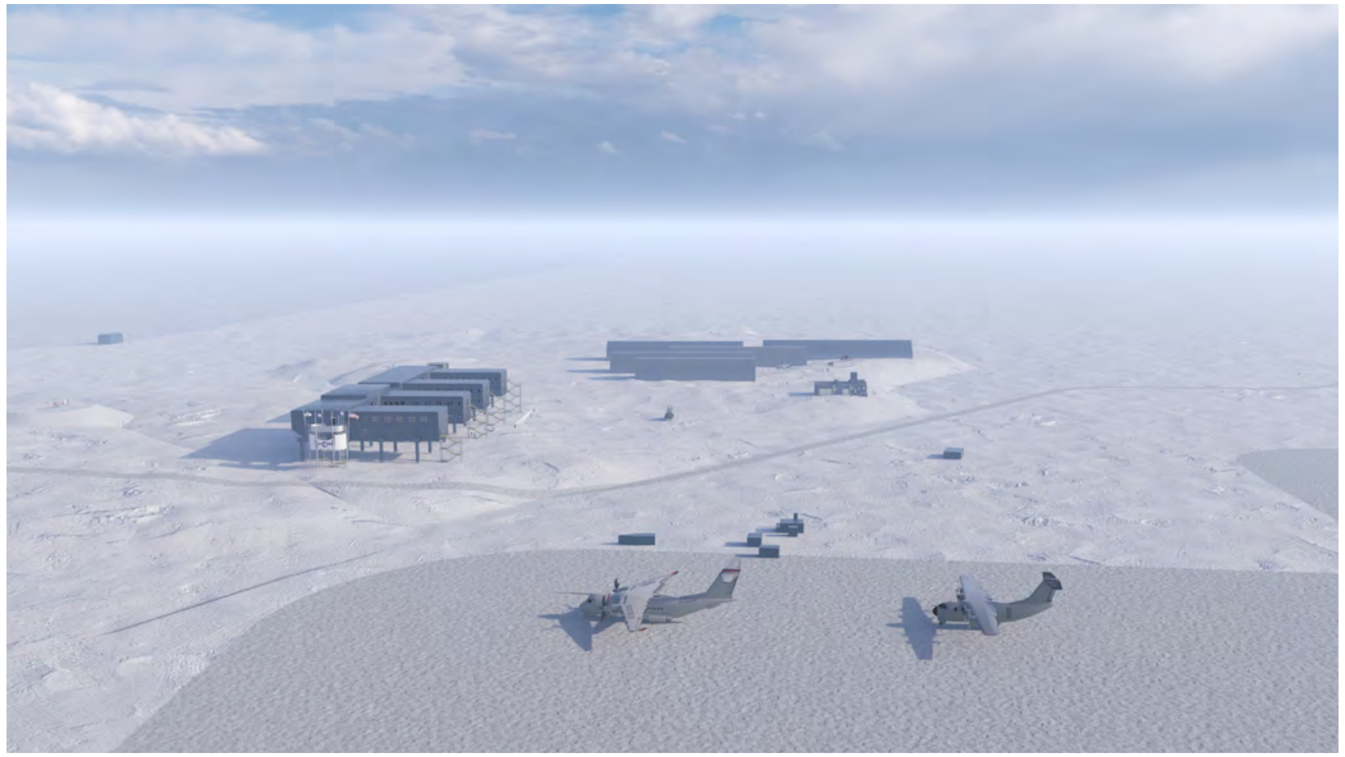


Figure 7.24. 3D rendering of master plan concept: Aerial view looking grid east. Airfield in foreground. Elevated Station on left. Replacement arches in distance. Configuration of arches provided for illustrative purposes only.

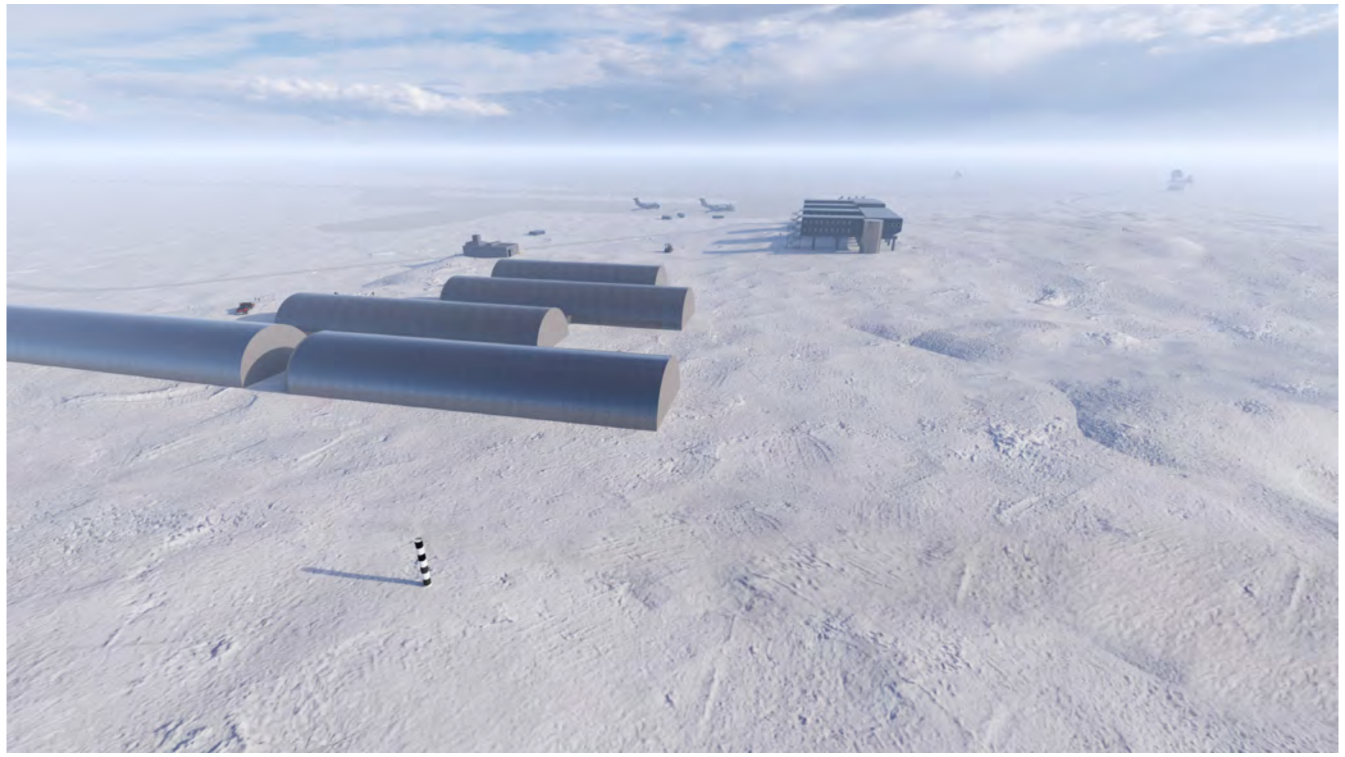


Figure 7.23. 3D rendering of master plan concept: Aerial view looking grid west towards Dark Sector. New arches shown in the foreground. A black and white post marks the approximate location of the Geographic South Pole in the year 2035. Configuration of arches provided for illustrative purposes only.

Figure 7.25. 3D rendering of master plan concept: Aerial view looking gird north. New arches shown in the top right of image. Configuration of arches provided for illustrative purposes only.

Capital Infrastructure Projects

This section includes a high level summary of capital infrastructure projects and studies that support of the implementation of the SPS Master Plan. Project identifiers in the left column of Section 8 tables correspond to recommendations in Section 6: SPS Area Plans. Projects identified as “ADD” for “additional” are supplementary efforts that support overall implementation of the SPS Master Plan.

The SPS Master Plan capital infrastructure projects and studies are grouped into four phases. Each phase is described in more detail in Sections 8.2 through 8.5. All projects and studies are listed in order of general priority within each phase. Project and study priority is subject to change based on emerging conditions, changes to regulatory requirements, and new policy.

Capital Infrastructure Projects

8.1 PROJECT AND STUDY SUMMARY

PHASE 1: MOBILIZATION/CONSTRUCTION READINESS	
PHASE 1 PROJECTS (FY25 TO FY35)	
WS 2	REPLACE RODWELL & WATER LINE
HSW 2	REPLACE SEWER OUTFALL
ITT 6	SOUTH POLE LAND MOBILE RADIO SYSTEM FULL REPLACEMENT
OZ 12	STATION & FIELD COMMUNICATIONS IMPROVEMENTS
CAS 4	PURCHASE SCIENTIFIC RESEARCH FACILITY LIFTING EQUIPMENT AND RAISE ARO BUILDING
D 1	RAISE ELECTRICAL BUILDING 61
ADD A1	REPLACE NOAA TOWER
ADD A2	CONSTRUCTION EQUIPMENT PROCUREMENT
D 2A	RAISE MAPO BUILDING
ADD A3	BART INSTALLATION
HSW 7/ OZ 10	BERM INVENTORY AND RETROGRADE REMOVAL
ITT 3	UPGRADE UHF/AM AIR GROUND RADIO SYSTEMS
ADD A4	DEMOLISH ABANDONED BUILDINGS 90A, B, AND C

PHASE 1 STUDIES (FY25 TO FY30)	
SPS 1	DESIGN ARCH SYSTEM REPLACEMENT
WS 3/ HSW 6	EVALUATE UTILITY TUNNEL REPLACEMENT OPTIONS
E 3	EVALUATE ON-SITE ENERGY PRODUCTION FEASIBILITY
WS 1	ASSESS EXISTING WATER LINES & INFRASTRUCTURE TO AVOID CRITICAL FAILURES
WS 4/ HSW 1	DESIGN PIPING SYSTEMS TO ENABLE PERIODIC BUILDING RAISES
E 2	EVALUATE LIFE EXPECTANCY OF ALL MAIN POWER PLANT COMPONENTS
OZ 13	EVALUATE TIMING OF ELEVATED STATION LIFT AND CONSEQUENCES OF NO ACTION
SPoT 2	COST-BENEFIT ANALYSIS OF INFRASTRUCTURE UPGRADES FOR ON-SITE TRANSFER OF FULL SHIPPING CONTAINERS
WS 5	EVALUATE BACK-UP SNOWMELT SYSTEM CAPACITY
AIR 2	COST-BENEFIT ANALYSIS OF AVAILABLE AIRCRAFT MODELS
AIR 3	EVALUATE ALTERNATIVE METHODS OF FIELD FUEL CACHE RESTOCKING

PHASE 2: PRIMARY INFRASTRUCTURE	
PHASE 2 PROJECTS (FY30 TO FY38)	
E 1A/ OZ 1	ARCH REPLACEMENT - POWER PLANT ARCH
E 1B/ OZ 1	ARCH REPLACEMENT - FUEL ARCH
ADD A5	SOUTH POLE CARGO ELEVATOR REPLACEMENT
OZ 1A	ARCH REPLACEMENT - VMF ARCH
D 2C	RAISE DSL BUILDING
D 2B	RAISE ICL BUILDING
OZ 1B	ARCH REPLACEMENT - LOGISTICS ARCH

PHASE 2 STUDIES (FY30 TO FY38)	
OZ 8	DEVELOP SPS UTILITY MASTER PLAN
UC 1	EVALUATE REPLACEMENT TIMELINE FOR MAIN TRUNK FIBER OPTIC CABLES
FS 5/ TR 2	COST-BENEFIT ANALYSIS OF OVER-WINTER SPACE FOR LARGE EQUIPMENT
TR 1/ FS 1	COST-BENEFIT ANALYSIS OF LIGHT TRAVERSE PLATFORM AT SPS
ITT 7	EVALUATE EMERGENCY COMMUNICATION METHODS
ITT 12	RESEARCH NEW TECHNOLOGIES TO REDUCE DATA & COMMUNICATIONS SERVICE GAP
ITT 4	COST-BENEFIT ANALYSIS OF BROADBAND POLAR ORBITING COMMUNICATIONS SYSTEMS
WS 6	EVALUATE EXISTING RODWELL BUILDING LIFESPAN & ABILITY TO BE RELOCATED
FS 1	EVALUATE TEMPORARY HOUSING MODELS FOR FIELD SCIENCE TEAMS

Capital Infrastructure Projects

8.1 PROJECT AND STUDY SUMMARY

PHASE 3: SUPPORT FACILITIES	
PHASE 3 PROJECTS (FY39 TO FY45)	
OZ 5A	ELEVATED STATION RAISE
OZ 5E	RAISE SUPERDARN BUILDING AND ANTENNAS
OZ 5B	RAISE RF BUILDING
OZ 5C	RAISE DSCS BUILDING

PHASE 3 STUDIES (FY39 TO FY45)	
D 3	EVALUATE SAFE DISTANCES FOR RF EMITTING DEVICES
OZ 2	EVALUATE MOVING SCIENCE FUNCTIONS TO NEW FACILITIES TO REDUCE EMI
ITT 1	CONDUCT RIGHT-SIZING ASSESSMENT FOR RF BUILDING SIZE
ITT 5	UNINSTALL 9M ANTENNA AND PRESERVE PLATFORM
ITT 9	EVALUATE FUTURE COMMUNICATIONS INFRASTRUCTURE SITE
ITT 10	CONDUCT ENGINEERING EVALUATION OF AIRSTRIP AND ELEVATED STATION DISTANCES
SPS 2	DEVELOP EMI GOVERNANCE/MANAGEMENT PLAN

PHASE 4: MAINTENANCE	
PHASE 4 PROJECTS (FY46 TO FY50)	
WS 2	REPLACE RODWELL & WATER LINE
HSW 2	REPLACE SEWER OUTFALL
OZ 5E	RAISE RADOME BUILDING
OZ 5D	RAISE TDRSS RELAY (SPTR) BUILDINGS
QS 1	REPLACE SPRESSO INFRASTRUCTURE

PHASE 4 STUDIES (FY46 TO FY50)	
WS 7 / HSW 4	INVESTIGATE GREY-WATER TREATMENT & RE-USE SOLUTIONS
HSW 5	INVESTIGATE BLACK WATER & WASTE TECHNOLOGY
ITT 2	IDENTIFY POTENTIAL SITE FOR A FUTURE COMMUNICATIONS COMPLEX

Capital Infrastructure Projects

8.2. PHASE 1: MOBILIZATION/CONSTRUCTION

Phase 1 prepares SPS and the SPS logistics chain for major construction activities, while raising smaller utility structures and the most deeply buried science structures. Phase 1 projects and studies are listed below in order of program priority. Figures 8.1 and 8.2 identify general on-site locations for these projects.

PROJECTS (FY25 TO FY30)

ID	Title / Description
WS 2	REPLACE WATER RODWELL & WATER LINE Construction of new Rodwell #4 and associated Rodwell building and infrastructure.
HSW 2	REPLACE SEWER OUTFALL Transition of existing Rodwell #3 into the new sewer outfall.
ITT 6	SOUTH POLE LAND MOBILE RADIO SYSTEM FULL REPLACEMENT Evaluation of the existing LMR system followed by replacement of LMR equipment and associated infrastructure.
OZ 12	STATION & FIELD COMMUNICATIONS IMPROVEMENTS Work with NIWC to implement new HF radios and support infrastructure.
CAS 4	PURCHASE SCIENTIFIC RESEARCH FACILITY LIFTING EQUIPMENT AND RAISE ARO BUILDING Procurement of a scientific research facility lifting system that will allow all existing scientific research facilities to be lifted to above the current snow grade. After procurement of the system, this project will complete a building lift of the existing ARO scientific research facility to an elevated position above the snow grade.
D 1	RAISE ELECTRICAL BUILDING 61 A building lift of the Dark Sector Electrical Substation (Building 61) to an elevated position above the snow grade and adjustment of utility connections to maintain electrical service to the Dark Sector scientific research facilities.
ADD A1	REPLACE NOAA TOWER Replacement of existing NOAA tower.

PROJECTS (FY25 TO FY30) Continued

ID	Title / Description
ADD A2	CONSTRUCTION EQUIPMENT PROCUREMENT Procure heavy equipment required to support multi-year construction efforts at SPS, including, but not limited to, bulldozers, tracked cranes, loaders, and welding and fastening tools. A complete list of required equipment must be developed at the time of arch replacement design.
D 2A	RAISE MAPO BUILDING A building lift of the existing MAPO scientific research facility in coordination with the BART Installation project to an elevated position above the snow grade.
ADD A3	BART INSTALLATION Grant-funded replacement of the existing BART installation in coordination with the raise of the existing MAPO scientific research facility.
HSW 7/OZ 10	**BERM INVENTORY AND RETROGRADE PLAN** Excavation of buried waste within existing berms, processing and determination of potential material reuse, and packaging of waste and obsolete materials for phased transport to CONUS for disposal.
ITT 3	UPGRADE UHF/AM AIR GROUND RADIO SYSTEMS Upgrade the existing Iridium mobile satellite system and associated infrastructure.
ADD A4	DEMOLISH ABANDONED BUILDINGS 90A, B, AND C Demolition and retrograde of buildings 090A, 090B, 090C, and the attached Summer Camp sewer outfall piping complex.

Capital Infrastructure Projects

8.2. PHASE 1: MOBILIZATION/CONSTRUCTION

STUDIES (FY25 TO FY30)

ID	Title / Description
SPS 1	DESIGN ARCH SYSTEM REPLACEMENT Design of replacement arches, interior arch structures, and all associated infrastructure, including production of a logistics plan for construction completion.
WS 3/HSW 6	EVALUATE UTILITY TUNNEL REPLACEMENT OPTIONS An assessment of available systems and a cost-benefit analysis of those systems for new utility runs between the replacement arches and the existing Elevated Station.
E 3	EVALUATE ON-SITE ENERGY PRODUCTION FEASIBILITY A cost-benefit analysis and on-site assessment of power production systems that may be capable of harnessing on-site energy sources at SPS, including, but not limited to, on-site solar and waste-to-energy production systems that simultaneously reduce waste removal and fuel delivery requirements, culminating in design criteria recommendations for the replacement Power Plant and Fuel arches.
WS 1	ASSESS EXISTING WATER LINES & INFRASTRUCTURE TO AVOID CRITICAL FAILURES An on-site assessment of existing water and sewer line infrastructure for lessons learned, culminating in design criteria recommendations for new water and sewer line infrastructure to be installed with the replacement arches and during the Elevated Station raise.
WS 4/HSW 1	DESIGN PIPING SYSTEMS TO ENABLE PERIODIC BUILDING RAISES Engineering design of water and sewer line infrastructure based on design criteria recommendations identified through the “ASSESS EXISTING WATER LINES & INFRASTRUCTURE TO AVOID CRITICAL FAILURES” study.
E 2	EVALUATE LIFE EXPECTANCY OF ALL MAIN POWER PLANT COMPONENTS An on-site assessment of existing power plant infrastructure for remaining life expectancy and lessons learned, culminating in design criteria recommendations for the replacement power plant.

STUDIES (FY25 TO FY30) Continued

ID	Title / Description
OZ 13	EVALUATE TIMING OF ELEVATED STATION LIFT AND CONSEQUENCES OF NO ACTION An on-site assessment of existing Elevated Station conditions for remaining life expectancy at current snow grade and identification of requirements for the Elevated Station lift, culminating in a recommended timeline and impact mitigation plan for the first Elevated Station lift.
SPoT 2	COST-BENEFIT ANALYSIS OF INFRASTRUCTURE UPGRADES FOR ON-SITE TRANSFER OF FULL SHIPPING CONTAINERS A cost-benefit analysis of commercially available options for streamlined transfer of full shipping containers between McMurdo station, the SPoT platform, and SPS.
WS 5	EVALUATE BACK-UP SNOWMELT SYSTEM CAPACITY An on-site assessment of existing backup snowmelt system infrastructure for remaining life expectancy and capacity to determine if the snowmelt system is adequate to support construction populations.
AIR 2	COST-BENEFIT ANALYSIS OF AVAILABLE AIRCRAFT MODELS A cost-benefit analysis of aircraft that are compatible with the SP skiway conditions and may be suitable for cargo and personnel transportation between McMurdo Station and SPS.
AIR 3	EVALUATE ALTERNATIVE METHODS OF FIELD FUEL CACHE RESTOCKING An assessment of available systems and cost-benefit analysis of those systems for alternative field science fuel caching methods based out of SPS.

Capital Infrastructure Projects

8.2. PHASE 1: MOBILIZATION/CONSTRUCTION

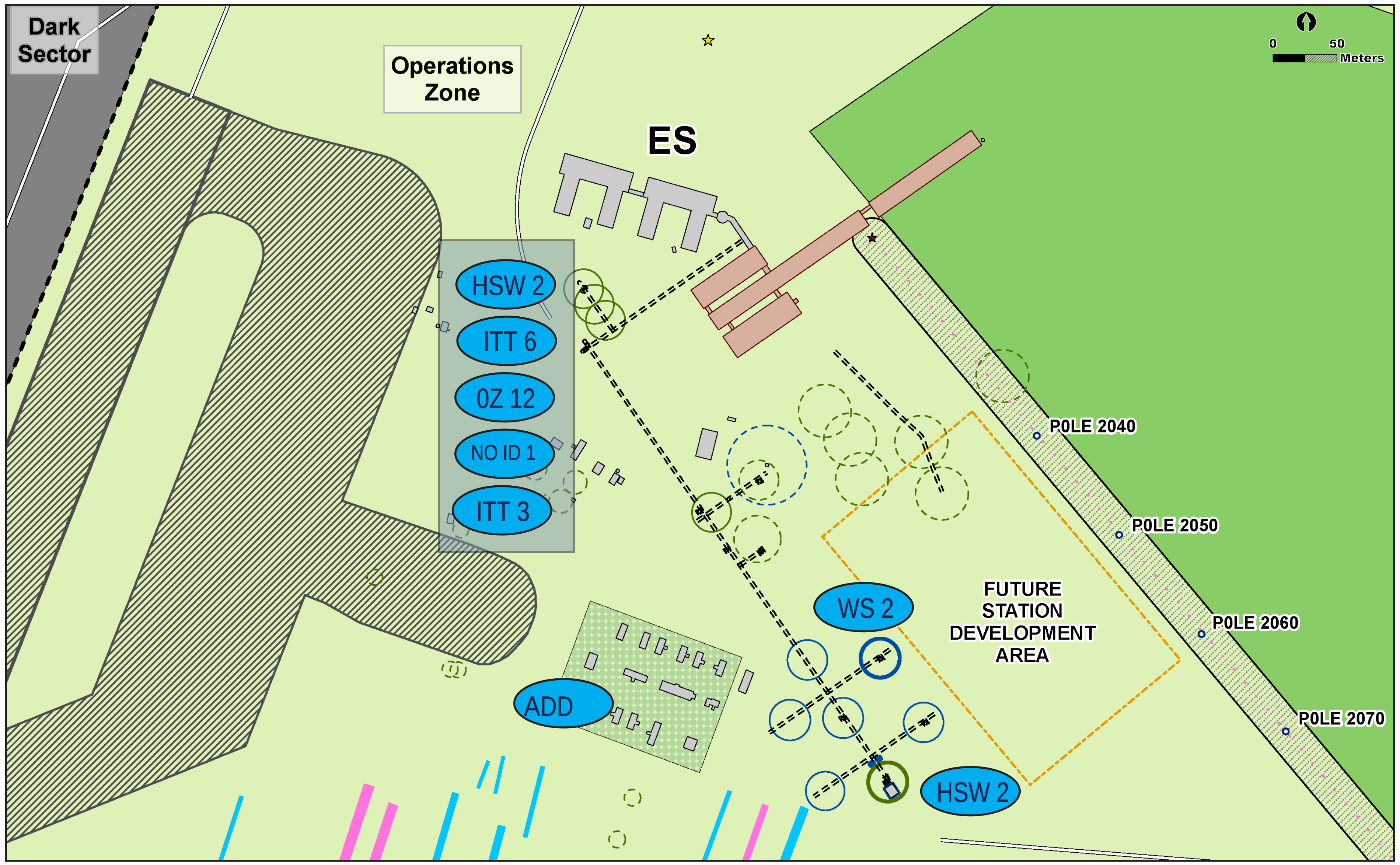


Figure 8.1. Phase 1: Operations Zone Core - Capital infrastructure project general locations

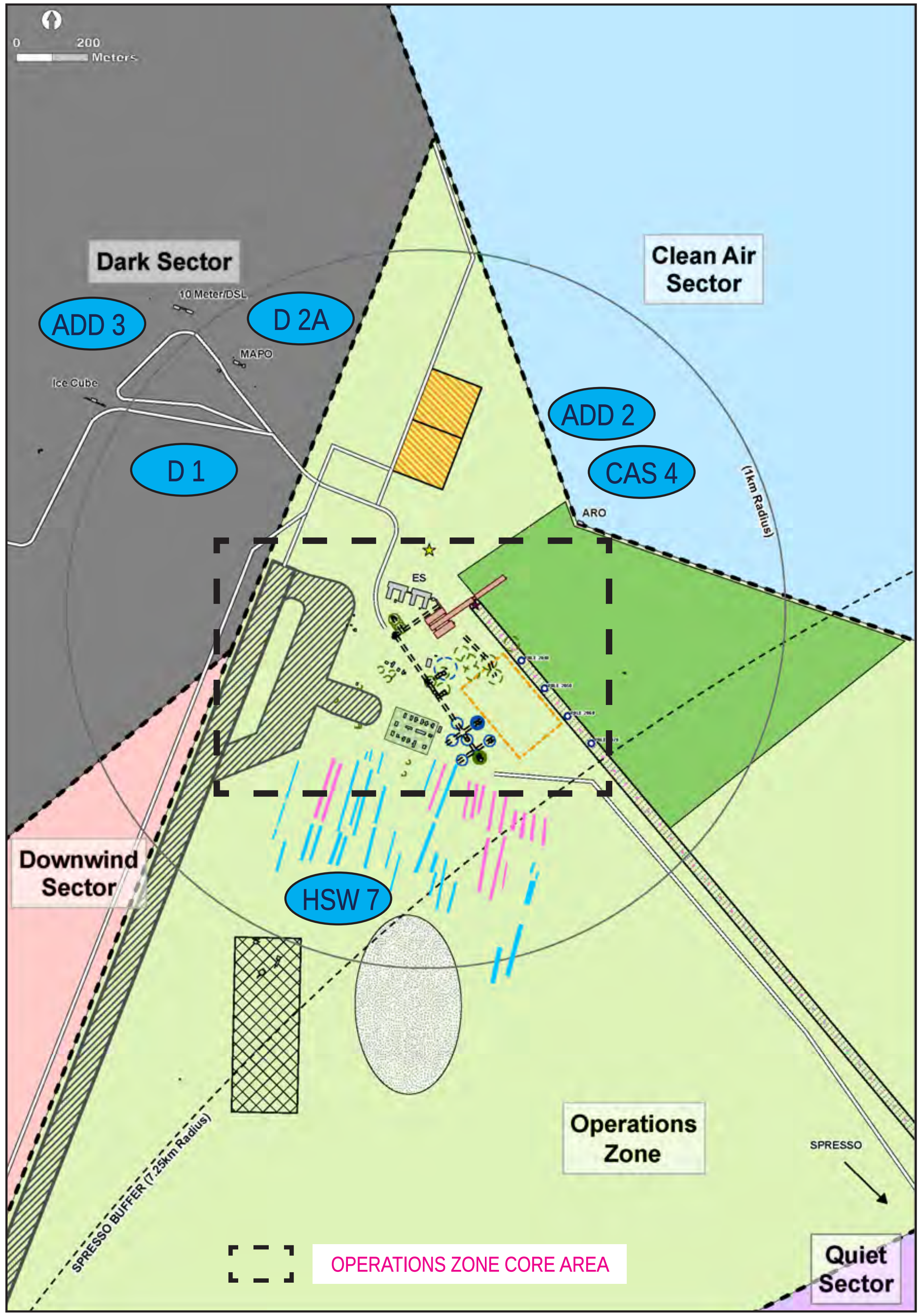


Figure 8.2. Phase 1: Overall SPS Area - Capital infrastructure project general locations

Capital Infrastructure Projects

8.3. PHASE 2: PRIMARY INFRASTRUCTURE

Phase 2 begins construction on arch replacements, and continues science structure raises. Phase 2 projects and studies are listed below in order of program priority. Figures 8.3 and 8.4 identify general on-site locations for these projects.

PROJECTS (FY31 TO FY38)

ID	Title / Description
E 1A/OZ 1	ARCH REPLACEMENT - POWER PLANT ARCH Replacement of the Power Plant Arch, Power Plant building, and all associated infrastructure.
E 1B/OZ 1	ARCH REPLACEMENT - FUEL ARCH Replacement of the Fuel Arch and all associated infrastructure.
ADD A5	SOUTH POLE CARGO ELEVATOR REPLACEMENT Redesign and replacement of the SPS Cargo Elevator within a new arch connection point to the Elevated Station.
OZ 1A	ARCH REPLACEMENT - VMF ARCH Replacement of the VMF Arch, VMF building, and all associated infrastructure.
D 2C	RAISE DSL BUILDING A building lift of the existing DSL scientific research facility to an elevated position above the snow grade.
D 2B	RAISE ICL BUILDING A building lift of the existing ICL scientific research facility to an elevated position above the snow grade.
OZ 1B	ARCH REPLACEMENT - LOGISTICS ARCH Replacement of the Logistics Arch, Logistics building, and all associated infrastructure.

STUDIES (FY31 TO FY38)

ID	Title / Description
OZ 8	DEVELOP SPS UTILITY MASTER PLAN Create a SPS utility master plan to survey existing utility lines and facilities, evaluate life expectancy of utility lines, propose utility line replacements, recommend best practices for utility line connections to address utility line movement, and establish utility access easements.
UC 1	EVALUATE REPLACEMENT TIMELINE FOR MAIN TRUNK FIBER OPTIC CABLES An evaluation to determine the life expectancy of the main trunk fiber optic cables and Dark Sector fiber optic cables for points of failure, location of new fiber optic cables, and replacement phasing.
FS 5/TR 2	COST-BENEFIT ANALYSIS OF OVER-WINTER SPACE FOR LARGE EQUIPMENT A cost-benefit analysis supporting determination of the ideal size for covered/unheated and covered/heated over-winter warehousing space for large equipment to protect electronic components and expedite dewinterization efforts each spring, culminating in design criteria recommendations for the replacement Logistics Arch and a future station.
TR 1/FS 1	COST-BENEFIT ANALYSIS OF LIGHT TRAVERSE PLATFORM AT SPS A cost-benefit analysis of the staging, storing, and servicing of a light traverse platform (light vehicles) over winter at SPS.
ITT 7	EVALUATE EMERGENCY COMMUNICATION METHODS An evaluation of communication methods that do not rely on the same technologies and are not subject to the same failure points to increase the resiliency and redundancy of emergency communications.
ITT 12	RESEARCH NEW TECHNOLOGIES TO REDUCE DATA & COMMUNICATIONS SERVICE GAP Research new technologies that may reduce daily data and communications service gap hours to reduce communication-related safety risks and meet science data transfer requirements.

Capital Infrastructure Projects

8.3. PHASE 2: PRIMARY INFRASTRUCTURE

STUDIES (FY31 TO FY38) Continued

ID	Title / Description
ITT 4	COST-BENEFIT ANALYSIS OF BROADBAND POLAR ORBITING COMMUNICATIONS SYSTEMS A cost-benefit analysis of the emergent broadband polar orbiting, satellite-based, communications systems technologies for communications and science data transfers.
WS 6	EVALUATE RODWELL BUILDING LIFESPAN & ABILITY TO BE RELOCATED An on-site assessment of the life expectancy of the existing Rodwell building. Determination of reuse potential of the existing Rodwell structure at any USAP locations.
FS 1	EVALUATE TEMPORARY HOUSING MODELS FOR FIELD SCIENCE TEAMS An assessment of available modular or prefabricated systems and a life cycle cost analysis of those systems for alternative field science housing supplies based out of McMurdo, but easily deployable to SPS.

Capital Infrastructure Projects

8.3. PHASE 2: PRIMARY INFRASTRUCTURE

Figure 8.3. Phase 2: Operations Zone Core - Capital infrastructure project general locations

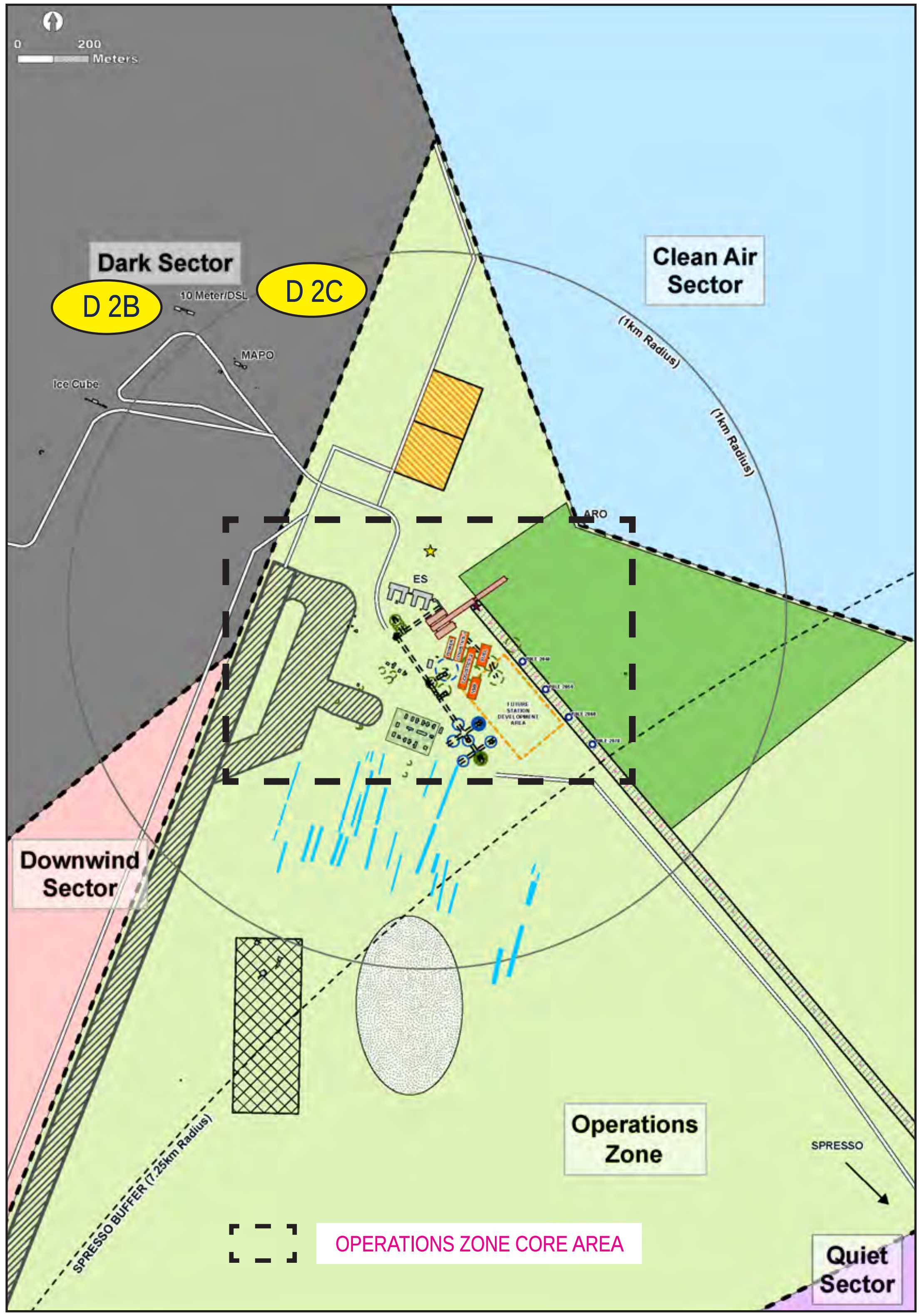


Figure 8.4. Phase 2: Overall SPS Area - Capital infrastructure project general locations

Capital Infrastructure Projects

8.4. PHASE 3: SUPPORT FACILITIES

Phase 3 completes remaining arch replacement structures and raises the Elevated Station, while raising remaining science structures. Phase 3 projects and studies are listed below in order of program priority. Figures 8.5 and 8.6 identify general on-site locations for these projects.

PROJECTS (FY39 TO FY45)

ID	Title / Description
OZ 5A	ELEVATED STATION RAISE A building lift of the existing Elevated Station and reconnection of associated infrastructure at an elevated position above the snow grade.
OZ 5E	RAISE SUPERDARN BUILDING AND ANTENNAS A building lift of the existing SuperDARN scientific research facility to an elevated position above the snow grade.
OZ 5B	RAISE RF BUILDING A building lift of the existing RF building to an elevated position above the snow grade.
OZ 5C	RAISE DSCS BUILDING A building lift of the existing DSCS building to an elevated position above the snow grade.

STUDIES (FY39 TO FY45)

ID	Title / Description
D 3	EVALUATE SAFE DISTANCES FOR RF EMITTING DEVICES Evaluate current operations communications equipment to determine safe operating distances to minimize EMI impacts on Dark Sector science, resulting in a data analysis to support the creation of an EMI governance/management plan.
OZ 2	EVALUATE MOVING SCIENCE FUNCTIONS TO NEW FACILITIES TO REDUCE EMI Once the new arches are complete, evaluate locations where appropriate science functions could be relocated to reduce EMI.
ITT1	CONDUCT RIGHT-SIZING ASSESSMENT OF RF BUILDING Assess the adequacy of the existing RF building(s) sizing to house redundant critical communications equipment that supports minimization of high-risk winter personnel visits.
ITT 5	UNINSTALL 9M ANTENNA & PRESERVE PLATFORM Remove the 9-meter antenna, retrograde the materials to CONUS, and preserve the platform for future reuse. Evaluate reuse options for the Radome building.
ITT 9	EVALUATE FUTURE COMMUNICATIONS INFRASTRUCTURE SITE Conduct engineering assessments in coordination with the Dark Sector research community to identify safe operating ranges for existing and expected future wideband satellite earth stations (ITT 5) and define site facility requirements (support buildings, utility runs, radiation hazard safe zones, etc.) for future communications infrastructure site.
ITT10	CONDUCT ENGINEERING EVALUATION OF AIRSTRIP AND ELEVATED STATION DISTANCES Conduct engineering studies to determine the optimum distance from the airstrip centerline to the Elevated Station for winter personnel safety, utility runs, and minimized EMI risks to Dark Sector science.
SPS 2	DEVELOP EMI GOVERNANCE/MANAGEMENT PLAN Prepare an EMI governance/management plan to codify equipment standards for SPS and NGOs to minimize EMI impact within the Dark Sector. Establish update cycle to address new technologies.

Capital Infrastructure Projects

8.4. PHASE 3: SUPPORT FACILITIES

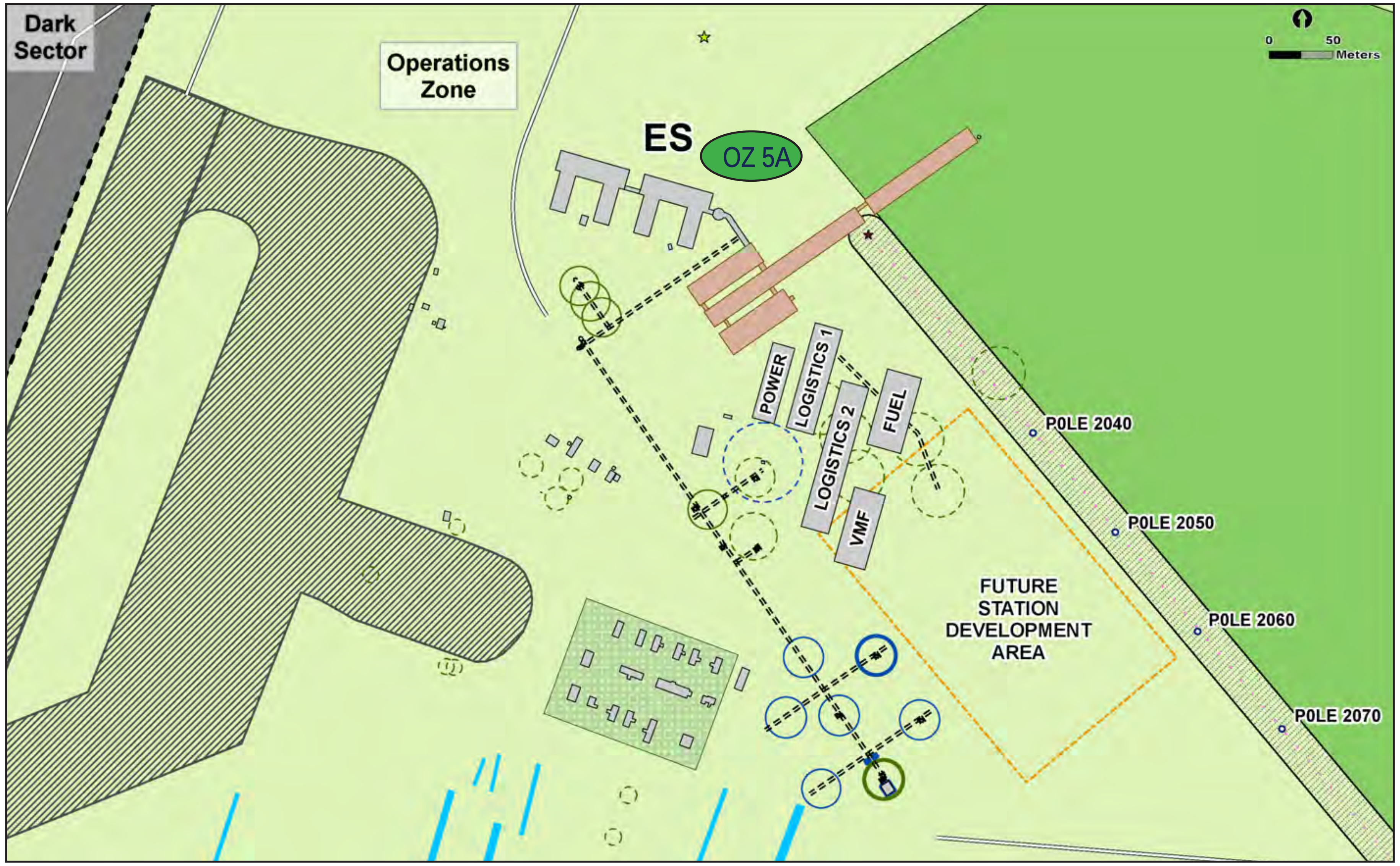


Figure 8.5. Phase 3: Operations Zone Core - Capital infrastructure project general locations

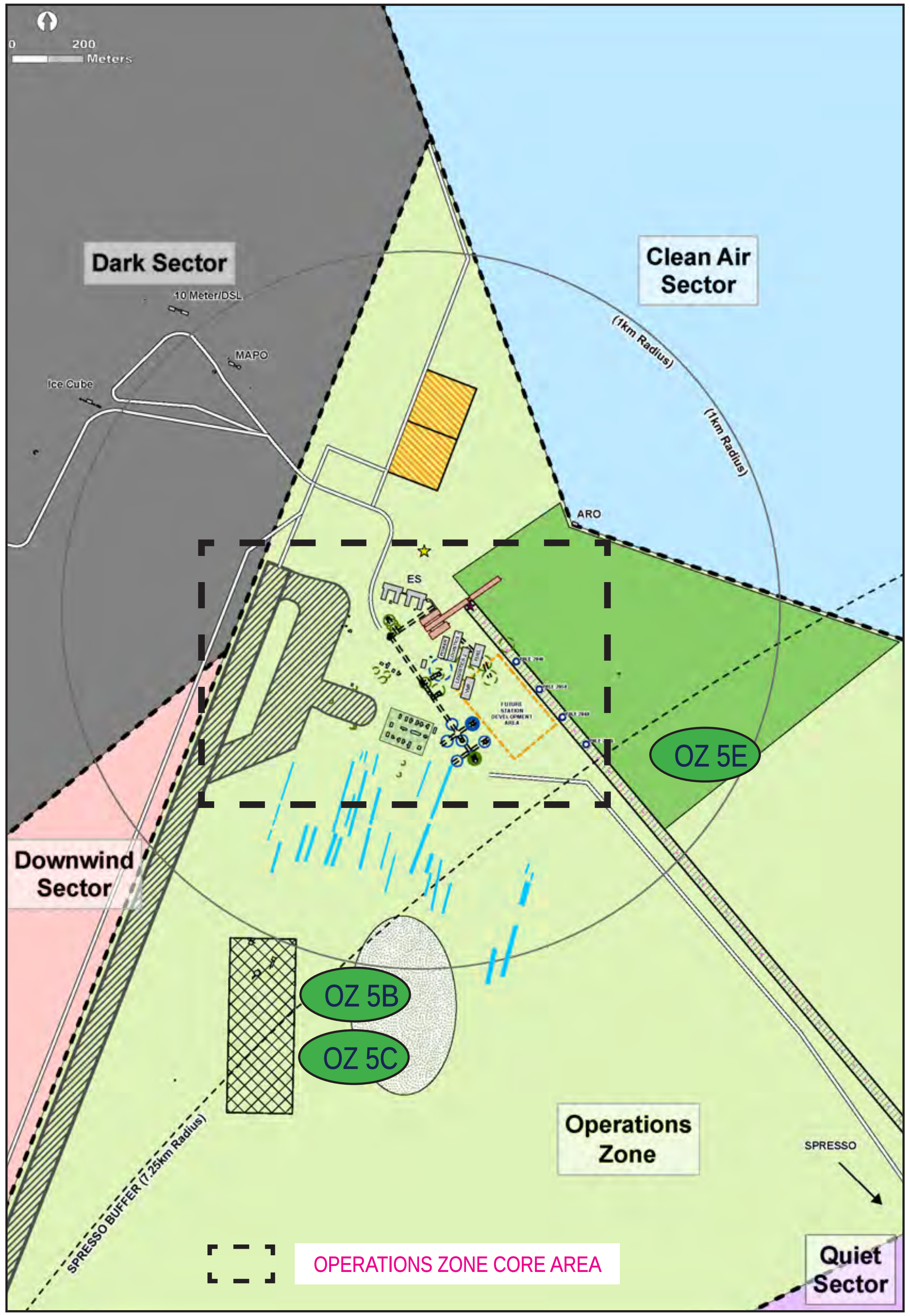


Figure 8.6. Phase 3: Overall SPS Area - Capital infrastructure project general locations

Capital Infrastructure Projects

8.5. PHASE 4: MAINTENANCE CYCLES

Phase 4 establishes the maintenance rhythm for future raises and replacements. Phase 4 projects and studies are listed below in order of program priority. Figures 8.7 and 8.8 identify general on-site locations for these projects.

PROJECTS (FY46 TO FY50)

ID	Title / Description
WS 2	REPLACE WATER RODWELL & WATER LINE Construction of new Rodwell #5 and associated Rodwell building.
HSW 2	REPLACE SEWER OUTFALL Transition of existing Rodwell #4 into a new sewer outfall.
OZ 5E	RAISE RADOME BUILDING A building lift of the existing Radome building to an elevated position above the snow grade.
OZ 5D	RAISE TDRSS RELAY (SPTR) BUILDINGS A building lift of the existing SPTR building to an elevated position above the snow grade.
QS 1	REPLACE SPRESSO INFRASTRUCTURE A full replacement of the existing SPRESSO vault and associated data and power lines at another location within the Quiet Sector.

STUDIES (FY46 - FY50)

ID	Title / Description
WS 7 / HSW 4	INVESTIGATE GREY-WATER TREATMENT & RE-USE SOLUTIONS A study of potential grey-water treatment and re-use options that may be considered in a future station design, culminating in design criteria recommendations for a future station.
HSW 5	INVESTIGATE BLACK WATER & WASTE TECHNOLOGY A study of potential black water and solid waste energy production options that may be considered in a future station design, culminating in design criteria recommendations for a future station.
ITT 2	IDENTIFY POTENTIAL SITE FOR A FUTURE COMMUNICATIONS COMPLEX A station campus area study to identify the ideal locations for future communications infrastructure, culminating in design criteria recommendations for a future station.

SPS will require continual maintenance of buildings and facilities beyond FY50. The following infrastructure projects require cyclical building raises and replacements:

- Raise Electrical Building 61
- Raise ARO Scientific Research Facility
- Raise NOAA Tower
- Raise MAPO Building & BART
- Raise ICL Building
- Raise DSL Building
- Raise SuperDARN Building & Antennas
- Raise RF Building
- Raise DSCS Building
- Raise Radome
- Raise SPTR Buildings
- Replace SPRESSO Infrastructure
- Raise Elevated Station
- Replace Rodwell, Outfall, & Water Line

Capital Infrastructure Projects

8.5. PHASE 4: MAINTENANCE CYCLES

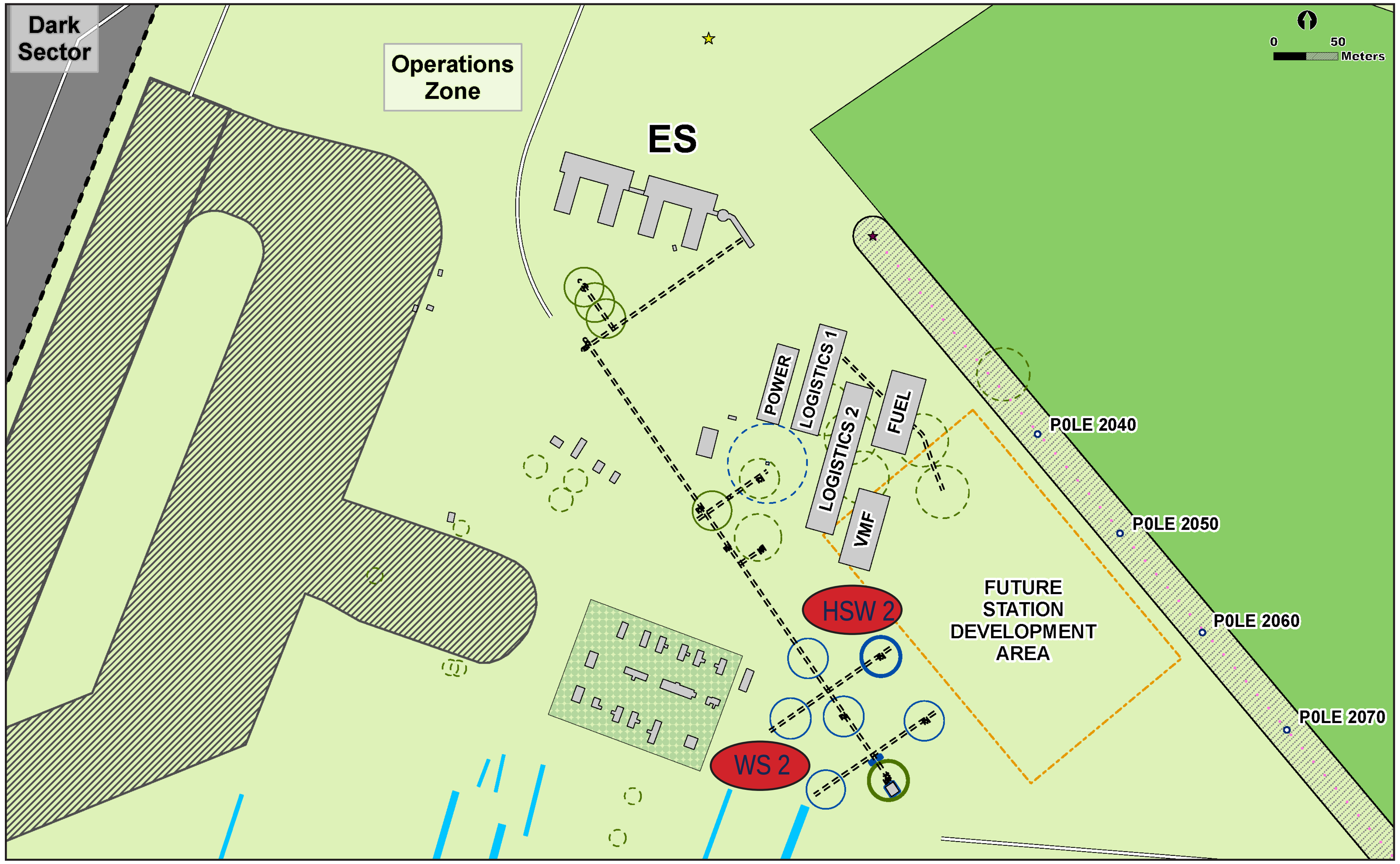


Figure 8.7. Phase 4: Operations Zone Core - Capital infrastructure project general locations

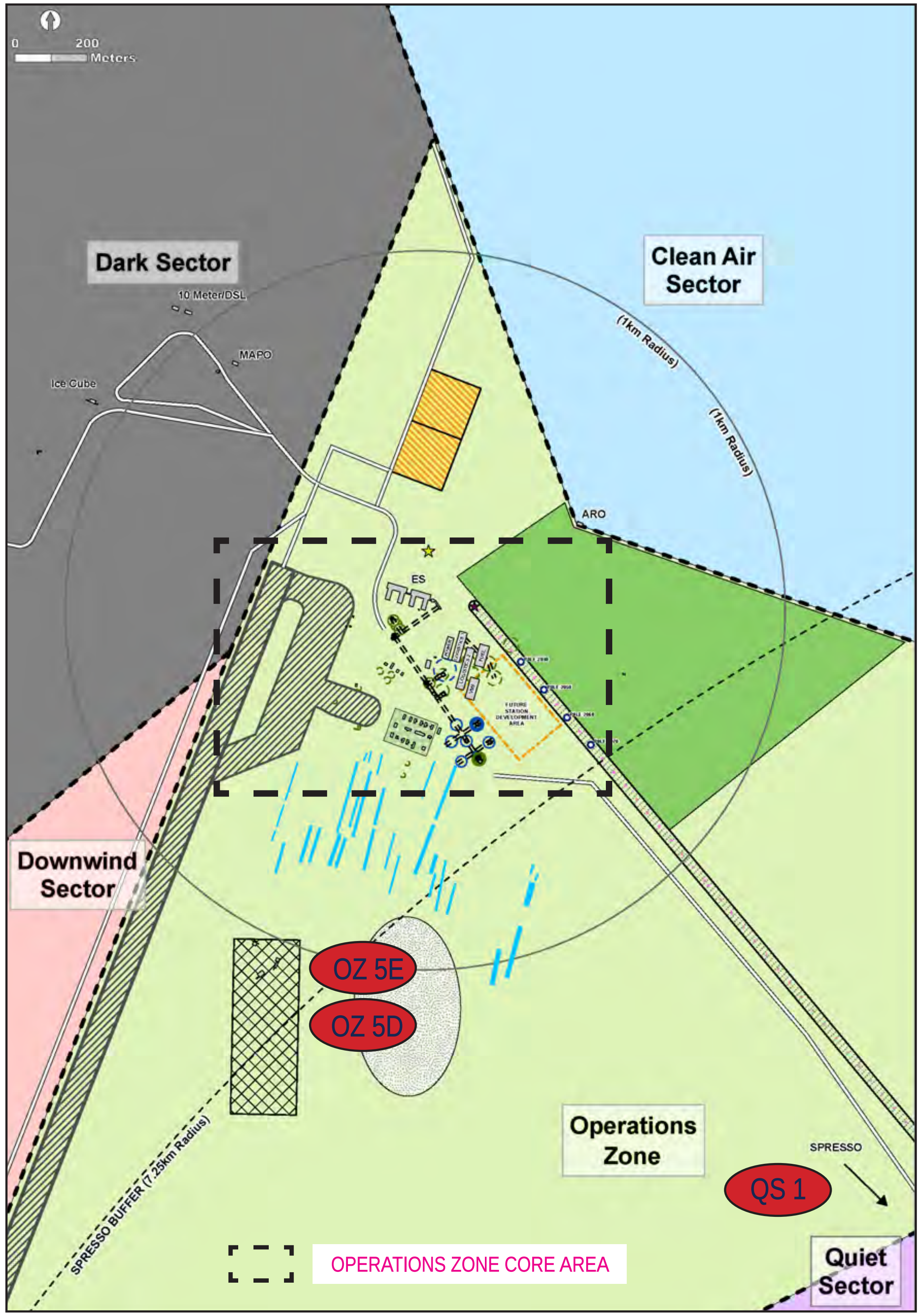


Figure 8.8. Phase 4: Overall SPS Area - Capital infrastructure project general locations

APPENDIX A

Glossary

° Degree
- Negative/minus
AIR Airfield
ANG Air National Guard
ARFF Aircraft rescue and fire fighting
ARO Atmospheric Research Observatory, operated by NOAA
ASC Antarctic Support Contractor
ASMA Antarctic Specially Managed Area: the Management Plan for Antarctic Specially Managed Area No.5 AMUNDSEN-SCOTT SOUTH POLE STATION, SOUTH POLE is referred to as “the ASMA” in the SPS Master Plan
ASPA Antarctic Specially Protected Area
ATCM Antarctic Treaty Consultative Meeting
AWS Automatic Weather Station, operated by NOAA
BASLER Modified Douglas DC-3 aircraft, updated with new avionics and engines
BIF Balloon Inflation Facility, operated by NOAA
Bldg. Building
BLUE BUILDINGS Colloquial name for the scientific structures MAPO, ICL, DSL, SPT, and ARO
BOD Basis of Design
C Celsius
CA California
CAS Clean Air Sector
CEP Committee for Environmental Protection
CLEAN AIR SECTOR Grid area northeast (upwind) of the Elevated Station within the Scientific Zone designated by the ASMA, dedicated to atmospheric research, and established to avoid contamination from exhaust fumes
COMM Communications
COMSUR Commercial Surface Cargo
CONSTRUCTION CAMP Worker Housing
CONUS Continental U.S.
CRREL Cold Regions Research and Engineering Laboratory
D Dark Sector
DAFMAN Department of the Air Force Manual
DARK SECTOR Grid area west of the Elevated Station within the Scientific Zone designated by the ASMA, where light pollution and electromagnetic interference are reduced; dedicated to astrophysical, astronomical, and aeronautical research
DESIGN PRINCIPLE Foundational guidance factor that informs the design of the built environment and is applicable across a wide variety of recommendations and objectives for maintaining, replacing, and operating current and future buildings and infrastructure at SPS; it is not a mandate
DISTRICT OVERLAY Land use organization tool used to identify areas where additional restrictions apply to the underlying land use district or Zone
DNF Do Not Freeze
DOE-Science Department of Energy/Office of Science
DOI Department of the Interior
DOMING Ice-floor surfaces of all arches are subject to gradual upward deflection while the arch wall foundations simultaneously settle under the weight of snowdrift and ice accumulation
DOWNWIND SECTOR Grid area southwest of the Elevated Station within the Scientific Zone designated by the ASMA, free from obstructions for balloon launches, aircraft operations, and other activities; it has operated largely as an extension of the Operations Sector for airfield and overland traverse purposes
DSCS Defense Satellite Communications System
DSL Dark Sector Laboratory (houses the South Pole Telescope)
E Energy
EASEMENT Land use organization tool applied to areas that should remain free of obstructions and where additional restrictions apply to the underlying land use district or ASMA Zone; they are similar to the ASMA Restricted Zones
EMI Electromagnetic interference
EMS Emergency Services
F Fahrenheit
FAA Federal Aviation Administration
FS Field Science
FSF Field Staging Facility
gal Gallon
GPS Global Positioning System
GSP Geographic South Pole
GSF Gross Square Feet
HF High-Frequency
hr Hour
HST Heavy Science Traverse
HSW Human and Solid Waste
HVAC Heating, ventilation, and air conditioning
HYPERTAT Blue modular housing facility, an improved Quonset hut design; named after the now defunct company that manufactured the structure
IAATO International Association of Antarctic Tour Operators
ICL IceCube Laboratory, a deep-ice neutrino observatory
IFR Instrument flight rules
IGY International Geophysical Year
Imaginary Surface Imaginary areas in space which are defined by the airport approach safety zone, transitional zones, horizontal zone, clear zone and conical surface and in which any object extending above these imaginary surfaces is an obstruction.
IPCC Intergovernmental Panel on Climate Change
IRIDIUM A privately owned telecommunications satellite constellation
IT Information technology
ITT Information technology & telecommunications
JTF-SFA Joint Task Force - Support Forces Antarctica, a combined unit of the U.S. military that supports the USAP
km kilometer
kW kilowatts
lb Pound
m meter
MAPO Martin A. Pomerantz Observatory
MW Megawatt
NASA National Aeronautics and Space Administration
NGO Non-Governmental Organization or Non-Government Organization /Tourism
NGV Non-Governmental Visitor
NIOSH National Institute for Occupational Safety and Health
NIWC Naval Information Warfare Center
No. Number
NOAA National Oceanic and Atmospheric Administration
NSF National Science Foundation
NYANG New York Air National Guard
NZ New Zealand
Old Pole The first station
OPERATIONS ZONE Contains the science support facilities and human activity areas.
OPP Office of Polar Programs
OZ Operations Zone
QS Quiet Sector
RF Radio Frequency
RICE Reciprocating Internal Combustion Engine
Rodwell Rodriguez Well
ROM Rough Order of Magnitude
ROS Required on Site
SAD Seasonal Affective Disorder
SAHPR Sexual Assault/Harassment Prevention and Response
sf square foot / square feet
SME Subject Matter Expert
SP South Pole
SPoT South Pole Traverse
SPRESSO South Pole Remote Earth Science and Seismological Observatory
SPRI South Pole Retrograde Initiative
SPS Amundsen-Scott South Pole Station (the immediate station infrastructure)
SPT South Pole Telescope
SPTR South Pole TDRSS Relay
Summer Camp Area outside of the Elevated Station that was created to provide temporary lodging and support facilities during construction of the Elevated Station
SuperDARN Super Dual Auroral Radar Network
TDRSS Tracking and Data Relay Satellite System
Temp. Temporary
The Protocol 1991 Environmental Protocol to the Antarctic Treaty
TR Overland Science Traverse
UC Utility Cabling
U.S. United States
USACE U.S. Army Corps of Engineers
USAF United States Air Force
USAP U.S. Antarctic Program
USGS United States Geological Survey
VMF Vehicle Maintenance Facility
WS Water System

APPENDIX B

Area Recommendations Summary

The following is a consolidated list of the SPS Master Plan recommendations from Section 6 South Pole Station Area Plans. An asterisk indicates which recommendations are a project or study in the Capital Infrastructure Plan (Section 8).

SECTORS

SOUTH POLE STATION

SPS 1* Conduct a cost-benefit analysis regarding whether lifting or full replacement of Science Research Facilities and communications facilities is the most practical and cost-efficient path.

- Raise Science Research Facilities and communications facilities in the near future to prevent structural failure and maintain researcher access to the buildings.
- Evaluate if structural skids or skis can be attached to the foundations (i.e., Science Research Facilities and other science buildings) where possible to simplify snowdrift management and allow regular building relocation via towing.

SPS 2* Develop EMI governance/management plan with implementing procedures for SPS, to include EMI screening criteria for the selection of future electro-mechanical systems, facility UPS systems, and other EMI-emitting infrastructure and equipment. Implement a sustainable Radio Frequency (RF) spectrum monitoring system to track background noise emissions and to provide a real-time aid for finding and resolving spurious EMI events.

SPS 3 Conduct a cost-benefit analysis to compare other airframes versus continued use of LC-130s, Baslers, and Twin Otters for potential cost savings and improved air travel reliability for the USAP. (AIR 2)

DARK SECTOR

D1* Raise Building 61 to maintain telecommunications and electrical power distribution to the Dark Sector.

D2* Raise MAPO, ICL, and DSL buildings in the near future.

D3* Conduct engineering evaluations in cooperation with the radio astronomers to devise safe distance estimates for typical RF emitting devices (e.g., consumer grade equipment and satellite communications earth stations)

D4 Study ways to deconflict crossing the skiway for personnel accessing the Dark Sector.

CLEAN AIR SECTOR

CAS 1 Locate a new NOAA science building up to 1 km northeast of the current ARO building, to add operational space, de-conflict NGO activities, and ensure air quality.

CAS 2 Identify an access control easement along the 110-degree and 340-degree line to manage access into Sector.

CAS 3 Draft a management plan to regulate access into the CAS line.

CAS 4* Raise the ARO building to prevent structural failure and maintain researcher access to the building.

QUIET SECTOR

QS 1* If the SPRESSO program is replaced, evaluate the cost/benefit of relocating it northeast of the current location closer to Clean Air Sector to deconflict interferences with the Operations Zone.

QS 2 If the SPRESSO program will continue, establish a SPRESSO buffer of 8 km radius creating a buffer to restrict interference.

QS 3 Continue monitoring the quality and function of SPRESSO power and data cables to anticipate when they need to be replaced.

OPERATIONS ZONE

OZ 1*	Construct replacement structures for all facilities and uses within existing arches. Additional storage and warehouse spaces to be included in future structure designs. Auxiliary structure storage should be consolidated into a new structure to reduce the energy demands of disparate, decentralized structures serving similar purposes.
OZ 2*	Evaluate moving some science functions to new facilities and/or locations to reduce EMI.
OZ 3	Designate vehicular circulation organized around an efficient station layout.
OZ 4	Inventory all berm contents to determine what can be re-purposed to reduce retrograde, storage, and shipping demands. Retrograde reduction plans shall be included with each new project to maintain a compact station footprint and prevent future berm growth and warehousing overruns.
OZ 5*	Raise the Elevated Station, communications buildings and SuperDARN facilities.
OZ 6	Demolish old buildings and Retrograde the remnants of the old Summer Camp.
OZ 7	Study the future cost/benefits for facilities to support a field science hub.
OZ 8*	Develop a Utility Master Plan that establishes utility rights-of-way for routing of fiber optic telecommunications cables, electrical lines, and water and sewer lines. The Utility Master Plan should monitor geospatial locations of the rights-of-way from year to year to account for ice sheet movement.
OZ 9	Determine the future demands for SPoT and other traverse options for improving personnel rotations, as well as cargo and fuel deliveries.
OZ 10*	Conduct a retrograde initiative to reduce accumulation, maintenance costs, labor and resource demands, and the station’s environmental impact.
OZ 11	Expand the current area for snow storage to manage the snow and ensure snow accumulation does not impact the Operations Zone activities.
OZ 12*	Relocate HF Antennas to de-conflict them from the long term drift challenges at the current site, and changing elevations to the modern elevation in the Operations Zone.
OZ 13*	Evaluate the timing for the first Elevated Station lift, and the end-of-life expectancy of the Elevated Station if no action is taken to lift the ES.

PRIMARY INFRASTRUCTURE

WATER SYSTEM

WS 1*	Replace water distribution lines and associated infrastructure to avoid critical points of failure in the piping system.
WS 2*	Replace the existing Water Rodwell by 2030. Locate the replacement Rodwell building relative to the ice tunnel beneath the structure so that a ladder shaft from the ice tunnel to the building can be configured for easier waterline and utility maintenance.
WS 3*	Evaluate utility tunnel replacement options.
WS 4*	Design piping systems, appendages, and structures to enable periodic building raises.
WS 5*	Conduct an analysis to determine if the back-up snow melt system capacity needs to be upgraded to support the summer population at SPS in the event of a Rodwell outage.
WS 6*	Evaluate the existing Rodwell building to determine its lifespan and ability to be relocated.
WS 7*	Investigate and recommend grey-water treatment options and re-use solutions to be used in future station designs to extend Rodwell lifespans and reduce long-term Rodwell planning and installation costs.

HUMAN AND SOLID WASTE

HSW 1*	Design piping systems, appendages, and structures to enable periodic building raises.
HSW 2*	Replace the sewer outfall Rodwell immediately.
HSW 3	Conduct an analysis of alternatives study and recommend a wastewater treatment plant to the human waste system to mitigate environmental impacts.
HSW 4*	Investigate and recommend grey-water treatment and re-use solutions to be used in future station designs to extend Rodwell lifespans and reduce long-term Rodwell planning and installation costs.
HSW 5*	Investigate black water and waste technology as potential alternative fuel sources in future station designs to reduce the environmental impacts of SPS activity.
HSW 6*	Evaluate utility tunnel replacement options.
HSW 7*	Conduct a retrograde initiative to reduce accumulation, maintenance costs, labor and resource demands, and the station’s environmental impact. (OZ 10)

ENERGY

E 1* Augment the power plant and fuel storage with energy efficient proven technologies.

E 2* Conduct a comprehensive study of the life expectancy of all main power plant components, including the structures beneath the arch and the arch itself, to finalize replacement timelines.

E 3* Conduct a comprehensive study of energy production feasibility to determine the appropriate energy production portfolio for a replacement power plant.

E 4 Conduct on-site proofing of current renewable energy technologies to determine suitability for the South Pole environment.

E 5 Engage in future partnerships with other national Antarctic programs in the continued study of and/or creation of alternative energy production systems that could reliably perform in the South Pole environment.

UTILITY CABLING

UC 1* Evaluate timing for the replacement of the main trunk fiber optic cables and local Dark Sector fiber optic cables if appropriate to occur in tandem with Building 61 raising.

UC 2 Discontinue fixed-point connections for cabling and implement a connection system that accounts for ice sheet movement.

UC 3 Proactively account for network expansion at precise locations to prevent future ad hoc cabling decisions.

UC 4 Explore the colocation of utility cables.

INFORMATION TECHNOLOGY & TELECOMMUNICATIONS

ITT 1* Conduct right-sizing assessment on RF Building size to support future requirements to include space for needed equipment redundancy to minimize the need for high-risk winter personnel visits.

ITT 2* Identify potential site for a future communications complex.

ITT 3* Upgrade the existing UHF/AM air-ground radio systems to maintain aviation communication capabilities.

ITT 4* Conduct a cost-benefit analysis of the emergent broadband polar orbiting, satellite-based, communications systems to evaluate the viability of emerging technologies for science data.

ITT 5* Uninstall 9 m antenna and retrograde, evaluate potential reuse of the radome, and preserve the antenna platform as a future resource to support future wideband low Earth orbit satellite systems for Enterprise-scale high speed communications (examples: SpaceX Starlink Community Gateway, Telesat Lightspeed Private Access terminal, AWS Kuiper private gateway terminal).

ITT 6 Upgrade the Land Mobile Radio system to maintain communications availability for timely emergency response.

ITT 7* Research communication methods that do not rely on the same technologies and are not subject to the same failure points to increase the resiliency and redundancy of emergency communications.

ITT 8 Coordinate spectrum selection and waveforms (i.e., occupied spectrum) of Land Mobile Radio system with Dark Sector research community to harmonize on emissions that minimize harmful EMI while maximizing safety/operational needs.

ITT 9* Conduct engineering assessments in coordination with the Dark Sector research community to identify safe operating ranges for existing and expected future wideband satellite earth stations (per ITT 5) and define site facility requirements (support buildings, utility runs, radiation hazard safe zones, etc.) for future site build-out.

ITT 10* Conduct engineering studies to find optimum trade-off between distance from airstrip centerline to main Elevated Station for winter personnel safety and utility runs vs. isolation distance needed to minimize EMI risks to Dark Sector (especially radio astronomy) to acceptable levels.

ITT 11 Refresh HF antenna requirements (design, number, purpose) to align with near-term NIWC HF Radio Modernization Capital Project for NIWC project to implement needed replacements.

ITT 12* Research new technologies that may reduce data and communications service gap hours each day and be installed at SPS to reduce communication-related safety risks and meet growing science data requirements.

FIELD SCIENCE

FS 1* Conduct a cost-benefits analysis for operating a field science facility based out of SPS for access to Eastern Antarctica science sites.

FS 2 Continue to centrally manage field support and Search and Rescue assets from a centralized location at McMurdo Station to provide continuity, efficiency, and a lighter footprint at SPS.

FS 3 Evaluate providing remote emergency response equipment storage structure adjacent to the airfield to enhance resiliency of the emergency response program.

FS 4 Utilize the existing arches, once vacated, for field science supplies as a temporary location until replacement facilities are constructed.

FS 5* Include dedicated VMF/warehouse space in a future station for staging the large and often voluminous equipment of multi-year, field science projects.

EMERGENCY SERVICES

EMS 1 Consolidate Emergency Services storage and staging space in the Elevated Station and directly adjacent to or integrated with field and aircraft staging areas.

EMS 2 In a Future Station, account for gurney space and maneuverability in Emergency Services treatment areas.

EMS 3 Upgrade the Land Mobile Radio system to maintain communications availability for timely emergency response. (ITT 6)

TRAVERSES

SOUTH POLE TRAVERSE (SPoT)

SPoT 1 Evaluate increasing traverse capacities and capabilities to reduce the reliance on and costs related to using LC-130s.

SPoT 2* Evaluate infrastructure upgrades to allow for loading and unloading full 20- and 40-foot shipping containers onto and from the traverse platform at McMurdo Station and SPS to expedite cargo delivery and reduce reliance on berms.

OVERLAND SCIENCE TRAVERSE

TR 1* Conduct an analysis assessing the cost-benefits to procure, operate, and store light science polar equipped wheeled vehicles based out of SPS for access to Eastern Antarctica science sites.

TR 2* Provide storage space in a future warehouse and VMF building for wheeled vehicles.

NGO/TOURISM

NGO 1 Encourage NGO operators to evaluate new communications equipment and deploy solutions that minimize EMI conflicts.

NGO 2 Maintain current practices and protocols while adapting approach corridors to the geographic South Pole that account for the movement of the geographic South Pole to the grid-east of the archway systems.

NGO 3 Transition the NGO campsite to an area closer to the Elevated Station and the NGO aircraft parking area to increase the buffer between the campsite and the Clean Air Sector.

NGO 4 Create an easement over the geographic South Pole trajectory to prevent future operational and facility conflicts with NGO-visitor foot, ski, and vehicle traffic.

NGO 5 Designate an NGO camp site grid-east of the future Elevated Station. The relocated NGO camp will be located immediately adjacent to the geographic South Pole trajectory for ease of visitor access and elimination of potential conflicts with operational activities. This would occur when a new station is built around 2060 or beyond.

DOWNWIND SECTOR

AIRFIELD

AIR 1 Evaluate ways to minimize conflicts with crossing the skiway to and from the Dark Sector. Conduct a cost-benefit analysis on shifting the skiway to deconflict crossings and Clean Air contamination.

AIR 2* Conduct a cost-benefit analysis to compare other aircraft models versus continued use of LC-130s, Baslers, and Twin Otters for potential cost savings and improved air travel reliability for the USAP.

AIR 3* Explore alternative methods of field fuel cache restocking currently supported by LC-130 airdrops to reduce the number of small aircraft flights required to recover the dropped supplies for each primary flight to the field.

Land Use Districts Matrix

The land use districts, district overlays, and easements presented in this document have been created for USAP-internal guidance of future development at SPS and are not intended to replace, supersede, or conflict with any existing Antarctic Treaty, Environmental Protocol, or ASMA agreement, directive, or requirement.

LAND USE CATEGORIES	ASMA OPERATIONS ZONE	LAND USE DISTRICTS					EASEMENTS			
		AIR SUPPORT	CULTURAL	PRIMARY INFRASTRUCTURE	STATION AREA SCIENCE	STATION SERVICES	CAS BUFFER	ACCESS CONTROL	GEOGRAPHIC SOUTH POLE	UTILITY ACCESS
SCIENCE										
Scientific research activities minimally impacted by daily operational activities, including but not limited to: vibrations, signals, frequencies, emissions, water vapor plumes, and traffic	●	*If no impact on airfield operations			●	●	●			
Equipment shelters and balloon inflation facilities	●	●			●					
Fixed scientific instrumentation	●	*If no impact on airfield operations			●					
Heated science staging and storage	●	●		●	●	●				
Field science staging and supply storage	●	●		●	●	●				
SUPPORT STAGING & STORAGE										
Hazardous, combustible, or noxious cold storage	●	●		●	*Scientific use only					
Non-hazardous, non-combustible cold storage	●	●		●	*Scientific use only	●				
Hazardous, combustible, or noxious Do Not Freeze (DNF) storage	●	●		●	*Scientific use only					
Non-hazardous, non-combustible Do Not Freeze (DNF) storage	●	●		●	*Scientific use only	●				
Fuel storage	●	●		●						
Heavy equipment storage	●			●						
Spare parts storage	●			●		●				
Construction materials storage	●			●						
General cargo staging	●	●		●						
Waste retrograde staging	●	●		●						
TRANSPORTATION										
Pedestrian pathways	●	*For station use only	●	*For station use only	●	●	●	●	●	
Vehicle and equipment pathways	●	*For station use only	●	●	●	●	●	●	●	
Transportation that does NOT produce emissions	●	●	●	●	●	●	●		●	
Transportation that produces emissions	●	●	●	●		●			●	
Airfield and associated infrastructure	●	●								
Aircraft parking or hangar	●	●	●							
Vehicle maintenance facilities	●			●						
Vehicle storage	●		●	●		●				
Heavy equipment maintenance facilities	●			●						
Fueling stations	●	●		●						

LAND USE CATEGORIES	ASMA OPERATIONS ZONE	LAND USE DISTRICTS					EASEMENTS			
		AIR SUPPORT	CULTURAL	PRIMARY INFRASTRUCTURE	STATION AREA SCIENCE	STATION SERVICES	CAS BUFFER	ACCESS CONTROL	GEOGRAPHIC SOUTH POLE	UTILITY ACCESS
EMERGENCY SERVICES										
Medical treatment facilities	●	●		●		●				
Life safety infrastructure	●	●	●	●	●	●	●	●		●
Emergency response staging and equipment storage	●	●	●	●	●	●	●			
Winter emergency survival accommodations	●	●		●		●				
UTILITIES										
Telecommunications facilities and infrastructure	●	●	●	●	●	●	●			●
Renewable energy infrastructure that does NOT produce emissions	●	●	●	●	●	●				●
Renewable energy infrastructure that produces emissions	●	●	●	●						●
Buried utility lines	●	●	●	●	●	●	●		●	●
Overhead utility lines	●		●	●	●	●	●		●	●
Power production facilities	●			●		*Emergency only				
Combined Heat/Power (CHP) system facilities and equipment	●			●						
Water and waste treatment and/or processing facilities and equipment	●			●						
OTHER										
Tourism and NGO activities	●		●						●	
Historic markers	●		●						●	
Visitor's center	●	●	●							
Heavy trades shop	●			●						
Light carpentry and trades shop	●			●		●				
Offices	●					●				
Recreation	●					●				
Food and beverage services	●					●				
Lodging	●					●				
Commissary	●					●				
Restroom facilities	●		*By NGO only	●		●				
All other personnel support services	●					●				
Temporary structures	●		*By NGO only	*Only with overlay		*Only with overlay				

Attachment: Comments submitted in response to

Request for Public Comment: Draft South Pole Station Master Plan

Federal Register document 2024-10774 (89 FR 42904)

From:	Eric Morgan
To:	SPMasterPlan
Subject:	[EXTERNAL] - Comment on Draft South Pole Station Master Plan
Date:	Friday, June 14, 2024 2:21:47 PM

The Scripps CO2 program has been measuring CO2 in flasks collected at SPS since 1957. The Scripps O2 program has been measuring O2/N2, CO2, and Ar/N2 in flasks collected at SPS since 1991. Changes to sampling criteria, sample location, or the addition of local influences has the possibility to impact our time series, so we have read the Master Plan with interest.

As proposed we do not have any specific concerns with any of the proposed changes to the Clean Air Sector (which, from the Plan, seems to only be the creation of stricter controls on access to the CAS via an official easement, which we welcome).

Thus, our only comment is that if the recommendation CAS 1 is followed (a new NOAA science building is built within the CAS), that the construction of it be carefully coordinated with atmospheric sampling activities (i.e., construction activities are not ongoing within a certain period before and during sampling, agreed upon in advance by relevant stakeholders).

--

Eric J. Morgan
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212 Vaughan Hall
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Tel: +[redacted]

https://ejmorgan.scrippsprofiles.ucsd.edu/

From:	Lee J Welhouse
To:	SPMasterPlan
Cc:	MATTHEW A LAZZARA
Subject:	[EXTERNAL] - South Pole Master Plan comments
Date:	Wednesday, July 17, 2024 12:32:57 PM

Hello,

I work with the Antarctic Meteorological Research and Data Center on the Automatic Weather Station project (O-283-M/S) and I would like to indicate support for much of the master plans comments. Three areas of particular importance are weather observations at South Pole, the clean air sector, and storage/use of South Pole as a hub for visiting stations in the region.

Maintaining the clean air sector for observations and research is key, as well as having observations at the skiway. Both are important for understanding the weather and climate of South Pole station in supporting research as well as operations.

The clean air sector is extremely important, and the various plans that raise the ARO or provide additional support in the area are great to see and could definitely provide opportunities for increased work done out of South Pole.

Finally, it is heartening to see a number of options that increase or organize the storage of equipment at South Pole. Our group has primarily used South Pole as a hub to reach other equipment via Twin Otter Aircraft and the expectation is that will continue. In the past equipment storage, and workspace was very difficult to come by during the timeline, and it resulted in delays and other mixups involving equipment placement. While our group only works out of South Pole every few years, any efficiency gains in using the space would be appreciated.

Thanks,
Lee

Argonne NATIONAL LABORATORY

2024-07-11

Dear Michael Gencarelli, the Office of Polar Programs, & the National Science Foundation,

We have reviewed the draft South Pole Station Master Plan (SPSMP). We are writing as a group of researchers from the U.S. Department of Energy's (DOE) Argonne National Laborato1y. We are pa.it of a team along with reseai·chers at the DOE's National Renewable Energy Laborato1y that have been studying the economic and technical challenges and benefits of renewable energy technologies at the South Pole. Our study, "Techno-economic analysis of renewable energy generation at the South Pole" has been published in the peer-reviewed journal Renewable and Sustainable Energy Review (https://doi.org/10.1016/j.rser.2023.114274). We have the following comments on the SPSMP for your consideration, specifically related to the consideration ofrenewable energy, or 'alternative' energy as it is refened to.

We strongly suppo1t the plan for the consideration of alternative/renewable energy infrastrncture and that under all three scenarios the concept for the SPSMP plans to:

- "Initiate an alternative energy production system design and constiuction effort. "

We appreciate the reference to our study on page 57 in section titled 'Alternative Energy'. We note that the study is not a white paper as stated, but instead a peer-reviewed article that was initially submitted on June 23, 2023 and published January 9, 2024. Our study explored several different combinations of solar panels, wind turbines and energy storage using tailored models of the energy generation conditions and economics at the South Pole. All combinations, from summer-only solar panels to a year-round hybrid system of solar·, wind, and batte1y energy storage, resulted in diesel fuel savings between 40-95%. This is a significant opportunity, as the ti·ansition would both reduce carbon emissions and save operating costs (with a payback time of 2-3 yeai·s on the initial capital investment). As noted on page 42 this is one of the key goals for further environmental sustainability of the station. Reducing the amount of diesel fuel consumed has the additional benefit of reducing the size of the yearly overland ti·averse and aircraft fuel deliveries, freeing these valuable assets. Therefore, again, we would like to express our suppo1t and sti·ongly encourage the fmther studies and system design proposed in the SPSMP. We would also be happy to share any further details or products from this study that would be of use towai·ds these goals.

We also sti·ongly suppo1t the following recommendations outlined in the SPSMP on page 36:

- E4 "Conduct onsite testing of cunent renewable energy technologies to dete1mine suitability for the South Pole environment."
- ES "Engage in future partnerships with academic institutions to engage the academic community in the continued study of and/or creation of alternative energy production systems that could reliably pe1fo1m in the South Pole environment."

We agree that demonsti·ations of existing technology on-site is a well-motivated and impo1tant step to a lai·ger ti·ansition to renewables. We also sti·ongly suppo1t the idea of partnerships and engagement with institutions and the academic community as pa.it of the continued study. We hope to further collaborate and conti·ibute to the development of a renewable energy production system for the South Pole.

Again, thank you for your consideration of our comments. We welcome any contact on these comments. Please direct them to [redacted] .

Sincerely,

Dr. Amy N. Bender, Physicist, High Energy Physics Division
Ralph Muehleisen, Ph.D., P.E., LEED AP, FASA, Chief Building Scientist, Building and Industrial Technologies Group Leader, Energy Systems and Infrastructure Analysis Division
Susan Babinec, Program Lead – Stationary Storage, ACCESS: Argonne Collaborative Center for Energy Storage Science

American Physical Society
1 Physics Ellipse
College Park, MD 20740

July 17, 2024

RE: Draft South Pole Station Master Plan

Michael Gencarelli
Office of Polar Programs
National Science Foundation
2415 Eisenhower Avenue
Alexandria, VA 22314

Dear Mr. Gencarelli,

As President of the Ame1ican Physical Society (APS), I am writing along with the leadership of the U.S. high-energy physics users' organizations ofFennilab, SLAC, and the Large Hadron Collider, on behalf of the physics community to comment on the draft South Pole Station Master Plan. We strongly endorse effo1ts to recapitalize the infrastmcture at the NSF Amundsen-Scott South Pole Station **and urge that these vital activities be undertaken in a manner that allows for the Cosmic Microwave Background Stage Four (CMB-S4) project and upgrades to the IceCube experiment tocontinue, while minimizing delays to the extent feasibly possible.** We are pa1ticularly concerned with the recently announced decision to not allow the CMB-S4 project to progress to the design stage "in its cunent f01m." The cunent recapitalization plan provides little detail about what scientists can expect for the future of physics at the Pole. The safety of the scientists and suppo1t staff in Antarctica is paramount, so we hope recapitalization can be canied out in a way that p1ioritizes safety while also avoiding the loss of nearly a decade of scientific progress.

The 2023 Pruticle Physics Project Prio1itization Panel (PS) repo1t, *Exploring the Quantum Universe: Pathways to Innovation and Discovery in Particle Phvsics*, is unequivocal about the impo1tance of the South Pole for science: "Maintaining the capabilities of NSF's infrastrncture at the South Pole, focused on enabling future world-leading scientific discoveries, is essential." Both the PS repo1t and the National Academy of Sciences decadal smvey, Pathways to Discove1y in Astronomy and Astrophysics for the 2020s. emphasize the impo1tance of the South Pole for CMB-S4 and IceCube-Gen2. Additionally, CMB-S4 is the highest priority major new initiative recommended by PS dming the 2025-35 timeframe.

Cosmic Microwave Background (CMB) measurements explore physics, cosmology, and astrophysics from the eru·ly to the late-time universe, providing a path to probing physics at energy scales and early times far beyond the capabilities of terrestrial accelerators. The combination of high altitude and extremely low humidity with little diurnal variation at the South Pole results in uniquely stable and transmissive atmospheric conditions for measurements of the CMB. The unique advantages of the South Pole site for CMB science led to prioritization of a ‘next-generation cosmic microwave background program’ as one of three strategic focus areas across all of Antarctic scientific research in the 2015 NAS report “A Strategic Vision for NSF Investments in Antarctic and Southern Ocean Research.” These advantages led CMB-S4 to propose an ultradeep survey from the South Pole as the optimal experimental configuration to make a transformational measurement of the CMB.

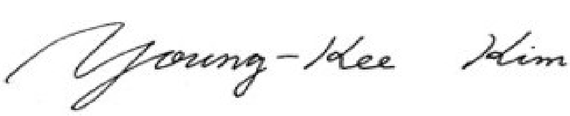
In addition to the CMB studies, the South Pole is also critical for furthering our understanding of neutrinos. The IceCube Neutrino Observatory deploys detectors into the ice to detect the neutrinos that originate in high-energy cosmic accelerators, thereby opening a new window into the high-energy universe. IceCube’s study of cosmic neutrino events is also complementary to terrestrial neutrino experiments, further enabling studies of fundamental neutrino properties. The ongoing IceCube Upgrade will increase the observatories’ sensitivity to low-energy neutrinos, allowing for a uniquely sensitive measurement of neutrino properties. IceCube-Gen2 will boost the sensitivity to cosmic neutrinos by an order of magnitude and increase its energy range by three orders of magnitude, probing the nature of the highest energy particles observed from the Universe.

CMB and neutrino experiments at the South Pole perform many compelling explorations of physics and astronomy beyond those described above. The data collected is used to study everything from the nature of dark energy to the properties of cosmic rays and neutrinos to delving into the mystery of dark matter. These experiments and data sets support a vibrant scientific community and provide important training and development opportunities for the next generation of scientists and engineers. Hundreds of students and postdoctoral scholars are active participants and leaders in the current experiments, making the South Pole Station an essential facility for building the talented STEM workforce necessary for the US to maintain its leadership in science, technology, and innovation.

We fully support the urgently needed recapitalization of the NSF Amundsen-Scott South Pole Station. Robust infrastructure including bedspace, cargo transport, and power generation should be supported at levels that enable maintenance of existing equipment, and construction of new experiments. However, it is vital that South Pole infrastructure recapitalization occur in a manner that enables future scientific investigations there, especially CMB-S4 and IceCube-Gen2, to continue with minimal delay, and which minimizes the disruption to the careers of the talented young scientists who drive these projects forward.

We thank you for your consideration of our input.

Sincerely,



Young-Kee Kim
President, American Physical Society

Also endorsed by:

André de Gouvêa, Northwestern University, APS Division of Particles and Fields (DPF) Chair
R. Sekhar Chivukula, UC San Diego, DPF Past Chair

Heidi Schellman, Oregon State University, DPF Chair Elect
Sarah Eno, University of Maryland, DPF Vice Chair
Harvey Newman, Caltech, US LHC Users Executive Committee Chair
Caterina Vernieri, SLAC, SLAC Users Organization Chair
Jane Nachtman, University of Iowa, Fermilab Users Executive Committee Chair

CC:
Jean Cottam Allen, Acting Director, NSF Office of Polar Programs
Stephanie Short, Section Head, Antarctic Infrastructure and Logistics, NSF Office of Polar Programs
Sarah Ruth, Acting Section Head, Antarctic Sciences, NSF Office of Polar Programs
Harriet Kung, Acting Director, DOE Office of Science
Alexandra Isern, NSF Assistant Director for Geosciences
Denise Caldwell, Acting Assistant Director, NSF Division of Mathematical and Physical Sciences
Regina Rameika, Associate Director, DOE Office of High Energy Physics,
Saul Gonzalez, Division Director, NSF Physics Division

Bob Clauer, Newport News, VA, [redacted]

South Pole Plan comments. Page 10: Missing support for deep field activities to support remote autonomous instruments that are important to Atmospheric, Geospace, Seismology and Glaciology sciences... Page 38: South Pole is already a de-facto hub to support field operations. This must be in the plan to move forward. "if" should not be in the sentence. Increasing traverse support, particularly from South Pole is an excellent choice for field operations in the future since this activity is less impacted by weather conditions than small aircraft, and could carry larger payloads with less staging required than aircraft. I should think that the traverse would pose somewhat less danger than aircraft as well.

DATE: 17 July 2024

TO: National Science Foundation / Office of Polar Programs

RE: A Community Response to the South Pole Station Master Plan

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As professors, researchers, mentors, and academic advisors of future scientists and engineers with a vested interest in research at the United States Amundsen-Scott South Pole Station (SPS), we herein provide selected overarching comments on the draft South Pole Station Master Plan (SPS Master Plan) per 89 FR 42904 published on May 16, 2024. We appreciate this opportunity, and look forward to continued engagement with NSF/OPP on this topic.

Given its unique scientific location and important geopolitical position, the South Pole Station should be recognized and supported as the linchpin for U.S. efforts to maintain Antarctica for cutting edge science across a wide array of disciplines and for international cooperation and peace. The South Pole scientific community supports many of the baseline assumptions outlined in the SPS Master Plan, including maintaining at least a 150-bed capacity for the next 35-50 years with decadal reviews of the SPS Master Plan. Nonetheless, we suggest updating recommendation FS 3 (page 38) to say, “Complete an evaluation for temporary housing models to provide accommodation for field science teams at the South Pole for temporary excess population and for pass-through populations.” The SPS Master Plan emphasizes logistical support that may require additional beds for staff at the expense of science; it is necessary to have a plan for the continued support of scientific activities.

We do not agree with the decision to base the supportable levels of scientific activity and operations at the South Pole on 2024 levels (page 4), which were unusually low due to the ongoing logistical recovery from the pandemic. While it is not possible to foresee three decades into the future as to what frontier science will be conducted at the SPS, it is clear that scientific activity levels must be improved from 2024. Therefore, any decisions made now should not support a potential long-term retreat from scientific endeavors at the South Pole and in Antarctica. Rather than using 2024 as the base year, we encourage NSF to use this process, as well as other Antarctic-related projects such as the International Polar Year in 2032-33, to establish an ambitious research program and research budget that will guide the development and utilization of SPS through 2075.

We agree with the missions and objectives identified (page 6) but must point out the absence of one key point. NSM-23, which the White House released on May 17, 2024, states, “The United States will continue to lead cooperative international efforts through the Antarctic Treaty System (ATS) to maintain the Antarctic Region for peaceful purposes, protect its relatively pristine environment and ecosystems, and conduct scientific research.” The South Pole has a critical role in achieving this goal by demonstrating that the United States does not recognize overlapping territorial claims. This provides the United States preferential logistical access to the vast interior of the continent. Thus, any future for the SPS Master Plan must acknowledge and account for the significant geopolitical and logistical importance of the site. In fact, the SPS is already a de-facto hub to support scientific field operations, both between McMurdo Station, and the deep field.

Missing from the report is support for deep field activities that enable remote autonomous instruments critical to many disciplines. An important discipline requiring such deep field access is that of upper atmosphere and ionosphere research that defines the near space environment (Geospace) above the Antarctic continent. Because there is no continent in the north, such frontier polar research cannot be accomplished in the Arctic.

We support the decision to continue to conduct research at SPS that could not take place elsewhere. Specifically, we agree that Atmospheric Sciences, Astrophysics and Cosmological Science, Geospace Sciences, Glaciology, Seismology, and Medical Research should take priority (page 10). Recognizing the importance of these very distinct research fields, we encourage NSF to prioritize projects that have significant support by the research communities. For example, we encourage NSF to take steps to reverse the May 2024 decision to indefinitely halt the CMB-S4, which is a significant priority for astronomers and particle physicists.

It is further important to note that the Particle Physics Prioritization Panel (P5) emphasized the significance of the SPS for science in its most recent 2023 report, Pathways to Innovation and Discovery in Particle Physics: "Maintaining the capabilities of NSF's infrastructure at the South Pole, focused on enabling future world-leading scientific discoveries, is essential." Both the P5 report and the National Academies Decadal Survey on Astronomy and Astrophysics 2020 further emphasized the importance of the SPS for future science projects such as CMB-S4 and IceCube-Gen2.

While acknowledging that no science will occur at SPS if key utilities, notably energy, are not improved, we urge NSF to make realistic plans for how to maintain the full range of scientific operations even as renovation work is being undertaken at SPS. Such plans should again account for additional temporary beds (e.g., Hypertats) to accommodate staff that are conducting the upgrades, rather than reducing the number of scientists able to conduct their research. In addition, increasing traverse support from SPS to field sites will enhance field operations in the future since this activity is less impacted by weather conditions than small aircraft, and could carry larger payloads with less staging required than aircraft. Such capability will become increasingly important as research on the East Antarctic Ice Sheet expands.

We are pleased that sexual assault/harassment prevention and response is specifically mentioned in the SPS Master Plan. We encourage NSF and its contractors, including from other U.S. Government entities, to place a high priority on taking timely and effective actions to increase the safety of all at the SPS.

On behalf of the U.S. scientific community, we present these overarching comments that impact a large swath of the South Pole science community. Specific remarks will also be submitted by individual science teams. In closing, we thank you for the opportunity to comment on this draft and look forward to continued engagement with NSF and all relevant decision-makers.

Sincerely,

Dr. Allan T. Weatherwax, MIT Haystack Observatory
U.S. Alternate Delegate to the Scientific Committee on Antarctic Research (SCAR)

Signatories are listed in alphabetical order:

- *Dr. Byron Adams, University Professor and Chair, Department of Biology, Brigham Young University*
- *Dr. Zeeshan Ahmed, Associate Professor of Particle Physics and Astrophysics, SLAC National Accelerator Laboratory and Stanford University*
- *Dr. Denis A. Barkats, Research Associate, Harvard University*
- *Dr. Amy Bender, Physicist, Kavli Institute for Cosmological Physics, University of Chicago*
- *Dr. Bradford A. Benson, Associate Professor of Astronomy & Astrophysics, University of Chicago*
- *Dr. Colin Bischoff, Associate Professor, Department of Physics, University of Cincinnati*
- *Dr. James J. Bock, Marvin L. Goldberger Professor of Physics, California Institute of Technology and Jet Propulsion Laboratory*
- *Dr. William Bristow, Professor of Atmospheric Sciences, Pennsylvania State University*
- *Dr. John E. Carlstrom, Subramanyan Chandrasekhar Distinguished Service Professor, University of Chicago*
- *Dr. C. Robert Clauer, Professor Emeritus, Virginia Tech*
- *Dr. Thomas Crawford, Research Professor, Department of Astronomy & Astrophysics, University of Chicago*
- *Dr. Jeffrey Filippini, Associate Professor, University of Illinois Urbana-Champaign*
- *Dr. Andrew J. Gerrard, Professor of Physics and Director of the Center for Solar-Terrestrial Research, New Jersey Institute of Technology*
- *Dr. Francis Halzen, Vilas Research Professor and Gregory Breit Professor at the University Wisconsin*
- *Dr. Michael Hartinger, Space Science Institute, UCLA*
- *Dr. William Holzafpel, Professor of Physics, University of California, Berkeley*
- *Dr. Deneb Karentz, Professor of Biology, University of San Francisco, Delegate to the Scientific Committee on Antarctic Research (SCAR)*
- *Dr. Kirit S. Karkare, Associate Scientist, Kavli Institute for Particle Astrophysics and Cosmology*
- *Dr. Albrecht Karle, Professor of Physics, University of Wisconsin*
- *Dr. Hyomin Kim, Associate Professor, New Jersey Institute of Technology*
- *Dr. John Kovac, Professor of Astronomy and of Physics, Harvard University*
- *Dr. Louis J. Lanzerotti, Distinguished Research Professor, New Jersey Institute of Technology*
- *Dr. Marc Lessard, Research Professor, Physics and Astronomy, University of New Hampshire*
- *Dr. Lu Lu, Assistant Professor, Department of Physics and Wisconsin IceCube Particle Astrophysics Center, University of Wisconsin*
- *Dr. Jim Madsen, Executive Director at Wisconsin IceCube Particle Astrophysics Center*
- *Dr. Daniel P. Marrone, Professor of Astronomy, University of Arizona*
- *Dr. Robert C. Moore, Professor of Electrical and Computer Engineering, University of Florida*
- *Mr. William Muntean, U.S. Department of State (retired)*
- *Dr. Hien Nguyen, Research Scientist, Jet Propulsion Laboratory, California Institute of Technology*
- *Dr. Clement Pryke, Professor of Physics, University of Minnesota*
- *Dr. Carsten Rott, Professor and Jack. W. Keuffel Chair, Department of Physics & Astronomy, University of Utah*
- *Dr. Ted A. Scambos, Senior Research Scientist, ESOC/CIRES, University of Colorado*
- *Dr. Greg Sullivan, Professor of Physics, University of Maryland*
- *Dr. Abigail Vieregg, Professor, Depts. of Physics, Astronomy & Astrophysics, the Enrico Fermi Institute, David N. Schramm Director, Kavli Institute for Cosmological Physics, University of Chicago*

To: U.S. National Science Foundation (NSF) and the Office of Polar Programs
From: U.S. Department of Energy National Renewable Energy Laborato1y (NREL), including Nate Blair, Ian Baring-Gould, Silvana Oviatt, and Dan Olis

To NSF staff:

NREL staff have paiiicipated with Argonne National Laborato1y staff for the last two yeai·s examining the economic oppo1iunities and engineering challenges of deploying renewable technologies and energy storage at the South Pole. This study presents a techno-economic analysis for the implementation of a hybrid renewable energy system at the South Pole. This study specifically examined the idea of providing renewable power to a lai·ge science project. This collaboration resulted in a peer-reviewed paper published in *Renewable and Sustainable Energy Reviews*, "Techno-Economic .Analysis of Renewable Energy Generation at the South Pole." These comments ai·e from the NREL authors of this study and represent our thoughts based on this analysis.

First, to smnmai·ize our analysis, we found that transitioning from 100% fossil-fueled power generation to hybrid renewable energy generation and energy storage can expand the options for energy delive1y to South Pole-based research. Expanding the use of renewable energy as pa1i of a hybrid energy system can reduce carbon emissions, which impacts both global and local environmental conditions. Additionally, a hybrid energy system can expand the range of the cmTent energy system, ease South Pole fuel transport logistics, and reduce the high costs of powering the South Pole while expanding energy system resilience.

The reseai·ch team explored a tailored model of renewable resource availability and economics for solar photovoltaics (PV), wind turbine generators, lithium-ion energy storage, and long-duration energy storage at this site in different combinations with and without existini diesel energy generation. NREL's Renewable Energy Integration and Optimization (REopt'j platfonn was used to determine the optimal system component sizing and the associated system economics and environmental benefit. We found that the least-cost system includes fossil-fueled generation, solai·PV, wind power, and lithium-ion energy storage. For an example steady-state load of 170 kW, this hybrid system included the addition of 180 kW-DC of PV panels, 570 kW of wind turbines, and a 3.4-MWh lithium-ion batte1y energy storage system coupled with fossil-fueled generation. This system reduced diesel consumption by 95% compared to an all-diesel configuration, resulting in approximately 1,200 metric tons of cai·bon footprint avoided annually. During the 15-yeai·analysis period, the reduced diesel usage led to a net savings of $57 million, with a time to investment payback of approximately two yeai·s. All the scenai·ios modeled showed that the transition to renewables is highly cost-effective under the unique economics and constraints of this extremely remote site.

As a result of this analysis, following ai·e our comments related to the NSF South Pole Master Plan:

15013 Denver West Parkway
Golden, CO 80401
Phone--

NREL is a nationa.1laboratory of the U.S.Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

- Our team and our analysis fully support the statements in the Master Plan related to renewable energy. These include the energy recommendations on page 36, Recommendation E4: "Conduct on-site testing of cmTent renewable energy technologies to detennine suitability for the South Pole environment." Our team folly suppo1is this. We hope to be pa1i of this process, building on our cmTent effo1is designing solar and wind power systems tailored to the South Pole.
- We also support the statement on page 42 to "Introduce renewable energy sources" at the South Pole Station. We recommend fuiiher research on areas highlighted in the paper, such as expanding the understanding of potential renewable-based electromagnetic interference mitigation measures and assessing ice-based foundations for wind and solar technologies. We also recommend the near-te1m deployment of a pilot PV/wind/batte1y system at the South Pole before moving to a larger system. This process would align well with the idea of introducing renewable energy sources. We support this concept integrated with ongoing energy efficiency and energy supply improvements as indicated in the Master Plan.
- We suppo1i the entire section on Alternative Energy on page 57, and we appreciate the mention of our paper.
- We note that the potential locations for renewable energy systems, cited on maps on pages 69 and 72, might be fa1iher removed from the main station than required or advised based on fuiiher analysis. We would be happy to comment and interact on future siting analyses, incorporating additional factors such as grid stability analysis and the potential for more distributed renewable energy deployment. Relatedly, the planning for the station area science district (page 62) indicates the need to allocate space for renewable technology. Although PV and wind generators can be positioned broadly at the station, we advocate for integrating the planning for renewables more tightly with this process so that changes do not need to be made later.
- Similarly, in the Regulating Plans (page 60), we suppo1i integrating sustainability goals into all future plans, as mentioned. We add that not only is renewable energy a factor in sustainability and fuel logistics, but it is also economically wananted. Our analysis shows a two-year payback on renewable energy investments via fuel savings, and those fuiids and associated labor, etc., could be redirected to ongoing scientific activities. We suggest making this more pronounced in this guidance.
- Building on the sustainability goals, the addition of a renewable energy and storage system to the South Pole grid will improve power system flexibility and adaptability (page 60) by expanding the station's ability to conduct critical research, something that is cunently limited by the size of the cmTent power system and the amount of fuel that can be transported to the station. Although driven by natural sources, the addition of solar, wind, and energy storage can expand the capacity of energy supply compared to one provided by only impo1ied fossil fuel sources.

Finally, although the entire Master Plan focuses only on the South Pole Station, moving to a high-renewable energy supply could include expanded analyses of McMurdo Station, Palmer Station, and other Antarctic sites, building on extensive previous work in this area. An integrated analysis would suppo1i economies of scale and redundancies of equipment supply, and it could gamer greater interest from the renewable energy industry to engage with design and deployment and to streamline maintenance.

We welcome any feedback on these comments. Please direct feedback t[redacted]

Sincerely,
Nate Blair, Group Manager, Solar and Energy Storage Expe1i
Ian Baring-Gould, Senior Researcher, Microgrid and Wind Expert
Silvana Ovaitt, Researcher, Solar Technology Expe1i
Dan Olis, Senior Researcher, System Optimization Modeling Expe1i

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NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

July 15, 2024

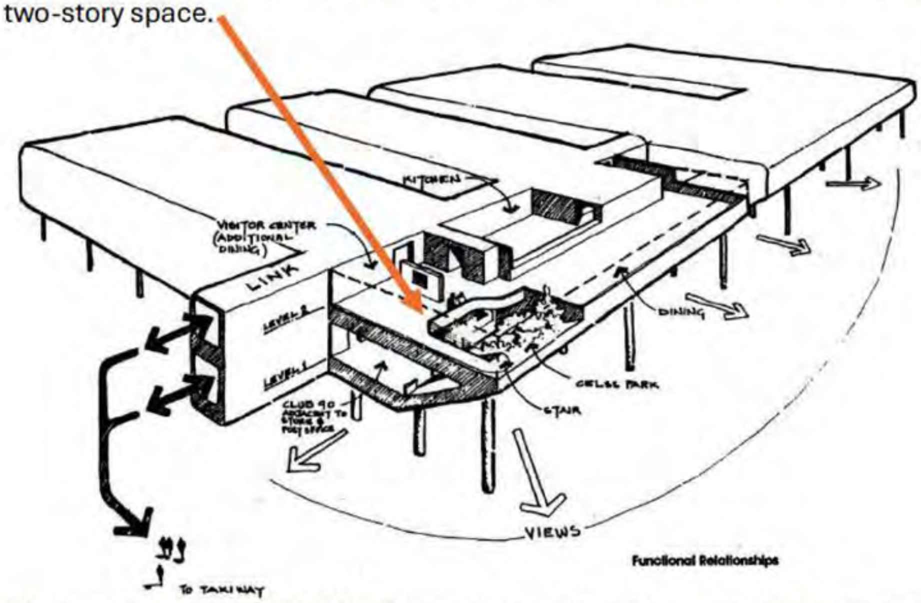
Mike Gencarelli
Antarctic Infrastructure and Logisticcs
National Science Foundation
Office of Polar Programs

Re: SOUTH POLE STATION MASTER PLAN COMMENTS

Thank you for providing the South Pole Station Master Plan for public review and commentary. Having been involved directly with the1990's masterplan and station design, I greatly appreciate the effort required to produce such a document.

I have a few comments which I present below for consideration:

1. Green Space for Improved Wellbeing: In the conceptual design for the current above surface station, the hydroponics space was envisioned in a larger footprint and within a two-story space.



Functional Relationships

   Working with NASA, CELSS hydroponic crop production was to be supplemented with tilapia farming. Although the concept was greatly downsized due to budget and program square footage budgets, the current hydroponics space is reported to be a much-valued retreat for station personnel. I highly recommend that these type spaces be incorporated into future facilities for food production and to enhance the general wellbeing of the station's personnel.

2. I concur with the proposed general location of the new powerplant, fuel storage and Logistics buildings. I acknowledge that the individual building design recommendations are at best, conceptual at this stage of the planning process. Locating L1 and L2 down wind of the raised power plant and fuel storage, however as indicated in one scenario, will impact both L1 and L2 structures with downwind drifts.

3. I highly encourage that all significant buildings be elevated for longer lifespan and reduced snow plowing and its fuel expenditure. Smaller buildings such as the Balloon Launch facility, should be designed for on surface with easy means for relocation. Our design team was opposed to the reuse and reconstruction of the arches in the redevelopment of the station in the late 90s. It's now obvious that their lifespan has been minimized when compared to the above surface station. We also explored alternative methods for raising the elevated station. I would encourage such studies to continue for new elevated structures that can be easily raised incrementally for differential settlement and extended life.

4. Realizing that the current power plant within the arch structure will need to be replaced, I recommend that pre-manufactured modular conex type structures be developed in CONUS and reassembled on a modular raised platform similar but heftier than the satellite tracking platform at the station. The modules would include both diesel engines and green power systems. This modular construction type was utilized in the design of the Vostok Station.

Thank you for the opportunity,

Joe Ferraro, FAIA, LEED AP

Principal

July 17, 2024

To: National Science Foundation
Michael Gencarelli, Office of Polar Programs

From: Dr. Brent Minchew, Associate Professor of Geophysics at the Massachusetts Institute of Technology & Co-Founder of the Arête Glacier Initiative

Subject: Response to Draft South Pole Station Master Plan Public Comment

Summary: The National Science Foundation's Office of Polar Programs, in addition to updating infrastructure at the Amundsen-Scott South Pole station, should invest in and build logistical infrastructure to monitor vulnerable areas of West Antarctica. While the South Pole Master Plan is an important step toward revitalizing Antarctic infrastructure to support cutting-edge scientific research and promoting US interests in the region, a focus only on infrastructure needs at the Amundsen-Scott South Pole station would miss a crucial opportunity. NSF should also invest in infrastructure that can support ongoing scientific research on the West Antarctic Ice Sheet (WAIS), whose potential instability could raise global sea levels at alarming rates and displace millions of people around the world. These consequences could be felt within the 50-year horizon of the Pole plans. Major investments in infrastructure that provide scientists with significantly improved and reliable access to WAIS to better understand how and how fast it may decline in a warming climate will help bolster national security and provide crucial insights to help address sea-level rise.

Specifically, NSF should assign high priority to developing and maintaining critical logistical infrastructure such as the US Antarctic Fleet, modernizing equipment and facilities at McMurdo Station, and increasing infrastructure and support for field campaigns in WAIS. In addition, among the three specific concepts the NSF has identified for the South Pole Station, we recommend Master Plan - Concept One as the option that strikes the best balance between long-term, flexible planning and cost-effectiveness. However, we note that these plans will only be viable with the crucial infrastructure updates described above.

The Challenge

Declining investments in Antarctica threaten US security: Though the United States has historically played a pivotal role in shaping the governance, scientific research, and environmental stewardship of Antarctica, US advantage is threatened by declining investments and ailing infrastructure. In the past year, the NSF has halted new field research efforts, cutback on research vessels, and delayed high-profile research projects. Meanwhile, countries like China have made strides in opening new research facilities. If this trend continues, the United States risks losing its leadership position in Antarctic research and its ability to influence international policies governing the continent.

Little to no investment in locations outside of South Pole Station that would support urgent *sea-level rise research:* This NSF South Pole Master Plan is a positive step but is not sufficient to promote US interests and mitigate catastrophic climate risk. The South Pole Station is currently a hub for groundbreaking high-energy particle physics and astronomy research, partly due to its unique geographic location at the Earth's southernmost point. However, the station's location on the stable East Antarctic Ice Sheet makes it much less suited for studying critical climate change questions, such as glacial dynamics and sea-level rise. Enhancing infrastructure at the South Pole Station alone will do little to answer these pressing climate questions.

The importance of prioritizing Antarctic research on sea-level rise: The National Science Foundation should prioritize studying the relationship between glacial dynamics and sea-level rise because estimates suggest that by 2100, sea levels will rise between 0.2 and 2 meters; the most acute threat of this is the collapse of the Thwaites Glacier in West Antarctica, which could raise global sea levels by more than 1 meter and inundate numerous American cities. A rapid disintegration of WAIS could displace tens to hundreds of millions of people around the globe, which will undoubtedly lead to economic and geopolitical challenges. Protecting Thwaites and WAIS is the difference between a manageable future and a calamitous one.

Recommendations: To both support the current South Pole Master Plan and research that combats the threat of catastrophic sea-level rise, the NSF should:

1. **Develop and maintain critical infrastructure, especially upgrading the U.S. Antarctic Fleet Aircraft.** Successful research at the South Pole station and future potential sites in West Antarctica will require a robust logistical system of advanced air, ground, and sea assets to support the science and scientists. NSF should continue to maintain and develop this critical infrastructure, including updating its Antarctic Fleet Aircraft so scientists and equipment can move across the continent. To do so, NSF should also engage with the Department of Defense and Congressional liaisons to fund and procure this equipment.

2. **Invest in McMurdo Station.** The NSF should bolster support at bases outside the South Pole, especially McMurdo Station, and ensure their equipment is modernized and upgraded. McMurdo serves as a pivotal base for studying Antarctic ice sheets, and serves as a starting point for access to the South Pole. However, the station's infrastructure is in dire need of modernization, as many of the existing facilities were built decades ago and struggle to meet the demands of contemporary scientific research.

3. **Increase support for infrastructure and field campaigns in West Antarctica.** In the coming years, the NSF should consider increasing support and field campaigns to West Antarctica. This is the only way to ensure that climate questions critical to US interests, such as the risk of the Thwaites Glacier collapsing and the subsequent impact of sea-level rise, are addressed. Specific needs include developing infrastructure to conduct continuous field measurements in and monitoring of WAIS; working with NASA and Congressional liaisons to fund satellite programs that can map surface velocities along with the surface and bed elevations in the Antarctic and Greenland Ice Sheets;

supporting targeted on-the-ice monitoring and data collection and analysis; and ensuring funding to a suite of models for projecting sea-level rise.

The suggestions above will not only support future work in West Antarctica, which will inform timely climate and sea-level rise questions, but they will also bolster current efforts at the South Pole Station and Arctic regions. These investments will help the US regain its global leadership in polar regions.

Preferred concept for the South Pole Master Plan: In addition to these broad suggestions, we also appreciate and understand that the NSF has provided three proposed concepts for how it could support infrastructure and operational improvements in the South Pole Master Plan specifically. Of the three concepts proposed, we believe that Master Plan - Concept One strikes the essential balances that create a high-functioning research station while managing costs and complexities. All these plans, however, will still require updating much of the critical support infrastructure described above.

Conclusion: The South Pole Master Plan represents a solid step forward in rebuilding Antarctic infrastructure and regaining U.S. leadership in the region. Comprehensive efforts are needed to ensure the success of this plan and to support essential research on preventing catastrophic sea-level rise. By expanding and modernizing Antarctic research infrastructure, the NSF can bolster current efforts at the South Pole Station *and* future work in West Antarctica, ultimately protecting U.S. interests and addressing pressing climate challenges.

South Pole Station Master Plan Draft 2024 – IAATO Comments

General Points:

- In theory, Norway is a co-sponsor of ASMA-5 (ATCM40- WP014 rev.1) but there appears no reference to them at all in the Master Plan.
- VISION – Tourism (and non-governmental) activities have numerous references and specific pages devoted to them (see P.27, 40, 63 & Recommendations) but are not included on the Vision/Objectives page (P.6).

P.27

- SP Tourism numbers quoted as increasing to ~300. This is probably close to accurate and may increase further.
- The Statement "*As tourism continues to grow…. Separation of uses, especially surrounding the Geographic South Pole, is becoming more important each year*" rings very true, and IAATO appreciate being part of the conversation to alleviate any operational confusion.
- Approach Routes – While compilers have taken Antarctic Logistics and Expeditions (ALE) info and included it in the Master Plan, this should be broadened to cover all DF Operators
    - WEST APPROACH – based on ALE's routing. White Desert & Ultima Expeditions may have different approach routes.
        - Perhaps just add, "WEST APPROACH – FROM HERCULES INLET, MESSNER START, RONNE ICE SHELF and Dronning Maud Land"
    - SOUTH APPROACH – has comment "*Call ALE Comms*…etc," should be broadened to include all NGO DF Operations

P.30 SPS Recommendations

- "SPS 2 Develop EMI governance/management plan" – a concern for NGOs. Currently use of Starlink, Wi-Fi, Bluetooth by NGOs prohibited in ASMA-5

P.31 Dark Sector

- "*EMI emissions from NGO camps*…" also an issue of concern, especially overuse of Starlink, see also P.37

P.40 NGO/Tourism

CONCERNS

- The NGO operations have EMI impacts on Dark Sector and other science facilities.
- Current NGO approach corridors and operations conflict with both Dark and Clean Air Sector science.
- The Geographic South Pole (GSP) trajectory needs to be protected for access of NGO visits

RECOMMENDATIONS

NGO 1 Encourage NGO operators to evaluate new communications equipment and deploy solutions that minimize EMI conflicts.

NGO 2 Maintain current practices and protocols while adapting approach corridors to the Geographic South Pole that account for the movement of the Geographic South Pole to the grid-east of the archway systems.

NGO 3 Transition the NGO campsite to an area closer to the Elevated Station and the NGO aircraft parking area to increase the buffer between the campsite and the Clean Air Sector.

NGO 4 Create an easement over the Geographic South Pole trajectory to prevent future operational and facility conflicts with NGO-visitor foot, ski, and vehicle traffic.

NGO 5 Designate an NGO camp site grid-east of the future Elevated Station. The relocated NGO camp will be located immediately adjacent to the Geographic South Pole trajectory for ease of visitor access and elimination of potential conflicts with operational activities. This would occur when a new station is built around 2060 or beyond.

IAATO Comments (NGO/Tourism):

- NGO 1 – Use of Starlink, currently prohibited, would alleviate this. The EMI issue is over Starlink Wi-Fi but unites can be hard wired to reduce stray EMI.

- NGO 3 – position was set by NSF as they did not want the NGO camp to be too near to the station to reduce the likelihood of station personnel visiting. ALE are happy to move closer but an inadvertent issue may be snow drift onto the station form NGO camp area caches.
- NGO 3 – Fully Agree. Current drift grid NW is causing ever longer trek to the GSP. Now it is over the Utilidors, understandably a concern to NSF.

P.48 Physical Planning

- Further recognition needed for moving location of GSP over duration of planning and build cycle.

P.58 Airfields

- Re-positioning might to take account of potentially longer taxiway needed for DF Operators to reach the Ceremonial and Geographic SPs and to the NGO ski aircraft parking area/campsite

Sections 7-MASTER PLAN and 8-CAPITAL INFRASTRUCTURE PLAN - No comments.

South Pole Station Master Plan

July 17, 2024

Submitted by: Michele Mantello, KBR

We offer the following comments and recommendations regarding the South Pole Station Master Plan (SPSMP) following the Federal Register notice of June 6, 2024.We appreciate the opportunity for public comment as this document represents a major step in ensuring that important scientific discoveries continue at the South Pole in a way that maximizes the scientific merit while maintaining efficient use of US taxpayer resources. We acknowledge the excellent work has gone into the big picture zoning, land use and replacement infrastructure concepts in the SPSMP. The capital infrastructure project list is particularly impressive as a schedule concept.

Specific comments and recommendations are noted below.

1. The SPSMP notes the desired expansion of astrophysical and cosmological science at the South Pole with projects such as CMB-S4 and Icecube Gen-2. This expansion may require additional beds, power, and facilities which would contradict the apparent plan to not expand beds and power. This decision presumably springs from the weighing of 'the estimated total cost of ownership of each scenario against Antarctic Treaty and USAP requirements and national research priorities' referenced in paragraph 2 of the **Executive Summary.** This could be a point of disappointment with the 'big' science communities at the South Pole Station.

   Recommendations:

   - Provide additional detail on the weighing of the costs, requirements, and priorities that led to the decision to forego bed and power expansion.
   - Include in the SPSMP an analysis to confirm whether such projects can be adequately supported within the current bed and power numbers. If not state how NSF plans to either increase resources at the South Pole or state that the desired expansions are not feasible at this time.

2. In the second paragraph of the **Executive Summary**, the NSF states that "implementation of the recommendations of this SPS Master Plan can reduce operational demands and maximize future scientific support at SPS." It is not clear in the SPSMP which operational roles NSF anticipates could be reduced and which items in the plan would account for this reduction. We note that construction and infrastructure projects will involve a temporary but significant increase in operational staff, so an overall reduction in operational staff appears to be a long-term goal.

   Recommendation: Provide additional details on operational impacts of various plans presented in the SPSMP.

3. On Page 14 the SPSMP lists:
   - Average winter population: 42
   - Average winter population ratio: 4-1 support staff to science

   With ~10 scientists on site each winter and ~32 support staff, the ratio would be 3-1 support staff to science.

   Recommendation: Change "4-1" to "3-1."

4. On Page 20 in the **Utility Cabling** section the SPSMP states "A substantial portion of the existing SPS immediate area also contains scattered subsurface vaults, decommissioned Rodwells, and antennas, further complicating future structural placements within the area" without specific details.

   Recommendation: Include a map of these historic waste sites for context.

5. On page 23 in the **Field Science** section the plan states that transient field teams "compete for bed space with other SPS-based researchers and operational and infrastructure-project personnel'.

   Recommendation: NSF should consider requesting transient field teams to camp at the South Pole as they will be once they deploy into the field.

6. On page 25 in the **Logistics and Transportation** section it is not clear that the NSF has considered the impact of poor operational performance by the ANG LC130s, which is considered to by a critical issue for South Pole logistics. This is touched on in the **Airfield** section on page 40, but without previous narrative. On page 28 in the **Airfield** section the "reliance on LC-130 support for personnel transport is anticipated to continue" is discussed. The SPSMP also discusses that expansion of the traverse could eclipse almost all the need for LC130 support.

   Recommendation: Provide additional information on the political landscape that mandates a degree of use of the LC130s.

7. On page 28 in the Airfield section lacks recognition of the significant impact of the exhaust output from the Power Plant on certain days that sends an impenetrable fog out over the skiway. This is another point supporting the relocation of the skiway.

   Recommendation: Provide information about the impact of Power Plant exhaust on airfield operations.

8. The SPSMP states "…the frequency and volume of personnel movements and cargo in and out of South Pole is lower than desired….' This concern is also expressed in the **Operations Zone** and **Field Science** sections. The plan doesn't fully address options available to mitigate this concern.

   Recommendation: Assess the benefit of rotating personnel through Chile via Union Glacier by large jet and to SPS via Basler DC3. The passenger count southbound and northbound to Union Glacier by Basler is 18 people and shorter than the McMurdo to South Pole route.

9. The SPSMP notes that there is hot competition for bed space in the SPS. Airfield staffing contributes to that competition. Due to the nature of the SPS, the current ARFF team (7 people) has little ability to be effective in the event of an aircraft incident. Reclassification of the South Pole Skiway to an "austere skiway" would allow it to run under the same ARFF staffing as a large camp such as WAIS Divide (zero ARFF). This would make available 7 beds currently occupied by an ARFF team.

   Recommendation: Evaluate the potential reclassification of the South Pole Skiway as an "austere skiway."

10. On page 31, the SPSMS expresses the need to lift Building 61.

    Recommendation: Explore the removal of the dormant generator on the end of building 61. Building 61 could be raised as a standard crane lift as has been done in the past with the similarly sized Rodwell buildings. This lift could be done as part of standard summer tasking.

11. Presumably, all new facilities, utilities, equipment and infrastructure will include maintenance and lifecycle planning for long-range planning purposes.

    Recommendation: If the presumption is correct, state this in the SPSMP.

12. The SPSMS notes “Solid waste retrograde represents a long and costly supply chain for disposal of solid waste materials to CONUS.”

    Recommendation: Add an additional option: HSW 7 – Explore Micro Auto Gasification Systems (MAGS) to reduce solid waste by 95% and radically reduce the long and costly supply chain.

13. The SPSMS notes “Field science is often delayed when Baslers and Twin Otter aircraft are grounded due to weather” This concern also expressed in the **Overland Science Traverse** section. Impacts on Field science due to weather are not limited to Twin Otters, but also Baslers and LC130s. Mission attempts are often impacted not only by poor weather but also by poor forecasting. The Charleston weather forecasting is anecdotally thought to produce a poor-quality forecasting product.

    Recommendation: Conduct an in-depth analysis of forecast accuracy from the Charleston service and consider options to improve forecasting quality, including use of experienced and proven on-continent forecasters.

Michael Gencarelli
Office of Polar Programs
National Science Foundation
2415 Eisenhower Avenue
Alexandria, VA 22314

July 16, 2024

Dear Mr. Gencarelli,

We have read the draft South Pole Station Master Plan and are very happy that NSF is undertaking these actions. The plan is comprehensive and detailed. In this letter, we address a few items relevant to IceCube and more generally to multimessenger astrophysics at the South Pole.

We submit the following observations and recommendations for consideration:

1) Power plant replacement: The current power plant supports a nominal target of 680 kW (page 19). The proposed replacement allocates three similarly sized (750 kW prime rating at the site) diesel engine generators. We would like to draw attention to the choice of the rating. We suggest planning for ~25% more power to create a margin that allows for future science projects, such as world-class science projects in astrophysics, cosmology, or other areas of research. It is understood that such projects are not currently in the planning stage. However, we want to emphasize that a decision about power has severe long-term implications. A replacement of the power plant with the currently proposed ceiling would block any future science projects that need additional power for decades to come. It would thus severely constrain future science at the South Pole.

2) As highlighted in the document, it is clear that the ICL must be raised sometime in the future. We want to draw attention to the fact that the main sensors in IceCube, the digital optical modules (DOMs), should not remain unpowered for extended periods. Even in a period as short as 24 hours, there is a risk that some DOMs could become permanently inoperable.

3) SPOT: We welcome all three recommendations: SPOT 1, SPOT 2, and SPOT 3. Indeed, we recommend giving the SPOT upgrade a high priority and implementing it as early as practical. As noted in the document, a significant amount of fuel is currently still transported by LC-130 fuel tankers. The planned SPOT upgrade will also enable more transportation of heavy cargo for science

when needed. An upgraded SPOT will likely also benefit the infrastructure upgrade execution.

4) We welcome the plans to refurbish the equipment to enable temporary summer housing and evaluate future needs. We are concerned that additional population for infrastructure needs, such as for raising the station, could constrain the science population, e.g., for IceCube maintenance and operation. We propose rewording recommendation FS 3 to “Complete an evaluation for temporary housing models to provide accommodation for field science teams at the South Pole for temporary excess population or for pass-through populations.”

5) We welcome the opportunities to engage in future conversations to optimize the science possible within available resources. We encourage engaging all of the science community.

We note that the South Pole station has had an exemplary record of conducting science in the past two decades. More than 200 journal papers were published by the IceCube Collaboration, including eight articles in the journals *Science* and *Nature*. These papers include the discovery of high-energy astrophysical neutrinos, the observation of neutrinos from our galaxy, and the identification of two active galaxies as candidate neutrino sources. Meaningful upgrades to the infrastructure will ensure the South Pole remains a competitive site for science in the coming decades.

Sincerely,

- University of Wisconsin–Madison
  Francis Halzen, Principal Investigator IceCube
  Albrecht Karle, Principal investigator IceCube Upgrade
  John Kelley, Director, Maintenance & Operations
  Vivian O’Dell, Project Director, IceCube Upgrade
  Lu Lu, IceCube Collaboration
- Georgia Institute of Technology,
  Ignacio Taboada, Spokesperson of the IceCube Collaboration
- Columbia University
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Cooperative Institute for Research in Environmental Sciences
UNIVERSITY OF COLORADO **BOULDER**

Earth Science Observation Center • Dr. Ted Scambos

To: SPMasterPlan@nsf.gov
CC:

Subject: Input on the South Pole Station Master Plan

To NSF, NSF-OPP, and its partners in USAP:

I greatly appreciate that the National Science Foundation is preparing to address South Pole's infrastructure needs, and that it has sought input from the community to inform its master planning.

The United States has played a pivotal role in shaping the governance, scientific research, and environmental stewardship of Antarctica. There are aspects of the USAP program that far surpass the capabilities and science achievements of any other Antarctic nation. However, the need for infrastructure upgrades at South Pole Station has reached a critical state. I am concerned that the U.S. advantage in polar astronomy and physics, and in Antarctic science generally, is threated by declining investments and ailing infrastructure — while foreign competitors are accelerating their presence in the region.

Overall the draft master plan options are clearly stated and reasonable. But they will be expensive and time-consuming to complete. **The United States cannot afford an indefinite or decades-long delay in South Pole research advances**. Yet these next steps (CMB4, IceCube2, drilling and airborne mapping efforts) require a more robust South Pole infrastructure. NSF should ensure that any selected plan can be efficiently completed. I support Plan 2 in the Master Plan – but more important than any one plan is the need to accomplish significant upgrades quickly and with minimal impact on science activities.

None of the three plans proposed will be viable absent **significant attention to upgrading and replacing critical support infrastructure, including the LC-130 ANG fleet.** Reliable aircraft are needed to move both materials and people, **not just at Pole but throughout the large Antarctic region that US scientists have worked in for nearly the past 70 years.** NSF's urgent attention to these issues – including further engagement with the Department of Defense and with Congressional liaisons – is necessary.

I appreciate that the plan calls for **the creation of a Field Science Camp and Staging area** at South Pole Station. **I recommend that this area have the ability to comfortably support ~15 researchers and affiliated support staff for a December 1 — January 30 season each year.** Such a capability would be of very high science interest, especially for exploration and field missions to East Antarctica. This would enable exploration of past climate histories through shallow and deep ice coring, management of weather and geophysical installations; meteorite collection teams; radar profiling traverses; and geological and geophysical surveys. While 'compact' (~15 researchers), it should be a robust facility that will meet all the needs for staging (e.g., heated space for equipment testing and re-configuration, small workshop for electrical and mechanical needs, outdoor area for practice deployments).

It was dismaying to see that the berthing improvements to SPS in the early 2000s were quickly consumed by the astronomy and physics communities, with few if any beds available for deep field research. **The Field Science Camp should be reserved for field research as a first priority for its use in any year.**

I am surprised that the master plan does not highlight a greater use and implementation of renewable energy. The cost of delivered fuel to South Pole ($20-$30/gallon) makes this an obvious path to saving money and extending existing logistical capabilities that can be used in other ways. While smaller grids with high percentages of wind and solar are difficult to manage, isolated wind-solar-battery grids for large experiments could address this issue, reducing the impact on the backbone grid.

I also strongly recommend that NSF augment the existing McMurdo-South Pole resupply traverse, to further reduce the need for airlift, and enhance construction speed. **I also strongly recommend that NSF add a science overland traverse capability as soon as possible** so that the opening of deep field base camps such as Byrd Station, Herc Dome, central Thwaites Glacier, or East Antarctic sites can be opened reliably in the early part of the season. The perennial delay in opening deep field camps has been a major factor in reducing the science that can be accomplished by funded grants. Scientists commit months and even years of time in preparation for deep field work, only to see the promised field time evaporate with field camp opening delays. With hub bases opened earlier, and sufficient small-aircraft contractor time, additional deep field tasks that have languished for several years (AWS, PoleNet, seismic stations) can be addressed.

I was glad to see the master plan imagines continued cooperation and limited collaboration with NGO groups bringing visitors to the vicinity of the South Pole. These efforts help build goodwill and public interest in South Pole science, and support for Antarctic research generally.

It is my hope that NSF could finish master plan improvements in time for the 5th International Polar Year in 2032. This year will surely mark major attention to Antarctic research — and major efforts from international competitors looking to establish increased Antarctic presence and new outposts.

NSF must act with urgency to rally support for NSF's Antarctic activities that are important to science, and national influence and security, on the southern continent.

Sincerely,

Ted Scambos
Senior Research Scientist, ESOC/CIRES
University of Colorado Boulder

South Pole Station Draft Masterplan

Steve Theno Comments:

1. General Observation - There is a general movement in new facilities planning away from configurations utilizing multiple small units to combining all necessary functions into one large composite facility. This was the case for the updated McMurdo Station Masterplan, it seems to be the preferred direction for the new South Pole Station Masterplan and it has been the trend in remote facilities in Alaska as well. The benefits are apparent; enhanced interior environments, improved facility thermal efficiency, improved logistics flows and internal operational efficiencies, more compact centralized systems and infrastructure with the benefits of improved system efficiencies and reduced first cost. It may be that the use of larger composite facilities are more practical now with expanded capacity in the remote locations logistics chains and expanded, more capable construction infrastructure. However, as part of developing the vision for a plan that will shape the development of South Pole Station for the next 30 to 50 years, it may be desireable to revisit the pros and cons of multiple small units versus single large composite facilities to insure the selected approach offers the best overall solution. In the past, significant value was placed on the flexibility offered by multiple small units, the inherent redundancy, simplified and more rapid on-site construction, enhanced ability to phase, ease of module to module isolation and fire protection, and perhaps easier to periodically level and jack.
2. General Observation - Similarly there is a continual movement from simple systems to more complex systems forming the infrastructure within built facilities. While this is tangentially discussed under Simplicity and Standardization in the Design Principals section (Pg 60); the reality is modern systems, the performance requirments/expectations and the adoption of advancing technology all drive complexity. This is especially apparent in environmental systems, MEP, fire protection and monitoring and control. While this is probably unavoidable, given the extreme harsh environment, isolation and remote location of South Pole Station, it would be important to emphasize the need to carefully design critical systems to incorporate redundancies, avoid single point failure modes and provide independent back-ups to assure the ability for continued operations under all plausible scenarios. Another aspect of technology driven systems is the significant change in how operators interface with systems and how preventive maintenance and repairs are accomplished. The skills, experience and tools needed today are much different than that required of systems in the past. Emphasis should be given to establishing recruiting and training programs as well as maintenance delivery systems that respond to the change.
3. General Observation - The elevated station and all the dark sector modules were designed to be raised to maximize their useful life. With the exception of Aero, I believe, none of the facilities have been raised. The Masterplan notes this, notes the current urgency in doing so, and also explores the advantages/disadvantages of different construction types (elevated, on the surface, below surface). Ultimately the Masterplan recommends raising the existing structures and, for the most part, elevating new structures as well. I agree with the proposed direction, but would recommend that the Masterplan explore why the existing structures have never been raised. Are there important lessons learned or factors here that have not been accounted for? During design of the existing elevated station it was clear that an elevated structure would offer a lower life

cycle cost over a surface structure by significantly reducing annual snow maintenance costs. It was also apparent that to maximize this benefit, the station would need to be cable of jacking and that jacking capability was incorporated into the design. Snow drift modeling showed, and the design analysis made it clear that that the station would need to be jacked after about 20 years. Yet the station was never jacked. The elevated station and the dark sector modules are now in a situation that negates the life cycle cost benefit of the structures. These facilities bear the added first cost for elevating and making jackable while now also experiencing high annual snow maintenance costs. Again, I agree that the elevated approach is the better approach, but I would recommend identifying why the existing facilities have not been jacked and if those factors can be mitigated going forward.

4. Ref Pg 49 – Conceptual Building Forms – A table is provided summarizing existing "Arch GSF", "Replacement GSF" and basic rational for the proposed sizes of four key facilities or functions currently located in arches. It is unclear if the listed GSF is the arch itself that houses the buildings (so the actual conditioned building square footage is something less) or if the listed gsf is that of the buildings and the arches would be larger. Within the text both buildings and arches are referred to. Recommend clarifying.
5. Ref Pg 49 – Conceptual Building Forms – The table bases the replacement power plant size on the existing and basically recommends the same size. Suggest considering the replacement power plant would logically enable integrating and accommodating renewable energy sources within the Masterplan timeframe and therefore recommend some additional space be used at this planning level for the powerplant. Also, even if it is the intent that the replacement power plant utilizes diesel engine generators matching the existing, updated environmental emissions protocols could require new engine selections, changes in heat recovery characteristics and additional emission control systems all of which would require expanded power plant space.
6. Ref Pg 51 – Discussion of pros/cons for elevated structures – First cost is listed as a con and reduced annual snow maintenance is listed as a pro. I agree but suggest noting the overall evaluation should be made with respect to life cycle cost.
7. Ref Pg 51 – Discussion of pros/cons for elevated structures – Another challenge or con to consider for elevated structure is dealing with transitioning heavy equipment and bulk cargo between the structure and the surface.
8. Ref Pg 52 – Discussion of pros/cons for arches – One of the listed pros is "Snow floors can be regraded periodically to counteract long term snowpack settlement along arch bearing lines". Is it feasible to effectively regrade snow floors with buildings (or racks, tanks, etc) in place on the snow floors?
9. Ref Pg 53 – Geodesic dome evaluation – Under the general discussion of the geodesic dome it indicates the previous dome at Pole performed well as related to the snow drift characteristics and resultant longevity of the structure. It also identifies this characteristic as one of the pros for this type of structure in the pros/cons analysis. My understanding from discussions during the evaluation of existing facilities in preparation for design of the elevated station is that the dome UNDERPERFORMED relative to snow drifting and the ability of the structure to accommodate snow loading. This was one of the factors driving development of the new station. The snow drift

pattern that developed around the dome caused an asymmetric loading on the dome structure and as a result, excessive structural deflection. The dome required additional snow removal efforts to avoid premature failure. The drift pattern that developed may have been influenced by the adjacent arches, nevertheless, the dome underperformed from expectations.

10. While there is discussion about candidate building forms (Pgs 50-53), there is no discussion about building construction types and comparative pros and cons. There is a brief mention of this under Design Principals (Pg 60). Recommend this be addressed in more substantive detail as it has major implications on design opportunities and constraints, construction logistics, cost and long-term performance. Examples would include modularization, panelization, site-built, prepackaged major equipment/system assemblies and perhaps others.
11. Ref Pg 55 – Power Plant – The Masterplan recommends replacing the existing powerplant. I agree with this recommendation. The Masterplan also recommends a similar plant capacity (750kw) using diesel generators in much the same configuration as the existing. Matching engine-generator units burning AN-8 will not now meet current emissions criteria. The existing engines are classified Tier II. Tier IV would now be required if current emissions standards are to be met. Commercially available Tier IV engines have much different performance and waste heat profiles. The size, capacity, quantities and characteristics of both the engines and associated auxiliary systems will be different and likely require more space than the current plant and more than is currently allocated for planning purposes. Furthermore, the additional emissions control systems necessary for new compliant engines will likely require additional subsystems to be incorporated into the new plant. Recommend this be addressed in the Masterplanning.
12. Ref Pg 55 – Power Plant – Also listed for the new Power plant are heating circulation pumps and expansion tanks. The existing PP has a supplemental heating boiler and presumably the new PP will as well. These further impacts planning level space requirements. Recommend both requirements be addressed.
13. Ref Pg 55 – Power Plant – A new Wastewater Treatment Plant (WWTP) is listed for the new PP. Recommend this be discussed in the Sewer System Section (Pg 54) as well for overall clarity and the additional planning level space requirements be accommodated.
14. Ref Pg 55 – Electrical Utility Lines – The Masterplan recommends consolidating utility cabling within utilidors and tunnels to maximize cabling life. While this will offer significant improvement in the life of the cabling, it will be expensive. Recommend clarifying if the intent is to place the majority of new and existing cabling within utilidors and tunnels or just where cable routing and utility tunnels are co-located.
15. Ref Pg 55 – Electrical Utility Lines – The Masterplan anticipates using equipment and panels in the existing powerplant to initially splice together new feeders from the new powerplant to serve existing facilities. This may not be possible. The existing equipment and panels are within the existing powerplant. By the time the new powerplant is fully operational the existing powerplant arch and associated powerplant building may be unuseable.
16. The Masterplan is based on no change in the design peak electrical demand and no change in design station population. I would agree with the station population as it is a factor that can be tightly controlled and, given the continued movement towards automation using technology, a

valid assumption. But, recommend reconsidering the decision to plan under the assumption the peak electrcial demand will not increase, especially for a 30-50 year planning horizon. I understand that several growth scenarios were modeled and evaluated using life cycle cost and that NSF directed the no electrical growth scenario be used for the masterplanning effort. However, going forward it is difficult to envision that the demand and pressure for more science opportunities will subside. Furthermore, the general trend in technology growth and development now is power intensive. The explosion of AI is an example. Inevitably this demand will be felt at Pole. And in terms of technologies ability to reduce other O&M costs, it may actually result in a lower life cycle cost long term, even if the electrcial demand increased. Also consider that as Pole moves towards implementation of renewables and reducing the carbon footprint, it will likely be based on increased electrification. While this too will actually reduce operating costs, it will also likely result in an increase in power demand and peak power limits. Even if the power plant generation equipment is capped, the electrical switchgear systems will likely require capacity increase. Here are some additional factors and program requirements to consider that will likely drive future power increases:

i. -surge housing
ii. -100 person construction camp
iii. -expanded g/s and logistics facilities
iv. -expanded new station
v. -adding heated indoor vehicle parking
vi. -development of Pole as regional hub for remote science; including regional traverse infrastructure
vii. -general movement towards electrification to achieve global decarbonization goals
viii. -likely migration to electric vehicles, possibly short range aircraft and drones included for local transportation and remote science support
ix. -possible migration to hybrid hydrogen/electric aircraft and vehicles for long range transportation that Pole would need to support
x. -general movement towards expanded capability and role of AI and resultant computing and power demand
xi. -never ending pressure for increased science support capacity

17. Ref Pg 56 - Comms Network - The Masterplan recommends that “every attempt” be made to route comms cabling in utilidors and tunnels to maximize cable life. The point is well taken that the ice sheet movement stresses cabling direct buried in the ice and shortens cable life. However, given the expense of utilitidors/tunnels recommend the Masterplan provide guidance for alternative installation procedures or protective measures for cabling that cannot reasonably be co-located within utilitidors/tunnels.
18. Ref Pg 56 - Space Assessment for RF Building Redesign - The Masterplan recommends to “conduct a thorough space assessment of RF Building size to support future facility redesign.”. If I understand this correctly, the RF Building is to be replaced and the assessment is to determine space requirements for the future facility. Irrespective of the results of the assessment, recommend providing generous unassigned space for future needs. Comms facilities are usually quite modest in size. Comms technology changes rapidly and almost all Comms buildings, it seems, are eventually outgrown. The incremental cost of increasing the building footprint during initial construction is probably much less than attempting future expansion or replacement.

Supporting HVAC and power systems can always be upgraded in future as loads grow and become more defined.

19. Ref Pg 57 – Alternative Energy – The masterplan in this section acknowledges the potential benefits of renewables in reducing carbon emissions and energy costs, notes the on-going technology research in this field, and suggests modeling of various renewable energy technologies and combinations for South Pole application. I offer the following comments:
    a. Recommend the Masterplan make a stronger statement in advancing the transition to renewables at Pole and establish more specific milestones or objectives. Given the 30-50 year time frame for the Masterplan it is hard to imagine South Pole Station not transitioning significantly, if not entirely well within that period.
    b. Recommend establishing a program to design, procure and install commercially available renewable energy technologies in the near term at South Pole Station. These initial installations could be integrated with the new powerplant energy system for benefit now, while providing on-site operational data for long term modeling and evaluation of various technology types, vendors, installation lessons learned, and operating and maintenance lessons learned to support informed decision making for scaling to more significant renewable integration in the Station energy profile. Solar PV and wind are maturing technologies now and operating at utility class; as are Li-ion energy storage systems. The challenge for Pole in waiting for the relevant research to be done and technology proven is that the Pole environment is so unique, it may not be realized. Testing likely technologies now provides a path. Futhermore, given the long project timelines for Pole, considering funding, design, procurement, logistics and construction constraints it will likely take decades to complete a large scale transition to renewables. The sooner the process starts, the greater the long term benefit.
    c. Consider including planning level space in the new power plant and associated electrical systems to accommodate integrating renewable energy systems.
20. From an overall energy planning perspective the Masterplan essentially continues with the legacy energy infrastructure profile. AN-8 is the primary energy source; used directly in most surface transportation equipment, aircraft, and in the production of electricity with diesel engine generators. It's 100% fossil fuel based. This is understandable given that USAP overall has standardized on AN-8 as the universal energy source; and logistic chains and energy infrastructure is standardized on it. While this likely falls outside the scope of the South Pole Station Masterplan, recommend that a long-term plan for energy infrastructure across the USAP program be undertaken. It is difficult to imagine that looking out a 30-50 year planning horizon that fossil fuels would continue to be the foundational energy source in Antarctica. Perhaps the long-term solution will involve electrification with renewables and green hydrogen for long term energy storage. Surface transportation might be EV or hybrid for long range travel. Aviation may transition to hydrogen based. In any case, the transition will likely need to be uniform across all stations, will take significant time and planning now will aid in this process.
21. Ref Pg 65 - Master Plan Concept One – Agree with this concept as the preferred plan. I offer the following comments:
    a. While the mass of building blocks within the Operations Zone is generally aligned with the prevailing winds, the individual buildings are arranged with some downwind of others and some oriented with their longitudinal axis perpendicular to the wind. This would not appear optimum from a snow drift standpoint. I recognize the masterplan recommends a detailed snow drift study as part of implementation, and I agree. However, presenting a more optimum planning level layout now might help assure the space and layout planning is realistic. Perhaps consider aligning the buildings with their

longitudinal axis parallel with the prevailing winds and the buildings situated along a single line perpendicular with the prevailing winds. If the powerplant, fuel storage and VMF were constructed in sequence first, then perhaps the logistics could be constructed in the areas vacated by the retrograded PP, shop and existing logistics, keeping the infrastructure development within the allocated block.

b. The concept will create quite a long walk from the Skiway to the future Station for passengers. Perhaps a passenger terminal and surface transportation will need to be planned for at the time.
c. Verify the arrangement provides sufficient maneuvering space for fuel traverse off loading and cargo traverse offloading.
d. The concept considers using one of the existing arches, once vacated, for heated vehicle storage. I assume the heated vehicle storage would be a new conditioned building within the existing arch, not the arch itself. Clarify.
e. Option Two includes increasing the runway setback to 2500’. Consider revisiting this for the preferred option. Accomplishing the greater set back now would de-conflict all surface operations (except NGO aircraft taxing) for the forseeable future. It eliminates potential conflict between airfield operations and the Clean Air Sector. And it opens up additional expansion areas for the Dark Sector as well as the Operations Zone.
f. Option Two utilizes an elevated building form for logistics rather than arches. Consider revisiting this for the preferred option. It is my understanding the current logistics operations have been hampered by the floor settlement in the arches, which challenges operating loading vehicles and maintaining storage racks within useable limits.

South Pole Observatory Feedback to the South Pole Station Master Plan

Submitted July 17 2024 by the South Pole Observatory

The South Pole Observatory (SPO) is composed of the experimental teams that operate the ongoing cosmic microwave background (CMB) experiments located at the NSF South Pole Station — the 10 meter South Pole Telescope (which also supports the Event Horizon Telescope (EHT)) and the BICEP telescopes — and the science collaborations that analyze the resulting data. SPO activities at the South Pole leverage the skills and efforts of more than two hundred scientists, of which roughly a third are senior scientists, a third are early career scientists including postdoctoral fellows, and a third are graduate students. In addition, over four hundred scientists are involved in the global EHT collaboration, with a similar distribution across career stages. These scientists are supported by a much smaller number (roughly 20) who deploy to the South Pole each austral summer to maintain and upgrade the instruments and to ensure that the data acquired is of the highest quality. In addition, SPO efforts are supported by four highly specialized and trained scientists, or engineers, who winter over at South Pole Station to keep the instrumentation operational and interface with the larger science teams.

We have reviewed the South Pole Station Master Plan and are pleased to see a well thought-out plan for addressing the maintenance and upgrade of the infrastructure of the South Pole Station. In this submission, we are writing as a group to provide a few high-level comments and suggestions for aspects of the master plan that most impact the ability of the station to support and advance world-class science. Many of us may also separately submit individual detailed comments on the document.

Our feedback addresses four areas for which we offer actionable suggestions:

1. The SPS Master Plan cannot sacrifice the world-class science conducted at the South Pole, which must continue to advance alongside the critical maintenance and upgrades of the infrastructure specified in the SPS Master Plan.
2. The proposed construction camp in the SPS Master Plan will be key to accommodating additional personnel for the infrastructure upgrades and / or house additional surge population.
3. The proposed increase in the capacity of the South Pole Overland Traverse (SPoT) in the SPS Master Plan will be critical to accommodating the increased infrastructure demands and reduce the burden on the LC130 fleet.
4. The SPS Master Plan refurbishment of the power plant should include considerations for increased power capacity and the incorporation of renewable energy, to reduce the needs for fuel.

The South Pole Station has been extremely successful in supporting a vibrant range of unique, world-class science. It is a valuable national resource for scientific research. Owing to modern facilities and infrastructure, and excellent logistical support, the NSF and USAP have made it possible for unique, world-class science using complex state-of-the-art instrumentation to be conducted by students, early career and senior scientists at the extremely cold and remote site.

The SPS Master Plan clearly sets out a set of maintenance and infrastructure priorities that are needed to ensure the station can support science into the future. The plan does not prioritize specific science projects, nor should it, but we feel strongly that it should be designed to be clear in its intent to sustain progress in fields of science that have proven their value at the South Pole, and, critically, to be flexible to support science yet to be envisioned.

Our SPS Master Plan feedback is directed at building such flexibility into the plan.

SPS Master Plan Feedback

1. Advance world-class science while maintaining and upgrading the infrastructure

We firmly believe that realizing the NSF vision for the station, as articulated in the SPS Master Plan, requires the continued advancement of world-class science while maintaining and upgrading the infrastructure. This vision is stated on page 6: 'the SPS master plan will ensure SPS remains a viable platform for supporting Antarctic Science for the next 35-50 years' by 'providing the flexibility to adapt to the evolving needs of U.S. scientific research in Antarctica over a 35–50 year planning horizon" and "ensuring an 'active and influential presence' in Antarctica in a manner consistent with U.S. stature in the international research community."

The SPS Master Plan includes a thorough list of maintenance and infrastructure projects. These projects "have been prioritized based on current project activities, current conditions, projected station and logistics resource availability, and anticipated project cost profiles" [page 76]. The projects are grouped into four phases, although no time scales are included. It is critical that NSF collaborate with the active South Pole science groups to understand how best to sequence the infrastructure projects and science activities to ensure the continuation of world-class science. The continuation of research and planning activities of the Antarctic science communities is also critical to the workforce training of the future scientific leaders.

We suggest that the SPS Master Plan specifically include a standing working group, such as a subcommittee of the OPP's Advisory Committee, composed of representatives from NSF and the science projects to work toward an optimum sequencing and implementation plan of infrastructure and science projects. This group should also include representatives of nationally recognized, high priority new science projects, so their logistical needs can be understood and all stakeholders can plan accordingly. Major science projects require many years of planning before construction can start, which provides adequate time for understanding and planning their infrastructure needs.

We believe that waiting for the completion of the SPS Master Plan maintenance and infrastructure projects before engaging in the planning of new major science projects will lead to the loss of U.S. science leadership.

2. Construction camp to accommodate the additional personnel required to upgrade infrastructure

We strongly endorse the inclusion of a construction camp, under all scenarios, in the plan to accommodate the extra personnel needed to carry out the planned maintenance and upgrades to infrastructure (recommendation OZ 6, pages 34 and 67). The ability to house additional "surge" to the population has proven to be essential during major construction efforts in the past, both for infrastructure and science projects. The construction camp would also help ensure the advancement of world-class science while infrastructure is being upgraded by allowing a sustaining number of scientists to be deployed throughout the construction period.

We suggest that the SPS Master Plan specifically include the ability to re-use the construction camp in the future to allow new infrastructure upgrades or new science construction to proceed without impacting the population required for ongoing operations and science projects.

3. The South Pole Overland Traverse (SPoT)

We strongly endorse the expansion of SPoT in the master plan. SPoT has already paid enormous dividends through the transportation of fuel, saving considerable cost and reducing the burden on the aging LC-130 fleet (page 24). We fully support the recommendation to increase the SPoT capacity to benefit from further savings and the ability to carry cargo (recommendations SPoT 1, 2, & 3, page 39). Using the SPoT to transport containers or large pre-constructed pieces of scientific equipment or infrastructure would reduce construction activities at the South Pole. **We suggest that the SPS Master Plan specifically include the ability for SPoT to transport large pre-constructed pieces of scientific equipment or infrastructure.**

4. Power generation capability, including renewable energy

We stress the importance of including flexibility in the power generation in the SPS Master Plan to adapt to the anticipated needs of future science projects. We agree with the master plan that increased power needs for future science projects is a concern (page 36). **We strongly endorse the plan to install a new power plant, including new generators (page 55).**

We suggest that the SPS Master Plan specifically include the ability to accommodate larger capacity generators. Any new power infrastructure (cabling, transformers, switchgears etc.) should be sized so it will not be the limiting factor if a greater generator capability is needed in the future of this long-term (50 year) plan. Furthermore, when the power plant is refurbished with new equipment (page 55), we suggest that the current set of 750 kW generators be replaced with 1MW or larger capacity generators.

We strongly endorse the inclusion of renewable energy in the SPS Master Plan (referred to as alternative energy within the plan, page 57, and covered by recommendations E 4 & 5, page 36) and we strongly encourage planning efforts to build on the initial study referenced in the report.

Summary

We thank you for the opportunity to provide feedback to the South Pole Station Master Plan. We look forward to the advancement of U.S. leadership in Antarctic science at the South Pole. If you have any follow-up questions please reach out to the SPO leadership by emailing [redacted].

SPO signatories in alphabetical order:

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Feedback to the South Pole Master Plan

Submitted July 17, 2024 by members of the BICEP/*Keck* Collaboration and the BICEP Array Replacement Tower project.

For the past several decades, the US Antarctic Program has supported successive generations of Cosmic Microwave Background experiments in the South Pole's radio-quiet Dark Sector. Since 2005, through close planning coordination between NSF and USAP contractors and the BICEP/*Keck* Collaboration, we have deployed a sequence of instruments including BICEP1, BICEP2, and *Keck Array,* and currently operate BICEP3 and BICEP Array. Owing to the unique characteristics of the South Pole site and enabled by USAP's unparalleled logistical support, the BICEP/*Keck* Collaboration has produced world-leading ground-based measurements of Cosmic Microwave Background polarization. Looking ahead, collaborative efforts between NSF and the BICEP Array Replacement Tower project aim to modernize existing support facilities to support the long-term operation of the BICEP Array telescope.

We have reviewed the South Pole Station Master Plan posted to the Federal Register (document number 2024-10420). We applaud NSF's ongoing planning effort to address the maintenance and upgrade needs of South Pole Station infrastructure. In this submission, we have collected detailed, point-by-point comments from our group on the Master Plan draft. This submission is intended to complement letters from the South Pole Observatory, the American Physical Society Division of Particles and Fields, and others, which provide higher-level comments on the aspects of the master plan that most impact the ability of the station to support ongoing and future world-class science.

We have grouped comments into several overarching themes, organized in sections below.

Master Planning Process

a) **Downselect Process**
    i) Page 3 states that "the Final Master Plan will only provide one scenario which best achieves the Vision established for the SPS." We suggest that the Master Plan include more information on how this downselection is planned and on the process that will be followed to select the final scenario.

b) **Quantification of Capital Investments**
    i) Page 76 contains "a draft prioritization of capital investments that support NSF's Vision for the future of SPS and implement the recommendations of the SPS Master Plan." We suggest that the Master Plan include more information on how the prioritization of capital investments will be determined. The ongoing process of collecting information on the risk, urgency, and costs associated with each concern and/or project should continue to advance in partnership with all stakeholders.

c) **Integration of Science Priorities**
    i) Page 4 states: "A scientific community engagement charrette was conducted prior to the development of this master plan to identify the broad needs and future priorities of the scientific research community across all major South Pole-based scientific fields." The

Master Plan draft does not mention the 2015 "Development of a Strategic Vision and Implementation Plan for the U.S. Antarctic Program at the National Science Foundation" decadal study from the National Academies. This report laid out a clear plan for the future priorities of the scientific research community and should be considered as an input in the master planning process. Additionally, since OPP's most recent 2015 science prioritization, the Academies have conducted agency-sponsored decadal reviews in fields of science strongly represented at the South Pole, including astronomy, particle physics, and geophysics. Priorities established by these studies should also be considered as inputs in this process.

ii) Page 4 also states: "The result of these efforts is a SPS Master Plan presenting a cohesive, integrated approach to future redevelopment of the South Pole area based on current (2024) supportable levels of scientific activity and support operations." The document does not describe why the current level of science support constitutes the chosen boundary condition for the master planning process and why this choice sufficiently fulfills NSF's mandate to support science at the Pole. The "2023 Update on Science Support and Infrastructure in Antarctica" Dear Colleague Letter released on June 12, 2023 (NSF 23-117) acknowledged that "[d]ue to compounding constraints, the upcoming 2023-2024 Antarctic season will be significantly curtailed." We argue that the master planning process should not base its long-term vision for scientific research at the South Pole based on current "significantly curtailed" logistical constraints.

iii) Page 6 states that "integrat[ing] the planning of future national science priorities" is one of the Goals of the SPS Master Plan. However, the projects outlined in the Capital Infrastructure Projects Prioritization (Section 8.2, page 76) include activities needed to maintain current experiments only. In keeping with its stated goals, the planning process should anticipate specific activities associated with highly-ranked future national science priorities.

d) **Ongoing input from Science Stakeholders**

i) As outlined in the response letter authored by the South Pole Observatory, we suggest the creation of a standing working group composed of representatives from NSF and the science projects. Regular communication within this group would ensure that medium- and long-term planning can proceed in partnership with—and leverage the expertise of—all stakeholders.

Key Resources

a) Station Population

i) Page 14 states that: "Large, long-standing science projects, such as IceCube and SPT, did not exist before the design of the Elevated Station, and their associated staffing, power, and ifnormation [sic] technology (IT) support needs were not anticipated. As a result, higher levels of support services at the station are required, including, but not limited to, IT and power generation technicians, fuel and cargo staff, and dining and emergency service personnel." This paragraph describes the growing level of support staff needed to operate the station as being caused by increased scientific activity. Rather, the majority of infrastructure and maintenance needs are driven by the Elevated Station's design, accommodations, and functionality. Consider the following examples:

1) Generator maintenance and upgrades are driven by runtime. The power plant's specifications and maintenance needs were effectively set during its design phase and have not been affected by the trajectory of science projects since then.
2) The number of emergency service personnel (physician, physician assistant, and ARFF team) is set by operational factors (US Air Force regulations) and the design population of the station. Emergency personnel are required on site regardless of the levels of science staffing.
3) The vast majority of IT infrastructure (satellite and radio communications, internal phone, Wi-Fi and computer networks) needs to exist and to be maintained regardless of how much scientific data is generated.

We suggest this paragraph be reworded to correct the implication that the growth of support staff levels are primarily driven by increased scientific activity.

ii) Page 67 recommends the "Construct[ion of] a Construction Camp. A Construction Camp will be established to accommodate up to 100 personnel." We fully endorse this recommendation as a key resource for supporting the surge personnel needed for infrastructure and science projects, on a flexible and occasional basis.

b) **South Pole Traverse**

i) Page 24 states that "due to the short length of the austral summer, additional SPoT missions are not currently possible." This statement could be reworded–as is, it might support the misconception that the primary limitation on traverse capacity is the duration of the austral summer season, rather than the current size of the SPoT fleet. As stated further below on the same page, SPoT capacity could be easily scaled through a larger volume of vehicles and staff. We applaud the fact that this possibility is clearly identified in the document, and hope that increasing Traverse capacity in this manner will emerge as a key recommendation of the Master Planning process.

c) **Alternative Energy**

i) Page 18 describes that "Two Hypertats are also equipped with solar panels that produce enough energy to support themselves and add a small amount of energy to the power grid." The past deployment of solar panels is an encouraging development of renewable energy at the Pole. The Master Plan should describe what the lessons learned are from this installation and what the implications are for existing and future structures at the Pole.

ii) Page 57 states that: "A techno-economic analysis for implementation of a hybrid renewable energy system at the South Pole in Antarctica, which currently hosts several high-energy physics experiments with nontrivial power needs [sic: punctuation] should be conducted." The NREL/Argonne study Babinec et al. (2024) (mentioned in the previous paragraph) conducted such an analysis in the context of the CMB-S4 project. The Master Plan should address takeaways and feasibility of next steps described in this study.

iii) Overall, this draft recommends conducting further renewable energy analysis/modeling work and identifies potential locations for full-size solar or wind fields. Experience at the South Pole has shown that progress in this area will benefit from an incremental, experimentation-based research and deployment plan. We recommend that a phased research and field deployment plan be developed in collaboration with science groups. Such a plan could utilize existing structures wherever possible (for example, the BART and/or blue buildings that are due to be raised).

d) **Spectrum Management**

i) Page 66 recommends the "Implement[ation of] a sustainable RF spectrum monitoring system to track background noise emissions and to provide a real-time aid for finding and resolving spurious EMI events." We applaud the fact that the need for spectrum management systems is addressed in the Master Plan and highlight that this has been an ongoing area of successful partnership between science stakeholders of the RFI working group and NSF as well as station staff. This coordination, which extends beyond just spectrum selection for the Land Mobile Radio system noted elsewhere in the Master Plan, could be noted in the text here and should be built upon in future planning.

Signed by (in alphabetical order of last name):
Rebecca Baturin, Smithsonian Astrophysical Observatory ([redacted])
Prof. John Kovac, Harvard University ([redacted])
Erik Nichols, Remote Science Services LLC ([redacted])
Dr. Matthew Petroff, Harvard University ([redacted])
Prof. Clement Pryke, University of Minnesota ([redacted])

Appendix: Copy Editing

Below we list a number of typographical, editorial, and punctuation mistakes found in the document.

- Page 3: "one scenario which" => "one scenario that"
- Page 5: There is a reference to "Figure 2.1," which is presumably the figure on the same page, but said figure is not labeled.
- Page 5: "Arc GIS" => "ArcGIS"
- Page 7 has duplicated identical paragraphs ("The Elevated Station and current SPS infrastructure [...] involve a variety of U.S. Federal agencies, such as:").
- Page 9: typo "MMAPO"
- Page 13: typo "DLS"
- Page 14: typo "ifnormation"
- Page 23: typo "to sure as a support hub for field science"
- Page 28: A stray graphic is blocking the caption for the Twin Otter photo
- Page 58: The nine bullet points for Option Two and Option Three appear to be identical.
- Page 68 and following: correct "rational" to "rationale"
- Page 76: "implement" => "implements"
- Page 78: "Survey" under USGS is improperly colored

July 3, 2024

Michael Hartinger

Space Science Institute and UCLA

Michael Gencarelli

Office of Polar Programs

National Science Foundation

RE: Request for Public Comment: Draft South Pole Station Master Plan, Document Citation 89 FR 48447, Document Number 2024-12410

Dear Michael Gencarelli and NSF Office of Polar Programs:

This letter provides feedback on the Draft South Pole Station Master Plan (SPSMP). I'm a Research Scientist at Space Science Institute and an Associate Researcher at UCLA. I'm writing in my own personal capacity, though these comments are from the perspective of a space weather researcher and Principal Investigator of an NSF project involving field work at South Pole Station (SPS), as well as someone who has deployed to SPS twice. I appreciate the opportunity to provide feedback on this report and furthermore all the work that went into generating this report over many years.

I support many of the assumptions and recommendations in the SPSMP, with a few exceptions reflected in these comments:

- Page 4 - "based on current (2024) supportable levels of scientific activity and support operations." 2024 and recent years represent a retreat from US scientific activities in Antarctica, with many field seasons cancelled/curtailed and future projects uncertain. A statement should ideally be added to the report here or elsewhere that 2024 represents a (hopefully) temporary low-point in US-scientific activities in Antarctica (e.g., https://www.nsf.gov/news/news_summ.jsp?cntn_id=309388&org=OPP) and that the aim moving forward would be for increased support for scientific activities at SPS. This would enable the US to continue playing a leading role in critical scientific research in the future, including for the International Polar Year 2032-2033 and beyond.
- On page 10, Deep Field Activities should be mentioned here as part of section 4 (History & Background), perhaps as they relate to each individual science area or as a group. Field Science is mentioned on page 23, but it's not tied to any specific research areas. Deep Field activities remain a key part of the overall scientific activities at SPS, and many field teams use labs and facilities at SPS to repair their equipment, test their instrumentation, etc., so they should be mentioned in a section on History & Background of SPS.

- On page 23 in the Field Science section, the words “...changing locations of scientific interest that may exclude SPS as a support hub…” should ideally be re-worded. While it’s true that scientific interests for individual projects and more narrow research areas may change year-to-year, it’s unlikely broader research interests would shift away from SPS as a de factor field support hub. Perhaps alternate words could be used e.g. “...changing locations of scientific interest that may require fewer resources from SPS as a support hub…”
- On page 38 under Field Science Concerns, “...needs to be evaluated if the SPS is going to be a hub…” should ideally be changed to “...needs to be evaluated in order to continue or expand SPS's role as a hub…” since SPS is already a de facto hub and the scientific rationale remains very strong for this to continue, for example to enable remote autonomous instruments critical to seismology, terrestrial weather/climate, space weather, and many other disciplines.

Related to the final comment above, I fully support the inclusion in the SPSMP of discussion of different traverse capabilities and their use in field research, in particular the light science traverse systems which are a new capability that has recently been demonstrated for projects at SPS and holds promise for increasing logistical support efficiencies for deep field activities.

Thank you again for the opportunity to provide feedback on this report and for all the work that went into the report. I look forward to future discussions with NSF OPP on how to best utilize SPS to support scientific activities, and many more years of groundbreaking research supported by SPS.

Sincerely,

Michael Hartinger

From:	Jeff Zivick
To:	SPMasterPlan
Subject:	[EXTERNAL] - Request for Public Comment: Draft South Pole Station Master Plan
Date:	Monday, June 3, 2024 5:26:13 PM

Greetings,

Thank you for the opportunity to submit the following comments.

Dr. Jeff Zivick

1. The document mentions a 10-year cycle for reviewing and adjusting future plans for the Amundsen-Scott South Pole station (SPS). Science changes continuously and it seems everyone would benefit from more frequent and regular collaborations between NSF and the science community to actively plan for and stay ahead of needed changes. Letting 10 years elapse is too long for changes to be identified and acted on.

2. Page 14: It is unclear how the Median summer population over the past 5 years was 147 but the Average summer population over the past 5 years was 128? This would require many years where the actual summer population is far below the Average value and only one or two instances where the population was much higher than Average. Are these numbers, as stated in the document, correct? Showing the actual populations per year would be helpful in understanding the demand for bed space.

3. Page 19: It would be helpful if citations were provided for these statements. "There is no shortage of wind at the South Pole, although the speeds are typically less than ideal for extended periods. Storm winds can exceed the turbine limitations.”

4. Page 19: Please clarify if the “prime power" consumption of 600kW is per generator or for all 3 generators. What is the total electrical power demand for the SPS?

5. Page 19: Please clarify if the power plant efficiency calculation is based on running one generator continuously, 2 generators continuously, or all 3 generators continuously.

6. Page 55: It surprising that the plan for a new power plant provides only the same capacity as the existing plant. This assumes no increase in demand which will inherently limit expanded scientific capabilities. Studies (as discussed on page 57) do not need to be complete for plans to be included in a Master Plan.

7. Did NSF consider using organic Rankine cycle (ORC) generators to capture and convert the waste heat of the diesel generators into electrical power to increase the overall efficiency of the power generation plant?

8. Page 55: There is no mention of renewable energy systems in the power plant plans which is in conflict with the statement on page 42, "Introduce renewable energy sources.” It is prudent and environmentally responsible to include renewable energy as part of the master plan. At the very least, the power distribution network and switching equipment could be

included to accommodate future expansion/inclusion of renewable power generation.

9. Page 56: Why is there no discussion of laying a fiber optic communications between SPS and McMurdo? It would create a massive increase in data capacity and reduce dependency on satellites. If fiber cables can be laid across the Pacific Ocean, surely they can be laid across the snow in Antarctica. New fiber could be laid anytime a traverse occurs.

Gencarelli, Michael O

From: Timothy Hurd <[redacted]>
Sent: Thursday, May 23, 2024 9:18 AM
To: SPMasterPlan
Subject: [EXTERNAL] - Proposed Ideas for development of educational program for planning, design, and construction of new South Pole Infrastructure and beyond.
Attachments: United Nations Sustainable Development Goals_240523_091456.docx

Please see attached document for summarized proposed ideas.

Dream Big,
Timothy Hurd

- Renew Antarctic Treaty to Include all nations under the alliance of the United Nations

Operation Green Ice

1. Convert South Pole Station to alternative clean energy.
2. Develop educational program that teaches students globally the process of planning, designing, and building the project in real time.
3. Work with existing universities, colleges, trade schools, National

Science Foundation organizations, and corporations.

4. Establish central command facility where guest speakers, lecturers, and professional experts will give in person and Broadcasted lectures.

Hope for Humanity

1. Develop sustainable micro economy's with the purpose of the care and support of orphans, elderly, and refugees.
2. Develop agriculture program that produces food and teachs agriculture science to students.
3. Develop Engeering program that

teaches and builds infrastructure

4. Develop educational program for teachers to teach as they learn.
5. Develop Apprenticeship program for skilled trades such as plumbing, carpentry, and electrical