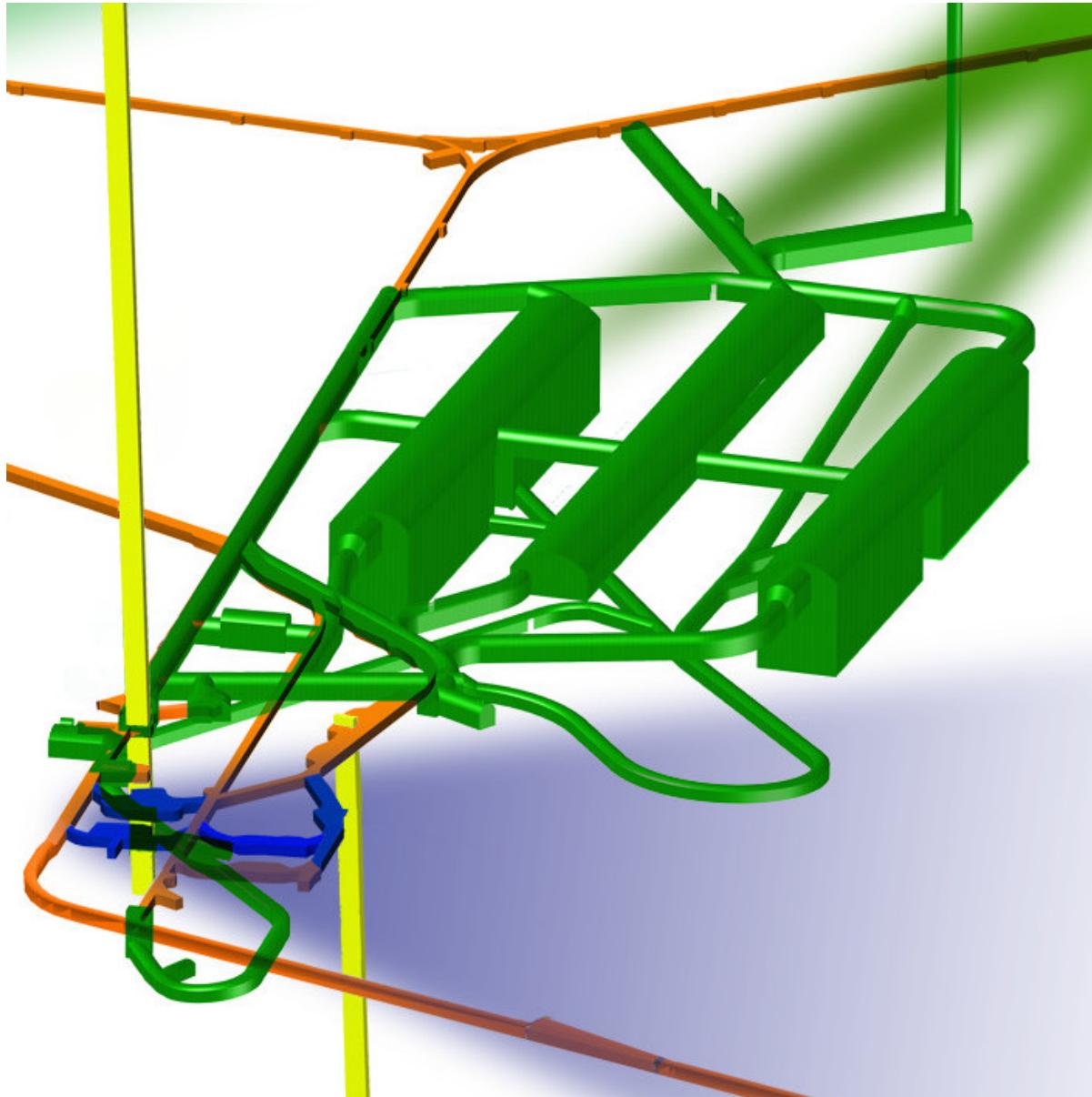


¹
²
The Long-Baseline Neutrino Facility (LBNF)
Far Site Conventional Facilities

³
Preliminary Design Report



⁴

⁵

October 6, 2015

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1 Todo list

2 now part of LBNF/beamline, right?	2
3 I am adding citations/references	3
4 citation	19
5 I don't find this; probably described in cryo annex	21
6 Need orig; too fuzzy	25
7 add link to new section on site preparation activities (coming from Josh)	25
8 This figure doesn't have dimensions on it; which figure do you want?	30
9 should be in surface chapter	41
10 Josh says: Need to determine whether this terminology is acceptable from Pepin	46

¹ Chapter 1

² Introduction

³ 1.1 The Long-Baseline Neutrino Facility for DUNE

⁴ The global neutrino physics community is developing a multi-decade physics program to measure
⁵ unknown parameters of the Standard Model of particle physics and search for new phenomena.
⁶ The program will be carried out as an international, leading-edge, dual-site experiment for neutrino
⁷ science and proton decay studies, which is known as the *Deep Underground Neutrino Experiment*
⁸ (*DUNE*). The detectors for this experiment will be designed, built, commissioned and operated
⁹ by the international DUNE Collaboration. The facility required to support this experiment, the
¹⁰ *Long-Baseline Neutrino Facility* (*LBNF*), is hosted by the Fermi National Accelerator Laboratory
¹¹ (Fermilab) and its design and construction is organized as a DOE/Fermilab project incorporating
¹² international partners.

¹³ Together LBNF and DUNE will comprise the world's highest-intensity neutrino beam at Fermilab,
¹⁴ in Batavia, IL, a high-precision near detector on the Fermilab site, a massive liquid argon time-
¹⁵ projection chamber (LArTPC) far detector installed deep underground at the Sanford Underground
¹⁶ Research Facility (SURF), 1,300 km away in Lead, SD, and all of the conventional and technical
¹⁷ facilities necessary to support the beamline and detector systems.

¹⁸ The strategy for executing the experimental program was presented in the LBNF/DUNE Con-
¹⁹ ceptual Design Report (CDR)^{cd-1r-cdr}[1]. The program has been developed to meet the requirements set
²⁰ out in the P5 report^{p5-report-04}[2] and takes into account the recommendations of the European Strategy
²¹ for Particle Physics[3]. It adopts a model in which U.S. and international funding agencies share
²² costs on the DUNE detectors, and CERN and other participants provide in-kind contributions to
²³ the supporting infrastructure of LBNF. LBNF and DUNE will be tightly coordinated as DUNE
²⁴ collaborators design the detectors and infrastructure that will carry out the scientific program.

²⁵ The scope of LBNF is

- ²⁶ • an intense neutrino beam aimed at the far site

- 1 • a beamline measurement system at the near site

2 now part of LBNF/beamline, right?

- 3 • conventional facilities at both the near and far sites

- 4 • cryogenics infrastructure to support the DUNE detector at the far site

5 The DUNE detectors include

- 6 • a high-performance neutrino detector located a few hundred meters downstream of the neu-
7 trino source
- 8 • a massive liquid argon time-projection chamber (LArTPC) neutrino detector located deep
9 underground at the far site

10 The scope of LBNF at SURF includes both conventional facilities (CF) and cryogenics infras-
11 structure to support the DUNE far detector. The requirements on LBNF derive from DUNE
12 Collaboration science requirements[4], which drive the space and functions necessary to construct
13 and operate the far detector. Environment, Safety and Health (ES&H) and facility operations
14 requirements also provide input to the design. The DUNE far detector is designed as a set of four
15 10-kt fiducial mass modules. The caverns and the services to the caverns will be as similar to one
16 another as possible to enable efficiency in design and construction as well as operation. Figure 1.1
17 shows the layout of the underground caverns that will house the detector modules, with a separate
18 cavern to house utilities and cryogenics systems.

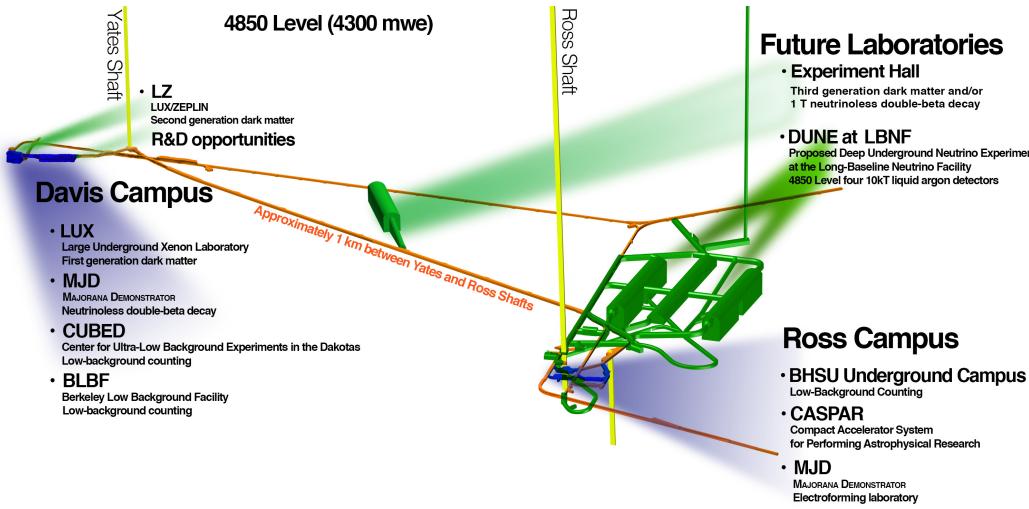


Figure 1.1: Underground cavern layout (SRK, Courtesy SURF)

1 1.2 The LBNF Far Site CF Preliminary Design Report

2 The *LBNF Far Site Conventional Facilities Preliminary Design Report* describes the preliminary
3 designs for the conventional facilities planned for the Sanford Underground Research Facility
4 (SURF), the LBNF Far Site. This document is an evolution of *LBNF/DUNE CDR Annex 3C: Conventional Facilities (CF) at the Far Site*, prepared for the LBNF/DUNE CD-1-Refresh Review
5 in July 2015. Design documents based on the LBNF/DUNE Conceptual Design Report volumes
6 and their annexes provide supplementary information to this document.

7
8 I am adding citations/references

9 1.3 Introduction to the Far Site Conventional Facilities

10 This PDR presents the scope and necessary steps required to develop the LBNF Far Site Conven-
11 tional Facilities (FSCF) at SURF. The key element of the FSCF is the underground space required
12 to install and support the operations of the multi-module DUNE far detector. An overview of the
13 4850L at SURF where the underground facilities will be developed is shown in 1.1.

14 While the SURF site already meets many requirements from the geological, scientific and engi-
15 neering standpoint, significant work is required to provide adequate space and the infrastructure
16 support needed for the experiment's installation and operation. The present and future state of the
17 site, evaluation and assessments of the facilities and the associated provisioning of infrastructure
18 such as power, water, plumbing, ventilation, etc., are described in this report. Also described are
19 the safety measures and planned steps to develop the surface and underground structures.

20 The scope of the FSCF includes design and construction for facilities on the surface and un-
21 derground at SURF. The underground conventional facilities include new excavated spaces at
22 the 4850L for the detector, utility spaces for experimental equipment, utility spaces for facility
23 equipment, drifts for access, as well as construction-required spaces. Underground infrastructure
24 provided by FSCF for the experiment includes power to experimental equipment, cooling systems
25 and cyberinfrastructure. Underground infrastructure necessary for the facility includes domestic
26 (potable) water, industrial water for process and fire suppression, fire detection and alarm, normal
27 and standby power systems, a sump pump drainage system for native and leak water around the
28 detector, water drainage to the facility-wide pump discharge system, and cyberinfrastructure for
29 communications and security. In addition to providing new spaces and infrastructure underground,
30 FSCF enlarges and provides infrastructure in some existing spaces for use, such as the access drifts
31 from the Ross Shaft to the new caverns. New piping is provided in the shaft for cryogens (gas
32 argon transfer line and nitrogen compressor suction and discharge lines) and water as well as power
33 conduits and cyberinfrastructure.

34 As it exists today, SURF has many surface buildings and utilities, some of which will be utilized for
35 LBNF. The scope of the above ground FSCF includes only that work necessary for LBNF, and not
36 for the general rehabilitation of buildings on the site, which remains the responsibility of SURF.

1 Electrical substations and distribution will be upgraded to increase power and provide standby
2 capability for life safety. Additional surface scope includes remodeling of an existing building for
3 both office space and to house an experiment/facility control room, and a new building to support
4 cryogen transfer from the surface to the underground near the existing Ross Shaft. To reduce risk
5 of failure of essential but aging support equipment during the construction and installation period,
6 several SURF infrastructure-reliability activities are included as early activities in LBNF. These
7 include completion of the Ross Shaft rehabilitation, rebuilding of hoist motors, and replacement
8 of the Oro Hondo fan; if not addressed, failure of any of this aging infrastructure could limit or
9 stop access to the underground.

10 This PDR is supported by a Design Report from the independent engineering firm, ARUP^[5].
arup:fscf100pdr

11 **1.4 Structure of this Report**

12 The scope of this Preliminary Design Report (PDR) is limited to the LBNF Far Site Conventional
13 Facilities (FSCF); the cryogenics infrastructure is not included.

- 14 1. This chapter provides a short introduction to LBNF, DUNE and the FSCF.
15 2. Chapter 2 summarizes the management structure for LBNF.
16 3. Chapter 3 describes the existing site conditions at SURF.
17 4. Chapter 4 describes the existing and planned surface buildings that will support the DUNE
18 far detector, planned for installation at the 4850L of SURF.
19 5. Chapter 5 discusses the planned underground excavation.
20 6. Chapter 6 describes the underground infrastructure that will directly interface to the DUNE
21 far detector modules.

¹ Chapter 2

² Project Management

intro-pm

³ 2.1 Project Structure and Responsibilities

⁴ The LBNF Project is charged by Fermilab and DOE to design and construct conventional and technical facilities needed to support the DUNE Collaboration. LBNF is organized as a DOE/Fermilab project incorporating in-kind contributions from international partners. At this time, the major international partner is CERN, the European Organization for Nuclear Research. LBNF works closely with DUNE through several coordinating groups to ensure scientific direction and coordination for executing the LBNF Project such that the requirements of the program are met.

¹⁰ LBNF works closely with SURF management to coordinate design and construction for the far site conventional facilities for the DUNE far detector. CERN is providing cryogenics equipment and engineering as part of the cryogenics infrastructure at SURF. The design and construction of LBNF is supported by other laboratories and consultants/contractors that provide scientific, engineering, and technical expertise. A full description of LBNF Project Management is contained in the LBNF/DUNE Project Management Plan^[?].

¹⁶ LBNF coordinates with DUNE through regular technical team interactions between the two Projects as well as more formally through the Joint Management Team where day-to-day management coordination occurs, and the Experiment-Facility Interface Group, where major issues regarding interfaces and items affecting both Projects are discussed. In addition, the Projects share common Project Office staff and systems, and include a single, integrated project resource-loaded schedule and configuration management system.

²² LBNF consists of two major L2 subprojects, Far Site Facilities and Near Site Facilities, coordinated through a central Project Office located at Fermilab. Each L2 Project consists of two large L3 subprojects corresponding to the conventional and technical facilities, respectively, at each site. The project organizational structure, which includes leadership from major partners, is shown in Figure 2.1.

²⁷ The LBNF Project team consists of members from Fermilab, CERN, South Dakota Science and

- ¹ Technology Authority (SDSTA), and BNL. The team, including members of the Project Office as
² well as the L2 and L3 managers for the individual subprojects, is assembled by the Project Director.
³ The Project team is shown to WBS Level 3 in Figure 2.2. Line management for environment, safety
⁴ and health, and quality assurance flows through the Project Director.
- ⁵ Through their delegated authority and in consultation with major stakeholders, the L2 Project
⁶ Managers determine which of their lower-tier managers will be Control Account Managers (CAMs)
⁷ for the Project WBS. L2 and L3 Project Managers are directly responsible for generating and
⁸ maintaining the cost estimate, schedule, and resource requirements for their subprojects and for
⁹ meeting the goals of their subprojects within the accepted baseline cost and schedule.

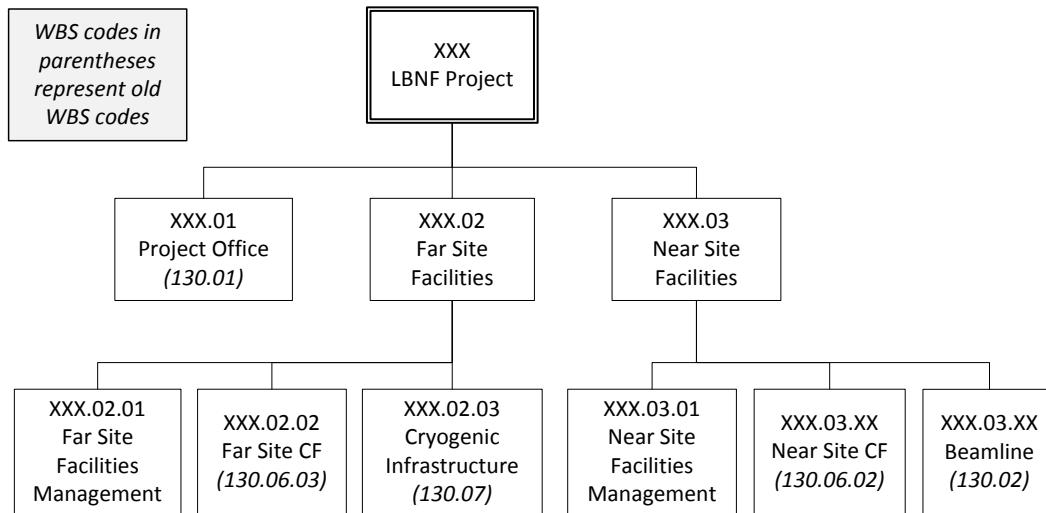


Figure 2.1: LBNF Work Breakdown Structure (WBS) to level 3

fig:lbnf

2.2 SDSTA and SURF

- ¹⁰ LBNF plans to construct facilities at SURF to house the DUNE far detector. SURF is owned by
¹¹ the state of South Dakota and managed by the SDSTA.
- ¹³ Current SURF activities include operations necessary for allowing safe access to the 4850L of the
¹⁴ former mine, which houses the existing and under-development science experiments. The DOE
¹⁵ is presently funding SDSTA ongoing operations through Lawrence Berkeley National Laboratory
¹⁶ (LBNL) and its SURF Operations Office through FY16; this is expected to change to funding
¹⁷ through Fermilab starting in FY17.
- ¹⁸ The LBNF Far Site Facilities Manager is also an employee of SDSTA and is contracted to Fer-
¹⁹ milab to provide management and coordination of the Far Site Conventional Facilities (CF) and
²⁰ Cryogenics Infrastructure subprojects. LBNF contracts directly with SDSTA for the design of the
²¹ required CF at SURF; whereas the actual construction of the CF will be directly contracted from
²² Fermilab. Coordination between SDSTA and the LBNF Project is necessary to ensure efficient
²³ operations at SURF. This will be facilitated via an agreement between SDSTA and Fermilab (not

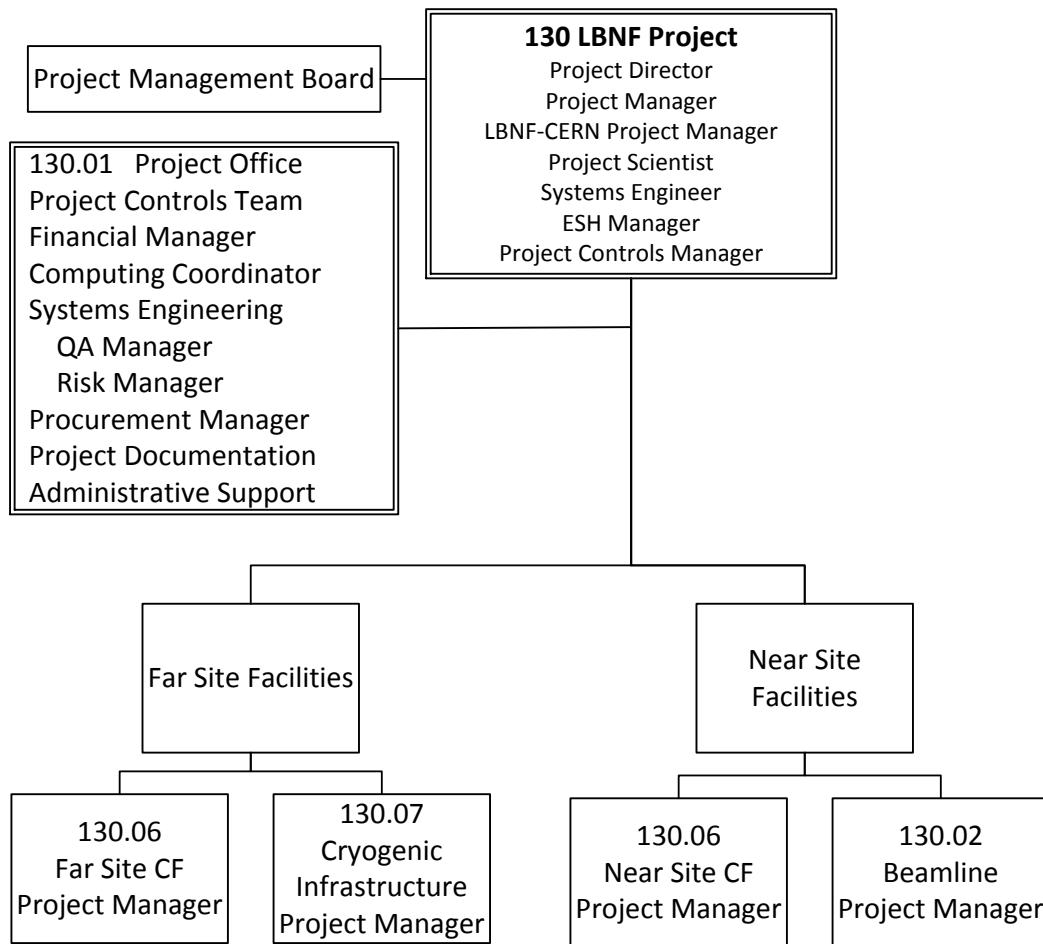


Figure 2.2: LBNF organization

fig:lbnf

1 yet available) that defines responsibilities and methods for working jointly on LBNF Project design
2 and construction. A separate agreement will be written for LBNF Operations.

3 **2.3 CERN**

4 The European Organization for Nuclear Research (CERN) is expected to significantly contribute
5 to LBNF with technical components, required to support the deployment of the DUNE detectors
6 and of the neutrino beamline.

7 **2.4 Coordination within LBNF**

8 The LBNF Project organization is headed by the LBNF Project Director, who is also the Fermilab
9 Deputy Director for LBNF; this person reports directly to the Fermilab Director.

10 Within Fermilab's organization, two new divisions are being created to execute the Far Site Fa-
11 cilities and Near Site Facilities subprojects. The heads of these divisions will report to the LBNF
12 Project Manager. Any personnel working more than half-time on these subprojects would typi-
13 cally be expected to become a member of one of these divisions, while other contributors will likely
14 be matrixed in part-time roles from other Fermilab Divisions. The heads of the other Fermilab
15 Divisions work with the L1 and L2 project managers to supply the needed resources on an annual
16 basis. The management structure described above is currently being transitioned into and will not
17 be fully in place until the Fall of 2015.

18 The LBNF WBS defines the scope of the work. All changes to the WBS must be approved by
19 the LBNF Project Manager prior to implementation. At the time of CD-1-Refresh, the LBNF
20 WBS is in transition. Both the current (post CD-1-Refresh Review) WBS is shown in Figure 2.1
21 to demonstrate how the scope will map from one WBS to the other. SDSTA assigns engineers
22 and others as required to work on specific tasks required for the LBNF Project at the SURF site.
23 This is listed in the resource-loaded schedule as contracted work from Fermilab for Far Site CF
24 activities. CERN and Fermilab are developing a common cryogenics team to design and produce
25 the Cryogenics Infrastructure subproject deliverables for the far site. CERN provides engineers
26 and other staff as needed to complete their agreed-upon deliverables. LBNF has formed several
27 management groups with responsibilities as described below.

28 **Project Management Board:** LBNF uses a Project Management Board to provide formal
29 advice to the Project Director on matters of importance to the LBNF Project as a whole. Such
30 matters include (but are not limited to) those that

- 31 • have significant technical, cost, or schedule impact on the Project
32 • have impacts on more than one L2 subproject

- 1
 - affect the management systems for the Project
- 2
 - have impacts on or result from changes to other Projects on which LBNF is dependent
- 3
 - result from external reviews or reviews called by the Project Director
- 4 The Management Board serves as the
 - 5 • LBNF Change Control Board, as described in the Configuration Management Plan [?]^{CMP-10760}
 - 6 • Risk Management Board, as described in the Fermilab Risk Management Procedure for
7 Projects [?]^{fnal-risk-mgmt}
- 8 **FSCF Neutrino Cavity Advisory Board:** The Far Site CF (FSCF) Project has engaged three
9 international experts in hard rock underground construction to advise it periodically through the
10 design and construction process regarding excavation at SURF. The Board meets at the request of
11 the FSCF-PM, generally on site to discuss specific technical issues. The Board produces a report
12 with its findings and conclusions for Project information and action.

13 **2.5 LBNF/DUNE Advisory and Coordinating Structures**

14 A set of structures is established to provide coordination among the participating funding agencies,
15 oversight of the LBNF and DUNE projects, and coordination and communication between the two
16 projects. These structures and the relationships among them are shown in Figure 2.3 and are
17 described in this section.^{fig:lbnfdune-org}

18 **2.5.1 International Advisory Council (IAC)**

19 The International Advisory Council (IAC) is composed of regional representatives, such as CERN,
20 and representatives of funding agencies that make major contributions to LBNF infrastructure or
21 to DUNE. The IAC acts as the highest-level international advisory body to the U.S. DOE and
22 the FNAL Directorate and facilitates high-level global coordination across the entire enterprise
23 (LBNF and DUNE). The IAC is chaired by the DOE Office of Science Associate Director for High
24 Energy Physics and includes the FNAL Director in its membership. The council meets as needed
25 and provides pertinent advice to LBNF and DUNE through the Fermilab Director.

26 Specific responsibilities of the IAC include, but are not limited to, the following:

- 27
 - During the formative stages of LBNF and DUNE the IAC helps to coordinate the sharing
28 of responsibilities among the agencies for the construction of LBNF and DUNE. Individual
29 agency responsibilities for LBNF will be established in bilateral international agreements with
30 the DOE. Agency contributions to DUNE will be formalized through separate agreements.

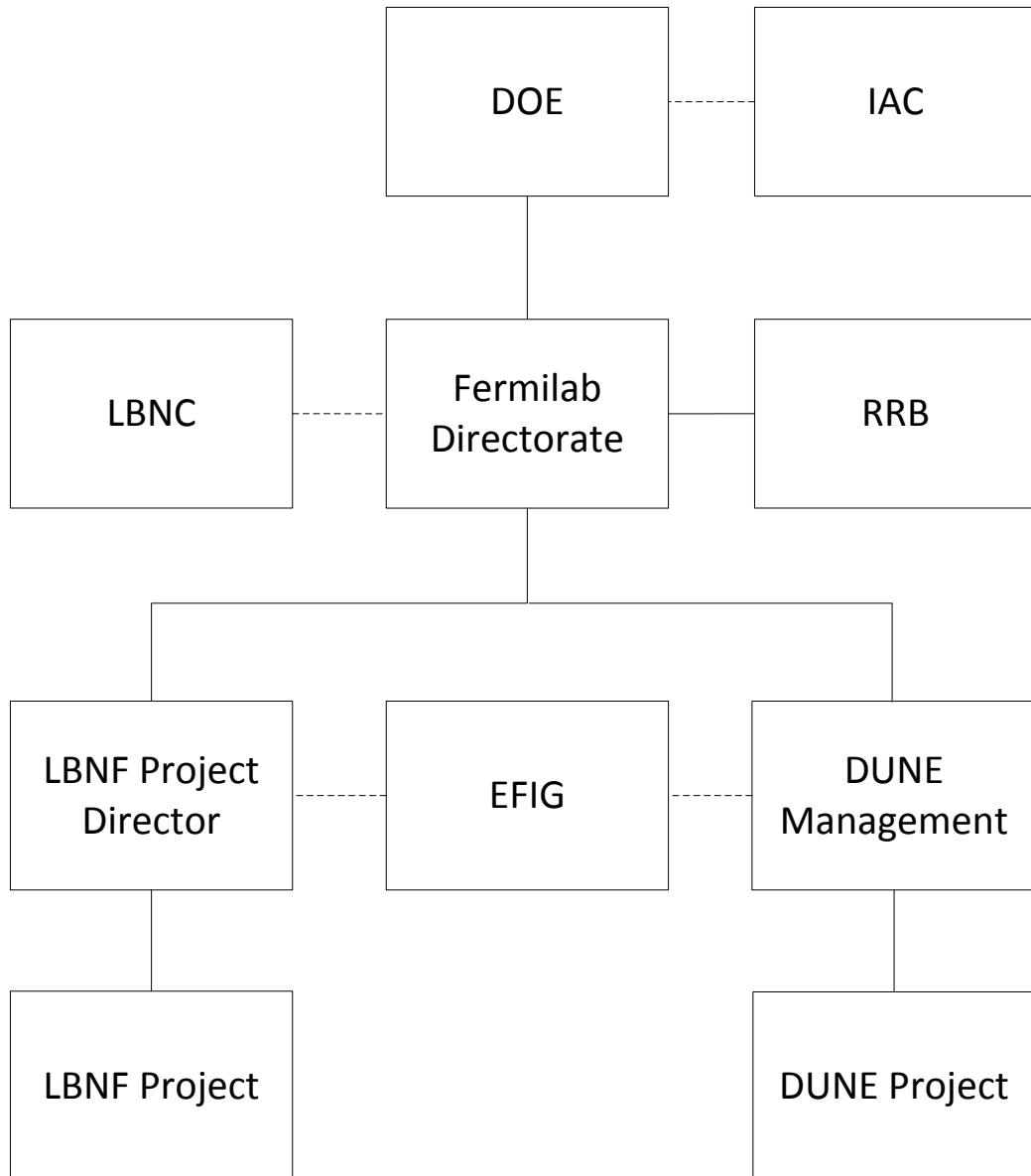


Figure 2.3: Joint LBNF/DUNE management structure

fig:lbnf

- 1 ● The IAC assists in resolving issues, especially those that cannot be resolved at the Resources
2 Review Boards (RRB) level, e.g., issues that require substantial redistributions of responsi-
3 bilities among the funding agencies.
 - 4 ● The IAC assists as needed in the coordination, synthesis and evaluation of input from Project
5 reports charged by individual funding agencies, LBNF and DUNE Project management,
6 and/or the IAC itself, leading to recommendations for action by the managing bodies.
- 7 The DUNE Co-Spokespersons and/or other participants within the Fermilab neutrino program
8 will be invited to sessions of the IAC as needed. Council membership may increase as additional
9 funding agencies from certain geographic regions make major contributions to LBNF and DUNE.

10 **2.5.2 Resources Review Boards (RRB)**

11 The Resources Review Boards (RRB) are composed of representatives of all funding agencies
12 that sponsor LBNF and DUNE, and of the Fermilab management. The RRB provides focused
13 monitoring and detailed oversight of each of the Projects. The Fermilab Director in coordination
14 with the DUNE RC defines its membership. A representative from the Fermilab Directorate chairs
15 the boards and organize regular meetings to ensure the flow of resources needed for the smooth
16 progress of the enterprise and for its successful completion. The managements of the DUNE
17 Collaboration and the LBNF Project participates in the RRB meetings and make regular reports
18 to the RRB on technical, managerial, financial and administrative matters, as well as status and
19 progress of the DUNE Collaboration.

20 There are two groups within the RRB: RRB-LBNF and RRB-DUNE. Each of these groups monitors
21 progress and addresses the issues specific to its area while the whole RRB deals with matters that
22 concern the entire enterprise. The RRB will meet biannually; these meetings will start with a
23 plenary opening session and be followed by RRB-LBNF and RRB-DUNE sessions. As DUNE
24 progresses toward experimental operations, RRB-Computing sessions will convene.

25 DUNE Finance Board members who serve as National Contacts from the sponsoring funding
26 agencies will be invited to RRB sessions.

27 The RRB employs standing DUNE and LBNF *Scrutiny Groups* as needed to assist in its responsi-
28 bilities. The scrutiny groups operate under the RRB, and provide detailed information on financial
29 and personnel resources, costing, and other elements under the purview of the RRB.

30 Roles of the RRB includes:

- 31 ● assisting the DOE and the FNAL Directorate, with coordinating and developing any required
32 international agreements between partners
- 33 ● monitoring and overseeing the Common Projects and the use of the Common Funds
- 34 ● monitoring and overseeing general financial and personnel support

- 1 ● assisting the DOE and the FNAL Directorate with resolving issues that may require reallo-
2 cation of responsibilities among the Project’s funding agencies
- 3 ● reaching consensus on a maintenance and operation procedure, and monitoring its function
- 4 ● approving the annual construction, and maintenance and operation common fund budget of
5 DUNE

6 **2.5.3 Fermilab, the Host Laboratory**

- 7 As the host laboratory, Fermilab has a direct responsibility for the design, construction, commis-
8 sioning and operation of the facilities and infrastructure (LBNF) that support the science program.
- 9 In this capacity, Fermilab reports directly to the DOE through the Fermilab Site Office (FSO).
- 10 Fermilab also has an important oversight role for the DUNE Project itself as well as an impor-
11 tant coordination role in ensuring that interface issues between the two Projects are completely
12 understood.
- 13 Fermilab’s oversight of the DUNE Collaboration and detector construction project is carried out
14 through
 - 15 ● regular meetings with the Collaboration leadership
 - 16 ● approving the selection of Collaboration spokespersons
 - 17 ● providing the Technical and Resource Coordinators
 - 18 ● convening and chairing the Resources Review Boards
 - 19 ● regular scientific reviews by the PAC and LBNC
 - 20 ● Director’s Reviews of specific management, technical, cost and schedule aspects of the de-
21 tector construction project
 - 22 ● other reviews as needed

23 **2.5.4 DUNE Collaboration**

- 24 The Collaboration, in consultation with the Fermilab Director, is responsible for forming the
25 international DUNE Project team responsible for designing and constructing the detectors. The
26 Technical Coordinator (TC) and Resource Coordinator (RC) serve as the lead managers of this
27 international project team and are selected jointly by the spokespersons and the Fermilab Director.
28 Because the international DUNE Project incorporates contributions from a number of different
29 funding agencies, it is responsible for satisfying individual tracking and reporting requirements

¹ associated with the different contributions.

² 2.5.5 Long-Baseline Neutrino Committee (LBNC)

³ The Long-Baseline Neutrino Committee (LBNC), composed of internationally prominent scientists
⁴ with relevant expertise, provides external scientific peer review for LBNF and DUNE regularly.
⁵ The LBNC reviews the scientific, technical and managerial decisions and preparations for the
⁶ neutrino program. It acts in effect as an adjunct to the Fermilab Physics Advisory Committee
⁷ (PAC), meeting on a more frequent basis than the PAC. The LBNC may employ DUNE and LBNF
⁸ Scrutiny Groups for more detailed reports and evaluations. The LBNC members are appointed by
⁹ the Fermilab Director.

¹⁰ 2.5.6 Experiment-Facility Interface Group (EFIG)

¹¹ Close and continuous coordination between DUNE and LBNF is required to ensure the success
¹² of the combined enterprise. An Experiment-Facility Interface Group (EFIG) was established in
¹³ January 2015 to oversee and ensure the required coordination both during the design/construction
¹⁴ and operational phases of the program. This group covers areas including:

- ¹⁵ • interface between the near and far detectors and the corresponding conventional facilities
- ¹⁶ • interface between the detector systems provided by DUNE and the technical infrastructure
¹⁷ provided by LBNF
- ¹⁸ • design and operation of the LBNF neutrino beamline

¹⁹ The EFIG is chaired by two deputy directors of Fermilab. Its membership includes the LBNF
²⁰ Project Director, Project Manager and Project Scientist, and the DUNE Co-Spokespersons, Tech-
²¹ nical Coordinator, Resource Coordinator and the CERN-LBNF Project Manager. In consultation
²² with the DUNE and LBNF management, the EFIG Chairs will extend the membership as needed
²³ to carry out the coordination function. In addition, the DOE Federal Project Director for LBNF,
²⁴ the Fermilab Chief Project Officer, and a designated representative of the South Dakota Science
²⁵ and Technology Authority (SDSTA) will serve ex officio. The EFIG Chairs designate a Secretary
²⁶ of the EFIG, who keeps minutes of the meetings and performs other tasks as requested by the
²⁷ Chair.

²⁸ It is the responsibility of the EFIG Chairs to report EFIG proceedings to the Fermilab Director and
²⁹ other stakeholders. It is the responsibility of the DUNE spokespersons to report EFIG proceedings
³⁰ to the rest of the Collaboration. The EFIG meets weekly or as needed.

¹ Chapter 3

² Existing Site Conditions

³ site-cond The SDSTA currently operates and maintains the Sanford Underground Research Facility (SURF)
⁴ at the former Homestake mine in Lead, South Dakota. The SURF property comprises 186 acres
⁵ on the surface and 7,700 acres underground. The SURF Surface Campus includes approximately
⁶ 253,000 gross square feet (gsf) of existing structures. Using a combination of private funds through
⁷ T. Denny Sanford, South Dakota Legislature-appropriated funding, and a federal Department
⁸ of Housing and Urban Development (HUD) Grant, the SDSTA has made significant progress
⁹ in stabilizing and rehabilitating the SURF facility to provide for safe access and prepare the
¹⁰ site for new laboratory construction. These efforts have included dewatering of the underground
¹¹ facility and mitigating and reducing risks independent of the former Deep Underground Science
¹² and Engineering Laboratory (DUSEL) efforts and funding.

¹³ fig:regional-context Figure 3.1 shows SURF's location within the region as a part of the northern Black Hills of South
¹⁴ fig:surf-complex Dakota. Figure 3.2 outlines the SURF site in relationship to the city of Lead, South Dakota, and
¹⁵ points out various significant features of Lead including the surrounding property that still remains
¹⁶ under the ownership of Barrick Gold Corporation.

¹⁷ 3.1 Existing Site Conditions Evaluation

¹⁸ ond-eval The existing facility conditions were assessed as part of the DUSEL Preliminary Design and docu-
¹⁹ mented in the DUSEL PDR, Section 5.2.4, [10] which is excerpted below. The portions of DUSEL's
²⁰ assessment included here have been edited to reflect current activities and to reference only that
²¹ portion of the assessment that are pertinent to the LBNF Project. References to the DUSEL
²² Project are from that time, and are now considered historic.

²³ Site and facility assessments were performed during DUSEL's Preliminary Design phase by HDR
²⁴ to evaluate the condition of existing facilities and structures on the Yates, and Ross Campuses.
²⁵ The assessments reviewed the condition of buildings proposed for continuing present use, new
²⁶ use, or potential demolition. Building assessments were performed in the categories of architec-

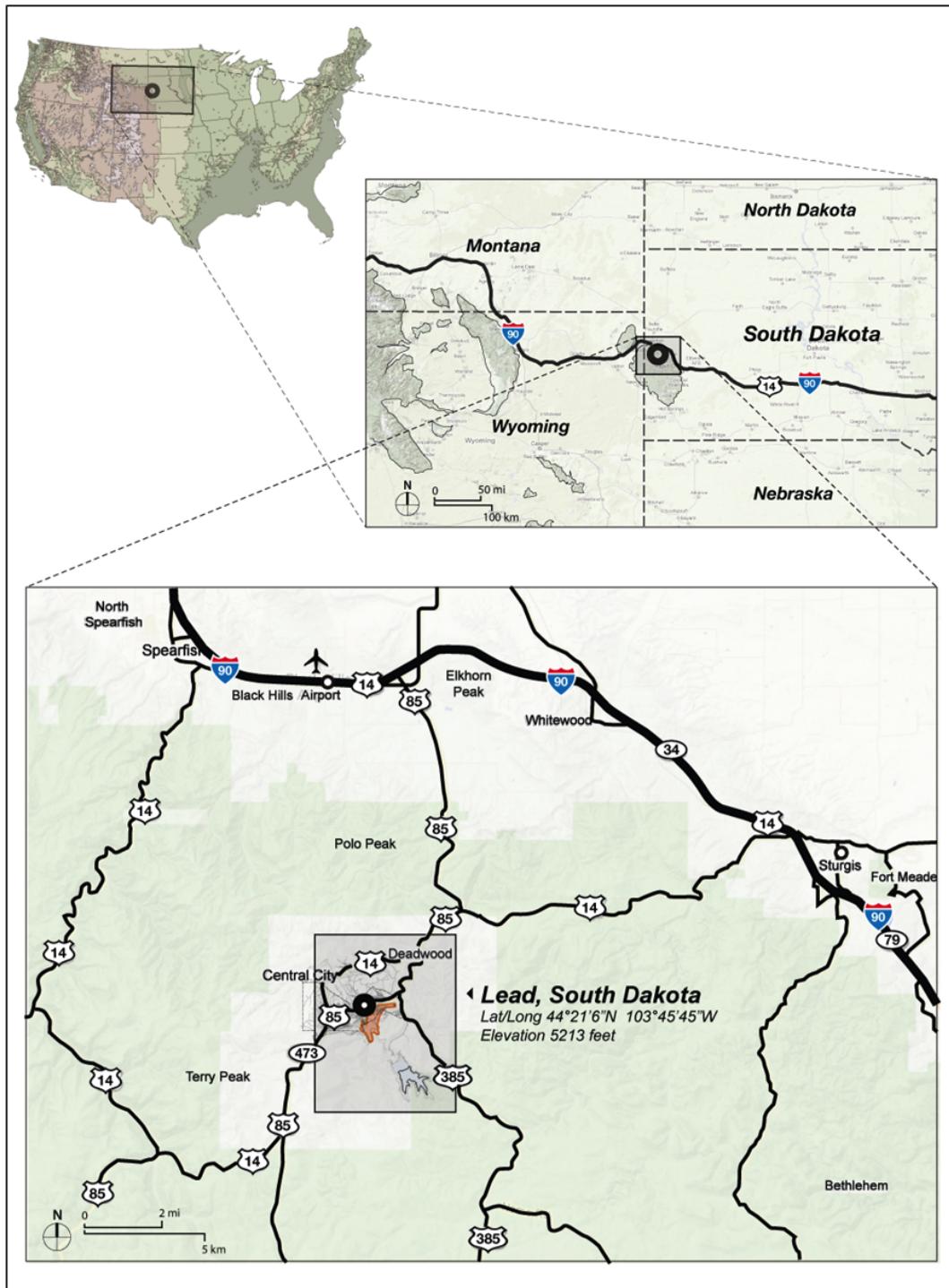


Figure 3.1: Regional context showing the city of Lead, South Dakota. (Dangermond Keane Architecture, Courtesy SURF)

fig:regi

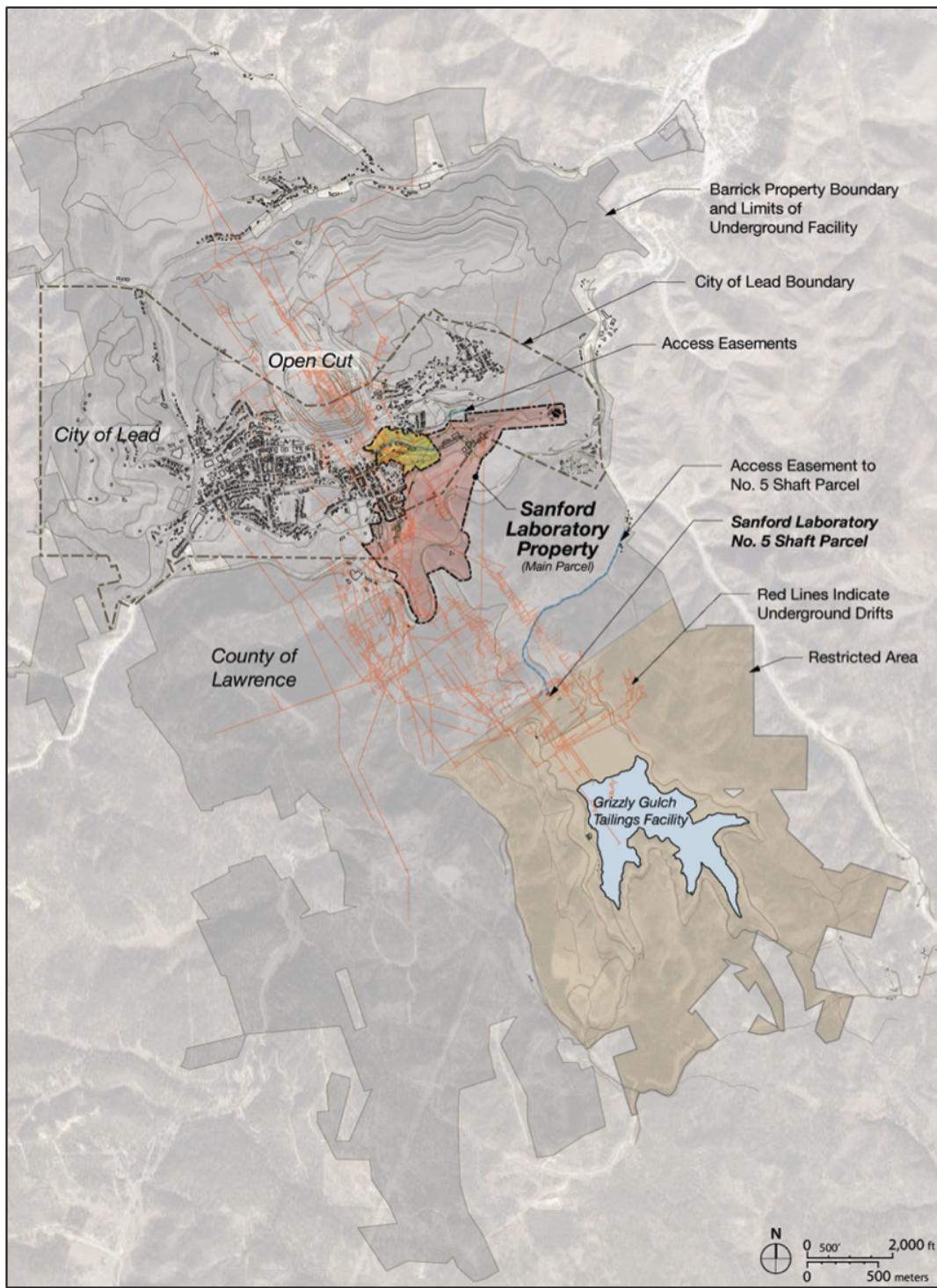


Figure 3.2: SURF Complex shown in the context of the city of Lead, South Dakota, and the property remaining under ownership of Barrick. Area shown in yellow is a potential future expansion of the SDSTA property. [Dangermond Keane Architecture, Courtesy of SURF]

fig:surf

tural, structural, mechanical/electrical/plumbing (MEP), civil, environmental, and historic. Site assessments looked at the categories that included civil, landscape, environmental, and historic. Facility-wide utilities such as electrical, steam distribution lines, water, and sewer systems were also assessed. The assessment evaluation was completed in three phases. The detailed reports are included in the appendices of the DUSEL PDR as noted and are titled:

- Phase I Report, Site Assessment for Surface Facilities and Campus Infrastructure to Support Laboratory Construction and Operations (DUSEL PDR Appendix 5.E)
- Phase II Site and Surface Facility Assessment Project Report (DUSEL PDR Appendix 5.F)
- Phase II Roof Framing Assessment (DUSEL PDR Appendix 5.G)

The site and facility assessments outlined above were performed during DUSEL's Preliminary Design as listed above and includes a review of the following:

- Buildings proposed for reuse were evaluated for preliminary architectural and full structural, environmental, and historic assessments
- Buildings proposed for demolition were evaluated for preliminary historic assessments
- Preliminary MEP assessments were performed on the Ross Substation, #5 Shaft fan, Oro Hondo fan, Oro Hondo substation, and general site utilities for the Ross, Yates, and Ellison Campuses
- The waste water treatment plant (WWTP) received preliminary architectural and structural assessments and a full MEP assessment
- Preliminary civil assessments of the Kirk Portal site and Kirk to Ross access road were also completed.

3.2 Evaluation of Geology and Existing Excavations

LBNF Far Site facilities are planned to be constructed at SURF which is being developed within the footprint of the former Homestake Gold Mine, located in Lead, South Dakota. The accessible underground mine workings are extensive. Over the life of the former gold mine over 360 miles of drifts (tunnels) were mined and shafts and winzes sunk to gain access to depths in excess of 8,000 feet. A number of underground workings are being refurbished by SURF and new experiments are being developed at the 4850L, the same level as proposed for LBNF facilities. Geotechnical investigations and initial geotechnical analyses were completed for the DUSEL Preliminary Design [10] and are described in detail in the DUSEL PDR. Additional geotechnical investigation and analysis was performed in 2014 specific to the LBNF project. Below are summaries these two effort, including work completed for DUSEL that is applicable to LBNF as excerpted from the DUSEL Preliminary Design Report, Chapter 5.3. Much of the work completed for the alternative

- ¹ detector technology considered during DUSEL [water Cherenkov detector (WCD)] is also applicable
² to the current design at the 4850L.

³ 3.2.1 Geologic Setting

⁴ SURF is sited within a metamorphic complex containing the Poorman, Homestake, Ellison and
⁵ Northwestern Formations (oldest to youngest), which are sedimentary and volcanic in origin. An
⁶ amphibolite unit (Yates Member) is present within the lower known portions of the Poorman
⁷ Formation. The LBNF cavity has been located in the Poorman formation to isolate it from the
⁸ remainder of the level. The layout adopted on the 4850L attempts to optimize the needs for
⁹ ventilation isolation, access control, and orientation relative to the beam line.

¹⁰ 3.2.2 Rock Mass Characteristics: LBNF

¹¹ Following a similar strategy as DUSEL, the LBNF project initiated a second geotechnical program
¹² in 2013 to evaluate the specific location under consideration and evaluate its appropriateness for
¹³ the proposed design. This was undertaken in two phases. The first phase was a mapping of the
¹⁴ existing spaces surrounding the proposed rock mass using both visual techniques and laser scanning
¹⁵ to understand the rock mass and inform the scope of the second phase. The second phase included
¹⁶ drilling of four HQ (2.5-in diameter) core holes ranging in length from 477 to 801 feet as well as
¹⁷ two 6-in diameter core holes ~30 ft each. The smaller diameter cores were then evaluated for the
¹⁸ following characteristics:

- ¹⁹ • core recovery percent
- ²⁰ • rock quality designation (RQD) percent
- ²¹ • rock type, including color, texture, degree of weathering, and strength
- ²² • mineralogy and presence of magnetic sulfides
- ²³ • character of discontinuities, joint spacing, orientation, aperture
- ²⁴ • roughness, alteration, and infill (if applicable)

²⁵ Representative samples were selected from the overall core to test material strength and chemi-
²⁶ cal characteristics. The ^{tip:core-loc} geotechnical site investigations area on the 4850L, showing boreholes is
²⁷ presented in Figure 3.3.

²⁸ The holes from which the smaller diameter core was removed were studied in several ways. An
²⁹ absolute survey was conducted to allow the core holes to be plotted relative to cavern designs. An
³⁰ optical televiewer was passed through each small hole to visualize the rock mass. This technique
³¹ allows visualization of foliation, joint openings, healed joints, and geological contact between rock

types. An acoustical imaging device was also used in one hole to complement the optical information. The permeability of the rock was tested by pressurizing the small holes at various intervals to determine if joints allowed for the flow of water outside of the holes (hydraulic conductivity). In all cases, the hydraulic conductivity was well below what can be accomplished using manmade techniques such as grouting. Two of the small holes were plugged and instrumented to determine if water would flow into the holes over time. This test found very low flow rates (.0013 – .0087 gpm). Ongoing evaluation of pressure build in these holes was inconclusive, as blast induce fracturing near the existing drifts allow the holes to depressurize outside of the test instruments.

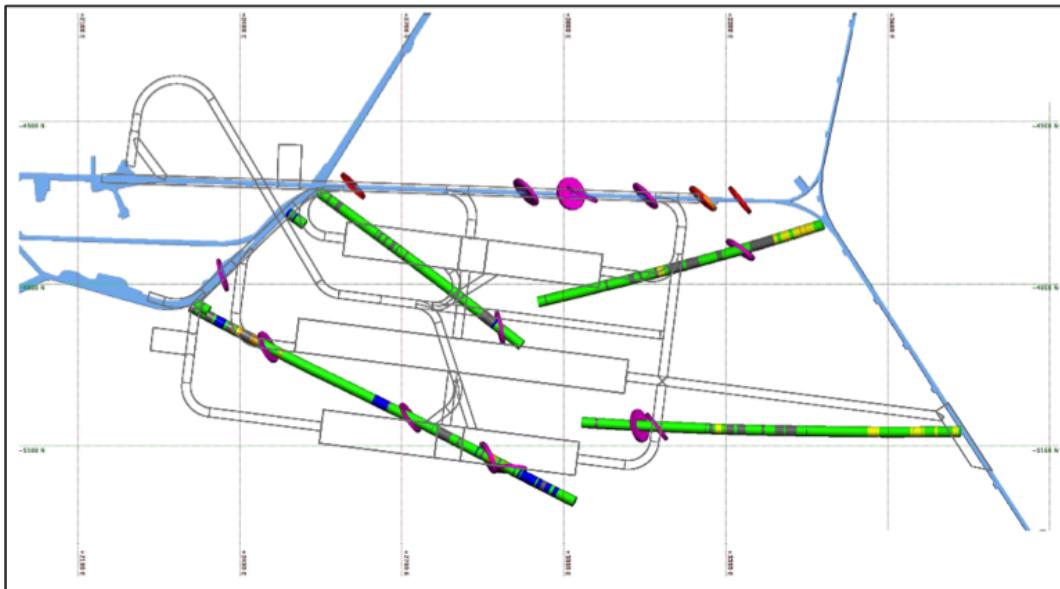


Figure 3.3: LBNF core locations and geological features

fig:core

The larger (6-in) diameter cores and holes were used for strength and stress testing. In-situ stress was tested by drilling a smaller diameter hole first, then gluing a strain gage at 30 – 36 feet within the depth. As the larger diameter core was removed, this strain gage recorded the relaxation of the rock. The removed core was re-drilled to provide smaller diameter samples at specific orientations for strength testing, as the strength of the material varies based on applied force direction relative to the foliation of the rock. These samples were also tested for time dependent movement.

LBNF followed a review approach for the analysis performed by Arup by enlisting industry leaders as part of a Neutrino Cavity Advisory Board (NCAB). This board reviewed the philosophy and results of the geotechnical investigation program as well as the preliminary excavation design. Their conclusions indicated that no additional drilling would be required to provide design information for the project and the overall design approach was appropriate. They provided many recommendations that will benefit the advancement of design, for example, the replacement of wire mesh with fiber-reinforced shotcrete in all excavations, reduction of the distance between caverns, and optimization of the ground support in order to replace cable support wherever possible.

For further details, see Arup's Geotechnical Interpretive Report [11].

citation

3.2.3 Geologic Conclusions

The recovery of rock cores, plus geologic mapping, was performed to determine if discontinuities in the rock mass exist that would cause difficulties in the construction and maintenance of planned excavations. In general, the proposed locations of the excavations do not appear to be complicated by geologic structures that cause undue difficulties for construction. This information, along with measurement of in situ stresses, allowed initial numerical modeling of the stresses associated with the anticipated excavations. A sample of some of the modelling done is provided in Figure 3.4.

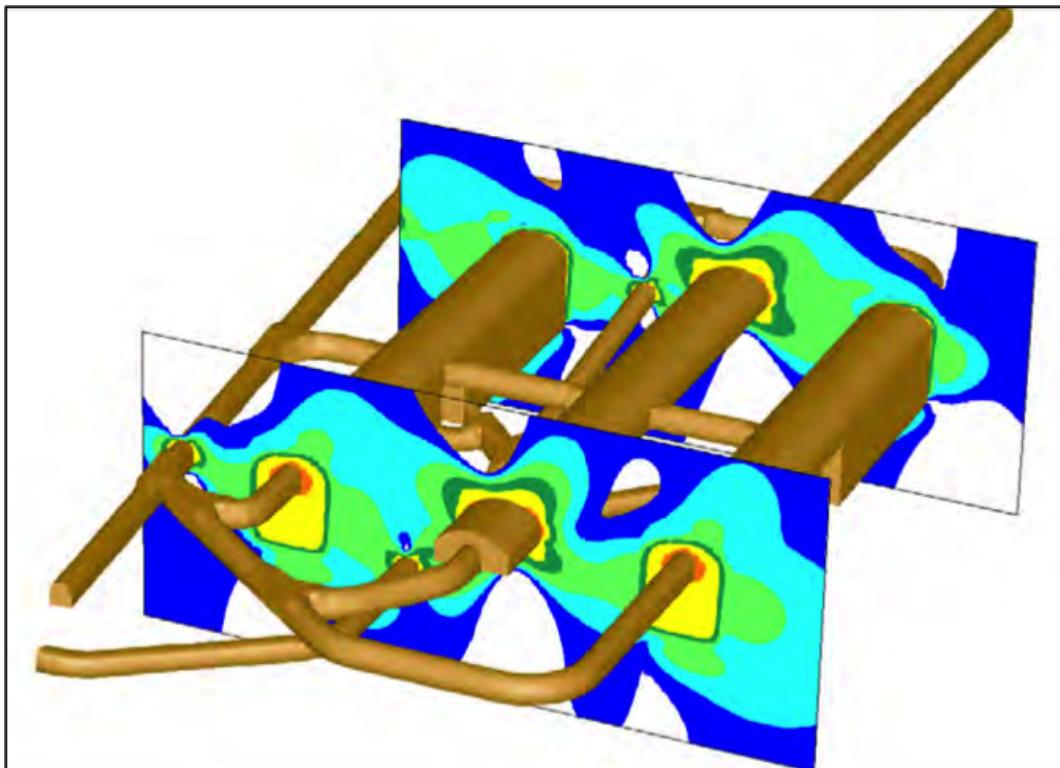


Figure 3.4: Contour of stress safety factor indicating influences between caverns

¹ Chapter 4

² Surface Facility

³ 4.1 Existing Surface Facility

⁴ The SURF property of 186 acres consists of steep terrain and man-made cuts dating from its
⁵ mining history. There are approximately 50 buildings and associated site infrastructure in various
⁶ states of repair. A select few of these buildings at the Ross Complex and the main utilities are
⁷ needed by the LBNF experiment and will be upgraded and rehabilitated as necessary. A layout
⁸ of the overall SURF architectural site plan for the LBNF Project is found in Figure 4.1. The
⁹ Ross Complex will house the facility construction operations, the Command and Control Center
¹⁰ for the experiment and facility, a new Cryogenics Compressor building, and will continue to house
¹¹ the SURF maintenance and operations functions. Layout of surface facilities in the vicinity of the
¹² Ross Shaft is shown in Figure 4.2.

¹³ 4.2 Surface Buildings

¹⁴ Surface facilities utilized for the LBNF include those necessary for safe access and egress to the
¹⁵ underground through the Ross Shaft, as well as spaces for offices. Existing buildings necessary for
¹⁶ LBNF will be rehabilitated to code-compliance and to provide for the needs of the experiment.
¹⁷ The only new building will be to provide space for compressors used to transfer cryogens from
¹⁸ new receiving tanks on surface to the detectors underground. The existing Ross Dry building
¹⁹ will be modified to provide space for a surface control room (the Command and Control Center)
²⁰ and offices. Much of the text below is excerpted from the 100% Preliminary Design Report [12]
²¹ provided by Arup, USA.

²² A new building and surrounding concrete slabs are planned to provide space for equipment to allow
²³ conversion of liquid argon and liquid nitrogen to gaseous form and compression of the nitrogen for
²⁴ delivery through the shaft to the underground where they are returned to liquid form as described
²⁵ later in this PDR in Chapter 4.

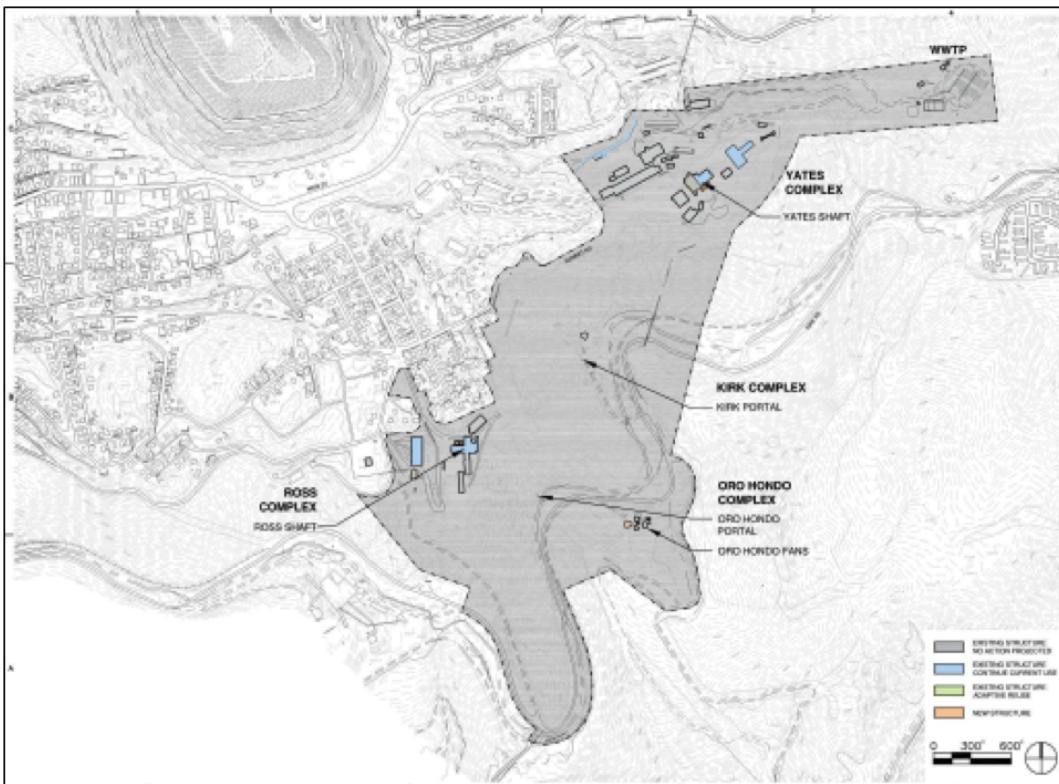


Figure 4.1: Architectural site plan (HDR)

fig:arch

I don't find this; probably described in cryo annex

- 2 The location of this building was selected based on proximity to the shaft and truck accessibility, as thousands of truckloads of argon are required to fill the detectors underground.
- 4 In addition to housing nitrogen compressors inside the building, concrete slabs are provided around the building to allow for installation of argon and nitrogen receiving dewars for truck unloading, vaporizers to boil the liquids into gas, and electrical transformer to supply power to the (4) 1,500 Hp compressors, a standby generator, and cooling towers to reject heat generated through compression. All equipment except the cooling towers and associated circulation pumps is provided by the Cryogenics Infrastructure Project. The architectural layout of this building and surrounding equipment is provided in Figure 4.3.

4.2.1 Ross Dry

- 11 The Ross Dry building is in use by SURF to provide office and meeting space in addition to men's and women's dry facilities and emergency response capabilities. As a scope option, the design has included a complete renovation of this building to upgrade those existing capabilities and add space for an above-ground Control and Command Center. This control center itself is not a scope option, but all other refurbishment is. This design includes flexible space that can be tailored to individual user's needs as the project transitions from construction to operations.

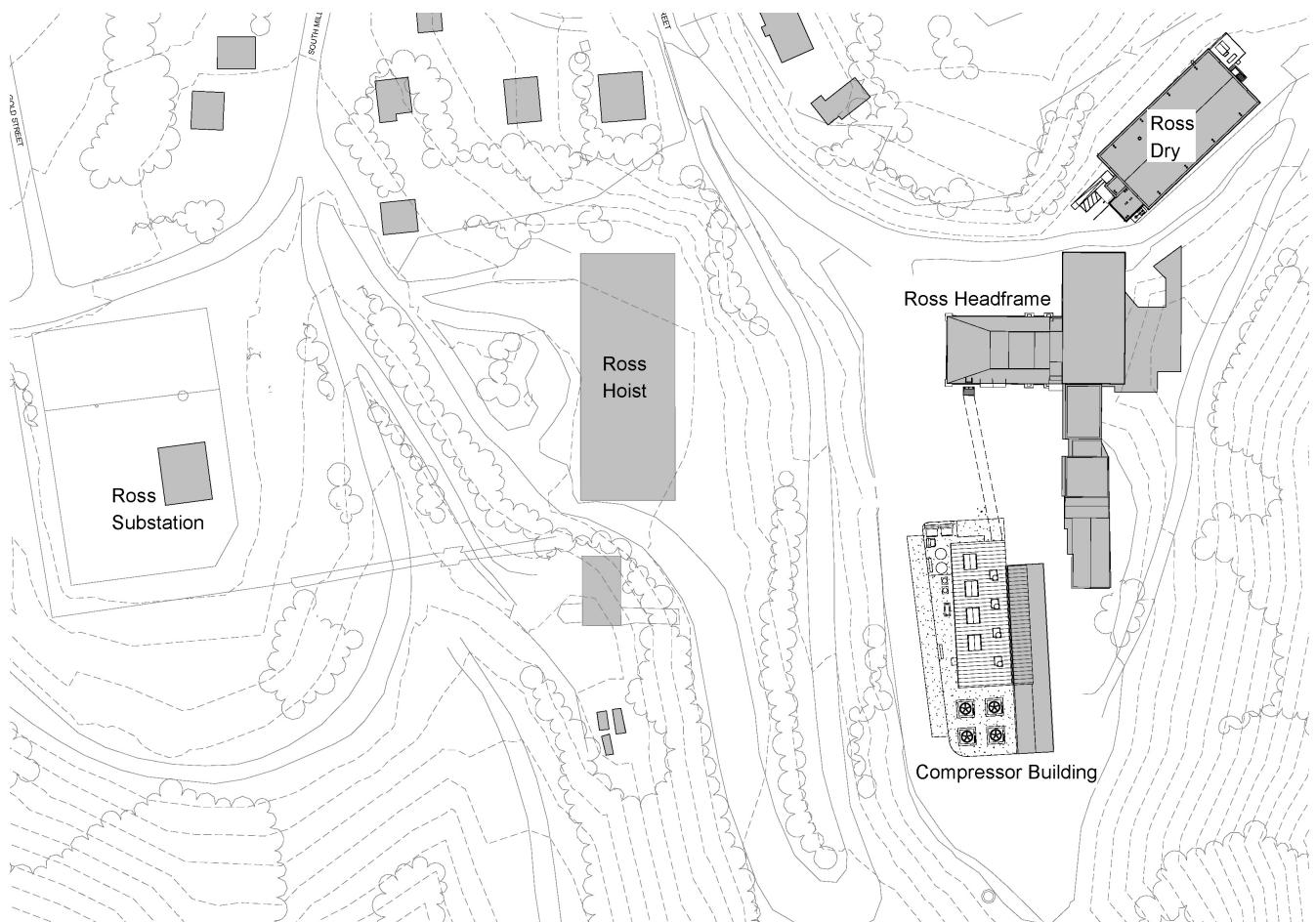


Figure 4.2: Ross Complex architectural site plan (Arup)

fig:ross

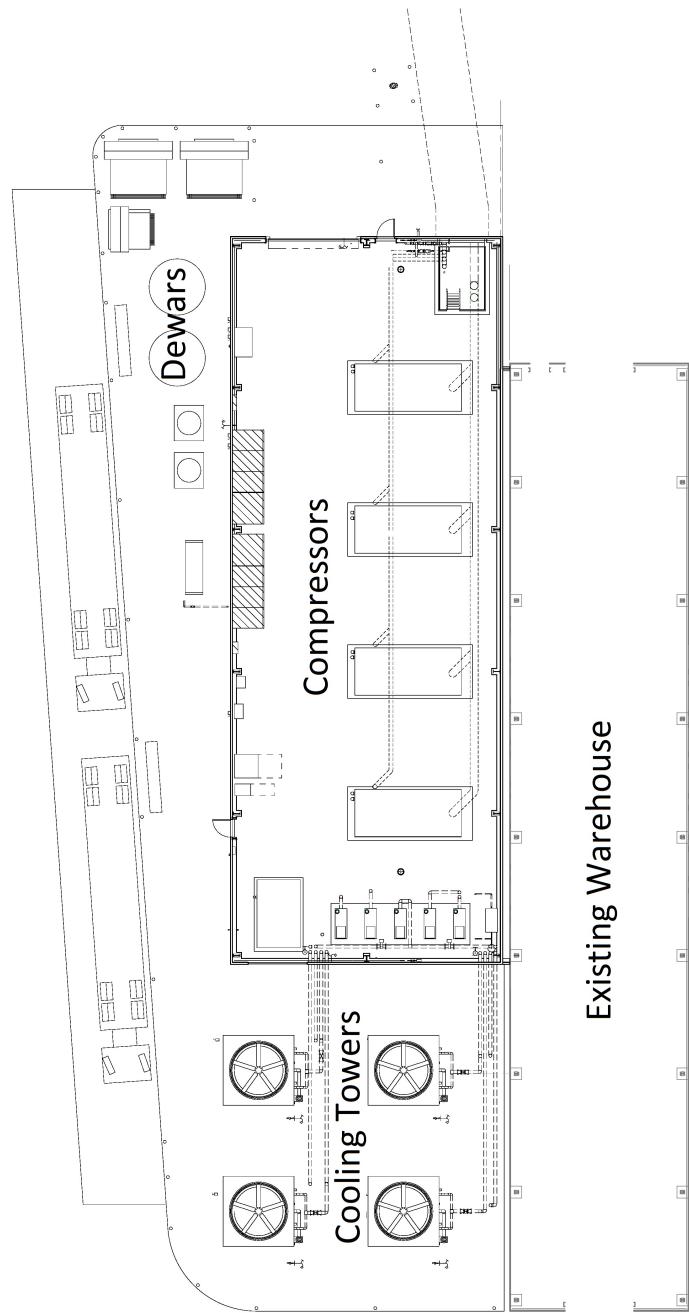


Figure 4.3: Architectural layout of LBNF Cryogenics Compressor Building

fig:comp

- 1 The exterior of the Ross Dry is shown in Figure 4.4. The renovations of this building are shown
2 in Figures 4.5 and 4.6.



Figure 4.4: Photo of Ross Dry exterior (HDR)

Need orig; too fuzzy

fig:ross

4.2.2 Ross Headframe and Hoist Buildings

- 3 crosshead
- 4 The headframe and hoist buildings at the Ross Campus provide services for LBNF use. The Ross
5 Headframe Building will be the main entry point for construction activities as well as the ongoing
6 operations and maintenance functions. Gas pipe from the LBNF Cryogenics Compressor Building
7 will pass through this building to get to the shaft.
- 8 Following shaft rehabilitation, the LBNF project will include structural reinforcement of the Ross
9 Headframe to meet current codes and standards. The headframe will also be modified somewhat
10 to accommodate longer loads than are currently possible. This project will occur concurrently with
11 other site preparation activities planned to be performed outside of the CD-3a scope, as described
12 in section

13 add link to new section on site preparation activities (coming from Josh)

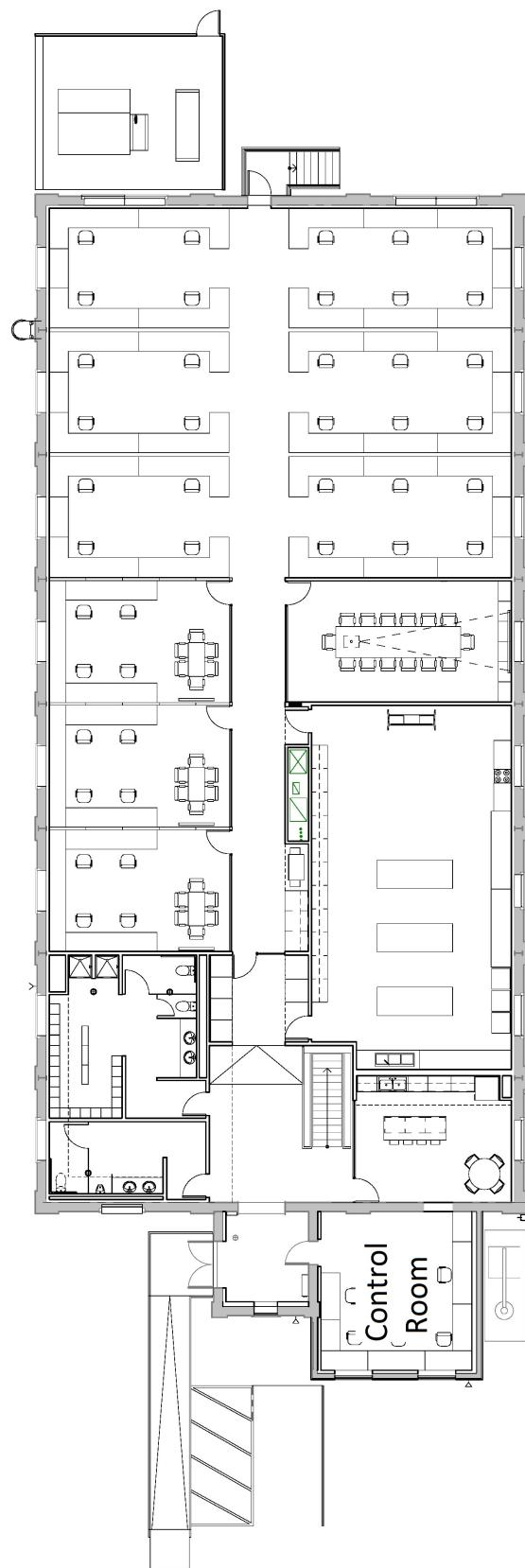


Figure 4.5: Ross Dry Building renovation, main floor, showing the planned location for the control room (Command and Control Center).

fig:cmd-

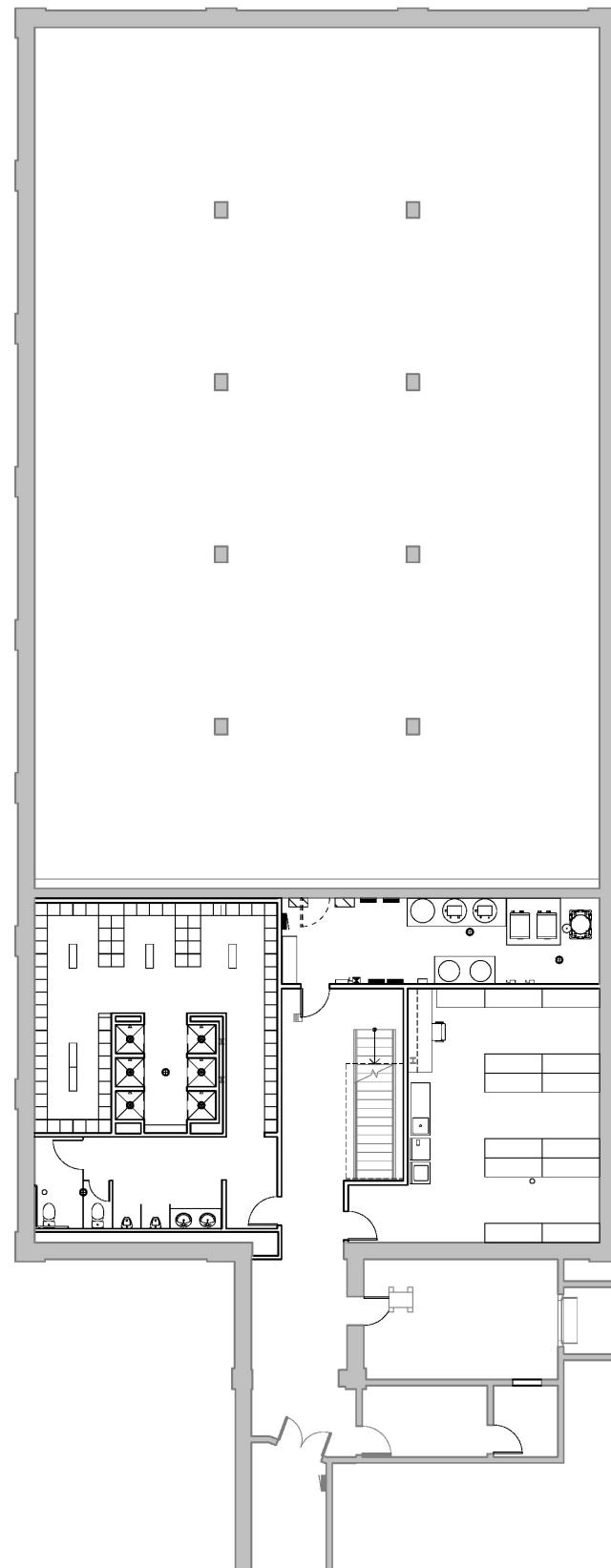


Figure 4.6: Ross Dry Building renovation, basement.

fig:cmd-

1 4.2.3 Yates Headframe Building

ateshead
2 The headframe at the Yates Campus provide services for LBNF use. One scope option is to provide
3 a redundant fiber optic backbone through this shaft, and the shaft will be used for delivery of people
4 and materials for construction and operation of LBNF. One specific time frame where this shaft
5 will be critical is during the installation of gas piping through the Ross shaft, during which time
6 no other uses beyond emergency egress are possible. Due to this demand, the LBNF project will
7 include structural reinforcement of the Yates Headframe to meet current codes and standards.
8 This project will be completed prior to the installation of gas piping through the Ross shaft to
9 ensure reliable operation during that time.

10 4.2.4 Ross Crusher Building

scrusher
11 The existing Ross Crusher Building is a high bay space that contains rock crushing equipment that
12 will be used for construction operations. The exterior of the building will be repaired to create
13 a warm, usable shell. The upgrade of the existing ~~seclifc-und-waste-rock~~ crusher equipment is part of the waste rock
14 handling work scope (see Section 6.7) and not part of the building rehabilitation.

15 4.3 New Surface Infrastructure

face-new
16 Surface infrastructure includes surface structures such as retaining walls and parking lots, as well
17 as utilities to service both buildings and underground areas. Existing infrastructure requires both
18 rehabilitation as well as upgrading to meet code requirements and LBNF needs. The ~~dune-sci-req~~ experiment
19 needs were documented in the requirements found in LBNF Requirements Document[4] and com-
20 bined with facility needs for the design detailed in the Arup 100% Preliminary Design Report[5].

21 No new roads or parking lots are required for LBNF at SURF. The Ross Complex site will require
22 minor demolition of power lines and a fire hydrant that are no longer used to provide adequate
23 accessibility for truck traffic to the new Cryogenics Compressor Building. An existing space will
24 be designated for handicap parking adjacent to the Ross Dry Building. Additional road work is
25 required for truck transportation of waste rock, as described in the waste rock handling section.

¹ Chapter 5

² Underground Excavation

³ The main excavated spaces necessary to support the LBNF experiment are a combination of
⁴ excavations required for the experiment and those required for constructability. Experimental
⁵ spaces on the 4850L include the detector chambers, drifts for access and utility routing, and the
⁶ Central Utility Cavern. Spaces identified as likely necessary for the excavation subcontractor
⁷ include mucking drifts connected to the Ross Shaft to enable waste rock handling and equipment
⁸ assembly shops to provide space to assemble and maintain excavation equipment underground. In
⁹ addition, a spray chamber is provided for heat rejection from the chilled water system. All spaces
¹⁰ are identified on the 100% Preliminary Design excavation drawings produced by Arup[5]. The
¹¹ spaces are shown in Figure 5.1.

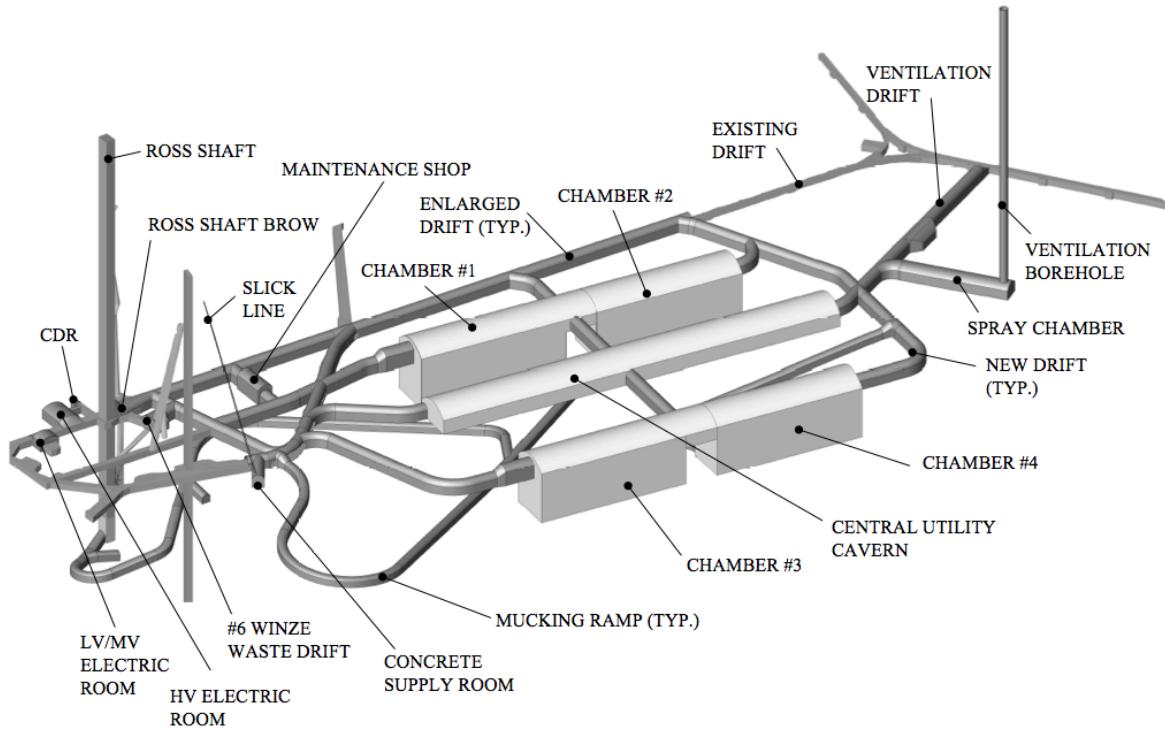


Figure 5.1: Spaces required for LBNF at 4850L (SURF)

5.1 LBNF Cavities

5.1.1 Detector Cavities

The required experimental spaces were defined through interaction with the DUNE design team and are documented in LBNF Requirements Document [14]. The size and depth of the LBNF cavities were prescribed to suit the scientific needs of the experiment. The overall main cavern sizes are shown graphically in Figure 5.2. The DUNE experiment will be housed in four detector chambers within two main caverns at the 4850L. Siting deep underground is required to shield from cosmic rays, as detailed in Report on the Depth Requirements for a Massive Detector at Homestake [15]. The 4850L is deeper than what is absolutely required, but is used because of existing access at this level.

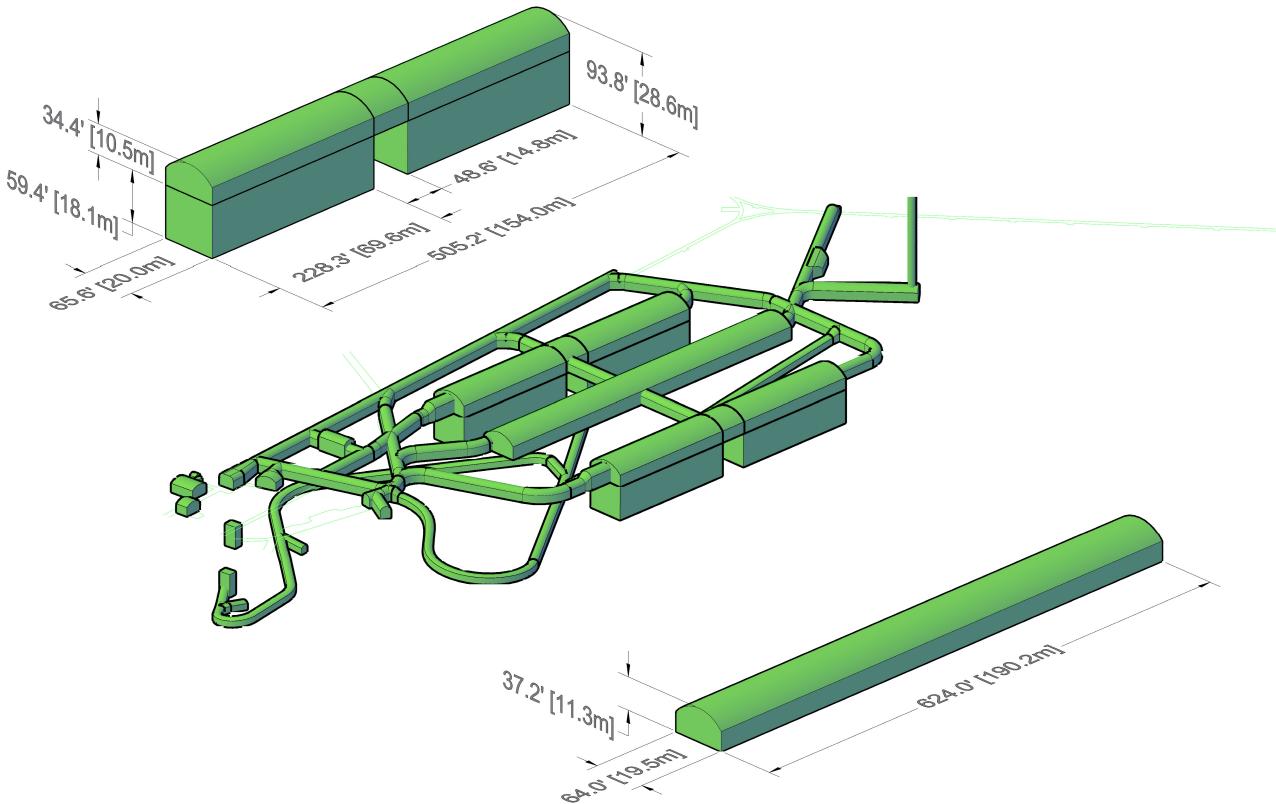


Figure 5.2: Dimensions of the main LBNF cavern excavations (final dimensions will be slightly smaller). (SURF)

The limits on size for the detector are determined by rock strength and the limits on the ability to produce large dimension anode and cathode plane arrays. Space occupied by the free-standing steel structure, vessel insulating liner, and an intentional exclusion zone reduce the fiducial volume of the detector below the volume of the excavation. Current assessment of rock quality indicates that a cavity of this size is reasonable with the rock quality assumed for this formation.

16 Preliminary modeling of the proposed excavations included 2D and 3D numerical modeling. The
17 intact rock strength and joint strength had the greatest impact according to the 2D modeling, and
18 3D modeling confirmed that the complex geometry is possible.

19 The far detector cavity and drifts will be supported using galvanized rock bolts/cables, wire mesh,
20 and shotcrete for a life of 30 years. The floor of the cavity has been evaluated and does not
21 require support. All experience, analysis, and field testing at the 4850L of SURF indicate that the
22 volume of water to be encountered will be very minor (<1 lpm), but the location of these small
23 seeps is unpredictable. To accommodate whatever water is encountered, a groundwater drainage
24 system will be placed behind the shotcrete in the arch and walls of the far detector cavity rock
25 excavation. This drain system will collect groundwater (native) seepage and eliminate the potential
26 for hydrostatic pressure build-up behind the shotcrete. Channels will be placed in the concrete
27 invert to drain groundwater to the sump system.

28 **5.1.2 Structure and Cranes**

29 The LBNF caverns require monorail cranes to facilitate the construction of the detector compo-
30 nents. Rock bolts will be coordinated with the excavation contractor to provide anchorage to
31 support these monorails.

32 **5.2 LBNF Central Utility Cavern**

1 LBNF requires spaces for cryogenics equipment outside of the detector caverns. These requirements
2 have been combined with that for the conventional facilities utilities in an independent Central
3 Utility Cavern. This area will house the experiment's cryogen system, electrical equipment to
4 supply power for facility and experiment needs, sump pump access and controls, fire sprinkler room,
5 air handling units (AHUs), chilled water system, and ducting. The centralized location minimizes
6 overall utility distribution costs. Isolating the utilities from the experiment simplifies electrical
7 ground isolation to avoid interference with sensitive detector electronics, and also provides the
8 opportunity to optimize ventilation to control heat emanating from the equipment in the Central
9 Utility Caverns.

10 **5.3 Access/Egress Drifts**

11 In order to accommodate deliveries, the drift connections from the Ross Shaft to new excavations
12 required for LBNF will be optimized to accommodate the maximum load size possible through the
13 shaft plus the utilities required to service the facility. At the writing of this document, an assumed
14 size of 5m wide by 6m tall is used for all access and egress drifts. All new excavations, or drifts
15 enlarged for LBNF will be provided with a shotcrete wall (rib) and ceiling (back) and a concrete
16 floor (sill).

17 **5.4 Excavation Sequencing**

18 A key goal of both LBNF and DUNE is to complete construction of one 10 kt detector as soon as
19 possible. To facilitate this, the excavation will be sequenced to allow DUNE to begin installation
20 of a cryostat in the first detector chamber while excavation continues. A temporary wall will be
21 built in the detector installation laydown space between detector chambers to isolate one area
22 from another. This wall must be of sturdy construction to withstand air shock waves associated
23 with drill and blast type construction. Further evaluation of vibration limits and controls must be
24 considered as the design advances to avoid damaging the cryostat during assembly.

25 In addition to controlling the impacts from blasting, logistical coordination is a key concern with
26 a sequenced excavation allowing cryostat construction concurrent with excavation. Many exper-
27 iment components will be delivered through the Ross shaft, competing with excavation and other
28 construction. A logistics study^{lbnf-logistics}[6] has been performed to evaluate whether this can be done without
29 impact on either civil or experiment construction. This study confirmed that with good coordina-
30 tion, led by the construction manager, this single shaft can support all anticipated material and
31 personnel deliveries. The Yates shaft can provide some relief during high intensity work periods
32 as well, but this was not considered in the study to evaluate the most conservative approach.

33 Most excavated material will travel through a mucking ramp starting at the base of each detector
34 pit and ending at the waste dump near the Ross Shaft. This route is completely independent
1 of all other traffic and includes a separate ventilation stream to keep diesel exhaust from other
2 occupied spaces. During times when excavation is establishing the upper sections of the caverns
3 and developing a means of dumping excavated material to this lower elevation, material will need to
4 be transported at the 4850L. To alleviate any potential interferences, the first phase of construction
5 will establish a connection from the 4850L to the mucking ramp, as well as ventilation paths to
6 avoid contaminating the air in spaces that have been turned over for cryostat construction.

7 Delivery of cryostat components to the individual pits can be accomplished in one of two ways.
8 All materials are delivered through the shafts to the 4850L, which is 18m above the base of the
9 pits. During construction of the first cryostat, while excavation continues in the other areas, all
10 materials will be delivered to the detector installation laydown area between the first and second
11 detector chambers and/or to the west end of the first detector chamber. An overhead crane will be
12 used to lower this material into the pits. All excavation will be completed before any construction
13 is required in the third and fourth detector pits, providing the option of using the excavation
14 mucking ramp for delivery of cryostat components. This ramp has been designed at an 8% grade
15 to from the west side to allow for this possibility.

16 **5.5 Interfaces between DUNE, Existing Facilities, Cryogenics 17 and Excavation**

18 There are several points at which the experiment and the facility interface closely. These are
19 managed through discussions between DUNE design team, the Cryogenics Infrastructure design

20 team, and the Conventional Facilities design team and design consultants.

21 • The LBNF cryostat is a freestanding structure requiring infrequent access for inspection
22 around the vessel.

23 • The utility spaces to house the cryogen system are directly influenced by the size of the
24 cryogen system equipment.

25 • The size and construction sequencing of the detector chambers are critical to the experimental
26 strategy.

27 In addition to these interfaces, the LBNF excavation will require coordination with existing facil-
28 ities, including experiments in relatively close (~ 100 m) proximity to the planned excavation. To
29 manage the risks associated with vibrations and air blast overpressure created by drill and blast
30 excavation techniques, a test blast program has been designed to study the actual response of
31 the rock mass in this area. This test blast program is being coordinated closely with the existing
32 experiments as of the writing of this report, and the actual physical test is planned to be completed
33 within the first quarter of FY16. The results of this test should either confirm that the planned
34 excavation approach is appropriate, or define modifications that may be necessary in the areas
35 closest to the existing facilities.

³⁶ Chapter 6

¹ Underground Infrastructure

- ² The requirements for underground infrastructure for the LBNF Project will be satisfied by a
³ combination of existing infrastructure, improvements to those systems, and development of new
⁴ infrastructure to suit specific needs. The Project must consider the other tenants underground at
⁵ SURF for which infrastructure is required, including both the existing Davis Campus experiments
⁶ and the Ross Campus Experiments. The Ross campus experiments in particular are in relatively
⁷ close proximity (~150 m) to LBNF.
- ⁸ The systems must support the LBNF Conventional Facilities (CF) construction activities, Cryo-
⁹ genics Infrastructure, DUNE experiment installation, and operations of both CF Equipment and
¹⁰ the experiment. These three scenarios were analyzed and the most demanding requirements chosen
¹¹ from each situation were used to define the requirements for design.
- ¹² Some of the SURF infrastructure that requires upgrading for LBNF will be rehabilitated prior to
¹³ the beginning of LBNF construction funding. This includes Ross Shaft rehabilitation, Yates Shaft
¹⁴ focused maintenance and repair, and ground support activities at the 4850L between the Yates
¹⁵ and Ross Shafts. Additional discussion of this work is included in section 3.5 .
- ¹⁶ The conceptual underground infrastructure design for LBNF has been performed by several en-
¹⁷ tities. The primary designer referenced in this document is Arup, USA. Arup's scope includes
¹⁸ utility provisions and fire protection- life safety (FLS) strategy, covering infrastructure from the
¹⁹ surface through the shafts and drifts, to the cavity excavations for the experiment. Utility infras-
²⁰ tructure includes fire/life safety systems, permanent ventilation guidance, HVAC, power, plumbing
²¹ systems, communications infrastructure, lighting and controls, per the experimental utility require-
²² ments provided by DUNE and through coordination with LBNF, SURF and the excavation and
²³ surface design teams. The design is described in Arup's LBNF 100% Preliminary Design Report^[5]
²⁴ and in the conceptual design drawings. This chapter summarizes the work done by Arup and
²⁵ utilizes information from that report. Arup:fscf100p
- ²⁶ Shaft rehabilitation and waste rock handling design were previously provided for the DUSEL
²⁷ PDR. This chapter uses excerpts from the DUSEL Preliminary Design Report, Chapter 5.4 [10].
²⁸ The research supporting this work took place in whole or in part at the Sanford Underground

29 Laboratory at Homestake in Lead, South Dakota. Funding for this work was provided by the
1 National Science Foundation through Cooperative Agreements PHY-0717003 and PHY-0940801.
2 The assistance of the Sanford Underground Laboratory at Homestake and its personnel in providing
3 physical access and general logistical and technical support is acknowledged.

4 **6.1 Fire/Life Safety Systems**

5 Life safety is a significant design criterion for underground facilities, focusing on events that could
6 impact the ability to safely escape, or if escape is not immediately possible, isolate people from
7 events underground. Design for fire events includes both preventing spread of fire and removing
8 smoke and/or cryogenic gasses through the ventilation system. The evaluation and establishment
9 of requirements for cryogenic gas removal is performed by the cryogenics group and provided to
10 CF.

11 Life safety requirements were identified and the design developed by Arup, utilizing applicable
12 codes and standards, including NFPA 520: Standard on Subterranean Spaces, which requires
13 adequate egress in the event of an emergency. Facility fire detection and suppression systems, as
14 well as personnel occupancy requirements are defined in accordance with NFPA 101: Life Safety
15 Code. The design was reviewed by Aon Risk Solutions and the recommendations documented
16 in Fire Protection/Life Safety Assessment for the Conceptual Design of the Far Site of the Long
17 Baseline Neutrino Experiment [16]. Due to the unique nature of the experiment and its location, a
18 number of potential variances will require approval from the authority having jurisdiction (AHJ).
19 Significant examples include use of elevators for egress and use of drifts as air *ducts*. The AHJ for
20 Lead, SD is familiar with the facility and the project, and is expected to provide reasonable and
21 timely feedback for proposed variances.

22 Based on data provided by SURF the maximum occupant load of the 4850L will be controlled
23 at 144 occupants following completion of the Ross Shaft Rehabilitation. This limit is based on
24 both the ability of the shafts to provide egress within one hour and the capacity of the existing
25 refuge chamber. This can support the anticipated 42 Underground Operations staff, 50 science
26 staff for LBNF (during installation), and 20 science staff associated with the existing experiments.
27 A logistics study^[6] was completed by Arup evaluating the occupancy load during CF construction
28 as well, confirming the adequacy of this number.

29 Compartmentation will be needed for egress routes to separate them from adjacent spaces to
30 limit the horizontal and vertical spread of fire and smoke. Use of compartmentation will help
31 to reduce the likelihood of fire and smoke spreading from the area of fire origin to other areas
32 or compartments. Compartmentation will also help limit the spread of other materials such as
33 cryogenic gases, leaks and spills. This results in design criteria of minimum 4-hour fire separation
34 between the LBNF cavities and adjacent drifts, while all rooms that connect directly to the egress
35 drift at 4850L, as well as the shafts, will have 2-hour minimum fire separation. Fire and life safety
36 systems to meet the design criteria described above are included in the following sections.

37 6.2 Shafts and Hoists

1 The Ross and Yates Shafts provide the only access from the surface to the underground, and are
2 therefore critical to the function of the Facility. Both shafts provide service from the surface to the
3 4850L, though not every intermediate level is serviced from both shafts. The shafts also provide a
4 path for all utilities from the surface to the underground.

5 The Ross and Yates Shafts were both installed in the 1930s and have operated since installation.
6 These shafts, along with their furnishings, hoists, and cages, were well maintained during mining
7 operations, but have experienced some deterioration as described in this section. A complete
8 assessment of the Ross and Yates shafts was conducted for the DUSEL Project, and is documented
9 in the Arup Preliminary Infrastructure Assessment Report (DUSEL PDR Appendix 5.M [10]).

10 6.2.1 Ross Shaft

11 The Ross Shaft will be used for facility construction, including waste rock removal, routine facility
12 maintenance, and egress path for the finished underground campuses. It will also be used for
13 LBNF experiment primary access. Excavation for LBNF cannot begin until the Ross Shaft is
14 rehabilitated by SURF.

15 The Ross Shaft is rectangular in shape — 14 ft 0 in (4.27 m) by 19 ft 3 in (5.87 m), measured to
16 the outside of the set steel. The shaft collar is at elevation 5,354.88 ft (1,632.17 m) and the 5000L
17 is the bottom level at elevation 277.70 ft (84.64 m) above sea level. Service is provided to 29 levels
18 and five skip loading pockets. The shaft is divided into seven compartments: cage, counterweight,
19 north skip, south skip, pipe, utility, and ladder way. See Figure 6.1 below showing shaft layout.

20 The Ross Shaft was in operation until the Homestake Gold Mine closed in 2003. Deterioration
21 through corrosion and wear on the shaft steel, including studdles (vertical steel members placed
22 between steel sets), sets, and bearing beams, prompted a full *strip and re-equip* project being
23 performed by SURF. The Ross Shaft layout will not be significantly modified from the existing
24 configuration. The set spacing is being increased from 6 ft to 18 ft, but the general configuration
25 is remaining the same to allow for emergency egress during rehabilitation. The shaft was installed
26 with limited ground support, electing to utilize lacing to prevent spalled rock from reaching the
27 personnel conveyances. The new design replaces this system with a pattern bolting system to
28 control rock movement. The requirements for this shaft are safety, performance, and code driven
29 and defined by the existing configuration. Shaft rehabilitation through calendar year 2016 has been
30 executed by SURF with non-LBNF Project funds. The rehabilitation is just over 60% complete as
31 of this report and is planned to be completed in 2017. Beginning in January 2017, the funding for
32 the balance of the rehabilitation project will come from the LBNF project. This will also include
33 rehabilitation of the skip loading pocket for waste rock handling, and replacement of skips, cage,
34 and ropes..

35 The production and service hoists at the Ross Shaft are located on the surface in a dedicated
36 hoistroom west of the shaft. The service hoist operates the service cage and the production hoist

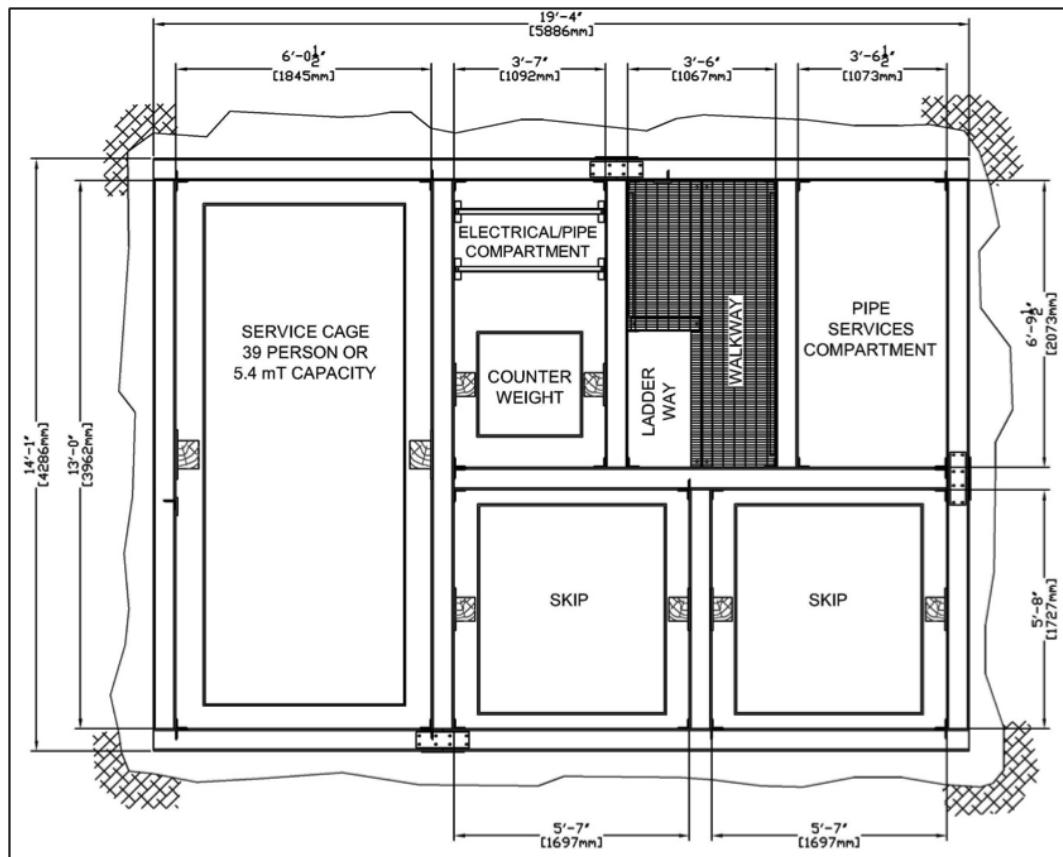


Figure 6.1: Ross Shaft, typical shaft set (SRK, Courtesy SURF)

fig:ross

37 operates the production skips. The DUSEL PDR describes the condition assessment of the elec-
1 trical and mechanical hoisting systems which are described in detail in the Arup Preliminary
2 Infrastructure Assessment Report (DUSEL PDR Appendix 5.M [10]). These electrical and me-
3 chanical systems will have standard maintenance performed on them to make them in like new
4 condition, but will not be modified from the existing design. The Ross Headframe steel requires
5 some strengthening and modifications to meet code requirements. All of this work is captured in
6 the LBNF scope.

7 **6.2.2 Yates Shaft**

8 The Yates Shaft is rectangular in shapeâ€”15 ft-0 in (4.572 m) by 27 ft-8 in (8.433 m) measured
9 to the outside of the set timbers. There are two cage compartments and two skip compartments
10 as shown in Figure 6.2.  In addition to the cage and skip compartments, there are two other
11 compartments in which shaft services are located. The shaft collar is at 5,310.00 ft (1,618.49 m)
12 elevation and the 4850L is the bottom level at elevation 376.46 ft (114.75 m) above sea level.
13 Service is provided to 18 levels plus four skip-loading pockets. Sets are made up of various length
14 and size timbers located to maintain compartment spaces. The Yates Shaft is timbered except for a
15 fully concrete-lined portion from the collar to the 300L. Recent repairs include full set replacement
16 from the concrete portion to the 800L and additional set repair below this level where deemed
17 critical.

18 The Yates Service Hoist and Production Hoist are planned to be used as existing, with main-
19 tenance performed to bring them into like new condition. Further details regarding the condition
20 of the Yates Hoists' electrical and mechanical condition can be found in Section 2.2 of the Arup
21 Preliminary Site Assessment Report (DUSEL PDR Appendix 5.M) [10].

22 **6.3 Ventilation**

23 The ventilation system will utilize the existing mine ventilation system for most of the distance
24 to the surface, with modifications made near the LBNF caverns to improve capacity. Fresh air for
25 the LBNF cavities and the utility drifts will be provided by pulling air directly from the existing
26 drifts, which is supplied from the Yates and Ross Shafts. Air will be exhausted from the LBNF
27 cavities and utility drifts through a spray chamber rejecting heat from the LBNF chilled water
28 system into new borehole connecting to the 3500 level of the facility, a short distance from the
29 Oro Hondo shaft, which provide direct connection to the fan at the surface. 230,000 cfm design
30 is required for heat extraction. 27,500 cfm passes through the each main experimental area and
31 21,500 through the central utility cavern, with the balance of the air required for heat rejection
32 coming directly from the shafts through connections to existing drifts. The environmental design
33 criteria for LBNF underground spaces are shown in Table 6.1. 

¹During operations, occupancy of the LBNF cavities is 20. Temperature, humidity and filtration requirements in localized areas of these spaces may differ, dependent on requirements. This will be provided by the experiment installation design team. The internal conditions stated above will be used to inform the design of plant and services for each space

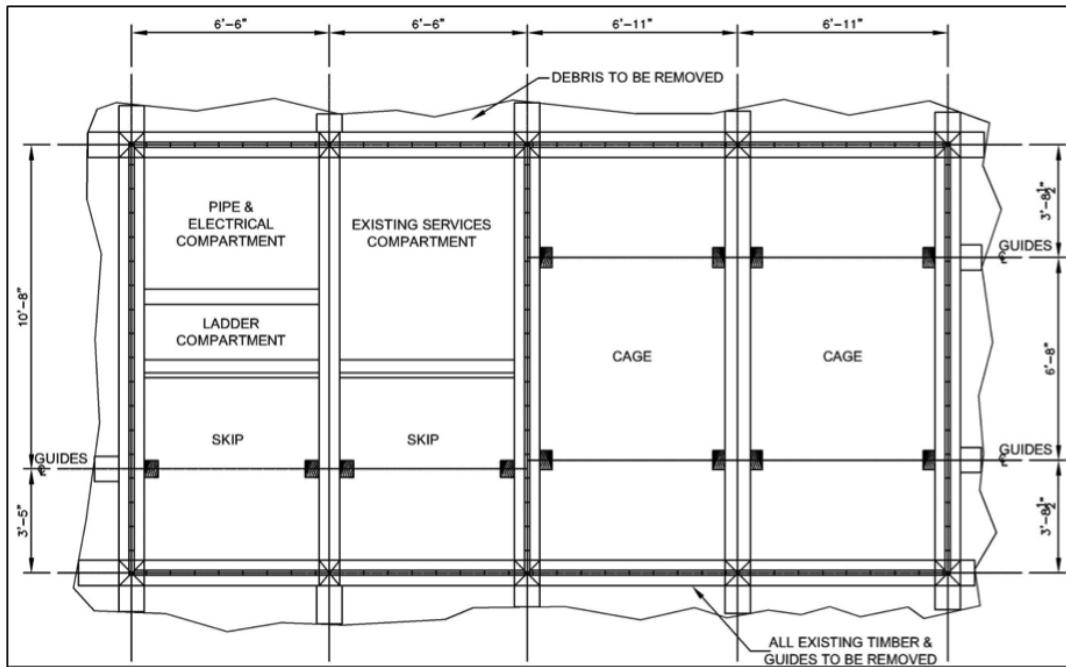


Figure 6.2: Existing Yates Shaft layout (Adapted from SRK, Courtesy SURF)

fig:yate

Table 6.1: Environmental design criteria (Arup)

Room	Internal Temperature	Humidity Range	Min. Vent. Rate/ Fresh Air Changes	Occupancy (during assembly)
LBNF Cavities	40 – 82°F (10 – 28 °C)	15 – 85%	1	20(50) ¹
Access Drifts	Min 50°F (10 °C)	Uncontrolled		Transient space
Utility spaces / Electrical rooms	50 – 95 °F (10 – 35 °C)	Uncontrolled	1	
Storage Rooms	59 – 104 °F (15 – 40 °C)	Uncontrolled	Min 15 cfm/person	Room-dependent

ign-crit

34 Per historical data, outdoor temperatures can drop below -20°F ; therefore, the intake air requires
1 heating to prevent ice build-up in the shafts which could potentially disrupt hoisting operations
2 and damage shaft support members, cables and piping. The existing shaft heaters are expected to
3 be adequate for normal operation, but temporary supplemental heating may be necessary during
4 excavation due to higher demands. A study will be performed during final design to determine if
5 waste heat from the cryogenic systems surface compressors can be used for energy savings to heat
6 the intake air.

7 **6.4 Electrical**

ind-elec

8 The underground facilities at the 4850L will have electrical power for normal operations as well as
9 standby power for emergency occupant evacuation. LAr experiment power requires standby power
10 for circulation of cryogens to avoid rapid boil-off and loss of argon.

11 **6.4.1 Normal Power**

12 The estimated electrical loads for both the far detector experiment and the underground infras-
13 tructure serving the experimental spaces are included in the facility load determination and design;
14 the loads are listed in Table 6.2.

15 Power to serve the far detector experiment will originate from the Ross substation and be routed
16 down the Ross Shaft to the 4850L. One set of 15-kV mining cables shall be installed down the
17 Ross Shaft to the 4850L and shall be cable rated for mine use, highly flame retardant, low smoke
18 toxicity with high tensile strength and self-supporting. At the 4850L, the 15-kV mining cables
19 will terminate in 15-kV switchgear located in a new Ross underground substation. This will be
20 provided early in the construction process to allow it to be used for construction.

21 **6.4.2 Standby and Emergency Power**

energ-pwr

22 A 300kW emergency/standby diesel generator will be provided in the Central Utility Cavern to
23 serve standby and emergency loads. 48 hours of diesel fuel will be provided to operate the generator
24 when surface power is inoperable. This duration aligns with the stored LN for controlling argon
25 boil off, both of which were derived from historical power outages at the facility. Note that the
26 facility is fed by the local utility provider in a loop infrastructure, and therefore power to the site
27 has historically been very reliable – on the order of a few hours down per year. Within the facility,
28 power outages due to maintenance or unforeseen events are also at a very low rate. The following
29 4850L electrical loads are anticipated to be installed to the emergency/standby power system:

- 30 • Security

unless specific requirements that differ from this are provided by LBNF/SURF or the lab experiment design teams.

Table 6.2: Underground Electrical Loads

Underground Electrical Load by Area	kW
Cryostat 1&2 Detector Electronics	450
Cryostat 1&2 Argon Pumps	98
Cryostat 1&2 CF	350
Total Cryostat 1&2	898
Cryostat 3&4 Detector Electronics	450
Cryostat 3&4 Argon Pumps	98
Cryostat 3&4 CF	342
Total Cryostat 3&4	890
Central Utility Cavern - Detector Cryogenics	956
Central Utility Cavern - DAQ	36
Central Utility Cavern - CF	753
Total Central Utility Cavern	1745
Spray Chamber	165
Maintenance/Assembly Shops (2)	84
Drifts	152
Total (other spaces)	401
Total non-CF	2088
Total CF	1846
Total	3934
Aggregate Demand Factor	0.736
Total × Aggregate Demand Factor	2894

Table 6.3: Surface Electrical Loads

should be in surface chapter

Surface Electrical Load	kW
Cryogen Building	5000
Control Room	250
Emergency/Standby Generator	50
Total Surface Load	5300

- 31 ● IT System for communications
- 1 ● Smoke control fans
- 2 ● Mono rail
- 3 ● Cryostat system controls
- 4 ● Lighting

5 **6.4.3 Fire Alarm and Detection**

- re-alarm
- 6 The 4850L will have notification devices installed to alarm the occupants of a fire. Notification
 - 7 devices will consist of speakers and strobe lights. Manual pull stations will be provided within
 - 8 200 ft of egress. Phones will be installed in the liquid argon chambers and every 400 ft along the
 - 9 access drifts to communicate with the surface level command center.
 - 10 An air sampling and gas detection system will be installed in the drifts and liquid argon detector
 - 11 chamber as an early detection of a fire condition. The air sampling system will be connected into
 - 12 the fire alarm system.
 - 13 The fire alarm system will also interface with the oxygen deficiency hazard (ODH) system to
 - 14 activate the fire alarm system and initiate an alarm at the respective level fire alarm panel and
 - 15 at the surface level command center. Specific sounds and strobe colors will be identified based on
 - 16 the type of alarm (fire, ODH, etc.).

17 **6.4.4 Lighting**

- and-light
- 18 Suspended lights mounted at a height just below the lowest obstruction will be provided for all
 - 19 drifts and ramps. Mounting is to be coordinated with conduit and supports of other systems
 - 20 running overhead. Maintained average illumination of approximately 24 lux (2.4 foot candles) at
 - 21 floor level will be provided throughout the drifts. Lighting control in drifts will be via low voltage
 - 22 occupancy sensors and power packs suitable for high humidity environments. Emergency lights
 - 23 will be provided in all areas with 90 minutes backup power supply. Note that all occupants are
 - 24 required by SURF policy to have cap lamps readily available for emergency use as well.

25 **6.4.5 Grounding**

- rounding
- 26 The grounding system will be designed to provide effective grounding to enable protective devices
 - 27 to operate within a specified time during fault conditions, and to limit touch voltage under such
 - 28 conditions. The grounding system will be designed for a maximum resistance of 5 ohms where

29 possible based on Mine Safety and Health Administration (MSHA) recommendations for ground
1 resistance in mines. Ground beds, consisting of an array of ground rods, will be installed at each
2 substation to provide low impedance to ground.

3 Electrical separation between the cryostat detectors and cavern utilities will be achieved by sepa-
4 rating the metal components (rebar, structure support, etc.) from each other. Inductors will be
5 installed between grounding systems to control noise between systems while also controlling touch
6 potential for safety.

7 **6.5 Plumbing**

8 Plumbing provided by CF, but specific to DUNE, includes plumbing for the cooling systems and
9 gas piping for nitrogen and argon delivery from the Cryogenics Compressor Building on surface to
10 the Central Utility Cavern. Beyond this the facility requires supplies of both potable and industrial
11 water, as well as a means to remove water inflows.

12 **6.5.1 Industrial Water**

13 An existing 4-inch industrial water riser will be used for construction and as a secondary fire
14 service. It is not feasible to run an uninterrupted main water supply line from grade level down
15 to serve the lower levels due to the extremely high hydrostatic pressure that would occur in the
16 system. A series of pressure reducing stations are located at regular intervals in intermediate levels
17 and at the 4850L in order to maintain the pressure within the capability of readily available piping.

18 **6.5.2 Potable Water**

19 Potable water is not required in large quantities for LBNF. The SURF experience has been that
20 plumbing potable water through the shafts for low volumes is not effective, as the pressure reducing
21 systems have the potential to introduce biological contaminants that result in the water no longer
22 meeting drinking water standards, especially in low flow situations. To address this, local filters
23 and ultraviolet treatment is done at the 4850L to make industrial water meet drinking water
24 standards. This system has been used successfully for several years at SURF.

25 **6.5.3 Chilled Water**

26 The DUNE equipment will produce a significant amount of heat which will be removed by LBNF-
27 provided chillers. Three chillers at 50% each have been selected to provide N+1 redundancy to
28 allow for maintenance. Heat from the chillers and various process loads will be rejected using a

spray chamber located at the east end of the 4850L LBNF caverns immediately before exhausting into a new borehole providing a direct connection to the exhaust shaft to surface. The ventilation air is a mixture of air from the Yates and Ross Shafts at approximately 68 degrees F. This volume of air is such that the total heat rejected (2.9 MW or 822 Ton) will raise the air temperature to no more than 95 degrees F.

6.5.4 Fire Suppression

6 The source of fire water main will be the existing 4-inch industrial water main at Ross Shaft. The
7 connection to this line will be at the 4100L, where a new sump with at least 27,000 gallons capacity
8 will be built using sump walls in an existing drift to provide 90 minutes of capacity even if the
9 supply were cut off. The fire protection system at the 4850L Campus will be a gravity fed system.
10 There will be a connection to an existing 6-in industrial water main in the west drift fed from Yates
11 Shaft, where a similar, but slightly larger at 50,000 gallons, sump has been built by SURF. This
12 provides redundant supply from surface. All new and/or enlarged excavations created for LBNF,
13 with the exception of excavation specific mucking ramps, will be provided with fire suppression
14 systems. In the detector caverns, pre-action type systems, which require two indications of fire
15 before activating, will be provided.

6.5.5 Drainage

17 Drainage [17] from the drifts, mechanical electrical rooms (MERs), and any areas where spillage
18 is likely to occur will be collected locally in sumps. Sumps will be located every 500 feet in any
19 areas where drainage to the drifts is not practical. Sumps will be equipped with sump pumps in a
20 staged configuration where each pump discharging to the adjacent sump until water is discharged
21 to the #6 Winze, where it flows to the primary facility pool approximately 1,000 feet below the
22 4850L. From there, the existing SURF dewatering system pumps the water in stages to the surface
23 where it is treated before discharge into a nearby stream.

6.5.6 Sanitary Drainage

²⁵ No sanitary drainage is included in the requirements for LBNF. Existing SURF facilities are
²⁶ planned to be used.

6.5.7 Nitrogen and Argon Gas Piping

²⁸ Two 16-in and three 8-in mild steel pipes are provided by CF from the surface Cryogenics Com-
²⁹ pressor Building to the shaft, through the shaft, and across the 4850L to the Central Utility Cavern

30 west entrance. The design and specifications of this piping are the responsibility of the Cryogenics
 1 Infrastructure Project team. The supply and installation within the Cryogenics Compressor
 2 Building and the central Utility Cavern is also the responsibility of the Cryogenics Infrastructure
 3 Project.

4 6.6 Cyberinfrastructure

5 The Structured Cable System design will be based on uniform cable distribution with a star
 6 topology. New fiber connections will be extended to the 4850 level from the Ross Dry Building,
 7 and will be dedicated to the use of LBNF experiments at the 4850 level. The design provides one
 8 (1) 96-strand single mode armored fiber optic cable from the DUNE Control room dedicated to
 9 the experiments. A second 96 stand single mode armored fiber optic cable has been identified as
 10 a scope option and, if included, will be routed through the Yates shaft to provide redundancy for
 11 data systems. Figure 6.3 shows the fiber distribution network for LBNF.
 fig:fiber-distrib

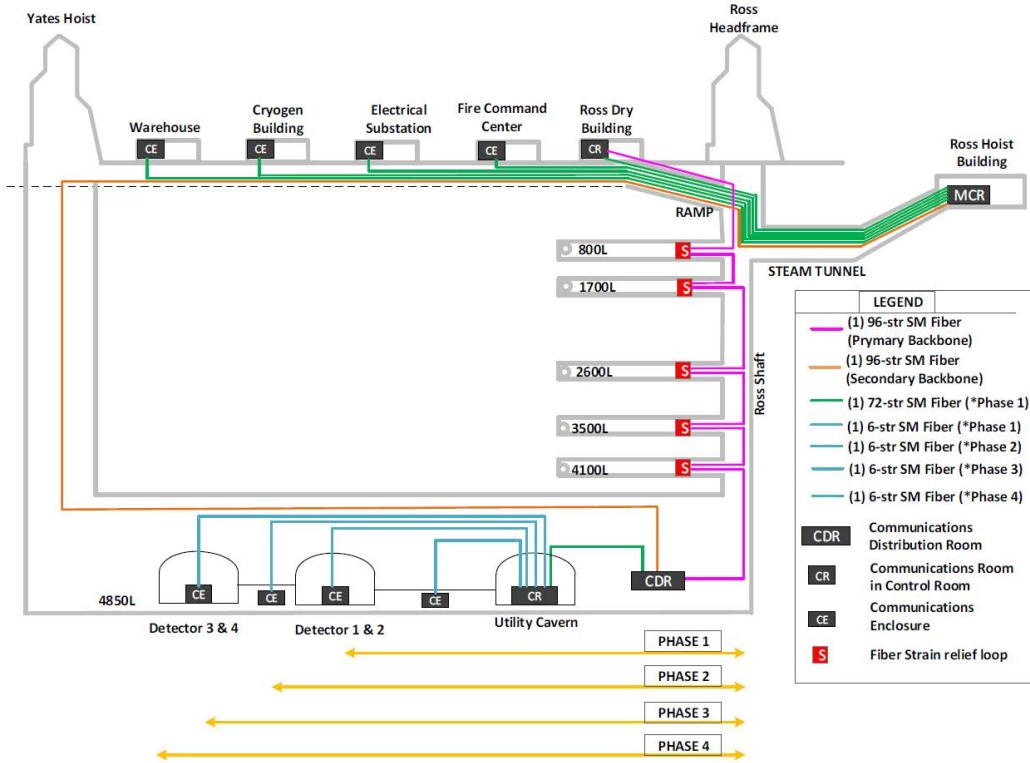


Figure 6.3: Fiber distribution system for LBNF (Arup)

12 Voice communications are provided via two-way radios and phones distributed throughout the
 13 underground spaces (in every room as well as every 500 ft in drifts). Two-way radios and cellular
 14 phones utilize a leaky feeder system to ensure communications over long distance without line
 15 of site. These leaky feeders are cables that act as antennas installed the length of all drifts and
 16 shafts. The leaky feeder is planned as a scope option. Standard phones utilize Voice over Internet
 17 Protocol (VoIP) to provide communication though the fiber optic data backbone.

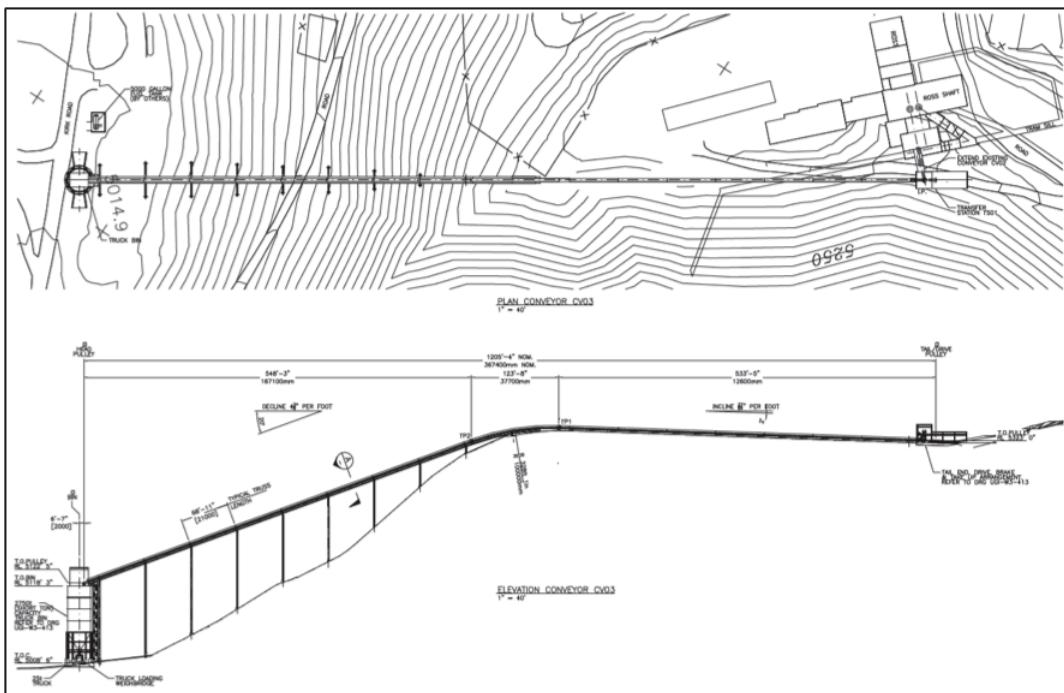
- 18 The data system is designed to provide 10-Gigabit Ethernet in the backbone and 1-Gigabit Ether-
 1 net to connected systems (computers). This system is intentionally left at a lesser level of design
 2 due to the continuous progression and advancement of technology that will almost certainly result
 3 in more advanced technologies than are currently available being utilized at the time of construc-
 4 tion.

5 6.7 Excavated Material Management

- 6 Prior to the commencement of any excavation activities, it will be necessary to establish a excavated
 7 material management system

8 Josh says: Need to determine whether this terminology is acceptable from Pepin

- 9 . The capacity of this system will be equivalent to what was in place during mining. There are a
 10 number of components to the management system, including refurbishing the Ross Shaft hoisting
 11 system, the Ross Shaft crushers, and a new conveying system. As of this report, two options have
 12 been identified for final repositories. The former Gilt Edge mine is located approximately 7 miles
 13 from the SURF property and would require truck haulage as a component of the transportation
 14 system. In this option, a new conveyor is provided to transport rock downhill to the Kirk Road,
 15 as seen in Figure 6.4. *fig:waste-rock-sys*



9 Figure 6.4: Waste rock handling system route (SRK, Courtesy SURF)

- 16 The alternative option to provide a repository for excavated material is the Homestake Open cut,
 17 located less than 1 mile from the SURF property. A conveying system is possible in this option

18 that would transport material directly to the final location, avoiding the need for over-the road
1 transportation. The path of this conveying system would be designed to follow a route formerly
2 used to transport material from the open cut to the former Homestake mills.

3 A final decision on which repository to use will be made prior to the CD3a approval. Both options
4 have been evaluated in detail and are not significantly different in cost or installation schedule.
5 The reference location as of this report is the Gilt Edge mine.

6 The systems utilize experience and equipment from the former Homestake Mining Company legacy,
7 where rock was removed to the surface using skips in both the Yates and Ross Shafts. At the
8 headframe of each shaft, the material was crushed to a nominal 3/4 in, passed through ore bins,
9 and was transported via underground rail to the mill system. All systems from the underground
10 to the crushers will be rehabilitated from the original systems, though the material may not be
11 required to be crushed as fine as it was historically, and therefore some components of the system
12 may not be re-used.

¹³ References

- ¹ [1] LBNF/DUNE, “LBNF/DUNE Conceptual Design Report (CDR),” tech. rep., 2015. DUNE Doc 180-183.
- ²
- ³ [2] Particle Physics Project Prioritization Panel, “Building for Discovery; Strategic Plan for U.S. Particle Physics in the Global Context,” 2014. http://science.energy.gov/~/media/hep/hepap/pdf/May%202014/FINAL_P5_Report_Interactive_060214.pdf.
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- ⁶ [3] CERN Council, “The European Strategy for Particle Physics, Update 2013,” 2013. <http://council.web.cern.ch/council/en/EuropeanStrategy/ESParticlePhysics.html>.
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- ⁸ [4] LBNF/DUNE, “LBNF/DUNE Science Requirements,” tech. rep., 2015. DUNE Doc 112.
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- ¹⁰ [5] Arup, “LBNF FSCF 100% Preliminary Design Report ,” tech. rep., 2015. DUNE Doc 136.
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