Status of the LBNF Project for the DUNE TGIR kick-off Meeting

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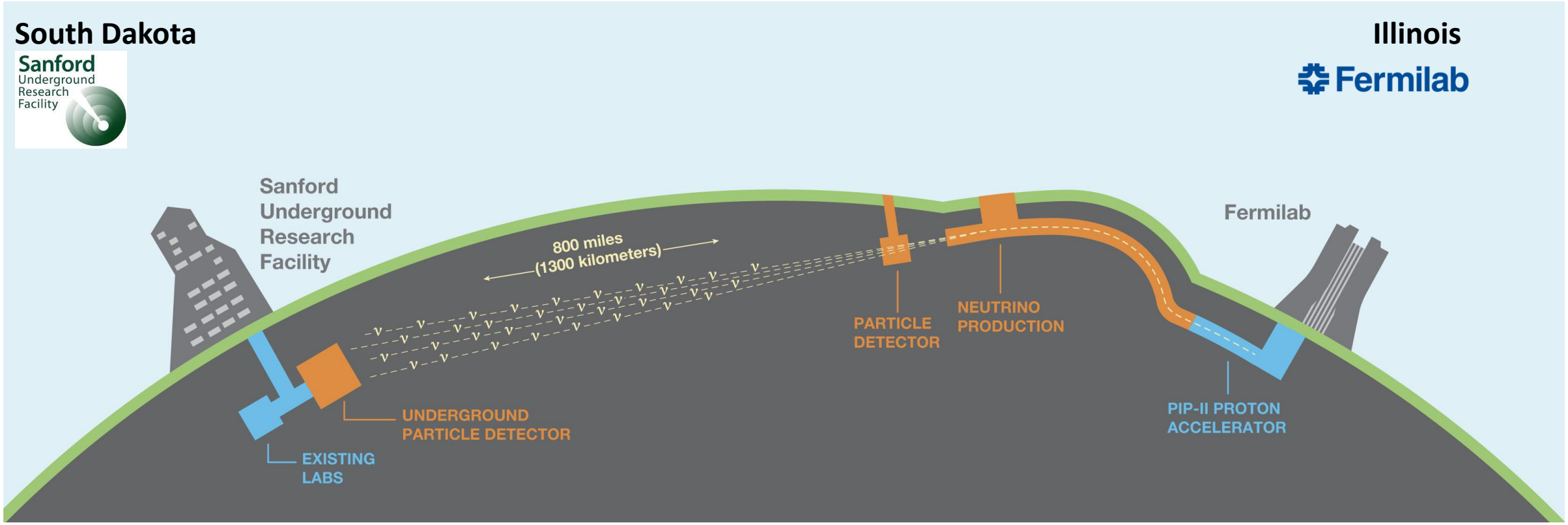
LBNF/DUNE-US Project Director
25 May 2021

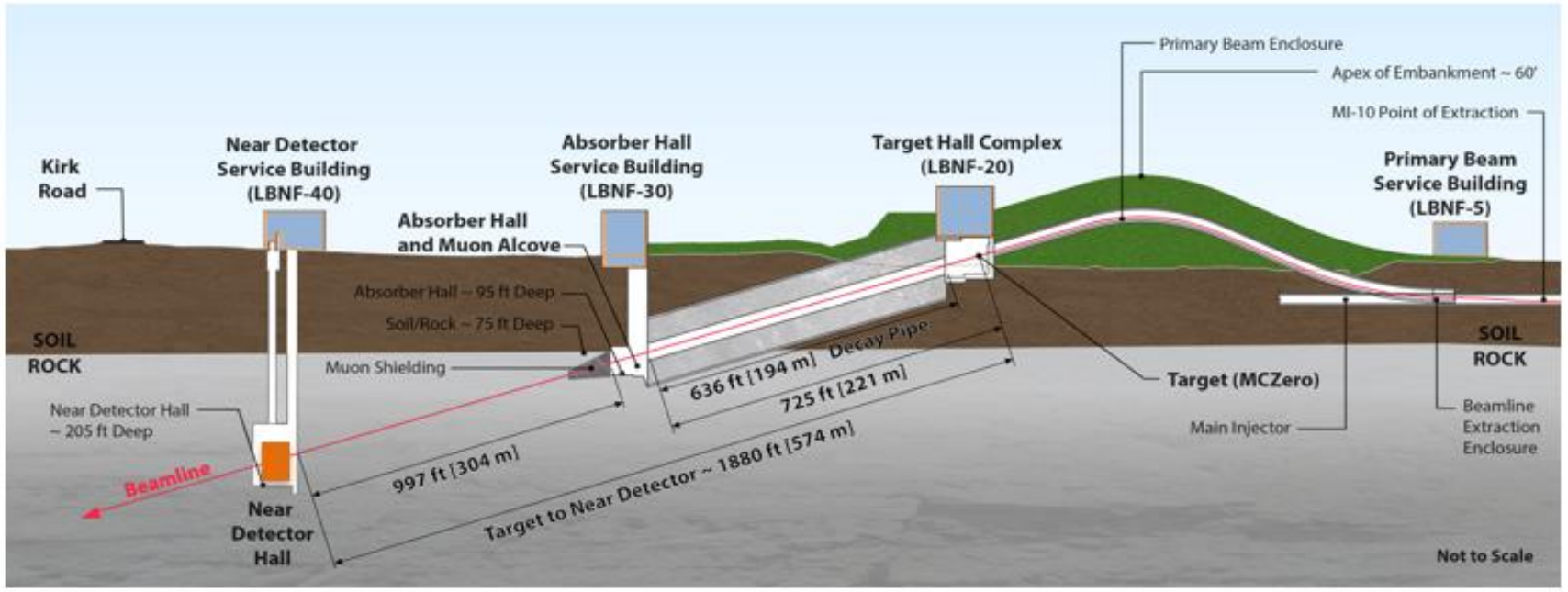
Outline

- Overview
- Near Site Scope and Status
- Far Site Scope and Status
- Project Tailoring and Baselining Plan
- Schedule
- Summary

The Long-Baseline Neutrino Facility (LBNF) supporting the international Deep Underground Neutrino Experiment (DUNE)



LBNF Project Scope – Near Site



Component	Scope
LBNF NS Facilities	
NS Conventional Facilities	Project management, preliminary and final design, and construction to support 1.2MW upgradable Beamline and Near Detector complex
Beamline	1.2MW beam power, designed to be upgradeable to 2.4MW (with future changes to targets, horns, cooling and shielding)
NS Cryogenic Infrastructure	LAr and LHe systems for day-one Near Detector
Near Detector	DUNE-US contributions to Day-1 Near Detector Components
NS Integration	Infrastructure & personnel to support ND installation

At the near site, the LBNF project scope includes committed critical in-kind contributions from:

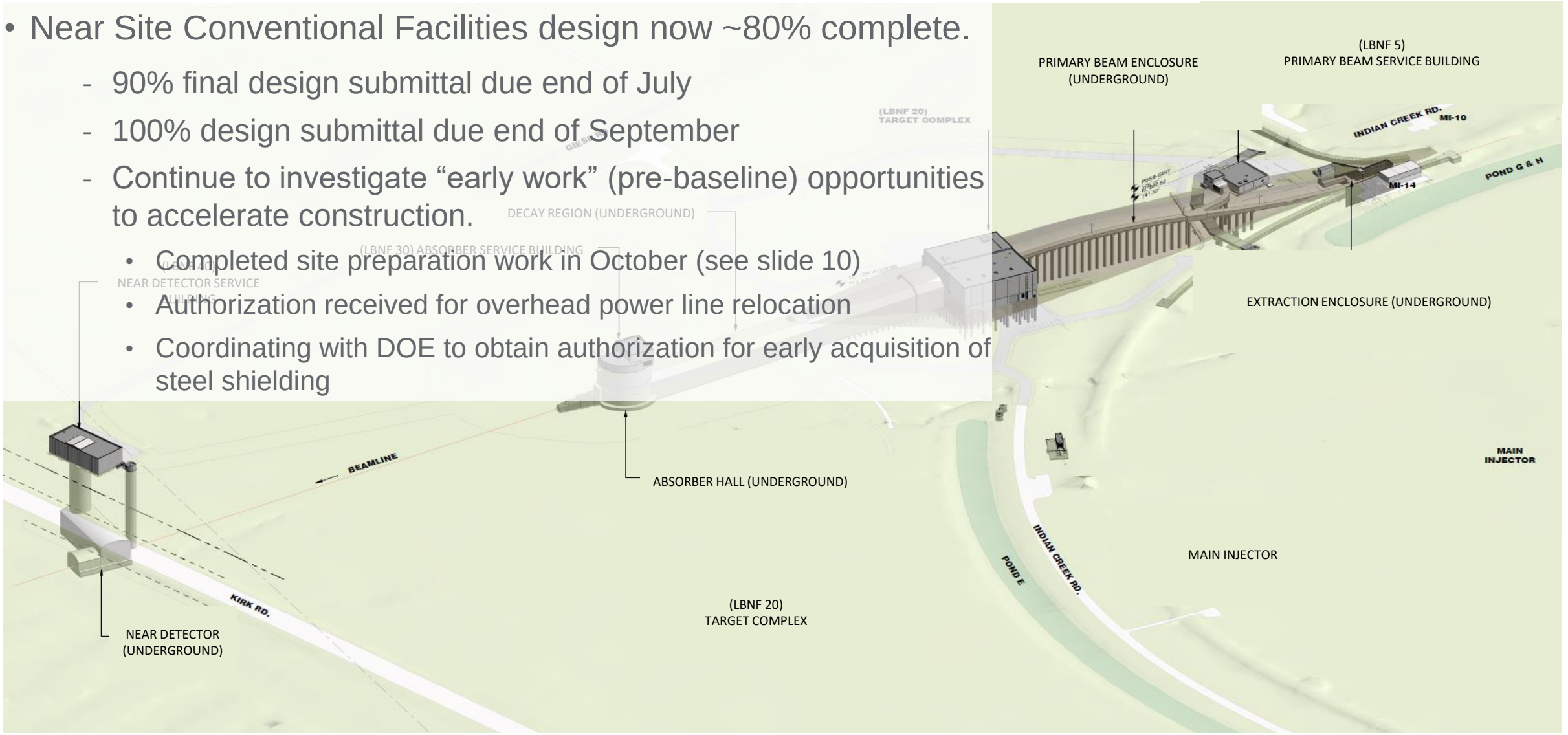
- UK/RAL – Neutrino target and baffle, design of cooling system
- India/BARC – Dipole and quadrupole primary beam magnets
- China/IHEP – Corrector primary beam magnets
- Japan/KEK – Prototyping hatch cover and stripline feed throughs
- CERN – LAr cryogenic components

Primary and Neutrino Beamline

- Driving physics considerations are long baseline neutrino oscillation analyses.
- Beam directed towards Sanford Underground Research Facility in Lead, South Dakota, 1300 km from Fermilab (5.8 degree overall vertical bend).
- Primary beam will transport high intensity protons (60 – 120 GeV energy range) to the LBNF target.
- All systems are designed for 1.2 MW initial proton beam power and facility is upgradeable to 2.4 MW proton beam power.
- Neutrino beam will be broad band, sign selected with spectrum to cover 1st (2.4 GeV) and 2nd (0.8 GeV) oscillation maxima covering 0.5 ~ 5.0 GeV.
- All systems that are prone to failure, such as water-cooled systems, are designed to be repairable and/or replaceable.
- Facility assumed to operate for 20 years within a 30 year span. Design life of Target and Absorber Hall complexes and of Decay Pipe is 50 years.
- Overall beamline design maturity now at 60%

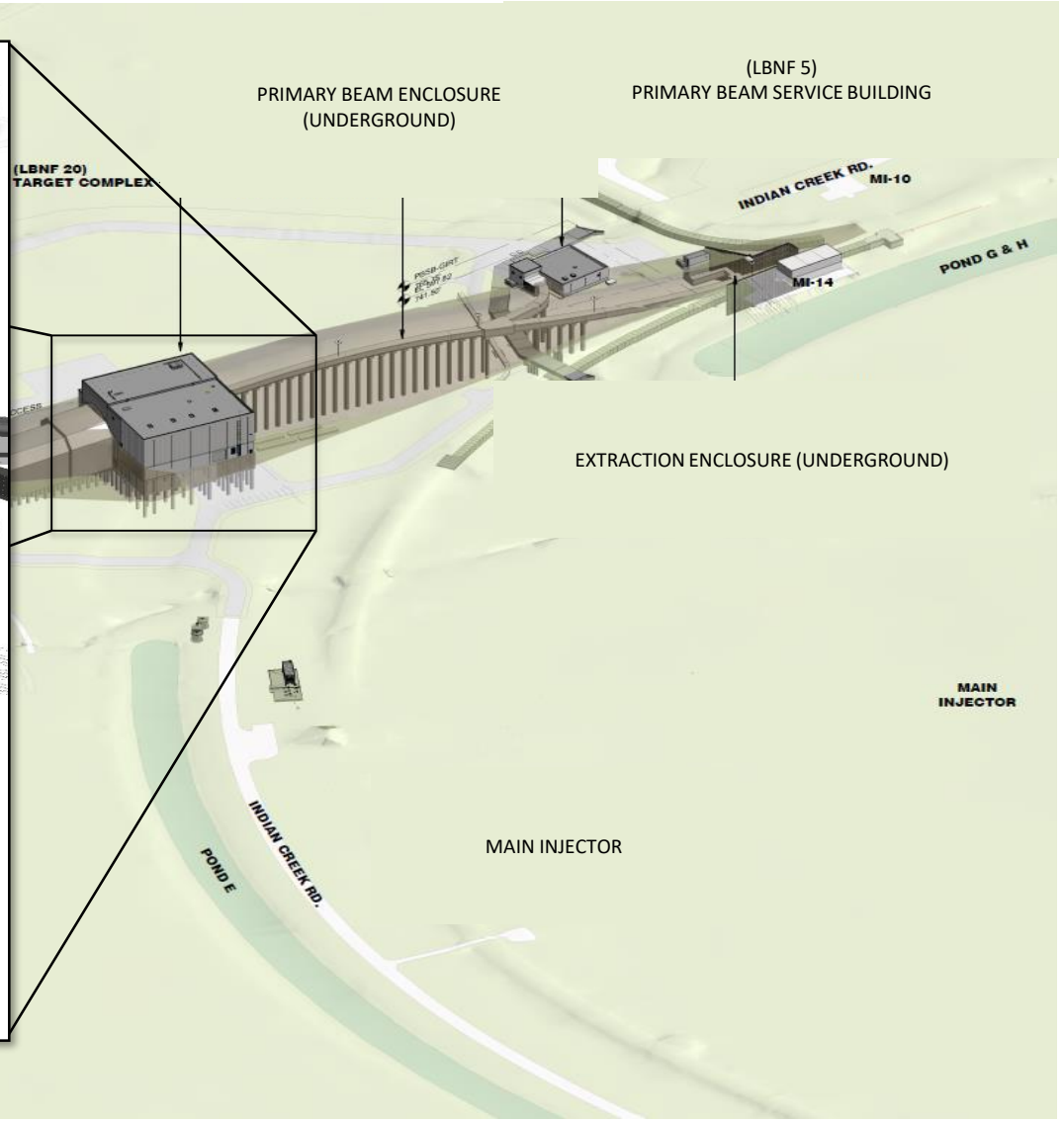
Near Site Conventional Facilities

- Near Site Conventional Facilities design now ~80% complete.
  - 90% final design submittal due end of July
  - 100% design submittal due end of September
  - Continue to investigate “early work” (pre-baseline) opportunities to accelerate construction.
    - Completed site preparation work in October (see slide 10)
    - Authorization received for overhead power line relocation
    - Coordinating with DOE to obtain authorization for early acquisition of steel shielding

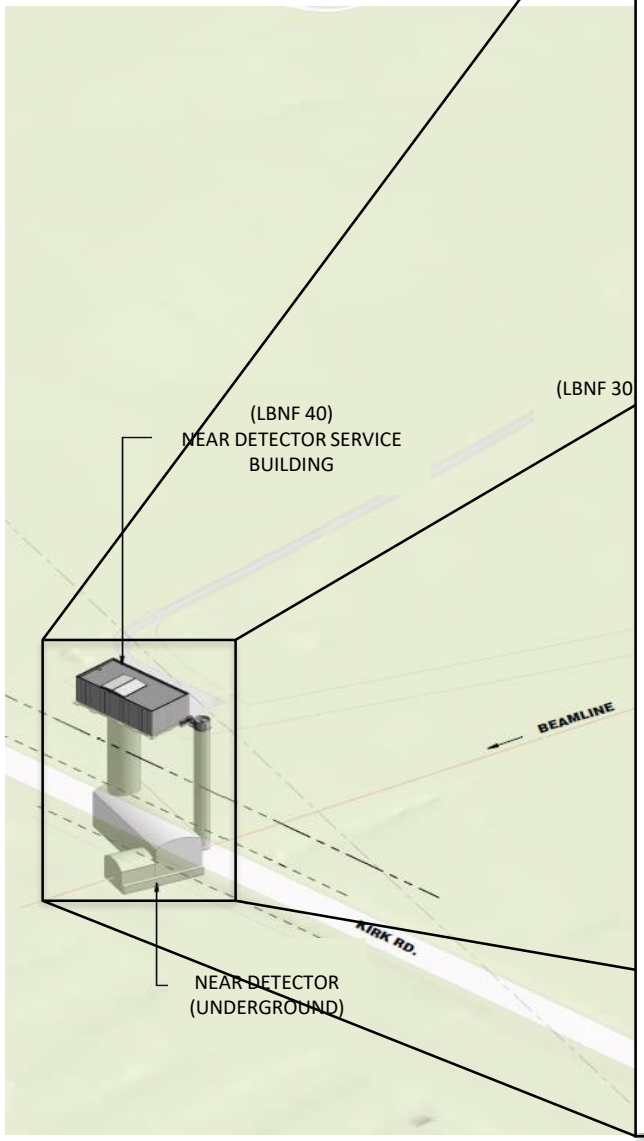


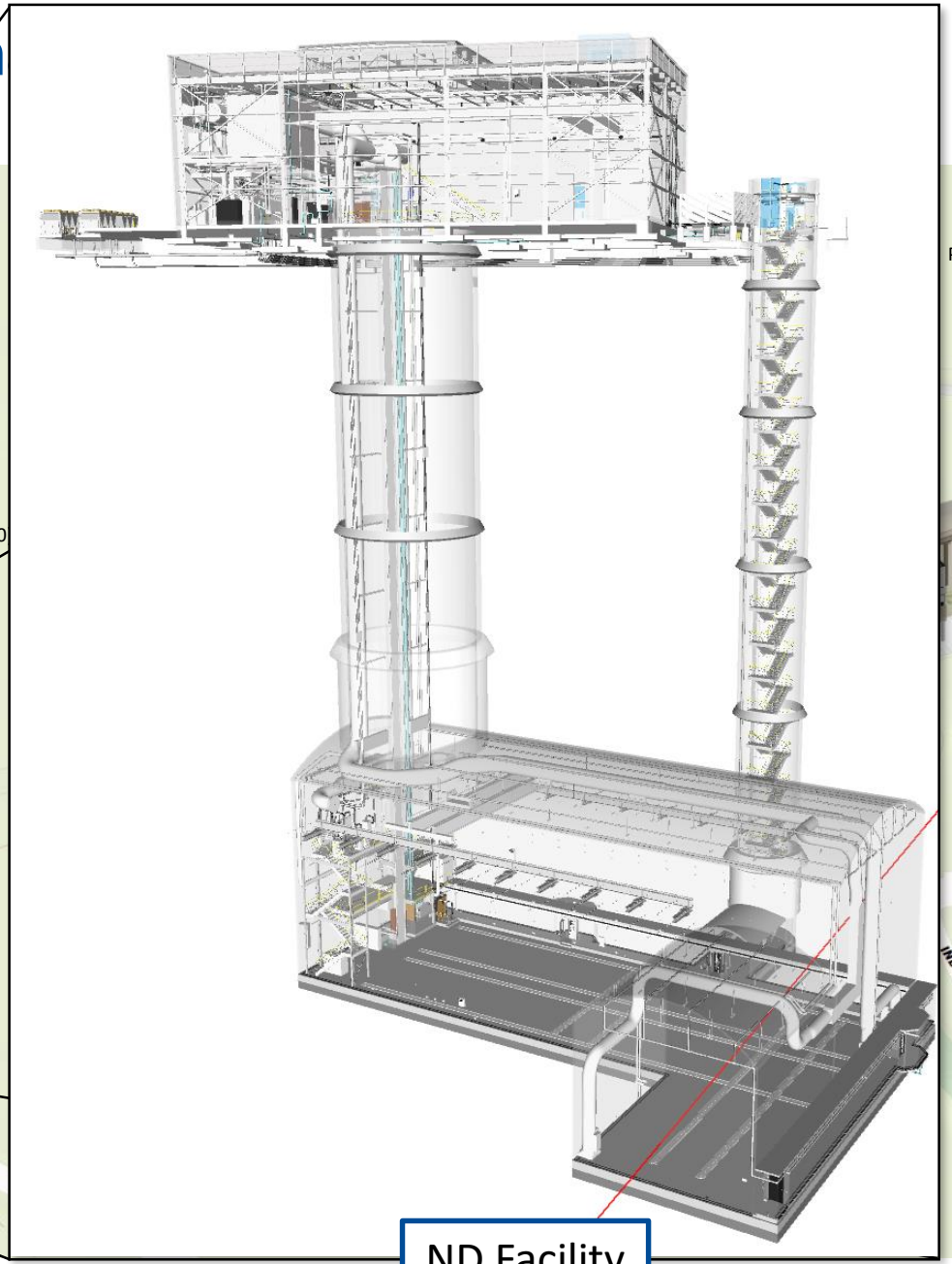
Near Site Conventional Facilities

Target Complex

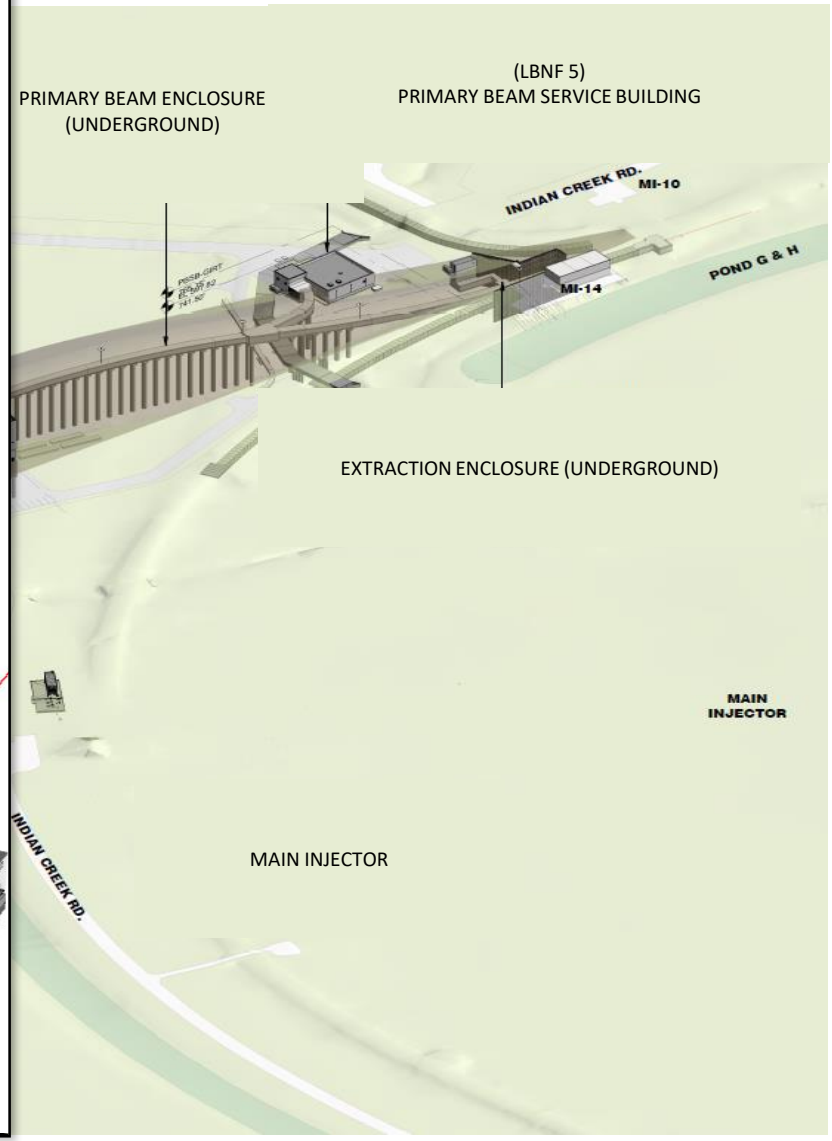


Near Site Convention

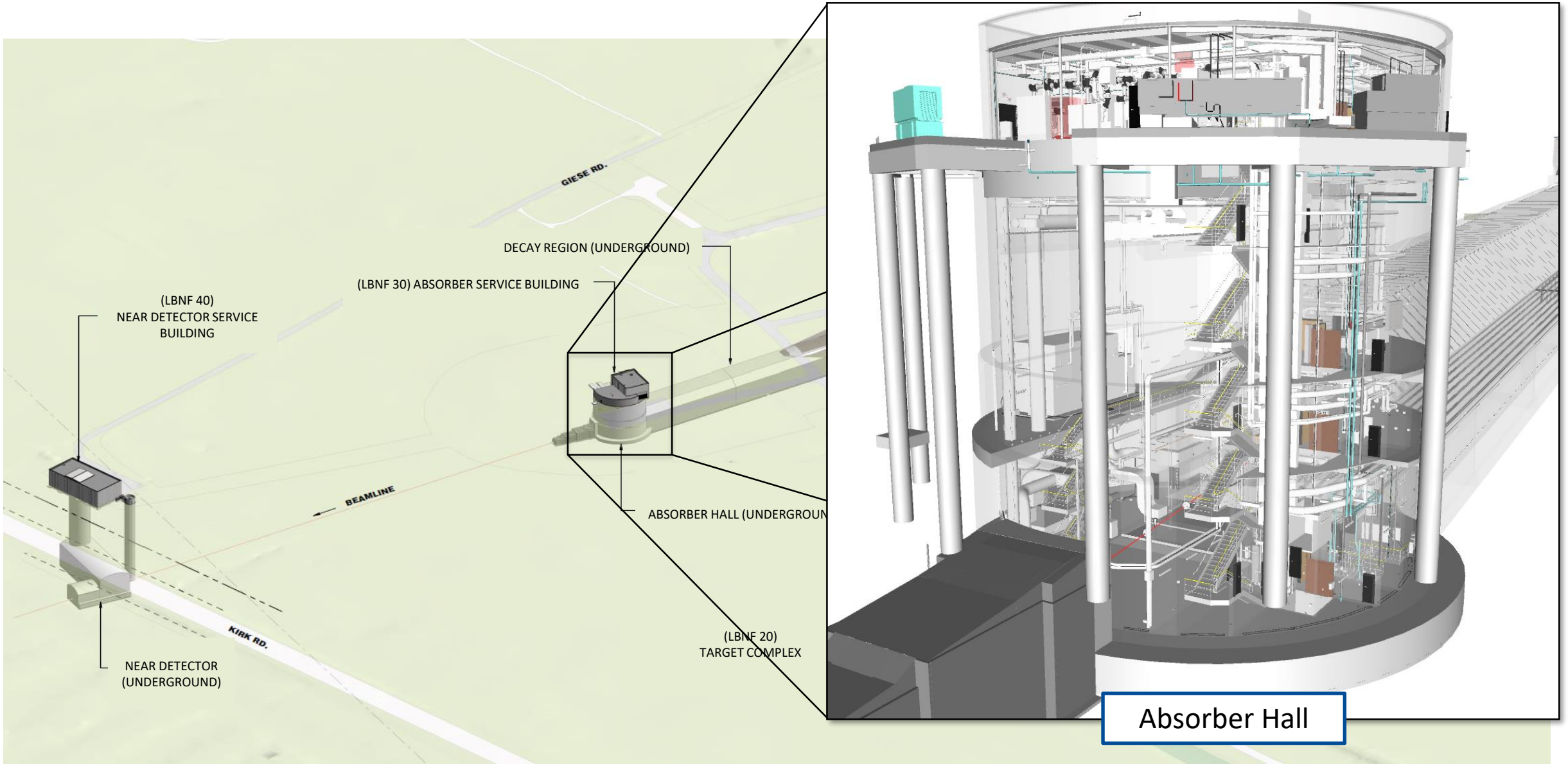




ND Facility



Near Site Conventional Facilities



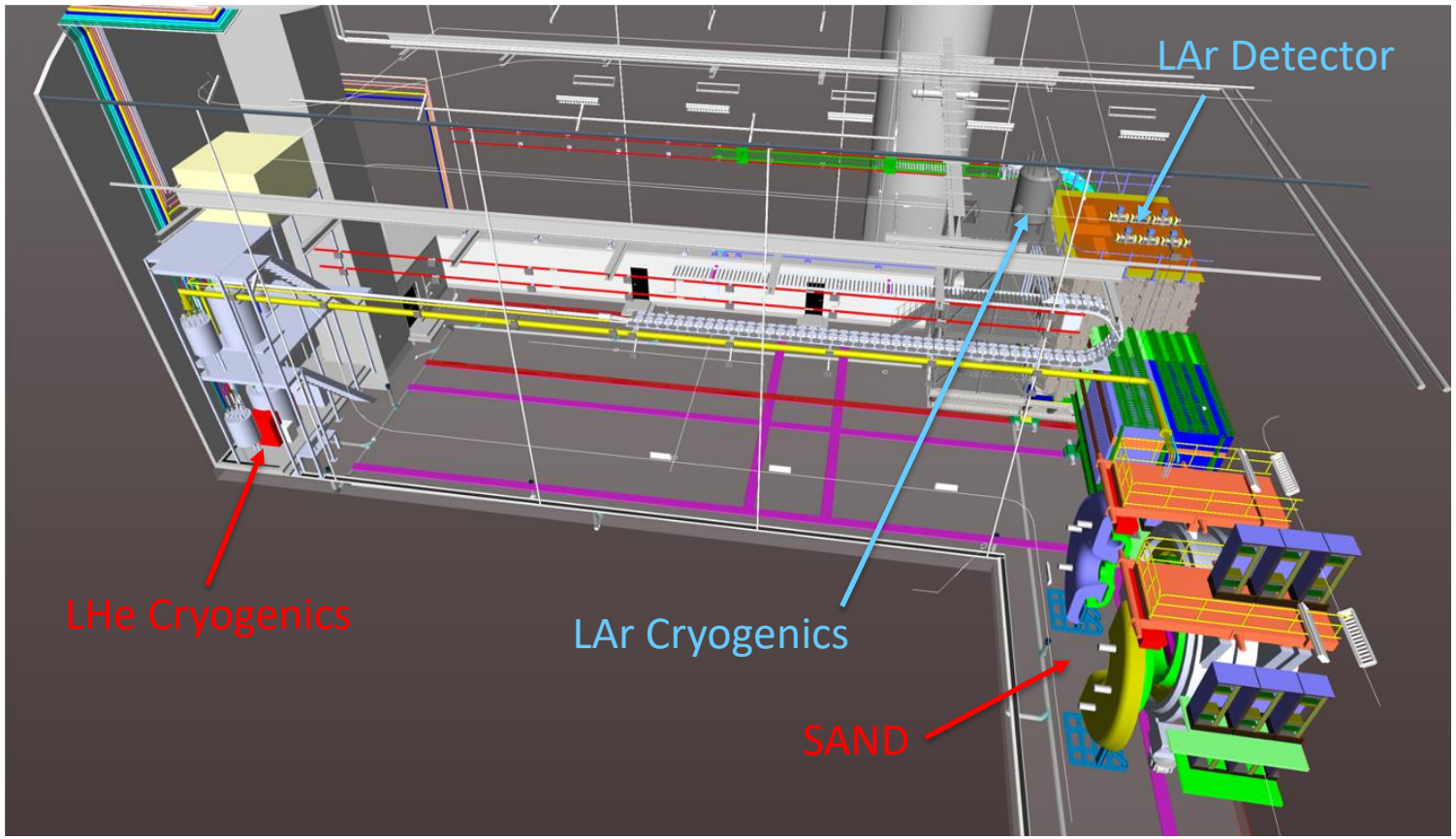
Near Site Conventional Facilities - Site Preparation Work

- Prepared site for LBNF Beamline facilities. Rerouted Indian Creek, relocated utilities, replaced Fermilab cooling pond with cooling tower.
- Completed on schedule in October 2020.

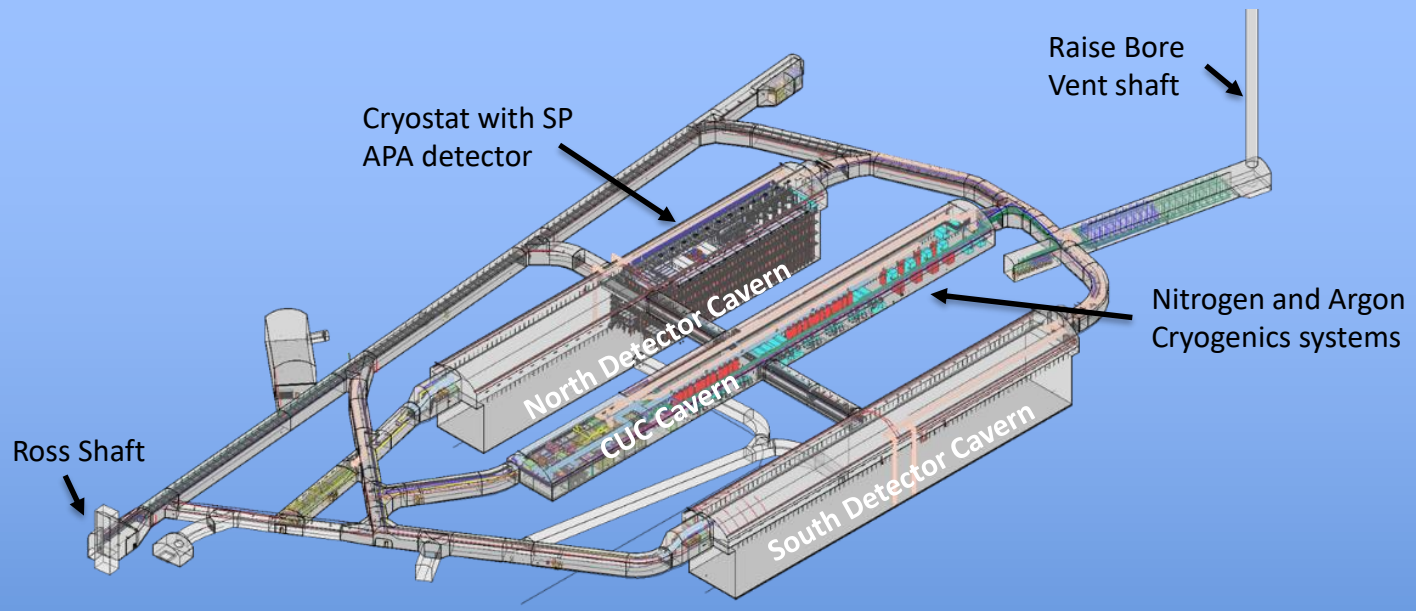
Rerouting Indian Creek with a new 140m long culvert system with fish channel

Near Site Cryogenic Infrastructure

- Scope includes LHe system to support SAND superconducting magnet and LAr system to support Near Detector TPC
  - LAr Cryogenics builds on successful systems at ProtoDUNE at CERN and SBN at Fermilab. Procurement requirements in development.
  - LHe Cryogenics builds on system for KLOE magnet at INFN and will be upgradable to support future ND-GAr. RFP in development for refrigeration system.
- Preliminary designs are complete.



Project Scope – Far Site



Component	Scope
LBNF FS Facilities	
FS Conventional Facilities	Project management, preliminary and final design, and construction for surface and u/g facilities & infrastructure for 4 detector modules
FS Cryogenics Infrastructure	Two cryostats; cryogenics systems to support two detector modules; 34 ktons of Argon
Far Detector	DUNE-US contributions to a Single-Phase APA-based detector and a Vertical Drift detector
FS Integration	Support & coordinate post-CF installations + detector installation infrastructure

At the far site, the LBNF project scope includes committed critical in-kind contributions from:

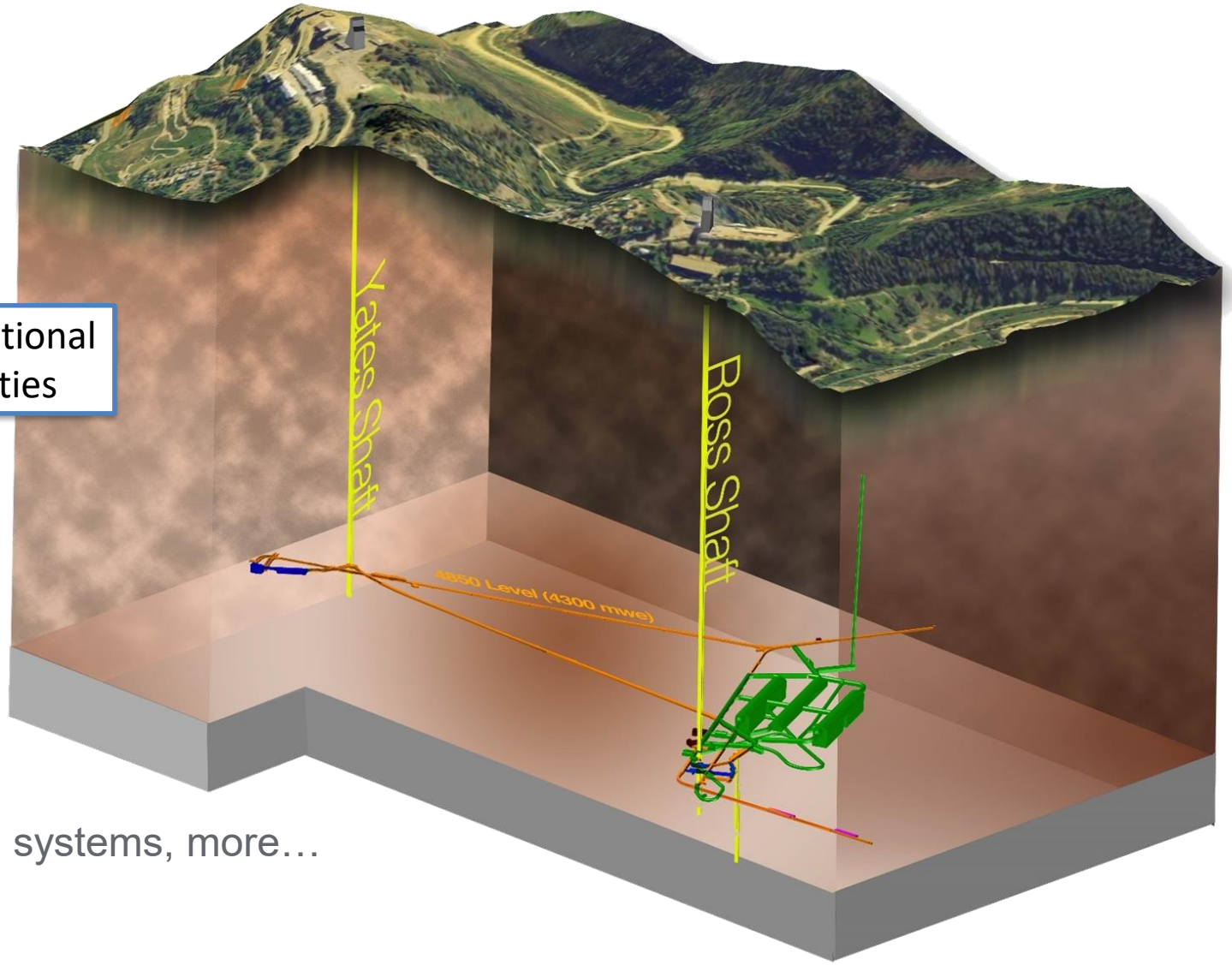
- CERN – Membrane cryostat and portions of argon receiving facility (tanks)
- Brazil/UNICAMP – Argon purification and recirculation systems
- Switzerland/SERI – Argon condensing system
- Poland/WUST – Internal cryogenics systems

We are currently working with DOE, CERN, and other LBNF partners to support second far detector module in project base scope

Far Site – LBNF Phases of Work

1. **Reliability Projects**
   - Ross shaft rehabilitation
   - Hoist motor replacement, new drives, brakes, clutches, more…
2. **Pre-Exc Construction**
   - Rock disposal systems
   - Ross headframe upgrade, sub-station upgrade, more…
3. **Exc & Surface Construction**
   - Brow enlargement, drifts, central utility and detector caverns, more…

Conventional Facilities



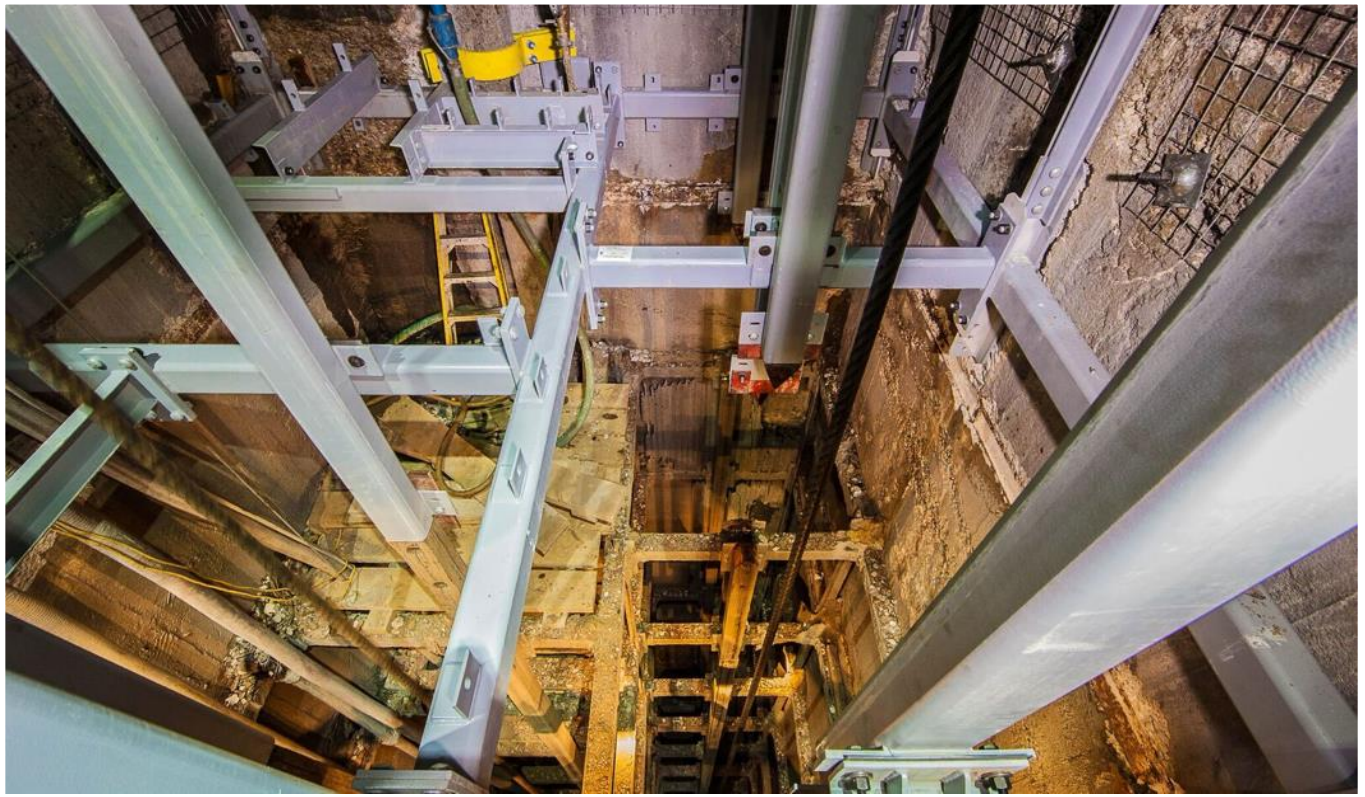
4. **Cryostats/Cryogenic Systems**
   - Cryostats
   - Nitrogen refrigeration and Argon purification systems, more…
5. **Detector Installation**

Far Site Conventional Facilities Status

Reliability Projects

- ✓ Refuge Chamber Capacity Increase
- ✓ Oro Hondo Fan VFD Replacement
- ✓ Ross Crusher Roof Replacement
- ✓ Ross Shaft Cage Replacement
- ✓ Ross Shaft Skips Replacement
- ✓ Ross Hoist Motor Replacement
- ✓ Ross Hoist Bearing/Bushing Refurb
- ✓ Ross Hoist Mech/Electrical Components Upgrades
- ✓ Ross Shaft Rehabilitation

Reliability work started in 2012 with the start of renovation of the 1.5km deep Ross shaft



Renovation of Ross Shaft in progress, with old and new structural steel sets visible.

Reliability Work - New Hoist Components – Motors and Brake Shoes

New AC 1,700HP Motors

New Service Hoist Brake Shoes

Reliability Work – New Drive, Brake, and Clutch Hoist System at Ross Shaft

1930-era Control System - Foot Pedals, Analog Gauges, and Hand Levers

Reliability Work - New Hoist Control System

New Climate Controlled Hoist Cabs

Operator Hoist Control Center with Flat Screen Monitors and Joystick Controls

Far Site Conventional Facilities Status

Pre-Excavation Scope

- ✓ Empty & Repair Ore Pass
- ✓ Replace Skip Loading System
- ✓ Replace/Restore Rock Crushing System
- ✓ Rehabilitate the Existing Tramway
- ✓ Install New Conveyor System
- ✓ Install additional Electrical Capacity at Ross Substation
- ✓ Structural Reinforcement of Ross Headframe
- ✓ Install Shaft Utilities
- ✓ Early Ventilation Improvements

Groundbreaking for pre-excavation work was held in August 2017

LBNF Groundbreaking held at 4850L (1.5km underground) at Sanford Lab. Participants included:

- – International funding agencies: CERN, INFN, and STFC
- – Congressional delegation and the Governor of South Dakota
- – Executive Office of the President (Michael Kratsios, OSTP) and DOE
- – Fermilab and Sanford Lab

Underground Preparation for Cavern Excavation Work

- ✓ Chamber to support drilling of 1200’ “raise bore” to improve ventilation and heat removal at 4850L
- ✓ Seven blast doors to support excavation
- ✓ 700’ long new drift to spray chamber
- ✓ System to load rock for transport to surface

“Jumbo” drilling blasting hole


Skip loader at 4850L

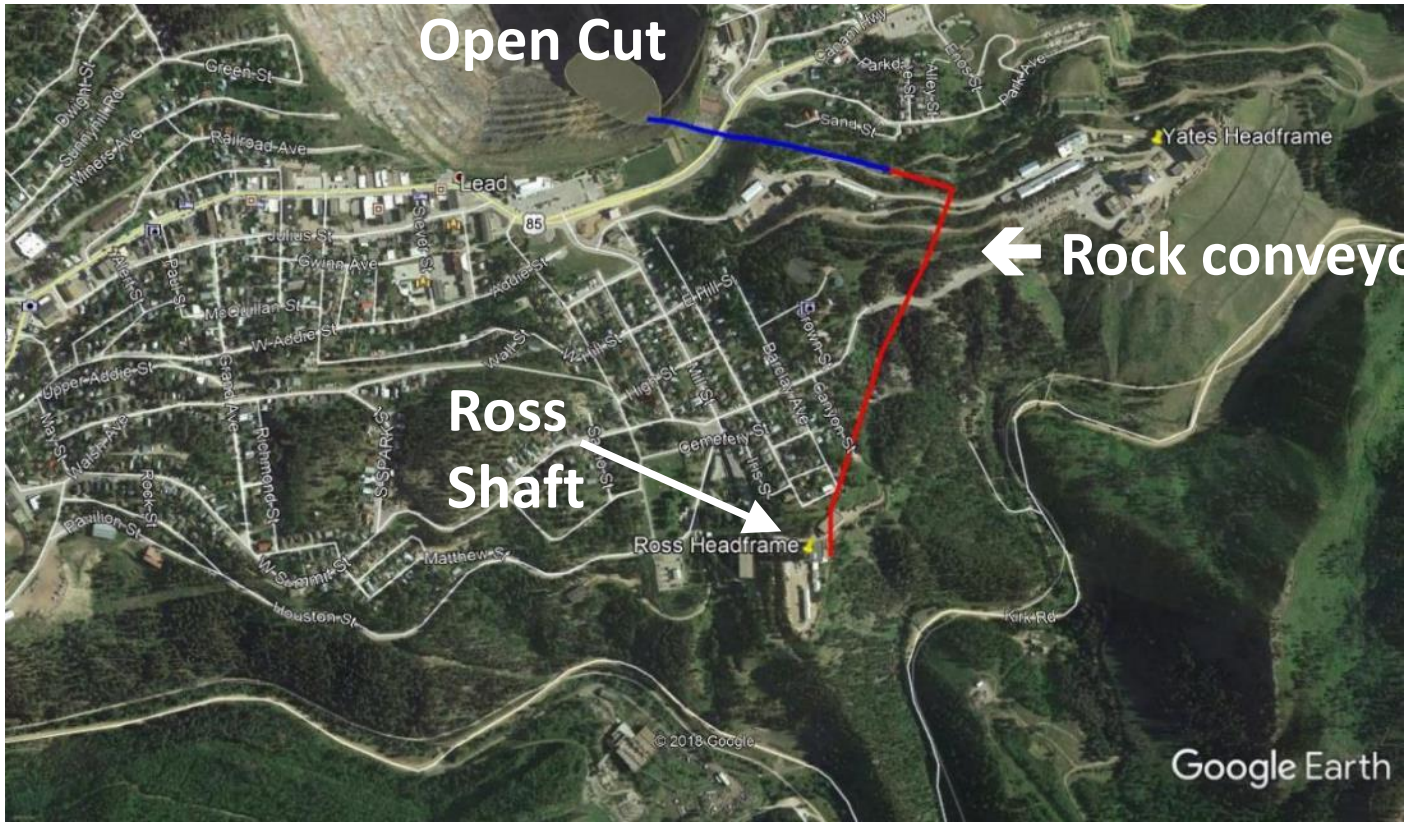

3650L raise bore chamber


4850L pilot drift to spray chamber


Blast doors installed

Rock Conveyor for Cavern Excavation Work

- ✓ 1280m long conveyor to move excavated rock from rock crusher at the top of Ross Shaft to the Open Cut in Lead, SD for disposal.

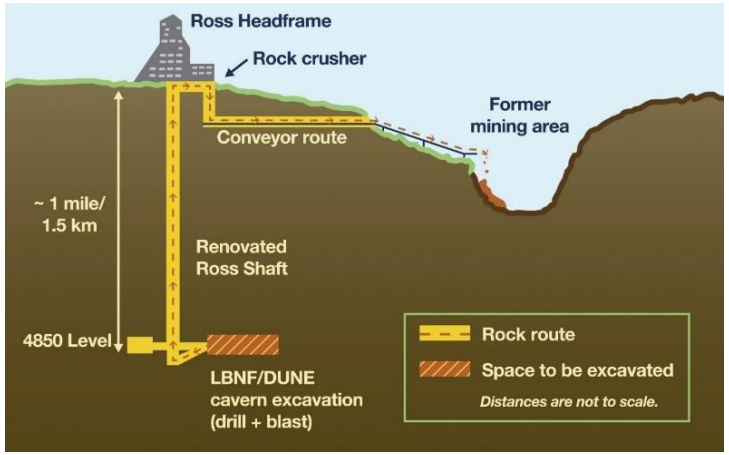


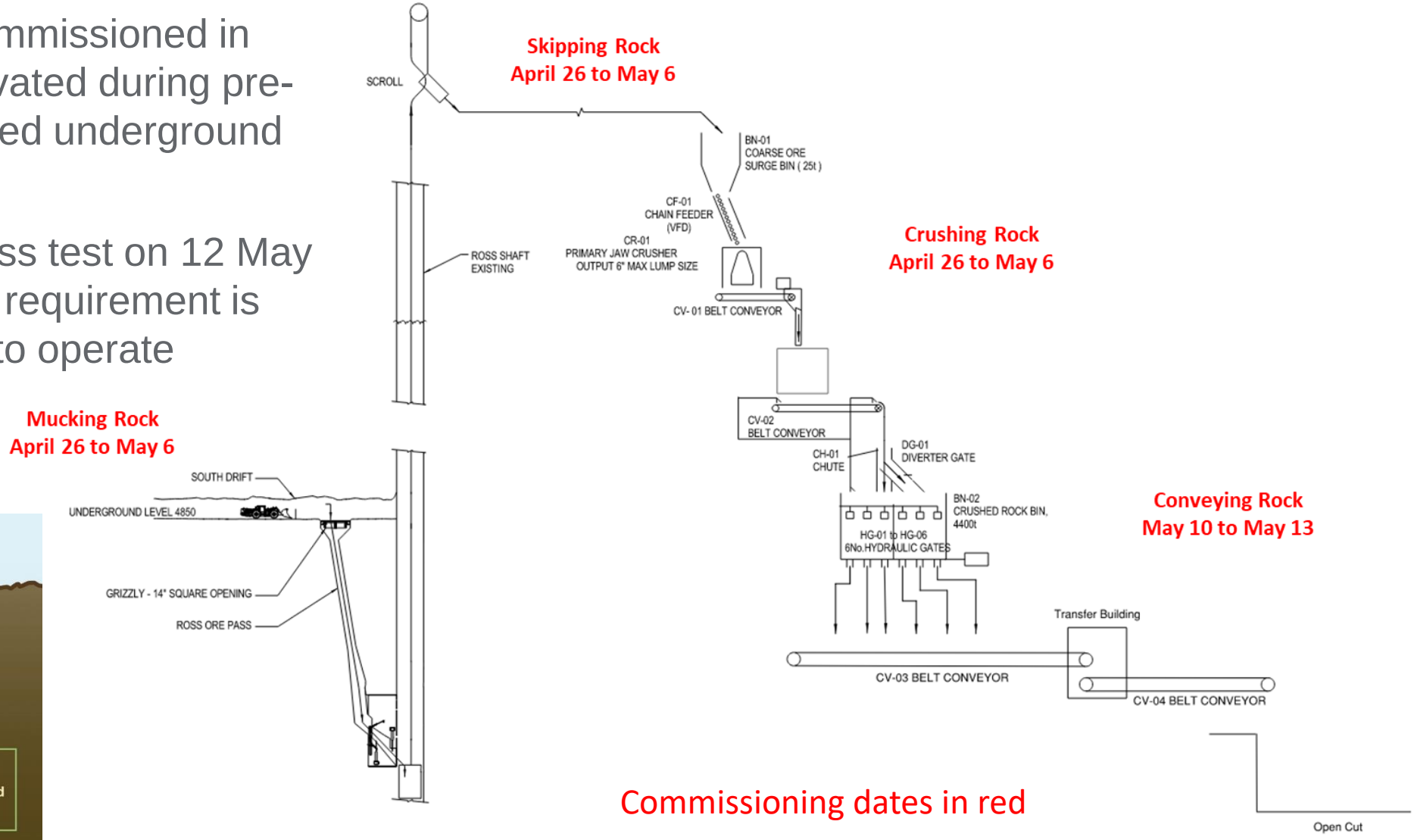

Conveyor from tramway to open cut


Conveyor in underground tramway

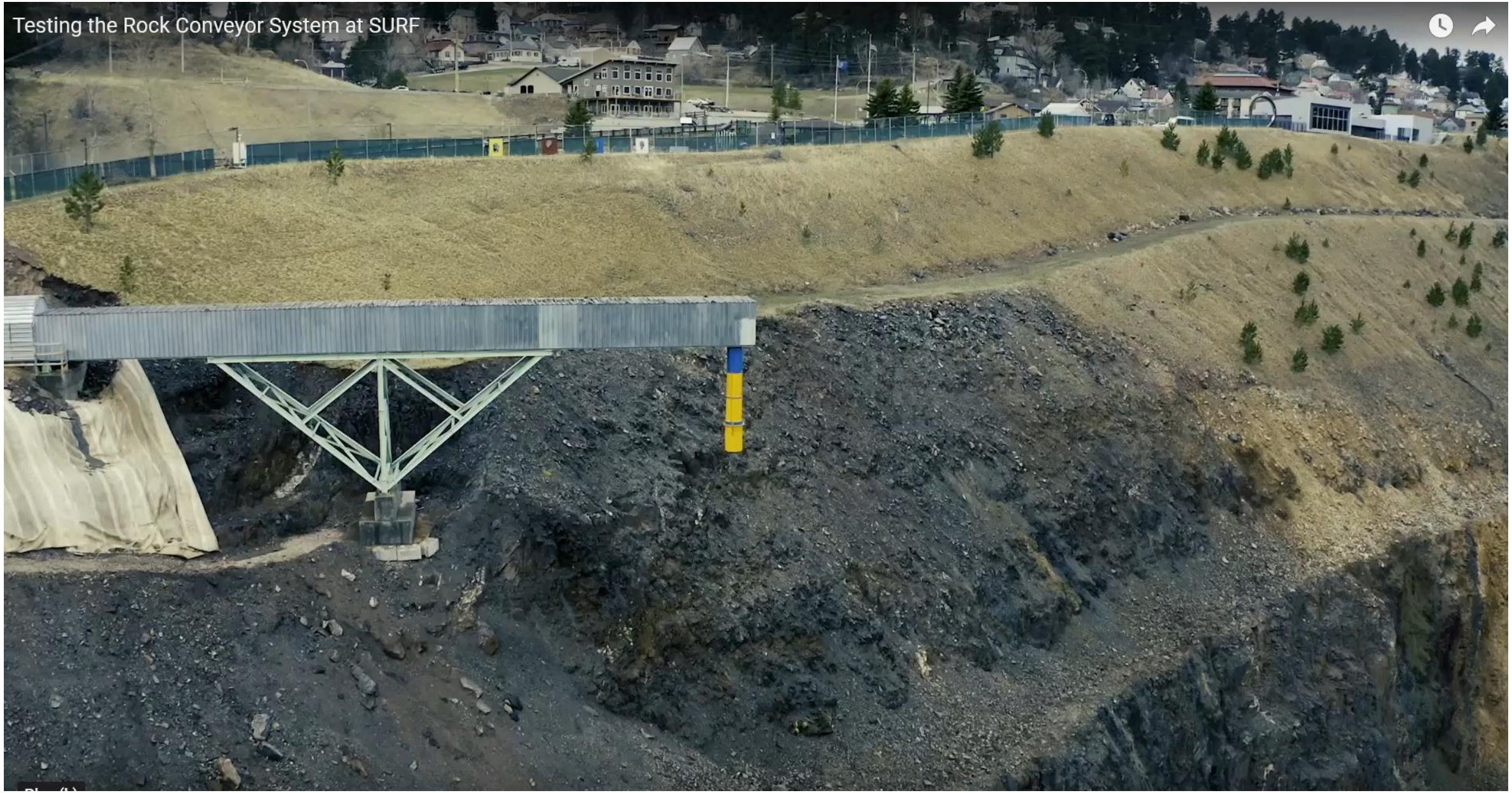
Pre-excavation Work Complete, including Rock Removal System Commissioning

- Rock removal system commissioned in April-May with rock excavated during pre-excavation work and stored underground temporarily
- System completed a stress test on 12 May @ 450 tons/hour (design requirement is 390 tons/hour, expected to operate at < 200 tons/hour)



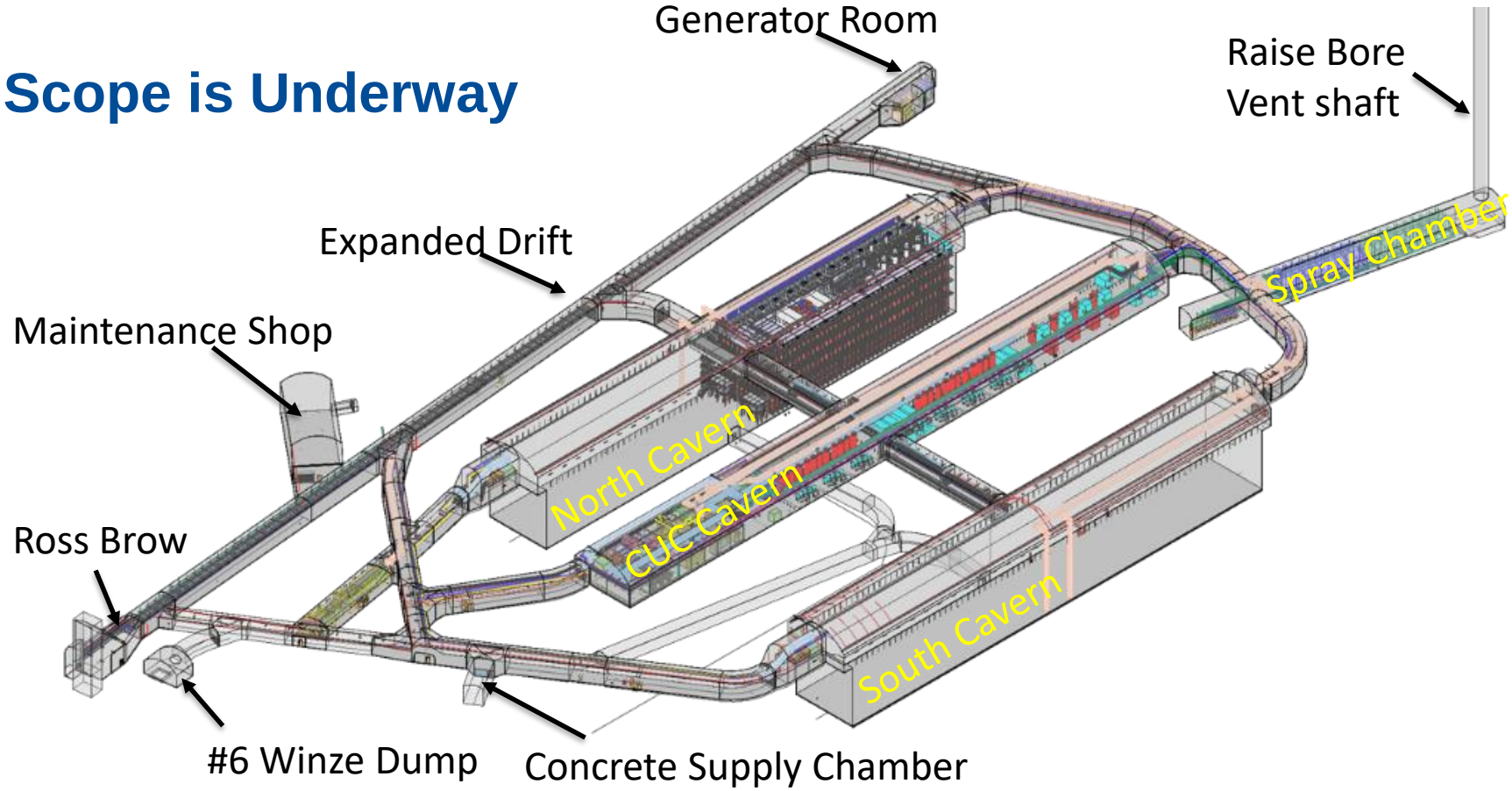


Video courtesy of Matt Kapust, SDSTA



Main Cavern Excavation Scope is Underway

- Main excavation contract started work on 5 April; planned for 36 months
  - Approximately 800,000 tons of rock to be excavated to create 17,000 m^3 floor area
    - ~24 months for blasting and rock removal to create drifts and caverns
    - ~12 months for concrete base, cryostat foundation, cranes, hoists, etc.
- Then start to install cryostats and complete utility systems; contracts planned for award in 2023 – 2024 timeframe.

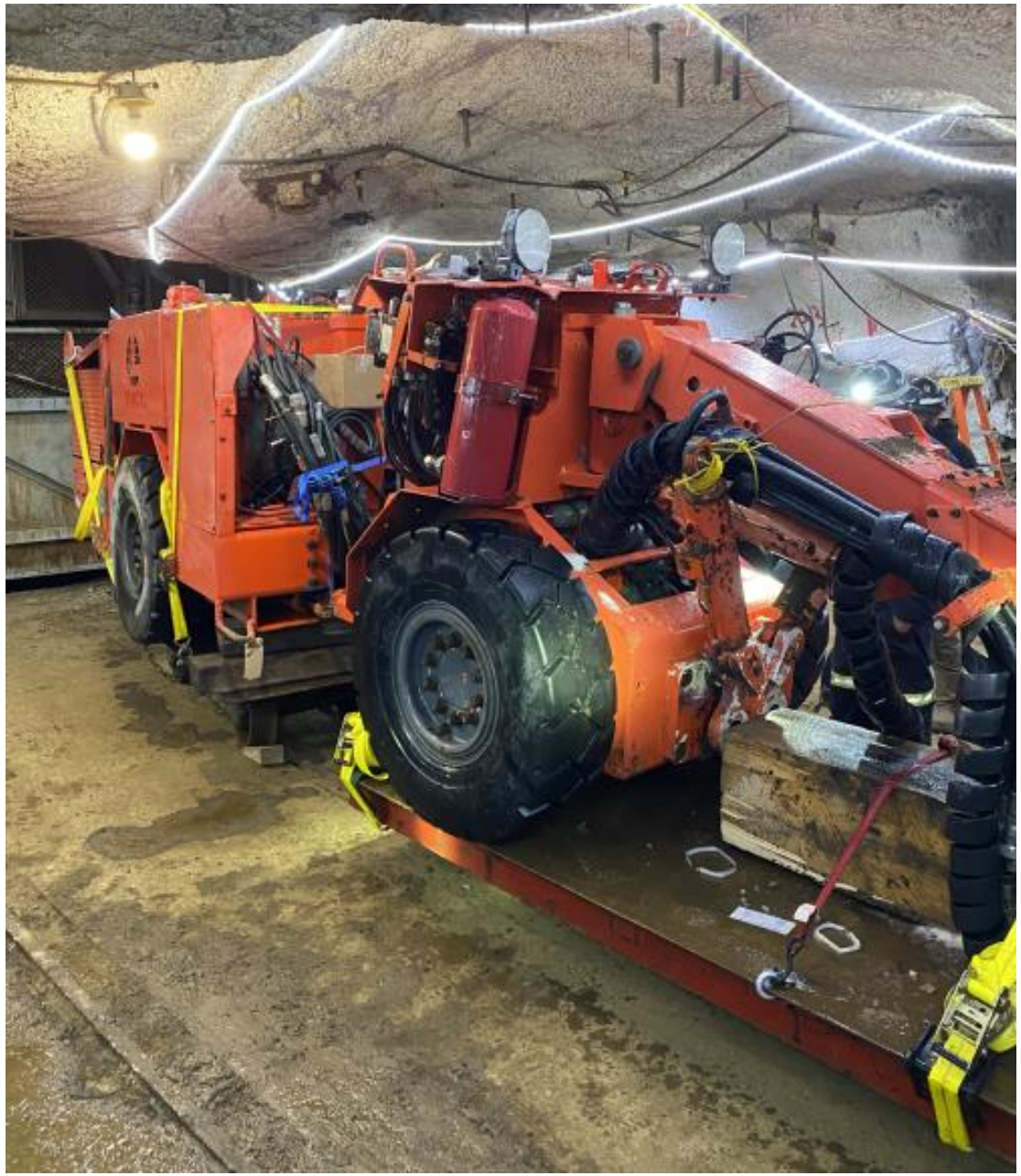


2 x Detector Caverns:
145m L x 20m W x 28m H

1 x Central Utility Cavern (CUC):
190m L x 20m W x 11m H

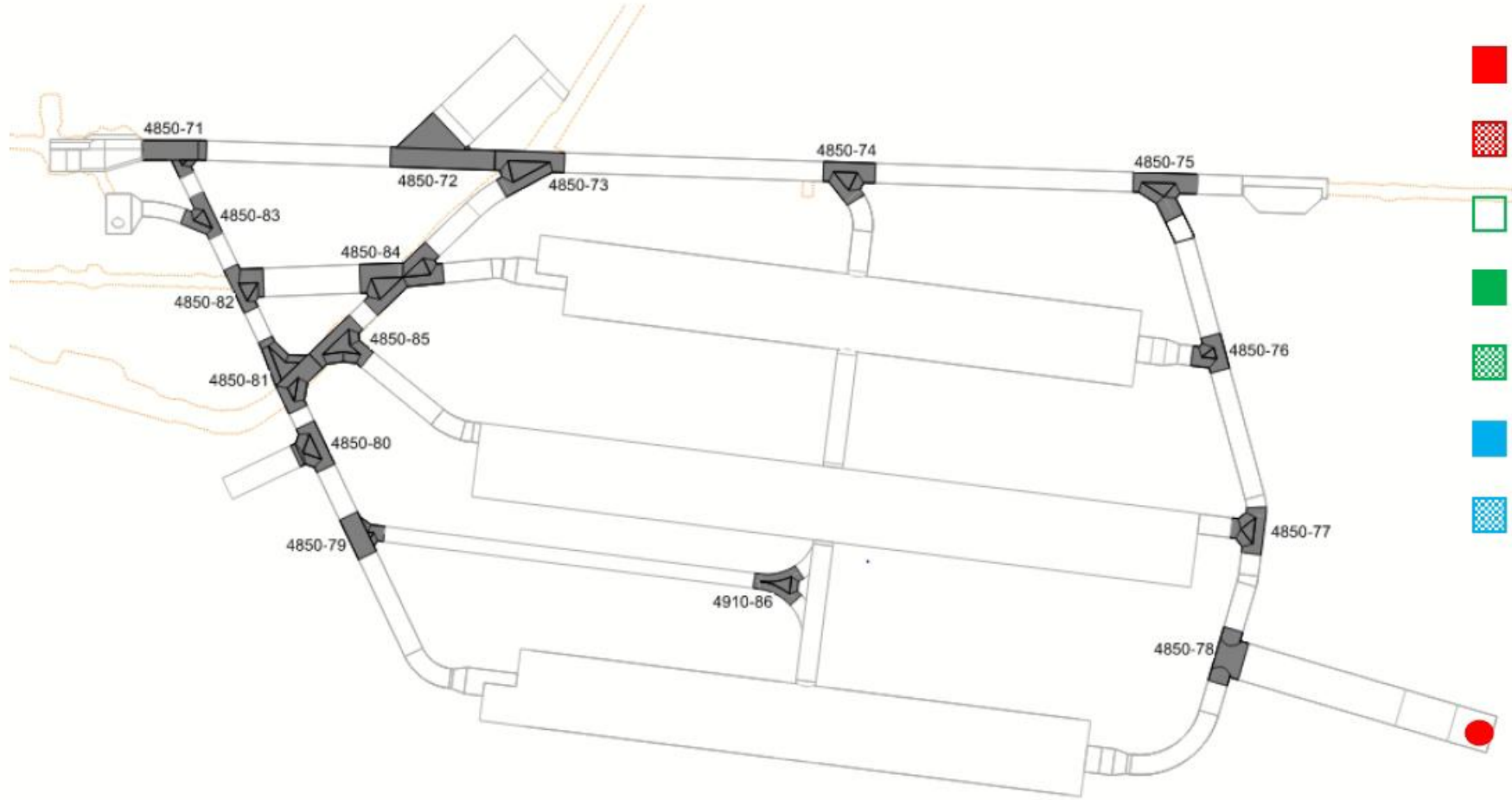
Excavation Mobilization

First underground equipment to arrive at 4850L: Shotcrete Transporter



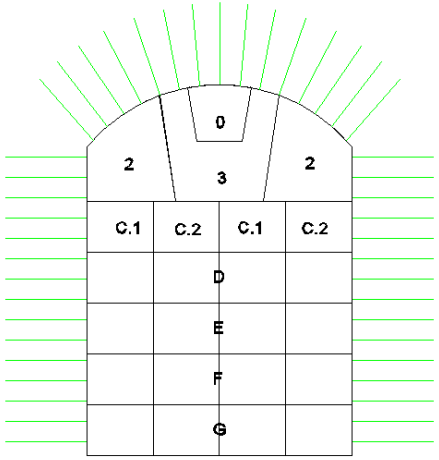
Drill & Blast “Jumbo” pallets arriving on 4850L

Sequence of Work for Main Cavern Excavation – 4850L



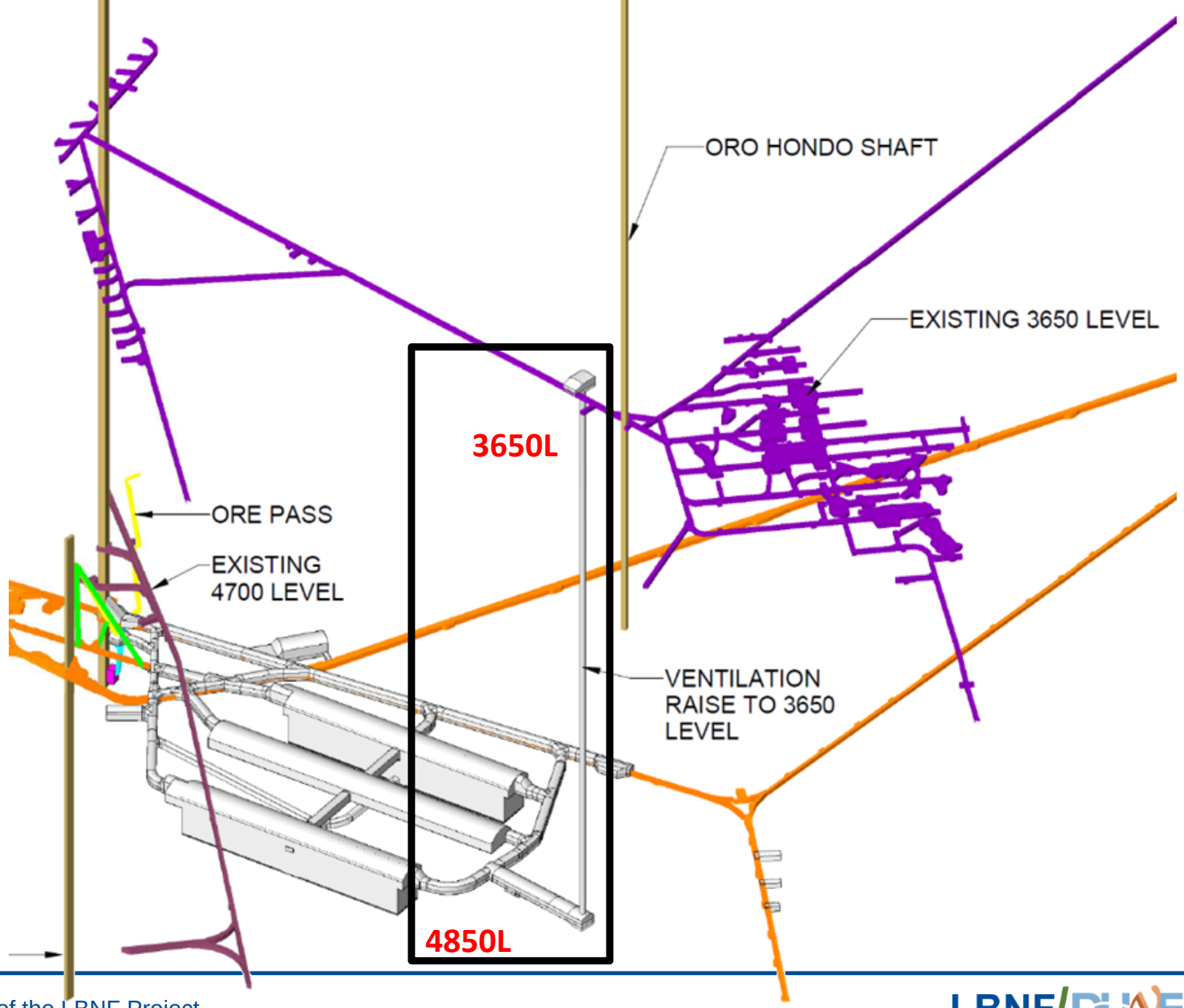
Bench B
Bench C
Bench D
Bench E
Bench F
Bench G

Excavation
Past Excavation
Concurrent Shotcrete
Shotcrete
Past Shotcrete
Concrete
Past Concrete



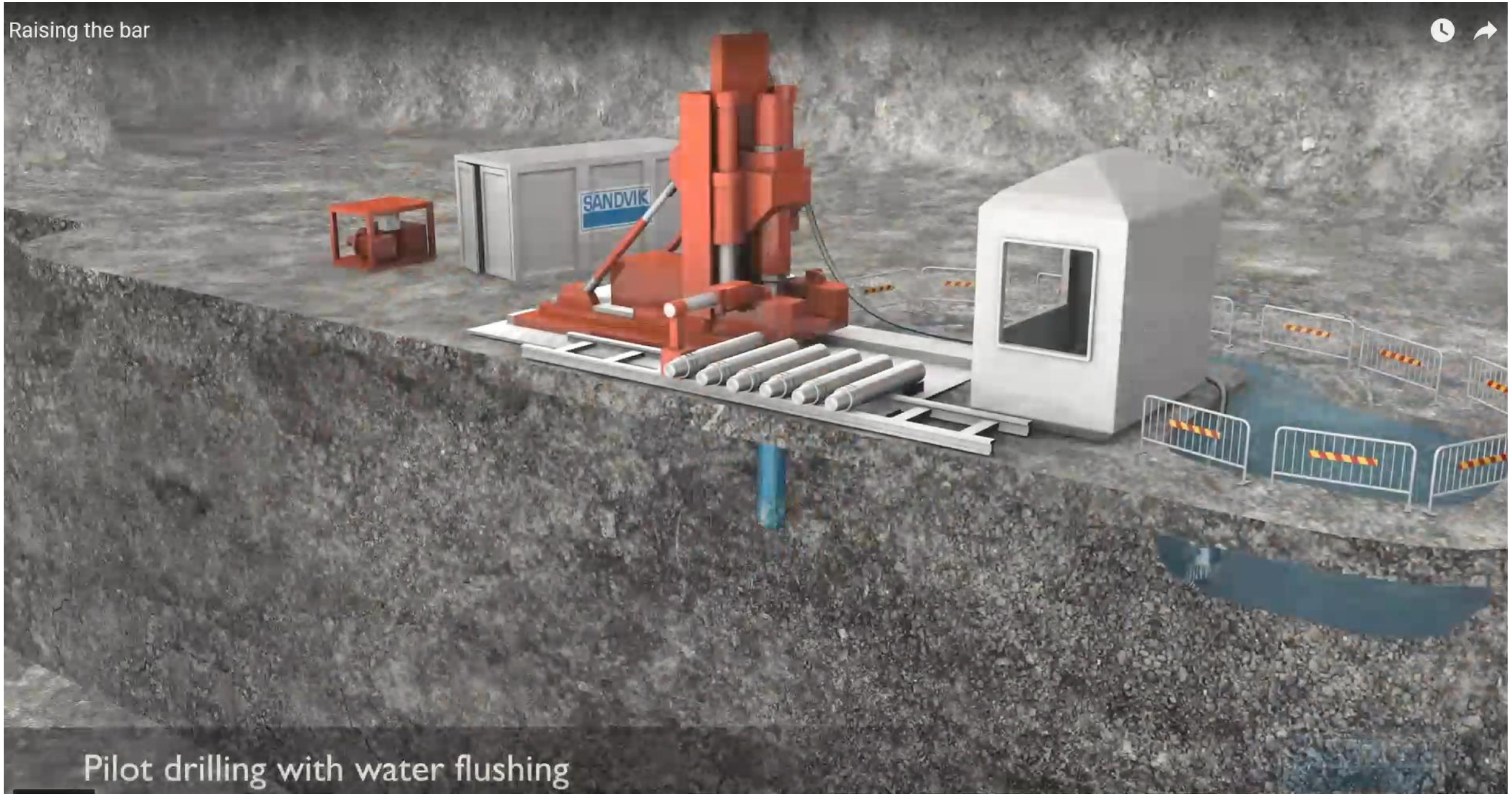
1200’ (366m) Raise Bore 3650L to 4850L

- Raise bore pilot shaft to start work this week; complete in November



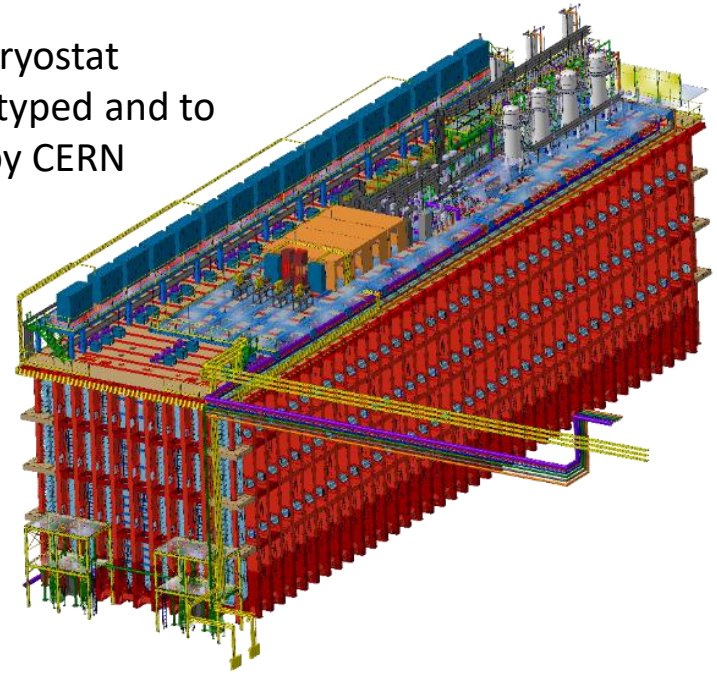
Preparations to start Raise Bore

Raise Bore Machine being assembled in 3650L cavern

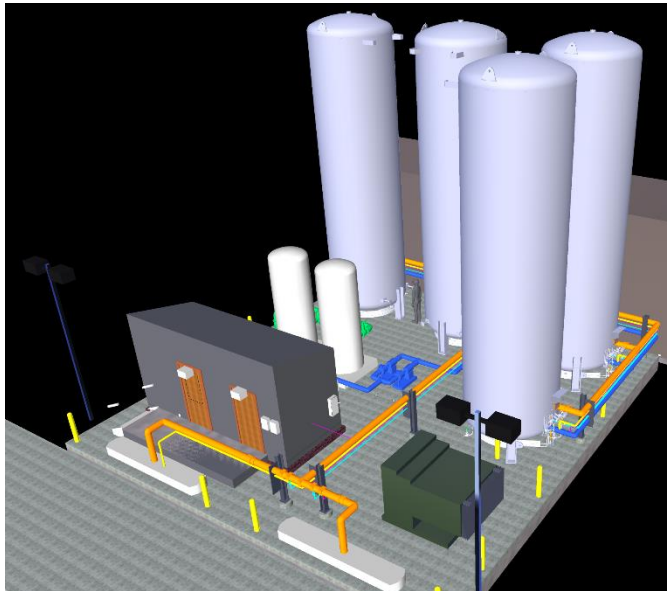

Raising the bar
SANDVIK
Pilot drilling with water flushing

Far Site Cryogenics Infrastructure

Membrane cryostat engineered, prototyped and to be installed by CERN



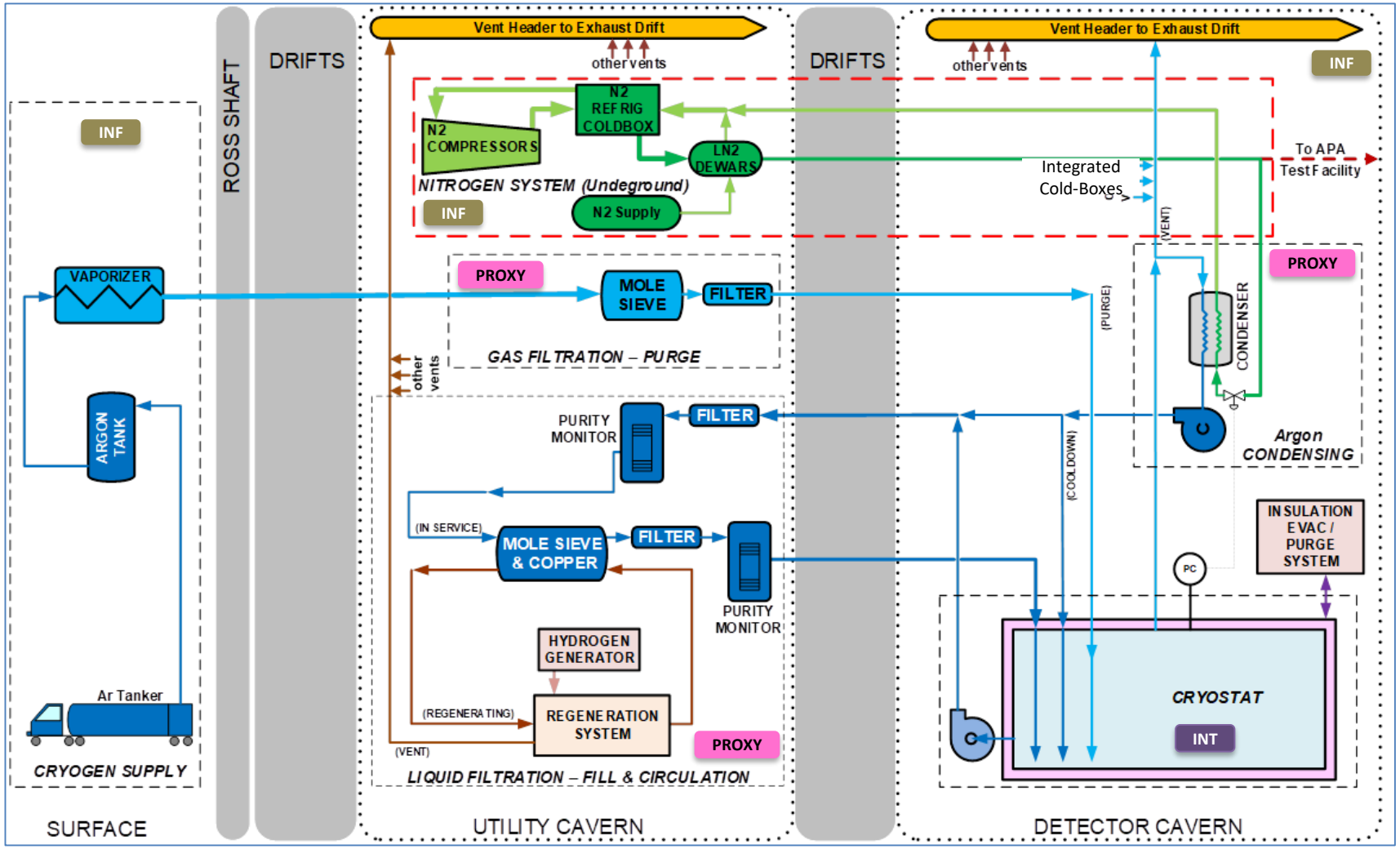
- Cryostat:
  - Warm structure final design completed in Nov 2018
  - Membrane design completed by GTT in April 2019.
  - CERN leadership has submitted proposal for 2nd cryostat to be included in MTP budget; hope for approval at the June CERN Council meeting.
- Nitrogen System
  - Proposals received for phase 1 Pre-FEED study at pre-determined fixed price. Vendors will progress design in ~ 3-4 months sufficiently for them to provide phase 2 proposal.
  - Phase 2 proposals from these vendors will be due January 2022 and will contain all cost/schedule information for remaining design, manufacturing and installation at firm fixed price with economic price adjustments based on indices.
- Performing CFD simulations of LAr motion for Vertical Drift detector configuration.



Updated Argon receiving facilities at Surface

Cryogenics Infrastructure Process Flow Diagram

- Liquid argon will be delivered at the surface, then vaporized and delivered underground where it is re-condensed.
- Nitrogen refrigeration system will be completely located at 4850L underground.



Plan for DOE Baselining

- *Baselining* is a critical decision milestone (“CD-2”) in DOE project management process, described in Order 413.3B.
  - Establishes the final cost and schedule performance parameters for a project
- LBNF baselining drivers and considerations:
  - Project currently has “advance” construction authority (“CD-3a”) from DOE for excavation work; project needs additional construction authority to complete all excavation work
    - ► Additional authority needed NLT March 2022
    - ► DOE policy is that additional construction authority will only be provided for baselined scope
  - There are varying maturity levels for different project elements – designs for Far Site Conventional Facilities are fully mature; designs/prototyping for second far detector and near detector are less mature.
    - ► This makes successfully completing a baseline review for the *entire* project by the fall of this year challenging
    - ► For DOE baselining process, certainty regarding who will deliver what scope, including for detectors, is critical for success.
  - These factors, and others, create the motivation to use a “subproject” approach, which will allow project elements to be baselined as soon as ready.

Considerations used to develop Subprojects

- **Maturity of subproject scope:**
  - Design/technical/prototyping maturity
  - Planning maturity, including the status of commitments and dependencies for any non-DOE contributions
- **Ability of each subproject to deliver a complete product:**
  - Clear deliverables with defined boundaries
  - Objective means to establish completion
  - Clear, independent Key Performance Parameters (KPPs)
- **Manageability of subprojects**
  - Minimal and manageable interfaces and dependencies between subprojects
  - Organizational implications including adequate subproject management
  - Reporting – ability to produce representative EVMS or progress data and reports
- **Timing of necessary construction authorizations (CD-3x's)**

Proposed Approach – 5 Subprojects

Subproj Abbrev	Subproject Title	Subproject Description	Design Maturity
FSCF	Far Site Conventional Facilities	All Far Site (FS) conventional facilities (CF) including all detector caverns and support infrastructure	100%
NSCF+B	Near Site Conventional Facilities + Beamline	All Near Site (NS) conventional facilities (CF) including beamline facilities, detector cavern and support infrastructure; Primary and Neutrino Beamline (B)	80% (CF) 60% (BL)
FD1+C	Far Detector 1 + Cryogenics	Far Detector 1 (FD1), including integration/installation, and all cryogenic infrastructure (C) to support both Far Detectors 1 and 2 except LAr fluids for FD2	90% (FD) 25% (C)
FD2	Far Detector 2	Far Detector 2 (FD2) including integration/installation and LAr fluids for FD2	25%
ND	Near Detector	Near Detector (ND) including integration/installation and cryogenic systems	40%

Subproject approach allows the project to employ a “baseline as soon as ready” strategy

Tailoring Strategy – Proposed Baseline (CD-2) Review Timing

Oct 2021

Apr 2022

Oct 2022

Sub-Projects – Boxes represent relative size (DOE project TPC only)

Near Site Conventional Facilities + Beamline

Scope:
All conventional facilities at near site
Primary and Neutrino Beamline

Partner agreements: 2

Comments: NSCF design complete by Sept, beamline design currently > 60% final, ready to baseline by fall of 2021

Far Site Conventional Facilities

Scope:
All conventional facilities at far site
LBNE/Conceptual Design

Partner agreements: 0

Comments: design complete, in execution, 75% under contract, ready to baseline now

FD1 + Cryogenics

Scope:
FD1 Components
Far Site Cryogenic Infrastructure
FD1 Cryogens
Installation/Integration

Partner agreements: 7

FD2

Scope:
FD2 Components
FD2 Cryogens
Installation/Integration
Partner agreements: 6

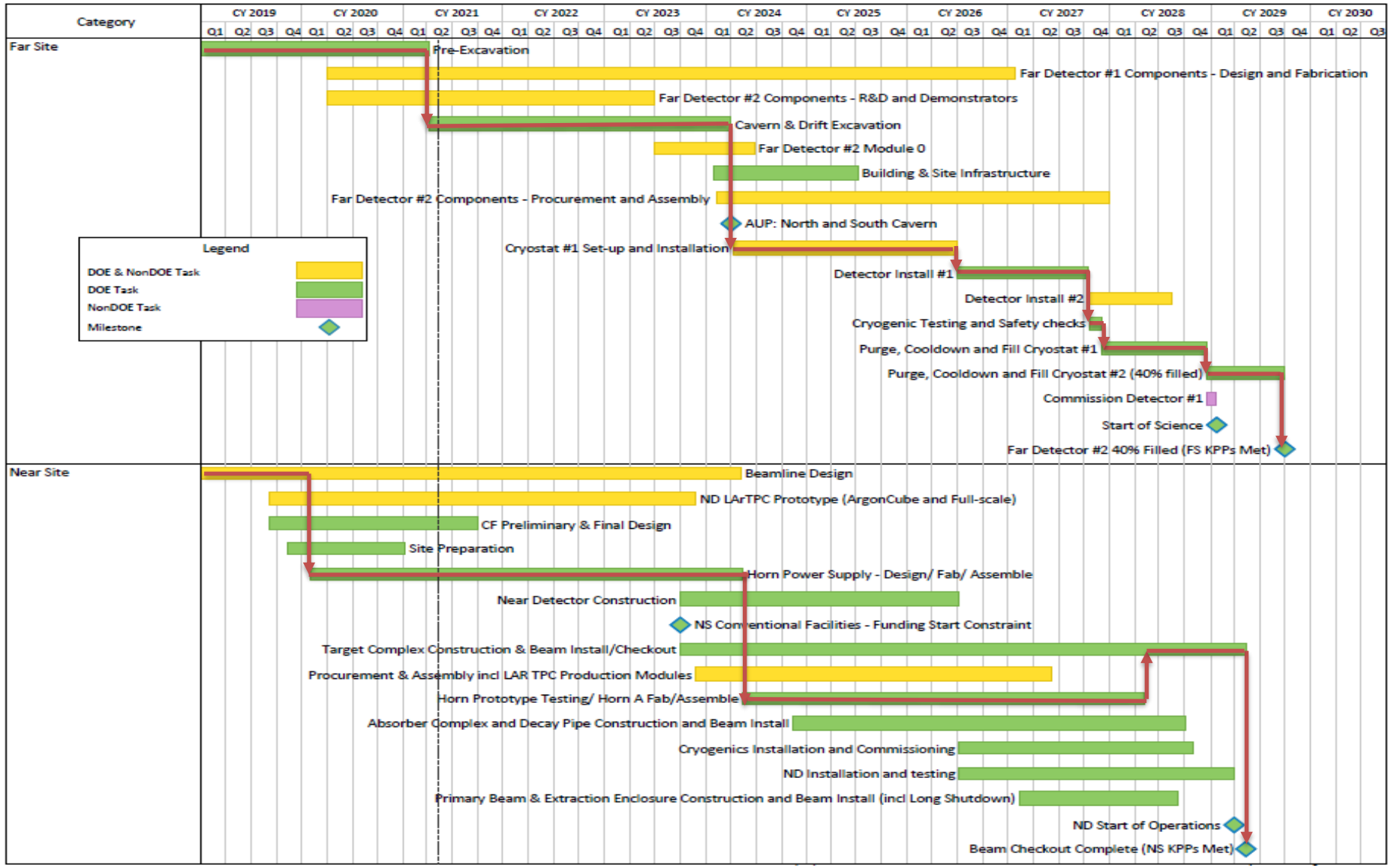
ND

Scope:
ND Comp
ND Cryo
I&I
PA: 5

LBNF DUNE Summary Schedule

- Schedule for FD2 is estimated
- Schedule is dependent on funding profile which will not be finalized until CD-2 baseline is approved by DOE

NS/ FS Critical Paths



Summary

- Project has entered a major new phase of work at the far site, with the start of cavern excavation work.
  - Planned 36-month duration
  - Timeline for follow-on scope now being developed in detail
- Optimistic that CERN Council will support second cryostat at budget meeting next month
- Near Site conventional facilities design is in final stages; completing in September.
- In coordination with collaboration leadership, project has developed a five subproject tailoring/baselining strategy to allow work to receive DOE approvals as each work scope matures and as soon as it is ready.