Update on LBNF to Fermilab Physics Advisory Committee

C. J. Mossey, LBNF Project Director

11 November 2016

Fermilab CERN Sanford Underground Research Facility U.S. DEPARTMENT OF ENERGY Office of Science

Topics

- Update
  - CD-3a, Phases, Schedule
  - “Reliability Projects”
  - Fiscal/Appropriations outlook
  - Procurement
  - Final Design Update
  - Miscellaneous
- Summary

Initial Far Site Construction for LBNF APPROVED

- On 9/1/16, DOE Under Sec'ty for Science and Energy **approved** the CD-3a milestone
- Paves the way to start ~$300M in construction at far site in FY17
- This approval:
  - Signifies DOE's **strong commitment** to move the project forward,
  - Provides impetus to solidify international partnerships, and
  - Positions DUNE to rapidly pursue its science objectives.

Critical Decision 3a, Approve Initial Far Site Construction for the LBNF/DUNE Project

Recommendations:

The undersigned "Do Recommend" (Yes) or "Do Not Recommend" (No) approval of Critical Decision 3a, Approve Initial Far Site Construction for the LBNF/DUNE Project at the SURF site as noted below.

ESAAB Secretariat, Office of Project Assessment — 9/1/16 Date — Yes ✓ No ___

Representative, Non-Proponent SC Program Office — 9/1/2016 Date — Yes ✓ No ___

Concurrence:

C. A. Murray
Director, Office of Science — 9/1/16 Date — Yes ✓ No ___

Approval:

Based on the information presented in this document and at the ESAAB review, I approve Critical Decision-3a, Approve Initial Far Site Construction for the LBNF/DUNE Project.

Franklin M. Orr, Jr.
Under Secretary for Science and Energy — 9/1/16 Date

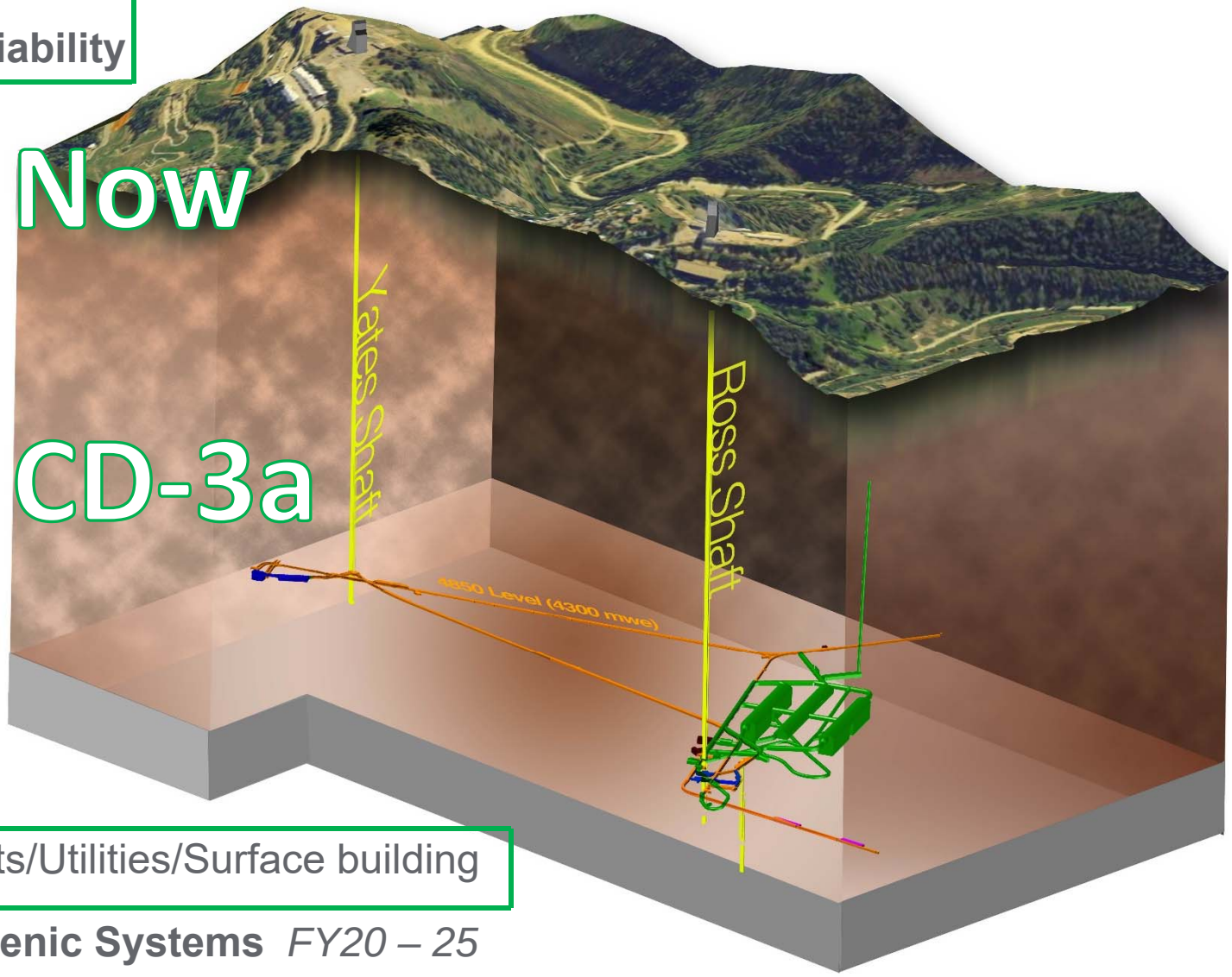
Far Site Scope – Phases of Work for LBNF

1. **Sanford Lab Reliability Projects**
   FY16 – 18
   - Ross shaft rehab
   - Hoist motor rebuilds, more…

2. **Pre-Excavation**
   FY17 - 18
   - Rock disposal systems
   - Ross headframe upgrade, more…

3. **Excavation/ Construction**
   FY18 – 22
   - Brow/Caverns/Drifts/Utilities/Surface building

4. **Cryostats/Cryogenic Systems** *FY20 – 25*

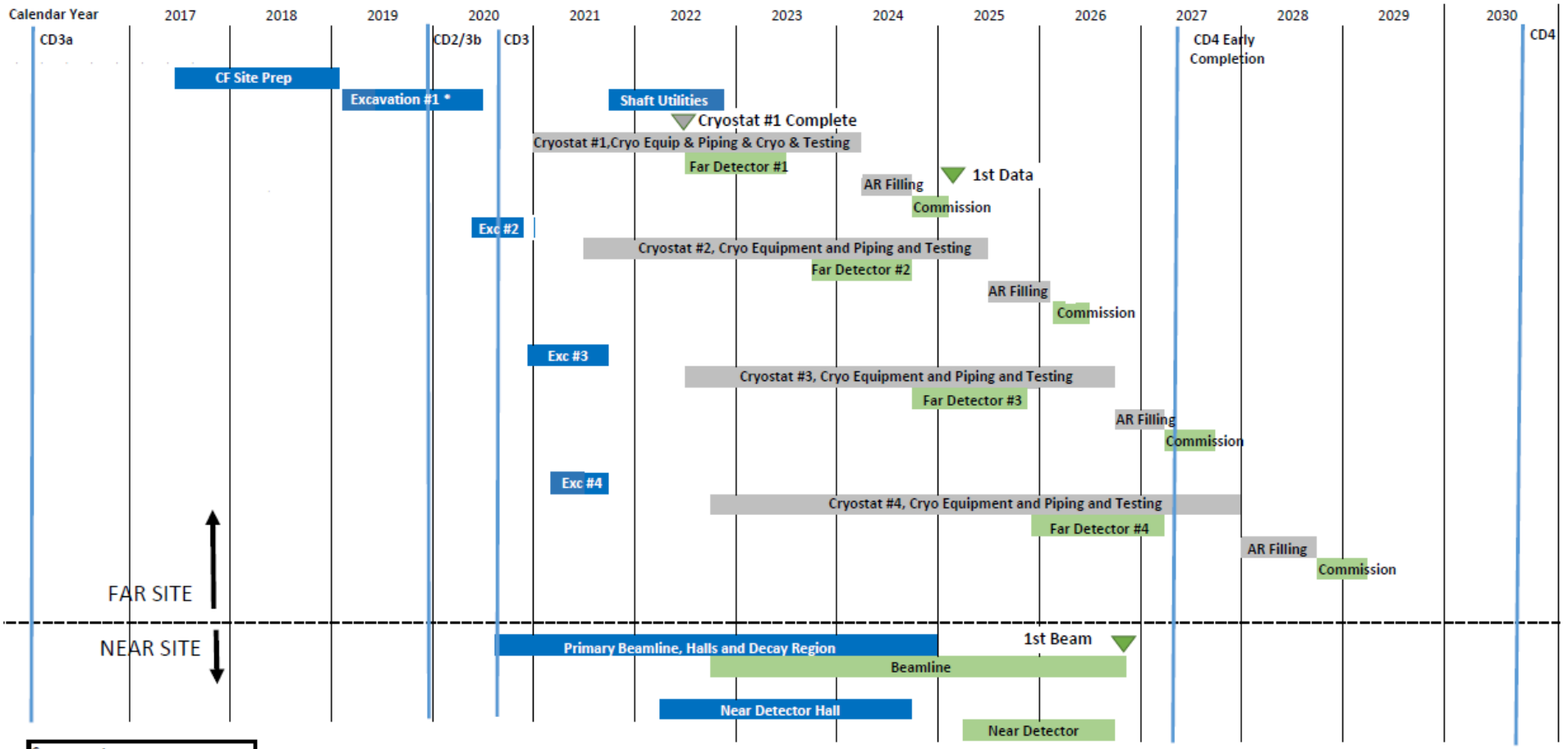


CD-3a ESAAB Approval Provided New Funding Guidance

$M	Prior	FY 17	FY 18	FY 19	FY 20	FY 21	FY 22	FY 23	FY 24	FY 25	FY 26	FY 27	Total
CD-1R ESAAB	142.0	70.0	110.0	150.0	180.0	180.0	180.0	180.0	160.0	82.0	23.0	0.0	**1,457.0**
CD-3a IPR	147.0	70.0	110.0	150.0	180.0	180.0	180.0	180.0	160.0	82.0	23.0	0.0	**1,462.0**
CD-3A ESAAB	147.0	45.0	95.0	145.1	170.0	183.0	204.0	200.0	180.0	150.0	16.9	0.0	**1,536.0**
Delta		**-25.0**	**-15.0**	**-4.9**	**-10.0**	**3.0**	**24.0**	**20.0**	**20.0**	**68.0**	**-6.1**	0.0	**79.0**

- CD-3a ESAAB Approval Memorandum provided **new funding profile**
  - Ramps up more slowly in FY17–FY20; higher peak in FY22–FY25
  - Adds to total funding to offset escalation and extended PM costs
  - Funding profile represents **guidance** until CD-2 baselining, planned in Dec 2019
  - Have implemented this new profile in the project's resource loaded schedule. High-level impacts to "stakes in the ground":
    - Slides the start of DUNE detector **installation** and start of detector **operations** to the right by about 6 months
    - Keeps neutrino "beam on" date in 2026
  - Overall project contingency is at 36%

Overall Project Schedule with CD-3a ESAAB Funding Profile



In comparison to CD-1R ESAAB funding profile:

- Slides the start of DUNE detector installation and start of detector operations to the right by about 6 months
- Keeps neutrino "beam on" date in 2026

LBNF Status of LBNC Milestones

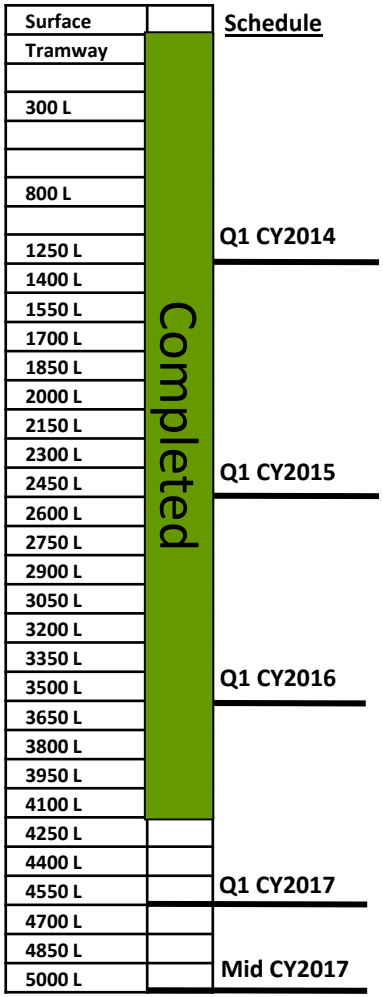
USFY	Quarter	Milestone	2016				2017				2018
LBNF milestones											
2016	Q4	CD-3a approved				9/1/16 A					
	Q4	Pre-excavation final design complete				On-Track					
2017	Q1	CMGC contract in place					On-Track				
	Q3	Ross shaft refurbishment complete							On-Track		
2018	Q1	Main excavation final design complete									On-Track

- CD-3a milestone achieved on 9/1/2016
- Pre-excavation final design on track
- CM/GC currently on track for March 2017 award
- Ross Shaft refurbishment on track for Sept 2017 completion
- Main excavation final design on track for 1st Quarter FY2018 completion

Reliability Projects

Including Ross Shaft Refurbishment

Ross Shaft Refurbishment Update
4,196 feet down from surface (82% completed overall)



- Ross Shaft constructed in 1930s. Legacy shaft infrastructure cannot support the structural loads and duty cycle needed for LBNF, thus rehabilitation was initiated to modernize the shaft.
- SDSTA self-performing rehabilitation. Scope includes removal of old shaft steel and installation of new ground support and ~6M pounds of new shaft steel.
- Rehabilitation started in August 2012. SDSTA provided the first $20M and also purchased the structural steel for entire project.
- Starting in Jan 2016, LBNF funded a contract between LBNL and SDSTA to continue the refurbishment through the end of November 2016.
- LBNF will fund a new contract between Fermilab and SDSTA for the remaining rehab work down to the 5000 foot level
- On track for a Sept 2017 completion

SURF Reliability Projects - assure safe & reliable construction

LBNF performed risk assessment and determined that this work is needed to support project requirements:

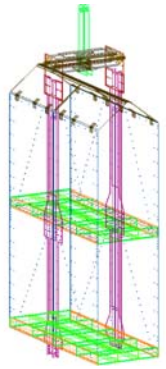
- **Oro Hondo Fan replacement**
  - Main exhaust fan – VFD obsolete
  - If fails, shuts down diesel equipment underground

- **Refuge Chamber Capacity Increase**
  - Increase capacity from 72 people for 96 hours to 150 people through addition of supplies and upgrades to HVAC and CO_2 scrubbing.

- **Hoist Motor/Generator Rebuilds**
  - Degraded motor insulation risks motor failure – shuts down hoist

SURF Reliability Projects - continued

- **Hoist Clutches & Brakes**
  - Replace 1930's technology doesn't meet code and risks shaft operation and potentially personnel safety



- **Cage/skip replacements**
  - Needed to move people & materials in the shaft

➢ Working on acquisition strategy – expect to contract majority of this work to SDSTA to execute based on specific scope, cost, and schedule
  - Newly hired SDSTA Engineering Director is POC

Fiscal Update

DOE Funding Status: Appropriations and Authorities

- **FY17 Funding Status:** No change from June PAC
  - President's budget submit requested $45M for LBNF/DUNE
  - House and Senate both propose to increase LBNF funding in FY2017 above the President's budget request:
    - House: +$5M
    - Senate: +$10M
- **Construction Start Authority**
  - DOE has determined that the project has existing authority to start construction at far site in FY17
- **Continuing Resolution (CR) Plan:** No change from June PAC
  - CR's have potential to significantly impact project execution at this stage of execution, with year-over-year funding significantly ramping up.
  - Currently operating under FY17 CR through 9 December.
  - Have implemented a 3 month CR plan, and have developed 6 month and 1 year CR scenarios. CRs > 4 to 5 months will negatively impact project schedule.

Procurement Update

Update on CM/GC – Actions since June PAC Meeting

Pre-proposal conference – July 19th 2016

- ✓ CM/GC contract (construction manager/general contractor) has been advertised for potential bidders – 28 Jun 2016
- ✓ Pre-proposal conference held in South Dakota in July 2016
- ✓ Over 50 contractor representatives participated in conference; all representing well known and capable firms.
- ✓ Proposals currently due Dec 1, 2016

- Based on feed back from potential proposers and DOE contracting experts (SLAC; ORNL), we have requested a revised pricing structure.
- Extensive discussions with FSO and Chicago IRB since August
- Final package addressing all concerns forwarded to FSO on 11/8/16
- Next steps: review by IRB, then HCA
- Will assess whether it will be necessary to extend receipt of proposals

Many Procurements in Support of LBNF in process

- Other procurements (than CM/GC) underway now:
  - **2017 Ross Shaft rehab work**:
    - Since Jan 2016, work accomplished under LBNL-SDSTA cost-reimbursable construction contract
    - Putting similar Fermilab-SDSTA contract in place – working through sole source, authority for work on non-federal property, and other contractual/legal issues with DOE
    - Working to have contract in place asap, NLT end of 2016
- First quarter CY2017 awards:
  - **SURF Reliability Contract(s)**
    - Acquisition plan under development
    - In general, anticipate most of this work will be done by SDSTA
    - Developing best approach in conjunction with Fermilab's SURF Services (Operations) contract for FY17
  - **Waste Rock Handling system**
    - Developing a design/fabricate contract for long lead items; plan installation to be done by CM/GC contractor
  - **Arup Final Design Services**
- Fourth quarter CY2017 awards:
  - **Ross Shaft Operations Crew Services contract**
  - **LN2 Systems through a design-fab-install contract**

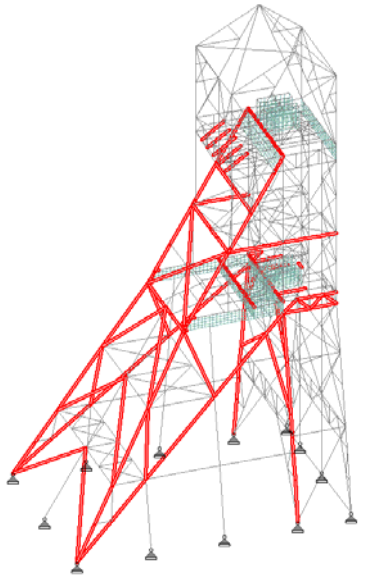
Design Update

Final FSCF Design Plan

- Final design includes pre-excavation, excavation (EXC), and buildings and site infrastructure (BSI) scopes
  - Deliverables planned at 30%, 60%, 90%, and 100% of final design
  - Provides defined points for stakeholder review
  - **With approval of CD-3a, it is now understood by stakeholders that design is under configuration control; all proposed changes are evaluated for cost and schedule impact**
  - CM/GC's involvement during EXC & BSI through independent cost / schedule estimate generation and estimate reconciliations and constructability reviews
- In addition to construction contract document production (drawings and technical specifications), cost estimates and schedules, the final design scope includes:
  - Basis of Design report
  - Geotechnical Baseline Report and 3D geotechnical modeling
  - A geotechnical instrumentation and ground monitoring program
  - Concept of Operations report
  - Fully integrated 3D revit CAD model

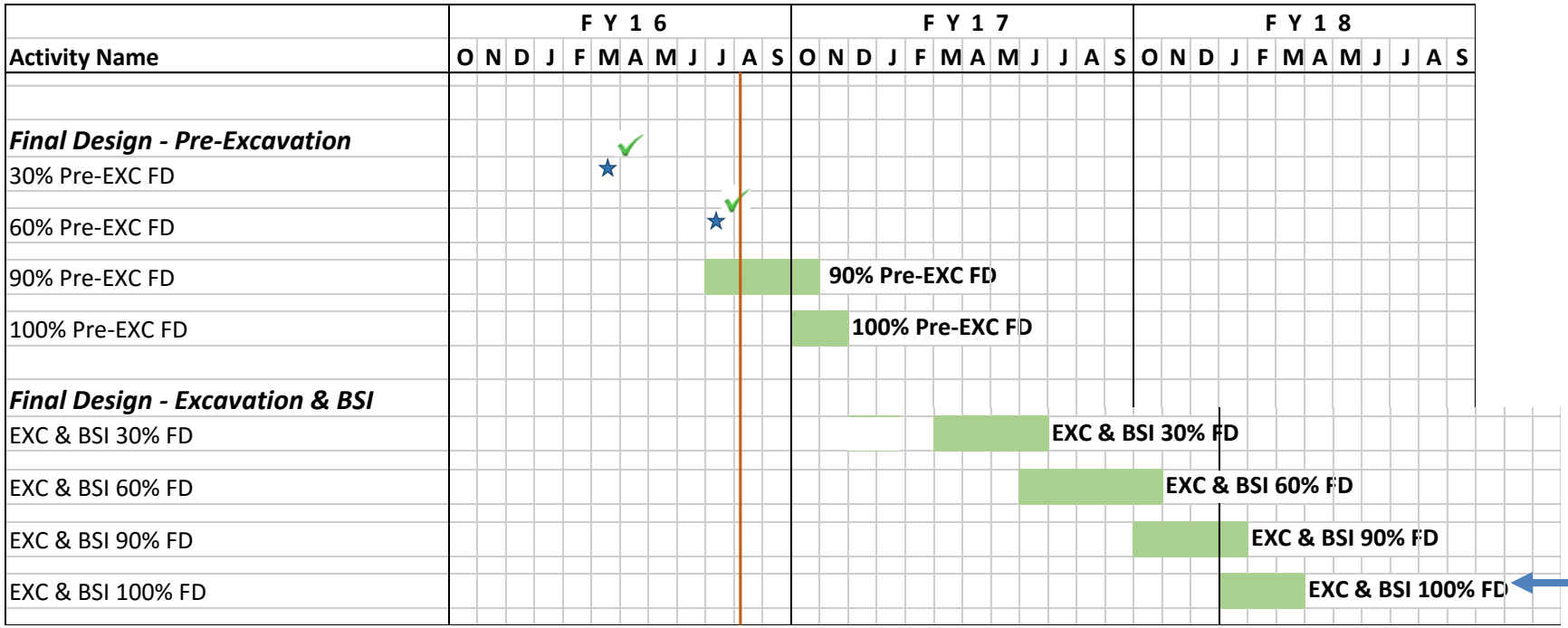
Recent Design Progress

- **90% pre-excavation design technical submittal just received**. Cost and schedule submittal due 11/18/2016.
  - Surface rock handling system with pipe conveyor to Open Cut
  - Underground rock handling system at shaft
  - Shaft infrastructure including fiber optic and power cables, water and gas piping
- Achieved concurrence from SDSTA for increasing the upper limit of peak particle velocity from 0.5 in/sec to 2 in/sec; one of several positive results of the test blast program completed in the spring. Planned bulkhead systems expected to mitigate any expected impacts to adjacent operations.
- Extensive 4850L fire and smoke modeling to get Fermilab AHJ concurrence on fire/life safety strategy – meeting scheduled in November with Lead AHJ, including Fermilab AHJ
- 4850L substation location trade study to eliminate excavation impact on Ross shaft & provide needed temporary construction-period spaces
- Worked with SDSTA to get concurrence on Ross Shaft headframe design loading cases for strengthening the headframe to meet code requirements.



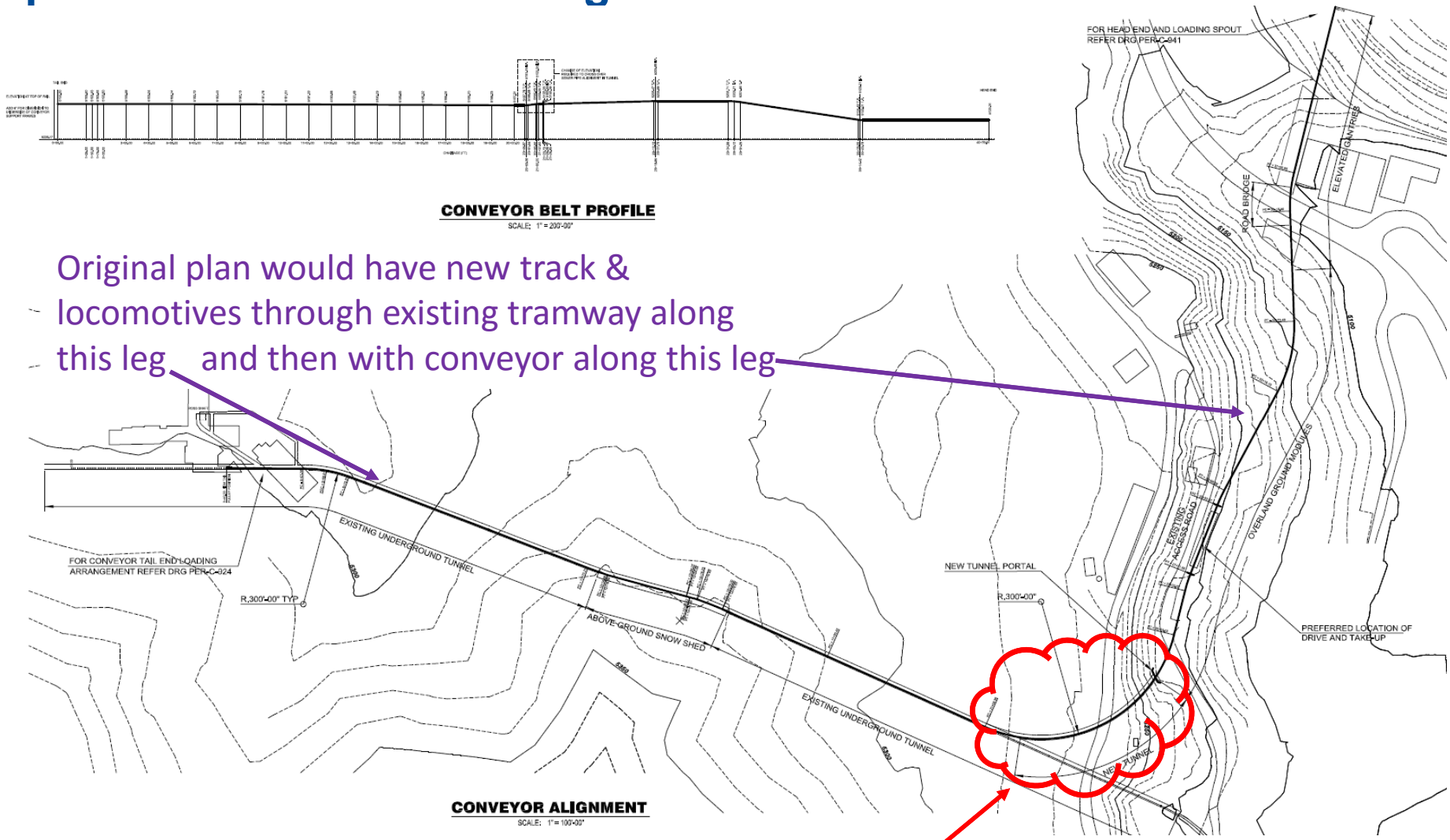
Ross Shaft headframe

FSCF Final Design Schedule



- Start of final design for main scope is tied to start of the CM/GC in project schedule - start date of March 2017.
- Since 100% design will be done for all preparatory activities, main design only has to be done in time to support excavation start in January 2019. This leaves almost 5 months of float, even starting in March.

Waste Rock Handling System change recommended after 60% pre-excavation Final Design



A single conveyor can be used if a new ~600’ long tunnel and portal is excavated.

Misc Updates

LBNF Staffing Updates since June PAC Meeting

- New hires in place:
  - Project engineer (based at SURF)
  - QA manager for LBNF and DUNE (based at FNAL)
  - ESH coordinator (based at SURF)
- New assignments
  - Senior Procurement Administrator – from FNAL procurement group; have been fully matrixed into LBNF
- Replacements:
  - Mike Headley transitioned to full time SDSTA ED/Lab Director
    - In process of recruiting far site ~~facilities~~ logistics manager position
  - New LBNF/DUNE Financial manager – also serving as DUNE RC (secretary for CRB)
  - New senior procurement manager – recruitment action being initiated

Property Considerations

- DOE-SDSTA lease executed for LBNF-dedicated spaces in May 2016
- Temporary Construction Easement finalized for all non-leased areas in October 2016. Flexible to allow amendment as space needs change.
  - Reliability Projects, including Ross shaft rehabilitation
  - Surface rock handling
  - Laydown and storage spaces
- Developing understanding personal and real property ownership of DOE-acquired materials installed in SDSTA non-leased spaces, such as hoist equipment
  - Fermilab Real Property Team working with DOE Fermi Site Office to resolve
  - Everyone's desire is to have SDSTA be responsible for their own systems

Logistics

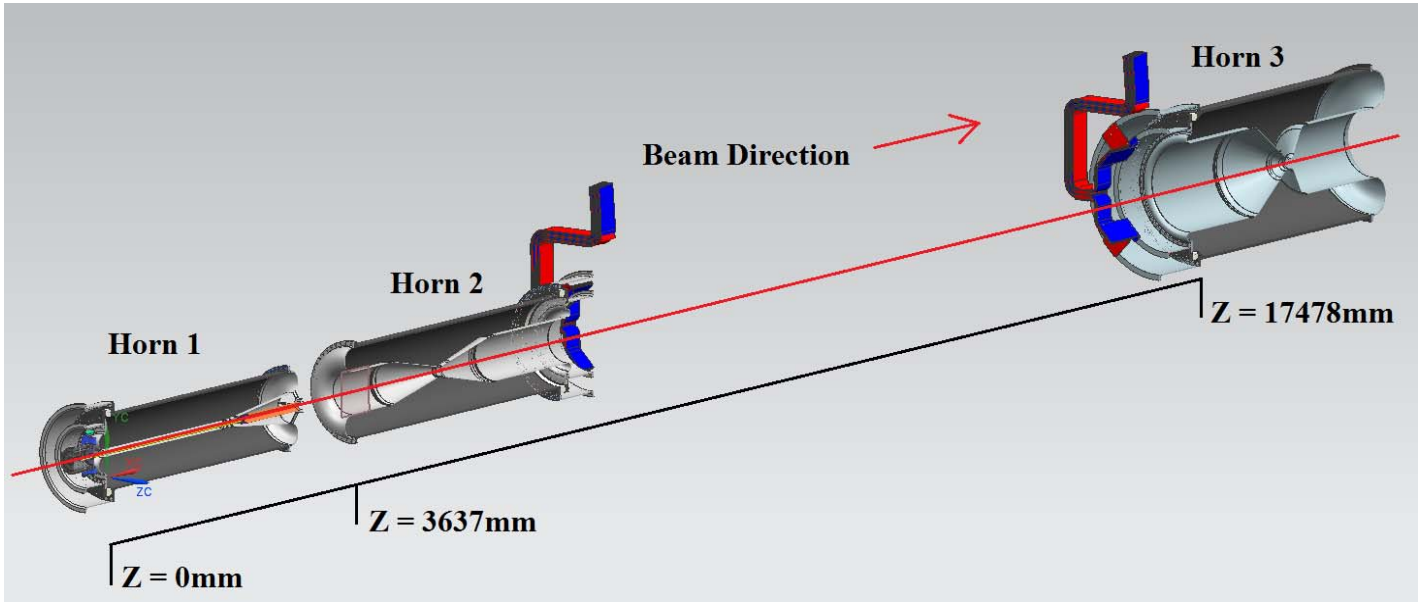
- SDSTA working with local area leaders to identify transportation options for materials movement to Black Hills area.
  - Supports CERN requests for better understanding of options for cryostat material movement and storage
  - Provides groundwork for future transportation planning with Far Detector team
  - Discussions last few months with local and regional rail representatives
- SDSTA identifying spaces at SURF for temporary laydown space and logistics support
  - Recent plan to purchase adjacent 33 acres
- Further detailed logistics planning requires CM/GG and LBNF effort, expected to start in early 2017.

Beamline recent activities

- **Optimizing target and focusing horns for better sensitivity to CP violation**. This would require a 4 (instead of 2) interaction length target and 3 (instead of 2) magnetic horns.
  - Completed first iteration of mechanical models, energy deposition and FEA complete for the optimized horns. Second iteration to follow.
  - Collaborating with RAL on the conceptual design of the optimized target and its mounting on the first horn.
  - Evaluating impacts of optimized designs on target/horn support structures, horn power supply, remote handling, target shield pile and decay pipe shielding and cooling, hadron absorber and muon shielding, conventional facilities.
- **Conceptual design is being developed for nitrogen in the chase** – (additional gas-tight liner, leak-tight seals at the chase cover plates and feed-throughs, analyzing associated thermal/structural impacts).
- **Collaboration with IHEP/China**: prototyping process for a corrector magnet started in October 2016; SOW for corrector magnets at advanced stage. Also, currently discussing additional collaboration on other beamline systems, e.g. Decay Pipe beam window.

Beamline Design Timeline

- Decision on Beamline final conceptual design planned in September 2017 to support start of preliminary design in October 2017.
  - Decision timeline requires that all conceptual design optimization efforts be completed by August 2017 to allow for evaluation and comprehensive technical design and cost project reviews to support Sept 2017.
  - Decision could be full-scale optimized, partial implementation with hooks for full implementation, reference with hooks for full implementation, etc).

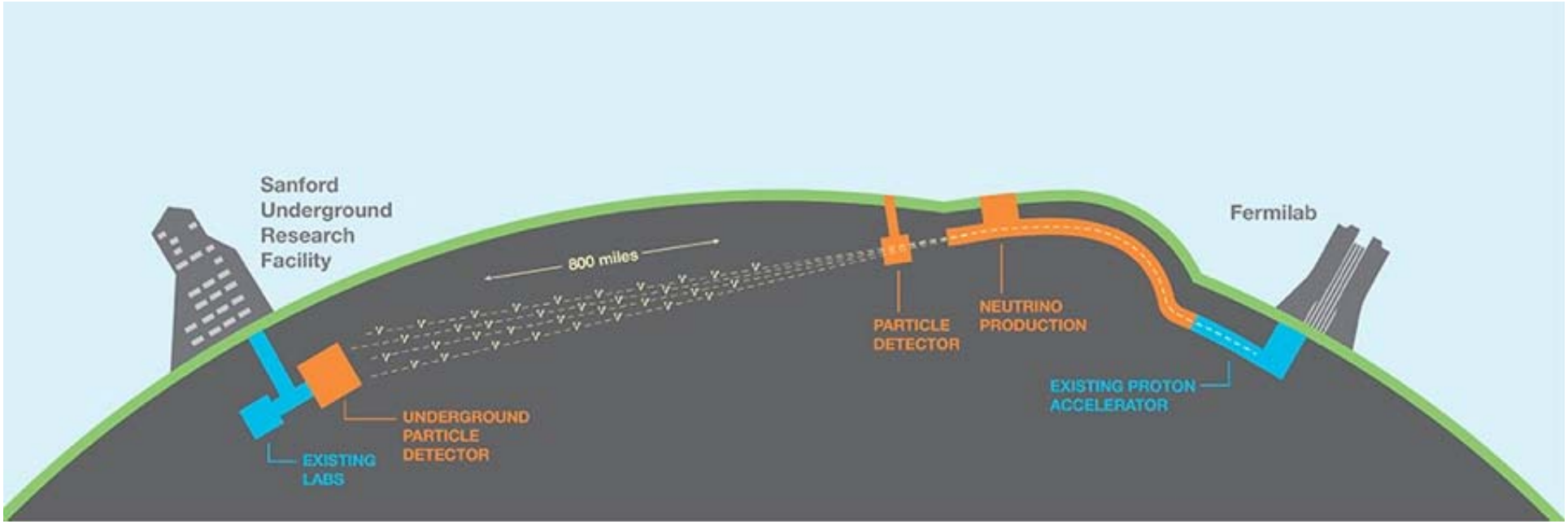


Summary

LBNF Activities Recently Completed, Underway and Planned

- ✓ Began execution by DOE/FNAL of Sanford Lab “Reliability Projects” such as Ross Shaft refurbishment, to reduce risk during main excavation operations
- ✓ Began final design for Far Site conventional facilities
- ✓ Executed Lease for LBNF exclusive use areas at Sanford Lab
- ✓ Achieve DOE CD-3a milestone
- Award CM/GC contract
- Start construction activities at Sanford Lab in 2017
- Initiate major cavern excavation construction work in 2018
- Complete first cryostat and cryo systems construction to enable detector install to begin in 2022, with commissioning in 2025
- Produce neutrino beam in 2026!

Questions?



Animation Links:

- LBNF/DUNE animation (YouTube)
- Video page (FNAL website)

Social Media Links:

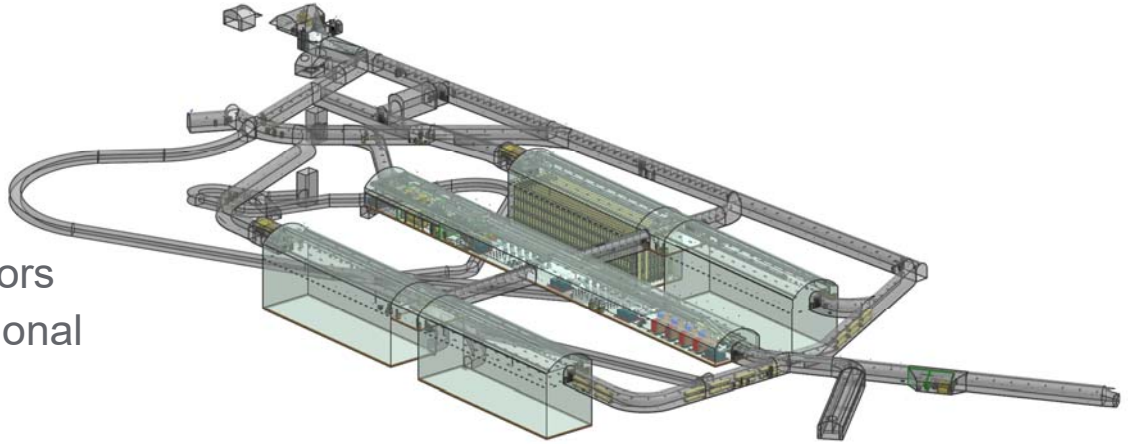
- LBNF Facebook
- DUNE Facebook
- LBNF Twitter
- DUNE Twitter

- Backup slides

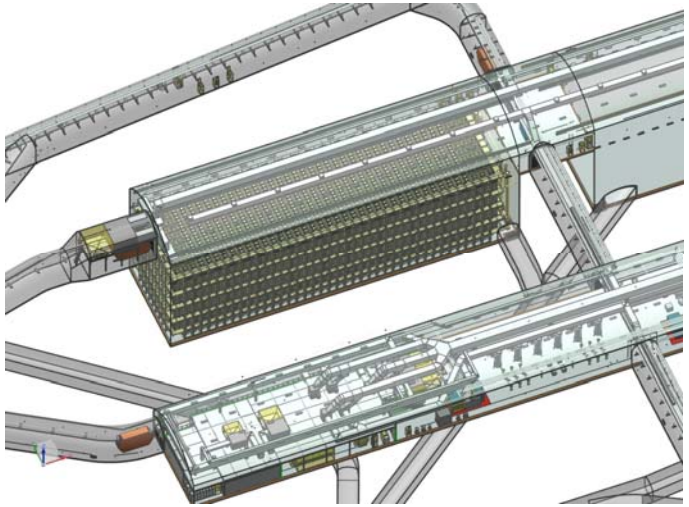
Overview – "Far Site" – LBNF at Sanford Lab, Lead, SD

- **Conventional Facilities**:
  - Surface and shaft Infrastructure including utilities
  - Drifts and two caverns for detectors
  - Central utility cavern for conventional and cryogenic equipment
- **Cryostats**:
  - Four membrane cryostats supported by external steel frames
- **Cryogenic Systems**:
  - LN2 refrigeration system for cooling and re-condensing gaseous Argon
  - Systems for purification and recirculation of LAr
- **Argon:**
  - 70kt LAr (~40kt "fiducial" mass)

LBNF facilities will support DUNE experiment

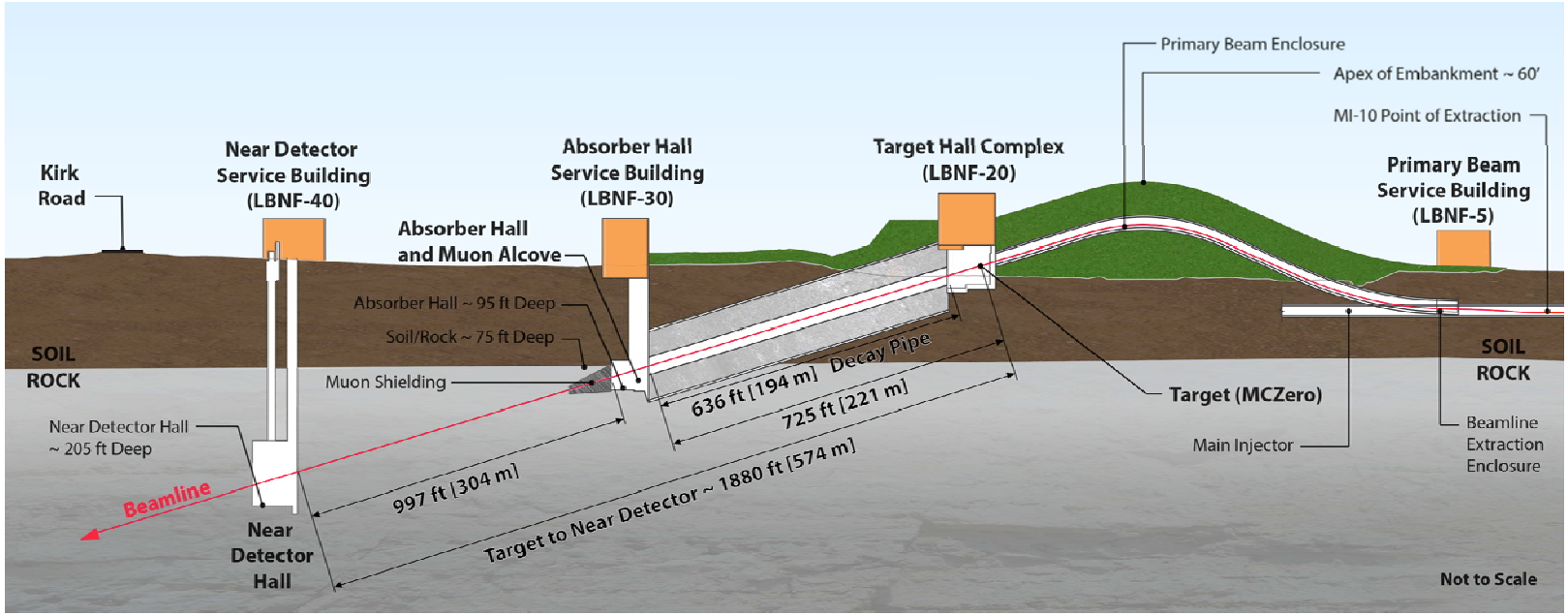


4850L caverns and drift layout



Single cryostat and portion of central utility cavern

Overview - “Near Site” – LBNF at Fermilab, Batavia, IL



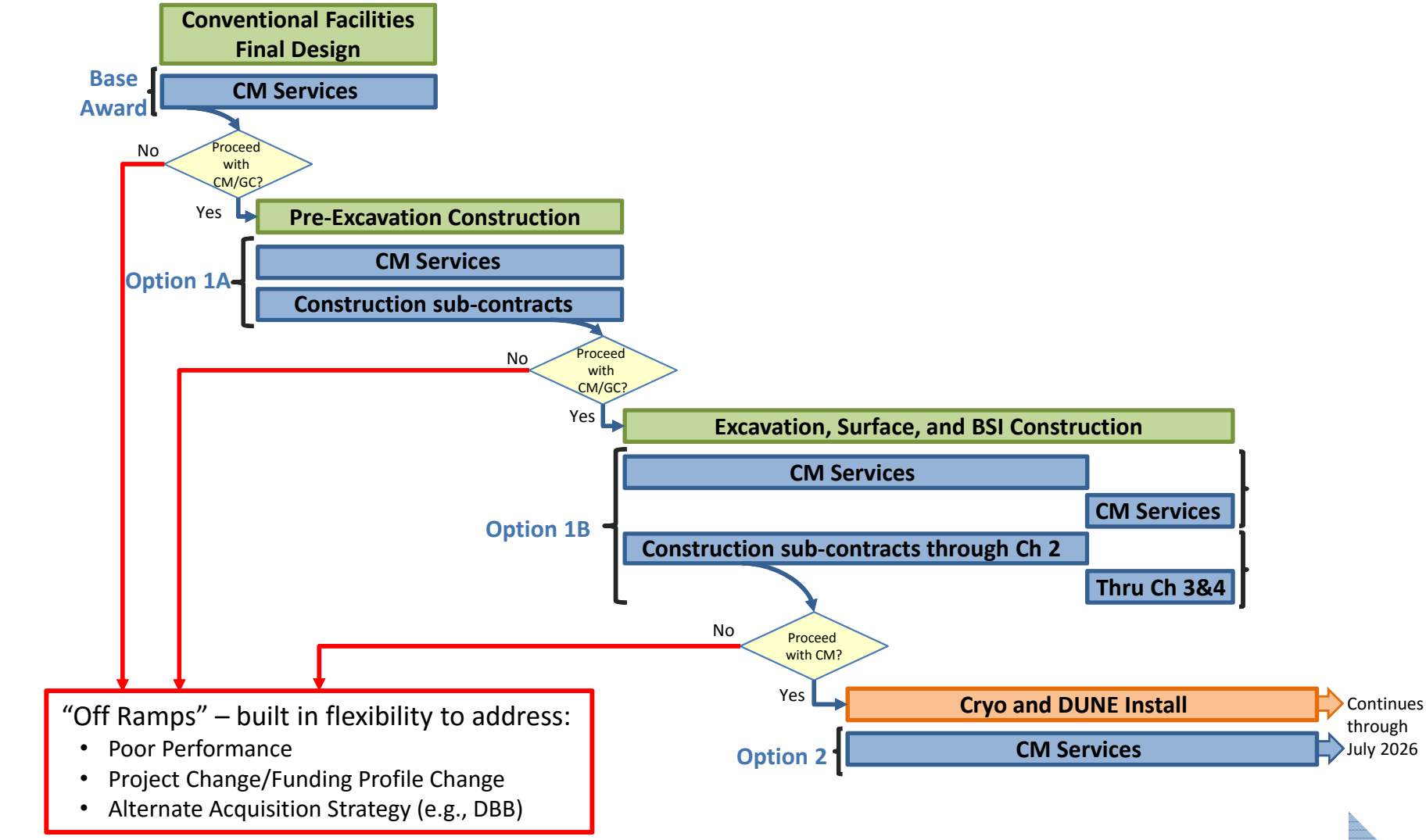
- Primary proton beam @ 60-120GeV extracted from Main Injector
- Initial 1.2 MW beam power, upgradable to 2.4 MW
- Embankment allows target complex to be at grade and neutrino beam to be aimed to Lead, SD
- Decay region followed by absorber
- Four surface support buildings
- Near Detector facility

Beamline design based on Fermilab’s NuMI beam, currently the most powerful neutrino beam in the world

CM/GC Acquisition Strategy

- Refresher: why did project select CM/GC contract approach?
  - Use CM Services component of contract to obtain the best industry insight while finalizing design, with focus on optimizing logistics approach
  - Create contracting vehicle to execute multiple fixed-price work packages as scope is definitized
    - Packages can be shaped based on available funding profile
  - Maintain FRA flexibility to “off-ramp” if necessary, for example if have:
    - Inability to reach agreement on fair and reasonable prices
    - Poor performance by contractor
  - Minimize the amount of unknown risks that contractors are forced to price in their proposals

CM/GC Acquisition Strategy for Far Site Conventional Facilities



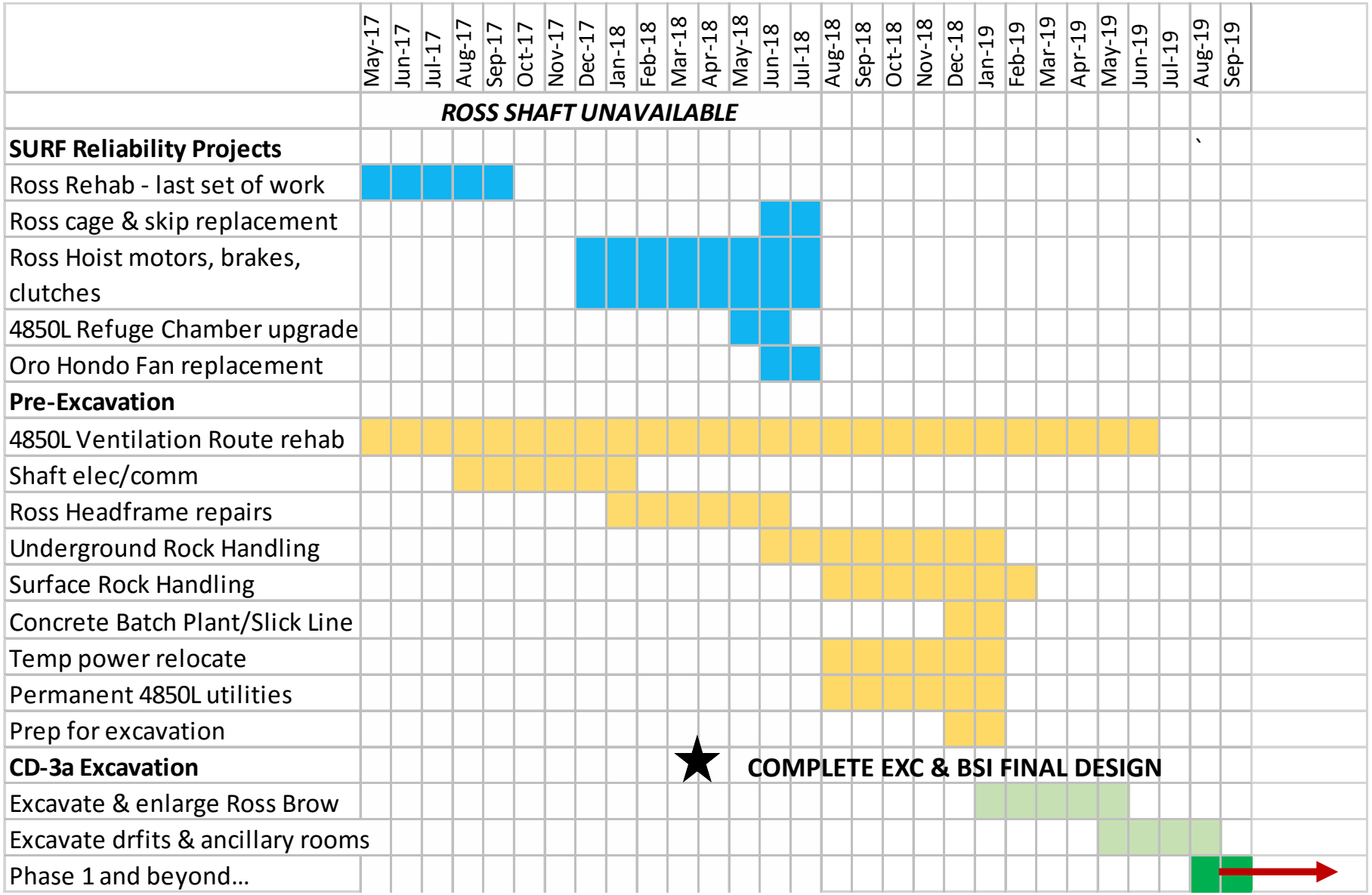
LBNF coordination with SURF Operations

- As of 1 October 2016, the DOE funding for SURF operations moved from LBNL to Fermilab.
- Fermilab COO led the work to develop framework for the procurement ("SURF Services Contract") and operational approach.
  - LBNF Project Director and Project Manager have been informed and involved as appropriate.
  - Hiring of new SURF Operations Manager
- Coordination between Fermilab SURF Services and LBNF is occurring, evidenced in planning
  - Use of SDSTA staff (particularly engineering & Ross shaft crew) for LBNF work and ensuring no gaps or overlaps
  - Responsibility for construction power costs
  - Responsibility for ESH & reporting (identified by who is doing the work and whether in leased vs non-leased spaces

International Codes and Standards

- As an international project with major in-kind contributions, LBNF/DUNE needs the ability to accept non-U.S. design standards within DOE 10CFR851 construct.
- Fermilab has finalized and implemented new FESHM Chapter 2110 – Establishing Code Equivalency with International Codes and Standards.
- Working with SBN project team, have developed priority sequence to review non-U.S. mechanical and electrical design standards proposed for equipment coming from CERN. Task forces formed to complete focused reviews.
- Code equivalency review status:
  - EN13455 – Unfired Pressure Vessels – complete
  - EN13480 – Metallic Industrial Piping – underway
  - EN 12434 Cryogenic Flexible Hoses, EN 13458 Cryogenic Vessels, EN 13648 Cryogenic Vessels-Safety Devices for Overpressure protection, and ISO 4126 Safety Devices for Overpressure protection – planned
  - Similar strategy for Electrical device standards underway

FSCF Construction Schedule to Chamber 1 Excavation



Conveyor Path from SURF to the Open Cut