Near Detector I&I - Assessment meeting at FNAL

Overview of the Near Detector Installation

2024-02-15

Fabrice Matichard, Gordon Cline

Outline

- ND I&I Overview
- ND Subsystems overview
- Installation Process 30,000 ft view
- Resources overview
- Equipment

The I&I core lead team

Fabrice Matichard – ND I&I L2/CAM

- 14 years with LIGO (Laser Interferometer Gravitational-Wave Observatory) at MIT
- Led the remote team performing assembly, installation, testing and commissioning at the observatories
- Lead engineer for the near detector since February 2021

Michael Wilking – ND I&I Physicist

- Faculty, Stony Brook University
- Activities on previous neutrino experiments (MiniBooNE, NuPRISM, Super-Kamiokande & T2K)
- Member of DUNE since 2015 (Field cage modules for ProtoDUNE, Leader of the DUNE-PRISM oscillation analysis group, DUNE-US L2 PRISM manager since 2020)

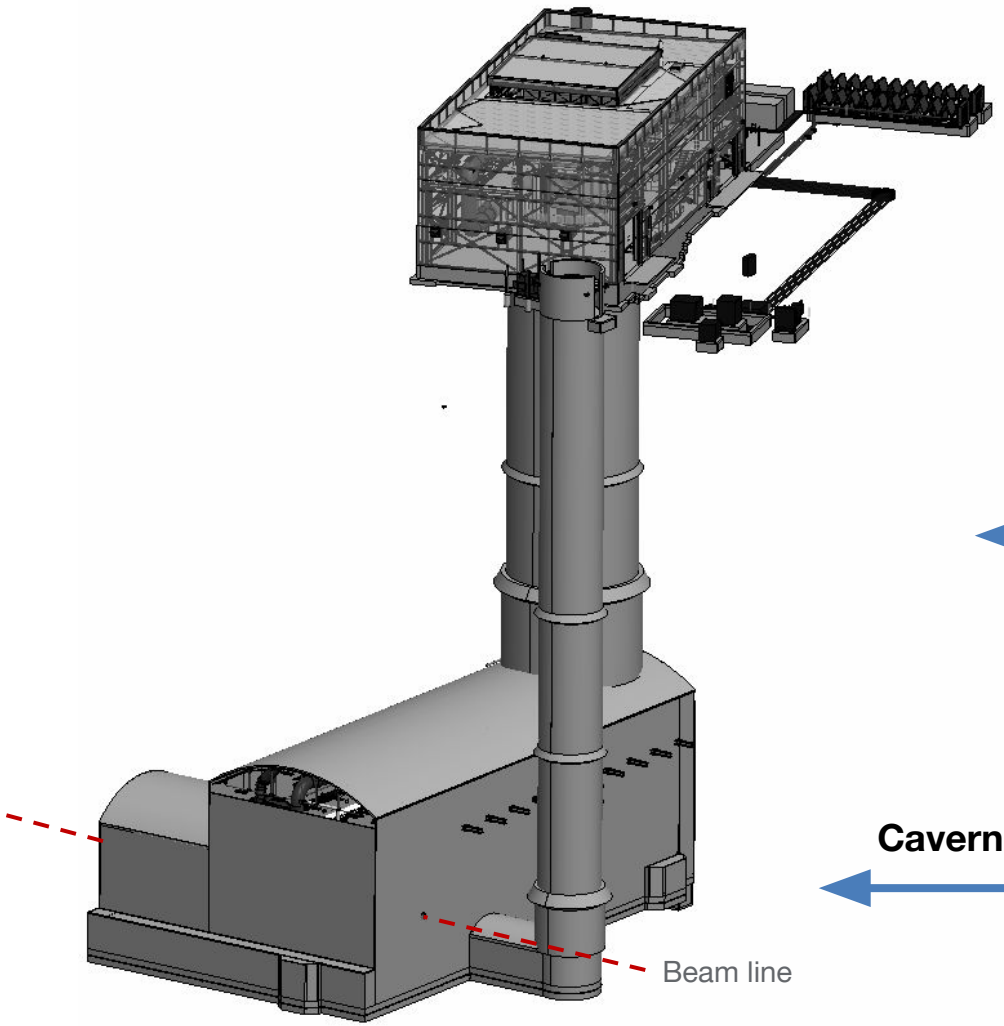
Gordon Cline – ND Systems and I&I Engineer

- 8 years in private sector power generation OEM (Siemens Energy)
- Sub-system engineering lead, component design, vibration analysis and testing
- Led the management of requirements and ins interfaces for DUNE I&I at LBNL

ND I&I Overview

The Near Detector Complex

NSCF has reached 100% final design

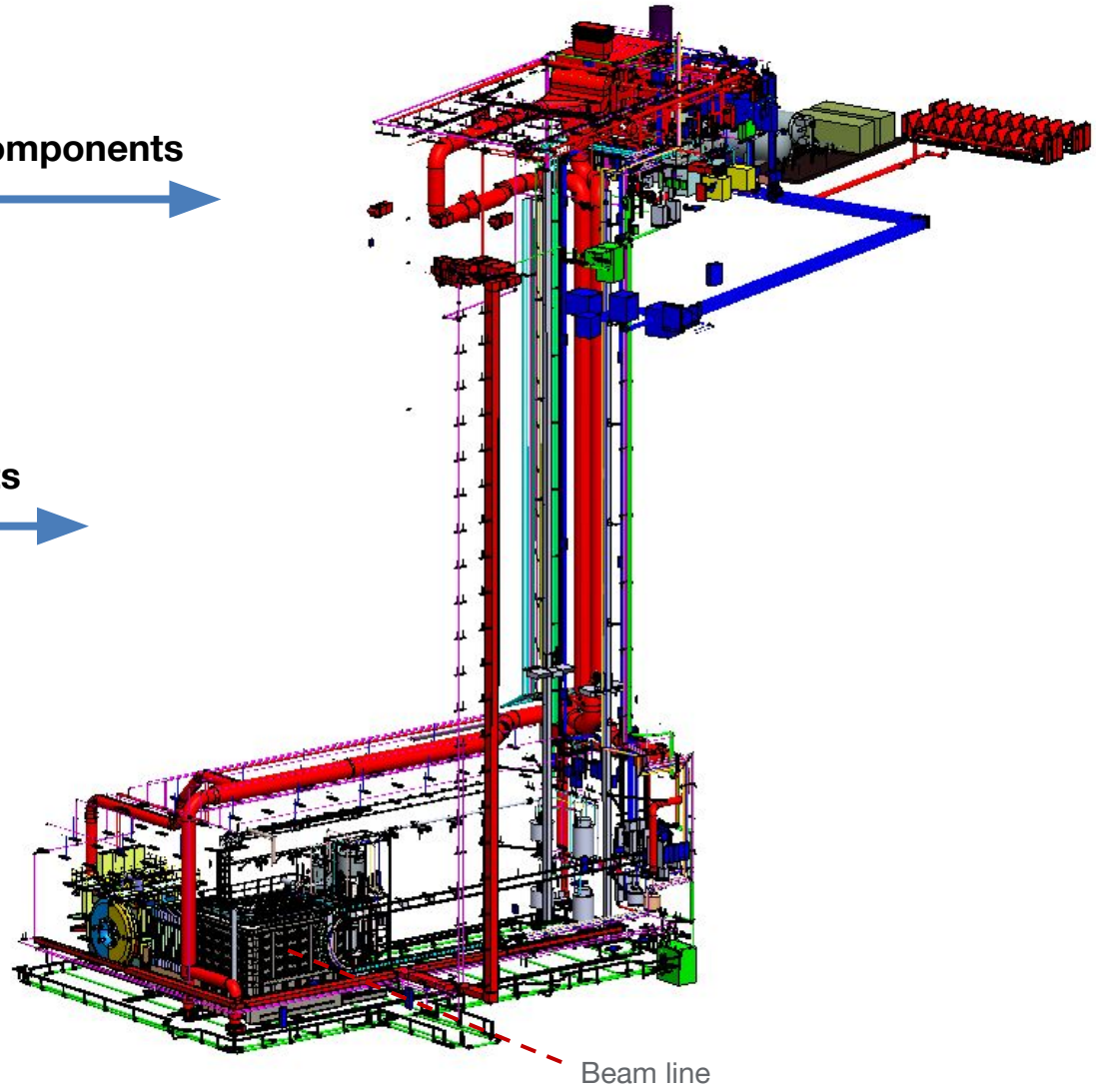


Near Detector and Near Site Conventional Facilities

Surface components

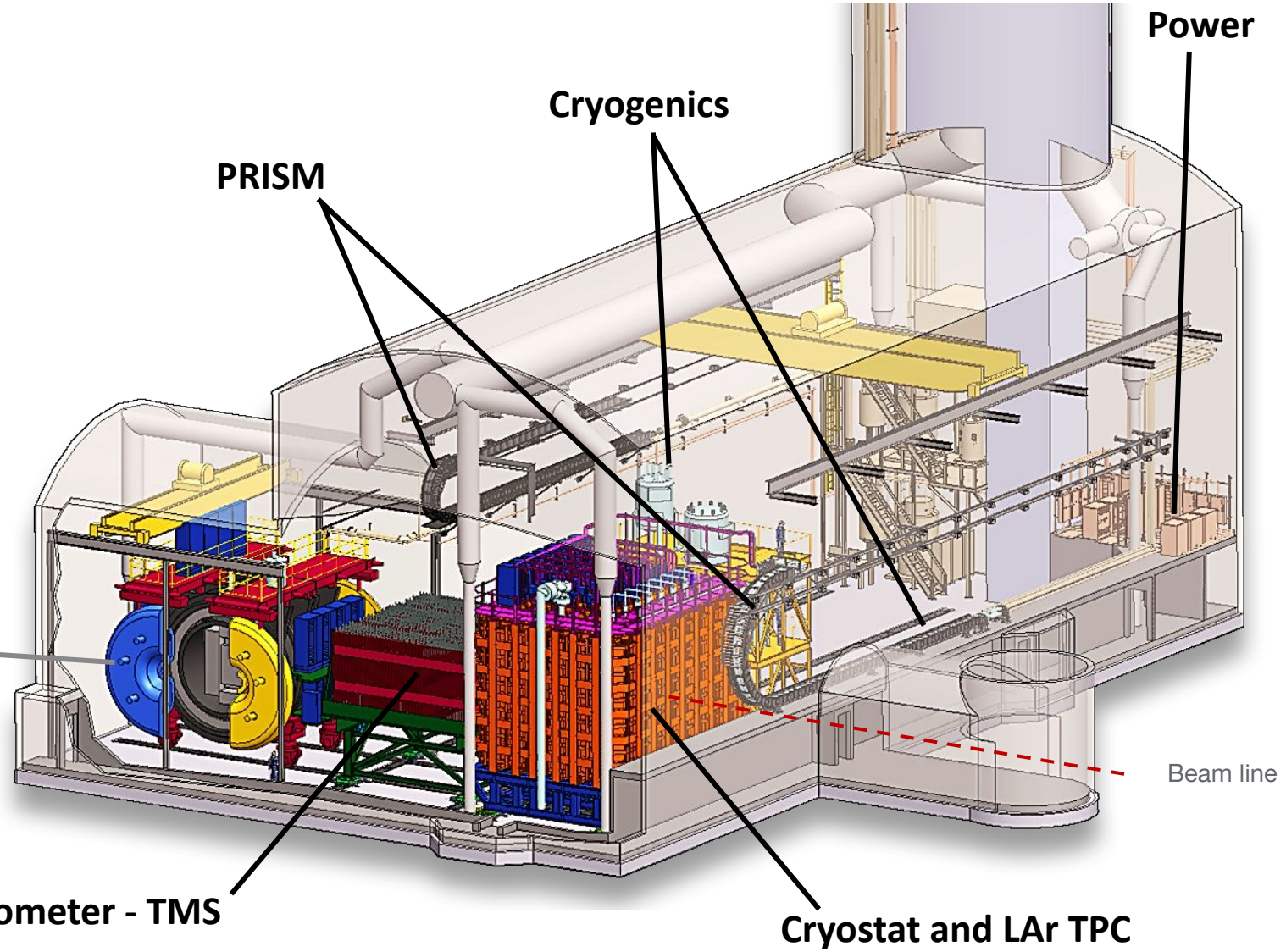
Shaft components

Cavern components



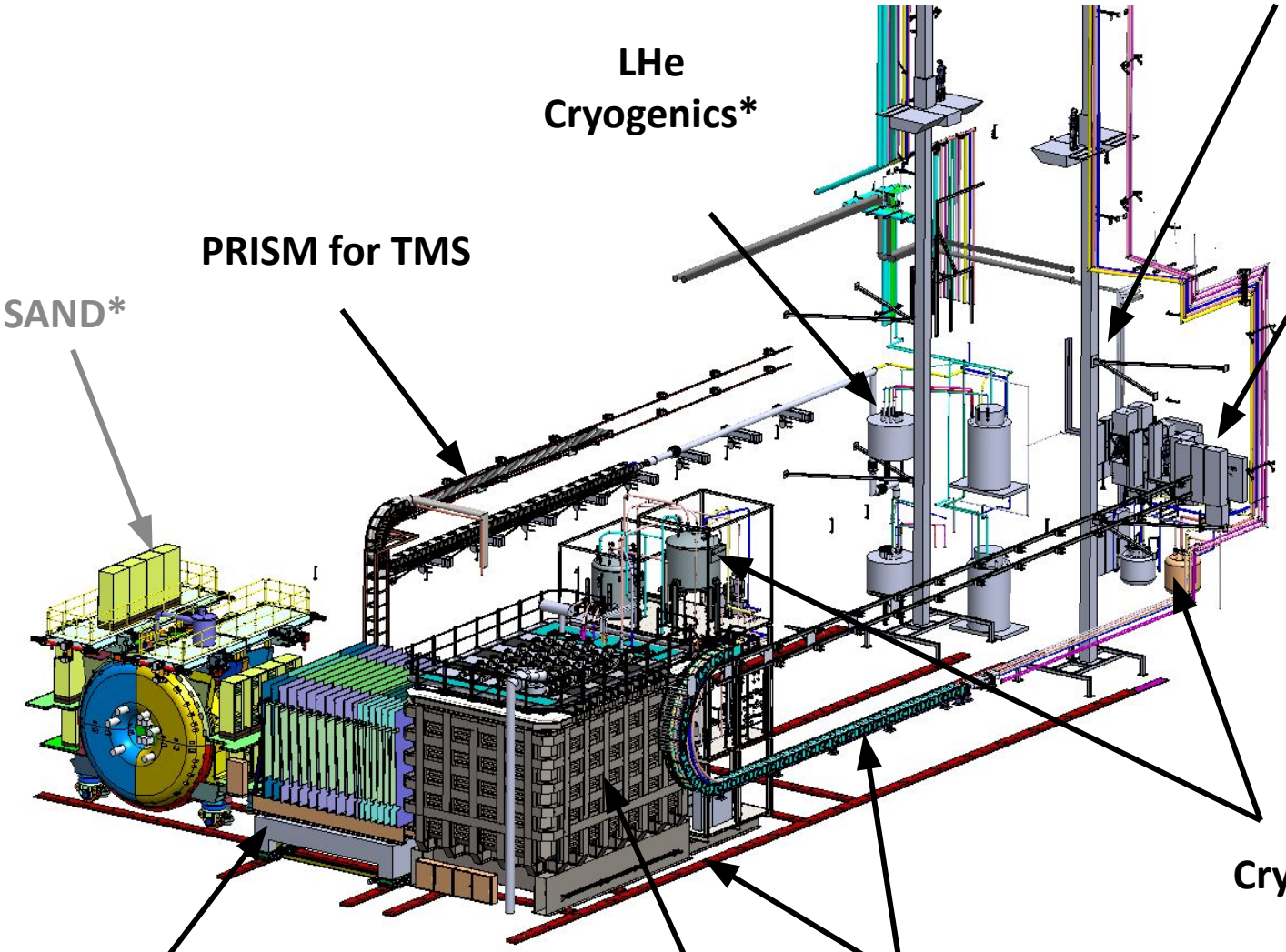
I&I supports the installation of the LAr & TMS detectors, PRISM, Cryogenics, DAQ and Slow Controls

131.ND	Near Detector
131.ND.01	ND Management
131.ND.02	ND LArTPC
131.ND.03	ND LArTPC Cryostat
131.ND.04	ND Muon Spectrometer
131.ND.06	ND DAQ and Slow Controls
131.ND.07	ND PRISM Movement System
131.ND.08	Near Detector Cryogenics Infrastructure
131.ND.09	ND Integration and Installation



We are working on the preliminary integrated design

- Design at the interfaces
  - With NSCF
  - In between subsystems



SME comments:

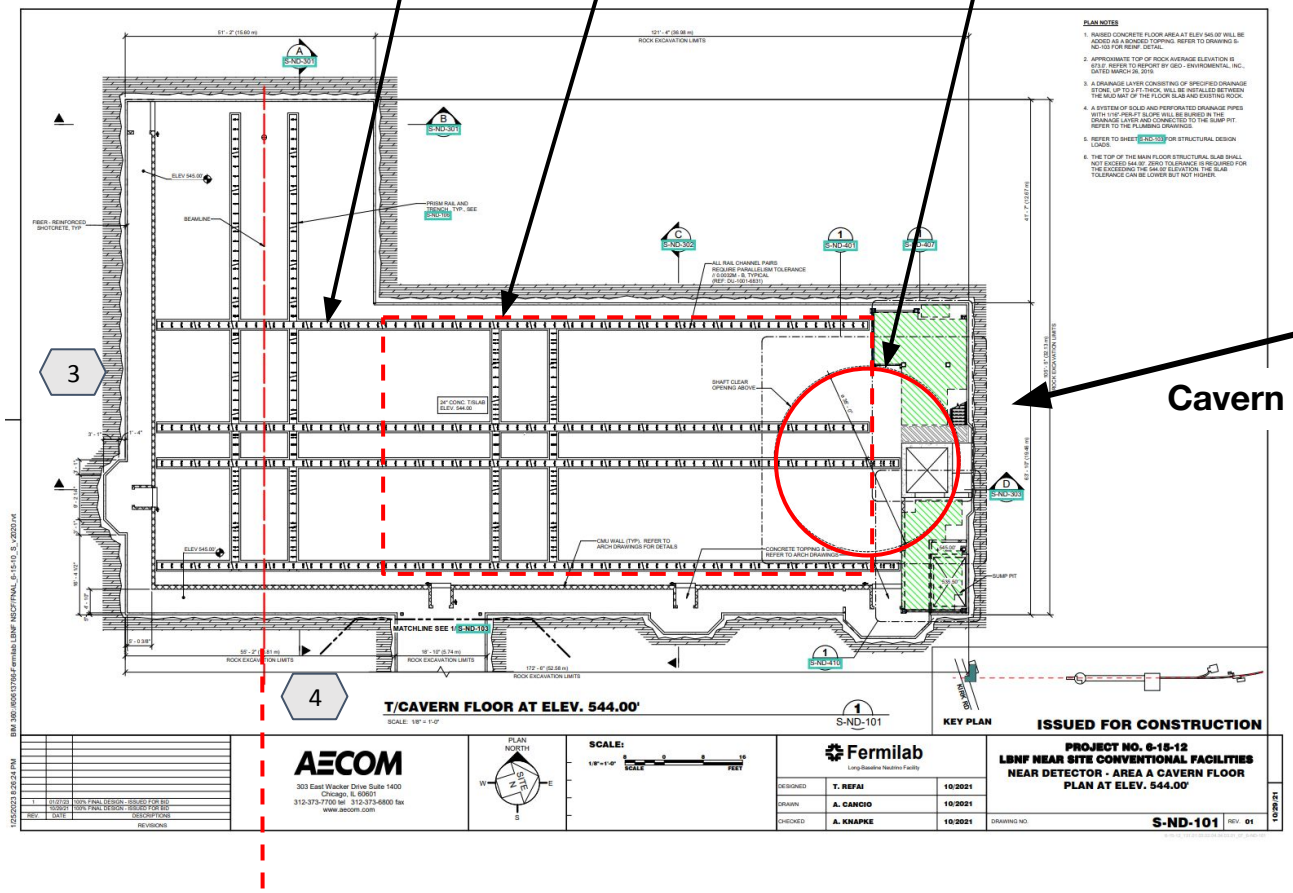
- Considerations:
  - Confined spaces
  - Fall protection
  - Escape personnel
  - Removal plans
  - Work Planning packages

Top view of the surface and cavern space

(1) Rails

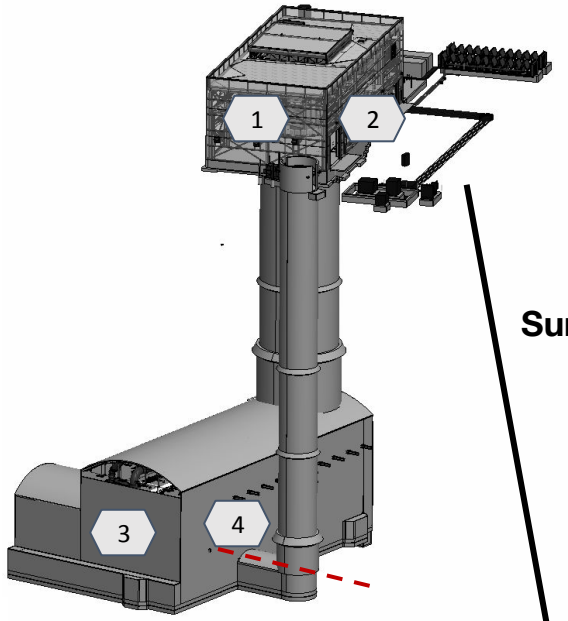
(2) Cavern Crane Coverage (60 US Tons)

(3) Shaft



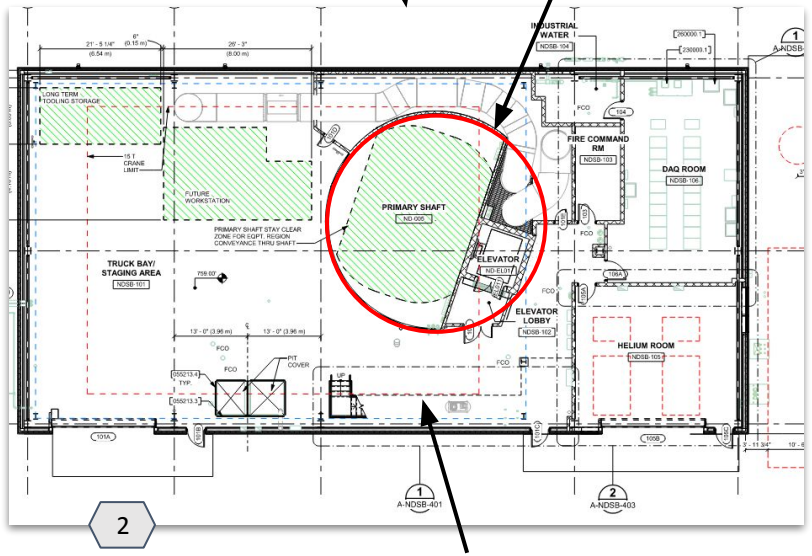
Beam line

Cavern Level



Surface Level

Shaft



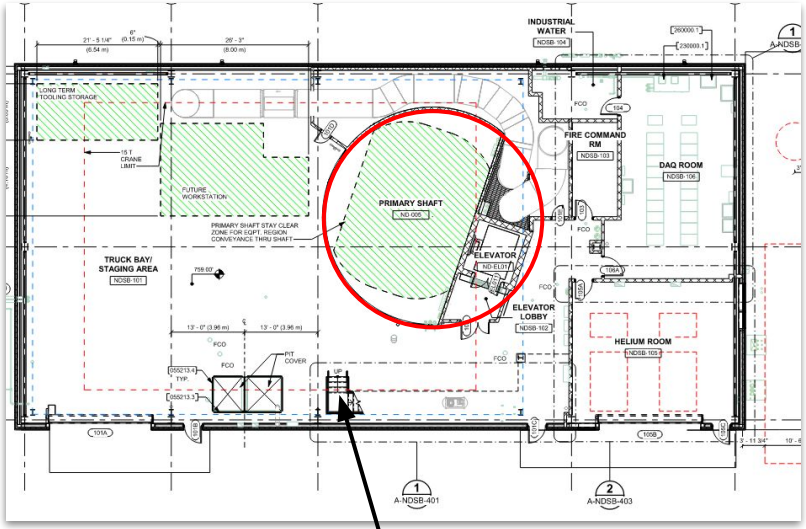
Surface Crane Coverage (15 US Tons)

Top view of the surface and cavern space

SME comments:

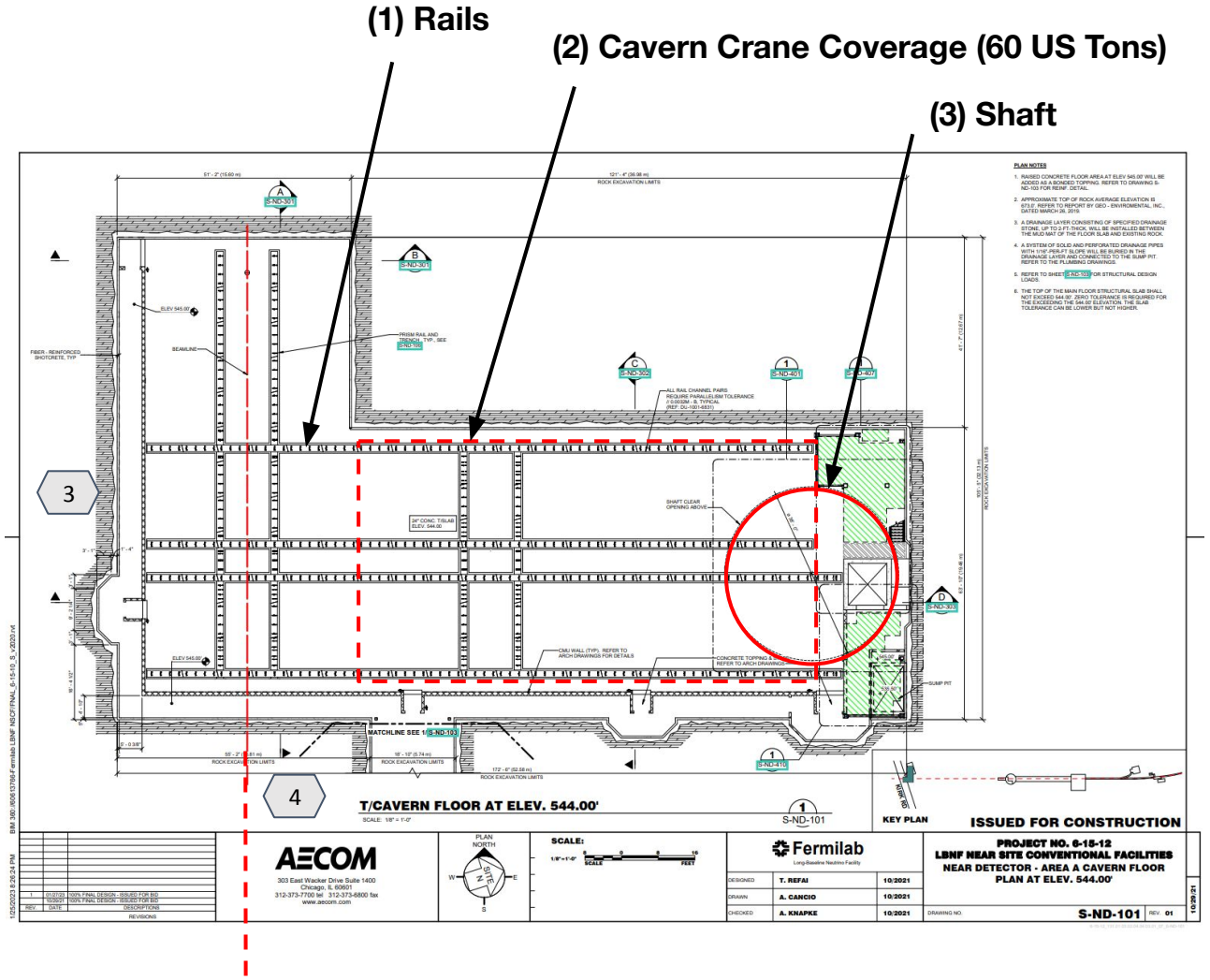
- Shaft Crane may have limited mobility when lowering equipment, due to the design of the crane cables and the crane drum.
  - Crane cables form a v as the crane extends

- Crane capacity is 15 ton, SMEs comment that this is a low capacity in their perspective.
  - Undersized crane are a frequent issue at FNAL
  - SBN had to increase crane capacity for BOTH cranes.
    - SBN 20 -> 23 ton
    - Icarus 2x30 -> 2x33 ton
  - Detector equipment was still in design during building design/construction, and weight estimates grew after detector design matured and exceeded crane capacity.
  - Investigate heaviest objects and their design maturity. Add weight margins proportional to maturity.



Surface Crane Coverage (15 US Tons)

Top view of the surface and cavern space



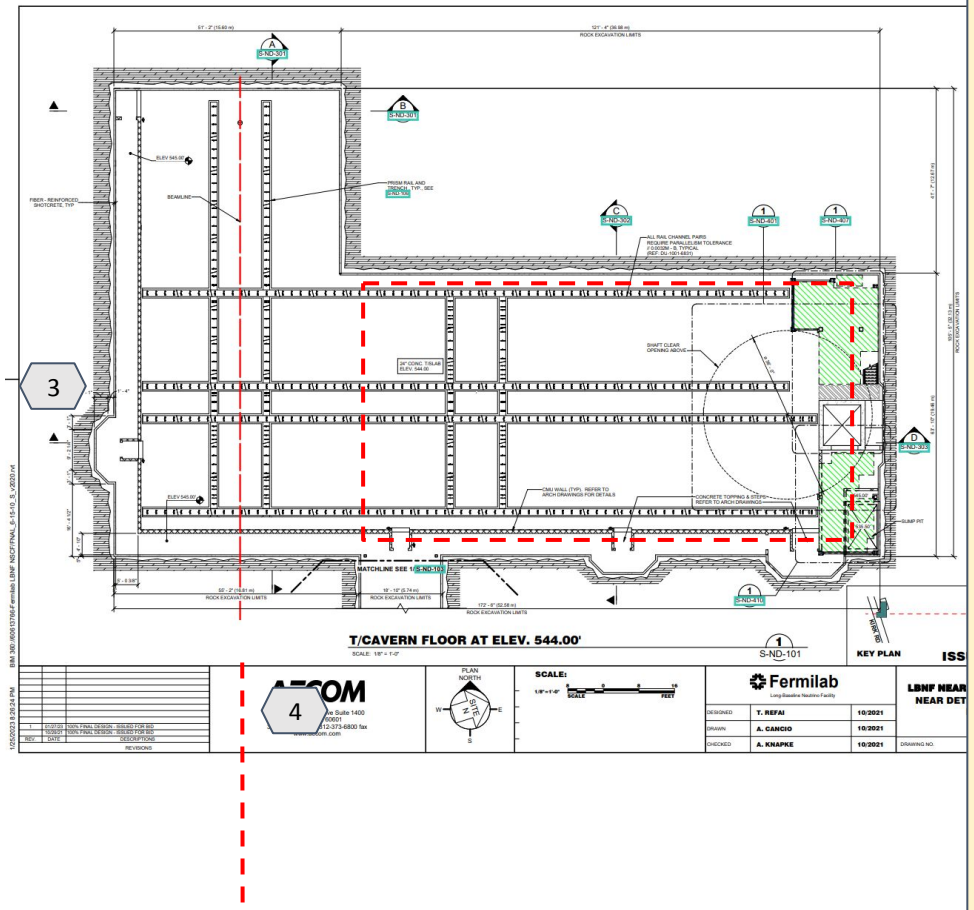
Beam line

Cavern Level

SME comments:

- As crane capacity increases, speed decreases. In the cavern, the 60 ton capacity crane may lead to increased handling times for lighter items.
  - CDF: 50 ton crane with 10 ton aux hook, about 2x increase in vertical lifting speed on low capacity hook.
- Cavern crane coverage does not cover the center of the shaft. This will cause issues with lifting components lowered into the cavern by the surface crane. Need to ensure we can access lowered components with the cavern crane.
  - Cavern crane coverage starts 4' off from the shaft centerline
  - What is the geometrical center of the shaft open space?

Top view of the surface and cavern space



Beam line

SME comments:

Safety

- What is the clearance zone that needs to be excluded when work is happening in the shaft?
- What precautions need to be taken while shaft cryo work is taking place? Netting on top and bottom?
- DOE imposed an occupancy limit on the MINOS facility that was stricter than the facility requirement. To be confirmed
- Work planning and safety coordination need to be tightly coordinated.
  - Detector teams will write a higher level installation procedure, which is then reviewed by technicians who provide input on the work plans, which are then reviewed and approved by safety.
  - Work plans for all installation steps are to be written by/with technicians
  - Work planning should be prepared as far in advance as possible.

The I&I Organization is well established and key staff is in place

ND I&I core team

L2/CAM: Fabrice Matichard

Engineer: Gordon Cline

Physicist: Mike Wilking

CAD: Joe Angelo

ND Sub-Systems/Consortia I&I

LBNF Cryogenics: J. Prat (FNAL), R. Doubnik (FNAL)
ND-LAr Detector: A. Lambert, A. Karcher, D. Dwyer, (LBNL)
ND Cryostat: P. Tennessen (LBNL), Shishir (FNAL)
SAND Beam Monitor*: C. Montanari (FNAL/INFN), L. Stanco (INFN)
PRISM: M. Wilking, R. Maramara (Stonybrook)
TMS: T. Mackievitz, M. Oruno, T. LeCompte (SLAC), H. Budd (U. Rochester)
DAQ: Asher Kaboth (RHUL, UK)
Slow Controls: TBD

DUNE Support

Electrical Engineering: T. Shaw, S. Chappa, L. Bagby, A. Ghosh (FNAL)

LBNF/DUNE Systems Engineering: J. Fowler (Duke Univ.)

ND Systems Engineering: Gordon Cline (LBNL)

NSCF Interface: T. Hamernik, K. Hartsfield (FNAL)

ES&H: M. Andrews, D. Newhart (FNAL)

QA/QC: Kevin Fahey (FNAL)

Generic division of scope

I&I provides

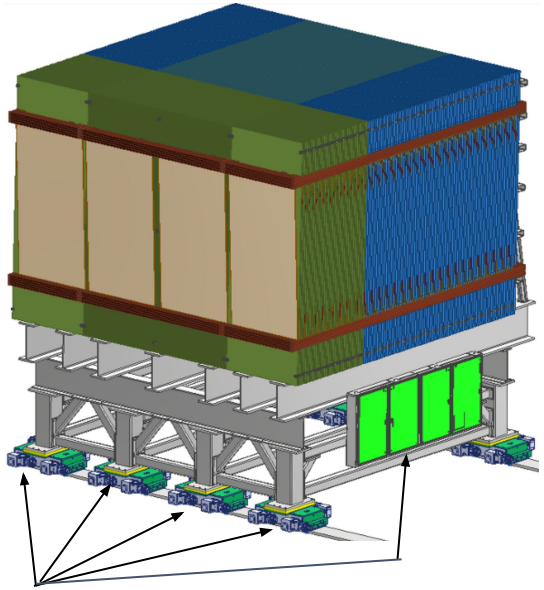
- Coordination of **installation planning**
- **Integrated CAD models** with installation configurations
- **Power distribution design**
- Coordination with **NSCF**
- Coordination of **installation activities**
- **Material handling** and infrastructure support
- Labor for **riggers**, crane operators, forklift operators
- Rented **lifting equipment** for loads which exceed capacity of surface and cavern cranes
- **Alignment**/control networks
- Power distribution (**M&S and installation**)
- **Electrical Engineering oversight**

Sub-systems/Consortia provide

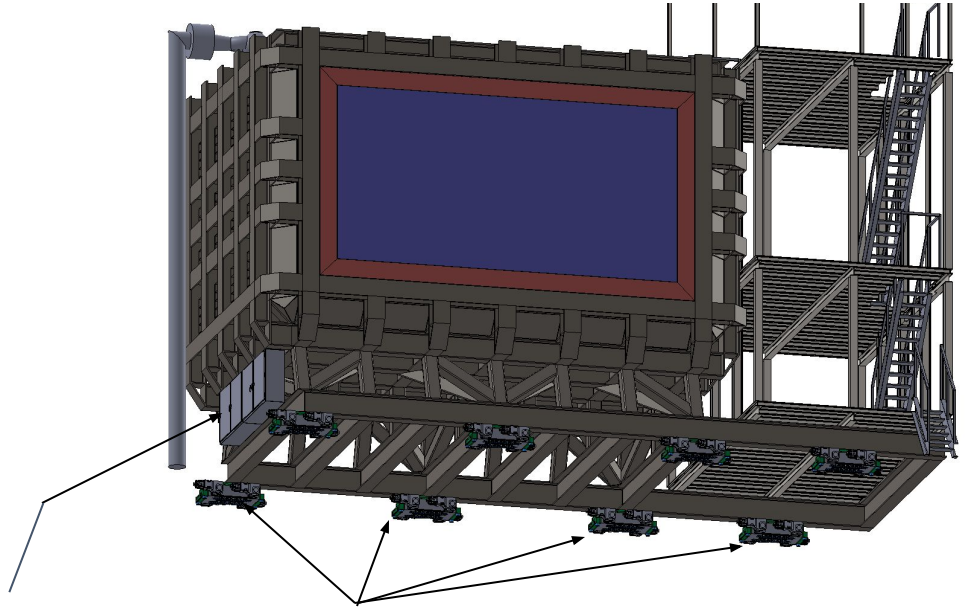
- Detailed **planning and engineering of the detectors assembly and installation process**
- Creation of **assembly** processes, **QA/QC** plans, and **safety documentation** of the detectors
- **Labor for assembly and tests** (others than riggers provided than I&I)
- **Custom tooling**, integration and installation fixtures (generic tooling provided by I&I)
- Detectors **internal metrology** (Global surveying capability provided by I&I)
- **Testing and verification**

Subsystems Overview

PRISM Components and Assembly overview

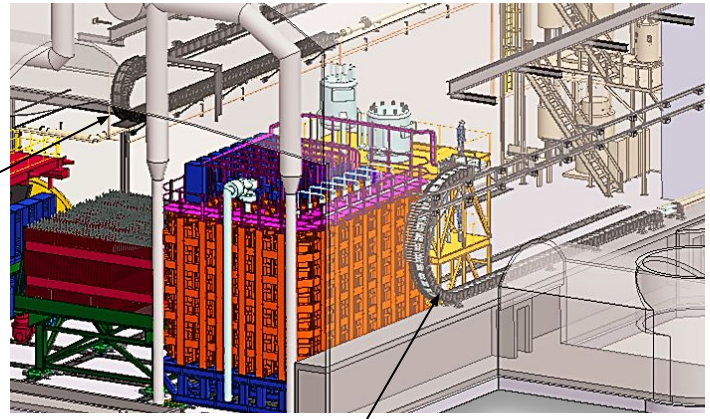


TMS Movement System



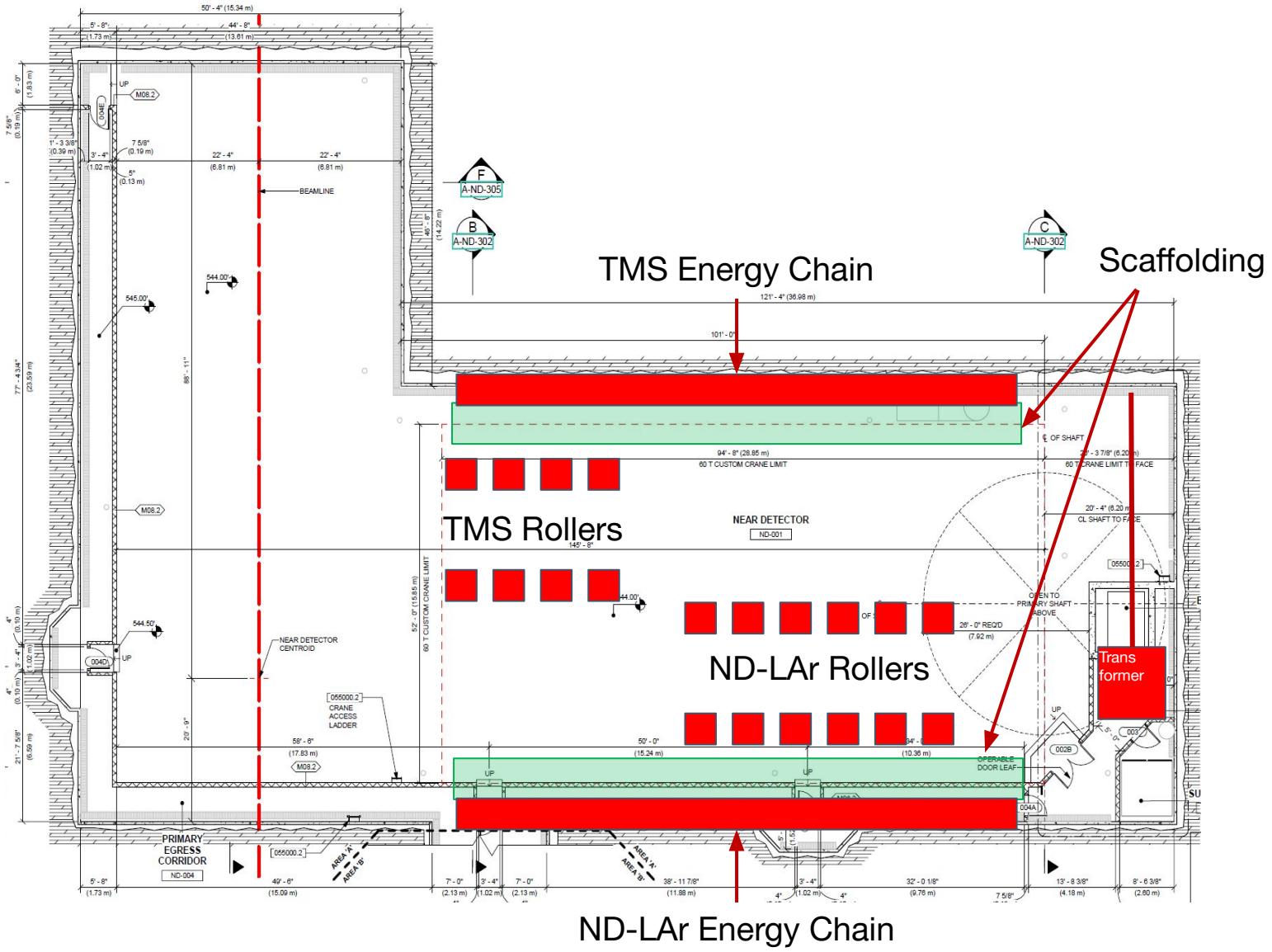
ND-LAr Movement System

TMS Energy Chain

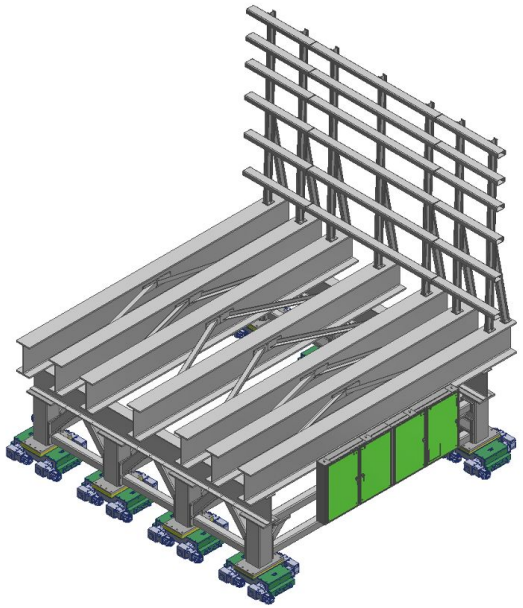


ND-LAr Energy Chain

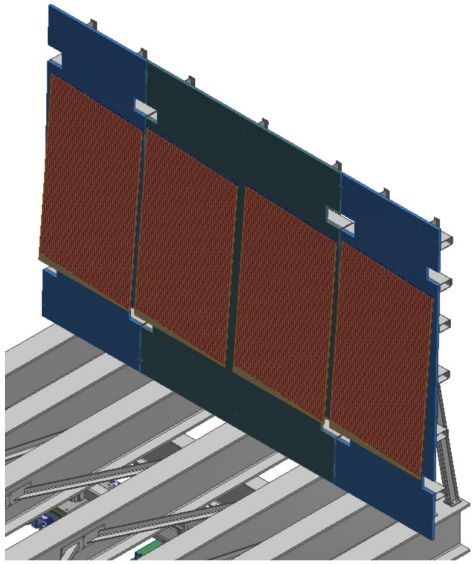
PRISM I&I Layout



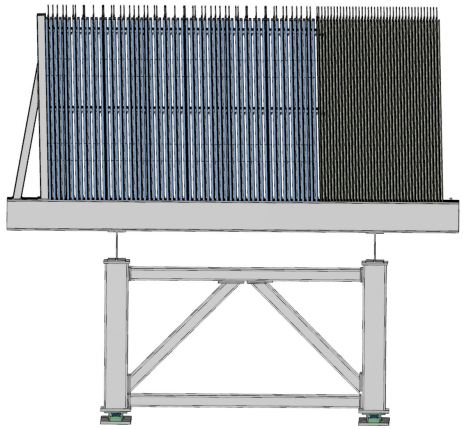
TMS Components and Assembly overview



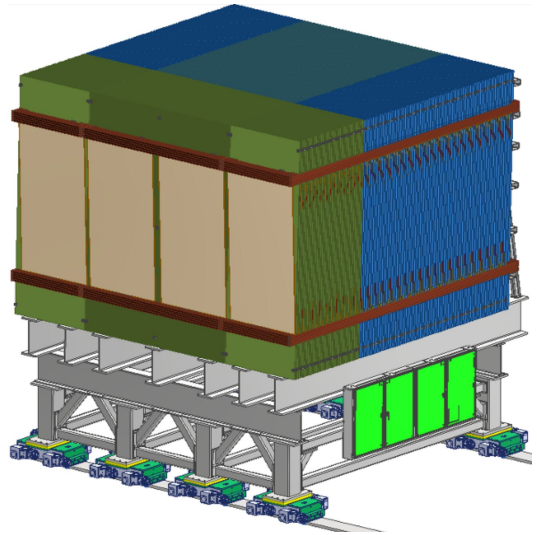
Support structure



1st TMS layer



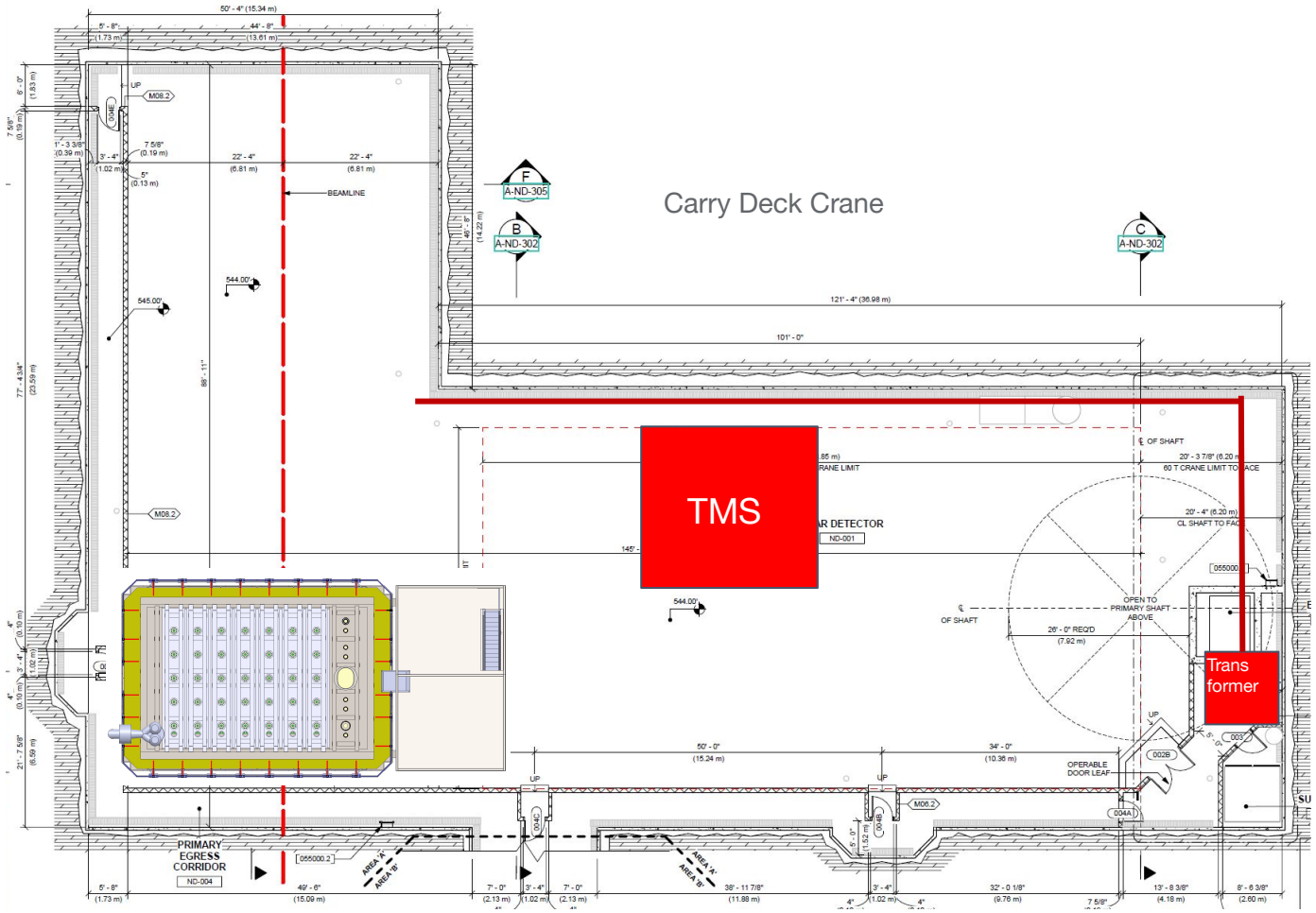
100 TMS layers



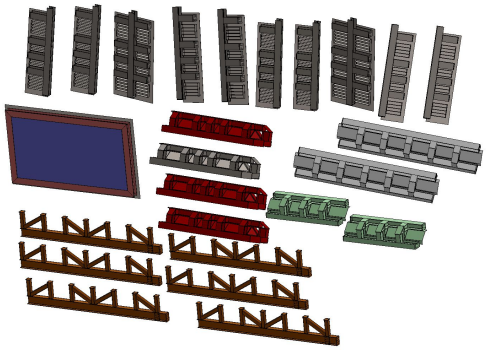
Magnet Coils

Number	Dimensions (mm)	Weight per plate (pounds)
40	15 x 3498 x 5022	4638
80	15 x 1749 x 5022	2319
60	40 x 3498 x 5022	12367
120	40 x 1749 x 5022	6183
Total		1855020

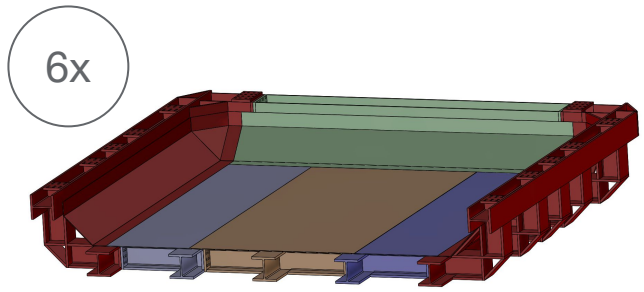
TMS I&I Installation Layout



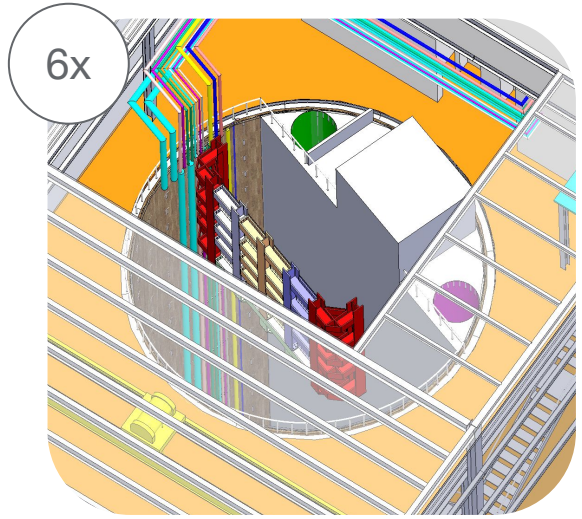
Cryostat Assembly Process Overview



1. Receive 160 metric tons of warm structure parts in 40 pieces



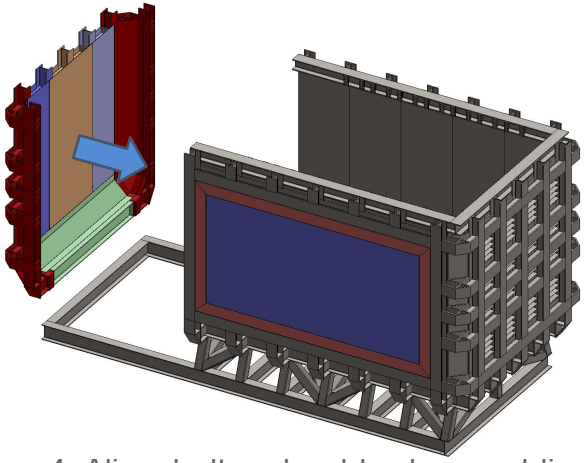
2. Align and bolt pieces into subassemblies



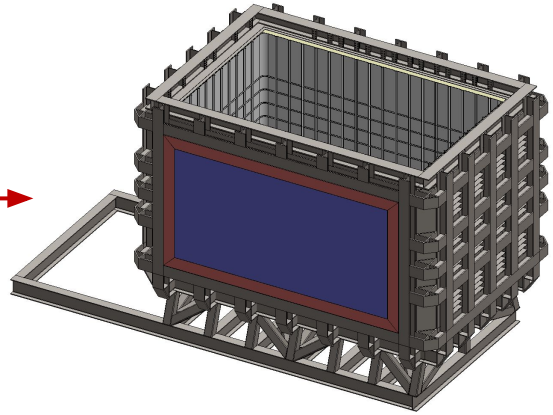
3. Lower 15-50 metric ton subassemblies into cavern

Surface

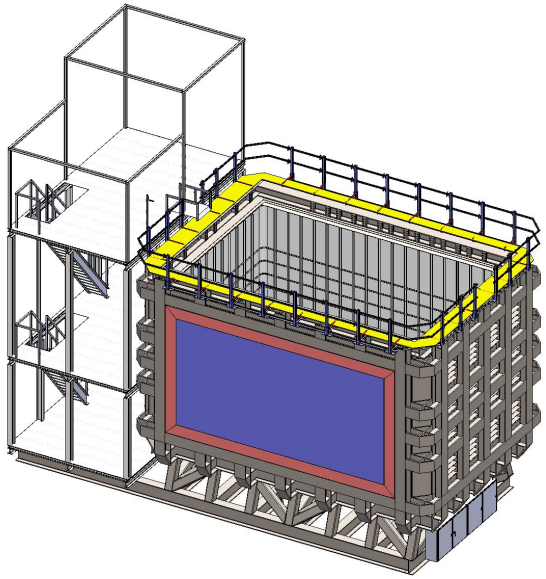
Cavern



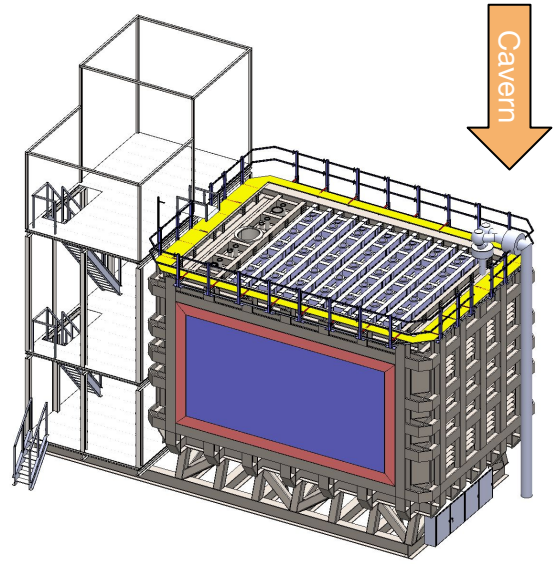
4. Align, bolt and weld subassemblies to form warm structure



5. Install cold membrane



6. Install mezzanines

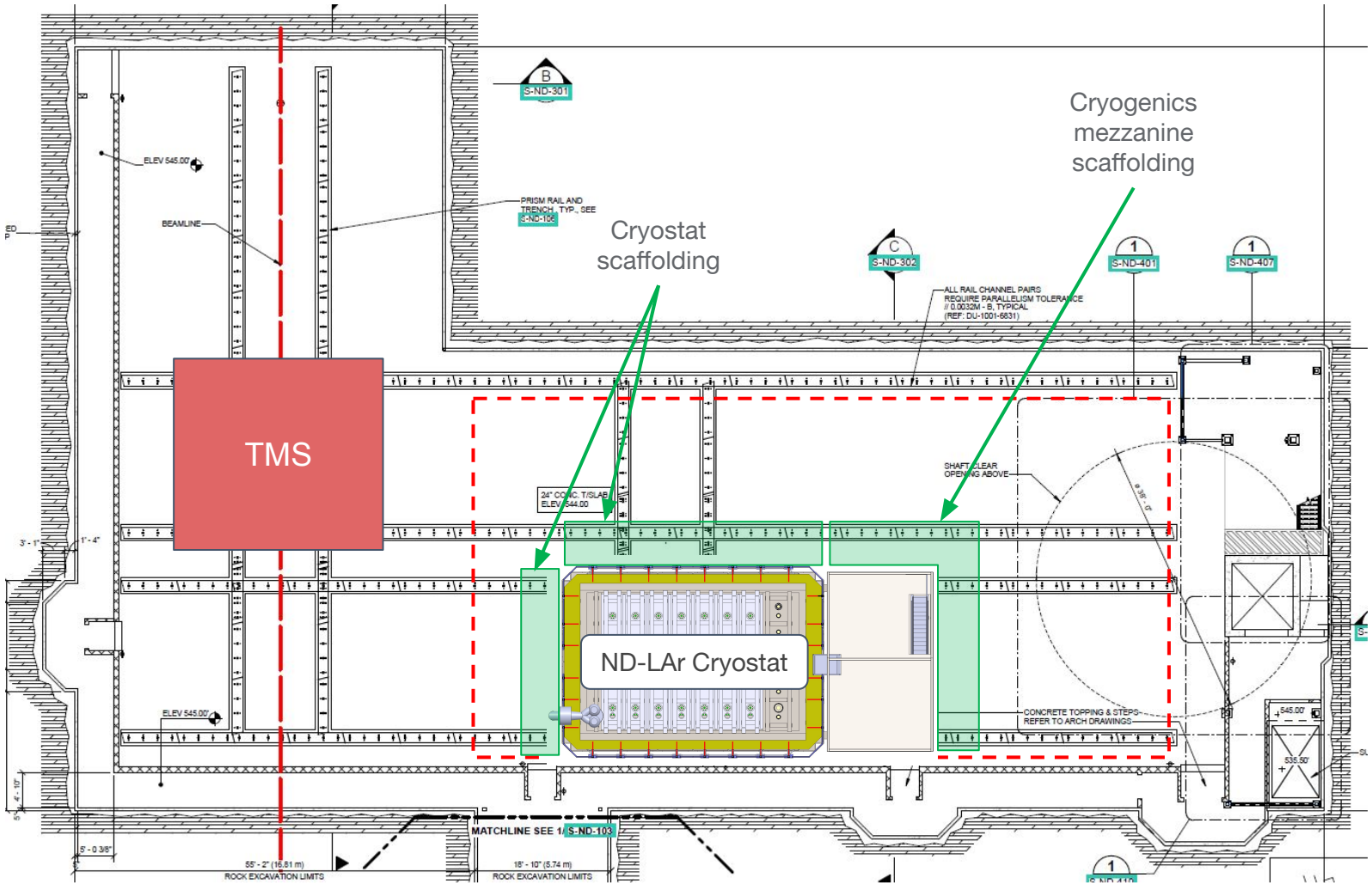


7. Install TPC rows and lid sections

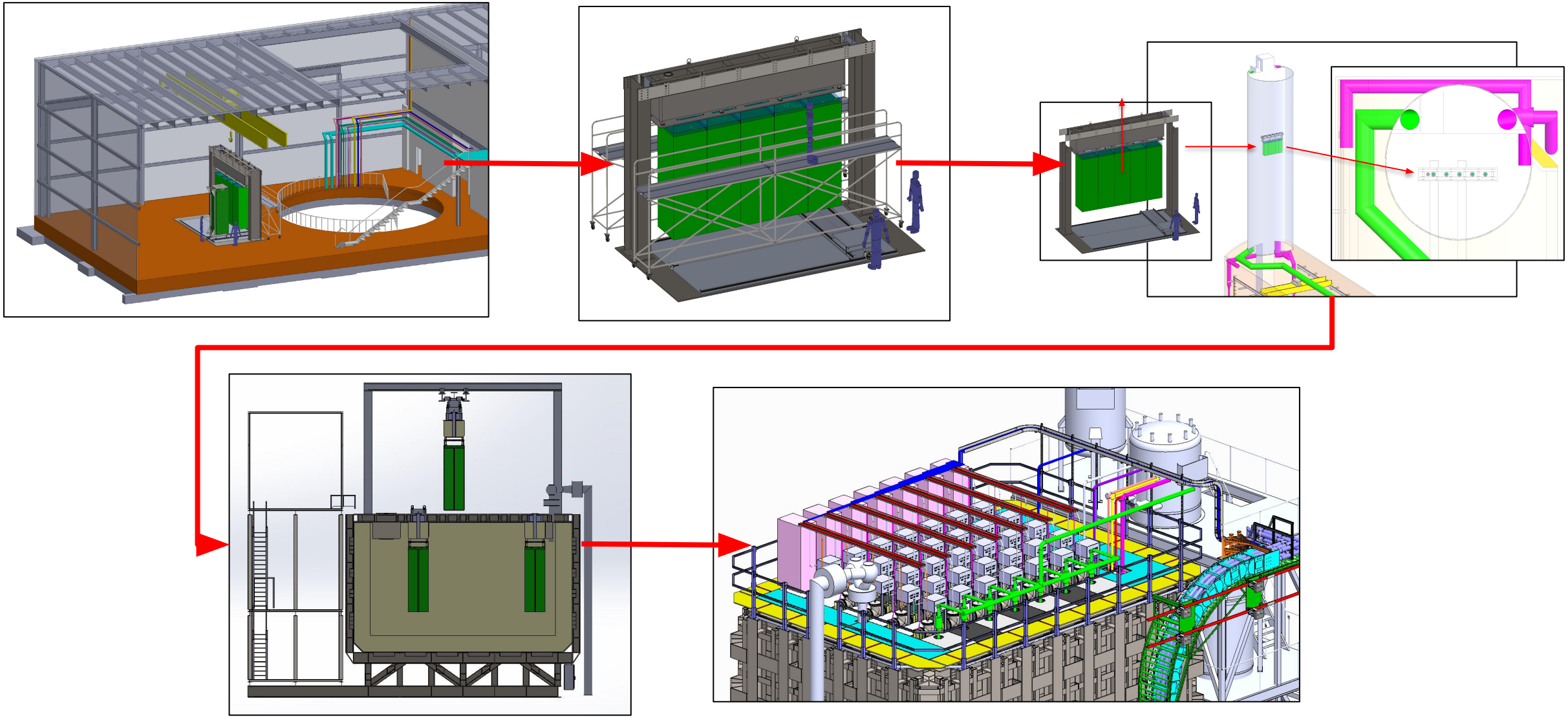
Cavern Assembly Layout

SME comments:

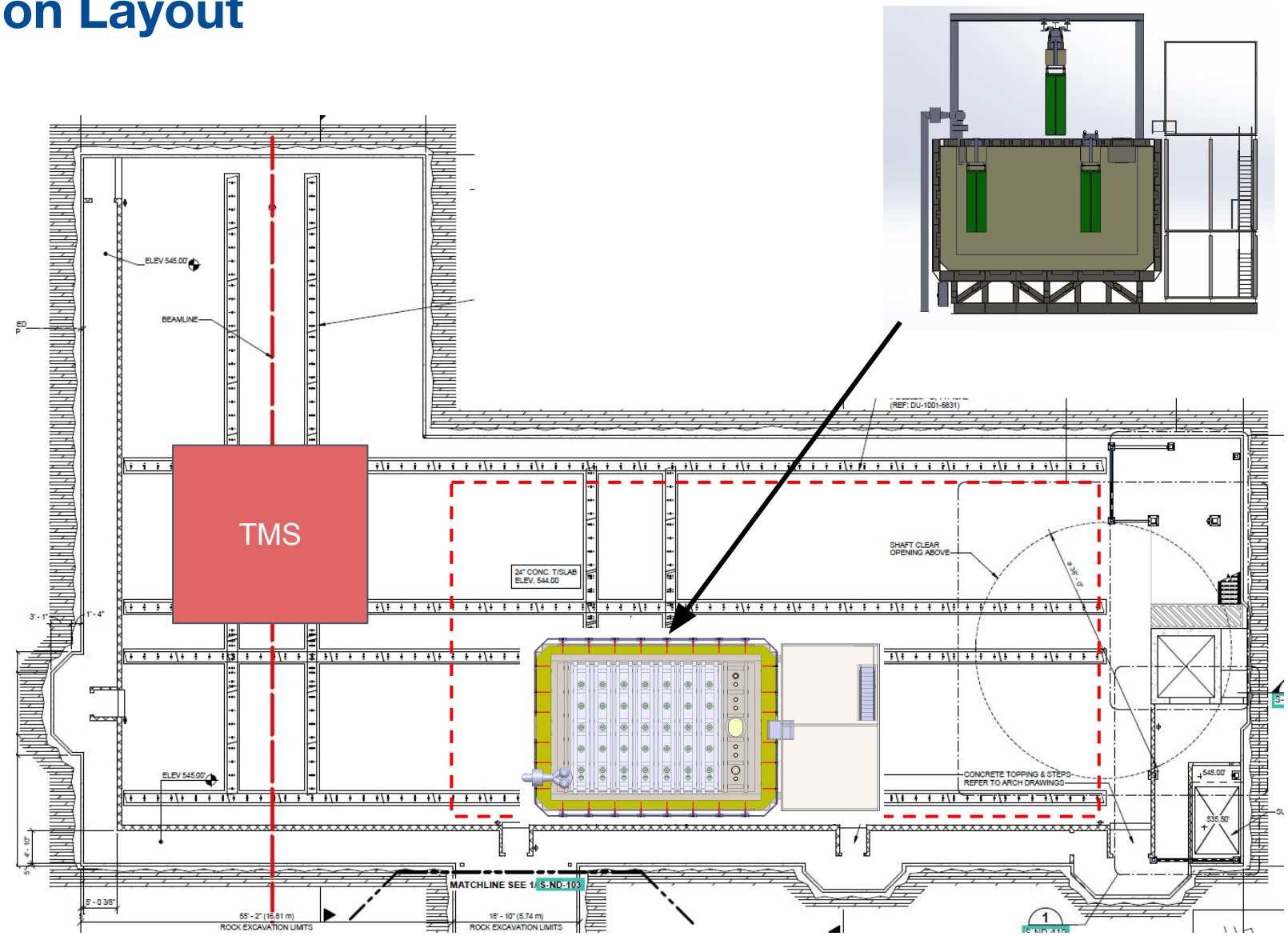
- Consider a gantry for TMS
- Staging of equipment: fixtures to stage equipment for installation? Reverse order of lowering
- Bundling may decrease the time down the shaft, but will increase the labor down in the cavern.



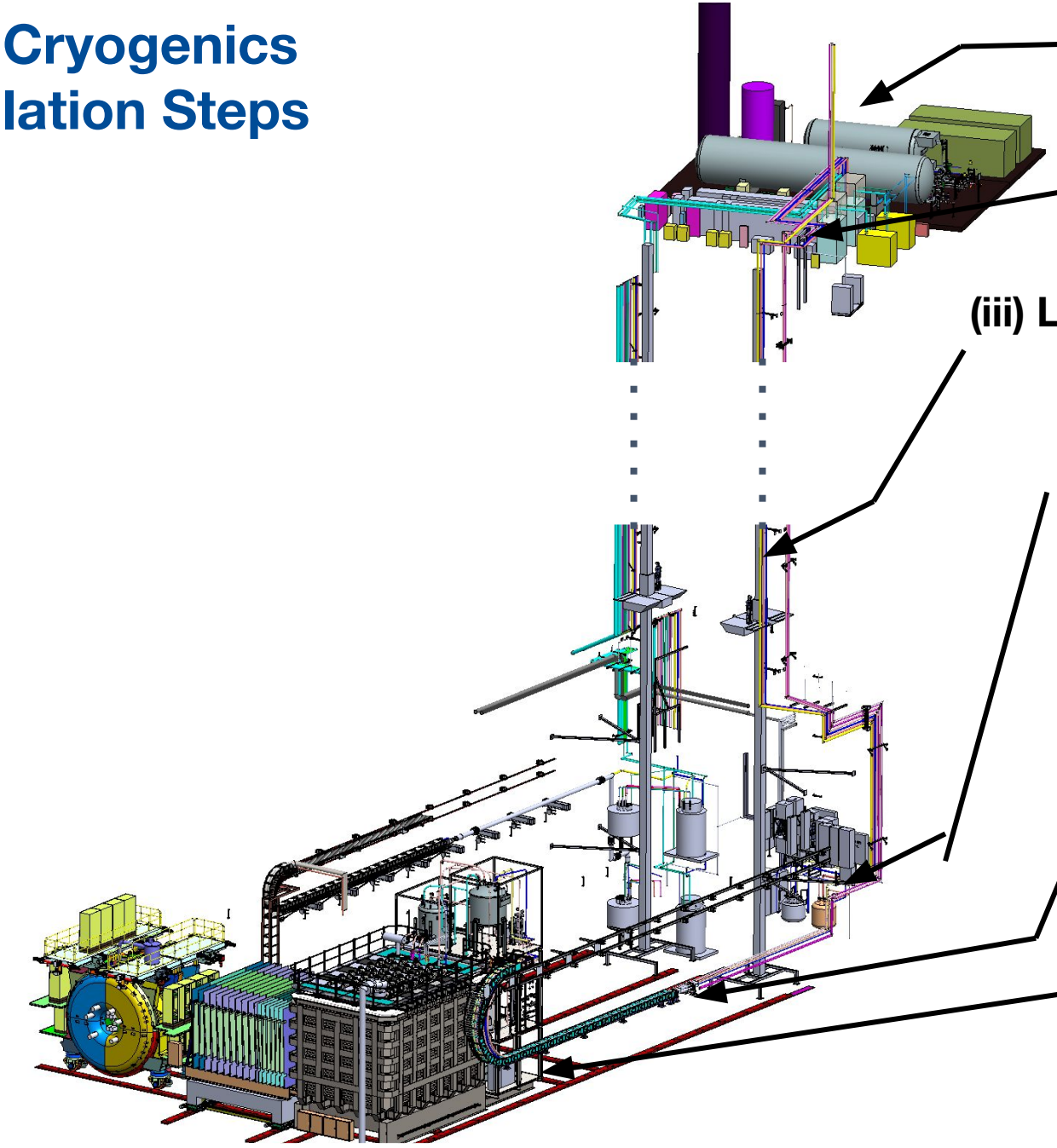
ND-LAr TPC Installation Process Overview



TPC Installation Layout



Main Cryogenics Installation Steps



(i) External Cryogenics

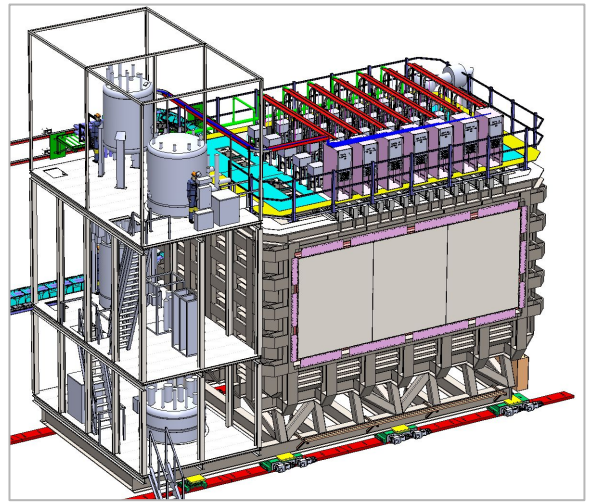
(ii) Surface Cryogenics

(iii) LAr Shaft Cryogenics

(iv) Fixed Mezzanine Cryogenics

(v) Energy Chain Cryogenics

(vi) LAr Proximity Cryogenics



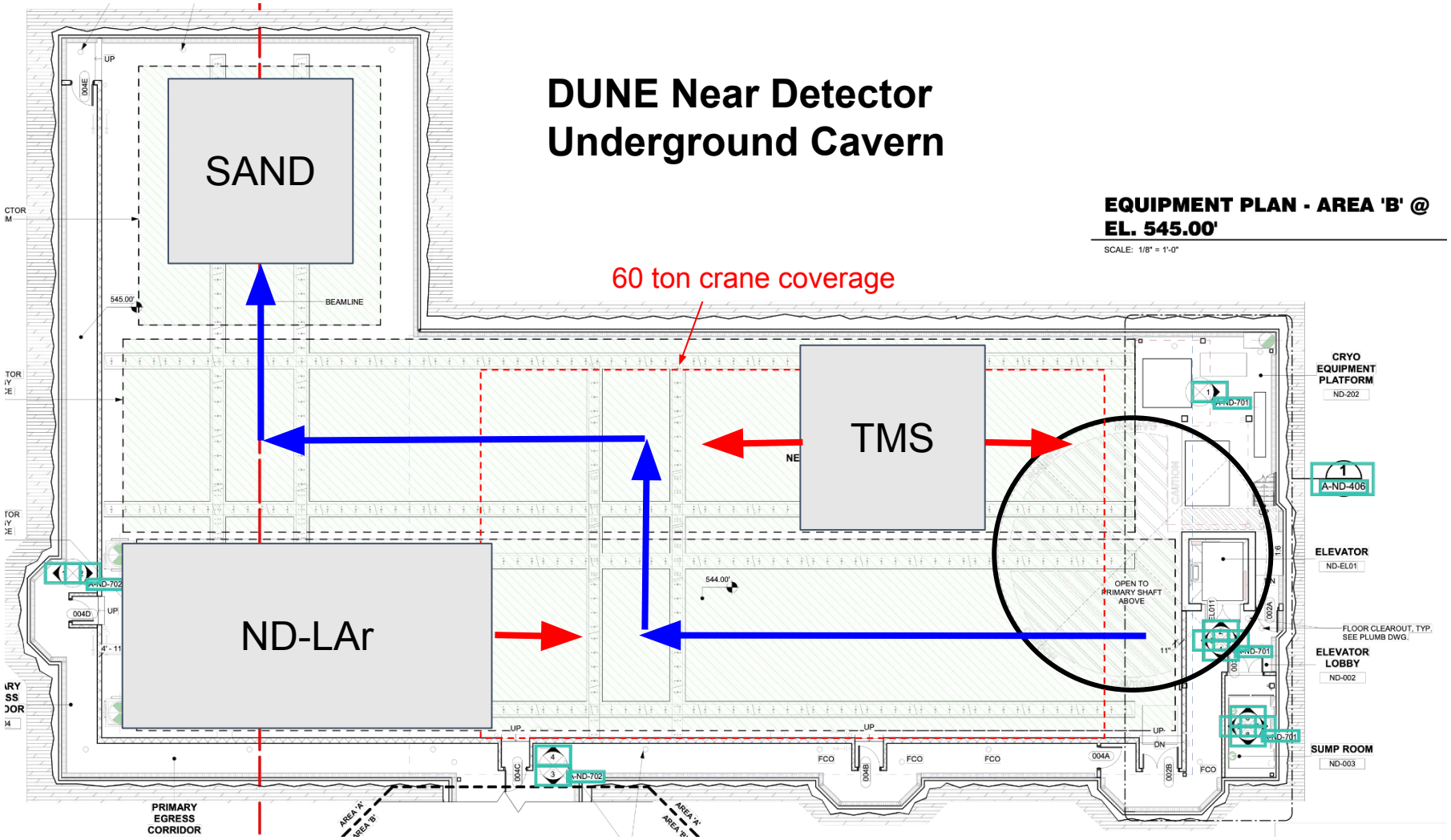
Charge: Timeline

- T1: Is the duration allocated for the installation of each sub-system reasonable?
- T2: What is the most optimal installation sequence, paying close attention to activities which can and cannot be done in parallel. How much can we serialize?
- T3: Please explicitly call out any activities that will require 100% (solo) occupancy of the hall because of crane usage needs or otherwise.
- T4: Have we properly accounted for the time needed for safety reviews and ORCs?
- T5: Have we clearly defined the boundary between the end of project-supported installation activities and the start of commissioning for each subsystem?
- T6: How do we validate the installation?
- T7: Does the overall efficiency of work seem reasonable? Please consider both surface and underground activities.
- T8: What is our total estimated duration of near detector installation underground?
- T9: Please identify any impacts the installation sequencing may have on possible design features (re: safety, tooling, motorized vs. manual PRISM movement).

Installation Process

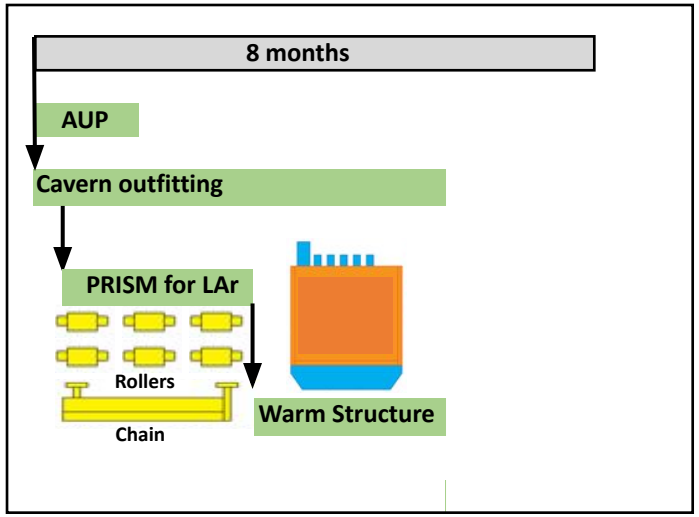
30,000 ft view

The rail structure is designed to allow SAND to be installed at the beginning or at the end of the installation process



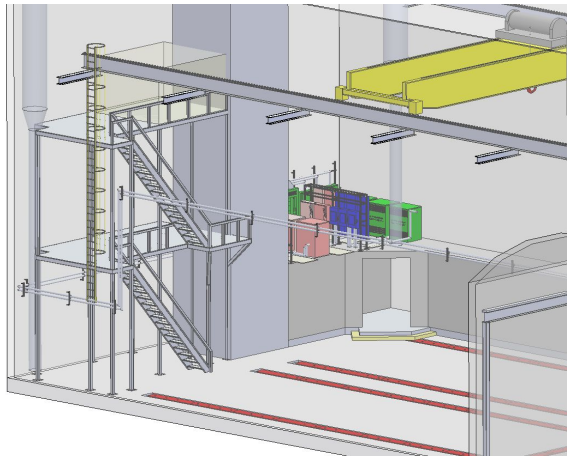
Step 1: Cavern Outfitting, PRISM for LAr, and Cryostat Warm Structure

Charge - T1, T2, T3

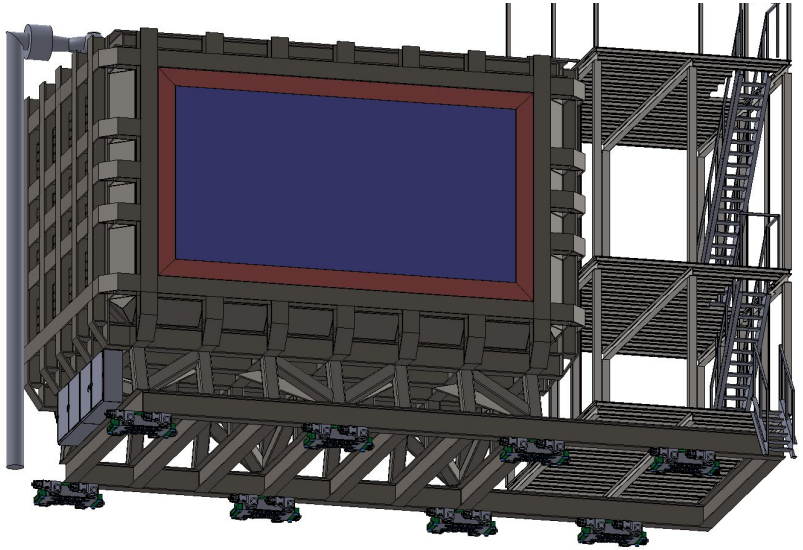


Inspections, Staging, Rental equipment

Power Distribution

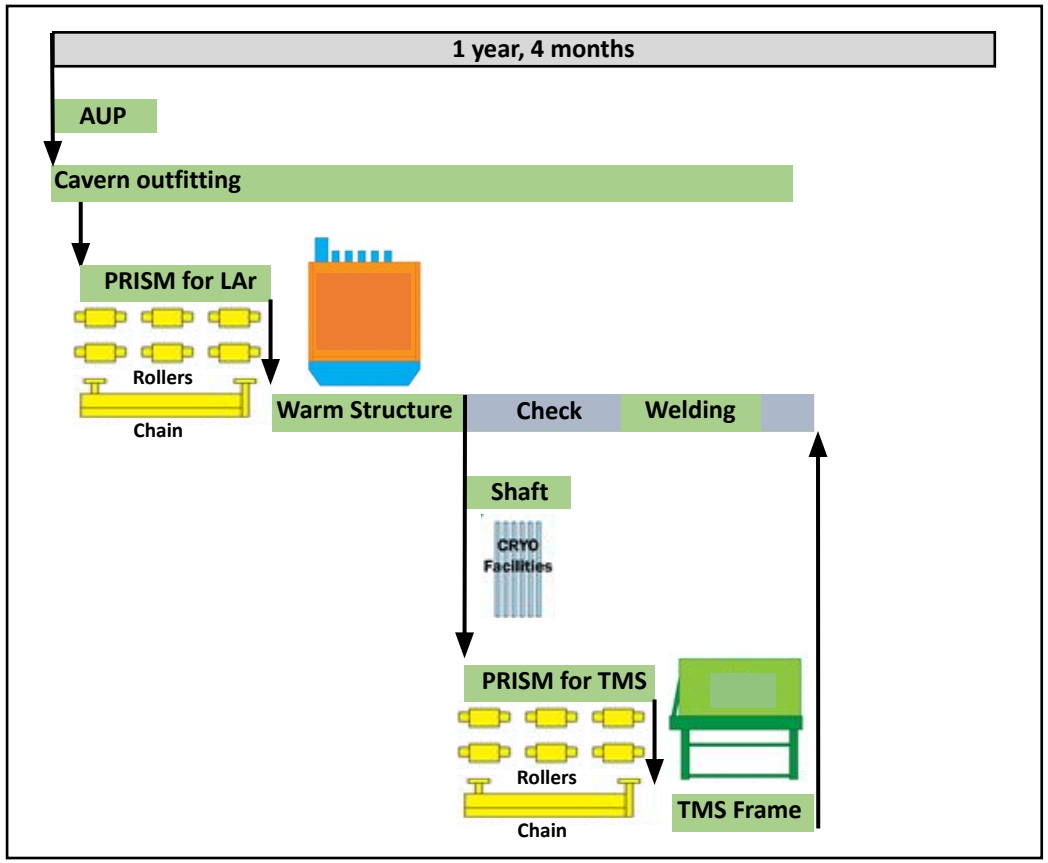


PRISM and Cryostat

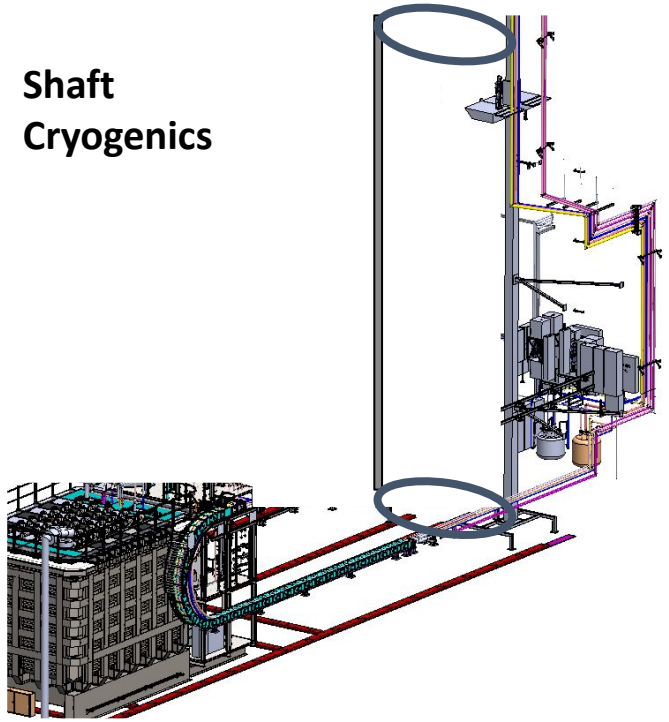


Step 2: Shaft Cryogenics, PRISM for TMS, TMS Frame, and TMS first layer

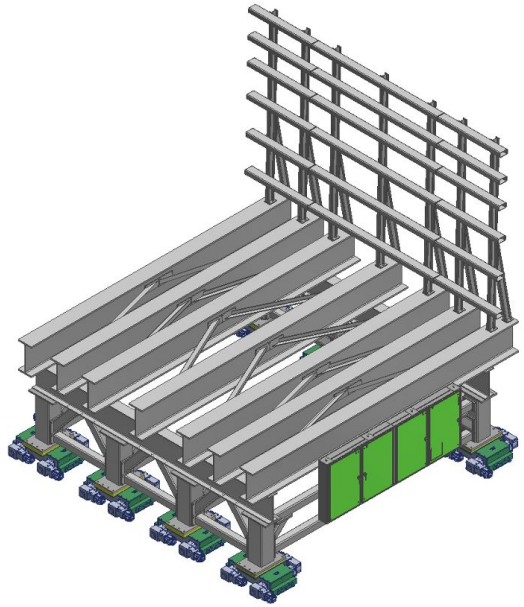
Charge - T1, T2, T3



Shaft Cryogenics

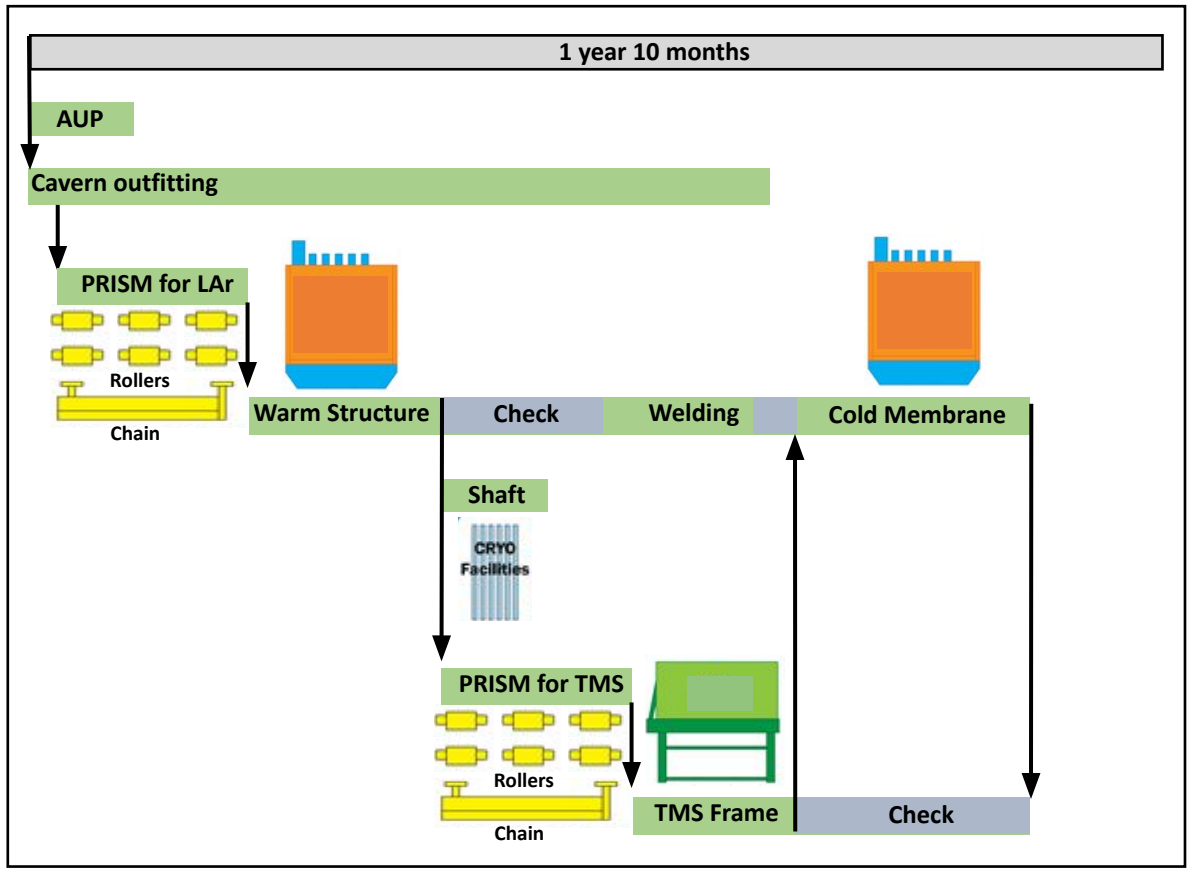


PRISM and TMS

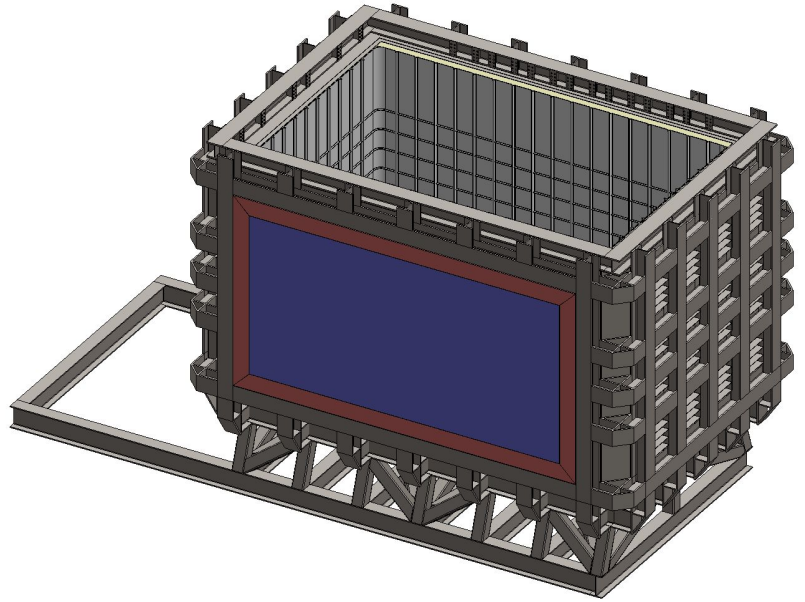


Step 3: Cold Membrane

Charge - T1, T2, T3

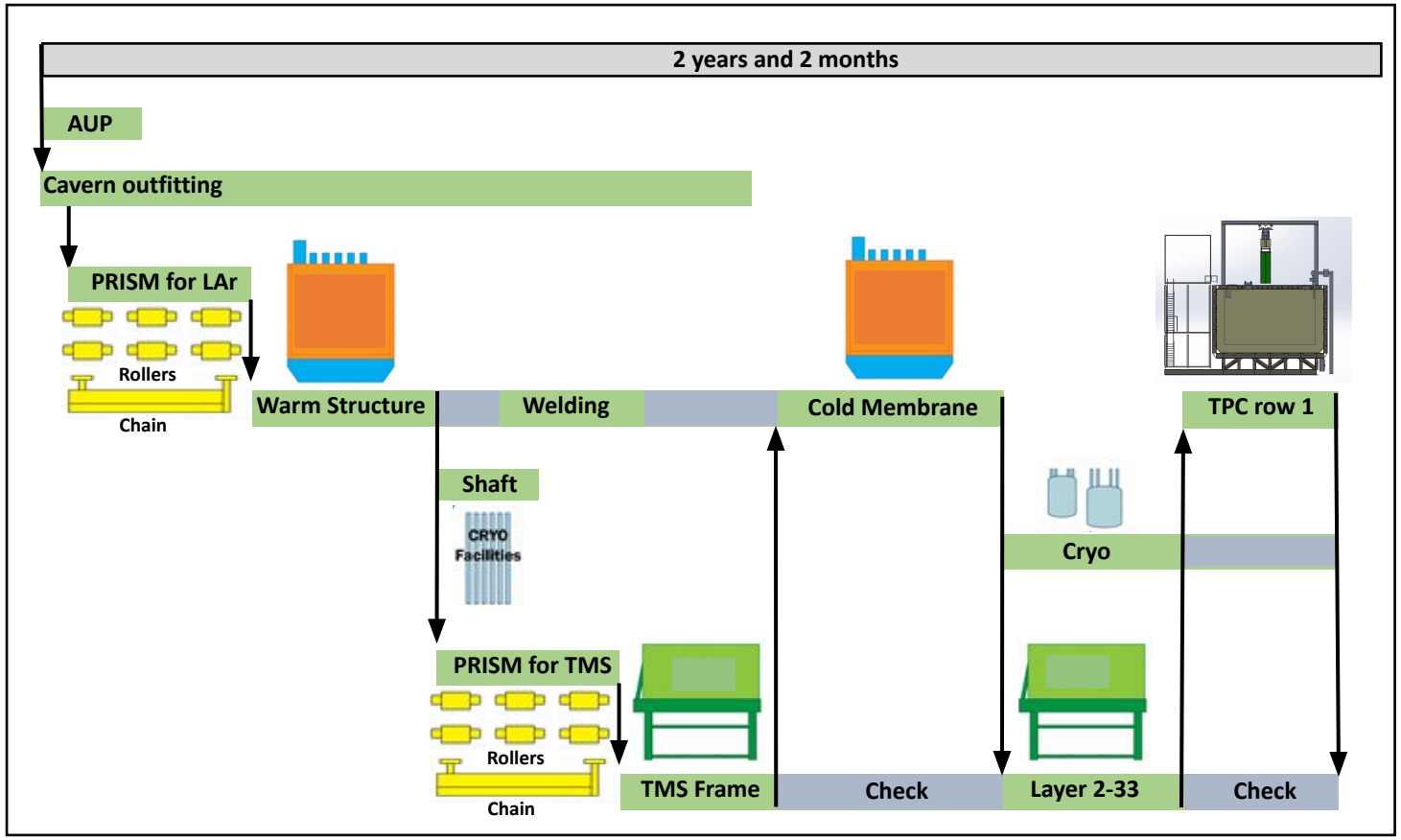


Cold Membrane

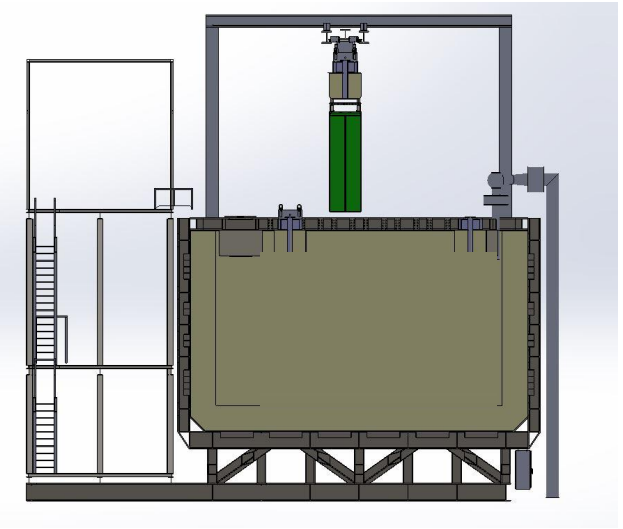


Step 4: TMS Layers 2-33, Cryogenics service row, TPC row 1

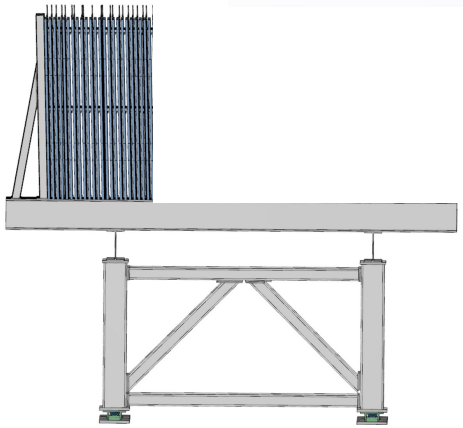
Charge - T1, T2, T3



TPC Rows

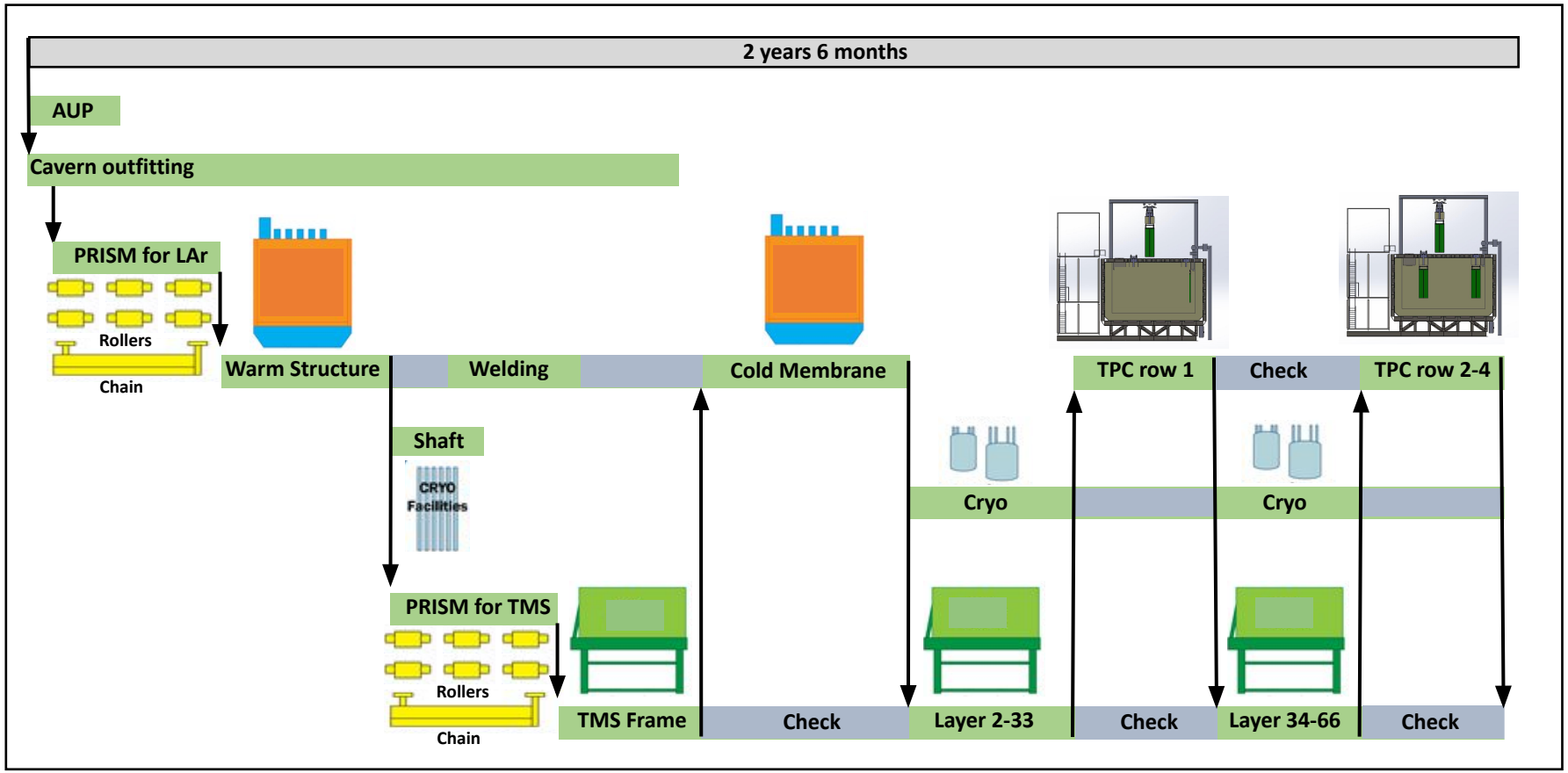


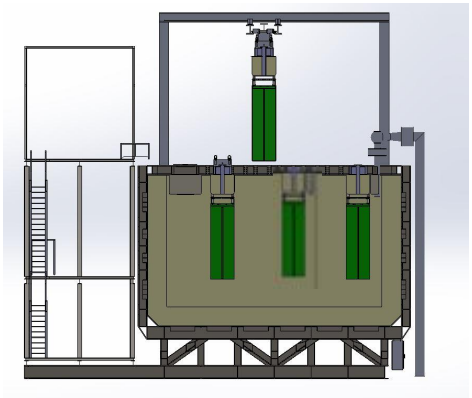
TMS Layers



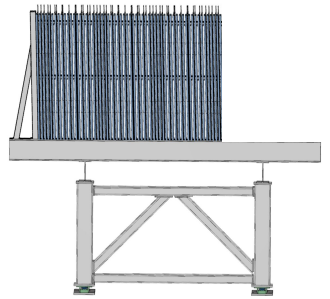
Step 5: TMS Layers 34-66 and TPC row 2-4

Charge - T1, T2, T3



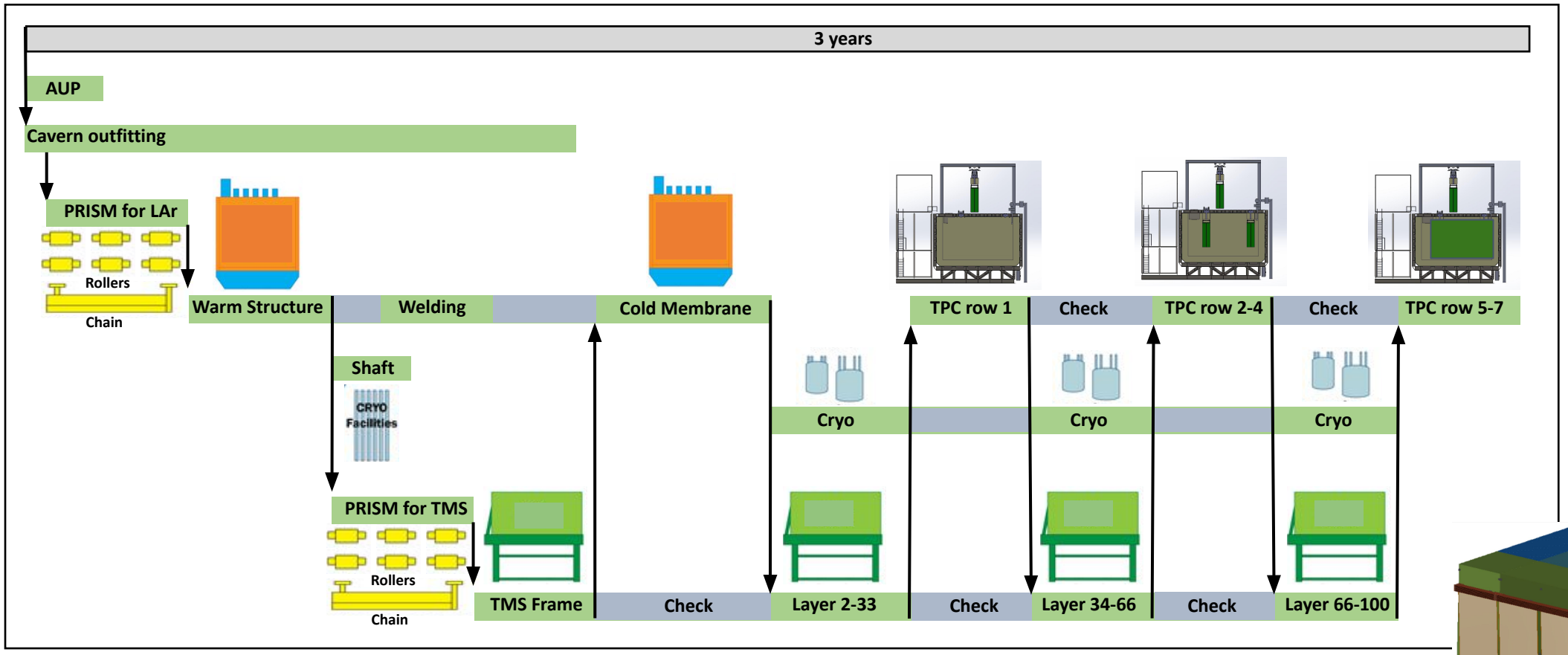


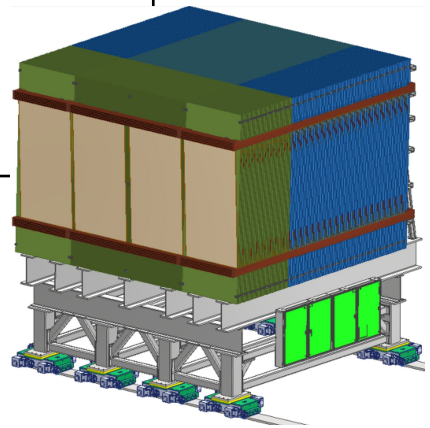
TMS Layers



Step 6: TMS Layers 34-66 and TPC row 2-4

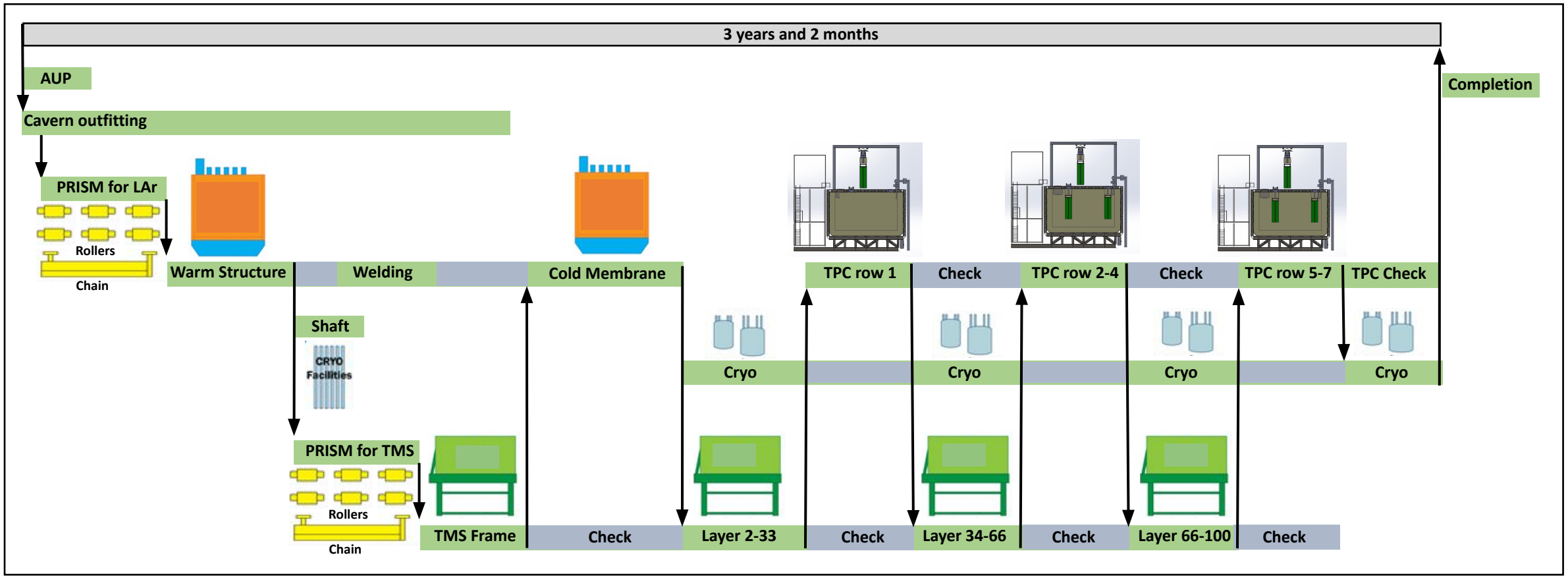
Charge - T1, T2, T3

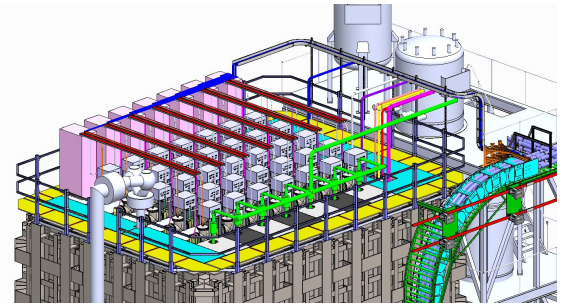




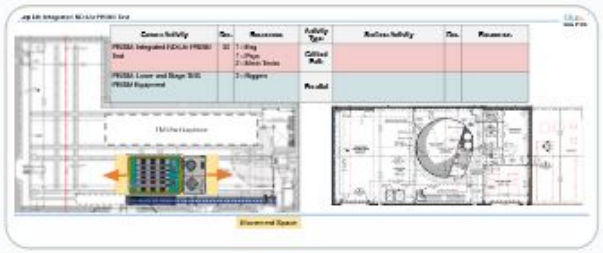
Step 7: Final connection, Completion

Charge - T5, T6, T8





Storyboard



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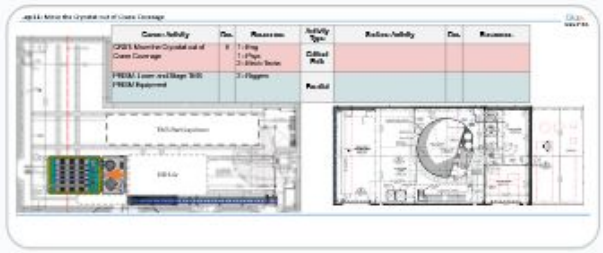

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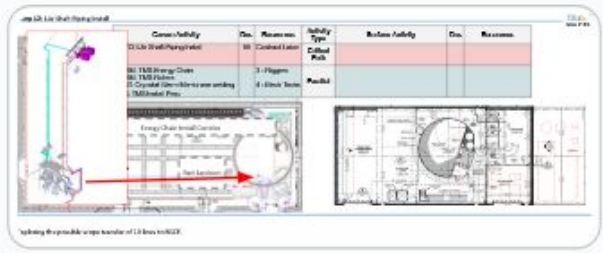

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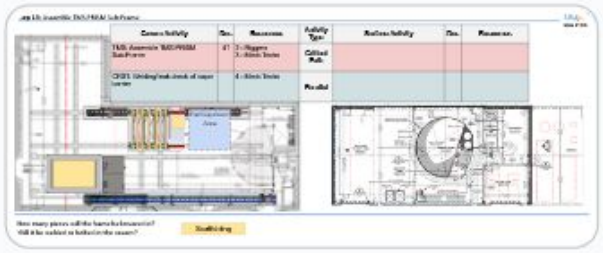

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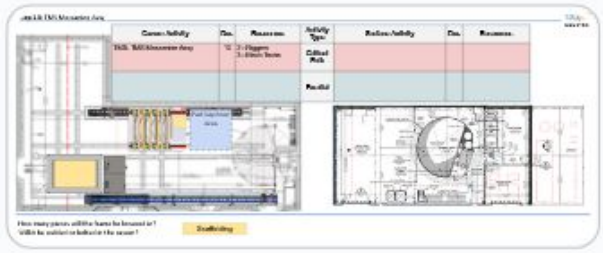

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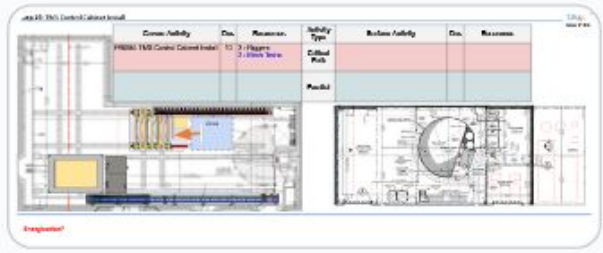

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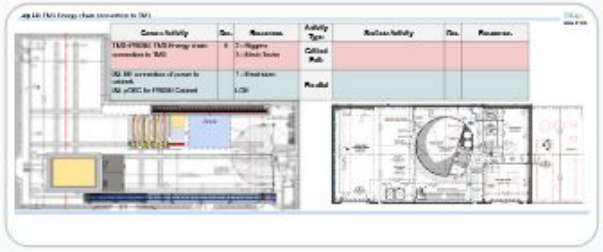

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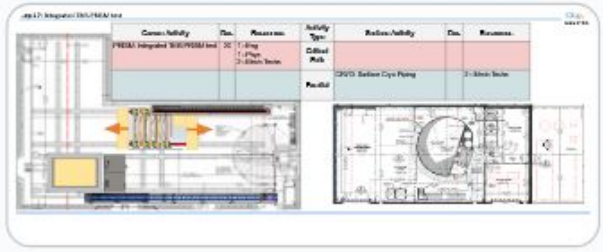

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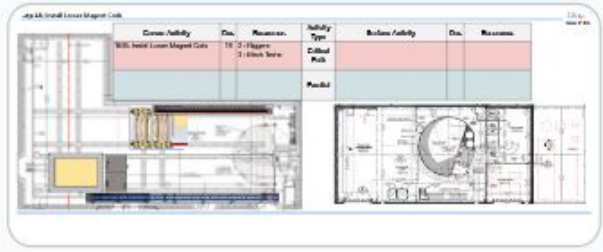

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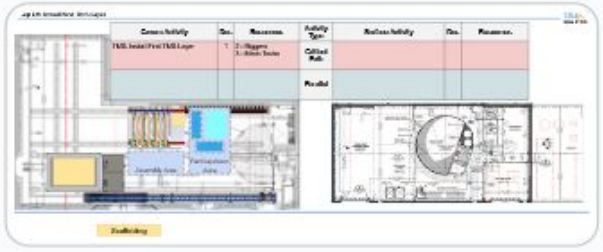

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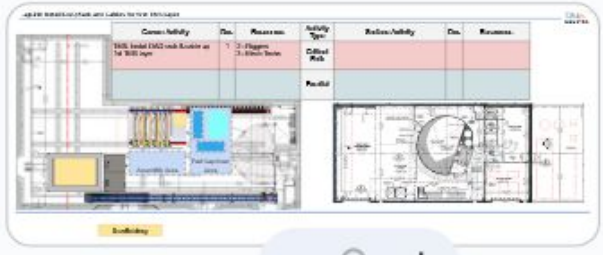

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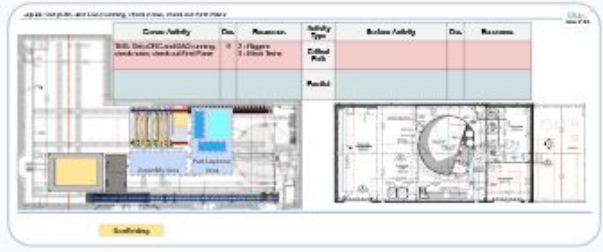

21

Storyboard

SME comments:

- Step 2: external cryo , 1 rigger + 2 techs vs 3 riggers?
- Step 7: energy chain mechanical connection to be captured earlier.
- Step 8: ORC preparation on project, ORC team off project. Scheduling of ORC takes a couple days. Date and time can be scheduled with a two weeks notice. Linda can provide guidance.
- Step 10: Test the full length of the rails
- Step 11: Laydown area should not be under or near the shaft
- Step 12: install early the portion of energy chain close to the shaft
- General note: personnel can be under the bridge, not under the load
- Step 15: one of the riggers will be upstair to operate the crane
- Step 16: Consider minimizing electrician work, using plug in approach. Scheduling electricians is hard, and causes delays (9 months on the 2x2)
    - Mary Congary (sp?) what is the beamline staffing plan for electricians?
- General note: Hire an electrician?
- Slide 18: Parallel activities can include studs welding, scaffolding install
- Step 21: laydown area too close from the shaft. Or can we implement a net?

Storyboard

SME comments:

- Step 21: power supplies, a few 1000 amps, about the size of 4 racks, may require cooling
- Step 24: Scaffolding operations require certification, it might be possible to have Gabaddi do it
- Slide 28: Power needs to be ready for TMS test.
- Barrier in surface to protect TPCs from trucks.
- Slide 31: TMS pre-commissioning + Gantry for TMS?
- General note: Trench cover / gap fillers (plastic blocks would work, doesn't have to be perfect)
- Step 48: Row position metrology required
- General note: work on ORC ahead of time
- General note: hire a dedicated electrician as a contractor. Does it require a task manager? Or term FNAL staff contract for an electrician?
- General note: implementing guard rails and decking on Cryostat is easy

Resources

Charge: Resources

- R1: Does the level of costed resources in support of near detector installation seem reasonable given how similar installations have occurred at Fermilab? Please also consider what we are considering for uncosted labor.

- R2: Are we double counting any installation resources held in I&I and at the detector subsystem level?

- R3: Please review assumptions about on-project equipment rental versus existing resources at Fermilab. Are there any resources we are including on-project that would instead be provided by the host lab?

Additional questions about rigging

- How do we “book” the riggers?
- Can we book only 2 riggers, or do we need to book the whole team?
- Do we generally book the riggers for the whole day?
- What is the size of the whole team?
- Can ND realistically occupy the entire FNAL rigging team for 3+ years during install? No
- Do we need to hire riggers specifically for ND install? Likely Yes
- What is the typical daily schedule?
- Does the rigging team work on Friday?
- Can we supplement rigging personnel with mech techs? (for spotting lifts, operating cranes, etc) to minimize rigging team utilization.

ND I&I Management and Coordination

	Management and Coordination	
Resources in I&I WBS	**Hours**	**FTE**
Detector Installation Coordinator (FNAL)	5,304	1.00
Detector Installation Engineer (FNAL)	4,862	0.92
Detector Manufacturing Engineer (FNAL)	3,599	0.68
Electrical Engineering (FNAL)	3,122	0.59
Detector Installation Designer (LBNL and/or FNAL)	2,652	0.50
L2/CAM (LBNL and/or FNAL)	2,652	0.50
Total	22,191	**4.18**

Installation Coordinator

- Coordination of I&I readiness (pre-installation years)
- Coordination with FNAL rigging, EE, receiving and distribution teams
- On the field coordination of I&I activities (installation years)
- I&I on the field ES&H
- Areas:
  - From storage to surface
  - From Storage to Cavern (shaft)
  - Cavern activities

SME comments:

Coordinate/ ensure/verify readiness for

- Staff, materials, procedures, work permits, safety
- Verify that floor managers have work plans and safety approval in place

	Management and Coordination	
Overall Installation Duration (Days)	663	
Resources in I&I WBS	**Hours**	**FTE**
Detector Installation Coordinator (FNAL)	**5,304**	**1.00**
Detector Installation Engineer (FNAL)	4,862	0.92
Detector Manufacturing Engineer (FNAL)	3,599	0.68
Electrical Engineering (FNAL)	3,122	0.59
Detector Installation Designer (LBNL and/or FNAL)	2,652	0.50
L2/CAM (LBNL and/or FNAL)	2,652	0.50
Total	**22,191**	**4.18**

Installation Engineer

- Coordination of installation engineering and planning with the subsystems/consortia
- Coordination with EE and NSCF
- Management of I&I interfaces and requirements
- Management of the overall installation sequence
- Installation layouts
- Equipment layouts (mezzanines, floor space)
- BOE development support

SME comments:

Floor Manager Top Floor, responsible for:

- IMPACT, job hazard analysis, approval, link the engineering notes
- Work Activity Plan, Job hazard analysis, burn permits…
- Print, review and collect signoff on job cards

	Management and Coordination	
Overall Installation Duration (Days)	663	
Resources in I&I WBS	**Hours**	**FTE**
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L2/CAM (LBNL and/or FNAL)	2,652	0.50
Total	**22,191**	**4.18**

Material planning engineer

- Planning of materials logistics and receiving from storage and to the surface building and cavern
- Verification of QA/QC readiness ahead of receiving materials
- Verification of safety readiness ahead of receiving materials
- Readiness of assembly areas
- Readiness of installation equipment
- Readiness of installation teams
- Manufacturing knowledge to handle specification deviations

SME comments:

- Floor Manager - Bottom Floor

	Management and Coordination	
Overall Installation Duration (Days)	663	
Resources in I&I WBS	**Hours**	**FTE**
Detector Installation Coordinator (FNAL)	5,304	1.00
Detector Installation Engineer (FNAL)	4,862	0.92
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Electrical Engineering (FNAL)	3,122	0.59
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L2/CAM (LBNL and/or FNAL)	2,652	0.50
Total	**22,191**	**4.18**

Summary Data from P6: activity based resources

Charge - R1, R2

	Cavern outfiting		TMS		NDLarTPC		LAr Cryostat		PRISM		Cryogenics	
Overall Duration (Days)	**100**		**298**		**472**		**402**		**234**		**477**	
Rigging Duration (Days)	**50**		**259**		**196**		**344**		**117**		**115.5**	
Rigging Duration (Days)	**50%**		**87%**		**42%**		**86%**		**50%**		**24%**	
Resources in I&I WBS	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Lead Rigger (Hours)	420	1.05	1,530	0.74	2,076	1.32	1,496	0.54	1,072	1.15	1310	1.42
Riggers (Hours)	980	2.45	2,472	1.19	4496	2.87	4,762	1.73	1,624	1.74	2056	2.23
Electrical Technician (Hours)	0	0.00	292	0.12	0	0.00	0	0.00	160	0.09	0	0.00
Survey and Alignment (Hours)	1,036	*1.30*	0	0.00	0	0.00	0	0.00	320	0.17	0	0.00
Total	2,436	**3.05**	4,294	**1.80**	6,572	**1.74**	6,258	**1.95**	3,176	**1.70**	3366	**0.88**
Resources in Sub-systems WBS	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Lead Technician (Hours)	0	0	0	0	0	0.00	4640	1.44	0	0.00	0	0.00
Mech Technicians (Hours)	0	0	6254	2.62	3,532	0.94	5600	1.74	0	0.00	0	0.00
Elec Technicians (Hours)	0	0	0	0	1,800	0.48	0	0.00	0	0.00	0	0.00
Engineer oversight (Hours)	0	0	468	0.20	1,086	0.29	2460	0.76	933	0.50	2326	0.61
Welder (Hours)	0	0	0	0.00	0	0.00	800	0.25	0	0.00	2197	0.58
Cryogenics Technicians (Hours)	0	0	0	0.00	0	0.00	0	0.00	0	0.00	**1,604**	0.42
Total Hours	0	0	6,722	**2.82**	6,418	**1.70**	13,500	**4.20**	933	**0.50**	6,127	**1.61**
Grand Total on Project			**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Hours Estimate	2,436	**3.05**	11,016	**4.62**	12,990	**3.44**	19,758	**6.14**	4,109	**2.19**	9,493	**2.49**
In-Kind Contribution			**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Grad Student	0	0.00	0	0.00	7,264	1.92	0	0.00	0	0.00	0	0.00
Physicist	0	0.00	0	0.00	3,632	0.96	0	0.00	0	0.00	0	0.00
Total Hours	0	**0.00**	*320*	0.13	10,896	**2.89**	0	0.00	0	0.00	0	0.00

Summary Data from P6: activity based resources

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	Cavern outfiting		TMS		NDLarTPC		LAr Cryostat		PRISM		Cryogenics	
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Total Hours	0	0	6,722	**2.82**	6,418	**1.70**	13,500	**4.20**	933	**0.50**	6,127	**1.61**
Grand Total on Project			**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
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Total Hours	0	**0.00**	*320*	0.13	10,896	**2.89**	0	0.00	0	0.00	0	0.00

Text

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Rigging Duration (Days)	**50**		**259**		**196**		**344**		**117**		**115.5**	
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Total Hours	0	0	6,722	**2.82**	6,418	**1.70**	13,500	**4.20**	933	**0.50**	6,127	**1.61**
Grand Total on Project			**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Hours Estimate	2,436	**3.05**	11,016	**4.62**	12,990	**3.44**	19,758	**6.14**	4,109	**2.19**	9,493	**2.49**
In-Kind Contribution			**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Grad Student	0	0.00	0	0.00	7,264	1.92	0	0.00	0	0.00	0	0.00
Physicist	0	0.00	0	0.00	3,632	0.96	0	0.00	0	0.00	0	0.00
Total Hours	0	**0.00**	*320*	0.13	10,896	**2.89**	0	0.00	0	0.00	0	0.00

- The sum of work days across the subsystems is 1983 working days
- Given that the duration of ND installation is 703 days (3 year and 2 month), the average number of parallel activities is 2.82

Text

	Cavern outfiting		TMS		NDLarTPC		LAr Cryostat		PRISM		Cryogenics	
Overall Duration (Days)	**100**		**298**		**472**		**402**		**234**		**477**	
Rigging Duration (Days)	**50**		**259**		**196**		**344**		**117**		**115.5**	
Rigging Duration (Days)	**50%**		**87%**		**42%**		**86%**		**50%**		**24%**	
Resources in I&I WBS	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Lead Rigger (Hours)	420	1.05	1,530	0.74	2,076	1.32	1,496	0.54	1,072	1.15	1310	1.42
Riggers (Hours)	980	2.45	2,472	1.19	4496	2.87	4,762	1.73	1,624	1.74	2056	2.23
Electrical Technician (Hours)	0	0.00	292	0.12	0	0.00	0	0.00	160	0.09	0	0.00
Survey and Alignment (Hours)	1,036	*1.30*	0	0.00	0	0.00	0	0.00	320	0.17	0	0.00
Total	2,436	**3.05**	4,294	**1.80**	6,572	**1.74**	6,258	**1.95**	3,176	**1.70**	3366	**0.88**
Resources in Sub-systems WBS	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Lead Technician (Hours)	0	0	0	0	0	0.00	4640	1.44	0	0.00	0	0.00
Mech Technicians (Hours)	0	0	6254	2.62	3,532	0.94	5600	1.74	0	0.00	0	0.00
Elec Technicians (Hours)	0	0	0	0	1,800	0.48	0	0.00	0	0.00	0	0.00
Engineer oversight (Hours)	0	0	468	0.20	1,086	0.29	2460	0.76	933	0.50	2326	0.61
Welder (Hours)	0	0	0	0.00	0	0.00	800	0.25	0	0.00	2197	0.58
Cryogenics Technicians (Hours)	0	0	0	0.00	0	0.00	0	0.00	0	0.00	**1,604**	0.42
Total Hours	0	0	6,722	**2.82**	6,418	**1.70**	13,500	**4.20**	933	**0.50**	6,127	**1.61**
Grand Total on Project			**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Hours Estimate	2,436	**3.05**	11,016	**4.62**	12,990	**3.44**	19,758	**6.14**	4,109	**2.19**	9,493	**2.49**
In-Kind Contribution			**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Grad Student	0	0.00	0	0.00	7,264	1.92	0	0.00	0	0.00	0	0.00
Physicist	0	0.00	0	0.00	3,632	0.96	0	0.00	0	0.00	0	0.00
Total Hours	0	**0.00**	*320*	0.13	10,896	**2.89**	0	0.00	0	0.00	0	0.00

- TMS and Cryostat are require riggers most of the days
- LAr TPC and PRISM require riggers about half of the days
- Cryogenics require riggers about a quarter of the days

Rigging resources

Charge - R1, R2

	Cavern outfiting		TMS		NDLarTPC		LAr Cryostat		PRISM		Cryogenics	
Overall Duration (Days)	**100**		**298**		**472**		**402**		**234**		**477**	
Rigging Duration (Days)	**50**		**259**		**196**		**344**		**117**		**115.5**	
Rigging Duration (Days)	**50%**		**87%**		**42%**		**86%**		**50%**		**24%**	
Resources in I&I WBS	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Lead Rigger (Hours)	420	1.05	1,530	0.74	2,076	1.32	1,496	0.54	1,072	1.15	1310	1.42
Riggers (Hours)	980	2.45	2,472	1.19	4496	2.87	4,762	1.73	1,624	1.74	2056	2.23
Electrical Technician (Hours)	0	0.00	292	0.12	0	0.00	0	0.00	160	0.09	0	0.00
Survey and Alignment (Hours)	1,036	*1.30*	0	0.00	0	0.00	0	0.00	320	0.17	0	0.00
Total	2,436	**3.05**	4,294	**1.80**	6,572	**1.74**	6,258	**1.95**	3,176	**1.70**	3366	**0.88**
Resources in Sub-systems WBS	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Lead Technician (Hours)	0	0	0	0	0	0.00	4640	1.44	0	0.00	0	0.00
Mech Technicians (Hours)	0	0	6254	2.62	3,532	0.94	5600	1.74	0	0.00	0	0.00
Elec Technicians (Hours)	0	0	0	0	1,800	0.48	0	0.00	0	0.00	0	0.00
Engineer oversight (Hours)	0	0	468	0.20	1,086	0.29	2460	0.76	933	0.50	2326	0.61
Welder (Hours)	0	0	0	0.00	0	0.00	800	0.25	0	0.00	2197	0.58
Cryogenics Technicians (Hours)	0	0	0	0.00	0	0.00	0	0.00	0	0.00	**1,604**	0.42
Total Hours	0	0	6,722	**2.82**	6,418	**1.70**	13,500	**4.20**	933	**0.50**	6,127	**1.61**
Grand Total on Project			**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Hours Estimate	2,436	**3.05**	11,016	**4.62**	12,990	**3.44**	19,758	**6.14**	4,109	**2.19**	9,493	**2.49**
In-Kind Contribution			**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Grad Student	0	0.00	0	0.00	7,264	1.92	0	0.00	0	0.00	0	0.00
Physicist	0	0.00	0	0.00	3,632	0.96	0	0.00	0	0.00	0	0.00
Total Hours	0	**0.00**	*320*	0.13	10,896	**2.89**	0	0.00	0	0.00	0	0.00

- There are about 25,000 hours of rigging captured in the I&I WBS
- That averages close to 4.5 riggers a day (over 3 years and 2 months)
- Cavern outfitting activities requires 3 riggers in average
- **TMS, LArTPC, Cryostat and PRISM activities require about 2 riggers in average**
- **Cryogenics require one rigger in average**

Assembly resources

	Cavern outfiting		TMS		NDLarTPC		LAr Cryostat		PRISM		Cryogenics	
Overall Duration (Days)	**100**		**298**		**472**		**402**		**234**		**477**	
Rigging Duration (Days)	**50**		**259**		**196**		**344**		**117**		**115.5**	
Rigging Duration (Days)	**50%**		**87%**		**42%**		**86%**		**50%**		**24%**	
Resources in I&I WBS	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Lead Rigger (Hours)	420	1.05	1,530	0.74	2,076	1.32	1,496	0.54	1,072	1.15	1310	1.42
Riggers (Hours)	980	2.45	2,472	1.19	4496	2.87	4,762	1.73	1,624	1.74	2056	2.23
Electrical Technician (Hours)	0	0.00	292	0.12	0	0.00	0	0.00	160	0.09	0	0.00
Survey and Alignment (Hours)	1,036	*1.30*	0	0.00	0	0.00	0	0.00	320	0.17	0	0.00
Total	2,436	**3.05**	4,294	**1.80**	6,572	**1.74**	6,258	**1.95**	3,176	**1.70**	3366	**0.88**
Resources in Sub-systems WBS	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Lead Technician (Hours)	0	0	0	0	0	0.00	4640	1.44	0	0.00	0	0.00
Mech Technicians (Hours)	0	0	6254	2.62	3,532	0.94	5600	1.74	0	0.00	0	0.00
Elec Technicians (Hours)	0	0	0	0	1,800	0.48	0	0.00	0	0.00	0	0.00
Engineer oversight (Hours)	0	0	468	0.20	1,086	0.29	2460	0.76	933	0.50	2326	0.61
Welder (Hours)	0	0	0	0.00	0	0.00	800	0.25	0	0.00	2197	0.58
Cryogenics Technicians (Hours)	0	0	0	0.00	0	0.00	0	0.00	0	0.00	**1,604**	0.42
Total Hours	0	0	6,722	**2.82**	6,418	**1.70**	13,500	**4.20**	933	**0.50**	6,127	**1.61**
Grand Total on Project			**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Hours Estimate	2,436	**3.05**	11,016	**4.62**	12,990	**3.44**	19,758	**6.14**	4,109	**2.19**	9,493	**2.49**
In-Kind Contribution			**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Grad Student	0	0.00	0	0.00	7,264	1.92	0	0.00	0	0.00	0	0.00
Physicist	0	0.00	0	0.00	3,632	0.96	0	0.00	0	0.00	0	0.00
Total Hours	0	**0.00**	*320*	0.13	10,896	**2.89**	0	0.00	0	0.00	0	0.00

- There are about 35,000 hours to perform assembly and installation
- That averages to 6 staff members a day (while we will perform 3 activities in parallel)
- Aout 20% of this staff is engineering oversight
- **Cryostat requires 4 staff members**
- **TMS requires 3 staff members**
- **TPC and cryogenics require less than 2 staff members**

Total on project

Charge - R1, R2

	Cavern outfiting		TMS		NDLarTPC		LAr Cryostat		PRISM		Cryogenics	
Overall Duration (Days)	**100**		**298**		**472**		**402**		**234**		**477**	
Rigging Duration (Days)	**50**		**259**		**196**		**344**		**117**		**115.5**	
Rigging Duration (Days)	**50%**		**87%**		**42%**		**86%**		**50%**		**24%**	
Resources in I&I WBS	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Lead Rigger (Hours)	420	1.05	1,530	0.74	2,076	1.32	1,496	0.54	1,072	1.15	1310	1.42
Riggers (Hours)	980	2.45	2,472	1.19	4496	2.87	4,762	1.73	1,624	1.74	2056	2.23
Electrical Technician (Hours)	0	0.00	292	0.12	0	0.00	0	0.00	160	0.09	0	0.00
Survey and Alignment (Hours)	1,036	*1.30*	0	0.00	0	0.00	0	0.00	320	0.17	0	0.00
Total	2,436	**3.05**	4,294	**1.80**	6,572	**1.74**	6,258	**1.95**	3,176	**1.70**	3366	**0.88**
Resources in Sub-systems WBS	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Lead Technician (Hours)	0	0	0	0	0	0.00	4640	1.44	0	0.00	0	0.00
Mech Technicians (Hours)	0	0	6254	2.62	3,532	0.94	5600	1.74	0	0.00	0	0.00
Elec Technicians (Hours)	0	0	0	0	1,800	0.48	0	0.00	0	0.00	0	0.00
Engineer oversight (Hours)	0	0	468	0.20	1,086	0.29	2460	0.76	933	0.50	2326	0.61
Welder (Hours)	0	0	0	0.00	0	0.00	800	0.25	0	0.00	2197	0.58
Cryogenics Technicians (Hours)	0	0	0	0.00	0	0.00	0	0.00	0	0.00	**1,604**	0.42
Total Hours	0	0	6,722	**2.82**	6,418	**1.70**	13,500	**4.20**	933	**0.50**	6,127	**1.61**
Grand Total on Project			**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Hours Estimate	2,436	**3.05**	11,016	**4.62**	12,990	**3.44**	19,758	**6.14**	4,109	**2.19**	9,493	**2.49**
In-Kind Contribution			**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**	**Hours**	**FTE**
Grad Student	0	0.00	0	0.00	7,264	1.92	0	0.00	0	0.00	0	0.00
Physicist	0	0.00	0	0.00	3,632	0.96	0	0.00	0	0.00	0	0.00
Total Hours	0	**0.00**	*320*	0.13	10,896	**2.89**	0	0.00	0	0.00	0	0.00

- 25,000 hours of rigging + 35,000 hours of assembly = 60,000 hours on project
- That is 4 Riggers + 6 Staff member for assembly ~ 10 people on project (for 3 parallel activities)
- There are also 4 FTE at level of effort in I&I Coordination (upcoming presentation)
- So grand total 14 people in average in I&I on project
- That doesn't account for external contractors (GTT, Cryo, EE)
- That doesn't account for in kind contributions (only BD LAr has uncosted contributions captured in P6)
- Expected total occupancy about 25 people average, 35 peak (Capacity 42, for cavern alone)

Resources

SME comments:

- What is the beamline schedule? Will we be competing for resources? Do we need to hire external contractors?
  - Augment the FNAL rigging team with external contractors, managed by FNAL riggers as task supervisors.
  - FNAL employees would need to get certain certifications to serve as task supervisors, but it should be manageable with enough lead time.

- Minos Example:
  - Shaft crane operation was controlled by external contractors.
  - FNAL rigging team took charge at the bottom of the shaft
  - No real reason for this, either arrangement could work

- Not feasible for ND alone to occupy all 4 FNAL riggers for the entire installation duration.
  - Almost certainly need to supplement FNAL team with external contractors.
  - Cost for contract employees is not much different from internal employees.
  - Outside contractor teams are usually scheduled 5 at a time. FNAL personnel can be scheduled in smaller teams.
  - With proper lift plans, mechanical technicians may be capable of handling many lifts.

Resources

SME comments:

- Alignment and survey team will never show up in groups less than 3, usually 3-5.
- Welders are also in high demand at FNAL, need to be scheduled in advance like riggers
  - Can negotiate dedicated welders for long periods with FNAL weld shop.
- Work Schedules
  - 4-10s: Alignment and FNAL riggers
  - 5-8s: Neutrino division mech techs
- Floor Managers:
  - one needed at cavern and surface,
  - manages organization of installation activities and spaces
  - reports to installation coordinator
- FTE around 0.80+ should likely be set to 1
- IMPACT - FNAL work planning tool, may have been replaced by ‘28.
- Combine Installation coordinator and CAM roles?
- Move M&S for “Additional rigging trade labor” as a risk.

Job Codes

Resources in I&I WBS	
Lead Rigger (Hours)	c_FNn_MECH_TECH_SPVSR Mechanical Technician Supervisor
Riggers (Hours)	c_FNd_MECH_ASMBY_TECH Mechanical Assembly Technician
Electrical Technician (Hours)	c_FNd_ELEC_TECH Electrical Technician
Survey and Alignment (Hours)	c_FNd_METROLOGIST Metrologist

Resources in Sub-systems WBS	
Lead Technician (Hours)	c_FNd_MECH_TASK_MNGR Mechanical Task Manager
Mech Technicians (Hours)	c_FNd_MECH_ASMBY_TECH Mechanical Assembly Technician
Elec Technicians (Hours)	c_FNd_ELEC_TECH Electrical Technician
Engineer oversight (Hours)	LBN_FNLB_P_MECH_ENG Mechanical Engineer - LBNL*
Welder (Hours)	c_FNd_WELDER Welder
Cryogenics Technicians (Hours)	c_FNd_CRYO_TECH_SR Cryogenics Technician Sr (also use FNd_)

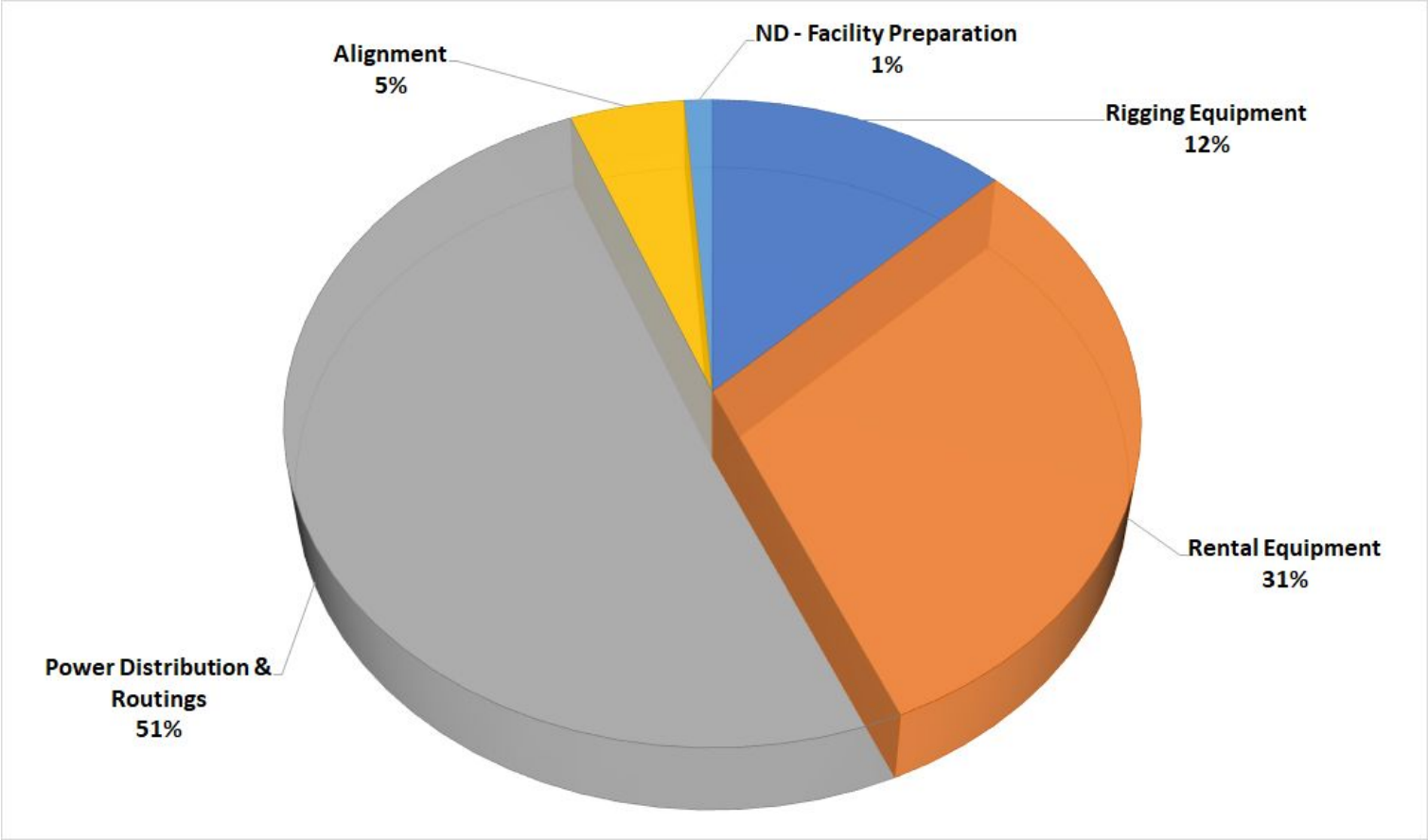
Other engineer oversight resource codes used accross subsystems
LBN_FNLB_P_MECH_ENG Mechanical Engineer - LBNL (LAr)
LBN_FNLWP_MCH_SR Mechanical Engineer Sr - LBNL (Cryostat)
LBN_FNSL_P_MECH_DES Mechanical Designer - SLAC (PRISM)
LBN_FNSL_P_MECH_ENG Mechanical Engineer - SLAC (PRISM)
LBN_FNSBP_MECH_ENG Mechanical Engineer Stony Brook (PRISM)
c_FNd_CRYO_SR Cryogenics Engineer Sr (Cryo)
c_FNd_MECH_DESIGN_EN Mechanical Design Engineer (Cryo)

In-Kind Contribution	
Grad Student	LBN_FNTA_U_GRAD_STDN_EN Grad Student (Engineer) Uncosted - University of Texas/Arlington
Physicist	LBN_FNTA_U_PHYST Physicist Uncosted - University of Texas/Arlington

Equipment

Infrastructure and installation equipment breakdown

	Total, Burdened
Infrastructure and Instal. Equipment	$ 3,762,684
Rigging Equipment	$ 471,790
Rental Equipment	$ 1,162,606
Power Distribution & Routings	$ 1,905,441
Alignment	$ 178,827
ND - Facility Preparation	$ 44,020



BOE P6 data

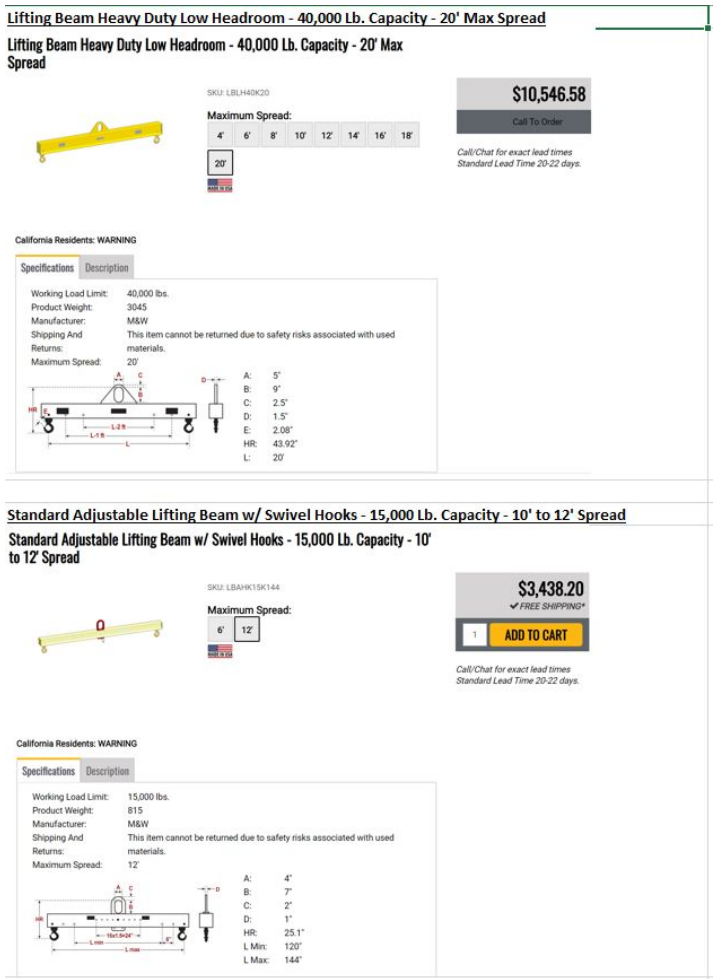
Charge - R3

WBS	Activity ID	Activity Name	Duration	Contingency Rule	Estimate Uncertainty %	Budget/Objective	Hours	Direct Cost - M&S Only	Fully Burdened Costs	Link to Supporting document (mandatory)
131.ND.09.02.01 Rigging Equipment							**300**	**356,776**	**471,790**	Link Here
	A10330	Procure & Store the lifting fixtures	249	M5	50%	Budget		230,841	281,726	
	A10360	Procure & Store Misc Tooling	249	M5	50%	Budget		30,575	37,315	
	A10350	Put Lifting fixtures in service	60	L5	50%	Budget	240		27,358	
	A10370	Put Misc Tooling in Service	30	L5	50%	Budget	60		6,771	
	A10380	Additional Rigging Trade Labor	205	M5	50%	Budget		95,360	118,621	
131.ND.09.02.02 Rental Equipment							**660**	**869,310**	**1,162,606**	Link Here
	A10400	Setup Shaft Mobile Crane (for SAND and Cryostat components)	60	L5	50%	Budget	120		13,679	
				L5	50%	Budget	60		11,574	
				M5	50%	Budget		480,000	591,427	
	A10420	Setup Cavern Lifting Equipment Rentals	30	L5	50%	Budget	240		27,083	
				L5	50%	Budget	240		40,738	
				M5	50%	Budget		347,148	425,043	
	A10430	Allowance for portable toilets	539	M5	50%	Budget		42,162	53,062	
131.ND.09.02.03 Power Distribution & Routings							**100**	**1,547,376**	**1,905,441**	Link Here
	A10440	Procure unistruts and cable tray systems	249	M5	50%	Budget		368,009	449,130	
	A10680	Procure power distribution systems	249	M5	50%	Budget		1,179,367	1,439,337	
	A10450	Install unistruts and cable tray systems	30	L5	50%	Budget	60		10,184	
	A10690	Install power distribution systems - Oversight	30	L5	50%	Budget	40		6,790	
131.ND.09.02.04 Alignment							**1,036**		**178,827**	
	13142.A36880	Install & Measure Control Network in LBNF Near Detector Hall	10	L5	50%	Budget	240		37,708	
	13142.A36890	Calculate Near Detector Hall Control Network & Incorporate into Alignment Dat	20	L5	50%	Budget	80		21,309	
	13142.A36950	Near Detector - Final Alignment	30	L5	50%	Budget	716		119,810	
131.ND.09.02.05 ND - Facility Preparation							**380**		**44,020**	
	13142.A1434	Storage And Laydown Space Preparation	20	L5	50%	Budget	40		4,514	
				L5	50%	Budget	320		36,111	
				L5	35%	Budget	20		3,395	

Rigging Equipment

Charge - R3

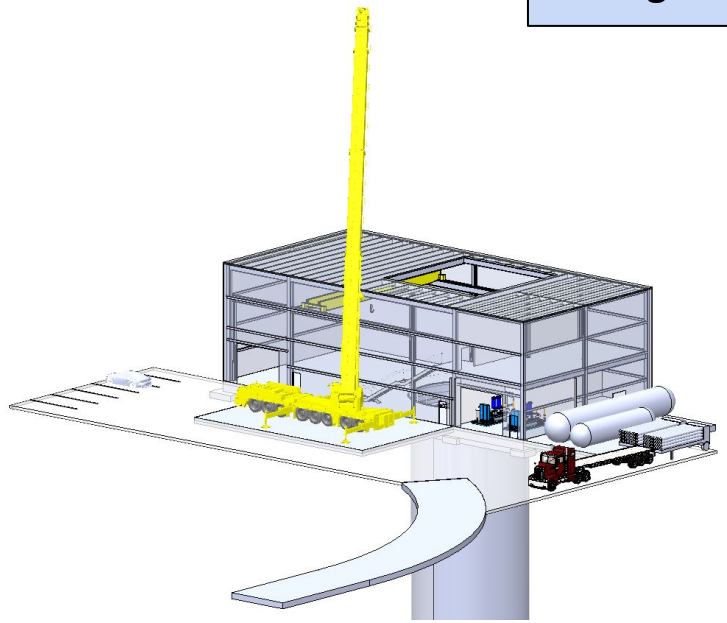
Component number / Component cost	Unit Cost	Qty	Numbers/cost	Links
LIFTING FIXTURES				
Spreader Beam Adjustable - 80,000 Lb. Capacity - 14' - 20' Spread	$ 8,386	0	$ -	
Lifting Beam Heavy Duty Low Headroom - 40,000 Lb. Capacity - 20' Max Spread	$ 10,547	2	$ 21,094	Quote
Standard Adjustable Lifting Beam w/ Swivel Hooks - 15,000 Lb. Capacity - 10' to 12' Spread	$ 3,438	2	$ 6,876	Quote
Lifting Slings	$ 1,095	16	$ 17,520	Quote
Lifting Shackles	$ 469	24	$ 11,256	Quote
High Load Chain Hoist for Load Leveling	$ 15,486	2	$ 30,972	Quote
Regular Chain Hoist for Load Leveling	$ 4,784	2	$ 9,568	Quote
Adjustable Beam Lifting Clamps	$ 6,116	4	$ 24,464	Quote
25-ton Beam Clamp	$ 4,411	4	$ 17,644	Quote
Pipe Lifting Clamp	$ 661	4	$ 2,644	Quote
Miscellaneous Supplies (Corner Protectors, Bolts, etc.)	$ 20,000	1	$ 20,000	
Heavy Duty Telescoping Spreader Beam 20139 100000 Lb. Capacity 14'-20'	$ 11,611	1	$ 11,611	Quote
Lifting Slings-62.5 US ton Cap. 12ft	$ 2,474	6	$ 14,844	Quote
Lifting Shackles- 85 US ton	$ 806	12	$ 9,672	Quote
Leg Chain Sling w/ 2Grab Hooks- 30.5 US ton Cap.	$ 1,391	6	$ 8,346	Quote
Measurement Equip.	$ 10,000	1	$ 10,000	
Load Cell-110 US Ton, w/ Radiolink	$ 14,330	1	$ 14,330	Quote
MISCELLANEOUS				
Hardware and Tooling	$ 30,575	1	$ 30,575	
Vendor Labor or Fabrication Labor Total Cost				
Additional Rigging Trade Labor	$ 149	640	$ 95,360	
Total			**$ 356,776**	



Rental Equipment

Charge - R3

Rental Equipment Component number / Component cost	Unit Cost	Qty	Numbers/cost	Links
SHAFT MOBILE CRANE RENTAL				
Shaft Mobile Crane Rental	$ 1,000	480	$ 480,000	Quote
Cavern Equipment Rental				
Scissor Lift	$ 1,775	18	$ 31,950	Quote
Telescopic Boom Lift	$ 8,136	18	$ 146,448	Quote
Carry Deck Crane	$ 5,650	18	$ 101,700	Quote
Fork Lift	$ 3,725	18	$ 67,050	Quote
Allowance for Portable Toilets				
Allowance for Portable Toilets			$ 42,162	
Total			**$ 869,310**	



Note:

- No gasoline in the cavern.
- Electric is preferred.
- Diesel is possible, but the 10 CRF 851 ACGIH limits for Nitrogen Dioxide (NO2) is pretty tight at 0.2 ppm TWA (it used to be 3ppm). This has caused problems at the far site, and we'll have to have a well thought out plan for it. I believe that we can achieve it at the near site. We'll have less space to ventilate and likely less equipment underground, but it will be a topic that might draw more inspection.

Equipment

SME comments:

- Some equipment may be available at FNAL:
  - Spreader beams may be available - depending on capacities
  - Slings are “consumables” that wear out over time, we should plan to buy all new ones, perhaps re-buy over the course of the project.
- Lifting equipment needs to be load tested for critical lifts.
  - Almost every lift for ND will be a critical lift.
  - “Critical Lift” framework is somewhat new, so experience on how to operate under this framework is slim.
- Counterbalances lifting beam used on Icarus
- 50A limits on lithium batteries (may require lead-acid batteries?)
- Revisit the requirements for fork trucks. Maybe we can borrow them for shorter durations.
  - Identify in the installation plan what individual steps require each piece of equipment.
  - Scissor lifts and boom lifts are becoming preferable to ladder usage

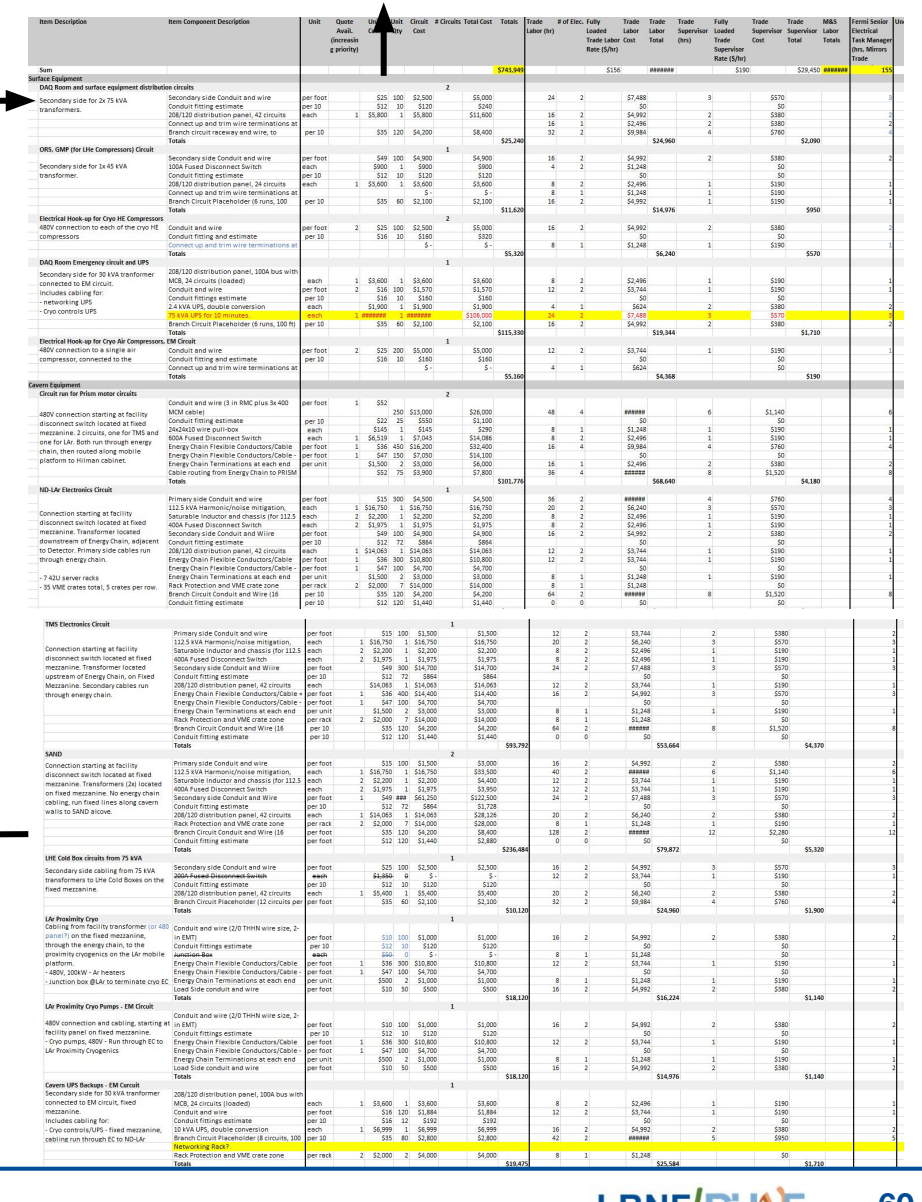
Power Distribution & Routings

Charge - R3

Power Distribution and Routings Component number / Component cost	Unit Cost	Qty	Numbers/cost	Links
Power Distribution Systems				
Power Distribution Hardware			$ 743,949	Quote
Power Distribution Trade Labor			$ 440,666	Quote
Unistrut and Cable Tray Systems				
Data Cable Routing	$ 96,222	1	$ 96,222	
Unistrut	$ 121	300	$ 36,300	Quote
Unistrut Hardware	$ 49	200	$ 9,800	Quote
Unistrut Mount Bolts	$ 23	500	$ 11,500	Quote
Unistrut Connectors (Typical)	$ 24	300	$ 7,200	Quote
Unistrut Post Base (Typical)	$ 57	200	$ 11,400	Quote
Unistrut Conduit/Pipe Clamp (SS, Typical)	$ 35	400	$ 14,000	Quote
Unistrut Channel Beam Clamps	$ 15	200	$ 3,000	Quote
Unistrut Channel Angle Bracket	$ 7	200	$ 1,400	Quote
Brackets and Unistrut Installation Trade Labor	$ 129,600	1	$ 129,600	
Miscellaneous Tooling	$ 47,587	1	$ 47,587	
Total			$ 1,552,624	

Unit Qty	Circuit Cost	# Circuits	Total Cost	Totals
				$743,949

Item Description	Item Component Description	Unit	Quote Avail. (increasing priority)	Unit Cost	Unit Qty	Circuit Cost	# Circuits	Total Cost	Totals
			Equipment Estimate						
ND-LAr Electronics Circuit							1		
Connection starting at facility disconnect switch located at fixed mezzanine. Transformer located downstream of Energy Chain, adjacent to Detector. Primary side cables run through energy chain. - 7 42U server racks - 35 VME crates total, 5 crates per row.	Primary side Conduit and wire	per foot		$15	300	$4,500		$4,500	
	112.5 kVA Harmonic/noise mitigation, shielded	each	1	$16,750	1	$16,750		$16,750	
	Saturable Inductor and chassis (for 112.5 kVA	each	2	$2,200	1	$2,200		$2,200	
	400A Fused Disconnect Switch	each	2	$1,975	1	$1,975		$1,975	
	Secondary side Conduit and Wiire	per foot		$49	100	$4,900		$4,900	
	Conduit fitting estimate	per 10		$12	72	$864		$864	
	208/120 distribution panel, 42 circuits (loaded),	each	1	$14,063	1	$14,063		$14,063	
	Energy Chain Flexible Conductors/Cable	per foot	1	$36	300	$10,800		$10,800	
	Energy Chain Flexible Conductors/Cable -	per foot	1	$47	100	$4,700		$4,700	
	Energy Chain Terminations at each end	per unit		$1,500	2	$3,000		$3,000	
	Rack Protection and VME crate zone protection	per rack	2	$2,000	7	$14,000		$14,000	
	Branch Circuit Conduit and Wire (16 circuits, 75	per 10		$35	120	$4,200		$4,200	
	Conduit fitting estimate	per 10		$12	120	$1,440		$1,440	
	Totals								$83,392



Summary

- We assembled our first bottom up installation estimates in 2021-2022. Our resource loaded schedule has since then been based on bottom-up estimates, and we periodically update it as the design of the detectors matures toward preliminary design.
- In 2023, it became clear we need to rely on PRISM to move the detectors in and out of the crane coverage. We are engineering the support structures and interface elements to enable this installation sequence. In the past few months, we have worked with subsystems on updating the installation sequence and the logic in P6 to reflect this approach.
- The planned duration of the ND installation is 3 years and 2 months. We'll transition to operation after completion of (i) The gas pressure test of the Cryostat (ii) The warm checks of the 5 TPC module rows installed into the cryostat (iii) Final check of 100 TMS layers and the 2 magnets (iv) Final check of PRISM (v) Installation verification of the Cryogenics infrastructure (step by step pressure test, valve check, etc…)
- The high level summary of resources on project, in average is: 4 FTE for coordination/management, 4 FTE for riggers, 6 FTE for assembly
- Cryostat requires 2 Riggers + 4 Tech, TMS requires 2 Riggers + 3 Tech, LAr requires 2 Riggers + 2 Tech
- Equipment estimates include rigging equipment (~$350k direct) and rental equipment (~350k direct). Additional budget for external crane is being removed.

Action Items

- Revisit surface building crane capacity **[Infrastructure]**
  - List of Lifts, include uncertainty
  - Produce a justification for a potential BCR
- Revisit cavern crane coverage of shaft centerline **[Infrastructure]**
- Check whether we need an auxiliary (higher speed) crane in the cavern? **[Infrastructure]**
- Revisit bathroom budget, and include standard porta potties underground **[Infrastructure]**
- Verify TMS power supply size, location and cooling needs **[Infrastructure]**
- Barrier in surface to protect TPCs from trucks. **[Infrastructure]**

- Define safety perimeter around the shaft **[Safety]**
- Gather and summarize information on work permits process, IMPACT - FNAL work planning tool **[Safety]**

Action Items

- Send list of lifting fixtures to Dave Pushka to check what items are available at FNAL **[Equipment]**
- Consider a gantry for TMS **[Equipment]**

- Further develop electrical installation activities **[Installation]**
  - Plan for the time required to get the electricians
  - Plan for the time required to get the inspections
  - Get electrical work and inspections out of critical paths everywhere possible

- Test the full length of the rails **[Testing]**

Action Items

- Adjust roles definitions and FTEs for level of effort **[Resources]**
- Meet with Tom Wicks for additional guidance on rigging team organization **[Resources]**
- Keep communicating with FermiLab operations on the total FTE required **[Resources]**
  - We likely need to hire a team of riggers for the entire duration of the ND installation
  - We should consider hiring an electrician for the entire duration of the ND installation
  - We need to refine plans for survey and alignment
  - We'll need to communicate welder needs
  - We will need Task Managers (TMC Job Code) qualified as Construction Coordinator to oversee all this external labour