LBNF/DUNE Cryogenics

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LBNC Review

18-21 February 2018

Thanks to

- Mark Adamowski.
- Johan Bremer.
- Michel Chalifour.
- Joaquim Creus Prats.
- Marzio Nessi.
- Stephen Pordes.

Outline

- LBNC Recommendation 2.1.
- Agenda items.
- DOR IPR Recommendations
- Summary.

LBNC Recommendation 2.1

- **R:** Ensure that the cryogenics performance testing is given priority on ProtoDUNE and sufficient attention to collect data, baseline simulations, and iterate as needed.
- ***A:*** *We believe that we have adequately addressed the recommendation by providing:*
  - *Detailed commissioning plan for the cryogenic system (as it will be performed by the manufacturer before delivery and after installation).*
  - *Commissioning plan for the cryostat + cryogenics + detector inclusive of GAr purge, cool-down, filling, steady state operations (LAr purification, GAr boil-off recondensation and purification).*
  - *DUNE has installed a comprehensive set of temperature monitors including two gradient monitors (one fixed and one movable) to measure the temperature inside the cryostat at the few mK level. This will help validate the CFD simulations of the motion of the LAr inside the cryostat.*
- **Status:** Closed (Feb 5, 2018).

Agenda item 1

- **Q:** Provide an update on the development of plans for pressure testing the far site cryostats.
- **A:** *Work in progress. Changes in LBNF Cryo-safety panel leadership.*
  - New leadership (Chair and Deputy) visited CERN end of Jan 2018 and met with CERN Neutrino Platform leadership and engineers.
  - Looking at all documentation that was provided to understand the feasibility of the proposed test plan within the Lab ES&H policy.
  - Goal is to prepare a risk analysis of the proposed test plan and make a determination soon.
  - No further updates.

Agenda item 2 – Intro

- **Q:** Provide a plan for testing of cryogenics during the commissioning of ProtoDUNE as previously recommended.
- **A:** *Quality Plan from Demaco (manufacturer of the Proximity Cryogenics): https://edms.cern.ch/document/1900702/1. Highlights in next slides.*
- **Specs:**
  - EN13445 & EN13480.
  - PED (2014/68/EU).
  - Design P: 10 bara.
  - Design T: 77-300 K (all cryo but regen) and 500 K (regen).
- **Additional testing:**
  - Warm piping testing (Pressure test + He leak check).
  - Controls test.
  - Synchronization.

Agenda item 2 – Highlights 1/2

- **Testing during fabrication** (at Demaco):
  - Welds (piping & vessels)→ Visual, X-ray, dye penetrant.
  - Assembly → He leak check, Pressure test, Vacuum retention test.
  - Instruments test → Valves, heaters, P/T sensors
  - PSVs → Set pressure.
  - Bellows → He leak check.
  - Electrical breaks → Cold cycles, Pressure test, He leak check, electrical resistance (by CERN).
- **Final Inspection** (at Demaco):
  - Documentation.
  - SEP statement.
  - CE Declaration of Conformity.
  - CE marking.
- **Factory Acceptance Test** (at Demaco before shipping):
  - Dimensional check.
  - Pressure test.
  - Helium leak check.
  - PSVs pressure setting check.

Agenda item 2 – Highlights 2/2

- Testing during Installation (at CERN):
  - Incoming inspection.
  - Hydraulic continuity.
  - Vacuum.
- On Site Acceptance Test (Warm Acceptance Test):
  - Purge & Flush system.
  - Pressure Test.
  - Helium leak check.
- On Site Acceptance Test (Cold Acceptance Test):
  - All interfaces installed and ready.
  - Cold test with LN2.
  - Helium leak check.

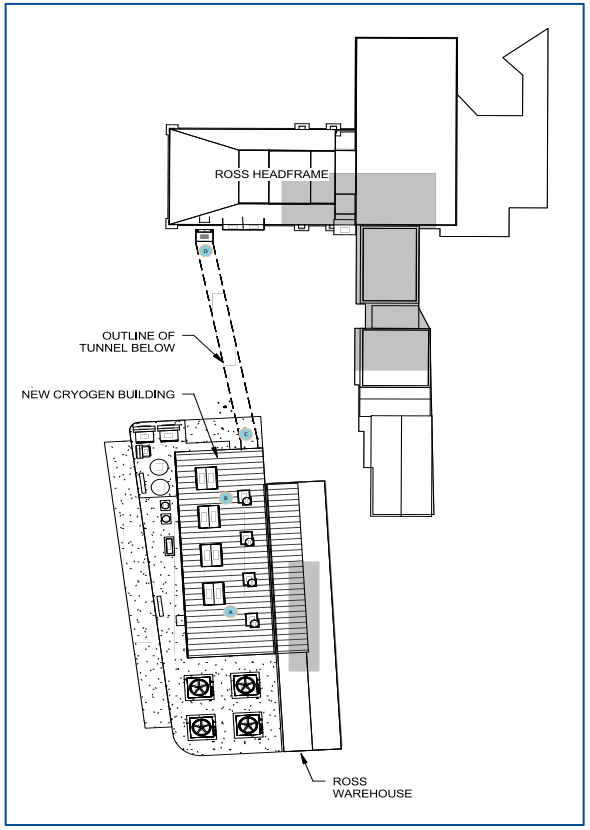
DOE IPR Recommendation 9

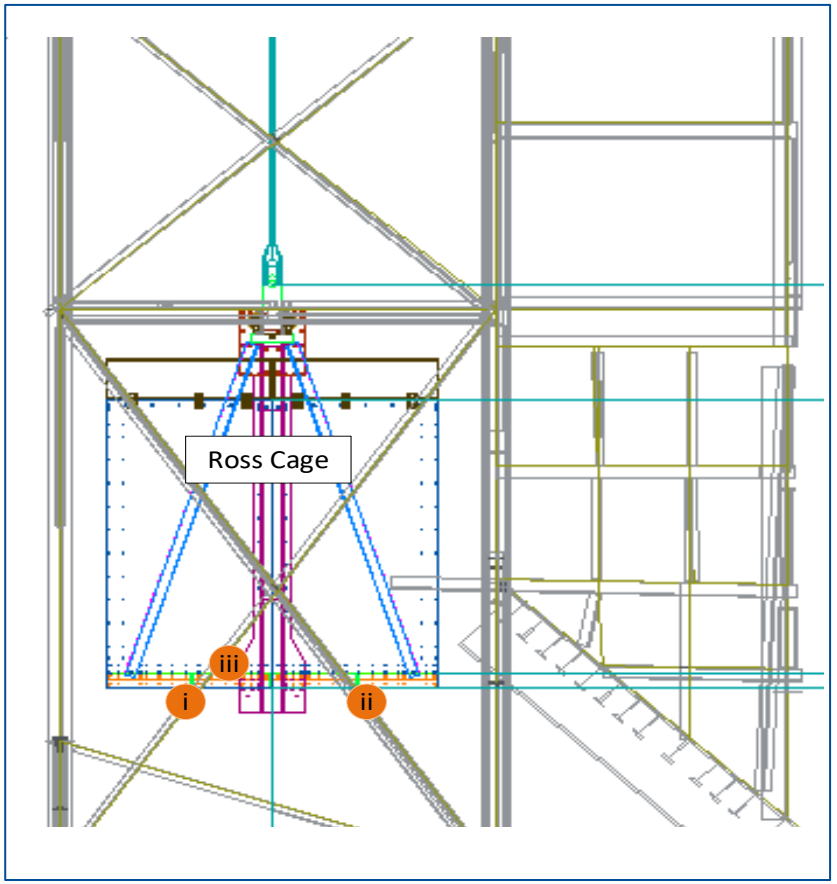
- **R:** Commit additional resources either within or interfacing with the cryogenic team to address areas such as system integration, controls and commissioning six to twelve months prior to CD-2.
- ***A:*** *We acknowledge the need to augment the staff to address areas that now require more attention, like cryogenics systems integration. We are working on a plan to identify these resources and add them in a timely fashion. LBNF/DUNE Integration is done at the Project Office level, with a group led by Jack F. One of them will be a designer shared with Systems Engineering.*
- **Status:** Open.

DOE IPR Recommendation 10

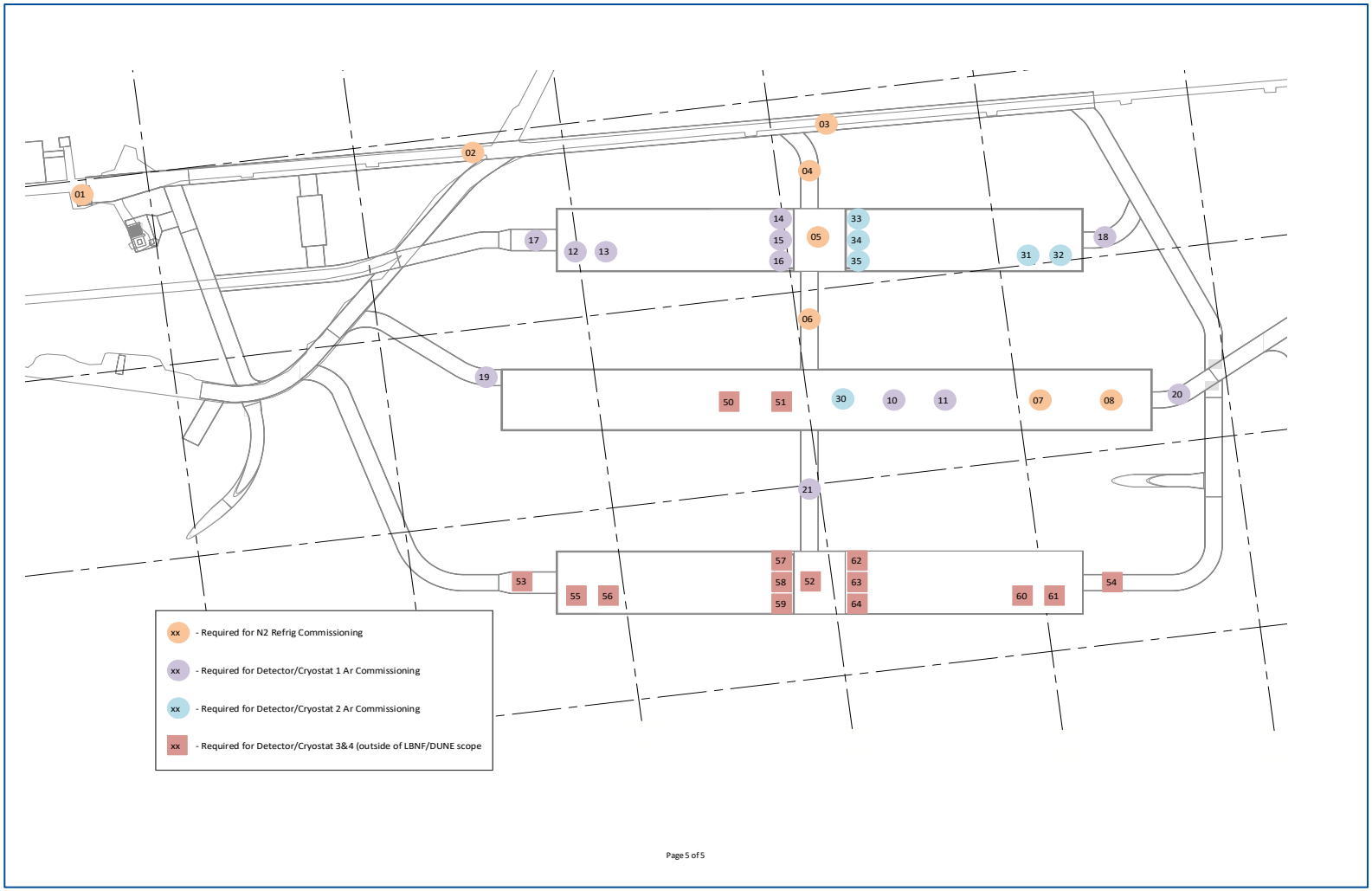
- **R:** Review and ensure all elements of the DOE scope are contained within the WBS (such as ODH system, cryogenic controls, system integration, commissioning of integrated system) by the next SOE/SC review.
- ***A:*** *The ODH system was identified as missing scope. We have prepared a map of ODH heads/control boxes, tabulated wiring and programming and included the resources needed for the implementation. Details in next slides. We will do a Change Request after DOE OPR (schedule is already frozen) to add it to RLS.*
- **Status:** Open (working towards resolution).

DOE IPR Recommendation 10 – ODH Sensors/Control Boxes Above Ground and Ross Cage





DOE IPR Recommendation 10 – ODH Sensors/Control Boxes Underground



DOE IPR Recommendation 10 – ODH Info 1/2

- Surface/Cavern productivity factors for working at SURF (from Jacobs).
- Route complexity factors (from LBNF Cryo).
- 8 Man-hr to pull 50 feet of cable (from TD Cryo Sector).
- 16 Man-hr to install/program chassis (from TD Cryo Sector).
- Derived:
  - Surface/Cavern cable pulling factors.
  - Surface/Cavern control boxes installation and programming factors.

DOE IPR Recommendation 10 – ODH Info 2/2

Estimate of LBNF/DUNE ODH Monitoring System

Estimator: Mark Adamowski
Date: Jan 24, 2018
Scope: Analysis covers only Cryogenics systems for Detectors #1 and #2.
References: Cost/Schedule information from Fermilab Technical Division/Cryo Sector.
LBNF Cryogenics Cost and Schedule report (Jacobs, 2015).
Engineering judgement.

ODH Sensor	Count	ODH control box	Location	Must be active before	notes	est of wiring distance	route complexity factor	pull cable man-hrs	control box man-hrs
A	1	1	Compressor Building	ROSS/4850 GN2 commission		100	1	33.55	33.55
B	1	0	Compressor Building	ROSS/4850 GN2 commission		100	1	33.55	0.00
C	1	0	utlility tunnel comp bldg to Ross shaft	ROSS/4850 GN2 commission		100	1	33.55	0.00
D	1	0	utlility tunnel comp bldg to Ross shaft	ROSS/4850 GN2 commission		100	1	33.55	0.00
i	1	1	Ross cage	ROSS/4850 GN2 commission	self contained O2 monitoring / alm	30	2	20.13	33.55
ii	1	0	Ross cage	ROSS/4850 GN2 commission	travels with cage	30	2	20.13	0.00
iii	1	0	Ross cage	ROSS/4850 GN2 commission		30	2	20.13	0.00
01	1	1	Ross shaft 4850L	ROSS/4850 GN2 commission		800	1	268.40	33.55
02	1	1	Governors corner, West drift	ROSS/4850 GN2 commission		400	1	134.20	33.55
03	1	0	Drift past branch drift to cavern 1 center	ROSS/4850 GN2 commission	positioned in downstream ventilation flow after GN2 pipe turns into branch drift	100	1	33.55	0.00
04	1	0	branch drift to cavern 1 center	ROSS/4850 GN2 commission		100	1	33.55	0.00
05	1	1	on top of rock pillar between detector 1 and 2	ROSS/4850 GN2 commission		100	1	33.55	33.55
06	1	0	drift between cavern 1 center and CUC center	ROSS/4850 GN2 commission		300	1	100.65	0.00
07	1	1	near LN2 refrig units	ROSS/4850 GN2 commission		200	1	67.10	33.55
08	1	0	near LN2 refrig units	ROSS/4850 GN2 commission		200	1	67.10	0.00
10	1	1	CUC near GAr 1&2 purfication	Ar commission for cryostat 1		200	1	67.10	33.55
11	1	0	CUC near LAr 1 purification	Ar commission for cryostat 1		200	1	67.10	0.00
12	1	1	Detector 1 mezzanine	Ar commission for cryostat 1		200	2	134.20	33.55
13	1	0	Detector 1 mezzanine	Ar commission for cryostat 1		200	2	134.20	0.00
14	1	1	Detector 1 floor by pumps	Ar commission for cryostat 1		100	3	100.65	33.55
15	1	0	Detector 1 floor by pumps	Ar commission for cryostat 1		100	3	100.65	0.00
16	1	0	Detector 1 floor by pumps	Ar commission for cryostat 1		100	3	100.65	0.00
17	1	1	Drift at West end of Cavern 1	Ar commission for cryostat 1	monitors West Drift connected to cavern 1	200	1	67.10	33.55
18	1	0	Drift at East end of Cavern 1	Ar commission for cryostat 1	monitors exhaust Drift from Cavern 1	300	1	100.65	0.00
19	1	1	Drift at West end of CUC	Ar commission for cryostat 1	monitors West Drift connected to CUC	300	1	100.65	33.55
20	1	0	Drift at East end of CUC	Ar commission for cryostat 1	monitors exhaust Drift from CUC	400	1	134.20	0.00
21	1	1	Drift between CUC center and cavern 2 center	Ar commission for cryostat 1	monitors South Drift connected to CUC center	200	1	67.10	33.55
30	1	0	CUC near LAr 2 purification			200	1	67.10	0.00
31	1	1	Detector 2 mezzanine			200	2	134.20	33.55
32	1	0	Detector 2 mezzanine			100	2	67.10	0.00
33	1	1	Detector 2 floor by pumps			100	3	100.65	33.55
34	1	0	Detector 2 floor by pumps			100	3	100.65	0.00
35	1	0	Detector 2 floor by pumps			100	3	100.65	0.00
	33	**Total O2 sensor count for LBNF**						**2677.29**	
	$ 49,500	**Est of sensor procurement cost**							
								469.70	
		14	**Total ODH control boxes (for estimating purposes)**						
		$ 70,000	**Est of ODH control box procurement cost**						

Total man-hrs for pulling cable

man-hrs to install/prog ODH control box

Total M&S	**$ 119,500**	
Total Labor	**2677.29**	**man-hrs for pulling cable**
	469.70	**man-hrs to install/prog ODH control box**

Notes:

1) *Added a "Route Complexity Factor" to account for working at different levels and at different elevations in the detector's cavern.*
2) *Surface and cavern productivity factors from Jacobs.*

$120k M&S
2,700 man-hr wiring (techs)
470 man-hr programming (Eng)

Summary

- We believe that we have addressed the review recommendations from the Oct-2017 LBNC meeting and provided an update of the activities covering the proposed agenda items.
- We have a plan to address the recommendations from the 2017 DOE IPR.
- Another contribution will present the current status of the LBNF Cryogenics.

Thanks

Backup

Commissioning Plan (from DUNE Collaboration Meeting)

Commissioning Plan

DEEP UNDERGROUND NEUTRINO EXPERIMENT

Cryo-Instrumentation Commissioning				
		Duration	Specs	Tech Resp
T-Grad Monitors Purity Monitors Slw Ctrl		S: E: Jun 15 (Fri)		pDUNE-SP

CRYOGENICs Commissioning						
Task	**Duration**	**Start/End**	**Specs**	**Tech Resp**	**Shift Resp**	**Monitoring**
GAr Purging	1w + 1w (conting.)	S: Jun 18 (Mon) E: July 1 (Sun)	- 20 Vol/day - leaks checks and repairs	CERN-NP	CERN-NP	
Safety Clearance	1d		All documentation ready	CERN-NP		
Cooling	1 w	S: July 2 (Mon) E: July 8 (Sun)	- 1 K/hr, $\Delta T \approx 200$ K	CERN-NP	CERN-NP	Temp
LAr Filling	3 w + 1 w (conting.)	S: July 9 (Mon) E: Aug 5 (Sun)	- ~**550 kL** - 2 trucks/day into 2x20000 L storage dewars - 40000L/day, 5 days/week	CERN-NP	CERN-NP + ProtoDUNE-SP	Temp T-Gradient LAr Level
LAr Recirc. & Purific.	1w (conting.)	S: Aug 6 (Mon) E: Aug 12 (Sun)	*Goals:* Stable Cryo Cond. $\tau_e \approx 2$ms	CERN-NP pDUNE-SP	ProtoDUNE-SP + CERN-NP	T-Gradient LAr Purity

5 Jan 31, 2018 Flavio Cavanna | *DUNE Collaboration Mtg* Fermilab DUNE