Long Baseline Neutrino Committee

FERMILAB, September 2020

CLOSEOUT Report

September 16, 2020

Acknowledgements

The LBNC has enjoyed examining the advances being made the LBNF project and by the DUNE Collaboration. We were shown construction progress at SURF, analysis results from ProtoDUNE SP and operations in ProtoDUNE DP. Important progress with the Near Detector CDR technology was discussed. The plans for Computing were nicely amplified. We thank DUNE for the clarity of their presentations and discussions.

The committee also thanks Fermilab, its Directorate and support staff, for their support.

LBNC Meeting Charge Draft 9/14/2020

- The LBNC would like to hear about the general status of LBNF. The LBNC understands that there may be progress with the excavation contracts. Of continuing interest are the planning for DOE-IPRs, the current schedule, and any options for early delivery of beam.

- The LBNC would like to hear from DUNE its overall status and progress from a high level, providing a basis for the details which follow. The situation with respect to the IPR process and the approach to a Baseline review appears to be fluid. The LBNC would like to hear how DUNE is approaching this. This should include mention of the ND Day-1 detector.

LBNC Meeting Charge Draft 9/14/2020

- **Time has been allotted for discussions of the advances in the Technical Coordination of DUNE. At the previous meeting there was concern about how TC was handling its multiple responsibilities for construction and R&D. At this stage the incorporation of the Near Detector in the TC should be addressed.**

LBNC Meeting Charge Draft 9/14/2020

- **The LBNC would like to hear about the progress with the Far Detector SP technology. The presentation(s) should cover:**

  a) A summary of the ProtoDUNE SP photon detection situation including results of the Xenon tests should be described.

  b) Physics analysis of the PD-SP data (briefly)

  c) SP technical progress including the TPC electronics development and the progress towards a choice.

  d) Progress in understanding of, and tests, of installation plans and procedures for DUNE.

Substantial time has been reserved for breakout discussions which we suggest could be used for some of these discussions.

LBNC Meeting Charge Draft 9/14/2020

- **ProtoDUNE DP (NP02) has undergone HV surgery and further operations since the previous meeting. These operations are set to end early September, so a discussion of what has been learned is of particular interest. Understanding the ongoing R&D on, for example the LEM construction, continues to be important. This leads towards a plan for a second phase of NP02 operation. In this context the LBNC would like to understand the planning for configuration of NP02 for future tests. We note that in the plenary session in-depth discussion is not possible but that there is substantial breakout time.**

LBNC Meeting Charge Draft 9/14/2020

- **Since the previous meeting DUNE submitted their Conceptual Design Report for the Near Detector complex for review. The LBNC provided, in writing, an extensive critique. After digestion the LBNC ND team met with the DUNE ND team to discuss development of responses and to discuss clarifications. At this stage, the full LBNC would like to hear brief comments on this, on the technical progress, and on the Day-1 Detector. There will then be extensive breakout time which should be shared between these three aspects of the Near Detector planning.**

LBNC Meeting Charge Draft 9/14/2020

- **The LBNC continues to be interested in the development of the Computing Consortium. We continue to be interested in a (more) coherent view of the computing and software project. We would like to see a path toward a TDR, starting maybe with a CDR highlighting where all the pieces fit together.**

  For example, it would be important to understand what are the steps that the DUNE computing consortium is taking toward the definition of the computing system to be used for production, which will eventually be described in the TDR.

  We are also interested in understanding how this coherent vision covers the needs of the various communities FD SP, DP, ProtoDUNE, Near Detector.

  Finally a short update of progress during the past 6 months is desirable.

This is a considerable ask, so we have tentatively suggested a substantial breakout. Failing that the presntation at this meeting should be a precursor to follow-up at subsequent LBNC meetings.

LBNC Meeting Charge Draft 9/14/2020

- **The LBNC will develop a Closeout Report which it will deliver at 12:15 CDT September 16. Subsequently this will be refined into a LBNC Meeting report.**

LBNC Meeting Assignments 3/4/2020

LBNF Status	**Fuerst**, Laxdal, Peterson
DUNE Status	**Saoulidou**, Gray, Kopp, Charlton,
Dual Phase	**Spalding,** Behnke, Galbiati, Kajfasz, Para, Wood
Single Phase	**Pitts**, Fava, Liu, Parsons, Pla-Dalmau
Technical Coordination	**Charlton**, Fuerst, Laxdal, Peterson
Near Detector Status	**Oser**, Behnke, Mondal, Kopp, Saoulidou
Computing	**Campana**, Charlton, Gray

LBNC Meeting Assignments 3/4/2020

Breakouts

Dual Phase	**Spalding**, Galbiati, Kajfasz, Wood,
Single Phase	**Pitts**, Fava, Liu, Parsons,Pla-Dalmau
Near Detector	**Oser**, Behnke, Mondal, Kopp, Saoulidou
Beamline	**Laxdal**, Fuerst, Peterson
Computing	**Campana**, Charlton, Gray

LBNF Status

Findings

- **Reliability projects** - 36M$ in work is on-going, all projects report as on track for completion April 2021 (delayed from Dec 2020 due to COV-19)
- **Pre-excavation construction** - Work is fully underway, expected completion date now April 2021 (from DEC2020) – 75% of work completed – delays due to COV-19 and additional unforeseen work required to rock wall reinforcement in the rock removal system – early excavation drill and blast work is ongoing since June 2020
- **FS Excavation** – reputable contractor identified with name delivered to DOE Aug 10 2020 – IPR for excavation planned for Sep22-24, 2020. The North cavern completion was reported last Dec. as stretching beyond Oct 2022 now both caverns are shown as complete April 2024
- Supporting FSCF redesign to integrate N2 system underground and relocation of DUNE DAQ to detector
- Far site integrated model now at V6
- Far site safety record – 899 days without incident – 1 DART case

LBNF Status

Findings (cont'd)

- **Near site –** site preparation design complete and work underway - 100% preliminary design completed end of March 2020 – final design due Aug. 2021- Site preparation is reported as `on schedule' – moving cooling ponds, re-routing power and access roads due for completion Dec. 2020
  - Analysis of ND-hall crane upgrade from 15 ton to 60 ton is under-way.
  - ND cryogenics – preliminary design review July 2020
- **Nitrogen Refrigeration Equipment acquisition:**
  - The Acquisition Plan for the liquid nitrogen system and auxiliaries (Nitrogen Refrigeration Equipment) is in DOE review now and the RFP is in development. The system will be procured based on vendor design, fabricate and install. Contract awarding required before Sept 2022.
  - Procurement is planned in two phases, with an initial competition based on established criteria to select three most qualified vendors. The second phase then involves a competition across Phase 1 vendors based on evaluation of a completed study. Then a subcontract is awarded to the best-value offeror for the remainder of the engineering work, the manufacture, the installation, and the commissioning of the equipment.
  - FRA selected the phased acquisition strategy as a result of feedback received during an extensive market research and benchmarking effort.

LBNF Status

Findings (cont'd)

- **LBNF strategy:**
  - All previously unassigned scope for FS and NS has now been assigned in preparation for CD-2
  - Project plans to initiate 3A construction after green light from DOE hopefully after Sept 22-24, 2020 review - with completion by Sept 2022 - then request DOE CD-2/3b IPR for baselining in summer timeframe of 2021 (goals: resolve path to second detector, complete PDR for US-ND scope, get to 40% contingency – now 36%)
  - Budgeted and Earned hours for the past 6 months are approximately equal - Actuals hours approximately 10% below earned hours - next few months will require a ramp up of 20% in effort as agreed with FNAL management

LBNF Status

Comments

- LBNF continues to make significant and impressive progress at the far site with, among other deliverables, significant progress on rock conveyance infrastructure
- The slippage in completion of pre-excavation work from Dec 2020 to April 2021 is partly due to COV-19 and was expected – the additional delays concerning required refurbishing to the Rock wall is a reminder that the excavation schedule needs contingency for such unforeseen events
- The presented slides show that the caverns are now scheduled for completion April 2024 (was Oct 2022 for north cavern) – this underscores the importance of launching the excavation contract in April 2021 to prevent any further slippage
- Resource allocations for LBNF seem to be tracking requirements except for slip in March 2020 (probably due to COV-19) but the next months will be challenging as 20% ramp is expected with an additional 10 engineers to join the effort as agreed by FNAL management
- Previous concerns expressed by LBNC, with unassigned scope, have now been dealt with by absorbing those elements in the project – this will reduce cost and schedule risk moving forward towards CD-2

LBNF Status

Comments (cont'd)

- The LBNF management and CMGC should be congratulated on the excellent safety record.
- The liquid nitrogen system will be unique and challenging as a nitrogen refrigeration system condensing Argon in a deep underground location. The Project has developed an acquisition plan for the Nitrogen Refrigeration System which recognizes that challenge and should, following DOE approval and any subsequent modifications, provide a strong framework for managing the procurement.

Recommendations

- none

Beamline

Findings

- **Beamline status:**
  - design presently at a 55% level: final design completed in beam optics**,** preliminary designs completed in key areas (primary vacuum, Horn A, Hadron absorber, hatch covers, Modules, Target hall shielding), five more to go, prototyping in progress
  - international partners: BARC (dipole and quads), RAL (target systems), IHEP (correctors), KEK (stripline/hatch covers) - regular meetings with RAL and BARC in progress
  - baseline shows the beamline/target at early CD-4 by Q4 CY2029 with critical path in Conventional Facilities
  - resources mostly ok but critical design resource is a pulsed power engineer for Horn PS
- **Beamline strategy towards CD2**
  - integrated unallocated international scope now absorbed by project as of April 2020
  - completed re-estimation of all significant fabrication and installation costs
  - updated procurement plans and installation schedule - completing interface definitions - completing resource agreements within FNAL matrix structure
  - 27 design reviews scheduled before CD-2 - IPR scheduled for Jan 2021 - Director’s review Spring 2021 and CD2 Aug 2021

Beamline

Findings

- **Project schedule to first beam:**
  - If cash-flow was not a constraint the project could advance the target area readiness by ~1 year (to Q4 2028) with no change in total project cost. This would require more money over 2023-2025 and critical support from Electrical engineering for pulsed power supply for horn testing - Critical path would move to horn production and not CF

Beamline

Comments

- The beamline/target team continues to make impressive gains with steady and systematic progress and with evidence of good support from FNAL management.
- LBNC thanks the team for exploring how the time to `target ready' can be reduced by optimizing the cash flow. The beamline schedule as presented now shows that there is a 1 year plateau after CD-3 where there is technical and CF design readiness to move ahead but insufficient cash to match. Not only will the addition of cash reduce the timeline to first science but will maintain project momentum with some gain in over-all efficiency. Such a strategy will move the critical path from CF to the technical. A pulsed power engineer has been identified as a critical resource for developing the horn PS and resource sharing with other FNAL projects (PIP-II) needs careful planning but is assessed as solvable.
- The project has a well conceived plan for nailing down loose ends before CD-2 in mid-2021. This includes updated cost and schedule estimates augmented by vendor quotes, establishing resource agreements within FNAL, completing interface definition and many planned technical and project reviews. Previous concerns expressed by LBNC, with unassigned scope, have now been dealt with by absorbing those elements in the project – this will de-risk cost and schedule moving forward towards CD-2

Beamline

Recommendations

- Continue to pursue a modified cash flow to advance the beamline/target schedule

DUNE Status

•The LBNC is pleased to see a continued growth of the collaboration together with information on the level of the contributions expected from new groups. We encourage DUNE to continue and intensify the efforts on this front.

•LBNC is very pleased to see progress being made towards ProtoDUNE II acknowledging its central role on the final characterization of all detector components and sub-systems in “Module 0” form.

•LBNC commends DUNE for the extensive ongoing work on the DP technology. LBNC urges DUNE to revise and update the plan and timeline for resolving remaining issues. Related to this, LBNC would like to better understand how and when decisions on the detector technology for Modules beyond the first one, will be made.

DUNE Status

•LBNC commends DUNE for making progress on defining the “Day 1 ND”. LBNC would like to see further studies for the Temporary Muon Spectrometer, and its ability to achieve the main physics goals of the experiment. LBNC would also like to see SAND design and optimization finalized. In particular LBNC would like to see studies on how a SAND detector helps PRISM achieve its goals, and how different designs have an impact on the final oscillation measurements.

•LBNC commends DUNE for the significant progress made in establishing funding from international institutions.

• LBNC notes that there is progress made on the formation of the ND consortia, and would like to continue to be informed as the consortium structure evolves.

Technical Coordination

• The LBNC thanks DUNE for the Technical Coordination presentation, which included the steps towards ProtoDUNE-II-SP containing “module-0” components, on the road to the Far Detector first module. The committee notes the progress across the SP consortia, and the good functioning of the Review Office.

• The strategy of using ProtoDUNE-II-SP also to progress work on installation and integration, and to test the laser calibration system, are endorsed by the LBNC.

• The experience from ProtoDUNE-I-SP has informed design updates to ProtoDUNE-II-SP. Similar lessons from ProtoDUNE-II-SP may require re-engineering for FD Module-1. Estimated re-engineering time, after completion of ProtoDUNE-II-SP, should be included explicitly in the FD Module-1 schedule.

• Further information was provided about the interaction of TC with different subsystems. The LBNC expects to see a description in the Near Detector CDR of how TC interfaces to, and manages where appropriate, ND design, planning, construction, and installation and integration.

Technical Coordination

• The LBNC is pleased to hear that the staffing levels of TC are in line with current requirements, and would like to see summaries of effort available-vs-required in TC and the consortia on a regular basis.

Recommendation

• Provide updates on the overall schedules for the different parts of the project (FD SP, ProtoDUNE-II, ND …) regularly at future meetings.

Dual Phase

Findings-1

- ProtoDUNE-DP operation has ended and the removal of the LAr has started. It is expected that access to the DP detector will be possible by mid-November.
- On June 17 an intervention to repair a short between the HV extender and the field cage was carried out using special tooling and procedures. This required draining ⅓ of the LAr which was then replenished using the liquid from ProtoDUNE-SP.
- A declogging of the recirculation filter was required in early July.
- Good purity was achieved, growing to >15ms e-drift lifetime by the end of operation.
- In commissioning the HV system, a flashover between the surgically disconnected field cage rings and adjacent rings resulted in ~3 sparks per minute. In addition a filter resistor in the circuit failed resulting in unstable current draw. This limited HV operation to approximately 120 kV with unstable sparking and field.
- The upper ⅓ of the cryostat was exposed to air during the HV surgery, and after filling, bubbling and surface ripples were significantly worse. The use of an additional camera has identified specific locations on the field cage rings and the cryostat walls where bubbles appear. These studies will continue as the cryostat is emptied.

Findings-2

- While the LEM spark rate was unchanged after the HV intervention, the Grid spark rate increased significantly. The rate was reduced via a “burn-off” procedure with the CRP raised above the surface, but remained high.
- This is circumstantial evidence for a filament-like contamination on the Grid planes, although there is also evidence that wire tension has been lost in at least one location.
- A minimal working point for CRP voltage settings allowed limited operation of 70 minutes in which cosmic tracks were reconstructed.
- The “microphonic” effect previously observed in the pedestal-RMS was studied using sound injected by a subwoofer. Resonances in the region 240-286 Hz where observed. This technique will allow appropriate damping to be developed in the next CRP design.
- The photon detection system continued to operate throughout these studies, with the expected effects of the Xe and N2 in the LAr clearly seen. The efficiency of the two WLS candidate materials PEN and TPB were measured.
- Together these measurements will allow an assessment of the need for reflectors in the full design.

Findings-3

- A detailed “forensic investigation” is planned once the cryostat environment is safe for access, entailing in-situ analysis and removal of components for bench studies.
- The R&D program for an improved CRP design described at the last LBNC meeting, which targets reduced sparking and improved stiffness, is ongoing. The plan is to build new CRPs for a second protoDUNE run in NP02.
- The availability of a new cold box, fully capable of supporting the extensive testing program is critical for this effort and is likely to drive the schedule.
- A workshop is planned for November to assess lessons learned and to plan the path forward.
- R&D towards an alternative design, building on the experience with the vertical drift, will also be assessed in this workshop. This will lead to planning for the future operation of NP02 in protoDUNE-II.

Dual Phase

Comments-1

- LBNC congratulates the team for the careful execution of the HV surgery, and for the extensive studies completed during the run.
- The forensic studies planned to pinpoint the failure in the HV extender and filtering resistor, and to identify the origin of the increased Grid sparking are critical and will likely take several weeks after access is available. The results will be important for future designs.
- The schedule for validating a new design is likely to take longer than anticipated. The new cold box and study capabilities are critical. A plan for sufficient resources is needed.
- LBNC strongly endorses the proposal of the DUNE management for the workshop in November. The scope of the workshop is necessarily quite broad and follow-up workshop/reviews may be needed in developing the plan for future running in NP02.
- The plan for developing and testing the 600 kV HV system for 12 meter drift should be evaluated in this process. This is undoubtedly very challenging.

Dual Phase

Comments-2

- LBNC strongly encourages narrowing the R&D scope as early as possible, avoiding major alternative designs competing in NP02
- LBNC would welcome a debriefing from the November workshop at the next meeting
- DP remains in the R&D phase with significant development remaining. The LBNC is concerned about broadening the technology front on the tight timeline required for the first two modules

Recommendations

- At the next LBNC meeting, provide a debriefing from the November workshop on the lessons learned and plans going forward, including a description of the status of R&D and conceptual designs for alternatives
- During the workshop/review process, update the LBNC on the strategy for developing and deploying technologies beyond SP

Single Phase I

Findings

- Detector physics as well as LAr-hadron, shower and cosmic physics.
- First ProtoDUNE paper submitted.
- Track based and purity both show lifetimes above 20ms.
- Rayleigh scattering length consistent with L_R = 90 cm.
- Over 2020, doped LAr with Xe for photon detector studies.
- Light yield seen to grow with Xe doping, saturation at about 11ppm.
- Physics investigations/studies/measurements presented include: proton/pion-LAr cross section, transverse kinematic imbalance.

Single Phase II

Comments

- We congratulate the ProtoDUNE-SP team and analyzers on their excellent work.
- ProtoDUNE-I photon detector light yield stability results are encouraging. Longer term studies continue.
- In order to understand secondary interactions, DUNE will require good measurements of exclusive pion scattering on Argon. We encourage the collaboration to exploit ProtoDUNE data as much as possible in this respect.
- The Xe-doping results are encouraging. What is the longer range collaboration plan regarding a decision/strategy?

Recommendations

- None

Single Phase (Breakout) I

Findings

- Cheng-Ju Lin (LBNL) has been appointed Deputy Technical Lead.
- Development/prototype/submission cycle for ASICs continues:
  - ColdADC 2nd prototype received early September
  - LArASIC expected mid-October
  - COLDDATA to be submitted late September
  - CRYO expected to be submitted later this fall
- Progress has been made on FEMBs for both solutions
- Warm Interface Board is compatible with both options, considerable firmware development
- ICEBERG running slowed by COVID, progress made on improving operations.
- Improvements made based upon analysis of ICEBERG incident that damaged FEMB channels.
- CERN Cold Box operations affected by COVID.
- Progress made on top of cryostat components/services and installation studies.

Single Phase (Breakout) II

Comments

- We congratulate the team on considerable progress on many fronts.
- Demonstrable progress has been made with each successive ASIC fabrication cycle. The solutions developed appear to be on a track to success.
- The next submission for COLDATA is planned for next week. However, simulations with full parasitics are still underway and have recently identified issues with the modified PLL design. This means very little time will be available for the critical step of full-chip simulation, with parasitics. The team will need to carefully weigh the technical risk of proceeding with the submission versus the loss of 1-2 months of float. Arrangements should be made now to allow for submission in October if next week's submission cannot be safely met.
- Submission of the COLDATA chip, which is on the critical path for the 3 ASIC solution, is currently limited by Fermilab engineering availability (due to conflicts with other projects) and challenges moving the orders through the Fermilab purchasing process. Given the tight schedule, these near-term resources should not be the limiting factor.

Single Phase (Breakout) III

Comments (continued)

- Testing of the v2 (nEXO) version of the CRYO chip has found a sizable correlated noise contribution, which needs to be addressed before submission of the next version. The time available for understanding and fixing this issue is short, given the overall cold electronics schedule.
- To meet the ProtoDUNE-II schedule, the final ASIC choice needs to be made by June 2021, and orders must be placed for ASICs by summer 2021. Although potentially achievable, this will be challenging and leaves little room for unexpected issues. Pushing to make the schedule might affect decisions, so it is important that the collaboration have a realistic timeline for all ProtoDUNE-II components.
- Investigations of the ICEBERG incident that damaged a number of FE chips revealed several potential issues with the setup, and a likely culprit as the cause identified but not definitively proven. Subsequent changes, including in hardware interlocks, have been made and there has been no recurrence so far. The issue stresses the importance of installation reviews and operational procedures, which should be documented and fully implemented and enforced via Technical Coordination.

Single Phase (Breakout) IV

Comments (continued)

- Tests in the Cold Box at CERN will be an important aspect of the system testing. We encourage DUNE to work with the Neutrino Platform at CERN to develop a detailed plan for tests of the TPC electronics in the ProtoDUNE Cold Box. This will ensure that ASIC/FEMB testing can be carried out as planned ahead of final design reviews.
- The collaboration needs to consider the timing for the procurement of the components of the 2nd far detector module, in particular for the ASICs, including an analysis of the risks related to a delay in these procurements.

Recommendations

- DUNE should finalize a plan of what validation of the final ASICs is required using data collected during the warm and cold ProtoDUNE-II operation before submitting the production ASIC orders, carefully balancing technical risk versus schedule float.
- The possibility of delaying by several years the purchase of sufficient ASICs for a second FD module introduces a number of very significant risks. We encourage the collaboration to work toward procuring in a timely manner sufficient ASICs to meet its total potential needs.

Near Detector Status

- **CDR:** We congratulate DUNE for delivering the first draft of the ND CDR. The LBNC has provided extensive feedback on this draft. DUNE has been very responsive to our feedback so far. We look forward to receiving a revised CDR by the end of 2020.

- **Day 1 Detector Plan:** DUNE's plan for Day 1 detectors includes ND-LAr, SAND, DUNE-PRISM, and a temporary magnetic spectrometer (TMS) based on a magnetized range stack design. This is closely aligned with previous LBNC recommendations. We re-iterate that all of these elements are needed from Day 1. We endorse DUNE's general strategy to have TMS as a Day 1 replacement for ND-GAr if resources for ND-GAr cannot be found in time. We require additional information about the technical design of the TMS and demonstrations that it can meet DUNE's initial requirements. We emphasize that the TMS cannot be a long-term solution and should be replaced by ND-GAr as soon as possible. Ideally resources will be found so that ND-GAr can be available on Day 1. We are very interested to learn more about an alternative Day 1 solution, using the magnet of ND-GAr with a temporary simple tracker.

- **DUNE-PRISM:** Adding data runs at alternate horn currents improves the ability to model the high energy part of spectrum with the PRISM technique.

Near Detector Status

- **SAND:** DUNE is considering two technologies for the SAND beam monitor's inner tracker: a 3D scintillation tracker (3DST) with surrounding TPC or straw tube tracking, and a tracker based on layers of straw tubes and thin layers of target mass. The LBNC believes that either option is viable and will allow SAND to fulfill its critical mission as a beam monitor. The SAND group is also considering adding an active liquid argon target inside SAND, but no technical details of this or articulated physics case for it have been shown to the LBNC. We were surprised to see this described as part of the reference design, since we believe the case for this component has not been made. Cross-section measurements, which in SAND do not benefit from the DUNE-PRISM approach for breaking degeneracies between flux and cross section, should not be design drivers for SAND. Accommodating multiple nuclear targets, including a liquid argon target, leads to additional complexity.

- **ND-LAr:** The design of the full-sized LAr-TPC modules has advanced significantly. In July DUNE demonstrated a scalable pixel anode. The 2x2 prototype has incurred 6 months of COVID delays. The team has put together a prototyping and R&D plan, but significant work remains before CD2. Additional effort is needed in simulations and reconstruction.

Near Detector Status

- **ND-GAr:** DUNE's new reference design, for ND-GAr's magnet, called SPY, features a partial return yoke and based on JINR's MPD magnet. The LBNC welcomes this new reference design. DUNE presented an outline of an R&D plan for ND-GAr, which we encourage them to flesh out and develop into a schedule. Funding for ND-GAr is still a work in progress. DUNE is also exploring an alternative Day 1 configuration using the SPY magnet with scintillator planes, as a step towards ND-GAr and as an alternate to the TMS. This approach has some advantages over TMS, but costs a little more in the short term, and is not currently the reference design for Day 1. We encourage continued exploration of this option.

- **Recommendations:**
  - **Deliver a revised ND CDR by the end of November 2020**
  - **Provide detailed technical information and physics studies for the TMS to LBNC, so we can review its suitability as a Day 1 detector. This should take the form of document in the spirit of a CDR chapter describing the TMS and how it would meet the Day 1 requirements.**
  - **Determine as soon as possible the latest date at which DUNE must commit to building the TMS in place of ND-GAr for Day 1**
  - **Prioritize finding additional resource commitments for ND-GAr**
  - **Choose expeditiously between the two options for SAND's inner tracker, without letting cross-section measurements in SAND be a design driver**

Computing

- We congratulate the DUNE Computing Consortium for its continuous work of developing a computing system for the start of DUNE data taking, while providing a usable environment for protoDUNE and simulation activities.
  - A CDR being produced by the end of 2020, to be reviewed in early 2021. We expect that the CDR, and in future the TDR, will cover aspects related to both Near and Far Detectors in a comprehensive manner.

- Projections of the DUNE computing and storage resource needs were presented.
  - A good starting point for the CDR which should elaborate on the assumptions used for those estimates.
  - Hardware resource needs are considerable already in 2021/2022. We encourage DUNE to establish the right channels to secure resources for those needs, which might require visibility at the RRB level
  - DUNE is participating in the important process of network requirements gathering initiated by ESNET. We encourage DUNE to go through a similar exercise with other Research and Education Networks providers

Computing

- DUNE computing leverages several tools and services developed by other HEP experiments and WLCG.
  - The LBNC supports this approach (optimise effort, guarantee long term sustainability).
  - We encourage DUNE to consider the risks, mitigations and effort needed in the collaboration to integrate those components, and spell them out in the CDR.

- The LBNC supports the approach taken by the Frameworks Task Force, of defining the requirements starting from the physics needs
  - We support identifying a unique framework that can cover the needs of all DUNE communities.
  - Different options will be considered, including leveraging existing frameworks, adapting them to the DUNE needs. We are eager to learn the outcome of this work in the next meetings.

Computing

- The ND community clarified several aspects brought up in the context of the ND CDR.
  - The large uncertainties concerning resource needs relate mostly to the amount of simulation for systematic studies. ND is progressively acquiring a better understanding of those needs and we expect those uncertainties to reduce in the next few years.
  - The ND is working on its data model and we consider essential a strategy of defining a common model with the FD.

Recommendations

- We note that the algorithmic aspects of software are not part of the computing consortium and we believe that the proper channels of communication should be established between the communities. **We recommend** that DUNE identifies those channels and reports back at one of the next LBNC meetings. We also understand that the hardware database is an area where coordination with many consortia is critical.

DUNE Executive Summary

- We enjoyed hearing about the impressive progress of the **LBNF Project** especially of the pre-excavation**.** The path towards both placing the excavation contracts and baselining of the overall **LBNF-US DUNE Project** has also made considerable progress.
- We also heard in some detail about the **Beamline sub-project.** We are pleased that this part of the project is emphasizing the exploration of ways to accelerate the schedule.

- DUNE **Technical Coordination** has an expanding scope with the concurrent preparation for installation at DUNE, the preparation for ProtoDUNE II campaigns in NP02 and NP04, the continued FD R&D, and the incorporation of a multi-facetted Near Detector. It will be important for the collaboration to ensure that the organization continues to be well defined, and adequately staffed to maintain the schedule. Consequently we are requesting some standardised presentation of schedule data in future presentations.

DUNE Executive Summary

- The **Single Phase Far Detector** work has enjoyed a stellar campaign in NP04 and the physics and technical validation is impressive. The LBNC has concentrated on understanding the considerable progress with the final stages of design and development, in particular the electronics. While this continues to require close attention, the progress corresponds to the schedule needed.

- The **Far Detector Dual Phase** work has continued to concentrate on completing the ProtoDUNE DP work in NP02. High voltage repair work was executed and the run continued until September. However, while much has been learned, the viability of the technology at scale has not been demonstrated. Planning for future work, R&D, design modifications and preparation for future ProtoDUNE work in NP02 and eventual use in DUNE must therefore be made with care.

DUNE Executive Summary

- The **Near Detector** consortia have drafted a Conceptual Design Report (CDR) which the LBNC has reviewed and provided considerable feedback. A further draft is expected before the end of the calendar year with approval expected to follow. In addition to the documentation, considerable advances in the technical issues are seen. New to this meeting was the concept of a **Day-1 Near Detector**. This features a simplified muon spectrometer constrained by initial resources. The LBNC expects to receive material enabling it to review the capability of this Day-1 Detector configuration.

- The coherence and completeness of the discussion of **DUNE Computing** and its presentation showed a marked stride forward since the previous Meeting. The LBNC can now see the path for DUNE towards documentation of the computing plans in a CDR, and eventually a TDR. We continue to encourage explicit connection between the Algorithm teams and the Computing Consortium.

DUNE Executive Summary

- For the **DUNE Collaboration**, establishing a CD2 Baseline for the LBNF/US-DUNE Project is of prime importance. The successes with ProtoDUNE SP have provided a solid basis for the initial Far Detector configuration. Establishing the corresponding confidence in the Near Detector involves a clear understanding of the Near Detector Conceptual design and excellent progress has been made in this direction. In the short term, articulation and scrutiny of, a Day-1 Near Detector, which, for the LBNC, started at this meeting, will require dedicated effort from both DUNE and the LBNC.

- For the longer term there are many challenges, strategic, technical, fiscal and sociological, associated with creating a clear plan for all Far Detector Modules. The LBNC looks forward to hearing, in the near future, about the technologies under discussion and the process for making a selection.