

## **Proposed working groups and work breakdown structure for the DUNE single phase TPC cold electronics**

This document describes the proposed WBS structure for the Single Phase TPC cold electronics consortium. It includes an evolving dictionary that maps into the deliverables for the consortium, and it highlights the point of contacts and possible overlaps with the activities/deliverables of other far detector consortia and working groups. This document will evolve with time and reflect changes in the organization of the consortium and the discussions between consortia on where to set boundaries between the activities of the different consortia. It will be frozen at the time of the CD2/3b review.

Please see the revision history at the end of this document to track changes.

We plan to have a one-to-one match between the working group and the WBS structure of the project that will be used inside Primavera P6 and MS Project to monitor and report on the progress of the activities of the consortium.

We propose to have five working groups, at least in an initial phase. There will be a corresponding L3 area in the WBS for each of the working group. We plan to have more than one convener for each working group. For the DOE project we will choose one of those conveners as the L3 manager, which involves additional responsibilities including schedule development and reporting. The L3 manager may also be asked to serve as control account manager for part, or all, of the activities that fall under her/his responsibility.

We remark that for the DOE project software activities that involve only the use of non-costed scientific personnel (university professors, postdocs, students, laboratory scientists and postdocs) will be tracked only at the level of milestones and deliverables. A detailed description of the activities will be included only in the MS Project schedule. This applies to items (5.1.5), (5.1.6), (5.2.6), (5.2.7) below as well as to the entire Software part of the WBS (item 7).

The five working groups (and corresponding L3 areas) that we propose are:

- components inside the cryostat;
- components outside the cryostat;
- development of test facilities;
- integrated tests;
- software.

In the WBS we also have two additional L3 areas that do not correspond to working groups:

- management including system engineering;
- milestones and external constraints (needed only in scheduling software).

Below we describe the various L3 areas / working groups, including a more detailed structure down to the L5 level. Preliminary dictionaries are included for all the L3 and most L4 WBS elements, whereas for some L4 and all L5 elements we give (for the moment) only the name, under the assumption that the dictionary is derived from the parent in the work breakdown structure.

Where appropriate we mention where input from other groups / consortia is needed ("Contacts with others") and where we think that the interface between two consortia requires further discussion to avoid conflicts / duplication of work ("Overlap with others).

For the moment we use xx.yy.zz.aa as a place holder for the official project identifier(s) in Primavera P6 and MS Project (in P6 xx.yy.zz.aa corresponds to 131.02.02.20.04).

### **1) xx.yy.zz.aa.1 - Milestones and connections to other consortia and external constraints**

**Dictionary:** This WBS elements contains only milestones that are used to tie the activities in the DUNE single phase TPC cold electronics WBS to calendar constraint milestones (start of each quarter in each fiscal year), constraints from funding agencies (dates of reviews and availability of funding), constraints from the LBNF/DUNE project, milestones for the project completion, and milestones that are used to implement connections between this WBS and other WBS in the DUNE project (both within the US and the international scope).

- **xx.yy.zz.aa.1.1** - Calendar constraint milestones
- **xx.yy.zz.aa.1.2** - Funding agencies milestones (includes reviews and funding)
- **xx.yy.zz.aa.1.3** - Constraints from the LBNF/DUNE project (includes submission of technical proposal and TDR, internal reviews and decisions, completion dates for the project)
- **xx.yy.zz.aa.1.4** - L4 milestones for the subproject (assume L2/L3 milestones are in the master schedule file)
- **xx.yy.zz.aa.1.5** - Interfaces between this WBS and the WBS for other consortia in the DUNE project (both for US and international scope)
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### **2) xx.yy.zz.aa.2 – Management (convener/L3 manager - M. Verzocchi)**

**Dictionary:** This WBS encompasses the management tasks for the DUNE single phase TPC cold electronics component of the LBNF/DUNE project. It also includes the system engineering, including the development of the detector grounding and shielding plan, the analysis of the complete system from the point of view of minimizing the detector noise and checking the interfaces between all the components of this part of the DUNE detector and the other detector parts. System engineering will also include the oversight of all the detector safety system aspects.

**Contact with others:** during preparation of the documentation, interact with all the relevant consortia and working groups. For system engineering, interact with other consortia and working groups to ensure that noise is not injected into the cryostat from other systems.

- **xx.yy.zz.aa.2.1** - Preparation of technical proposal
- **xx.yy.zz.aa.2.2** - Preparation of technical design report
- **xx.yy.zz.aa.2.3** - Preparation of material for DOE CD2/CD3b reviews
- **xx.yy.zz.aa.2.4** - System engineering
- **xx.yy.zz.aa.2.5** - Validation of the final design against protoDUNE data and result from system test stands.

### **3) xx.yy.zz.aa.3 - DUNE single phase TPC cold electronics components inside the cryostat (conveners/L3 manager – TBA)**

**Dictionary:** This WBS elements covers the development, the construction, the testing, and the installation of the detector components for the single phase TPC electronics that are either installed on the APAs or inside the cryostat. The detector components are the ASICs, the front-end motherboards, the infrastructure required for the installation on the APAs, all the cables inside the cryostat, the signal flanges and the feedthroughs. The QA/QC process for these components is also included.

- **xx.yy.zz.aa.3.1** – ASICs [**Dictionary:** This WBS element covers the Front-End ASIC, the ADC ASIC, and the COLDATA ASIC, and for a possible integrated solution. For each ASIC, the design phase, including the fabrication and testing of prototypes, the production phase, and the testing phase are included. **Contacts with others:** ASIC specification requires input/check from physics and simulation WGs.]
  - **xx.yy.zz.aa.3.1.1** - Front-End ASIC
  - **xx.yy.zz.aa.3.1.2** - ADC ASIC (includes the testing of commercial and other ADCs)
  - **xx.yy.zz.aa.3.1.3** - COLDATA ASICs
  - **xx.yy.zz.aa.3.1.4** - Integrated ASIC (this should not be taken as a commitment to fund the development of a solution based on the nEXO chip), kept as a place-holder for monitoring its progress and eventually switching to the integrated ASIC for the construction. The development of integrated solutions merging just the ADC and COLDATA ASICs could be moved in here at a later time.
- **xx.yy.zz.aa.3.2** - Front-End Motherboards [**Dictionary:** This WBS element covers the R&D, including the fabrication and testing of prototypes, the production and the testing of the front-end motherboards. The motherboards are tested first in the cold electronics QC centers and then again at the APAs integration facility. **Contact with others:** electrical / mechanical interface with the CR boards (APA consortium) interface to slow controls and monitoring (slow controls and cryostat consortium).]
- **xx.yy.zz.aa.3.3** – Cables [**Dictionary:** This WBS elements covers the selection and validation, the fabrication and procurement, and the testing of all the low voltage, bias, and signal cables that are housed inside the cryostat. **Contact with others:** not necessary, but monitor work done in the double phase TPC consortium and in the single and double phase photon system consortia.
- **xx.yy.zz.aa.3.4** - Infrastructure inside and at the boundary of the cryostat [**Dictionary:** This WBS element covers the development of the cables routing plan, the design and the fabrication of the front-end motherboard boxes and of the cable support structures, the flanges, and the feed-throughs. **Contact with others:** mechanical interface with the APAs (APA consortium) and with the LBNF group responsible for the cryostats.]
- **xx.yy.zz.aa.3.5** – Installation [**Dictionary:** This WBS element covers the installation of the front-end motherboards on the APAs, the cabling of the detector, including tests on the complete APAs. It also includes the connection of the cables to the flanges and the feed-throughs after the APAs are moved into the cryostat. **Contact with others:** the installation of the FE motherboards and the cables on the APA depends on the availability of the APAs. The final connection of the cables to the feedthroughs depends on the installation of the APAs inside the cryostat. **Overlap with others:** the installation of the FE motherboards on the APAs, the tests of the complete APAs, and the routing of the cables on the APAs are activities that could also be considered part of the APA consortium WBS. We assume that the welding of the chimneys containing the feedthroughs and the flanges to the cryostat and the following integrity tests are under the responsibility of the LBNF cryostats group.]

- **xx.yy.zz.aa.3.5.1** - Installation of FE motherboards on APAs and detector cabling
- **xx.yy.zz.aa.3.5.2** - Test of complete APAs in the cryostat
- **xx.yy.zz.aa.3.5.3** - Electronic tests on the feedthroughs

#### 4) **xx.yy.zz.aa.4 - DUNE single phase TPC cold electronics components outside the cryostat (conveners/L3 manager – TBA)**

**Dictionary:** This WBS elements covers the development, the construction, the testing, and the installation of the detector components for the single phase TPC electronics that are installed outside the cryostat. The detector components are the warm electronics crate and backplane, the warm interface boards, the power timing cards and all the cables running outside the cryostat. The QA/QC process for these components is also included.

- **xx.yy.zz.aa.4.1** - Warm electronics crate and backplane [**Dictionary:** This WBS covers the design, the fabrication, and the testing of the backplane and of the mechanical components for the warm electronics crate, and the assembly of the complete crates. **Contact with others:** any interaction with the LBNF cryostat group? do the crates need supports and anchoring points to the surface of the cryostat or are they just mounted on the chimneys and supported by them? is the weight of the crates taken into account in the design of the chimneys? do the crates need a cooling system? is forced air sufficient, or is an heat exchanger needed? does this complicate the interface to the cryostat?]
- **xx.yy.zz.aa.4.2** - Warm interface boards. [**Dictionary:** This WBS covers the design, fabrication, firmware development, and testing of the warm interface boards. **Overlap with others:** the exact boundary between the cold electronics consortium and the DAQ consortium need to be defined very clearly. The design of part of the warm interface boards and the firmware development clearly depend on the trigger and DAQ architecture, and could fall under the responsibility of each of the two consortia. **Contact with others:** DAQ and slow controls consortia.]
- **xx.yy.zz.aa.4.3** - Power and timing cards [**Dictionary:** This WBS covers the design, fabrication, firmware development, and testing of the power and timing cards. **Contact with others:** DAQ and slow controls consortia.]
- **xx.yy.zz.aa.4.4** – Cables [**Dictionary:** This WBS elements covers the selection and validation, the fabrication and procurement, and the testing of all the low voltage and bias voltage cables that are installed outside the cryostat. **Contact with others:** not necessary, but monitor work done in the double phase TPC consortium, and in the single and double phase photon system consortia. **Note:** we assume that the fiber plant connecting the warm interface boards to the DAQ backend, as well as any cables or fibers for the slow controls are under the responsibility of the DAQ and slow controls consortia, respectively.]
- **xx.yy.zz.aa.4.5** - Power supplies [**Dictionary:** This WBS elements covers the selection and validation, the procurement, and the testing of all the low voltage power supplies and bias voltage supplies. **Contact with others:** not necessary, but monitor work done in the double phase TPC consortium, and in the single and double phase photon system consortia. Develop interface with slow controls and detector safety system (slow controls and cryo instrumentation).]

- **xx.yy.zz.aa.4.6** - Installation at SURF [**Dictionary:** This WBS element covers the installation of the warm electronics crate and the corresponding boards on the chimneys on the cryostat, the installation of all the low voltage power supplies and of the bias voltage power supplies, as well as the connection of all the cables.]

## 5) **xx.yy.zz.aa.5 - Test facilities development (conveners/L3 manager – TBA)**

**Dictionary** - This WBS covers the development of all the test facilities (from test facilities for individual components to test facilities for integrated tests, from facilities used during the R&D phase to those used during final construction), including the development and maintenance of the relevant software. This includes the development of a QA/QC plan and procedures, and the development of a hardware database for tracking components and calibrations.

- **xx.yy.zz.aa.5.1** - Test facilities for ASICs and FE motherboards [**Dictionary:** This WBS covers the development of the test facilities for the ASICs and the front-end motherboards. **Contact with others:** interface with the SW group responsible for developing a common hardware database solution.]
  - **xx.yy.zz.aa.5.1.1** - ASIC test stands
  - **xx.yy.zz.aa.5.1.2** - Front end motherboards test stands
  - **xx.yy.zz.aa.5.1.3** - Cable test stands
  - **xx.yy.zz.aa.5.1.4** - Cryogenic systems for ASIC and FE motherboards test stands
  - **xx.yy.zz.aa.5.1.5** - Test stand for feed-throughs
  - **xx.yy.zz.aa.5.1.5** - Software for test stands and QC documentation
  - **xx.yy.zz.aa.5.1.6** - Hardware database for component and calibration tracking
- **xx.yy.zz.aa.5.2** - Test facilities for warm electronics [**Dictionary:** this WBS covers the development of the test facilities for the boards installed in the warm electronics crates (warm interface boards, power and timing cards), for all the cables installed outside the cryostat and for power and bias voltage supplies. **Contact with others:** interface with the SW group responsible for developing a common hardware database solution.]
  - **xx.yy.zz.aa.5.2.1** - Warm interface board test stands
  - **xx.yy.zz.aa.5.2.2** - Power and timing cards test stands
  - **xx.yy.zz.aa.5.2.3** - Cables test stands
  - **xx.yy.zz.aa.5.2.4** - Low voltage power supplies test stands
  - **xx.yy.zz.aa.5.2.5** - Bias voltage test stands
  - **xx.yy.zz.aa.5.2.6** - Software for test stands and QC documentation
  - **xx.yy.zz.aa.5.2.7** - Hardware database for component and calibration tracking
- **xx.yy.zz.aa.5.3** - Electronics integration test facility [**Dictionary:** This WBS covers the development of a test facility where the entire electronic chain is tested at once, including the output to the DAQ backend, including a system to inject pulses in the FE motherboards. **Contact with others:** interface with the DAQ and slow controls and cryo interfaces consortia.]
- **xx.yy.zz.aa.5.4** - Detector integration test facility [**Dictionary:** This WBS covers the development of a test facility where increasingly large TPCs (from a small prototype to an entire APA) are tested in an environment as close as possible to the final DUNE single phase detector. **Contact with others:** interface to all the far detector consortia. The construction of the TPC and/or appropriate

cryostats / cold boxes should be covered in other consortia (to be discussed). **Overlap with others:** the development of specific APAs or cryostats or the use of protoDUNE for integrated test require the contribution or could fall under the responsibility of other consortia / WG.

## 6) xx.yy.zz.aa.6 - Integrated tests (conveners/L3 manager – TBA)

**Dictionary:** This WBS covers the test of the full electronics chain and tests of an entire APA in conditions as close as possible to the final DUNE single phase detector.

- **xx.yy.zz.aa.6.1** - Integrated tests of the full electronic chain [**Dictionary:** This WBS covers tests of the full electronic chain from the injection of signals into the FE motherboards to the DAQ backend. **Contact with others:** interface to the DAQ consortium. **Overlap with others:** this could also be under the DAQ consortium.]
- **xx.yy.zz.aa.6.2** - Integrated detector tests [**Dictionary:** This WBS covers tests of the full detector system, from the APA to the DAQ backend, either in cold boxes or cryostats. **Contact with others:** interface to all the far detector consortia. **Overlap with others:** the operation of these tests could also be under the APA and DAQ consortia.]

## 7) xx.yy.zz.aa.7 – Software (conveners – TBA)

**Dictionary:** This WBS covers the development and the maintenance of the online and offline software.

- **xx.yy.zz.aa.7.1** - Online software [**Dictionary:** This WBS covers the development and maintenance of the software required for the detector operation, including run control, calibration, online monitoring, and detector safety system. **Contact with others:** DAQ and slow controls and cryo instrumentations consortia, software working group.]
  - **xx.yy.zz.aa.7.1.1** - Interface to run control and detector configuration.
  - **xx.yy.zz.aa.7.1.2** - Calibration software and interface to calibration database.
  - **xx.yy.zz.aa.7.1.3** - Interface to detector safety system.
  - **xx.yy.zz.aa.7.1.4** - Detector conditions monitoring.
  - **xx.yy.zz.aa.7.1.5** - Data monitoring.
- **xx.yy.zz.aa.7.2** - Offline software [**Dictionary:** This WBS covers the development and maintenance of the offline software. **Contacts with others:** software and physics working group.]
  - **xx.yy.zz.aa.7.2.1** - Simulation of the detector structures inside the cryostat
  - **xx.yy.zz.aa.7.2.2** - Simulation of the response of the electronics - analog signals.
  - **xx.yy.zz.aa.7.2.3** - Simulation of the response of the electronics - digital signals.

## Appendix 1: Match to deliverables

This section contains a match between the list of deliverables (taken from [DUNE-DocDB 4466-v3](#) of 13 Jul 2017) and the WBS entries listed above. The deliverables listed above under items **6** are new in this document, although their presence was somehow implied as being part of the plan presented in the old document.

- Hardware Deliverables

- Front-end ASIC
  - Design [3.1.1]
  - Production [3.1.1]
  - Test Stand Design [5.1.1]
  - Testing [3.1.1]
- ADC ASIC
  - Design [3.1.2]
  - Production [3.1.2]
  - Test Stand Design [5.1.1]
  - Testing [3.1.2]
- COLDATA ASIC
  - Design [3.1.3]
  - Production [3.1.3]
  - Test Stand Design [5.1.1]
  - Testing [3.1.3]
- Front-end Motherboards
  - Design [3.2]
  - Production [3.2]
  - Test Stand Design [5.1.2]
  - Testing [3.2]
- Cold Low-voltage Cables
  - Selection/Validation [3.3]
  - Fabrication/Procurement [3.3]
  - Test Stand Design [5.1.3]
  - Testing [3.3]
- Cold Bias-voltage Cables
  - Selection/Validation [3.3]
  - Fabrication/Procurement [3.3]
  - Test Stand Design [5.1.3]
  - Testing [3.3]
- Cold Signal Cables
  - Selection/Validation [3.3]
  - Fabrication/Procurement [3.3]
  - Test Stand Design [5.1.3]
  - Testing [3.3]
- APA Electronics Infrastructure
  - Develop Cable Routing Plan [3.4]
  - Design FEM boxes and Cable Support Structures [3.4]
  - Fabricate FEM boxes and Cable Support Structures [3.4]
  - Develop Installation Plan [3.5]
  - Install electronics/cables on APAs (Integration Facility?) [3.5]
  - Test electronics/cables on APAs (Integration Facility?) [3.5]
- Signal Flanges
  - Develop Cable Routing Plan [3.4]
  - Design Flange and Cable Support Structures [3.4]
  - Procure/Fabricate Flange and Cable Support Structures [3.4]
  - Develop Plan for connecting cables to feed-throughs [3.5]
  - Install cables to feed-throughs during APA installation (SURF) [3.5]

- Cold Electronics Feed-through
  - Design [3.4]
  - Fabrication [3.4]
  - Test Stand Design [5.1.5]
  - Testing [3.5.3]
- Warm-electronics Crate and Backplane
  - Design [4.1]
  - Backplane fabrication [4.1]
  - Backplane testing [4.1]
  - Fabrication of mechanical crate components [4.1]
  - Crate Assembly [4.1]
  - Installation of crates on feed-throughs (SURF) [4.6]
- Warm Interface Boards
  - Design [4.2]
  - Firmware Development [4.2]
  - Fabrication [4.2]
  - Test Stand Design [5.2.1]
  - Testing [4.2]
  - Installation and Commissioning (SURF) [4.6]
- Power & Timing Cards
  - Design [4.3]
  - Fabrication [4.3]
  - Test Stand Design [5.2.2]
  - Testing [4.3]
  - Installation and Commissioning (SURF) [4.6]
- Warm Low-Voltage Cables
  - Selection/Validation [4.4]
  - Fabrication/Procurement [4.4]
  - Test Stand Design [5.2.3]
  - Testing [4.4]
- Warm Bias-Voltage Cables
  - Selection/Validation [4.4]
  - Fabrication/Procurement [4.4]
  - Test Stand Design [5.2.3]
  - Testing [4.4]
- Low-Voltage Power Supplies
  - Selection/Validation [4.5]
  - Procurement [4.5]
  - Test Stand Design [5.2.4]
  - Testing [4.5]
- Bias-Voltage Supplies
  - Selection/Validation [4.5]
  - Procurement [4.5]
  - Test Stand Design [5.2.5]
  - Testing [4.5]
- Software Deliverables
  - Simulation Code



- Analog Signal Processing [7.2.2]
    - Digital Readout [7.2.3]
  - Calibration
    - Run Control Software [7.1.1]
    - Analysis Software [7.1.2]
    - Calibration Database [7.2.2]
  - Hardware Database
    - QC Documentation [5.1.5, 5.2.6, 5.3, 5.4]
    - Component Tracking [5.1.6, 5.2.7]
  - Data Collection
    - Hardware Initialization/Configuration Code [7.1.1]
    - Hardware Monitoring Code [7.1.3, 7.1.4]
  - Data Monitoring Code [7.1.5]
- Physics Deliverables
  - Validation of Cold Electronics Requirements with respect to Physics Performance [2.1, 2.2]
  - Cold Electronics Performance Validation via ProtoDUNE Data Analysis [2.5]
  - Editing of TDR chapter [2.2]
- Integration Deliverables
  - Detector Grounding & Shielding Plan [2.4]
  - System Engineering
    - Internal Interface Specifications (within TPC electronics subsystem) [2.4]
    - External Interface Specifications (with other subsystems) [2.4]
  - Development of QA Plan (specification of tests/facilities) [5.1.5, 5.2.6, 5.3, 5.4]
  - Development of QC Plans (for all components) [5.1.5, 5.2.6, 5.3, 5.4]
  - Electronics Integration Test Facility [5.3]
    - Design [5.3]
    - Fabrication [5.3]
    - Operation [6.1]
  - Detector Integration Test Facility
    - Installation & Commissioning of TPC Electronics Components [5.4]
    - Operation [6.2]
    - Analysis of TPC Electronics Performance [6.2]

## Appendix 2: Revision History

V1 (15 September 2017) - First version of this document

V2 (15 September 2017) – Identical in content to V1, add the revision history and the DUNE DocDB number.