ND-LAr TPC Module Assembly and Testing Status

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DUNE ND-LAr Management Meeting

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TPC Module A&T Scope

- TPC Module Assembly and Testing ("A&T") for ND-LAr involves:
  - Assembly of 35 ND-LAr modules (+ spares)
  - Full-module QC for 35 ND-LAr modules (+ spares)
  - QA for above activities in preceding small, large-scale prototypes
- Includes assembly/testing plans and procedures, assembly fixtures, and associated QA
  - For 2x2, FSD, and MATF; support role during I&I
- Production for TPC Module A&T will occur at MATF (Module Assembly and Testing Facility) at Fermilab IERC (Integrated Engineering Research Center) **between 2027 and 2029**

TPC Module A&T Scope

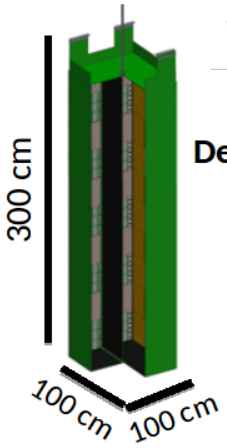
MATF Operations

2021

Module 0

SingleCube,
then 1 module (Module 0),
then 4 modules (2x2)

Operated in cryostat at Bern,
then FNAL in NuMI beam

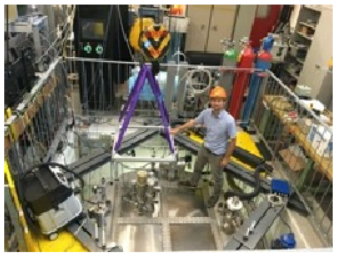


Start in 2023

Full-Scale Demonstrator (FSD)

Start in 2022

ArgonCube 2x2



2027-2029

Production

1 production 'first article'

35 (+5) Production modules
Each fully tested in single-module cryostat

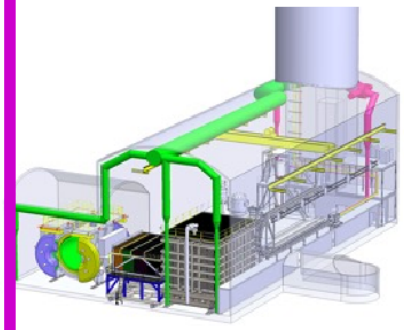
Deliverable: modules packed and ready for installation underground

2030-2031

Installation

Support of TPC module installation in Near Site

Activity driven by Near Site Integration (NSI)



TPC Module A&T Scope

MATF Testing Modality

- Original plan was to test 35 ND-LAr modules (+ spares) in LAr at MATF
  - Use of two cryostats w/ LAr recirculation systems
  - Discussed in detail at June 2021 Internal Review
- DUNE budget update could not accommodate costs of testing all modules in LAr (reflected mainly in MATF WBS)
- TPC Module Testing Task Force convened to address testing requirements, thus MATF testing modality
  - Chair: Christopher Mauger
  - Members: Mike Mooney, Saba Parsa, Louise Suter
- Final report not ready yet but leaning toward GN2 or LN2 testing at MATF w/ enhanced QA of field structures at FSD

Scope Table

Task/Item	Qty	Spares	Institutions	Funding Source	Funding Status	Detailed Description
Cryostat Design			CSU	DUNE-US Project	Allocated	FSD/MATF cryostat design (CAD)
Cryostat Lid Design			CSU	DUNE-US Project	Allocated	FSD/MATF cryostat lid design (CAD, structural/thermal FEAs)
Assembly Fixture Design			CSU	DUNE-US Project	Allocated	Design of assembly fixtures (CAD)
Assembly Plans			CSU	DUNE-US Project	Allocated	Plans and procedures for assembling TPC modules
Testing Plans			CSU	N/A	N/A	Plans and procedures for testing assembled TPC modules
TPC Mechanical Mock-Up	1		CSU	DUNE-US Project	Allocated	Mock-up used for TPC module QA
TPC Mounting Plate	1		CSU	DUNE-US Project	Allocated	Plate that integrates TPC module to physics lid
Assembly Fixture	1		CSU	DUNE-US Project	Allocated	Fixture used in integrating TPC module components
Rotation Fixture	1		CSU	DUNE-US Project	Allocated	Fixture used to rotate TPC module upright prior to installation into cryostat
Module External Frame	35	2	CSU	DUNE-US Project	Allocated	Frames used for handling of assembled TPC module (also included in shipping crate)
Transport Jig	1		CSU	DUNE-US Project	Allocated	Jig used to transport TPC module during assembly and testing
Physics Lid	2		CSU	DUNE-US Project	Allocated	Inner cryostat lid that TPC module is mounted to (includes feedthroughs for HV, readout)
Lifting Fixture	1		CSU	DUNE-US Project	Allocated	Fixture used to lift TPC module assembly (including physics lid) into or out of cryostat
Lid Support Structure	1		CSU	DUNE-US Project	Allocated	Structure that supports physics lid while TPC module is integrated to physics lid
General Tooling	1		CSU	DUNE-US Project	Allocated	Tools used during TPC module assembly and testing
Hoist System	1		CSU	DUNE-US Project	Allocated	System used to integrate TPC module to physics lid prior to installation into the cryostat
Portable Faro Arm	1		CSU	DUNE-US Project	Allocated	Instrument used to measure external dimensions of TPC modules
Storage Cabinets	2		CSU	DUNE-US Project	Allocated	Cabinets for storing TPC module components (including spares)
Workbench	1		CSU	DUNE-US Project	Allocated	Flat surface used for TPC module assembly
2x2 Support			CSU	N/A	N/A	Support of TPC Module A&T activities at 2x2
FSD Support			CSU	DUNE-US Project	Allocated	Support of TPC Module A&T activities at FSD
MATF Support			CSU	DUNE-US Project	Allocated	Support of TPC Module A&T activities at MATF
I&I Support			CSU	DUNE-US Project	Allocated	Support of I&I activities during I&I
A&T Engineering Labor			CSU/LBNL	DUNE-US Project	Allocated	Engineering labor for A&T activities

- Note: above table reflects TPC Module A&T WBS only; it does not include facility scope (2x2, FSD, MATF)

PDR Documentation Table

Document	Status	Location
Risk Registry	Fairly Mature	Google Drive
Requirements	Fairly Mature	Google Drive, EDMS
FSD Interface	Fairly Mature	EDMS
MATF Interface	Mature	EDMS
Subsystem Interfaces	Defined but Immature	N/A
PDR Chapter	Needs Revising (TPC Module Testing Strategy Changes)	Overleaf
Cryostat CAD	Mature	Windchill
Assembly, Lifting, and Handling Fixture CADs	Needs Revising (TPC Module Design Changes)	Windchill
Assembly Plan	Lacking	EDMS (planned)
Testing Plan	Started	EDMS
QA/QC Plan	Started	EDMS
Procurement Plan	Lacking	EDMS (planned)

High-level Risks

Risk ID	Title	Summary	Mitigation	Response	Probability	Schedule Impact (Months)			Cost Impact ($k)			Technical Impact
	Brief description	*"If x were to occur, then y is the consequence."*	*Actions being taken to address/reduce the probability of the risk.*	*Actions to take if risk comes true.*	*0 to 100%*	*"a - b - c months" where a is minimum, b is likely, c is maximum delay if risk comes true.*			*"a - b - c k$" where a is minimum, b is likely, c is maximum cost if risk comes true.*			*"None", "Negligible", "Moderate", "High" impact to technical performance (reqs/specs) of detector if risk comes true.*
INT-001	MATF Cryogenics System Commissioning Delays	If MATF commissioning is delayed due to initial failure of cryogenic system, then would start testing of modules at MATF later than initially anticipated	Commission the cryogenics system for the MATF as early as possible (at least six months prior to operation)	Ask for additional help from local (FNAL) cryogenics experts to debug issues with cryogenics system	20%	1	3	6	50	150	300	0 Negligible
INT-002	Module Testing Timescale at MATF Longer than Anticipated	If module testing timescale at MATF longer than anticipated, then additional installation labor cost will be incurred and beginning of ND installation/commissioning would be delayed	Install two cryostats to allow for faster testing cycles	Reassess QA/QC criteria to allow for shortening of testing timescale if possible, otherwise incur delay to ND installation schedule	25%	2	3	6	100	150	300	0 Negligible
INT-003	Module Components Damaged at MATF	If module components damaged at MATF, then minor delays to module tests at MATF would be incurred due to waiting for component replacement	Ensure testing procedures are fully developed (both cold and warm testing), ask subsystem experts for input on handling/testing of their subsystem's components, ensure training of operators is complete and consistent Subsystems shall deliver spare components as required by their production yields	Send module components back to responsible institutions for repair/replacement	45%	2	3	4	100	200	300	0 Negligible
INT-004	Catastrophic Damage to Module at MATF	If catastrophic damage to module at MATF occurs to e.g. a module being dropped from a crane, then modest testing delays would result as well as increase in costs	Develop extensive safety plan to be reviewed by Fermilab ESH, ensure training of operators is complete and consistent	Evaluate components to see if they can be recycled, send back to responsible institutions for repair/replacement, reevaluate safety plan with help from Fermilab ESH; if damage is severe, eliminate a spare	10%	0	0	0	0	0	0	1 Somewhat Substandard
INT-005	Cryogenic System Failure During MATF Operations	If cryogenic system fails during operation of MATF, then significant delays to testing schedule would result	Ensure cryogenics experts are available on-site for quick repair of the system	Ask for additional help from local (FNAL) cryogenics experts to debug issues with cryogenics system	25%	1	2	4	50	100	200	0 Negligible
INT-007	Personnel Injury	If personnel working at the MATF were to be injured, there would be delays in operations due to review of safety procedures	Develop extensive safety plan to be reviewed by Fermilab ESH, ensure training of operators is complete and consistent	Reevaluate safety plan with help from Fermilab ESH	10%	1	2	3	50	100	150	0 Negligible
INT-009	Insufficient Module Storage Space	IF there is insufficient storage for completed modules, then MATF operations could be affected/delayed	Find and document committed storage location at FNAL	Scale back rate of integration/testing	10%	3	6	9	150	300	450	0 Negligible
INT-012	Insufficient FNAL Technical Support	IF FNAL technical support is not available to meet our resource plan, then cost and schedule will be impacted	Coordinate with FNAL ND to ensure availability of technical support, investigate technical resources from other lab/university partners	Utilize more students/postdocs in assembly/testing AND incur schedule slip	30%	3	6	9	50	100	150	1 Somewhat Substandard

- Primary risk categories include module/component damage at MATF, longer testing timescale, tech availability issues
- Main impact is A&T schedule slip (+ associated labor costs)

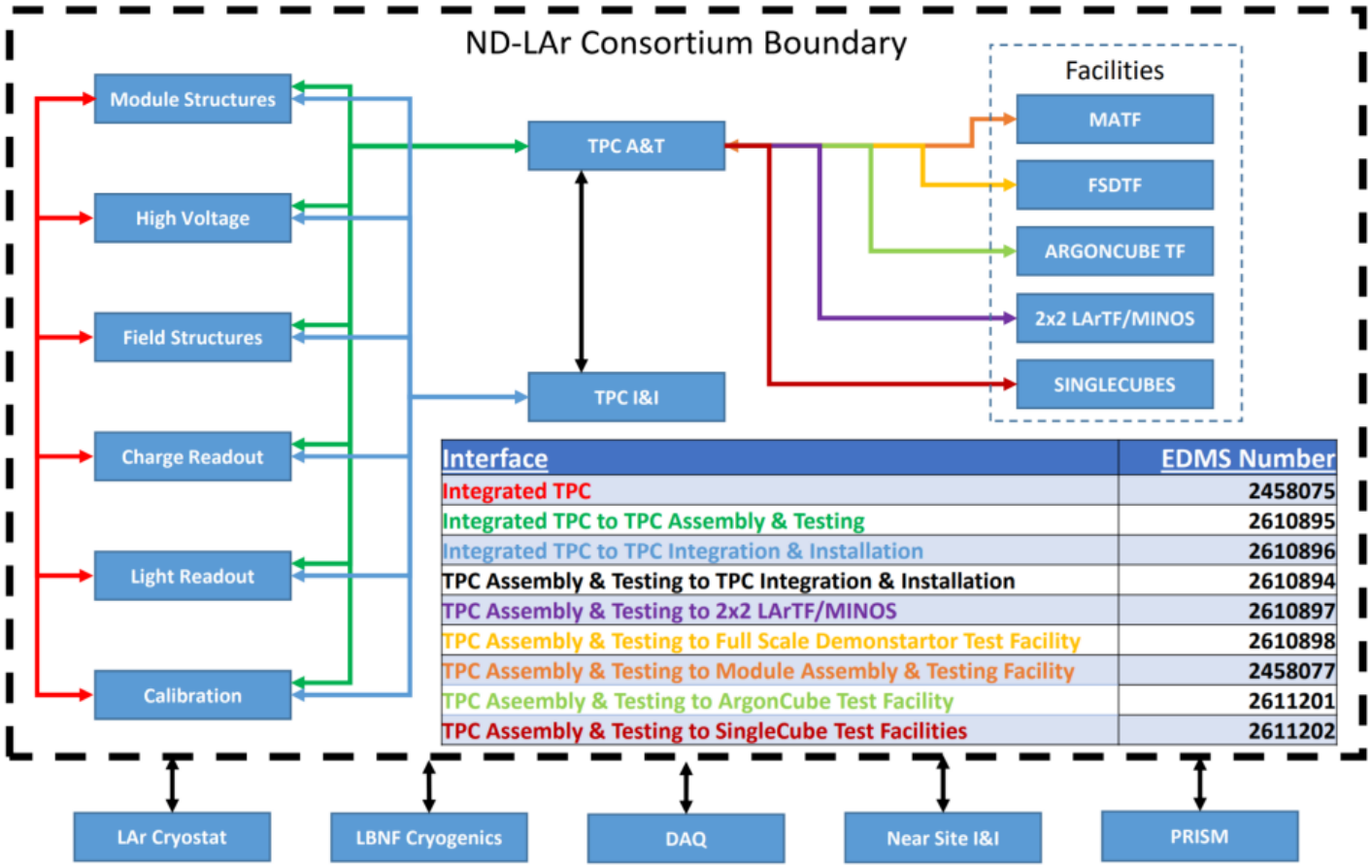
Prototyping Plan

- Prototype tests at 2x2 and FSD will serve as QA for TPC module assembly and testing procedures
  - Also fold in experience from running CSU SingleCube
- Assembly fixtures will undergo QA at CSU prior to use at FSD and MATF
- Further development of assembly procedures at CSU during local QA of assembly fixtures
  - Includes use of TPC module mechanical mock-up
- Physics lid fabricated at CSU but will be sent to SLAC/FNAL for testing w/ cryostat prior to FSD/MATF operations
  - Specifically pressure test for integrated lid assembly
  - Caveat: physics lid may be procured through cryostat vendor (currently investigating option)

BACKUP SLIDES

Interface Documentation

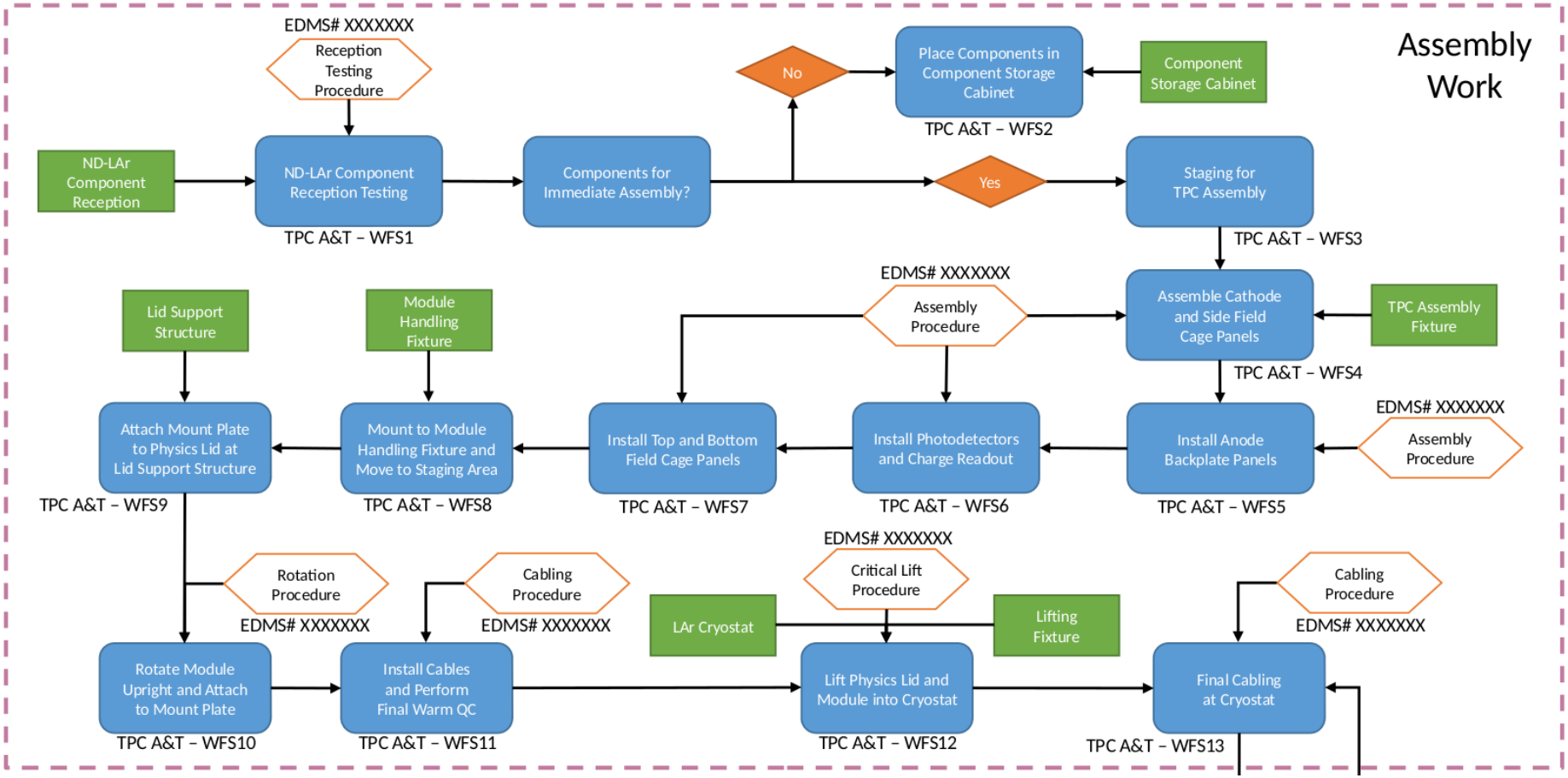
A. Lambert



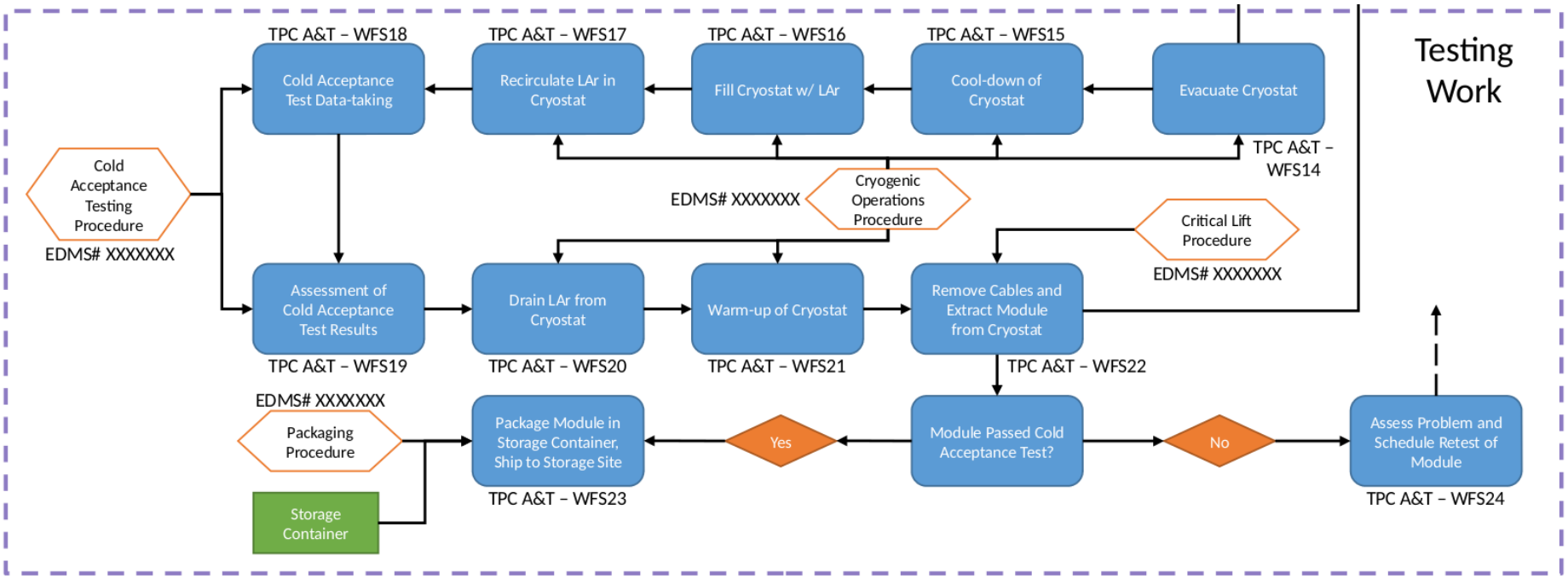
Interface	EDMS Number
Integrated TPC	2458075
Integrated TPC to TPC Assembly & Testing	2610895
Integrated TPC to TPC Integration & Installation	2610896
TPC Assembly & Testing to TPC Integration & Installation	2610894
TPC Assembly & Testing to 2x2 LArTF/MINOS	2610897
TPC Assembly & Testing to Full Scale Demonstartor Test Facility	2610898
TPC Assembly & Testing to Module Assembly & Testing Facility	2458077
TPC Aseembly & Testing to ArgonCube Test Facility	2611201
TPC Assembly & Testing to SingleCube Test Facilities	2611202

Interface Control Document List: ND-LAr External	EDMS #
— ND-LAr Detector to LBNF Cryogenics	2458074
— ND-LAr Dectector to DAQ	2458098
— ND-LAr TPC to LAr Cryostat	2458099
— ND-LAr TPC to Near Site I&I	2450639
— ND-LAr Detector to PRISM	2458097

Assembly Flow



Testing Flow



TPC Module Testing Task Force

Plan for TPC Module A&T

The A&T effort is responsible for coordinating the assembly and testing of the TPC modules. The conceptual design for module assembly is not impacted by recent decisions, but the concept for testing each module in high-purity LAr was not funded by the DUNE-US project. Overall the quality assurance, prototyping, 2x2, and full size demonstrator programs rely as an integral part on testing each module in liquid argon before proceeding to further integration steps (rows) and installation in the cryostat. The DUNE US projects as well as the recent internal design review committee are not convinced of the need of LAr testing, or at least the review was unable to make a vocal statement in favor of this testing plan.

This leaves us with an unacceptable risk (too high, too critical) of at least one module not working properly after installation. This needs to be resolved before going into the PDR. The US project funding decisions and the review points to an insufficient development of the requirements for the testing program, its role in the overall QA/QC, the consequences on the physics program, as well as inadequate risk estimates and mitigations.

To get this effort back on track, we must revisit the QA/QC requirements, including those for the testing of fully-assembled modules. The main questions are:

- What are the major risks for the performance of assembled ND-LAr TPC modules, and what are the consequences should these risks be realized?
- Which of these risks can be mitigated through component testing alone or via a single engineering demonstrator (i.e. FSD), and which ones can only be addressed via direct testing of each production module?
- For those risks that require direct testing of each module, what is the minimally-sufficient test that would retire the risk? Are the resources (personnel, equipment, time) required for such tests commensurate with the risk? Are there alternative QA plans that could replace the test and mitigate these risks?

TPC Module Testing Task Force

(1) We propose that the requirements for TPC Module Testing be revisited by a task force appointed by the ND-LAr Consortium. This task force shall re-evaluate and document TPC testing requirements, with specific focus on testing requirements that must be validated on fully-assembled production TPC Modules. The document should address the specific questions listed above. The task force should consider the overall QA/QC strategy of ND-LAr when assessing the testing (QC). The task force shall deliver this document to the ND-LAr Consortium leadership for review and approval.

(2) After approval of the updated TPC Module Testing Requirements, the appointed task force shall generate and document a conceptual design that meets the approved testing requirements. The task force shall deliver a document detailing this conceptual design to ND-LAr Consortium leadership for review and approval. Note: Consortium Management and Consortium Engineering Meetings may be used as venues for presentation of conceptual design progress. Additionally, the conceptual design must be built in the context of component level QC programs (i.e. what risks are mitigated by component level QC?).

Task Force Members:

- Christopher Mauger (chair)
- Mike Mooney
- Louise Suter
- Saba Parsa
- For the details of the testing setups and possibilities it might be good to involve Geynisman