Detector Support System Cost estimate at Conceptual Design

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DUNE CDR: DSS Review

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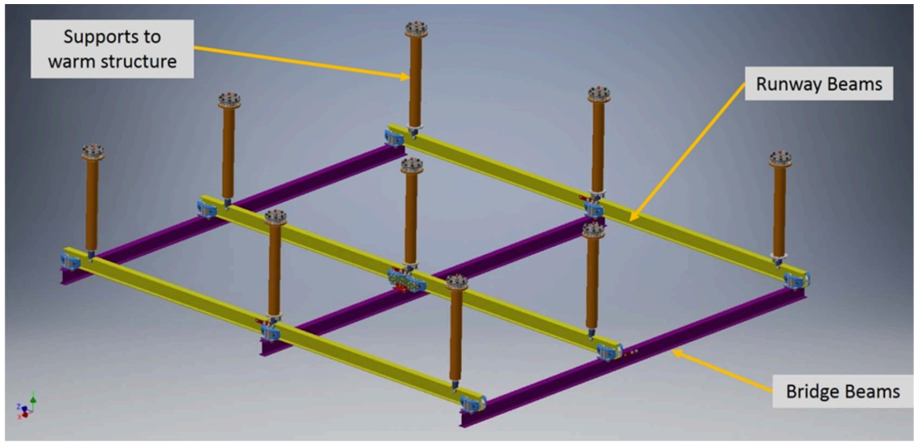
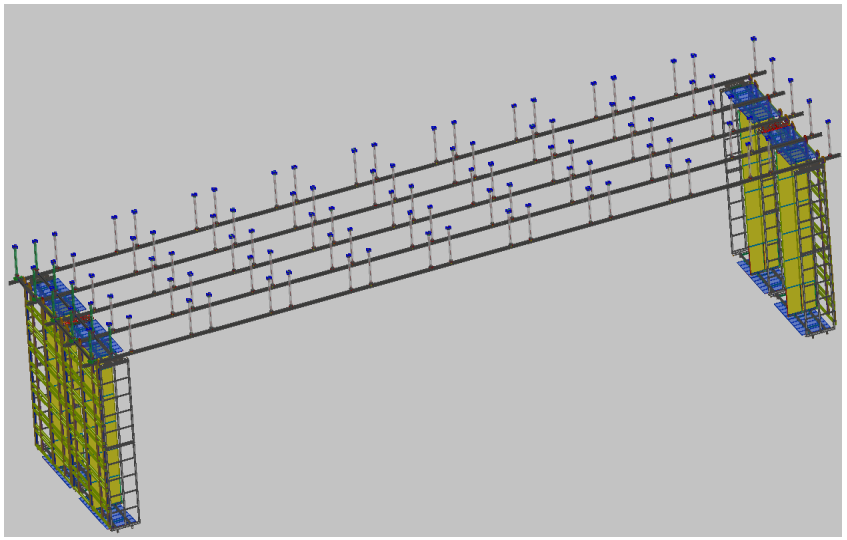
INDICO Agenda
https://indico.fnal.gov/event/17719/other-view?view=standard

Content

- Methodology for the Cost Estimate
- Overview of the Scope
- Estimate Details
  - Support Feedthrus
  - I-Beam supports
  - Switchyard
  - Production Costs
  - Installation Costs

ProtoDUNE-SP and DUNE-SP





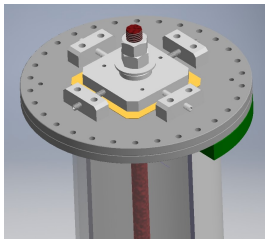
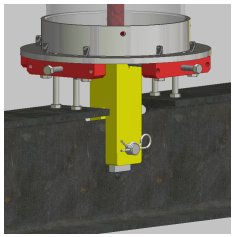
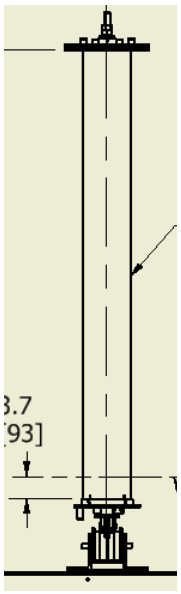
- The ProtoDUNE-SP DSS has many features in common with the DUNE-SP DSS but also many differences.
  - Common: Same type I-Beam, similar load requirements, cryostat roof interface, cleanliness requirements, alignment tolerance.
  - Differences: DUNE has a switchyard, detector height is different, thermal expansion mitigation is different, ProtoDUNE had bridge and runway beams DUNE has only bridge beams, DUNE is bigger.

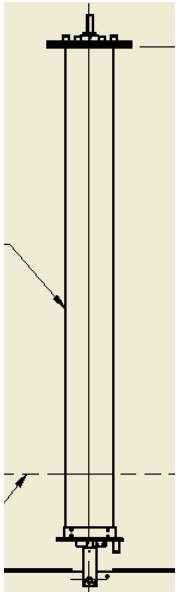
Methodology used for cost estimating

- A cost estimate was generated prior to this conceptual design review based, where possible, on actual cost numbers from ProtoDUNE-SP. I felt that the actual purchase cost of the ProtoDUNE-SP components was more reliable than estimates of components where the design is still evolving.
  - The purchase costs for the ProtoDUNE-SP components were collected.
  - The costs were then scaled by the number of feedthrus or the number of pounds of fabricated I-Beams.
- Activities and equipment where there was not equivalent at ProtoDUNE were estimated based on engineer evaluation.
  - Examples: Installation, assembly QA, I-Beam crawler

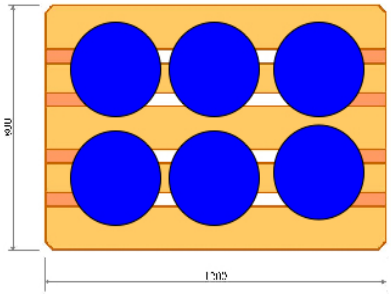
DSS Scope

- 100+5 DSS Supports
- Machined S8x18.4 laser fused I-Beams
  - 45 detector support beams
  - 25 switchyard beams
- Miscellaneous components
  - Trollies, crawlers, I-Beam couplers, switch hardware, end-wall support blocks
- Installation tools underground
- Assembly and testing equipment with shipping crates.





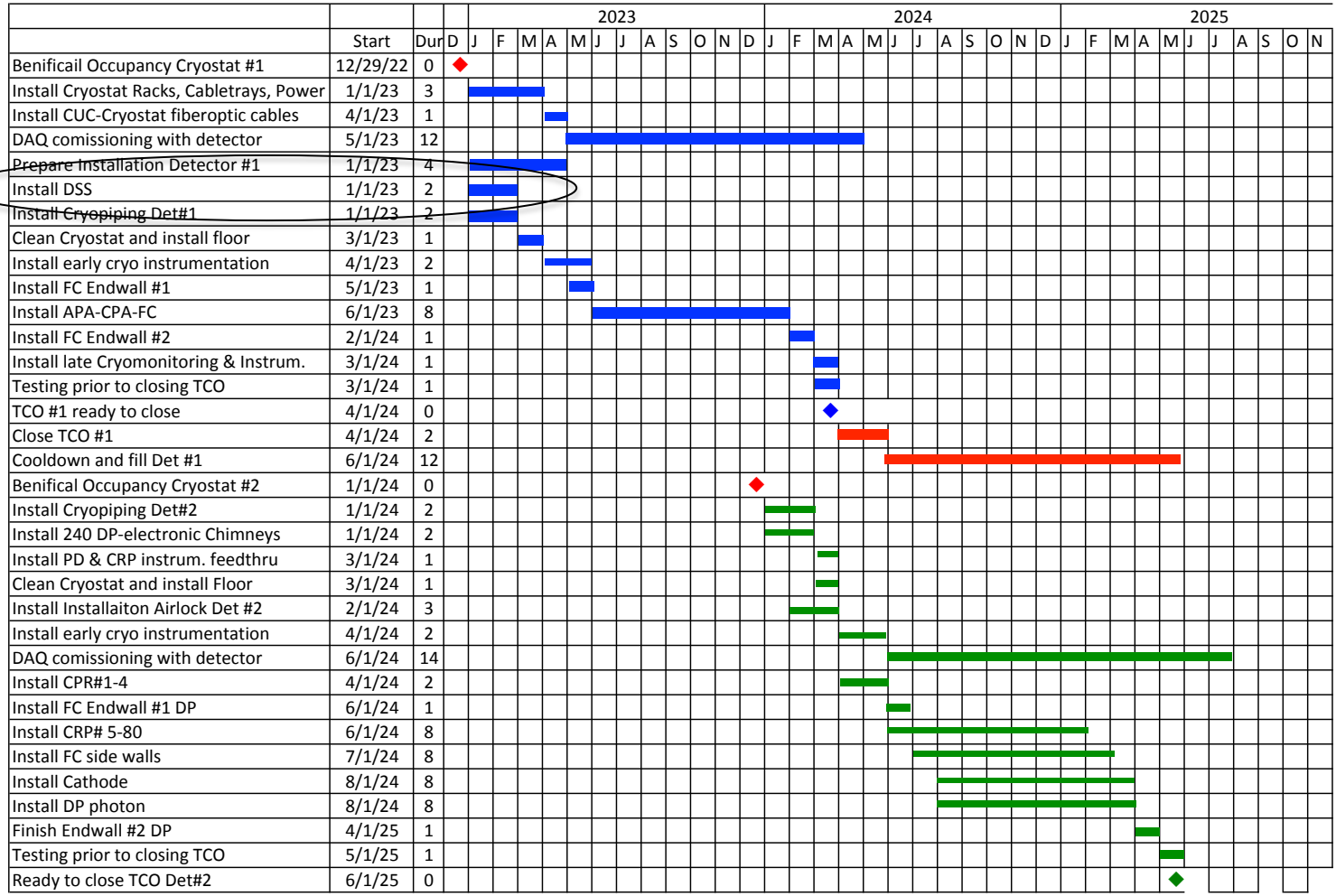


Assumptions used to estimate

- It is assumed that some progress will be made before April but that the preparations for the TDR and various reviews till take a majority of the time. This implies significant engineering and design needs to be done after next April.
- It is assumed that the assembly and testing can be done at the ITF in parallel to other work. No cost is included for the cleanroom for the assembly or the cleanroom outfitting as this is included in the ITF cost.
  - Includes all QA for I-Beams, DSS supports, switchyard components etc.
- It is assumed that an efficiency factor of 0.7 is applied for underground work.
- Work at SURF will be done in 10hr shifts to reduce the impact of non-productive time (getting underground, cleanroom gowning, safety meeting)
- With the present labor estimate the installation can probably be done in 1 shift.

Top Level Schedule

	Start	Dur
Benificail Occupancy Cryostat #1	12/29/22	0
Install Cryostat Racks, Cabletrays, Power	1/1/23	3
Install CUC-Cryostat fiberoptic cables	4/1/23	1
DAQ comissioning with detector	5/1/23	12
~~Prepare Installation Detector #1~~	1/1/23	4
Install DSS	1/1/23	2
~~Install Cryopiping Det#1~~	1/1/23	2
Clean Cryostat and install floor	3/1/23	1
Install early cryo instrumentation	4/1/23	2
Install FC Endwall #1	5/1/23	1
Install APA-CPA-FC	6/1/23	8
Install FC Endwall #2	2/1/24	1
Install late Cryomonitoring & Instrum.	3/1/24	1
Testing prior to closing TCO	3/1/24	1
TCO #1 ready to close	4/1/24	0
Close TCO #1	4/1/24	2
Cooldown and fill Det #1	6/1/24	12
Benifical Occupancy Cryostat #2	1/1/24	0
Install Cryopiping Det#2	1/1/24	2
Install 240 DP-electronic Chimneys	1/1/24	2
Install PD & CRP instrum. feedthru	3/1/24	1
Clean Cryostat and install Floor	3/1/24	1
Install Installaiton Airlock Det #2	2/1/24	3
Install early cryo instrumentation	4/1/24	2
DAQ comissioning with detector	6/1/24	14
Install CPR#1-4	4/1/24	2
Install FC Endwall #1 DP	6/1/24	1
Install CRP# 5-80	6/1/24	8
Install FC side walls	7/1/24	8
Install Cathode	8/1/24	8
Install DP photon	8/1/24	8
Finish Endwall #2 DP	4/1/25	1
Testing prior to closing TCO	5/1/25	1
Ready to close TCO Det#2	6/1/25	0



- April 2019 to Jan 2022 is available for Post-TDR design effort.
- One year is assumed to purchase all the components assemble and test them.
- DSS will be installed in ~2 months early 2023
  - DSS is critical path so we will want to be working in more than one location

Cost Estimate

- The cost estimate was generated so the data can be easily used for the DUNE Neutrino Cost committee review. This meant that the design costs were estimated in a separate spreadsheet from the production and installation spreadsheet.
- Only the costs after the TDR submittal in April were estimated.
- Materials costs were estimated as direct costs so no overheads or escalation are applies.
- Labor hours by skill set are estimated but no cost is derived from this.
- Contingency was computed, but it is unclear if it will be used.
- The cost estimate is stored in DocDB 9453
  - BOE 2.1.3 Design xlsx
  - BOE 2.1.4.1 DSS Production xlsx

Cost files on DocDB

DUNE Cost Book: SP-TC (WBS 2.1)

Document #:
DUNE-doc-9453-v6
Document type:
DUNE document
Submitted by:
Steve Kettell
Updated by:
Jim Stewart
Document Created:
13 Jul 2018, 12:07
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15 Aug 2018, 13:46

Username:

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Watch Document

Abstract:
DUNE Cost Book for the DUNE single phase technical coordination

Files in Document:

- BOE 2.1.1 management xlsx (BOE_2.1.1_management-v4.xlsx, 1.8 MB)
- BOE 2.1.3 Design xlsx (BOE_2.1.3_design_worksheet-v3.xlsx, 235.6 kB)
- BOE 2.1.4.1 DSS Production xlsx (BOE_2.1.4.1_DSS_Production_Worksheet-v2.xlsx, 3.4 MB)
- BOE 2.1.4.2 SP Detector Infrastructure Production xlsx (BOE_2.1.4.2-SP_Detector_Infrastructure_Production_v2.xlsx, 8.0 MB)
- BOE 2.1.4.3 Common Detector Infrastructure production xlsx (BOE_2.1.4.3_Common_Infrastructure_Production_v2.xlsx, 7.3 MB)
- BOE 2.1.5.1 ITF production xlsx (BOE_2.1.5.1_ITF_Prod_worksheet-v3.xlsx, 6.6 MB)
- BOE 2.1.5.2 Installation Production xlsx (BOE_2.1.5.2_Installation_Production-v3.xlsx, 23.6 MB)
- BOE 2.1.6 ITF execution xlsx (BOE 2.1.6 SP Integration Execution.xlsx, 92.3 kB)
- BOE 2.1.7 SP Detector Installation Execution xlsx (BOE_2.1.7_SP Detector Installationv2.xlsx, 109.1 kB)
- Future To-Do list (BOE-ToDO-List-v9.xlsx, 44.4 kB)
- Labor Overview spreadsheet (WBS-2.1 Technical Coordination (SP-DP TPC)v7.xlsx, 248.2 kB)
- TC WBS with Cost Estimates (DUNE TC WBS.xlsx, 0 bytes)

Get all files as tar.gz, zip.

Design Cost Estimate

- Design spreadsheet has only one line for DSS design cost

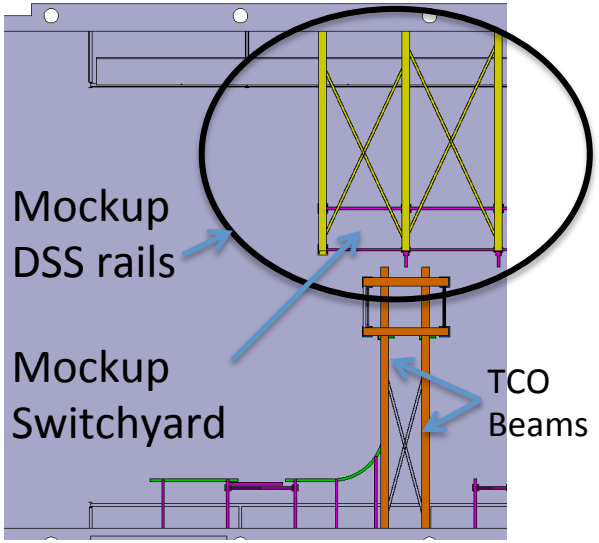
	Duration	Direct Cost	Engineer		Designer		Technician		Scientist	
Deliverable	months	$	hours	Man Month	hours	Man Month	hours	Man Month	hours	Man Month
SP-DSS	32	$50,000	1760	12	1760	12	440	3		

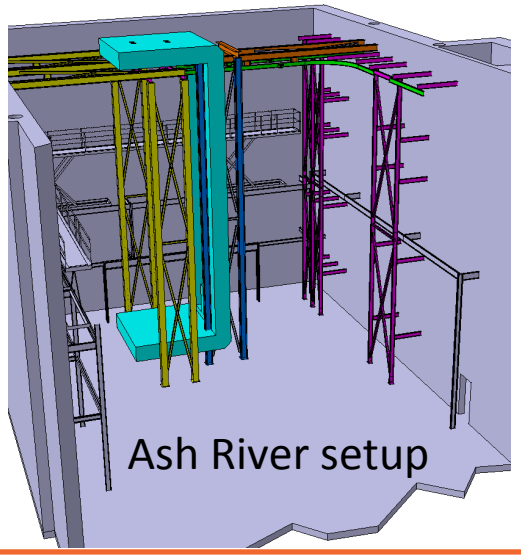
Scope
The SP-DSS will be in preliminary design at the time of the TDR. It is expected that draft 2-D drawings will exist but not all the interfaces will be completely designed. The design will be sufficiently advanced to allow the AR phase-I prototype to progress. In this design phase the engineering design will be complete and a partial prototype of the switchyard designed and constructed for the Phase-I AR test. After this test the designs will be revised based on the results of the testing and final drawings, analysis, procedures, and safety documents generated.

- Roughly 6 mo of Engineer and designer with a small amount of technician time have been needed to bring the design to the present status.
- Extrapolating from this 12 months of engineer and designer will be needed to finish the design.
- Final design will include: 3-D model, all approved 2-D drawings with tolerances, QA plan and testing procedures, bid packages for all high value items, detailed installation plan with procedures.
- Description of the prototype ($50k + 3mo tech) is on the next slide.

DSS prototyping and Ash River Test

- A small prototype of the switchyard and rails will be constructed at ANL to de-bug the switches and insure the safety aspects are understood. This will be build close to the ground and all motions with full loads will be tested.
- When successful this will be transported to ash river where it will form part of a larger installation test.





DSS Production Cost

- The basis of estimate workbook is divided into a summary tab and 5 sub categories.
  - Summary
  - DSS Production
  - Support M&S
  - I-Beam M&S
  - Misc. M&S
  - DSS Installation
- The estimates for the support feedthrus, the I-Beams, and the miscellaneous equipment are for M&S only.
- DSS Production covers the labor estimate to produce the DSS and all the equipment related to the production and testing.
- DSS installation covers the labor for the DSS installation

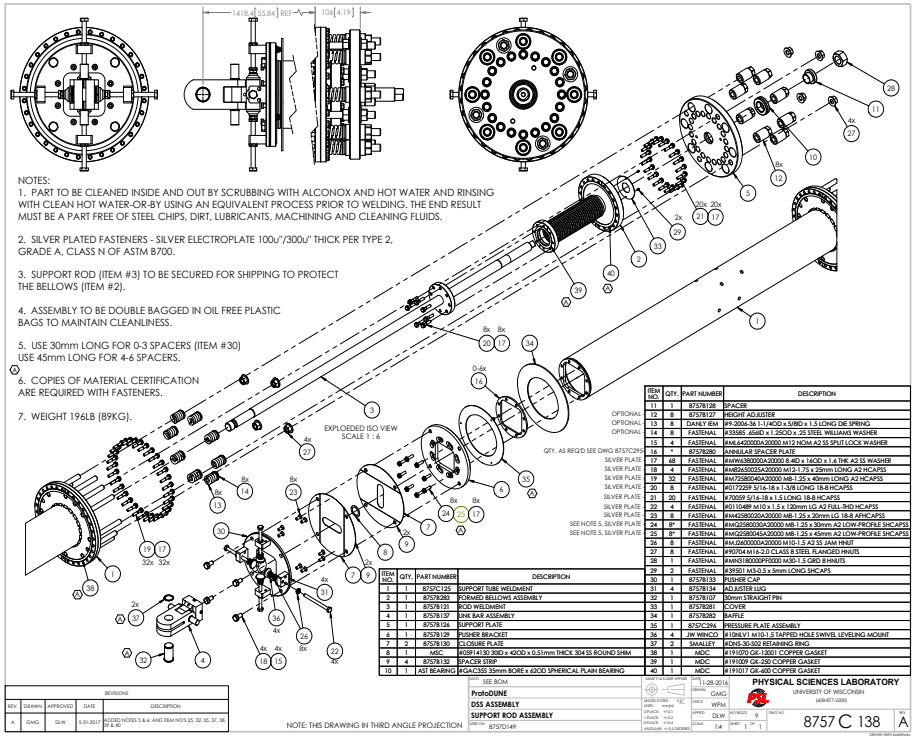
Summary of M&S direct cost

Material costs	M&S Direct Cost	AVG Contingency	Cost with Contingency
DSS Production	$92,226	26%	$116,585
Support M&S	$1,002,566	20%	$1,203,080
I-Beam M&S	$127,187	20%	$152,625
Misc. M&S	$284,832	25%	$357,167
DSS Installation			
Total M&S	**$1,414,586**	21%	**$1,712,872**

The materials cost is dominated by the 105 support feedthrus

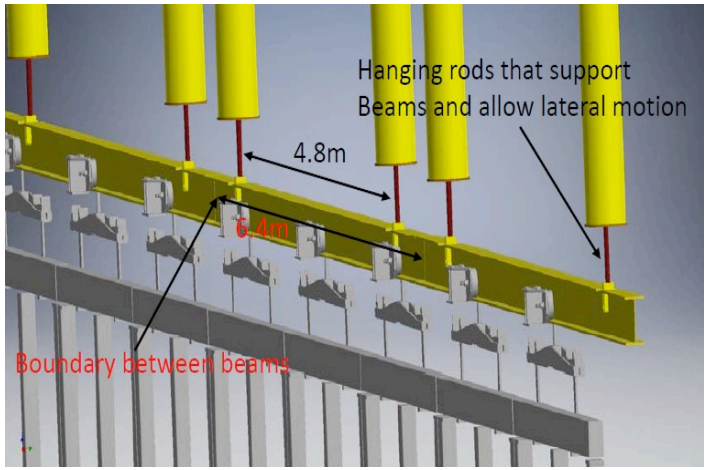
Support Feedthru Cost

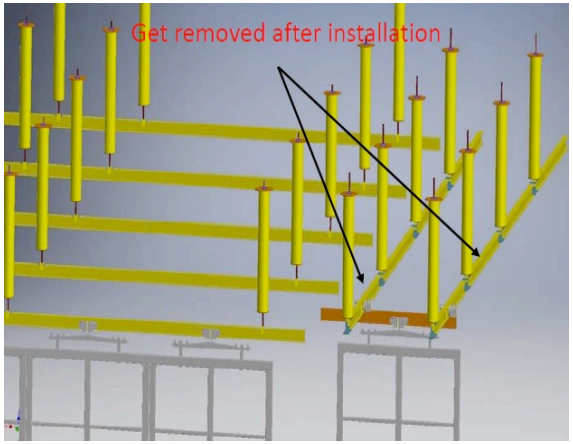
- The cost is computed by calculating the unit cost of the ProtoDUNE-SP feedthru and then scaling to the 105 DUNE-SP feedthru
- The BOM for the used and the cost for each significant part was documented based on the actual purchase
  - I had to estimate the cost of one support plate -> 2k
  - The cost per feedthru was $9548
  - Scaling with the total number of feedthrus of 105 gives the total cost.
  - Total = $1,002,566



I-Beam Cost

- The quote PSL had for the I-Beams gave a cost per pound for the fabricated S-8 x 18.4 laser fused I-Beams
  - Cost per pound = $6.40
  - The beams weigh 18 lb per ft
- The cost per beam is then calculated from the length of beams from the model.





Part Description	Beam length m	Beam length ft.	Beam weight lb./ ft.	Unit Cost $/lb.	Number of Beams	Cost per I-Beam	Cost per detector
APA/CPA support beams S8x18.4	6.4	20.9984	18	6.4	45	$2,419	$108,856
Switchyard Shuttle beams S8x18.4	2.3	7.5463	18	6.4	5	$869	$4,347
Switchyard runway beams	3.5	11.4835	18	6.4	10	$1,323	$13,229
Switchyard shuttle support stubs	0.2	0.6562	18	6.4	10	$76	$756
				I-Beam Total Cost			**$127,187**

More recent quotes confirm these estimates.

Cost of miscellaneous items

Part Description	Unit Cost	Quantity	Cost per detector	Contingency	Contingency Cost
TCO transfer rail			$8,500	30%	$11,050
Trollies	$885	8	$7,080	25%	$8,850
Beam Crawlers	$3,700	8	$29,600	25%	$37,000
Switchyard locks and controls			$15,000	25%	$18,750
Rail to CPA coupler	$335	100	$50,000	25%	$62,500
Rail to APA coupler	$335	75	$50,000	25%	$62,500
Tools to install the feedthrus			$3,500	30%	$4,550
Tools to install the DSS Beams			$8,500	30%	$11,050
Endwall support blocks	$2,500	16	$40,000	40%	$56,000
Survey targets			$800	10%	$880
DSS installation tool	$50,000	1	$50,000	20%	$60,000
Gantry Crane - assembly	$1,911	2	$3,822	10%	$4,204
Curtained cleanroom	$9,015	2	$18,030	10%	$19,833
		Total	**$284,832**	25%	$357,167

Estimates are a mix of experience from ProtoDUNE, Engineering estimate, and Quotes

Production equipment

Component	Manufacturer	Part Number	quantity	unit cost	cost	
leak detector	Pfeiffer	ASM 380	1	$50,000	$50,000	Evacuate 1 m^3 in few minutes
Tooling for acceptance testing					$10,000	
Vacuum Vessel to test support feedthrus			1	$5,000	$5,000	
Shipping/storage rigs for the feedthrus			17	$500	$8,500	
Al Pallets	Uline	H_4062	20	$309	$6,180	Quote
Shipping crates for the I-Beams			12	$1,000	$12,000	
Company Site visits			0	$2,000	$0	
Work Benches	McMaster Carr		3	$182	$546	Quote
Ultrasonic cleaner			1		$24,000	Web search -will be custom
Shrink-wrap and dispenser	Amazon		1	$300	$300	
				Total	**$92,226**	

- Material needed to assemble test and ship the feedthrus underground

1760hr = 1FTE yr

Labor Estimate Production

- During the year where all the parts are ordered assembled, tested, and prepared for shipment underground ½ FTE of engineering is budgeted.
- Technician activities are:

Component	Action	hours	Number of units	Productive hours
DSS I-Beams	Acceptance Testing	1	70	70
DSS Support Feedthrus	Component acceptance testing	1	105	105
DSS Support Feedthrus	Cleaning, Assembly and testing, bagging	12	105	1260
Assemble Support storage shipping racks	Assembly	2	18	36
Crate I-Beams for transport	Crate Assembly	8	12	96
Assemble gantry crane and assembly area for support feed thru assembly	Crane Assembly	20	1	20
DSS support installation tool	Construct and test	100	1	100
Acceptance testing of Misc. Parts	Acceptance Testing	100	1	100
			Total	**1787**

1 FTE of technician

Installation Labor

Efficiency factor accounts for time getting underground, gowning, breaks, lunch …

		Hours per Unit		Total Productive Hours			Total Hours	
Task	Unit	Eng. Hours	Tech Hours	Eng. Hours	Tech Hours	Efficiency Factor	Eng. Hours	Tech Hours
Locate feedthroughs on cryostat	100	0.5	2	50	200	0.7	71	286
Bolt feedthrough flange/align	100		1	0	100	0.7	0	143
Leak Testing	100		1		100	0.7	0	143
Move I-beams into cryostat	50	0.5	2.5	25	125	0.7	36	179
Setup tripod/gantry and beam lifting cable	50	0.5	5	25	250	0.7	36	357
Lift beam and attach to clevis	50	0.5	8	25	400	0.7	36	571
Align and Fix Beam	50	1	8	50	400	0.7	71	571
Survey and Adjust position						0.7		
Move N-S Shuttle support beams into cryostat	10		2	0	20	0.7	0	29
Setup tripod and lifting cable for shuttle beam	10	0.5	5	5	50	0.7	7	71
Lift and mount shuttle support beams	10	0.5	8	5	80	0.7	7	114
Align Shuttle support beams	10	0.5	4	5	40	0.7	7	57
Mount shuttle beams	5	1	8	5	40	0.7	7	57
Mount shuttle beam electric and controls	1	10	120	10	120	0.7	14	171
Total				**205**	**1925**		**293**	**2750**

- 9 technicians working 2 months for the installation of 100 support feedthru and 70 I-Beam sections.
- One full time engineer overseeing the work
- Not shown but also 6 surveyors working one shift during this period.

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DSS Installation			
Total M&S	**$1,414,586**	**21%**	**$1,712,872**

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Next steps

- When the drawings are sufficiently advanced we will seek quotes based on the DUNE drawings.
  - Quotes will be at the part level.
- Assembly, testing, and installation procedures need developed in detail.
  - When the procedures are in draft form the labor estimate needs to be revised.
- Design work on tooling is needed to refine these costs.
- Need to understand the cryostat installation plan to see if we can optimize the joint installation.
  - Will the cryostat have scaffolding in place that would simplify the DSS installation?
  - Can we install the support feedthru before the cryostat installation is finished?

Summary

- The material costs are reasonably well understood for this stage of the design thanks to the detailed information from ProtoDUNE-SP.
- A first pass over the labor estimate is complete.
  - Input from this committee is greatly appreciated.
- It is planned to revise the cost estimate based on DUNE-SP drawings after this review is complete.