

Cost & Schedule

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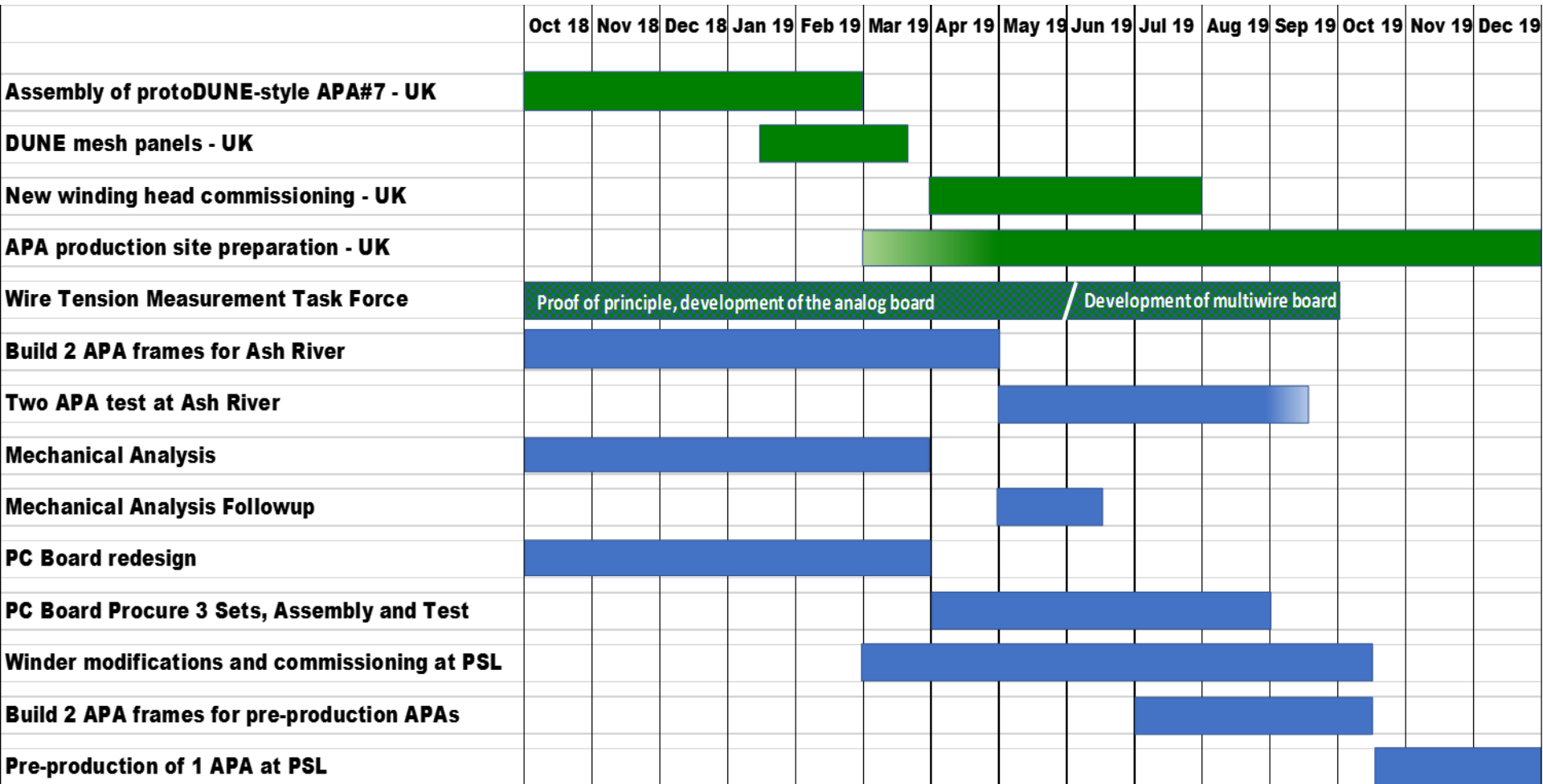
APA 60% Design Review

March 27, 2019

Outline

- Prototype schedule
 - Frames, mesh panels & boards
 - New winding head
 - Board for electrical wire tension method
- Pre-production APAs for integration test and as “module 0” for protoDUNE phase II
- APA production time and labor resources
- APA production plan
- Cost for APA production

Prototype Activities in 2019



Pre-production APAs

- In US, 1 APA built at PSL in the Fall 2019, to be shipped to CERN for integration test with PD and CE
 - Integration test to be completed by first half of 2020
- In UK, the plan is to build two (possibly four) APAs starting summer of 2020 that will then be shipped via the new custom shipping container to CERN
 - UK APA production planned to start July 2020
- In US, presently 1 additional APA built at Yale or Chicago to be shipped to CERN late 2020
- 3 pre-production APAs to be used as “module 0” in protoDUNE phase II (~Spring 2021)

2019 Engineering resources

US

FY19 APA Engineering Effort (hrs)	ME	EE	CAD	Tech
PSL_Two APA test at Ash River				
DOE				
NSF	600		225	
PSL_Build two APA frames for Ash River				
DOE	20			180
NSF	100		75	
PSL_Build two APA frames for integration test				
DOE	20			180
NSF	50			
PSL_Production planning				
DOE		225		
NSF	150		120	
PSL_Mechanical Analysis				
DOE	600			
PSL_Mechanical Analysis Followup				
DOE	200			
PSL_PC Board redesign and procure 3 sets				
DOE		750	450	
PSL_PC board assembly and test				
DOE		72		1200
PSL_Tooling and Process Improvements				
DOE		300		500
NSF	450			
PSL_Winder Modifications & commissioning				
DOE		450		600
NSF	450		300	

UK

Effort available at Daresbury from now until the end of September for pre-construction work, after which it will transition to DUNE construction project

Alan Grant 0.5FTE

Design Engineer 0.7FTE

Technician Engineer 0.7FTE

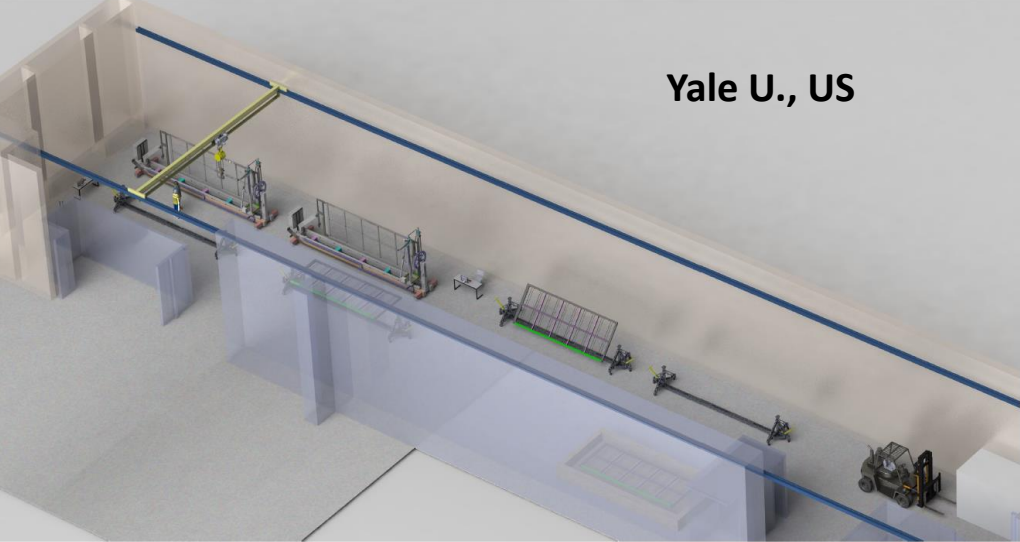
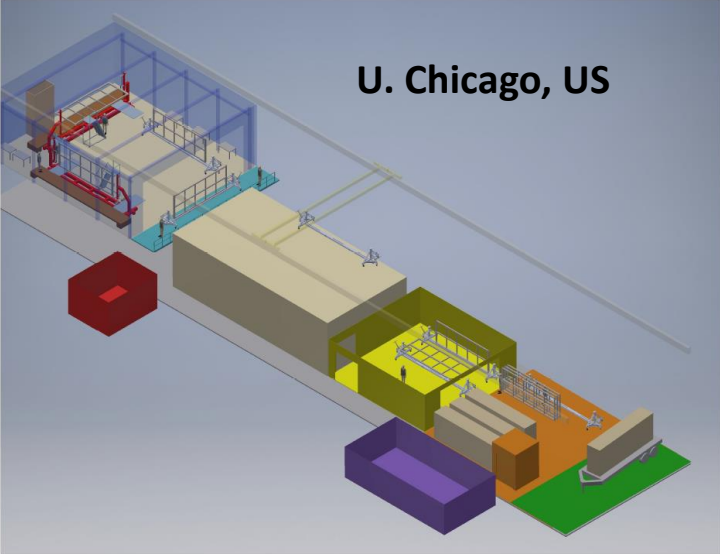
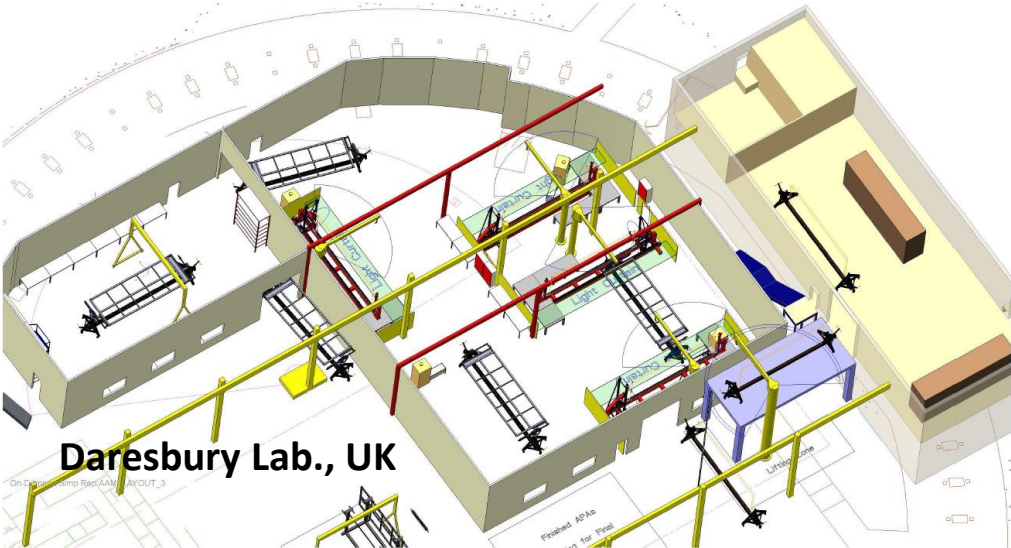
APA Assembly shift summary

DUNE FD	TASK	Calendar		
		DAYS >>	UK	US
		Hrs ↓	Shifts ↓	Shifts ↓
	<i>Frame Prep</i>	4	1	1
	<i>Photo Detector Rails</i>	4		
	Mesh Installation (new attachment method)	6		
	ALL (8) comb bases Assemblies (Tooling X 2)	24	4.25	3.5
	Remedial comb (epoxy) work, install X-boards	4		
	Transfer to Winder	1		
	Wind x-layer	24		
	x-layer Tape / Soldering / Trim Wires	6	5.63	6
	x-layer Tension tests / retensioning	8		
	x-layer electrical tests	6		
	v-layer combs and boards, side A	10		
	v-layer combs and boards, side B	10		
	Wind v-layer	34	11.5	12
	v-layer Tape / Soldering / Trim Wires	8		
	v-layer Tension tests / retensioning	24		
	v-layer Electrical tests	6		
	u-layer combs and boards, side A	10		
	u-layer combs and boards, side B	10		
	Wind u-layer	34	11.5	12.5
	u-layer Tape / Soldering / Trim Wires	8		
	u-layer Tension tests / retensioning	24		
	u-layer Electrical tests	6		
	g-layer combs and boards, side A	10		
	g-layer combs and boards, side B	10		
	Wind g-layer	24	8	7
	g-layer Tape / Soldering / Trim Wires	6		
	g-layer Tension tests / retensioning	8		
	g-layer Electrical tests	6		
	Move to Process Cart	1		
	Fit Tees	4		
	Install (2) Harnesses & SHV board	6		
	Install G bias boards	6		
	Install CR boards	6		
	Head cover boards side B, comb covers, cover boards side beam and foot	14	6.5	6.5
	Swap interface frame - foot	1		
	Head cover boards side A, comb covers, cover boards other side beam and foot	14		
	CE Fastener Hardware (Check & Pack to Ship)			
	Adapter Bds (Check & Pack to Ship)			
	Install APA protection panels	4	1.25	1.5
	Transfer to transport box (Crate)	6		
			49.6	50

APA Production Resources

- Using an improved wiring machine and two process carts to parallelize pre- and post-wiring processing the wall clock time required is **40 shifts/APA**
- Resources per winding station:
 - 0.5 FTE research physicist/senior postdoc (Production manager)
 - 0.5 FTE postdoc (responsible for QA/QC, at least for a 6 month period)
 - 1 student (Assembler/operator, 6 months periods)
 - 1 FTE engineer (winder maintenance: mechanical, electrical, controls)
 - 2.5 professional technicians (at least one professional solder, one with crane operation certification, material handling)

APA Production sites layout



APA Production Plan

- UK starts APA production July 2020, site preparation well underway
- In US
 - Planning of APA production sites in 2019
 - Winders production in 2020 (2 @ Yale, 2 @ Chicago with help from PSL)
 - Start APA production Jan 2021
- Hold individual APA Production Site Design Reviews in summer 2019 to assess space layout, crane equipment, safety procedures, staffing plan (APA Consortium internal reviews)
- Hold individual Production Readiness Reviews for each APA production Site (external reviews)

APA Production

☐ Production of APAs for Detector #1

- US-APA production (76 APAs): Jan 4, 2021 – Dec 7, 2023
- UK-APA production (76 APAs): Jul 6, 2020 – Nov 6, 2023

APA Production/year

Production Site	2020	2021	2022	2023
Daresbury	6	24	26	20
Yale		10	13	7
Chicago		10	13	7
PSL		3	7	6
TOT	6	47	59	40

☐ Production of APAs for Detector #2

- US-APA production (76 APAs): Jul 5 2023 - Jun 26, 2026
- UK-APA production (76 APAs): Aug 14, 2023 - Nov 16, 2026

APA Production Cost

- **Production Setup**, fabrication of all tooling necessary for APA assembly
 - Fabrication of 8 additional winders and 18 additional process carts
 - Fabrication of jigs & tooling for each winder
- **APA Components Production**, it includes procurement, fabrication and inspection of all APA components (for 152 APAs for each 10 kt detectors & spare boards)
 - Frames and mesh panels
 - X, V, U, G boards, CR boards, adapter boards, G-bias boards, SHV boards and cable harness
 - Combs, wire, solder & epoxy, electron diverters, CE brackets and tees, yokes, 2-APA linkages
 - Fabrication of shipping boxes (2 APAs/box)
- **APA Assembly**, it includes setting production sites, manpower resources for the assembly of APAs, and shipping costs to SURF

APA cost summary (production of 1 detector)

WBS Element name	WBS dictionary	M&S	Engineer	Designer	Technician	Student	Grad Student	Post-Doc	Lab Research Staff
DUNE									
Single-Phase Far Detector									
Anode Plane Assembly (SP-APA) I	This includes all activities for 152 APAs for the first 10 kton detector module: Management, Physics and Simulations, Design, Engineering and R&D, Production Setup, Production, Integration, and Installation.	13,784,081	72,300	-	206,010	19,360	51,520	25,040	25,040
Production Setup	It includes the fabrication of all tooling necessary for APA assembly and database software for APA manufacturing and assembly.	1,638,142	13,642	-	4,032	7,200	1,440	-	-
Winder	It includes fabrication of 8 additional winders	747,440	13200		3600	7200			
Process cart	It includes fabrication of 18 process carts (2/winder)	367,200			432		1440		
Jigs and test hardware	It includes fabrication for 7 additional winders	523,502							
Production planning	It includes reviews of production procedures & documentation, and implementation of database for tracking APA componenets to factories and APA assemblies to ITF		442						
Production	It includes procurement and fabrication of all APA components, setup of factories and assembly lines, and production of APA assemblies with associated manpower resources.	12,145,939	58,658	-	201,978	12,160	50,080	25,040	25,040
APA Components Production	It includes procurement, fabrication and inspection of all APA components (for 152 APAs & spare boards)	10,728,977	3,848	-	74,528	12,160	-	-	-
APA Assembly	It includes a list of all factories in US and UK with associated assembly lines and detailed production schedules. It details manpower resources for setting up production lines and for production of APA assemblies. It includes a detailed shipping sequence from factories to SURF.	1,416,962	54,810	-	127,450	-	50,080	25,040	25,040

APA Components cost (production of 1 detector)

WBS Element name	WBS dictionary	M&S	Engineer	Designer	Technician	Student	Grad Student	Post-Doc
APA Components Production	It includes procurement, fabrication and inspection of all APA components (for 152 APAs & spare boards)	10,728,977	3,848	-	74,528	12,160	-	-
Frames	Production of 152 frames	2,860,336			12160	12160		
Mesh	Production of mesh panels for 152 APAs	578,968						
Wire	Purchase of wire for 154 APAs	92,928						
Combs	Production of combs for 154 APAs	427,966						
X Layer Boards (head and foot)	Production for 154 APAs, purchase 10% more material	334,527	308		7700			
V Layer Boards (head, side, and foot)	Production for 154 APAs, purchase 10% more material	595,901	308		13151.6			
U Layer Boards (head, side, and foot)	Production for 154 APAs, purchase 10% more material	622,820	308		12628			
G Layer Boards (head and foot)	Production for 154 APAs, purchase 10% more material	326,207	308		4096.4			
Cover boards	Production for 154 APAs, purchase 10% more material	155,663			924			
CR Boards	Production for 154 APAs, purchase 10% more material	984,808	1232		10780			
G-bias boards	Production for 154 APAs, purchase 10% more	138,442	308		4620			
Adapter (Interface) Boards	Production for 154 APAs, purchase 10% more	278,221	308		4620			
SHV Boards & Cable Harness	Production for 154 APAs, purchase 10% more	76,076	616		3696			
Solder & Epoxy	Production for 154 APAs	185,470						
Electron diverters	Production for 154 APAs	112,420						
CE boxes brackets (tees)	Production for 152 APAs	1,088,320						
Support hardware (yoke)	Production for 152/2 APAs	279,984	152		152			
2-APA linkage	Production for 152/2 APAs	69,920						
Shipping Boxes	It includes fabrication of 76 shipping boxes (2 APAs/box)	1,520,000						