#### Installation schedule and labor estimates

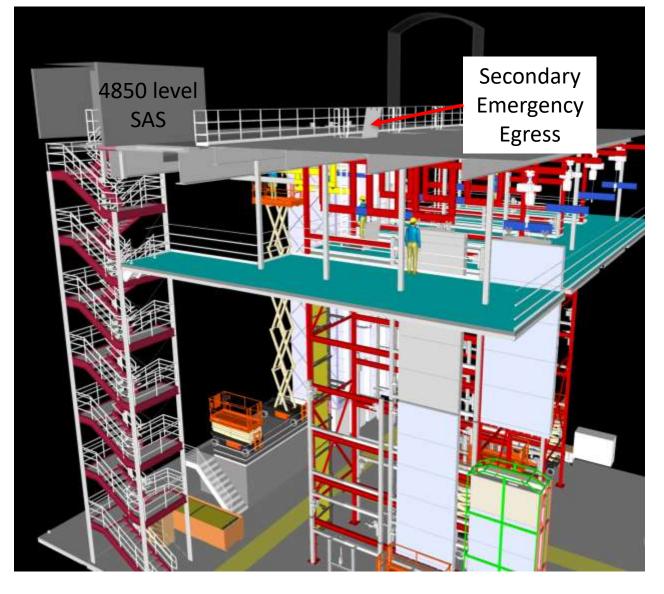
Task	Group	Month	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	1	4	7	10	13	16	19	22	25	28	31	34	37	40	43	46	49	51	54	57	60	64	67	70
Logistics Facility	DUNE										LF in	fra										Log	istics	Facil	ty Op	erati	ons	- 70							/	
Excavation Cavern #1	CF	41					N	orth	Cave	m & (	CUC I	BSI	BSI																							
Excavation Cavern #3	CF	20									So	uth	Cave	rn		BSI																				
Install Warm Dec #1	CERN	15												W	arm/	1																				
CUC Infrastruc and DAQ	DUNE	20												CUC	nfra		DA	4Q																		
Install Cold Dec #1	GTT	12																Co	old St	uct.	#1															
Det #1 Installation Setup	DUNE	13										_						Det	#1 Se	tup																
Assembly SP Dec #1	DUNE	10																				De	etecto	or #1	SP											
TCO Closing	CERN	2																							TCO											
Complete Detector #1	DUNE	3																																		
Purge/Fill Dec #1	CERN	18																									Pur									
Install Warm Dec #2	CERN	9										_						V	Varm	1									Fill D	et #1						
Install Cold Dec #2	GTT	12																				Co	old St	ruct.	#2											
Det #2 Installation Setup	DUNE	12										_										D	et #2	Setu	р											
Assembly Dec DP #2	DUNE	10										_														D	etec	tor#2								
TCO Closing	CERN	2										_																	TCO							
Complete Detector #2	DUNE	3																																		
Purge/Fill Dec #2	CERN	20										_																			Pur	-	Fill D	et #2	2	
Install Cryo Equipment	CERN	36						19150													ryoge		-	latio	n											
				PFG	IP GAL	994		_	_	_	mba						er sh	ft-A	sum	2.51	lift's p	er di	BY .													
CF-Day			80	80	80	80	80	80			80			-	110/3-00	40																				
CF-Night			70	70	70	70	70	70	70	70	70	55			55	35															-				-	
LBNF/CERN-Warm-Day				-	-	-		-	-	_		-	25	25			25			25	20	-				-		-		-	-				-	
LBNF/CERN-Warm-Night												-	25	25	25	25	25	25	25	25	15	and Name		5000	1900				2/2/2							
GTT-Cold-Day											$\vdash$	-		-		40	10	-	25	25	25	-	25	25	25		70		10			-				
LBNF/CERN-Cryo				-									20	20	20	10	10	20	20	20	20	20	20	20	20	20	20	4	4	4	4	4	4	4	4	4
1&I-Underground Day				-							-	11	29		29	29	46	46	46	46	46	46	46	46	46	46	46	46	46	46	27	27	27	27	27	27
I&I-Underground Night												11	29	29	29	29	46	46	46	46	46	46	46	46	46	46	46	46	46	46	27	27	27	27	27	27
DUNE-Consortia-Day												-				5	5	5	10	10	36	36	36	36	36	36	36	36	36	36	30	20	20	5	5	5
DUNE Consortia-Night			40	15	45	10	15	15	15	40	40	20	20	20	20	20	20	5	10	10	35	35	35	35	35	35	35	35	35	35	30	20	20	5	30	20
SURF-Day			15	15	15	15	15	15	15	15		20	20 10	_	20	20	20 10	20	20	20	20	20	20	20 10	20	20	20	20	20	20	20	20	20	20	20	20
SURF-Night	ar Davi	chite	5	20.00	5	5	5	5	5	5		10	1000		10	10		10	10	10	10	10	10		10	10	10	10	10	10	10	10	10	10	10	10
Total FTEs Underground p	er Day	Shirt	95	95	95	95	95	95	95	95	95	86	129	129	129	129	100	141	146	146	100	100	146	146	146	121	121	105	115	105	81	71	71	56	56	56

## Cleanroom Design

As we continue to test mechanical installation procedures at Ash River, we have modified the cleanroom design. Major changes include:

- Going to a single level work platform for easy access to the TBP CE on the top and access via scissor for the middle connection
- Moved secondary emergency egress path from work platform to ladder and trap door to cleanroom roof
- Added small personnel SAS for people to move directly from the 4850 level to the work platform

**DUNE Schedule and Labor Update** 

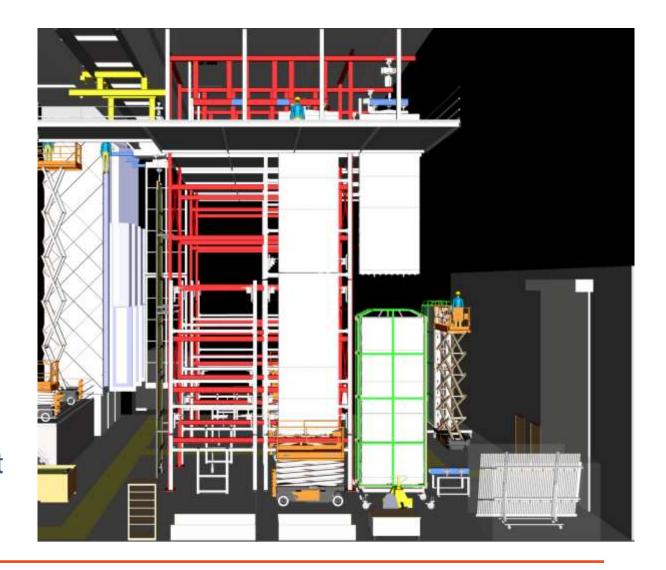


APA Assembly Towers allow staging of up to 8 APA Doublets



#### **Installation Process**

- TPC CE cable tests on the APA Assembly tower at Ash River have shown the slotted cable conduit concept works successfully and allows the installation of PDs
  - This eliminated 3 shifts of extra labor per APA Doublet underground
- Successfully tested APA Doublet assembly at Ash River and have also improved PD connection between top and bottom APA. Improved access requirements for the cleanroom
- Have added both PD and HV equipment and workspace required in cleanroom





## Working with APA & CE Consortia we have updated labor estimates for DUNE-APA Assembly

																We	ek 1													Wee	ek 1					
										Da	y 1			Da	y 2			Da	у 3			Day	y 4			Da	y 5			Da	y 6			Day	77	
	Labor Force								Shi	ift 1	Shi	ft 2	Shi	ift 1	Shi	ift 2	Shi	ft 1	Shi	ft 2	Shi	ft 1	Shif	t 2	Shi	ft 1	Shi	ft 2	Shi	ft 1	Shi	ft 2	Shift	1	Shif	t 2
	Task					Surv		Location	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00
		APA	CE	PD	HV	Cal	INT																													
	Line # 1																																			
1	Move APA Bottom and top to APA	2							2																											
1	Assembly frame						3	line#1	3																											
2	Connect PD Cables, test, connect linkage	2								2																										
2	test and form APA doublet						3	line#1		3																										
	APA wire tension, Install CR Boards,																																			
3	install bias voltage Hareness	4						line#1			4	4	4	4																						
4	Install CE FEBMs top and bottom APA		4					line#1							4	4	4	4																		
	Move APA Doublet to cabling station and																																			
5	install cable trays		4																4																	
6	Install top and bottom CE cables		4					line#1												4																
7	CE Cable management/PD Cable		4					line#1													4															
8	Test electronics warm +Bias test/PD test		4					line#1														4	4													
0	Remove Protective panels move to front	3						line#1																3												
,	of Cold Box						3	IIIIewi																3												
10	Photogrammetry/survey	1						line#1	1	1																										
10	Priotogrammetry/survey						2	IIIIe#1	2	2																										
11	Move to cold box and cable		2					Cold Box #1			2	2																								
-11	INOVE to cold box and cable						2	COIG BOX #1			2	2																								
12	Warm check APA and close box		2					Cold Box #1					2	2	2	2																				
13	Cool down Cold Box		2					Cold Box #1									2	2	2	2																
14	Cold test Cold Box		2					Cold Box #1													2	2	2	2												
15	Warm up Cold Box		2					Cold Box #1																	2	2	2	2								
16	Move out of cold box and uncable, move		2					Cold Box #1	2	2																										
10	to switchyard						2	COID BOX #1	2	2																										



#### PD Labor estimates Underground

																Wee	ek 1							
										Da	y 1			Da	y 2			Da	у 3			Da	y 4	
	Labor Force								Shi	ft 1	Shi	ft 2	Shi	ift 1	Shi	ft 2	Shi	ft 1	Shi	ft 2	Shi	ift 1	Sh	ift 2
	Task					Surv		Location	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:0
		APA	CE	PD	HV	Cal	INT																	
	Photon Detector Integration	# FTE																						
1	Photon Detector Supervisors-1 per shift			1					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	Photon Detector Scientist/Postdoc-1 per shift			1					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	Test PD in scanner			4				cleanroom	4	4													4	4
6	Install PD top APA and test-APA#1			4				PD Area			4	4												
7	Install PD Bottom APA and Test-APA #1			4				PD Area					4	4										
8	Install PD top APA and test-APA#2			4				PD Area							4	4								
9	Install PD Bottom APA and Test-APA #2			4				PD Area									4	4						
10	Install PD top APA and test-APA#3			4				PD Area											4	4				
11	Install PD Bottom APA and Test-APA #3			4				PD Area													4	4		

Potential labor reduction after extensive trial and motion studies at Ash River



#### **HV Consortia**

																We	ek 1							
										Da	y 1			Da	y 2			Da	у 3	-		Da	y 4	
	Labor Force								Sh	ft 1	Shi	ft 2	Shi	ift 1	Shi	ft 2	Sh	ift 1	Shi	ft 2	Shi	ft 1	Shi	ft 2
	Task					Surv		Location	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00
		APA	CE	PD	HV	Cal	INT																	
	HV Consortia Supervisor/Scientist-1 per				1				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	CPA Pair #1							1																
1	Bring CPA & FC boxes in						2	Mat Han		2														
2	Lift CPA1A and bolt to frame				4			CPA 1	4	4														
3	Lift CPA1b and bolt to frame				4			CPA 1			4	4												
4	Add Field Shaping at profiles				4			CPA 1					4											
5	Add disfuser and Top FC				4			CPA 1						4										
	CPA Pair #2							11																
1	Bring CPA & FC boxes in						2	Mat Han					2											
2	Lift CPA2A and bolt to frame				4			CPA 2							4	4								
3	Lift CPA2b and bolt to frame				4			CPA 2					0				4	4						
4	Add Field Shaping at profiles				4			CPA 2					0						4					
5	Add disfuser and Top FC				4			CPA 2												4				
	Build FC and End Walls							1																
1	Bring in Frames, profiles, electrical						2	Mat Han				2												
2	Build FC Frame				2				2	2		-	2	2			2	2			2	2		
3	Install Profiles and test				2						2	2			2	2			2	2		1	2	2
4	Clean, removal of boxes, repair and test				4																4	4	4	4
								Total HV FTE	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7

Potential labor reduction after extensive trial and motion studies at Ash River



#### APA Cabling in the cryostat-Does include FTEs on top

																We	ek 1							
										Da	y 1			Da	y 2			Da	у 3			Da	y 4	
	Labor Force								Shi	ft 1	Shi	ft 2	Shi	ft 1	Shi	ft 2	Shi	ift 1	Shi	ft 2	Shi	ft 1	Shi	ft 2
	Task					Surv		Location	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00
		APA	CE	PD	HV	Cal	INT																	
	Cabling of TPC Electronics in Cryostat																							
	APA Pair #1																							
1	Move APA to cryostat-Position						3	Cryostat			3	3												
	Final Calla Communication States		2										2	2	2	2								
2	Final Cable-Cryostat-in & out						2	Cryo					2	2	2	2								
3	DAQ Test/seal flange/He Leak check		2					Cryo									2	2						
_							2	~./~									2	2						
	CPA Pair#1																							
4	Move CPA to cryostat-Position						3	Cryo					3	3										
	APA Pair #2																							
5	Move APA to cryostat-Position						3	Cryo							3	3								
6	Final Cable-Cryostat-in & out		2					Сгуо									2	2	2	2				
(nita)							2										2	2	2	2				
7	DAQ Test/seal flange/He Leak check		2				-	Cryo			2	2												
/	CPA Pair#1						2				2	2												
8	Move CPA to cryostat-Position						3	Cryo									3	3						
	APA Pair #3							Cijo									-							
5	Move APA to cryostat-Position						3	Cryo											3	3				
	[ [6] 63 (1835) (10 ) (10 ) (13		2				2	88													2	2	2	2
6	Final Cable-Cryostat-in & out						2	Cryo													2	2	2	2
7	DAQ Test/seal flange/He Leak check		2					Cruo	2	2														
1	DAQ Test/sear flange/ne Leak check						2	Cryo	2	2														



## APA & CE Supervisor, APA Rotation, Weekends

																We	ek 1													We	ek 1				
										Da	ay 1			Da	y 2			Da	у 3			Da	y 4			Da	y 5		1	Da	y 6	-		Da	y 7
	Labor Force								Sh	ift 1	Sh	ift 2	Shi	ft 1	Sh	ift 2	Shi	ft 1	Shi	ft 2	Shi	ft 1	Shi	ft 2	Shi	ift 1	Sh	ift 2	Shi	ft 1	Shi	ft 2	Shir	ft 1	Shift 2
	Task					Surv		Location	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00	6:00	11:00	17:00 22:0
	-	APA	CE	PD	HV	Cal	INT																												
	APA Consortia Supervisor/Scientist	1							1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1											
	CE Consortia Supervisor/Scientist		1						1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
	CE Consortia Supervisor/Engineer		1						1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1									2-1		
	I&I on the weekend						2																		2	2	2	2	2	2	2	2	2	2	
	1&I-Cleanroom/SAS Cleaning						2				2	2			2	2			2	2	2	2	2	2	2	2			2	2			2	2	
	APA Prep in Cavern																																		
4	D-1-1- ADA F	2						6.000	2				2				2																		
	Rotate APA Frame and mount to cart.						3	Cavern																											
-4	Remove outer covers. Move APA Frame	2						Cavern		2				2				2																	
Ž	to SAS remove inner bags						3	Cavern																											
-		2						Carran													2	2	,												
3	Misc. cleanup of dunnage to surface						3	Cavern																											

- Both APA and CE consortia have a steady state supervisor on each shift
- Steady state I&I technicians on both shifts over the weekend
- Steady state 2 "cleaning technicians or contract" afternoon shift during the week and day shift on the weekend
- The APA rotation is done by the by the rigging crew with the help from the APA consortia



#### Updates to the labor schedule

- We have redone with the appropriate consortia the step by step procedures in the cleanroom as we have learned from our experience with the Ash River Trial Assembly
- Jim worked in project with Filippo and worked out a detailed set of tasks for the Installation Infrastructure on top of the cryostat and cleanroom setup.
  - This was a several month-long process with numerous modifications to get all the tasks, durations and predecessors reasonable
  - I have then taken these tasks and attempted a **FIRST PASS** estimate to resource load for each task.

- There is still some details to work out on how the schedule for the swap from SP 1 to SP 2. These tasks have not had the same vetting, I just took all the same estimates for the first infrastructure setup, we know that some of these will change.
- Added a worksheet to show the Field Cage deployment at the end of the CPA installation
- Confirmed that most tasks match closely with P6 estimates, still getting additional feedback at this collaboration meeting

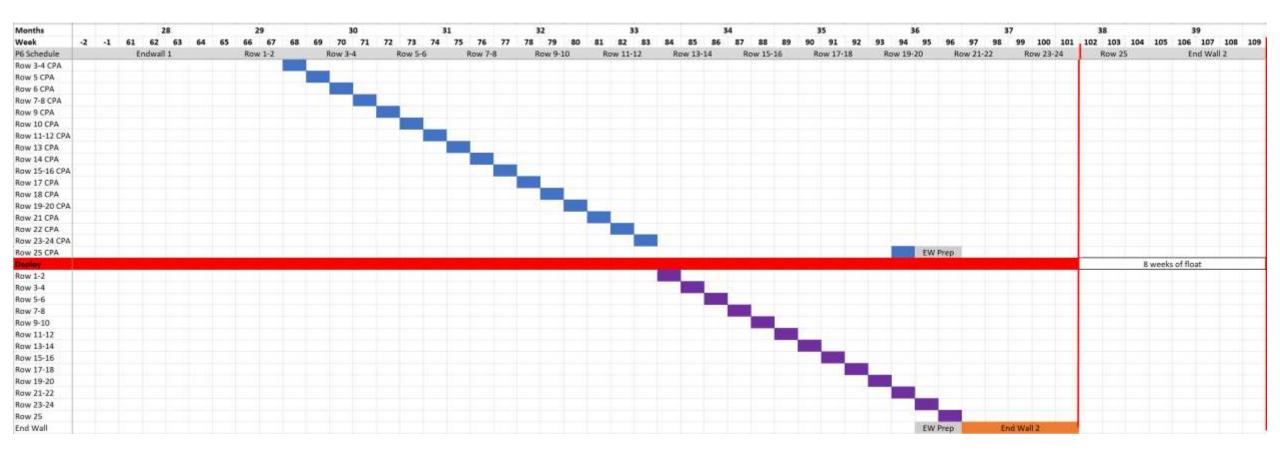


# Deployment Plan-Wait till ~Row 19

Months				2	28				29			3	30			3	31				32			3	3			3
Week	-2	-1	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
P6 Schedule			E	ndwal	1			Rov	w 1-2			Row 3-	4		Row 5-	6		Row 7-	8		Row 9-1	.0	R	ow 11-	12	R	ow 13-1	14
TASK																												
End Wall	EW	Prep		Е	nd Wa	all 1																						
APA Pair 1				AF	PA 1	CB1																						
APA Pair 2					Δ	PA 2	CB2																					
APA Pair 3						А	PA 3	CB3																				
Row 1 APA							R	low 1																				
APA Pair 4						А	PA 4	CB1																				
APA Pair 5							A	APA 5	CB2																			
APA Pair 6								AF	PA 6	CB3																		
Row 2 APA									Ro	w 2																		
APA Pair 7								APA7	CB1																			
APA Pair 8									APA8	CB2																		
APA Pair 9										APA9	CB3																	
Row 3 APA											Row3																	
APA Pair 10									AP10	CB1																		
APA Pair 11										AP11	CB2																	
APA Pair 12											AP12	CB3																
Row 4 APA												Row4																
APA Pair 13										AP13	CB1																	
APA Pair 14											AP14	CB2																
APA Pair 15												AP15	CB3															
Row 5 APA													Row5															
APA Pair 16											AP16																	
APA Pair 17												AP16	CB2															
APA Pair 18													AP18	CB3														
Row 6 APA														Row6														



# Complete HV Row 24-Start FC deployment





# Deployment sequence-Does not show the people on the cryostat

																We	ek 1							
										Da	y 1			Da	y 2			Da	y 3			Da	y 4	
	Labor Force								Shi	ft 1	Shi	ft 2	Sh	ift 1	Shi	ift 2	Sh	ift 1	Shi	ift 2	Shi	ift 1	Shi	ift 2
	Task					Surv		Location	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00	6:00	11:00	17:00	22:00
		APA	CE	PD	HV	Cal	INT					, ,												
	Deployment of Drift Volume-In Cryostat											Ro	w 1							Ro	w 2			
	Drift Volume 1																							
1	Remove floor, clean, install temp, test					1		Cryo	1	1							1	1						
1	Kelliove floor, clean, flistali tellip, test						3		3								3							
2	Deploy T&B FC Drift Volume 1						3	Cryo		3								3						
3	Final Test and HV Elec Connections		2		2			Cryo			2	2							2	2				
	Drift Volume 2 & 3																							
4	Parana flancialism to the					1		Cryo					1	1							1	1		
4	Remove floor, clean, install temp, test						3						3								3			
5	Deploy T&B FC Drift Volume 2						3							3								3		
6	Final Test and HV Elec Connections		2		2			Cryo							2	2							2	2
4	Remove floor, clean, install temp, test					1							1	1							1	1		
*	Kemove noor, clean, mstan temp, test						3						3								3			
5	Deploy T&B FC Drift Volume 3						3	Cryo						3								3		
6	Final Test and HV Elec Connections		2		2			Cryo							2	2							2	2
	Drift Volume 4																							
1	Romava floor close install town toot					1		Cryo	1	1							1	1						
1	Remove floor, clean, install temp, test						3		3								3							
2	Deploy T&B FC Drift Volume 1						3	Cryo		3								3						
3	Final Test and HV Elec Connections		2		2			Cryo			2	2							2	2				



## **Updated Ash River Trial Assembly Schedule**





Food for thought-Shift Change

- With ~144 FTE coming underground at shift change, ~30-minute trip cycle and 36 FTE it means 4 staggered shifts and it takes ~2 hours to get everyone underground!
- This complicates morning work planning and safety meetings with the different work groups

coming underground at shift nute trip cycle and 36 FTE it			Load	Unload	Load	Unload	Total Round-	12 6	haft Tim 200 ft/m 00 ft/mi 00 ft/mi	in n
red shifts and it takes ~2 hours underground!	<u>Head -</u> <u>Frame</u>	<u>Lift Type</u>	Ross Frame	4850	4850	Ross Frame	trip Loading	Down	Up	TTL Round trip Time
diacigiodia:			Min.	Min.	Min.	Min.	Min.	Min.	Min.	Min.
	Ross Cage	Personnel Lift	5.0	5.0	5.0	5.0	20.0	5.36	5.36	30.71
s morning work planning and	Ross Cage	In-Cage Lift	20.0	20.0	5.0	5.0	50.0	5.36	5.36	60.71
3 morning work planning and	Ross Cage	Over-High Lift	30.0	30.0	5.0	5.0	70.0	5.36	5.36	80.71
with the different work groups	Ross Cage	Under Cage	30.0	30.0	5.0	5.0	70.0	11.79	5.36	87.15
with the different work groups	Ross Skip	Suspended	30.0	30.0	0.0	0.0	60.0	9.95	5.36	75.31
Group Month -2 -1 1 4 7 10 13 16 19 22 25	28 31	34 37 40	43 46	49	51 54	57 6	0 64	67 70	12	

Task	Group	MOUNT	-2	-1	1	4	,	10	13	10	19	22	25	28	31	34	3/	40	43	40	49	21	54	5/	00	04	0/	70
				Es	timat	ted N	lumb	er if I	TES	Unde	rgrou	and p	er sh	ift-As	sum	e 2 st	nifts (	oer d	ay									
CF-Day			80	55	55	55	55	40																				
CF-Night			70	55	55	55	55	35																				
LBNF/CERN-Warm-Day					25	25	25	25	25	25	25	25	20	20														
LBNF/CERN-Warm-Night	1 1				25	25	25	25	25	25	25	25	15	15														
GTT-Cold-Day										25	25	25	25	25	25	25	25				10							
LBNF/CERN-Cryo								10	10	20	20	20	20	20	20	20	20	20	20	4	4	4	4	4	4	4	4	4
I&I-Underground Day				11	29	29	29	29	46	46	46	46	46	46	46	46	46	46	46	46	46	46	27	27	27	27	27	27
I&I-Underground Night				11	29	29	29	29	46	46	46	46	46	46	46	46	46	46	46	46	46	46	27	27	27	27	27	27
DUNE-Consortia-Day								5	5	5	10	10	36	36	36	36	36	36	36	36	36	36	30	20	20	5	5	5
DUNE Consortia-Night					_					5	10	10	35	35	35	35	35	35	35	35	35	35	30	20	20	5	5	5
SURF-Day			15	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
SURF-Night			5	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Total FTEs Underground p	er Day S	Shift	95	86	129	129	129	129	106	141	146	146	166	166	146	146	146	121	121	105	115	105	81	71	71	56	56	56
Total FTEs Underground p	er Night	Shift	75	76	119	119	119	99	81	86	91	91	105	105	90	90	90	90	90	90	90	90	67	57	57	42	42	42