59th Annual

WESTERN WINTER WORKSHOP

Challenges of planning and costing for an underground research facility

By: Jelena Djurovic and Ankit Desai

February 27 - March 1, 2020 | Renaissance Indian Wells Resort & Spa

Speakers

Jelena Djurovic: Arup, SF, Cost Lead

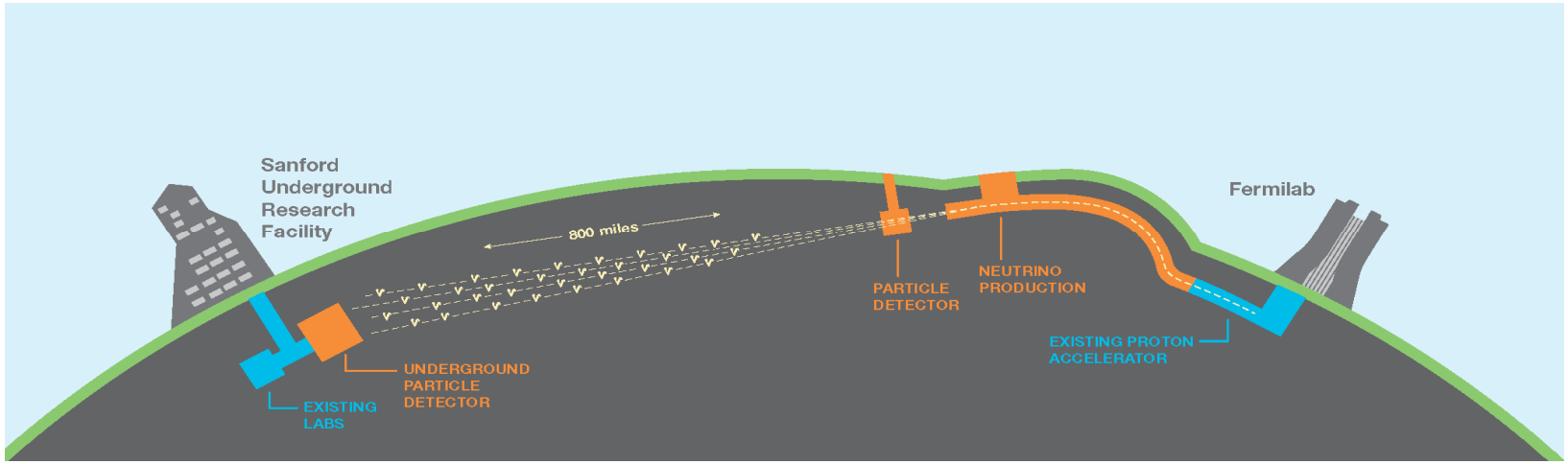
Jelena leads the Cost Consulting Team in San Francisco office, providing comprehensive financial and contractual services both to other Arup teams and to external clients. She has 22 years of experience including major infrastructure projects.

Ankit Desai: Arup, SF, Schedule Lead

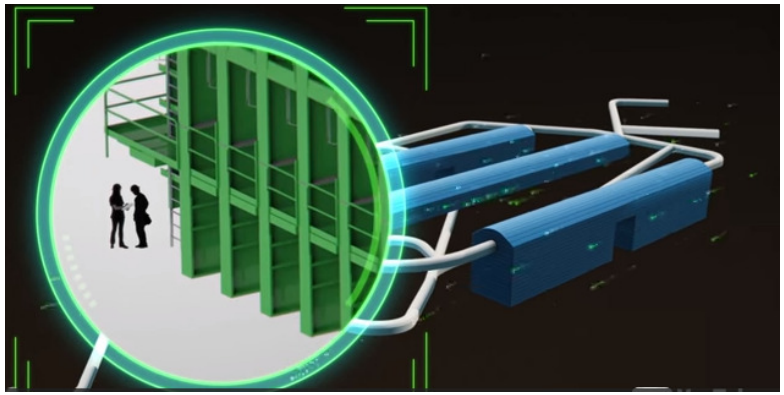
Ankit Desai is a Senior Consultant in the Cost Engineering & Management Group for the Americas Region providing schedule, cost, project controls consulting and project management support on a multitude of large scale building and infrastructure projects throughout the Americas.

Overview

- Introduction: Long-Baseline Neutrino Facility (LBNF)
- History of the Project
- Project Overview
- Site Information
- Scope of Work
- Project Constraints
- Arup's Impact
- Questions & Contact



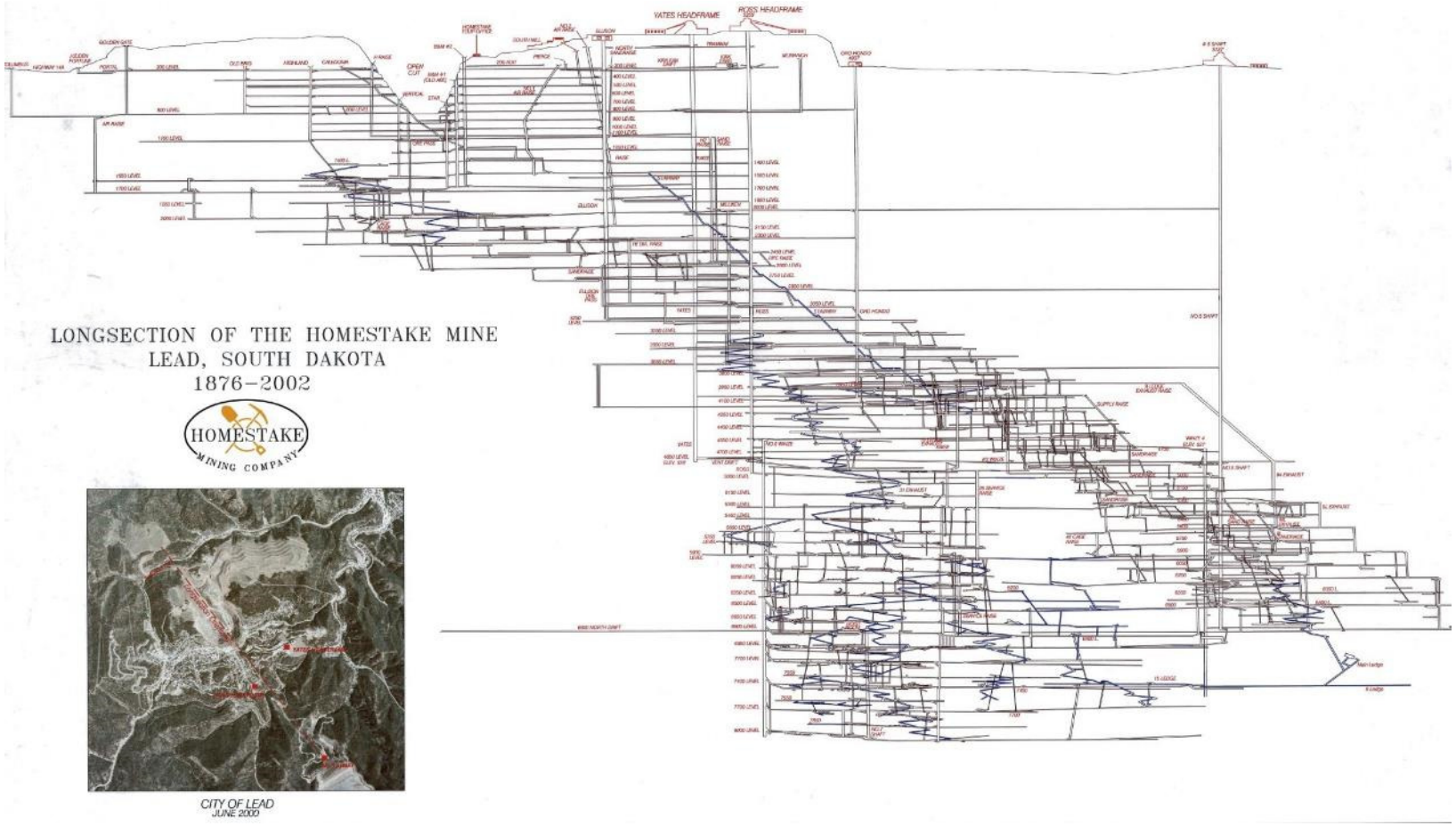
Video



Introduction: Long-Baseline Neutrino Facility (LBNF)

History of the site

Existing layout

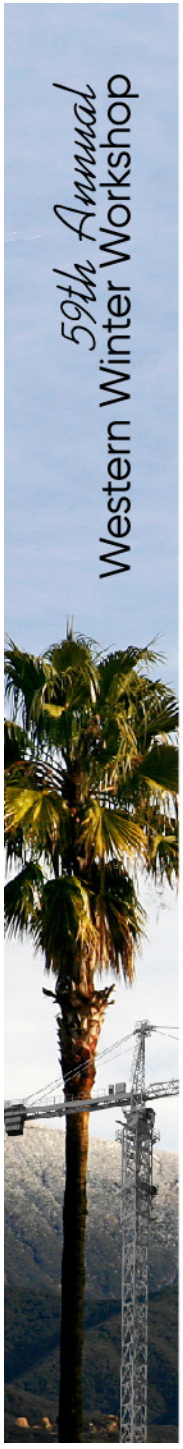


Yates Shaft Cage

Open Pit

Underground Services

Arup @LBNF



Project overview

- Host – Fermilab Research Alliance
- With $1bn+ capital program (conventional facilities & experiment) at Far Site – Funded by U.S. Department of Energy (DOE) and the European Organization for Nuclear Research (CERN)
- Scope required for the development of four 10kT liquid argon neutrino detectors to be installed at the 4850 level below the surface includes:
  - Excavation (EXC) and
  - Building, site and infrastructure (BSI)
- The procurement method used was Construction Manager/ General Contractor

Organizational chart

DOE

Fermilab (DOE Contractor)

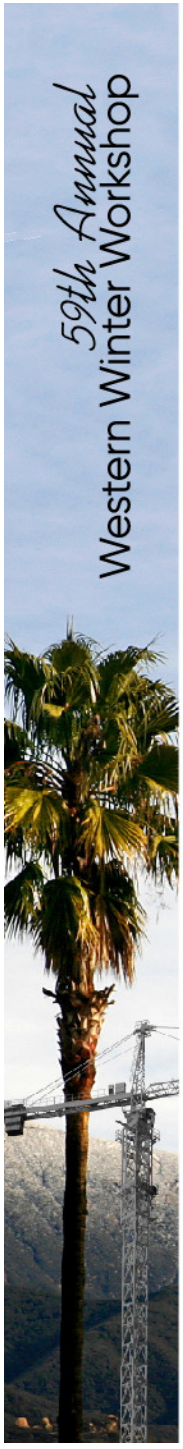
Conventional Facilities

DUNE Collaboration Team (Science)

SDSTA (Host Site)

KAJV (CM/GC)

Arup EXC / BSI (Sub Contractor)



Arup team organization

Arup

Dangermond Keane

Davis Brody Bond

TSP

RESPEC

G.L. Tiley

Albertson

Power Engineering

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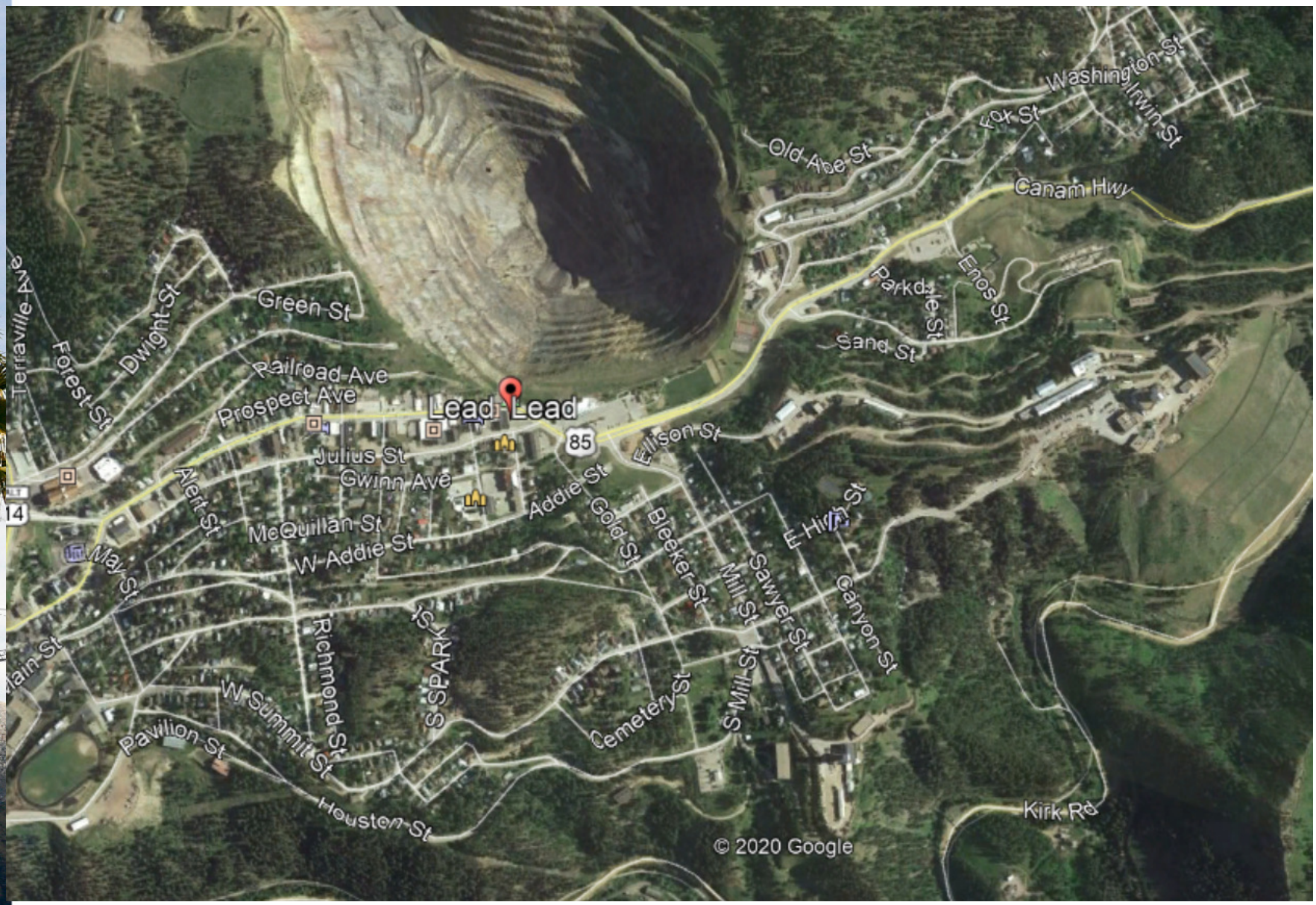
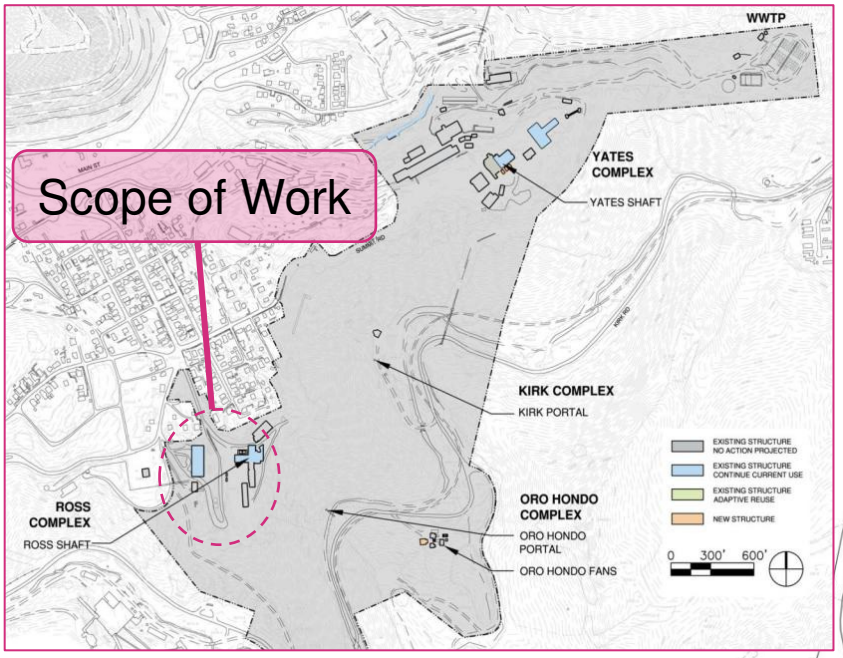
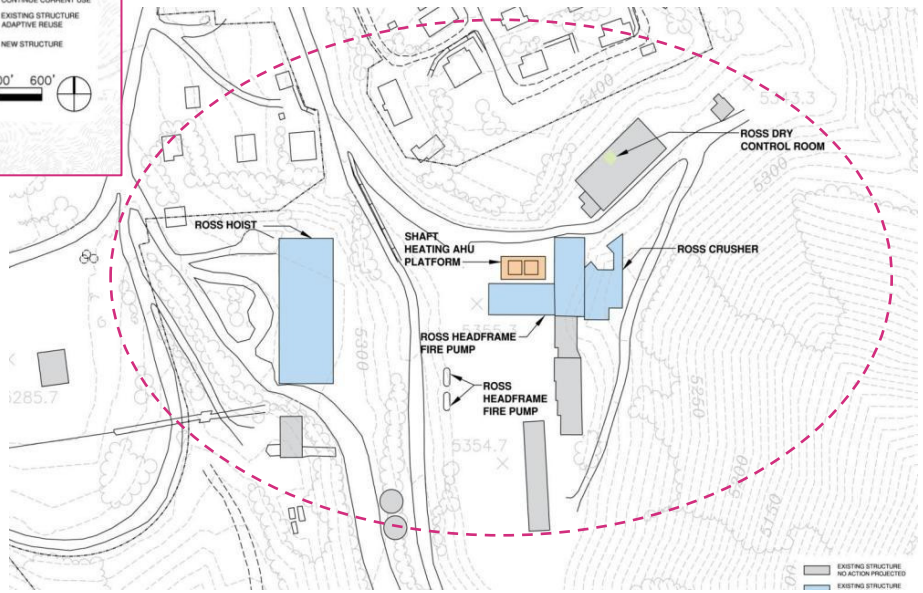
Western Winter Workshop

Project Location

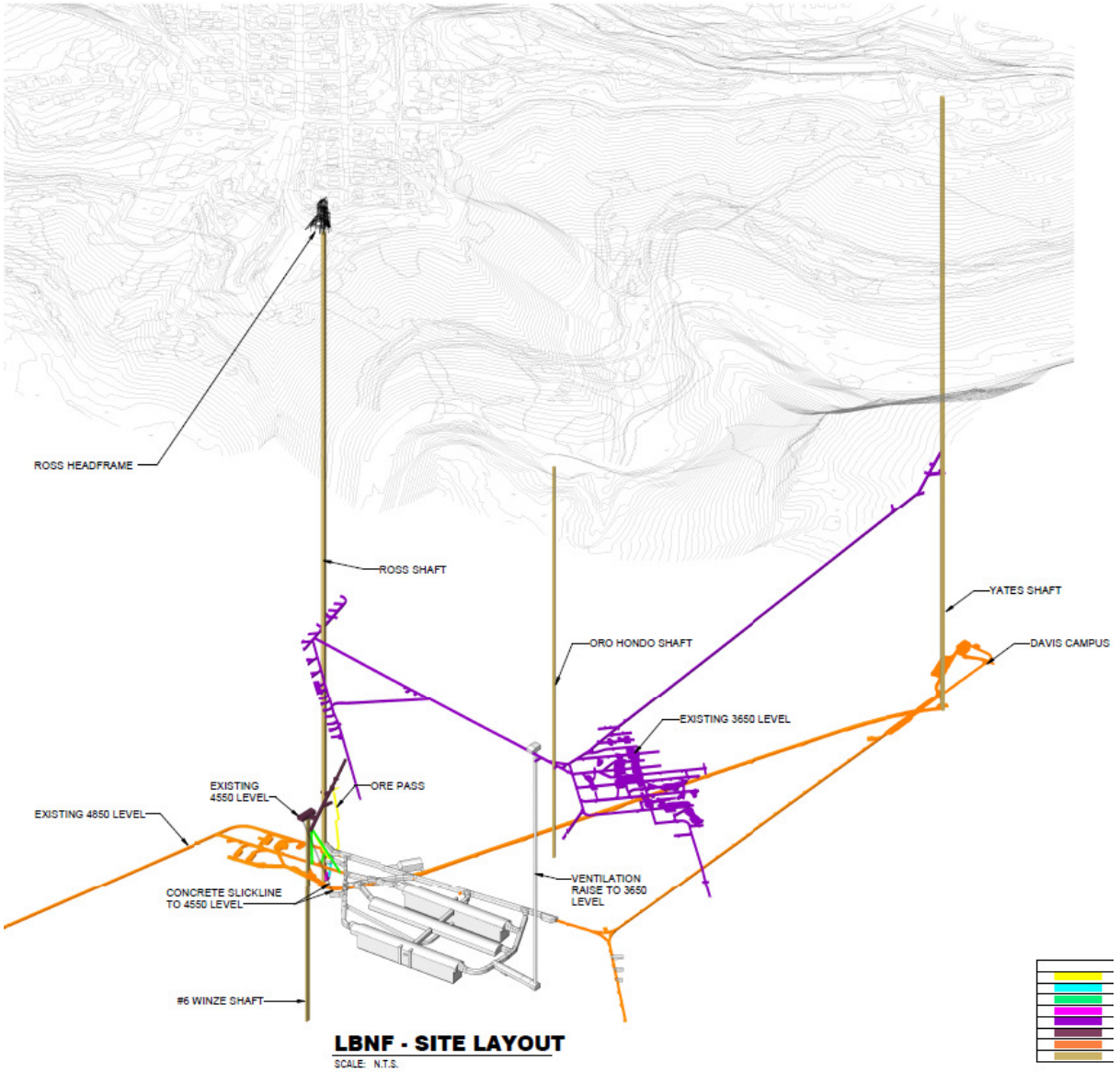


Site information

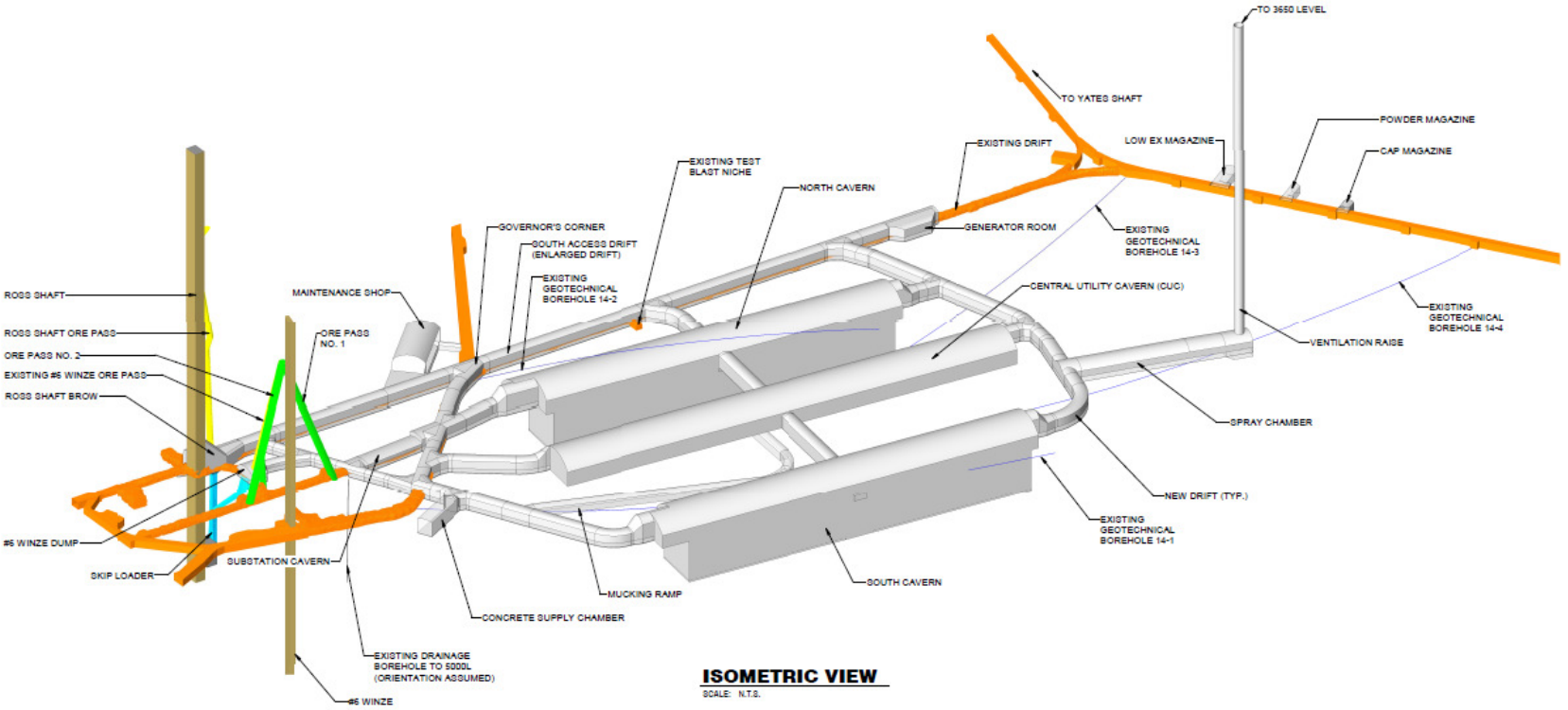




Site information



4850 Level


TO 3650 LEVEL
TO YATES SHAFT
POWDER MAGAZINE
CAP MAGAZINE
EXISTING DRIFT
LOW EX MAGAZINE
EXISTING TEST BLAST NICHE
NORTH CAVERN
GOVERNOR'S CORNER
SOUTH ACCESS DRIFT (ENLARGED DRIFT)
EXISTING GEOTECHNICAL BOREHOLE 14-2
GENERATOR ROOM
EXISTING GEOTECHNICAL BOREHOLE 14-3
ROSS SHAFT
MAINTENANCE SHOP
ROSS SHAFT ORE PASS
ORE PASS NO. 1
ORE PASS NO. 2
EXISTING #6 WINZE ORE PASS
ROSS SHAFT BROW
CENTRAL UTILITY CAVERN (CUC)
EXISTING GEOTECHNICAL BOREHOLE 14-4
VENTILATION RAISE
SPRAY CHAMBER
NEW DRIFT (TYP.)
EXISTING GEOTECHNICAL BOREHOLE 14-1
#6 WINZE DUMP
SKIP LOADER
SUBSTATION CAVERN
MUCKING RAMP
SOUTH CAVERN
CONCRETE SUPPLY CHAMBER
EXISTING DRAINAGE BOREHOLE TO 5000L (ORIENTATION ASSUMED)
#6 WINZE
ISOMETRIC VIEW
SCALE: N.T.S.

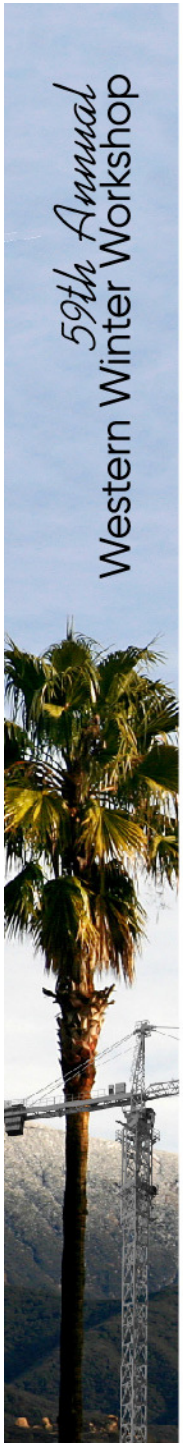
Scope of work

Arup's role:

- Owner's Engineer - Involved since 2008
- Core scope of work features:
  - drill and blast tunnel excavations
  - shaft refurbishment
  - cryogenic facilities
  - surface support facilities

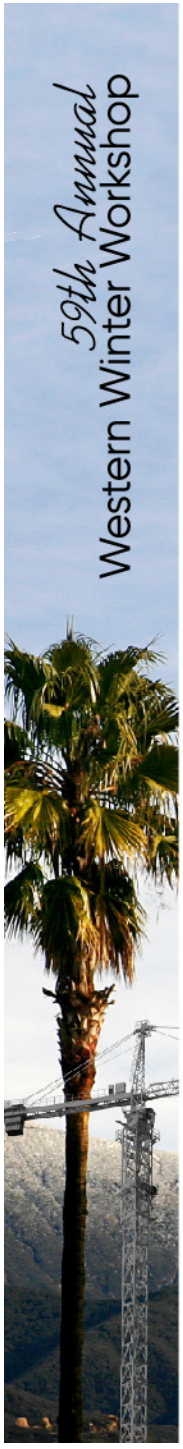
Tasks:

- Project Definition, Feasibility
- Detail Design, Estimate and Schedule for 30, 60, 90, and 100%
- Work on Value Engineering
- Led cost, schedule and risk reconciliation workshops with CMGC



Project constraints

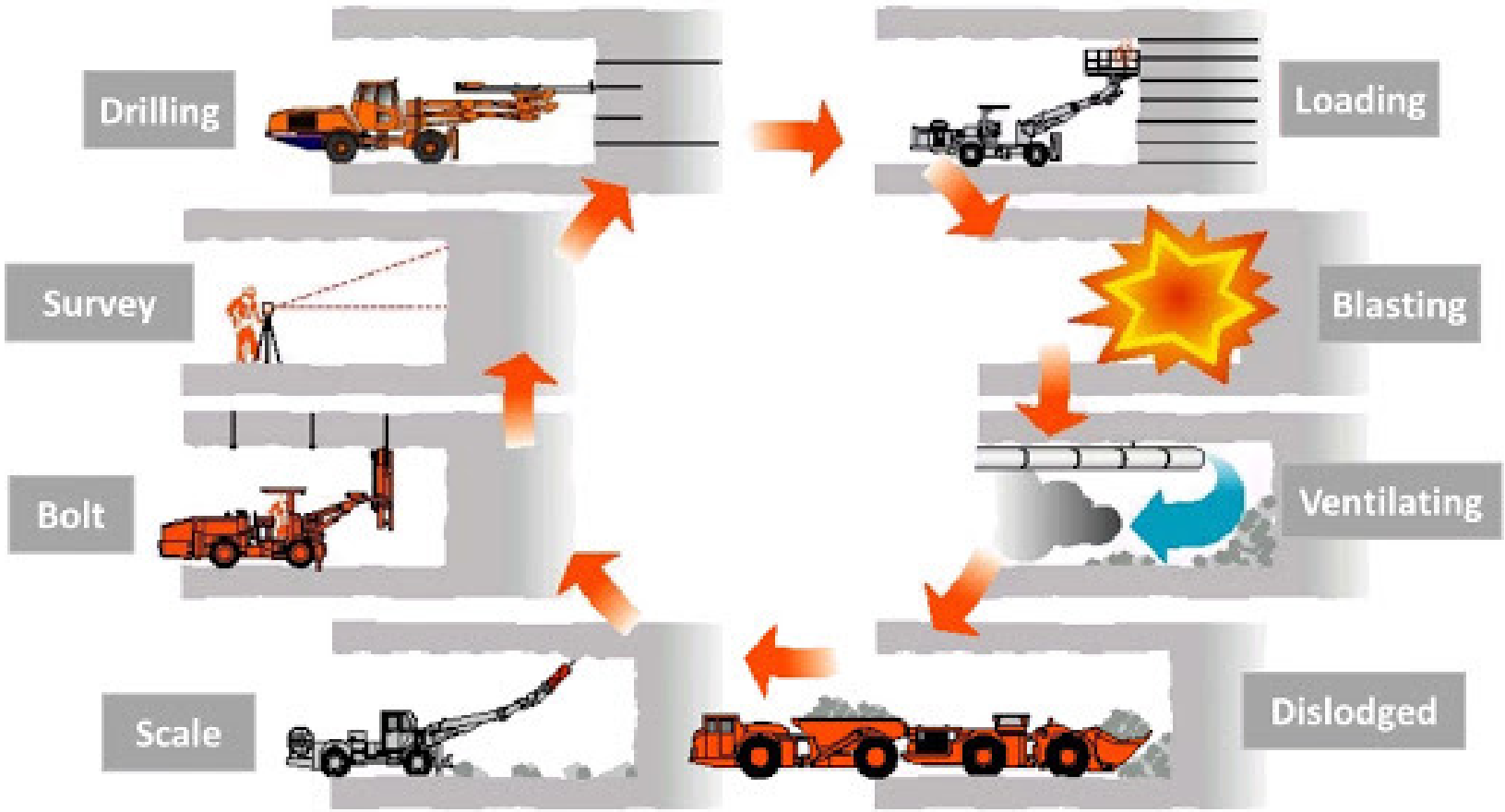
- Technical complexity of the project
- Project location
- Site constraints:
  - Labor productivity
  - Storage area
  - Site access
  - Incorporate the Ross Shaft in schedule
- Ongoing underground experiments
- Weather considerations in South Dakota



Project elements

- Excavation
  - Tonnes of muck ~812,000
  - Lbs of explosives ~3,000,000
  - Surface Area of shotcrete ~560,000 SF
  - No. of rockbolts ~24,000 (15 - 30ft)
- BSI
  - LF of pipes ~96,000
  - Lbs of ducts ~150,000
  - LF of power feeders ~520,000
  - LF for communication feeders ~140,000

Drill and blast process



EXC – Cycle development

PRODUCTION RATES - CYCLE TIMES																	
CYCLE: DRILL AND BLAST																	
CYCLE: MUCKING																	
CYCLE: SHOTCRETE 2" FLASH COAT + 2" DESIGN COAT																	
CYCLE: BOLTING																	
	TOTAL ACTIVITY PRODUCTION RATE - HCSS ACTIVITY FRICTION BOLTS- offline	Bolts/HOUR	15														
CYCLE: Tunnel Invert Slab- offline																	
	Tunnel Invert Slab- includes placing rebar, form work and pouring concrete	CY/HR	20		20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00		
	Blow Bottom	SF/HR	1000		1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00		
	Install ASCE 60LB Rail	LF/HR	20		20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00		
	Install Drainage Channel	LF/HR	150		150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00		
	Install Drainage Channel Grating	LF/HR	250		250.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00		
	Install Cavidrain	SF/HR	200		200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00		
	Install Single Size Granular Filter Stone	CY/HR	20		20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00		
	Install 4" Diameter Perforated Pipe	LF/HR	200		200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00		
	Install Clean Outs	Units/HR	5		5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00		
	Sawcut Construction Joints and Fill	LF/HR	50		50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00		
	Polythene Slip Memberane	SF/HR	200		200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00		
	Install Galv L 1 1/2 x 1 1/2x 3/16 Angle Section	LF/HR	100		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00		
	Mud Slab	CY/HR	50		50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00		
SUMMARY MAJOR CYCLES																	
	MINS PER ROUND: DRILL/BLAST	MINS	45%	37460.64	339.39	362.21	362.21	314.36	314.36	314.36	337.57	416.17	561.47	385.36	416.17		
	MINS PER ROUND: MUCKING	MINS	15%	12813.16	127.90	137.27	167.59	77.46	72.27	75.73	283.88	122.54	248.33	183.31	133.75		
	MINS PER ROUND: WIRE MESH	MINS	1%	466.54													
	MINS PER ROUND: SHOTCRETE FLASH COAT	MINS	12%	9652.66	89.41	105.99	105.99	102.43	102.43	102.43	128.48	154.74	194.73	121.91	154.74		
	MINS PER ROUND: SHOTCRETE DESIGN COAT	MINS	11%	9365.71	89.41	105.99	105.99	102.43	102.43	102.43	128.48	154.74	194.73	121.91	154.74		
	MINS PER ROUND: BOLTING	MINS	16%	13680.09	139.97	195.46	193.54	101.21	106.87	99.51	150.11	207.23	388.24	139.84	194.95		
	TOTAL MINS PER ROUND	**MINS**		83438.79	**786.08**	**906.93**	**935.32**	**697.90**	**698.36**	**694.46**	**1028.51**	**1055.42**	**1587.51**	**952.34**	**1054.35**		
	HOURS PER ROUND: DRILL/BLAST	HOURS			5.66	6.04	6.04	5.24	5.24	5.24	5.63	6.94	9.36	6.42	6.94		
	HOURS PER ROUND: MUCKING	HOURS			2.13	2.29	2.79	1.29	1.20	1.26	4.73	2.04	4.14	3.06	2.23		
	HOURS PER ROUND: WIRE MESH	HOURS															
	HOURS PER ROUND: SHOTCRETE FLASH COAT	HOURS			1.49	1.77	1.77	1.71	1.71	1.71	2.14	2.58	3.25	2.03	2.58		
	HOURS PER ROUND: SHOTCRETE DESIGN COAT	HOURS			1.49	1.77	1.77	1.71	1.71	1.71	2.14	2.58	3.25	2.03	2.58		
	HOURS PER ROUND: BOLTING	HOURS			2.33	3.26	3.23	1.69	1.78	1.66	2.50	3.45	6.47	2.33	3.25		
	TOAL HOURS PER ROUND	**HOURS**			**13.10**	**15.12**	**15.59**	**11.63**	**11.64**	**11.57**	**17.14**	**17.59**	**26.46**	**15.87**	**17.57**		
	Drift/Cavern Length (ft)	FT			348.06	550.90	119.46	77.57	53.75	139.20	275.00	73.40	55.50	139.40	296.05		
	Round Length	FT			10	15	15	10	10	10	10	15	15	10	15		

Factors affecting productivity - EXC

Drill

- Survey time
- Drill jumbo penetration rate
- Workmanship time to drill holes

Blast

- Load explosives for maximum efficiency
- Blasting time
- Ventilation time

Muck

- Forward and backward velocity of hauling equipment
- Muck disposal site

Primary Support

- Shotcrete pumping rate
- Logistical complexity of shotcreteing
- Rock bolting efficieny

Factors affecting productivity - BSI

Portal to Portal

People, material and equipment should move from portal to portal

Confined Space

Limited dimensions for equipment and material movement

Material Laydown / Staging

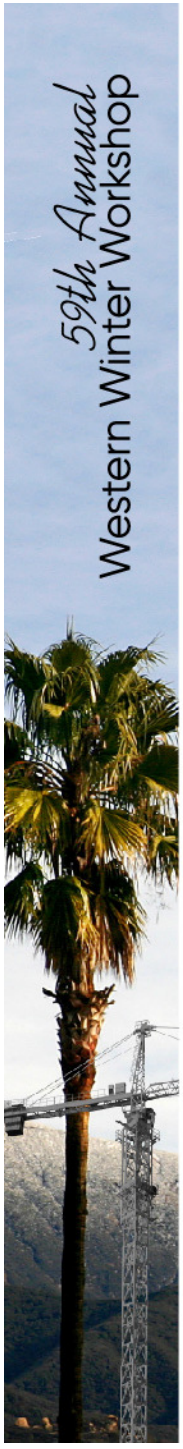
Material handling in limited space, more trips

Stacking of Trades

Multiple trades working simultaneously

BSI – Labor productivity adjustment

Factor	Portal-to-Portal	Confined Space	Material Lay-Down/Staging	Stacking of Trades	Productivity Adder
- Select -	0%	0%	0%	0%	0%
Site - Civil	4%	0%	0%	0%	4%
Cryogen Building	4%	0%	0%	0%	4%
Ross Dry	4%	0%	0%	0%	4%
Utility Tunnel	4%	5%	3%	0%	12%
Ross Headframe	4%	0%	3%	0%	7%
Generator Room	30%	0%	5%	5%	40%
North Cavern	30%	10%	5%	5%	50%
Spray Chamber & Vent Raise	30%	3%	5%	5%	43%
South Cavern	30%	10%	5%	5%	50%
Drifts	30%	3%	10%	3%	46%
Substation Cavern	30%	0%	5%	0%	35%
Central Utility Cavern	30%	10%	5%	15%	60%
Ross Shaft & Ross Shaft Brow	30%	5%	15%	15%	65%

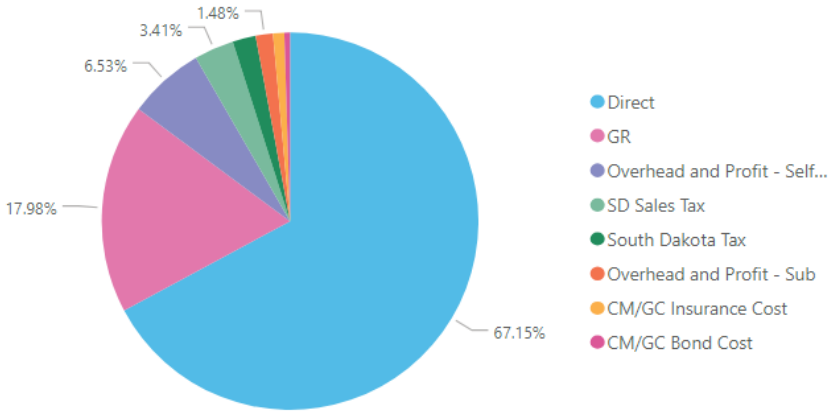


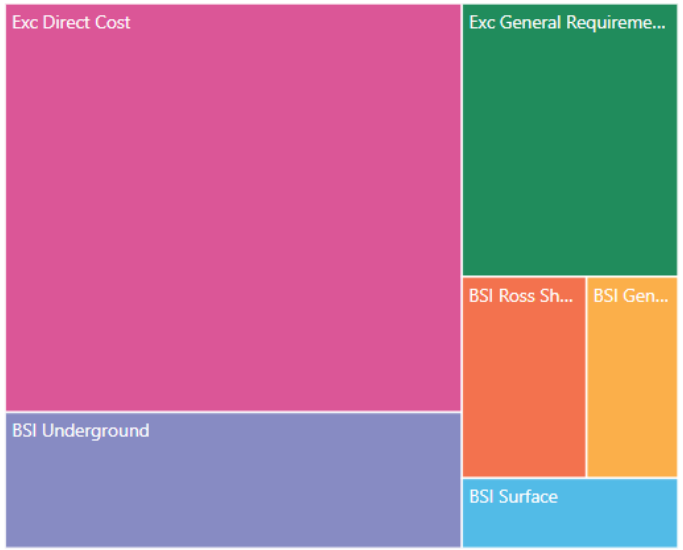
Project cost distribution

Long Baseline Neutrino Facility - 100% Design

Total Construction Cost

Cost Distribution



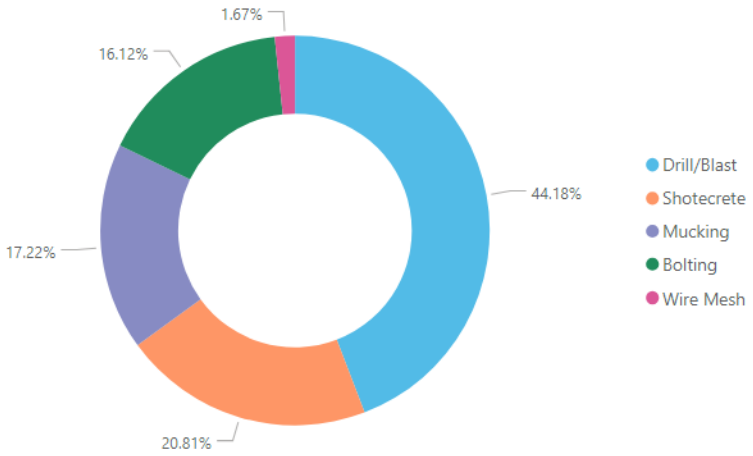


Cost distribution - EXC

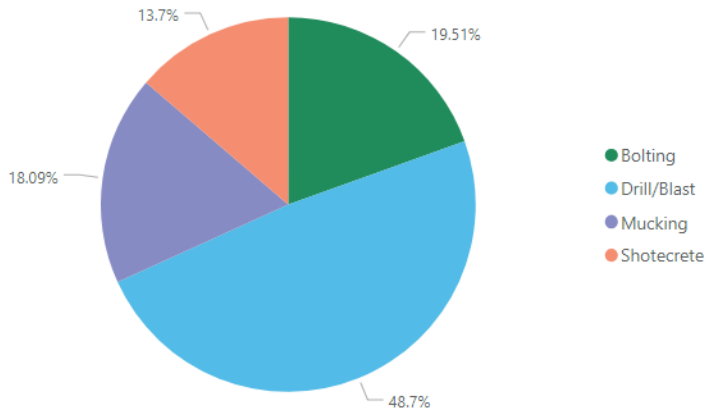
LBNF Excavation

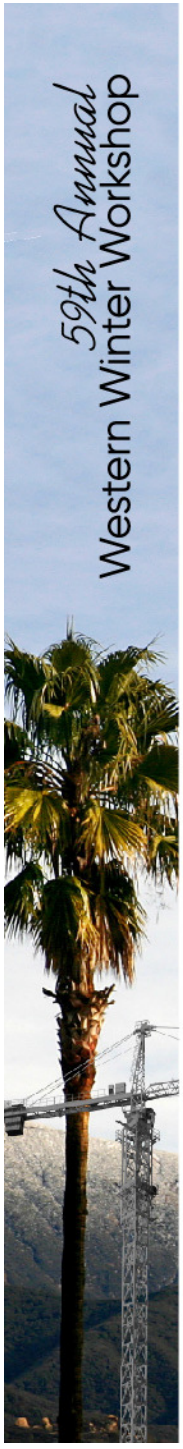
Cost Components

Project Components - Duration



Project Components - Cost



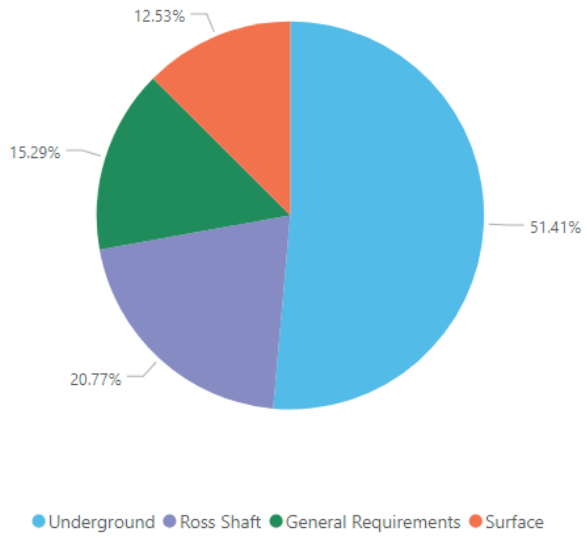


Cost distribution - BSI

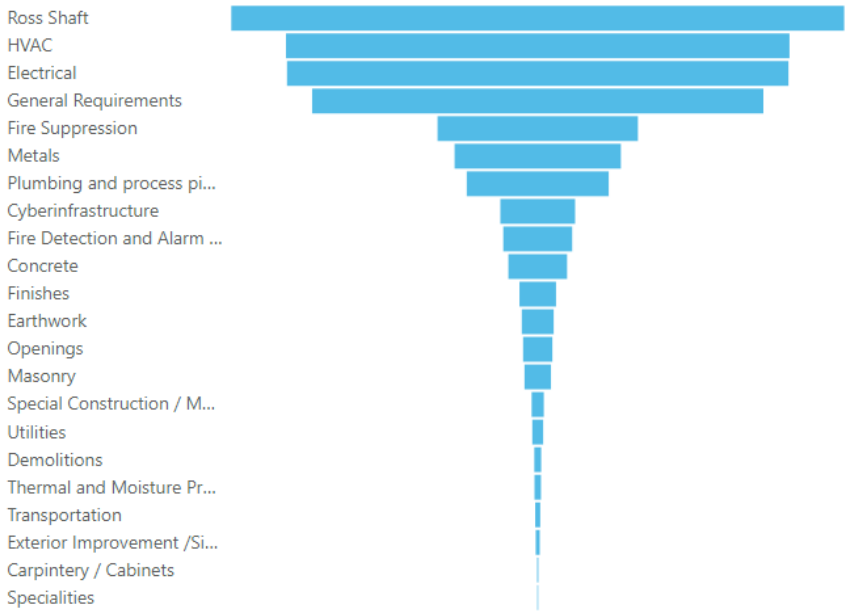
LBNF BSI

Cost Components

Project Locations



Cost Distribution per Discipline



Project Schedule

LBNF-100% Final Design-EXCAVATION BSI — Classic Schedule Layout — 24-May-19 14:30

Activity ID	Activity Name	Original Duration	Start	Finish	Total Float
LBNF-100% Final Design-EXCAVATION & BSI		1925	01-Jun-20	16-Oct-27	0
Excavation		1188	01-Jun-20	19-Dec-24	737
FSCF Construction		1188	01-Jun-20	19-Dec-24	737
Cavern & Drift Excavation (EXC)		1188	01-Jun-20	19-Dec-24	737
Milestones and Procurements		1181	01-Jun-20	09-Dec-24	744
EXC Construction Milestones		1107	01-Jun-20	09-Dec-24	709
EQ-NTP	NTP for Equipment Procurement	0	01-Jun-20*		4
EQ-Order	Order Equipment	0	01-Jun-20		4
EXC-NTP	NTP for Construction	0	09-Nov-20*		0
EXC-1C to BSI	Handoff After Stage C EXC to BSI	0		09-Dec-24	709
Procurement & Delivery		330	01-Jun-20	22-Sep-21	67
PROC100	Procurement & Delivery of Small Equipment	124	01-Jun-20	25-Nov-20	5
PROC110	Procurement & Delivery of Big Equipment	330	01-Jun-20	22-Sep-21	67
Summary		1002	09-Nov-20	19-Dec-24	31
A1020	Ross Shaft Operation (EXC)	805	09-Nov-20	02-Mar-24	102
A1060	Crew 1-Excavation (Small Equipment)	292	04-Dec-20	17-Feb-22	72
A1030	Crew 3- 3650	38	29-Dec-20	25-Feb-21	147
A1080	General Crew	40	04-Feb-21	05-Apr-21	133
A1120	Batch Plant Set up Crew	64	13-Feb-21	18-May-21	231
A1040	Batch Plant Operation-EXC	875	15-Mar-21	04-Oct-24	0
A1000	Crew 2-Excavation (Big Equipment)	573	09-Feb-22	12-Jun-24	0
A1010	Crew 1-Excavation (Big Equipment)	442	09-Feb-22	29-Nov-23	141
A1100	North Cavern Monorail Crane Crew	25	06-Oct-22	15-Nov-22	103
A1070	Concrete Crew	477	01-Nov-22	15-Oct-24	73
A1110	South Cavern Monorail Crane Crew	25	15-May-23	20-Jun-23	0
A1090	Ross Shaft Operation (BSI)	77	22-Aug-24	19-Dec-24	31
A1050	Batch Plant Operation-BSI	15	04-Oct-24	29-Oct-24	3
General Mobilization		996	09-Nov-20	09-Dec-24	708
EXCMOB	Mobilization	15	09-Nov-20	04-Dec-20	0
EXC(SE) Milestone	Delivery of Small Equipment	0	04-Dec-20		0
EXCASS (SE)	Assembly of Small Equipment in 4850 L (and 3650)	15	04-Dec-20	29-Dec-20	0
EXC(LE) Milestone	Delivery of Large Equipment	0	03-Jan-22		0
EXCASS (LE)	Assembly of Large Equipment in 4850 L	25	03-Jan-22	09-Feb-22	0
EXCDEMOB	Demobilization - EXC	11	21-Nov-24	09-Dec-24	708
EXC-Completed	Complete All Excavation	0		09-Dec-24	708
STAGE A		295	24-Nov-20	11-Feb-22	82
Stage A Milestone		147	29-Dec-20	03-Aug-21	178
131122.0403.EXC1A	FSCF - EXC - Phase 1 Summary (LOE)	147	29-Dec-20	03-Aug-21	178
EXC-S-A	Start Stage A Excavation	0	29-Dec-20		0
EXC-S-A-C1	Crew 1 Ready (Small Eq)	0	29-Dec-20		0
EXC-F-Ph1A	Complete Stage A Excavation	0		03-Aug-21	178
4860-47 CONCRETE BATCH PLANT		64	13-Feb-21	18-May-21	231
4850-47.1	Ground Support/Prep	10	13-Feb-21	01-Mar-21	231
4850-47.2	R/F/P Invert & Collar	10	01-Mar-21	15-Mar-21	231
4850-47.3	Construct Batching Equipment & MEP	20	15-Mar-21	13-Apr-21	231
4850-47.4	Shotcrete / Concrete Testing Program	24	13-Apr-21	18-May-21	231
Demolition of Existing Condition		8	04-Dec-20	17-Dec-20	164
4550-101	Demolition of Existing Condition	8	04-Dec-20	17-Dec-20	164
Ventilation and Blast Containment		21	24-Nov-20	29-Dec-20	3
BLAST/SECURITY DOORS		21	24-Nov-20	29-Dec-20	3
B0D100	Construct & Install Blast Doors	21	24-Nov-20	29-Dec-20	3
B0D120	Construct & Install Construction Doors	12	30-Nov-20	17-Dec-20	9

Remaining Level of Effort · Remaining Work · Milestone
Actual Work · Critical Remaining Work · Summary

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TASK filter: All Activities

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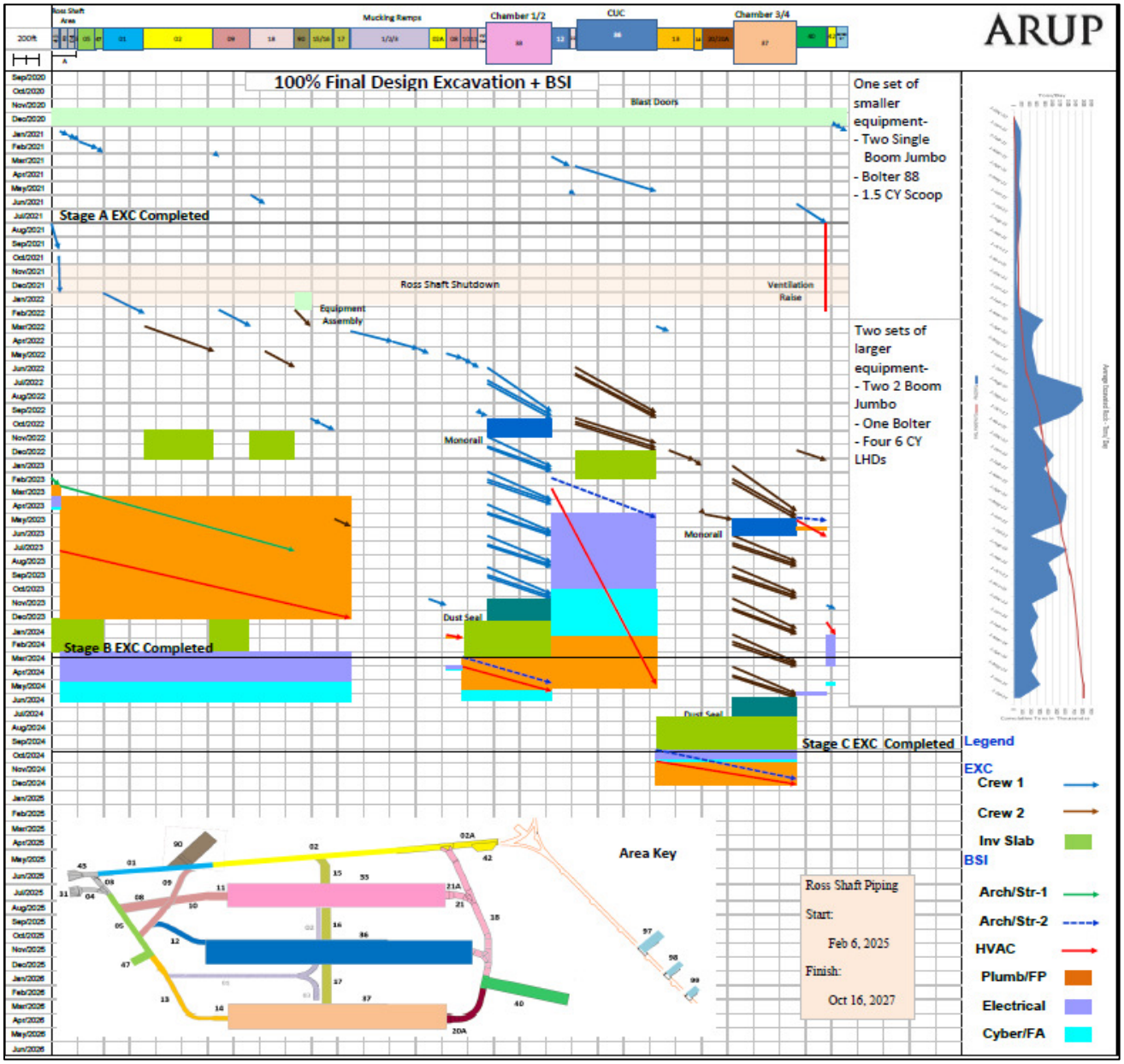
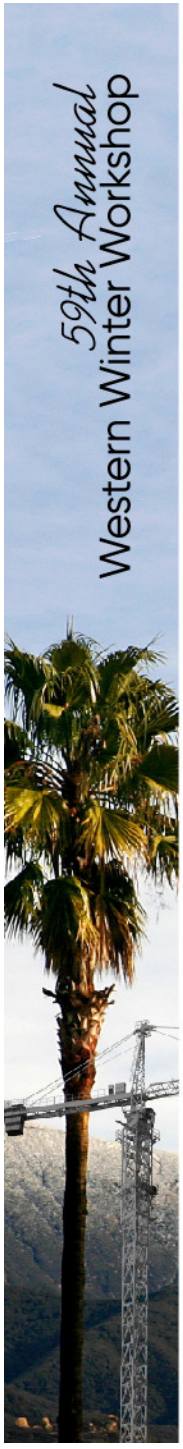
Time Location Diagram





Arup's impact

- Ross Shaft options – alternative shaft, moving cooling towers underground
- Reconfiguration of the excavation – moving support facilities
- Reconsidering ventilation options during excavation to shorten the construction schedule
- Muck transportation off site – cost effective option
- Re-evaluating effective contract procurement
- Forecast funding requirements

Questions and contact

Jelena Djurovic – Jelena.djurovic@arup.com
Phone – 415-861-9143

Ankit Desai – ankit.desai@arup.com
Phone – 415-470-8935

59th Annual

WESTERN WINTER WORKSHOP

Thank you.