

Logistics Sensitivity Analysis

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Upgrade Logistics Review
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Our approach to logistics sensitivity analysis

- Follow our project general Risks Registry rubric
- For each shipping package (78 entries) and personnel arrival at Pole (11 entries), assess probability of delays and estimate cost of recovery from that delay
- Delay probabilities and costs of recovery are assessed for a 48 hour, one week, two week, and four week delay
- Cost of recovery is based on the personnel cost for extending stays at the South Pole or bringing in alternates later (that season or the following season) for catchup work
- Note: This only tracks on-project paid labor, and does not track contributed labor

Excerpt from the Cargo Risk spreadsheet (1/3)

Cargo Item #	WBS L2	Item Description	Contents	Date Item expected or arrived to MCM	Date/Month for Items needed at South Pole	Logistical Mode
17	1.2	8' Refit Container	Priority refit materials including tools, flowmeter assemblies, motor drive installation kits, hardware, fittings, sensors, & consumables	1/15/2022	11/15/2022	LC-130
18	1.2	20' Refit Container A	Refit materials incl. submersible pumps, hardware, filtration components, fall arrest towers, tools, & hose crimper	1/15/2022	12/1/2022	LC-130/SPoT

Excerpt from the Cargo Risk spreadsheet (2/3)

Cargo Item #	WBS L2	Item Description	Contents	48hrs		168hrs (1 wk)		336 hrs (2 wks)		672 hrs (4 wks)	
				Probability	Estimated Cost Impact	Probability	Estimated Cost Impact	Probability	Estimated Cost Impact	Probability	Estimated Cost Impact
17	1.2	8' Refit Container	Priority refit materials including tools, flowmeter assemblies, motor drive installation kits, hardware, fittings, sensors, & consumables	Moderate	0	Moderate	49680	Low	99360	Low	149040
18	1.2	20' Refit Container A	Refit materials incl. submersible pumps, hardware, filtration components, fall arrest towers, tools, & hose crimper Bulky materials incl. cable trays, vertical turbine	Moderate	0	Moderate	24840	Low	49680	Low	99360

Excerpt from the Cargo Risk spreadsheet (3/3)

Cargo Item #	WBS L2	Item Description	Contents	1 week Cost impact notes	2 week Cost impact notes	4 week Cost impact notes
17	1.2	8' Refit Container	Priority refit materials including tools, flowmeter assemblies, motor drive installation kits, hardware, fittings, sensors, & consumables	Work stoppage - 8 drillers for 1 week - 432 hours lost - early season work contingent on 8' container contents	Work stoppage - 8 drillers for 2 weeks - 864 hours lost - early season work contingent on 8' container contents	Work stoppage - 8 drillers for 3 weeks - 1296 hours lost - early season work contingent on 8' container contents assumes Container A arrived 12/1
18	1.2	20' Refit Container A	Refit materials incl. submersible pumps, hardware, filtration components, fall arrest towers, tools, & hose crimper	Work stoppage - 8 people 3 days - 216 hours	Work stoppage - 8 people 6 days - 432 hours	Work stoppage - 8 people 12 days - 864 hours

Field Season 1 Cargo & Personnel

Item	Date expected or arrived in MCM	Date/Month for items needed at SP
Gen 2 - housed in 20' container	In McMurdo	1/1/2023
Gen 3 - housed in 20' container	In McMurdo	12/1/2022
287 Loader	In McMurdo	12/1/2022
Fuel Tower	In McMurdo	1/1/2023
Container Ski Stack (comprised of 5 sleds) - currently staged in Pt. Hueneme	1/15/2022	12/15/2022
8' Refit Container	1/15/2022	11/15/2022
20' Refit Container A	1/15/2022	12/1/2022
20' Refit Container B	1/15/2022	12/15/2022
ARA Trailer	1/15/2022	12/15/2022
Controls infrastructure - Motor drives, PLCs, electrical hardware, and motor drive mounting kits	11/1/2022	12/1/2022
ARA Drill System Components - Crate 1	11/1/2022	12/15/2022
ARA Drill System Components - Crate 2	11/1/2022	12/15/2022
FY23 Fuel	11/1/2022	12/1/2022
Personnel – 8	11/1/2022	11/15/2022

Field Season 2 Cargo & Personnel

Item	Date expected or arrived in MCM	Date/Month for items needed at SP
Gen 1 - housed in 20' container	In McMurdo	12/1/2023
Gen hoods Discharge Hoods - currently staged in McMurdo	In McMurdo	1/1/2024
Firn Drill	In McMurdo	12/15/2023
Firn Drill Components - 1	In McMurdo	12/15/2023
Firn Drill Components - 2	In McMurdo	12/15/2023
Weight stack and crates	In McMurdo	12/15/2023
HPU 1	In McMurdo	1/1/2024
Generator Intake Hood - currently staged in Pt. Hueneme	1/15/2023	1/1/2024
Generator Discharge Hoods - currently staged in Pt. Hueneme	1/15/2023	1/1/2024
Drill Hose - currently staged in Pt. Hueneme	1/15/2023	1/1/2024
Drill Hose - currently staged in Pt. Hueneme	1/15/2023	1/1/2024
Return Water Cable Reel (RWCR)	1/15/2022	12/1/2023
Main Cable Reel (MCR)	1/15/2022	12/1/2023
ICL power and timing electronics	11/1/2023	12/1/2023
ICL patch cables and patch panels	11/1/2023	12/1/2023
Camp Hose - currently staged at PSL	1/15/2022	12/1/2023
Bull wheel	11/1/2023	2/1/2024
Load member cable reel	11/1/2023	12/15/2023
DOM Handling Facility (DHF) - ASC shoulders majority of impact - their workforce will construct	1/15/2023	12/15/2023

Item	Date expected or arrived in MCM	Date/Month for items needed at SP
Spare Combo cable	1/15/2024	2/1/2024
Spare Drill Cable	1/15/2024	2/1/2024
Computing/controls components	11/1/2023	11/15/2023
Driller resupply/refit components - 8' Container	11/1/2023	11/15/2023
Drill refit components	11/1/2023	11/15/2023
Drill Head DNF - Y	1/15/2024	2/1/2024
Drill Head DNF - R	1/15/2024	2/1/2024
Installation Hardware 87-93	2/6/2024	2/15/2024
Installation Weights 87-93	2/6/2024	2/15/2024
Installation Hardware 87-93	2/6/2024	2/15/2024
Installation Weights 87-93	2/6/2024	2/15/2024
Calibration Devices 87-88	11/1/2023	12/15/2023
Special Devices 87-88	11/1/2023	12/15/2023
Misc. Science Equipment - FY24	11/1/2023	12/1/2023
Surface Junction Boxes	1/15/2023	12/10/2023
Surface Cable Assemblies	1/15/2023	11/20/2023
Breakout cables for strings 87-88	1/15/2024	1/25/2024
Calibration Devices 87-88	11/1/2023	1/15/2024
FieldHub electronics	11/1/2023	12/1/2023
String Sensors 87 & 88 (MSU)	11/1/2023	1/15/2024
String Sensors 87 & 88 (GE)	11/1/2023	1/15/2024
String Sensors 87 & 88 (Chiba)	11/1/2023	1/15/2024
FY24 Fuel	11/1/2023	12/1/2023
Personnel – 14	11/1/2023	11/15/2023

Field Season 3 Cargo & Personnel

Item	Date expected or arrived in MCM	Date/Month for items needed at SP
Computing/controls components	11/1/2024	11/15/2024
Special devices 89-93	11/1/2024	11/25/2024
Calibration Devices 89-93	11/1/2024	11/25/2024
Misc. Science Equipment - FY25	11/1/2024	12/1/2024
Dust logging device	11/1/2024	11/25/2024
Breakout cables for strings 89-93 (MSU)	1/15/2024	11/25/2024
Main (downhole) load members 87-93 (MSU)	1/15/2024	12/1/2024
Main (downhole) cables 87-93 (MSU)	1/15/2024	12/1/2024
String Sensors 89-93 (MSU)	11/1/2024	11/1/2024
String Sensors 89-93 containers (MSU)	11/1/2024	11/1/2024
DM-Ice	11/1/2024	11/25/2024
String Sensors 89-93 (GE)	11/1/2024	11/25/2024
Special Devices 89-93 (GE)	11/1/2024	11/25/2024
Calibration Devices 89-93 (GE)	11/1/2024	11/25/2024
String Sensors 89-93 (Chiba)	11/1/2024	11/25/2024
String Sensors 89-93 (Chiba)	11/1/2024	11/25/2024
FY25 Fuel	11/1/2024	12/1/2024
Personnel – 28	11/10/2024	11/15/2024

Monte Carlo treatment

- Thousand realizations of the three field seasons
- Cost impacts calculated for each realized risk instance
- Even if effort was previously in-kind, the mitigated labor is assumed on budget
- Annual 95% confidence level cost exposures:

Installation Year	Cost Exposure (\$)	Cost Exposure (Labor Hours)
Year 1	<u>\$ 47,201</u>	410
Year 2	<u>\$ 94,262</u>	820
Year 3	<u>\$ 342,111</u>	2975

Additional hours to cover risk exposure

	Population (people)	Available Labor Hours	Risk Exposure in Labor Hours	Percentage of available workhour pool needed for risk coverage
Year 1	8	4128	410	10%
Year 2	14	7224	820	11%
Year 3	28	14448	2975	21%

Additional labor could be people extending their season, or additional people deployed that season (or following season)

Monte Carlo Notes

- Assumes all events are uncorrelated, so impact on the critical path is determined by latest item in a season
- Assumes people are mostly fungible, with the more specialized labor partially managed with spares versus repairs
- And mitigated with more person-hours on ice, whether through alternates or extended season
- More nuanced analysis is difficult to automate
- To expand on the MC, we can show some “What-If” scenarios to illustrate the effects and mitigations of some sample delays

Season 1: What if the 8' Refit Container is delayed?

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				Probability	Estimated Cost Impact	Probability	Estimated Cost Impact	Probability	Estimated Cost Impact	Probability	Estimated Cost Impact
17	1.2	8' Refit Container	Priority refit materials including tools, flowmeter assemblies, motor drive installation kits, hardware, fittings, sensors, & consumables	Moderate	0	Moderate	49680	Low	99360	Low	149040

- This is important material for the early season work, and is to be sent by LC-130
- A few day delay can be taken up with some rescheduling (no real cost)
- Can check if it's due for the next flight, or is further up the logistics chain...
- Each week of delay though costs hundreds of person-hours of delayed work, which would have to be done later in that season, or with additional people the following season
- Full risk realized after three weeks of delay

Season 2: What if the drill team is delayed?

Cargo Item #	WBS L2	Item Description	Contents	1 week Cost impact notes	2 week Cost impact notes	4 week Cost impact notes
82	1.2	2 people delayed PY6		Cost equal to hours delay (54 hours per person week) x labor rate of \$115	Cost equal to hours delay (54 hours per person week) x labor rate of \$115	Cost equal to hours delay (54 hours per person week) x labor rate of \$115 x 1.5 (additional labor will be required to overcome delays)
83	1.2	4 people delayed PY6		Cost equal to hours delay (54 hours per person week) x labor rate of \$115	Cost equal to hours delay (54 hours per person week) x labor rate of \$115	Cost equal to hours delay (54 hours per person week) x labor rate of \$115 x 1.5 (additional labor will be required to overcome delays)

- If it's a couple of days late, we know we can be flexible enough to reschedule other work.
- After that, we have a linear push on the schedule for the 2 or 4 delayed people
- For basic drill activities, all drillers can safely perform the work and shut systems down as needed, based on training

Season 3: What if a pallet of mDOMs is delayed?

Cargo Item #	WBS L2	Item Description	Contents	1 week Cost impact notes	2 week Cost impact notes	4 week Cost impact notes
67	1.3	String Sensors 89-93	Optical sensors for 5 strings from Germany (mDOMs) (spares not included) - Do Not Deep Freeze	Drill season extended by 1 week 1512 hours	Drill season extended by 2 weeks 3024 hours	Drilling can no longer be accomplished

- A few day delay will require some rescheduling of the handling and testing of the modules before deployment
- Would check to ensure they are coming on the next flight, if so, maybe delay next hole drilling by a day or two (take a two or three day weekend), and the total delay could be small
- If the modules haven't arrived in a week, you could be looking at a week longer drill season, or potentially some adjusting of which modules go onto which string (not all combinations are possible, but small changes would have small physics impacts)
- Longer delays push the season out longer, or would require a string with somewhat lower performance installed, a lot depends on whether this is the only delayed item or other modules are also delayed (correlated shipping issues)
- Eventually this would force an additional season of drilling, or face a reduced scope of the project

Conclusions

- The project is very cargo-dependent, and the most effective risk mitigation would be earlier shipping to Antarctica
- Sensitivity analysis has reinforced that delays will require potentially extending stays of deployed individuals and/or deploying additional personnel
- Extended delays which preclude activities in one season can, in some cases, be mitigated with additional work and personnel in the subsequent season
- We have used quantitative tools such as the Monte Carlo analysis of shipping delays as a complementary method to individual line item "what-if" analysis
- Analyses will be used as part of seasonal work planning every year and based on past season performance