IceCube Upgrade Logistics – Analysis of Alternatives

Change Log

Rev	Description : Author	Date
1	Original document : I. McEwen	7/10/2022

1. Table of Contents

2. Purpose of this Document

This document provides background on ICU project rebaseline logistics plans and describes the analysis of alternatives that was conducted by IceCube Upgrade (ICU) in response to AIL's May 2022 release of an updated logistics support capacity with a "probability of not meeting commitment" clarification. We report the details of modified transportation approach and details of the analysis that lead to the proposed solution.

Thorough analysis determined that an effective reduction of the identified risk is possible by transferring the mode of fuel transportation from LC-130 aircraft missions to overland transport. A risk analysis was performed for several alternatives with only one resulting in 97% or greater probability of logistics success in all seasons. This alternative includes the employment of four 25k liter 20' ISO tank containers on available SPOT positions in FY24, FY25, & FY26, as well as a revised warehousing plan developed with ASC to maximize DNF storage capacity at the South Pole.

3. Background

The Project Year 4 (PY4) rebaseline planning was completed using the ICU Planning Capacities (Figure 1) provided by OPP/AIL in January of 2022. The outyear logistics look ahead allowed for much greater fidelity in field season planning and provided for significant reduction in instances of Just-in-Time (JIT) delivery over previous logistics models. In the PY4 rebaseline plan, much of the project's non-sensitive cargo was shifted to overland transport with South Pole Traverse (SPOT) from air delivery (New York Air National Guard LC-130 aircraft). Project fuel transport was limited to LC-130 delivery, however, as SPOT does not possess assets to support additional overland fuel transport.

ICU Planning Capacities
OPP-AIL, 1/31/2022

Year	FY23	FY24	FY25	FY26	FY27
Vessel South (TEUs)	18*	as needed	as needed	n/a	n/a
Vessel North (TEUs)	n/a	17	50	17	50
LC-130: Hours/Flights^	12/2	114/19	60/10	42/7	36/6
SPoT-1 (Sleds/Weight, lbs)	3/180,000	3/180,000	3/180,000	3/180,000	3/180,000
SPoT-2 (Sleds/Weight, lbs)	3/180,000	3/180,000	3/180,000	3/180,000	3/180,000
SPoT-3 (Sleds/Weight, lbs)	3/180,000	3/180,000	3/180,000	3/180,000	3/180,000
Pole Population (Nov-Jan)	0	11	21	46~	4

*If ICU needs more space to move things ahead, we will find a way to make more TEUs available.

^This does not fully meet the goal to have all fuel required on site prior to the FY26 main drilling season. AIL will continue to look at ways to mitigate that risk as planning moves forward.

~This is a hard maximum and needs to be reviewed again for ways to bring it down if at all possible.

In general:

1. Our supportability is dependent on moving as much cargo to Pole as possible in FY24. This means getting as much cargo on the FY23 vessl or, if needed, getting it to MCM via commercial surface shipment/C17 no later than Nov. 2024.
2. FY27 info is provided in advance of IPT discussion/clarification on retro requirements.
3. Temperature controlled storage (at MCM and Pole) is likely still an issue that needs to be resolved with this capacity.

Figure 1: ICU Planning Capacities - January 2022

As seen in Figure 2, the project's planned logistics requirements (blue column) for vessel and SPOT do not completely consume the ICU Planning Capacity (white column) in the PY4 Rebaseline plan. Air cargo delivery, however, completely utilizes all available LC-130 missions from FY23 through the FY26 drill season for the movement of fuel and sensitive cargo.

Year	FY23 Capacity	FY23 Planned	FY24 Capacity	FY24 Planned	FY25 Capacity	FY25 Planned	FY26 Capacity	FY26 Planned	FY27 Capacity	FY27 Planned
Vessel South (TEU)	18	6.25	as needed	5.25	as needed	3.25	n/a	n/a	n/a	n/a
Vessel North (TEU)	n/a	-	17	0.5 (EST)	50	0.5 (EST)	17	-	50	TBD
LC-130: Flights / Cargo [lbs]	2 missions	0/0	19 missions	0.6/11,445	10 missions	2/43,103	7 missions	3.6/73,939	6 missions	TBD
LC-130: Flights / Fuel [gallons]		2/6,000		18.4/55,200		8/24,000		3.4/10,200		TBD
SPOT-1 (Sleds/lbs)	3/180,000	3/21,601	3/180,000	2/56,900	3/180,000	2.9/56,143	3/180,000	2.5/110,362	3/180,000	TBD
SPOT-2 (Sleds/lbs)	3/180,000	3/109,405	3/180,000	0/0	3/180,000	0.45/16,302	3/180,000	0/0	3/180,000	TBD
SPOT-3 (Sleds/lbs)	3/180,000	1/28,000	3/180,000	0/0	3/180,000	0/0	3/180,000	3/46,791 R	3/180,000	TBD
Pole Population (Nov-Jan)	0	0	11	11	21	21	46	46	4	TBD

Figure 2: ICU Planning Capacities vs PY4 Rebaseline plan

Project Year 4 (PY4) rebaseline planning was completed prior to the May 2022 probability release which is shown in Figure 3. The new OPP/AIL planning capacities include failure probabilities as indicated in the columns with blue border and show high probability of failure for the FY24 LC-130 leg and medium probability of failure for FY23 vessel, FY24-FY26 LC-130, and FY23-FY26 South Pole Operational Traverse (SPOT) 3. FY27 probability was not addressed in the analysis of alternatives as FY27 retrograde activities are outside the scope of the project.

ICU Planning Capacities
OPP-AIL, May 2022

Year	FY23	FY23 probability*	FY24	FY24 probability	FY25	FY25 probability	FY26	FY26 probability	FY27	FY27 probability
Vessel South (TEUs)	18	Medium	as needed	Low	as needed	Low	n/a	n/a	n/a	n/a
Vessel North (TEUs)	n/a	n/a	17	Low	50	Low	17	Low	50	Low
LC-130: Hours/Flights	12/2	Low	114/19	High	60/10	Medium	42/7	Medium	36/6	Medium
SPoT-1 (Sleds/Weight, lbs)	3/180,000	Low	3/180,000	Low	3/180,000	Low	3/180,000	Low	3/180,000	Low
SPoT-2 (Sleds/Weight, lbs)	3/180,000	Low	3/180,000	Low	3/180,000	Low	3/180,000	Low	3/180,000	Low
SPoT-3 (Sleds/Weight, lbs)	3/180,000	Medium	3/180,000	Medium	3/180,000	Medium	3/180,000	Medium	3/180,000	Medium
Pole Population (Nov-Jan)	0	n/a	11	Low	21	Medium	46	Medium	4	Low
ASC Staffing	0	Low	3	Low	4	Low	9	Medium	0	Low
Equipment Support	crane	Low	crane	Low	crane	Low	crane	Low	n/a	n/a

*probability of NOT being able to meet the commitment

Figure 3: ICU Planning Capacities updated with failure probability – May 2022

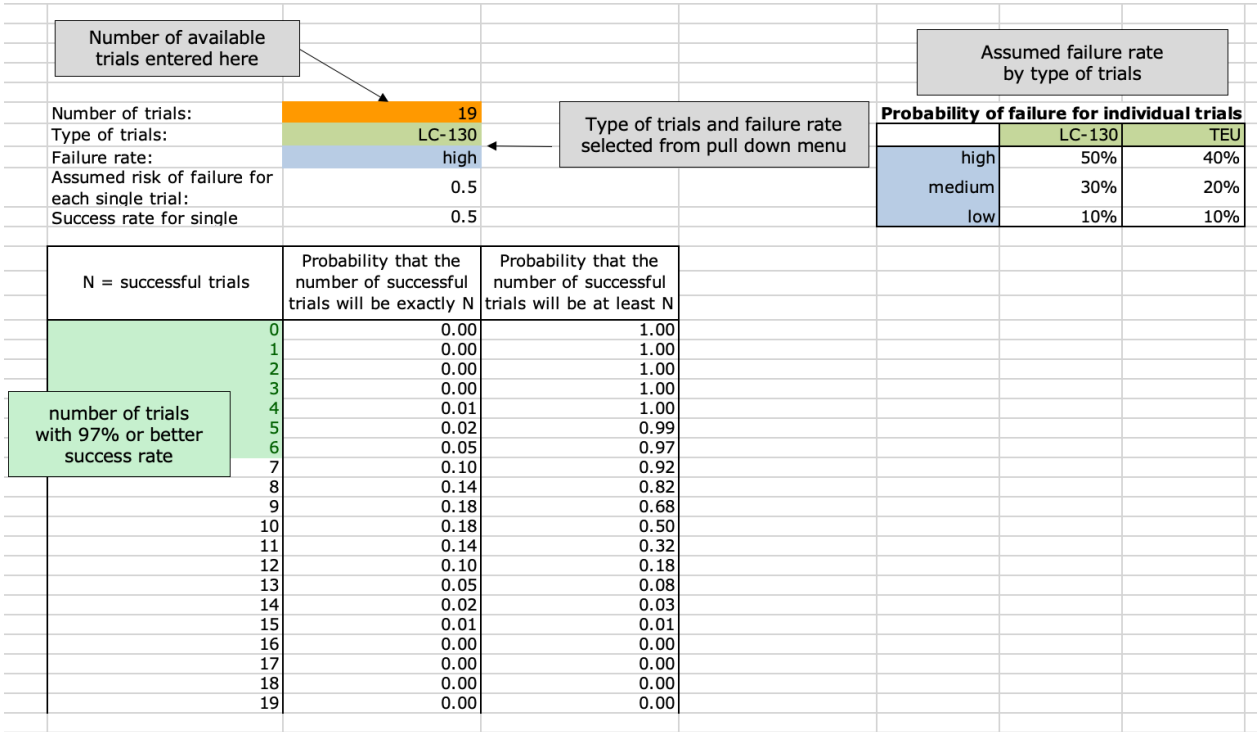
4. Probability Analysis Methodology

A quantitative risk model was developed to produce systematic risk estimates for logistics risks associated with LC130 missions and the USAP Vessel/SPOT for each of the alternate options.

Given a single trial failure probability and a specified number of trials, the model calculates the number of trials for a 97% or higher probability of success. The single trial failure probability depends on the trial mode (LC-130 mission or USAP Vessel/SPOT twenty-foot equivalent unit) and has been chosen as indicated in the "assumed failure rate by trial type" table in Figure 4.

In the worksheet shown below, the model is used to estimate the capacity for the FY24 LC-130 missions. The table in Figure 3 shows 19 flights with a high probability of failure. The failure estimate is assumed to be 50%. The output of the model is that at least 6 flights have a probability of success of 97% or better.

It should be noted that the success probabilities are based on the AIL capacities as stated in the January 2022 ICU Logistics Capacities. Should missions be reallocated elsewhere and no longer be available to support ICU, the probability of logistics success would be impacted negatively.



Number of trials:	19
Type of trials:	LC-130
Failure rate:	high
Assumed risk of failure for each single trial:	0.5
Success rate for single	0.5

Probability of failure for individual trials

	LC-130	TEU
high	50%	40%
medium	30%	20%
low	10%	10%

N = successful trials	Probability that the number of successful trials will be exactly N	Probability that the number of successful trials will be at least N
0	0.00	1.00
1	0.00	1.00
2	0.00	1.00
3	0.00	1.00
4	0.01	1.00
5	0.02	0.99
6	0.05	0.97
7	0.10	0.92
8	0.14	0.82
9	0.18	0.68
10	0.18	0.50
11	0.14	0.32
12	0.10	0.18
13	0.05	0.08
14	0.02	0.03
15	0.01	0.01
16	0.00	0.00
17	0.00	0.00
18	0.00	0.00
19	0.00	0.00

Figure 4: quantitative risk modeling worksheet

5. Alternatives to PY4 rebaseline plan

In the PY4 rebaseline plan (Figure 2), the transport of project fuel by LC-130 aircraft consumes 31.8 of the available 38 mission. Cargo requires 6.2 missions as overland delivery is planned for the vast majority of project cargo.

All alternatives analyzed focused, therefore, on the adjustment of fuel transport method, as compared to the rebaseline plan, in order to mitigate the LC-130 logistics pathways that were identified as having a medium or high probability of failure.

A probability analysis was conducted for both FY23 USAP vessel and FY23-FY26 SPOT3, as discussed later in this document. No mitigations were required to address vessel and SPOT 3 failure probabilities as the utilization of these pathways is within the much lower than the available capacity and well within the success rate predicted by our model.

Three different overland fuel hauling configurations were considered in the logistics alternatives analysis. One utilized the current process for fuel hauling, bladder-sets (Figure 5). It should be noted that bladder-sets replace sleds; a traverse tractor can pull either sleds or a single bladder-set but not both.

Figure 5: SPOT offloading bladder-set at Amundsen-Scott South Pole Station from https://photolibrary.usap.gov/PhotoDetails.aspx?filename=Fuels_South_Pole_Hose_Bladder_transfer.jpg

The other two configurations rely on procurement of new assets, 25K liter 20’ ISO tank containers (Figure 6), to support fuel transport. ISO container tanks are a Commercially available off-the-Shelf (COTS) item with a robust construction as they are designed for intermodal transport and marine environments. SPOT sleds are configured to readily accept 20’ ISO containers with locking mechanisms (twist locks) that engage with the container corner pockets.

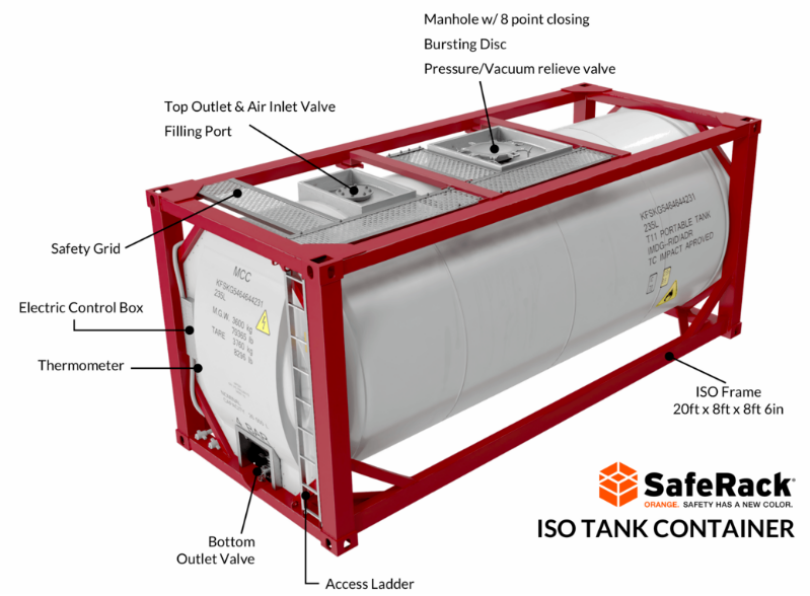


Figure 6: ISO Tank Container from https://www.saferack.com/glossary/iso-tank-containers/

Three different overland fuel hauling configurations were considered in the logistics alternatives analysis:

- A single bladder set (comprised of six 3,000 gallon bladders w/18k gallons total capacity) to SPOT in the FY23, FY24, and FY25 field seasons.

Figure 7: SPOT Tractor hauling 18k bladder set (USAP Photo Library)

- Utilization of three 25k liter 20' ISO tank containers on open sled positions (Figure 8**Error! Reference source not found.**) - (FY24-FY26)

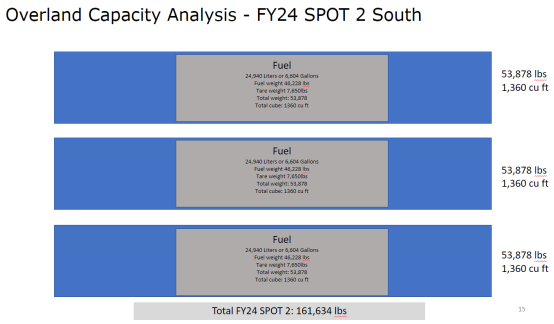


Figure 8: Model of three ISO tank container on SPOT sleds

- Utilization of four 25k liter 20'ISO tank containers on open sled positions (Figure 9) - (FY24-FY26)

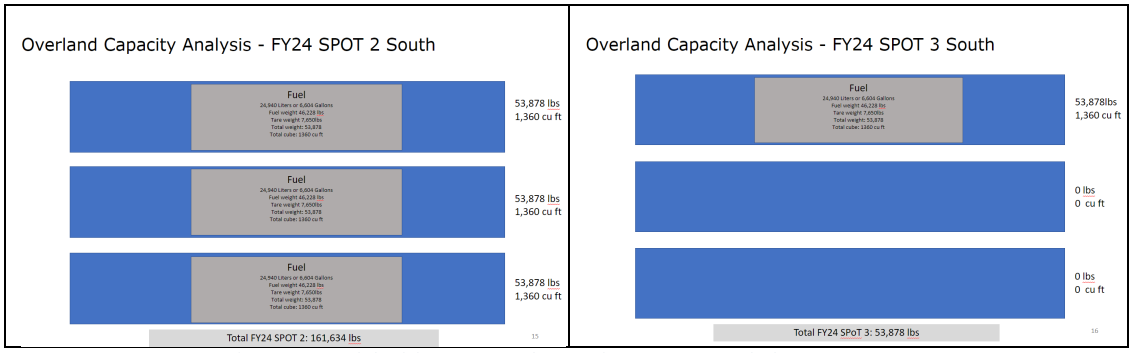


Figure 9: Model of four ISO tank container on SPOT sleds

6. Proposed solution: Four 25k liter 20' ISO tank containers & adjustment to the South Pole DNF storage plan

6.1. Findings summary

Of the alternatives analyzed, only one offers 97% probability of success for all field seasons. In this plan a large reduction in LC-130 reliance is accomplished with a 79% reduction of LC-130 missions in FY24, a 70% reduction in FY25, and a 57% reduction in FY26.

This alternative logistics plan utilizes four 25k liter 20' ISO container tanks traveling overland on SPOT sleds, as well as a different approach to South Pole DNF warehousing. The four ISO tank containers are procured and shipped to Lyttelton, New Zealand where they are either loaded onto vessel or flown on a Special Assignment Airlift Mission (SAAM) to McMurdo Station during FY23. In the FY24, FY25, & FY26 field seasons, SPOT 2 hauls three full ISO tanks to the South Pole on open sled positions, SPOT 3 hauls one in FY23 & FY25 and SPOT1 hauls one in FY26. Fuel is offloaded into the South Pole fuel arch and the tanks return empty to McMurdo for the winter. This fuel delivery profile requires less overwinter storage capacity than the rebaseline plan (shown in Figure 10).

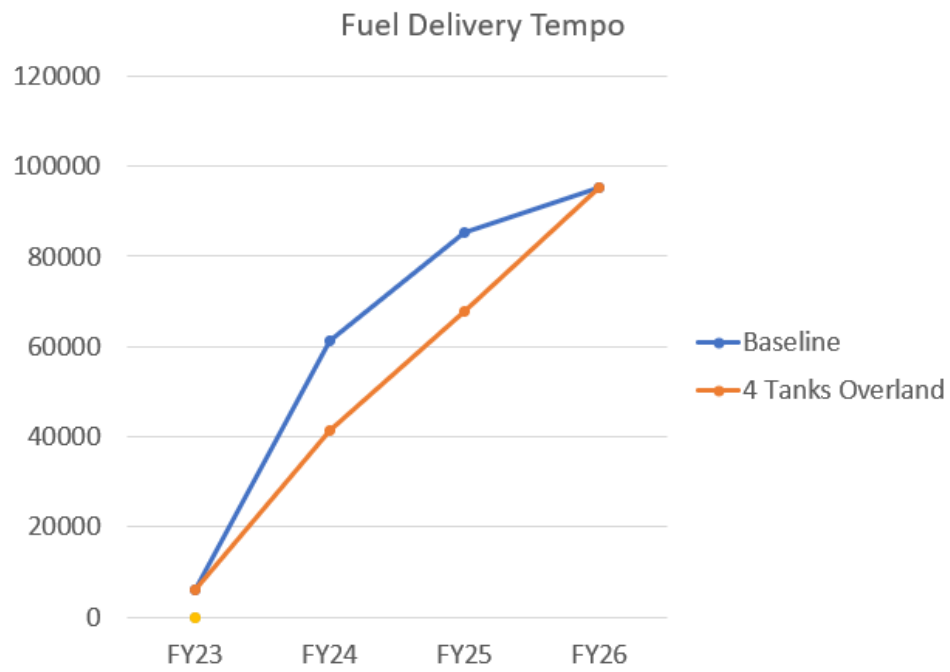


Figure 10: Fuel delivery tempo; PY4 Rebaseline vs four ISO tank/DNF adjustment

The adjustment to the DNF warehousing strategy provides adequate FY25 South Pole winter storage capacity to store all D-Eggs, breakout cables, special/calibration devices, drill heads, and two strings of mDOMs within existing heated South Pole structures. Additionally, this reduces instances of Just-in-Time inventory (JIT) significantly, in turn reducing project risk. The increase in warehousing capacity provides the ability to shift one LC130 mission from FY26 to FY25, reducing the FY26 mission count from four to three. With this change, FY26 success probability increases to 97%. In order to maintain a "contingency mission" in FY25, a fuel flight is shifted to FY24 where three contingency missions were held.

- FY24 - Utilization of 19% of LC130 missions reduces high probability of failure to low. The probability analysis conducted for this high risk shows a 100% likelihood of completing 4 missions. 2 additional missions could be flown without dropping below 97% success probability.
- FY25 - Utilization of 30% LC130 missions reduces moderate probability of failure to low. The probability analysis conducted for this moderate risk shows a 100% likelihood of completing 3 missions. 1 additional mission could be flown without dropping below 97% success probability.
- FY26 - Utilization of 43% LC-130 missions reduces probability of failure from moderate to low. The probability analysis conducted for this moderate risk shows a 97% likelihood of completing 3 missions. In addition to overland fuel hauling, the South Pole DNF storage plan has been adjusted to allow for warehousing of an additional string of instrumentation.

6.2. Logistics Support Pathway Table

Four 25k liter (6604 gallon) ISO fuel tank concept w/ 26,416 gallon seasonal haul capacity v2													79,248 gallons of 95,400 delivered overland
Total mission reduction: 69%		Total missions: 11.6 (Baseline 38)											
Year	FY23 Capacity	FY23 Baseline Plan	FY23 Alternate Plan	FY24 Capacity	FY24 Baseline Plan	FY24 Alternate Plan	FY25 Capacity	FY25 Baseline Plan	FY25 Alternate Plan	FY26 Capacity	FY26 Baseline Plan	FY26 Alternate Plan	
Vessel South (TEU)	18	6.35	10.35	as needed	5.25	5.25	as needed	3.25	3.25	n/a	n/a	n/a	
Vessel North (TEU)	n/a		-	17	0.5 (EST)	0.5 (EST)	50	0.5 (EST)	0.5 (EST)	17	-	-	
LC-130: Flights / Cargo [lbs]	2 missions	0/0	0/0	19 missions	0.6/9,817	0.6/9,817	10 missions	2/43,103	3/55,095	7 missions	3.6/73,939	2.6/73,939	
LC-130: Flights / Fuel [gallons]		**2/6,000**	**2/6,000**		**18.4/55,200**	**3/9,000**		**8/24,000**	**0/0**		**3.4/10,200**	**.4/1,152**	
SPOT-1 Sleds / Cargo [lbs]	3/180,000	3/21,601	3/21,601	3/180,000	2/56,900	2/56,900	3/180,000	2.9/56,143	3.0/63,143	3/180,000	2.5/110,362	2.5/110,362	
SPOT-1 Sleds / Fuel [gallons]		**0/0**	**0/0**		**0/0**	**0/0**		**0/0**	**0/0**		**0/0**	**.5/6,604**	
SPOT-2 Sleds / Cargo [lbs]	3/180,000	3/109,405	3/109,405	3/180,000	0/0	0/0	3/180,000	0.45/16,302	0.25/5,502	3/180,000	0/0	0/0	
SPOT-2 Sleds / Fuel [gallons]		**0/0**	**0/0**		**0/0**	**3/19,812**		**0/0**	**3/19,812**		**0/0**	**3/19,812**	
SPOT-3 Sleds / Cargo [lbs]	3/180,000	1/28,000	1/28,000	3/180,000	0/0	0/0	3/180,000	0/0	0/0	3/180,000	3/46,791 R	0/0 R	
SPOT-3 Sleds / Fuel [gallons]		**0/0**	**0/0**		**0/0**	**1/6,604**		**0/0**	**1/6,604**		**0/0**	**0/0**	
Pole Population (Nov-Jan)	0	0	0	11	11	11	21	21	21	46	46	46	
					FY24 mission reduction	**81%**		**FY25 mission reduction**	**70%**		**FY26 mission reduction**	**57%**	

Figure 11: Logistics table - baseline vs. Tank/DNF alternative

6.3. DNF warehousing adjustments

The baseline and rebaseline logistics plans stored cargo in the South Pole Cryogen Facility's Helium Bay where there are rollers to receive Air Force pallets. In this alternate plan, the rollers are removed from the Helium Bay and the skids from the Air Force Pallets (AFP) they arrive on. This allows for far tighter packing of materials and full utilization of available footprint. Additionally, a portion of the Nitrogen Bay and some of IceCube Lab is used. Below is the loading plan for the Helium and Nitrogen Bays. Walkways are not shown but are accounted for.

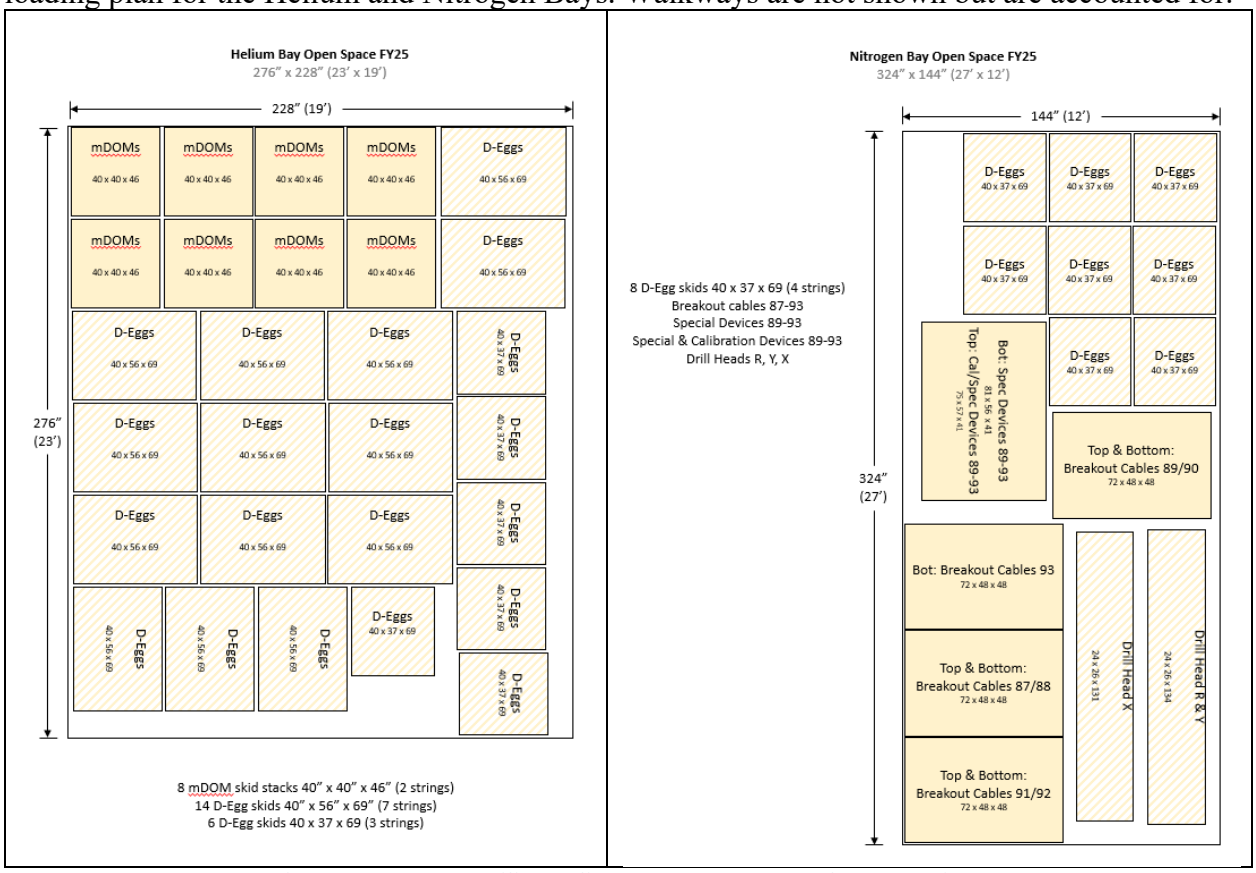


Figure 12: Cryogen Facility, Helium Bay - DNF storage plan FY25 winter

7. Other options considered

7.1. Alternative Analysis: Addition of single bladder set to SPOT in the FY23, FY24, and FY25 field seasons.

Adding 18k gallons of additional capacity to SPOT for the FY23, FY24, & FY25 seasons reduces reliance on LC130's by 47% and the total mission count from 38 (rebaseline plan) to 20 missions. 54,000 gallons of fuel can be delivered of the project's total requirement of 95,361 gallons. While this represents a significant shift in fuel transport pathway from air to surface, it is not adequate to achieve a 97% probability of success in all three field seasons.

- FY24 - Utilization of 24% of LC130 capacity reduces high probability of failure to meet commitment to low. The probability analysis conducted for this high risk shows a 97% likelihood of completing 6 missions. One additional mission could be flown without dropping below 97% success probability.
- FY25 - Utilization of 80% of LC130 capacity does not reduce moderate probability of failure to low. The probability analysis conducted for this moderate risk shows a 97% likelihood of completing 4 missions. This option requires 8 missions dropping the success probability to 38%.
- FY26 - Utilization of 77% of LC130 capacity does not reduce probability of failure from moderate to low. This option requires 6 missions dropping the success probability to 33%. The addition of climate-controlled warehousing at the South Pole and increased overland fuel hauling capacity is required for further reduction.

One additional bladder set w/ 18,000 gallon seasonal haul capacity - Three seasons													54,000 gallons of 95,361 delivered overland
Total mission reduction: 47%		Total missions: 20 (Baseline 38)											
Year	FY23 Capacity	FY23 Baseline Plan	FY23 Alternate Plan	FY24 Capacity	FY24 Baseline Plan	FY24 Alternate Plan	FY25 Capacity	FY25 Baseline Plan	FY25 Alternate Plan	FY26 Capacity	FY26 Baseline Plan	FY26 Alternate Plan
Vessel South (TEU)	18	6.35	6.35	as needed	5.25	5.25	as needed	3.25	3.25	n/a	n/a	n/a
Vessel North (TEU)	n/a	-	-	17	0.5 (EST)	0.5 (EST)	50	0.5 (EST)	0.5 (EST)	17	-	-
LC-130: Flights / Cargo [lbs]	2 missions	0/0	0/0	19 missions	0.6/9,817	0.6/9,817	10 missions	2/43,103	2/43,103	7 missions	3.6/73,939	3.6/73,939
LC-130: Flights / Fuel [gallons]		**2/6,000**	**2/6,000**		**18.4/55,200**	**4/12,000**		**8/24,000**	**6/18,000**		**3.4/10,200**	**1.8/5,400**
SPOT-1 Sleds / Cargo [lbs]	3/180,000	3/21,601	3/21,601	3/180,000	2/56,900	2/56,900	3/180,000	2.9/56,143	3.0/63,143	3/180,000	2.5/110,362	2.5/110,362
SPOT-1 Sleds / Fuel [gallons]		**0/0**	**0/0**		**0/0**	**0/0**		**0/0**	**0/0**		**0/0**	**0/0**
SPOT-2 Sleds / Cargo [lbs]	3/180,000	3/109,405	3/109,405	3/180,000	0/0	0/0	3/180,000	0.45/16,302	0.25/5,502	3/180,000	0/0	0/0
SPOT-2 Sleds / Fuel [gallons]		**0/0**	**0/0**		**0/0**	**0/0**		**0/0**	**0/0**		**0/0**	**0/0**
SPOT-3 Sleds / Cargo [lbs]	3/180,000	1/28,000	1/28,000	3/180,000	0/0	0/0	3/180,000	0/0	0/0	3/180,000	3/46,791 R	0/0 R
SPOT-3 Sleds / Fuel [gallons]		**0/0**	**1/18,000**		**0/0**	**1/18,000**		**0/0**	**1/18,000**		**0/0**	**0/0**
Pole Population (Nov-Jan)	0	0	0	11	11	11	21	21	21	46	46	46
					FY24 Mission reduction	76%		FY25 Mission reduction	20%		FY26 Mission reduction	23%

Figure 13: Logistics table - Rebaseline vs. SPOT fuel bladder-set

7.2. Alternative Analysis: Utilization of three 25k liter 20' ISO tank containers on open sled positions - (FY24-FY26)

In this alternative for fuel transport there is no change to the FY23 logistics plan as compared to the rebaseline schedule. Two LC30 mission are utilized for the delivery of 6000 gallons of fuel to the South Pole. Three ISO tank containers are procured and shipped to Lyttelton, New Zealand where they are either loaded onto vessel or flown on a Special Assignment Airlift Mission (SAAM) to McMurdo Station during FY23. Beginning in FY24 SPOT 2 hauls three full ISO tanks to the South Pole on open sled positions. Fuel is offloaded into the South Pole fuel arch and the tanks return empty to McMurdo for the winter. In FY24 and FY25 this process is repeated hauling full fuel tanks overland to the South Pole on SPOT 2 and offloading into the fuel arch.

By utilizing three 25k liter ISO tanks on SPOT 2 to haul 19,812 gallons of fuel, the reliance on LC130's is reduced by 52% and the total mission count is reduced from 38 (rebaseline plan) to 18 missions. 59,436 gallons of fuel can be delivered of the project's total requirement of 95,361 gallons in this scenario. Similar to the previous alternative, while a substantial reduction in LC130 mission use is accomplished, it is not adequate to achieve a 97% probability of success in all three field seasons.

- FY24 - Utilization of 35% of LC130 capacity does not reduce high probability of failure to low. The probability analysis conducted for this high risk shows a 97% likelihood of completing 6 missions. The option requires 7 missions dropping the success probability to 92%.
- FY25 - Utilization of 50% of capacity does not reduce moderate probability of failure to low. The probability analysis conducted for this moderate risk shows a 97% likelihood of completing 4 missions. The option requires 5 missions dropping the success probability to 92%.
- FY26 - Utilization of 66% of capacity does not reduce probability of failure from moderate to low. This option requires 4 missions dropping the success probability to 87%. The addition of climate-controlled warehousing at the South Pole and additional fuel hauling capacity is required for further reduction.

Three 25k liter (6604 gallon) ISO fuel tank concept w/ 19,812 gallon haul capacity												59,436 gallons of 95,361 delivered overland
Total mission reduction 52%		Total missions: 18.2 (Baseline 38)										
Year	FY23 Capacity	FY23 Baseline Plan	FY23 Alternate Plan	FY24 Capacity	FY24 Baseline Plan	FY24 Alternate Plan	FY25 Capacity	FY25 Baseline Plan	FY25 Alternate Plan	FY26 Capacity	FY26 Baseline Plan	FY26 Alternate Plan
Vessel South (TEU)	18	6.35	9.35	as needed	5.25	5.25	as needed	3.25	3.25	n/a	n/a	n/a
Vessel North (TEU)	n/a	-	-	17	0.5 (EST)	0.5 (EST)	50	0.5 (EST)	0.5 (EST)	17	-	-
LC-130: Flights / Cargo [lbs]	2 missions	0/0	0/0	19 missions	0.6/9,817	0.6/9,817	10 missions	2/43,103	2/43,103	7 missions	3.6/73,939	3.6/73,939
LC-130: Flights / Fuel [gallons]		**2/6,000**	**2/6,000**		**18.4/55,200**	**6/18,000**		**8/24,000**	**3/9,000**		**3.4/10,200**	**1/2,964**
SPOT-1 Sleds / Cargo [lbs]	3/180,000	3/21,601	3/21,601	3/180,000	2/56,900	2/56,900	3/180,000	2.9/56,143	3.0/63,143	3/180,000	2.5/110,362	2.5/110,362
SPOT-1 Sleds / Fuel [gallons]		**0/0**	**0/0**		**0/0**	**0/0**		**0/0**	**0/0**		**0/0**	**0/0**
SPOT-2 Sleds / Cargo [lbs]	3/180,000	3/109,405	3/109,405	3/180,000	0/0	0/0	3/180,000	0.45/16,302	0.25/5,502	3/180,000	0/0	0/0
SPOT-2 Sleds / Fuel [gallons]		**0/0**	**0/0**		**0/0**	**3/19,812**		**0/0**	**3/19,812**		**0/0**	**3/19,812**
SPOT-3 Sleds / Cargo [lbs]	3/180,000	1/28,000	1/28,000	3/180,000	0/0	0/0	3/180,000	0/0	0/0	3/180,000	3/46,791 R	0/0 R
SPOT-3 Sleds / Fuel [gallons]		**0/0**	**0/0**		**0/0**	**0/0**		**0/0**	**0/0**		**0/0**	**0/0**
Pole Population (Nov-Jan)	0	0	0	11	11	11	21	21	21	46	46	46
					FY24 mission reduction	**65%**		**FY25 mission reduction**	**50%**		**FY26 mission reduction**	**34%**

Figure 14: Logistics table - Rebaseline vs. 3 ISO tank containers

7.3. Alternative Analysis: Utilization of four 25k liter 20' ISO tank containers on open sled positions - (FY24-FY26)

As in the previous, there is no change to the FY23 logistics plan as compared to the rebaseline schedule for this option. Two LC-130 mission are utilized for the delivery of 6000 gallons of fuel to the South Pole. Four ISO tank containers are procured and shipped to Lyttelton, New Zealand where they are either loaded onto vessel or flown on a Special Assignment Airlift Mission (SAAM) to McMurdo Station during FY23. In the FY24, FY25, & FY26 field seasons, SPOT 2 hauls three full ISO tanks to the South Pole on open sled positions, SPOT 3 hauls one in FY23 & FY25 and SPOT1 hauls one in FY26. Fuel is offloaded into the South Pole fuel arch and the tanks return empty to McMurdo for the winter.

By utilizing four 25k liter ISO tanks on SPOT in FY24-FY26 to haul 26,416 gallons of fuel overland, reliance on LC130's is reduced by 69% and the total mission count from 38 (rebaseline plan) to 12. 79,248 gallons of project fuel (81%) can be delivered of the project's total requirement of 95,361 gallons in this option. The probability of success, according to ICU's calculations, is 100% in FY24 and FY25. The FY26 success probability, however, is 87%. In order to increase the FY26 probability to 97% additional mitigations will need to be employed.

- FY24 - Utilization of 16% of LC130 capacity reduces high probability of failure to low. The probability analysis conducted for this high risk shows a 97% likelihood of completing 6 missions. Three additional missions could be flown without dropping below 97% success probability.
- FY25 - Utilization of 30% of LC130 capacity reduces moderate probability of failure to low. The probability analysis conducted for this moderate risk shows a 97% likelihood of completing 4 missions. One additional mission could be flown without dropping below 97% success probability.
- FY26 - Utilization of 43% of LC-130 capacity does not reduce probability of failure from moderate to low. This option requires 4 missions with a success probability of 87%. In order to reduce 1 mission in FY26, and achieve 97% success probability, the addition of climate-controlled warehousing at the South Pole is required. The warehousing would need to accommodate roughly two strings worth of cargo to be delivered in the available FY25 mission.

Four 25k liter (6604 gallon) ISO fuel tank concept w/ 26,416 gallon seasonal haul capacity v1													79,248 gallons of 95,361 delivered overland
Total mission reduction: 69%		Total missions: 11.6 (Baseline 38)											
Year	FY23 Capacity	FY23 Baseline Plan	FY23 Alternate Plan	FY24 Capacity	FY24 Baseline Plan	FY24 Alternate Plan	FY25 Capacity	FY25 Baseline Plan	FY25 Alternate Plan	FY26 Capacity	FY26 Baseline Plan	FY26 Alternate Plan
Vessel South (TEU)	18	6.35	10.35	as needed	5.25	5.25	as needed	3.25	3.25	n/a	n/a	n/a
Vessel North (TEU)	n/a	-	-	17	0.5 (EST)	0.5 (EST)	50	0.5 (EST)	0.5 (EST)	17	-	-
LC-130: Flights / Cargo [lbs]	2 missions	0/0	0/0	19 missions	0.6/9,817	0.6/9,817	10 missions	2/43,103	2/43,103	7 missions	3.6/73,939	3.6/73,939
LC-130: Flights / Fuel [gallons]		**2/6,000**	**2/6,000**		**18.4/55,200**	**2/6,000**		**8/24,000**	**1/3,000**		**3.4/10,200**	**.3/888**
SPOT-1 Sleds / Cargo [lbs]	3/180,000	3/21,601	3/21,601	3/180,000	2/56,900	2/56,900	3/180,000	2.9/56,143	3.0/63,143	3/180,000	2.5/110,362	2.5/110,362
SPOT-1 Sleds / Fuel [gallons]		**0/0**	**0/0**		**0/0**	**0/0**		**0/0**	**0/0**		**0/0**	**.5/6,604**
SPOT-2 Sleds / Cargo [lbs]	3/180,000	3/109,405	3/109,405	3/180,000	0/0	0/0	3/180,000	0.45/16,302	0.25/5,502	3/180,000	0/0	0/0
SPOT-2 Sleds / Fuel [gallons]		**0/0**	**0/0**		**0/0**	**3/19,812**		**0/0**	**3/19,812**		**0/0**	**3/19,812**
SPOT-3 Sleds / Cargo [lbs]	3/180,000	1/28,000	1/28,000	3/180,000	0/0	0/0	3/180,000	0/0	0/0	3/180,000	3/46,791 R	0/0 R
SPOT-3 Sleds / Fuel [gallons]		**0/0**	**0/0**		**0/0**	**1/6,604**		**0/0**	**1/6,604**		**0/0**	**0/0**
Pole Population (Nov-Jan)	0	0	0	11	11	11	21	21	21	46	46	46
					FY24 mission reduction	**84%**		**FY25 mission reduction**	**70%**		**FY26 mission reduction**	**42%**

Figure 15: Logistics table - baseline vs. 4 ISO tank containers

8. Summary

Only the four ISO tank container/DNF warehousing adjustment alternative offers 97% probability of success for all three field seasons. Large reductions on LC130 reliance are made in this scenario with a 79% reduction of LC130 missions in FY24, a 70% reduction in FY25, and a 57% reduction in FY26. Key components are four 25k liter 20' tank container traveling overland on SPOT sleds to support the majority of the projects fuel transport and a different approach to DNF warehousing that provides capacity during the FY25 South Pole winter to store all D-Eggs, breakout cables, special/calibration devices, drill heads, and two strings of mDOMs within existing South Pole heated structures.

9. Appendix

9.1. Fuel delivery tempo table: Baseline LC130 delivery vs. 4 tank overland delivery

Plans compared: Baseline vs 4 tank overland

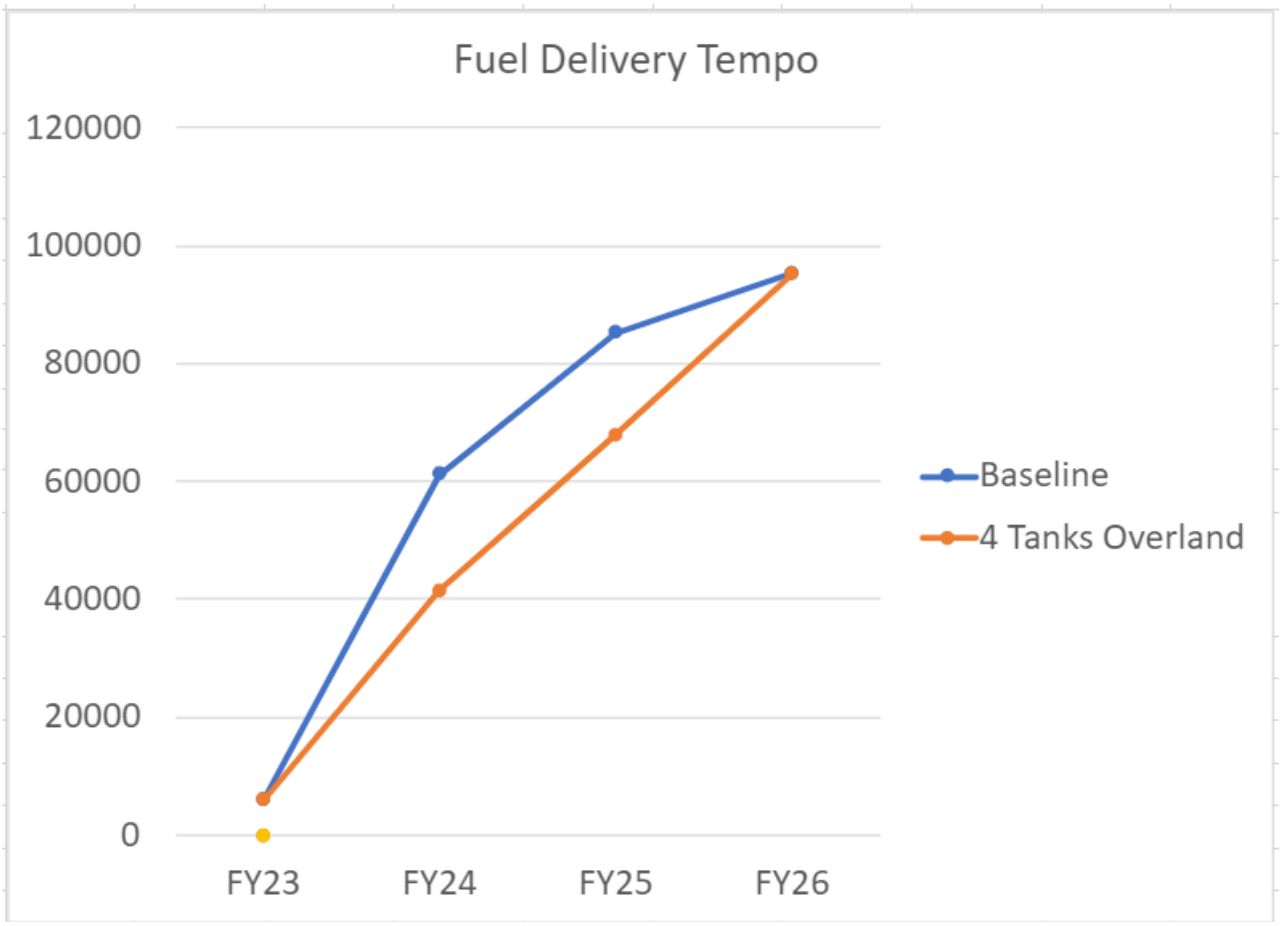
Baseline

Year	FY23	FY24	FY25	FY26
LC-130: Flights / Missions	2	18.4	8	3.4
LC-130: Flights / Fuel [gallons]	6000	55200	24000	10200
SPOT-1 Sleds / Fuel [gallons]	0	0	0	0
SPOT-2 Sleds / Fuel [gallons]	0	0	0	0
SPOT-3 Sleds / Fuel [gallons]	0	0	0	0
Baseline	6000	61200	85200	95400

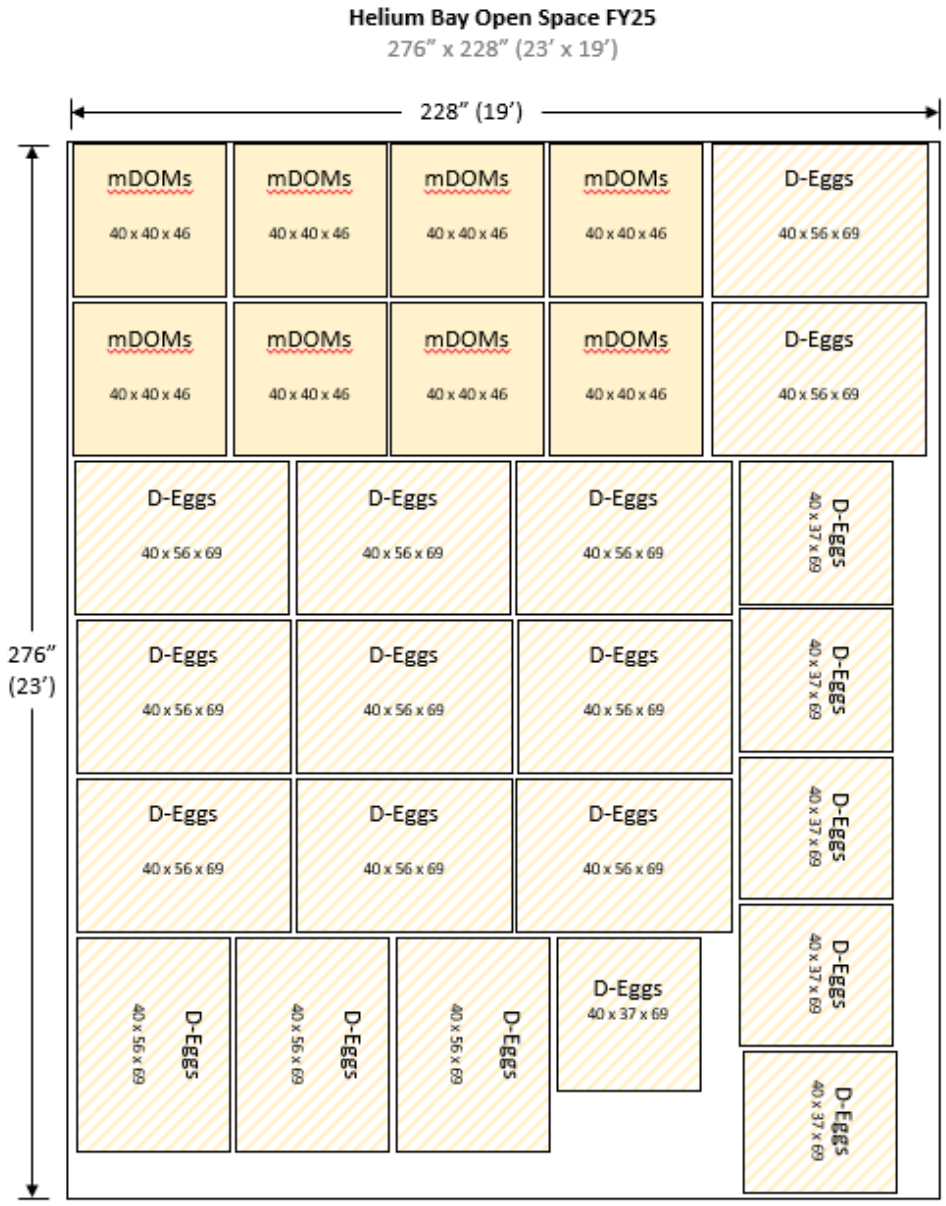
4 Tanks Overland

Year	FY23	FY24	FY25	FY26
LC-130: Flights / Missions	2	1	1	0.3
LC-130: Flights / Fuel [gallons]	6000	9000	0	1152
SPOT-1 Sleds / Fuel [gallons]	0	0	0	6,604
SPOT-2 Sleds / Fuel [gallons]	0	19,812	19,812	19,812
SPOT-3 Sleds / Fuel [gallons]	0	6,604	6,604	
4 Tanks Overland	6000	41416	67832	95400

9.2. Fuel delivery tempo graph: Baseline LC130 delivery vs. 4 tank overland delivery



9.3. South Pole Cryogen Facility, Helium Bay, DNF warehousing FY25



8 mDOM skid stacks 40" x 40" x 46" (2 strings)
14 D-Egg skids 40" x 56" x 69" (7 strings)
6 D-Egg skids 40 x 37 x 69 (3 strings)

9.4. South Pole Cryogen Facility, Nitrogen Bay, DNF warehousing FY25